

WARF



ENCYCLOPEDIA OF GEOGRAPHY

1



WARF



ENCYCLOPEDIA OF GEOGRAPHY

2



WARF



ENCYCLOPEDIA OF GEOGRAPHY

3



WARF



ENCYCLOPEDIA OF GEOGRAPHY

4



WARF



ENCYCLOPEDIA OF GEOGRAPHY

5



WARF



ENCYCLOPEDIA OF GEOGRAPHY

6

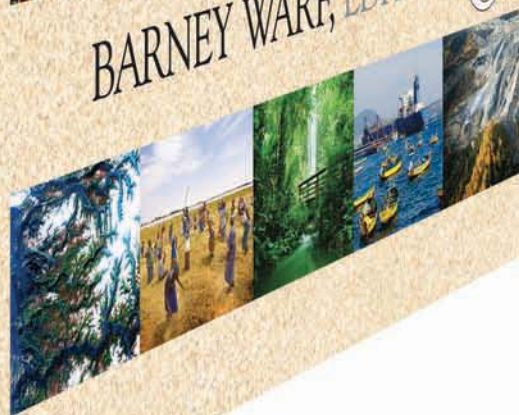


ENCYCLOPEDIA OF Geography



BARNEY WARF, EDITOR

6



ENCYCLOPEDIA OF
Geography

EDITORIAL BOARD

Editor

Barney Warf
University of Kansas

Associate Editors

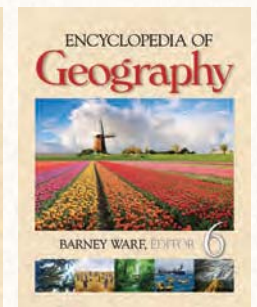
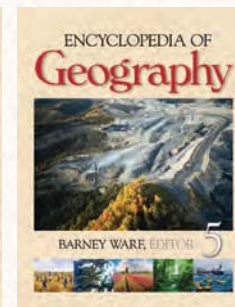
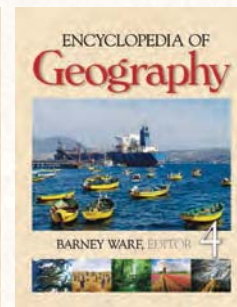
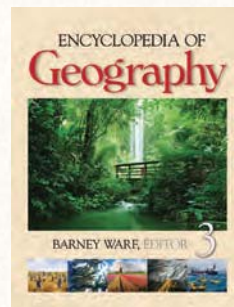
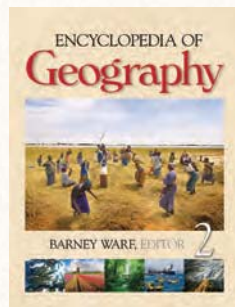
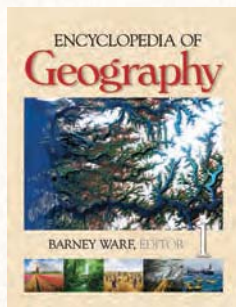
Piotr Jankowski
San Diego State University

Barry D. Solomon
Michigan Technological University

Mark Welford
Georgia Southern University

Managing Editor

Jonathan Leib
Old Dominion University



ENCYCLOPEDIA OF Geography

BARNEY WARF, EDITOR
University of Kansas

1



Los Angeles | London | New Delhi
Singapore | Washington DC

Copyright © 2010 by SAGE Publications, Inc.

All rights reserved. No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

For information:



SAGE Publications, Inc.
2455 Teller Road
Thousand Oaks, California 91320
E-mail: order@sagepub.com

SAGE Publications Ltd.
1 Oliver's Yard
55 City Road
London, EC1Y 1SP
United Kingdom

SAGE Publications India Pvt. Ltd.
B 1/I 1 Mohan Cooperative Industrial Area
Mathura Road, New Delhi 110 044
India

SAGE Publications Asia-Pacific Pte. Ltd.
33 Pekin Street #02-01
Far East Square
Singapore 048763

Printed in Singapore.

Library of Congress Cataloging-in-Publication Data

Encyclopedia of geography, volume I - VI / edited by Barney Warf.

6 v., p. cm.

Includes bibliographical references and index.

ISBN 978-1-4129-5697-0 (cloth)

1. Geography—Encyclopedias. I. Warf, Barney, 1956-

G63.E554 2010

910.3—dc22

2010009453

This book is printed on acid-free paper.

10 11 12 13 14 10 9 8 7 6 5 4 3 2 1

<i>Publisher:</i>	Rolf A. Janke
<i>Assistant to the Publisher:</i>	Michele Thompson
<i>Acquisitions Editor:</i>	Robert Rojek
<i>Developmental Editor:</i>	Diana E. Axelsen
<i>Reference Systems Manager:</i>	Leticia Gutierrez
<i>Reference Systems Coordinator:</i>	Laura Notton
<i>Production Editor:</i>	Tracy Buyan
<i>Copy Editors:</i>	QuADS Prepress (P) Ltd.
<i>Typesetter:</i>	C&M Digitals (P) Ltd.
<i>Proofreaders:</i>	Penelope Sippel, Rae-Ann Goodwin, Annette Van Deusen
<i>Indexer:</i>	Julie Sherman Grayson
<i>Cover Designer:</i>	Ravi Balasuriya
<i>Marketing Manager:</i>	Amberlyn McKay

Volume 1 cover photo: The fjords of Sogn og Fjordane dominate this image of the western coastline of Norway. Carved out of mountains by glaciers, the flooded U-shaped valleys are surrounded by steep cliffs, verdant slopes, and snowcapped mountain tops. Courtesy of the U.S. Geological Survey.

CONTENTS

1

List of Entries

vii

Reader's Guide

xviii

About the Editor

xxix

Contributors

xxx

Introduction

xlix

Entries

A **1**

B **183**

C **311**

LIST OF ENTRIES

- | | | |
|---|---|--|
| <p> Abler, Ronald
 Absolute Space
 Accessibility
 Acid Rain
 Actor-Network Theory
 Adaptation to Climate Change
 Adaptive Harvest Management
 Adaptive Radiation
 Adiabatic Temperature
 Changes
 Aerial Imagery: Data
 Aerial Imagery: Interpretation
 African Union
 Agamben, Giorgio
 Agent-Based Models
 Agglomeration Economies
 Aging and the Aged,
 Geography of. <i>See</i> Elderly,
 Geography and the
 Agnew, John
 Agricultural Biotechnology
 Agricultural Intensification
 Agricultural Land Use
 Agriculture, Industrialized
 Agriculture, Preindustrial
 Agrobiodiversity
 Agrochemical Pollution
 Agroecology
 Agrofoods
 Agroforestry
 AIDS, Geography of. <i>See</i>
 Disease, Geography of;
 HIV/AIDS, Geography of
 Air Masses </p> | <p> Air Pollution. <i>See</i> Atmospheric
 Pollution
 Albedo
 al-Idrisi
 Altitude
 Ambient Air Quality
 American Geographical Society
 Analytical Operations in GIS
 Anarchism and Geography
 Anaximander
 Animal Geographies
 Annales School
 Anselin, Luc
 Antevs, Ernst
 Anthropogenic Atmospheric
 Change. <i>See</i> Anthropogenic
 Climate Change;
 Stratospheric Ozone
 Depletion
 Anthropogenic Climate Change
 Anthropogeography
 Antiglobalization
 Antipodes
 Antisystemic Movements
 Applied Geography
 Appropriate Technology. <i>See</i>
 Sustainable Development;
 Sustainable Development
 Alternatives; Sustainable
 Production
 Aquaculture
 Archipelago
 Architecture and Geography
 Argumentation Maps </p> | <p> Arid Topography
 Aristotle
 Armstrong, Marc
 Art and Geography
 Asia-Pacific Economic
 Cooperation
 Association of American
 Geographers
 Association of Geographic
 Information Laboratories
 for Europe
 Association of Southeast Asian
 Nations
 Atmospheric Circulation
 Atmospheric Composition and
 Structure
 Atmospheric Energy Transfer
 Atmospheric Moisture
 Atmospheric Particulates
 Across Scales
 Atmospheric Pollution
 Atmospheric Pressure
 Atmospheric Remote Sensing
 Atmospheric Variations
 in Energy
 Atoll
 Automobile Industry
 Automobility
 Avalanches
 Aviation and Geography

 Barrier Islands
 Barrows, Harlan
 Basin and Range Topography </p> |
|---|---|--|

- | | | |
|---|--|---|
| Batty, Michael | Business Models for Geographic Information Systems | Class, Geography and Class, Nature and Client-Server Architecture |
| Bayesian Statistics in Spatial Analysis | Buttimer, Anne | Climate: Dry |
| Behavioral Geography | | Climate: Midlatitude, Mild |
| Berkeley School | | Climate: Midlatitude, Severe |
| Berry, Brian | Cadastral Systems | Climate: Mountain |
| Bhopal, India, Chemical Disaster | CAD Systems | Climate: Polar |
| Biblical Mapping | Câmara, Gilberto | Climate: Tropical Humid |
| Biodiversity | Canadian Association of Geographers | Climate Change |
| Biofuels | Cancer, Geography of | Climate Policy |
| Biogeochemical Cycles | Carbonation | Climate Types |
| Biogeography | Carbon Cycle | Climatic Relict |
| Biome: Boreal Forest | Carbon Trading and Carbon Offsets | Climatology |
| Biome: Desert | | Clouds |
| Biome: Midlatitude Deciduous Forest | Carcinogens | Clusters |
| Biome: Midlatitude Grassland | Carrying Capacity | Coal |
| Biome: Tropical Deciduous Forest | Cartograms | Coastal Dead Zones |
| Biome: Tropical Rain Forest | Cartography | Coastal Erosion and Deposition |
| Biome: Tropical Savanna | Cartography, History of | Coastal Hazards |
| Biome: Tropical Scrub | Castells, Manuel | Coastal Zone and Marine Pollution |
| Biome: Tundra | Caverns | |
| Biophysical Remote Sensing | Cellular Automata | Cold War, Geography of |
| Bioregionalism | Census | Collaborative GIS |
| Biosphere Reserves | Census Tracts | Colonialism |
| Biota and Climate | Centers of Domestication | Color in Map Design |
| Biota and Soils | Central Business District | Columbus, Christopher |
| Biota and Topography | Central Place Theory | Commodity Chains |
| Biota Migration and Dispersal | Chemical Spills, Environment, and Society | Common Pool Resources |
| Biotechnology and Ecological Risk | Chernobyl Nuclear Accident | Common Property Resource Management |
| Biotechnology Industry | Chicago School | Commons, Tragedy of the |
| Biruni | Childhood Spatial and Environmental Learning | Commonwealth of Independent States |
| Blaikie, Piers | Children, Geography of | Communications Geography |
| Blaut, James | Chinooks/Foehns | Communism and Geography |
| Blindness and Geography | Chipko Movement | Community-Based Conservation |
| Body, Geography of | Chlorinated Hydrocarbons | Community-Based Environmental Planning |
| Borderlands | Chlorofluorocarbons | Community-Based Natural Resource Management |
| Borders and Boundaries | Cholera, Geography of | Community Forestry |
| Bourghassi, Carmina | Chorley, Richard | Commuting |
| Bowman, Isaiah | Chorology | Comparative Advantage |
| Brownfields | Choropleth Maps | Competitive Advantage |
| Built Environment | Chrisman, Nicholas | Complexity Theory |
| Bunge, William | Christaller, Walter | Complex Systems Models |
| Bush Fallow Farming | Circuits of Capital | Conference of Latin Americanist Geographers |
| Business Cycles and Geography | Citizenship | |
| Business Geography | Civil Society | |
| | Clark, Andrew | |
| | Clark, William | |

- Conflation
 Conservation
 Conservation Zoning
 Consumption, Geographies of
 Continental Drift. *See* Plate Tectonics
 Cook, Captain James
 Coordinate Geometry
 Coordinate Systems
 Coordinate Transformations
 Coral Reef
 Coral Reef Geomorphology
 Coriolis Force
 Corporate Voluntary Environmental Initiatives and Self-Regulation
 Cosgrove, Denis
 Cosmopolitanism
 Cost-Benefit Analysis
 Council for Mutual Economic Assistance (COMECON)
 Countermapping
 Counterurbanization
 Coupled Human and Animal Systems
 Coupled Human and Natural Systems
 Creep
 Crime, Geography of
 Crisis
 Critical Geopolitics
 Critical GIS
 Critical Human Geography
 Critical Studies of Nature
 Crop Genetic Diversity
 Crop Rotation
 Cross-Border Cooperation
 Cultural Ecology
 Cultural Geography
 Cultural Landscape
 Cultural Turn
 Cyberspace
 Cyborg Ecologies
 Cyclones: Extratropical
 Cyclones: Occluded
 Dangermond, Jack
 Darby, Henry Clifford
 Darwinism and Geography
 Dasymetric Maps
 Database Management Systems
 Database Versioning
 Data Classification Schemes
 Data Compression Methods
 Data Editing
 Data Format Conversion
 Data Indexing
 Data Querying in GIS
 Datums
 Davis, William Morris
 Dear, Michael
 Debt and Debt Crisis
 Decolonization
 Deep Ecology Movements
 Deforestation
 Deindustrialization
 Delta
 Democracy
 Demographic Transition
 Dendrochronology
 Dependency Theory
 Derechos
 Desertification
 Desert Varnish
 Deterritorialization and Reterritorialization
 Developing World
 Development Theory
 Diamond, Jared
 Diaspora
 Diastrophism
 Difference, Geographies of
 Differential Heating
 Differential Vulnerabilities to Hazards
 Diffusion
 Digital Divide
 Digital Terrain Model
 Digitizing
 Disability, Geography of
 Disaster Prediction and Warning
 Disaster Preparedness
 Discourse and Geography
 Disease, Geography of
 Distance Decay
 Distributed Computing
 Distribution of Resource Access
 Division of Labor
 Domestication Centers. *See* Centers of Domestication
 Domestication of Animals
 Domestication of Plants
 Domino Theory
 Dot Density Maps
 Drought Risk and Hazard
 Drugs, Geography of
 Dunes
 Dynamic and Interactive Displays
 Earle, Carville
 Earthquakes
 Earth's Coordinate Grid
 Eastman, Ronald
 Ecofeminism
 Ecological Economics
 Ecological Fallacy
 Ecological Footprint
 Ecological Imaginaries
 Ecological Justice
 Ecological Mapping
 Ecological Modernization
 Ecological Regimes
 Ecological Risk Analysis
 Ecological Services. *See* Environmental Services
 Ecological Zones
 E-Commerce and Geography
 Economic Base Analysis
 Economic Geography
 Economies of Scale
 Economies of Scope
 Ecoregions
 Ecoshed
 Ecosystem Decay
 Ecosystems
 Ecotone
 Ecotourism
 Education, Geographies of
 Egenhofer, Max
 Elderly, Geography and the
 Electoral Geography
 Electronic Atlases
 Electronics Industry, Geography of
 El Niño
 Emerging Markets

- | | | |
|------------------------------------|-------------------------------------|---------------------------------|
| Emotions, Geography and Empiricism | Environmental Protection | Feminist Environmentalism |
| Endogenous Growth Theory. | Environmental Racism | Feminist Geographies |
| <i>See</i> Knowledge Spillovers; | Environmental Refugees | Feminist Methodologies |
| Learning Regions | Environmental Restoration | Feminist Political Ecology |
| Energy and Human Ecology | Environmental Rights | Fertility Rate |
| Energy Models | Environmental Security | Fieldwork in Human |
| Energy Policy | Environmental Services | Geography |
| Energy Resources | Environmental Social | Fieldwork in Physical |
| Enlightenment | Movements. <i>See</i> International | Geography |
| Enterprise GIS | Environmental Movements | Film and Geography |
| Environmental Certification | Environment and Development | Filtering |
| Environmental Determinism | Epistemology | Filtration |
| Environmental Discourse | Equator | Finance, Geography of |
| Environmental Entitlements | Equinox | Fisher, Peter |
| Environmental Ethics | Eratosthenes | Fish Farming |
| Environmental Footprint. | Error Propagation | Fjords |
| <i>See</i> Ecological Footprint | Ethics, Geography and | Flash Floods |
| Environmental History | Ethnicity | Flexible Production |
| Environmental Imaginaries | Ethnicity and Nature | Flocculation |
| Environmental Impact | Ethnic Segregation | Floodplain |
| Assessment | Ethnocentrism | Floods |
| Environmental Impacts of | Eurocentrism | Flow |
| Agriculture | Euromarket | Flow Maps |
| Environmental Impacts of | European Green Movements | Folding |
| Cities | European Union | Folk Culture and |
| Environmental Impacts of | Everglades Restoration | Geography |
| Manufacturing | Everyday Life, Geography and | Food, Geography of |
| Environmental Impacts of | Existentialism and Geography | Food and Agriculture |
| Mining. <i>See</i> Open-Pit | Exotic Species | Organization (FAO) |
| Mining | Exploration | Footprint Analysis. |
| Environmental Impacts of | Exploratory Spatial Data | <i>See</i> Ecological Footprint |
| Oil Fields | Analysis | Fordism |
| Environmental Impacts of | Export-Led Development | Fordism |
| Pipelines | Export Processing Zones | Foreign Aid |
| Environmental Impacts of | Externalities | Foreign Direct Investment |
| Roads | Extinctions | Forest Degradation |
| Environmental Impacts of | Extractive Reserves | Forest Fragmentation |
| Tourism | Extreme Geography | Forest Land Use |
| Environmental Impacts of War | Exurbs | Forest Restoration |
| Environmental Impact | | Fotheringham, A. Stewart |
| Statement | Factors Affecting Location | Frank, Andrew |
| Environmental Justice | of Firms | Frontiers |
| Environmental Law | Fair Trade and Environmental | Fronts |
| Environmental Management | Certification | |
| Environmental Management: | Famine, Geography of | Gaia Theory |
| Drylands | Faulting | Gama, Vasco da |
| Environmental Mapping | Fear, Geographies of | Game Ranching |
| Environmental Perception | Febvre, Lucien | Gated Community |
| Environmental Planning | Feminist Environmental | Gays and Lesbians, |
| | Geographies | Geography and/of |
| | | Gazetteers |

- Gender and Environmental Hazards
 Gender and Geography
 Gender and Nature
 General Circulation Model (GCM). *See* Anthropogenic Climate Change; Atmospheric Energy Transfer; Climate Change
 Genetically Modified Organisms (GMOs)
 Genocide, Geographies of
 Gentrification
 Geocoding
 Geocollaboration
 Geocomputation
 Geodemographics
 Geodesy
 Geographical Ignorance
 Geographical Imagination
 Geographically Weighted Regression
 Geographic Information Systems
 Geography Education
 Geolibraries
 Geologic Timescale
 Geomancy
 Geometric Correction
 Geometric Measures
 Geomorphic Cycle
 Geomorphology
 Geophagy
 Geopolitics
 Geosensor Networks
 Geoslavery
 Geospatial Industry
 Geospatial Semantic Web
 Geostatistics
 Geothermal Energy
 Geothermal Features
 Geovisualization. *See* Cartography; Dynamic and Interactive Displays; Three-Dimensional Models
 Getis, Arthur
 Ghetto
 Giddens, Anthony
 Gilbert, Grove Karl
 GIS, Environmental Model Integration and
 GIS, History of
 GIScience
 GIS Design
 GIS Implementation
 GIS in Archaeology
 GIS in Disaster Response
 GIS in Environmental Management
 GIS in Health Research and Health Care
 GIS in Land Use Management
 GIS in Local Government
 GIS in Public Policy
 GIS in Transportation
 GIS in Urban Planning
 GIS in Utilities
 GIS in Water Management
 GIS Software
 GIS Web Services
 Glaciers: Continental
 Glaciers: Mountain
 Global Climate Change. *See* Anthropogenic Climate Change
 Global Environmental Change
 Globalization
 Global Positioning System
 Global Sea-Level Rise
 Global Warming. *See* Anthropogenic Climate Change
 Globes. *See* Cartography; Map Projections
 Glocalization
 Golledge, Reginald
 Goodchild, Michael
 Goode, J. Paul
 Google Earth
 Gottmann, Jean
 Gould, Peter
 Governance
 Governmentality and Conservation
 Gravity Model
 Great American Exchange
 Greenbelts
 Green Building
 Green Design and Development
 Greenhouse Gases
 Green Revolution. *See* Environmental Impacts of Agriculture
 Gregory, Derek
 Gross Domestic Product/Gross National Product
 Ground Reference Data
 Groundwater
 Growth Machine
 Growth Poles
 Gully Erosion
 Guyot, Arnold
 Hadley Cell
 Hägerstrand, Torsten
 Haggett, Peter
 Hanson, Susan
 Harley, Brian
 Hartshorne, Richard
 Harvey, David
 Hate, Geographies of
 Haushofer, Karl
 Hayden, Ferdinand
 Health and Health Care, Geography of
 Heavy Metals as Pollutants
 Hegemony
 Herbicides
 Herodotus
 Hettner, Alfred
 Heuristic Methods in Spatial Analysis
 High-Performance Computing
 High Technology
 Hipparchus
 Historical Geography
 Historicism
 Historic Preservation
 History of Geography. *See* Cartography, History of; GIS, History of; Human Geography, History of; Physical Geography, History of
 HIV/AIDS, Geography of
 Home
 Homelessness
 Hou Renzhi

- | | | |
|--|--|---|
| <p>Housing and Housing Markets
Housing Policy
Hoyt, Homer
Human Dimensions of Global
 Environmental Change
Human Ecology
Human Geography, History of
Human-Induced Invasion of
 Species
Humanistic Geography
Humanistic GIScience
Human Rights, Geography and
Humboldt, Alexander von
Humidity
Hunger
Hunting and Gathering
Huntington, Ellsworth
Hurricane Katrina
Hurricanes, Physical
 Geography of
Hurricanes, Risk and Hazard
Hybrid Geographies
Hybridization of Plant and
 Animal Species
Hydroelectric Power
Hydrological Connectivity
Hydrology
Hydrothermal Energy. <i>See</i>
 Geothermal Energy</p> <p>Ibn Battuta
Ibn Khaldūn
Ice
Identity, Geography and
Idiographic
Image Enhancement
Image Fusion
Image Interpretation
Image Processing
Image Registration
Image Texture
Imaging Spectroscopy
Immigration
Imperialism
Impermeable Surfaces
Import Substitution
 Industrialization
Incubator Zones
Indigeneity
Indigenous Agriculture</p> | <p>Indigenous and Community
 Conserved Areas
Indigenous Cartographies
Indigenous Environmental
 Knowledge
Indigenous Environmental
 Practices
Indigenous Forestry
Indigenous Reserves
Indigenous Water Management
Industrial Districts
Industrial Ecology
Industrialization
Industrial Revolution
Inequality and Geography
Informal Economy
Information Society
Infrastructure
Innovation, Geography of
Input-Output Models
Institute of British Geographers
Interactive Mapping. <i>See</i> Map
 Animation
Intergovernmental
 Environmental
 Organizations and Initiatives
International Criminal Court
International Environmental
 Movements
International Environmental
 NGOs
International Geographical
 Union
International Monetary Fund
International Watershed
 Management
Internet. <i>See</i> Communications,
 Geography of; Cyberspace;
 Digital Divide;
 Telecommunications and
 Geography
Internet GIS
Interoperability and Spatial
 Data Standards
Interviewing
Invasion and Succession
Isard, Walter
Island Biogeography
Islands, Small
Isopleth Maps</p> | <p>Jackson, John Brinckerhoff
Jefferson, Thomas
Johnston, R. J.
Journey-to-Work. <i>See</i>
 Commuting
Justice, Geography of</p> <p>Kant, Immanuel
Karst Topography
Kates, Robert
Keystone Species
Knowledge, Geography of
Knowledge Spillovers
Köppen, Wladimir
Köppen-Geiger Climate
 Classification
Kropotkin, Peter
Krummholtz
Kuhn, Werner
Kwan, Mei-Po
Kyoto Protocol. <i>See</i> Climate
 Policy</p> <p>Labor, Geography of
Lahar. <i>See</i> Volcanoes
Land Degradation
Landfills
Landforms
Land Reform
Landscape and Wildlife
 Conservation
Landscape Architecture
Landscape Biodiversity
Landscape Design
Landscape Ecology
Landscape Interpretation
Landscape Quality
 Assessment
Landscape Restoration
Landslide
Land Tenure
Land Tenure Reform
Land Use
Land Use Analysis
Land Use and Cover Change
 (LUCC)
Land Use and Land Cover
 Mapping
Land Use History
Land Use Planning</p> |
|--|--|---|

- Land-Water Breeze
 Languages, Geography of
 La Niña
 Lapse Rate
 Latent Heat
 Latitude
 Law, Geography of
 Learning Regions
 Lefebvre, Henri
 Legal Aspects of Geospatial Information
 Lewis, Peirce
 Lewis and Clark Expedition
 Ley, David
 LiDAR and Airborne Laser Scanning
 Lightning
 Lillesand, Thomas
 Linear Referencing and Dynamic Segmentation
 Literature, Geography and
 Livingstone, David
 Locality
 Locally Unwanted Land Uses (LULUs)
 Location-Allocation Modeling
 Location-Based Services
 Location Quotients
 Location Theory
 Logical Positivism
 Longitude
 Los Angeles School
 Lösch, August
 Love Canal
 Lynch, William
- MacEachren, Alan
 Mackinder, Sir Halford
 Magellan, Ferdinand
 Mahan, Alfred Thayer
 Malaria, Geography of
 Malthusianism
 Manufacturing Belt
 Map Algebra
 Map Animation
 Map Design
 Map Evaluation and Testing
 Map Generalization
 Map Projections
 Map Visualization
- Marcus, Melvin G.
 Marginal Regions
 Marine Aquaculture
 Maritime Spaces. *See* Oceans
 Mark, David M.
 Market-Based Environmental Regulation
 Marsh, George Perkins
 Marxism, Geography and
 Masculinities and Geography
 Massey, Doreen
 Mass Wasting
 Mather, John Russell
 Maury, Matthew Fontaine
 McKnight, Tom L.
 Media and Geography
 Medical Geography
 Meinig, Donald
 Mental Maps
 Mercator, Gerardus
 Metadata
 Metropolitan Area
 Microwave/RADAR Data
 Migration
 Military Geography
 Military Spending
 Miller, Harvey J.
 Minerals
 Mining and Geography
 Mitchell, Don
 Mixed Farming
 Mobile GIS
 Mobility
 Models and Modeling
 Modernity
 Modernization Theory
 Modifiable Areal Unit Problem
 Money, Geographies of
 Monmonier, Mark
 Monsoons
 Morrill, Richard
 Morse, Jedediah
 Mortality Rate
 Most Favored Nation Status
 Movimento Sem Terra
 Multimedia Mapping
 Multispectral Imagery
 Multistakeholder Participation
 Multitemporal Imaging
 Multivariate Analysis Methods
- Multivariate Mapping
 Music and Sound, Geography and
 Nation
 National Aeronautics and Space Administration (NASA)
 National Center for Geographic Information and Analysis
 National Council for Geographic Education
 National Geographic Society
 Nationalism
 Natural Growth Rate
 Natural Hazards and Risk Analysis
 Nature
 Nature-Society Theory
 Neighborhood
 Neocolonialism
 Neogeography
 Neoliberal Environmental Policy
 Neoliberalism
 Neo-Malthusianism
 Network Analysis
 Network Data Model
 New International Division of Labor
 Newly Industrializing Countries
 New Urbanism
 Nitrogen Cycle
 Nomadic Herding
 Nomadism
 Nomothetic
 Nongovernmental Organizations (NGOs)
 Nonpoint Sources of Pollution
 Nonrenewable Resources
 Nonrepresentational Theory
 Nonvisual Geographies
 North American Free Trade Agreement (NAFTA)
 North Atlantic Treaty Organization (NATO)
 Not in My Backyard (NIMBY)
 Nuclear Energy

- | | | |
|---|---|---|
| Nutrient Cycles | Patches and Corridors in
Wildlife Conservation | Positionality |
| Nyerges, Timothy | Path Dependence | Positivism. <i>See</i> Logical
Positivism |
| Object-Based Image Analysis | Patriarchy, Geography and | Postcolonialism |
| Oceanic Circulation | Peasants and Peasantry | Post-Fordism. <i>See</i> Flexible
Production |
| Oceans | Peat | Postindustrial Society |
| Offshore Finance | Pedology. <i>See</i> Soils | Postmodernism |
| Oil Spills | Peet, Richard | Poststructuralism |
| Okabe, Atsuyuki | Penck, Walther | Poverty |
| Olsson, Gunnar | Periglacial Environments | Powell, John Wesley |
| Ontological Foundations of
Geographical Data | Permaculture | Prairie Restoration |
| Ontology | Permafrost | Prairies |
| Open Geodata Standards | Pesticides | Precipitation, Global |
| Open Geospatial Consortium
(OGC) | Pest Management | Precipitation Formation |
| Open-Pit Mining | Petroleum | Pred, Allan |
| Open Source Geospatial
Foundation | Peuquet, Donna | Primate Cities |
| Open Source GIS | Phenomenology | Prime Meridian. <i>See</i> Longitude |
| Open Space | Phosphorus Cycle | Privacy and Security of
Geospatial Information |
| Organic Agriculture | Photochemical Smog | Producer Services |
| Organisation for Economic
Co-operation and
Development (OECD) | Photogrammetric Methods | Product Cycle |
| Organization of the
Petroleum Exporting
Countries (OPEC) | Photography, Geography and | Production of Space |
| Organophosphates | Physical Geography, History of | Psychoanalysis, Geography and |
| Orientalism | Pickles, John | Ptolemy |
| Ortelius | Pilgrimage | Public Housing |
| Other/Otherness | Place | Public Participation GIS |
| Outsourcing | Place Names | Public Policy, Geography of |
| Overpopulation. <i>See</i>
Malthusianism; Neo-
Malthusianism | Place Promotion | Public-Private Partnerships |
| | Plantations | Public Space |
| | Plate Tectonics | Public Water Services |
| | Playas | Pyrogeography |
| | Point Pattern Analysis | |
| | Point Sources of Pollution | Qualitative Methods |
| | Poles, North and South | Quantitative Methods |
| | Political Ecology | Quantitative Revolution |
| | Political Economy | Queer Theory |
| | Political Economy of Resources | |
| | Political Geography | |
| | Polychlorinated Biphenyls
(PCBs) | |
| | Popular Culture, Geography and | Race and Empire |
| | Population and Land
Degradation | Race and Nature |
| | Population and Land Use | Race and Racism |
| | Population Density | Racial Segregation |
| | Population, Environment, and
Development | Radiation: Solar and
Terrestrial |
| | Population Geography | Radical Geography |
| | Population Pyramid | Radiometric Correction |
| | Portolan Charts | Radiometric Normalization |
| | Ports and Maritime Trade | Radiometric Resolution |
| | | Railroads and Geography |
| | | Raisz, Erwin |

- Rank-Size Rule
 Ratzel, Friedrich
 Real Estate, Geography and
 Realism
 Reclus, Élisée
 Recycling of Municipal Solid
 Waste
 Redistricting
 Refugees
 Regional Economic
 Development
 Regional Environmental
 Planning
 Regional Geography
 Regional Governance
 Regional Science
 Regional Science Association
 International (RSAI)
 Regions and Regionalism
 Regulation Theory
 Relational Space. *See* Relative/
 Relational Space
 Relative/Relational Space
 Religion, Geography and
 Relph, Edward
 Remittances
 Remote Sensing
 Remote Sensing: Platforms and
 Sensors
 Remote Sensing in Disaster
 Response
 Renewable Resources
 Rent-Gap
 Representations of Space
 Research and Development,
 Geographies of
 Resilience
 Resistance, Geographies of
 Resource Economics
 Resource Geography
 Resource Management. *See*
 Environmental Management
 Resource Management,
 Decision Models in
 Resource Mapping
 Resource Tenure
 Restoration Ecology. *See*
 Environmental Restoration
 Restructuring
 Retail Trade, Geography of
 Rill Erosion
 Risk Analysis and Assessment
 Ritter, Carl
 Rivers
 Rock Weathering
 Rose, Gillian
 Royal Geographical Society
 Rural Development
 Rural Geography
 Rural-Urban Migration
 Russian Geographical Society
 Satellites and Geography
 Sauer, Carl
 Scale, Social Production of
 Scale in GIS
 Schaefer, Fred
 Science, Technology, and
 Environment
 Science and Technology Studies
 Scott, Allen
 Sedimentary Rock
 Sedimentation
 Segregation and Geography
 Self-Organizing Maps
 Semantic Interoperability
 Semantic Reference Systems
 Semple, Ellen Churchill
 Sense of Place
 Sequent Occupance
 Services. *See* Producer Services
 Settlement Geography
 Sexuality, Geography and/of
 Shifting Cultivation
 Shortest-Path Problem
 Single Large or Several Small
 (SLOSS) Debate
 Situated Knowledge
 Smart Growth
 Smith, Neil
 Smog. *See* Photochemical Smog
 Social and Economic Impacts
 of Climate Change
 Social Construction of Nature
 Social Darwinism
 Social Forestry
 Social Geography
 Socialism and Geography
 Social Justice
 Social Movements
 Soil Conservation
 Soil Degradation
 Soil Depletion
 Soil Erosion
 Soils
 Soja, Edward
 Solar Energy
 Solstices
 Sovereignty
 Space, Production of. *See*
 Production of Space
 Space of Flows
 Spaces of Representation/
 Representational Spaces
 Spatial Analysis
 Spatial Autocorrelation
 Spatial Cognition
 Spatial Cognitive Engineering
 Spatial Data Infrastructures
 Spatial Data Integration
 Spatial Data Mining
 Spatial Data Models
 Spatial Data Structures
 Spatial Decision Support
 Systems
 Spatial Econometrics
 Spatial Fix
 Spatial Inequality
 Spatial Interaction Models
 Spatial Interpolation
 Spatialization
 Spatially Integrated Social
 Science
 Spatial Multicriteria Evaluation
 Spatial Optimization Methods
 Spatial Resolution
 Spatial Statistics
 Spatial Strategies of
 Conservation
 Spatial Turn
 Species-Area Relationship
 Spectral Characteristics of
 Terrestrial Surfaces
 Spectral Resolution
 Spectral Transformations
 Spit. *See* Coastal Erosion and
 Deposition
 Sports, Geography of
 Squatter Settlements
 State

- | | | |
|-------------------------------|-----------------------------------|------------------------------|
| Steel Industry, Geography of | Textile Industry | United Nations Conference on |
| Stereoscopy and Orthoimagery | Thales | Environment and |
| Storper, Michael | Thermal Imagery | Development |
| Strabo | Thornthwaite, C. Warren | United Nations Environmental |
| Strahler, Arthur | Three-Dimensional Data | Summits |
| Stratospheric Ozone Depletion | Models | United Nations Environment |
| Strip Mining | Three Mile Island Nuclear | Programme (UNEP) |
| Structural Adjustment | Accident | United States Census Bureau |
| Structuralism | Thrift, Nigel | United States Geological |
| Structuration Theory | Thunderstorms | Survey (USGS) |
| Subaltern Studies | Thünen Model | University Consortium for |
| Suburban Land Use | Timber Plantations | Geographic Information |
| Suburbs and Suburbanization | Time, Geographies of | Science |
| Sui, Daniel | Time-Geography | Unsupervised Classification |
| Suitability Analysis | Time-Space Compression | Unwin, David |
| Sunbelt | T-in-O Maps | Urban and Regional |
| Supervised Classification | Tobler, Waldo | Development |
| Supranational Integration | Tomlinson, Roger | Urban and Regional Planning |
| Surface Water | Topological Relationships | Urban Ecology |
| Surveillance | Toponymy | Urban Environmental Studies |
| Surveying | Topophilia | Urban Gardens |
| Sustainability Science | Tornadoes | Urban Geography |
| Sustainable Agriculture | Tourism | Urban Green Space |
| Sustainable Cities | Township and Range System | Urban Heat Island |
| Sustainable Development | Trade | Urban Hierarchy |
| Sustainable Development | Transhumance. <i>See</i> Nomadism | Urbanization |
| Alternatives | Transnational Corporation | Urban Land Use |
| Sustainable Fisheries | Transnationalism | Urban Metabolism |
| Sustainable Forestry | Transportation Geography | Urban Planning and |
| Sustainable Production | Trap Streets | Geography |
| Symbolism and Place | Travel Writing, Geography and | Urban Policy |
| Symptoms and Effects of | Tree Farming | Urban Solid Waste |
| Climate Change | Trewartha, Glenn | Management |
| | Triangulated Irregular | Urban Spatial Structure |
| | Network (TIN) Data Model | Urban Sprawl |
| Taphonomy | Troll, Carl | Urban Storm Water |
| Taylor, Griffith | Tropical Rain Forests. <i>See</i> | Management |
| Taylor, Peter | Biome: Tropical Rain Forest | Urban Sustainability |
| Technological Change, | Tsunami | Urban Underclass |
| Geography of | Tsunami of 2004, Indian | Urban Water Supply |
| Telecommunications and | Ocean | Usability of Geospatial |
| Geography | Tuan, Yi-Fu | Information |
| Teleconnections | Turner, Billie Lee, II | |
| Television and Geography | Typhoons. <i>See</i> Hurricanes, | Vagueness in Spatial Data |
| Temperature Patterns | Physical Geography of | Vance, James |
| Temporal GIS | Typography in Map Design | Varenius |
| Temporal Resolution | | Vectorization |
| Terrain Analysis | Underdevelopment | Vernacular Landscapes |
| Territory | Uneven Development | as Expressions of |
| Terrorism, Geography of | United Nations | Environmental Ideas |
| Text/Textuality | | |

-
- | | | |
|---|------------------------------------|---|
| Via Campesina (International Farmers' Movement) | Water Needs | Wine Terroir |
| Vidal de la Blache, Paul | Water Pollution | Wise Use Movement |
| Video Games, Geography and | Watershed Management | Wittfogel, Karl |
| Viewshed Analysis | Watershed Yield | Wood, Denis |
| Virilio, Paul | Water Supply Siting and Management | Woodfuel |
| Virtual and Immersive Environments | Watts, Michael | Woodlots. <i>See</i> Forest Fragmentation |
| Virtual Geographies | Wayfinding | World Bank |
| Virtual Globes | Weather and Climate Controls | World Cities |
| Vision and Geography | Weber, Alfred | World Court |
| Volcanic Eruptions as Risk and Hazard | Web Geoprocessing Workflows | World Health Organization (WHO) |
| Volcanoes | Web Service Architectures for GIS | World Summit on Sustainable Development |
| Voronoi Diagrams | Wetlands | World-Systems Theory |
| Vulnerability, Risks, and Hazards | White, Gilbert | World Trade Organization (WTO) |
| | Whiteness | Wright, Dawn |
| Waldseemüller, Martin | Whittlesey, Derwent | Wright, John Kirtland |
| Walker, Richard | Wilderness | Writing |
| War, Geography of | Wildfires: Risk and Hazard | |
| Waste Incineration | Wilson, John | Xeriscaping |
| Wastewater Management | Wind | |
| Water Degradation | Wind Energy | Zelinsky, Wilbur |
| Water Management and Treatment | Wind Erosion | Zoning |
| | Wine, Geography of | |

READER'S GUIDE

The Reader's Guide is designed to assist readers in finding articles on related topics. Headwords are organized into six major categories: Physical Geography; Human Geography; Nature and Society; Methods, Models, and GIS; History of Geography; and People, Organizations, and Movements. Note, however, that many topics defy easy categorization and belong to more than one grouping.

Physical Geography

Biogeography

Adaptive Radiation
Animal Geographies
Biodiversity
Biogeochemical Cycles
Biogeography
Biome: Boreal Forest
Biome: Desert
Biome: Midlatitude Deciduous Forest
Biome: Midlatitude Grassland
Biome: Tropical Deciduous Forest
Biome: Tropical Rain Forest
Biome: Tropical Savanna
Biome: Tropical Scrub
Biome: Tundra
Bioregionalism
Biosphere Reserves
Biota and Climate
Biota and Soils
Biota and Topography
Biota Migration and Dispersal
Coral Reef
Ecoregions
Ecoshed
Ecosystem Decay

Ecosystems
Ecotone
Exotic Species
Extinctions
Gaia Theory
Great American Exchange
Human-Induced Invasion of Species
Invasion and Succession
Island Biogeography
Keystone Species
Nutrient Cycles
Organophosphates
Peat
Permaculture
Phosphorus Cycle
Prairies
Pyrogeography
Resilience
Single Large or Several Small (SLOSS) Debate
Species-Area Relationship
Taphonomy
Wetlands

Climatology

Adiabatic Temperature Changes
Air Masses

Albedo
Anthropogenic Climate Change
Atmospheric Circulation
Atmospheric Composition and Structure
Atmospheric Energy Transfer
Atmospheric Moisture
Atmospheric Particulates Across Scales
Atmospheric Pressure
Atmospheric Variations in Energy
Carbonation
Carbon Cycle
Carbon Trading and Carbon Offsets
Chinooks/Foehns
Chlorinated Hydrocarbons
Chlorofluorocarbons
Climate: Dry
Climate: Midlatitude, Mild
Climate: Midlatitude, Severe
Climate: Mountain
Climate: Polar
Climate: Tropical Humid
Climate Change
Climate Policy

Climate Types
Climatic Relict
Climatology
Clouds
Coriolis Force
Cyclones: Extratropical
Cyclones: Occluded
Derechos
Differential Heating
El Niño
Equinox
Filtration
Fronts
Global Sea-Level Rise
Hadley Cell
Humidity
Hurricanes, Physical
 Geography of
Köppen-Geiger Climate
 Classification
Krummholtz
Land-Water Breeze
La Niña
Lapse Rate
Latent Heat
Lightning
Monsoons
Precipitation, Global
Precipitation Formation
Radiation: Solar and
 Terrestrial
Solar Energy
Solstices
Stratospheric Ozone
 Depletion
Symptoms and Effects of
 Climate Change
Teleconnections
Temperature Patterns
Thunderstorms
Tornadoes
Urban Heat Island
Weather and Climate
 Controls
Wind

Geomorphology

Archipelago
Arid Topography

Atoll
Barrier Islands
Basin and Range
 Topography
Caverns
Coastal Erosion and
 Deposition
Coral Reef Geomorphology
Creep
Delta
Diastrophism
Dunes
Earthquakes
Faulting
Fjords
Flocculation
Floodplain
Flow
Folding
Geologic Timescale
Geomorphic Cycle
Geomorphology
Geothermal Features
Glaciers: Continental
Glaciers: Mountain
Groundwater
Gully Erosion
Hydrological Connectivity
Hydrology
Ice
Impermeable Surfaces
Islands, Small
Karst Topography
Landforms
Mass Wasting
Minerals
Nitrogen Cycle
Oceanic Circulation
Oceans
Periglacial Environments
Permafrost
Plate Tectonics
Playas
Rill Erosion
Rivers
Rock Weathering
Sedimentary Rock
Sedimentation
Soils
Surface Water

Volcanoes
Wind Erosion

Human Geography

Economic Geography

Agglomeration Economies
Applied Geography
Automobile Industry
Aviation and Geography
Biotechnology Industry
Business Cycles and Geography
Business Geography
Central Business District
Central Place Theory
Circuits of Capital
Clusters
Commodity Chains
Comparative Advantage
Competitive Advantage
Cost-Benefit Analysis
Crisis
Debt and Debt Crisis
Deindustrialization
Dependency Theory
Developing World
Development Theory
Division of Labor
E-Commerce and Geography
Economic Base Analysis
Economic Geography
Economies of Scale
Economies of Scope
Electronics Industry,
 Geography of
Emerging Markets
Euromarket
Export-Led Development
Export Processing Zones
Externalities
Factors Affecting Location of
 Firms
Finance, Geography of
Flexible Production
Food, Geography of
Fordism
Foreign Aid
Foreign Direct Investment
Geospatial Industry
Globalization

Glocalization
Gravity Model
Gross Domestic Product/Gross National Product
Growth Poles
High Technology
Import Substitution
Industrialization
Incubator Zones
Industrial Districts
Industrialization
Industrial Revolution
Informal Economy
Information Society
Infrastructure
Innovation, Geography of
Input-Output Models
Knowledge, Geography of
Knowledge Spillovers
Labor, Geography of
Learning Regions
Location Theory
Manufacturing Belt
Marginal Regions
Military Spending
Modernization Theory
Money, Geographies of
Most Favored Nation Status
Neocolonialism
Neoliberalism
New International Division of Labor
Newly Industrializing Countries
Offshore Finance
Outsourcing
Peasants and Peasantry
Plantations
Political Economy
Ports and Maritime Trade
Postindustrial Society
Poverty
Producer Services
Product Cycle
Railroads and Geography
Real Estate, Geography and
Regional Economic Development
Regulation Theory
Remittances

Research and Development, Geographies of
Restructuring
Retail Trade, Geography of
Rural Development
Rural Geography
Satellites and Geography
Space of Flows
Spatial Fix
Steel Industry, Geography of
Structural Adjustment
Sustainable Development
Sustainable Development Alternatives
Technological Change, Geography of
Telecommunications and Geography
Textile Industry
Thünen Model
Trade
Transnational Corporation
Transportation Geography
Underdevelopment
Uneven Development

Geographical Theory

Absolute Space
Actor-Network Theory
Anarchism and Geography
Behavioral Geography
Complexity Theory
Complex Systems Models
Cosmopolitanism
Critical Human Geography
Cultural Turn
Cyborg Ecologies
Difference, Geographies of
Discourse and Geography
Empiricism
Epistemology
Ethics, Geography and
Ethnocentrism
Eurocentrism
Existentialism and Geography
Feminist Geographies
Feminist Methodologies
Gender and Geography
Historicism
Humanistic Geography

Hybrid Geographies
Idiographic
Locality
Logical Positivism
Malthusianism
Marxism, Geography and
Models and Modeling
Nomothetic
Nonrepresentational Theory
Ontology
Orientalism
Other/Otherness
Panopticon
Path Dependence
Phenomenology
Place
Postcolonialism
Postmodernism
Poststructuralism
Production of Space
Queer Theory
Race and Racism
Radical Geography
Realism
Regional Geography
Regional Science
Regions and Regionalism
Relative/Relational Space
Representations of Space
Scale, Social Production of
Science and Technology Studies
Sense of Place
Situated Knowledge
Spaces of Representation/Representational Spaces
Spatially Integrated Social Sciences
Spatial Turn
Structuralism
Structuration Theory
Subaltern Studies
Text/Textuality
Time-Geography
Time-Space Compression
Vision and Geography

Medical Geography

Cancer, Geography of
Carcinogens

Cholera, Geography of
Disease, Geography of
Health and Health Care,
Geography of
HIV/AIDS, Geography of
Malaria, Geography of
Medical Geography

Political Geography

Borderlands
Borders and Boundaries
Cold War, Geography of
Colonialism
Communism and Geography
Critical Geopolitics
Cross-Border Cooperation
Decolonization
Democracy
Deterritorialization and
Reterritorialization
Domino Theory
Electoral Geography
Frontiers
Geopolitics
Governance
Hegemony
Imperialism
Military Geography
Nation
Nationalism
Political Geography
Public Policy, Geography of
Redistricting
Regional Governance
Socialism and Geography
Sovereignty
State
Supranational Integration
Territory
Transnationalism
War, Geography of
World-Systems Theory

Social and Cultural Geography

Accessibility
Antiglobalization
Antisystemic Movements
Architecture and Geography

Art and Geography
Automobility
Blindness and Geography
Body, Geography of
Built Environment
Census
Census Tracts
Childhood Spatial and
Environmental Learning
Children, Geography of
Citizenship
Civil Society
Class, Geography and
Communications Geography
Consumption, Geographies of
Crime, Geography of
Cultural Geography
Cultural Landscape
Cyberspace
Demographic Transition
Diaspora
Diffusion
Digital Divide
Disability, Geography of
Distance Decay
Drugs, Geography of
Education, Geographies of
Elderly, Geography and the
Emotions, Geography and
Ethnicity
Ethnic Segregation
Everyday Life, Geography
and
Extreme Geography
Famine, Geography of
Fear, Geographies of
Fertility Rate
Film and Geography
Folk Culture and Geography
Gays and Lesbians, Geography
and/of
Genocide, Geographies of
Geodemographics
Geographical Ignorance
Geographical Imagination
Geography Education
Geomancy
Geophagy
Geoslavery
Hate, Geographies of

Historical Geography
Home
Human Rights, Geography and
Hunger
Identity, Geography and
Immigration
Indigeneity
Inequality and Geography
Justice, Geography of
Languages, Geography
and/of
Law, Geography of
Literature, Geography and
Masculinities and Geography
Media and Geography
Mental Maps
Migration
Mobility
Mortality Rate
Music and Sound,
Geography and
Natural Growth Rate
Nonvisual Geographies
Palimpsest
Patriarchy, Geography and
Photography, Geography and
Pilgrimage
Place Names
Place Promotion
Popular Culture, Geography
and
Population Density
Population Geography
Population Pyramid
Psychoanalysis,
Geography and
Racial Segregation
Refugees
Religion, Geography and
Resistance, Geographies of
Segregation and Geography
Sexuality, Geography and/of
Social Geography
Social Justice
Spatial Cognition
Spatial Cognitive Engineering
Spatial Inequality
Sports, Geography of
Surveillance
Symbolism and Place

Television and Geography
Terrorism, Geography of
Time, Geographies of
Toponymy
Topophilia
Tourism
Travel Writing, Geography and
Vernacular Landscapes as
Expressions of
Environmental Ideas
Video Games, Geography and
Virtual Geographies
Wayfinding
Whiteness
Wine, Geography of

Urban Geography

Commuting
Counterurbanization
Exurbs
Filtering
Gated Community
Gentrification
Ghetto
Growth Machine
Historic Preservation
Homelessness
Housing and Housing
Markets
Housing Policy
Los Angeles School
Metropolitan Area
Neighborhood
New Urbanism
Not in My Backyard
(NIMBY)
Participatory Planning
Primate Cities
Public Housing
Public-Private Partnerships
Public Space
Rank-Size Rule
Rent-Gap
Rural-Urban Migration
Settlement Geography
Smart Growth
Squatter Settlements
Suburban Land Use
Suburbs and Suburbanization

Sunbelt
Sustainable Cities
Township and Range System
Urban and Regional
Development
Urban and Regional Planning
Urban Ecology
Urban Environmental Studies
Urban Gardens
Urban Geography
Urban Green Space
Urban Hierarchy
Urbanization
Urban Land Use
Urban Planning and
Geography
Urban Policy
Urban Spatial Structure
Urban Sprawl
Urban Underclass
World Cities
Zoning

Nature and Society

Agriculture

Agricultural Biotechnology
Agricultural Intensification
Agricultural Land Use
Agriculture, Industrialized
Agriculture, Preindustrial
Agrobiodiversity
Agrochemical Pollution
Agroecology
Agrofoods
Agroforestry
Aquaculture
Bush Fallow Farming
Centers of Domestication
Crop Genetic Diversity
Crop Rotation
Environmental Impacts of
Agriculture
Fish Farming
Genetically Modified
Organisms (GMOs)
Indigenous Agriculture
Marine Aquaculture
Mixed Farming
Organic Agriculture

Shifting Cultivation
Sustainable Agriculture

Environment and People

Adaptive Harvest
Management
Biotechnology and Ecological
Risk
Carrying Capacity
Chipko Movement
Class, Nature and
Corporate Voluntary
Environmental Initiatives
and Self-Regulation
Coupled Human and Animal
Systems
Coupled Human and Natural
Systems
Critical Studies of Nature
Cultural Ecology
Deep Ecology Movements
Deforestation
Desertification
Domestication of Animals
Domestication of Plants
Ecofeminism
Ecological Economics
Ecological Footprint
Ecological Imaginaries
Ecological Justice
Ecological Modernization
Ecological Regimes
Ecological Risk Analysis
Ecological Zones
Ecotourism
Energy Models
Energy Policy
Environmental Certification
Environmental Discourse
Environmental Entitlements
Environmental Ethics
Environmental History
Environmental Imaginaries
Environmental Impact
Assessment
Environmental Impacts of
Cities
Environmental Impacts of
Manufacturing

Environmental Impacts of
Oil Fields
Environmental Impacts of
Pipelines
Environmental Impacts of
Roads
Environmental Impacts of
Tourism
Environmental Impacts of War
Environmental Impact
Statement
Environmental Justice
Environmental Law
Environmental Management
Environmental Management:
Drylands
Environmental Perception
Environmental Planning
Environmental Protection
Environmental Racism
Environmental Refugees
Environmental Restoration
Environmental Rights
Environmental Security
Environmental Services
Environment and
Development
Ethnicity and Nature
Everglades Restoration
Fair Trade and Environmental
Certification
Feminist Environmental
Geographies
Feminist Environmentalism
Feminist Political Ecology
Forest Degradation
Forest Fragmentation
Forest Land Use
Forest Restoration
Game Ranching
Gender and Nature
Global Environmental Change
Human Dimensions of Global
Environmental Change
Human Ecology
Hunting and Gathering
Hybridization of Plant and
Animal Species
Indigenous and Community
Conserved Areas

Indigenous Environmental
Knowledge
Indigenous Environmental
Practices
Indigenous Forestry
Indigenous Reserves
Industrial Ecology
Intergovernmental
Environmental
Organizations and Initiatives
Land Degradation
Land Reform
Landscape Architecture
Landscape Biodiversity
Landscape Design
Landscape Ecology
Landscape Interpretation
Landscape Quality Assessment
Landscape Restoration
Land Tenure
Land Tenure Reform
Land Use
Land Use Analysis
Land Use and Cover Change
(LUCC)
Land Use History
Land Use Planning
Locally Unwanted Land Uses
(LULUs)
Market-Based Environmental
Regulation
Mining and Geography
Multistakeholder Participation
Nature
Nature-Society Theory
Neoliberal Environmental Policy
Neo-Malthusianism
Nomadic Herding
Nomadism
Open Space
Parks and Reserves
Pesticides
Pest Management
Political Ecology
Population and Land
Degradation
Population and Land Use
Population, Environment, and
Development
Prairie Restoration

Race and Nature
Regional Environmental
Planning
Science, Technology, and
Environment
Social and Economic Impacts
of Climate Change
Social Construction of Nature
Social Forestry
Soil Conservation
Soil Degradation
Soil Depletion
Soil Erosion
Suitability Analysis
Sustainability Science
Sustainable Fisheries
Sustainable Forestry
Sustainable Production
Urban Metabolism
Urban Storm Water
Management
Urban Sustainability
Urban Water Supply
Wilderness
Wine Terroir
Wise Use Movement
Xeriscaping

Hazards and Disasters

Avalanches
Bhopal, India, Chemical
Disaster
Chernobyl Nuclear Accident
Coastal Hazards
Differential Vulnerabilities to
Hazards
Disaster Prediction and
Warning
Disaster Preparedness
Drought Risk and Hazard
Flash Floods
Floods
Gender and Environmental
Hazards
Hurricane Katrina
Hurricanes, Risk and Hazard
Landslide
Natural Hazards and Risk
Analysis

Oil Spills
Remote Sensing in Disaster Response
Risk Analysis and Assessment
Three Mile Island Nuclear Accident
Tsunami
Tsunami of 2004, Indian Ocean
Volcanic Eruptions as Risk and Hazard
Vulnerability, Risks, and Hazards
Wildfires: Risk and Hazard

Pollution and Waste

Acid Rain
Ambient Air Quality
Atmospheric Pollution
Brownfields
Chemical Spills, Environment, and Society
Coastal Dead Zones
Coastal Zone and Marine Pollution
Greenhouse Gases
Heavy Metals as Pollutants
Herbicides
Landfills
Love Canal
Nonpoint Sources of Pollution
Photochemical Smog
Point Sources of Pollution
Polychlorinated Biphenyls (PCBs)
Recycling of Municipal Solid Waste
Urban Solid Waste Management
Waste Incineration
Wastewater Management
Water Pollution

Resources and Conservation

Biofuels
Coal
Common Pool Resources
Common Property Resource Management
Commons, Tragedy of the

Community-Based Conservation
Community-Based Environmental Planning
Community-Based Natural Resource Management
Community Forestry
Conservation
Conservation Zoning
Distribution of Resource Access
Energy Resources
Extractive Reserves
Geothermal Energy
Governmentality and Conservation
Greenbelts
Green Building
Green Design and Development
Hydroelectric Power
Landscape and Wildlife Conservation
Nonrenewable Resources
Nuclear Energy
Open-Pit Mining
Patches and Corridors in Wildlife Conservation
Petroleum
Political Economy of Resources
Renewable Resources
Resource Economics
Resource Geography
Resource Management, Decision Models in
Resource Tenure
Spatial Strategies of Conservation
Strip Mining
Timber Plantations
Tree Farming
Wind Energy
Woodfuel

Water

Indigenous Water Management
International Watershed Management
Public Water Services

Water Degradation
Water Management and Treatment
Water Needs
Watershed Management
Watershed Yield
Water Supply Siting and Management

Methods, Models, and GIS

Cartography

Altitude
Argumentation Maps
Cadastral Systems
Cartograms
Cartography
Choropleth Maps
Color in Map Design
Coordinate Geometry
Coordinate Systems
Coordinate Transformations
Countermapping
Dasymetric Maps
Data Classification Schemes
Datums
Dot Density Maps
Earth's Coordinate Grid
Ecological Mapping
Electronic Atlases
Environmental Mapping
Equator
Flow Maps
Gazetteers
Geodesy
Geolibraries
Geometric Correction
Geometric Measures
Indigenous Cartographies
Isopleth Maps
Land Use and Land Cover Mapping
Latitude
Longitude
Map Algebra
Map Animation
Map Design
Map Evaluation and Testing
Map Generalization
Map Projections

Map Visualization
Multimedia Mapping
Multivariate Mapping
Participatory Mapping
Poles, North and South
Portolan Charts
Resource Mapping
Self-Organizing Maps
Surveying
Trap Streets
Typography in Map Design
Virtual Globes
Voronoi Diagrams

GIS

Analytical Operations in GIS
Business Models for Geographic Information Systems
CAD Systems
Cellular Automata
Client-Server Architecture
Collaborative GIS
Conflation
Critical GIS
Database Management Systems
Database Versioning
Data Compression Methods
Data Editing
Data Format Conversion
Data Indexing
Data Querying in GIS
Digital Terrain Model
Digitizing
Distributed Computing
Dynamic and Interactive Displays
Enterprise GIS
Error Propagation
Exploratory Spatial Data Analysis
Geocoding
Geocollaboration
Geocomputation
Geographic Information Systems
Geospatial Semantic Web
GIS, Environmental Model Integration and
GIScience
GIS Design

GIS Implementation
GIS in Archaeology
GIS in Disaster Response
GIS in Environmental Management
GIS in Health Research and Health Care
GIS in Land Use Management
GIS in Local Government
GIS in Public Policy
GIS in Transportation
GIS in Urban Planning
GIS in Utilities
GIS in Water Management
GIS Software
GIS Web Services
Global Positioning System
Google Earth
Ground Reference Data
Heuristic Methods in Spatial Analysis
High-Performance Computing
Humanistic GIScience
Internet GIS
Interoperability and Spatial Data Standards
Legal Aspects of Geospatial Information
Linear Referencing and Dynamic Segmentation
Location-Based Services
Metadata
Mobile GIS
Neogeography
Network Analysis
Network Data Model
Ontological Foundations of Geographical Data
Open Geodata Standards
Open Source GIS
Privacy and Security of Geospatial Information
Public Participation GIS
Scale in GIS
Semantic Interoperability
Semantic Reference Systems
Spatial Data Infrastructures
Spatial Data Integration
Spatial Data Mining
Spatial Data Models

Spatial Data Structures
Spatial Decision Support Systems
Spatialization
Supervised Classification
Temporal GIS
Temporal Resolution
Terrain Analysis
Three-Dimensional Data Models
Topological Relationships
Triangulated Irregular Network (TIN) Data Model
Unsupervised Classification
Usability of Geospatial Information
Vagueness in Spatial Data
Vectorization
Viewshed Analysis
Virtual and Immersive Environments
Web Geoprocessing Workflows
Web Service Architectures for GIS

Qualitative Techniques

Fieldwork in Human Geography
Interviewing
Participant Observation
Participatory Learning and Action
Participatory Rural Appraisal
Positionality
Qualitative Methods
Writing

Quantitative Models

Agent-Based Models
Bayesian Statistics in Spatial Analysis
Ecological Fallacy
Fieldwork in Physical Geography
Geographically Weighted Regression

Geostatistics
Location-Allocation Modeling
Location Quotients
Modifiable Areal Unit Problem
Multivariate Analysis Methods
Point Pattern Analysis
Quantitative Methods
Shortest-Path Problem
Spatial Analysis
Spatial Autocorrelation
Spatial Econometrics
Spatial Interaction Models
Spatial Interpolation
Spatial Multicriteria
 Evaluation
Spatial Optimization Methods
Spatial Statistics

Remote Sensing

Aerial Imagery: Data
Aerial Imagery: Interpretation
Atmospheric Remote Sensing
Biophysical Remote Sensing
Energy and Human Ecology
Geosensor Networks
Image Enhancement
Image Fusion
Image Interpretation
Image Processing
Image Registration
Image Texture
Imaging Spectroscopy
LiDAR and Airborne Laser
 Scanning
Microwave/RADAR Data
Multispectral Imagery
Multitemporal Imaging
Object-Based Image Analysis
Panchromatic Imagery
Photogrammetric Methods
Radiometric Correction
Radiometric Normalization
Radiometric Resolution
Remote Sensing
Remote Sensing: Platforms and
 Sensors
Spatial Resolution
Spectral Characteristics of
 Terrestrial Surfaces

Spectral Resolution
Spectral Transformations
Stereoscopy and
 Orthoimagery
Thermal Imagery

History of Geography

Annales School
Anthropogeography
Antipodes
Berkeley School
Biblical Mapping
Cartography, History of
Chicago School
Chorology
Darwinism and Geography
Enlightenment
Environmental Determinism
Exploration
GIS, History of
Human Geography, History
 of
Lewis and Clark Expedition
Modernity
Physical Geography, History
 of
Quantitative Revolution
Race and Empire
Sequent Occupance
Social Darwinism
T-in-O Maps

People, Organizations, and Movements

Biographies

Abler, Ronald
Agamben, Giorgio
Agnew, John
al-Idrisi
Anaximander
Anselin, Luc
Antevis, Ernst
Aristotle
Armstrong, Marc
Barrows, Harlan
Batty, Michael
Berry, Brian
Biruni

Blaikie, Piers
Blaut, James
Bourghassi, Carmina
Bowman, Isaiah
Bunge, William
Buttimer, Anne
Câmara, Gilberto
Castells, Manuel
Chorley, Richard
Chrisman, Nicholas
Christaller, Walter
Clark, Andrew
Clark, William
Columbus, Christopher
Cook, Captain James
Cosgrove, Denis
Dangermond, Jack
Darby, Henry Clifford
Davis, William Morris
Dear, Michael
Dendrochronology
Desert Varnish
Diamond, Jared
Earle, Carville
Eastman, Ronald
Egenhofer, Max
Eratosthenes
Febvre, Lucien
Fisher, Peter
Fotheringham, A. Stewart
Frank, Andrew
Gama, Vasco da
Getis, Arthur
Giddens, Anthony
Gilbert, Grove Karl
Golledge, Reginald
Goodchild, Michael
Goode, J. Paul
Gottmann, Jean
Gould, Peter
Gregory, Derek
Guyot, Arnold
Hägerstrand, Torsten
Haggett, Peter
Hanson, Susan
Harley, Brian
Hartshorne, Richard
Harvey, David
Haushofer, Karl
Hayden, Ferdinand

Herodotus
Hettner, Alfred
Hipparchus
Hou Renzhi
Hoyt, Homer
Humboldt, Alexander von
Huntington, Ellsworth
Ibn Battuta
Ibn Khaldūn
Isard, Walter
Jackson, John Brinckerhoff
Jefferson, Thomas
Johnston, R. J.
Kant, Immanuel
Kates, Robert
Köppen, Wladimir
Kropotkin, Peter
Kuhn, Werner
Kwan, Mei-Po
Lefebvre, Henri
Lewis, Peirce
Ley, David
Lillesand, Thomas
Livingstone, David
Lösch, August
Lynch, William
MacEachren, Alan
Mackinder, Sir Halford
Magellan, Ferdinand
Mahan, Alfred Thayer
Marcus, Melvin G.
Mark, David M.
Marsh, George Perkins
Massey, Doreen
Mather, John Russell
Maury, Matthew Fontaine
McKnight, Tom L.
Meinig, Donald
Mercator, Gerardus
Miller, Harvey J.
Mitchell, Don
Monmonier, Mark
Morrill, Richard
Morse, Jedediah
Nyerges, Timothy
Okabe, Atsuyuki
Olsson, Gunnar
Ortelius
Parsons, James
Peet, Richard

Penck, Walther
Peuquet, Donna
Pickles, John
Powell, John Wesley
Pred, Allan
Ptolemy
Raisz, Erwin
Ratzel, Friedrich
Reclus, Élisée
Relph, Edward
Ritter, Carl
Rose, Gillian
Sauer, Carl
Schaefer, Fred
Scott, Allen
Semple, Ellen Churchill
Smith, Neil
Soja, Edward
Storper, Michael
Strabo
Strahler, Arthur
Sui, Daniel
Taylor, Griffith
Taylor, Peter
Thales
Thornthwaite, C. Warren
Thrift, Nigel
Tobler, Waldo
Tomlinson, Roger
Trewartha, Glenn
Troll, Carl
Tuan, Yi-Fu
Turner, Billie Lee, II
Unwin, David
Vance, James
Varenus
Vidal de la Blache, Paul
Virilio, Paul
Waldseemüller, Martin
Walker, Richard
Watts, Michael
Weber, Alfred
White, Gilbert
Whittlesey, Derwent
Wilson, John
Wittfogel, Karl
Wood, Denis
Wright, Dawn
Wright, John Kirtland
Zelinsky, Wilbur

Geographical Organizations

American Geographical Society
Association of American Geographers
Association of Geographic Information Laboratories for Europe
Canadian Association of Geographers
Conference of Latin Americanist Geographers
Institute of British Geographers
International Geographical Union
National Center for Geographic Information and Analysis
National Council for Geographic Education
National Geographic Society
Open Geospatial Consortium (OGC)
Open Source Geospatial Foundation
Regional Science Association International (RSAI)
Royal Geographical Society
Russian Geographical Society
University Consortium for Geographic Information Science

Political and Economic Organizations

African Union
Asia-Pacific Economic Cooperation
Association of Southeast Asian Nations
Commonwealth of Independent States
Council for Mutual Economic Assistance (COMECON)
European Union
Food and Agriculture Organization (FAO)
International Criminal Court
International Monetary Fund

National Aeronautics and
Space Administration
(NASA)
North American Free Trade
Agreement (NAFTA)
North Atlantic Treaty
Organization (NATO)
Organisation for Economic
Co-operation and
Development (OECD)
Organization of the Petroleum
Exporting Countries (OPEC)
United Nations
World Bank
World Court
World Trade Organization
(WTO)

Scientific Organizations

United Nations Conference on
Environment and
Development
United Nations Environmental
Summits
United Nations Environment
Programme (UNEP)
United States Census Bureau
United States Geological
Survey (USGS)
World Health Organization
(WHO)
World Summit on Sustainable
Development

Social Movements

Antisystemic Movements
Chipko Movement
Deep Ecology Movements
European Green Movements
International Environmental
Movements
International Environmental
NGOs
Movimento Sem Terra
Nongovernmental
Organizations (NGOs)
Not in My Backyard (NIMBY)
Social Movements
Via Campesina (International
Farmers' Movement)

ABOUT THE EDITOR

Barney Warf is a professor of geography at the University of Kansas. His research and teaching interests lie within the broad domain of human geography. Much of his career effort concerns economic geography, with an emphasis on producer services and telecommunications. His work straddles contemporary political economy and social theory on the one hand and traditional quantitative, empirical approaches on the other. He has studied, among other things, New York as a global city, telecommunications, offshore banking, international networks of financial and producer services, and the geographies of the Internet. He has also written on military spending, voting technologies, the U.S. Electoral College, and religious diversity in different national contexts. He has coauthored or coedited 6 books, including 2 textbooks, 35 book chapters, and 90 refereed journal articles. He has

served or serves on the editorial boards of *Geographical Review*, *Annals of the Association of American Geographers*, *Growth and Change*, *The Professional Geographer*, *Urban Geography*, *International Regional Science Review*, and *Geografiska Annaler*. His articles have appeared in the *Annals*, *The Professional Geographer*, *Economic Geography*, *Urban Geography*, *Political Geography*, *Geographical Review*, *Regional Studies*, *Urban Studies*, *Tijdschrift voor Economische en Sociale Geografie*, *International Regional Science Review*, *Transactions of the Institute of British Geographers*, *Area*, *The Southeastern Geographer*, *Environment and Planning A and D*, and *Journal of Geography*. His teaching interests include urban and economic geography, the history of geography, globalization, social theory, and East Asia. This is the second encyclopedia he has edited.

CONTRIBUTORS

Scott R. Abella
*University of Nevada,
Las Vegas*

Yohannes Aberra
Addis Ababa University

Damian Absalon
University of Silesia

Michael Adams
University of Wollongong

Fenda Aminata Akiwumi
University of South Florida

Todd H. Albert
Bowling Green State University

Jochen Albrecht
Hunter College CUNY

Josep Antoni Alcover
*Institut Mediterrani d'Estudis
Avançats (CSIC-UIB)*

Derek H. Alderman
East Carolina University

Jared Aldstadt
*State University of New York
at Buffalo*

David E. Alexander
University of Florence

Melinda Alexander
Arizona State University

Saleem H. Ali
University of Vermont

John All
*Human Environment Linkages
Program*

John Logan Allen
University of Wyoming

Scott Anderson
*State University of New York
at Cortland*

Sharolyn Anderson
University of Denver

Gennady Andrienko
Fraunhofer Institute IAIS

Natalia Andrienko
Fraunhofer Institute IAIS

Yuko Aoyama
Clark University

Seth Appiah-Opoku
University of Alabama

J. Clark Archer
University of Nebraska–Lincoln

Kevin Archer
University of South Florida

Santa Arias
University of Kansas

Richard Peter Armitage
University of Salford

Michael Christopher
Armstrong
DePaul University

David L. Arnold
Frostburg State University

Jennifer S. Arrigo
East Carolina University

R. Rochelle Arrington
Florida State University

Yasushi Asami
University of Tokyo

Bjørn Asheim
Lund University

Walker S. Ashley
Northern Illinois University

Genevieve Atwood
University of Utah

Ivonne Audirac
Florida State University

Louis Awanyo
*Luther College, University of
Regina*

Rikke Baastrup
Danish Cancer Society

Andrew J. Bach
*Western Washington
University*

Sharmistha Bagchi-Sen
*State University of New York
at Buffalo*

John E. Bailey
University of Alaska

Keiron Bailey
University of Arizona

Mark Ian Bailey
*University of Newcastle upon
Tyne*

Robert G. Bailey
USDA Forest Service

Robert Bailis
Yale University

Earl J. Baker
Florida State University

John Richard Bale
Keele University

Shivanand Balram
Simon Fraser University

Greg J. Bamber
Griffith University

Abhijit Banerjee
*Northeastern Illinois
University*

Aniruddha Banerjee
*Indiana University–Purdue
University Indianapolis*

Kezia Barker
*Birkbeck University
of London*

Justin R. Barnes
North Carolina Solar Center

Trevor J. Barnes
University of British Columbia

Clive Barnett
Open University

Keith Barney
York University

Stewart Barr
University of Exeter

Roger G. Barry
University of Colorado

Bipasha Baruah
*California State University,
Long Beach*

S. Willis Bassett
Florida State University

Pratyusha Basu
University of South Florida

Ranu Basu
York University

Dean Bavington
Nipissing University

Jamie Baxter
University of Western Ontario

Ryan E. Baxter
Pennsylvania State University

Kate Beard-Tisdale
University of Maine

Hartmut Behr
Newcastle University

Matthew F. Bekker
Brigham Young University

Scott Bell
University of Saskatchewan

Thomas L. Bell
University of Tennessee

Karina Benessaiah
McGill University

Lawrence D. Berg
*University of British
Columbia*

Susan Bergeron
West Virginia University

Richelle M. Bernazzoli
*University of Illinois at
Urbana-Champaign*

Ruggero Bertani
Enel

Nicholas L. Betts
Queen's University Belfast

Kirsten M. M. Beyer
University of Iowa

William Beyers
University of Washington

Keshav Bhattarai
University of Central Missouri

Ling Bian
University at Buffalo

Jess Bier
*City University of New York,
Graduate Center*

Phil Birge-Liberman
Syracuse University

Mark D. Bjelland
Gustavus Adolphus College

Chris Blackden
University of Kentucky

Stefano Bloch
University of Minnesota

Andrew Blohm
University of Maryland

Talja Blokland
*Institut für
Sozialwissenschaften*

Darcy Boellstorff
Bridgewater State College

Hans-Georg Bohle
University of Bonn, Germany

Gregory S. Bohr
*California Polytechnic
State University, San Luis
Obispo*

Lowe Börjeson
Stockholm University

Saturnino M. Borrás Jr.
*Erasmus University
Rotterdam*

Keith Bosak
University of Montana

Fernando Javier Bosco
San Diego State University

Pablo Bose
University of Vermont

Brian H. Bossak
Georgia Southern University

Pere Bover
*Institut Mediterrani d'Estudis
Avançats (CSIC-UIB)*

Dawn S. Bowen
*University of Mary
Washington*

John Bowen
Central Washington University

Mark W. Bowen
University of Kansas

Ben Bradshaw
University of Guelph

Richard R. Brandt
Salem State College

Anthony J. Brazel
Arizona State University

Leah Bremer
*San Diego State University/
University of California,
Santa Barbara*

Amanda DeeAnn Briney
*California State University,
East Bay*

Ray Bromley
University at Albany, SUNY

John O. Browder
*Virginia Polytechnic Institute
and State University*

Dwight A. Brown
University of Minnesota

Marilyn A. Brown
*Georgia Institute of
Technology*

Michael Brown
University of Washington

Alec Brownlow
DePaul University

Joe Bryan
*University of Colorado,
Boulder*

Karin Bryan
University of Waikato

William R. Buckingham
*University of Wisconsin at
Madison*

Michaela Buenemann
New Mexico State University

Rebecca Burnett
University of Washington

Amy C. Burnicki
University of Wisconsin

Jeffrey Bury
*University of California,
Santa Cruz*

Jason Byrne
Griffith University

John Byrne
University of Delaware

Maria Caffrey
University of Tennessee

David A. Call
Ball State University

Angus Cameron
University of Leicester

Harrison S. Campbell Jr.
*University of North Carolina
at Charlotte*

Étienne Cantin
Université Laval

Huhua Cao
University of Ottawa

Andrew M. Carleton
Pennsylvania State University

David L. Carr
*University of California,
Santa Barbara*

John I. Carruthers
*U.S. Department of Housing
and Urban Development*

Eric D. Carter
Grinnell College

Jennifer L. Carter
*University of the Sunshine
Coast*

Norman Carter
San Diego State University

Guillermo Castilla
University of Calgary

Noel Castree
Manchester University

Brian Ceh
Ryerson University

Ryan Centner
Tufts University

Jayajit Chakraborty
University of South Florida

Charlotte N. L. Chambers
Otago University

Kang-Tsung (Karl) Chang
Kainan University

Thomas Chapman
Old Dominion University

Igal Charney
University of Haifa

Omair Chaudhry
Ordnance Survey

Deborah Che
Independent Scholar

DongMei Chen
Queen's University

Jin Chen
Pennsylvania State University

Nalini Chhetri
Arizona State University

Netra B. Chhetri
Arizona State University

Timothy M. Chowns
University of West Georgia

Nicholas Chrisman
Université Laval

George Christakos
San Diego State University

Torben R. Christensen
Lund University

Brett Christophers
Uppsala University

Robert W. Christopherson
*American River College/
Geosystems*

Julie Cidell
University of Illinois

Eric Clark
Lund University

Jennifer Clark
*Georgia Institute of
Technology*

Abigail R. Clarke-Sather
*Michigan Technological
University*

Sebastian Cobarrubias
University of North Carolina

Sharon C. Cobb
University of North Florida

Craig A. Coburn
University of Lethbridge

David M. Cochran Jr.
*University of Southern
Mississippi*

Alisa W. Coffin
U.S. Geological Survey

David Cohen
*Indiana University of
Pennsylvania*

Kim M. Cohen
Utrecht University

Jill S. M. Coleman
Ball State University

Ashley R. Coles
University of Arizona

Elizabeth R. Congdon
Georgia Southern University

Heather Congdon Fors
University of Gothenburg

Jamison Conley
Pennsylvania State University

Dennis Conway
Indiana University

Michael P. Conzen
University of Chicago

Karen S. Cook
University of Kansas

Jon Corbett
*University of British
Columbia–Okanagan*

Dov Corenblit
King's College London

Marci Cottingham
*Indiana University of
Pennsylvania*

Lloyd L. Coulter
San Diego State University

Rosie Cox
*Birkbeck, University of
London*

James Craine
*California State University,
Northridge*

Valorie A. Crooks
Simon Fraser University

John A. Cross
*University of
Wisconsin–Oshkosh*

Sean M. Crotty
San Diego State University

Jeff R. Crump
University of Minnesota

Karen Culcasi
West Virginia University

Julie Cupples
University of Canterbury

Judd Michael Curran
Grossmont College

Giorgio Hadi Curti
San Diego State University

Kevin M. Curtin
George Mason University

Scott Curtis
East Carolina University

Donald C. Dahmann
*George Washington
University*

Peter H. Dana
University of Texas at Austin

Raju J. Das
York University

Conny Davidsen
University of Calgary

Fiona M. Davidson
University of Arkansas

Joyce Davidson
Queen's University

Jason Davis
*University of California,
Santa Barbara*

Alastair Dawson
*Aberdeen Institute for
Coastal Science and
Management*

Shari Daya
University of Cape Town

Anthony P. D'Costa
Asia Research Centre

Mark de Socio
Salisbury University

Keith G. Debbage
*University of North
Carolina–Greensboro*

Eric Delmelle
*University of Charlotte, North
Carolina*

Urška Demšar
*National University of Ireland,
Maynooth*

Hannes Dempewolf
University of British Columbia

Mary Dengler
*Royal Holloway, University
of London*

Elizabeth R. DeSombre
Wellesley College

Pierre Desrochers
University of Toronto
Mississauga

Pauline Deutz
University of Hull

Boris Dev
San Diego State University

Raymond J. Dezzani
University of Idaho

Jose R. Diaz-Garayua
Kent State University

Jacqui Dibden
Monash University

Jason Dittmer
University College London

Jerome E. Dobson
University of Kansas

Katarina Doctor
George Mason University

Klaus Dodds
Royal Holloway

William Donner
Indiana University of
Pennsylvania

Richard Donohue
University of
Wisconsin–Madison

Ronald I. Dorn
Arizona State University

Percy H. Dougherty
Lehigh County/Kutztown
University

Ian Douglas
University of Manchester

Victoria S. Downey
University of Minnesota

Joni A. Downs
University of South Florida

Suzana Dragicevic
Simon Fraser University

Christine Drennon
Trinity University

Jiunn-Der Duh
Portland State University

Robert A. Dull
University of Texas at Austin

Michael Dunford
University of Sussex

Cheryl Morse Dunkley
University of Vermont

Jeffrey Dunn
University of Connecticut

Leslie A. Duram
Southern Illinois University

Joshua D. Durkee
Western Kentucky University

Chris S. Duvall
University of New Mexico

Mark J. Dwyer
University of Cambridge

Robert Edsall
University of Minnesota

Stephen L. Egbert
University of Kansas

Patricia Ehrkamp
University of Kentucky

Kajsa Ellegård
Linköping University

Deborah L. Elliott-Fisk
University of California, Davis

Jean T. Ellis
University of Southern
California

James B. Elsner
Florida State University

Michael Emch
University of North Carolina
at Chapel Hill

Ewald Engelen
University of Amsterdam

Dirk Enters
Universität Bremen

Stefan Erasmí
University of Goettingen

Christine Eriksen
University of Wollongong

Tahire Erman
Bilkent University

Veronica Escamilla
University of North Carolina
at Chapel Hill

Jamey Essex
University of Windsor

Jürgen Essletzbichler
University College, London

Lawrence E. Estaville
Texas State University

Andres Etter
Javeriana University

Frances Fahy
National University of Ireland,
Galway

Juliet J. Fall
Université de Genève

Carol Farbotko
University of Tasmania

Kathleen A. Farley
San Diego State University

David Featherstone
University of Glasgow

Tobias Federwisch
Friedrich-Schiller–Universität
Jena

Robert Feick
University of Waterloo

Michael P. Ferber
King's University College

Dinali Nelun Fernando
Rutgers University

Carlos Ferras
University of Santiago de Compostela

Peter F. Ffolliott
University of Arizona

Richard Field
University of Nottingham

Brian L. Finlayson
University of Melbourne

Manfred M. Fischer
Vienna University of Economics and Business

Peter Fisher
University of Leicester

Robin Flowerdew
University of St. Andrews

Steven Flusty
York University

Emily A. Fogarty
Suffolk County Community College

Kenneth Foote
University of Colorado at Boulder

Timothy W. Foresman
Johnson, Mirmiran & Thompson, Inc.

Benjamin Forest
McGill University

Jennifer Forkes
University of Toronto

A. Stewart Fotheringham
National University of Ireland, Maynooth

Witold Fraczek
ESRI

Grant Fraley
San Diego State University

Richard V. Francaviglia
University of Texas at Arlington

Benjamin Fraser
Christopher Newport University

James Freeman
Concordia University

Lisa M. Freeman
University of Toronto

Hugh M. French
University of Ottawa

Kenneth French
University of Wisconsin–Parkside

Karen E. Frey
Clark University

Anders Friis-Christensen
Joint Research Center, Aalborg University

Joy A. Fritschle
West Chester University

Patricia Frontiera
San Francisco Estuary Institute

Christopher M. Fuhrmann
University of North Carolina

Jayson J. Funke
Clark University

Maia Gachechiladze
Central European University

Karsten Gaebler
Friedrich-Schiller–University Jena

Stefan Gaertner
Institute for Work and Technology

Jennifer L. Gagnon
Virginia Tech

J. C. Gaillard
University of Grenoble

Francis A. Galgano
Villanova University

Nikolaos Galiatsatos
Durham University

Nick Gallent
University College London

Ryan E. Galt
University of California, Davis

Julia A. Gamas
U.S. Environmental Protection Agency

Peng Gao
Syracuse University

Isabel-María García-Sánchez
University of Salamanca

Rita Gardner
Royal Geographical Society and Institute of British Geographers

Gregg M. Garfin
University of Arizona

Rebecca R. Gasper
University of Maryland

Roland Gehrels
University of Plymouth

Jonathan Henry Geisler
Georgia Southern University

Christian Geißler
Universität Tübingen

Paul Gepts
University of California, Davis

Peter Gething
University of Oxford

Gennady Gienko
University of the South Pacific, Fiji

Alan Gilbert
University College London

Aaron Gilbreath
University of Kansas

Robert Welch Gillespie
Population Communication

Thomas Gillespie
*University of California,
Los Angeles*

Jessey Gilley
University of Kansas

Mark Giordano
*International Water
Management Institute*

François Girard
CEMAGREF

Sonya Glavac
*University of New England,
Australia*

Brian J. Godfrey
Vassar College

Joseph Godlewski
*University of California,
Berkeley*

Christopher Malcolm Gold
University of Glamorgan

Daniel W. Goldberg
*University of Southern
California*

Dominic Golding
Worcester Polytechnic Institute

Michael F. Goodchild
*University of California,
Santa Barbara*

Hugh S. Gorman
*Michigan Technological
University*

Alan Grainger
University of Leeds

Dennis Grammenos
*Northeastern Illinois
University*

Nicholas Gray
University College London

Michael R. Greenberg
Rutgers University

Richard P. Greene
Northern Illinois University

Nicholas Grenier
*University of Nevada,
Las Vegas*

William J. Gribb
University of Wyoming

Carl J. Griffin
Queen's University, Belfast

Liza Griffin
University of Westminster

Daniel A. Griffith
University of Texas at Dallas

John R. Grimes
Eastern Kentucky University

Karl Grossner
*University of California,
Santa Barbara*

Diansheng Guo
University of South Carolina

Barry Haack
George Mason University

Karl R. Haapala
*Michigan Technological
University*

Joshua Hagen
Marshall University

Chris Hagerman
Portland State University

Euan Hague
DePaul University

Martin J. Haigh
University of Chicago

David Hall
University of Greenwich

Sarah J. Halvorson
University of Montana

Jeffrey D. Hamerlinck
University of Wyoming

Dean M. Hanink
University of Connecticut

Kathy Hansen Crawford
Montana State University

Paul E. Hardwick
*San Diego State
University Research
Foundation*

James W. Harrington Jr.
University of Washington

Richard Harris
McMaster University

Trevor M. Harris
West Virginia University

John Harrison
Loughborough University

Francis J. Harvey
University of Minnesota

David Havlick
*University of
Colorado–Colorado
Springs*

Kingsley E. Haynes
George Mason University

John W. Hearne
*Royal Melbourne Institute of
Technology*

Brent Hecht
Northwestern University

C. Patrick Heidkamp
*Southern Connecticut State
University*

Michael K. Heiman
Dickinson College

Carola Hein
Bryn Mawr College

Eileen H. Helmer
USDA Forest Service

Sabine Henning
*United Nations, Population
Division*

Jeffrey W. Henquinet
*Michigan Technological
University*

John Heppen
University of Wisconsin–River Falls

Martin Herold
Global Observation for Forest and Land Cover Dynamics

Darrel Hess
City College of San Francisco

Amy E. Hessler
West Virginia University

Nina Hewitt
York University

Miriam Helen Hill
Jacksonville State University

Tobin Hindle
Florida Atlantic University

William Hipwell
Victoria University of Wellington

Kyle R. Hodder
University of Regina

Briavel Holcomb
Rutgers University

Meg Holden
Simon Fraser University

William N. Holden
University of Calgary

Peter J. Holmes
University of the Free State

Mark W. Horner
Florida State University

Peter Hossler
University of Georgia

Chris Houser
Texas A&M University

Serin D. Houston
Syracuse University

Thomas Frederick Howard
Armstrong Atlantic State University

Richard Howitt
Macquarie University

Shunfu Hu
Southern Illinois University, Edwardsville

Matthew T. Huber
Clark University

Matthew B. Hufford
University of California, Davis

Christopher Hugenholtz
University of Lethbridge

Peter J. Hugill
Texas A&M University

Hilary Hungerford
University of Kansas

Thomas A. Hutton
Centre for Human Settlements, Vancouver

Niem Tu Huynh
Texas State University–San Marcos

Sungsoon Hwang
DePaul University

Kevin Hyde
University of Montana

Jennifer Hyndman
Syracuse University

Jonathan Iliffe
University College London

Jungho Im
SUNY College of Environmental Science and Forestry

Moshe Inbar
University of Haifa

Jack D. Ives
Carleton University

Andrés D. Izeta
Consejo Nacional de Investigaciones Científicas y Técnicas

Mark Jackson
University of Bristol

Trish Jackson
University of Kansas

R. Daniel Jacobson
University of Calgary

Donald G. Janelle
University of California, Santa Barbara

Marta Jankowska
San Diego State University

Piotr Jankowski
San Diego State University

Krzysztof Janowicz
University of Muenster

Helen Jarvis
Newcastle University

Timothy L. Jenkins
Michigan Technological University

Ryan R. Jensen
Brigham Young University

Erika S. Jermé
University of Toronto

Jason Bryan Jindrich
Brown University

Scott Jiusto
Worcester Polytechnic Institute

Pascale Joassart-Marcelli
San Diego State University

Ola Johansson
University of Pittsburgh at Johnstown

Jennifer Johns
University of Liverpool

Corey M. Johnson
University of North Carolina–Greensboro

Diana N. Johnson
Geosciences Consultants

Donald L. Johnson
University of Illinois

Douglas L. Johnson
Clark University

Jay T. Johnson
University of Kansas

Merrill Johnson
University of New Orleans

Nicholas H. Johnson
*Michigan Technological
University*

Timothy Lawrence Johnson
*U.S. Environmental Protection
Agency*

William C. Johnson
University of Kansas

Zachary Forest Johnson
University of Texas

Ron Johnston
University of Bristol

Andrew E. G. Jonas
University of Hull

David Jordhus-Lier
University of Manchester

Gabriel Judkins
Arizona State University

Patricia Julio-Miranda
*Universidad Autónoma de
San Luis Potosí*

Jaan-Henrik Kain
*Chalmers University of
Technology*

Ronald V. Kalafsky
University of Tennessee

Ezekiel Kalipeni
*University of Illinois at
Urbana-Champaign*

Nagaraj Kanala
Ohio State University

Pavlos Kanaroglou
McMaster University

Kristin Kane
Global Footprint Network

David H. Kaplan
Kent State University

Hassan A. Karimi
University of Pittsburgh

Aharon Kellerman
University of Haifa

John Kelly
University of Kansas

Ilan Kelman
*Center for International
Climate and Environmental
Research, Oslo*

Thomas Kemeny
*University of California, Los
Angeles*

Paul S. Kench
University of Auckland

Dylan Keon
Oregon State University

Thembele Kepe
University of Toronto

Carsten Keßler
University of Münster

Lisa Keys-Mathews
University of North Alabama

Lawrence Morara Kiage
Georgia State University

Changjoo Kim
University of Cincinnati

Daehyun Kim
Texas A&M University

Richard Kingston
University of Manchester

Scott Kirsch
University of North Carolina

Danielson R. Kisanga
Miami University Middletown

Erik Kjems
Aalborg University

Dorothea Kleine
*Royal Holloway, University of
London*

Alexander Klippel
Pennsylvania State University

Dan Klooster
University of Redlands

Gerrit Jan Knaap
University of Maryland

Lawrence Knopp
*University of Washington,
Tacoma*

Audrey Kobayashi
Queen's University

Julia Koschinsky
Arizona State University

John Kostelnick
Illinois State University

Ashish Kothari
Kalpavriksh

Kraig H. Kraft
University of California, Davis

Barry Kronenfeld
George Mason University

Rob J. Krueger
Worcester Polytechnic Institute

Richard Kujawa
St. Michael's College

Lado Kurdgelashvili
University of Delaware

Hiroyuki Kusaka
University of Tsukuba

Kristopher Kuzera
San Diego State University

Reginald Yin-Wang Kwok
University of Hawaii at Manoa

Derrick Yuk Fo Lai
McGill University

Jennifer S. Lalley
*University of the
Witwatersrand*

Marcus B. Lane
*Commonwealth Scientific
and Industrial Research
Organisation, Australia*

Ruth Lane
*Royal Melbourne Institute of
Technology*

Andrei G. Lapenas
University at Albany

Soren C. Larsen
University of Missouri

Stephen S. Y. Lau
University of Hong Kong

Ian T. Lawson
University of Leeds

Yves-François Le Lay
*National Center for
Scientific Research,
University of Lyon*

James L. LeBeau
*Southern Illinois University
Carbondale*

Valerie Ledwith
*National University of
Ireland, Galway*

Jonathan Leib
Old Dominion University

Robin M. Leichenko
Rutgers University

Walter Leimgruber
University of Fribourg

Michael Leitner
Louisiana State University

Dave Lemberg
Western Michigan University

Jonathan D. Lepofsky
Independent Scholar

Samuli Leppälä
Turku School of Economics

Deborah Leslie
University of Toronto

Agnieszka Leszczynski
University of Washington

Shawn Lewers
Florida State University

Laura R. Lewis
*University of Maryland,
Baltimore County*

Martin W. Lewis
Stanford University

Selma Lewis
University of Maryland

Mei-Hui Li
National Taiwan University

Wei Li
Arizona State University

Xingong Li
University of Kansas

Zhilin Li
*Hong Kong Polytechnic
University*

Johan Liebens
University of West Florida

Joshua Lieberman
Traverse Technologies

Arika Ligmann-Zielinska
Michigan State University

Yangrong Ling
*National Oceanic and
Atmospheric Administration*

Christopher D. Lippitt
San Diego State University

Lisa Jordan
Florida State University

Emanuele Lobina
University of Greenwich

Tatiana Loboda
University of Maryland

Gary Lock
Oxford University

Mahtab A. Lodhi
University of New Orleans

Alex Loftus
*Royal Holloway, University of
London*

Paul A. Longley
University College London

Anna Carla Lopez
San Diego State University

Andrew Lothian
Scenic Solutions

Alexander Malcolm Lovell
Queen's University

Chris Lukinbeal
University of Arizona

Jan Lundqvist
Stockholm University, Sweden

Jennifer K. Lynes
University of Waterloo

William S. Lynn
Williams College

Kin M. Ma
Grand Valley State University

Juliana A. Maantay
*Lehman College, City
University of New York*

Neil Macdonald
University of Liverpool

William Mackaness
University of Edinburgh

Virginia W. MacLaren
University of Toronto

Phil Macnaghten
Durham University

Alan D. MacPherson
University at Buffalo

Yahia Mahmoud
Lund University

Minelle Mahtani
University of Toronto

Philippe Maillard
*Universidade Federal de
Minas Gerais*

Jacek Malczewski
University of Western Ontario

Melissa L. Malin
Northland College

Julia Mambo
*University of the
Witwatersrand*

Charles Manyara
Radford University

Everisto Mapedza
*International Water
Management Institute*

Jennifer Mapes
*University of Southern
California*

Hug March Corbella
*Universitat Autònoma de
Barcelona*

W. Andrew Marcus
University of Oregon

Bryan G. Mark
Ohio State University

Philip M. Marren
University of Melbourne

Stuart E. Marsh
University of Arizona

Lisa Marshall
*University of North
Carolina—Chapel Hill*

Richard A. Marston
Kansas State University

Robert J. Mason
Temple University

Aron Massey
Kent State University

Joy Nystrom Mast
Carthage College

Christine W. Mathenge
Indiana University

Anne E. Mather
University of Plymouth

Ian J. Mauro
University of Victoria

Jeff May
University of Toronto

Chris Mayda
Eastern Michigan University

Clive McAlpine
University of Queensland

James McCarthy
Pennsylvania State University

Linda McCarthy
*University of
Wisconsin—Milwaukee*

George F. McCleary Jr.
University of Kansas

Sarah McCormack
University of Kentucky

Daniel McGowin
Florida State University

Molly McGraw
*Southeastern Louisiana
University*

Sara McLafferty
*University of Illinois at
Urbana—Champaign*

Brenden E. McNeil
West Virginia University

Thomas G. Measham
CSIRO Sustainable Ecosystems

David B. Mechem
University of Kansas

Kimberley E. Medley
Miami University

Lars Meier
*Institute for Employment
Research (IAB)*

Mariselle Meléndez
University of Illinois

Assefa M. Melesse
*Florida International
University*

Jaymie R. Meliker
Stony Brook University

Tom Mels
University of Gotland, Sweden

V. Ernesto Méndez
University of Vermont

Qingmin Meng
*University of North Carolina
at Charlotte*

Timothy Mennel
American Planning Association

Jessica Mercer
Macquarie University

Christopher D. Merrett
Western Illinois University

Peter Merriman
Aberystwyth University

Peter Meserve
Fresno City College

Victor Mesev
Florida State University

Sara Metcalf
*State University of New York
at Buffalo*

Sandra Metoyer
Texas A&M University

Michelle Marie Metro-Roland
Indiana University

Peter Meusburger
Heidelberg University

Burghard C. Meyer
*Technische Universität
Dortmund*

Bryon D. Middlekauff
Plymouth State University

Byron Miller
University of Calgary

Jennifer Miller
University of Texas at Austin

Matthew Miller
University of Georgia

Hugh Millward
Saint Mary's University

Phillipa Marlis Mitchell
University of Auckland

Ivan Mitin
*Russian Institute for Cultural
& Natural Heritage*

Ines M. Miyares
Hunter College

Sami Moisis
*University of Turku,
Finland*

Mariana Mondini
*Consejo Nacional de
Investigaciones Científicas y
Tecnológicas*

Burrell Montz
East Carolina University

Debnath Mookherjee
*Western Washington
University*

Toby Moore
RTI International

Bruno Moriset
*University of Lyon–Jean
Moulin*

Penny L. Morrill
*Memorial University of
Newfoundland*

Richard Morrill
University of Washington

William G. Moseley
Macalester College

Alison Mountz
Syracuse University

Aditi Mukherji
*International Water
Management Institute*

Joshua Muldavin
Sarah Lawrence College

Samantha L. Muller
Macquarie University

Tiffany Muller Myrdahl
University of Minnesota

Beverley Mullings
Queen's University

Dustin R. Mulvaney
*University of California,
Santa Cruz*

A. Sebastián Muñoz
*Consejo Nacional de
Investigaciones
Científicas y Tecnológicas*

Yuji Murayama
University of Tsukuba

James T. Murphy
Clark University

Alan T. Murray
Arizona State University

Brian Murton
University of Hawaii

Christine Mango Mutiti
Miami University

Garth Myers
University of Kansas

Soe Win Myint
Arizona State University

Harini Nagendra
Indiana University

David Nally
University of Cambridge

Nazanin Naraghi
Simon Fraser University

Rizwan Nawaz
University of Leeds

Elisabeth S. Nelson
*University of North
Carolina at Greensboro*

David J. Nemeth
University of Toledo

Markus Neteler
Fondazione Edmund Mach

Benjamin Newton
Southern Illinois University

Andrea Joslyn Nightingale
University of Edinburgh

Silvia Nittel
University of Maine

Bram F. Noble
University of Saskatchewan

Emma Norman
University of British Columbia

Fungisai Nota
Wartburg College

Samuel Nunn
*Indiana University–Purdue
University Indianapolis*

Benjamin Kofi Nyarko
University of Cape Coast

Timothy Nyerges
University of Washington

Ann M. Oberhauser
West Virginia University

Nancy J. Obermeyer
Indiana State University

Karen L. O'Brien
University of Oslo

Segun Ogunjemiyo
*California State University,
Fresno*

Oladele Ogunseitan
University of California, Irvine

Shannon O'Lear
University of Kansas

Thomas O'Loughlin
University of Wales, Lampeter

John A. Olson
Syracuse University

Ola Olsson
University of Gothenburg

Giok-Ling Ooi
*Nanyang Technological
University*

Kathleen O'Reilly
Texas A&M University

Ibrahim M. Oroud
Mu'tah University

William Y. Osei
Algoma University

Francis Owusu
Iowa State University

Tonny J. Oyana
Southern Illinois University

Rachel Pain
Durham University

Joni M. Palmer
*University of Colorado at
Boulder*

Anupam Pandey
*St. Mary's University,
Halifax*

Maria Paradiso
University of Sannio

Mark Paterson
University of Exeter

Marianna Pavlovskaya
Hunter College

Serge Payette
Centre d'études nordiques

Margaret Wickens Pearce
Ohio University

Mauri S. Pelto
Nichols College

Jim Penn
Grand Valley State University

Clifford Pereira
Royal Geographical Society

Reed Perkins
*Queens University of
Charlotte*

George L. W. Perry
University of Auckland

Evelyn J. Peters
University of Saskatchewan

Frederick E. Petry
Naval Research Laboratory

Martin Phillips
University of Leicester

Alan G. Phipps
University of Windsor

James B. Pick
University of Redlands

Jenny Pickerill
University of Leicester

Michael Pidwirny
*University of British
Columbia–Okanagan*

Sonja K. Pieck
Bates College

Bruce Pietrykowski
*University of
Michigan–Dearborn*

Stephanie Pincetl
*U.S. Forest Service/University
of California, Los Angeles*

John S. Pipkin
*State University of
New York*

Tara M. Plewa
University of South Carolina

Thomas Poiker
Simon Fraser University

George Pomeroy
Shippensburg University

Robert Gilmore Pontius Jr.
Clark University

Jessie P. H. Poon
*State University of New York
at Buffalo*

Barbara S. Poore
U.S. Geological Survey

Gregory A. Pope
Montclair State University

Gabriel Popescu
Indiana University South Bend

Deborah E. Popper
*College of Staten Island/
City University of New York*

William Todd Powell
*University of North Carolina
at Greensboro*

José-Manuel Prado-Lorenzo
University of Salamanca

Valerie Preston
York University

Patricia L. Price
*Florida International
University*

Narcisa Gabriela Pricope
University of Florida

Jesse Proudfoot
Simon Fraser University

Ruiliang Pu
University of South Florida

Hardy Pundt
*University of Applied Sciences
Harz*

Virginia Pungo
Independent Scholar

Darren Purcell
University of Oklahoma

Heather R. Putnam
University of Kansas

Xiaomin Qiu
Missouri State University

Steven Quiring
Texas A&M University

Grzegorz Rachlewicz
*Adam Mickiewicz
University*

Elsbeth Rae
University of New South Wales

Atiqur Rahman
Jamia Millia Islamia University

Steven James Rainey
McNeese State University

Kevin Ramsey
University of Washington

Mahesh Rao
Humboldt State University

Samuel Ratick
Clark University

Martin Raubal
*University of California,
Santa Barbara*

Julia Rauchfuss
University of Minnesota

Lisa Rausch
University of Kansas

Steven Reader
University of South Florida

S. M. Reaney
Durham University

Rajyashree Reddy
University of Minnesota

Maureen G. Reed
University of Saskatchewan

Tim Reiffenstein
Mount Allison University

Wolfgang Peter Reinhardt
UniBw Muenchen

Dennis Reinhartz
*University of Texas at
Arlington*

Robert N. Renner
*U.S. Department of Housing
and Urban Development*

Lynn M. Resler
*Virginia Polytechnic Institute
and State University*

Kevon Christopher Rhiney
University of the West Indies

Pedro Ribeiro de Andrade
*National Institute for Space
Research*

Edward Rice
City University of New York

Robert A. Rice
Smithsonian Institution

Douglas Richardson
*Association of American
Geographers*

Mathieu Richaud
*California State University,
Fresno*

Jeffrey P. Richetto
University of Alabama

Laurie S. Richmond
University of Minnesota

Claus Rinner
Ryerson University

George F. Roberson
University of Massachusetts

David J. Roberts
University of Toronto

David J. Robinson
Syracuse University

George W. Robinson
*Michigan Technological
University*

Pamela Robinson
*School of Urban and Regional
Planning*

Peter J. Robinson
University of North Carolina

Wilder Robles
University of Manitoba

Agustin Robles-Morua
*Michigan Technological
University*

Dianne E. Rocheleau
Clark University

Gilbert L. Rochon
*Purdue University, Purdue
Terrestrial Observatory*

Christine M. Rodrigue
*California State University,
Long Beach*

Jean-Paul Rodrigue
Hofstra University

Paul Rollinson
Missouri State University

José Luis Romanillos
University of Bristol

Adam Rose
University of Southern California

Deborah Bird Rose
Macquarie University

William I. Rose
*Michigan Technological
University*

Mark W. Rosenberg
Queen's University

Amy Ross
University of Georgia

David A. Rossiter
*Huxley College, Western
Washington University*

Robert E. Roth
Pennsylvania State University

Robin J. Roth
York University

Graham D. Rowles
University of Kentucky

Shouraseni Sen Roy
University of Miami

James M. Rubenstein
Miami University

Simón Ruiz
*Mediterranean Institute for
Advanced Studies*

Bradley C. Rundquist
University of North Dakota

Matthias Ruth
University of Maryland

Stephanie Rutherford
Macalester College

Alan Saalfeld
Ohio State University

Dorothy Sack
Ohio University

Ahmad Safi
University of Nevada, Las Vegas

Robin Saha
University of Montana

Dipti Saletore
University at Buffalo

David S. Salisbury
University of Richmond

Luis Sánchez
Universidad de los Andes

Heather Sander
University of Minnesota

Mary V. Santelmann
Oregon State University

Antoinette W. Satterfield
Kansas State University

David Saurí
Universitat Autònoma de Barcelona

Nathan F. Sayre
University of California, Berkeley

Bastian Schaeffer
University of Muenster

Michael E. Schaepman
University of Zurich

Simon Scheider
University of Muenster

Kolson Schlosser
Clarkson University

Ginger L. Schmid
Minnesota State University

Thomas W. Schmidlin
Kent State University

Dietrich Schmidt-Vogt
Asian Institute of Technology, Thailand

Laura C. Schneider
Rutgers University

Justin T. Schoof
Southern Illinois University

Yda Schreuder
University of Delaware

Zachary N. Schulman
George Washington University

Nadine Schuurman
Simon Fraser University

Joan M. Schwartz
Queen's University

Leonard J. Scinto
Florida International University

Christopher Scott
University of Arizona

Leonie Seabrook
University of Queensland

David Seamon
Kansas State University

Anne-Marie Séguin
Insitut National de la Recherche Scientifique

Christian Sellar
University of Mississippi

Jason C. Senkbeil
University of Alabama

Bongman Seo
Hitotsubashi University

Susanna Servello
University of Parma

Gary W. Shannon
University of Kentucky

Martha B. Sharma
National Cathedral School

Ian Graham Ronald Shaw
University of Arizona

Shih-Lung Shaw
University of Tennessee, Knoxville

Marshall Shepherd
University of Georgia

Douglas J. Sherman
Texas A&M

Kathleen Sherman-Morris
Mississippi State University

Xun Shi
Dartmouth College

Michael Shin
University of California, Los Angeles

Takeshi Shirabe
Vienna University of Technology

John F. Shroder
University of Nebraska at Omaha

J. Matthew Shumway
Brigham Young University

Laura Kathryn Siebeneck
University of Utah

Jennifer J. Silver
Simon Fraser University

Sunhui Sim
Florida State University

Daniel Simberloff
University of Tennessee

Nicole Simons
San Diego State University

Alex David Singleton
University College London

Todd Sink
Indiana State University

Henry Sivak
University of California, Los Angeles

Emily Skop
University of Colorado at Colorado Springs

André Skupin
San Diego State University

Adrian Smith
Queen Mary, University of London

Janet L. Smith
University of Illinois at Chicago

Jeffrey S. Smith
Kansas State University

Jonathan M. Smith
Texas A&M University

William James Smith Jr.
University of Nevada, Las Vegas

Thomas A. Smucker
Ohio University

Michael Solem
*Association of American
Geographers*

Barry D. Solomon
*Michigan Technological
University*

Kean Huat Soon
Pennsylvania State University

André Sorensen
University of Toronto

John Sorensen
*Oak Ridge National
Laboratory*

Catherine Souch
Royal Geographical Society

Jane Southworth
University of Florida

Dale Splinter
*University of Wisconsin–
Whitewater*

Dana Sprunk
*Friedrich-Schiller–University
Jena*

Anna Stanley
*National University of Ireland,
Galway*

David Stea
Center for Global Justice

Johannes Steiger
University Blaise Pascal Geolab

Philip E. Steinberg
Florida State University

Stefan Steiniger
University of Calgary

Susanne Stenbacka
Uppsala University

Rolf Sternberg
Montclair State University

Kristin L. Stewart
Florida State University

Olof Stjernström
Umeå University

Kristin Stock
University of Nottingham

Glenn Davis Stone
Washington University

Roger R. Stough
George Mason University

Douglas Alan Stow
San Diego State University

Jeppe Strandsbjerg
Copenhagen Business School

Elaine Stratford
University of Tasmania

Daniel Z. Sui
Ohio State University

Selima Sultana
*University of North Carolina
at Greensboro*

Björn Surborg
University of British Columbia

Laurel Suter
*University of California, Santa
Barbara*

John W. Sutherland
*Michigan Technological
University*

Paul C. Sutton
University of Denver

Brendan Sweeney
Queen's University

Martin Swobodzinski
San Diego State University

Mattias Tagseth
*Norwegian University of
Science and Technology*

Tyson Taylor
Boise State University

Yvette Taylor
Newcastle University

Philippe M. Teillet
University of Lethbridge

Rajiv Thakur
University of South Alabama

Rajesh Bahadur Thapa
University of Tsukuba

Lisa Theo
*University of Wisconsin–
Stevens Point*

Colin Edward Thorn
*University of Illinois at
Urbana-Champaign*

Jane R. Thorngren
San Diego State University

Jocelyn Thorpe
*University of British
Columbia*

Grant Thrall
University of Florida

Graham A. Tobin
University of South Florida

Marina A. Tolmacheva
American University of Kuwait

Brian Tomaszewski
Pennsylvania State University

R. Tomlinson
Queen's University Belfast

Daoqin Tong
University of Arizona

Nancy K. Torrieri
*American Community Survey
Office*

Ramzi Touchan
University of Arizona

Kostas A. Triantis
University of Oxford

Ming-Hsiang Tsou
San Diego State University

Lysandros Tsoulos
*National Technical University
of Athens*

Steven Tufts
York University

Benjamin Tuttle
University of Denver

James Tyner
Kent State University

Elizabeth Underwood-
Bultmann
University of Washington

Jon Unruh
McGill University

Michael A. Urban
University of Missouri

Julie Urbanik
*University of Missouri–
Kansas City*

Philip Edward van Beynen
University of South Florida

Hein-Anton van der Heijden
University of Amsterdam

Mark van der Meijde
*International Institute for Geo-
Information Science and
Earth Observation (ITC)*

Harald van der Werff
*International Institute for Geo-
Information Science and
Earth Observation (ITC)*

Thom van Dooren
*University of Technology,
Sydney*

Corné P. J. M. van Elzakker
*International Institute for Geo-
Information Science and
Earth Observation (ITC)*

Scott Van Keuren
University of Vermont

William M. Van Lopik
College of Menominee Nation

Dalia Varanka
U.S. Geological Survey

Maria Vasardani
University of Maine

Stefano Vassere
*Archivio dei nomi di luogo,
Bellinzona, Switzerland*

Geir Vatne
*Norwegian University of
Science and Technology*

Elizabeth Vaughan
Ball State University

Gregory L. Vert
University of Nevada

Paolo Vignolo
*Universidad Nacional de
Colombia, Bogotá*

Robert Voeks
*California State University,
Fullerton*

Igor Vojnovic
Michigan State University

Tim Vorley
University of Cambridge

Monica Wachowicz
*Wageningen University and
Research Centre*

Mathis Wackernagel
Global Footprint Network

Roland M. Wagner
University of Muenster

Jayme Walenta
University of British Columbia

Johnathan Walker
James Madison University

Alan Walks
University of Toronto

Candice Wallace
University of Kentucky

Julie Wallace
McMaster University

Andy Walter
University of West Georgia

Sarah M. Wandersee
San Diego State University

Enru Wang
University of North Dakota

Jinfei Wang
University of Western Ontario

Shaowen Wang
*University of Illinois at
Urbana-Champaign*

Wenfei Winnie Wang
University of Bristol

Yi-Chen Wang
*National University of
Singapore*

Young-Doo Wang
University of Delaware

Barney Warf
University of Kansas

Timothy A. Warner
West Virginia University

John F. Watkins
University of Kentucky

Peter Waylen
University of Florida

Joe Weber
University of Alabama

John R. Weeks
San Diego State University

Robert Weibel
University of Zurich

Tony Weis
University of Western Ontario

Sally A. Weller
Victoria University

Jeremy Wells
Clemson University

Qihao Weng
Indiana State University

Elizabeth A. Wentz
Arizona State University

Benno Werlen
*Friedrich-Schiller-University
of Jena*

George W. White
Frostburg State University

Mark Whitehead
Aberystwyth University

Robert J. Whittaker
University of Oxford

Thomas J. Wilbanks
*Oak Ridge National
Laboratory*

Wolfgang Wilcke
Johannes Gutenberg University

Margaret Wilder
University of Arizona

Forrest D. Wilkerson
Minnesota State University

Richard Wilkie
*University of Massachusetts,
Amherst*

Michael Williams
Oxford University

Stewart Williams
University of Tasmania

Cort J. Willmott
University of Delaware

Carl Wilmsen
*University of California,
Berkeley*

David Wilson
*University of Illinois at
Urbana-Champaign*

Matthew W. Wilson
University of Washington

Gordon M. Winder
Ludwig-Maximilians-Universität

Jamie Winders
Syracuse University

Antoinette M. G. A.
WinklerPrins
Michigan State University

Morton D. Winsberg
Florida State University

Ben Wisner
Oberlin College

Frank Witlox
Ghent University

Eric B. Wolf
University of Colorado

Poh Poh Wong
*National University of
Singapore*

Joseph S. Wood
University of Baltimore

Jared Wouters
City Colleges of Chicago

Pamela Wridt
*University of Colorado
Denver*

Dawn J. Wright
Oregon State University

Ningchuan Xiao
Ohio State University

Zhen Xiong
*University of New
Brunswick*

Bisheng Yang
Wuhan University

Lakshman Yapa
Pennsylvania State University

Robert Yarbrough
Georgia Southern University

Stephen R. Yool
University of Arizona

Kenneth R. Young
University of Texas at Austin

Donald M. Yow
Eastern Kentucky University

Hongbo Yu
Oklahoma State University

May Yuan
University of Oklahoma

Kathryn Yusoff
University of Exeter

Alessandro Zanazzi
Georgia Southern University

Peyman Zawar-Reza
University of Canterbury

Donald J. Zeigler
Old Dominion University

Chuanrong Zhang
University of Connecticut

Tong Zhang
*Wuhan University of
Technology*

Yun Zhang
University of New Brunswick

Dennis Zhao
Chinese Academy of Sciences

Tingting Zhao
Florida State University

Wolfgang Zierhofer
University of Basel

Kaj Zimmerbauer
University of Oulu

Matija Zorn
*Scientific Research Centre of
SASA*

Ashley B. Zung
University of Kansas

Alex Zvoleff
San Diego State University

INTRODUCTION

Long misunderstood by the general public as an infantile field obsessed with drawing boundaries and memorizing capital cities, contemporary geography exhibits, in contrast, a fecund, robust, and increasingly sophisticated understanding of the world. Previously confined to the margins of academia and earning little respect, geography in the past four decades has been decisively transformed into an innovative and dynamic field that has earned the respect, even the admiration, of scholars in the sciences, humanities, and social sciences.

Literally “earth description” (*geo-graph*), geography may broadly be defined as the art and science of understanding the space of Earth’s surface. At its simplest, geography studies the locations of things and the explanations that underlie spatial distributions of different types. Fundamentally, geographers ask “Why are things where they are?” Now, such a wide definition obscures the enormous diversity of the discipline and the multiple meanings of space itself. Space may mean, for example, the biophysical surface of Earth, an arena of class confrontation, or an intangible set of meanings. Geography is notorious, even infamous, for its eclecticism and for the very wide range of topics that it addresses. Not only do geographers tackle a great span of issues, but they do so from a multitude of theoretical and conceptual angles. Some fear that this diversity robs the discipline of a central narrative: At first glance, quantitative geomorphologists and feminist deconstructivists might seem to share little in common. Moreover, geographers approach their issues from an astonishingly diverse set of conceptual perspectives, ranging from complex mathematical models

and geographic information systems (GIS) to post-structuralist discourse analysis. Geography speaks with more than one voice, which is part of the key to its growing contemporary popularity and vitality. The various ways in which space can be understood will be discussed in more detail below.

The Rising Popularity of Geography Today

The surge in geography’s popularity today reflects much more than its own internal intellectual metamorphosis. Profound forces at work throughout the world have made geographical knowledge increasingly important to understanding numerous human dilemmas and our capacity to address them. Four of these are emphasized here: (1) globalization, (2) environmental destruction, (3) new geospatial technologies, and (4) cyberspace.

Globalization

Contrary to much received opinion, globalization—that complex set of often contradictory processes that operate at a transnational scale—has made geographical location more, not less, relevant. As neoliberal capital operates ever more effortlessly on a worldwide stage, small differences among regions become increasingly important. The persistent inequality between the global North and South, that is, the world’s economically developed and underdeveloped regions, as well as continuing war and famine have drawn many people’s attention to the role of space in perpetuating, and at times challenging, such problems. Moreover, far from simplistic and naive assertions about the

“death of distance” or the “end of geography,” place has become increasingly central to the behavior of transnational corporations, trade, immigration, tourism, and global financial flows. Discourses of national competitiveness in a global economy thrive as place-centered ways of coping with increasingly mobile capital, which operates on a worldwide scale. Opposition to globalization, including terrorism, has also increased the importance of learning about other cultures. At a moment when more than half the human race lives in cities, questions of how urban areas are interconnected (or not) loom large, as does the need for an understanding of deeply geographical issues such as rural-to-urban migration. Rising inequality worldwide speaks to processes that have disproportionately favored the elites at the expense of the working classes and the poor. For many people, matters of social justice are thus inescapably spatial ones. Increasingly, what happens in one part of the world has important ramifications in other parts—a fundamentally geographic phenomenon. Moreover, globalization itself plays out in different ways in different places, so that the global and the local are deeply entangled with one another.

Contemporary globalization has also undermined commonly held notions of absolute, Euclidean space by forming linkages among disparate producers and consumers intimately connected over vast distances through flows of capital, information, and goods. In generating new landscapes twisted like origami and filled with wormholes, in giving rise to ever-changing patterns of centrality and peripherality, the tsunami of globalized time-space compression has forced many people to recognize that geographies are always and everywhere dynamic, incomplete, forever coming into being, and perpetually in flux. The period of rapid globalization in the late 20th and early 21st centuries was accompanied, not coincidentally, by an explosion of theoretical work in human geography, in which the discipline firmly came to view space as a social construction, embedded in its historical context and filled with political and cultural meanings. The relational perspective on the world’s landscapes today, which depicts them in terms of flows, rhizomes, and networks, is a far cry from the archaic study of places as discrete, bounded, and isolated and has played a large role in electrifying human geography.

Environmental Destruction

Another patently obvious role that geography plays today concerns the rapidly rising seriousness of global ecological and environmental problems. Issues that once could be understood and contained within relatively localized contexts, such as air or water pollution, are increasingly approachable only on a worldwide basis. Acid rain crosses national borders with ease. The enormous crisis of biodiversity unfolding across the world is inseparable from global patterns of population growth, habitat destruction, deforestation, desertification, soil erosion, and resource consumption. The oceans have been confronted with systematic overfishing and coastal pollution, including agricultural runoff and chemical spills. As protection and preservation of the environment have risen on the political agenda, geographers’ work in these domains has gained attention accordingly. Hazards, such as the devastating Indian Ocean tsunami of 2004, have drawn the attention of worldwide audiences. The 2010 earthquake in Haiti triggered a response from millions around the globe. Combating global transmissions of diseases, such as AIDS, entails a geographical understanding of their genesis and diffusion. Limited global supplies of resources, including petroleum, have helped elevate the notion of the limits to growth in popular consciousness.

And of course, looming over all these issues is the dark shadow of global warming: As evidence mounts daily of rapidly melting ice caps and glaciers, of rising sea levels and more extreme weather events, of ecosystems turned upside down overnight and mass extinctions, the origins, impacts, and control of greenhouse gases have become increasingly problematic issues. Because environmental issues are unevenly distributed across space and because geography as a discipline has a long history of investigating human-environment interactions, space and spatiality have become crucial dimensions in understanding and tackling these problems.

Geospatial Technologies

Geography and cartography have always been close cousins, and for many people, mapping is their first entry into the world of spatial analysis. As technologies for surveying, mapping, and

monitoring Earth's surface have proliferated in number, accuracy, and sophistication, geographical awareness about Earth's surface, both popular and academic, has grown correspondingly. Geospatial technologies, including GIS, global positioning systems (GPS), remote sensing, and location-based services, have infiltrated many corners of everyday life. Many cars and cell phones today have them. The enormous flood of data that such techniques have generated have allowed geographers to study the world's social and environmental issues in novel ways, testing models and hypotheses, enhancing forecasting abilities, and attracting widespread attention and enthusiasm. Increasingly, mapping has become not the preserve of an isolated elite group of experts but a popular activity, in which users create their own displays uniquely suited to their own contexts and problems. More people today create, disseminate, and use larger volumes of geographic information than ever before. Novel quantitative approaches (e.g., spatial autocorrelation) have supplemented the ability to understand spatial patterns in new and fecund ways. Indeed, many people would argue that such techniques form the engine that drives the growth of much academic geography. The engagement between human geographers and practitioners of GIS has opened fertile new fields to explore, including neogeography, humanistic GIS, and Web 2.0 mashups.

Cyberspace

Finally, the rise of cyberspace and the Internet has also elevated issues of spatiality in several ways. The Internet, an unregulated electronic network connecting an estimated 1.7 billion people (or 26% of the planet) in 2009, allows users to transcend distance virtually instantaneously. Telecommunications systems have become the central technology of postmodern capitalism, vital not only to corporations but also to individual consumption, communication, entertainment, education, politics, and numerous other domains of social life. As Internet usage becomes more popular and widespread in nature, including diverse applications such as e-mail, online shopping, banking, airline and hotel reservations, multiplayer video games, electronic job searches, instant messaging, e-marketing, chat rooms,

VOIP telephony, distance education, downloading of music and television shows, digital pornography, blogs, YouTube and MySpace, and simply "Googling" of information, cyberspace has profound effects on social relations, everyday lives, culture, politics, and many other spheres of social activity. Indeed, for many people who spend a great deal of time in the digital world, cyberspace has become such an important part of everyday life that the once solid boundary between the real and the virtual has essentially dissolved: It is difficult today to tell where one ends and the other begins. In allowing people and firms to "jump scale," to connect effortlessly with others around the world at the click of a mouse, cyberspace has been instrumental in the production of complex, fragmented, jumbled spaces of postmodernity.

There are, of course, many other reasons why geography remains important. Shortages of resources including water as well as a dwindling oil supply have intensified competition for the remaining stocks. The world's oceans are being emptied of their food reserves and are suffering ecosystem collapse at dizzying rates. Massive, ongoing technological changes have led to a proliferation of new industries, occupations, and products, even as old ones disappear. Knowing where one is located is vital to knowing one's identity, and as spaces have been reconfigured, so, too, have individual and collective notions of self and the other. Poverty-stricken populations the world over have spoken out against the causes of their oppression and made their voices heard. Concerns over distant strangers have multiplied as geographical imaginations have expanded in the face of rising long-distance social and personal relations and media coverage. In short, in a world in which the future arrives all too soon, whenever larger numbers of people must daily contend with questions of difference, when nature repeatedly inserts itself into the news, matters of geography have become not a luxury but a necessity.

The Multiple Meanings of Space

One reason for the diversity of geographical knowledges is that space has many dimensions and can be understood in widely different ways.

Space as a Biophysical Landscape

Space as the biophysical surface of the Earth is one such dimension. For physical geographers, Earth's surface has traditionally been seen as a set of atmospheric, hydrologic, biological, and geomorphologic processes. Biogeographers focus on the spatial distribution of life forms, as evolutionary forces have generated webs of ecological relations that vary enormously over time and space. Many physical geographers traditionally paid little attention to human dynamics and often felt that they had more in common with their intellectual brethren in geology, biology, or meteorology than they did with fellow geographers. Conversely, for many human geographers, the natural environment has amounted, at best, to a set of resources. However, the schism between physical and human geography is gradually closing, and increasingly, physical geographers have come to recognize that social activities must be taken seriously, just as many human geographers have slowly come to see that social relations do not simply unfold over a blank surface but are intensely wrapped up with a complicated natural terrain that exhibits a complex logic in its own right. Just as human geographers have grudgingly come to accept that the biophysical world does play an important role in shaping the distributions of human activity, so too have many physical geographers gradually acknowledged that nature does not simply exist outside society but is shaped by human beings and given meaning only within a variety of social contexts.

Space as Places That People Create and Inhabit

A second way in which space may be approached is as a set of places that people create and inhabit. Human geography—the analysis of how societies are stretched over Earth's surface—is thus the study of people in space in much the same way as history views people in time. Indeed, because space and time are inseparable, historical and geographical analyses are necessarily fused. Thus, human geography includes the study of how societies construct places, how different types of activities (cultural, economic, and political) are differentially located and connected, and how all these constantly change, with important ramifications for their

inhabitants' quality of life. Regional geographers have long been interested in the specific conjunctions of processes in individual locales, and the creative tension between understanding the unique and the general continues to reverberate throughout the discipline, as it has for centuries. The generation and transformation of human geographies occur at a variety of spatial scales, and scale has become important not only to cartographers but also to those seeking to understand how different social processes play out at different scales, ranging from the local to the global. Indeed, scale itself has widely become viewed as a human product. Some geographers focus on the most personal and intimate of scales, the body: While bodies appear as “natural,” or given, human geographers view them as social constructions, filled with gendered, racialized, and other meanings. Increasingly, as globalization has linked the planet's diverse societies into an increasingly integrated totality, it has become impossible to separate the local from the global. Integral to this perspective are questions regarding how people use the surface of the Earth, modify it, and in turn are affected by it. The interrelations between people and nature are a long-standing and hugely important part of the discipline. As the ties between human and physical geography have grown, many have rejected the long-standing notion that nature lies “outside” social relations; rather, everywhere, nature has been changed by people and been given meaning by them, even as it changes societies, a notion well encapsulated by relatively recent approaches such as political ecology.

Space as Representation of Earth's Surface

Third, space exists as a set of representations of Earth's surface, the most literal meaning of *geo-graph*. Geography is concerned with much more than the tangible worlds of mountains or factories, rivers or farms; it also includes the study of how people bring the world into consciousness, make sense of it, and give it meaning. Cartography, for example, is perhaps the most common way in which geographical knowledge has been constructed throughout its history. Maps of one form or another date back deep into human prehistory, when hunters and gatherers formed their own symbolic geographies. Voluminous,

detailed, often encyclopedic descriptions of the locations of places are another form of geographical representation.

Shortly after World War II, many geographers adopted the scientific method; using quantitative techniques, they initiated a tradition of modeling space that continues to this day. Geographical models take a diversity of forms and serve many different purposes, ranging from traffic planning to watershed analysis. Models are central to many academic and nonacademic applications of geography, as they simplify the dynamics of the world to reveal its causal properties. This tradition was greatly assisted by the rise of GIS, which allow for the integration and analysis of diverse forms of spatial information. Often integrated with remotely sensed high-altitude or satellite photography, GIS has become a hugely popular, powerful, and important part of the discipline.

In stark contrast, other geographers approached the question of spatial representation in a dramatically different way. The behavioral tradition explored mental maps and cognitive models of space. Humanistic geographers, drawing on a rich philosophical tradition of existentialism and phenomenology, are concerned with the textures of human experience, the role of language and discourse, and how individual understandings are wrapped up with social configurations of power and knowledge. Discourse analysis, which lies at the core of contemporary poststructuralist approaches, insists that geographic knowledges are always social in origin and social in consequence and thus inevitably linked to power interests.

A Very Brief Historical Sketch

Geography has a long, rich, and fascinating history. For any society to exist, it must create a landscape, and its geography is central to how it is organized and changes. Thus, as long as there have been human beings, there have been human geographies.

The history of geography is important because all ideas, including geographical ones, are embedded within and reflect their historical contexts. For example, classical Greek geography, which included both encyclopedic descriptions and mathematical treatises, reflected the location of city-states at the intersections of Africa, Asia, and Europe and the trade relations that sutured them

together. In the medieval era, European geography labored under the yoke of theological suppression, and its intellectual development suffered accordingly. Conversely, Arab geographers were among the world's best, skilled in mapping and providing rich portrayals of the places strewn throughout the Muslim *ecumene*.

During the Renaissance and Enlightenment, periods in which European empires extended their tentacles across the planet and the "West" as we know it began to come into being, cartography grew explosively—a testimony to geography's long history of service to imperial interests. Exploration and geography have long been tied together, but geography was vital in mapping the world's resources and understanding the diverse peoples falling under the tsunami of colonialism.

In the late 19th century, infected by a racist and unscientific form of Darwinism, geography in the form of environmental determinism was widely used to justify and naturalize colonial inequalities. Geopolitics became a central part of colonial rivalries, and political geography made its first appearance. Finally, new strains such as anarchist geography made their appearance. Simultaneously, geography became institutionalized within academia, with a variety of professional organizations and university departments.

In the early 20th century, retreating from the disaster of environmental determinism, geographers entombed themselves within empty empiricist descriptions—an era that continues to haunt the discipline's public image today. In this paradigm, the region, untheorized and taken for granted, ruled as the core of the geographer's craft. However, cultural geographers, such as Carl Sauer, paved the way for new understandings of landscapes as social creations, infusing the discipline with historical sensitivity.

Following World War II, scientific cartography was born. Armed with statistics and an enthusiasm for the scientific method, the quantitative revolution decisively transformed the field, offering a concern for methodological rigor, models, and conceptual abstraction. Physical geography, drawing on 19th-century roots, expanded into quantitative climatology, geomorphology, and biogeography.

The late 20th century and the current era gradually witnessed an intellectual renewal, which took various forms. Diverse schools of thought

rejuvenated human geography, such as Marxism, feminism, humanistic thought, and, more recently, poststructuralism and postcolonialism. The discipline exhibited mounting methodological sophistication, including GIS, remote sensing, and quantitative modeling. Work concerned with the social construction of nature and human-environment relations began to heal the long-standing schism between human and physical geographers. Understandings of natural hazards, anthropogenic climate change, complexity theory, contingency and path dependency, gender, everyday life, race and ethnicity, Eurocentrism, sexuality, class, power, and uneven development proliferated. Long a borrower of ideas from other fields, geography today has experienced a renaissance that has made it increasingly interesting to nongeographers, as exemplified by the “spatial turn” widespread throughout the social sciences and humanities.

A Note on This Project

This encyclopedia sets for itself an ambitious task: to offer a reasonably comprehensive and useful summary of the state of the discipline in the early 21st century. As geographical knowledge has exploded in quantity, diversity, and sophistication, many people, including students and the informed lay public, find it difficult to know where to turn. This project attempts to fill that gap. No single project, of course, can do justice to the gargantuan amount of information that characterizes any discipline today; at best, it can hope only to trace the broad contours. Thus, readers should not expect the entries to attempt a comprehensive portrait of their topics; space limitations have forced the authors to focus only on the most important aspects of their respective essays. With 1,224 entries, the encyclopedia encapsulates an enormous diversity of topics in all subdisciplines. Cross-references at the end of each entry point to the innumerable connections among them, which, in conjunction with the suggestions for further readings, allow all readers to pursue topics as deeply as they wish. Because a picture is worth a thousand words, many entries are accompanied by art and graphics that lend depth and realism to the text. In addition to the more than 900 pieces of art in the A-to-Z entries, the encyclopedia includes an atlas with maps, found in the last volume.

To assist readers in locating relevant topics, the Reader’s Guide at the beginning of Volume 1 decomposes geography into the six broad subject areas listed below. While the ones used here are relatively conventional, it should be noted that there are as many ways to organize geographical knowledge as there are geographers. (Indeed, geography is such a notoriously diverse and broad discipline that any categorization of it is bound to offend someone.) Note, too, that many topics defy easy categorization and belong to more than one grouping.

1. Physical Geography
 - a. Biogeography
 - b. Climatology
 - c. Geomorphology
2. Human Geography
 - a. Economic Geography
 - b. Geographical Theory
 - c. Medical Geography
 - d. Political Geography
 - e. Regional Geography
 - f. Social and Cultural Geography
 - g. Urban Geography
3. Nature and Society
 - a. Agriculture
 - b. Environment and People
 - c. Hazards and Disasters
 - d. Pollution and Waste
 - e. Resources and Conservation
 - f. Water
4. Methods, Models, and GIS
 - a. Cartography
 - b. GIS
 - c. Qualitative Techniques
 - d. Quantitative Models
 - e. Remote Sensing
5. History of Geography
 - a. Cartography
 - b. GIS
 - c. Human Geography
 - d. Physical Geography
6. People, Organizations, and Movements
 - a. Biographies
 - b. Geographical Organizations
 - c. Political and Economic Organizations

- d. Scientific Organizations
- e. Social Movements

Acknowledgments

*This work is dedicated to all
geographers, wherever they may be,
past, present, and future.*

A multivolume encyclopedia is such a large and complex undertaking that it demands the time and energy of a large number of people. So many people have contributed to this project that it is impossible to name them all. All I can do here is give my heartfelt thanks to all of those responsible for bringing these six volumes into being.

First, the bulk of the credit lies with the authors—all 942 of them, from dozens of countries—of the 1,224 entries, who agreed to write on their respective topics, often under short deadlines, revised their contributions as necessary, corrected me when I was wrong, and often came up with a wonderful array of graphics. Their works reveal the richness, diversity, and sophistication of contemporary geography, and I learned more from reading their contributions—1.78 million words—than I can put into words. I thank you all.

Second, the associate editors of this venture played an enormously valuable strategic role. Piotr Jankowski handled the GIS and cartography

entries with aplomb; Barry Solomon rounded up a large number of skilled authors to write great essays on human-environmental relations; Mark Welford collected excellent physical geography entries with admirable grace; and Jonathan Leib, working quietly behind the scenes, served as an effective managing editor.

Third, the staff at SAGE demonstrated the utmost professionalism, working far beyond the call of duty. Rolf Janke and Robert Rojek served as acquisitions editors and made this encyclopedia possible. Diana Axelsen deserves special merit for her extraordinarily thorough review of each and every entry and helpful feedback. Among numerous other coordinators, assistants, copy editors, and graphics specialists who deserve a round of applause are Laura Notton, Yvette Pollastrini, Tracy Buyan, Eileen Gallaher, Leticia Gutierrez, Rebecca Johnson, Sheri Gilbert, and Shamila Swamy. Their meticulous assessment of all the contributions, identification of errors, suggestions for improvement, and patient corrections greatly improved the appearance and quality of the entire encyclopedia. There are many others who also lent a hand, and their work is much appreciated.

All these parties, with thousands of e-mails and often enduring drudgery, have worked tirelessly to produce a product of which they, and I, can be justly proud.

Barney Warf



ABLER, RONALD (1939–)

Ronald F. Abler, president of the International Geographical Union (IGU) during 2008–2012, former president of the Association of American Geographers (AAG) (1985–1986), and executive director of the AAG (1989–2002), contributed to the geographical study of communication while fostering collaborative geographical research through communication among geographers and between geographers and the wider academy.

Abler received his geography degrees from the University of Minnesota (PhD, 1968) and served on the faculty (1967–1995) and as head of the geography department (1976–1982) at the Pennsylvania State University, where he is professor emeritus. His research explored how societies use communication technologies, most recently with respect to telecommunications and cyberspace, to shape space and place. In addition to numerous research publications, Abler coauthored a groundbreaking 1971 textbook on spatial organization and led two atlas projects significant for their scale and scholarly importance, one on America's major metropolitan regions and the other a state atlas on Pennsylvania.

As director of the Geography and Regional Science Program at the National Science Foundation (1984–1988), Abler helped build important research capacity in universities, expanded funding for physical geography, and championed the National Center for Geographic

Information and Analysis (NCGIA). As president and executive director of the AAG, he led a substantial increase in the scale of the organization's activities and outreach, bolstered the development of geographic information systems (GIS), and was scientific administrator (1994–2002) for the AAG's Global Change and Local Places project.

Abler has worked to ensure geography's visibility by serving on the boards of the American Council of Learned Societies, the Consortium of Social Science Associations, the National Humanities Alliance, the International Geographic Information Foundation, the NCGIA, the Renewable Natural Resources Foundation, and the University Consortium for Geographic Information Sciences, among others. He was a member of the IGU's Commission on Geography of Communications and Telecommunications (1984–1992), and he organized the IGU's Columbian Quincentenary meeting in Washington, D.C. (1992), for which he also coedited a critical overview of contemporary American geography. After serving as IGU vice president (1996–2000 and 2006–2008) and IGU secretary general (2000–2006), he was elected IGU president in 2008 for a 4-year term.

Among Abler's many awards and honors are Fellow of the American Association for the Advancement of Science (1985), Centenary Medal of the Royal Scottish Geographical Society (1990), Association of American Geographers Honors (1995), Victoria Medal of the Royal Geographical



Society/Institute of British Geographers (1996), and the American Geographical Society's Samuel F. B. Morse Medal (2004) for encouragement of geographical research. The AAG also named its Distinguished Service Honors Award in honor of Abler's service to the profession.

Joseph S. Wood

See also **Association of American Geographers; Communications Geography; International Geographical Union; Telecommunications and Geography**

Further Readings

- Abler, R. (Ed.). (1976). *A comparative atlas of America's great cities: Twenty metropolitan regions*. Minneapolis: University of Minnesota Press.
- Abler, R., Marcus, M., & Olson, J. (Eds.). (1992). *Geography's inner worlds: Pervasive themes in contemporary American geography*. New Brunswick, NJ: Rutgers University Press.
- Adams, J., Abler, R., & Gould, P. (1971). *Spatial organization: The geographer's view of the world*. Englewood Cliffs, NJ: Prentice Hall.



ABSOLUTE SPACE

Geographical space may be viewed from a variety of conceptual vantage points, all of which reflect and sustain various ideologies and interests in society at large. The division between absolute and relative space is one of the most long-standing and important of these contending theoretical frameworks. Absolute space is typically represented as fixed, mathematized, geometrified, asocial, and atemporal.

Absolute space has a long lineage in Western history that can be traced back to classical Greece. Plato, for example, equated light with the good, in which the cave is a metaphor for the *kosmos*, the world of human ignorance. For Plato, time was a moving image of eternity, an imperfect and untrustworthy mirror of eternal forms embedded in space that transcend time. Time is derived from

change in space, which preexisted time. Space exists in its own right by virtue of its visibility, whereas time is derivative of changes in the spatial order. Time, then, was a facade, and space as the realm of changeless, permanent forms took precedence in his thought. Intellectual progress consisted of attempting to discover transcendental forms located outside of time. For Plato, the process of becoming belonged to the domain of time and illusion, in contrast to the state of being, which was empirically observable in space and thus more "real."

Similarly, Greek geometry reflected the mathematization of terrestrial and celestial space. Aristotle reasoned that since Earth's shadow on the moon was an orb, and only a sphere could throw such a shadow, the Earth must therefore be spherical. Many Greek intellectuals subscribed to the dichotomy between *chora*, or space as an empty container, and *topos*, space that is bound, inhabited, and given meaning. Hipparchus came up with the system of locating every place in a coordinate grid, dividing Earth's circumference into 360°, inventing the mathematical vocabulary of cartography still in use today. Euclidean geometry, grounded in the assumption of one uniform, continuous space, dominated the mathematics of spatial representation for the next two millennia. Ó Tuathail (1996) asserts that "Greek geography, geometry, and cartography are all suffused with the teleological dream of displaying space as a simultaneous, synchronic totality" (p. 70). The tradition of Greek geometry initiated by Euclid, Aristotle, Plato, and Pythagoras powerfully informed Western metaphysics for the next two millennia and initiated a long history of Western ocularcentrism.

The explicit division between absolute and relative space can be traced back to the famous debate in the 17th century between two geniuses, Sir Isaac Newton and Gottfried Leibniz. Newton, greatly influenced by the recent popularity of the clock, viewed time and space as abstract, absolute entities that existed independently of their measurement; that is, their existence was absolute, for their reality remained real regardless of what they contained or how they were measured. Leibniz, in contrast, held that time and space were relational—that is, comprehensible only with reference to specific frames of interpretation: Distance, for example,



could only be understood through appeal to the space between two or more objects situated in space. Space and time, therefore, had no independent existence but were derivative of how we measured them. Eventually, for reasons having little to do with inherent intellectual merit and much to do with the emergence of early capitalist modernity, Newton's view triumphed.

Absolute space was greatly advanced in popularity, utility, and sophistication by Renee Descartes, a central figure of the Renaissance, who may be regarded as the founder of the doctrine that equates perspective with the abstract subject's mapping of space. Descartes proposed a mechanical view of the world centered on what has come to be known as the Cartesian cogito: a disembodied, rational mind without distinct social or spatial roots or location (but implicitly male and white). Cartesian rationalism was predicated on the distinction between the inner reality of the mind and the outer reality of objects; the latter could only be brought into the former, rationally at least, through a neutral, disembodied gaze situated above space and time. Such a perspective presumes that each person is an undivided, autonomous, rational subject with clear boundaries between "inside" and "outside," that is, between self and other, body and mind. With Descartes' cogito, vision and thought became funneled into a spectator's view of the world, one that rendered the emerging surfaces of modernity visible and measurable and rendered the viewer body-less and placeless. Illumination was conceived to be a process of rationalization, of bringing the environment into one's consciousness through the modality of vision, which is but one of several competing forms of gaining understanding. Cartesianism was thus simultaneously a model of knowledge and of the "individual." Ideologically, this process led to the mathematization of the sciences, the search for a single set of universal laws, and an enormously powerful scientific worldview that greatly expedited Europe's technological progress.

Co-catalytic with the Cartesian model of the human subject was the geometric view of space that it suggested; the ascendancy of vision as a criterion for truth merged Euclidean geometry with the notion of a detached observer. This worldview had powerful social and material consequences. In Renaissance Europe, Cartesian views

of space were instrumental in the development of geometry, cartography, land surveying, civil engineering, and architecture. The Cartesian/Euclidean notion of space—infinite, absolute, and homogeneous—was replicated throughout the Renaissance and the Enlightenment, forming the basis for Newtonian physics and the theory of gravity. For European navigators, it was instrumental in smoothing space by reducing it to distance, rendering the oceans navigable, and ordering the multitude of the world's places in a comprehensible schema. The projection of Western power across the globe necessitated a Cartesian conceptualization of space as one that could be easily crossed, a function well performed by the cartographic graticule. Inserting various places in all their unique complexity into a global graticule of meridians and longitudes positioned countries, and locales within them, into a single, unified, coherent, and panopticonic understanding of the world designed by Europeans for Europeans, allowing places to be compared and normalized within an affirmation of a godlike view over Cartesian space at the global level. In all these cases, space was robbed of substantive social context to become an ordered, uniform system of abstract linear coordinates. By presenting space as fixed, asocial, and unchanging, Cartesian space accentuated the long-standing Western practice of emphasizing the temporal over the spatial. Some observers maintain that contemporary geographic information systems continue to uphold the old Euclidean/Cartesian view of absolute space, relying as they do on geometric coordinate systems.

Barney Warf

See also **Historicism; Logical Positivism; Relative/Relational Space; Time-Space Compression**

Further Readings

Cosgrove, D. (1988). The geometry of landscape: Practical and speculative arts in sixteenth-century Venetian land territories. In D. Cosgrove & S. Daniels (Eds.), *The iconography of landscape* (pp. 254–276). Cambridge, UK: Cambridge University Press.



- Gregory, D. (1994). *Geographical imaginations*. Cambridge, MA: Blackwell.
- Harvey, D. (1990). Between space and time: Reflections on the geographical imagination. *Annals of the Association of American Geographers*, 80, 418–434.
- Ó Tuathail, G. (1996). *Critical geopolitics*. Minneapolis: University of Minnesota Press.



ACCESSIBILITY

Accessibility refers to the ability of people to overcome distance or other constraints and reach locations, activities, or services that are important to them. A number of different accessibility measures and concepts exist, though these can be classified into two distinct categories: (1) proximity (or zonal or aggregate) and (2) individual (or space-time or disaggregate) measures. Proximity measures show the nearness of one or more origin locations to a set of destinations, whether measured using distance, travel time, or other impedances. The closer an origin is to more destinations, the greater the accessibility of that origin. This notion is commonly calculated for points (such as cities) or zones (such as tracts) representing areas within a city. Origins might represent home locations, while destinations include jobs, recreation facilities, and health care or other services. In contrast, space-time measures are based on the mobility and time constraints of individuals during the course of their daily activities. The greater an individual's mobility and the fewer the time constraints, the greater his or her accessibility will be.

Aggregate Accessibility Measures

The topological or Shimbel measure is based on graph theory and the representation of a network as nodes (origins and destinations) and links (connections between nodes). This measure was introduced in geography in 1960 by William Garrison. Row sums in a filled impedance matrix represent the sum of shortest paths from one origin to all destinations and the accessibility of that origin.

The market or population potential measure of accessibility incorporates the attractiveness of destinations (such as the size or square footage of retail space), with higher accessibility resulting from being closer to more and larger destinations. As in the related gravity model of spatial interaction, distance is usually weighted to reflect the declining importance or utility of destinations farther away. There is no consensus about the specification of the weights attached to distance or the problem of self-potential, in which the distance of an origin to itself is zero and so does not allow the population or attractiveness of the origin to be included.

Simpler measures count the number of destinations within a certain radius of origin locations. These may use a single radius, such as a quarter mile, although more elaborate conceptualizations of distance are possible. In some cases, the counts of destinations may simply refer only to those within the origin zone.

Accessibility Studies

Accessibility studies became common in the 1960s during the quantitative revolution in geography. These studies provided a measure of the spatial structure of economies and cities, and they related socioeconomic indicators to accessibility to jobs or services at the intraurban level or economic variables at the interurban level. Before-and-after studies were (and remain) common. In this type of study, accessibility within a city or region is compared at multiple points in time before and after a major transport project, such as a freeway or railroad system, is completed. Accessibility improvements are then related to changes in economic development. Causality in these studies remains uncertain, and there is also the possibility that in developed countries the provision of transport infrastructure in the past half-century has lessened the importance of accessibility.

In recent decades, accessibility is often used as a variable in other studies, including those on commuting, shopping, recreation, voting, or health care provision or outcomes. The measurement of accessibility has also been expanded to incorporate the presence of competition for jobs or services or to serve as a measure of network



survivability. In all such cases, low levels of accessibility would be treated as a problem.

Time-Space Accessibility

In 1970, Torsten Hagerstrand introduced the concept of time-geography, which examined how the presence of authority, coupling, and capability constraints affected human mobility. Each person has a daily space-time path that reflects these constraints and the need to move around to take part in activities. Within a three-dimensional space, time-geography maps out a space-time prism that can be reduced to a two-dimensional potential path area. Time-geography provides a map of all areas that an individual could have reached during the course of his or her daily activities. This space and its contents have been used as accessibility indicators, with a larger space containing a larger set of potential destinations that can be visited for longer periods indicating higher accessibility.

Accessibility in Geographic Information Systems

Calculating aggregate measures is relatively simple, though if more than a few origins or destinations are present, it quickly becomes labor intensive. The use of computers was therefore essential for early studies. The availability of geographic information systems (GIS) street network data sets with the topological data model has allowed accessibility to be carried out quite easily and has facilitated the use of travel time or cost instead of straight-line distances. GIS has also allowed much richer representations of origins and destinations at increasingly finer spatial scales.

For individual measures, GIS has made calculation within network space feasible since the early 1990s. Studies have explored the accessibility of individuals within differing urban environments and household types and found that individuals living at the same location can possess considerably different accessibility levels, which will also vary by time of day. These measures are currently undergoing considerable development.

Aggregate and individual measures remain distinct and produce different spatial patterns when

mapped at the urban level. Recently, an entirely different notion of accessibility has emerged, based on laws such as the Americans with Disabilities Act, which ensure that public facilities have suitable access for the disabled. While this approach has so far rarely appeared in geographical studies, it suggests a future focus for the concept beyond infrastructure and intra-urban mobility.

Joe Weber

See also GIS in Transportation; Gravity Model; Network Analysis; Quantitative Revolution; Time-Geography; Transportation Geography

Further Readings

- Garrison, W. (1960). Connectivity of the interstate highway system. *Papers and Proceedings of the Regional Science Association*, 6, 121–137.
- Hagerstrand, T. (1970). What about people in regional science? *Papers of the Regional Science Association*, 24, 7–21.
- Kwan, M., & Weber, J. (2003). Individual accessibility revisited: The implications of changing urban form and human spatial behavior. *Geographical Analysis*, 35, 341–353.



ACID RAIN

Acid rain refers to a mixture of wet and dry deposition of chemical compounds from the atmosphere containing higher than normal amounts of nitric acid and sulfuric acid (HNO_3 and H_2SO_4 , respectively). Rain with a pH of 5.0 or stronger is considered acidic, which is slightly more acidic than clean or unpolluted rainwater (around 5.2–5.6). Extreme cases have been measured at a pH of between 3.0 and 4.5. Pure, unpolluted water has a pH of around 7.0. The phenomenon of acid rain and deposition has resulted in geographically and regionally pronounced effects, leading in some cases to dead lakes, fish, and trees, and damaged soils, crops, and national monuments in many countries. Nitric acid and sulfuric acid also damage human health. Concern with this problem began in the late 1960s and 1970s and,



Acid-rain-damaged trees at dusk, petrochemical plant in the distance.

Source: David Woodfall/Getty Images.

following substantial research efforts, culminated in government action in Europe, North America, and East Asia in the 1980s and 1990s.

The precursors of acid rain formation come from both natural sources, for example, decaying vegetation and volcanoes, and anthropogenic sources, especially emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from coal and oil combustion. High-sulfur coal-fired power plants and copper smelters are particularly important sources, and in some areas, motor vehicles. Acid rain occurs when these gases react in the atmosphere with rain, snow, or fog and oxygen and other chemicals to form various acidic compounds (acid aerosols). If the weather is dry, the acid chemicals can mix with dust particles or smoke. Either way, the result is a mild mix of HNO_3 and H_2SO_4 . When SO_2 and NO_x are released from fossil-fueled power plants and other

sources, prevailing winds can blow the compounds across state and national borders, sometimes over hundreds of miles from the combustion sources. The widespread use of tall chimneys in coal-fired power plants and other industrial facilities in the 1970s and 1980s in North America and Europe led to an increase in this problem.

In the United States, there are two national networks (both supported by the U.S. Environmental Protection Agency) that monitor acid rain and dry-acid deposition: the National Atmospheric Deposition Program and the Clean Air Status and Trends Network. Similar monitoring networks exist in Europe and East Asia. While some areas have naturally acidic lakes and soils, the regional patterns of the problem have been fairly clear for decades. Areas suffering from especially strong levels of acid rain and deposition include the Adirondack and Catskill Mountains (New York),



the rest of the northeastern United States, and some mountainous areas of the southeastern United States; southeastern Canada; Poland, Czech Republic, Slovakia, Germany, Greece, Russia, northeastern England, Southern Sweden, Norway, and Finland in Europe; and China, India, Japan, and Malaysia in Asia.

The most serious adverse effects of acid rain are those affecting freshwater aquatic environments (lakes, streams, creeks, marshes, and fish), forests, and human health; serious effects can also occur to buildings, other materials, automotive coatings, and visibility. The lower pH and higher aluminum levels in acid rain can damage a variety of ecosystems. This is especially problematic in watersheds whose soils have a limited ability to neutralize acidic compounds (called “buffering capacity”). At extreme levels, fish will develop tumors, and their eggs will not hatch; mortality rates increase; and biodiversity decreases. In the case of forests, acid rain does not usually kill trees but instead weakens them by damaging their leaves, limits the nutrients available to them, or exposes them to the slow release of toxic substances in soils. Human health effects from acid rain result from the important role of sulfate and nitrate aerosols as fine particles, as well as the role of NO_x in tropospheric ozone formation. These pollutants can result in a variety of morbidity and mortality risks associated with lung inflammation, including asthma, chronic bronchitis, emphysema, vascular inflammation, and atherosclerosis. Particulate pollution can also result in lower levels of visibility. Building or monument damage can occur when H_2SO_4 rain reacts with calcium deposits in the stones to create gypsum, which will eventually flake off.

Lakes and streams suffering the ill effects of acid rain have often been limed to increase the alkalinity and pH level, clearly a short-term fix. Unfortunately, liming can have adverse effects on wetland plant species. Long-term control of acid rain requires a significant reduction in the precursor pollutants, SO_2 and NO_x . After researching the problem for many years, acid rain control programs have been enacted and implemented in Europe (Convention on Long-Range Transboundary Air Pollution of 1979, or LRTAP); North America (U.S. Clean Air Act Amendments of 1990—Title IV and the U.S.–Canada Air

Quality Agreement of 1991); and China (which approved its so-called total Amount Control Program for Eastern China in 1998). The first European Country to take acid rain seriously, which ultimately led to LRTAP, was Norway, followed by Sweden. Norway was also the first to instigate legal, cross-border action against any perpetrator—in this case, the United Kingdom. It has also seen the greatest post-1979 improvement in its lakes and freshwater fisheries. The U.S. Acid Rain Program is most well-known for its groundbreaking SO_2 emissions trading program, which was implemented among fossil-fueled power plants and is widely seen as successful, setting the stage for greenhouse gas trading.

Given the great attention paid to acid rain in the 1980s and 1990s, many people consider the problem under control. While great strides have been made in the reduction of emissions, the recovery of acid-damaged ecosystems is a long-term process that will take decades. Thus, the acid rain problem will be around for a while, and emission control programs need to be assessed for their interaction with other serious environmental problems, most famously global climate change.

Barry D. Solomon

See also **Ambient Air Quality; Atmospheric Pollution; Market-Based Environmental Regulation; Point Sources of Pollution**

Further Readings

- Burtraw, D., Krupnick, A., Mansur, E., Austin, D., & Farrell, A. (1998). Costs and benefits of reducing air pollutants related to acid rain. *Contemporary Economic Policy*, 16, 379–400.
- Ellerman, A. D., Joskow, P. L., Montero, J. P., Schmalensee, R., & Bailey, E. M. (2000). *Markets for clean air: The U.S. Acid Rain Program*. New York: Cambridge University Press.
- Jenkins, J. C., Roy, K., Driscoll, C., & Buerkett, C. (2007). *Acid rain in the Adirondacks*. Ithaca, NY: Cornell University Press.
- Menz, F., & Seip, H. (2004). Acid rain in Europe and the United States: An update. *Environmental Science & Policy*, 7, 253–265.



ACTOR-NETWORK THEORY

Actor-network theory is an approach that attempts to capture the complexity of the social world by uncovering the relations among human and nonhuman actors. Supporters of this approach argue that it is only through the tracing of all types of connections between actors that one can come to understand how different social processes and phenomena arise. Because of its emphasis on relations, actor-network theory is also called the sociology of associations: The focus is always on the connections among disparate things rather than on the similarities or regularities that may appear to be grouping actors together.

Actor-network theory shares some antiessentialist sentiments (an opposition to fixed entities and essences) with other strands of postmodern and poststructural thinking. As a result, the approach is suspicious of explanations that draw on common social theory constructs or conceptual aggregates such as social ties, structure, context, and so on. Actor-network theory also adopts a unique view of agency. Rather than being limited to intentional human action, actor-network theory locates agency in any “actant” (any human or nonhuman entity) that can be identified as the source of action. However, those engaging in this approach should keep in mind that the ultimate aim of actor-network theory is to reassemble the social through detailed studies of all the elements and connections that come together to produce whatever phenomena are being studied. In this sense, actor-network theory moves away from mere critique or deconstruction and instead offers explanations that are based on analysis of the effects of the relations among different types of entities.

Actor-network theory had its origins in studies of the sociology of science and technology carried out by some of the theory’s main proponents, Bruno Latour, John Law, and Michael Callon. Today, the approach has transcended its original disciplinary boundaries and goals. Actor-network theory is one of several relational perspectives adopted in the past decade by critical human geographers. In the process, geographers have further refined the vocabulary of actor-network

theory and built on some of its foundations in the development of other conceptual approaches such as nonrepresentational theory and hybrid geographies. Geographers also have developed more complex accounts of the geographic implications of adopting the actor-network perspective. For example, despite being a theory identified with networks, the approach does not lend itself to the traditional representations of networks based on Euclidean space common in some strands of spatial and network analysis. Instead, actor-network theory adopts a relational view of spatiality where society and space are mutually constituted, where the positions and roles of actors in a network lead to different configurations of power relations through space-time, and where places are not territorially circumscribed but rather are always in the process of being formed through relations. Rather than imagining space as a container, actor-network theory imagines multiple spatialities operating simultaneously, performed through networks and constantly becoming. Geographers have fruitfully adopted this imagery and vocabulary to conduct studies that range from analyses of urban and environmental planning to tracings of global wildlife protection networks.

Fernando Javier Bosco

See also Critical Human Geography; Hybrid Geographies; Network Analysis; Nonrepresentational Theory; Poststructuralism; Relative/Relational Space; Science and Technology Studies

Further Readings

- Latour, B. (2005). *Reassembling the social: An introduction to actor-network theory*. New York: Oxford University Press.
- Law, J., & Hassard, J. (1999). *Actor-network theory and after*. New York: Wiley.
- Murdoch, J. (2006). *Poststructuralist geography: A guide to relational space*. Thousand Oaks, CA: Sage.
- Whatmore, S. (2002). *Hybrid geographies: Natures, cultures, spaces*. Thousand Oaks, CA: Sage.



ADAPTATION TO CLIMATE CHANGE

International efforts to seriously curtail rising atmospheric greenhouse gas levels seem unlikely to be effective in the next decade, and inertia in the climate system means that some climate change will occur no matter what mitigation strategies are undertaken. Thus, many policymakers and researchers are focusing on the more realistic and politically palatable policy of “adaptation to climate change,” which is becoming increasingly vital. This approach assumes that environmental systems will become less stable as greenhouse gas levels increase, and thus humans must undertake actions that increase social and ecological resilience to perturbations. Such a policy has the additional benefit of offering “no regrets” or “win-win” outcomes—that is, even if global climate change does not unfold as expected, there are no regrets for having made these adaptations because they address other current issues of societal concern. Current adaptation targets include improved irrigation for agriculture, coastal protection from severe storms, preparation for extreme events, a strong public health infrastructure, and biodiversity preservation. The recent Bali Action Plan was created under the United Nations Framework Convention on Climate Change to focus on stronger climate change policies, and it urges far more aggressive action on adaptation than do past agreements. Those most vulnerable to climate change impacts are also those least able to adapt, so capacity building in all sectors will lead to the best adaptation strategies.

Regional Case Studies

Because specific climate change impacts cannot be perfectly modeled, case studies that examine social and ecological responses to climate variability are a valuable tool for climate change adaptation. Past responses to drought or extreme events in sensitive areas can be extrapolated to other regions that may experience these stresses in a climatologically altered

world. Some examples are cost-benefit analysis that indicates the need for a planned retreat from hurricane-prone coastlines and vulnerability studies in areas that are currently climatologically marginal that examine how producers respond to current droughts or other weather anomalies. These studies are occurring in less developed areas, such as the African Sahel region (grazing impacts), Southern Africa (agriculture, wildlife, and flooding), and Southern Asia (agriculture and extreme events), and also in more developed regions, such as London (heat stress), Arizona (water availability), and Greenland (resource extraction).

Environmental Management Goals

Specific management goals for climate change adaptation differ depending on the environmental systems examined, but efforts have generally focused on the most climatologically sensitive systems—human health, agriculture, water resources, forestry, coastal areas, and natural ecosystems. Climate change impacts will depend on system sensitivity as well as ability to adapt. For example, rain-fed cotton production in West Texas is already sensitive to subtle shifts in precipitation, and even a small change will have a large impact. Small changes in more humid parts of the world will require less adaptation. Humans have adapted to the environment throughout history. The climate change adaptation process will merely be a more rapid and better thought out process instead of an ad hoc one—proactive rather than reactive—so that the overall costs to society can be minimized, at least in the wealthier nations. Current and historic losses from climate variability (droughts, hurricanes, etc.) without any change in greenhouse gas levels have been extreme at times, and thus no-regrets policies are relatively easy for society and policymakers to support. However, poor or low-lying countries such as Bangladesh and the Maldives have little or no ability to adapt to climate change effects such as a rise in the sea level.

Autonomous planning—where individuals respond to changing conditions—can be skewed by unavailability of information, lack of financial and capital resources, and cultural preferences.



Planned adaptation at the policymaker level will be far more effective because incentives to individuals can be changed wholesale through insurance, capital availability, land tenure, and subsidies to encourage society to maximize resilience-seeking activities. Individual cost-benefit decisions will have to be influenced by government because individuals do not have sufficient information to plan effectively in a rapidly changing climate and environment. Unfortunately, this type of societal decision making is difficult and requires cross-sectoral support for success.

Adaptation Targets

Climate change is expected to lead to an intensification of extreme events. Society has adapted to a range of climate and weather variability based on past events. However, extreme events will increasingly exceed society's ability to withstand them and lead to major societal impacts. Increases in heavy precipitation events already have been documented by numerous authorities in the midlatitude regions. Natural variability masks trends in tropical storm frequency and intensity, and this, compounded by inadequate lengths of records, means that while larger and more frequent storms are modeled to occur, they have not yet been documented unequivocally. The most important adaptation measure for extreme events is to encourage people to remove themselves from harm's way—that is, not building and living on hurricane-prone shorelines, in floodplains, and in drought-prone agricultural areas. This is difficult to do in many parts of the world where population densities are high and space is limited. Resilience to storms can also be developed through improved building codes and shoreline protection. Shoreline protection includes government infrastructure improvements, removing subsidies on insurance, removing development from inappropriate locations, and strong enforcement of building ordinances through inspections. In the long term, none of these measures will likely suffice, and more stringent development limits on vulnerable shorelines will probably be needed.

Public health infrastructure, especially disease early-warning systems based on climate conditions, can enable public health officials to engage in timely interventions including immunizations

and focused vector habitat removal. Education of populations regarding long-term risks will yield major dividends, and monitoring of current fringe populations will enable rapid response. These are classic “no-regrets” policies because they make sense immediately and their benefits will grow through time no matter what happens with climate change.

Agricultural adaptation includes major farm-level responses such as changes in crop types and more minor changes such as shifts in crop-planting dates. Climate changes will not necessarily be negative for agriculture, and adaptation measures must both reduce risk and help capture opportunities. Major challenges will be tackling new pest species, coping with more frequent drought, and weathering extreme events. Many necessary agricultural adaptations are identical to proposals within the sustainable agriculture literature, and links between the two will no doubt grow.

There is a major risk of new pest species that are resistant to variable climate moving into croplands during the expected poleward movement of pest species into new habitats. Controlling new pest insects and diseases can be accomplished through a variety of techniques, including increased surveillance and response capabilities, elimination of breeding and overwintering sites, and targeted pesticide use. However, recent dramatic increases in insect resistance to individual pesticides and environmental concerns limit the efficacy of these chemicals in many cases.

Climate variables play such a critical role in agricultural success from year to year that small-scale adaptations are likely to have marginal effects. Agricultural irrigation and other major structural adjustments are more likely to provide long-term benefits—if adequate water supplies are available. Additionally, crops better suited to the new climate conditions will be the most successful in the long run. Even so, the uncertainties in modeled future climates are large enough so that specific crop replacements will likely be an autonomous adaptation, while policy-level adaptation is best focused on removing the structural impediments to capital shifts—likely poleward—while providing alternative options for areas experiencing drier or less favorable growing conditions. Changing tillage practices to reduce water loss is a short-term solution that is providing



immediate benefits. Unfortunately, this can also increase insect or weed population pressures and compound the problem of new pests. Drought early-warning systems also can provide current and long-term benefits.

The effect of extreme events will have the greatest impact on agriculture—both frequent intense drought and storms that will physically damage crop plants—and these effects are the most difficult to model and to create policy adaptations to help mitigate. While drought measures are noted above, severe storm damage is typically addressed only through crop insurance. Yet crop insurance may slow agricultural adaptation because it subsidizes past behavior that may no longer be appropriate and could discourage reallocation of capital to more climatologically logical uses. Finally, the major no-regrets global policies will be to reduce food security risk and protect genetic resources so that new climate-adapted crops can potentially be discovered.

Biological systems will be the hardest hit by climate change because they require the greatest amount of time to adapt. The recent United Nations Millennium Ecosystem Assessment projected that climate change will be the dominant driver of biodiversity loss in the coming century. Biodiversity adaptations will also be difficult because of lower economic investments in this sector. Adaptation must include both new research and policy measures. Necessary research includes establishing current environmental condition baselines, increasing the availability of species data, and selecting the indicators of change. Once this data process has begun, policy goals include maintaining native ecosystems and ecosystem services, controlling alien species, developing and maintaining wildlife corridors to facilitate species migration, increasing management outside of protected nature reserves, and potentially translocating species into new habitat—“assisted colonization.” Many authorities posit that adaptation at the species level will be insufficient and may lead to even more widespread extinction than is already occurring. Species may be able to thrive in new environments if they are able to reach them. However, the fragmented nature of land use indicates that the major adaptation goals must be to promote the dispersal of species and reduce the non-climate-change pressures on habitats.

Ecosystem services such as soil conservation, clean water, and other benefits are no-regrets measures that assist society in multiple ways during climate change adaptation.

Water is already a critical global environmental issue because of increasing populations and degrading water quality. Climate change will worsen this situation dramatically. Required adaptations are already under way to address current crises in many parts of the world, and climate change adaptation will hasten this process. Important measures include developing the infrastructure for water resources, managing societal risk, and addressing uncertainties about water quantity and quality. In spite of rising human populations, it will be necessary to reduce the demand for water through increased conservation and water use efficiency, especially in agricultural use (which is the number one global use of water). Also, populations will have to be protected from extreme events—both drought and flood—as noted above. Water use adaptation can be facilitated through community education and outreach programs, including those for more efficient water use.

Confounding Issues

Human population growth is the major factor confounding climate change adaptation. Increasing numbers of people require an increasing number of resources, and these may not be available in a transitioning world. Human barriers to migration, such as a country's borders, will be an ever-increasing problem, as more people seek to flee climatologically sensitive regions. Many governments are beginning to explore the potential national security issues involved. Additionally, unanticipated potential nonlinear responses to climate forcing cannot be modeled or addressed currently in adaptation planning. Finally, while case studies provide analogies, there still are major knowledge gaps regarding the specific adaptations required for a given region. Overall, adaptation becomes far more difficult depending on how much climate change occurs before mitigation has reduced the risks. A significant reduction in greenhouse gas concentrations is the only long-term solution.

John All



See also **Anthropogenic Climate Change; Climate Policy; Environmental Management; Greenhouse Gases; Human Dimensions of Global Environmental Change; Resilience; Social and Economic Impacts of Climate Change; Symptoms and Effects of Climate Change**

Further Readings

Easterling, W., Hurd, B., & Smith, J. (2004). *Coping with global climate change: The role of adaptation in the United States*. Arlington, VA: Pew Center on Global Climate Change.

Food and Agriculture Organization of the United Nations. (2007). *Adaptation to climate change in agriculture, forestry and fisheries*. Rome, Italy: FAO Press.

Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: Impacts, adaptation and vulnerability* (Working Group II contribution to the fourth assessment report of the IPCC). Cambridge, UK: Cambridge University Press.

National Research Council. (2001). *Climate change science*. Washington, DC: National Academies Press.



ADAPTIVE HARVEST MANAGEMENT

Adaptive harvest management is a methodology used in natural resources and environmental management. It is based on the concept of adaptive management, which evolved in the 1970s because geographers and other scientists realized that conventional resource management could not guarantee that species were used sustainably. Emphasizing that human activities ultimately affect resource sustainability, adaptive management evaluates the additional social factors that affect how humans use their resources rather than simply managing the nonhuman resources.

Adaptive approaches conceptualize management as a learning process that is either inherent in data analysis or part of a less formal but, nevertheless, rational and structured decision process. The approach is a relatively recent methodological innovation and, despite its limitations,

can facilitate faster and less expensive problem solving.

The Need for a New Approach

Managing commercially harvested resources such as game and timber species, water, and other renewable resources traditionally relied on quantitative data analysis and predicting the optimal harvest level. These analyses necessitated overharvesting a species before managers could determine an optimal take. Reducing harvest effort after that optimal take had been regulated was difficult to implement because the authorities had to enforce a harvest reduction or buy back licenses issued for harvest.

Even after calculating and enforcing an optimal harvest level, managers noticed dramatic fluctuations in biological populations and needed objective decisions about their exploitation, especially where species crossed multiple jurisdictional boundaries. Continuous species monitoring showed that population demographics remained dependent on factors such as stochastic events, unknown habitat features, or underlying landscape processes. Managing commercially harvested resources was more complicated than estimating the populations of nonharvested species because the behaviors of people, political decisions, market fluctuations, and the values of stakeholders, including those allocated some of the resource, affected management efficacy.

Adaptive Management as a Learning Experiment

Adaptive management forefronts the complexity and interdependence of natural and social systems, their constant adaptation to change, and the inherent risk and uncertainty characteristic of management processes. In complex systems, a positive feedback loop perpetuates change, and a negative feedback loop retards change. Some responses to change reduce the natural variability and diversity of a system, and thus its resilience and capacity to create alternative responses.

Adaptive management relies on a feedback learning loop after managers implement alternative policies as field “experiments” that inform



progressive decisions made at regular intervals. Information about the state of a system is collected and interpreted; alternative management scenarios are considered; decisions are implemented, evaluated, and reinterpreted; and responses are altered accordingly. The cycle starts again as the manager or researcher observes the state of the new system.

Harvested Populations

Adaptive harvest management incorporates ecological data about the abundance and reproductive parameters of a species, as well as information about the impacts of various harvest policies (e.g., the costs and benefits of annual quotas, of daily bag limits or sizes and equipment limits in fish and waterfowl hunting, or of retaining brood stock to increase populations).

Dominant approaches to adaptive harvest management apply a recursive computer-generated algorithm to estimate the expected utility of future harvests based on present information. Over a sequence of time intervals, alternative harvest policies are implemented, and their probability as the optimal harvest strategy for the current system is estimated. These estimates are combined with updated ecological data (e.g., the new population size after restricting hunting to a particular area or season) to inform a subsequent iteration of the algorithm. Each iteration recursively adjusts the model probabilities using the impacts of the previous decision and the calculated change in population size. The optimal harvest strategy maximizes the expected cumulative harvest value at any particular point in time.

Types of Adaptive Harvest Management

Adaptive management is sometimes categorized as either active or passive, depending on whether uncertainty is made explicit. Active adaptive management refers to more systematic and rigorous experimentation and decision-making processes in which feedback learning about the harvest policy and the state of the resource are incorporated into various mathematical models that have weighted parameters based on previous analyses. Passive adaptive management is sometimes used

to refer to nonexperimental analyses that rely on trial-and-error learning, which can be more pragmatic and attractive to practitioners.

Humans have always adapted to their environments, and many indigenous societies, small-scale farmers, and people with local knowledge of resources use locally adaptive harvest management. Sometimes comanagement systems develop where community representatives establish and enforce agreed-on harvest rules, and public agencies benefit because the local people observe resource trends at a finer scale than broadscale commercial management with its faster and more cost-effective responses. Local strategies cannot be applied, however, to control harvesters from outside a community without government devolution of power to local groups to enforce the rules. Furthermore, local knowledge may not reflect broader regional trends.

Criticisms and Challenges

Although natural and human-induced changes occur in socionatural systems, adaptive harvest management is criticized because change may be attributed to one, human intervention that is inferred as causal. Furthermore, causal factors are themselves subject to change and uncertainty.

Other criticisms of adaptive management arise from difficulties with measuring social processes (e.g., when political pressures override agreement on how to value and allocate harvest policies) or suggest that the adaptive approach may be used to justify taking a particular policy stance.

Adaptive management cannot take the place of rigorous and systematic scientific experimentation, but adaptive management is faster and less expensive. The traditional approaches frequently cannot produce environmental solutions in the time required by managers, which is critical in the face of global climate change and other rising uncertainties about the sustainability of ecosystems and their components.

Jennifer L. Carter

See also **Renewable Resources; Sustainability Science; Sustainable Agriculture; Sustainable Fisheries; Sustainable Forestry; Sustainable Production**



Further Readings

- Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, 10, 1251–1262.
- Holling, C. S. (Ed.). (1978). *Adaptive environmental assessment and management*. London: Wiley.
- Walters, C. (1986). *Adaptive management of renewable resources*. New York: Macmillan.
- Walters, C., & Holling, C. (1990). Large-scale management experiments and learning by doing. *Ecology*, 71, 2060–2068.



ADAPTIVE RADIATION

Adaptive radiation is a term used to describe a period in evolutionary history when a single or a few species diversified and underwent relatively rapid speciation. The event is distinguished from the background pattern of evolution in two ways: in pace and in the extent of diversification. These deviations from the slow and gradual flow of evolution are “adaptive” in that they are driven by natural selection as new species expand into vacant ecological niches. They are “radiation” events in that they result in expansion of the taxonomic group from one or a few to several or many species.

This rapid speciation is often accompanied by an increase in extinction rates as well, because not all the initial emergent forms are successful. For example, if one were to consider an incomplete assemblage of the fossil record, a seemingly linear history could be traced to today’s genus of horses (*Equus*) from its ancestor *Hyracotherium* some 55 mya (million years ago). However, the true lineage of this group of mammals actually involves several branching events with subsequent extinctions. Rather than a straight line from one species evolving into the next, its history resembles a bush with many branches cut short and a rather crooked path leading from *Hyracotherium* to *Equus*. Adaptive radiations can be considered times of evolutionary experimentation, when many new traits are tested but only a fraction survive the process of natural selection. The

Cambrian explosion was a rapid diversification in animal body forms that occurred between 545 and 525 mya. Over the past 100 years, studies of the fossil record of one particular area, the Burgess Shale in the Canadian Rocky Mountains, have provided unique insights into this process. Of the 60,000 unique fossils found at the location, most represent species now extinct, with some of them not clearly related to any animals existing today.

Adaptive radiations typically follow one of three events: (1) the emergence of an evolutionary innovation, (2) colonization of a new habitat, or (3) a mass extinction. In each case, relatively rapid speciation is driven by natural selection favoring individuals that have escaped their competitors and/or reached unoccupied ecological niches. An ecological niche is defined as the totality of an individual’s role in its environment, including its habitat requirements and competitive constraints.

First, an adaptive radiation can follow the evolution of an innovative characteristic that gives a taxon access to a novel niche. These radiations are typically widespread, even worldwide, rather than regional. Examples include the radiations following the colonization of land by plants, insects, and tetrapods, each involving the evolution of innovative characters facilitating success on land. A more specific case would be the evolution of flight in an ancestral dinosaur that led to the radiation of birds, which are now the most diverse terrestrial vertebrates, with approximately 10,000 species. Another example is the radiation of angiosperms (flowering plants) into more than 250,000 species after divergence from gymnosperms between 200 and 140 mya.

Second, a population may reach a novel habitat by colonizing a relatively empty system free from traditional competitors, such as an island. Adaptive radiation can be seen in the divergence following the initial colonization of these relatively isolated ecosystems. Examples of these regional events are found in archipelagoes and island-like systems around the world. The most famous example are the finches of the Galapagos, which served as a partial muse for Charles Darwin’s theory of natural selection and descent with modification. Current evidence suggests that an ancestral population of approximately 30 individuals colonized the islands some 2.3 mya, having been carried on ocean wind currents, and then evolved to include



the 14 species known today. An example of an island-like system that displays the same principle can be found in the cichlid fishes in Lakes Malawi, Victoria, and Tanganyika in East Africa. The genetic and geographic origin of these fishes appears to be Lake Tanganyika, with subsequent speciation leading to 2,500 species in East Africa in as little as 100,000 years.

Third, large-scale adaptive radiations have followed all the five mass extinctions of the past, when the survivors expanded into the many vacated niches of the victims. The best-known example of this type of expansion is the radiation of the mammals approximately 65 mya following the extinction of the dinosaurs. Prior to this extinction event, most mammals were small and probably nocturnal. Once released from competition and predation pressure from dinosaurs, mammals underwent rapid speciation to reach today's 5,300 species with diverse morphologies and ecologies. While this view of mammal evolution is common and a clear example of an adaptive radiation, some recent studies have suggested that the timing of the diversification may not have coincided with the extinction of the dinosaurs. More research is needed on this topic.

Elizabeth R. Congdon

See also **Archipelago; Biogeography; Island Biogeography**

Further Readings

Grant, P. (Ed.). (1998). *Evolution on islands*. Oxford, UK: Oxford University Press.

Schluter, D. (2000). *The ecology of adaptive radiation*. Oxford, UK: Oxford University Press.



ADIABATIC TEMPERATURE CHANGES

When air rises or subsides in the atmosphere, its temperature changes as a result of the change in pressure. This is called adiabatic temperature change, and understanding what happens in this process is essential for understanding

condensation and evaporation in the atmosphere, which in turn explain cloud formation and precipitation. The rates of temperature change of rising or subsiding air are known, but they vary according to several factors, such as whether there is condensation or evaporation taking place and the temperature of the air.

Rising and Subsiding Air

Rising air experiences a drop in temperature, *even though no heat is lost to the surrounding environment*. Air is a poor conductor of heat, so a rising air parcel will tend to remain discrete from the surrounding air, not mixing rapidly. The temperature drops because there is a decrease in atmospheric pressure at higher altitudes. As the pressure of the surrounding air is reduced, the rising air parcel will expand. This results in cooling, since there is an inverse relationship between the volume of an air parcel and its temperature. During either expansion or compression, the total amount of energy in a discrete parcel of air remains the same (none is added or lost). The energy can be used either to do the work of expansion or to maintain the temperature of the parcel, but not both. If no heat is added or lost to the surroundings, then when an air parcel rises and expands, its temperature drops. Conversely, when the parcel is compressed, its temperature rises. So if the parcel of air descends into altitudes where the pressure is greater, it would be compressed and would warm up again without taking in heat from the outside.

This is the process of adiabatic heating and cooling. The term *adiabatic* implies a *change in temperature* of the air parcel *without gain or loss of heat* from outside the air parcel. Air parcels may rise or subside in the atmosphere as the result of variations in temperature and of the dynamics of the atmosphere, and this in turn affects their pressure and temperature. Adiabatic processes are very important in the atmosphere, and the cooling of rising air is necessary for cloud formation.

Adiabatic Lapse Rates

Dry Adiabatic Lapse Rate

In the atmosphere, the decrease in temperature of rising, unsaturated air is about 10 °C per



1,000 m (meters) altitude. For example, if a parcel of air is at 24 °C at sea level and it rises to 1,000 m, its temperature will go down to 14 °C. If unsaturated air subsides, it *warms up*, also at 10 °C per 1,000 m. So if a parcel of air at 4,000 m altitude has a temperature of −10 °C and it subsides to 3,000 m, its temperature will warm up to 0 °C. If it continues to subside, then at sea level it would have a temperature of 30 °C. This rate of temperature change of unsaturated air that is rising or subsiding is called the *dry adiabatic lapse rate* (DALR).

Note that this applies to *moving air*, not *still air*. The change in temperature of still air (air that is not rising or subsiding) follows the environmental (or average or normal) lapse rate, which varies considerably but averages about 6.5 °C per 1,000 m. Thus, the rate of temperature change in still air is not as great as the rate of change in rising air; that is, the air parcel does not cool off as fast.

Saturated Adiabatic Lapse Rate

When the moving air parcel is saturated, the change in temperature is more complicated. Consider a parcel of air that is rising—and getting colder. One of the basic rules in meteorology is that there is an inverse relationship between the temperature of a parcel of air and its relative humidity. As a parcel of air cools, its relative humidity increases. As a parcel of air warms, its relative humidity decreases. (Note that the relative humidity changes, even though the total moisture content of the air parcel remains the same in both cases.)

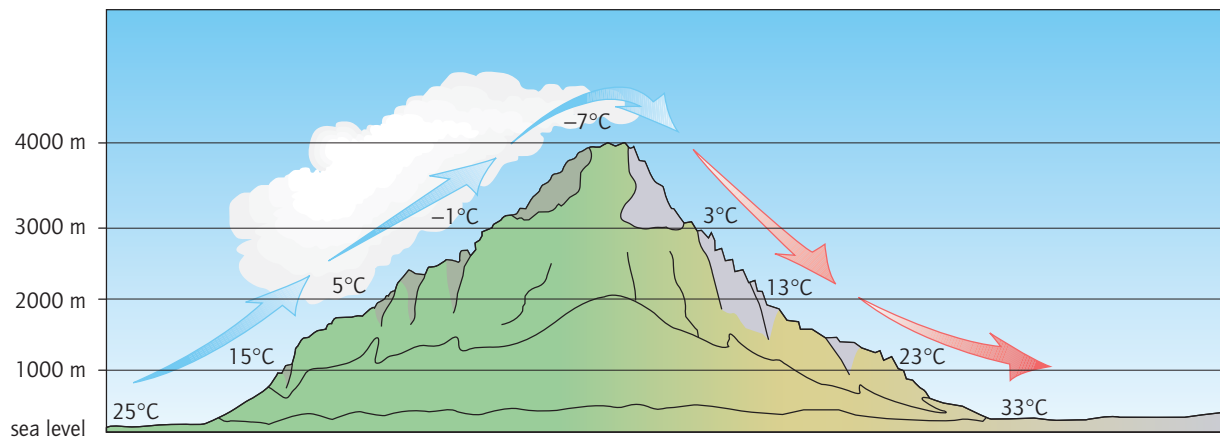
So if we look at a parcel of air that is rising and cooling at the rate of 10 °C per 1,000 m, eventually it's going to cool off enough for the relative humidity to reach 100%, and at that point condensation can take place. The dew point is the temperature at which air becomes saturated and condensation begins. The lifting condensation level is the altitude at which air reaches the dew point.

This condensation of moisture influences the temperature. When water changes its physical state (evaporating to form water vapor or condensing to form liquid water in this case), energy is involved. The energy gained or released when

water changes state is called latent heat. When water evaporates, latent heat is absorbed (by the water molecule as it evaporates). When water condenses, latent heat is released (by the water molecule to the surrounding air). The amount of latent heat released by condensation is almost 600 calories per gram of water vapor. So when condensation takes place, latent heat is released to the surrounding air. When the rising air parcel reaches 100% relative humidity, there are then two opposing trends going on at the same time within the parcel. The parcel is rising and cooling, but there is also condensation, which warms up the air. The question is, will the air get colder, or will it get warmer?

What happens is that the air will still cool off as it rises, but more slowly. If water vapor in rising air is condensing, the rate of cooling is *less* than the DALR. This is the *saturated adiabatic lapse rate* (SALR), also called the wet adiabatic lapse rate or moist adiabatic lapse rate. The SALR is not constant, like the DALR, but varies inversely with the original temperature of the air parcel. A typical value for the SALR would be about 5 to 6 °C per 1,000 m. If the original temperature of the air is relatively high, the SALR of rising air will be lower, while if the temperature of the air is low to begin with, the SALR will be higher—and closer to the DALR. The reason for this is that a parcel of air with a high temperature will be able to contain a greater mass of water vapor than a parcel with a lower temperature. So when this larger mass of water condenses, a lot of latent heat is released. A parcel of air with a lower temperature to begin with will have less water vapor. So when this smaller amount of water condenses, less latent heat is released (Figure 1).

For example, if wind runs into a mountain and starts moving up the mountainside, it will likely start cooling at the DALR as it rises. However, as it cools, the relative humidity increases. When the air cools enough for the relative humidity to reach 100%, the rising air will continue to cool, but more slowly, following the SALR. Using a reasonable value of 6 °C per 1,000 m for the SALR, if an air parcel reaches saturation at a temperature of 5 °C and an altitude of 2,000 m, then as it continues rising to 3,000 m, it will cool 6 °C, to −1 °C. If the air subsequently descends on the leeward side of the mountain, it will warm up—at



Copyright © 2008 Pearson Prentice Hall, Inc.

Figure 1 Temperature changes in a hypothetical parcel of air passing over a 4,000-meter-high mountain

Source: McKnight, T., & Hess, D. (2008). *Physical geography: A landscape appreciation* (9th ed., p. 155). Copyright © 2008. Reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey.

the SALR if there is evaporation taking place or at the DALR if there is no evaporation.

In general, the windward side of a mountain range, with rising air, is likely to have more precipitation than the leeward side, with subsiding air. The leeward side of a mountain range is often said to be in the “rain shadow” of the mountains. The rising and adiabatic cooling of air are necessary for cloud formation and the development of precipitation.

Jane R. Thorngren

See also Atmospheric Pressure; Clouds; Humidity; Lapse Rate; Latent Heat; Precipitation Formation

Further Readings

- Aguado, E., & Burt, J. (2006). *Understanding weather and climate*. Upper Saddle River, NJ: Prentice Hall.
- Barry, R. G. (2003). *Atmosphere, weather, and climate*. New York: Routledge.
- McKnight, T., & Hess, D. (2008). *Physical geography: A landscape appreciation* (9th ed.). Upper Saddle River, NJ: Prentice Hall.

- National Weather Service. (2009, January). Synoptic weather. *JetStream: Online School for Weather*. Retrieved January 19, 2008, from www.srh.weather.gov/jetstream/synoptic/clouds.htm
- Thorngren, J. (2002, August). Adiabatic processes and lapse rates. *Humidity* [Electronic version]. Retrieved January 19, 2009, from <http://daphne.palomar.edu/jthorngren/humidity.htm>



AERIAL IMAGERY: DATA

As one of the main sources of high-resolution images, aerial imagery is the primary data of airborne remote sensing, which involves taking photographs and images using an airborne sensor. Thus, the term *aerial imagery* refers to aerial photographs or aerial images. Airborne sensors, mounted on airplanes, helicopters, balloons, rockets, or other platforms, automatically collect aerial images of Earth's surface. A photograph or an image taken by a handheld camera is also a type of aerial imagery; that is, the camera should not be placed on a ground structure.



Development

Aerial photographs are the first type of aerial imagery. The first known aerial photograph was taken from a hot balloon by the French photographer Felix Tournachon, who used the nom de plume Nadar, in 1858. One of the earliest aerial photographs taken in the United States is the Balloon View of Boston, taken in 1860 by James Wallace Black. Photography from aircraft was widely applied during World War I. The early aerial photographs are typical nondigital photographs and in black and white. Data are usually stored in films or prints. The American Society of Photogrammetry was founded in 1934 to advance aerial photography. The U.S. Geological Survey began using aerial photographs for mapping in the 1930s.

Aerial photography evolved to a high level of sophistication during World War II and the Korean War. Since then, color infrared photography has become important in identifying vegetation types, detecting disease, and quantifying biomass. Multispectral aerial imagery, taken at the same time with different portions of the electromagnetic spectrum, was developed and tested with the data of true-color and false-color aerial photographs. Data are saved in magnetic, optical, solid-state media with digital images of the matrix of numbers, using the technology of digital photography. Now, most aerial imagery is stored in digital image format.

Innovation

The most important innovations in the development of aerial imagery are black-and-white film, color film, conventional cameras, multiband cameras, digital cameras, aerial hyperspectral imagery, side-looking airborne radar (SLAR), and aerial light detection and ranging (LIDAR). The black-and-white film traditionally used in aerial imagery is panchromatic black-and-white film, which is often used for a wide range of resolutions, gradations, and sensitivities. Compared with color film, an advantage of black-and-white film is that it can be combined with appropriate filters for bad weather, such as a misty day.

Color film includes color diapositive film, color negative film, and color infrared film. Color

diapositive film is typically used in large-scale and medium-scale photogrammetry for mapping and interpretation. Color negative film, which results in a high geometric resolution, is suitable for all types of applications. Color infrared film, also called false-color film, is typically used to generate a color photograph of yellow, green, and the red of the near-infrared spectrum, which offers the most useful information in vegetation analysis.

Traditional cameras include mapping frame cameras, frame reconnaissance cameras, panoramic cameras, and strip cameras. A multiband camera is used for capturing images in a variety of wavelength bands and usually consists of a set of three or more cameras to suit a specific spectrum. A digital camera is used to record and store photographic images in digital format. Images are usually created through a photosensor with a charge-coupled device (CCD). The captured images can be stored in the camera or directly uploaded on a computer. Images also can be archived on a photographic disc or external hard drive. Currently, digital cameras often have a liquid crystal display (LCD) for viewing both captured and archived images. With the help of Web-based instruments, aerial imagery can be proofed by clients immediately.

Aerial hyperspectral remote sensing, also called aerial imaging spectroscopy, is a relatively new technology employed to detect and identify minerals, terrestrial vegetation, man-made landscapes, and other ground materials and background. Hyperspectral imagery generally is composed of more than 100 spectral bands with a narrow bandwidth of 5 to 10 nanometers; therefore, a detailed pixel spectrum indicates much more information about a surface than multispectral remote sensing, and hyperspectral data can be seen as continuous points in an n -dimensional data space. A very advanced aerial hyperspectral imaging system is the Airborne Real-Time Cueing Hyperspectral Enhanced Reconnaissance (ARCHER), with an attached global positioning system (GPS) and an inertial navigation system. ARCHER is the most sophisticated hyperspectral imaging technology and generates one square meter per pixel of hyperspectral images and 8 cm (centimeters) $\times$ 8 cm per pixel panchromatic imagery.



SLAR images are acquired by transmitting microwave energy to the ground and recording the signals reflected and scattered from the ground. The signals are recorded in digital values that also can be represented on photographic film. SLAR imagery can be collected and produced in all kinds of weather and at any time of the day.

Aerial LIDAR is a remote sensing technology applying light detection and ranging systems to produce accurate and detailed aerial imagery or maps of ground objects. It uses an active sensor with a laser and is attached with airborne GPS to measure distances to objects and the ground. Compared with the conventional methods of topographic mapping using photogrammetry, aerial LIDAR technology is a fast, economical, accurate, and reliable airborne method for creating a digital terrain model with the three-dimensional (3D) data obtained and for creating digital orthophotomaps (orthoimages) with intensity values. However, LIDAR-intensity imagery could be noisy because of dynamic survey geometry and complex laser interactions among ground features.

Data Types

Oblique and vertical images are the two types of aerial imagery data. Vertical imagery is taken directly above the ground, so that there are relatively small errors of scale and azimuth in it. It is relatively easy to complete measurements with moderate accuracy. Scale also is relatively constant across the whole captured area. But vertical imagery provides a view of the subject from above Earth's surface, which is an unfamiliar view of Earth objects. Oblique imagery is usually taken from the side of an airplane. In this case, the aircraft need not fly directly over the area to be imaged. The horizon can be seen in a high oblique image but not in a low oblique one. Disadvantages of oblique images are that scale decreases from foreground to horizon and measurements are difficult to take even by way of trigonometric computation.

Orthophotography is probably the most widely used aerial imagery in analysis. An orthophotograph is a maplike aerial image with the spatial attributes of a map and the spectral

characteristics of imagery. Directions, dimensions, and plan positions can all be scaled from orthophotographs, which makes them very useful, although an orthophotograph looks like an aerial photograph. An orthophotograph contains all visible information without the simplified symbols of a map. Orthophotographs can be stored both in hardcopy and as digital imagery.

According to the aerial sensor and media characteristics, aerial imagery can be classed into black-and-white aerial images, natural-color aerial images, color infrared aerial images (false-color aerial images), SLAR imagery, aerial hyperspectral images, and LIDAR-intensity imagery.

Aerial LIDAR-intensity imagery is highly accurate black-and-white digital imagery, which is generated directly from the intensity of the LIDAR return signals.

Data Sources

Data sources of aerial imagery are usually of three types: paper, film, and digital. Earlier, captured aerial imagery was usually saved in paper or film format. Digital cameras are now widely used, and most of the aerial imagery is saved in MrSID, GeoTiff, or TIFF format.

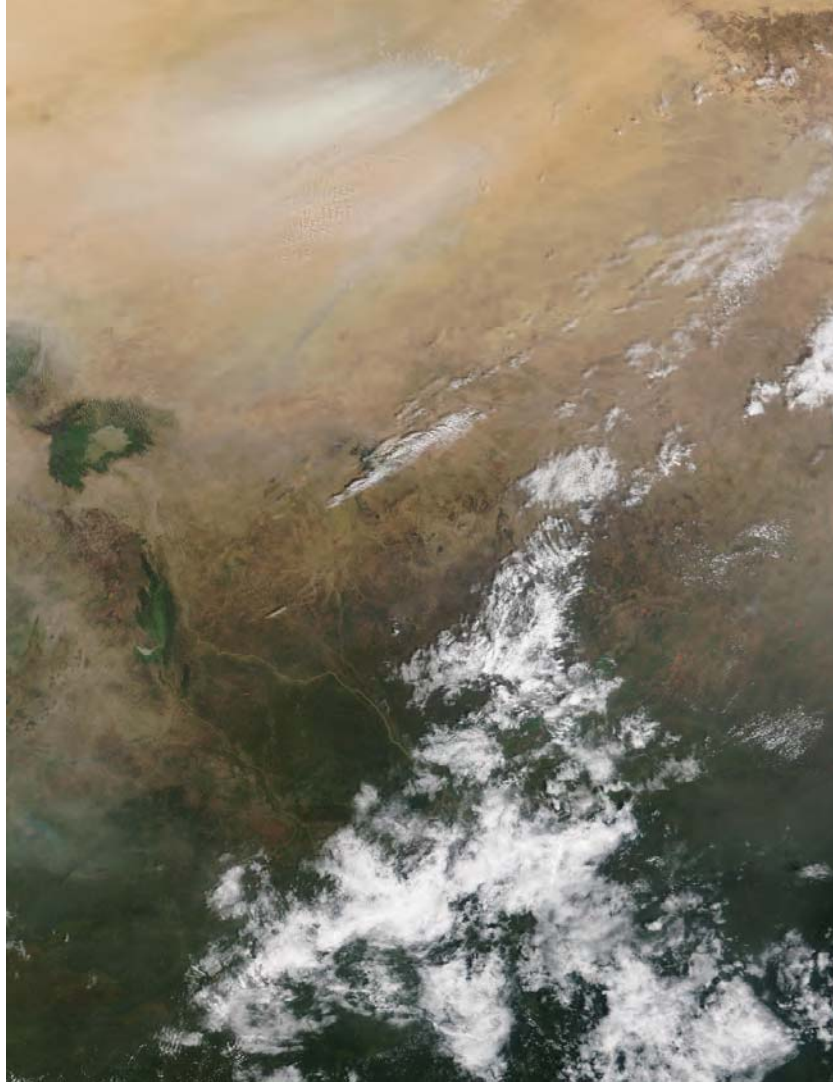
Digital imagery has many advantages over traditional film. For instance, (a) the photographer can immediately review the picture and correct the problem or take another picture if necessary; (b) numerous shots of the same scene with slightly different settings can be taken, and only the best one needs to be printed; and (c) computer- and Web-based approaches make it much easier to store, distribute, review, process, analyze, and print aerial imagery. However, digital imaging needs a powerful battery. Sometimes, there is apparent multicolored image noise in digital pictures.

Many countries have specific agencies to collect and distribute aerial imagery, in addition to numerous private companies. The National Aerial Photography Program (NAPP), formerly the National High Altitude Photography (NHAP) program, has been an invaluable source of high-quality, cloud-free, quad-based photography for the conterminous United States since 1980. NAPP supplies 1-m (meter) aerial imagery. The National Agriculture Imagery Program (NAIP), established



Three different typhoons were spinning over the western Pacific Ocean on August 7, 2006, when the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite acquired this image. The strongest of the three, Typhoon Saomai (lower right), formed in the western Pacific on August 4, 2006, as a tropical depression. Within a day, it had become organized enough to be classified as a tropical storm. While Saomai was strengthening into a storm, another tropical depression formed a few hundred kilometers to the north, and by August 6, it became tropical storm Maria (upper right). Typhoon Bopha (left) formed just as Maria reached storm status and became a storm itself on August 7. As of August 7, the University of Hawaii's Tropical Storm Information Center predicted that Bopha and Saomai would continue on tracks that would take each into China, while Maria would move northwest across the southern end of Japan. Saomai was predicted to gather strength, while Maria and Bopha were projected to remain near their current strengths. This photo-like image was acquired at 12:35 p.m. local time (04:35 UTC) on August 7. It is unusual, but certainly not unprecedented, to have three storm systems all in the same general area at one time. Bopha, the youngest at just a few hours old, shows only the most basic round shape of a tropical storm. Maria, a day older, shows more distinct spiral structure with arms and an apparent central eye. Despite their differences in appearance, both storms were around the same size and strength, with peak sustained winds of around 90 and 100 km/hr. (58 and 63 mph), respectively. A day older than Maria is the much more powerful Typhoon Saomai. At the time of this image, the typhoon had sustained winds of around 140 km/hr. (85 mph), and forecasters predicted that it would continue to gather strength before coming ashore in China, according to the University of Hawaii's Tropical Storm Information Center. The typhoon's well-developed structure (including a distinct, closed eye in the center) in comparison to Maria is clear in this image. The slanting diagonal feature through the image is sunlight bouncing off the ocean into the MODIS instrument, a phenomenon called sunglint. The very bright patch is where the reflection is strongest.

Source: Jeff Schmaltz.



In the south-central reaches of Northern Africa's Sahara Desert, a dust storm is whipping up the sand (top center) and moving it southward over an already-struggling Lake Chad (left center edge). Regional water demands, and perhaps climate change, have shrunk the surface area of the lake dramatically, and sand dunes (tan striations) can be seen encroaching into the dense vegetation surrounding the small lake. Scattered fires (red dots) were detected as well in this true-color MODIS image captured on October 31, 2002, by the Terra satellite.

Source: Jeff Schmaltz, MODIS Land Rapid Response Team, NASA/GSFC.

in 2001 and 2002, acquires leaf-on imagery and delivers aerial imagery to the U.S. Department of Agriculture County Service Centers to maintain land boundaries and to assist in crop management. NAIP supplies two types of aerial images: (1) 1-m ground sample distance image with a horizontal accuracy of within 5 m of a reference orthoimage and (2) 2-m ground sample distance image with a horizontal accuracy of within 10 m of a reference orthoimage.

Applications

Aerial imagery is used by scientists, administrators, developers, planners, engineers, and surveyors to explore and analyze geographic phenomena with accurate spatial information of the environment, natural resources, agriculture, urban infrastructure, telecommunications, and corridor arrangement. Aerial imagery is usually processed by geographic information systems (GIS) through



data integration with scanned or digitized analog images, digital images, and other digital geographical data on population, air pollution, and transportation. Aerial imagery is extensively applied in the following fields: cartography (especially topographic mapping), 3D modeling and geovisualization, land cover/land use planning, environmental studies, natural resources assessment, urban planning, transportation planning, surveillance, and archaeology.

Social Impacts

From a simple landscape shot to natural resources management and assessment to environmental and hazard analysis to urban and infrastructure geovisualization and planning, aerial imagery, as the data source of aerial remote sensing, has become a part of our daily lives. Privacy laws usually do not apply to what one can clearly view from a public space. When people are in aircrafts or balloons, they are in a public space. Therefore, taking aerial photographs or images does not break the law of privacy. From high above Earth's surface, one can legally image everything, including private events on private lands, which can lead to distressing situations.

Challenges

Although the advances in optics and camera technologies have been rapid, there are still some challenges. Aerial imagery is often taken at a certain angle to the object on the ground. This may result in an incorrect perspective, so that near objects look too large when compared with far-away targets. The process of perspective correction distorts the image, with the result that equal-sized features on the ground could have equal size in aerial imagery. When we need aerial imagery with high spatial resolution for a large area, many images will have to be taken and then compiled together, which seems like a simple process but may take hours or days of preparation.

There are some special challenges in using aerial hyperspectral imagery, although it is fascinating. Hyperspectral imagery often needs accurate atmospheric corrections before further analysis. Many hyperspectral analyses also require the use

of known material spectra for spectral classification or segmentation. Additionally, aerial hyperspectral imagery is not as often available as other types of remotely sensed data. The airborne visible/infrared imaging spectrometer (AVIRIS), developed by the National Aeronautics and Space Administration, is one of the main airborne hyperspectral sensors.

There are also some challenges in the use of aerial LIDAR. Constraints are typically associated with the collection and delivery of LIDAR imagery: Flights can be delayed due to the weather; postprocessing of a huge number of raw data points could be time-consuming; currently, there is no standard file format, although raw point data often are preprocessed and delivered in ASCII format; dense vegetation makes it difficult to map Earth's surface; and certain ground surfaces, such as water, asphalt, tar, clouds, and fog, absorb near-infrared radiation (NIR) and result in null or poor returns, since LIDAR lasers usually use NIR radiation.

Qingmin Meng

See also **Aerial Imagery: Interpretation; Biophysical Remote Sensing; Image Interpretation; Image Processing; Image Registration; Image Texture; Imaging Spectroscopy; LiDAR and Airborne Laser Scanning; Multispectral Imagery; Multitemporal Imaging; Remote Sensing**

Further Readings

- Colwell, R. (Ed.). (1983). *Manual of remote sensing* (2nd ed.). Falls Church, VA: American Society of Photogrammetry.
- Jensen, J. (Ed.). (2007). *Remote sensing of the environment: An Earth resource perspective* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.



AERIAL IMAGERY: INTERPRETATION

Aerial images are photographic or digital images captured from a position above the ground. These



images provide visual information over a wide area that is difficult to obtain at the ground level. Interpretation is the act of examining these images for the purpose of identifying, characterizing, and measuring objects and phenomena and judging their significance. Interpretation is not considered to be an exact science, and the interpretations are often based on the probability that an object is identified accurately. Successful interpretations depend on practical training and experience, disciplined approaches using knowledge of aerial imagery and application of that knowledge, as well as the inherent talents of the interpreter. Computer technology can aid in interpretation, but final identification by a knowledgeable human is often necessary. Interpretation is key for linking remotely sensed information to ground information on Earth's surface. This entry discusses the fundamental approaches to aerial imagery interpretation.

Interpretation Tasks

There are four tasks in image interpretation, listed in order of increasing sophistication: *detection*, *identification*, *measurement*, and *problem solving*. Detection is the lowest order and determines the presence or absence of an object or phenomenon on the ground. An example is the detection of buildings or roads in an urban environment. Identification is more advanced and involves the labeling of detected objects, such as schools or highways. Measurement allows the quantification of ground objects measured directly from the imagery, such as the number and area of buildings or the length of a highway. Problem solving is the most complex task and uses information from the first three tasks for higher-level identification, such as commercial building density.

Types of Aerial Imagery

The type of aerial imagery used can determine the level of interpretation. Aerial imagery is captured at varying spectral wavelengths, from panchromatic imagery across visible light wavelengths, to color infrared imagery, which captures energy in the visible and near-infrared wavelengths (see Figure 1), to hyperspectral imagery, which divides captured energy into many narrow

bands of information. Figure 1 shows a typical color infrared image, where green wavelengths are represented by blue in the RGB spectrum, red wavelengths are green, and near-infrared wavelengths are red. The wavelengths at which imagery is captured and viewed can affect successful interpretation. For instance, in Figure 1, healthy vegetation can be easily identified as red, because high amounts of energy are reflected by plants in the near-infrared wavelengths, shown here as the red band. Imagery is also captured at a number of angles, from directly above to oblique. Stereoscopic imagery, with multiple oblique views of the same landscape, can aid interpretation by giving the image a three-dimensional perspective. The spatial resolution of imagery can also vary based on the type of camera used, as well as the height of the camera from the ground. The spatial resolution refers to the smallest possible feature that can be distinctly detected from its surroundings. Imagery captured at a higher altitude will have coarser spatial resolution than the same imagery from a lower altitude.

Interpretive Elements

There are several elements that can be interpreted from aerial imagery. The most basic elements can be easily interpreted using a computer. However, computers have difficulty with more complex elements, which require expert knowledge from a human for interpretation, where cognition can vary from person to person.

The primary and most basic element is *tone* or *color*. Tone represents the level of grayness in panchromatic (black-and-white) imagery, where black represents low energy return and white is high energy return. In color imagery, differences in color are based on energy returned at specific wavelengths. Tone can vary in three dimensions: intensity, hue, and saturation. Intensity is the brightness of the energy. Hue is the dominant wavelength that controls the color appearance in the image. Saturation is the purity of color relative to the gray level.

The secondary level of image interpretation includes *size*, *shape*, and *texture*. The size of an object within an image can be a clue to the identification of that object. The size can be measured relative to other objects in an image, or it can be



Figure 1 False color digital ortho quarter quad (DOQQ) of Del Mar, California, on June 15, 2002, at 3-foot spatial resolution

Source: Center for Earth Systems Analysis Research (CESAR), Department of Geography, San Diego State University.

absolute, based on the known scale of the imagery. Certain features can have characteristic shapes that aid in their identification. Cultural features tend to be geometric with distinct boundaries, such as buildings and roads. Natural features tend to be less regular, such as rivers and forests. Texture represents the subtle changes in tone based on nearby features within the image. Texture gives the impression of “smoothness” or “roughness” of an object within an image. Texture tends to be scale dependent, where more discrete patterns can be revealed with higher resolution.

The tertiary level of interpretation includes *pattern*, *height*, and *shadow*. Pattern represents the spatial arrangement of objects in an image. Repeated pattern characteristics can aid in the identification of features in an image, such as

houses in a neighborhood. Shadow indicates the absence of direct illumination. The length, size, and shape of the shadow can determine an object’s height as well as its shape. Shadow can also be a hindrance within an image by obscuring information with low illumination. Height can be determined in the absolute and the relative sense, and it can be better identified with oblique or stereographic imagery.

The most complex level of interpretation includes *context*, in terms of *site* and *association*. Context is the highest level of image cognition and integrates all other elements of interpretation. Site is the location of an object in relation to its environment. Association is its location in proximity to other objects being studied, often related to these features or activities.



Humans generally use the higher-order elements of interpretation more successfully than a computer due to their qualitative nature, while computers are more successful at characterizing the lower-order, more quantitative elements. Computers are less biased than human interpreters, but they may also be less accurate in higher-order interpretation, due to the difficulty of understanding context in interpretation. Most successful interpretations use a combination of both human and computer interpretive approaches.

Kristopher Kuzera

See also Aerial Imagery: Data; Panchromatic Imagery; Remote Sensing; Remote Sensing: Platform and Sensors; Spatial Resolution; Stereoscopy and Orthoimagery

Further Readings

Jensen, J. R. (2007). *Remote sensing of the environment: An Earth resource perspective* (2nd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Paine, D. P., & Kiser, J. D. (2003). *Aerial photography and image interpretation* (2nd ed.). Hoboken, NJ: Wiley.



AFRICAN UNION

The African Union (AU) is a regional organization that aims to strengthen continental solidarity, territorial integrity and sovereignty, and development. The AU officially began in 2002, emerging out of what had been the Organization of African Unity (OAU). It has 53 member states, comprising all of Africa's continental and island independent states except Morocco and including the nonindependent Sahrawi Arab Republic (Western Sahara). The AU is particularly pertinent to political geographers as an example of the 21st-century phenomenon of growing significance for supranational and international organizations amid contemporary globalization.

In 1999, the OAU decided to relaunch itself, but it took three more years to officially become

the AU. The AU can be distinguished from its predecessor mostly through its commitment to invoking African unity to further the development interests of member states. The AU forthrightly prioritizes economic development through integration of economic policies and solidarity on global trade issues. Four of its eight "portfolios" are directly related to economic development (Economic Affairs, Rural Economy and Agriculture, Trade and Industry, and Infrastructure and Energy). Fostering the idea of a smaller group of member countries' leaders for a New Partnership for Africa's Development (NEPAD) has been chief among the AU's achievements, following the 2001 adoption of NEPAD as an AU program. The AU seeks to implement NEPAD's economic agenda for what is characterized as African solutions to African problems.

The AU has retained the strategic agenda of the OAU, with portfolios dedicated to Political Affairs and Peace & Security. The AU supports NEPAD's peer review mechanism, an institutionalized means for strengthening democracy and governance on the continent. Another key area of operation is peacekeeping—notably, in the AU's early years, in Sudan's Darfur region. In both peer review and peacekeeping, the AU strongly advocates for pan-Africanism, but with a practical orientation. In 2008, the introduction to its Web site contained the key pan-Africanist phrase "Africa Must Unite," but with this caption: "An Efficient and Effective African Union for a New Africa." The AU also operates in social and cultural spheres, but its role in these areas is muted in comparison with its political and economic priorities.

The AU has many supporters but also a wide array of critics. One common vein of criticism is that the AU remains captive to development policies imposed from the Global North. Critics from the Global North in turn often cite the failure of the AU to condemn violations of its own standards for human rights and social justice in non-democratic member states. Others have seen its peacekeeping operations in Darfur as inadequate. Although its record thus far is mixed, the AU can legitimately claim to have improved on the OAU's performance in both the political and the economic spheres.

Garth Myers



See also **Decolonization; Developing World; Geopolitics; Political Geography; Supranational Integration**

Further Readings

- Makinda, S. M., & Okumu, F. W. (Eds.). (2008). *The African Union: Challenges of globalization, security, and governance*. New York: Routledge.
- Murithi, T. (2005). *The African Union: Pan-Africanism, peacebuilding and development*. Burlington, VT: Ashgate.



AGAMBEN, GIORGIO (1941–)

Giorgio Agamben is one of the most prominent Italian philosophers of the late 20th and early 21st centuries. His oeuvre has been particularly influential for those dealing with questions of law, modern citizenship, subjectivity, power, and community. While Agamben has conducted a wide range of philosophical inquiries, his writing generally hones in on contemporary issues of ethics and biopower (a form of power through which political entities articulate their subjects as populations and manage them through control over life). Within these issues, Agamben portrays the modern world as strongly shaped by the legacy of the Nazi Holocaust as well as characterized by the large number of people who exist in ambiguous relationships to states, such as Europe's large number of international *sans-papiers* (people without legal documents), those across the world living in refugee camps, or those excluded from civic life in their countries of origin. Such a vision reveals a fundamental disjuncture between existing as what Agamben labels *homo sacer* ("bare life") versus living life as a fully endowed political subject. For Agamben, and the geographers influenced by his work, the key questions of politics center on controlling the relations of power that coalesce to uphold or break down this distinction, as well as how those relations of power gain spatial expression in the world.

Agamben often identifies the camp (as in the Nazi concentration camps) as the space most evident of the contemporary world's manifestation of ethics and biopower. He uses the camp as a metaphor for and an example of an actually existing space within the modern world to show how spaces of exclusion from the law create political subjects who exist merely as bare life and who can then become the legitimate outlets for state-sponsored violence—a space beyond the reach of ethics. Agamben repeatedly argues that the production of this space outside the law is a key component of the state's capacity to uphold its power and employ tactics of biopolitics. Agamben posits that such spaces are historically generated during periods of crisis and emergency and represent a movement away from the normal functions of the political body. However, Agamben shows how the modern state normalizes this state of emergency so that such spaces become indistinguishable from spaces of the law. He further argues that the basis of sovereign power in the modern world depends on the capacity to produce and maintain an indistinguishable relationship between spaces inside the law (inhabited by those granted political life) and those outside the law (inhabited by those banned from political life and thrust into bare life). This indistinctness structures the relations between those who can no longer clearly recognize their position as being within or outside the camp. From this, ethics breaks down into relations of violence as biological, not political, creatures encounter each other. In short, Agamben portrays a world in which the camp is the norm, not the exception, and a space inherent to and inside the space of the law, not outside it.

Agamben's work is of significance to geographers in three primary ways. First, Agamben's investigations of *homo sacer* as a condition of modern political subjectivity have allowed geographers to investigate the spaces in which bare life is cultivated, maintained, and resisted through biopower. This approach has allowed geographers to locate places such as the U.S. military prison in Guantánamo Bay, Cuba, or international refugee camps within a map of modern political life and explain them not as spaces outside the normal functions of the law but as central to legitimated state-space. The geographies of *homo sacer* extend political geographers' capacity to explain the ways



in which law and space come together to produce political subjects in the world, political subjects who seem to exist outside the law because of their exposure to seemingly illegitimate and arbitrary violence. Geographers, guided by Agamben, have been able to give a logic to these spaces.

Second, Agamben's investigations of the hybridity of human beings as political and biological forms focuses attention on the animality of human beings. This offers an expansion of the idea of bare life to explain more clearly how bare life gets produced and how this expression of bare life can become rearticulated as the basis for ethical relationships. In Agamben's work, and opening up possibilities for geographers to follow suit, it identifies the spaces between the human world of the *polis* (the forerunner of the nation-state and its guarantees of citizenship) and the wilderness outside the boundaries of the polis as spaces of ethical encounter (rearticulating the content of those ethics as something more than what is codified into law). Geographers have extended this to explore the ways in which modern political subjects reclaim their biopolitical power against the machinations of the state and produce spaces of biopolitical resistance.

Third, building from Agamben's contributions to rethinking the idea of community as a way to envision the ethics that might emerge from the normalization, and therefore collectivization, of *homo sacer*, geographers have been able to extend his theory of the "coming community" into a spatialized articulation of a poststructuralist collective subject. This subject is recognized by certain attributes: (a) that of becoming (over being), (b) that of nonessentialism (over classification), and (c) that of situated ethics (over universal morality). Agamben argues that the politics of community should be postrepresentational; that is, it should not strive for recognition as a representational organ within the body politic of the state but rather recognize its ontological condition of commonality. As such, geographers have deployed Agamben's theory to find a radical politics of potentiality that transforms spaces of exclusion from a repressive apparatus of state power into a space of pure (and ethical) being together, imbuing bare life with human being.

Jonathan D. Lepofsky

See also **Human Rights, Geography and; Poststructuralism**

Further Readings

- Agamben, G. (1998). *Homo Sacer: Sovereign power and bare life* (D. Heller-Roazen, Trans.). Stanford, CA: Stanford University Press.
- Gregory, D., & Pred, A. (Eds.). (2006). *Violent geographies: Fear, terror and political violence*. New York: Routledge.
- Lepofsky, J. (2003). Towards community without unity: Thinking through dis-positions and the meaning of community. *disClosure*, 12, 49–75.
- Minca, C. (2007). Agamben's geographies of modernity. *Political Geography*, 26(1), 78–97.
- Mitchell, K. (2006). Geographies of identity: The new exceptionalism. *Progress in Human Geography*, 30(1), 95–106.
- Special issue on Agamben. (2006). *Geografiska Annaler, Series B: Human Geography*, 88(4), 363–485.



AGENT-BASED MODELS

Agent-based models (ABMs) are digital representations of systems, composed of a community of heterogeneous and interacting individuals distributed within a shared environment, which they transform to achieve their objectives. Agents, implemented as computer programs, are viewed as autonomous entities that decide for themselves what needs to be done to meet their goals. Equipped with atomic decision rules that drive their behavior, agents are the basic units of action in the model. They can epitomize humans, animals, and higher-order entities such as companies, tribes, agencies, or herds. Within the geographic domain, the critical element of agent-based modeling is the spatially differentiated environment that represents economies, ecosystems, and societies. ABMs are characterized by a variety of complex system facets that are relevant to modeling dynamic processes within human-environment systems. For that reason, ABMs are often referred to as computational laboratories that allow



experimentation with changes within artificial societies. Due to their modular nature, ABMs are implemented using object-oriented programming. They are applied to address various spatially explicit problems, from urban growth to deforestation, to migration, to traffic congestion. The most important challenges of ABMs are the construction of proper cognitive models to represent decision making, the scarcity of social data, and the extensive parameterization that leads to a plethora of outcomes.

Rationale for Agent-Based Modeling

Complex systems involve dynamic and nonlinear linkages between the constituting parts that lead to unexpected and often perpetuating changes at the aggregate level, which are called emergent phenomena. As such, they are difficult to study *in vivo*, and hence, we must turn to computational environments to explore complex geographic realities.

ABMs offer a solid framework for the direct inclusion of many aspects of complex systems, such as heterogeneities of actors and landscapes, dynamic feedbacks, path dependence, and bottom-up emergence. As an example, consider the process of slum formation, which occurs throughout urban outskirts in developing countries. Due to rural overpopulation, people are forced to move to cities looking for employment. Yet local labor markets cannot accommodate such a rapidly growing urban population, which leads to poverty of the migrants. Consequently, they settle on the urban-rural fringe in makeshift houses that constitute the shantytowns. Since existing slums are the breeding ground for additional victims of poverty, the process leads to a self-reinforcing inner feedback of constantly growing slums.

Consider an ABM that emulates this phenomenon. The basic components of the model would involve migrants as the core decision makers and, in addition, villages, urban areas, and local labor markets situated within a particular region. As is the case in the real-world situation, the migrating agents would have incomplete information about the available opportunities. Restricted in their capabilities and disparate in sociodemographic characteristics such as age, family size, or health,

the migrants would be programmed to move around the landscape in search of work and a new place to live.

The complex system of local market interdependencies could be implemented as a nested hierarchy of socioeconomic institutions with built-in feedback loops. Positive feedbacks lead to path dependence, in which the outcomes of a system are very sensitive to specific initial conditions. Following the example, the existence of shantytowns in a particular locality could be induced by illegal access to electricity, growing with each new dwelling tapped to the grid.

Within the spatial context, two types of changes pertaining to an agent can occur during model execution: (1) *attribute value* change (e.g., from an unemployed state to employment) and (2) *relocation* (such as a move from a village to a city). ABMs also enable us to observe two types of system-level changes: (1) quantitative changes (such as an areal increase of slums) and (2) qualitative, often abrupt changes (such as an outbreak of a disease due to poor sanitation). In short, by offering a better symbolic representation of societies, ABMs facilitate system comprehension by professionals and novices alike.

Components of Agent-Based Models

An ABM is a dynamic simulation model that integrates the system structure with its processes. Agents and environments are two key elements of ABMs. An agent is equipped with *attributes* describing its characteristic states, *rules* guiding its decision making, and *actions* performed after the decision is made. Unlike the rational “averaged” individuals present in traditional economic models, ABMs offer a nonuniform representation of system actors. Multifformity can manifest itself as parametric heterogeneity or functional diversity. The former can be exemplified by different levels of economic status and the latter by variable decision rules.

Agents can be animate (farmers, residents) or inanimate (firms). They can be also grouped into fixed entities (building footprints, cities, and road networks) and movable objects (pedestrians, vehicles, relocating firms, and migrating households). Based on agent architecture, we deal with weak and strong agents. Whereas weak agents



have a simplified internal structure and primitive behavior, strong agents, with their roots in artificial intelligence, are capable of learning, problem solving, and planning.

Direct representation of individual behavior lies at the heart of ABMs. Various cognitive frameworks have been employed in agents, ranging from *reactive* models, based on a simple stimulus-response mechanism that excludes past experiences, to *proactive* ones, with attentive agents that can take the initiative. More elaborate agents are able to learn and adapt to the exogenous changes based on “memory.” Finally, agents can be deliberative and socially aware, or they can be equipped with “personality” in the form of values, beliefs, attitudes, and desires.

Agent decision making is mostly implemented using two approaches: rule based and mathematical. Rule-based systems operate on the basis of a series of *if-then* conditional statements (“if the agent is unemployed, it moves to a city”). Mathematical models use various forms of utility functions that attach a weight to a particular choice. Traditional models deal with homogeneous optimizers that make rational decisions based on complete information about their environment. An alternative approach is based on bounded rationality, which assumes that an agent has limited access to information about options. As a result, the perception of option utility varies from individual to individual. Within the bounded-rationality realm, decision-making heuristics can be grouped into random choice, satisfier choice, and ordered choice. In random choice, the agent randomly picks one of the opportunities with equal probability of selection. The satisfier choice is characterized by picking any alternative that is “good enough” with respect to a threshold value of a selected criterion. With ordered-choice heuristics, the agent orders options based on their utilities. It then picks the opportunity with the highest score. Hybrid-choice heuristics have also been proposed.

Unlike cellular automata, where interaction is constrained to geometrically fixed neighborhoods, ABMs permit “action at a distance,” in which the agent’s decisions influence and are influenced by drivers physically situated all over the landscape and, possibly, comprising social or political networks.

The spatial environment may differ in its extent, from buildings and neighborhoods, through villages, cities, and local habitats, to large-scale regions. An important aspect of agent-based simulations is their spatiotemporal resolution, which defines the smallest spatial unit that builds the landscape, the duration of model execution (the number of iterations), and the characteristic time step. More complex models, containing diverse agent types with varying dynamics, cause a challenge for model design. An ABM that emulates a city could include buildings that change their structure over years, as well as pedestrians, who change their location over minutes. Depending on the modeling objectives, such dilemmas are resolved by fixing state values of some objects while updating others.

As noted above, the agent framework is particularly suitable to model different interactions, such as cognitive, social, and biophysical processes. Interactions occur among agents or between agents and their environment. In particular, agent-agent interaction is expressed as cooperation among nonantagonistic agents, negotiation among self-interested agents, and competition where agents work against each other. In addition, the endogenous interrelationships in spatial ABMs include topological and nontopological relations such as adjacency, accessibility, or containment, which affect the behavior of the model over geographic space.

Agent-Based Modeling Applications

Two types of spatially explicit ABMs have been recognized: abstract and empirical. Abstract models, which dominated during the 1980s and the early 1990s, are often composed of designed agents and/or environments. They are aimed at building theories and testing hypotheses about macrostructures arising from a limited set of local behavioral rules.

More recently, agent-based modeling has been applied to many real-world geographic problems, such as resource management, the evolution of settlements and societal collapse, and the effects of policy regulations on land development, or for simulating travel behavior, to name but a few examples. Empirically grounded ABMs comprise detailed, multiscale, and multisource



data, coupled with multiple modeling techniques. Such models are extensively parameterized, calibrated, validated, and used for scenario analysis, policy testing, and forecasting. However, predictive applications of agent-based modeling, which are based on trend extrapolation, are often criticized due to the high level of uncertainty associated with the processes built into the model.

Constructing Agent-Based Models

Implementation of agent-based modeling starts from a conceptual model that reflects the objectives of the research. With a conceptual model at hand, we can move to the design phase. At this step, the key challenge is to decide which components, driving mechanisms, and interactions are crucial to the problem studied. Since ABMs tend to be highly dimensional, it is important to construct a sufficiently simple model that, nevertheless, accurately mimics the system. In addition, choices should be made about the necessary data (such as elevation, roads, or preservation areas) and data representation (discrete objects vs. continuous fields). What follows is the coding stage. Implementation of agent-based modeling is carried out using object-oriented programming languages such as Java, C++, and Python or specialized agent toolkits such as REPAST (Recursive Porous Agent Simulation). In addition to two broad modules that stand for the agents and the environment, an ABM is typically equipped with a scheduler that manages the sequence of model execution.

Once the program has been built, it undergoes a process of verification that focuses on checking whether the implemented model represents the conceptual ABM. Sensitivity analysis is then performed, with the objective of measuring the effect of alterations in the initial conditions on the results of model execution. The changes in input values are usually drawn from boundary conditions that constrain the parameter space. The final phase of building an ABM is the most demanding. It involves model validation, which tests whether the model really emulates the system under study. Comprehensive validation enhances model credibility and defensibility, which is especially necessary for subsequent applications.

Challenges

Over the past decades, ABMs have experienced momentous development. However, there are still some fundamental obstacles that pose a challenge to the agent-based modeling community. Among other things, empirical ABMs are limited by expensive social-behavioral data. If such data are available, their quality may be inadequate due to the subjectivity of qualitative judgments, inappropriate scale of representation, or lack of longitudinal observations. A closely related problem is the accurate representation of choice behavior. In this respect, the disaggregated decision making of ABMs constitutes both their advantage and their shortcoming.

Arika Ligmann-Zielinska

See also **Cellular Automata; Complexity Theory; Complex Systems Models; Land Use and Land Cover Mapping; Models and Modeling; Path Dependency**

Further Readings

- Benenson, I., & Torrens, P. M. (2004). *Geosimulation automata-based modeling of urban phenomena*. New York: Wiley.
- Gimblett, R. (Ed.). (2002). *Integrating geographic information systems and agent-based modeling techniques for simulating social and ecological processes* (Santa Fe Institute Studies in the Sciences of Complexity). New York: Oxford University Press.
- Matthews, R., Gilbert, N. G., Roach, A., Polhill, J. G., & Gotts, N. M. (2007). Agent-based land-use models: A review of applications. *Landscape Ecology*, 22, 1447–1459.
- Parker, D., Berger, T., & Manson, S. (Eds.). (2002). *Agent-based models of land-use and land-cover change: Report and review of an international workshop, October 4–7, 2001, Irvine, California, USA*. Bloomington: LUCC Focus 1 Office, Indiana University. Retrieved May 20, 2008, from www.globallandproject.org/Documents/LUCC_No_6.pdf
- Parker, D., Manson, S., Janssen, M., Hoffman, M., & Deadman, P. (2003). Multi-agent systems for the simulation of land use and land cover change:



A review. *Annals of the Association of American Geographers*, 93, 314–337.

REPAST. (2008). *Agent simulation toolkit*. Retrieved May 20, 2008, from <http://repast.sourceforge.net>

Wooldridge, M. (1999). Intelligent agents. In G. Weiss (Ed.), *Multiagent systems: A modern approach to distributed artificial intelligence* (pp. 27–42). Cambridge: MIT Press.

AGGLOMERATION ECONOMIES

By clustering in close proximity to one another, firms can lower their production costs and raise profits. This process is enormously important to many forms of production and is titled agglomeration economies—that is, the benefits derived from grouping together. By forming dense webs of production and embedding themselves within them, firms usually can produce more efficiently and profitably.

Agglomeration economies take several forms. Production linkages accrue to firms locating near producers that manufacture their inputs. By clustering, transportation and assembly costs are reduced. Service linkages occur when enough firms locate in one area to avail themselves of specialized support services. For example, the advertising industry in New York is concentrated within a short distance of Madison Avenue, investment banks form a dense wad in southern Manhattan, and film companies agglomerate in Hollywood. By locating near one another, firms can acquire up-to-date information on the latest trends in their sector, technological changes, shifts in policies and markets, clients, hires, and new products and processes, and they can keep an eye on the competition. Marketing linkages occur when a cluster of similar firms is large enough to attract specialized distribution services. The small firms of the garment industry in New York City have collectively attracted advertising agencies, showrooms, buyer listings, and other aspects of product distribution that deal exclusively with the garment trade. Firms within the cluster have a cost advantage over isolated

firms, which must acquire these benefits for themselves.

Agglomeration economies may be temporary, are found to different extents in different industries, and may be offset through various forms of economic, technological, and geographic change. Typically, agglomeration economies reflect firms' need for close interaction with clients and suppliers, often on a face-to-face basis. Thus, they are most pronounced in vertically disintegrated types of production, in which firms have many linkages “upstream” and “downstream” in the production process. (In contrast, vertically integrated firms, with relatively few external linkages, are less dependent on agglomeration.) Firms in markets with low degrees of uncertainty (usually due to slow rates of technical change, the market structure, or the regulatory environment), in contrast, are less dependent on agglomeration to minimize costs and maximize profits. As firms grow, they often become more vertically integrated and more capital intensive, have fewer external linkages, and come to substitute economies of scale for agglomeration economies.

Because agglomeration economies provide powerful incentives for firms to locate in close proximity to one another, they are most heavily manifested in large metropolitan areas. The prime motivation behind the agglomeration of firms in metropolitan regions is the ready access they offer to clients, suppliers, and ancillary services, most of which is accomplished through face-to-face interaction. Often, personal relationships of trust and reputation are of paramount significance. Agglomeration thus maximizes access to information, much of which is tacit, irregular, and non-standardized, and helps firms minimize uncertainty. Firms in these locations have an advantage, within limits, over similar firms in rural areas. Cities provide the markets, specialized labor forces and services, utilities, and transportation connections required by manufacturing. *Urbanization economies*, therefore, are a combination of production, service, and marketing linkages concentrated at a particular location. Agglomeration forms the basis for the comparative advantage of cities in forms of production, which typically consist of relatively labor-intensive, vertically disintegrated firms in highly competitive markets with high degrees of uncertainty and change.



Agglomeration economies have been manifested in numerous industries throughout the historical geography of capitalism. They were critical during the early Industrial Revolution, when many small firms in industries such as watch making or gun manufacturing clustered in the cores of British cities. Since the emergence of post-Fordist “flexible production” in the late 20th century, the competitiveness of regions such as California’s Silicon Valley, Italy’s Emilia-Romagna, or Germany’s Baden-Wurtenburg has relied heavily on agglomeration. Finally, producer services (business and financial services that cater primarily to other firms) rely heavily on agglomeration economies, often in “global cities,” forming complexes of service firms comparable to other types of highly concentrated production.

Barney Warf

See also **Economic Geography; Flexible Production; Industrial Districts; Knowledge, Geography of; Knowledge Spillovers; Learning Regions**

Further Readings

Stutz, F. P., & Warf, B. (2005). *The world economy: Resources, location, trade, and development* (4th ed.). Upper Saddle River, NJ: Prentice Hall.



AGING AND THE AGED, GEOGRAPHY OF

See Elderly, Geography and the



AGNEW, JOHN (1949–)

One of the leading human geographers of the late 20th and early 21st centuries, John Agnew has made major contributions to the fields of political geography, international relations, and international political economy. Born in England in 1949, Agnew received his BA from the University

of Exeter and his MA and PhD from Ohio State University, receiving his doctorate in 1976. Since 1995, Agnew has been a professor of geography at the University of California, Los Angeles. From 1975 to 1995, he taught at Syracuse University. In 2008, he was elected president of the Association of American Geographers.

The author or editor of two dozen books and approximately 150 journal articles and book chapters, Agnew has been at the forefront of new research directions in several different areas of human geography. Starting in the late 1980s and continuing through today, Agnew has been the leading figure in the effort to create a theoretically informed, place-based electoral geography. In his work on politics in Italy and the United States, Agnew has moved the subfield beyond its former rampant empiricism and lack of concern for social theory. As part of this effort, Agnew has played an important role in theorizing and problematizing the concept of place.

Agnew has been a key figure in the formation of the field of critical geopolitics. Critical geopolitics seeks to make apparent the geographical assumptions and understandings, and implicit and explicit meanings that foreign policymakers and others give to places that serve to justify their geopolitical actions. In his work, Agnew traces the historical foundations of the modern geopolitical imagination through the 19th and 20th centuries.

Agnew has also played an important role in reconceptualizing the main concepts of international relations, most famously through his critique of the “territorial trap,” problematizing the state-centrism that dominates much of geopolitical and international relations thought. In addition, he has been a leading writer in the areas of hegemony, sovereignty, and globalization.

In studies of international political economy, Agnew has demonstrated the important role that regional, national, and global economies and economic policies play in (geo)politics; detailed the uneven spatial impacts of globalization within countries; and recognized the role of core-periphery impacts and relations within countries, as well as across countries, within the world economy.

Through his many publications, John Agnew has played a critical role in political geography’s renaissance in the late 20th century and is



recognized today as one of human geography's leading scholars.

Jonathan Leib

See also **Critical Geopolitics; Political Geography**

Further Readings

- Agnew, J. (1987). *Place and politics: The geographical mediation of state and society*. Boston: Allen & Unwin.
- Agnew, J. (1987). *The United States in the world economy*. Cambridge, UK: Cambridge University Press.
- Agnew, J. (2002). *Place and politics in modern Italy*. Chicago: University of Chicago Press.
- Agnew, J. (2003). *Geopolitics: Re-visioning world politics* (2nd ed.). London: Routledge.
- Agnew, J. (2005). *Hegemony: The new shape of global power*. Philadelphia: Temple University Press.
- Agnew, J. (2009). *Globalization and sovereignty*. Lanham, MD: Rowman & Littlefield.
- Agnew, J., & Corbridge, S. (1995). *Mastering space: Hegemony, territory and international political economy*. London: Routledge.



AGRICULTURAL BIOTECHNOLOGY

Agricultural biotechnology has been a topic of considerable social and environmental controversy since it was first pursued by researchers and later adopted by industrial agriculture. The term usually refers to living agricultural inputs, such as seeds that use genetic engineering, though some institutions define it much more broadly. According to the Organisation for Economic Co-operation and Development, *biotechnology* means the application of science and technology to living organisms and their parts, products, and models thereof and to alter materials for the production of knowledge, goods, and services. Such a broad definition applied to food and agriculture can describe everything from beer brewing and bread

baking to all of plant breeding since the start of sedentary civilization. The international Convention on Biological Diversity defines biotechnology in similar terms in its biosafety protocol and revenue-sharing agreements for genetic resources. The use of broader meanings normalizes genetic engineering techniques and lumps them together with traditional and conventional plant breeding.

The first pronouncements of the promise of agricultural biotechnology in the early 20th century suggested that bioreactors could produce single-cell proteins that could feed the poor. Similarly, today agricultural biotechnology proponents cite the promise of genetic engineering solutions to mitigate hunger, chemical pollution, fertilizer use, and soil erosion. The use of genetic engineering techniques allows scientists to move and manipulate an organism's DNA (deoxyribonucleic acid), which gives them an unprecedented range of novel genetic combinations. The rapid adoption of genetically engineered corn, soy, canola, and cotton on over 100 million hectares by 2008 has led some to call this seed technology the most rapidly adopted in history. These seeds predominantly (>99.9%) exhibit the traits of either insect resistance (using genes from *Bacillus thuringiensis*, Bt) or herbicide tolerance, though many other kinds of crop traits are in development.

The first product of agricultural biotechnology to receive considerable public attention was the deliberate release of the "ice minus" bacterium developed by a University of California biologist. The concern with this genetically engineered organism (GEO) aroused local legal reactions in the California Bay Area cities of San Francisco, Berkeley, and Oakland. The project was to spray potatoes in Northern California with an "ice-nucleation-active" bacterium in order to inhibit the formation of frost on the plants. The National Institute of Health's Recombinant DNA Advisory Committee eventually approved these field tests. But the activist Jeremy Rifkin, of the Foundation on Economic Trends, obtained a court injunction to stop the release, arguing that the experiment posed an environmental hazard and that there were no adequate containment protocols in place. The fallout from the controversy led to a new round of discussions about how GEOs should be regulated, ultimately leading to a decision by the U.S. Congress in 1985 to regulate them through



the existing regulatory system. Under what is known as the “Coordinated Framework,” the U.S. Food and Drug Administration evaluates food safety concerns, the U.S. Environmental Protection Agency oversees concerns about toxicity from mobile plant tissues such as pollen and root exudates, and the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service oversees problems related to increased weediness and biological invasion. Many activists and ecologists simply saw the Coordinated Framework as an effort to manage GEO introduction instead of regulating it.

Since the first plans to release them in the early 1980s, products of agricultural biotechnology have received criticism from the Ecological Society of America, which subsequently released a statement noting the potential ecological and environmental hazards associated with releasing GEOs. They noted that the products of genetic engineering posed no new classes of ecological hazards. However, the novelty of the new technology warranted regulatory oversight, because there is potential for more extreme and uncertain ecological hazards. They strongly advocated a robust system of containment to prevent the escape of the genes into the environment, by either seed dispersal or cross-pollination. They also argued for early ecological risk assessments of GEOs to ensure that they did not pose significant risk to native biota. The early planning for ecological risks poses challenges, given the importance of trade secrets in the development of these commercial products.

Ecologists’ opinions on the risks from GEOs vary widely. Some ecologists suggest that some organisms pose threats to the environment, while others argue that GEOs will suffer greater fitness consequences from having their physical expression altered in ways that make them more dependent on human intervention to live in areas outside of agricultural production. They urge an approach to evaluating the risks of biotechnology, recognizing that uncertainty, complexity, and incomplete knowledge must be factored into any regulatory approach, from postrelease monitoring to more comprehensive ecological risk assessments.

The specific categories of risks discussed regarding agricultural biotechnologies include

those related to food safety—for example, potential toxics and allergies from the novel combinations or antibiotic resistance from the marker genes used in the new genetic constructs. They include a range of ecological risks, from those associated with invasive plants or weeds to those related to loss of genetic diversity. Additionally, there may be nontarget impacts, as was discovered by one scientist who investigated the impact of Bt corn on the monarch butterfly.

Of the more controversial products of agricultural biotechnology is Posilac (originally developed by Monsanto and now controlled by Eli Lilly and Company), a recombinant bovine growth hormone given to cows to gain considerable rises in milk production per cow. It receives far less oversight in the United States than in Europe, where the growth hormone is banned. While there were few ecological risks presented by Posilac, its role in fostering utter infections is partly responsible for the high levels of antibiotics in milk. This also raises ethical questions about the use of these hormones in the context of animal health. For cows using Posilac, some argue, there are significant productivity gains that are painful for the animal. It also raised questions about the role of agricultural biotechnology in raising productivity, and forcing down commodity prices, a situation that could foster concentration in the food system. Several other Monsanto products have received negative publicity, including their RoundUp Ready seed lines for corn, cotton, canola, and soy. While makers of herbicide-tolerant seeds argue there are benefits for preventing soil erosion and simplifying crop management, others argue that overuse of the herbicides tied to these seeds will foster the evolution of weeds that are resistant to the chemical, eventually requiring a transition to more toxic chemicals. Monsanto has also received negative publicity for its terminator technology that renders seeds sterile as a sort of patent protection.

Dustin R. Mulvaney

See also **Biotechnology and Ecological Risk; Biotechnology Industry; Ecological Risk Analysis; Factors Affecting Location of Firms; Genetically Modified Organisms (GMOs)**



Further Readings

- Kloppenborg, J. (2005). *First the seed: The political economy of plant biotechnology* (2nd ed.). Madison: University of Wisconsin Press.
- Mills, L. (2003). *Science and social context: The regulation of recombinant bovine growth hormone in North America*. Montreal, Quebec, Canada: McGill-Queen's University Press.
- National Research Council. (2000). *Genetically modified pest-protected plants*. Washington, DC: National Academies Press.



AGRICULTURAL INTENSIFICATION

There are a variety of definitions of agricultural intensification, but they all essentially refer to a process whereby inputs of capital and/or labor are increased to raise the productivity or yield (output) of a fixed land area. The academic interest in agricultural intensification has been concerned with the technical, social, and ecological details of local intensification processes as well as more broadly with agricultural intensification as key in the rise of complex societies and development in general. Agricultural intensification is a process that involves both societal (social, political, and economic) and environmental processes of change, and it has been an important research topic in geography, particularly during the second half of the 20th century. The challenge of meeting future global food demands, as well as framing policies for more sustainable food production and land use systems, means that agricultural intensification is likely to remain an important concept during the 21st century.

It is common to distinguish between two ways of intensifying agricultural production by increasing inputs of capital or labor. Capital-intensive agriculture depends on high inputs of capital, such as machinery, energy, and biotechnology, while labor-intensive agriculture primarily depends on high inputs of manual labor. If high inputs of land are used in an agricultural system, while capital and labor inputs are kept at a minimum, it is referred to as *extensive* agriculture, indicating its

character of being the opposite strategy to that of *intensive* agriculture. Hence, a farming system with long fallow periods (e.g., swidden systems, slash-and-burn, or shifting cultivation) that in its totality encompasses a relatively large land area is more extensive than a system based on permanent tillage (i.e., with no or minimum fallow periods) of the same amount of land. Levels of agricultural intensity are thus commonly graded on a scale from “extensive” to “intensive” systems. A labor-intensive farming system is thus characterized by relatively high inputs of manual labor on rather small arable fields, while a capital-intensive system requires high inputs of capital investments per land area. This grading is part of the standard evolutionary model of agricultural and societal development, where societies are understood to progress from a primitive state—that is, with low technical and social complexity, low population density, and extensive production systems—to more advanced, complex, densely populated, and socially stratified societies with increasing levels of agricultural intensity. But, as detailed studies of agricultural intensification have shown, this historical scenario does not fit in all places. In some areas, intensive practices were also part of early agricultural strategies.

Studies of agricultural intensification have been closely linked to a broad range of issues related to the development of human societies and their use of natural resources, such as the evolution of political centralization, urbanization, land degradation, and population dynamics. Rapid population growth combined with limits on expanding cultivated land typically strengthens the imperative to intensify agricultural production, and from a policy perspective, concerns with agricultural intensification are generally grounded in the fundamental question of how to produce enough food for future consumers. To what extent processes of agricultural intensification can indeed satisfy the three critical development goals of (1) agricultural growth, (2) poverty alleviation, and (3) sustainable resource use is a critical issue in contemporary development research and policy debates. The Green Revolution, by which agricultural productivity was greatly enhanced in many countries during the 1950s to 1980s, is a classical and much debated case of the positive and negative effects of agricultural intensification.



A major contribution to the study of agricultural intensification as a historical and geographical process was the work by the Danish economist Ester Boserup (1910–1999). In her 1965 book *The Conditions of Agricultural Growth*, she argued against the Malthusian doctrine that population growth would necessarily lead to problems of insufficient food production and environmental and social stress. What Boserup convincingly showed was how farming societies in different parts of the world and in different historical contexts instead demonstrated a remarkable capacity to intensify agricultural production as population numbers increased and in many cases also succeeded in meeting the demands of a growing population. Boserup's theory of population-pressure-induced agricultural intensification has been extensively discussed, criticized, and modified, but it still remains a fundamental reference for contemporary studies of agricultural intensification.

By definition, agricultural intensification is a process that takes place in a specific geographical and historical context, and the academic study of agricultural intensification has consequently mainly relied on individual case studies of agricultural change, over both long and shorter time periods. But comparisons between different areas, regions, and historical periods have also been an important analytical method. Because agricultural intensification is a process that is always situated in a local context, it feeds on a complex set of interrelating factors (societal and environmental). In contemporary research, it is thus common to stress that the processes of agricultural intensification are often multicausal and dynamic. This means that there is great variety in how and why agricultural production has been intensified in different places. Nonetheless, most studies of agricultural intensification focus on a few key driving forces. Besides population pressure, the roles of markets, infrastructure, political pressures, and biophysical conditions (e.g., soils and climate) are the most important.

Lowe Börjeson

See also **Agricultural Land Use; Agriculture, Preindustrial; Environmental Impacts of Agriculture; Malthusianism; Neo-Malthusianism; Population and**

Land Use; Population, Environment, and Development; Shifting Cultivation; Soil Conservation; Sustainable Agriculture

Further Readings

- Boserup, E. (1965). *The conditions of agricultural growth*. London: George Allen & Unwin.
- Brookfield, H. (1984). Intensification revisited. *Pacific Viewpoint*, 25, 15–44.
- Lee, D., & Barret, C. (Eds.). (2001). *Tradeoffs or synergies? Agricultural intensification, economic development and the environment*. Wallingford, UK: CABI.
- Turner, B., II, Hyden, G., & Kates, R. (Eds.). (1993). *Population growth and agricultural change in Africa*. Gainesville: University Press of Florida.



AGRICULTURAL LAND USE

Agricultural land is land fit for producing crops and livestock. Land used for (a) cultivation of food products; fibers such as cotton, wool, and silk; and tobacco and medicinal plants and (b) livestock production, such as aquaculture, cattle and beef, dairy products, hogs and pork, and sheep, lamb, and mutton can be called agricultural land. Agriculture is the largest economic sector in the world, and it employs more than 30% of the world's population and is the economic backbone of many countries.

Cropland and pasture, vineyards, nurseries, orchards, horticultural areas, and groves are the general categories used in agricultural land use classifications. Land that is confined to feeding operations; breeding facilities in farms; and ditches, canals, and small farm ponds are also categorized under agricultural land use. Cropland and pasture, the most basic category of agricultural land use, include harvested lands, fallow lands, annual or seasonal croplands, and croplands used for improving soils and legumes. Land used for permanent crops such as fruit plantations and nuts and land used for cultivation of vines are classified as orchards, groves, and vineyards. Specialized livestock production facilities and large enterprises with confined feeding, poultry

farms, and built-up or open facilities with a large animal population can be categorized under agricultural land with confined feeding operations. Horse farms and storage facilities cannot be included in this category. Breeding facilities, farm lanes, canals, small farm ponds, and horse farms cannot be classified under any of the above-specified categories and are termed as other agricultural lands. Arable land, land under permanent crops, and permanent pastures are the basic classifications used by the Food and Agriculture Organization of the United Nations. Distinguishing boundaries for agricultural land use is difficult in places where there is a mixture of land uses, such as wetlands. Cropland, grassland, pasture and range land, and forests account for 76% of land in the world, and land classified as agriculture constitutes more than 46% of land in the United States (Figure 1).

Agricultural land use often gets converted to other incompatible, nonagricultural land uses, such as residential, commercial, recreational, and industrial land uses, which can be broadly classified as urban land use. Understanding the factors driving agricultural land use conversions is critically important because policy initiatives need to be formulated to confront this dangerous trajectory.

Agricultural land value frequently determines agricultural land use and is often considered in calculating farm sector economic indicators. Because of its economic value as a source of crop production, as a habitat for wildlife, and as a source of open space, agricultural land plays a vital role in the agrarian economy. Socio-economic factors, policy reforms, demographic changes, technological developments, and urban growth are some of the major factors leading to agricultural land use conversion. Over the past

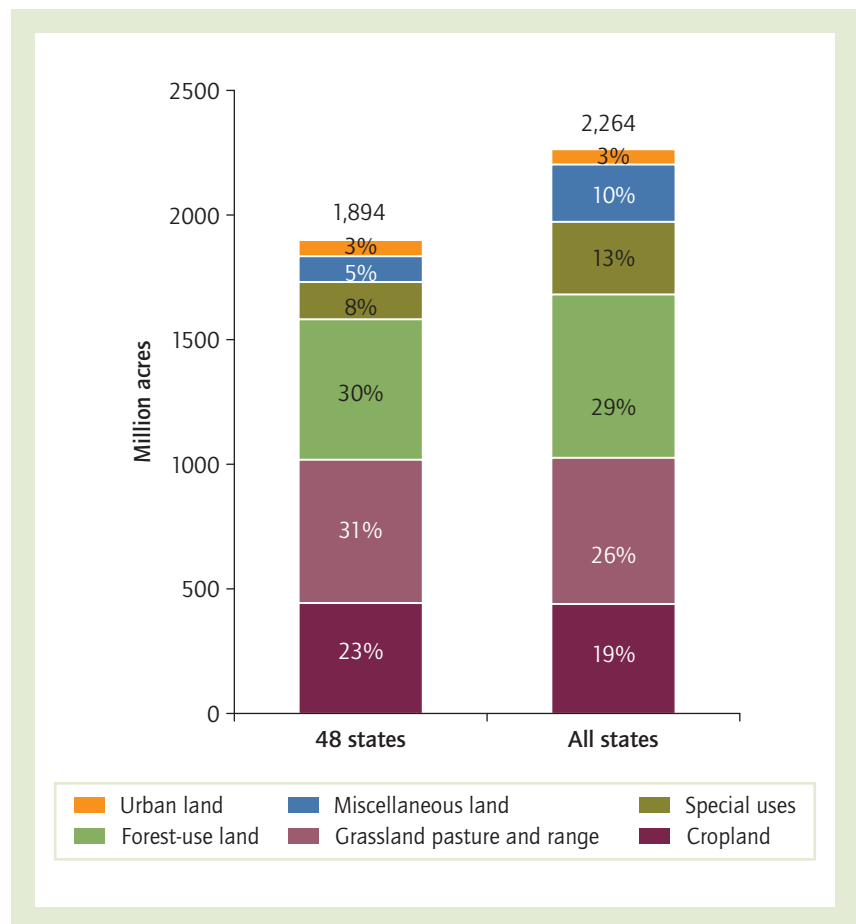


Figure 1 Major uses of land in the United States, 2002

Source: U.S. Department of Agriculture, Economic Research Service. (2002). *Land use, value and management: Major uses of land*. Retrieved December 10, 2008, from www.ers.usda.gov/Briefing/LandUse/majorlandusechapter.htm.

few years, the majority of agricultural land has been converted to forest land, urban land, or built-up land. Conversion of agricultural land to forest land is attributed to reclassification and policy reforms. Net shifts between cropland and forest land are illustrated in Figure 2. Conversion of agricultural land to urban or built-up land is mostly due to urban sprawl and the higher values placed on land that is developed within suburban and peri-urban areas.

The majority of the lands converted from nonagricultural uses to agricultural use between 1982 and 1997 were forest lands (55%). During the same period, most of the agricultural lands that were converted to nonagricultural lands became some sort of “built-up” land. Net land use shifts are demonstrated in Table 1.

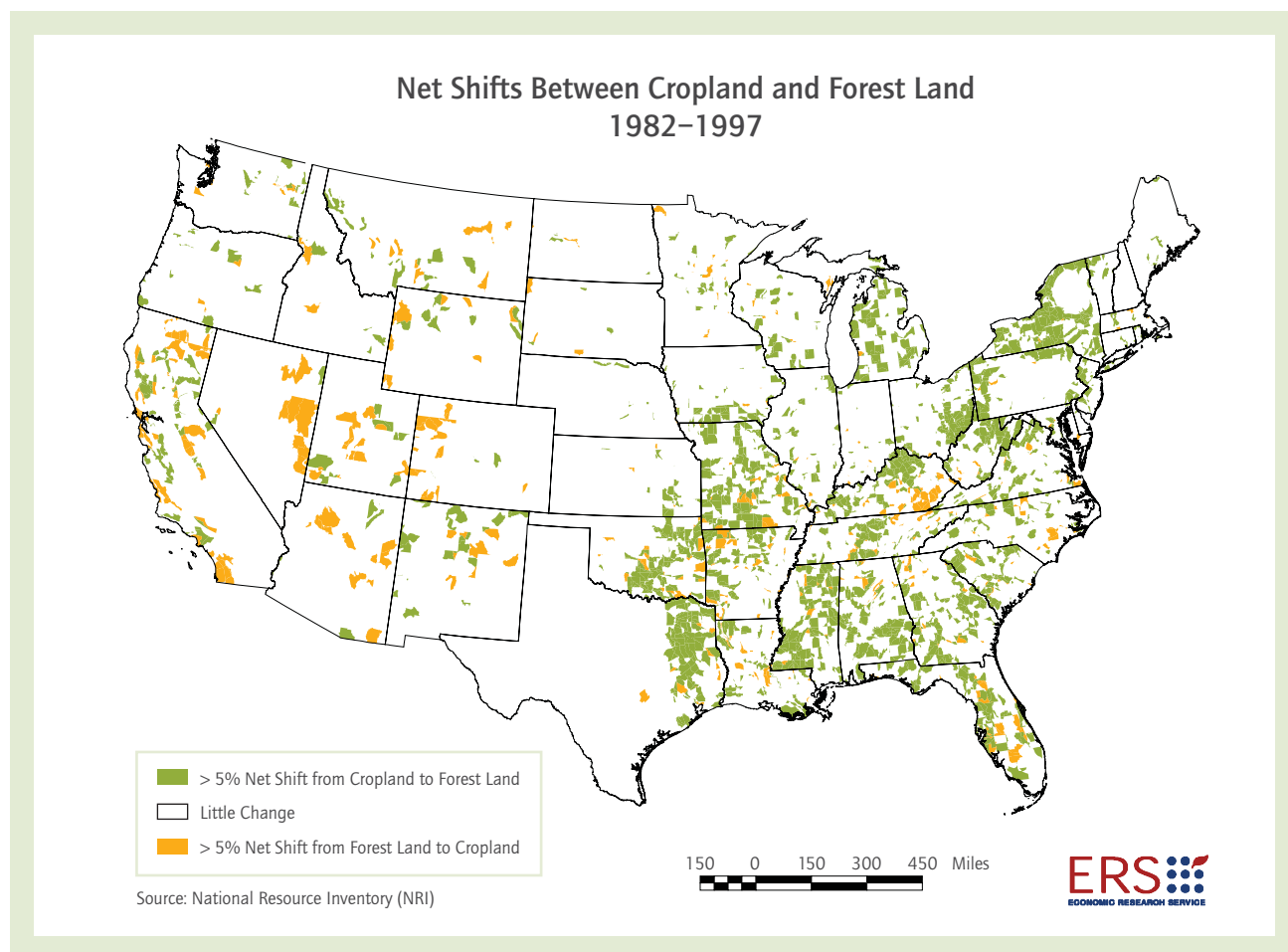


Figure 2 Net shifts between cropland and forestland, 1982–1997

Source: U.S. Department of Agriculture, Economic Research Service. (2002). *Land use, value and management: Major uses of land*. Retrieved December 10, 2008, from www.ers.usda.gov/Briefing/LandUse/agchangechapter.htm.

<i>Land Use</i>	<i>Nonagricultural Shifts to Agriculture (1,000 acres)</i>	<i>Agricultural Shifts to Nonagricultural Uses (1,000 acres)</i>	<i>Net Land Use Shifts (1,000 acres)</i>
Forest land	8,304	22,720	–14,416
Minor land	3,120	6,481	–3,361
Urban and built-up land	3	13,924	–13,921
Rural transportation	383	685	–302
Water areas	654	1,500	–846
Federal land ^a	2,685	4,101	–1,416
Total	15,148	49,410	–34,262

Table 1 Sources of land use shifting into and out of agriculture, 1982–1997

Source: U.S. Department of Agriculture, Economic Research Service. (2002). *Land use, value and management: Major uses of land*. Retrieved December 10, 2008, from www.ers.usda.gov/Briefing/LandUse/agchangechapter.htm.

a. “Federal land” is not a land use. While the Natural Resources Inventory (NRI) shows federal land, it does not account for land use changes on federal land.



<i>Cropland (million acres)</i>	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003 ^a	2004 ^a
Cropland used for crops ^b	337	330	339	332	346	349	345	344	345	340	340	341	336
Cropland harvested ^c	305	297	310	302	314	321	315	316	314	311	307	315	312
Crop failure	8	11	7	8	10	7	10	8	11	10	17	10	9
Cultivated summer fallow	24	22	22	22	22	21	20	20	20	19	16	16	15
Cropland idled by all													
Federal programs ^b	55	60	49	55	34	33	30	30	31	34	34	34	35
Annual programs	19	23	13	18	0	0	0	0	0	0	0	0	0
Conservation Reserve Program	35	36	36	36	34	33	30	30	31	34	34	34	35
Total, specified uses ^{b,d}	392	390	388	388	380	382	375	374	376	374	374	376	372

Table 2 Major uses of cropland, United States, 1992–2004. Includes the contiguous 48 states. Fewer than 200,000 acres were used for crops in Alaska and Hawaii.

Sources: Adapted from Economic Research Service (ERS), U.S. Department of Agriculture. (2006). *Land use*. Washington, DC: Economic Research Service; National Agricultural Statistics Service (NASS), 1999; and unpublished data from the USDA Farm Service Agency, ERS, and NASS. Retrieved December 10, 2008, from www.ers.usda.gov/publications/arei/eib16/chapter1/1.1.

a. Preliminary, subject to revision.

b. Breakdown may not add to totals due to rounding.

c. A double-cropped acre is counted as 1 acre.

d. Does not include cropland pasture or idle land not in federal programs that is normally included in the total cropland base.

Decreases in total cropland constitute the largest decrease in agricultural land use during the same period. Except for conservation reserves and croplands used only for pasture, all other forms of agricultural land, such as cropland, idle cropland, and grassland pastures, have decreased during this period (Table 2).

Trends in land use shifts were different among the regions. Urban sprawl has negatively affected croplands in the northeastern part of the country for a considerable period of time. At the same time, grassland and pastureland conversions have led to an increase in the number of agricultural lands in the mountain regions. Figures 3, 4, and

5 depict a series of images that reflect land use shifts by region: major land covers, 1987 (Figure 3); shares of land in major uses, 2002 (Figure 4); and increase in developed land, 1992–1997 (Figure 5).

Factors Driving Agricultural Land Use Change

Land use change is often based on the opportunities and constraints involved in socioeconomic and demographic factors and policy reforms. Population growth or increase in population density, housing growth, and residential development

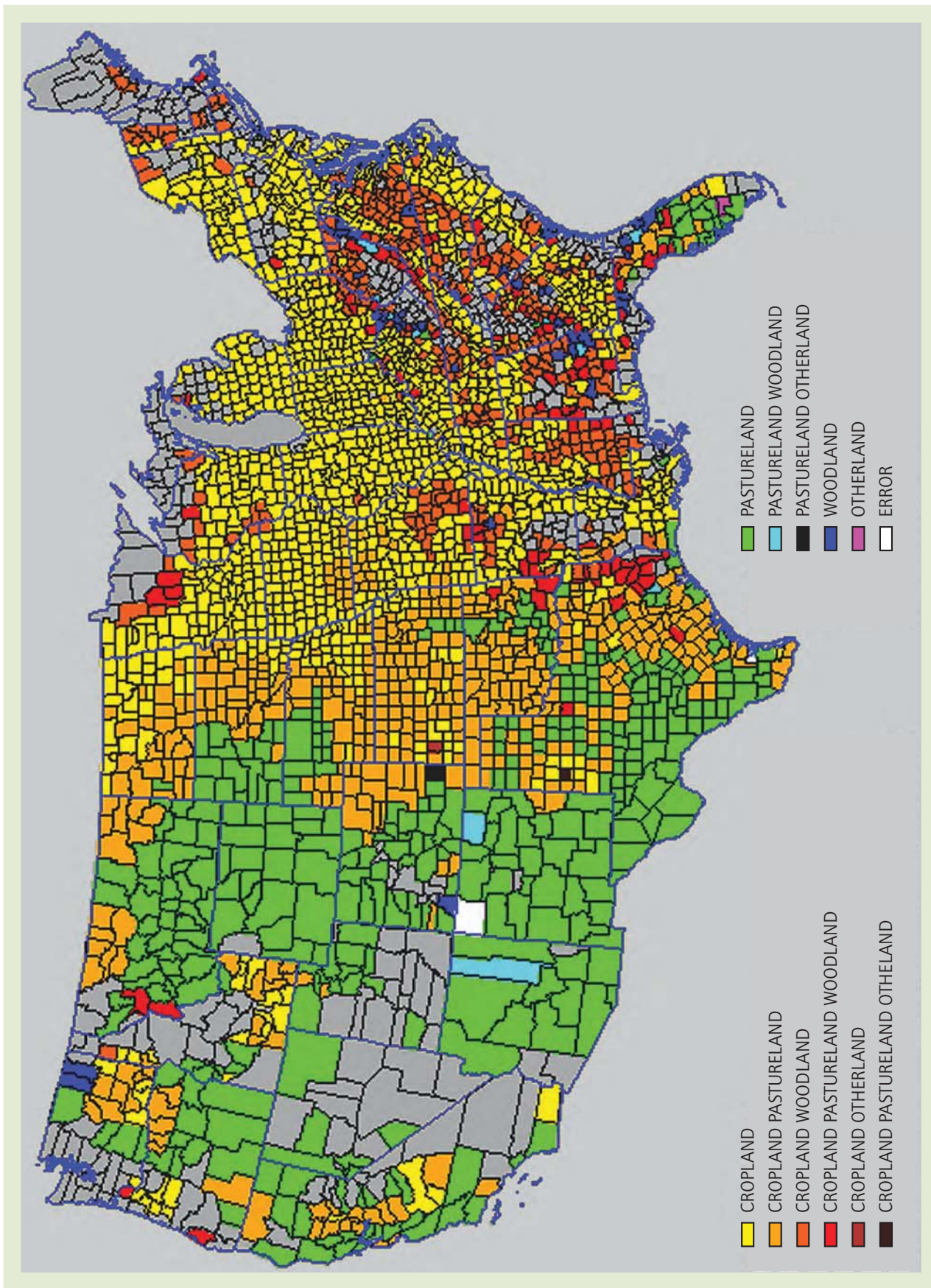


Figure 3 Major land covers from the 1987 census of agriculture

Source: Gisliger, A., Cooper, E. S., Riggle, S., Limp, W. F., & Hodgson, T. W. (1997, August). *RCA III cultural resources in America and agricultural land use: An initial national profile* (Working Paper No. 17, Figure 20, p. 21). Fayetteville: University of Arkansas, Center for Advanced Spatial Technologies.

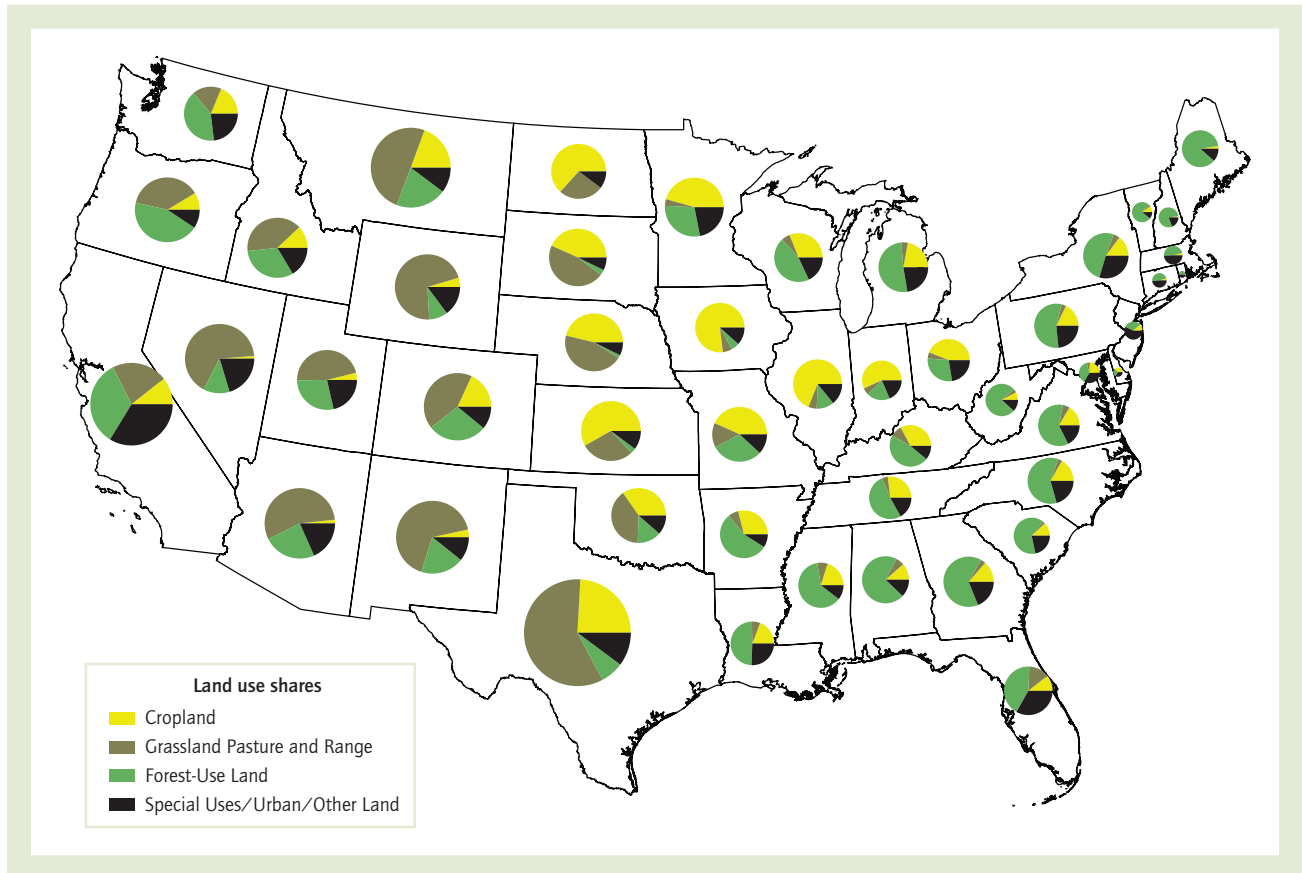


Figure 4 Shares of land in major uses, 48 contiguous states, 2002

Source: U.S. Department of Agriculture, Economic Research Service. (2007). Data sets—Major land uses: Map. Retrieved March 17, 2010, from <http://www.ers.usda.gov/data/majorlanduses/map.htm>.

are some of the demographic factors that lead to decisions to convert agricultural land use to other uses. Household incomes, type of employment, accessibility to markets, income earnings on crop production, and distance from urban areas are some of the socioeconomic factors leading to land use conversions. Most of these factors are attributed to urbanization, population growth, migration, rise in land values, changes in employment, income growth, increasing demand for residential land, rise in house rents, and increasing housing and road densities.

Increase in urban and built-up areas forces the urban fringe to develop rapidly, and often agricultural land is the most economical and accessible land located at the urban-rural fringe. Increase in housing density leads to construction of new roads and infrastructure facilities, which

leads to more land use conversions. Typically, suburban development consists of small parcels for single-family and multifamily housing developments extending well beyond the urban core. Eventually, as the urban area expands, these areas develop into major activity centers, driving the urban area to more rapid growth.

High growth rates associated with increased land values help developers lure farmers to make more money by selling their land. Increased marketing opportunities lead to shifts in agricultural operations that result in a decrease in traditional farming communities. Increased access to labor and higher land values further help these conversions. Employment patterns change over time, and so do land values. Over a period of time, this becomes a cyclic process, and the newly developed urban fringe starts looking for expansion



Seeing

SPRAWL

The federal Natural Resources Inventory tracks how much farm, forest and open space acreage gets developed.

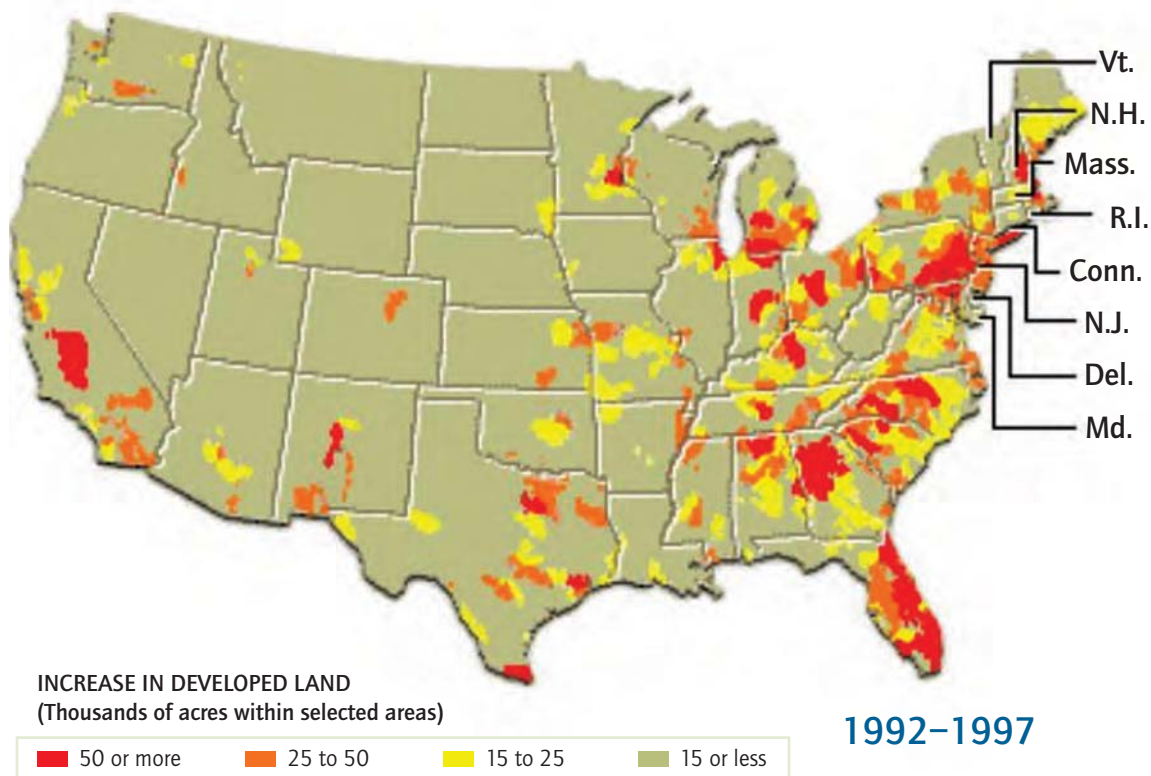


Figure 5 Seeing urban sprawl: Increase in developed land, 1992–1997

Source: U.S. Department of Agriculture. (2002). *Land use*. Delaware, OH: Northeastern Research Station. Retrieved December 10, 2008, from www.fs.fed.us/ne/delaware/biotrends/trends_humanpop.html.

again. Local governments tend to ignore or overlook the land use policies targeted at land management and protection of agricultural lands. Policies such as purchases of development rights and those targeted at residential and infrastructure development are also factors leading to conversions. Changes in land value calculation and tax assessment policies may result in a decrease in the annual benefits accruing from land that is still under agricultural production. Lack of stringent policies for protection of open spaces, soil conservation, and biodiversity also helps developers hunt for suitable land beyond the permissible limits.

Protecting Agricultural Land

Throughout the world, the demand for food products has resulted in programs and policies for protecting agricultural lands. In the United States, several farmland protection measures at various levels (right-to-farm laws, transfer of development rights, agricultural zoning, agricultural districts, smart growth and growth management strategies) have been developed to strengthen local agrarian communities and provide for rural amenities and open space. The U.S. Department of Agriculture coordinates with other federal, state, and local agencies and nongovernmental



organizations to protect farmland through various programs.

Nagaraj Kanala

See also **Agricultural Intensification; Agriculture, Industrialized; Agrofoods; Food, Geography of; Land Reform; Land Use Analysis; Land Use and Cover Change (LUCC); Rural Geography; Sustainable Agriculture**

Further Readings

- Fischel, W. A. (1982). The urbanization of agricultural land: A review of the National Agricultural Lands Study. *Land Economics*, 58(2), 236–259.
- Lubowski, R., Claassen, R., Bucholtz, S., Cooper, J., Gueorguieva, A., Johansson, R., et al. (2006). *Environmental effects of agricultural land-use change: The role of economics and policy*. Washington, DC: U.S. Department of Agriculture. Retrieved December 10, 2008, from www.ers.usda.gov/Publications/ERR25
- Lubowski, R., Vesterby, M., Bucholtz, S., Baez, A., & Roberts, A. (2006). *Major uses of land in the United States*. Washington, DC: U.S. Department of Agriculture. Retrieved December 10, 2008, from www.ers.usda.gov/publications/EIB14
- Wiebe, K., Tegene, A., & Kuhn, B. (1996, November). *Partial interests in land, policy tools for resource use and conservation* (AER-744). Washington, DC: U.S. Department of Agriculture, Economic Research Service.



AGRICULTURE, INDUSTRIALIZED

The industrialization of agriculture is the foundation of modern societies in dominant theories about economic development. Embedded in this vision of progress is the assumption that increasingly mechanized agriculture will constitute a declining share of the employment structure over time. This shift has been most dramatic in the

temperate heartlands of industrial agriculture in North America, Europe, Australia, and the southern cone of South America. On a global scale, agriculture has also constituted a declining share of the total workforce, a phenomenon sometimes described as “de-peasantization.” Though the pace of global de-peasantization has been highly uneven, the net magnitude is indicated by the fact that while the world’s population was still predominantly rural and agrarian at the outset of the 20th century, only a century later half of humanity was living in urban areas.

The positive association with this trajectory is best encapsulated in the imagery of industrialized agriculture releasing or freeing people from the drudgery of farmwork and rural life. Immeasurably less attention has been given to its precarious biophysical foundations, intractable externalities, and subsidized competitiveness (both directly and indirectly) and the social upheavals associated with fast-paced and job-scarce de-peasantization.

Yield Gains Versus Ecological Problems

One of the basic systemic tendencies in the industrialization of agriculture is to simplify farm environments—reducing biological diversity on a range of scales, from extensive monoculture fields and massive animal factories to soil micro-biota and plant and animal genetics—in order to replace labor with technology and standardize methods of production. When coupled with the heavy use of inputs and scientific innovations in crop breeding (“enhanced seeds”), this transformation was associated with phenomenal yield gains, particularly in the 1960s and 1970s. But this should not obscure the fact that nature is an uncooperative partner in the construction of scale economies in agriculture and that mechanization and homogenization of farm environments lead to a host of inexorable biophysical problems.

Monocultures and mechanized plowing, planting, and spraying increase vulnerability to soil erosion and nutrient loss, such that industrial farms are often described as mining the soil. To address the chronic degradation of soil fertility, industrial farms require regular application of external inputs, most crucially nitrogen and secondarily phosphorus and potassium, which come overwhelmingly from inorganic chemical sources.



The yield gains of industrial agriculture throughout the 20th century are inconceivable apart from the soaring production of inorganic fertilizer, in particular the natural-gas-dependent manufacture of synthetic nitrogen fertilizer (the Haber-Bosch process), which accounts for almost 60% of the world's total fertilizer consumption. Inorganic fertilizers also have the advantage of getting absorbed more quickly by plants than do most organic sources, which enhances the consistency of nutrient uptake, especially when coupled with irrigation. However, inorganic fertilizers ultimately rest on a nonrenewable resource base and are hence only a temporary fix for the soil problems of industrial agriculture.

Biological homogenization also increases the problems posed by pests, weeds, fungus, and disease, which entail the use of a range of petrochemical-based pesticides, herbicides, and fungicides. This dependence is compounded by the notorious treadmill effect, which describes the need for protracted chemical usage as natural predators and controls are eliminated and for new chemicals to be introduced as resistance develops over time. High-yielding, high-input crop varieties have necessitated massive expansions in irrigation infrastructure and water usage, as well as the unsustainable drawdown of underground aquifers, most famously the vast Ogallala Aquifer, which underpins the productivity of the arid Midwestern United States.

The Livestock Revolution

The yield gains of industrial monocultures are tightly linked to what has been called the “livestock revolution,” the rising place of animal flesh and derivatives in agricultural systems and ultimately in human diets. The growth of livestock populations since 1950 has dwarfed that of humankind, reflected in a momentous dietary shift on a global scale: Human beings now eat roughly twice as much meat as they did half a century ago, with industrialized countries consuming more than two and a half times as much meat per capita as developing countries. Pioneered in the United States, the integration of industrial grain and livestock production is now occurring very quickly and dramatically in China and other rising economies.

The increasing cycling of grains (led by maize) and oilseeds (primarily soybeans) through livestock has allowed farm animal populations to increase far beyond rangeland stocking capacities. This has gone hand in hand with the proliferation of concentrated animal-feeding operations (CAFOs), or “factory farms,” and animal-breeding innovations that have accelerated weight gain and egg and milk production. Because large percentages of usable plant protein, carbohydrates, and fiber are lost in the process of cycling grains and oilseeds through livestock, as the level of meat production expands, so too does the area of land needed for agriculture and the volume of industrial inputs required.

As with monoculture farming, the application of industrial techniques and the drive for economies of scale in livestock rearing face serious biophysical constraints. Crowded animal populations are highly susceptible to disease outbreaks, induce deviant behaviors that are detrimental to production, and generate levels of fecal waste and by-products that cannot be absorbed in nearby landscapes. The biophysical limits to scale in industrial livestock rearing are overridden through a combination of technological fixes, such as mass applications of antibiotics, disinfectants, and hormones; large fecal cesspools and lagoons; and the assembly-line debeaking of chicks.

Role of Multinational Corporations

One of the most important dimensions of the industrialization of agriculture is the rising control over decision making and value possessed by transnational corporations. The agro-input industry is a complex and ever more oligopolistic web in which corporations control large shares of the global markets in chemicals, fertilizers, seeds, and animal pharmaceuticals and weave together input usage. Corporate control over agricultural processing, distribution, and retailing is also intensifying, with vertical and horizontal integration occurring at a swift pace. The concentration of value and power on both the input and the output sides of industrial agriculture is a significant factor in the long-term increase in input costs and decline in farm-gate prices, which has pushed farmers to grow in scale or be driven out of business.



According to the U.S. Department of Agriculture, in the beginning of July 2009, there were 11.6 million head of cattle being fattened for slaughter on feedlots in the United States. About 84 % of these (9.8 million) were on large feedlots, with a capacity of 1,000 or more head. Shown above is the former Montfort feedlot near Greeley, Colorado. Established in 1930, it was the first U.S. feedlot with a capacity of 100,000 head. It was sold to ConAgra in 1987.

Source: Glowimages/Getty Images.

In sum, industrial agriculture has radically reconfigured the biophysical nature of farming from relatively closed nutrient and energetic systems into a through-flow process of corporate-dominated inputs and outputs. This transformation hinges on fossil energy and petrochemical derivatives to a tremendous and often underappreciated extent, from heavy machinery to the manufacture, application, and transport of fertilizer and agrochemicals, to the long-distance movement of food durables. In addition to being thus implicated in the rising carbon emissions, industrial agriculture, and the rising livestock populations in particular, is also a large source of methane emissions. In 2008, the Intergovernmental Panel on Climate Change identified global livestock

production as a major force in the destabilization of Earth's atmosphere.

External Costs and Subsidies

The environmental costs of industrial agriculture extend much further than this atmospheric burden. The collective impact of fertilizer and agrochemical runoff, CAFOs, and large-scale abattoirs makes industrial agriculture the principal cause of water contamination wherever it is practiced, with diffuse and difficult-to-measure impacts on human and ecosystem health. The cost of soil degradation is even harder to measure, given the longer temporal horizon needed. The intensive confinement of suffering animals in battery cages



Large operation in northeastern Colorado with many silage choppers and trucks harvesting corn silage (ensilage) in a circular field, with a beef feedlot in the distance

Source: Dunbar Arnold/AgStock Images/Corbis.

and gestation crates might also be seen to constitute another cost beyond measure. Yet whatever challenges there are in defining and measuring the environmental costs of industrial agriculture, it should be clear that they are overwhelmingly “externalized”; that is, they go unmeasured in conventional accounting systems and hence have no bearing on the competitiveness of industrial foods. Viewed another way, these unaccounted environmental costs might also be seen as an implicit subsidy to industrial agriculture.

Government subsidies have also enhanced the competitiveness of industrial agriculture, most notably in the United States and the European Union (EU). The agrosubsidy regimes of the United States and the EU were partly a response to the market problems facing farmers as the booming productivity of mechanized, input-intensive agriculture outpaced domestic demand, and these subsidies have helped keep these systems operational amid the “cost-price squeeze” noted earlier. However, they have done so by exacerbating the polarizing tendencies at work: At the same time as low unit margins have driven strong pressures for farmers to grow in scale,

agricultural subsidies have been concentrated very disproportionately on the largest farmers.

Given that one of the primary motives for these subsidy regimes has been to manage a state of chronic surplus, they are linked to an export imperative that was fostered over time via aid, trade promotion, and various forms of “dumping” (i.e., dispensing exports at prices below those in domestic markets). The flipside is that many of the world’s poorest countries have come to depend on the relatively cheap, industrial food imports and run persistent net food trade deficits. These imports—in which various implicit and explicit subsidies are embedded—have also presented competitive pressures for small farmers in many nations.

Current Social Issues

The precarious position of small farms in the face of market liberalization and subsidized industrial competition and the projected impacts of climate change pose vexing social challenges. In spite of the magnitude of global de-peasantization in the 20th century, small farmers still constitute more than two fifths of humanity, and in most of the world’s



poorest nations (especially in sub-Saharan Africa and South Asia), large shares of the workforce are still engaged in farming and face limited prospects of absorption into industry or the services.

At the same time, cracks in the biophysical foundation of industrial agriculture have begun to appear, manifested in the sharply rising global food prices since 2006. As global petroleum reserves decline and bring inevitable cost increases, a crucial implicit subsidy underpinning cheap industrial food correspondingly wanes. This is augmented by the fact that industrial agriculture has become a crucial source of liquid biofuels in response to declining oil reserves, especially in the United States and Brazil. The global volume of grains and oilseeds devoted to biofuel production is on a sharp incline, a trend that is again led by the temperate heartlands of industrial agriculture and with subsidies an important part of the process. The volume of industrial grains and oilseeds devoted to motor vehicles and to the still fast-rising livestock populations is projected to continue increasing in the coming decade.

The sudden price spikes in industrial foods after decades of steady decline in real terms has intersected profoundly with the food import dependencies in the world's poorest countries. Prior to the price increases, there were already an estimated 854 million people who were chronically malnourished, at the same time as an estimated 1.2 billion people were obese. With the primary agents directing industrial agriculture principally motivated by effective demand (i.e., purchasing power) rather than real human needs, the food-related social tremors witnessed in 2007–2008 threaten to intensify.

Conclusion

Ultimately, in place of the assumption that agrarian livelihoods will be progressively substituted by technology in modern societies, we see tremendous ecological and social instability and uncertainty. Machines and inputs that hinge on fossil energy and derivatives cannot continue to be substituted for human labor indefinitely, and agriculture that works with nature to enhance functional diversity, rather than to override and standardize it, is necessarily knowledge and labor intensive. The challenge of resubstituting scientific and local

ecological knowledge, skilled labor, more diverse cropping patterns for machines and inputs, and biological simplification may appear daunting, even counterhistorical, but it does not mean going back in time. Rather, this may be one of humanity's most urgent challenges in the 21st century.

Tony Weis

See also **Agricultural Biotechnology; Agricultural Intensification; Agrochemical Pollution; Agrofoods; Biofuels; Food, Geography of; Land Use Analysis; Land Use and Cover Change (LUCC); Rural Geography**

Further Readings

- Kimbrell, A. (Ed.). (2002). *The fatal harvest reader*. Washington, DC: Island Press.
- Mazoyer, M., & Roudart, L. (2006). *A history of world agriculture*. New York: Monthly Review Press.
- Weis, T. (2007). *The global food economy: The battle for the future of farming*. London: Zed Books.



AGRICULTURE, PREINDUSTRIAL

Throughout much of the world's history (indeed, dating back to the Neolithic Revolution 8,000 to 10,000 yrs. [years] ago), societies fed themselves through an assortment of preindustrial agricultural systems. Preindustrial or nonindustrial agricultural systems differ from industrialized ones in a variety of respects. Most important, preindustrial systems do not use the inanimate sources of energy that are vital to industrialized agricultural systems (e.g., fossil fuels) and, therefore, are markedly less energy intensive in nature. Rather, work in preindustrial farming systems is accomplished entirely through human or animal labor power. Thus, these types of farming are much more labor intensive. In societies fed predominantly through preindustrial agriculture, the vast bulk of people are engaged as farmers or peasants. Second, because preindustrial societies are often not fully commodified, that is, capitalist social relations have not come to dominate every aspect of production, preindustrial agricultural systems are



Farmer working in paddy field in Sekinchan Malaysia

Source: © Can Stock Photo Inc.

generally organized around production for subsistence rather than production for profit. Food, in other words, is mostly grown for local consumption rather than for sale in a market.

Preindustrial agricultural systems played an enormous role in the slave-based and feudal social systems that existed for millennia in most of the world. Roman *latifundia*—large estates worked by slaves—for example, formed the backbone of agricultural production in the Roman Empire. The expansion of medieval agriculture in the dense soils of Northern Europe was made possible by the introduction of the heavy plow and, later, the three-field system. The manorial system that formed the social and economic basis of feudal Europe involved peasants and serfs who rented land from large landowners, paying rent with a fraction of their output. Variations of peasant-based production continue to be important in many contexts.

Today, various forms of preindustrial agricultural systems are still found throughout the world, with large variations in the types of crops grown,

the methods used to plant and harvest them, their productivity, labor relations, and their relative vulnerabilities to drought or other hazards. While it is not technically a form of agriculture, many observers classify nomadic herding in this category, although it involves only the domestication of animals, not crops. Typically, nomadic herders measure their wealth in terms of livestock (generally cattle, goats, or reindeer) and often follow their herds in annual migratory cycles, such as transhumance, the movement between summer pastures in higher elevations and winter pastures in lower ones. Nomadic herding has been slowly vanishing throughout the world over the past two centuries, but contemporary examples include the Masai of East Africa, the Mongols in Mongolia and Northern China, the Tuareg of Northern Africa, and the Lapps of Northern Finland.

The best-known example of preindustrial agriculture is slash-and-burn, also known as swidden or shifting cultivation. This form is only found in tropical areas such as parts of Central America, the Amazon rain forest, West and Central Africa, and southeast Asia, to which it is ideally suited. Roughly 50 million people continue to be fed this way in these regions. Due to heavy rainfall and the subsequent leaching of nutrients, tropical soils are generally quite poor, and most nutrients are stored in the biomass. The first step in slash-and-burn, therefore, is to cut down existing trees and bushes in a given plot of land and burn them, releasing nutrients into the soil through the ash. Crops are then planted for several years. However, because the rate of nutrient extraction exceeds the rate of replenishment, the site can only be used for a brief period—generally 2 to 6 yrs.—and then farmers must move on to a new site. Abandoned sites may gradually recover with a sufficient fallow period. If there is rapid population growth and fallow periods are reduced, the soil may permanently decline in fertility. This form of farming was widely practiced in the Mayan kingdoms prior to the Spanish conquest, and declining soil fertility may have played a role in the collapse of the Mayan states.

A third form of preindustrial agriculture is the method of Asian rice paddy cultivation, which is widely practiced throughout a region stretching from Japan, Korea, and Southern China through southeast Asia into Eastern India. Rice is the staple crop for billions of people in Asia, and its cultivation



in this form goes back millennia. Young rice plants require standing pools of water, and to create spaces in which this can occur, Asian societies carved countless terraces out of hillsides along elevation contour lines to control the flow of water with vast networks of dikes and small levees. Furrows may be dug using water buffalos. Often, small fish are grown in these pools of water as a source of protein. The planting of rice is exceedingly laborious, giving rise to stereotypes of Asian peasants bent over their paddies. The supply of water may depend on monsoon rainfall.

Preindustrial agricultural systems have functioned effectively for thousands of years and continue to do so in many parts of the developing world. Boserup showed that the rising populations in such places often stimulate growth in productivity. In most places, the preindustrial systems are marginalized or threatened by the expansion of globalized, capitalist industrialized farming systems, including imports of subsidized grains from Europe or North America. However, preindustrial systems enjoy advantages of their own, including a diversity of crops (in contrast to industrialized monocultures) and freedom from dependence on pesticides and petroleum. Thus, it may be helpful to view these systems not as backward remnant forms of food production but as historical adaptations to particular social and environmental contexts—that is, as nonindustrial rather than preindustrial.

Barney Warf

See also [Agricultural Intensification](#); [Agriculture, Industrialized](#); [Bush Fallow Farming](#); [Food, Geography of](#); [Nomadic Herding](#); [Peasants, Peasantry](#); [Population and Land Use](#); [Population, Environment, and Development](#); [Shifting Cultivation](#)

Further Readings

- Boserup, E. (1965). *The conditions of agricultural growth: The economics of agrarian change under population pressure*. Chicago: Aldine.
- Food and Agriculture Association, United Nations. (1984). *Changes in shifting cultivation in Africa*. Rome, Italy: Author.
- Peters, W. (1988). *Slash and burn: Farming in the Third World forest*. Moscow: University of Idaho Press.



AGROBIODIVERSITY

The Convention on Biological Diversity (CBD) defines biodiversity as the variety of life on Earth and the natural patterns it forms. Our world's wide variety of plants, animals, and microorganisms and the genetic diversities within each species; the varieties of patterns they form in ecosystems; and the valuable products, services, and opportunities they provide are increasingly threatened by human exploitation. The CBD calls on all countries to conserve and sustainably use biodiversity in collaboration with local actors, such as farmers, because they take most of the actions that affect biodiversity.

Agriculture greatly affects biodiversity. Much of the world's farmlands are cultivated by small-landholding farmers in the developing countries, and the practices of these farmers affect biodiversity in a large part of the world. On the one hand, the practices of these farmers, such as the slash-and-burn agriculture of shifting cultivators in forest ecologies, have been derided as the primary cause of biodiversity loss. The conservation community has consequently called for biodiversity rehabilitation in such regions. On the other hand, there is an influential body of primary-research-based literature that is challenging this discourse on biodiversity endangerment by farmers in the developing world and instead emphasizes what can be learned from these farmers about in situ biodiversity conservation and sustainable use at both farm and landscape levels. This literature indicates that the farms and farming landscapes of hundreds of millions of farmers in developing countries are characterized by great diversity compared with the large uniform fields of farmers in the more developed world. Researchers and practitioners have noted the considerable extent to which small-landholding agriculture is related to the details of the landscape in which it occurs. Such agricultural strategies are the outcome of an accumulated body of local knowledge derived from experience and experimentation. This leads many small-landholding farmers to use the diversities of plant life on their fields to meet agroeconomic and livelihood goals; make optimal use of variations in agroecological conditions on their fields (such as differences in microclimate, soil



properties, and vegetation); and modify or transform their landscapes to produce a great variety of crops and genetic diversities of particular crops and also create local crop varieties (known as landraces). The varieties of crops cultivated are not static. They are conditioned by ecological, cultural, and socioeconomic factors and thus change through time.

This diversity of crops and other plants used by or useful to people in actively managed agricultural ecosystems is referred to as agrobiodiversity. The diversity of crops and other plants found in the fields of many small-landholding farmers is the result of the interaction of three factors: (1) biophysical diversity in the landscape; (2) the diversity, flexibility, and adaptability of agricultural management practices; and (3) the diversity of socioeconomic processes that condition the organization of agriculture. Biophysical diversity in landscapes refers to diversities of the biotic environment (such as plant genetic resources) and the abiotic environment. The diversity, flexibility, and adaptability of agricultural practices for managing this biophysical diversity are based on indigenous ecological knowledge and include selection and management of crop and plant varieties; combinations and rotations to suit particular ecological niches; management of successional vegetation during fallows; management of slopes, water, and soil fertility; and management of weeds, pests, and diseases. The agricultural factors and processes that affect biodiversity include the different types and modes of access to and control over land, labor, and manufactured capital—all of which vary by the income, gender, generation, and citizenship of farmers and may facilitate or undermine biodiversity. Processes relating to government policies and the uncertainties and risks of markets are also important aspects of agricultural organization.

Agrobiodiversity occurs in various kinds of agricultural fields. In sub-Saharan Africa, some of these are permanent intensively cultivated fields in close proximity to the residences of farmers or extensively cultivated fields farther away from residences, temporary bush fallow fields (which are alternately cropped and fallowed), planted and managed agroforests, and mixed home gardens. In West Africa, some innovative research has shown how the following practices have

conserved and allowed sustainable use of biodiversity: (a) soil fertility and soil property enhancement, weed control practices such as mounding and mulching of soils, and intercropping of specific crop combinations and (b) tree-biodiversity-friendly practices such as minimum tillage to protect the soil tree seed bank and seedlings; protection of saplings; coppicing; multiplying trees from suckers; selective weeding; deliberate fallow management, including planting and transplanting of trees; pruning and thinning of trees, giving priority to the preservation of tree species over crop yields; nurturing a variety of tree species that interact favorably with crops; and the extinction of fires. Several studies have documented the expansion of forests and their biodiversity as a result of such practices.

Agrobiodiversity also occurs in a variety of ecological niches where farmers use different crop plant combinations of immense genetic diversity and crop rotations over a range of land types and altitudes. In the Central Andes of Peru, Bolivia, and Ecuador, researchers have analyzed agroecosystems containing diverse world-renowned food plants, such as Andean potatoes, maize, quinoa, ulluco, barley, wheat, fava beans, and tarwi. They describe tiered agrobiodiversity zones of different elevations, although other researchers working in the same area suggest that the flexibility in practices has contributed to the current considerable overlap of land uses at different elevations and a patchwork of different crop types in adjacent fields.

Government policies, such as those that emphasize the Green Revolution and the gene revolution, food and labor market processes, and labor migration are among the factors that are severely undermining the capacities of small-landholding farmers to sustain their cultivation of biodiversity. The decline in the varieties of rice produced in India from 30,000 to only 10 is stark evidence of the magnitude of the threat to agrobiodiversity.

Louis Awanyo

See also **Agricultural Biotechnology; Agricultural Land Use; Agriculture, Preindustrial; Biodiversity; Biotechnology and Ecological Risk; Bush Fallow Farming; Population and Land Use; Population, Environment, and Development; Shifting Cultivation**



Further Readings

- Brookfield, H. (2001). *Exploring agrobiodiversity*. New York: Columbia University Press.
- Brookfield, H., Padoch, C., Parsons, H., & Stocking, M. (Eds.). (2002). *Cultivating biodiversity*. London: ITDG.

AGROCHEMICAL POLLUTION

An optimum nutrient level is essential for productive agriculture. Nutrients can be supplied either by natural sources or in the form of synthetic chemical fertilizers. However, the use of both natural and chemical fertilizers may result in an excess of nutrients, which can cause problems in water bodies and to health. This excess use of various fertilizers may pollute food crops and groundwater; this process is commonly called agrochemical pollution. Nitrates are highly soluble and, therefore, may quickly reach water bodies. Phosphates tend to be fixed to soil particles and can reach watercourses when soil is eroded. Phosphate-saturated soils and high phosphate levels in groundwater are found in many countries. This entry describes the main types of agrochemicals, the reasons for their use, and their effects.

Types of Agrochemicals

Agrichemical (or *agrochemical*) is a generic term for various chemical products used in agriculture. In most cases, agrichemical refers to the broad range of insecticides, herbicides, and fungicides, but it may also include synthetic fertilizers, hormones and other chemical growth agents, and concentrated stores of raw animal manure. Most agrochemicals are toxic, and all agrochemicals in bulk storage pose significant environmental and/or health risks, particularly in the event of accidental spills. Pollutants from agrochemical sources include fertilizers, manure, and pesticides. To these, we may add accidental spills of hydrocarbons used as fuel for agricultural machinery. The main effect of this is to introduce heavy metals and their compounds in soils—that is,

cadmium, arsenic, magnesium, zinc, and so on. Various harmful agrochemicals and their effects include the following:

Cadmium (Cd): Cd mainly comes from impurity in zinc-containing fertilizers. Its accumulation in the living system leads to growth retardation, diarrhea, kidney damage, liver injury, hypertension, and so on. Cd is soluble in water and is a major pollutant.

Chromium (Cr): Cr mostly comes from the fertilizer industry. It can lead to gastrointestinal ulceration, CNS (central nervous system) disease, cancer, and so on.

Copper (Cu): Cu also comes from chemical fertilizers. When Cu gets into living systems, it can lead to sporadic fever, hypertension, uremia, and even coma.

Mercury (Hg): Hg is a component of certain fungicides. It is a highly toxic chemical and acts as a cumulative poison, causing abdominal pain, headache, diarrhea, hemolysis, and so on.

Selenium (Se): Se is an ingredient of various fungicides and insecticides. Its effects can include damage to the liver, kidney, and spleen, fever, nervousness, vomiting, low blood pressure, blindness, and so on.

Zinc (Zn): Zn is an essential component of most fertilizers. It is one of the most common soil pollutants and can cause vomiting, cramps, and renal damage.

Effects of Agrochemicals

The use of pesticides in agriculture has been a major cause of pollution in soil ecosystems. Toxic, nondegradable chemicals from various pesticides accumulate in the soil and build up in concentrations that can threaten animals, crops, and plants. Agrochemicals pollute the soil directly by affecting the organisms that reside in it. Soil, however, acts as a vector for the pollution of surface water and groundwater. Persistent agrochemicals accumulate in soil and aquatic ecosystems, causing their biomagnifications in living organisms.

Agrochemicals may contaminate food crops and drinking water and endanger human health. They can lead to destruction of the soil's



The air-curtain orchard sprayer driven by the technician Andrew Doklovic uses multiple cross-flow fans to disperse pesticide to apple trees. Under some conditions, the smoother, gentler flow of air can reduce spray drift by half.

Source: Keith Weller/ARS/USDA.

microflora and fauna, leading to both physical and chemical deterioration and a severe reduction in crop yield. Agrochemical pollution has many ill effects on our agricultural systems. The most prevalent effect of agrochemicals is that they accumulate in the bodies of animals without killing them. If an animal receives small quantities of pesticides or other persistent pollutants in its food and is unable to eliminate them, the concentration within the animal's body increases over time. This process of accumulating higher and higher amounts of material within the body of an animal is called bioaccumulation. This phenomenon of increasing levels of a substance in the bodies of

higher-trophic-level organisms is known as biological magnification. Another problem associated with insecticides is the ability of insect populations to become resistant to pesticides, thus producing resistant species population. A third problem associated with pesticides is that they prove harmful for nontarget organisms, thus killing certain beneficial species as well.

Another dimension of agrochemical pollution was associated with the introduction of the Green Revolution in the 1970s for high production of food grains and multiple cropping. One side effect was the greatly increased use of agrochemical fertilizers in developing countries such as India and Mexico. Most high-yielding varieties of food crops can be sustained only with the help of an adequate freshwater supply, modern farming techniques, massive input of synthetic manures, and the use of chemical pesticides to ward off a variety of pests. Pests vary from insects and nematodes to fungi, herbs, and rodents. Generally, pesticides are used against a target group of organisms, usually insect pests, which are aimed to be controlled or exterminated. The important pesticides introduced were dichlorodiphenyl trichloroethane (DDT), BHC (benzene hexachloride), aldrin, and endrin, among others, and many of these are now banned by international treaty. It is unfortunate that when an insecticide is used with a particular insect pest as a target, many benevolent organisms are also exposed. These nontarget organisms are also affected. Any pesticide used in agriculture or horticulture and even for environmental sanitation in public health programs is a poison designed to kill a particular form of life and should not have negative effects on other forms of life. The effect that pesticides have on target as well nontarget organisms needs to be well studied and documented.

In India, pesticides were first introduced primarily to control mosquitoes and subsequently to control agricultural pests, starting with a modest use of a few tons. It has now reached a stage where there are approximately 120,000 metric tons of these poisonous chemicals used per year. Currently, India has 131 pesticides registered for use, some of which are under restricted use for public health purposes only. Yet some of these banned chemicals are easily available in the



market. In addition, some of the chemical pesticides, such as DDT, have a long residency period, about 20 years in the environment. The question that should be addressed is how much of the total amount of pesticide used in an agricultural area reaches the target organism. Unfortunately, some useful microorganisms such as nitrogen-fixing bacteria, which are responsible for the fertility of soil; insects such as the honeybee; and certain organisms such as frogs, birds, and snakes, which are natural allies in our war against insects, rodents, and pests, are also affected.

Soil organisms acquire pesticides by coming in direct contact with them in soil or plant roots. The longer a pesticide remains in the environment, the greater are the chances that it will spread or likely be transported to another area from the one where it was applied. Drift and run-off also result in sufficiently high quantities of pesticides getting into water bodies. Thus, it is well documented that pesticides on application in various ecosystems for control of a particular target pest also find their way into almost all the parts of the ecosystem. Once they reach different systems, including biotic ones, they are bound to affect the apex-level organisms in food chains. Biomagnification has been common with persistent organochlorines and particularly with those that are not readily metabolized by vertebrates (e.g., DDT, aldrin). Ultimately, this leads to death of the organisms at the top of the food chain or indirectly to reproductive failure. Younger animals and those in the reproductive phase are more susceptible to pesticides than others. Of course, the nontarget organism we are most concerned with is humans. Although pesticides have never been used to control the human population, almost all of us carry a heavy load of persistent pesticides in our bodies. Recent studies indicate that expectant mothers are transmitting these to unborn fetuses through the placenta and, after delivery, through milk to the newborn.

Other commonly used agrochemicals include herbicides, which are the group of chemicals used to kill undesirable vegetation. They can be divided into two categories—selective and nonselective herbicides. The first one kills certain types of vegetation and is used depending on the need, for example, a pesticide designed to control or kill plants, weeds, or grasses. Almost 70% of all

pesticides used by farmers and ranchers are herbicides. These chemicals have wide-ranging effects on nontarget species. Another important type of agrochemical is fungicides, which are used to control fungal diseases in agricultural crops. Common fungicides are sulfur and organic mercuric compounds such as methyl mercury and copper compounds. A third type is rodenticides, which are used against rodents, that is, rats and mice, which destroy agricultural crops. Important rodenticides are norbormide and strychnine.

Conclusion

Humans have been continuously increasing the quantity of pesticides in the environment. Also, some of the crop insect pests have developed immunity and resistance to these chemicals. On the other hand, most of the nontarget species that were taking care of these pests by devouring them may be killed or may have their reproductive systems impaired. Even humans, who have been targeting insects and other pests, may not be spared from the adverse effects of these silent killers, the pesticides. According to the United Nations Environment Programme, every year more than 10,000 people are killed from pesticide poisoning from agrochemical pollution in developing countries.

Atiqur Rahman

See also Agriculture, Industrialized; Agroecology; Agrofoods; Chemical Spills, Environment, and Society; Chlorinated Hydrocarbons; Heavy Metals as Pollutants; Nonpoint Sources of Pollution; Water Pollution

Further Readings

- Merrington, G. (2002). *Agricultural pollution: Problems and practical solutions*. London: Taylor & Francis.
- Prabhakar, V. (2001). *Environment and agricultural pollution*. New Delhi, India: Anmol.
- Scheierling, S. (1995). *Overcoming agricultural pollution of water*. Washington, DC: World Bank.



AGROECOLOGY

Agroecology is one of several fields that emerged as a response to the environmental and social impacts of industrialized agriculture (also termed *conventional agriculture*). Industrial agriculture's focus on maximizing yields and profits has resulted in negative impacts on social and ecological systems around the world. Many of the practices associated with industrial agriculture (e.g., soil tillage; excessive use of water, pesticides, and fertilizers) have led to increasing degradation of the long-term productivity and health of agricultural land. The term *agroecology* began appearing more frequently in the sustainable agriculture literature in the 1970s through contributions of academics based mostly in the United States and Latin America. Some of the most influential among these people were Stephen Gliessman, from the University of California, Santa Cruz; Miguel Altieri from the University of California, Berkeley; John Vandermeer, from the University of Michigan; and Charles Francis, from the University of Nebraska. However, in what is widely recognized as the first textbook in the field, Gliessman traces the first forms of agroecology to the German geographer K. Klages, who published an article on crop ecology in 1928. This was followed by the first actual use of the term *agroecology* by the Czechoslovakian agronomist Basil Bensin in 1930, as part of a proposal to the then International Institute of Agriculture in Rome for an agroecologically based research agenda for agriculture. However, it was not until the past 25 years that agroecology has become a vibrant field of research and practice, with increasing importance in policy, academic, and field applications.

Early definitions of agroecology focused on the application of ecological concepts and principles to the design and management of sustainable agroecosystems. This initial conception of agroecology remains the most widely known, but a recent key publication by a group of renowned agroecologists has redefined and expanded the term as an interdisciplinary field that explicitly addresses social, economic, and ecological factors associated with food systems. This new definition by Francis and colleagues (2003) defines

agroecology as “the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions” (p. 100). In Francis and colleagues' article and in subsequent contributions on the theoretical basis of the field, agroecologists have strongly shifted the focus from a farm-based approach to addressing the entirety of the food system, including production, processing, transportation, financial intermediation, marketing, and consumption.

Ecological Basis

Agroecology argues for a whole-systems approach to analyze agroecosystems and their surrounding environments, which examines components and their arrangements (structure), as well as their interactions and their impact on ecological processes (function). The ecological characteristics of the agroecosystem are linked to its plant, animal, and management components (Figure 1).

Natural Ecosystem and Traditional Agricultural Models

Agroecologists have usually relied on two main sources of inspiration to guide the design and management of agroecosystems and agricultural landscapes. The first one seeks to understand ecological processes in natural ecosystems, as they have proven to be resilient over time. The theory is that most of the ecological processes found in natural ecosystems can be replicated in agricultural fields, albeit in modified forms. An understanding of natural ecological processes is used to provide insight on how best to replicate these in an agricultural setting, with the goal of minimizing external synthetic inputs (e.g., fertilizers and pesticides) and maintaining important agroecosystem conditions, such as soil fertility.

The second source of inspiration for agroecological models is traditional agriculture, which is sometimes synonymously termed *local* or *indigenous*. Again, the idea is that agricultural systems that have persisted through time can provide lessons to design more sustainable modern agroecosystems. Many of the farming systems used as models by agroecologists come from the tropical regions, where agriculture has been practiced for thousands of years and where traditional systems

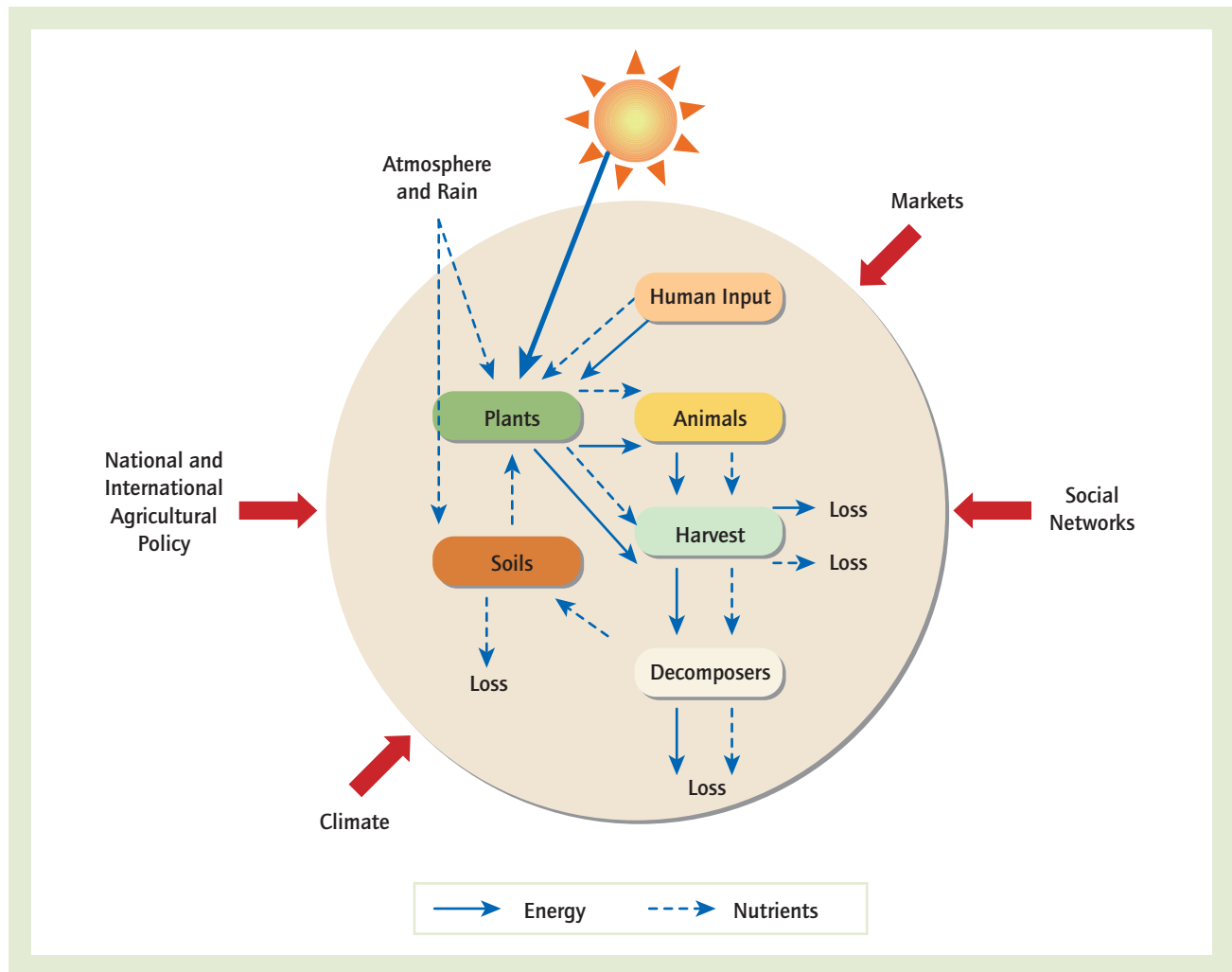


Figure 1 Schematic diagram of an agroecosystem and some of the external factors that affect it

Source: Adapted from Gliessman, S. (2007). *Agroecology: The ecology of food systems* (2nd ed.). Boca Raton, FL: Taylor & Francis.

have not yet been displaced by industrial systems. An example of traditional agriculture, with valuable lessons for sustainability, is agroforestry, a practice of integrating and managing trees and agricultural crops in the same land area. Many agroforestry systems illustrate important agroecological principles, such as replicating the structure and some of the ecological processes of local natural ecosystems (tropical forests). They have also survived for long periods of time through processes of cultural and ecological adaptation. Specific examples of tropical agroforestry with desirable agroecological characteristics include shade coffee and cacao plantations, mixtures of

trees and annual crops, and agroforestry home gardens (see photo).

A focus on supporting and maintaining key ecological processes on the farm is at the core of agroecological management. Gliessman has identified the following four broad ecological processes to be managed and monitored.

Energy Flow. In natural ecosystems, the primary source of energy is the sun, and this light energy gets captured and stored in plant biomass. In agroecosystems, additional energy is derived from human inputs, and plant biomass is removed from the system with each harvest.



An example of an agroforestry home garden in Cupilco, Tabasco, Mexico. Researchers at the University of California, Santa Cruz, and the Colegio de Postgraduados in Tabasco have documented that this home garden has maintained a very similar structure and crop composition for at least several decades. Some of the components of the home garden include fruit and timber trees, cacao, vanilla, medicinal and cooking herbs, and bananas.

Source: Author.

Nutrient Cycling. Nutrients are the chemical compounds organisms use to maintain their basic life functions; they include different forms of nitrogen, phosphorus, potassium, carbon, and many others. In natural ecosystems, nutrients get recycled in a relatively closed loop, while in agroecosystems there are more losses through leaching and harvest.

Population-Regulating Mechanisms. A population is a group of organisms of the same species.

In ecological communities, these populations interact with each other in different ways, such as predation (one organism feeding on the whole or part of the other), competition (two species competing for the same limited resources), or facilitation (interactions that do not harm or can benefit each other). In natural ecosystems, population interactions usually result in a self-regulating control of populations that prevents a particular species from excluding others. In contrast, the simplification of the ecological community in agroecosystems results in loss of self-regulation. This usually translates into large population outbreaks, which can turn into pests and require human interference to control them.

Resilience/Stability. Natural ecosystems usually attain a state of relative stability, maintaining their structure and function over long periods of time. Although disturbances continue to occur, the natural ecosystem is able to respond quickly and return to the state it was in prior to the disturbance (resilience). The simplification of agroecosystems, in terms of structure and function, has resulted in loss of resilience and stability. The high levels of disturbance that agroecosystems are subjected to and the complete removal of biomass through harvesting require that humans invest labor and inputs to maintain a certain level of stability.

The four ecological processes broadly outlined above can be used to compare natural ecosystems and agroecosystems. Agroecology has used these types of comparisons to try to design agricultural systems that “mimic” natural ecosystems as much as possible, in order to increase the efficiency and resilience of agroecosystems.

Social, Economic, and Cultural Basis

In agroecology, the agricultural and ecological characteristics of farming communities are seen as part of a broader social and ecological landscape in which farmers and other rural actors interact and negotiate to pursue their particular goals. The livelihoods of farming families and communities are central to agroecological research and practice. Livelihood refers broadly to the multiple resources and capacities that people use



to make a living. Understanding the social and ecological processes in local or traditional agriculture has been of particular importance to agroecological research. For example, agroecological work on agroforestry home gardens (see photo) in Mexico and Central America has shown that the ecological structure of these agroecosystems, in terms of plant arrangements and horizontal allocation of space, was mainly influenced by each family's livelihood strategies.

A notable contribution to the socioeconomic and cultural basis of agroecology has been provided by a group led by the rural sociologist Eduardo Sevilla-Guzmán at the University of Cordoba, Spain. The group's publications (most of them in Spanish) have critically examined agroecology as an option to support small-scale and peasant agriculture in the context of accelerating globalization. Through an analysis of the epistemological roots and characteristics of agroecology, these researchers have concluded that the field is an ideal foundation for "participatory and endogenous" rural development, with a focus on small-scale agriculture. These characteristics include (a) agroecology's value, use, and integration of different forms of knowledge, including scientific, indigenous, local, and experiential; (b) the ecological, not economic, basis of agroecological management; and (c) agroecology's concern for the social and cultural factors that interact with and affect agriculture.

Participatory Approaches and Direct Applications

Agroecology's concern for small-scale agriculture has led to interaction with and support for farmer organizations and social movements. Examples of this can be found in Spain (ecological olive grove cooperatives), Latin America (the Agroecological Movement of Latin America and the Caribbean [MAELA]), Brazil (the Landless Rural Workers' Movement [MST]), and Central America and Mexico (the Campesino a Campesino Movement [MCAC]).

Direct support for farmers has also taken the form of participatory approaches in agroecological research and implementation that seek to directly benefit farming communities. Most of these initiatives have used long-term participatory

action research, a process that combines research with direct action to directly benefit participating stakeholders (i.e., farmers, researchers, and rural communities). Examples of this work can be found among the shade coffee communities of Mesoamerica, olive growers in Spain, and strawberry farmers in California.

An increased focus on the food system has resulted in many agroecologists supporting alternative food network initiatives, such as Fair Trade, direct marketing, and eco-friendly farming. This has been done through participatory research on the role that alternative food networks (e.g., certifications, direct marketing) might play in increasing the sustainability of food systems. A recent example of this work addressed shade coffee production in Mexico and Central America and included an examination of "sustainable coffee" and the certifications associated with it (i.e., Fair Trade, organic, and eco-friendly). Other direct applications of agroecology exploring alternative food networks have been accomplished through researcher-NGO partnerships, such as the Community Agroecology Network (CAN, www.communityagroecology.net), which works on marketing innovations for small-scale coffee farmers in Mexico and Central America.

Agroecology and Sustainability

Although there is an ongoing debate on the meaning of sustainability and how to measure it, most would agree that it relates to maintaining or enhancing social and ecological conditions indefinitely. In agriculture, this refers to a way of farming that will not degrade the land in a way that hinders agricultural production in the future. It also includes factors related to social equity and economic viability for future generations. Agricultural sustainability has been one of the core issues addressed by agroecology. A large portion of current agroecological research is devoted to analyzing and developing agricultural management that is more sustainable. This is a daunting task and rife with debate and controversy. However, agroecology's integration of ecology, agriculture, and social and economic concerns renders it one of the most promising fields to help us better understand and resolve the challenge of sustainable food systems.



Critiques, Challenges, and Future Trends

Since the publications and interest in agroecology first appeared in the 1970s, the field has been challenged from supporters of industrialized agriculture and narrow disciplinary scientists. Some of the criticism against agroecology has been directed at its potential for major reduction in agricultural production and farmer profit, which would result from its widespread adoption. In addition, as an emergent, interdisciplinary field, agroecology has been questioned by the disciplines that it sought to integrate, mostly from purists in the fields of agronomy and ecology. Many of these critiques have dissipated because of the general consensus that industrialized agriculture has had negative social and ecological impacts; the need to keep sustainability in mind; evidence that organic agriculture, as a form of agroecological management, can produce comparable yields to industrialized agriculture; and a wider acceptance of interdisciplinary approaches as part of scientific inquiry. Nonetheless, there is still a strong financial and ideological sector that continues to support industrialized agriculture and that will continue to defy agroecology.

One of the greatest tasks faced by agroecologists is to be able to develop a fully integrated interdisciplinary approach. Agroecology has strong ecological roots, and early work in the 1970s and 1980s focused on analyzing and improving agronomic and ecological management. In-depth analyses of social, economic, and cultural aspects were incorporated later. One of agroecology's current challenges is to develop a flexible and adaptive interdisciplinary framework that fully integrates the ecological, social, economic, and cultural dimensions.

V. Ernesto Méndez

See also **Agricultural Biotechnology; Agricultural Intensification; Agricultural Land Use; Agriculture, Industrialized; Agrobiodiversity; Agrochemical Pollution; Agrofoods; Agroforestry; Ecosystems; Nonpoint Sources of Pollution; Population, Environment and Development; Sustainable Agriculture**

Further Readings

- Altieri, M. (1995). *Agroecology: The science of sustainable agriculture*. Boulder, CO: Westview Press.
- Bacon, C., Méndez, V., Gliessman, S., Goodman, D., & Fox, J. (Eds.). (2008). *Confronting the coffee crisis: Fair trade, sustainable livelihoods and ecosystems in Mexico and Central America*. Cambridge: MIT Press.
- Clements, D., & Shrestha, A. (Eds.). (2004). *New dimensions in agroecology for developing a biological approach to crop production*. Binghamton, NY: Food Products Press.
- Francis, C., Lieblein, G., Gliessman, S., Breland, T., Creamer, N., Harwood, R., et al. (2003). Agroecology: The ecology of food systems. *Journal of Sustainable Agriculture*, 22(3), 99–118.
- Gliessman, S. (2007). *Agroecology: The ecology of sustainable food systems* (2nd ed.). Boca Raton, FL: CRC Press.
- Uphoff, N. (Ed.). (2002). *Agroecological innovations: Increasing food production with participatory development*. London: Earthscan.



AGROFOODS

Sometimes spelled *agri-foods*, this term captures the increasingly long and complicated path food takes to our table. While we may like to think that the food we eat comes from a farm, it is only one place among many. Most farming is only possible with industrial inputs such as tractors and combines and chemical inputs such as fertilizers and pesticides. Farmers often require loans each season to buy what is needed to produce their crop. Farming also depends on energy to run the machines, pump water, produce fertilizers, and transport the finished product to the consumer. Farmers need expert information on what and when to plant, how to diagnose and treat plant diseases and destroy pests, the weather, and when and at what price to sell their crop. When one considers what goes into farming, it becomes apparent that farms are linked to



and have become dependent on many other places, such as places of industrial production, places of petrochemical and fuel production, banking centers, and universities and government institutions. What is done with farm outputs is equally complicated.

Farm output can remain in its original form and simply be graded, washed, and shipped to the consumer. However, most of the food that we consume in the developed world is not in an unprocessed or “raw” form. Most of the food consumed has been substantially modified and processed to be made durable through canning, freezing, or other methods. This series of changes is an important stage in the agrofood system because durable foods allow the spatial separation of production from consumption and make long-distance trade possible. In fact, the distinction between agriculture and industry has become so blurred that many foods have become known by the industrial process that have transformed them, for example, *homogenized* milk, *pasteurized* cheese, *refined* sugar, and so on. Agricultural products can be further industrialized by breaking them down into their constituent parts. For example, a starch, a sweetener, oil, and protein can be extracted from a grain. Processors attempt to break the product of the farm into as many parts as possible and then find profitable uses for all of them. These different “fractions” of whole farm products are used as inputs for manufactured foods or in other industrial processes.

The producers of manufactured foods have an advantage over farmers because they buy the farm output and have flexibility over what ingredients to use and where to source them. For example, the manufactured food requires a sweetener but not necessarily sugar derived from the sugarcane plant. It requires oil yet not necessarily oil from corn. It requires a starch, but that could be derived from a potato or wheat or a number of other grains. The production of potato chips provides a good example of this substitution effect: Producers can fry the chips in whatever oil is cheapest at the moment of production. This illustrates why farmers are often at a disadvantaged position within the agrofood system.

More toward the consumer end of the agrofood system is food distribution. Food reaches

consumers via food wholesalers, food retailers, and the restaurant and catering industry. Powerful economic entities in food distribution can shape the agrofood system with their purchasing power, such as when a fast-food restaurant chain decides to fry its french fries in healthier oil or add salad to its menu or when large grocery chains decide to carry some food products and not others.

At the end of the agrofood system is the final consumer. Food is unlike other commodities because we must eat daily to survive. Food is taken into the body and metabolized or used by our cells to provide energy. Our food choices affect our own bodies, but they also reverberate back and reshape the agrofood system. What we eat reflects demographic characteristics, such as the size and growth of the population and purchasing power, and social relations, such as the structure of the family. Obviously, advertising influences our food choices. But more subtly, the ever-quicken pace of the economy has led to the proliferation of “fast” foods (which can be consumed without the use of utensils) and other convenience foods meant to be consumed “on the go,” in the car or at the desk.

The backlash against foods high in carbohydrates has reduced the consumption of potatoes, rice, bread, donuts, and orange juice (to name just a few) and has had consequences for the places that produce these foods. But the changing attitudes also provide opportunities. For example, a food high in fat such as fried chicken, which was criticized during the time when a healthy diet was believed to be one low in fat, can now present itself as a healthier food choice because it is low in carbohydrates.

The geographies of the agrofood system are continuing to change as food technologists attempt to bypass the farm altogether by creating “nonfood foods,” or foods that are consumed but not metabolized by the body. These substances are made in the lab, not grown on the farm, and allow food producers to avoid the risks inherent in farming while providing greater control over the production process. Another important agrofood trend is “functional foods” (also called *nutraceuticals*), which attempt to marry foods and pharmaceuticals to create a substance consumed to create a desired effect in the body.



Examples are grape juice with added antioxidants intended to fight cancer and so-called smart drinks that have ginseng, caffeine, and vitamins added to them. Functional foods blur the line between drugs and food, and their producers know that foods that make health claims often have an advantage in a competitive marketplace. The changing agrofood system not only affects our bodies, but its changing technology and consumer choices have significant impacts in reshaping our geography.

John R. Grimes

See also **Agricultural Biotechnology; Agriculture, Industrialized; Agrochemical Pollution; Agroecology; Consumption, Geographies of; Food, Geography of**

Further Readings

- Bonanno, A., Busch, L., Freidland, W., Gouveia, L., & Mingione, E. (Eds.). (1994). *From Columbus to ConAgra: The globalization of agriculture and food*. Lawrence: University Press of Kansas.
- Friedmann, H. (1993). The political economy of food. *New Left Review*, 197, 29–57.
- Goodmann, D., & Redclift, M. (1990). *Refashioning nature*. London: Routledge.



AGROFORESTRY

Agroforestry is a term related to land use whose exact meaning has changed as different approaches to studying land use have arisen. The oldest use of the term, as the adjective *agroforestal*, was to name a category of land use. This meaning was introduced in the 1930s and was firmly established by the 1950s, a period when the areal differentiation approach in geography was prominent. Originally, *agroforestry* was used when an observer considered agriculture and forestry as distinct land uses but wished to combine these categories in mapping or analysis. This concept reflected the traditional view that agriculture did not include the cultivation or management of trees and that forestry did not pertain to

herbaceous plants. Although this narrow meaning has not been entirely superseded, in the 1950s and 1960s many geographers recognized that the distinction between agriculture and forestry is neither absolute nor clear in many landscapes, especially from the perspective of rural land managers in traditional societies. Thus, *agroforestry* came to designate land use in which farming, often including livestock husbandry, and tree cultivation and/or management are practiced, whether simultaneously or sequentially. In situations where livestock is prominent, the adjective *agro-silvo-pastoral* has been used.

The second broad meaning of *agroforestry* is a system of land use in which trees and crops, and often livestock, are deliberately associated in space and time. In other words, this meaning refers to land and resource management practices in areas where land use can be classified as agroforestry, according to the second sense described above. This meaning also has two distinct senses. First, “scientific agroforestry” is a field of study that uses agronomic methods to analyze productivity in settings where trees and crops are grown together. The concept and pursuit of scientific agroforestry became prominent beginning in the 1960s, although there were earlier “scientific” efforts to combine agriculture and forestry. For example, during the 1880s in colonial Burma, British foresters developed the *taungya* system, now widely practiced in southeast Asia, in which forests are cleared for timber plantations and crops are grown among saplings for several years. Scientific agroforestry represents a positivist approach to agricultural development that many international research and development institutions have promoted. While scientific agroforestry has been more important in the applied natural sciences than in geography, the social and environmental effects of its promotion interest many geographers. Second, agroforestry has been used to describe the resource management practices of rural land managers in traditional societies where trees are an integral part of farming systems. In this sense, the term is often qualified as “indigenous agroforestry,” although many nonindigenous, traditional peoples—such as the Brazilian *caboclos*—also rely on trees and crops for food and other resources. Many indigenous/traditional agroforestry practices serve to manage



Planting peanuts in Mali, West Africa

Source: Author.

soil fertility, as in the Southern African *citimene* system, where tree branches are collected from a large area and burned on a field to release nutrients. Many geographers have studied indigenous/traditional agroforestry, mostly taking the perspective of either cultural ecology or political ecology. For instance, a cultural ecological study might examine how agroforestry practices relate to local soil and vegetation conditions, while a political ecological study might examine how multiscale political economic processes affect agroforestry practices.

Many cultural, social, demographic, and environmental processes are embedded in agroforestry systems. Indigenous/traditional agroforestry systems generally reflect culturally specific values and histories, and their persistence depends on the persistence of associated knowledge cultures. Ancient agroforestry systems unlike any known today can be deduced from archaeological evidence,

such as the raised beds found widely in the Amazon Basin. Indigenous/traditional agroforestry systems reflect the constraints of specific biophysical environments, and many systems are sustainable if certain environmental conditions remain relatively constant. Conversely, alteration of indigenous/traditional agroforestry practices may lead to significant environmental changes, such as erosion or changes in the composition of vegetation. Indeed, the characteristic vegetation of many cultural landscapes is the product of long, co-adaptive histories of human-environment interaction within agroforestry systems. For example, although farmers clear new fields every 5 to 10 years in West Africa's woodlands, this practice does not cause permanent deforestation because trees that can reproduce vegetatively dominate the vegetation (see photo). Farmers fell trees to reduce their competition with crops but strictly avoid damaging the tree roots, which will



sprout and become trees again, reconstituting the woodland vegetation.

Indigenous/traditional agroforestry systems continuously change as people develop new practices in response to demographic, environmental, and social change. Although Esther Boserup did not use the term *agroforestry*, she argued that farming systems including trees are expected in situations of intermediate population density. Agroforestry systems generally represent moderately intensive land use; agroforestry often supplants forests, but in highly intensive farming, most trees are removed to allow greater crop-plant density. Environmental changes can force people to develop new practices, but agroforestry systems can show significant resilience because trees are less susceptible than crops to short-term events, such as drought.

Social processes are more important than environmental adaptation in shaping indigenous/traditional agroforestry practices over the short term. Tree and crop management practices can vary considerably among individuals based on gender, age, wealth, and other social factors, reflecting the varying rights, roles, or authority people have within societies. Thus, knowledge of plant use is strongly gendered because in many societies women have less control over land and labor resources and must rely on noncrop plants to meet subsistence needs during difficult times, whereas men can more easily travel and seek wage labor. Struggles over agroforestry practice may express struggles over social rights, roles, or authority. Agroforestry systems also vary among societies. In particular, the practices and principles of scientific agroforestry often differ from those of indigenous/traditional agroforestry systems. Historically, promoters of scientific agroforestry portrayed indigenous/traditional agroforestry systems as unproductive, environmentally damaging, or even atavistic. For instance, African colonial regimes forcefully imposed scientific agroforestry practices because European scientists believed that indigenous practices created permanent deforestation. Negative perceptions of indigenous/traditional agroforestry linger in some institutions. While scientific agroforestry has widely contributed to agricultural productivity and sustainability, it has also been socially disruptive and has served to extend

state authority. Indeed, promotion of the *taungya* system in colonial Burma helped end anticolonial resistance.

Chris S. Duvall

See also **Deforestation; Forest Fragmentation; Forest Land Use; Indigenous Agriculture; Indigenous Forestry**

Further Readings

- Brookfield, H. (2001). *Exploring agrodiversity*. New York: Columbia University Press.
- Buck, L., Lassoie, J., & Fernandes, E. (Eds.). (1999). *Agroforestry in sustainable agricultural systems*. Boca Raton, FL: CRC Press.
- Carne, R. (2004). Agroforestry land use: The concept and practice. *Australian Geographical Studies*, 31(1), 79–90.
- Dove, M. (1983). Theories of swidden agriculture, and the political economy of ignorance. *Agroforestry Systems*, 1(2), 85–99.



AIDS, GEOGRAPHY OF

See **Disease, Geography of; HIV/AIDS, Geography of**



AIR MASSES

The most common definition of an air mass is a large body of air, relatively homogeneous with respect to temperature, humidity, and vertical lapse rates. While this definition is generally valid, it is true only for air masses that remain within their source regions. Once in motion, air masses begin to modify, in some cases quickly, especially if they move significant latitudinal distances. Eventually, modification renders the air mass unrecognizable with respect to its source region.



Source Regions

Air masses form in regions of generally uniform surfaces where winds are typically light for extended periods of time, usually days to weeks. Over periods of time, the overlying air takes on the properties of the underlying surface through radiative and convective processes. These regions tend to be located near the centers of semipermanent high-pressure centers due to the weak pressure gradients found in these regions. Climatologically, these semipermanent highs are located in the polar and subtropical latitudes.

In the Northern Hemisphere there is little land in the polar latitudes, so in most cases air mass source regions are located over pack ice. The thermal character of pack ice is much different from that of snow-covered land, with the underlying Arctic Ocean exchanging heat with the overlying atmosphere. As a result, winter polar air masses, with the Siberian exception, are milder than in the Southern Hemisphere. For this reason, air masses that form in the “High Arctic” are commonly referred to as polar, while only Antarctic and Siberian air masses are considered truly Arctic in nature.

There is also much variability among subtropical source regions due to land cover type. In general, land surfaces within subtropical highs are desert-like, with very little water available. As a result, more of the incoming solar radiation that reaches the surface is available to heat the air, so dry bulb temperatures are quite high and dew point temperatures quite low. The result is very low relative humidity and great drying power of the air. Ocean surfaces, on the other hand, convert a significant proportion of solar irradiance to latent heat, which leaves much less sensible heat to increase the air temperature.

Air Mass Types

Based on common reference to air mass source regions as polar, subtropical, land covered (continental), or maritime, four primary air mass types are recognized: (1) continental polar (cP), (2) maritime polar (mP), (3) continental tropical (cT), and (4) maritime tropical (mT). Continental arctic (cA) air is usually considered a special case of cP air, while maritime arctic air (mA) is an air

mass rarely recognized because for air to be considered truly arctic, it must develop over an ice-covered surface.

This classification scheme has become popular among geographers because of its simplicity, which has been considered an important consideration in introductory courses. For example, there are cold air masses originating in the higher latitudes that are either moist (mP) or dry (cP and cA), depending on whether the surface type over which they formed was ocean or land, and warm air masses that develop in the lower latitudes that are either moist (mT) or dry (cT).

There are two other air masses referred to on occasion: equatorial and superior air. The term *equatorial (E) air* is sometimes used to separate the slighter, warmer, and less humid air of the subtropics from the cooler, more humid air of the tropics, although attempting to distinguish between the two at the surface is difficult at best. Superior (S) air is a special form of cT air in the Southern Plains of the United States with a source region over the Mexican Plateau. As this already hot dry air advects northeastward, it's mixed down to the surface, and with compression, it further heats and dries. The boundary that separates this air at the surface from the mT air to the east is often referred to as the “dryline” or “Marfa front.”

The vertical character of the primary air mass types is typically considered to be consistent for each air mass. For example, cP air and cA air typically exhibit deep inversions from the surface up to the midlevel of the troposphere, with rapid cooling with height; that is, both air masses are considered to be absolutely stable. mT air, on the other hand, is assumed to be conditionally unstable, while cT air is absolutely unstable, although typically with little more than high-based cumulus humilis clouds due to the lack of water vapor. More often than not, however, multiple air masses exist at any midlatitude point location, which adds complexity to the situation. For example, in the Northern Hemisphere it is not uncommon to observe cP air advecting southward at the surface in response to a surface high to the north, while a southwesterly mid- and upper-level flow brings in warmer and sometimes moister air from the lower latitudes up and over the top of the cP air. When multiple air masses are moving through a region



at different heights, the situation is often referred to as “differential advection.” Differential advection can lead to air mass stabilization or destabilization depending on the resulting vertical thermal stratification.

Air Mass Modification

As air masses move out of their source regions, they continue to take on the characteristics of the underlying surfaces but at a rate proportional to the speed of migration. Generally speaking, polar air masses will become warmer as they advect toward lower latitudes due to increased solar angles of incidence, while subtropical air masses cool as they move toward lower latitudes not only due to the smaller angles of incidence but, in winter, also due to the existence of snow cover. It should also be understood that air masses either lose (precipitation) or gain (evaporation) water vapor as they migrate out of their source regions. This not only changes the static stability of the air mass but can result in a completely different air mass type as time progresses.

In general, there are five factors involved in understanding air mass modification: surface temperature, surface moisture, topography, trajectory, and migration rate. Each of these plays an important role depending on the time and location of modification.

The difference in temperature between the air mass and the surface results in a vertical exchange that commonly affects air mass stability. Since gradients are always directed from an area of surplus to an area of deficit, air masses that are colder than the surface over which they move experience a net gain in heat from that surface. In time, this decreases the vertical thermal lapse rate, which has a stabilizing effect on the air mass; however, this vertical exchange can be vigorous while the difference is still large, with intense convective cells developing in response. These intense convective cells are a condition of deep moist convection (DMC), which tends to produce thunderstorms and generally brief periods of heavy rainfall. When air masses are warmer than the surface over which they are moving, then the exchange of heat is from the air mass to the ground surface. Over time, this reduces the condition of absolute static stability to that of

neutrality; however, as long as a gradient exists, a strong capping inversion will work to keep the air stagnant.

The static stability of air masses is so important to the resulting weather that an additional letter, *w* or *k*, is added to the standard air mass acronym. The letter *w* is used when the air mass is warmer than the surface over which it lies, implying a statically stable environment, and the letter *k* refers to a condition where the air mass is colder than the surface and the air is conditionally or absolutely unstable. For example, an mTk air mass is unstable, promoting upward vertical exchange between the surface and the air mass, and mTw represents a stable condition favoring downward vertical exchange. The only air mass for which this convention is not used is S air.

Air masses may also be modified by a vertical exchange of water (vapor, liquid droplets and drops, and ice). Water is removed from air masses via precipitation and gained through evaporation. These exchanges can be in response to either dynamic (forced ascent) or thermodynamic (free convection) processes. In general, the greater the cumulative precipitation, the more water the air mass loses; however, moisture advection and convergence on meso- and local scales can resupply limited areas within larger air masses with enough water vapor to support heavy precipitation at the same time, so the air mass as a whole loses no water at all.

In terms of evaporation, larger water bodies tend to supply a greater amount of water to an air mass, but since this supply is a function of evaporation, the warmer and windier the surface, the more water vapor will be available. The addition of water is greatest when an upward vertical exchange occurs under unstable conditions, such as when a cold air mass moves over a warm body (e.g., cPk). In these situations, however, the large addition of water vapor into an unstable air mass will usually result in convective precipitation and, ultimately, loss of the water gained.

Topography plays a role in air mass modification through mechanical lift that in some cases produces precipitation, thus removing water from the air. Once the air crosses the crest and its density is greater than that of the surrounding air, it will subside down the slopes of the leeward side,



resulting in considerable compressional heating. If water vapor is not added to the air in this process, then the relative humidity decreases to very low levels, perhaps contributing to desert-like environments commonly referred to as a “rain shadow.”

The trajectory an air mass follows—that is, in terms of its curvature, which is the result of a force either pushing (anticyclonic) or pulling (cyclonic) the air mass—has an effect on the conditional stability or instability of that air. For anticyclonic flow, air masses tend to stabilize due to subsidence, while cyclonic flow tends to support convective instability in response to lift. It should be noted here that convective instability and conditional instability refer to two different situations. Convective instability occurs when the upper parts of an air layer cool at more rapid rates than its base when lifted. Conditional instability, on the other hand, exists when the air is stable if unsaturated but unstable if saturated.

The speed of air mass migration affects air mass modification rates as faster-moving air is exposed to the underlying surface for shorter periods of time than slower-moving air. In other words, an inverse relationship exists between the rate of change of air mass character and the speed of air mass migration. This means that for arctic air to reach Central North America and Europe, it must travel very quickly from Siberia over the pole into North America, what is commonly referred to as a cross-polar flow.

David L. Arnold

See also **Adiabatic Temperature Changes; Anthropogenic Climate Change; Atmospheric Circulation; Atmospheric Composition and Structure; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure; Atmospheric Variations in Energy; Climate Change; Climate Types; Climatology; Temperature Patterns**

Further Readings

Barry, R., & Chorley, R. J. (2003). *Atmosphere, weather, and climate* (8th ed.). London: Routledge.

- Blair, T. (1946). *Weather elements*. New York: Prentice Hall.
- Carlson, T. (1998). *Midlatitude weather systems*. Boston: American Meteorological Society.
- Rauber, R., Walsh, J., & Charlevoix, D. (2002). *Severe and hazardous weather*. Dubuque, IA: Kendall.
- Wallace, J., & Hobbs, P. V. (2006). *Atmospheric science* (2nd ed.). St. Louis, MO: Elsevier.



AIR POLLUTION

See Atmospheric Pollution



ALBEDO

Albedo refers to the amount of solar radiation reflected by an object. Specifically, it is the ratio of reflected to incident solar radiation. *Albedo* is derived from the Latin *albus*, which means “to be white.” Albedo is a unitless measure of reflectivity that varies from 0 (*no reflectance*) to 1 (*complete reflectance*), although it is also commonly shown as a percentage (0% to 100%). The albedo of an object is a function of the surface properties of the object (i.e., color, roughness, transparency), the zenith angle of the sun, and the wavelength of the incident radiation. Albedo is usually determined based on the visible portion of the spectrum (0.4–0.7 μm [micrometer]).

Planetary albedo is the fractional amount of solar radiation reflected by Earth (both the atmosphere and Earth’s surface). Based on measurements from satellites and modeling experiments, it has been determined that Earth’s albedo is ~0.31 (31%). The albedo of a surface is extremely important because it determines how much of the incident solar radiation is reflected and how much is absorbed. Small changes in albedo can have a large influence on the surface energy budget of an object. For example, if Earth’s albedo

decreased by 0.01, it would increase Earth’s temperature by 1 °C.

Geographic and Seasonal Variations

Because Earth’s surface is varied with regard to its composition, the amount of solar radiation that is reflected and absorbed varies by location and by season. Albedo for natural surfaces ranges from ~0.03 to 0.95 (Table 1). Generally, dark-colored surfaces (e.g., dark soils) have low albedos, and light-colored surfaces (e.g., snow and white sand) have high albedos. Albedo is also influenced by the solar zenith angle. Water generally has a relatively low albedo (<0.10), except when the sun is near the horizon. The albedo of snow also varies greatly. Freshly fallen snow initially has a high albedo, but as the snow ages and dust and soot are deposited on top of the snow surface, its albedo decreases. The presence of snow can significantly lower the albedo of the land surface, which in turn leads to colder temperatures that support further expansion/accumulation of snow (e.g., a positive feedback).

Many of the changes in albedo take place naturally due to the changing of the seasons, which can lead to changes in vegetation or snow cover, or variations in the weather, which can influence the density and health of vegetation

Surface	Details	Albedo
Bare soil	Dark and wet	0.05–
	Light and dry	0.40
Sand		0.15–0.45
Grass		0.16–0.26
Agricultural crops		0.18–0.25
Forests	Deciduous	0.15–0.20
	Coniferous	0.05–0.15
Water	Low zenith angle	0.03–0.10
	High zenith angle	0.10–1.0
Snow	Old	0.40–
	Fresh	0.95
Ice	Sea	0.30–0.45
	Glacier	0.20–0.40
Clouds	Thick	0.60–0.90
	Thin	0.30–0.50

Table 1 Representative albedos of natural surfaces
Source: Created using data from Oke (1987).

and soil saturation. However, human activities can also have a major influence on albedo. Deforestation and urbanization are two examples of how human activities can change the albedo of the land surface, which then modifies the local and regional climate.

Steven Quiring

See also **Anthropogenic Climate Change; Climate Change; Land Use and Cover Change (LUCC); Radiation: Solar and Terrestrial; Weather and Climate Controls**

Further Readings

Kiehl, J. T., & Trenberth, K. E. (1997). Earth’s annual global mean energy budget. *Bulletin of the American Meteorological Society*, 78, 197–208.
Oke, T. R. (1987). *Boundary layer climates*. New York: Routledge.

AL-IDRISI
(CA. AD 1100–1165)

al-Idrisi was arguably the greatest medieval geographer. A descendant of the prophet Muhammad, this Arab scholar was titled al-Sharif al-Idrisi but known in the West as *Geographus Nubiensis*, the Nubian geographer. Born in Morocco and educated in Cordoba, he worked in Sicily at the Palermo court of the Norman king Roger II, after whom his book of world geography was called *Kitab Rujjar* (*Book of Roger*) in 1154; its full Arabic title is *Nuzhat al-mushtaq fi ‘khtiraq al-afaq* (Entertainment for One Desiring to Travel Far). A later, shorter world geography, sometimes called “the Little Idrisi,” is known by various Arabic titles. Both are extensively illustrated with maps; the maps in *Nuzhat al-mushtaq* are full or half-page in size and oriented to the south, while the maps in the later book are smaller and often oriented to the east.

al-Idrisi presided over a collective project, and his *Geography* is a synthesis of information and cartographic traditions from both Islamic and European cultures. He had traveled in Asia Minor, Europe, and North Africa, and in Sicily,



he was able to consult both European and Islamic sources. Because the data were procured from earlier books and travel reports (only 10 authors are named), they are sometimes out-of-date, but the book and accompanying maps are unsurpassed in medieval geography.

The text is a detailed description of the map, supposedly based on the Arabic version of Marinus's map, created under Caliph al-Ma'mun (AD 813–833) and engraved on a silver disk. The silver prototype was lost, but the text is accompanied by a round, schematic map of the world and 70 rectangular maps of the 70 parts into which al-Idrisi had divided the world. The projection used remains unexplained, although al-Idrisi followed the Ptolemaic foundation, adopted by the early Islamic scholars, whereby the round Earth is divided into quarters and only the Inhabited Quarter is described. It is astronomically divided into seven latitudinal belts, "climates," leaving off the extreme north and the equatorial south. Although familiar with coordinates, al-Idrisi did not use them. His innovation was in using, instead of meridians, 10 longitudinal divisions of the parallel latitudinal climates. The climates are numbered from south to north, as in the scheme developed by Eratosthenes, and the numbers of sections go west to east. After a brief general introduction, the text follows the map's division into 70 sections. al-Idrisi names the most place names since Ptolemy, expands and updates the medieval Arabic geographical inventory, and describes for the first time many identifiable locations, which he connects by itineraries.

Earth is shown surrounded by Encircling Sea *al-Bahr al-Muhit* (the Greek Ocean). The western limit is the prime meridian drawn through the westernmost part of Africa (the Fortunate Isles in the Atlantic are also included). The easternmost country is *Sila* (Korea), supposedly at 180°. The southern portion of the round world map is filled with the African landmass, not shown on sectional maps. Africa is extended eastward to form the southern coast of the Indian Ocean, which remains open in the Far East. The northern limit is 64°, practically coinciding with the Polar Circle. The maps are color coded and distinctive and, together with the special features of the text, make it possible to speak of the "Idrisi school," which influenced both Arabic and European cosmographers.

The book *Nuzhat al-mushtāq* became the first secular Arabic work printed in Europe (in Rome in 1592); a Latin translation was published in 1619 in Paris. These editions did not include the maps, but a pieced-together Latin version of the sectional map of the world was produced in Paris by Petrus Bertius in the 1620s. In honor of the Arab scholar, the name IDRISI has been given to a grid-based geographic analysis system and related GIS (geographic information system) and remote sensing software and to an Arabic electronic search engine with bilingual (Arabic/English) indexing and publishing capabilities.

Marina A. Tolmacheva

See also **Biruni; Ibn Battuta; Ibn Khaldun; Travel Writing, Geography and**

Further Readings

- Ahmad, S. (1992). Cartography of al-Sharḥ al-Idrīsī. In J. Harley & D. Woodward (Eds.), *The history of cartography: Vol. 2, Book 1. Cartography in the traditional Islamic and South Asian societies* (pp. 156–174). Chicago: University of Chicago Press.
- Tolmacheva, M. (1995). The medieval Arabic geographers and the beginnings of modern Orientalism. *International Journal of Middle East Studies*, 27(2), 141–156.
- Tolmacheva, M. (1996). Bertius and al-Idrīsī: An experiment in Orientalist cartography. *Terrae Incognitae*, 28, 49–59.



ALTITUDE

Altitude is the distance between a position and a vertical reference surface. Distance might be measured in angular or length units. The position might be the point location of an object or a specified point along a vehicle track or satellite orbit. The surface might be one of many vertical datums, such as the center of the Earth, the surface of the ocean, the topographic surface of the Earth, the top of the built environment, or a constant barometric pressure surface.



The precise distance between a surface and a position depends on the definition of the line between them. For example, the line might be perpendicular to a plane tangent to the reference surface, or it might extend from the position toward the center of the mass of the Earth.

The terms *altitude*, *elevation*, and *height* are sometimes used interchangeably. In different contexts, these words take on different meanings, and the modifiers attached to them can sometimes clarify their usage. *Elevation* is often associated with the distance from a defined surface, such as the geoid, the theoretical equipotential gravity surface of the Earth, or a physically defined gravity surface model, such as a specific mean-sea-level datum, or with respect to the actual local-level plane as measured at the position. *Height* is sometimes reserved for the distance between a reference ellipsoid and a position or for the distance from the bottom to the top of an entity, such as a building or a mountain peak. The height of an aircraft might be the distance above the topographic surface of the Earth, while the height of a geodetic survey monument might be its vertical distance from a reference ellipsoid.

This sentence appears in a text on surveying principles: “Therefore, the altitude at which the plane must fly is calculated by adding the elevation of the mean datum to the flying height.” The *altitude* of the aircraft is above mean sea level, the flying *height* is the distance between the aircraft and the ground, and the ground (the mean datum) has an *elevation* with respect to mean sea level.

Altitude is modified by words that further specify the meaning. *Absolute altitude* refers to the distance above the physical surface of the sea or land. *Angular altitude* is the vertical angle between some plane (such as local level) and a line from the observation point to an object such as a mark on a surveyor’s rod or a star. *Barometric altitude* is the distance from one constant pressure surface (an isobaric surface) to another. *Meridian altitude* is the vertical angle to an object measured along a line of longitude.

Peter H. Dana

See also **Datums; Geodesy; Latitude; Longitude; Surveying**

Further Readings

- American Society of Civil Engineers, American Congress on Surveying and Mapping, & American Society for Photogrammetry and Remote Sensing. (1994). *The glossary of mapping sciences*. Bethesda, MD: Author.
- Kavanagh, B. F., & Glenn Bird, S. J. (2000). *Surveying: Principles and applications*. Upper Saddle River, NJ: Prentice Hall.
- National Geodetic Survey. (1986). *Geodetic glossary*. Rockville, MD: National Geodetic Information Center, Charting and Geodetic Services, National Ocean Service, National Oceanic and Atmospheric Administration.



AMBIENT AIR QUALITY

Ambient air quality refers to the concentration of gases, particles, or other elements in the outdoor atmosphere—from either natural or anthropogenic sources. The term *quality* is objective and gives an indication of what the concentration of a constituent of air is in relation to certain thresholds or standards. If a concentration is above the threshold, air quality is considered poor or, in some cases, even hazardous to human health. An applicable geographic area is often termed a “nonattainment” area. In these instances, the air is considered “polluted,” and the elevated constituent is a pollutant. Thresholds for different pollutants are determined with reference to human health. Standards are set by the World Health Organization (WHO), though in some countries thresholds have been modified by national or local authorities.

As an example, carbon dioxide (CO₂) is a naturally occurring gas in the atmosphere, which in very small concentrations is necessary for life. If its concentration builds over certain thresholds, however, it can become detrimental and so will be termed a hazardous air pollutant. This process was tragically exemplified in 1986 by the Lake Nyos disaster in Cameroon, West Africa, when an upwelling of CO₂ from the lakebed had lethal consequences for the local human population and

animals. In this case, both the pollutant and the emission source were naturally occurring. Pollutants such as sulfur oxides, nitrogen oxides, and heavy metals, however, can only be caused by human activities.

Air quality issues came to the forefront of scientific and societal attention during the 1950s. In 1952, London's "killer fog" was linked to a large increase in human fatalities (4,000 excess deaths), especially among people with a history of cardiopulmonary problems. The episode resulted in the implementation of air pollution mitigation measures by the London authorities. The air pollution in question was caused by smoke emissions from the burning of coal and other raw materials into a winter atmosphere already dense with mist and fog from the River Thames. This type of pollution is now termed London-type smog (smoke plus fog). In the same decade, another type of photochemical smog formed by chemical reactions in the atmosphere gained notoriety and became known as Los Angeles smog. Later, during the 1970s, acid rain emerged as a top environmental concern.

Most urbanized regions in the developed world have monitoring stations dedicated to assessing air quality on an hourly basis. Some, like Melbourne, Australia, even provide daily forecasts for ambient air quality, much like a typical weather forecast. This is made possible by the strong link between ambient air quality and weather.

Air quality is influenced by two major factors. The first is the emission of polluting substances into the air. Polluting emissions can be from urban, industrial, agricultural, or rural sources, or they can be totally natural. The second of these factors is the pollution potential of the atmosphere, or its ability to transport, diffuse, chemically transform, and remove pollutants. This involves three important processes: (1) *dispersion*, which is the horizontal and vertical spread and movement of pollutants; (2) *transformation*, which involves chemical reactions between pollutants or in pollutants under certain temperature and sunlight conditions; and (3) the *removal* of pollutants through mechanisms such as dry and wet deposition.

These three processes are controlled in turn by synoptic conditions, the intermediate scale of atmospheric activity between the global and



Don Bock, senior air pollution specialist with the Minnesota Pollution Control Agency, explains the functions of an air particle monitor located at the Anoka County Airport in Blaine, Minnesota, on June 2, 2003. Clean Air Minnesota officials announced their plans to decrease harmful ozone in the twin cities of Minneapolis–St. Paul.

Source: AP Photo/Jim Mone.

regional scales. Synoptic conditions include circulation systems such as anticyclones and cyclones. Atmospheric circulation at this scale is an important control on air pollution, influencing clouds (amount, thickness, height, and type), the temperature and relative humidity of air, the type and amount of precipitation, and wind speed and direction. These parameters, in turn, influence the vertical temperature structure of the atmosphere, which—by controlling the vertical extent pollutants can disperse—determines atmospheric stability. The layer through which the mixing of pollutants occurs is called the *mixed layer*, and



the height to which pollutants mix is termed the *mixing depth* or *mixing height*. Poor dispersion occurs when a region is under the influence of anticyclonic synoptic-scale circulation. Here, vertical mixing is suppressed by an elevated inversion; combined with light winds, this suppression of vertical mixing can cause air quality to deteriorate rapidly. The clear skies created by the anticyclone can also allow the formation of nocturnal, surface-based inversion layers, which contribute to poor air quality at night.

Pollutants often undergo chemical transformations in the air, producing what are called secondary pollutants. The damaging London smog of 1952 ultimately killed 12,000 people with sulfuric acid fogs, which remained stagnant for 4 days. Such fogs occur when sulfur dioxide (SO_2)—which is generated by fuel combustion, particularly coal with high sulfur content—is oxidized in the air to sulfur trioxide (SO_3). This, in the presence of catalysts, then reacts with water vapor (H_2O) to form sulfuric acid mist. More common in recent decades is the formation of photochemical smog, where elevated levels of ozone have been detected. Ozone is a secondary pollutant formed by photochemical reaction of precursors such as NO_x ($\text{NO} + \text{NO}_2$), reactive organic gases, and many other gases.

Air quality can be improved by pollutant removal through processes such as gravitational settling and dry and wet deposition. Gravitational settling removes larger particulates, with the rate of removal related to the size and density of the particles and the strength of the wind. Dry deposition is a turbulent process, in which there is a downward flux of pollutants to the underlying surface. The amount of deposition depends on the characteristics of the turbulence, with increased rates under stronger turbulence.

Wet deposition involves the removal of air pollutants through absorption by precipitation elements (water droplets, ice particles, and snowflakes) and consequent deposition to the Earth's surface during precipitation. This removal process includes the attachment of pollutants to cloud droplets during cloud formation, in-cloud scavenging (also known as *washout*), and coalescence of raindrops with material below the cloud (*rainout*).

Peyman Zawar-Reza

See also **Acid Rain; Atmospheric Circulation; Atmospheric Particulates Across Scales; Atmospheric Pollution; Photochemical Smog**

Further Readings

- Arya, S. P. (1998). *Air pollution meteorology and dispersion*. New York: Oxford University Press.
- Seinfeld, J. H., & Pandis, S. N. (2006). *Atmospheric chemistry and physics* (2nd ed.). New York: Wiley-Interscience.



AMERICAN GEOGRAPHICAL SOCIETY

Founded in 1851, the American Geographical Society (AGS) is the oldest professional geographical organization in the United States. It is known globally as a pioneer in geographical research and education, whose mission is to link the business, government, professional, and scholarly worlds in the creation and application of geographical knowledge, methods, and techniques to address economic, social, and environmental problems.

For 158 years, the AGS has informed public policy. Specific priorities and programs evolve, but the commitment of service to government, the business community, and the world at large continues unchanged. Throughout World War I, President Woodrow Wilson commissioned the AGS to lead "The Inquiry," a massive analysis of foreign intelligence to support the peace negotiations that would follow. As part of that effort, the AGS was responsible for drafting his famous "14 Points" and for supporting the American delegation at the Paris Peace Conference. Earlier, the AGS played an instrumental role in siting the Panama Canal, the Transatlantic Telegraph Cable, and the Transcontinental Railway.

From its earliest days, the AGS was a leading proponent and sponsor of Arctic, Antarctic, and Andean exploration. A notable artifact from that era is the AGS Fliers' and Explorers' Globe, which has been signed by 80 of the world's most renowned explorers of the past century.



Through its journals, the *Geographical Review* and *FOCUS on Geography*, and through consulting, lectures, and educational travel services, the AGS presents clear, concise, and relevant geographical information that can be understood by policymakers and the public as well as by professional geographers.

The AGS is best known for its pioneering work in exploration and cartography, its invaluable geographical research library, and its research, mapping, and consulting services for government and business at the highest levels. In 1978, its library, then valued at \$15,000,000, was given to the University of Wisconsin at Milwaukee. Then and now, the American Geographical Society Library contains the largest collection of geographical literature, maps, charts, and globes in the Western Hemisphere and perhaps the world.

From 1925 to 1945, the AGS mapped all of Latin America at 1:1,000,000 scale, the most authoritative maps of that area until well after World War II. Currently, the AGS is promulgating a new world standard for cartographic representation of land mines, minefields, and mine actions.

In 1912, AGS sponsored the Transcontinental Excursion, a 13,000-mile lecture and study tour on which more than 40 of the world's most prominent foreign geographers and 100 American geographers traversed the country by rail from New York to the Pacific Coast and back. A *New York Times* correspondent traveled along and sent news dispatches from every stop. Today, the AGS continues to sponsor educational trips around the globe that include lectures by leading geographers.

The AGS is led by a council of 27 professional geographers and other devotees of geography from academia, business, and government. Most AGS fellows are Americans, but 40% of its journal subscriptions are from outside the United States. Individuals, corporations, and businesses wishing to support the AGS can join its Galileo Circle or Humboldt Club. Its office is located at 120 Wall Street in New York City.

Jerome E. Dobson

See also **Association of American Geographers; Bowman, Isaiah; Human Geography, History of**

Further Readings

American Geographical Society: www.amergeog.org



ANALYTICAL OPERATIONS IN GIS

Geographic information systems (GIS) have grown to be big and somewhat unwieldy software packages with hundreds, sometimes thousands, of functions. The majority of these are, however, devoted to facilitating data input/output and general data management. Only a small fraction is devoted to what arguably distinguishes a GIS from other software packages, the set of analytical operations. A practical definition of “analytic” in the context of this entry is an operation that fully supports the “I” in GIS. In other words, an analytical GIS operation creates new information beyond what has explicitly been stored in the database.

Based on this definition, a database query is not an analytical GIS operation because it merely retrieves what has been stored before, though possibly in a different organizational structure. The boundary between analytical and other GIS operations is not always clear-cut because complex query operations can be expanded to be analytical operations proper. The litmus test in the end is whether the operation results in new data that did not exist before.

A classic example is the *overlay* operation. As opposed to conditional queries or recoding operations, the overlay results in the creation of new geometries not previously stored in the database, and these new geometries inherit their attributes from their parent geometries according to user- or system-specified rules (Figure 1).

The logic of this overlay operation is typically based on Boolean operands such as AND, OR, NOT, or XOR. Together with its cousin, the *buffer* operation, this analytical operation is responsible for more than half of the generally used analytical capabilities of GIS. Following an often cited characterization by Mike Goodchild, we can use the data model underlying the input

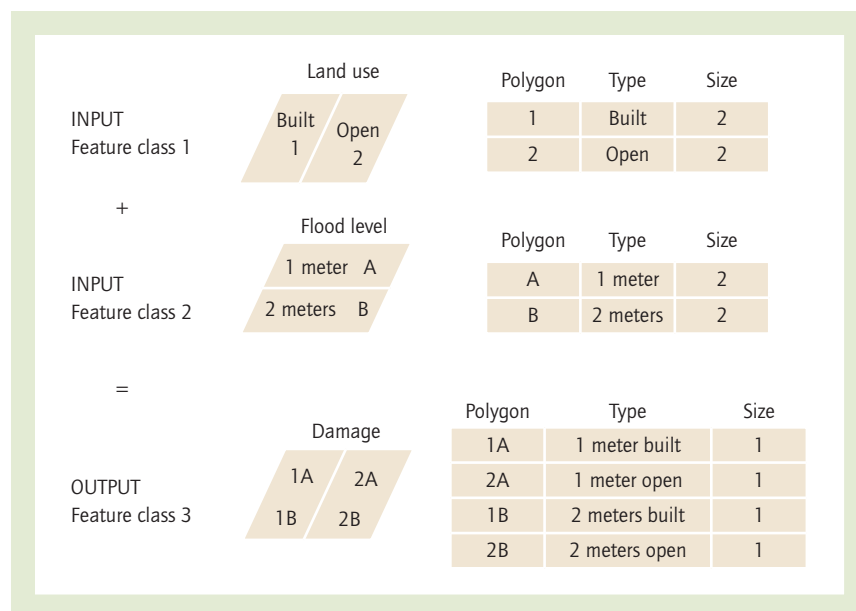


Figure 1 Schematic overlay operation illustrating the combination of new area definitions and attribute value calculations for a flood damage scenario

Source: Author.

and/or output to develop a hierarchy of ever more complex analytical GIS operations. On the object-centered side of analytical operations, one may (a) just describe point patterns, (b) create new geometries and attributes as in our overlay example, (c) perform some rather involved operations on transportation or hydrological networks, or (d) model the interaction between two or more objects. If we follow the field perspective of geospatial data, then we have the whole range of Map Algebra operations that truly get us into the modeling of geographic phenomena.

Jochen Albrecht generated a list of 20 so-called universal GIS operations from a user interface perspective that encompass a wide range of GIS tasks. Although this list seems surprisingly short and already contains a few exotic or rarely used examples, it has been shown that it covers most of what a wide range of GIS users actually want to see in a GIS. The question then arises, What makes analytical GIS operations so important? And the answer lies not in their quantity but in their overwhelming usefulness once they become part of a larger geoprocessing workflow.

While originally developed for desktop GIS, this set of data model-independent analytical GIS operations is now the focus of numerous endeavors to standardize the analytical component of GIS Web services. In both cases, there is a need for well-specified operations that can be concatenated to workflows and larger models in support of spatial decision making. The description of analytical GIS operations is hence not aimed anymore at improving GIS user interfaces but at the automatic generation of scripts that allow clients to create mash-ups for Web-based GIS applications that range from object-based image analysis and environmental model integration to geocollaboration and multicriteria decision support.

Well-defined analytical GIS operations also form the building blocks for libraries, not of data but of models that help us analyze data and that can be shared or sold. These model libraries will eventually capture geographic knowledge and serve the electronic central role that the discipline of geography plays in the orchestra of sciences. But it all starts with a small number of analytical GIS operations.

Jochen Albrecht

See also **Agent-Based Models; Cellular Automata; Geocomputation; GIScience; Spatial Analysis; Spatial Optimization Methods**

Further Readings

- Albrecht, J. (2007). *Key concepts and techniques in GIS*. London: Sage.
- Goodchild, M. (1991). Spatial analysis with GIS: Problems and prospects. In *Proceedings GIS/LIS'91* (pp. 41–48). Falls Church, VA: ASPRS/ACSM.



ANARCHISM AND GEOGRAPHY

Anarchism is a political philosophy named from the Greek word *anarchos*, which means “without a ruler.” The key tenets of anarchist thought are antiauthoritarianism and the formation of a new social order based on mutual collaboration and decision making. Advocates of anarchism see the elimination of the state and other forms of authority as part of a necessary progression toward the formation of a voluntary and self-sustaining society. Anarchists may emphasize individualism, as an extension of liberalism, or socialism, which rejects private property and espouses cooperative ownership. Anarchists often argue for ecological preservation, advocating that societies should live in harmony or equilibrium with the natural world. Two well-known anarchists writing during the late 19th century, Peter Kropotkin and Élisée Reclus, were also influential geographers. During the 1960s and 1970s, geographers engaged with anarchist thought as part of reinvigorating approaches to theory, research, and teaching. As radical geographies emerged, scholarly focus on anarchism dwindled; instead, Marxism, feminism, queer theory, and postcolonialism received further attention. While there has been little theoretical development of anarchist ideas in geography, recent work by a small number of scholars explores anarchist ideas as expressed and practiced in alter-globalization and environmental direct-action movements.

The intersection of anarchism and geography remains underexplored. The main contributions of anarchism include the principle of mutual aid as explained by Peter Kropotkin, environmental preservation, theories and practices that attempt new forms of social order, and uses of space that disrupt and decentralize authority.

Early Anarchist Geographers

Élisée Reclus (1830–1905) was a French geographer who participated in the Paris Commune of 1871, when Parisian workers seized control of the city government. He was imprisoned and then exiled to Switzerland, where he wrote several volumes of geographic works that were thoroughly

interlaced with anarchist thought. Reclus proposed an equitable distribution of the world’s resources, arguing that decisions about production and distribution should be made by local communities. This was a direct response to imperialist claims on the resources of the global South; he argued that existing social inequalities were the result of authoritarian social and political organization rather than productive capabilities or overpopulation. Reclus was also an early advocate for environmental preservation.

Peter Kropotkin (1842–1921) was a Russian prince, high-ranking military officer, and physical geographer, who credited fieldwork in Siberia with readying him to become an anarchist. His theory of mutual aid analyzed cooperation among animals, using examples in the natural world as a scientific basis for collaborative human organization. This was a response to the Social Darwinists of the time, who were proponents of competition. Kropotkin’s essay “What Geography Ought to Be” proposed educational reform and emphasized shared humanity across international borders, an important argument that weakens the legitimacy of the state.

Their background in geographic scholarship influenced both men, engendering a distinctive understanding of humanity in different cultural and economic contexts and a broader comprehension of possible social and economic structures.

Anarchism and Radical Geography: The 1960s and 1970s

During the late 1960s and 1970s, a number of geographers drew from anarchist thought in attempts to reinvigorate and rethink aspects of the discipline, especially to inject practical and socially useful practices into research and teaching methodologies. In a special issue of the journal *Antipode*, meant to stimulate new interest in anarchist ideas, Richard Peet criticized geographical scholarship and challenged his colleagues to use anarchist principles as transformative tools. He wrote that geography, as a descriptive discipline, had become an instrument for the scientific justification of existing inequalities rather than an active challenger of the status quo.

The Situationist International (SI) was a political and artistic movement mostly active from the mid 1950s through the mid 1970s in Western



Europe. The Situationists practiced drifts (or *dérives*) and psychogeography to disrupt the authority of capitalist spectacle. The anarchist scholar and sociologist Richard Day drew on Situationist practices to discuss global social movements.

Current Scholarship

Despite spurring a brief moment of interest in the 1960s and 1970s, anarchism fell to the wayside as radical scholars instead turned to Marxism, feminism, queer theory, and postcolonialism as modes of inquiry. More recent activist scholarship, drawing on the principles of mutual aid and decentralization of authority, is more broadly linked to autonomous, alter-globalization, and other social movements. Anarchist practice and activism outside the academy have survived and taken myriad forms; geography and anarchism would benefit from a renewed encounter.

Melinda Alexander

See also **Human Geography, History of; Kropotkin, Peter; Marxism, Geography and; Radical Geography; Reclus, Élisée; Social Geography; Social Justice**

Further Readings

- Blunt, A., & Wills, J. (Eds.). (2000). *Dissident geographies: An introduction to radical ideas and practice*. New York: Prentice Hall.
- Peet, R. (1979). The geography of human liberation. *Antipode*, 10(3), 119–134.
- Pickerill, J., & Chatterton, P. (2006). Notes towards autonomous geographies: Creation, resistance, and self-management as survival tactics. *Progress in Human Geography*, 30(6), 1–17.



ANAXIMANDER (CA. 610–546 BC)

Anaximander (born in Miletus ca. 610 BC, died in Miletus ca. 546 BC) was a Grecian pre-Socratic philosopher who belonged to the Milesian

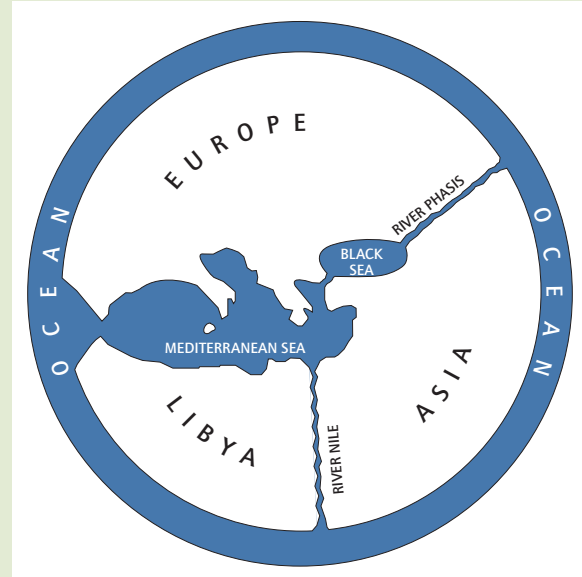


Figure 1 Re-creation of Anaximander's map

Source: Public domain.

school, whose thinkers observed natural phenomena to study and explain their rules independently of mythological belief. Only a few of his life anecdotes and works are known today; nevertheless, his contributions to geography, cartography, cosmology, and astronomy are extraordinarily important. He was the first to draw a map of the *ecumene* (inhabited land), and he is also said to have invented the gnomon (the part of a sundial that casts the shadow) and discovered the equinoxes, the solstices, and the inclination of the ecliptic (the plane on which the orbit of the Earth around the sun lies). He supposedly authored a work on nature that was the first philosophical text written in prose. Other works attributed to him are known nowadays under the titles *Around the Earth*, *The Sphere*, and *On Fixed Bodies*.

As a result of his observations of nature, Anaximander understood the hydrologic cycle by realizing how water on the Earth's surface evaporates and consequently comes down again in the form of precipitation. He also elaborated a theory that explained how lightning and thunder are generated by the collision of clouds and how earthquakes occur when high temperatures and heavy rains cause land to split. According to his view of the universe and the Earth, the first living



beings were aquatic and later adapted to life on the land. The seas are what still remains of primordial humidity, and they will disappear from Earth's surface when all the water evaporates because of increased solar energy. On the other hand, steam created the winds and caused the rotation of the sun and of the moon, which are both much bigger in size than our planet.

Anaximander conceived of the universe as a system of concentric blazing wheels with flames coming out through some holes and explained eclipses as being caused by the occlusion of those openings. The sun circles the nearest circle, while the stars revolve around the farthest. He considered Earth to be a cylindrical entity that hovers motionless in the universe without any support and is equidistant from other celestial bodies. Life has developed on its flat circular plane, which in the beginning was completely covered by water.

As far as cartography is concerned, Anaximander created the first map of the world by drawing three continents (Europe, Asia, and "Libya") separated by the Black Sea, the Phasis River, the Nile, and the Mediterranean Sea. He imagined waters to surround all those lands.

Susanna Servello

See also **Cartography, History of; Human Geography, History of**

Further Readings

- Couprie, D., Hahn, R., & Naddaf, G. (2002). *Anaximander in context: New studies in the origins of Greek philosophy*. Albany: State University of New York Press.
- De Santillana, G. (2000). *The origins of scientific thought: From Anaximander to Proclus 600 B.C. to 300 A.D.* Chicago: University of Chicago Press.
- Kahn, C. (1994). *Anaximander and the origins of Greek cosmology*. Indianapolis, IN: Hackett.



ANIMAL GEOGRAPHIES

The study of animal geographies is a burgeoning subfield of cultural geography that examines the

interplay between culture, society, and animals. Animal geographers examine a broad range of human-animal concerns, including, for example, habitat loss and species endangerment, domestication, animal entertainment and display, wildlife conservation, and more. Essentially, animal geographies explore nonhuman animals and their *place* in society—place meaning in both physical boundaries (material practices that shape the spaces where some animals are welcomed and others are not) and conceptual margins that call up matters of human identity and animal subjectivity. While the study of contemporary animal geographies is varied and diverse, we can think loosely in terms of three organizational themes: (1) animals and the making of place, (2) human identity and animal subjectivity, and (3) the role of ethics and how humans *ought to* treat animals. These categories often overlap and dovetail with concepts such as animal instrumentalism, anthropocentrism, and the human-animal continua. Moreover, animal geographers recognize the fluidity of boundaries, emphasizing not only the distinctions but also the connections, overlaps, and similitudes between human and animal worlds.

"Old" Animal Geography

While geography has always been concerned with the interface between human culture and the natural world, until recently, nonhuman animals were largely overlooked. Historically, animals in geography were considered no more than biological pieces of a larger ecological system, instruments for human use, or forms of symbolic natural capital. It is not that geographers showed no interest in animals; indeed, there was a field called *animal geography* as early as 1913, consisting of studies of animal populations and examination of floral and fauna regions. In the early days of animal geography, two approaches emerged, mirroring the widening gap between physical and human geography. Zoogeography, which considered mainly animal distributions, was rooted in zoology and physical geography; the other approach aligned with human geography and social sciences and focused on animal domestications. By the 1960s, however, owing to the low status of cultural geography (due partly to the Berkeley School's treatment of culture–economy relations),



Franz Marc, *The Dream* (1912)

Source: © Museo Thyssen-Bornemisza, Madrid. Photography: José Loren. Used with permission.

questions about human-environment relations receded from view. By the last quarter of the 20th century, the term *animal geography* had disappeared from the discipline altogether.

Today's animal geographies differ substantially from the "old" animal geography. The interplay between geography and social theory, cultural studies, and environmental ethics in the 1990s led to a rebirth of interest in nonhuman animals. The increased focus on animals, culture, and society came on the heels of growing public and academic concern about environmental degradation, habitat loss, species endangerment, and the plight of animals relegated to a dismal life (and untimely death) in shelters, labs, and factory farms. The 1970s and 1980s witnessed hundreds of new organizations created to lead social movements

involving animals and the environment. Animal rights groups (especially the more radical organizations such as People for the Ethical Treatment of Animals and the Animal Liberation Front) challenged people to reconsider their relationships with animals by suggesting, for example, that speciesism is equivalent to racism and sexism; that animal captivity is as heinous as human slavery; and that factory farms, fur farms, and research labs are tantamount to genocide. Alongside this tumultuous public activity, the legacies of modernity and modernist ways of thinking came under attack as critics argued (and still argue) that the achievements of modernity rested on race, class, and gender domination, as well as colonialism and imperialism, anthropocentrism, and the destruction of nature. Given this, scholars



in social theory and cultural studies began to rethink culture, and geographers (along with other social and natural scientists) began thinking about “the animal question” and the need to unpack the black box of nature.

Edited books by Jennifer Wolch and Jody Emel, and by Chris Philo and Chris Wilbert, brought human-animal interactions to the foreground in the past decade. Reviving and remaking the face of animal geography, today, animal geographers recognize animals both as foundational to our ontology and epistemology *and* as beings with inner lives and intentionality, worthy of consideration in their own right.

Material Boundaries: Animals and the Making of Place

Discussions in human geography about the social construction of landscapes have led to the exploration of how animals and their networks leave their imprint on places, regions, and landscapes over time. Animal geographers consider tangible places such as zoos, farms, experimental laboratories, and wildlife reserves as well as economic, social, and political spaces, such as the worldwide trade of captive wild animals. Even a relatively new space through which animals are woven into human culture—the “electronic zoo”—has been explored as an emerging form of animal display trading in digital images, rather than animal bodies such as traditional zoos and aquariums.

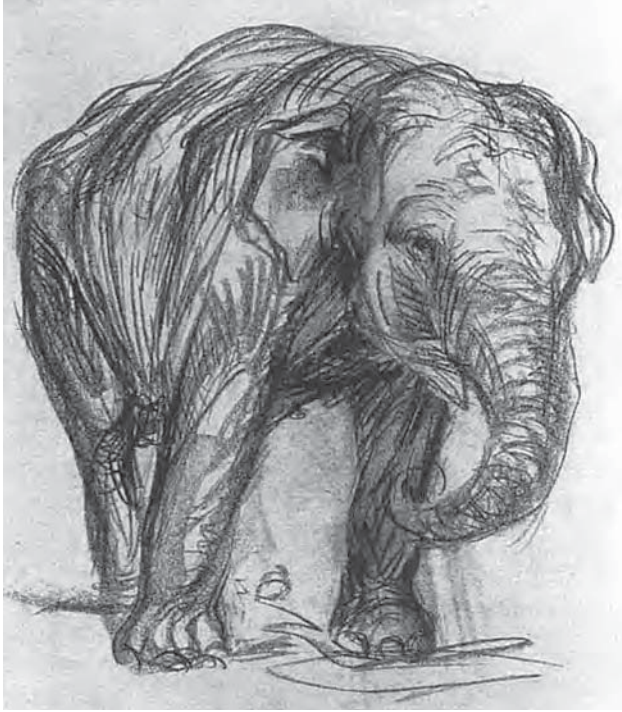
Animal geographers also consider places characterized by the presence or absence of animals and how human-animal interactions create distinctive landscapes. Researchers have studied the impact of land use practices on wildlife survival in the Peruvian Amazon, in boundary-making policy conflicts between urban and rural New Yorkers over the proper place of wolves, and in the changing relationships between people and mountain lions in California. Animal geographers also foreground links between humans and other animals—those consumed as meat, medicine, clothing, and beauty products, for example—that go mostly unseen in contemporary society, given the distance created by globalized commodity chains. Such borderland communities, where humans and animals share public and/or private

space, where some are loved while others are despised, and where so many are unconsciously consumed, reveal the contingent and often contradictory ways in which humans and animals interact with one another.

Borderland communities can span various places and spaces. Investigating human-dolphin encounter spaces, for example, requires a look at the material and well-defined (if often contested) boundaries of zoos and aquariums, as well as more amorphous boundaries. For example, borders are in flux in the open seas where humans and dolphins meet: While a growing number of tourism operators seek out dolphins for paying customers to closely interact and even swim along with, government officials and some animal advocates want to keep people and dolphins at least some distance apart from one another. Animal geographers interrogate such material, social, and political boundaries; what’s more, they acknowledge both human and nonhuman roles in the making, maintaining, and changing of animal geographies. In this case, to understand human-dolphin encounter spaces, scholars would strive to explicate not just human actions and viewpoints but also how the dolphins encourage or defy the human ordering of contested border waters. Examining these material places—from the zoo and the open ocean to the economic and policy arenas considered by those investigating human-dolphin encounter spaces, in this example—helps animal geographers illuminate the complex relationships between human and nonhuman worlds.

Conceptual Boundaries: Human Identity and Animal Subjectivity

Breaking from the traditional geographic approach to animals, contemporary animal geographers think about nonhuman animals as more than biotic elements of ecological systems. Not only are animals appreciated as foundational to countless cultural norms and practices, they are also valued as individuals with mental and emotional lives. Thus, animal geographers call for a more theoretically inclusive approach to thinking about humans and animals; both are considered to be embedded in social relations and networks with others on whom their social welfare depends.



Franz Marc, *Elephant* (1907)

Source: Public domain.

Such thinking suggests a reconceptualization of the “human-animal divide,” in which humans are vastly different from (and superior to) animals, and instead points toward a continuum that allows for a kinship of (although still acknowledging the differences between) humans and other animals.

Stressing the importance of *relations* in their work, some animal geographers conceptualize humans and animals in ways that resist typical characterizations. For example, some scholars highlight the many “inappropriate/d others” of our society that resist being represented within the conventional taxonomy—*cyborgs*, which are part human, part organic, and part mechanical. As such, any claims to hard-line distinctions are ontologically unstable, even those seemingly constant beings we label as human or nonhuman. To illustrate, animal geographies scholars who examined human-elephant relations have shown that *becoming an elephant* is a contingent process. Depending on whether the life (social and otherwise) of an elephant is experienced in the openness of a savanna or in the closed spaces of a zoo, those extremely varied life experiences will shape the elephant as an individual in entirely different

ways. Which, we might ask, should be called a “real” elephant (see illustration)?

Ethics, Humans, and Other Animals

Human relationships with animals have always been diverse and deeply complex, ranging from magnificent to malignant. In every case, humans remain the regulators of whether animals are conceived of as either “in place” or “out of place,” and it is moral sensibility that defines such orderings, with significant ethical implications. In many cases, animal geographers attribute instances of instrumentalism, exclusion, and exploitation of the nonhuman world to a history of anthropocentric, or human-centered, thinking. Critical of such activities, much of the animal geographies literature is concerned with the ethical task of advancing the well-being of animals. This is where animal geography largely departs from the theoretical positioning in the contemporary nature/culture debates in geography, which remain largely anthropocentric.

One way to advance this apparently normative project is to explicate societal values, which certainly determine human treatment of animals. For example, some animal geographers have considered how an animal’s position in the scientific community’s hierarchy of value (as determined by the rarity of species) can have significant influence on its fate. A crocodile that belongs to a species that is included in a global conservation policy, for instance, is “protected” and therefore privileged over animals that are not included in such a policy. With a change in conservation policy, or the “down-listing” of a particular species from the rank of endangered species, the same crocodile once protected and perhaps flourishing in its natural habitat could likely be removed for human use to a shortened and no doubt impoverished life as a factory farm animal.

Animal geographies also encourage thinking about animal agency and subjectivity, recognizing that animals have intentions and are communicative subjects with potential viewpoints, desires, and projects of their own. Many animal geographers suggest that nonhuman animals are best seen as “strange persons” or as marginalized, socially excluded people. But because animals cannot organize and challenge human activities



for themselves, animal geographers recognize that they require human representatives to speak and act in their interests.

Seeking to advance the well-being of both humans and animals, many animal geographers explicitly locate animals in the moral landscape, recognizing that ethical questions are present in all human and animal geographies. In these instances, animal geographers argue for the inclusion of animals in the moral community, valuing animals as ends in themselves rather than as simply the means to human ends. The practical consequences of such inclusion are considerable: For example, how are we to decide what is most important in environmental policy making? And who, exactly, gets to decide? Especially when human-animal needs clash in a world of finite space, a framework of normative principles suggested by animal geographies—principles inclusive of animal interests and desires—can guide human-animal relations and resolve the moral dilemmas that relate to conflicting wants and needs of both humans and animals. Thus, the study of animal geographies is an academic discipline as well as a moral and political project that seeks, at its basic level, to foreground nonhuman animals so that their needs and desires are not unthinkingly ignored or automatically secondary to our own but are thoughtfully considered as part of a more than human geography.

Kristin L. Stewart

See also [Berkeley School](#); [Biogeography](#); [Coupled Human and Animal Systems](#); [Cultural Geography](#); [Domestication of Animals](#); [Extinctions](#); [Hybrid Geographies](#); [Landscape and Wildlife Conservation](#)

Further Readings

- Fox, R. (2006). Animal behaviours, post-human lives: Everyday negotiations of the animal-human divide in pet-keeping. *Social & Cultural Geography*, 7, 525–537.
- Lynn, W. S. (1998). Contested moralities: Animals and moral value in the Dear/Symanski debate. *Ethics, Place and Environment*, 1, 223–242.

- Midgley, M. (1983). *Animals and why they matter*. Athens: University of Georgia Press.
- Philo, C., & Wilbert, C. (Eds.). (2000). *Animal spaces, beastly places: New geographies of human-animal relations*. London: Routledge.
- Plumwood, V. (2002). *Environmental culture: The ecological crisis of reason*. London: Routledge.
- Risan, L. C. (2005). The boundary of animality. *Environment and Planning D: Society and Space*, 23, 773–787.
- Whatmore, S. (2001). *Hybrid geographies: Natures cultures spaces*. London: Sage.
- Wolch, J., & Emel, J. (Eds.). (1998). *Animal geographies*. London: Verso.



ANNALES SCHOOL

The founders of the French Annales School of history, Lucien Febvre (1878–1956) and Marc Bloch (1886–1944), as well as its most prominent late-20th-century member, Fernand Braudel (1902–1985), were all heavily influenced by geography, both in their formative education and in their subsequent historical research. Febvre and Bloch were students of the French geographer Vidal de la Blache at the École Normale Supérieure, and Braudel fully absorbed the founders' enthusiasm for *la tradition vidalienne* (Vidalian tradition).

Specifically, Annalistes took from Vidal the notion that geographical landscapes are the result of human and natural processes in mutual adaptation, both historically and in the present. The constraints and opportunities provided by the enviroing natural environment thus play a crucial role in terms of the manner in which humans materially and culturally reproduce themselves and their societies. The human past thus involves the historical-geographic creation of “social natures” (*genres de vie*) that influence the day-to-day activities of individuals in society. In short, variations in the way nature becomes humanized provide the very foundation for the variations in the historical and cultural trajectories of societies.



The key to this Vidalian vision is that nature and society play equal roles in this process. This is known as *possibilisme*, a term popularized by Lucien Febvre in his book *La terre et l'évolution humaine*, in which he strongly promoted this geographical approach to his fellow historians. Vidal's notion of *genres de vie* thus provided the very basis for what Braudel calls the "geohistorical" approach of the Annales School. Specifically, *genres de vie* are constructed and reproduced only very slowly in time. This necessitates a consideration of what Annalists call the "longue durée" of historical time compared with the medium time frame of institutions and the day-to-day time frame of specific historical events. Social natures are long in the making and reproduce and change only slowly. Institutions—economic, social, and political—are less long in the making and less slow to change. Finally, historical events such as wars, political contests, and economic depressions occur and end relatively rapidly. To write history means to consider occurrences within each of these time frames in interrelation or otherwise as mutually influencing.

This layered view of historical time necessitates a holistic, interdisciplinary approach. To this end, Febvre and Bloch founded the journal *Annales: Histoire, Sciences sociales* in 1929. The format of this journal was certainly influenced by a journal published earlier, *La synthèse historique*, which also advocated interdisciplinarity. But significantly, the holistic format of the *Annales de Géographie*, first published in 1891 by Vidal de la Blache and Marcel Dubois, was also a crucial influence. This is not often acknowledged because, after Vidal, French geographers mostly lost his holistic, historical vision, particularly as Febvre in his book rendered *la tradition vidalienne* in terms that largely relegated geography to the description of physical landscape to make disciplinary room for the Annales kind of history. In the end, however, this new history is really merely a more truly Vidalian study of the human past.

Kevin Archer

See also **Cultural Geography; Febvre, Lucien; Historical Geography; Human Geography, History of; Vidal de la Blache, Paul**

Further Readings

- Braudel, F. (1992). *Civilization and capitalism, 15th–18th century: Vol. 1. The structure of everyday life*. Berkeley: University of California Press.
- Clavel, P. (2003). Fernand Braudel. *Geographers Biobibliography*, 22, 28–42.
- Clavel, P. (2004). Lucien Febvre. *Geographers Biobibliography*, 23, 35–49.



ANSELIN, LUC (1953–)

The year 2008 marks the 20th anniversary of the book *Spatial Econometrics: Methods and Models*, for which Luc Anselin is best known and which has been cited more than 2,600 times. One of Anselin's principal academic achievements has been his contributions to moving the discipline of spatial econometrics from the margins in 1988 to current acceptance in mainstream econometrics, thereby advancing the econometric foundations of geographic information science (GIScience). His publications include several hundred articles and seminal edited books (including *New Directions in Spatial Econometrics* in 1995 and *Advances in Spatial Econometrics* in 2004) in the fields of quantitative geography, regional science, GIScience, econometrics, economics, and computer science.

His development of spatial software further facilitated the establishment of spatial econometrics. Prominent software tools include *SpaceStat* (spatial econometrics), *GeoDa* (exploratory spatial data analysis and spatial regression modeling), and collaborative efforts such as *PySAL*, an open-source library of spatial analytic functions based on the Python programming language. The increased popularity of spatial analysis methods is illustrated by *GeoDa*'s worldwide adoption by more than 36,000 users within 5 years.

A native of Belgium, Luc Anselin graduated magna cum laude with a BS in economics in 1975 and summa cum laude with an MS in statistics, econometrics, and operations research in 1976, both from the Vrije Universiteit Brussel. Around this time, the origins of spatial econometrics



began to take shape in economics departments in the Netherlands and geography/regional science departments in the United Kingdom. In 1977, Anselin moved from Belgium to the United States to enroll in Cornell University's interdisciplinary doctoral program in regional science. This change provided the opportunity to work with Walter Isard, one of the founders of regional science in the United States, and William Greene, author of the standard textbook in econometrics. Luc Anselin earned his doctorate in regional science in 1980.

Anselin is currently Foundation Professor of Geographical Sciences and director of the School of Geographical Sciences and Planning at Arizona State University (ASU), where he attracted some of the leading spatial econometrics scholars of the next two generations. He also founded and directs the *GeoDa Center for Geospatial Analysis and Computation* at ASU to develop, implement, apply, and disseminate spatial analysis methods. He held prior appointments at the University of Illinois, Urbana-Champaign; University of Texas at Dallas; West Virginia University; University of California, Santa Barbara; and the Ohio State University. His (joint) appointments included a range of disciplines, including geography, urban and regional planning, economics, agricultural and consumer economics, political economy, and political science.

In recent years, several national and international awards recognized Luc Anselin's lifetime achievements, including his development of new spatial methodologies (e.g., local indicators of statistical association) and his widely adopted spatial software tools. The Regional Science Association International elected him as a fellow in 2004 and awarded him their Walter Isard Prize in 2005 and their William Alonso Memorial Prize in 2006. In 2008, Luc Anselin was awarded one of the nation's highest academic honors by being elected to the National Academy of Sciences.

Julia Koschinsky

See also [Automobility](#); [Quantitative Methods](#); [Regional Science](#); [Regional Science Association International \(RSAI\)](#); [Spatial Analysis](#); [Spatial Autocorrelation](#); [Spatial Econometrics](#)

Further Readings

Anselin, L. (1988). *Spatial econometrics: Methods and models*. Berlin, Germany: Springer.



ANTEVS, ERNST (1888–1974)

Ernst Antevs was a Swedish American geologist who specialized in glacial geology and did pioneering work in geomorphology.

Antevs was born Ernst Valdemar Eriksson in Vartofta-Åsaka, Southern Sweden, and adopted the name Antevs after finishing school in 1909. In 1917, he received his PhD at Stockholm University with a thesis on shell banks in southwestern Sweden. As a paleobotanist, Antevs joined expeditions within Scandinavia as well as to Bjørnøya in 1916 and Spitsbergen in 1918. In 1920, he came to North America on an expedition with his professor, Gerard De Geer, inventor of the clay-varve dating method. He returned to America and obtained U.S. citizenship in 1939. Supported by Swedish and American foundations and societies, he worked at the University of Arizona, where he was appointed to a research assistantship in 1957. Antevs's work there earned him an honorary doctorate of science in 1965. The Antevs Library at the University of Arizona is named after him.

Antevs studied glacial geology in New England and Canada, applying the clay-varve method to trace the recession of the Laurentide ice sheet. Although partly revised, parts of the work still hold true in detail. As a specialist in glacial geology, he was entrusted with the compilation of maps of Pleistocene glaciers and ice sheets, which he presented in 1928 at the symposium *The Centenary of the Glacial Theory* in New York.

Antevs was fascinated by the possibility of identifying climate variations by means of tree rings. In 1922, his lifelong work on North American archaeology and climate variations began with studies of pluvial lakes and arroyos in the Western United States, particularly in the Great Basin. One of his main interests was human-environment interaction. Together with his glacial-geological



work, this made Antevs a pioneer in geomorphology. He proposed a subdivision of the Holocene into Medithermal (0–4500 BP [before present]), Altithermal (4500–7000 BP), and Anathermal (7000–10500 BP). The scheme was criticized and partly revised, but the term *Altithermal* has remained in use. Antevs's pollen-analytical work (pollen analysis is the reconstruction of former vegetation and climate by means of pollen grains and spores in sediment layers) in the Great Basin led him into discussions resulting in the creation of the science of palynology (the science of pollen and spores).

Antevs's later works focus on climate change and dating problems and on the relationship between radiocarbon and other dating. They are published mainly in *American Antiquity* and *Journal of Geology*.

Jan Lundqvist

See also **Geomorphology; Glaciers: Continental; Glaciers: Mountain; Physical Geography, History of**

Further Readings

- Antevs, E. (1925). On the Pleistocene history of the Great Basin. In J. C. Jones, E. Antevs, & E. Huntington (Eds.), *Quaternary climates* (Monograph Series, No. 352, pp. 51–114). Washington, DC: Carnegie Institution.
- Antevs, E. (1925). Retreat of the last ice sheet in Eastern Canada. *Canada Department of Mines, Geological Survey, Memoir*, 146(126), 1–142.
- Antevs, E. (1929). Maps of the Pleistocene glaciations. *Bulletin of the Geological Society of America*, 40, 631–720.
- Smiley, T. L. (1977). Memorial to Ernst Valdemar Antevs 1888–1974. *Memorials: Geological Society of America*, 6, 1–7.



ANTHROPOGENIC ATMOSPHERIC CHANGE

See Anthropogenic Climate Change; Stratospheric Ozone Depletion



ANTHROPOGENIC CLIMATE CHANGE

In 2008, climate scientists celebrated the 50th anniversary of the Keeling Curve, one of the iconic images of science, rivaling the double helix or Darwin's sketches of finches. March 1958 marked the inception of the historical recording of atmospheric carbon dioxide levels at a small observatory on top of Hawaii's Mauna Loa. As the measurements progressed over the years, Dr. Keeling noted a steady increase of about 1.5 ppm (parts per million) per year (Figure 1). His plot provides clear evidence that carbon dioxide accumulates in the atmosphere as the result of mankind's use of fossil fuels, turning speculations about increasing CO₂ from a hypothesis into a fact.

The World Meteorological Organization and the United Nations Environment Program established the Intergovernmental Panel on Climate Change (IPCC) in 1988, assigning it to assess the scientific, technical, and socioeconomic information relevant to human-induced climate change and its potential risks. The IPCC does not support research directly or monitor climate-related data, but its assessment reports have often inspired scientific research in many climate-oriented fields, leading to new findings. The IPCC has published a total of four assessment reports, becoming the de facto accurate and relevant standard regarding scientific facts on global climate change and its impacts.

The IPCC has three Working Groups and one Task Force:

Working Group I (WGI) assesses the scientific aspects of the climate system and climate change.

Working Group II (WGII) measures the vulnerability and adaptation of socioeconomic and natural systems to climate change.

Working Group III (WGIII) evaluates the mitigation options for limiting greenhouse gas emissions.

The Task Force is responsible for the IPCC National Greenhouse Gas Inventories Program.

The WGI for the First Assessment Report (FAR) was completed in May 1990. Its nonquantitative findings for an anthropogenic interference

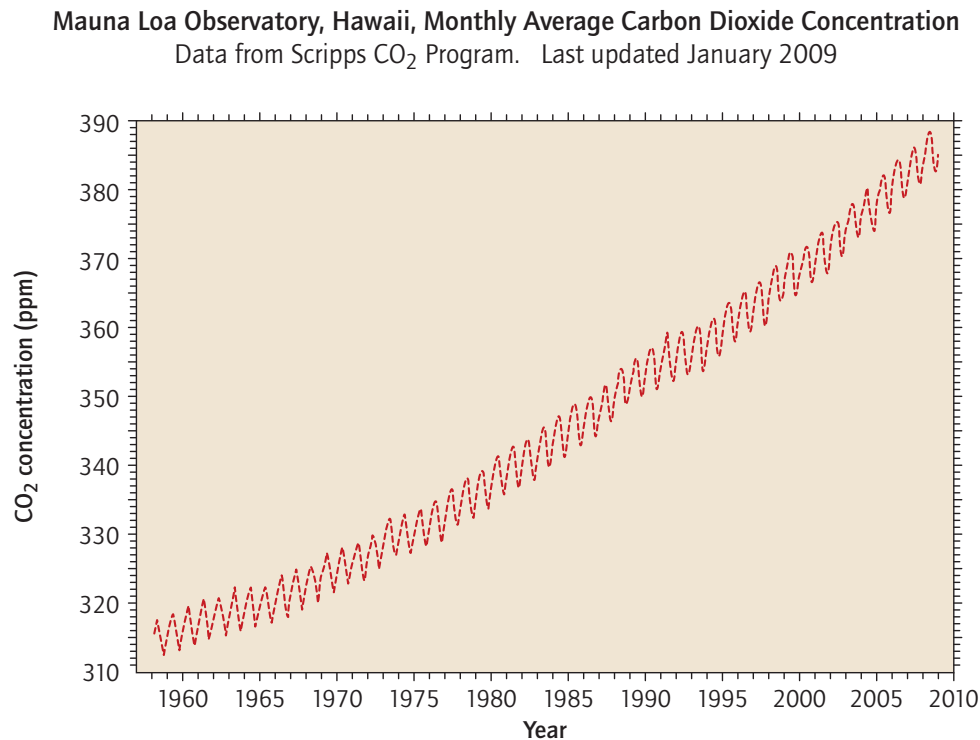


Figure 1 The Keeling Curve from 1958 to 2009

Source: Data from Scripps CO₂ Program. Retrieved December 10, 2009, from http://scrippsco2.ucsd.edu/graphics_gallery/mauna_loa_record/mauna_loa_record.html. Last updated January 2009.

Notes: Monthly average atmospheric carbon dioxide concentration versus time at Mauna Loa Observatory, Hawaii (20° N, 156° W), where CO₂ concentration is in parts per million (ppm) in the mole fraction. The curve is a fit to the data based on a stiff spline plus a 4-harmonic fit to the seasonal cycle with a linear gain factor.

with the climate system remain valid today. It correctly concluded that “emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: CO₂, CH₄, CFCs, N₂O.” The FAR introduced varying levels of confidence, ranging from “certainty” to expert “judgment” (Table 1).

The Second Assessment Report (SAR) was released in November 1995. The report reaffirmed that “the balance of evidence suggests a discernible human influence on global climate.” SAR provided key input to the negotiations that led to the adoption in 1997 of the Kyoto Protocol.

The Third Assessment Report (TAR) was approved at the government plenary in January

2001. The main conclusion from TAR strengthened the finding from SAR: “The Earth’s climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities.”

From observations of the increased global average air and ocean temperatures, the widespread melting of snow and ice, and the rising global average sea level, per the IPCC words in the latest assessment report released in November 2007, “there is very high confidence that the net effect of human activities since 1750 has been one of warming” over each continent (including Antarctica). Most of the observed increase in global average temperatures since



<i>Confidence Terminology</i>	<i>Degree of Confidence in Being Correct</i>
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Table 1 Standard terms used to define levels of confidence as given in the IPCC uncertainty guidance note

Source: Adapted from Le Treut, H., Somerville, R., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A., et al. (2007). Historical overview of climate change. In S. Solomon, D. Quin, M. Manning, A. Chen, M. Marquis, K. B. Averyt, et al. (Eds.), *Climate change 2007: The physical science bases* (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; p. 120, Box 1.1). Cambridge, UK: Cambridge University Press.

the mid 20th century is very likely due to the observed increase in anthropogenic greenhouse gas (GHG) concentrations.

Potential Future Climate Change and Its Impacts

Between 1970 and 2004, GHG emissions have increased 70%. The *IPCC Special Report on Emissions Scenarios* (SRES) projects a further increase of GHG emissions by 25% to 90% CO₂-eq (carbon dioxide equivalent) between 2000 and 2030, as fossil fuels maintain their dominant position as energy source. As the emissions continue, it is very likely that the warming will induce many changes in the global climate system during the 21st century that will be larger than those observed during the 20th century (Figure 2). Furthermore, warming would reduce terrestrial and ocean uptake of atmospheric CO₂, increasing the fraction of anthropogenic emissions remaining in the atmosphere.

The SRES includes six marker scenarios for GHG emissions. These emissions are driven by demographic development, socioeconomic development, and technological change, and though their future evolution is highly uncertain, they assist in climate change analysis, assessment of impacts, adaptation, and mitigation. This

exercise helps climate scientists determine the scope of consequences for a variety of possible fuel-use scenarios.

Four different narrative storylines were developed, each representing different demographic, social, economic, technological, and environmental developments. They were designated A1, A2, B1, and B2.

- **A1 storyline:** This describes a future world of very rapid economic growth, a global population that peaks in midcentury and declines thereafter, and the rapid introduction of new and more efficient technologies. It develops into three groups distinguished by their technological emphasis: (1) fossil intensive (A1FI), (2) nonfossil energy sources (A1T), or (3) a balance across the use of both fossil and nonfossil fuels (A1B).

- **A2 storyline:** This describes a very heterogeneous world where national identities and local and regional solutions to environmental and social equity issues predominate. Global fertility patterns result in continuously increasing world population. Economic development, per capita economic growth, and technological change are slower than in other storylines.

- **B1 storyline:** This describes a world with a peaking population midcentury and declining thereafter, as in the A1 storyline. The economy changes to a service and information economy and the introduction of clean and resource-efficient technologies. Environmental, economical, and social solutions are found globally but without additional climate initiatives.

- **B2 storyline:** This describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with a continuously increasing global population at a rate lower than in the A2 storyline, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

Future emissions differ tremendously between the different scenarios (Figure 3). The largest

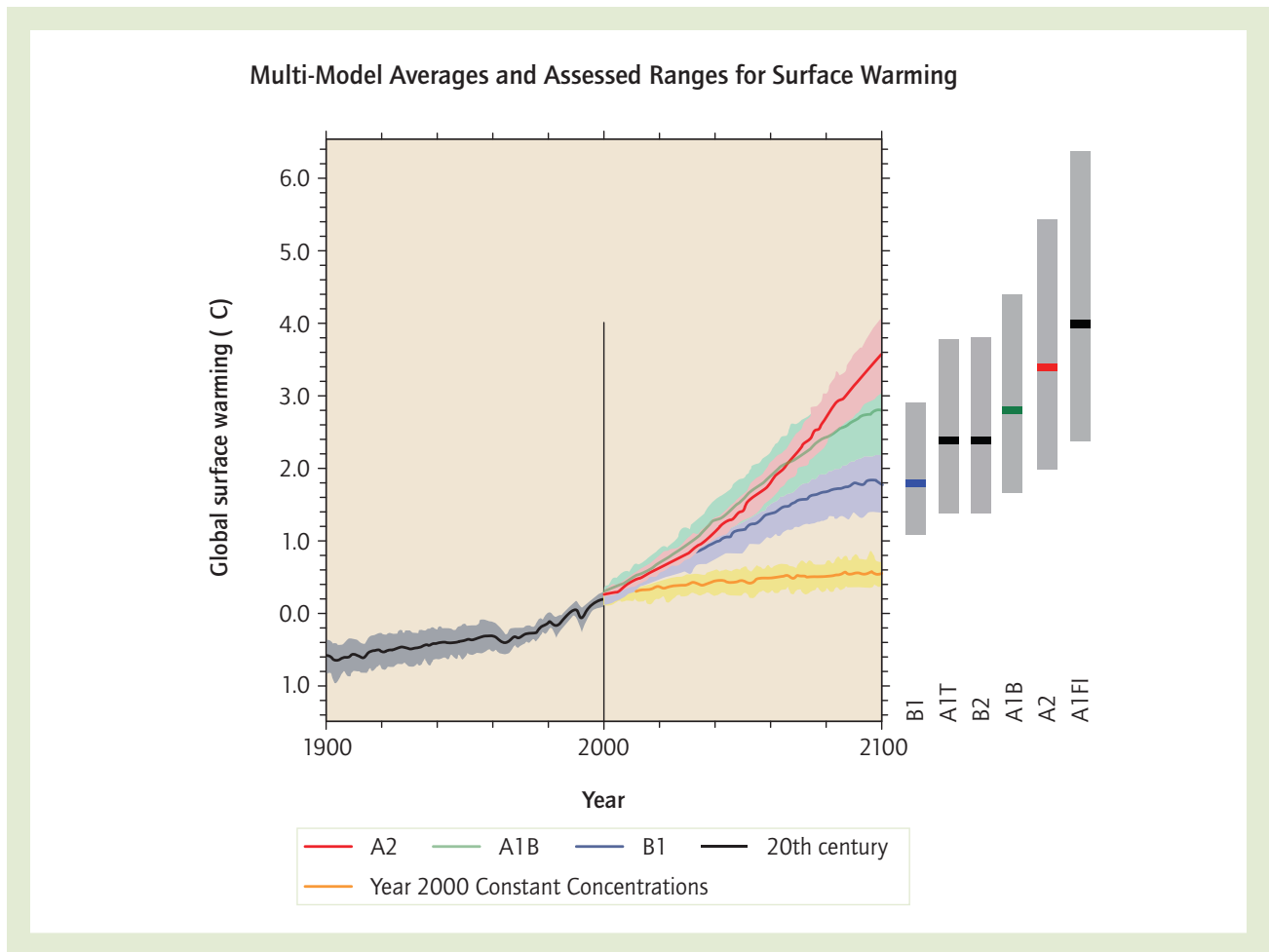


Figure 2 Total global annual CO₂ emissions from all sources (energy, industry, and land use change) from 1900 to 2100 (in GtC/yr., gigatons of carbon per year) for the six scenario groups, presented by the four storylines (A1, A2, B1, and B2)

Source: © Intergovernmental Panel on Climate Change (IPCC), 2007.

Notes: A1FI is the fossil-intensive fuel (comprising the high-coal and high-oil-and-gas scenarios); A1T is the predominantly nonfossil fuel; A1B is the balanced scenario. A2, B1, and B2 are presented in Figures 4b, 3c, and 3d, respectively. Each colored emission band shows the approximate range of carbon dioxide concentrations.

growth and cumulative release of CO₂ is associated with the A1FI fossil-fuel-intensive scenarios (1,550 ppm in 2100, or about 30 GtC/yr. [gigatons of carbon per year] emitted; Figure 4), while the smallest is associated with the B1 scenario (600 ppm in 2100, or less than 10 GtC/yr. emitted; Figure 4). The IPCC scientists made no attempt to estimate the likelihoods of any of these possible scenarios actually occurring; the uncertainties are simply too large.

The findings of these scenarios reinforce our understanding that the main driving forces of future greenhouse gas trajectories will continue to

be demographic change, social and economic development, and the rate and direction of technological change.

Climate Models

Climate scenarios and predictions for the future rely on the use of numerical models. Their evolution over the past three decades has enabled scientists to run ever more computationally demanding and complex models that incorporate more and more components and processes of the climate system (Figure 5).



Scenarios for GHG emissions from 2000 to 2100 (in the absence of additional climate policies) and projections of surface temperatures

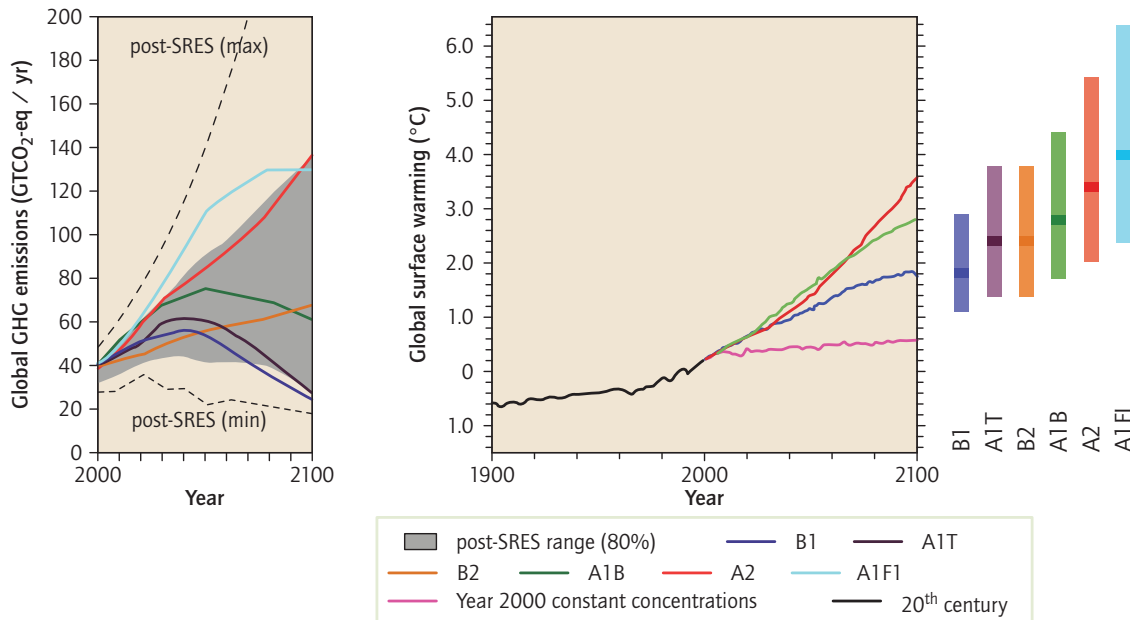


Figure 3 Scenarios of global climate change (Intergovernmental Panel on Climate Change, IPCC)

Source: © 2007 Intergovernmental Panel on Climate Change.

Notes: Left panel: Global greenhouse gas emissions in GtCO₂-eq (gigatons of carbon dioxide equivalent) in the absence of climate policies: six illustrative scenarios (colored lines) and the 80th percentile range of recent scenarios published since the release of the *IPCC Special Report on Emissions Scenarios* (SRES) in 2000 (gray-shaded area). Right panel: Solid lines are global averages of surface warming from climate models for scenarios A2, A1B, and B1 (see text). The bars at the right of the figure indicate the best estimate (solid line within each bar) and the likely range assessed for the six SRES marker scenarios from 2090 to 2099. All temperatures are relative to the period 1980 to 1999.

Climate models are computer codes expressing mathematical representations of the physical, chemical, and biological processes of the climate system, as well as their interactions. They are built to simulate the climate system as it exists today and are judged by how well they do. If their simulation of the modern-day climate (called the *control* case) is good, models are further tested against the very different conditions found in the past. The models that succeed in reproducing past climates are then used to simulate and predict future climate change.

The confidence in models arises from the fact that model fundamentals are based on established

physical laws, such as conservation of mass, energy, and momentum, along with a wealth of observations. The confidence factor is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). A second source of confidence comes from models being routinely and extensively assessed by comparing their simulations with observations of the atmosphere, ocean, cryosphere, and land surface. The Paleoclimate Modelling Intercomparison Project (PMIP) has been instrumental in bringing unprecedented levels of evaluation over the past decade in the form of organized multimodel “inter-comparisons.”

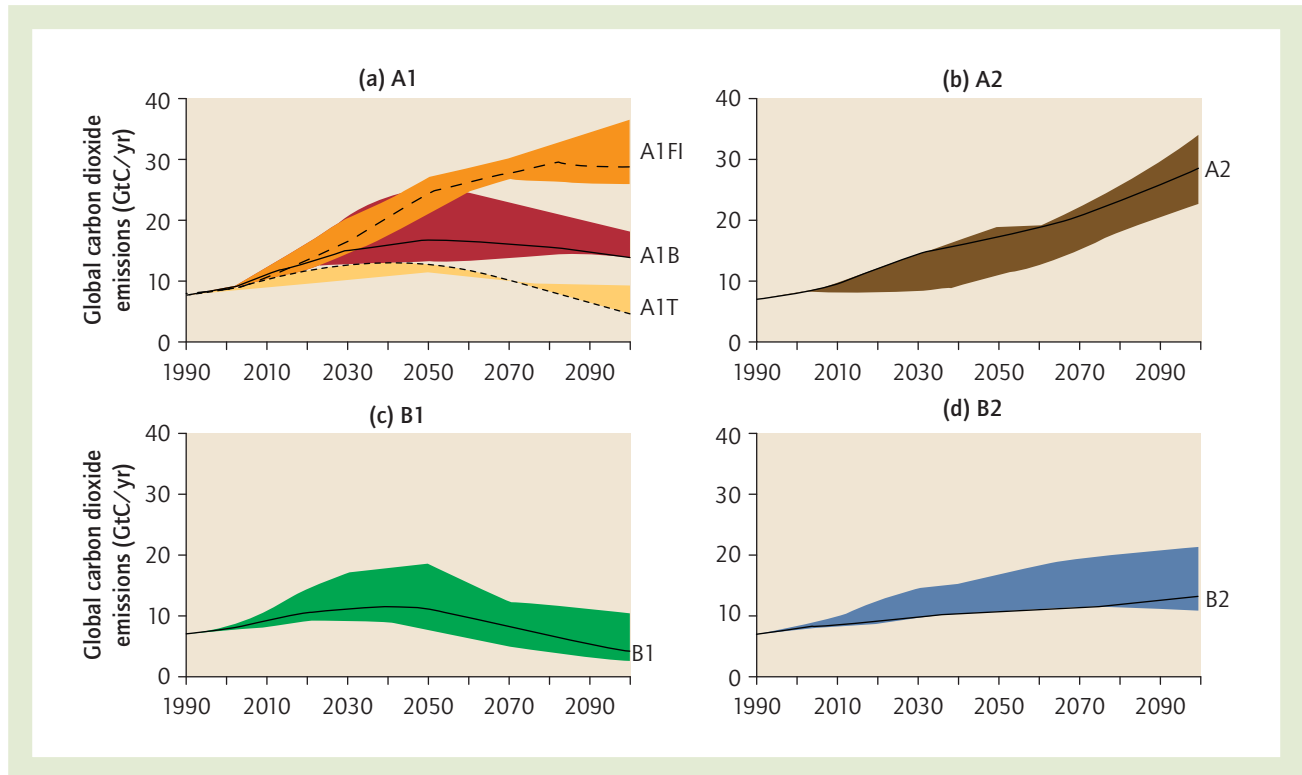


Figure 4 Projections of future global carbon dioxide emissions (GtC/yr., gigatons of carbon per year) for the A2, A1B, and B1 scenarios

Source: © 2007 Intergovernmental Panel on Climate Change.

Different Models, Different Uses

There are many different types of climate models—some very simple, some very complex. Simplicity can be achieved by a reduced number of equations (e.g., a single equation for the global surface temperature); by the reduced dimensionality of the model (one-dimensional [1D], vertical or latitudinal; two-dimensional [2D], latitude-altitude); or by restriction to a few processes (e.g., a midlatitude quasi-geostrophic atmosphere with or without the inclusion of moist processes).

One-dimensional climate models focus on the balance between incoming solar radiation and outgoing terrestrial energy (“heat”). Though simple, these models account for the greenhouse effect and feedback loops to determine temperature changes on Earth. Three-dimensional (3D) “general circulation models” (GCMs) provide the most complete numerical representations and simulations of the climate system. They take into

account the 3D structure of the atmosphere and oceans, the shape and arrangement of the continents, the bathymetry of the oceans, and the topography of the land (Figure 6). Many climatic variables are simulated; land surface temperatures, precipitation, atmospheric pressure, wind direction and strength at the surface and upper levels, ocean currents, temperatures, and salinity (Figure 5). There is considerable confidence that these models provide credible quantitative estimates of future climate change, particularly at continental and larger scales. Global circulation models can be complemented by regional models for a higher resolution over a given area or by process-oriented models, resolving clouds or large oceanic eddies. Earth models of intermediate complexity are used to investigate long timescales, such as a glacial to interglacial oscillation.

Although models have largely improved since their integration in the FAR of the IPCC, there is awareness among the climate research community

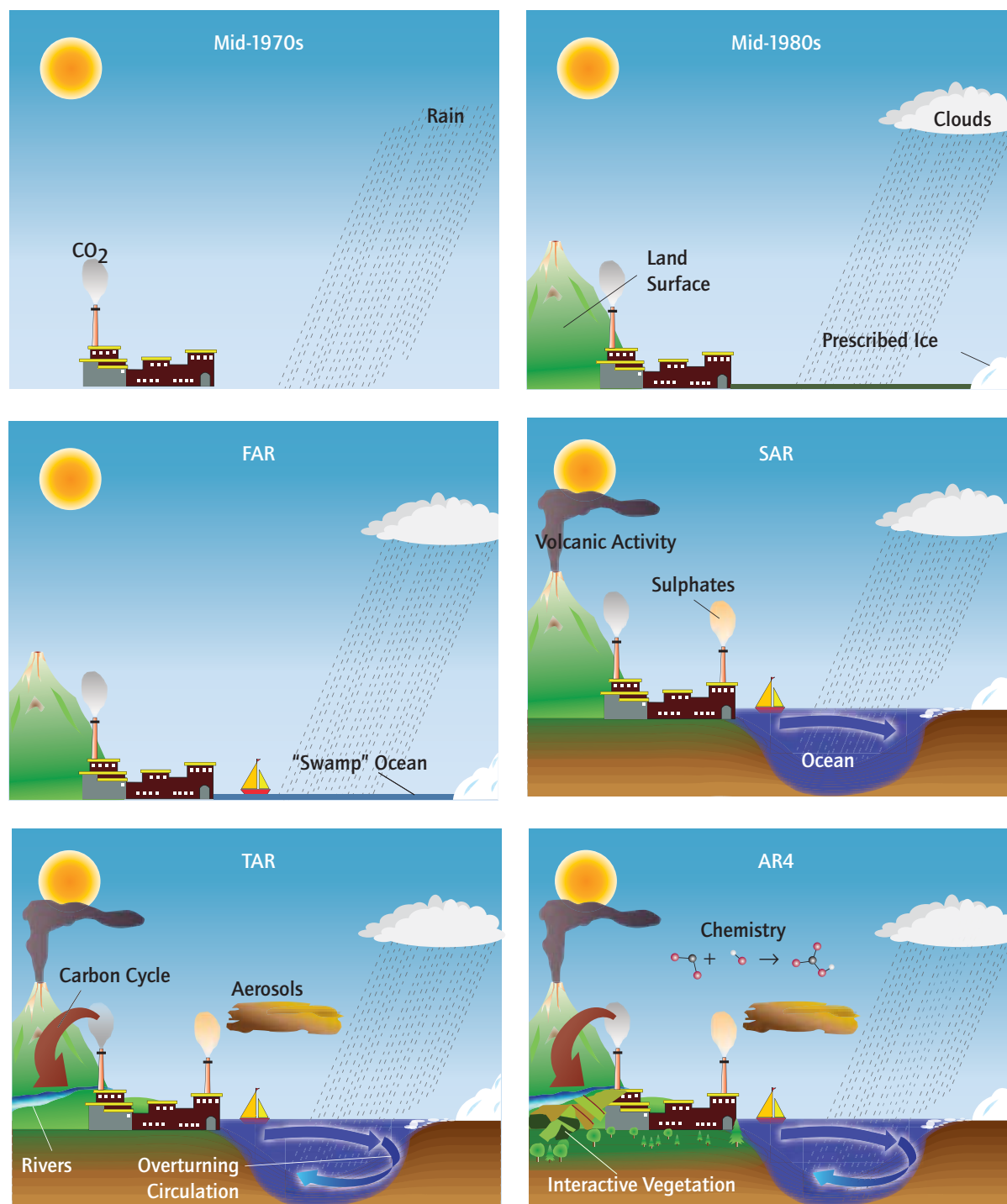


Figure 5 The complexity of climate models has increased over the past few decades. The illustrations represent the additional physical features incorporated in the models since the mid 1970s.

Sources: © Intergovernmental Panel on Climate Change (IPCC). FAR (First Assessment Report, IPCC, 1990), SAR (Second Assessment Report, IPCC, 1996), TAR (Third Assessment Report, IPCC, 2001), and AR4 (Assessment Report 4, 2007).

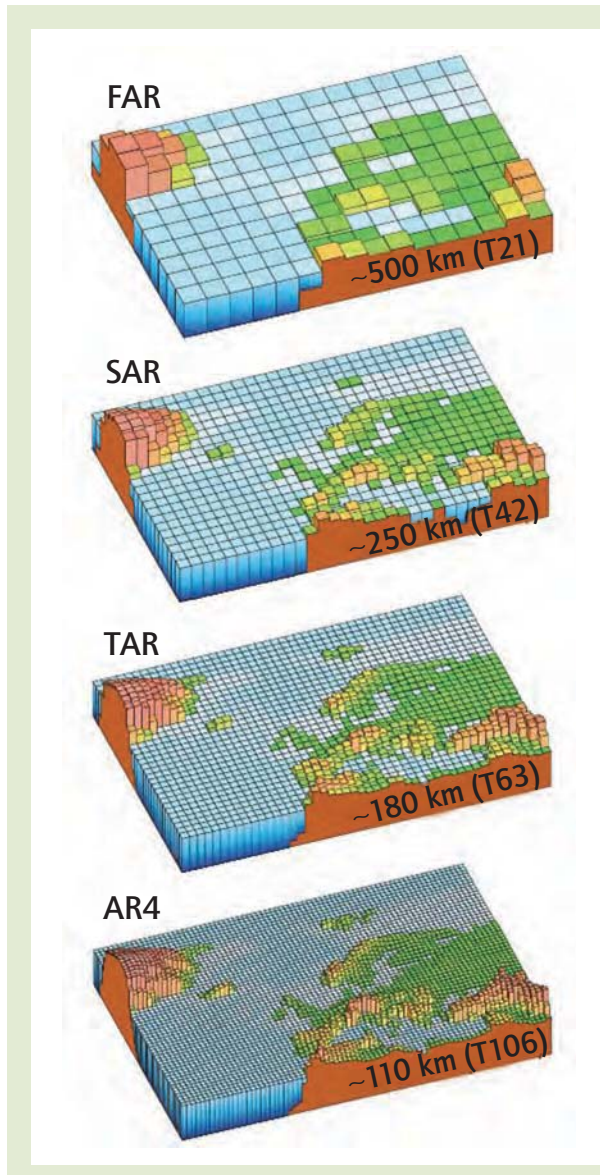


Figure 6 Geographic resolution characteristic of the generations of climate models used in the Intergovernmental Panel on Climate Change (IPCC) assessment reports

Sources: © 2007 Intergovernmental Panel on Climate Change. First Assessment Report (FAR, IPCC, 1990), Second Assessment Report (SAR, IPCC, 1996), Third Assessment Report (TAR, IPCC, 2001), and Assessment Report 4 (AR4, 2007).

Notes: Successive generations of general circulation models (GCMs) increasingly resolved Northern Europe. These illustrations represent the most detailed horizontal resolution used for short-term climate simulations. Century-long simulations cited in IPCC assessment reports after the FAR were typically run with the previous generation's resolution. Nowadays, the vertical resolution in both atmosphere and ocean models is about 30 levels in both atmosphere and ocean.

that models do not provide a perfect simulation of reality. Indeed, resolving processes at all important spatial or timescales remains far beyond current computing capabilities; clouds, vegetation, and oceanic convection cannot be represented in full detail in GCMs. In this case, physical parameters are said to be parameterized.

Analysis of model results showed a substantial model dependency over the simulated cloud processes and feedbacks. Models have produced changes in global average surface temperatures ranging from 1.9 to 5.4 °C (in a doubled atmospheric CO₂ concentration) by simply altering the way clouds would radiate heat and solar energy.

Furthermore, the behavior of any complex nonlinear system, such as climate, may be chaotic. As first described by H. A. Lorentz in the 1960s, climate models are intrinsically affected by uncertainty. Unpredictability, bifurcations (the equilibrium climate point leads to either a stable or an unstable equilibrium climate), and transitions (model goes from a stable to an unstable equilibrium climate state, or vice versa) to a chaotic mode happen even in simple models of ocean-atmosphere interactions, climate-biosphere interactions, or climate-economy interactions.

Feedback Mechanisms

Feedbacks are internal processes to Earth's climate system that either amplify changes in climate (positive feedback) or dampen/moderate them (negative feedback).

Positive Feedback

- An important positive feedback is the “water vapor feedback loop.” An initial increase in CO₂ in the atmosphere causes the atmosphere to warm. This warming translates as a greater evaporation of surface water, which adds water vapor in the atmosphere, thereby warming it even more. Furthermore, if this warming takes place at high latitudes, snow and ice can melt. Exposed ground or ocean will absorb more solar radiation because either surface is less reflective than snow (lower albedo index), warming the Earth still further.
- This “ice-albedo feedback” constitutes another very important positive feedback loop. Although



simple, a quantitative understanding of the effect is far from complete. For instance, it is difficult to ascribe high-latitude amplification of the warming signal to retreated ice.

- When scientists realized that global warming signals are amplified in high latitudes, research on the “permafrost-climate feedback” started. As permafrost thaws due to warmer climate, GHGs trapped in it are released to the atmosphere. The subsequent increase in atmospheric temperature results, then, in more thawing.
- A warmer ocean has less ability to absorb carbon dioxide.

Negative Feedback

- The “water vapor feedback loop” has also a negative feedback component to it. As water vapor condenses, clouds form. Models and observations point toward a net cooling effect of the clouds as they reflect solar radiation back to space.
- Another possibility lies with increased precipitation patterns that would enhance the growth of ice sheets and glaciers, both regionally and globally, which would result in regions with a higher albedo and lower thermal conductivity.
- The acidification of the surface oceans, by reducing the production of corals and phytoplankton, will slightly increase the ocean’s ability to take up carbon dioxide. When these organisms die, the CaCO_3 skeletons break down, and CO_2 is released to the water, lowering the ocean’s ability to take up atmospheric CO_2 .

Nevertheless, positive feedback outweighs negative feedback in the climate system on all but multimillennial timescales.

How Will Climate Change in the Next Century?

In its latest assessment report published in 2007, the IPCC writes that “observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.” Using different models and scenarios, scientists have come up with a range of possible trajectories for the future climate. The

predicted increase in global average from 2000 to 2100 is between 1 and 3 °C (1.8–5.4 °F) for the storyline that is the most aggressive toward cutting GHG emissions (i.e., B1), 1.5 and 4.5 °C (2.7–8.1 °F) for the “middle-of-the-road” storyline (A1B), and 2.5 and 6.5 °C (4.5–11.7 °F) for the least aggressive emission scenario (A1FI).

Precipitation Change

If the average global temperature increases, so does the overall rate of evaporation. More water vapor in the atmosphere will drive higher overall rates of precipitation. Thus, one might expect a faster water cycle, as more water will be “sucked up” into the atmosphere and then proceed to fall back out as rain and snow. There is a projected increase in winter precipitation in polar, subpolar, and equatorial regions, while the subtropics will see a decrease in rain precipitation (Figure 7).

However, the timing and regional shift in precipitation will not be distributed evenly over all regions. Some locations will get more snow, others will see less rain. Some places will have wetter winters and drier summers, and so on. Models indicate more frequent extreme precipitation, with drenching downpours more prevalent. The regions predicted to experience overall declines in average annual precipitation will actually be hit with short periods of more intense rainfall followed by longer periods between rain. The mid-continental areas will dry more during summer, indicating a greater risk of droughts in those regions.

Melting Ice and Rising Sea Level

A warmer climate leads to higher sea levels via two mechanisms: (1) the melting glaciers and ice sheets add water to the oceans, raising the sea level, and (2) the thermal expansion of the ocean displaces a greater volume, thus also raising sea levels.

During the 20th century, sea levels rose about 10 to 20 cm (centimeters; 4–8 in. [inches]). Thermal expansion and melting ice each contributed probably about half of the rise. Sea level is predicted to rise with global warming by 0.1 to 0.4 m (meters; 4 to 16 in.) by 2100.

The various IPCC emission scenarios predict that by 2100, sea level will rise between about

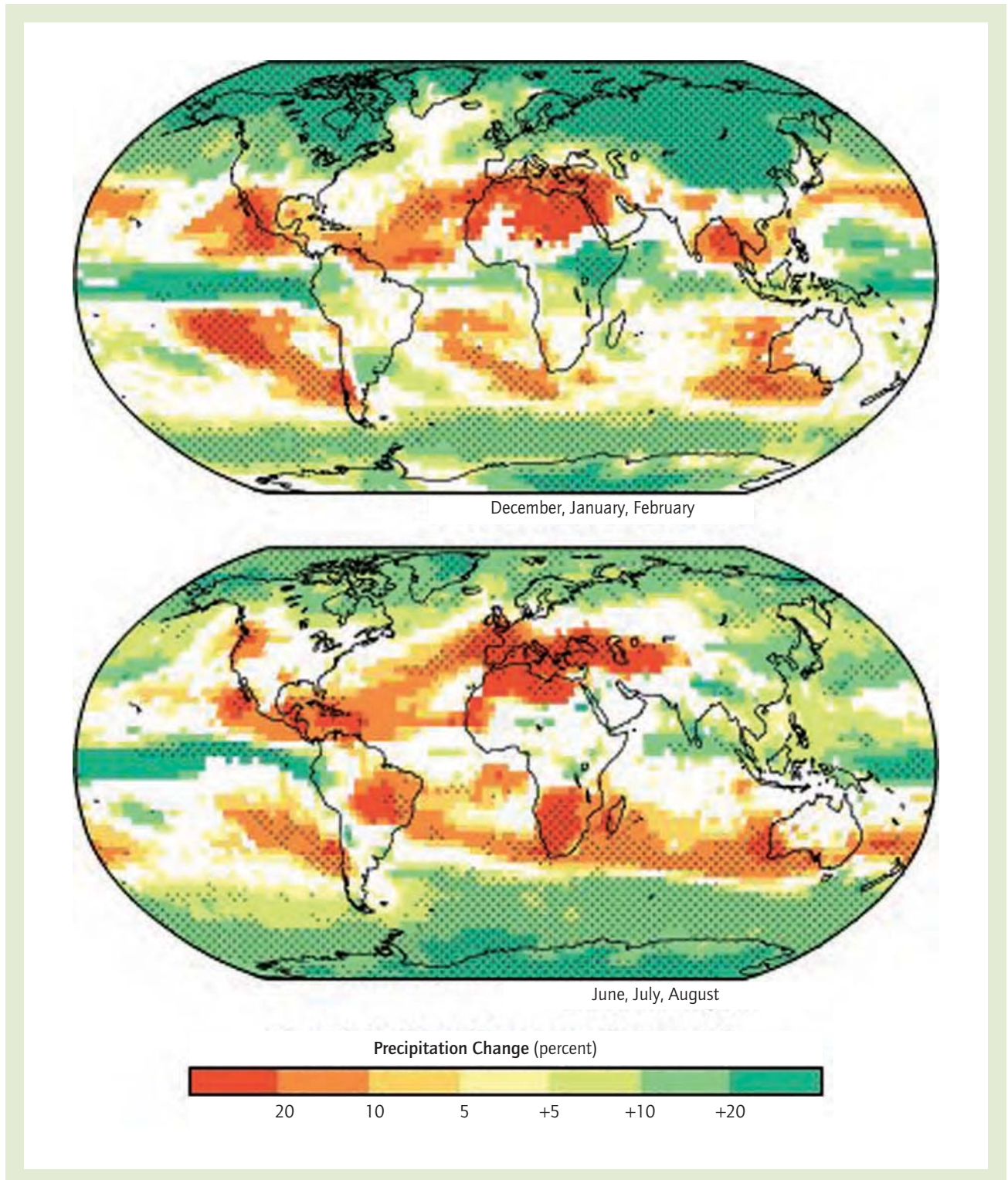


Figure 7 Modeled precipitation map for the winter months (*upper panel*) and the summer months (*lower panel*)

Source: © 2007 Intergovernmental Panel on Climate Change.

Note: With some exceptions, the tropics will likely receive less rain (orange) as the planet warms, while the polar regions will receive more precipitation (green). White areas indicate that fewer than two thirds of the climate models agreed on how precipitation will change. Stippled areas indicate where more than 90% of the models agreed.

0.19 to 0.59 m (8–23 in.) above the late-20th-century levels. However, these numbers do not include how the Greenland and Antarctic ice sheets will react to rising temperatures because modeling the response is very complicated.

However, in August 2008, a team of researchers reported in *Nature Geoscience* that sea level rise from the Greenland ice sheet could be double or triple the current estimates over the next century. According to this new study, and if the trend continues, sea level might rise 1 m (3.3 ft. [feet]) or more by 2100.

Changes in Extreme Weather

Since the TAR, there is a higher level of confidence in the projected increase in droughts, heat waves, floods, and frosts, as well as their adverse impacts. Changes are predicted to vary regionally.

The Unknowns in Predicting Climate Change

There are several “known unknowns” and “unknown unknowns” regarding the possible pattern of climate change ahead of us. Among the “known unknowns,” one should consider the following:

- Since 2000, the growth rate of global emissions has been about 3%. In the IPCC’s storylines, these emissions range between 1.4% and 3.4% between 2000 and 2010. This has attracted scientific and policy attention and could be evidence that these scenarios are too conservative. However, it should be clear that these emissions scenarios are long-range predictions, so it is also possible that the present trend is a short-term trend that will not result in a long-term deviation from the possibilities described by these emissions scenarios.
- What will be the steps taken by societies to mitigate GHG build up in the atmosphere, and how successful will these efforts be?
- As the major ice sheets are melting, just how rapidly will they melt, and how much will the sea level rise? These are still subjects of study.
- Could the release of freshwater from ice sheets and glaciers trigger a weakening of the thermohaline circulation (“conveyor belt”), and if so, when?

Among the “unknown unknowns,” one of the most important ones concerns whether the response of the climate to increased GHG will take an unpredicted path.

Mathieu Richaud

See also **Atmospheric Composition and Structure; Carbon Trading and Carbon Offsets; Climate Change; Climate Policy; Climate Types; Greenhouse Gases**

Further Readings

- Keeling, C. D., Piper, S. C., Bacastow, R. B., Wahlen, M., Whorf, T. P., Heimann, M., et al. (2005). Atmospheric CO₂ and 13CO₂ exchange with the terrestrial biosphere and oceans from 1978 to 2000: Observations and carbon cycle implications. In J. R. Ehleringer, T. E. Cerling, & M. D. Dearing (Eds.), *A history of atmospheric CO₂ and its effects on plants, animals, and ecosystems* (pp. 83–113). New York: Springer.
- Le Treut, H., Somerville, R., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A., et al. (2007). Historical overview of climate change. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, et al. (Eds.), *Climate change 2007: The physical science basis* (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, UK: Cambridge University Press.
- Mann, M., & Kump, L. (2009). *Dire predictions: Understanding global warming*. New York: DK Publishing.
- Nakicenovic, N., Davidson, O., Davis, G., Grubler, A., Kram, T., Lebre La Rovere, E., et al. (2000). *Special report on emissions scenarios: A special report of Working Group III of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press. Retrieved December 3, 2009, from www.grida.no/climate/ipcc/emission/index.htm
- Paleoclimate Modelling Intercomparison Project: <http://pmip2.lsce.ipsl.fr>
- Van Vuuren, D., & Riahi, K. (2008). Do recent emission trends imply higher emissions forever? *Climatic Change*, 91, 237–248.



ANTHROPOGEOGRAPHY

Anthropogeography is a term used predominantly in the late 19th and early 20th centuries that means roughly “the geography of humans.” The term comes from *Anthropogeographie*, the title of a two-volume work published in 1882 and 1891 by the German geographer Friedrich Ratzel, who is well known for his influence in early human geography, particularly his thought in political geography. Ratzel strongly influenced the thought of the well-known American geographer Ellen Churchill Semple, who presented Ratzel’s anthropogeography to North America through her 1911 work *Influences of Geographic Environment: On the Basis of Ratzel’s System of Anthro-Geo-graphy*. Some thinkers, like the geographer J. K. Wright, criticized Semple for not clearly stating which ideas were hers and which originated from Ratzel.

The British geographer Halford Mackinder had a positive view of anthropogeography and believed that it required the ability to understand and use many subjects, including physics, biology, and geology. In Mackinder’s opinion, this knowledge of various disciplines made anthropogeographers well-rounded scholars. Generally speaking, anthropogeography was an attempt to study and organize the relationships between people and their environments. More specifically, its goal was to systematically and scientifically describe the economic, historical, and political characteristics of people and the places they inhabited.

Unlike much geographical thought today that explores how humans affect their environments, anthropogeography focused on how humans were affected or “influenced” by their environments. In her essay “The Anglo-Saxons of the Kentucky Mountains: A Study in Anthropogeography,” Semple begins with a physical description of the Appalachian Mountains in Kentucky. She goes on to describe how the isolation caused by the rough terrain influenced its people to be inbred, violent, backward, and lawless. Since the publication of this essay in 1901, similar images of Appalachia have persisted to this day. The scientific appearance of Semple’s descriptions made them seem all the more believable. Semple described Appalachia

and its people as cut off from civilization and progress. At the same time, however, she praised the residents of the Kentucky Appalachians as people of good stock. Many considered Appalachians to be the purest Americans: They were white and were not corrupted by the negative aspects of progress like the rest of the country. They were thought to be frozen in time. This view was widespread and was not limited to Semple or anthropogeographers, but it does highlight the fact that anthropogeography was influenced by prevailing cultural discourses. It is also likely that it helped reinforce those discourses.

The term *anthropogeography* is rarely used today because of its overtones of social Darwinism and environmental determinism. Occasionally, it is used as a synonym for human geography or to refer to the aspects of human geography that intersect with anthropology. In its heyday, anthropogeography focused predominantly on the environment’s influence on humans. Despite its flaws, however, anthropogeography of the late 19th and early 20th centuries helped open the field of geography and its goal of exploring the relationships between humans and nature.

Jessey Gilley

See also Environmental Determinism; Human Geography, History of; Mackinder, Sir Halford; Ratzel, Friedrich; Semple, Ellen Churchill; Social Darwinism

Further Readings

- Hartshorne, R. (1939). The nature of geography: A critical survey of current thought in light of the past. *Annals of the Association of American Geographers*, 39, 173–645.
- Mackinder, H. (1895). Modern geography, German and English. *Geographical Journal*, 6, 367–379.
- Semple, E. (1901). The Anglo-Saxons of the Kentucky mountains: A study in anthropogeography. *Geographical Journal*, 17, 588–623.
- Semple, E. (1911). *Influences of geographic environment*. New York: Henry Holt.



ANTIGLOBALIZATION

Globalization—the diverse, complex set of processes that transcend national borders—is not a “natural” or inevitable phenomenon but a historical product and therefore contingent and malleable. Because globalization does not benefit everyone, contrary to popular neoclassical economic assertions that it forms a tide that lifts all boats, globalization often breeds resentment among those who bear its costs but enjoy relatively few of its benefits. For this reason, it may be said that globalization inevitably breeds its own opposition.

Resistance to globalization is as old as globalization itself. Thus, from the beginning, European colonial empires were met with heated opposition, often violent and generally unsuccessful. Examples include the Incan uprisings against the Spanish in the early 16th century, Zulu attacks on Dutch and British pioneers in Southern Africa, the great Sepoy Rebellion of India in 1857, and the long series of anticolonial and guerrilla struggles in Vietnam, Algeria, and much of sub-Saharan Africa, some of which persisted into the 1970s. For many contemporary opponents of globalization, current engagements are part of a long history of opposition that reaches back centuries.

Contemporary antiglobalization movements take a variety of forms. For many, the movements are relatively peaceful in nature, including protests, boycotts, demonstrations, and working through nongovernmental organizations (NGOs). For others, opposition takes on a decidedly more active, even violent form. Benjamin Barber’s famous book *Jihad vs. McWorld* noted this diversity of forms, using *jihad*, the Arabic expression for holy war, as a metaphor for the vast umbrella of groups opposed to contemporary globalization and “McWorld” as a metaphor for the American-led, information-intensive penetration of various societies by crass commercialism, including fast food, entertainment and media (particularly Hollywood cinema), and fashion, all of which are the most visible faces of Western hegemony and are seen by many as cultural imperialism.

Nonviolent Antiglobalization

Because of the dominant role of the United States in the contemporary world system, globalization in the minds of many people is synonymous with Americanization. Much of the world has a love-hate relationship with the United States, often adoring its popular culture but abhorring the foreign policies of the American government, which has earned enmity in part for its long support of unsavory dictatorships in many regions, particularly during the Cold War. Globalization, in this reading, consists of the one-way export of American culture to the rest of the world, a process that threatens cultural diversity through the imposition of a monoculture across the planet. Opposition to the United States, for example, may take the form of attacks on Ronald McDonald, the clown statue that serves as a mascot for that famous fast-food chain, as a symbol of American commercialism.

American-style globalization is most powerful when it seduces the young, for whom it promises fun, status, hope, sexual appeal, and the appeal of wealth and power. In this sense, McWorld infantilizes everyone, turning adults and children alike into teenagers, wearing the same clothes, listening to the same music, and watching the same movies. The young may rapidly adopt Western customs at the expense of time-honored traditions. For the elderly, however, globalization can present a bewildering mix of new customs, leading to a generation gap. Perhaps the biggest contest between globalization and its opponents is in the minds of youth.

A different form of antipathy to globalization is found in Western Europe. Many residents of France or neighboring countries, for example, are disgusted with the crassest aspects of American culture: its obsession with money, commodities, and status and its neglect of tradition and leisure. (Vacation times in Europe tend to be considerably longer than in the United States.) For example, when the French farmer José Bové drove his truck into a McDonald’s restaurant in 1999 to demonstrate his hostility to American fast food, he became a national hero. Other Europeans strenuously object to the import of American genetically modified foods. Given the state of social



Filipino protesters burn a sign during a rally in front of the main gate of the U.S. embassy in Manila, November 9, 2001, to protest the World Trade Organization's (WTO) ministerial meeting.

Source: Reuters/Corbis.

democracies in Europe, many Europeans abhor the intensity of American individualism, its denial of the social origins of people, and the correspondingly conservative lack of empathy for the poor and unfortunate that this ideology often produces. The United States, in this view, is overly tolerant of inequality and social injustice. Moreover, in Europe, an increasingly secular continent, there is widespread dislike of the prominent role that organized religion plays in American public life and of the profound religiosity of the American people, manifested, for example, in the rise of the “religious right” and attempts to limit the teaching of evolution in schools. Such phenomena are seen as symptomatic of a generalized anti-intellectualism in U.S. culture, which is stereotyped (accurately or not) as a culture in which

ideas and the life of the mind are held in low regard. Finally, many Europeans view the United States as a cowboy culture, given the widespread ownership of firearms and rates of violent crime that greatly exceed those of almost all industrialized countries. This celebration of violence extends to the American use of the death penalty, which is absent in all other economically developed states.

Grassroots Antiglobalization

Another variant of opposition to globalization emanates from a vast assortment of organizations of varying sizes and purposes that seek to resist neoliberal initiatives in various ways. Many such groups view globalization as something of a



cabal or conspiracy fomented by transnational corporations, producing policies that are secretive and antidemocratic, that work against the interests of the poor and disadvantaged, and that are environmentally destructive. There are tens of thousands of nongovernmental organizations (NGOs) worldwide that work to soften the bluntest edges of globalization, including charities, philanthropies, community organizers, human and animal rights groups, research institutes, environmental activists, and watchdog organizations. Such groups are part of the civil society of the world's peoples (i.e., belonging neither to the state nor to the market). Their numbers exploded in the late 20th century in the wake of neoliberal assaults on various parts of the world, and many use the Internet to form alliances and to work cooperatively.

Environmental groups, for example, may be concerned with sustainable development, desertification, soil erosion, the preservation of wilderness and biodiversity, endangered species, the treatment of domesticated and wild animals, global warming, rivers and wetlands, and environmental justice. If, in their opinion, transnational corporations view the world as a set of resources to be harvested, their goal is to protect the commons shared by all. Examples include Greenpeace, the World Wildlife Fund, the Global Institute for Sustainable Forestry, the Rainforest Alliance, Friends of the Earth, and more locally based groups such as the Philippine Association for Conservation and Development or the Mountain Trust in Nepal.

Human rights and labor movements form another dimension of grassroots globalization, including those concerned with protecting the interests and rights of women, children, refugees, the handicapped and retarded, and workers. Topics embraced by such groups range from poverty alleviation and human trafficking and slavery to the protection of endangered ethnic cultures. Some target the International Monetary Fund (IMF) and its Structural Adjustment Programs, as well as the World Bank, and demand debt relief for impoverished countries. Some engage in attacks on meetings of the IMF or World Trade Organization (WTO), such as the "Battle in Seattle" in 1995, the assault on the G-8 in Genoa in 2001, and the demonstrations against the WTO

in the Yucatan in 2005, which included strenuous opposition to subsidized American agricultural exports. Others are concerned with the preservation of tribal cultures and indigenous peoples, such as Australian aborigines, Native Americans, and the Ogoni of Nigeria. Global organizations in this vein include Amnesty International, Human Rights Watch, Doctors Without Borders, Handicap International, Academics for Justice, and the Union of Concerned Scientists. More local examples include the Ethiopian Women's Organization, the Pachamama Alliance, and Indian groups mobilizing on behalf of the *dalits*, or *untouchables*. The World Social Forum forms an umbrella for many such groups, with the slogan "Another World Is Possible."

Violent Antiglobalization

Although most opposition to globalization is peaceful, one variant engages in armed resistance. The origins of such groups, commonly labeled terrorists, lie in the complex transformations of many societies in the face of intense globalization. As a long tradition of Weberian social science has noted, modernity generates numerous secularizing changes in identity and behavior associated with the rise of markets, individualism, and commodity-based norms. Essentially, it may be held that Western, modern forms of life reduce identity to that of a buyer or seller of commodities, obliterating many time-honored, noncapitalist forms of life grounded in tradition. Particularly for people who experience severe disorientation through rural-to-urban migration, torn from local support systems, and the annihilation of systems of meaning that provided ontological security (honor, family, ancestors, God, etc.), modernity can be viewed as a sinister, morally offensive force. In the view of such victims of globalization, all that is holy is rendered profane. David Harvey (1990) notes that the disorienting changes in time and space that have accompanied the latest round of globalization often provoke a retreat into the local:

The more global interrelations become, the more internationalised our dinner ingredients and our money flows, and the more spatial barriers disintegrate, so more rather than less of the world's



population clings to place and neighbourhood or to national, region, ethnic grouping, or religious belief as specific marks of identity. Such a quest for visible and tangible marks of identity is readily understandable in the midst of fierce time-space compression. (p. 427)

Given that globalization is often viewed as a secularizing force, it is not surprising that some of the most heated violent opposition has emanated from religious groups. Indeed, in the wake of the end of the Cold War, religious fundamentalism has erupted around the world, often coupled with antiglobalization sentiments. In the United States, for example, the upsurge in the religious right, in conjunction with the Republican Party, has ignited conservative political activists. On the extreme fringes of this ideology are militias that engage in xenophobic violence against immigrants; others view the federal government in terms of paranoid fantasies, including Timothy McVeigh, who destroyed a federal office building in Oklahoma City. In Europe, such movements include British skinheads, German attacks on guest workers, and French xenophobes led by LePen. In India, Hindu fundamentalists include the Bharatiya Janata Party, which instigated the destruction of the Ayodhya mosque and attacks on Indian Muslims. In the world of Judaism, the most rapid growth has been among ultraorthodox Hasidim, who support conservative policies vis-à-vis the Palestinians; the Gush Emunim movement to establish Eretz Israel; and the settlers on the West Bank.

Of course, the upsurge in religious fundamentalism also includes Islam, the world's second largest religion, with 1.5 billion followers. While the Western media often portray the Muslim world in negative terms, the fact remains that the vast majority of Muslims are peaceful and law-abiding. Nonetheless, a tiny minority, fueled by indifferent, corrupt governments in the Arab world, blame their culture's relative powerlessness in the world, and particularly against Israel, on an ostensible departure from the teachings of the Holy Koran. Radical Islamists toppled the Shah of Iran in 1979 and installed the Ayatollah Khomeini, turning Iran into a medieval theocracy. Others include the Muslim Brotherhood, which

assassinated Anwar Sadat in 1982. In Afghanistan, the Taliban drove out the Soviets in 1989, reorganized the country along strictly fundamentalist lines, hosted al-Qaeda in 2001, and has fought the United States since the American invasion later that year. Among Palestinian nationalists, hitherto a relatively secular movement, as exemplified by the Palestine Liberation Organization, fundamentalist groups such as Hamas and Hezbollah have been associated with suicide attacks against Israel. And obviously, al-Qaeda (Arabic for "the base") exemplifies the most pernicious aspects of this trend: Led by the infamous Osama bin Laden, member of a Yemeni family that grew rich in Saudi Arabia, al-Qaeda has become the most visible face of Muslim opposition to globalization and the United States, as spectacularly exemplified by the attacks on the World Trade Center and the Pentagon on September 11, 2001. To understand such movements, it is imperative not to view them in simplistic terms as acts of insanity or cowardice but to understand the social origins that drive individuals and groups to seek such goals, the poverty, frustration, humiliation, and sense of powerlessness that globalization often generates.

Conclusion

Antiglobalization, like globalization, is a diverse set of groups and ideologies, some of which find common ground. At their best, such efforts help protect the defenseless and preserve endangered cultures and environments. At its worst, antiglobalization can commit sins worse than the global forces it opposes. Because globalization has increasingly come to mean Western cultural and economic neocolonialism and neoliberalism, antiglobalization will inevitably rise not simply as its opponent but as its birth child.

Barney Warf

See also **Antisystemic Movements; Colonialism; Globalization; Human Rights, Geography and; International Monetary Fund; Neocolonialism; Neoliberalism; Nongovernmental Organizations (NGOs); Resistance, Geographies of; Social Movements; Structural Adjustment; Terrorism, Geography of; World Bank**



Further Readings

- Barber, B. (1995). *Jihad vs. McWorld: How globalism and tribalism are reshaping the world*. New York: Ballantine.
- Hawken, P. (2007). *Blessed unrest: How the largest social movement in history is restoring grace, justice, and beauty to the world*. New York: Penguin.
- Stump, R. (2000). *Boundaries of faith: Geographical perspectives on religious fundamentalism*. Lanham, MD: Rowman & Littlefield.
- Warf, B., & Grimes, J. (1997). Counterhegemonic discourses and the Internet. *Geographical Review*, 87, 259–274.



ANTIPODES

The term *antipodes* refers both to an upside-down world at the other side of the planet and to its inhabitants, who supposedly live head down and feet up. The term, derived from the Greek *anti* (“against” or “opposed”) and *podus* (“foot”), appeared for the first time in Plato (ca. 427–347 BC), who used it to indicate a place diametrically opposite the city-state of Athens on the surface of the globe. Since then, the term became a crucial corollary of the theory of zones, the milestone of geographic speculation for almost 2,000 years. According to this theory, there are two temperate zones suited to human life, respectively in the boreal and in the austral hemisphere. The latter zone, called *antichtone* or antipodes, is unknowable because of the impossibility of crossing the Torrid Zone. Its scientific importance developed in parallel with its literary fortune: The antipodes challenged common sense and subverted the established order, becoming a great source of inspiration for artistic and social criticism.

A major problem arose when early Christian thinkers endeavored to reconcile hegemonic Greek-Roman geographical knowledge with Biblical topography. The existence of the antipodes contradicted both the common origins of humanity from Adam and the ecumenical aspiration of the evangelical message, jeopardizing the

entire Christian vision of the world. Augustine of Hippo successfully proposed considering the antipodes as monsters. The presence of fabulous beings in faraway lands, attested to by ancient authorities, confirmed the great variety of products from the Creation and did not contradict any religious dogma. From then on and throughout the feudal era, the antipodes were represented as anthropomorphic freaks with deformed feet, turned backward.

Starting in the 11th century, revolutionary changes in the topography of the Christian afterlife, related to the invention of Purgatory, challenged the traditional geographies of the faraway. The rising merchant class needed a more sophisticated image of otherness to accompany its commercial expansion and found in the antipodes a transitional paradigm to shift from the late-medieval cosmology to a modern vision of geographical space. Antipodes become a question of puzzling political actuality in the second half of the 15th century, when Portuguese expeditions in Western Africa crossed the equator, demonstrating the fallacy of the theory of zones and opening the way to their conquests.

During the Renaissance, the antipodes acted as a powerful performative and rhetorical device that allowed imagining new possible worlds through a sophisticated system of inversions and a rich *imaginary* built throughout the centuries. At least four great myths nourished it: (1) the Universal Empire, revitalized by the rising national states; (2) the Golden Age that humanism borrowed from ancient thought; (3) the Jewish-Christian quest for Eden; and (4) the carnivalesque land of Cocagne of medieval popular culture.

Practices and representations related to the antipodal *imaginary* reshaped naturalistic taxonomies and transformed the frontiers among animals, monsters, and human beings, contributing decidedly to the building of a new colonial order and of a modern subjectivity. As the material and symbolic appropriation of the world by European powers progressed, the antipodes progressively lost their importance. Nevertheless, it is precisely at the antipodes that the most powerful of modern myths originated—the myth of utopia.

Paolo Vignolo



See also **Biblical Mapping; Human Geography, History of**

Further Readings

Fausett, D. (1995). *Images of the antipodes in the eighteenth century: A study in stereotyping*. Amsterdam: Rodopi.



ANTISYSTEMIC MOVEMENTS

Antisystemic movements (ASMs) may be defined as political groupings that oppose and resist the prevailing productive forces and relations in a given historical era. Thus, antisystemic movements can be said to have existed throughout human history. Antisystemic movements achieved profound economic and political success in the post-1945 period in overthrowing structures of formal colonialism in the global political economy and establishing the acceptance of social democratic norms of limited wealth redistribution and the state provision of social welfare in rich, developed states. However, they simultaneously failed to achieve their principal objective of transforming the unequal relations of exchange among the different zones of the global political economy. Present-day antisystemic movements have their origins in the “new social movements” of the 1960s and 1970s, many of which were identity based, oppositional, and exclusively concerned with single-issue politics, for example, women’s rights, racial issues, antiwar and antinuclear movements, and environmentalist movements.

Themes of Protest

There are five principal themes of protest within contemporary anticapitalist, antisystemic movements: (1) trade regulation, (2) environmental degradation, (3) labor conditions, (4) militarism (especially in the guise of the “War on Terror”), and (5) human rights. Implicit within each campaign theme is the recognition that as each of these areas is becoming increasingly globalized, so too must counterhegemonic protest. The

overlying theme is therefore the delivery of social, political, and economic justice to those who have been or may be threatened by the globalization of a particularly fundamentalist form of free market capitalism.

Patterns and Aspects of Protest

ASMs campaign on a huge variety of issues, from trade unions to organizations of indigenous peoples, whose very existence is threatened by the process of capitalist globalization. A strong commitment is maintained to a nonhierarchical “politics of difference” within and between antisystemic strategies and movements. Of particular importance is the emphasis that anticapitalist groups have placed on the *global* scope of resistance, while acknowledging that small-scale actions in groups’ own locales contribute to a greater political-economic struggle.

Because of the failures of previous ASMs to enact systemic transformation through the capture of state power, current antisystemic movements emphasize the need to develop participatory forms of democratic practice “from the ground up.” Political power is thus concentrated at the lowest possible level, flowing upward only through the establishment of consensus through a loose network of affiliations and coalitions. Contemporary ASMs have also concentrated on constructing transnational connections between developed and developing world movements. The declared objective is the construction of forms of global civil society to combat exploitation of the global poor through the transnationalization of production and its concomitant creation of a class-conscious, transnational capitalist elite, especially in the post-Cold War era.

Most ASMs aim at political empowerment through the promotion of an agenda of constructive change in the global political economy. By encouraging participation in mass protests and other campaigns, there is an educative agenda that encourages activists to learn more about their world, the workings of the transnationalized networks of finance and production, and those anticapitalist movements and campaigns in operation in other areas of the world, thereby building consciousness of the global nature of the ASM agenda.



Methods and Tactics of Protest

ASM protests take a variety of forms. At the smallest scale, protest may constitute the boycotting of particular brands or acts of “culture jamming,” the defacement of advertisements. At the other end of the scale are mass protests, such as the 1999 Seattle anti-WTO protests and the 3-day anti-G8 protests in Genoa in July 2001. Such protests may not be limited to one location—the June 18, 1999, “Ambush of Global Capitalism” saw mass demonstrations take place across the world.

Participants in mass protests are activists and members of organizations from across the world. The Seattle demonstrations, for example, comprised groups from Europe, the Americas, Africa, and Asia and included environmentalists, community self-help groups, trade unions, debt and poverty relief campaigners, and organizations of indigenous peoples. Mass demonstrations have been specifically intended to disrupt, or even halt completely, major multilateral summits through direct action (as in Seattle). They also act as an affirmation of solidarity for activists involved within the ASMs, providing opportunities to meet and discuss future strategies for action or to attend teach-ins on the effects of globalization around the world. Third, mass protests attract the attention of the global media to movements’ antisystemic agendas, theoretically promulgating them to a global audience. Serious differences remain, however, between different movements over the use of violent tactics attracting unfavorable media attention at the expense of more substantive debate.

Paramount is the use of humor and absurdism within a tactical context of civilly disobedient direct action. The use of humor in civil disobedience can trace its origins to the “situationist” school that grew out of the student dissident movement in Paris in the late 1960s. In the present era, humor and the celebration of life without commercial intrusion have been the underlying themes behind the spontaneous (if immaculately organized) hijacking of major road junctions by organizations such as Reclaim the Streets to hold street parties/street theater. Subversive humor was also evident in the tactics of “Guerrilla Gardening,” employed during the A16 demonstrations in Washington, D.C., in April 2000 and

in the “Mayday Monopoly” theme of the 2001 protests in London.

Other forms of direct mass action include organizations such as San Francisco’s Critical Mass, which has organized mass bicycle rides to block traffic in urban centers around the world. In each case, the intention is to generate a global debate concerning a capitalist mode of social relations that regards material consumption as the key to happiness.

Mark Ian Bailey

See also **Antiglobalization; Countermapping; Globalization; Human Rights, Geography and; Justice, Geography of; Neoliberalism; Nongovernmental Organizations (NGOs); Resistance, Geographies of; Social Justice; Social Movements**

Further Readings

- Barlow, M., & Clarke, T. (2002). *Global showdown: How the new activists are fighting corporate rule*. Toronto, Ontario, Canada: Stoddart.
- Burbach, R., & Danaher, K. (Eds.). (2000). *Globalize this: The battle against the World Trade Organization and corporate rule*. Monroe, ME: Common Courage Press.
- Klein, N. (2000). *No logo: Taking aim at the brand bullies*. London: Flamingo.
- Wallerstein, I., Hopkins, T., & Arrighi, G. (1989). *Antisystemic movements*. London: Verso.



APPLIED GEOGRAPHY

First mentioned in the late 1800s, applied geography is a relatively recent discipline that has enjoyed controversy, acclaim, and change in its short life. Beginning as a merger of natural sciences and social sciences, applied geography has faced critics from both sides of science; however, it has also been hailed by both as having the ability to help humanity.

The term first appeared during a time when educational programs at the high school and college level were reevaluating the curriculum being taught then. Until this time, the discipline



of geography had included only the natural sciences, such as geology and meteorology. John Scott Keltie (1890) was influential in suggesting that it is possible for the gap between natural and social sciences to be bridged through the application of geographic science to human behaviors. Most of what was written about applied geography during this time emerged from Europe. The first college to develop an applied geography program in the United States was the University of California, Berkeley, and even then it was only included as a part of an economics program. Applied geography uses geographical theory and methodology to solve problems on many topics as long as a problem has a geographical component, and therefore, the field has found a home in disciplines outside of geography.

Some 20 years after the first academic program was created, applied geography classes and research emerged throughout the country. This was partly due to a U.S. federal requirement passed in 1914. The requirement mandated that all land grant universities must disseminate research and findings on agriculture and home economics to the public and surrounding communities in a way that was helpful and easily understood. Here, a distinct shift in the importance placed on theory versus working geography was shown. For the universities to maintain their government-granted land, geography, among other disciplines, had to prove its usefulness to society.

Although the field continued to grow in popularity over time, it was not until 1965 that an official definition for the term *applied geography* was created. A committee of professional geographers interested in applied geography was assembled under the name Committee on Applied Geography, and the definition they created reads as follows: "The application of geographical knowledge, methods, techniques, and ways of thinking to the solution of practical problems" (*Association Affairs*, 1996, p. 168).

Under the impetus of job cutbacks and program cuts at universities during the 1980s, the need for a clear application of programs traditionally centered in theory became apparent yet again. Professors who once simply taught geography began redefining their curriculum in applied geography terms, such as environmentalism, to make their jobs seem less dispensable. It was

during the 1980s that much of the current controversy emerged within the field, perhaps as a result of the shortage of jobs in academia during this period.

Past arguments show that applied geography was treated with some suspicion and uncertainty by academia. There was concern within the field that teaching a skills-based curriculum in addition to theory would cause a loss of prestige, a devaluation of theory, brain drain within the field, and a shortage of planning jobs. In a skills-based curriculum, students would be taught marketable skills and quantitative methodology that are not unique to geography and can be learned outside of the discipline, which would cause geography to become useless. Along with this was the fear that if students were being taught solely skills-based courses, the most successful students would try to find employment outside of academia in the hope of earning a higher salary. This trend would cause some of the best researchers, who could theoretically make great contributions to the field, to leave, thus creating a brain-drain effect.

For proponents of applied geography, a shift in focus from theory to skills allowed for more options for students, professors, and planners. For students who are not academia-bound, the chance to take courses that teach particular skills would increase the number of employment options they have after graduation.

However, setting the debate aside, geography has always been applied, long before applied geography became an identified academic discipline. Since the discipline of geography was established, individuals have used their knowledge in a variety of contexts and for various types of clients. Outside the universities, some of those trained as geographers have applied their skills to solve a range of problems, including, but not limited to, the following areas: locational analysis for retail or industrial site location; selecting sites for public services; identifying environmental problems and creating public policy to deal with such problems; selecting appropriate sites for solid waste disposal facilities; modeling the least-cost paths for transportation; identifying natural and environmental hazards; making military decisions; addressing issues in climatology; and allocation of resources. Understanding and resolving these types of problems are at the core of applied geography.



Applied geographers have careers in areas such as resource management; land use planning; remote sensing; geodemographics; retail analysis; site planning; town and city planning; international trade; the military; local, federal, and state governments; and geographic information systems (GIS) applications, just to name a few. It is this last field that has caused a resurgence in the popularity of applied geography. GIS turn geographic data into maps and decision-making tools by creating large databases of geographic information that enable geographers to store, manipulate, map, and analyze spatial data to solve a multitude of environmental, economic, urban, recreational, and social problems. Although this field is seen as a new frontier in the geographic discipline, it can also be seen as a modern type of applied geography. Although there is debate over the appropriateness and place of applied geography within the strata of university and occupational systems, most authors within the field agree that the future looks hopeful, especially with the popularity of GIS in solving real-world problems.

Sonya Glavac

See also **Business Geography; Geographic Information Systems; Geospatial Industry; GIS in Environmental Management; GIS in Land Use Management; GIS in Public Policy; GIS in Transportation; GIS in Urban Planning; GIS in Utilities; Location Theory; Models and Modeling**

Further Readings

- Bennett, D., & Patton, J. (2007). *Applied human geography*. New York: Kendall/Hunt.
- Ford, L. (1982). Beware of new geographies. *The Professional Geographer*, 34(2), 131–135.
- Keltie, J. S. (1908). *Applied geography: A preliminary sketch* (Rev. ed.). London: G. Philip.
- Ludwig, G. (1984). Extension geography: Applied geography in action. *The Professional Geographer*, 36, 236–238.
- Moorlag, S. (1983). Applied geography and new geographies. *The Professional Geographer*, 35(1), 88–89.
- Pacione, M. (1999). *Applied geography*. London: Routledge.



APPROPRIATE TECHNOLOGY

See Sustainable Development; Sustainable Development Alternatives; Sustainable Production



AQUACULTURE

Aquaculture is the controlled and/or targeted cultivation of specific freshwater or marine species by humans. An activity often likened to agriculture, aquaculture involves selecting a species for cultivation either because of market demand or subsistence requirements and because it displays traits amenable to highly successful reproduction or growth under regulated environmental conditions. Intensification in aquaculture has generally increased over time and currently varies depending on the aquaculturists' desired level of capital investment and scale of production. Aquaculture should be considered as an umbrella term that encompasses a variety of marine and freshwater culture activities such as captive grow-outs, fish farming (including genetic manipulation and embryo rearing/hatching), alga farming, mariculture, aquaponics, and so on.

Alongside resource extraction and food production more generally, seafood production has experienced rapid, and often state-supported, industrialization during the late 20th and early 21st centuries. Market demand for seafood products has also steadily increased during this time. Consequently, there is unprecedented interest in aquaculture, and according to the Food and Agriculture Organization (FAO) of the United Nations, it is currently one of the fastest growing food production sectors in the world. Thus, aquaculture is receiving much regulatory, academic, and corporate attention, and it is a growing research area in both the social and the physical sciences.

Development and Evolution

There seems to be general agreement that the earliest practice of aquaculture began in China



Fisheries in Chios Island, Greece

Source: Iraklis Klampanos/iStockphoto.

between 2000 and 2500 BC. At this time, methods involved holding, feeding, and growing fish in ponds or coastal entrapments until they reached the desired size or other food sources became scarce. However, there are many references to aquaculture activities scattered across ancient and modern history. A small selection of these include marine and freshwater habitat modification by indigenous peoples, capture and experimentation by the Egyptians and the Romans, and the hatching and release of numerous fish species in efforts to repopulate the dwindling recreational fish stocks in North America and Western Europe.

At present, aquaculture for subsistence purposes remains widely practiced, particularly in Asia and Africa. Precise data regarding volumes harvested and species cultured are limited; however, the significance of subsistence-driven aquaculture in these regions is substantial. Concurrently, industrial aquaculture is increasingly lucrative. By

incorporating scientific, technical, and marketing expertise, selected species are bred, reared from embryonic stages, harvested, and then fed into national and international networks of markets. Products commonly cultured currently include salmon, shrimp, trout, carp, tilapia, bivalves, kelp and other aquatic plants, and pearls. Tensions between these two modes of aquaculture stand to increase, especially in cases where they operate in close proximity to one another.

Impacts

In recent decades, aquaculture has been dubbed the “blue revolution,” a direct reference to the “green” revolution of the agricultural sciences in the 1960s. Indeed, it is frequently stated that industrial aquaculture has the potential to increase the economic productivity of coastal or freshwater social-ecological systems, supply protein, and



contribute to national gross domestic products. In addition, it offers an alternative to exhausted wild-harvest fisheries; and, for several reasons, many believe that cultured seafood products are more amenable to high-end seafood markets than is wild seafood. First, because it is reared so carefully, cultured seafood tends to have a more uniform or “appealing” appearance. Second, because of the controlled inputs and known growth and harvest rates, industrial aquaculture makes for a more predictable and steady supply. Third, and related to predictable supply, it is often better positioned than wild fisheries to achieve efficient economies of scale and pass cost savings on to consumers.

Yet concerns about the negative impacts linked to industrial aquaculture abound, particularly in European and North American public policy, academic, and activist circles. Harmful environmental impacts have thus far been the most frequently alleged by such groups, though consensus on their true implications has yet to be reached. Concerns include the introduction of exotic species, pollution/debris, and concentrated levels of feed and excrement into the surrounding environment; interactions between cultured and wild fish, including disease transfer and genetic weakening in wild stocks; and the harvest of smaller fish and crustaceans to manufacture feed for carnivorous fish.

Less frequently cited, though equally important, are a variety of aquaculture’s potential socioeconomic and cultural impacts. These include its interplay with long-standing systems of coastal tenure and potential to alter traditional arrangements for resource management; its contribution to, or conflict with, local food security; its ability to draw high levels of investment into rural communities; its frequent necessitation of new training and job skills, often among workers historically involved in wild fisheries or harvests; and its potential to contribute to resource user–stakeholder tension.

Frontiers in Aquaculture Research

Industry-driven research is focused foremost on improving production efficiencies and marketability and secondarily on reducing aquaculture’s

ecological footprint. Promising avenues for increased efficiencies include new species and product development, including genetic modification; integrated multitrophic aquaculture; and open-ocean/deep-water mariculture. The development of closed-containment and filtration systems, reductions in feed wasting, and plant-based fish feed all provide promising potential to diminish the intensity of industrial aquaculture’s environmental impacts. Interest from academics and development practitioners in aquaculture’s role in rural food security, particularly for less industrialized regions, also continues to grow.

Currently, most geographical research regarding aquaculture focuses on GIS or remote sensing technology for aquaculture siting and/or impact assessment; the social-environmental impacts and appropriateness of industrial aquaculture; and the politics and discourse surrounding aquaculture development, expansion, and siting. However, much space remains for political ecologists, economic and cultural geographers, environmental historians, hydrologists, and biogeographers to contribute to dialogue regarding aquaculture’s range of impacts and future development. Given the weakened state of many key fish stocks, the fluidity of industrial investment and capital, and growing concerns regarding food security, it seems unlikely that interest in either subsistence or industrial aquaculture will diminish.

Jennifer J. Silver

See also [Agrofoods; Environment and Development; Fish Farming; Food and Agriculture Organization \(FAO\); Industrialization; Marine Aquaculture; Sustainable Fisheries](#)

Further Readings

Food and Agriculture Organization of the United Nations. (2007). *World fisheries and aquaculture atlas* (4th ed.) [CD-ROM]. Rome, Italy: Author.

Taylor, W. W., Schechter, M. G., & Wolfson, L. G. (Eds.). (2007). *Globalization: Effects on fisheries resources*. Cambridge, UK: Cambridge University Press.



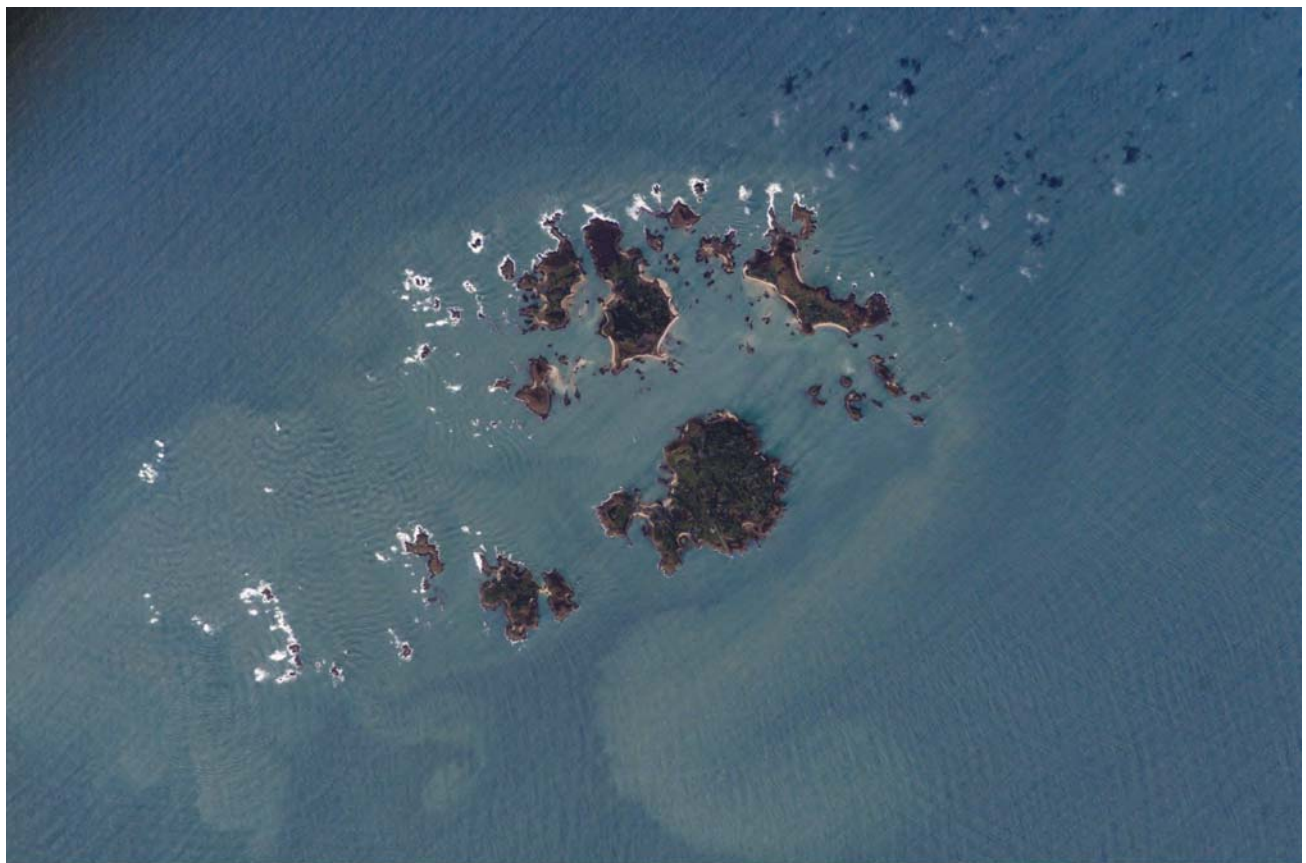
ARCHIPELAGO

The term *archipelago* is most commonly used to refer to a group or chain of islands, although it can also refer to a sea containing a large number of islands. These islands are typically tectonically formed island arcs resulting from volcanoes (e.g., the Galapagos Islands) or hot spots in the lithosphere (e.g., the Hawaiian Islands) but can also form from erosion, deposition, or land elevation. They are usually found in the open ocean, although occasionally archipelagoes are near large landmasses.

The word *archipelago* is ultimately derived from the Greek *arkhon*, meaning chief or ruler, and *pelagos*, meaning sea. The ancient Greek name for the Aegean Sea, which is dotted with small islands, was *Aigaion Pelagos*, which later became simply *Archipelago*. Today, the word is

used more broadly for any group of islands or sea containing many islands.

The largest archipelago in the world by number of islands is the Canadian Arctic Archipelago, with 94 major islands and 36,469 minor islands covering more than 1.4 million km² (square kilometers). The largest archipelago by area is the Malay Archipelago, which includes several nations spanning the distance between southeast Asia and Australia, including approximately 20,000 islands (depending on season and tide) and covering more than 2 million km². The Malay Archipelago encompasses the nations of Indonesia, the Philippines, Singapore, East Timor, Brunei, Malaysia, and Papua New Guinea. Some of these could be considered separate archipelagoes in their own right, particularly the Philippines. Other nations that are primarily archipelagoes include Japan, New Zealand, and the United Kingdom.



The Isles of Scilly, an archipelago of approximately 150 islands, is located some 44 km southwest of the westernmost point of England.

Source: NASA.



Archipelagoes have a unique relevance and usefulness among land formations for the study of evolution. According to island biogeography theory, the size of islands and the distance between them will interact to affect species immigration rates, colonization abilities, and local extinction rates. Their isolation from other systems increases the endemism of resident species (i.e., the likelihood that they are found nowhere else on Earth), and they are often the site of adaptive radiations. In fact, both Charles Darwin and Alfred Russel Wallace developed many features of their groundbreaking hypotheses with regard to natural selection and biogeography by studying archipelagoes—Darwin in the Galapagos, and Wallace in the Malay Archipelago.

Elizabeth R. Congdon

See also **Adaptive Radiation; Island Biogeography; Islands, Small**

Further Readings

Grant, P. R. (Ed.). (1998). *Evolution on islands: Originating from contributions to a discussion meeting of the Royal Society of London*. New York: Oxford University Press.

Wallace, A. R. (2000). *The Malay archipelago: Vols. 1 & 2. The land of the orang-utan, and the bird of paradise. A narrative of travel, with sketches of man and nature*. Berkeley, CA: Periplus Editions. (Original work published 1890)



ARCHITECTURE AND GEOGRAPHY

Geographers have had a long-standing interest in architecture, extending from early studies of the distribution and diffusion of folk-architectural styles in the 1930s to more recent analyses of the cultural and political symbolism, meanings, and uses of buildings and architectural environments.

Folk Architecture and the Vernacular Landscape

Architecture emerged as an important concern of scholars associated with the Berkeley School of cultural geography, most notably Fred Kniffen, in his studies of the distribution and diffusion of folk housing types from the 1930s to the 1960s. Kniffen approached folk houses as important cultural artifacts that could reveal a great deal about settlement and migration patterns in the United States, and he mapped the geographies of particular categories of house and barn in an attempt to identify regional differences in architectural styles and reconstruct historical changes in settlement patterns. Folk housing was approached as one component of the “vernacular” or “everyday” landscape of North America, but this work was not limited to the study of rural buildings or the rural landscape. The prolific landscape writer and editor J. B. Jackson documented diverse, everyday landscapes, including suburban, urban, and roadside architectures and landscapes, and his magazine *Landscape* (first published in 1951) contained contributions from historians, architects, landscape architects, planners, geographers, and others who had a significant influence on geographical writings on architecture and landscape in North America and farther afield.

Architecture, Power, and Cultural Symbolism

Architecture and the built environment have emerged as topics of concern for a broad array of geographers since the 1960s. At times, the planning and political decision making behind the production of the built environment have been of primary interest, but geographers have also shown how architectural environments reflect and refract political aspirations, contexts, and symbolisms in a range of ways. David Harvey famously showed how the Basilica de Sacré-Coeur emerged as a highly contested building project, dividing the Catholic Church, Republicans, politicians, and the Communards in late-19th-century Paris, while in later writings, he examined how shifts from modernism to postmodernism were reflected in changing attitudes and aesthetics in architectural



A luxurious hotel lobby interior. Geographers have examined the complex meanings and cultural-political symbolism of buildings and architectural environments.

Source: iStockphoto/Nikolai Okhitin.

and urban design. In these and other studies, architectural geographies are much more than the geographical distribution of building types, and in a wide array of studies influenced by the cultural turn of the 1980s and 1990s, geographers have examined the complex meanings and cultural-political symbolism of buildings and architectural environments.

Important studies have emerged of the cultural and political symbolism of colonial architecture and imperial cities, skyscrapers, shopping malls, zoos, war memorials, and other structures. Studies have focused on the broader discourses surrounding particular architectural aesthetics and movements, as well as the geographies of individual buildings such as St. Paul's Cathedral in London, the Red Road flats in Glasgow, the Mall of America in Minnesota, the New York World Building, and the Vancouver Public Library.

Geographers have often focused their attention on monumental and spectacular architectural structures, and less attention has been paid to the architectural geographies of more modest, mundane, or "ordinary" buildings, or the work of landscape architects and designers who knit structures into their broader surroundings. Architectural geographies are clearly closely entwined with the geographies of planning, engineering, and landscaping structures, while the start of the 21st century has seen an increasing number of academics calling for a focus on the inhabitation and use of architectural structures.

Inhabiting Architectural Spaces

In 2001, Loretta Lees drew on the emerging body of geographical writings on nonrepresentational



theory and cultures of consumption to suggest that geographers who examined the cultural and political symbolism of buildings and the production of architectural environments frequently overlooked or discounted the multiple and often mundane ways in which users inhabit and consume architectural environments. Earlier studies of consumption in shopping centers by Daniel Miller, Peter Jackson, and others had already shown how consumers inhabited the spaces of the mall or shopping center in ways not foreseen or desired by designers and managers, and Lees was keen to emphasize the role of building users in actively “producing” architectural environments through their consumption practices. Architectural environments are performed and encountered through the embodied movements of a diverse range of human actors, and since Lees’s call for geographers to turn their attention to the affective, performative, and nonrepresentational dimensions of buildings, a number of geographers have begun exploring the embodied geographies of architectural inhabitation.

Mark Llewelyn advanced a polyvocal methodology that could be used to explore the lived experience of a modernist housing estate in London—Kensal House—between the mid 1930s and 1950s. Combining archival research on the visions of architects and planners with oral histories of pioneer residents, Llewelyn constructed a critical geography of the diverse experiences of a utopian modernist housing project, showing how it was not merely “produced” by architects and “consumed” by residents but was continually “reproduced” by users on an ongoing, daily basis. Buildings affect their diverse users in all manner of ways. As Rob Imrie has shown, architects often design buildings to be inhabited by people with “normal” or “standard” bodies, with many architects (unless legislation requires it) neglecting to take account of the embodied capacities and spatialities of different users (including the disabled) who may be affected by a building in different ways.

Architectural geographies have come a long way since studies of the distribution and diffusion of building types in the 1930s. Geographers have engaged with the writings of architectural historians and architectural and urban theorists, tracing the spectacular *and* mundane, symbolic

and affective geographies of buildings and the people and things inhabiting them.

Peter Merriman

See also **Art and Geography; Berkeley School; Cultural Landscape; Jackson, John Brinckerhoff; Landscape Architecture; Symbolism and Place; Urban Planning and Geography; Zoning**

Further Readings

- Goss, J. (1988). The built environment and social theory: Towards an architectural geography. *The Professional Geographer*, 40, 392–403.
- Jacobs, J. M. (2006). A geography of big things. *Cultural Geographies*, 13, 1–27.
- Kraftl, P., & Adey, P. (2008). Architecture/affect/inhabitation: Geographies of being-in buildings. *Annals of the Association of American Geographers*, 98, 213–231.
- Lees, L. (2001). Towards a critical geography of architecture: The case of an ersatz colosseum. *Ecumene*, 8, 51–86.



ARGUMENTATION MAPS

Argumentation maps were proposed to facilitate participatory planning using Internet geographic information systems (GIS) technology. Argumentation mapping combines online discussion forums with online mapping to enable participants in discussions to provide explicit geographic references for their contributions. The concept draws on principles of geospatial data modeling and participatory GIS and poses new challenges for geographic information science. This entry describes the basic idea and conceptual model of argumentation maps, their multidisciplinary origin, and their potential applications.

The argumentation map concept combines elements from geographic data modeling and argumentation theory. Geographic data modeling defines various approaches for representing spatial phenomena, including the vector and the raster data models. Argumentation theory is concerned with formal modeling of human discourse.



Combining these two foundations, argumentation maps describe relations between geographic objects and argumentation elements. On the map side, geographic objects are being used as reference objects for contributions to discourses. On the argumentation side, elements of text messages are being linked to those geographic references.

Argumentation maps respond to an observation from participatory planning processes, where participants can be found to refer to different places in their expressed views. Whether in oral statements, written submissions, or online comments, people regularly refer to their home location, neighborhood, and place of work, as well as to the location of planned development projects. The argumentation map model aims at making these implicit linkages more explicit and available for further computer-based processing.

Conversely, argumentation between humans usually involves interconnected expressions of personal opinions, which include direct responses to existing statements as well as references to other contributions. More elaborate argumentation models include issue-based information systems, which use typed argumentation elements. The available types include issues, positions, and arguments that can be placed in predefined relations with each other. The older Toulmin model uses claims, data, warrants, and relationships between these elements to structure human argumentation. The linking of this argumentation logic to geographic objects adds a layer of complexity to the spatial relations between geographic objects. In this respect, argumentation mapping goes beyond map annotation, which adds comments to places on maps but does not connect these annotations themselves.

Related concepts in cartography and geographic information science include hypermaps and geotagging. The common principle is the use of standard geographic references (geographic features, coordinates, geospatial tags) to localize text and multimedia documents. GIS databases are usually not able to handle complex data of this nature. Argumentation tends to be relatively simple (e.g., the question-reply model), but through its above-mentioned internal logical structure, it poses additional demands on the data modeling and analytical functions of participatory GIS tools.

More fundamentally, argumentation mapping benefits from a paradigm shift in computer science that expanded the view of the computer as a data processor to include its function as a medium for human-to-human communication. An argumentation map provides a cartographic representation of a discussion and can be used to explore, query, analyze, and participate in this discussion. Participatory GIS and, more recently, geocollaboration examine the theoretical and practical implications of using computer networks to support collaborative decision making in the geospatial domain.

Within planning, the need for a combined analytic-deliberative approach has been recognized where spatial analysis can be used to model and forecast decision outcomes, while actual decision making is often based on deliberation in groups of stakeholders. Although GIS are powerful tools for the analytic approach, argumentation maps are among the few computer-based, structured approaches to support deliberation.

A number of case studies of using argumentation maps have been conducted by academic researchers. The applications ranged from university campus planning to sustainable neighborhood development and social housing debates. Technologies used for implementation of argumentation maps include the University of Minnesota MapServer, the MySQL database, the Apache Web server with the tomcat Servlet engine, and, more recently, the Google Maps API, as well as custom Java applets and PHP scripts.

Claus Rinner

See also **GIS in Urban Planning; Internet GIS; Multimedia Mapping; Participatory Planning**

Further Readings

- Goodchild, M. F. (1997). Towards a geography of geographic information in a digital world. *Computers, Environment and Urban Systems*, 21(6), 377–391.
- Horn, R. E. (2003). Infrastructure for navigating interdisciplinary debates: Critical decisions for



representing argumentation. In P. A. Kirschner, S. J. Buckingham Shum, & C. S. Carr (Eds.), *Visualizing argumentation: Software tools for collaborative and educational sense-making* (pp. 165–184). London: Springer.

Jankowski, P., & Nyerges, T. (2001). GIS-supported collaborative decision-making: Results of an experiment. *Annals of the Association of American Geographers*, 91(1), 48–70.

MacEachren, A. M. (2001). Cartography and GIS: Extending collaborative tools to support virtual teams. *Progress in Human Geography*, 25(3), 431–444.

Rinner, C. (2001). Argumentation maps: GIS-based discussion support for online planning. *Environment and Planning B: Planning and Design*, 28(6), 847–863.

Sieber, R. (2003). Public participation geographic information systems across borders. *The Canadian Geographer*, 47(1), 50–61.

amount, precipitation in desert regions tends to be sporadic in time and place. When storms do occur, they are often intense, delivering a substantial amount of precipitation over a short time. Although arid lands are typically vegetated, desert plants are specialized to cope with the moisture stress and do not form a continuous cover across the ground surface. With barren ground exposed between individual plants, loose rock and soil particles are easily moved downslope during sudden cloudbursts. As a result, unlike humid regions that have plenty of available moisture, a continuous coverage of vegetation, and a thick surface mantle of fine-grained (small particle size) soil covering the underlying rock, arid landscapes are more sparsely vegetated and are often visually dominated by outcrops of solid rock or loose, coarse-grained (large particle size) sediments. Far from being a wasteland, however, arid environments provide an austere and beautiful, yet fragile, home for a wide variety of specially adapted flora and fauna. In addition, because landforms and rock formations are not hidden under thick vegetation and soils, arid lands offer some of the most spectacular scenery on Earth.



ARID TOPOGRAPHY

One third of Earth's land surface is classified as arid or semiarid, and approximately 15% of the world's population lives in these regions. As population and the demand for resources continue to grow, these sensitive landscapes face intensifying pressures and the threat of greater environmental disturbance. Understanding arid topography—the principal landforms found in arid-region structural settings—and the major geomorphic (landforming) processes operating in arid lands is fundamental to limiting disturbance and minimizing hazards in these areas. Weathered rock, crusts and pavements, slope failures, desert streams, desert piedmonts, desert lakes, and landforms made by the wind are all influenced by the limited moisture availability in deserts.

Arid-Region Physical Geography

The terrain in arid climate regions has a distinctive appearance that can be attributed to the nature of the precipitation that falls in those landscapes. In addition to being low in average annual

Structural Setting

Volcanic and tectonic processes originate inside the Earth. Over geologic time, these processes have subjected Earth's surface to local and regional accumulations of volcanic rock and to various stresses, leading to the formation of mountains, basins, ridges, valleys, and plateaus. In many arid regions, these elements of geologic structure are well exposed and easy to identify. They form the large-scale relief features that the geomorphic processes originating on Earth's surface modify by breaking down rock (weathering), by eroding weathered rock materials from highlands, and by depositing those materials in lowlands.

Two generalized contrasting styles of arid-region topography are recognized, although they are best considered end members of a range of possible types. Mountain and basin deserts are those that retain considerable relief in the form of tectonically generated alternating uplands and depressions (see photo). This topography is created by a succession of uplifted and down-dropped fault blocks or large-scale upfolds and downfolds.



Upland, piedmont, and basin floor in a mountain and basin desert of active tectonism, Western Utah

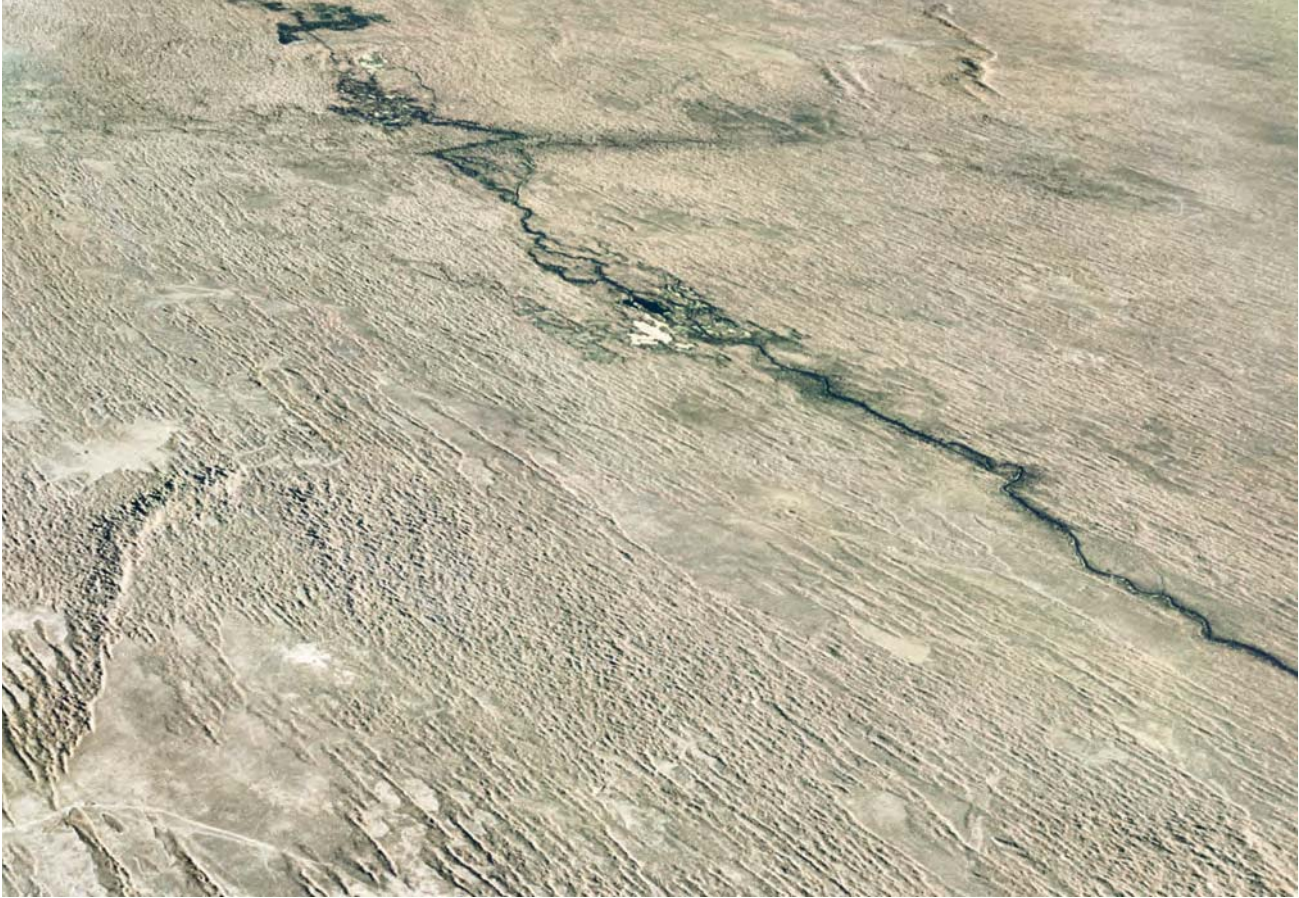
Source: Author.

The second general topographic style is marked by wide expanses of low relief, which is typical of large structural plateaus or tectonically stable continental shield locations. The Basin and Range physiographic province of Western North America exemplifies the mountain and basin desert setting; the Sahara in North Africa represents the shield and platform category. Most desert landforms are found in each of these structural settings, but some geomorphic features are especially well developed, or occur in distinctive associations, in mountain and basin or shield and platform deserts. Other differences exist within various mountain and basin deserts depending on whether or not the relief-building tectonic processes are still active.

Geologically, desert areas of tectonically active mountain and basin topography continue to undergo uplift of the highlands and depression of the lowlands. Streams transport eroded rock

material from the mountains and deliver it to the adjacent basin. However, because the ranges continue to be uplifted and the basins lowered through tectonic activity, the mountain ranges stay high despite erosion, and the depressions remain low despite considerable sedimentation. In an arid climate in this tectonic setting, the amount of surface water that accumulates on the floor of the topographic basin is not sufficient to spill over the drainage divide. Most tectonically active mountain and basin deserts, therefore, consist of closed basins of interior drainage.

If tectonism in mountain and basin deserts has become inactive, erosion of the uplands and sedimentation in the intervening basin will eventually decrease the overall relief by lowering the highlands and raising the basin floor. If sedimentation raises the level of the basin floor to the lowest point on the drainage divide, surface water will flow over the divide, creating a stream channel



Extensive arid region of low relief, dominated by deflated areas and linear sand dunes in Turkmenistan

Source: Author.

that will begin to convey water and an accompanying load of sediment out of the basin. If the outflowing stream connects to a drainage system that ultimately reaches the ocean, it will have achieved exterior drainage.

Dominated by broad expanses of low relief, shield and platform deserts have the most extensive systems of wind-created landforms on Earth (see photo). Other features in this setting include isolated knobs and ridges of resistant rock, uplifted plateaus, lava flows, active and relict stream channels, shallow lakes, and extensive gravel-strewn plains.

Weathering, Varnish, and Crusts

In arid lands, the same chemical and physical weathering processes that break down rocks into ions and sediments in other climate regions operate.

Because of the high removal rates of weathered products from arid-land slopes, exposed desert rocks commonly display visible evidence of chemical and physical weathering, including cracks, fractures, flaking, exfoliating layers, microchannels (rillen), loss of mineral grains, holes and recesses (tafoni), pedestals, and iron oxide deposits. Alternatively, some rocks that remain exposed and stable for long periods in the alkaline desert environment acquire dark coatings of rock varnish, which are atmospherically derived iron- and manganese-rich substances concentrated on the rock surface by microorganisms. Likewise, some stable areas of sediment and soil acquire substantial deposits of chemical precipitates in the void spaces between particles. These deposits may reach the surface and form hard surface crusts, or duricrusts. These substances accumulate when soil water or ground water evaporates through the



surface to the atmosphere, leaving behind salts that were dissolved in the water. Crusts develop from calcium carbonate (calcrete), calcium sulfate (gypcrete), iron compounds (ferrecrete), or silica compounds (silcrete).

Desert Pavement

Desert pavement consists of a surface layer of close-fitting stones that overlies a zone of much finer sediment, which in many cases is completely stone free. Varnish often forms on the exposed stone surfaces. Several explanations for desert pavement have been suggested. Some argue that the concentration of surface stones proceeds by wind and/or water removing surface fines from a deposit that originally consisted of a mix of gravel and fine-grained sediment. In these cases, the pavement represents a lag of clasts that were too heavy to be moved by the wind or water. Another explanation involves heaving processes in soils with expansive clays. The small cracks that form in the soil when the clays contract on drying allow only fine-grained sediments to fall to lower positions, not the gravel clasts, which over time become concentrated at the surface. Others have suggested that weathering rates may be higher within the soil than at the ground surface, leading to an accumulation of fine-grained products of weathering beneath the surface. Evidence from the American Southwest has demonstrated that desert pavement can also form from deposition of fines brought in as wind-blown dust, which sifts beneath larger stones. Thus, desert pavement represents an example of equifinality, with different processes working alone or in combinations to produce the same end product.

Mass Wasting

Desert hillslopes commonly have an angular appearance, with gentler ramps composed of weaker rocks and steeper cliffs representing rocks that are more resistant to weathering and erosion. When the force of gravity pulling down on cliff or slope material exceeds the forces binding that material to the upland, the rock matter moves downslope in a process called mass wasting. Mass wasting can occur in any environment and in many ways, ranging from a single rock falling off

a cliff to the catastrophic failure of an entire hillside. Common types of mass wasting affecting arid-land slopes are rockfall, rockslide, and debris flows. Rockfall involves a small or large mass of rock that breaks off from a cliff and falls freely through air before crashing down onto a flatter surface below. Evidence of rockfall consists of a steep slope of broken, angular rock pieces piled up at the base of the cliff. Rockslides occur when tilted rock strata fail and move downslope in continuous contact with stationary rock strata below. Debris flows often begin as rockfalls or rockslides triggered by intense precipitation that moves the chaotic jumble of poorly sorted broken rock fragments into and down canyon stream channels toward the mountain front. Tongue-shaped (lobate) masses of debris-flow sediments are commonly deposited on the more gentle slopes beyond the mountain front, where the flowing mass spills out of the channel.

Surface Runoff and Desert Streams

When precipitation occurs, some water enters the voids between soil particles at the ground surface. With little vegetation to delay delivery of the precipitation to the surface, the voids in arid-land soils fill with water quickly, rapidly instigating overland flow as unconcentrated sheet wash. Because of gravity, sheet wash preferentially flows toward low points, and it soon starts to concentrate in small channels. Small channels direct the flow to larger channels in a stream network.

Most streams in arid climates are ephemeral, flowing only during and shortly after precipitation events. When precipitation falls, these ephemeral channels, also known as washes or wadis, can conduct sudden flows of significant amounts of water. In the American Southwest, steep-walled, ephemeral gullies known as arroyos are created when there is disequilibrium in the natural system. Arroyos commonly develop because of changes in vegetation and runoff resulting from various human-induced alterations of the landscape, such as overgrazing.

Unlike most humid-region stream channels, which receive water directly into the channel sides and bottom from the subsurface, most arid-region streams lose water to the subsurface by seepage into the gravelly channel bed as well as to the



atmosphere by evaporation. Channel systems in some arid regions, such as those with hyperarid climates or active relief-building tectonics, do not reach the ocean, like most humid-region stream systems. Instead of having that exterior drainage to the sea, desert drainage systems of interior drainage terminate in a regional basin low point, which often contains a terminal lake (without outflow), such as Great Salt Lake in Utah or Lake Eyre in Australia. A few major rivers, such as the Nile and Colorado rivers, have enough water to flow all year across the desert and reach the ocean. These externally drained, exotic streams arise in distant regions of humid climate that provide sufficient water for the rivers to survive to the ocean despite high infiltration and evaporation losses when crossing the desert.

Badlands

Badlands develop in areas of very easily eroded rocks, such as shale, or geologically recent sediments, including ancient lakebeds. Rapid erosion rates make it difficult for vegetation, with its stabilizing influence, to become established, or to become reestablished once the plant cover is breached. The signature characteristic of badlands is that they are intensely channelized, leaving the terrain difficult to traverse. Areas of badlands have the highest drainage densities (total length of all channel segments per unit area) in the world. Although surface runoff dominates in most badlands, some badlands also exhibit considerable evidence of diversion of flowing water into shallow subsurface conduits, a process known as piping.

Desert Piedmonts

Adjacent basins and ranges comprise the principal geologic structural components of mountain and basin deserts, but not the only landforms. Geomorphic processes originating at Earth's surface modify the internally driven structural elements by weathering, erosion, transportation, and deposition. A major landscape element formed by surface processes in these desert settings is the piedmont, a transition zone between the steeply sloping mountain front of the upland and the near-horizontal surface of the basin.

Piedmonts constitute a zone of intermediate slope that links the upland and basin subsystems. The nature of this transition zone differs between mountain and basin deserts of active versus those of stable tectonism.

Alluvial Fans

In tectonically active mountain and basin deserts, continued uplift means that upland precipitation remains comparatively high and slopes steep. Under these conditions, mass wasting and surface runoff persist in delivering considerable sediment to upland stream channels. When stream flows or debris flows occur, they mobilize this sediment and transport it down-canyon. Just beyond the mountain-front canyon mouth, where stream channels are no longer as constrained by side slopes, channel widening leads to a decrease in flow velocity and therefore sediment deposition. Coarsest sediment is deposited first nearest the mountain front, with finer particles deposited farther out into the basin. During subsequent flow events, the stream changes course beyond the mountain front due to erosion of unstable channel banks or because of blockage of the channel by previous deposits. Debris flows overtop the channel, spread out, and form a lobate deposit. After many flow events, a fan-shaped deposit of stream and/or debris-flow sediments, called an alluvial fan, is constructed. Alluvial fans have their point of origin, the apex, at the canyon mouth and spread out toward the basin. The alluvial-fan surface is intermediate in slope angle between the mountain front and the basin, but its slope gradually decreases with grain size toward the basin floor. Where alluvial fans constructed at the mouths of several adjacent canyons coalesce into a laterally continuous deposit, the resulting landform is known as a bajada.

Pediments

In mountain and basin deserts of stable tectonism, external drainage transports products of upland erosion out of the local area. Little sediment accumulating in the piedmont zone and transportation of sediment across it create the pediment, an erosional piedmont, instead of a depositional one. Like alluvial fans and bajadas, pediments slope from the uplands to the lowlands



The Eastern Utah desert. Although arid lands are typically vegetated, desert plants are specialized to cope with the moisture stress and do not form a continuous cover across the ground surface.

Source: John J. Mosesso/NBII.Gov.

at an intermediate angle. Pediments have only a thin layer of surface sediment overlying coherent bedrock. Knobs of resistant rock that project above the relatively planar pediment surface are inselbergs.

Desert Lakes

Basins of topographic closure, in which surface water may accumulate as lakes, ponds, or marshes, form in many ways. Particularly common in arid regions are structural basins created by tectonics and generally smaller depressions formed by wind erosion. The former are common in mountain and basin deserts, the latter in shield and platform deserts. Unlike most humid-region lakes that have outflowing as well as inflowing streams, most desert lakes occupy terminal points in surface drainage; that is, they lack outflowing streams. Water can enter a terminal lake from streams and sheet wash, through direct precipitation onto the lake, and by seepage from groundwater. Water

leaves a terminal lake by evaporation to the atmosphere and by seepage to the subsurface. The Dead Sea in Israel and the Caspian Sea in Central Asia are examples of large terminal lakes that are perennial; that is, they contain water all year.

Terminal lakebeds that contain a shallow water body on an ephemeral or intermittent basis, rather than perennially, are playas. Many arid-region structural basins contain a playa, which occupies the lowest part of the depression. Playas dominated by the inflow of surface water consist of fine-grained sediment (clays and silts) and are very flat and hard. Those dominated by groundwater discharge have a high salt content and often considerable microrelief. Numerous playas likewise exist on extensive wind-blown plains in arid and semiarid settings, such as the U.S. Southern High Plains of Western Texas and Eastern New Mexico, a region that has thousands of small playas.

Many desert basins that are topographically and hydrologically closed today contained permanent lakes during times of greater effective



wetness in the recent geologic past. Evidence of these paleolakes consists of abandoned coastal landforms and lake sediments perched high above the present playa or perennial desert lake. When dated, these relict landforms and sediments provide excellent evidence for reconstructing past climate changes.

Wind Erosion

Wind is the least effective agent of erosion at Earth's surface, but it is capable of landscape modifications, particularly in arid environments with their limited vegetation and available loose sediment. Localized removal of sediment by the wind leaves deflation hollows—depressions in a surface of unconsolidated sediments. Once the wind acquires sediment, it has abrasive tools that can sculpt even solid rock into aerodynamic forms or carve out pits, flutes, and grooves. Wind-abraded stones with planar surfaces that meet at sharp edges are called ventifacts; larger wind-sculpted, aerodynamic ridges of rock or consolidated sediments are yardangs.

Sand Dunes

Sand dunes constitute some of the most beautiful scenery in arid regions. Although sheets of wind-deposited sand exist, the wind typically deposits sand in distinctive mounds or hills. Most sand dunes have one side, known as the slip face, which is steeper than its other sides. Dune shape and the location of the slip face reflect details of the sediment supply and wind regime. Major categories of dune types include those formed in association with obstacles, those with slip faces oriented perpendicular to the sand-transporting wind, and those elongated parallel to the sand-transporting wind. Where multiple individual dunes cluster together, they comprise a sand dune field. Huge sand seas, or ergs, of repeating dunes are best developed in shield and platform deserts, particularly those (such as the Sahara in North Africa and the deserts of interior Australia) that are influenced by the subtropical high-pressure zone along the Tropic of Cancer and the Tropic of Capricorn.

Dorothy Sack

See also Basin and Range Topography; Climate: Dry; Desert Varnish; Dunes; Environmental Management: Drylands; Mass Wasting; Playas; Rock Weathering; Wind Erosion; Xeriscaping

Further Readings

- Cooke, R., Warren, A., & Goudie, A. (1993). *Desert geomorphology*. London: UCL Press.
- Laity, J. (2008). *Deserts and desert environments*. Chichester, UK: Wiley-Blackwell.
- Lancaster, N. (1995). *Geomorphology of desert dunes*. New York: Routledge.
- Mabbutt, J. A. (1977). *Desert landforms*. Cambridge: MIT Press.
- Parsons, A. J., & Abrahams, A. D. (Eds.). (2009). *Geomorphology of desert environments*. Guildford, UK: Springer.
- Thomas, D. (Ed.). (1998). *Arid zone geomorphology*. Chichester, UK: Wiley.



ARISTOTLE (384–322 BC)

Many of the writings of the enormously influential Greek philosopher and scientist Aristotle (born in Stageira, 384 BC, died in Chalcis, 322 BC) played a fundamental role in the development of the discipline of geography. His geocentric model, which was perfected by Hipparchus and Ptolemy, considered Earth to be immobile at the center of the universe and was held by medieval Christianity as an incontestable truth. It had a huge influence on Western cosmology until the 16th century, when it was replaced by the heliocentric theory supported by Copernicus.

Aristotle believed the universe to be unique and finite and thought that nothing existed outside it. From his point of view, four elements (air, water, earth, and fire) combined to form the planet, while ether was considered to be the fifth element, which does not belong to this world: It is in the cosmos, which makes it immutable and thus differentiates it from Earth, where things continuously change.

Regarding the Earth, Aristotle asserted that its circumference was 400,000 stadia (1 stadion = about 185 meters) and presupposed the existence



of an enormous southern continent that provided a counterweight to the Northern Hemisphere. He called this land *Terra Australis Incognita*, and its discovery was the aim of many explorative missions of the following centuries, such as that of Captain James Cook in 1768. Aristotle had a critical opinion about representing the ecumene (the habitable zone of the world) as a circle, but he deduced the roundness of Earth and the other celestial bodies by observing that other planets cast round shadows during eclipses. To confirm the validity of his theory, he reported that at different latitudes, stars were not seen at the same place in the sky. He was not sure about the existence of what is now called the Dead Sea, he considered the origin of the Danube River to be in the Pyrenees, and he believed the Caucasus to be the highest mountains in the East.

In his *Meteorologica* (*Meteorology*) text, Aristotle observed the distribution of animals and vegetation on Earth's surface and drew the conclusion that it was related to latitude, realizing how the poles and the equator could be considered the least favorable areas for living beings. He also made observations of atmospheric phenomena such as wind, hail, frost, and rainbows, trying to analyze the reason why they occur in certain moments or places. He also explained his ideas about topics such as the origins of the rivers and the salinity of the seas, floods, earthquakes, and astronomical questions such as comets, shooting stars, and the Milky Way.

Susanna Servello

See also **Antipodes**; **Equator**; **Hipparchus**; **Human Geography**; **History of**; **Latitude**; **Poles**; **Ptolemy**

Further Readings

Martin, G. (2005). *All possible worlds. A history of geographical ideas* (4th ed.). New York: Wiley.



ARMSTRONG, MARC (1952–)

Marc P. Armstrong is a geographer who specializes in geographic information science (GIScience)

and has done pioneering work in computational geography.

Armstrong earned degrees in geography from the State University of New York College at Plattsburgh (baccalaureate), the University of North Carolina at Charlotte (master's), and the University of Illinois at Urbana-Champaign (doctorate). He has been a faculty member at the University of Iowa since 1984, rising to the rank of professor in 1998. He has held several academic leadership positions at the university, including continuous service as departmental executive officer of the department of geography since 2000 as well as other appointments, such as administrative fellow in the College of Liberal Arts and Sciences in 2006–2009, interim dean for research in the college in 2006, and interim director of the School of Journalism and Mass Communication, 2007–2009.

Dr. Armstrong's research is in the interdisciplinary area of GIScience. He has published more than 100 academic papers and is also coauthor or coeditor of several monographs. He has served as North American Editor of the *International Journal of Geographical Information Science*, and he now serves as an editorial board member of several journals in the broad area of GIScience.

Dr. Armstrong is known as a pioneer in computational geography, specifically for his contributions to the development of parallel processing methods for geographic problem solving. His approaches span novel problem representations, new methods and algorithms, benchmark evaluations of solution qualities, and a variety of geographic applications. For example, with his collaborators, Armstrong has developed a variety of evolutionary programming approaches to multicriteria spatial decision-making problems that often require evaluation by various stakeholders. Other recent work has investigated how geographic information technologies may be used to compromise personal privacy and how mobile geographic information technologies can improve geographic education.

Shaowen Wang

See also **GIScience**; **Spatial Multicriteria Evaluation**



Further Readings

- Armstrong, M., & Ruggles, A. (2005). Geographic information technologies and personal privacy. *Cartographica*, 40(4), 63–73.
- Armstrong, M., Xiao, N., & Bennett, D. (2003). Using genetic algorithms to create multicriteria class intervals for choropleth maps. *Annals of the Association of American Geographers*, 93(3), 595–623.



ART AND GEOGRAPHY

Geography, visual images, and creative visual representation have long been intertwined. These links may be most long standing and evident in cartography and in the conception and production of maps, which the International Cartographic Association defines as “symbolized images of geographic reality, representing selected features or characteristics, resulting from the creative effort of their authors’ execution of choices, and are designed for use when spatial relationships are of primary relevance.” But the interconnection between geography and art extends well beyond cartography and map design. This relationship can be discussed in terms of landscapes and representation, geography and the production of art, and the role of art in remaking places.

Landscapes and Representation

Geographers have long been interested in studying the visual arts. In particular, geographers have looked at art such as landscape paintings as texts that reveal the influence of particular places on the artists’ work as well as broader themes of climate change, attitudes toward and interactions with nature, and regional and national consciousness. In the 1980s, Stephen Daniels politically interpreted 19th-century English paintings to raise issues of how land is represented, changing social and power relations, and the sense of belonging. Likewise, Cosgrove noted that geographers needed to view landscape as more than an areal concept and to take on the view of artists (i.e., painters, literary writers, poets, and novelists) who explored links between

landscape, perspective, and visual ideology. Recently, geographers influenced by Cosgrove and Daniels have studied disparate art and themes, such as the discourse of antiurbanism in Edward Hopper’s paintings and murals in postapartheid South Africa, which provide insights into changing cultures and places and increasingly present local struggles over place, environment, identity, and history.

Geography and the Production of Art

Cultural geographers such as Donald Meinig and Yi-Fu Tuan have called on geographers to produce works of art. In his article “Geography as an Art,” Meinig noted that although geography has been described as both an art and a science, geography has tenuous links to the humanities. He felt that even much of humanistic geography remained tied to the sciences, with its analytical frameworks used to examine behavior and meaning through art and literature. Consequently, Meinig suggested that geographers become creators of literature and pointed to the few examples where regional geographic interpretations moved into the world of creative literature (i.e., Estry Evans’s *Mourne Country: Landscape and Life in South Down*, William Bunge’s *Fitzgerald: Geography of a Revolution*, and Henry Glassie’s *Passing the Time in Ballymenone*). Meinig suggested that other geographers make the shift from science to emotional, personal statements of art by following the example of sociologist Raymond Williams and his novel *The Country and the City*.

Perhaps in response to Meinig’s charge, geographers have increasingly been involved in the production of creative works. New outlets for publishing geography as an art have surfaced, including *Aether: The Journal of Media Geography*, which explores links between cultural politics, cultural industries, lived experiences, and the imagination, and *You are Here: The Journal of Creative Geography*, which delves into the concept of place through creative works including articles, fiction, poetry, essays, maps, photographs, and artwork.

Remaking Places Through Art

In addition to being produced and used to examine landscapes, art also can be a means for

economically reshaping places. Portrayal of a city through art (e.g., “booster” U.S. Post Office murals supported by the New Deal era’s Works Progress Administration) has been seen as a way to shape its economic future—whether or not those images fit reality. More recently, given the dominance of name brands in shaping consumer behavior, art can help brand cities or regions attract tourists, capital investment, and new residents. Given the substitutability of places, art events and attractions that are a good strategic and cultural fit can help create destination brand winners. According to Nigel Morgan, Annette Pritchard, and Roger Pride, brand winners are places that are rich in emotional meaning, have great conversational value, and create high anticipation for tourists. For art tourism, such destination winners include Santa Fe, New Mexico, with its Native American and U.S. western and southwestern regional art as well as its designation as the first UNESCO Creative City of the United States, and reinvented industrial cities such as Glasgow, Scotland, which, in its branding as “Scotland With Style,” prominently highlights its museums and galleries.

Art as a creative industry can also reshape geography. Recent economic geography literature has linked creative industries such as art with economic development. Richard Florida has argued that urban space should be transformed to draw footloose workers such as artists, engineers, writers, and entertainers. These workers’ talent, or human capital, can help cities build new-economy, high-technology, high-income industries. In addition to being a creative industry, art can attract needed talent to cities. Florida contended that cities that rank high in terms of factors such as coolness (measured by the availability of nightlife and cultural amenities such as art) and diversity, or openness to all people (i.e., racial, ethnic, and sexual minorities, immigrants), will attract the creative workforce they need to



The Dotty Wotty House on Heidelberg Street in Detroit, Michigan. The different dots connote diversity as well as equality.

Source: Permission to use kindly granted by The Heidelberg Project.

thrive in a postindustrial economy. Ann Markusen has stressed the need to disaggregate the fuzzy, creative class notion into its occupational components, as they have different spatial distributions in metropolitan areas, based on political leanings, levels of self-employment, and degrees of being footloose. Relatively footloose artists who gravitate toward central cities can boost regional growth through import-substituting consumption activities for residents, direct export activity, and contribution toward the design, production, and marketing of other products and services. While Florida’s ideas have been simultaneously lauded and critiqued, his emphasis on the need for “cool



The OJ (Obstruction of Justice) House and The Oval Room (depicting the blight the city of Detroit is experiencing and how to clean up the town and its government)

Source: Permission to use kindly granted by The Heidelberg Project.

cities” to attract and keep the creative class has influenced many involved in city, regional, and state planning and economic development.

Art can also literally reshape specific places in a direct, hands-on manner. Through the use of abandoned objects, polka dots, and bright orange paint, urban environmental art projects such as Detroit’s Heidelberg Project and “Detroit. Demolition. Disneyland” (Project Orange) have visually called attention to blight and the flight of people, capital, and jobs. These projects have issued a direct challenge to the status quo. While people might like safe, comfortable art, controversial art may best effect change. Geographers are working with artists and with children, asylum seekers, racial minorities, and so on to develop explicitly political, collaborative art practices involving critical spatial practices to reshape places.

Deborah Che

See also Cosgrove, Denis; Cultural Geography; Cultural Landscape; Popular Culture, Geography and; Representations of Space; Symbolism and Place; Vision and Geography

Further Readings

- Cosgrove, D. (1985). Prospect, perspective and the evolution of the landscape idea. *Transactions of the Institute of British Geographers*, 10(1), 45–62.
- Daniels, S. (1984). Human geography and the art of David Cox. *Landscape Research*, 9(3), 14–19.
- Florida, R. (2002). *The rise of the creative class*. New York: Basic Books.
- International Cartographic Association. (2008, April 21). *ICA mission*. Retrieved June 5, 2008, from <http://cartography.tuwien.ac.at/ica/index.php/TheAssociation/Mission>



Markusen, A. (2006). Urban development and the politics of a creative class: Evidence from a study of artists. *Environment and Planning A*, 38, 1921–1940.

Meinig, D. W. (1983). Geography as an art. *Transactions of the Institute of British Geographers*, 8(3), 314–328.

Morgan, N., Pritchard, A., & Pride, R. (2002). Introduction. In N. Morgan, A. Pritchard, & R. Pride (Eds.), *Destination branding: Creating the unique destination proposition* (pp. 3–10). Oxford, UK: Butterworth Heinemann.



ASIA-PACIFIC ECONOMIC COOPERATION

The Asia-Pacific Economic Cooperation (APEC) forum is a supranational association of Pacific Rim economies whose leaders and other representatives meet with the purpose of improving economic linkages within the region. Australia played a pivotal role in establishing APEC in 1989 at the end of the Cold War to promote economic growth and to strengthen the economies of the region.

APEC was formed against the background of increasingly protectionist sentiment around the world, particularly in the United States and the European Union (EU). APEC was conceived partly as the result of concern that the world could divide into three trading blocs: Asia, the European Union (EU), and the Americas. APEC exemplifies the growing interdependence among Asia-Pacific economies. The heads of government of all APEC members meet annually in a summit that rotates between APEC's member economies.

APEC is not a trade bloc, but it includes other trade blocs such as the Association of South East Asian Nations + 3 (ASEAN's 10 members plus China, Japan, and South Korea); North American Free Trade Agreement signatories (Canada, Mexico, and the United States); and Australia and New Zealand, which have a long-standing Closer Economic Relations (CER) Free Trade Agreement (FTA).

APEC is the largest loosely coupled economic community of its type in the world. It currently has 21 members: Australia, Brunei, Canada, Chile, China, Hong Kong, Indonesia, Japan, South Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, Philippines, Russia, Singapore, Taiwan, Thailand, the United States, and Vietnam (Figure 1).

APEC began as a relatively informal group of government officials, mainly from departments of trade or the equivalent. It claims to be the only intergovernmental group in the world operating on the basis of nonbinding commitments, open dialogue, and equal respect for the views of all participants. APEC's decision making by consensus and the diversity of its membership are sources of strength and weakness.

In contrast with the EU, the World Trade Organization (WTO), and other multilateral trade bodies, APEC does not require treaty obligations of its participants; members make commitments only on a consensual and voluntary basis. Thus, many of APEC's goals are expressed in vague terms that are more practicable for national governments' diplomats to agree on. The vague terms provide diplomats with space to negotiate trade agreements that cannot be covered in WTO treaties. There are benefits of using APEC as a channel for signing such bilateral trade agreements, which otherwise might not be practicable in other forums.

APEC has become a vehicle for promoting the liberalization of trade and investment around the Pacific Rim. This agenda includes promoting FTAs and other forms of practical economic cooperation such as facilitating economic development, the growth of small- and medium-sized enterprises, the mobility of businesspeople, and more equitable participation by women and young people in the labor market.

While APEC countries include approximately 40% of the world's population, they represent approximately 49% of world trade and 55% of world gross domestic product (GDP). APEC represents a dynamic economic region in the world, which has been fuelled especially by the rapid growth rates of China and some other Asia-Pacific economies.

In light of the diversity of its membership, it will not be easy for APEC to achieve an Asia-Pacific



Figure 1 APEC members. The Asia-Pacific Economic Cooperation Forum comprises 21 member states circling the Pacific Ocean.

Source: Map created by Barney Warf.

FTA among all of its members. APEC has been subject to criticism such that it lacks much of a social agenda. The criticisms are especially pointed in comparison with the EU. Another criticism is that at APEC meetings, for members' leaders, a significant amount of the focus appears to be on bilateral side meetings between other members rather than on the APEC agenda itself. Nevertheless, APEC is an important forum and has much potential.

Greg J. Bamber

See also Association of Southeast Asian Nations; European Union; Globalization; Newly Industrializing Countries; Trade; Transnationalism; World Trade Organization (WTO)

Further Readings

Asia-Pacific Economic Cooperation: www.apec.org
Bamber, G. (2005). How is the Asia-Pacific Economic
Cooperation (APEC) forum developing?
Comparative comments on APEC and
employment relations. *Comparative Labor Law &
Policy Journal*, 26(3), 423-444.



ASSOCIATION OF AMERICAN
GEOGRAPHERS

The Association of American Geographers (AAG) is a professional and scholarly association representing educators, researchers, and practitioners in geography. Founded in 1904 as a nonprofit scientific and educational society, its 10,000-plus members today share interests in the theory, methods, and practice of geography. The association is governed by an elected council, which sets the overall policy and appoints an executive director, who manages the affairs of the association, supported by numerous committees and a professional staff. The AAG headquarters is located in Washington, D.C.

The association hosts approximately 7,000 attendees each year at its annual meetings, sponsors international workshops and specialty conferences, and conducts research programs on a wide range of geographical topics. The AAG also publishes some of the world's most distinguished and influential scholarly journals, newsletters, books, and research reports. Publications include its flagship journals, *The Annals of the Association of American Geographers* and *The*



Professional Geographer, and the monthly AAG Newsletter.

Representing a discipline with a strong international perspective, the AAG also supports and recognizes geographers around the globe through its many professional development programs and prestigious grants and awards programs. The AAG outreach network consists of more than 30,000 colleagues worldwide. Scientific research and educational programs are conducted internationally, and scientific exchange and interaction occurs through the AAG's annual meetings, its leading scholarly journals, its newsletters, an extensive network of online interactive media and discussion groups, reciprocal membership programs, and other collaborative activities.

The AAG also sponsors 60 specialty groups, which promote geographic research and discussion on specific regional or topical geographic research areas. AAG specialty groups address a variety of geographic research topics, ranging across human and physical geography, geographic education, and geographical information sciences and technologies. AAG specialty groups are focused on Africa, China, Remote Sensing, Geographic Information Systems and Science, Spatial Analysis and Modeling, Regional Development and Planning, Economic, Urban, and Political Geography, as well as a host of other thematic topics crucial for sustainable development, such as Human Dimensions of Global Change, Climate, Hazards, Biogeography, and many others.

Fostering and conducting geographic research is also a key focus of the association's activities and mission. The AAG designs, develops, manages, and implements special research, education, and outreach projects that advance geography, both within the United States and internationally. The AAG manages several dozen special projects and research programs with approximately \$6 million in annual funding. Many of these initiatives are supported by grants from U.S. government agencies, such as the U.S. Agency for International Development, the National Science Foundation, the Department of Agriculture, the Department of Education, NASA, and others. Research projects often are conducted in partnership with universities or other organizations, including private sector and nonprofit entities as well as international agencies.

As the scientific, societal, and university context within which the discipline of geography continues to evolve, the AAG and the discipline of geography continue to interactively lead, adapt, and evolve in order to sustain and strengthen geography's intellectual and practical contributions to the needs of a rapidly changing world.

Douglas Richardson

See also **American Geographical Society; Institute of British Geographers; Regional Science Association International (RSAI)**

Further Readings

- Association of American Geographers: www.aag.org
 Association of American Geographers. (2009). *Guide to geography programs in the Americas and AAG handbook and directory of geographers* (2008–2009 ed.). Washington, DC: Author.
 James, P., & Martin, G. (1979). *The Association of American Geographers: The first seventy-five years*. Washington, DC: Association of American Geographers.
 Richardson, D., & Solis, P. (2004). Confronted by insurmountable opportunities: Geography in society at the AAG's centennial. *The Professional Geographer*, 56(1), 4–11.



ASSOCIATION OF GEOGRAPHIC INFORMATION LABORATORIES FOR EUROPE

The Association of Geographic Information Laboratories for Europe (AGILE) was established in early 1998 to ensure the continuation of the networking activities that have emerged as a result of the EGIS (Exhibition on Geographical Information Systems) Conferences and the European Science Foundation GISDATA Scientific Programmes. AGILE represents a community committed to promoting academic teaching and state-of-the-art research on advancing GI (geographic information) science. It consists of 96 research laboratories across Europe, counting hundreds of GI researchers, students, and academics (see Table 1).



<i>Country</i>	<i>AGILE Member</i>
Austria	Salzburg Research Forschungsgesellschaft Salzburg University Vienna University of Economics and Business Administration Technical University of Vienna Carinthian Technical Institute
Belgium	Brussels Free University Catholic University of Leuven University of Liege
Bosnia-Herzegovina	Energoinvest
Czech Republic	Masaryk University VSB Technical University
Denmark	Aalborg University University of Copenhagen Danish Forest and Landscape Research Institute Technical University of Denmark National Environmental Research Institute
Finland	Technical Research Centre of Finland Finnish Environment Institute SYKE Finnish Geodetic Institute University of Turku
France	University of Avignon University of Franche-Comté Lab. d'informatique, Université de Marne-la-vallée U.M.R. CEMAGREF-ENGREF Institut Géographique National (IGN-France) Louis Pasteur University CNRS/INSA de Lyon
Germany	Humboldt University HafenCity University Hamburg Leibniz University of Hannover Fraunhofer Institute for Factory Operation and Automation University of Applied Sciences FH Mainz University of Muenster University of the Bundeswehr University of Applied Sciences Oldenburg (FH OOW) University of Osnabrück University of Rostock University of Applied Studies and Research, Hochschule Harz
Greece	NTUA Harokopio University Foundation for Research and Technology-Hellas (FORTH) Aristotle University of Thessaloniki
Hungary	Applied GeoInformatics Laboratory (AGIL) University of West-Hungary
Ireland	University College Cork National University of Ireland
Israel	Tel Aviv University
Italy	Università di Bologna ENEA Università degli Studi di Cagliari



<i>Country</i>	<i>AGILE Member</i>
	Università di Cagliari Università degli Studi di Firenze Joint Research Centre Università di Padova Università di Milano-Bococca Università di Roma la Sapienza Politecnico di Torino
The Netherlands	Free University of Amsterdam Technical University of Delft TNO – STB ITC Van Hall Instituut University of Utrecht Wageningen University and Research Centre
Norway	University of Bergen
Poland	Jagiellonian University Institute of Geodesy and Cartography (IGiK)
Portugal	University of Minho ISEGI/UNL
Romania	Romanian Academy
Serbia	University of Nis
Slovenia	University of Ljubljana Scientific Research Centre of the Slovenian Academy of Sciences and Arts (ZRC SAZU)
Spain	University of Jaume I University of Girona University of Santiago de Compostela Technical University of Madrid University de les Illes Balears University of Zaragoza
Sweden	University of Gävle Linköping University Lulea University of Technology Royal Institute of Technology (KTH) Uppsala University
Switzerland	Swiss Federal Institute of Technology at Lausanne (EPFL) University of Zurich
Turkey	Anadolu University
U.K.	Forestry Commission University of Newcastle University of Nottingham University of Sheffield University of Edinburgh University of Glamorgan City University London University College London

Table 1 AGILE members

Source: Reprinted by permission of the Association of Geographic Information Laboratories for Europe (AGILE).



AGILE also maintains liaison with several organizations through memoranda of understanding, including Bentley Definiens, Environmental Systems Research Institute, Geomatics for Informed Decisions, Intergraph, Open Geospatial Consortium, Partnership for European Environmental Research, and University Consortium for Geographic Information Science.

The association is a registered nonprofit organization in the Netherlands and is coordinated by an eight-person council elected by its members every 4 years. The council meets two times a year, in addition to the association's annual general meeting and conference. Each member of the council holds a portfolio responsibility for various aspects of the organizational structure, dissemination activities, and member initiatives. The council is also supported by a number of external officers.

Mission

The aim of the association is to sustain and promote a vital GI research and education community in Europe by

- enhancing networking and new cooperation within AGILE members,
- promoting cooperation with other national educational research associations in Europe, and
- encouraging initiatives to support a leading research culture committed to open inquiry and improvement of education.

AGILE ensures that the different views and experiences of the GI community are fully represented in discussions on a solid European GI forum by focusing on promoting communication among its members and institutions in Europe, exchanging their know-how in conferences and workshops, and initiating initiatives on GI education, research, mobility, and strategic cooperation.

Annual Conferences

The AGILE conferences are hosted by a member every year. They provide a multidisciplinary forum for an increasingly varied landscape of scientific knowledge production and dissemination

to scientists around the world. The call for papers includes a full-paper submission track of original, unpublished, fundamental scientific research, the results of which are published by Springer Series on Lecture Notes in GeoInformation and Cartography (acceptance rate is usually around 40%). The call for papers also includes an abstract submission track of original scientific and strategic research work for presentation at the conference and published in the AGILE proceedings volume (with ISBN). All proceedings are available at the organization's Web site.

The authors include computer scientists, geographers, geomatic engineers, planners, and GIScience practitioners, just to mention a few. The contributions come from all four corners of Europe, as well as from countries on other continents. There are specific education sessions in the annual AGILE conferences and the biannual European GI Education Seminars, as well as specialist meetings on urgent topics in GI education. The main findings identified from these activities demonstrate the increase of public-private partnerships to pursue GI education toward meeting the needs of the GI sector.

Monica Wachowicz

See also **Geographic Information Systems; GIScience**

Further Readings

Association of Geographic Information Laboratories for Europe: www.agile-online.org



ASSOCIATION OF SOUTHEAST ASIAN NATIONS

An important trend in the global economy since the early 1990s has been the proliferation of regional initiatives among countries. The North American Free Trade Agreement (NAFTA) and the European Union (EU) best illustrate such a trend; however, regionalism among developing countries has also become popular. The Association of Southeast Asian Nations (ASEAN) represents



Figure 1 ASEAN members. ASEAN comprises virtually all countries in southeast Asia.

Source: Association of Southeast Asian Nations. Retrieved June 8, 2008, from www.aseansec.org.

the most advanced regional bloc in Asia (Figure 1). Conceived and formed in 1967, it has grown from 5 to 10 members (Table 1) and developed from an informal to a more formal entity, creating the ASEAN Free Trade Area (AFTA) and ASEAN Regional Forum (ARF) along the way. However, ASEAN has often been compared with the EU or NAFTA with the general observation that it has produced a system of practices that are undergoverned and underinstitutionalized. To understand the nature of ASEAN regionalism, this entry will highlight three themes, namely, (1) the historical context of regional processes in southeast Asia, (2) the ASEAN model of regionalism, and (3) the AFTA.

Historical Context

Unlike NAFTA, the impetus for ASEAN was not rooted in a desire among countries in southeast Asia for increased intraregional trade and investment. Rather, postcolonial southeast Asia in the 1960s was preoccupied with nation building and issues of sovereignty and identity. Galvanized by the outbreak of war in Vietnam, the five original members, Indonesia, Malaysia, Philippines, Singapore, and Thailand, embarked on a model of “relational control” that was effectively driven by concerns of regional security and stability. Such control included the containment of communist expansion from Indochina and the construction



<i>Year</i>	<i>Member</i>
1967	Indonesia, Malaysia, Philippines, Singapore, Thailand
1984	Brunei
1995	Vietnam
1997	Myanmar, Laos
1999	Cambodia

Table 1 Development of the Association of Southeast Asian Nations

Source: Association of Southeast Asian Nations. Retrieved June 8, 2008, from www.aseansec.org.

of an indigenous geopolitical space in the context of ideological competition between the Soviet Union and the United States.

A few attempts to develop regional consciousness and identity had preceded the formation of ASEAN but failed to gain widespread support among the countries. Japan, for example, had pursued a vision of regional co-prosperity in the 1920s by proposing an East and southeast Asian economic bloc. However, its activities in World War II precluded any role for Japanese leadership in the proposed regional initiative. Britain, too, had tried to promote the then Filipino leader Manuel Quezon's pan-Malayan union comprising the Philippines, British Malaysia, and the Dutch East Indies in the 1940s, but with little success.

By the 1960s, however, events were favorable for the formation of ASEAN. First, with the victory of Viet Minh forces in Vietnam in 1954, the United States began to pay greater attention to the region. The seeds of regional cooperation were sown, for instance, when the United States agreed to contribute funds and help establish the Asian Development Bank. Second, the ascension of new leadership under Indonesian President Suharto greatly reduced tensions between two of the original ASEAN members, namely, Malaysia and Indonesia, paving the way for improved regional relations. Third, conflicts in Indochina provided an incentive for increased engagement in regional problems.

However, given the region's tremendous ethnic, religious, economic, and political diversity as well as the fragility of recently acquired sovereignty, postcolonial southeast Asia was faced with the

challenge of forging a regional entity where national identities had hitherto been constructed from the outside. Indeed many of the countries' economic and political links were historically oriented toward Europe, and any decline in southeast Asian/European interactions was promptly replaced by increased economic and security interactions with the United States. Like Japan, South Korea, and Taiwan, some southeast Asian countries began to adopt export promotion policies, and many exports targeted the U.S. market. Table 2 summarizes the economic profiles of ASEAN countries. It shows a tremendous variation in economic development levels and sizes. For example, Singapore has about one-twelfth the population size of Myanmar, but its gross domestic product (GDP) is almost 13 times higher. The export-GDP ratio also confirms that countries such as Singapore and Malaysia are trade oriented. Furthermore, the United States is the top market for many countries here. Strong trans-Pacific interactions may have supported the export-promotion strategies of many southeast Asian countries, but they also pose a problem for the indigenous construction of a regional space, since the region tends to exhibit greater extraregional than intraregional tendencies. What, then, is the nature of ASEAN regionalism?

The ASEAN Model

The logic of regionalism in the West is thought generally to be underscored by several factors, of which two will be highlighted here. First, the EU experience suggests that institution building is an important mechanism for achieving greater integration between member countries. For this reason, institutionalists in the international relations literature view the lack of ASEAN institutional building in the first 30 yrs. (years) of its formation to be an impediment to the development of a regional identity. Central to the institutionalist argument is that the governance of regional space is necessarily supported by a regulatory process that lowers transaction costs. This, in turn, encourages the formation of institutional norms that ensure predictable regional practices. Such norms are further accompanied by legal rules of enforcement, so that the governance of EU space is highly formalized.



<i>Country</i>	<i>Population^a</i> (thousands)	<i>GDP^a</i> (US\$ million)	<i>GDP</i> <i>per Capita^a</i> (US\$)	<i>Exports^b</i> (US\$ million)	<i>Imports^b</i> (US\$ million)	<i>Foreign</i> <i>Direct</i> <i>Investment^b</i> (US\$ million)
Brunei Darussalam	396	12,317	31,076	7,619	1,489	434
Cambodia	14,475	8,662	598	3,514	2,923	483
Indonesia	224,905	431,718	1,920	100,799	61,066	5,556
Laos PDR	5,608	4,128	736	403	588	187
Malaysia	27,174	186,961	6,880	157,226	128,316	6,060
Myanmar	58,605	12,631	216	3,515	2,116	143
Philippines	88,875	146,895	1,653	47,410	51,774	2,345
Singapore	4,589	161,547	35,206	271,608	238,482	24,055
Thailand	65,694	245,702	3,740	121,580	127,108	10,756
Vietnam	85,205	71,292	837	37,034	40,236	2,360

Table 2 Summary of economic statistics among ASEAN countries. Exports and imports are based on merchandise trade.

Source: Association of Southeast Asian Nations. Retrieved June 8, 2008, from www.aseansec.org.

Note: a. 2007, b. 2006.

The constructivist school, however, maintains that norms are socially constructed, and institution building the American or European way fails to account for ASEAN's variegated geography; for example, propinquity has not led to much trade between neighboring countries. Analysis of trade patterns indicates that the Philippines, Thailand, and Indonesia are much more connected to Japan than to their neighbors. Yet economic theory informs us that regional economic blocs tend to arise out of "natural" geography, because lower transportation costs and cognitive distances encourage neighboring countries to trade more with one another than with distant countries. Hence, free trade areas such as NAFTA merely consolidate and formalize the high levels of trade that exist between the neighboring countries of Canada, United States, and Mexico. Second, more than 60% of Europe's trade is intraregional. On the other hand, intraregional trade among ASEAN countries has rarely risen above 30%, and this share even decreased during the 1980s. Unlike the EU or NAFTA, extraregional trade dominates the trading relationships of most southeast Asian countries. Furthermore, a significant share of intra-ASEAN trade is dominated by bilateral trade between Singapore and

Malaysia. Both the constructivist theory of international relations and the economic reality of relatively low intra-ASEAN trade suggest that it is difficult to transfer the experience of North American or European regionalism to southeast Asia.

Furthermore, security concerns were responsible for the creation of ASEAN. ASEAN's secretary general from 1998 to 2002, R. C. Severino, observed that regional supranational governance was generally viewed with suspicion in the 1960s among developing countries. In the case of southeast Asia, the countries were plagued by territorial disputes: They also had little, if any, historical experience of regional cooperation. Indeed, territorial disputes today continue to be adjudicated outside of ASEAN, with, for example, the role of the International Court of Justice in territorial disputes between Malaysia and Indonesia regarding the islands of Sipadan and Ligitan and between Malaysia and Singapore over Pedra Branca.

The "ASEAN way" emerged in response to southeast Asia's overriding concern over sovereignty issues in supranational initiatives. Regional interactions are characterized by informal agreements and diplomacy, consensus building, and



noninterference in members' internal affairs. The ASEAN way of regionalism, however, has seen a mixed record. On the one hand, it has been relatively successful in getting the original five ASEAN members to work toward a united front on the Indochina conflict, specifically by opposing the incursion of Vietnam to Cambodia. This helped pave the way for the eventual membership of countries in Indochina. On the other hand, the isolationist tendencies of Myanmar, along with its poor human rights record (e.g., the country's refusal to accept international aid despite widespread human suffering caused by a destructive cyclone in May 2008), have increased criticism regarding the ineffectiveness of ASEAN's principle of noninterference and its informal institutions to resolve regional problems. On the whole, however, constructivists consider the ASEAN model to be relatively successful and potentially a model of regionalism to emulate for other developing countries. They point to the region's engagement with large and middle powers through the ASEAN Regional Forum (ARF) as evidence of this success. The ARF was established in 1993, and it encourages security dialogues among some 26 participants ranging from countries in the EU, North America, and East Asia to Australia and New Zealand. More recently, in 2007, the 10 ASEAN members also signed the ASEAN Charter, which establishes the institutional framework for the organization, thereby allowing the organization to move toward a more formal means of governance.

ASEAN Free Trade Area

In 1992, ASEAN decided to form a regional free trade agreement, creating Asia's first such entity, AFTA. Despite relatively low levels of intraregional trade, concern about competition from China and India for foreign direct investment (FDI) increased the amenability among members for a more formal means of attracting economic and financial flows back to the region from its northern neighbors. Here again, commentators suggest that the logic of regionalism that underscores the formation of free trade areas played a less important motivation than the fear of FDI diversion from the region to China and India.

AFTA was preceded by other preferential trade arrangements (PTAs) in the 1970s. But like most PTAs among developing countries in that period, low income and development levels did not allow the realization of scale economies that the regional pooling of national markets was expected to bring about. Intraregional trade in ASEAN was around 15% in the 1970s. AFTA was conceived in a climate when both globalization and regionalism converged as multinational companies relocated their production and investment worldwide but often at the scale of the region. Hence, Singapore's then prime minister observed that

unless ASEAN can match the other regions in attractiveness both as a base for investments as well as a market for their products, investments by multinational companies are likely to flow away from our part of the world to the SEM (Single European Market) and NAFTA (North American Free Trade Agreement). If we do not synergise our strengths, ASEAN will risk missing the boat. (Severino, 2006, p. 224)

Right from the start, however, members sought temporary exclusions in various industries from the targeted list for tariff reductions. With the exception of Singapore, most ASEAN countries were pursuing import substitution industrialization that was supported by protectionist policies. Malaysia's national car project is one such example. Furthermore, targets of tariff reductions were pegged at 0% to 5% instead of 0% even for fast-track items. Fast-track items are products whose tariffs were already less than 20% at the time of tariff implementation. Tariff reductions for these items were targeted at 0% to 5% within a period of 5 yrs. The 5% figure arises from the fact that tariffs constitute a source of revenue for some countries; hence, some level of tariff remains important for these countries. In addition, industrial policies that promote specific industries are still popular, so that less developed southeast Asian countries have also been given more time to meet the tariff reduction targets.

Clearly, the above reflects the difficulties of regional governance among developing countries; as ASEAN Secretary General Ong Keng Yong (2003–2007) wrote recently,



Furthermore, in ASEAN, there are no supranational institutions to mandate region-based action. Member countries are still very much their own sovereign power. Regional action on a particular area works only if the national and regional agendas are aligned. Many issues in the social sector are ultimately national responsibilities. (Yong, 2004)

ASEAN's approach is to build institutions only when other arrangements have been exhausted. ASEAN's early development was unique. Uncertainty and confrontation characterized the region even as the grouping was being nurtured.

Nonetheless, AFTA represents the first step toward more formal regulation and institution building, which ASEAN has eschewed for nearly 3 decades. Indeed, many of the original six ASEAN members are already meeting their targets of tariff reductions.

Overall, ASEAN regionalism is a top-down process driven by political elites' concern for national sovereignty. This has resulted in a regional process that has largely resisted institutionalization in the first 3 decades. However, the countries appear to be broadening their regional relationships to include economic affairs and environmental problems, not just security. AFTA thus represents an important expansion of interests toward a broader scope of regional interactions. While this contrasts with the wider participation of EU actors that has seen the engagement of the organization with business, labor, environmental, and civic groups, it is too early to tell just how the recent broadening of the ASEAN agenda will result in regionalism that is more inclusive and that is less narrowly defined.

Jessie P. H. Poon

See also **Globalization; Newly Industrializing Countries; North American Free Trade Agreement (NAFTA); Trade**

Further Readings

Acharya, A. (1997). Ideas, identity, and institution-building: From the "ASEAN way" to the "Asia Pacific way"? *Pacific Review*, 10, 319–346.

Association of Southeast Asian Nations:
www.aseansec.org

Beeson, M. (2005). Rethinking regionalism: Europe and East Asia in comparative historical perspective. *Journal of European Public Policy*, 12, 69–85.

Bowles, P. (1997). ASEAN, AFTA and the "new regionalism." *Pacific Affairs*, 70, 219–233.

Eaton, S., & Stubbs, R. (2006). Is ASEAN powerful? Neo-realist versus constructivist approaches to power in southeast Asia. *Pacific Review*, 19, 135–155.

Moller, K. (1998). Cambodia and Burma: The ASEAN way ends here. *Asian Survey*, 38, 1087–1106.

Poon, J., Sajarattanachote, S., & Bagchi-Sen, S. (2006). The role of US exports in Asia Pacific regionalism. *Political Geography*, 25, 715–734.

Poon, J., Thompson, E., & Kelly, P. (2000). Myth of the triad: Geography of trade and investment blocs. *Transactions of the Institute of British Geographers*, 25, 427–444.

Severino, R. (2006). *Southeast Asia in search of an ASEAN community*. Singapore: Institute of Southeast Asian Studies.

Yong, O. K. (2004, August 18). *Community building in ASEAN's social sector*. In the ASEAN Plenary Session on Civil Society and Regional Cooperation, 31st International Conference, International Council on Social Welfare, Kuala Lumpur, Malaysia. Retrieved August 20, 2009, from www.aseansec.org/16324.htm



ATMOSPHERIC CIRCULATION

Occurring over various time periods and at various geographic scales, atmospheric circulation refers to the mass movement of air and energy through the Earth-atmosphere system. The driving force behind atmospheric circulation is the amount and intensity of solar energy, or *insolation*, which differs according to latitude, season, and hour of day. Topography, unequal land and water distribution, and land surface type also contribute to atmospheric circulation characteristics. In combination with ocean circulation, the



atmosphere is responsible for moving the surplus energy of the low latitudes poleward to counter-balance the energy deficit of higher latitudes.

Atmospheric circulation systems are classified according to their spatial and temporal extent. A direct relationship exists between the size of the atmospheric phenomenon and the timescale involved, with larger (smaller) systems usually enduring for longer (shorter) time periods. There are four major divisions of atmospheric features: planetary scale, synoptic scale, mesoscale, and microscale; sometimes, the planetary and synoptic scales are combined into a single class known as macroscale. However, not all atmospheric phenomena display characteristics exclusive to a single division, as some features may vary considerably in size and duration.

Macroscale Circulation

Planetary scale features are the largest, occurring on spatial scales ranging from 10,000 to 40,000 km (kilometers) (6,000–24,000 mi. [miles]) and with life cycles on the order of weeks to months. These features include three major latitudinal wind and pressure bands encircling the globe in each hemisphere: the convective Hadley cells of the tropics; the Ferrel cells of the midlatitudes, and the polar cells of the high latitudes. The three circulation cells represent an idealized model of the dominant planetary wind motions by means of two major simplifications: (1) a uniform surface (to eliminate complications with differential surface heating) and (2) no seasonal or diurnal insolation changes (i.e., the model assumes solar noon on the equinox so that all latitudes are receiving 12 hrs. [hours] of daylight and the sun is always directly over the equator).

The low latitudes, between approximately 0° and 30° latitude, are governed by the heat-driven Hadley cells, named after the English physicist and meteorologist George Hadley (1685–1768), who first proposed their existence in 1753. Around the equatorial region, warm, humid air ascends from daytime convective heating, often condensing into towering cumulonimbus clouds. These convective thunderstorms release large amounts of latent heat energy that increases the buoyancy of the air and provides the energy to direct the Hadley cell. The ascension of air is

further enhanced by surface convergence of the northeast and southeast trade winds that produce a low-pressure zone known as the *equatorial trough* or *intertropical convergence zone* (ITCZ). Consequently, locations around the ITCZ are associated with high annual precipitation, a marked daily regularity in rainfall, and a tropical wet climate with thick, broadleaf vegetation forests. Tropical rain forests are common around the Congo River basin in Africa, the Amazon River basin in South America, and the South China Sea region of southeast Asia.

Aloft, the upper-level flow of the Hadley cells is characterized by poleward-moving air that cools along the *tropopause* (the boundary between the weather-producing troposphere and the stable stratosphere). As the air propagates farther away from the ITCZ, it loses buoyancy and latent heat energy, and radiational cooling commences. The density of the air increases and begins to sink between 20° and 35° latitude. Since the Coriolis effect increases with increasing latitude, the poleward-moving air is also deflected, forcing the air into a west-east flow. The result is a convergence of air aloft that strengthens the subsidence and increases the surface pressure to produce an elongated subtropical high-pressure belt. Subtropical air is comparatively dry with a relatively low humidity, a by-product of (a) most of the moisture content being liberated near the equator and (b) the further warming of the air by adiabatic compression. Accordingly, the subtropics are often associated with dry conditions and clearer skies and are the site of the largest deserts in the world. The Sahara Desert of Northern Africa, the Atacama Desert of Western South America, the Arabian Desert of the Middle East, and the Great Sandy Desert of Australia are all positioned along this subtropical high-pressure zone.

In the middle latitudes lies the Ferrel cell, a secondary circulation feature arising from the separation of the more-defined Hadley and Polar cells. Named after the American meteorologist William Ferrel (1817–1891), the Ferrel cell is a thermally indirect cell in which cool air rises in the subpolar region around 60° latitude and warm air sinks in the subtropics around 30° latitude. Air diverges from the subtropical high-pressure belt and moves poleward, deflecting into a west-east flow. These prevailing westerlies generally



strengthen with height, reaching their maximum velocities near the tropopause level (around 10–12 km, or 6–7 mi.). Known as jet streams, these high-speed upper tropospheric winds, often in excess of 125 km/hr. or 75 mi./hr., form along a region of sharp thermal contrast and are embedded within the dominant westerly flow of the midlatitudes.

Two principal jet streams exist around the margins of the Ferrel cells, the polar or midlatitude jet stream on the poleward side and the subtropical jet stream on the equatorward side. The polar jet stream occurs alongside the polar front, the major frontal boundary separating air masses of polar origin from those of tropical origin. Frequently, midlatitude cyclones form along the polar front and are propelled eastward by the jet stream. The path of the polar jet stream is typically not linear or continuous but instead meanders northward and southward and may split into separate sections of high-velocity flow. Midlatitude locations are characterized by highly variable weather conditions depending on juxtaposition to the prevailing polar jet (and front). Somewhat slower and less defined than the polar jet, the subtropical jet is characterized by strong midtropospheric temperature contrasts that are most prevalent during the cold season; hence, the subtropical jet is a wintertime phenomenon. Occasionally, the polar and subtropical jet streams will merge, providing upper-level dynamic support for surface midlatitude cyclone development and/or intensification.

In comparison with the Hadley cells, the thermal structure of the high-latitude polar cells is weaker and less understood. Surface air circulation in the high latitudes is governed by the polar easterlies, arising from the Coriolis effect deflection of equatorward-moving air from the polar high-pressure regions. Rising motion occurs along the polar front, thereby establishing a low-pressure belt around 60° latitude. The circulation cell is completed as a portion of the subpolar air aloft is further cooled and subsides near the poles. The polar highs are further sustained by limited insolation (i.e., low sun angle, limited daylight in the cold season, and highly reflective snow-covered surface) and clear nighttime skies that promote radiational cooling.

The three-cell model is a simplified representation of the general atmospheric pressure and wind patterns. In reality, the global atmospheric

circulation patterns diverge from the model in accordance with insolation variability, topography, and land/water contrasts. The uniform zonal patterns of the model are replaced by discontinuous pressure belts or semipermanent cells of high and low pressure that vary seasonally. In the Northern Hemisphere, the Aleutian low in the Gulf of Alaska and the Icelandic low in the northern Atlantic are two such semipermanent pressure cells that bring much storminess to the midlatitudes.

Global atmospheric circulations also include expansive waves thousands of kilometers long encircling the Earth in the upper atmosphere, varying in amplitude to create a series of ridges and troughs (i.e., areas of higher and lower pressure regions). The waves are measured as the distance between the nadir of two successive troughs or the crest of two successive ridges. Longer (shorter) wavelengths with lower (higher) amplitudes indicate a principally zonal (meridional) flow and are associated with more (less) variable weather conditions. In the midlatitudes, these long waves are known as Rossby waves and largely propagate eastward within the prevailing westerly flow, but in rare instances, they have been known to move from east to west in a state known as retrogression. Rossby waves are responsible for transporting warm, subtropical air masses from lower latitudes toward the higher latitudes and cold, polar air masses to lower latitudes, particularly during strong meridional (north-south) flow. Between two and seven Rossby waves encircle the hemispheres at any given time, with three or four waves more typical. The number, length, and strength of Rossby waves vary seasonally, with the cold season displaying longer, fewer wavelengths in the company of strong wind speeds. Shorter-wavelength features (<10,000 km or 6,000 mi.) with comparatively diminished life spans (e.g., synoptic scale systems) often move through Rossby waves quickly in comparison with the overall net-long-wave movement.

Synoptic scale systems have life spans of days to weeks and vary considerably in size, from 100 to 10,000 km wide (60–6,000 mi.), with 2,000 to 3,000 km (1,200–1,800 mi.) being more common. Larger scale synoptic circulation features include anticyclones and cyclones that preside over regions of hundreds to thousands of square



kilometers. Midlatitude cyclones are low-pressure systems that develop along the polar front and have winds converging at their centers, rotating counterclockwise (clockwise) for the Northern (Southern) Hemisphere. The configuration of upper-level Rossby waves is also important in the development and intensification of surface cyclones and anticyclones. Midlatitude cyclones are associated with one or more additional synoptic scale features known as fronts, boundaries separating air masses with different temperature and moisture characteristics. At fronts, warmer, more buoyant air rises over cooler, denser air and initiates widespread cloud cover and likely precipitation development.

The smaller end of the synoptic scale includes tropical storms and hurricanes, though these features sometimes can be rather small and short-lived, bordering on the mesoscale class. Known also as typhoons in the western Pacific and cyclones in the Indian Ocean, mature hurricanes average about 600 km (375 mi.) in diameter but can range in size from a couple of hundred kilometers to around 1,500 km (or 930 mi.). In comparison with midlatitude cyclones, hurricanes are much smaller and more intense, with a steeper pressure gradient, lower central pressure, and stronger surface winds in excess of 33 m/s (meters per second, or 74 mph [miles per hour]).

Tropical cyclones generally form between 5° and 20° latitude during the late warm season when ocean temperatures are 27 °C (80 °F) and the vertical wind shear (changing wind speeds with height) is minimal. Hurricanes will not develop within 5° latitude of the equator, since the Coriolis effect is too weak to initialize surface convergence and rotation. Warm, moist air converges into the low center or eye and is forced upward, producing towering cumulonimbus clouds of intense convective precipitation and very strong winds around the storm center in a region known as the eye wall. Spiral rain bands of clouds and relatively weaker convective activity are located successively outward from the eye. Near the top of the tropical cyclone, the air diverges and transports air away from the storm center, sustaining the inward flow at the surface. Hurricane dissipation occurs when the system (a) travels along cooler sea surface temperatures and loses latent heat energy, (b) encounters the

stronger upper-level westerlies of the middle latitudes, and vertical wind increases, and/or (c) travels across land and friction slows wind speeds, and the system is removed from the primary moisture (and energy) source.

Mesoscale Circulation

Mesoscale circulations occur at scales ranging from approximately 2 to 2,000 km (1–1,200 mi.). Although markedly smaller than macroscale circulations, mesoscale circulations can cause equally intense weather events, such as torrential rain, thunderstorms, and dramatic changes in temperature. Mesoscale circulations include monsoons, sea breeze circulation, and thunderstorms.

The term *monsoon* itself means “season” and refers to the seasonal reversal of periodic sustained winds that establish prolonged periods of wet or dry conditions. Monsoonal circulations occur around the world. Perhaps the best-known example is over India, but other areas that experience monsoonal circulations include Indonesia, China, and northwestern Mexico and the southwestern United States. Monsoons result from movement of macroscale circulation features on a seasonal basis. In India, for example, the sun’s rays intensify in spring as the subsolar point moves into the Northern Hemisphere. This results in strong heating, causing air over the subcontinent to become very warm and buoyant. Cooler but wetter oceanic air begins moving over the subcontinent, creating clouds, showers, and thunderstorms. Orographic lifting by the Himalaya mountains also enhances the rainfall. During the winter monsoon, the process is reversed; maximum heating shifts south of India, and cold, dry air drains southward from Central Asia.

Other regional circulations, such as sea breezes, Santa Ana winds, and sandstorms, while smaller than monsoonal circulations, also can have significant effects on life and property. These circulations are all triggered by large physical features, such as bodies of water, mountains, and deserts.

Sea breezes and lake breezes are found near coastlines. On a clear, sunny day when no major weather systems—such as fronts—are nearby, land surfaces heat more quickly than adjacent bodies of water, because land has a lower specific heat capacity (i.e., the amount of energy required



to raise a substance 1 °C at atmospheric sea level pressure). As the temperature difference increases, colder, more dense air moves ashore, cooling areas near the body of water. After sunset, land cools more quickly than adjacent water and the process reverses, causing a land breeze.

Areas cooled by a sea breeze are separated from warmer air by a sea breeze front, which is merely a mesoscale cold front. Like other fronts, convergence and upward motion are common along the boundary; such motions may trigger clouds, showers, and even thunderstorms. On narrow peninsulas, such as the one comprising the state of Florida, converging sea and lake breeze fronts are responsible for a large percentage of summertime rainfall.

Like bodies of water, mountains also spawn mesoscale winds. On a calm, sunny day, air near the base of a mountain warms more quickly than air above it, leading to unstable conditions, rising air, and clouds. This wind pattern is termed a *valley breeze*. Similar to sea breezes, these breezes are most pronounced during the warmest time of the day (usually late afternoon). At night, the process is reversed, and cold air spills back down into the valleys, causing a mountain breeze, also known as a nocturnal drainage wind.

Katabatic winds are strong downslope winds that are generally more intense than typical mountain breezes. At their strongest, these winds can be as fast as hurricane wind speeds (>33 m/s or 74 mph). Most katabatic winds have location-based names. For example, warm, dry winds that descend the eastern slopes of the Rockies are called chinooks, while similar winds on the eastern slopes of the European Alps and Andes are called foehn winds and zonda winds, respectively. Such winds can increase temperatures 20 °C (or 46 °F) per hour and cause extremely low relative humidities. A similar katabatic wind sometimes blows from east to west into Southern California. This “Santa Ana wind” quickly dries out vegetation and contributes to California’s annual wildfire season. Not all katabatic winds are warm and dry, however. The *bora* (southeastern Europe), *mistral* (Southern France), and *coho* (northwestern United States) all result from very cold air moving downslope. Although this air warms as it descends, it is still much colder than the coastal air that it displaces.

Arid environments also create mesoscale circulations. Dust storms and sandstorms are endemic to most of the world’s subtropical deserts. Perhaps the most spectacular example is the haboob, a virtual wall of dust hundreds of meters high precipitated by thunderstorm outflow. Haboobs are native to areas near the Sahara desert (especially the Sudan) but have also been observed in the southwestern United States and Australia.

A mesoscale circulation that can occur almost anywhere is a thunderstorm. Thunderstorms are deep convection composed of cumulonimbus clouds that extend high into the atmosphere. Most thunderstorms are single cells; these usually last less than an hour and rarely cause severe weather. Thunderstorms also occur in multicellular groups such as linear lines of single cells (often near fronts) or mesoconvective complexes (large nocturnal groups of storms). Unusually large and long-lived thunderstorms are called supercells. Supercells last for hours and can be hundreds of kilometers in size. Identified by their rotating updraft, supercells are usually responsible for exceptional weather reports such as large hail (>5 centimeters) or strong tornadoes.

Microscale Circulation

Small-scale circulations (<2 km or 1 mi. in size) are considered microscale. Most of these are short-lived (typically lasting a few minutes) and nonhazardous—although tornadoes are an obvious exception. Tornadoes are rotating columns of violently rising air spawned by thunderstorms (primarily supercells). Although dramatic in appearance, most are short-lived and responsible for minor damage. Dust devils appear similar to tornadoes but form in a very different environment: clear skies with sunshine. Dust devils occur when air near the ground heats rapidly, rises, and begin to rotate. Most dust devils are too weak to cause any damage whatsoever. Waterspouts are rotating, rising columns of air over water. These form when very cold air moves over a warm body of water, causing great instability in the lower atmosphere. While typically longer-lived than other rotating updrafts, waterspouts usually do not cause widespread destruction. (It is also worth noting that a tornado that moves over water is



called a waterspout, although this is clearly a very different phenomenon.)

Humans are responsible for many microscale circulations as well, such as the channeling effect of wind between tall buildings, small-scale circulations between parking lots and adjacent undeveloped forests or fields, and pollution effects. Although they are often difficult to measure individually, collectively these circulations affect weather. For example, urban areas are associated with significantly warmer temperatures at night, lower net wind speeds, and downwind increases in clouds and precipitation.

Jill S. M. Coleman and David A. Call

See also **Adiabatic Temperature Changes; Air Masses; Anthropogenic Climate Change; Atmospheric Composition and Structure; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure; Atmospheric Variations in Energy; Chinooks/Foehns; Climate Types; Climatology; Coriolis Force; Fronts; Hurricanes, Physical Geography of; Monsoons; Thunderstorms; Tornadoes; Wind**

Further Readings

- Ahrens, C. D. (2009). *Meteorology today* (9th ed.). Belmont, CA: Brooks/Cole.
- Grenci, L. M., & Nese, J. M. (2006). *A world of weather: Fundamentals of meteorology*. Dubuque, IA: Kendall-Hunt.
- McIlveen, J. F. R. (1992). *Fundamentals of weather and climate*. London: Chapman & Hall.
- Rohli, R. V., & Vega, A. J. (2008). *Climatology*. Sudbury, MA: Jones & Bartlett.



ATMOSPHERIC COMPOSITION AND STRUCTURE

Generalizations of the size of Earth's atmosphere compared with its lithography (or the solid part of our planet) liken the gaseous shell surrounding Earth to the skin on an apple. Although many might believe the atmosphere to be uniform in gaseous composition or linear in temperature

change, this gaseous envelope is much more complex, similar to most environmental systems on Earth. In fact, Earth's atmosphere, while technically "thin," is nonuniform and consists of many distinct layers that can be classified according to individual parameters. Such parameters include gaseous composition, temperature (termed as the "thermal structure of the atmosphere"), and differences in ionic charge.

Composition of the Atmosphere

The atmosphere is composed of a mixture of gases and aerosols that, when considered in their elemental states, result in a surprisingly small number of major gases, trace gases, and a number of variable components that can be present depending on the location and conditions. The most important of these atmospheric constituents are the major gases, as their percent by volume of the atmosphere rarely changes from day to day or location to location. Given a random sample of air at sea level (therefore, representative of a 100% gaseous mixture), we can express the relative composition of individual gases and components in the atmosphere by their percentages. The three most prominent gases in the atmosphere, based on a relatively recent composition analysis are (1) nitrogen in its diatomic state (N_2), comprising approximately 78.1% of our air sample; (2) oxygen in its diatomic state (O_2); perhaps the best-known component of the atmosphere due to its respiratory function within the Kingdom Animalia), which comprises approximately 21% of the atmosphere; and (3) the noble gas argon (Ar) in its elemental state, which comprises less than 1% of the atmosphere. If one were to add up a more scientifically precise percent by volume for our sample of dry air by not rounding for simplicity's sake, these three components would comprise approximately 99.964% of all the detectible gases in the air mixture. Therefore, for each breath inhaled by human beings, the vast majority of that air consists of inert diatomic nitrogen and the relatively inert noble gas argon, with less than 21% of the air that we breathe consisting of oxygen. What gases and aerosols then comprise the remaining 0.036%?

The remaining 0.036% is changing in percent by volume at all times due to the dramatic increase



in the fourth most prevalent atmospheric gas, carbon dioxide (CO_2). At the time when careful measurements of the atmosphere were being conducted to determine atmospheric composition, CO_2 comprised nearly the entire 0.036% remaining. However, in recent years, the level of CO_2 in the atmosphere has been increasing both in percent by volume and in the number of molecules of a selected gas per million molecules sampled, known as parts per million or ppm. Expressed in this way, a few years ago, the concentration of CO_2 in the atmosphere was nearly 360 ppm (or almost 0.036%). Today, the concentration of CO_2 in the atmosphere is slightly more than 380 ppm (or a little more than 0.038%), resulting in slightly less of a percent by volume of the three major gases but only by a small fraction of a percent. However, this small fraction of a percent is leading many scientists today to worry about “climate change,” as there are inherent properties associated with the concentration of CO_2 in the atmosphere that affect the temperature of the atmosphere as well.

Occupying the fifth through ninth places on the list of most prevalent atmospheric gases are neon (Ne), helium (He), methane (CH_4), krypton (Kr), and hydrogen (H), respectively. The concentration of hydrogen is so low that expressed as a percent by volume, hydrogen makes up only 0.00005%, or just 0.5 ppm—this means that, on average, it would take a random sample of 2 million molecules present in air to find a single molecule of hydrogen. These figures should make it very clear as to why we refer to these gases (from CO_2 through H) as the trace gases.

Given that a sample of air will contain the gaseous constituents discussed above in approximately the same concentrations as described, it is important to note that accounting for 100% of the elemental gases in air does not equal accounting for 100% of the air mixture itself. In fact, there are other constituents of air that we must consider, and the first of these is water vapor.

Water vapor is nothing more than the gaseous phase of water (H_2O)—however, its concentration on Earth varies depending on weather conditions, the time of day, and even the individual location selected. The percent by volume of water vapor in the air can vary between 1 and 4. If one imagines a dry desert during a scorching summer

afternoon, an impression of dryness and lack of moisture will often be generated. This is not far from reality, wherein high temperatures and the scientific properties of water vapor result in very low humidities reflective of low atmospheric water vapor content. It is important to note that even in such environments, the amount of water vapor in the air is not equal to zero; some water vapor will still be present in the air. On the other hand, consider a rain forest in the Amazon region of Brazil following a torrential summer downpour, and an impression of high humidity, “stickiness,” and of condensation may be generated. Here, atmospheric moisture levels may approach the 4% high end of the spectrum. Similar to CO_2 in the atmosphere, water vapor plays a role in climate change because it is also an effective absorber of energy—resulting in higher temperatures at the surface. This will be discussed in more detail in the next section. It is also of interest to note that the contrails of jet aircraft are formed as water vapor is produced as a by-product of the combustion process in jet engines. This water vapor quickly cools in the cold atmosphere surrounding modern jet aircraft in flight, resulting in the formation of minute ice crystals and, hence, the human-process-generated clouds named contrails. A study of a contrail-less sky conducted in 2001 during the 3 days following the attacks of September 11 (the only lengthy period in modern times in which *all* civilian aircraft were grounded) found that the contrails produced in jet aircraft are actually playing a role in Earth’s climate—resulting in a difference of 3% in temperature changes than would take place without such humanmade clouds.

The atmosphere also contains a variable amount of suspended particulates that may be of solid or liquid consistency. Together, these airborne particulates are known as aerosols. There are many sources for these aerosols as well as different types of aerosols. For example, winds of sufficient intensity moving across the surface of a desert region may pick up the loose dust or clay particles forming the surface of such desert (the heavier sand composed of quartz or other minerals may become airborne during winds of significant force but typically remain within a few meters of the planetary boundary layer). Depending on the actual material hoisted into the



air by these winds (clay vs. dust), these particulates can travel for hundreds or even thousands of miles, riding the air currents that flow ribbon-like throughout Earth's atmosphere. As in this example, the concentration of actual aerosols in a given sample of air is highly dependent on many factors, including prevailing wind direction, wind speed, proximity to urban versus rural areas, and location near a coastline (e.g., salt spray) or power plant (e.g., soot from combustion). Due to the effect of gravity on these particulates, they are more concentrated at ground level and typically reduce in presence as one gains altitude.

Ozone also is present in the atmosphere but at widely differing concentrations. Ozone is the common name for triatomic oxygen, or O_3 . Ozone is present in minuscule amounts in the lower atmosphere (generally less than one part per 100 million) but is found in much higher concentrations in a layer high above Earth's surface called the ozone layer. This layer is present in a thermal layer of the atmosphere called the stratosphere, which exists from about 6 to about 30 mi. (miles) above the surface of the Earth. Ozone, at ground level, acts as a respiratory irritant, and is produced as a by-product of combustion, such as the burning of fossil fuels by automobiles, power plants, and other items of urban infrastructure. Temperature plays a role in the concentration of ozone—therefore, hot summer days in large urban areas exhibit the highest risk of ozone-induced respiratory distress such as asthma attacks, and there is clear evidence of increased emergency room visits for asthma attacks on summer days in which elevated ozone levels have been recorded. Many large cities now issue ozone warnings, advising susceptible individuals to stay indoors on days in which dangerous ground-level ozone limits may be achieved. At the level of the ozone layer, however, high up in the stratosphere, ozone is absolutely vital to life. Here, ozone acts as a shield, protecting the surface of the Earth from deadly ultraviolet (UV) radiation emitted by the sun by incorporating the UV light into a complex, self-sustaining chemical reaction. If the ozone layer were not present, it is likely that most life on Earth would not be able to survive open exposure on a sunny day, including humans. Unfortunately, man-made chemicals called chlorofluorocarbons (CFCs) were used as refrigerants for much of the

20th century, and these chemicals had a tendency to reach stratospheric heights—whereby these CFCs worked to destroy ozone and allow more UV light to strike Earth's surface. The result was a depletion of the ozone layer called the ozone hole. This “hole” in Earth's ozone layer was, and is, concentrated over the South Polar regions (Antarctica) because the chemical reaction that allows CFCs to destroy ozone progresses faster as the temperature of the air drops, and cold, snowy Antarctica has some of the coldest air on the planet. Fortunately, an international agreement was signed in 1987 that called for the abolishment of the use of CFCs due to the destruction of the ozone layer. As a result, the ozone layer is expected to recover to its formerly “normal” size—but only by the middle of the 21st century (a 50-yr. [year] recovery period).

Density of the Atmosphere

Since gravity affects even small molecules of gas just as it does items with larger mass, including people, the density of atmospheric gases is much higher at sea level than it is with even slight altitude increases. In fact, if one climbs to the top of a tall mountain, the amount of oxygen in the air is dramatically decreased, such that one can have difficulty breathing with even minimal exertion! One half of the atmosphere lies below an altitude of 3.5 mi., and the remainder decreases nonlinearly as altitude increases (diagramming this decrease demonstrates a curve with rapid decline in the lowest 50% of the atmosphere, with a slowing rate of decline above approximately 10 mi. in elevation). Therefore, the pressure exerted by all the gases in the atmosphere behaves in this fashion. This rapid decrease in atmospheric density is the reason why many mountain climbers must bring supplemental oxygen canisters to breathe while scaling high peaks and, similarly, why military high-altitude parachutists must wear oxygen tanks to keep from passing out when leaping from airplanes at cruising altitudes.

Thermal Structure of the Atmosphere

The most commonly used parameter in describing the structure of the atmosphere is the thermal



structure. The atmosphere is divided into four primary layers that share similar thermal characteristics. This does not mean that the temperature remains the same within each of these four layers; rather, this thermal homogeneity refers to similar temperature trends within these layers—for instance, temperatures may decrease with increasing altitude in one layer, whereas temperatures may increase with increasing altitude in another layer. The fact that temperatures may actually rise as one gets farther away from the surface of the Earth may come as some surprise for those not familiar with meteorological concepts; however, careful scientific measurements and observations have confirmed that this phenomenon is genuinely reflective of the thermal structure of the atmosphere. On the other hand, some reflection on the meaning of the word “temperature” will be required to fully comprehend the dramatic seesaws in temperature parameters that occur as altitude above the Earth increases.

The lowest thermal layer of the atmosphere is called the troposphere. It extends from the actual surface of the Earth upward to a height of approximately 7.5 mi. when averaged, although it can range from a low of near 5 mi. to a high boundary of approximately 10 mi. in altitude. The troposphere contains the majority of atmospheric gases due to the pull of gravity and a complicated concept called hydrostatic equilibrium—this, then, is the thermal layer in which almost all of Earth’s weather occurs. Although temperatures generally decrease throughout the troposphere, during certain conditions, temperatures can increase slightly with height before resuming their decrease. These small increases in temperature with height in the troposphere layer are called inversions.

At some point above the Earth’s surface, at the top of the troposphere, temperatures stop decreasing with altitude and remain fairly stable. This “pause” in the decrease of temperatures with increasing elevation is known as the tropopause, and it represents the boundary between the troposphere and the next thermal layer of the atmosphere—the stratosphere. Just as the height of the troposphere varies over the Earth’s surface due to climate patterns, so too does the tropopause vary in height.

The stratosphere extends from approximately 7.5 mi. in height (average) to approximately 30 mi.

in height—this is higher than most jet aircraft ever fly! There is very little “weather” in the stratosphere, although occasionally, strong thunderstorms can breach the tropopause and extend into the stratosphere in what are called “overshooting tops.” In the stratosphere, temperatures actually do not decrease with height as in the troposphere. Rather, they remain fairly stable just above the tropopause and then begin increasing with height. In fact, at an altitude of 30 mi. above the Earth, the temperature of the outside air can be as warm as the freezing point of water (32° F), much warmer than the air outside a passenger jet at cruising altitude! This brings up two important questions: (1) Why does the stratosphere get warmer with increasing height? (2) What do we mean when we use the word “temperature”?

As to the first, remember that the ozone layer is located in the stratosphere. In fact, the layer itself is concentrated in the middle of the stratosphere, between 10 and 20 mi. in altitude. The chemical reactions produced between the incoming UV sunlight and the ozone present in the layer produce heat as a by-product. Therefore, this chemical reaction serves to heat up the stratosphere so that temperature trends are essentially opposite to those in the troposphere. Now, as to the second item, *temperature* refers to the atomic motion within an object. At higher temperatures, this atomic motion increases. Therefore, an object with high temperatures exhibits rapid atomic motion, whereas colder objects have less atomic motion. All atomic motion ceases at *absolute zero*, which is -459.67°F —quite cold indeed. Above absolute zero, all objects contain atomic movement or motion. In the atmosphere, then, this means that as temperatures increase, the individual molecules of gas in the air have greater atomic motion and therefore move faster through the air mixture.

At the top of the stratosphere, there is another region of stable temperatures called the stratopause, which represents the boundary between the stratosphere and the next thermal layer, which is called the mesosphere. The mesosphere extends from the top of the stratosphere, approximately 30 mi. in height, to approximately 50 mi. in height, where the mesopause occurs. Temperatures decrease with altitude in the mesosphere, similar to the troposphere, and the lowest temperatures



in the atmosphere occur in this layer (as low as -130°F , on average). At the top of the mesosphere lies the mesopause, a region of stable temperatures with height.

Above the mesopause, at 50 mi. in altitude, the final thermal layer of the atmosphere exists, which is called the thermosphere. Here, the small fraction of atmospheric gas that remains exists between Earth and space, and in fact, the exact boundary between the atmosphere and what we consider to be space is not easy to define. In the thermosphere, there are few gas molecules present in a given volume; however, due to excitation by incoming solar energy, these gas molecules have extremely high temperatures. Approaching the top of the thermosphere at 90-plus mi. in altitude, temperatures can reach above and beyond $1,800^{\circ}\text{F}$. However, because the gas density is so low, it would not feel warm if you were to expose your hand to this environment. In fact, despite temperatures of such magnitude, your hand would likely freeze solid on such exposure, due to the large distance between such individually energetic gas molecules.

Additional Atmospheric Structure Conventions

In addition to the definitions of the composition, density, and thermal structure of the atmosphere, there are additional topics that can address the manner in which the atmosphere is constructed. One is the division of the atmosphere into two separate “shells” depending on the consistency of the atmospheric composition. From the mesopause down to the surface of the Earth, the ratio of gaseous components is fairly consistent, and this “shell” is therefore known as the homosphere. Above the mesopause, individual molecules form stratified layers in the atmosphere, with the heaviest elements at lower elevations and the lighter elements at higher elevations. This other “shell” of the atmosphere is known as the heterosphere, due to this stratification.

The atmosphere also contains a layer of positively charged nitrogen and oxygen ions, which is called the ionosphere. This portion of the atmosphere consists of three layers (D, E, and F), classified on the basis of their ionization properties. The F layer is the only layer to be charged both

day and night; as the sun’s energy sets below the horizon each day, the D and E layers generally lose their charges fairly rapidly. The ionosphere’s unique properties are often used in communications, such as by radio, to allow for extremely long-distance transmission and receiving by “skipping” radio waves off of the D and E layers and therefore extending transmission beyond the curve of the Earth.

Brian H. Bossak

See also **Adiabatic Temperature Changes; Air Masses; Anthropogenic Climate Change; Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure; Atmospheric Variations in Energy; Chinooks/Foehns; Climate Types; Climatology; Coriolis Force; Fronts; Hurricanes, Physical Geography of; Monsoons; Thunderstorms; Tornadoes; Wind**

Further Readings

Lutgens, F. K., & Tarbuck, E. J. (2007). *The atmosphere* (10th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Wallace, J. M., & Hobbs, P. V. (2006). *Atmospheric science* (2nd ed.). London: Elsevier/Academic Press.



ATMOSPHERIC ENERGY TRANSFER

There are two primary energy sources within the atmosphere: heat energy originating from the sun and angular momentum from Earth’s rotation about its axis. While solar irradiance is the primary control on Earth’s surface temperature, angular momentum and its variation over time have a large impact on the state of the climate system on subseasonal timescales.

Much temporal variability exists in both solar output and angular momentum, and to a certain extent the two may be related. But variability in Earth’s angular momentum clearly varies on smaller timescales than solar output. There are



some who believe that variance of only a few watts per square meter is negligible and therefore meaningless. However, one only needs to look at mean temperature time series plots to see just how close the association has been between solar output and temperature over the past 50 yrs. or more. This is not a well-recognized association, often hidden by the focus on global warming as a function of anthropogenic CO_2 increase. Nevertheless, it should always be remembered that solar radiation is the primary climate control.

Heat Energy

Heat energy available at the Earth's surface as a function of solar irradiance tends to converge in the warm season and diverge in the cold season. Variance in the direction of the net flux is due to seasonal and subseasonal temperature gradients.

During the warm season, heat convergence is typically large, with gradients operating both upward into the cooler overlying air and downward toward the cooler soil that lies beneath the surface. While there are many thermal characteristics to consider with respect to the material through which heat flows via conduction, the upward flux of heat (and in many cases water vapor) is usually very strong due to the superadiabatic (where temperature decreases with height at a rate of greater than 10°C per kilometer) nature of the lower planetary boundary layer (PBL).

In general, heat energy is not particularly well transmitted through air, since the molecules are only briefly in contact with one another; however, the ground surface is in immediate and frequent contact with atmospheric molecules in the lower atmosphere. From here the heat is transferred upward or downward in response to an upward- or downward-directed temperature gradient. If the gradient is directed downward, then the heat is transferred back into the surface layer, and if it is upward, then the transfer is accomplished via conduction through the convective boundary layer (CBL). It is at the top of the CBL that the upper boundary of the PBL is found.

As long as the capping inversion at the top of the PBL is not strong (generally less than 2°C), the convection process continues to drive heat upward until a layer of neutral static stability is found. If this does not occur until the air reaches

the upper levels of the troposphere, then deep moist convection (DMC) is the likely result.

Heat is also transferred upward via long-wave radiative flux. In this case, one must remember that Wien's law tells us that the wavelength of emission is inversely related to heat intensity. In cases where the greenhouse gasses of water vapor and ozone are highly concentrated, the upwelling long-wave radiation is rapidly absorbed and counter-radiated in all directions, with some being directed downward toward Earth's surface. For this reason, humid and/or cloudy nights generally result in greater than average overnight low temperatures. This is especially true in cities, where upwelling radiation is contributed by asphalt surfaces and concrete buildings, not to mention heat input from the buildings' mechanical systems. Ozone levels also tend to be much greater in cities due to automobile traffic, which improves the ability of the air to absorb upwelling long-wave radiation.

So there is little doubt that humans are warming local environments as urban sprawl continues to encroach on rural lands. In some cases, for example, morning low temperatures in cities can be 10° to 15° warmer than in rural areas surrounding the same cities. As urbanization overruns climate stations that had been within rural environments for many years, there is a marked increase in the mean temperatures of those stations simply due to the increase in overnight low temperatures.

Heat and Temperature

Temperature and *heat* are not synonymous terms. Heat represents the total molecular motion of a substance, while temperature represents the average speed of the molecules that strike the temperature sensor. It is said that temperature is a proxy for heat; however, temperature in reality represents only the heat intensity for the volume of substance in which the temperature sensor is immersed. Using temperature to estimate heat energy is generally valid within the troposphere, stratosphere, and much of the mesosphere; however, once the thermosphere is reached, temperature is a poor estimate of heat. This is because the molecules at that altitude move very quickly, since they absorb solar radiation directly with no



interference from other molecules, and as a result, the temperature is quite high. However, there are so few molecules that the heat content of the air is small.

Baroclinic Systems

In the middle latitudes, extratropical cyclones are accompanied by frontal systems, and in general, the life cycle of an extratropical cyclone involves the evolution of an occlusion process from the incipient stages of a stationary front. While there are two primary types of extratropical cyclones—the Type A frontal wave cyclone and Type B shortwave cyclone—the Type A cyclone is probably the most common. Type A cyclones begin as thermal advection strengthens along a stationary front, which tightens the pressure gradient and strengthens the wind. As thermal advection continues in response to increasing winds, the temperature gradient tightens and grows vertically into the midlevels. This, in turn, increases the pressure gradient there, and wind speeds also increase. As this process continues to develop upward, the pressure gradient strengthens due to an increasingly sloping pressure surface, and in combination with decreasing density and friction, wind speeds increase to jet streak speeds of more than 35 m/s (meters per second). The jet streaks, due to their accelerations, produce ageostrophic (where there is a vector difference between the real wind and the geostrophic wind) components that generate transverse circulations, so that uplift is found under the left front and right rear quadrants, and subsidence (the descending motion of air in the atmosphere) under the right front and left rear quadrants. While ascent in the left front and right rear quadrants work to increase the pressure gradient and cause the cycle to strengthen even further, subsidence in the right front and left rear quadrants work to weaken the thermal and pressure gradients, and the system begins to weaken, becoming quasi-barotropic (where fronts in the region exist but are weak), with a vertically stacked low-pressure center. This process involves converting potential energy stored within the initial stationary front to the kinetic energy of motion that powers cyclogenesis (i.e., the development and strengthening of a cyclone).

In the case of Type B cyclones, a preexisting shortwave passing through the flow, usually with an accompanying jet streak, initiates cyclogenesis through positive differential vorticity (e.g., clockwise or counterclockwise spin in the troposphere) advection. This increases thermal advection while the cyclone strengthens, resulting in fully developed fronts at the time of occlusion. In other words, while the Type A cyclogenesis represents a “bottom-up” process, a Type B cyclone represents top-down development.

On the other hand, moist deep convection is a thermally direct process by which potential energy, generally building within the PBL due to diabatic heating and thermal and moisture advection, is eventually “released” (i.e., converted from potential to kinetic energy), producing a vertical circulation that forces warm air rapidly upward, where it cools, and cold air rapidly downward, where it warms. This circulation works to minimize the vertical temperature gradient and return the system back to thermal equilibrium.

Global Angular Momentum

The term *angular momentum* simply refers to the speed of a rotating body such as the Earth. Earth’s rotation at the equator is generally considered to exhibit a speed of about 1,040 mi. (1,674.4 km) per hour, while the mean angular velocity of that rotation equals 7.2921150×10^{-5} radians per second.

The physical definition of angular momentum (L) is $L = mvr$, where m = mass, v = speed, and r = radius. Angular momentum is a conserved quantity; that means that it will remain constant unless a torque that is external to the system acts on it.

The term *torque* represents the movement of a force about a point, or the tendency of a force to rotate an object about an axis. In many cases, a torque is considered a “twist.”

The transfer of angular momentum in the lower troposphere is affected by two independent torques: mountain and frictional torque. Mountain torque, referred to as a normal stress, is associated with a difference in pressure between the eastern and western slopes of north-south orographic barriers. In the Northern Hemisphere, these include the Himalayas and the Rocky



Mountains, while the Andes Mountains are the primary barriers in the Southern Hemisphere. When the pressure gradient is oriented east-west, producing an easterly flow, the mountain torque is positive. When the gradient is oriented west-east, it is negative. Positive mountain torque has been shown to have a dominant impact on global angular momentum (GLAM) on short times scales of between 14 and 20 days. Positive mountain torque will increase the GLAM, actually shortening the length of day (LOD), while negative torque will lengthen it (timescales of ≈ 0.1 ms [milliseconds]). It has been shown that the seasonal dependence of mountain torque variance is proportional to the frequency of midlatitude extratropical cyclones near the Himalayas, Rockies, and Andes mountains, where the largest mountain torques occur. Surprisingly, the Andes Mountains torque is more than two times greater than either of the Northern Hemisphere's primary torques.

Frictional torque, on the other hand, is referred to as a tangential stress and becomes much more important than mountain torque on timescales exceeding about 3 wks. (weeks). It is interesting to note, and quite useful operationally to recognize, that global friction torque peaks about 10 days before global mountain torque. The frictional torque, usually at a maximum near 20° N and 20° S, transfers the Earth's angular momentum to the atmosphere in the presence of organized tropical convection to near 30° N and 30° S, which either increases or decreases the wind speed. Significant increases in wind speed produce the subtropical jet, which, unlike the thermally driven polar front jet, is higher in altitude (33,000–52,000 ft. [feet] above ground level) with generally weaker wind speeds.

Pacific friction torques associated with convective activity over the Indian Ocean/Western Pacific warm pool are closely tied to frictional GLAM changes. This is part of the Madden-Julian oscillation (MJO) that begins with organized convective clusters near Africa, which first migrate eastward to the Indo-Pacific warm pool, then out into the central Pacific to near or past the International Dateline. Rossby wave trains originating from the tropical convective clusters migrating eastward across the Pacific on 40- to 60-day (MJO) cycles dictate the midlatitude weather regimes and intra-annual climate

variability. Thus, both heat energy originating from the sun and angular momentum from the Earth's rotation about its axis contribute to the exchange of energy from the equator to the poles that balances the Earth's energy budget.

David L. Arnold

See also **Adiabatic Temperature Changes; Air Masses; Anthropogenic Climate Change; Atmospheric Circulation; Atmospheric Circulation; Atmospheric Composition and Structure; Atmospheric Moisture; Atmospheric Pressure; Atmospheric Variations in Energy; Chinooks/Foehns; Climate Types; Climatology; Coriolis Force; Fronts; Hurricanes, Physical Geography of; Monsoons; Thunderstorms; Tornadoes; Wind**

Further Readings

- Bluestein, H. (1992). *Synoptic-dynamic meteorology in midlatitudes, principles of kinematics and dynamics*. New York: Oxford University Press.
- Horvath, K., Lin, Y., & Ivan an-Picek, B. (2008). Classification of cyclone tracks over the Apennines and the Adriatic Sea. *Monthly Weather Review*, 136, 2210–2227.
- Marshall, J., & Plumb, R. A. (2008). *Atmosphere, ocean, and climate dynamics: An introductory text*. Burlington, MA: Elsevier/Academic Press.
- Weickmann, K. M., & Berry, E. (2009). The tropical Madden-Julian Oscillation and the global wind oscillation. *Monthly Weather Review*, 137, 1601–1614.
- Weickmann, K. M., & Sardeshmukh, P. D. (1994). The atmospheric angular momentum cycle associated with a Madden-Julian Oscillation. *Journal of the Atmospheric Sciences*, 51, 3194–3208.



ATMOSPHERIC MOISTURE

The atmospheric branch of the hydrologic cycle comprises moisture in three forms: (1) water vapor, (2) condensed (liquid) and sublimated (ice) water in clouds, and (3) precipitation (primarily rain and snow). Although radiation and energy budgets are the fundamental basis of physical



geographic processes, by themselves they are insufficient to generate weather and climate: Moisture is essential. Latent heat absorbed when water evaporates at Earth's surface, and released in condensation when clouds form, links the energy and moisture budgets. Moreover, atmospheric moisture modulates the incoming solar (i.e., shortwave, SW) radiation and Earth-emitted long-wave (LW) radiation streams, significantly affecting the surface net radiation (SW + LW) and energy budget. Much like CO₂ (carbon dioxide) and methane, water vapor is a greenhouse gas (GHG): More of it in the atmosphere reduces the surface diurnal temperature range (DTR) by limiting the overnight temperature drop compared with when there is little water vapor. The liquid water comprising most clouds lowers the clear-sky daytime temperature at Earth's surface and helps heat the atmosphere by absorbing SW radiation. Also, thick or multilayered clouds behave like "blackbodies" for LW radiation; they efficiently absorb and reradiate that energy back to Earth's surface, contributing to the natural greenhouse effect and, thereby, reducing the DTR compared with cloud-free skies. Clouds are integrators and tracers of atmospheric moisture and energy (Figure 1), and their large-scale patterns show associations with climatic teleconnections, particularly the El Niño Southern Oscillation (ENSO).

Most clouds exert a negative radiative forcing (i.e., the surface temperature is lower in their presence) because their reduction of the SW radiation received at Earth's surface exceeds their enhancement of the greenhouse effect. Cirrus clouds are the exception: They both transmit SW radiation and enhance the greenhouse effect, for most situations. Precipitation influences the atmospheric energy budget by cooling the air via evaporation.

Compared with Earth's surface and subsurface components of the water budget, atmospheric moisture amounts are very small (<0.05% of all freshwater), and residence times are only on the order of days; yet they are highly significant, participating directly in both weather and climate fluctuations. Considered globally, the dominant surface sources (sinks) of atmospheric moisture are the oceans, especially in the tropics and subtropics (land surfaces, especially in the subtropics

and middle latitudes). Because the atmospheric storage of moisture is negligible, the water budget can be estimated as the difference between evaporation (E) and precipitation (P). Maps of the long-term, annually averaged E-P show maximum positive values (i.e., $E \gg P$) over subtropical oceans, and maximum negative values ($E \ll P$) in the tropics and over middle-latitude oceans and adjacent land areas. Values are weakly negative over polar regions and weakly positive over subtropical land areas and the interior midlatitude deserts. The vertical exchanges of moisture (as E, P) between land surfaces and atmosphere, or "recycling," characterize the tropics all year and middle latitudes in summer. Elsewhere and at other times (e.g., middle latitudes in winter), the quasi-horizontal movement of moisture by the winds (i.e., advection) from warmer and/or moister regions dominates.

Characteristics

Most atmospheric moisture is found within the planetary boundary layer (PBL), or lowermost 1,000 m (meters) or so of the atmosphere, with lesser amounts in the free atmosphere. This arises because of the PBL's proximity to surface moisture in oceans, lakes, rivers, vegetation, and soil and the positive net radiation (SW + LW > 0) required for evaporation. The atmospheric water vapor content is expressed by a number of humidity measures, including the relative humidity (RH, %), specific humidity (q , in grams [g] per kilogram of dry air), absolute humidity (in g/m³ [cubic meter]), vapor pressure (in hPa [hectopascals]), and column-integrated precipitable water (PW, in mm [millimeters] or centimeters). All measures except RH give actual moisture amounts; the RH depends on the air temperature, which determines the maximum amount of water vapor that the air can hold (i.e., saturation). This Clausius-Clapeyron relationship is positive and nonlinear (i.e., warm air holds much more water vapor than cold air). Thus, latitude plots of the annually averaged absolute humidity or specific humidity show a maximum in the tropics and minima at the poles, whereas the relative humidity has two maxima (tropics, middle latitudes) and two minima (subtropics, polar regions). Seasonally, the hemisphere experiencing summer has the highest water vapor

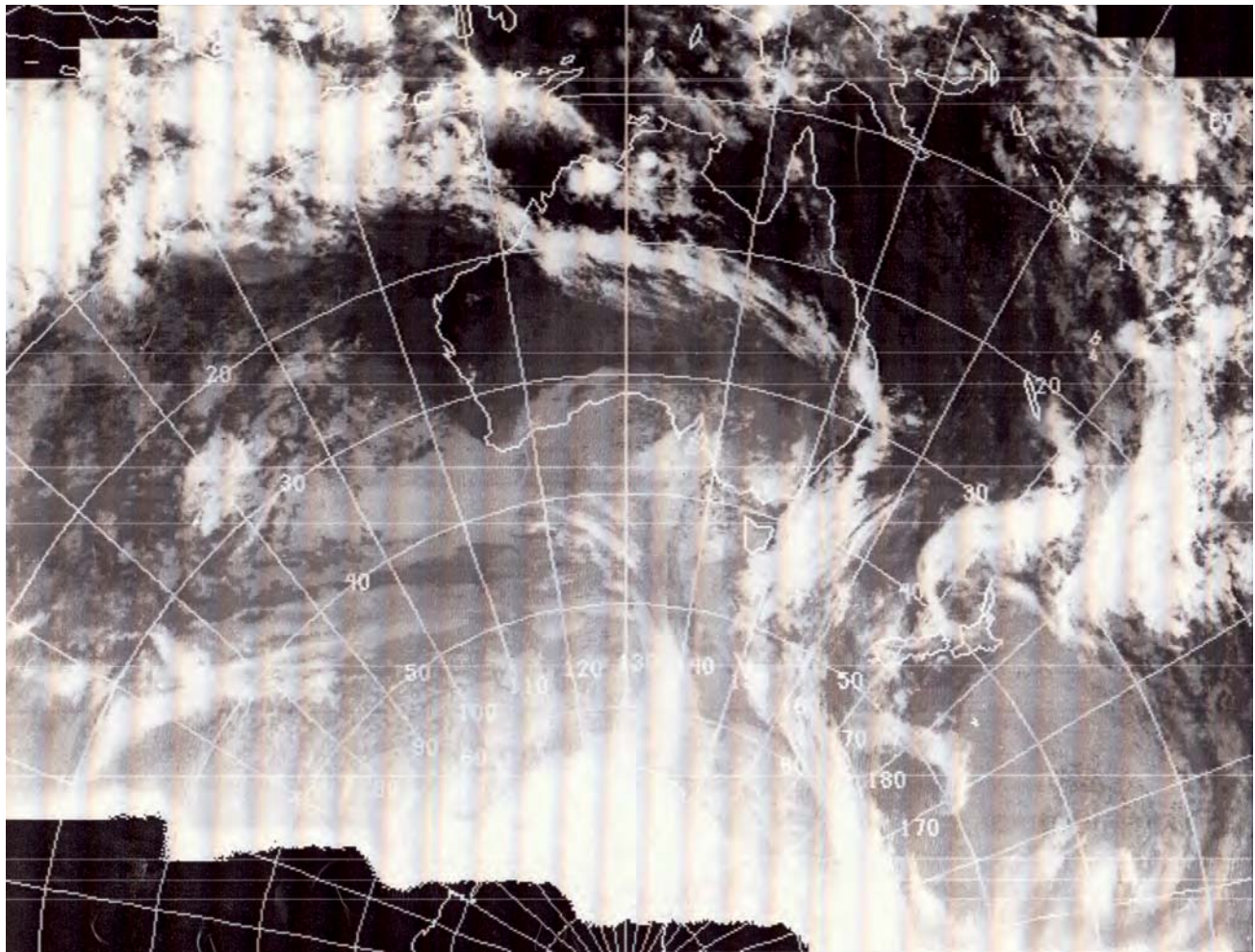


Figure 1 Sample satellite long-wave (LW) (cloud) image of the Australian sector (Geostationary Meteorological Satellite [GMS-5] of the Japanese Meteorological Agency)

Source: Australian Bureau of Meteorology, Melbourne (Peter Boemo).

amounts, because of the higher temperatures. Spatially, the area of greatest atmospheric moisture content is colocated with the “warm pool” of highest sea-surface temperatures (SSTs) in the tropical western Pacific, demonstrating the temperature-evaporation-humidity feedback. Moreover, the relationship between humidity and cloud cover is positive; high humidity in a given atmospheric layer increases the likelihood of clouds forming or persisting there. Indeed, in computer models of weather and climate that do not explicitly predict clouds, simulated high humidity values are a proxy for cloud cover.

The lapse rate of temperature with height increase ($-dT/dZ$) is combined with moisture in measures of the static stability, or the propensity

for air to rise (unstable), sink (stable), or remain at the same level (neutral) after removal of a mechanism that initially displaces air upward (i.e., solar heating of Earth’s surface; orographic uplift). Stability indices denote not only the dominant cloud type (cumuliform or stratiform) but also the probability of severe weather (thunderstorms, hail, tornadoes). Unstable air dominates over land in the warm season, helping move PBL moisture into the free atmosphere via the development of cumuliform (convective) clouds. The convective instability of air is greatest for high surface temperatures, large PBL moisture, and dry air aloft. Stable conditions prevail over cool surfaces (i.e., temperature inversion), the free atmosphere dries because of sinking air, and PBL



clouds are stratiform with any precipitation being light (e.g., drizzle).

Horizontal contrasts in lower-atmosphere humidity occur on a range of scales, from individual fields (e.g., irrigated agriculture adjacent to dryland; forest adjacent to crops), to regional and larger scales. For example, the *dry line* of the Central United States forms when warm, dry air from the plateaus of the southwest deserts overruns moist air from the Gulf of Mexico. The dry line promotes convective instability and severe weather development in the Great Plains. Both humidity and temperature contrasts characterize air-mass fronts. The widespread lifting of warm, moist air along a front, or *slantwise convection*, greatly increases the precipitation efficiency relative to cool air. Particularly in the colder season, moisture incorporated into frontal cyclones can originate within the tropics as deep convection and be carried to subtropical and middle latitudes, and even to polar regions, by the jet streams and fronts as very long yet narrow *tropical-extra-tropical cloud bands* (TECBs), or *moisture bursts* (Figure 1). These features may produce widespread flooding. The climatology of TECBs varies between hemispheres and also according to teleconnections, particularly ENSO.

On synoptic scales in the free atmosphere, spatial variations in water vapor—including RH—and clouds show associations with the vertical motion of air, as follows: (a) ascent, or *uplift*, and moistening within low pressure, and (b) descent, or *subsidence*, and drying in high pressure. Similarly, high clouds accompany rising air on the equatorward side of a jet stream; clear skies or only low clouds occur on the poleward side, owing to subsidence (e.g., over Central Australia in Figure 1).

On hemispheric to global scales, the advection of moisture by the vector wind (V), or *moisture transport* (qV), is a consequence of the atmospheric general circulation's (GC) continual attempt to balance Earth's heat and momentum budgets across latitude zones. On average, moisture is transported poleward everywhere except in the lower atmosphere within the tropics; there, the trade winds originating in the subtropical highs supply moisture to the Intertropic Convergence Zone (ITCZ) of low pressure, realized as deep convection and latent heat release in

the thunderstorm *hot towers* that power the ascending limb of the Hadley cell. The total (i.e., time and space averaged) qV can be separated into its *mean* and *eddy* components, which vary in importance by latitude and also by season. The mean circulation dominates in the tropics all year (Hadley cell), while eddy transport by the planetary waves and traveling high- and low-pressure systems dominates the extratropics, especially in the colder season. In middle latitudes, the moisture transport occurs rapidly along elongated yet narrow *atmospheric rivers*, ranging in size from mesoscale *low-level jets* to TECBs. Calculation of the net movement of moisture into or out of an atmospheric column due to the horizontal wind determines whether moisture flux convergence (i.e., ascending air and moistening) or divergence (subsidence and drying) is occurring. In the PBL, frictional contrasts between major land cover types (e.g., forest adjacent to crops), and along air density boundaries resulting from prior convection, encourages moisture convergence and renewed convection, which may result in precipitation.

Monitoring

Atmospheric moisture is monitored using direct observation and also remotely by satellites and radar. At Earth's surface, temperature, moisture (RH, dew point temperature), and precipitation observations are made at least once daily at manned weather and climate stations; these quantities, along with clouds, are monitored more frequently at higher-order and automatic weather stations. However, site characteristics significantly influence the measurements of temperature and humidity, such as when measurements are taken at a place that differs markedly from a standard grass surface (e.g., adjacent to a parking lot) or when they are taken at a nonstandard height, such as the top of a building, as well as precipitation where gauges are inadequately exposed (e.g., when partially covered by a roof or overhang). Spurious climate changes on local scales can result from these biases. Vertical variations of moisture within and above the PBL, along with temperature, pressure, and winds, are determined twice daily from rawinsondes launched mostly from land stations. Retrieved humidity

values are most reliable in the lower-to-middle troposphere; in the upper troposphere, low temperatures and small moisture amounts can result in substantial errors. Thus, detecting climate changes in moisture at high altitudes using rawinsonde data is problematic.

Although of shorter duration (since 1979), global observations of atmospheric layer-averaged RH and the PW made operationally from satellites are only limited in areas of frequent thick clouds and over ice and snow surfaces. Retrieval of the humidity in cloudfree or only partly cloudy conditions relies on the absorption and reemission of LW radiation by water vapor (thermal infrared [IR] sensing, microwave radiometry); in the midtroposphere (approximately 600- to 400-hPa pressure levels), this reemission of LW radiation peaks around $6.7\text{ }\mu\text{m}$ (micrometers). Determining water vapor amounts in layers closer to Earth's surface—important for prediction of severe weather—uses slightly longer IR wavelengths. Information on atmospheric water vapor is also acquired using global positioning system technology: The electronic signal is delayed as PW increases. Cloud detection in visible wavelength data relies on the increased reflectance of solar radiation to the satellite sensor by clouds over low reflectance Earth surfaces (ocean, snowfree land). To retrieve cloud information on climatically significant attributes such as cloud-top temperature and cloud height (the gray tones in Figure 1), the IR window region ($8\text{--}14\text{ }\mu\text{m}$) is used: The emission from a blackbody radiator decreases with decreasing temperature (Stefan-Boltzmann's law), and cloud temperature typically decreases with increased cloud height (normal lapse rate). Other climatically important cloud attributes, particularly the cloud liquid water content (CLW), rain occurrence and rain rate (mm/hour), and the presence of hail and large

snow aggregates in the upper parts of deep convective clouds, use passive microwave radiometry, notably, the Special Sensor Microwave/Imager (SSM/I): lower frequencies (i.e., longer wavelengths) for CLW and rain; higher frequencies (shorter wavelengths) for ice scattering. Combining spatial information on water vapor with near-surface winds (V)—the latter determined remotely from the wind's effect on a water surface—can depict mesoscale PBL moisture convergence and precipitation (the area near 55°S , 90°W in Figure 2).

High-resolution vertical profiles of cloud types and cloud structure, revealed by CLW, cloud ice content, and precipitation retrievals along a narrow subsatellite track, have been acquired by the cloud profiling radar on NASA's CloudSat for most latitudes since 2006. For cirrus clouds, lidar (light detection and ranging) based at Earth's surface and also satellite platforms yields information on cloud height and thickness as well as dominant ice crystal attributes (characteristic

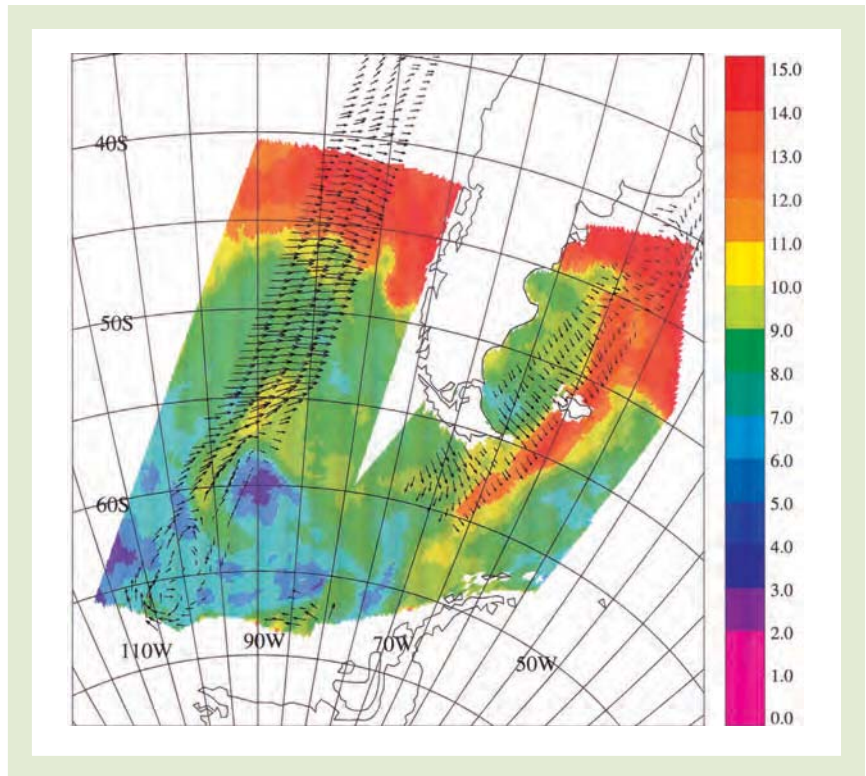


Figure 2 Sample SSM/I water vapor (in kilograms per square meter) and satellite radar-determined V , with Southern South America for reference

Source: Defense Meteorological Satellite Program (DMSP) image processed by Lynn McMurdie (University of Washington) and Andrew M. Carleton.



sizes, densities) important in radiative transfer studies. Compared with passive microwave retrievals of rain, satellite-based radar—such as the tropical rainfall measuring mission (TRMM)—generates higher-resolution rain-rate estimates for land as well as ocean, along with three-dimensional images of precipitating cloud clusters and mesoscale convective systems (MCSs).

Climatology

Spatial variations in annually and seasonally averaged atmospheric moisture parameters depict broad associations with the GC. The zones of maximum PW, cloud amount (e.g., from satellite-retrieved CLW), and precipitation rate located in the tropics are associated with convergence of air and deep convection in the ITCZ. In the middle latitudes, slantwise convection associated with the extratropical cyclones gives the secondary maxima in RH, clouds, and precipitation (e.g., Figure 2). Zones of low RH and a lack of deep precipitating clouds—the subtropics and polar regions, particularly Antarctica—are associated with sinking air, in the subtropical highs, where air subsides and warms adiabatically over a considerable depth, and near the poles, where cold, dry air is located at Earth's surface, respectively. Seasonally, cloud and precipitation zonal maxima and associated circulation features either shift latitude (the ITCZ, which follows the zone of maximum heating, or *thermal equator*) or change intensity (middle-latitude storm tracks are more pronounced in winter and weaker in summer). Longitudinal variations in humidity and cloud frequency accompany the summer monsoons of West Africa, South Asia, and also Northern Australia and Indonesia and the West Pacific—the so-called maritime continent (Figure 1).

Interannual variations in atmospheric moisture are large and dominated by ENSO. Over the tropical Pacific, water vapor increases during El Niño events relative to non-ENSO and La Niña conditions. The deep convection and heavy precipitation associated with the warm pool shift eastward to the international dateline and also increase in the tropical eastern Pacific during El Niño as the subtropical high weakens. There, the normally stable atmosphere containing extensive

yet shallow marine stratus is disrupted by convection resulting from greater surface receipts of solar radiation and increased SSTs.

Climatologies of rain rate for the low, subtropical, and lower-middle latitudes yielded by satellite microwave data (SSM/I, TRMM) are especially improved for ocean areas poorly sampled by conventional data. Moreover, the TRMM climatologies both confirm and add detail to the large spatial and magnitude variations in tropical rain rates associated with ENSO. Analysis of thermal IR “enhanced” images and SSM/I data on ice scattering have permitted development of climatologies of MCSs for a number of lower-latitude regions.

Changes

Recent (past 30–50 years) changes in atmospheric moisture include, on large scales, an increase in lower-atmosphere humidity for the middle latitudes accompanying reductions of DTR, especially in the warmer season, and a moistening of the normally dry lower stratosphere. For the 20th century considered as a whole, land-based total cloud amounts increased and precipitation increased generally in middle latitudes and, to an extent, in the tropics, while it decreased in many subtropical locations. Although the role of human activities in these large-scale changes is debated, particularly their connection to GHG-induced “global warming,” some regional-to-local-scale changes are more definitively tied to humans. These include increased summertime dew point temperatures in the intensively cropped Midwest of the United States and increased precipitation adjacent to areas of extensive irrigation in the High Plains (i.e., intensified recycling of moisture due to agriculture); reduced recycling in areas of tropical deforestation; increases in cirrus cloud cover in regions of frequent air traffic (from contrails); greater reflectivity of marine stratus due to pollution from ship stacks; and increasing convective precipitation downwind of large urban areas (from combinations of the urban heat island effect and greater atmospheric loading of particulates) yet suppression of frontal precipitation at locations downwind of major industrial areas. The last results from air pollution particles enhancing the formation of cloud droplets (cloud



reflectance increases), but these droplets have a smaller size than is optimal for precipitation formation. Some of the observed changes in atmospheric moisture, at least those on larger scales, are consistent with the intensified hydrologic cycle predicted by climate models under global warming.

Andrew M. Carleton

See also **Anthropogenic Climate Change; Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Remote Sensing; Atmospheric Variations in Energy; Clouds; Cyclones: Occluded; El Niño; Humidity; Hurricanes, Physical Geography of; Hydrology; Latent Heat; Monsoons; Precipitation Formation**

Further Readings

- Carleton, A., Travis, D., Master, K., & Vezhapparambu, S. (2008). Composite atmospheric environments of jet contrail outbreaks for the United States. *Journal of Applied Meteorology and Climatology*, 47, 641–667.
- Dai, A., Trenberth, K. E., & Karl, T. R. (1999). Effects of clouds, soil moisture, precipitation, and water vapor on diurnal temperature range. *Journal of Climate*, 12, 2451–2473.
- Daly, C., Gibson, W., Taylor, G., Doggett, M., & Smith, J. (2007). Observer bias in daily precipitation measurements at United States cooperative network stations. *Bulletin of the American Meteorological Society*, 88, 899–912.
- DeRubertis, D. (2006). Recent trends in four common stability indices derived from U.S. radiosonde observations. *Journal of Climate*, 19, 309–323.
- Dirmeyer, P. A., & Brubaker, K. L. (2007). Characterization of the global hydrologic cycle from a back-trajectory analysis of atmospheric water vapor. *Journal of Hydrometeorology*, 8, 20–37.
- Mo, K. C., Chelliah, M., Carrera, M. L., Higgins, R. W., & Ebisuzaki, W. (2005). Atmospheric moisture transport over the United States and Mexico as evaluated in the NCEP regional reanalysis. *Journal of Hydrometeorology*, 6, 710–728.

- Mohr, K. I., & Zipser, E. J. (1996). Mesoscale convective systems defined by their 85 GHz ice scattering signature: Size and intensity comparison over tropical oceans and continents. *Monthly Weather Review*, 124, 2417–2437.
- Neimann, P. J., Ralph, F. M., Wick, G. A., Lundquist, J. D., & Dettinger, M. D. (2008). Meteorological characteristics and overland precipitation impacts of atmospheric rivers affecting the west coast of North America based on eight years of SSM/I satellite observations. *Journal of Hydrometeorology*, 9, 22–47.
- Rosenfeld, D. (2000). Suppression of rain and snow by urban and industrial air pollution. *Science*, 287, 1793–1796.
- Sandstrom, M. A., Lauritsen, R. G., & Changnon, D. (2004). A Central-U.S. summer extreme dew-point climatology. *Physical Geography*, 25, 191–207.
- Sassen, K., & Wang, Z. (2008). Classifying clouds around the globe with the CloudSat radar: 1-year of results. *Geophysical Research Letters*, 35, L04805.



ATMOSPHERIC PARTICULATES ACROSS SCALES

Atmospheric particulates, also called particulate matter (PM), are a complex mixture of extremely small solid particles and liquid droplets suspended in the air. Particles are made up of several components, including acids (i.e., nitrates and sulfates), organic chemicals, metals, and soil or dust. PM sources can be anthropogenic or natural. Natural sources include volcanoes, dust storms, vegetation fires, and sea spray. Anthropogenic sources include coal and oil combustion, fossil-fuel power plants, and other industrial activity. The anthropogenic contribution to total atmospheric PM is estimated to be approximately 10%. Some of these particles are emitted directly into the air (primary emissions), while some are emitted as gases and subsequently form particles in the air (secondary emissions).

PM is categorized by size fractions. As particles are often nonspherical, categorization depends on their aerodynamic diameter. A particle with an



<i>Fraction</i>	<i>Size Range (μm)</i>	<i>Residency Time in Air</i>	<i>Travel Distance</i>
PM ₁₀ (thoracic fraction)	≤ 10	Minutes to hours	Up to tens of kilometers
PM ₁₀ –PM _{2.5} (coarse fraction)	2.5–10		
PM _{2.5} (respirable fraction)	≤ 2.5	Days to weeks	More than hundreds of kilometers
PM ₁	≤ 1		
Ultrafine (UFP)	≤ 0.1		

Table 1 Particulate characteristics

Source: Author.

Note: PM = particulate matter.

aerodynamic diameter of 10 μm (micrometers) moves in the air like a sphere with a diameter of 10 μm . PM diameters range from less than 10 nm (nanometers) to more than 10 μm . These dimensions represent the continuum from a few molecules up to the size where particles can no longer be carried by the atmosphere and settle because of gravity or turbulent impact on the surface. A typical notation such as PM₁₀ is used to describe particles of 10 μm or less, which are called *coarse* particles; and PM_{2.5} represents *fine* particles equal to or less than 2.5 μm in aerodynamic diameter. Particles between these two sizes are considered inhalable coarse particles. Everything below 100 nm, down to the size of individual molecules, is classified as ultrafine particles (UFP). In comparison, an average human hair is about 70 μm in diameter.

In general, the smaller and lighter a particle is, the longer it will stay in the air. Larger particles (greater than 10 μm in diameter) tend to settle to the ground in a matter of hours, whereas the smallest particles (less than 1 μm) can stay in the atmosphere for weeks and are mostly removed by precipitation (see Table 1).

The composition of particulates is determined by their source. Wind-blown mineral dust tends to be made of mineral oxides and other material, whereas sea salt consists mainly of sodium chloride originated from sea spray yet can include magnesium, sulfate, calcium, and potassium.

Secondary particles derive from the oxidation of primary gases such as sulfur and nitrogen oxides into sulfuric acid (liquid) and nitric acid (gaseous). The precursors for these acid aerosols may have an anthropogenic origin (e.g., coal

combustion) and/or a biogenic origin. The chemical composition of PM affects how it interacts with solar radiation, determining how much light is scattered and absorbed. In this manner, particulates can influence the global climate. Recent evidence suggests that anthropogenic PM can control cloud development by altering the size distribution of cloud condensation nuclei.

The effects of inhaling PM have been widely studied in humans and animals and include asthma, lung cancer, cardiovascular disease, and premature death. The large number of deaths and other health problems associated with particulate pollution was first demonstrated in the early 1970s. As a result, PM is subject to strict regulatory control.

The size of the particle is a main determinant of where in the respiratory tract it comes to rest when inhaled. Larger particles are generally filtered in the nose and throat and do not cause serious health problems, but PM₁₀ can settle in the bronchi and lungs and damage human health. PM₁₀ does not represent a strict boundary between respirable and nonrespirable particles but is used as a standard for monitoring of airborne PM by most regulatory agencies. Similarly, PM_{2.5} tends to penetrate deep into the gas-exchange regions of the lungs, and very small particles (<100 nm) can pass through the lungs to affect other organs. In particular, PM_{2.5} leads to high plaque deposits in the arteries, causing vascular inflammation and atherosclerosis, which can lead to heart attacks and other cardiovascular problems. Research suggests that even short-term exposure at elevated concentrations could significantly contribute to heart disease.



The smallest particles, less than 100 nm (nanoparticles) in size, may be even more damaging to the cardiovascular system. There is evidence that particles smaller than 100 nm can pass through cell membranes and migrate into other organs, including the brain. It has been suggested that PM can cause similar brain damage as that found in Alzheimer patients. In addition, particulates also carry carcinogenic components such as benzo[a]pyrenes adsorbed on their surface. One particle of 10- μm diameter has approximately the same mass as 1 million particles of 100-nm diameter, but it is clearly much less hazardous, as it probably will never enter the human body—but if it does, it can be quickly removed.

Because of the human health effects of PM, maximum ambient standards have been set by governments (the World Health Organization's guideline is that daily averaged PM_{10} should not exceed $50 \mu\text{g}/\text{m}^3$ [micrograms per cubic meter] of air). Many urban areas in the developed world still frequently violate PM standards, especially in Southern California and Pittsburgh, Pennsylvania, in the United States and in Belgium, Germany, Italy, and Albania, although in many areas there has been a downward trend. Much of the developing world exceeds the standards by a wide margin. The most concentrated PM pollution tends to be in densely populated metropolitan areas, especially Cairo (Egypt), Delhi and Kolkata (India), and Tainjin, Chongqing, and Linfen (China), all with PM levels commonly above $100 \mu\text{g}/\text{m}^3$. Thus, PM pollution control programs are very important worldwide.

Peyman Zawar-Reza

See also **Ambient Air Quality; Atmospheric Pollution; Clouds; World Health Organization (WHO)**

Further Readings

- Jacobson, M. (2002). *Atmospheric pollution: History, science, and regulation*. New York: Cambridge University Press.
- Seinfeld, J. H., & Pandis, S. N. (2006). *Atmospheric chemistry and physics: From air pollution to climate change*. New York: Wiley-Interscience.



ATMOSPHERIC POLLUTION

Atmospheric pollution describes harmful gases, solid particles, and liquid droplets that are present in the atmosphere in quantities above natural ambient levels. The main gases in the atmosphere are nitrogen (78.08%), oxygen (20.95%), and argon (0.93%). Carbon dioxide, a greenhouse gas, accounts for 0.038%. Given this composition, pollutants are present in very small proportions, usually measured as the mixing ratio of the number of molecules of the pollutant per total number of air molecules, such as parts per million (ppm) or parts per billion (ppb), or as a mass concentration per unit volume of air, such as micrograms per cubic meter ($\mu\text{g}/\text{m}^3$). Each year, millions of tons of pollutants are emitted into the atmosphere, and the effects on the health of the planet and its life forms can be devastating. Pollutants may be “primary” in origin, if they are emitted directly from a source, or “secondary,” if they are products of chemical reactions involving primary pollutants.

Air quality is directly linked to the levels of pollutants in the atmosphere and is rated on the basis of air quality indices. The most pervasive and toxic compounds, known as *criteria air pollutants*, are used to compute such indices. Though they vary with jurisdiction, the most common or “criteria” air pollutants (pollutants for which criteria have been established for their level and length of exposure to protect human health and welfare) are carbon monoxide, oxides of nitrogen, ozone, sulfur dioxide, volatile organic compounds, and fine particles. While some of these compounds occur naturally, anthropogenic activities significantly increase the levels of pollutants, introduce many of which that do not occur naturally, and elevate concentrations in populated areas. Particularly high concentrations are usually observed in urban areas where most pollution results from industrial activities and transportation, leading to enhanced human exposure.

Criteria Air Pollutants

Carbon Monoxide

Carbon monoxide (CO) is a by-product of fuel combustion, resulting from incomplete oxidation



Mexico City, which is partially surrounded by mountains, suffers from prolonged temperature inversions and severe smog episodes.

Source: Morguefile.

of carbon in the combustion process. In North America, about 80% of CO emissions come from internal combustion engines used in transportation. Natural sources include forest fires (which may also be anthropogenically driven) and volcanoes. Indoor sources of CO include wood burning and gas stoves or furnaces.

On a global scale, CO levels average about 100 ppb. In urban areas, the levels are elevated to a few ppm, while in traffic, values may be measured in tens of ppm. CO is a precursor to greenhouse gases such as methane and carbon dioxide.

In the human body, CO is attracted to hemoglobin in the bloodstream, replacing oxygen. Exposure to low levels may cause fatigue in healthy people and is more dangerous for persons with heart disease. High levels can be fatal and

because of its colorless and odorless characteristics, it is often called a “silent killer.”

Oxides of Nitrogen

Harmful oxides of nitrogen include nitric oxide or nitrogen monoxide (NO) and nitrogen dioxide (NO₂), which are collectively called NO_x. High energy is required to break the strong triple bond of molecular nitrogen to generate elemental nitrogen for oxidation. Hence, the formation of nitric oxide generally results from high temperature processes such as fuel combustion in transport engines or industries, such as those involved in thermal power generation. In North America, approximately 60% of anthropogenic NO_x gases result from transportation emissions and about 35% from industry, including electric power plants. Natural sources include lightening and microbial activity in soils. Nitric oxide has a lifetime of minutes, so once emitted it quickly oxidizes to NO₂. NO_x species play pivotal roles in the complex chemistry of the atmosphere, reacting with other gases, for example, in the creation and depletion of ground-level ozone.

Both nitric oxide and NO₂ are soluble in water. Nitric oxide creates weak nitrous acid (HNO₂), and NO₂ dissolves to create strong nitric acid (HNO₃). These gases contribute to the acidity in rain, ground, and surface waters and soils. The acids may also react with other compounds, such as ammonia, to form nitrate particles that are common components of particulate matter in the atmosphere.

NO₂ is a toxic gas that has detrimental health effects on the respiratory system, can damage the lining of the lungs, and exacerbate diseases such as asthma and bronchitis. The acids will irritate eyes and skin and cause damage to the respiratory system, while the particles contribute to health effects of particulate matter. The acids will also damage plants and infrastructure.

Ozone

Ozone (O₃) is a secondary pollutant created by reactions between precursor gases such as NO₂ and volatile organic compounds. It is one of the most consistently monitored pollutants, globally. O₃ occurs both in the stratosphere, where it forms



a protective layer to shield the Earth's surface from ultraviolet radiation, and in the troposphere, where it has detrimental effects on biota.

Sunlight is an essential component of O_3 production. Photolytic reactions use energy from the sun to dissociate NO_2 , producing nitric oxide and an oxygen atom (R1). The oxygen atom reacts with molecular oxygen, O_2 , to form ozone, O_3 (R2). Nitric oxide will also react readily with O_3 to produce NO_2 and oxygen gas (R3), thereby reducing the levels of O_3 .



The reactions often involve other gases such as volatile organic compounds. This cycle of reactions is most prolific in urban areas, where traffic and industry provide abundant precursor gases. The scavenging of O_3 by NO in high traffic areas leads to depletion in urban areas compared with rural locations.

Because of the sun's role, O_3 levels have diurnal and seasonal cycles, with highest concentrations on a summer day. O_3 can be transported for thousands of miles by prevailing winds, leading to high levels at downwind locations.

The O_3 level in unpolluted air is approximately 10 to 15 ppb. In polluted environments, this may rise to more than 100 ppb. O_3 irritates the respiratory system and aggravates diseases such as asthma and bronchitis. It is a primary component of "smog," a toxic mix of pollutants that causes poor air quality and severely impairs cardiopulmonary function. Severe smog episodes can lead to premature death.

Sulfur Dioxide

Sulfur dioxide (SO_2) results from the burning of compounds that contain sulfur. Coal is a primary source, and thus, coal-fire generating plants emit high levels, as do smelters, which extract metals from sulfur-bearing ores. Some fuels, such as those used in marine or rail transportation, also have high sulfur content. However, industry and electric power plants have traditionally been the major source.

SO_2 is soluble in water and forms sulfuric acid (H_2SO_4), creating acid rain that can devastate ecosystems. Further reactions will lead to the formation of sulfate particles in the air. This pollutant adversely affects the human respiratory system, worsening symptoms of lung diseases. In North America, emissions have been reduced significantly in the past 15 to 20 years but still remain a concern.

Volatile Organic Compounds

Volatile organic compounds (VOCs) include a large suite of carbon-based chemicals that evaporate readily under normal temperature and pressure conditions. While thousands of these compounds exist, about a hundred are considered when assessing air quality. Evaporated fuels such as those used in transportation and industry are the major contributor. Other significant sources include solvents used in commercial and industrial processes and in products such as cleaning fluids or paints. Natural sources include vegetation, such as plants that emit isoprene. VOCs are primary precursors for the creation of ground-level O_3 . Studies suggest that some are cancer-causing agents and can aggravate asthma and other lung diseases.

Fine Particulate Matter

Particulate matter describes solid or liquid particles in the atmosphere. Most particles are composed of sulfates, nitrates, carbon, soil particles, and organic materials such as pollen. Particulate matter is ubiquitous, with numerous anthropogenic sources that include industry, power plants, construction sites, road dust, open fields, and diesel fuel combustion. Secondary particles result from chemical interactions, which convert gases, such as SO_2 or NO_x , to sulfate and nitrate particles.

Natural sources include sea salt, desert sand, volcanoes, and carbon particles from forest fires. The finer particles are easily transported over long distances, and dust from the Sahara Desert has been tracked by satellite to locations in the middle United States and Northern Europe.

Particulate matter exists in various shapes and sizes and is classified according to the aerodynamic



diameter of the particles, measured in micrometers (μm). Particles of diameter less than $10\ \mu\text{m}$ (PM_{10}) and less than $2.5\ \mu\text{m}$ ($\text{PM}_{2.5}$) are of particular concern. Unpolluted $\text{PM}_{2.5}$ levels may be 0 to $5\ \mu\text{g}/\text{m}^3$, while polluted areas may have values exceeding $50\ \mu\text{g}/\text{m}^3$. Numerous epidemiological studies suggest that the finer particles penetrate and settle deep into the respiratory tract, causing inflammation. They are considered to be among the most detrimental air pollutants and have been implicated in cardiopulmonary diseases and premature death. They are also a primary component of smog.

Dispersion and Dilution

Dilution and dispersion of pollutants are key factors in reducing concentrations near the source. Meteorology and physiography can assist or inhibit dispersion rates. Winds transport pollutants vertically and horizontally away from the source and allow dilution through mixing with less polluted air. While reducing pollution near the source, transport increases concentrations downwind. If the air becomes stable, as in the case of temperature inversions, pollution levels rise quickly. Physiographic features such as basins or valleys restrict airflow and also promote the formation of temperature inversions. Locations such as Los Angeles and Mexico City, which are partially surrounded by mountains, suffer from prolonged temperature inversions and severe smog episodes.

Monitoring Air Pollution

In an effort to mitigate the health effects of air pollution, many countries establish air quality criteria for selected contaminants, which are monitored regularly. Monitoring can be accomplished in various ways. Most commonly, fixed systems comprising gas and particulate matter monitors are strategically placed in urban or rural environments to measure pollution levels continuously. This system works well to monitor local pollution levels near the monitoring unit and to record the long-term pollution patterns at that

location. Mobile systems, which comprise monitors mounted on aircraft or motor vehicles, can be used for periodic measurements over selected areas. These systems offer flexibility in selecting the time, location, and extent of the area to be monitored. Personal monitors are also available to assess an individual's exposure level. On a regional or global scale, air pollution can be detected by satellites, which orbit the Earth. These data are useful for monitoring pollution levels over large urban centers, tracking long-range transport of pollutants, and assessing the effects on global climate.

Atmospheric pollution also can be modeled using algorithms developed for computer simulations. Estimates of concentrations can be determined based on information about the pollution source and meteorology. These models can be used to simulate pollution effects under different scenarios, and in climate change models.

Reducing Air Pollution

The personal costs of air pollution include illness and premature death. There are also economic costs associated with health care and lost productivity as well as environmental damage and climate change. Efforts to reduce emissions include the development of new technologies such as hybrid or fully electric engines and the hydrogen fuel cell. Alternatives such as solar, wind, wave, and tide energy, and biofuels continue to be researched and developed. Legislation in some jurisdictions mandates cleaner fuels, and many countries encourage reduced reliance on car use. While there have been ongoing efforts to reduce pollution in North America and Europe, rapidly developing countries have increased pollution output immensely in recent years, leading to greater need for global cooperation to maintain clean air for health and the total environment.

Pavlos Kanaroglou and Julie Wallace

See also **Acid Rain; Ambient Air Quality; Anthropogenic Climate Change; Atmospheric Particulates Across Scales; Greenhouse Gases; Point Sources of Pollution; Urban Environmental Studies; Urban Heat Island**



Further Readings

- Gibilisco, S. (2006). *Alternative energy demystified*. New York: McGraw-Hill Professional.
- Office of Air and Radiation, United States Environmental Protection Agency: www.epa.gov/air
- World Health Organization. (2006). *Air quality guidelines global update 2005*. Retrieved November 9, 2009, from www.euro.who.int/Document/E90038.pdf



ATMOSPHERIC PRESSURE

The most basic atmospheric element is air pressure. Pressure itself is a measure of the force per unit area. The concept of force is usually best understood by considering Newton's second law, which states that the acceleration of a body is directly proportional to the force exerted on that body and inversely proportional to its mass. In other words, force (F) is equal to the product of mass (M) and acceleration (a).

Using International System (SI) units of measure, M is given in kilograms (kg) and acceleration in units of meters per second per second (m/s^2 , also expressed as m s^{-2}). Given $F = Ma$, then force is described in units of kg m s^{-2} , which is a newton. A newton (N) is equal to the amount of force required to accelerate a mass of 1 kg at the rate of 1 m/s^2 , or 1 m s^{-2} . So if force is given in newtons, then pressure must equal to N per unit area, or N/A or N A^{-1} . This unit of measure for pressure is known as a pascal (Pa). Given that a unit area would be provided in square meters (m^2), a pascal would be equal to $\text{kg m s}^{-2} \text{ m}^{-2}$, or $\text{kg m}^{-1} \text{ s}^{-2}$.

In general, the mass of the atmosphere varies slightly depending on location. When dealing with air, however, we need to consider Pascal's law, which states that fluids (gases and liquids) transmit pressure in all three dimensions. For this reason, mass of the atmosphere varies depending on the volume of space considered, so to compare pressure across space, one must standardize the unit of measure to a constant volume, a measure known as "density." Typically, the mass is given

in kg and the volume in cubic meters (m^3); therefore, we consider atmospheric mass, or density, in units of kg/m^3 (or kg m^{-3}).

Gravitational acceleration, the other term in force, also varies depending on distance away from the center point of Earth. If Earth were a perfect sphere, then gravitational acceleration would be constant at the same height. However, even though Earth is best described as a *geoid*, the variation in gravitational acceleration due to a nonspherical body within all heights of the troposphere are negligible. For this reason, and to simplify the situation, we assume gravitational acceleration within the troposphere to be a constant 9.8 m/s^2 . To ensure that this assumption is recognized, all heights above Earth's surface are referred to as "geopotential"; that is, with a vertical datum of mean sea level on a spheroid-shaped Earth.

Atmospheric pressure, then, is the summation of all mass within a 1-m^2 column of air that extends to outer space, where pressure is 0 Pa. On average, if we consider all sea level point locations over Earth 24 hrs. (hours) per day for 30 yrs. (years) or more, the pressure would be 101,325 Pa. Since geographers and atmospheric scientists frequently work with pressure, the SI units are simply too large to deal with on an operational basis. As a result, a new unit of measure called the millibar (mb) was developed in 1909 by Sir Napier Shaw. An mb equals 100 Pa, so average atmospheric pressure at sea level is 1,013.25 mb, or simply 1,013 mb.

Another common unit of measure for air pressure is inches (in.), used primarily for aviation purposes and included on most home barometers. A barometer is the instrument used to measure atmospheric pressure. First developed by Torricelli in the 17th century, the instrument includes a 30-in.-tall glass filled partially with mercury. The mercury rises and falls in response to changing pressure, so that the average mean sea level pressure produces a mercury column height of 29.92 in. from its base.

Pressure Gradients

Atmospheric motion is a function of imbalance in mass and/or heat across space. In other words, the Earth-atmosphere system is always working



to achieve a balance based on the spatial distribution of mass and heat energy. When imbalances exist, surplus mass or heat is moved by forces from regions of surplus to regions of deficit until equilibrium, or at least some steady state, is achieved. This is the basis of quasi-geostrophic (QG) theory.

The primary force that produces atmospheric motion is commonly referred to as the pressure gradient force (PGF). A PGF exists when an imbalance in atmospheric pressure exists over space. When this occurs, air is moved from areas of high (surplus) pressure to areas of low (deficit) pressure. In other words, the pressure gradient is directed from high to low pressure, so the PGF moves the air in that direction and at a speed proportional to the strength of the gradient. This process operates on all space scales from micro to planetary and is the basis for the study of atmospheric dynamics.

Pressure Change

Atmospheric pressure is not constant over space and time but varies in response to dynamic and thermodynamic processes. If we consider the equation of state, $p = \rho RT$, where p = pressure, ρ = density, R = gas constant for dry air, and T = temperature, then pressure change is proportional to density and temperature change. If we break density down into its component parts, then change in pressure is proportional to change in mass and inversely proportional to a change in volume. In other words, there are two primary ways in which pressure can change; through increases and decreases in temperature and mass and through changes in volume. Given that volume and temperature are inversely related, then temperature and density must also be inversely related. This means that as temperature increases (decreases), volume increases (decreases) and density decreases (increases), if we hold mass constant. On the other hand, if mass decreases (increases), pressure also must decrease (increase). Considering that 99% of atmospheric mass is made up of oxygen and nitrogen with atomic weights of 15.9994 and 14.0067, respectively, then replacing any nitrogen or oxygen atoms with hydrogen atoms with an atomic weight of 1.0079, which is what occurs when humidity increases,

will decrease the mass of the air and decrease the pressure.

When we consider pressure changes at some fixed point location, then thermal, moisture, and mass advection will have an effect on pressure. If warm air advection results in thermal convergence, then the pressure will fall as the air becomes lighter (less dense). If that warm air advection also results in moisture convergence, then the pressure will fall even further. These effects are the result of thermodynamic processes.

When convergence of mass occurs within a column of air anchored at some fixed point location, then the pressure will increase. The processes that may bring an increase of mass through a mass convergence process other than moisture advection are termed “dynamic.” Dynamic processes are most commonly the result of mass convergence or divergence that occurs within the middle and upper levels of the troposphere, the result of jet streaks and shortwaves. Jet streaks and shortwaves are sometimes considered together as *upper-level disturbances*. In the absence of thermal and/or moisture advection that occurs primarily within the planetary boundary layer (PBL), decreasing surface pressure over time can indicate the approach of an upper-level disturbance and an increased likelihood of precipitation.

Vertical Pressure Profile

Given the gravitational attraction that the Earth presents to air molecules, a great majority are found close to the Earth’s surface. This means that mass within the atmosphere decreases with increasing height and does so in an exponential fashion. As a result, almost half the atmospheric mass is reached at an altitude of about 18,300 ft. (feet).

The relationship between pressure and height is so reliable, varying only a few tens of meters depending primarily on season, that it is commonly used as a vertical coordinate.

For example, while we consider the sea level pressure to average near 1,013 mb, by the time a geopotential height of 4,781 ft. (1,457 m) is reached, the pressure has decreased to 850 mb. A further increase in altitude results in a pressure of 700 mb at about the 9,882-ft. (3,012-m) level,



500 mb at the 18,289-ft. (5,574-m) level, 300 mb at the 30,065-ft. (9,164-m) level, and 150 mb at 44,647 ft. (13,608 m). The 150-mb level typically marks the base of the tropopause during the warm season.

These average pressure-height relationships and associated values for temperature and density, based on international standards, were first established by the U.S. Committee on Extension to the Standard Atmosphere and published by the U.S. Government Printing Office in 1958. The most recent update to the standard atmosphere was published jointly in 1976 by the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the U.S. Air Force.

It is common for geographers and atmospheric scientists to refer to different height levels in terms of the average air pressure found there. For example, instead of analyzing the wind pattern at the 30,065-ft. (9164-m) level, we refer to it as the 300-mb level.

For purposes of many atmospheric analyses, the troposphere is divided up into three layers defined by specific pressure levels. Assuming that the surface is close to sea level (within 1,000 ft., or 305 m), the PBL would on average extend up to the 850-mb level, the midlevels to a height of 500 mb, and the upper levels to the tropopause (usually about 150 mb in the middle latitudes during summer and between 300 and 250 mb in winter).

When balloon soundings are developed from rawinsondes, measurements are required at specific altitudes as determined by their corresponding pressures. These are called the *mandatory levels*, which include measurements taken at 1,000, 850, 700, 500, 400, 300, 200, 150, 100, and 50 mb.

David L. Arnold

See also **Adiabatic Temperature Changes; Air Masses; Anthropogenic Climate Change; Atmospheric Circulation; Atmospheric Composition and Structure; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Variations in Energy; Chinooks/Foehns; Climate Types; Climatology; Fronts; Coriolis Force; Hurricanes, Physical Geography of; Monsoons; Thunderstorms; Tornadoes; Wind**

Further Readings

- Barry, R. G., & Chorley, R. J. (2003). *Atmosphere, weather, and climate* (8th ed.). London: Routledge.
- Gray, D. E. (1972). *American Institute of Physics handbook* (3rd ed.). New York: American Institute of Physics.
- Holton, J. R. (2004). *An introduction to dynamic meteorology* (4th ed.). St. Louis, MO: Elsevier.
- Marshall, J., & Plumb, R. A. (2008). *Atmosphere, ocean, and climate dynamics: An introductory text*. Burlington, MA: Elsevier/Academic Press.
- Wallace, J. M., & Hobbs, P. V. (2006). *Atmospheric science* (2nd ed.). St. Louis, MO: Elsevier/Academic Press.



ATMOSPHERIC REMOTE SENSING

Remote sensing can be broadly defined as the process of collecting data through means that do not involve physical contact. For example, the process of reading this text is an example of remote sensing, since your eye is gathering information about written letters on the page. A more technical definition of remote sensing describes the process of gathering data about a physical object using radiant energy, wave fields, or particles emanating from or interacting with the physical world. The NASA Remote Sensing Tutorial offers an appropriate definition:

A technology for sampling electromagnetic radiation to acquire and interpret non-contiguous geospatial data from which to extract information about features, objects, and classes on the Earth's land surface, oceans, and atmosphere (and, where applicable, on the exteriors of other bodies in the solar system, or, in the broadest framework, celestial bodies such as stars and galaxies). (<http://rst.gsfc.nasa.gov>, "Introduction: The Concept of Remote Sensing," I-2)

Atmospheric remote sensing applies remote sensing techniques for data collection and analysis of physical parameters or variables associated with the atmosphere such as temperature, moisture,

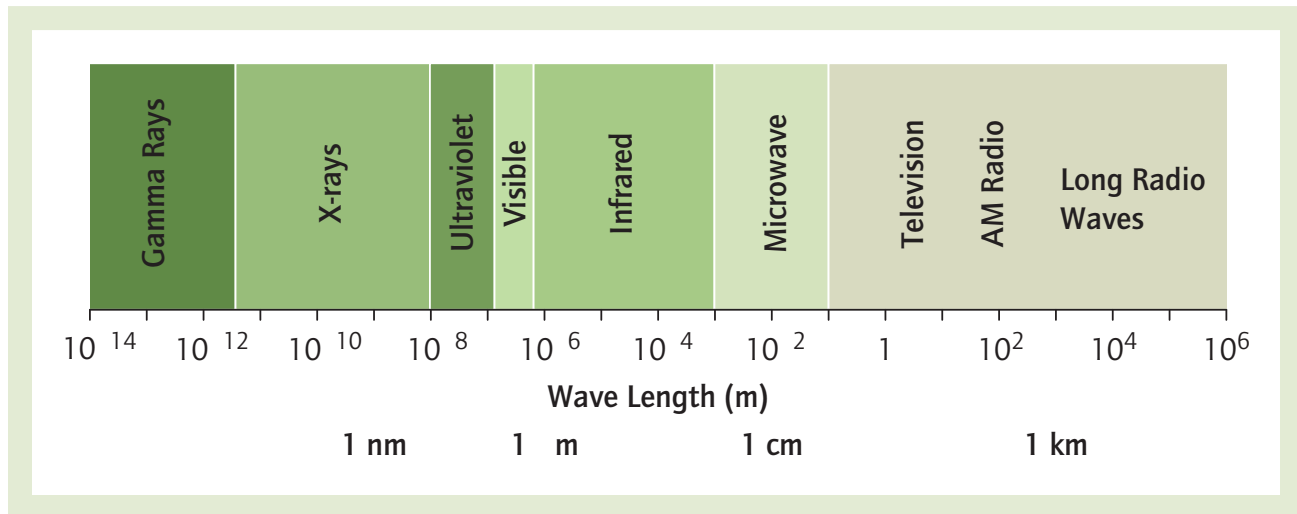


Figure 1 The electromagnetic spectrum

Source: NASA (<http://rst.gsfc.nasa.gov>).

clouds, precipitation, aerosols, chemical constituents, wind, or weather systems.

Characteristics of Atmospheric Remote Sensing

Active Versus Passive Instruments

Instruments used in atmospheric remote sensing can be characterized as active or passive. An active system generates and transmits an electromagnetic signal that interacts with a medium through reflection, absorption, or scattering. Examples of active systems include Doppler radar (radio detection and ranging) and optical lidar (light detection and ranging). A passive system does not transmit a signal but makes a measurement by receiving scattered, reflected, or emitted radiation. Examples of passive systems include visible cameras, infrared radiometers, and pyranometers. Figure 1 shows the electromagnetic spectrum.

Resolution

Atmospheric remote sensing highly depends on understanding spatial, temporal, spectral, and radiometric resolution. Such factors determine what component or constituent of the atmosphere can effectively be measured or quantified. Spatial resolution represents the small area or pixel resolvable by the remote sensor. Smaller areas represent

higher spatial resolution. For example, a 10-megapixel digital camera has higher resolution than a 5-megapixel digital camera because more small pixels can be resolved in the image. In the same manner, a 1-km (kilometer) satellite field of view ($1\text{-km} \times 1\text{-km}$ pixel) is higher in spatial resolution than a 10-km satellite field of view ($10\text{-km} \times 10\text{-km}$ pixel). Temporal resolution represents the time interval between measurements by the remote sensor. Spectral resolution represents the wavelength or frequency intervals of the electromagnetic spectrum that can be applied to make a measurement. Atmospheric remote sensing instruments can use one wavelength interval or many intervals (e.g., multispectral). Many advanced sensors such as the Moderate Resolution Imaging Spectroradiometer (MODIS) (<http://modis.gsfc.nasa.gov>) are multispectral. Some instruments are even classified as hyperspectral, if they can use an extremely large number of spectral bands. The width of the interval is a measure of the relative magnitude of the spectral resolution. Radiometric resolution represents the smallest quantization of steps of the measurements or the number of bits. It can be useful for characterizing the precision of the instrument measurement.

Vantage Point

Atmospheric remote sensing can be conducted from the vantage point of the ground, air, or space.



Doppler radar systems, upward-pointing radiometers, and acoustic sounders are often operated from the ground. Active and passive sensors are commonly placed on airborne or balloon-borne sensors to improve the field of view or enable three-dimensional (3D) measurements of the atmosphere. For even greater spatiotemporal fidelity, space-borne instrumentation can be applied. Geosynchronous and polar orbits are the two most common orbit strategies that have been employed for space-based atmospheric remote sensing.

Geosynchronous or *geostationary* orbits are achieved when a spacecraft is placed in an orbit approximately 36,000 km (~22,000 mi. [miles]) above Earth. At this altitude, the spacecraft is orbiting Earth in a circular path at rates near 11,052 km/hour (6,802 mph [miles per hour]). With this orbit strategy, the satellite is “geostationary” to a fixed area on the Earth. In other words, the satellite is synchronized with Earth’s rotation rate, or “geosynchronous.” The United States and several other countries maintain a fleet of geostationary satellites for monitoring atmospheric and environmental conditions.

Polar orbiting satellites are typically found at altitudes ranging from 300 to 1,500 km. Their orbits are typically highly inclined (i.e., low angles with respect to longitude lines) relative to Earth’s rotation and elliptical. This type of orbit causes the satellite to pass over the high-latitude polar regions. Many polar orbiting satellites are also sun-synchronous, which means that they pass over the same reference point on the Earth at the same local time. Other orbit strategies can be configured so that they cross equivalent latitudes in a sequence enabling observations associated with the diurnal or daily cycle. NASA’s Tropical Rainfall Measuring Mission (TRMM) has an orbit at approximately 36° to 38° inclination so that it can measure the diurnal cycle of precipitation at tropical latitudes (<http://trmm.gsfc.nasa.gov>). Relatively low inclination orbits that capture the diurnal cycle may be referred to as “walking” orbits.

Atmospheric remote sensing clearly can be described in many ways, but satellite-based remote sensing is quickly emerging as an important methodology. Therefore, the forthcoming discussion will focus primarily on the satellite-based perspective.

Evolution of Space-Borne Atmospheric Remote Sensing

The heritage of atmospheric science remote sensing can be traced to early missions such as the failed Vanguard 2 mission of 1959 and the early Explorer 6 and 7 missions. Using revolutionary radiometric technology by pioneering scientist Verner Suomi, Explorer 7 measured solar and terrestrial radiative energy associated with Earth’s global energy balance. The launch of TIROS I (Television and InfraRed Observation Satellite) on April 1, 1960, marked the beginning of a new era of observing Earth’s weather conditions from the vantage point of space. TIROS I was launched into a 450-mi. orbit and demonstrated the basic principles of using spectral regions of the electromagnetic spectrum (EM), or wavelengths of light. Many atmospheric observations are imaged in the visible portion of the EM. But like a camera or human eye, the visible wavelengths are not very useful under night conditions or obscured view. Many components of the atmosphere such as clouds, water vapor, and other gases have distinctive absorption-emission wavelengths, or bands. Such information can be applied to thermally imaged atmosphere features or constituents. For example, the advanced very high-resolution radiometer (AVHRR) has been a standard instrument on meteorological satellites over the past several decades. Table 1 provides a typical overview of visible and infrared channels used by the AVHRR and the associated meteorological applications.

From the simplistic video camera methods of TIROS I, the instrument evolution for atmospheric remote sensing advanced at a rapid pace.

The Nimbus Series (1964–1978) significantly advanced atmospheric remote sensing by introducing the use of the microwave portion of the EM and atmospheric sounding. Atmospheric constituents such as water vapor, cloud droplets, raindrops, and ice crystals can absorb (then reemit) or scatter microwave energy depending on the wavelength (or frequency). Microwave atmospheric remote sensing enabled observations and analysis in cloudy or cloud-free environments and provided new opportunities to measure water vapor, precipitation, and clouds. Atmospheric

Channel	Wavelengths (μm)	Atmospheric/ Meteorological Application
1	0.58–0.68	Day clouds, snow, ice
2	0.725–1.10	Surface water; snow, ice
3	3.55–3.93	Fires, clouds at night
4	10.30–11.30	Day/night cloud and surface temperatures and mapping
5	11.50–12.50	Same as 4, water vapor

Table 1 Typical channels of the advanced very high-resolution radiometer (AVHRR)

Source: Adapted from NASA (<http://rst.gsfc.nasa.gov>).

sounders provide measurements of the vertical distribution of infrared or microwave radiation emitted by atmospheric constituents at different levels of the atmosphere. This distribution can be used to provide temperature or humidity profiles (measurements from top to bottom). This type of information is traditionally provided by radiosondes (weather balloons) launched at specific locations two times per day. Satellite-based soundings can significantly extend the spatial and temporal coverage for meteorological, climatological, and numerical modeling applications. The textbook *Satellite Meteorology: An Introduction* by Kidder and Vonder Haar is an excellent reference for more information on historical satellite series, imagers, and sounders.

Though satellite remote sensing had its origins in the United States, many nations contribute an array of atmospheric remote sensing satellites. These countries include, but are not limited to, Japan, the European Union, China, Canada, and India. The Committee on Earth Observation Satellites is a good resource on the scope of international involvement (<http://idn.ceos.org>).

Current and Future Atmospheric
Remote Sensing Capabilities

Space-Borne Systems

Advanced satellite-based remote sensing capabilities in the post-2000 era and beyond have

revolutionized atmospheric sciences. It would be difficult to imagine living in a coastal community of Japan or Mexico and not being forewarned of an approaching hurricane. However, this is exactly what happened to the people of Galveston, Texas (United States), in 1900. Extensive loss of life and property occurred due to lack of warning that is now commonplace because of satellite remote sensing. As valuable as the space-borne perspective is to research and operational communities, the atmospheric community continues to advance forward with development. Space-borne platforms now employ active remote sensing instrumentation such as lidar (light detection and ranging) and precipitation radar (e.g., CloudSat, <http://cloudsat.atmos.colostate.edu>, or the Tropical Rainfall Measuring Mission [TRMM] Precipitation Radar, <http://trmm.gsfc.nasa.gov>) to extend research and prediction capabilities related to aerosols, cloud properties, and precipitation. For example, a 3D view or “cat-scan” through Hurricane Katrina was enabled by a suite of passive and microwave instruments aboard TRMM. Missions such as the planned Global Precipitation Measurement Mission will use a constellation of satellites carrying microwave instruments to further extend coverage and temporal resolution. When the technology becomes available, active instruments will move from low Earth orbiting to geosynchronous platforms.

The next generation of operational satellites, such as GOES-R and NPOESS in the United States (www.ipo.noaa.gov), is capitalizing on advanced instruments, new technologies, and higher resolutions (spatial, spectral, temporal, radiometric) that continue to emerge from coordinated research and development programs. New satellites can detect lightning (www.goes-r.gov), atmospheric aerosols (<http://envisat.esa.int>), 3D profiles of temperature and moisture (<http://aqua.nasa.gov>), atmospheric chemical composition (<http://aura.gsfc.nasa.gov>), and greenhouse gases (<http://oco.jpl.nasa.gov>). Even the international global positioning system satellite network used for navigation can be exploited to extract information on atmospheric moisture. Additionally, innovative formation-flying or constellation orbit strategies are being implemented to leverage unique capabilities of individual platforms.



Ground-Based Systems

Satellite remote sensing of the atmosphere has seen explosive development, but there are numerous exciting developments in ground-based or suborbital remote sensing as well. Next-generation weather radars will exploit information derived from polarimetric and continuous wave measurements. Ground-based Raman lidars and acoustic sounders provide important information on the vertical structure of temperature and moisture that, along with other remotely sensed data sets, can be used in weather analysis or as input for numerical weather prediction (NWP) models. Wind profilers provide high-temporal-resolution data on the vertical structure of wind, another critical element of weather analysis and NWP.

Obsolete or Not?

The elapsed time between the writing of this encyclopedia entry and your reading of it represents a relatively long period of time in technological development supporting atmospheric remote sensing. New ground, airborne, and spaceborne remote sensing techniques and instruments are constantly in some phase of conception, development, testing, implementation, or operation. Readers interested in atmospheric remote sensing should stay abreast of dynamic sources of information to remain at the forefront of the topics. New capacities will be critical as the requirements of the weather, climate, environmental, and societal stakeholder communities evolve.

Marshall Shepherd

See also **Aerial Imagery; Data; Aerial Imagery: Interpretation; Ambient Air Quality; Anthropogenic Climate Change; Atmospheric Moisture; Atmospheric Particulates Across Scales; Atmospheric Pollution; Biophysical Remote Sensing; El Niño; Floods; Greenhouse Gases; Hurricane Katrina; Precipitation, Global; Precipitation Formation; Remote Sensing; Remote Sensing: Platforms and Sensors; Weather and Climate Controls**

Further Readings

- Kidder, S. Q., & Vonder Haar, T. H. (1995). *Satellite meteorology: An introduction*. San Diego, CA: Academic Press.
- Short, N. (2009). *Remote sensing tutorial*. Retrieved November 9, 2009, from <http://rst.gsfc.nasa.gov>



ATMOSPHERIC VARIATIONS IN ENERGY

When we consider the atmospheric envelope that surrounds our solid Earth, there exists an upper boundary, the edge of outer space, and a lower boundary, the Earth's surface. Given the spherical nature of Earth, energy can only enter the atmosphere from the upper and lower boundaries.

Energy that enters the atmosphere through the upper boundary originates from the sun and passes through the voids of outer space, reaching the upper atmosphere at an altitude of somewhere near 650 km (kilometers). How much energy passes through the thermosphere (≈ 500 -km depth), mesosphere (≈ 85 km), and stratosphere (≈ 50 km) before reaching the troposphere is a function of the mass that exists within these layers. It is important to note that while the sun emits radiation across a large spectral range, the large majority of radiation originates from the ultraviolet, visible, and near-infrared portions of the electromagnetic spectrum. The manner in which this "shortwave" radiation interacts with the atmospheric mass it encounters varies depending on the character of the mass, particularly its size relative to the wavelength of radiation.

As solar radiation passes through the atmosphere, it can be scattered, absorbed, or transmitted. That which is absorbed raises the temperature of the absorbing body, and if a thermal gradient exists away from that body, heat will be radiated (in many cases "re-radiated") in that direction. Radiation that is scattered will in many cases be scattered multiple times before being absorbed or returned back to outer space. When the scattering occurs back in the general direction from where it came, it is referred to as



“backscattering,” sometimes also known as reflection. Radiation that is not backscattered is “forward scattered.”

On average, about 25% of the solar radiation that reaches the troposphere is absorbed and 25% is backscattered, which leaves about 50% that reaches the Earth’s surface. About 4% of the radiation that reaches the Earth’s surface is backscattered, so only about 47% of the roughly $1,352 \text{ W/m}^2$ (watts per square meter is a measure of radiant flux density using SI units) that reaches the top of the atmosphere (a value commonly referred to as the *solar constant*) is absorbed by the Earth’s surface. If we are considering anything other than a global average, all these values would vary considerably, and the solar angle of incidence would also have to be considered.

To understand that partitioning of local-scale atmospheric energy between its sensible and latent states we would also have to consider adiabatic processes, especially those associated with cloud and precipitation development and dissipation. So the variation of atmospheric energy on anything less than the planetary scale is infinitely complex, and interactions of all the processes is still not well understood. Nevertheless, numerical models continue to be constructed in an attempt to model these processes for purposes of forecasting future states of the atmosphere on a variety of space and timescales. Some of these are used to forecast weather from a couple of days to periods of 2 wks. (weeks), while others attempt to characterize the state of our climate system decades into the future. At this point in time, with our lack of knowledge regarding the interactions of some of these important processes, the difficulty in simulating cloud and precipitation processes is a limiting factor that cannot be overlooked. In fact, for meteorological purposes, there tends to be too much reliance on numerical models in developing weather forecasts. This situation has grown to the point where it has earned the title “meteorological cancer,” since too heavy a reliance on forecast models has resulted in a general deterioration of our forecasting skills.

Given the difficulty in addressing anything less than planetary scale atmospheric variations in energy, we will focus only on the general inputs and outputs of energy.

The primary inputs of energy into our atmosphere originate from the sun, the rotation of Earth about its axis, and Earth’s surface. Technically, we should also consider the revolution of Earth about the sun and the motion of our solar system with the galaxy, although this motion is generally considered negligible. We also need to consider that Earth’s surface is covered primarily with water, and given water’s large heat capacity, more energy is stored in the oceans with potential input to the atmosphere than in any other reservoir, including the atmosphere. In addition, the land surface is both a heat source and a heat sink, and it does provide orographic (of or relating to mountains) barriers that generate mountain torque, which affects the general atmospheric circulation.

Solar Energy

The sun is a mass of gas with a core, body, and surface. Altogether, the mass of the sun is a million times greater than that of Earth.

Solar energy is generated within the sun’s core primarily by the fusion of hydrogen nuclei into helium. Once that energy is produced, it must pass through the body of the sun, which is made up of thick layers of compressed gas. This takes about 200,000 yrs. before it can reach the sun’s surface, where it is released into outer space. This surface of the sun from where the energy is emitted is known as the *coronosphere*. Solar radiation is emitted from the coronosphere at the speed of light, but even so, it takes about 8 minutes to reach Earth’s atmosphere.

Despite use of the term *solar constant*, the sun’s output is anything but constant. For example, when Earth formed, some 4.6 billion yrs. (years) ago, solar output was only 70% of what it is now. At present, the sun is in the middle ages of its life cycle. As it continues to age, it will emit more solar energy, although we can assume it will radiate roughly within the same general range for the next 5 billion yrs. or so.

Even in its middle-age stage, solar irradiance varies over time. And while this variation is only on the order of a few watts per square meter at the top of the atmosphere, even minor variation can have significant impacts on temperature, as was the case during the Little Ice Age from the



mid 16th to mid 19th centuries. For this reason, the sun must be considered the primary climate control.

Solar variation appears to follow an 11-yr. cycle associated with sunspots and solar flares, which affect solar irradiance. This cycle was discovered in 1843 by Samuel Heinrich Schwabe. Rudolf Wolf reconstructed the cycle history back to the days of Galileo during the 17th century, although he began the modern solar cycle era with Solar Cycle 1 covering the period 1755 to 1766. During the year 2009, we entered Solar Cycle 24. This is the point where sunspots, solar flares, and solar output are at an 11-yr. minimum. Over the following 11 yrs., which is actually the average duration of a solar cycle (range of 10–13 yrs.), solar output will first increase for roughly $5\frac{1}{2}$ yrs., then decrease over the next $5\frac{1}{2}$ yrs. So holding all else constant, we would expect global temperatures to increase, reaching a peak in 2013, with another minimum in about 2019.

While cycle-to-cycle variability exists, there has been a smoothed 75-yr. cycle (ranges between 50 and 100 yrs.) where cycle-to-cycle peaks progress from large to small. When looking back at the Little Ice Age, temperatures were the coldest between 1650 and 1700, when almost no sunspots were observed, a period now known as the Maunder Minimum. A second extremely cold surge occurred from about 1780 to 1830 during the Dalton Minimum. Since about 1940, we have been within a period known as the Modern Maximum, although there are some solar scientists who believe we are heading back toward another long-term solar cycle minimum. Whether this would lead to another Little Ice Age is extremely difficult to say.

The significance of even very minor variations in solar irradiance is important and becomes obvious if annual values are plotted against U.S. annual mean temperatures during a 20th-century time series, as it corresponds much better with temperature than does exponentially rising atmospheric CO_2 .

Volcanic Eruptions

Major volcanic eruptions inject large volumes of sulfate aerosols into the troposphere and stratosphere that can circle the Earth for years,

reflecting incoming solar radiation back to outer space and increasing cloud cover. This will reduce incoming solar radiation, which can cause significant global cooling.

When Mt. Pinatubo erupted in the Philippines in June 1991, it became the largest volcanic eruption of the 20th century and the largest since the eruption of Mt. Krakatau in 1883. While Mt. St. Helens was significant on local scales, it was 10 times weaker than Pinatubo.

The Pinatubo blast spewed over 10 billion metric tons of lava and released between 15 and 30 million metric tons of sulfur dioxide into the atmosphere. In just 2 wks., the sulfate aerosol cloud had spread around Earth, covering the entire planet within a year. The reduction in the Northern Hemispheric average temperature was 0.5 to 0.6 °C, and for the entire globe, the reduction was 0.4 to 0.5 °C. In August 1992, the greatest reduction, of 0.73 °C, was recorded. Following the eruption, the United States recorded its third coldest and third wettest summer in 77 yrs.

When sulfur dioxide mixes with water and oxygen, it becomes sulfuric acid, which ultimately results in the destruction of ozone. During the period 1992 to 1993, after the Pinatubo eruption, the ozone hole over the South Pole reached record size.

In summary, the global impact of the Mt. Pinatubo eruption was greater than that of the El Niño the following summer, which shows how great an effect this single eruption had on the global environment.

Pacific and Atlantic Ocean Oscillations

Given the spatial extent of oceans on planet Earth, there is little doubt that the surface temperatures of these water bodies dominate the global temperature. Considering that coastlines and, to a certain extent, some inland areas exhibit maritime climates, it becomes clear that the ocean influence reaches beyond the limits of the ocean basins.

When we think of heat content, oceans have as much heat in their lower 2.5 m (meters) than does the entire atmosphere. However, ocean heat content is rather large all the way down to the thermocline, with an average depth of about 100 m. Considering that the oceans take in



about 85% of the heat absorbed by the entire Earth, ocean temperature has to be a good measure of global temperature.

The two largest oceans in the global climate system are the Pacific and Atlantic, although the Indian Ocean is a significant player. The largest ocean, the Pacific, would therefore be expected to dominate global ocean and air temperatures. There are cases where an anomalously warm Atlantic would offset some of the effect of a cool Pacific, although the Pacific signal would still be there. Take the period of time from about 2003 through 2009, when the Pacific entered its cool cycle (oscillation between cold and warm cycles is referred to as the Pacific Decadal Oscillation [PDO]). While land-based instrumental air temperature measurements have continued to detect a warming trend, these data could be warm biased, given that the “global” network is dominated by climate stations in Europe and the United States, particularly the Eastern United States. A recent survey of these climate stations found that 85% of them fail to meet the U.S. National Atmospheric and Atmospheric Administration standards for reliable climate measurements, with some of the violations being extreme, such as temperature sensors located immediately next to concrete buildings, air conditioning and heating vents, mechanical room exhaust fans, and so on. Not only that, but there has been a significant instrumentation change over the past 20 yrs., with studies showing the new Maximum Minimum Temperature Systems (MMTS) to be recording overnight low temperatures several degrees higher than the previous Cotton Region Shelter alcohol in glass thermometers. Given that daily mean temperatures are computed as simple averages between 24-hour maximum and minimum temperatures, this could have quite an effect. Also, many of the traditionally rural stations have been encroached on by urban environments, which has warmed the local climate considerably. In a recent study, it was found that while urban climate stations continue to observe rising temperatures, rural stations in the same regions continue to measure nearly constant, if not falling, temperatures. Both NASA satellites and NOAA ocean buoys that record temperatures over the oceans have detected a consistent cooling trend since 2003, so while some land areas appear

to be warming, rural land areas and oceans seem to be cooling. When all is said and done, global temperature appears to have begun cooling in 2003 at the same time the Pacific Ocean entered its cool phase. This cooling trend has continued to this day.

The Pacific Decadal Oscillation (PDO) exhibits a low-frequency periodicity of about 30 yrs. Prior to about 1977, the PDO was in its cold phase just as it has been at the time of this entry being written, which means that the Pacific Ocean as a whole was colder than average, with a predominance of strong La Niña events in the tropical Pacific. During a cold PDO, El Niño events do occur, as they must in reaction to the conclusion of a La Niña event, but they are not as frequent and not as strong. During a warm PDO, strong El Niño events dominate, which increases global temperatures, while weak and infrequent La Niña events are not uncommon. The El Niño/La Niña cycle, called the El Niño Southern Oscillation (ENSO), is well known, and a proper understanding requires recognition that the increase in sea levels due to a long period of a La Niña event necessitates the Pacific warm pool to “slosh” back toward the east, creating an El Niño environment.

By 1977, the PDO shifted dramatically to its warm phase, an event still called the “Great Pacific Climatic Shift.” From this time until the early 21st century, temperatures were much warmer than normal, since this was the PDO warm phase. Two of the most spectacular El Niño events occurred within this period: the 1982–1983 event and the record 1998–1999 event. Strong La Niña events were few and far between during this 25-yr. period.

Now that the PDO has shifted to its cold cycle, global temperatures, except those over land, have come down consistently at the same time as CO₂ has increased dramatically. This recent 6-yr. cooling cycle was not picked up by any of the climate models that suggest a runaway greenhouse effect and drastic global warming. So while CO₂ continues to increase at a dramatic rate, global temperatures controlled by the Pacific Ocean have cooled. Clearly, there are problems with these climate models, as alluded to earlier.

The Pacific Ocean is not the only oceanic consideration. The Atlantic Ocean also has cool and



warm phases, with a periodicity of 20 to 40 yrs. This modulation is called the Atlantic Multi-decadal Oscillation (AMO). During the mid 1920s through the late 1960s, the AMO was in its warm phase, and with all that heat available, hurricane frequency was rather large. By about 1970, the AMO entered its cold phase, and hurricane frequency decreased dramatically. However, in 1995, the AMO reentered its warm phase, and hurricane frequency picked up again dramatically. In 2009, the AMO appeared to be peaking in its warm mode. How long this will continue is difficult to say, but some predict it will begin to decline in about the year 2015. Until then, we can expect a higher-than-average frequency of hurricanes, and hurricanes that are more powerful than average. The only factors that will limit them during some years are El Niño events, when the upper-level wind shear is too strong to allow full development.

As it turns out, however, a warm AMO favors a blocking high near Greenland during the cold season, which amplifies Eastern U.S. troughs. With the polar jet ushering colder than normal air from the northwest, due in part to a cold PDO, then frequent snowstorms should be the rule. During cold AMO events, the upper-level troughs do not become as amplified, and a Greenland block does not exist, so the pattern is very progressive. The East Coast sees its share of snowstorms during this phase, but they move through quickly, leaving only light snow. And even though both oceans will be cold during about 2020 to 2030, which should result in much colder-than-average global temperatures, the milder Pacific air in a progressive flow across the continental United States will likely keep temperatures near to slightly above normal in the East Coast region.

David L. Arnold

See also **Adiabatic Temperature Changes; Air Masses; Anthropogenic Climate Change; Atmospheric Circulation; Atmospheric Composition and Structure; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure; Chinooks/Foehns; Climate Types; Climatology; Coriolis Force; Fronts; Hurricanes; Physical Geography of; Monsoons; Thunderstorms; Tornadoes; Wind**

Further Readings

- Bothmer, V. (2007). *Space weather*. New York: Springer-Verlag.
- D'Arrigo, R. D., Jacoby, G. C., Free, M., & Robock, A. (1999). Northern Hemisphere annual to decadal temperature variability for the past three centuries: Tree-ring and model estimates. *Climatic Change*, 42, 663–675.
- Houghton, H. G. (1985). *Physical meteorology*. Cambridge: MIT Press.
- Marshall, J., & Plumb, R. A. (2008). *Atmosphere, ocean, and climate dynamics: An introductory text*. Burlington, MA: Elsevier/Academic Press.
- Robock, A. (1979). The “Little Ice Age”: Northern Hemisphere average observations and model calculations. *Science*, 206, 1402–1404.



ATOLL

The term *atoll* is derived from the Maldivian word *atholu* and refers to a coral reef that forms a ring around a central lagoon. Above this coral rim are typically numerous small islets that are composed of coral sand, gravel, and aggregate. These islets, often known by the Polynesian word *motu*, are low lying and on average may be no more than 3 m (meters) above sea level. There are more than 250 atolls in the world; most occupy the warm tropical waters of the Pacific and Indian oceans, but some are found as far south as the Elizabeth and Middleton reefs in the Tasman Sea. Some atolls are very small, such as Rose Atoll in the Central Pacific, which has a combined land and lagoon area of only 7 km² (square kilometers), whereas one of the largest atolls in the world, Kwajalein in the Marshall Islands, has a lagoon area of 2,304 km² (see photo).

Atolls have long been of interest to geographers in terms of how they form, as well as the challenges faced by those who live in such isolated and unique environments. This entry will briefly review debates surrounding atoll formation, and it will discuss issues faced by atoll-dwelling communities.



Some atolls of the Marshall Islands

Source: William James Smith Jr. Reprinted with permission.

Atoll Formation

Charles Darwin first hypothesized the subsidence theory for the origin of atolls in 1842. Convinced of the existence of seabed subsidence to counterbalance tectonic uplift, his theory of subsidence suggested that atolls are a product of an evolutionary sequence of coral reef formation around the perimeter of subsiding oceanic seamounts and volcanoes. These fringing reefs maintain growth close to the sea's surface, the optimum depth for coral growth being less than 25 m. Over time and keeping pace with the subsiding landmass, these fringing reefs gradually evolve into barrier reefs and with the final submergence of the landmass, result in an atoll (Figure 1). Darwin's theory was

supported by the results of drilling in Bikini Atoll in 1947 and Eniwetok Atoll in 1951, both in the Marshall Islands, which found volcanic rock beneath reef limestone at depths of 1,600 and 1,405 m, respectively.

Although Darwin's explanation is widely promulgated, there have been two theories put forth as alternatives to his model of atoll formation by subsidence. Reginald Daly's "glacial control theory" took into account the effects of sea level rise as a consequence of historical glaciations and suggested that atolls were the product of weathering and erosion of marine terraces at times of low sea level. In contrast to Daly's proposition, the "karst control" or "antecedent karst" theory developed by Edward Purdy suggested that at times of low

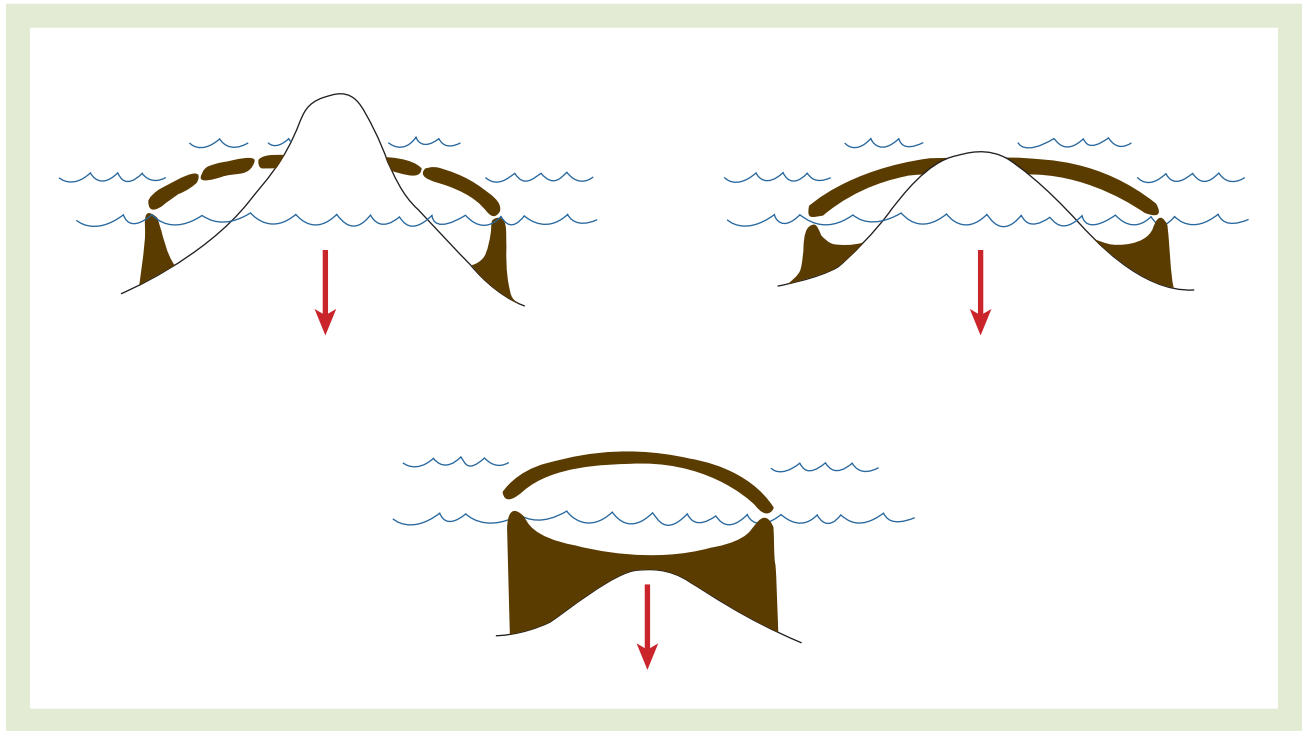


Figure 1 Subsidence theory of atoll formation as a consequence of subsiding landmass

Source: Adapted from Scoffin, T. P., & Dixon, J. E. (1983). The distribution and structure of coral reefs: One hundred years since Darwin. *Biological Journal of the Linnean Society*, 20, 13.

sea level, the exposure of the marine terraces to rainwater would actually result in karst topography. The rim of the marine terrace would result in rainwater runoff from the edge of the marine terrace and concentration of rainwater at the center. These differential rates of solution experienced at the rim and center would result in a depression at the center of the platform that, with subsequent sea level rise, would flood. Coral growth on the peripheral rim would thus form the barrier reef, and flooding of the interior depression in the central lagoon (Figure 2). Debates over atoll formation are ongoing.

Atoll Environments and Social Issues

Atoll environments, with their limited land area, poor soils, and restricted freshwater supplies, tend to support limited terrestrial flora and fauna and have very low levels of species endemism. Marshall Sahlins, most notably, suggested that the social structures of atoll-dwelling communities reflected the distinctive ecological conditions

of atoll environments. Although now widely criticized, his argument linked degree of social stratification to supply and distribution of resources and modes of production; atoll-dwelling communities with limited resources would generally be expected to have less hierarchical and more egalitarian social structures than their high-island counterparts.

Atolls retain a special place in popular imagery and are often described as “natural,” “pristine” environments and isolated and exotic “tropical paradises.” In contrast, however, their geographical remoteness from Western centers has resulted in atolls continuing to play important roles as nuclear testing grounds for Western military forces. The U.S. military, for example, conducted more than 23 nuclear tests on Bikini Atoll between 1946 and 1958, claiming that such tests and the resultant displacement of the entire Bikinian population were necessary for the good of humankind. French nuclear testing on Mururoa and Fangataufa atolls in French Polynesia continued up until 1995, although claims that such tests

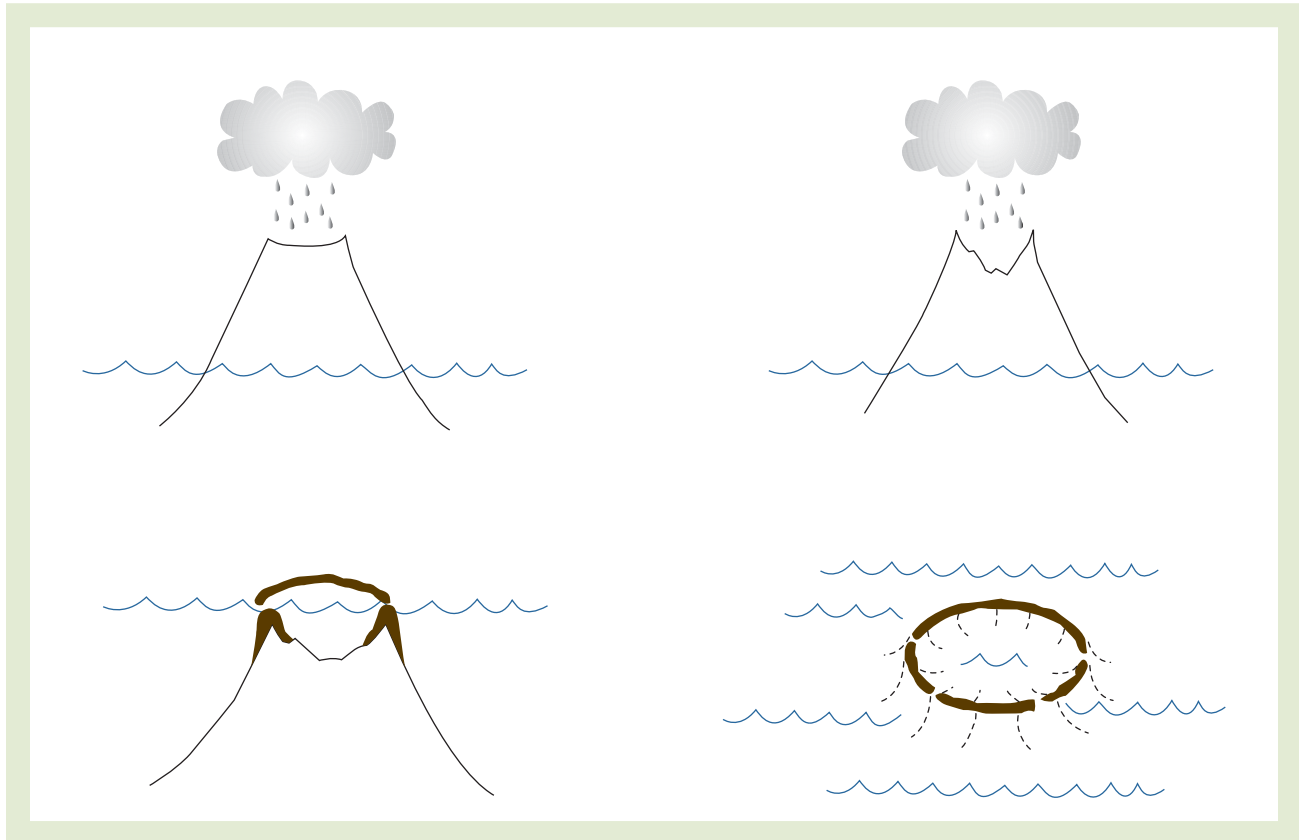


Figure 2 Karst control theory of atoll formation as a consequence of sea-level rise

Source: Adapted from Woodroffe, C. D. (2008). Reef-island topography and the vulnerability of atolls to sea-level rise. *Global and Planetary Change*, 62, 80.

were damaging to the environment continue to be dismissed by French authorities. U.S. military testing of its missile defense systems continues to this day on Kwajalein Atoll.

Atolls and Climate Change

Atolls are deemed to be particularly at risk from events associated with climate change such as sea-level rise, increasing frequency of extreme weather events, and rising sea-surface temperatures. The perceived vulnerability of atolls to such climate change-related phenomena is in part due to their physical characteristics, such as the high ratio of coastline to land area, low relief, and susceptibility to coastal erosion. In addition, many atolls support high population densities, which, combined with low levels of infrastructure, present significant challenges to the residents of such

island nations as Tuvalu and the Maldives, in terms of whether their environments will be able to sustainably support human settlements.

Charlotte N. L. Chambers

See also [Climate Change](#); [Coral Reef](#); [Coral Reef Geomorphology](#); [Global Sea-Level Rise](#); [Island Biogeography](#); [Islands, Small](#); [Karst Topography](#); [Oceanic Circulation](#)

Further Readings

- Barnett, J., & Adger, W. N. (2003). Climate dangers and atoll countries. *Climatic Change*, 61, 321–337.
- Daly, R. A. (1910). Pleistocene glaciation and the coral reef problem. *American Journal of Science*, 30, 297–308.



- Darwin, C. (1962). *The structure and distribution of coral reefs*. Berkeley: University of California Press. (Original work published 1842)
- Davis, J. S. (2007). Scales of Eden: Conservation and pristine devastation on Bikini Atoll. *Environment and Planning D: Society and Space*, 25, 213–235
- Purdy, E. G. (1974). Reef configurations: Cause and effect. In L. F. Laporte (Ed.), *Reefs in time and space* (Special Publication 18, pp. 9–76). Tulsa, OK: Society of Economic Paleontologists and Mineralogists.
- Sahlins, M. D. (1958). *Social stratification in Polynesia*. Seattle, WA: American Ethnological Society.



AUTOMOBILE INDUSTRY

Motor vehicle production constitutes an important industrial sector for many countries. More than 70 million *light vehicles* (defined as passenger cars and light trucks but excluding heavy-duty trucks) were produced worldwide in 2006. Production exceeded 1 million vehicles in 2006 in 16 countries on every continent: Brazil, Canada, China, France, Germany, India, Iran, Italy, Japan, South Korea, Mexico, Russia, Spain, Thailand, the United Kingdom, and the United States. During the first decade of the 21st century, global production of light vehicles was increasing at an annual rate of 4%.

With the growth of motor vehicle production worldwide has come an increasing concentration of producers. The two leading motor vehicle producers, Toyota and General Motors (GM), together manufactured one fourth of the world total. Eight other companies shared another one half of the market. Three dozen companies, mostly based in Asia, split the remaining one fourth, in part through joint ventures with one or more of the top 10 companies.

Small-scale commercial production of motor vehicles began in the United States and several European countries in the 1890s. Early carmakers located in places with expertise in producing key components, especially gasoline engines and bodies. Also critical was proximity to sources of capital willing to invest in a risky new industry with uncertain prospects.

Under the influence of the Ford Motor Company, the geography of motor vehicle production was set during the 1910s. Ford's low-cost Model T held more than one half of the market worldwide, not just in the United States; minimizing transport-related production costs was one way that Ford kept the Model T price low. Ford employees calculated that the optimal spatial arrangement for motor vehicle production was to assemble vehicles near the consumers.

As a bulk-gaining product, the cost of shipping finished vehicles to consumers was much higher than the cost of packing parts into freight cars and trucks. In addition, finished motor vehicles were fragile, high-value items subject to costly damage if shipped long distances. Consequently, Ford produced most of its parts in Michigan but actually assembled its cars at three dozen final assembly plants around the United States near major metropolitan areas where most of the customers were clustered. When GM replaced Ford as the leading carmaker in the 1920s, it too produced most of its parts in Michigan and shipped them to assembly plants near major population centers.

Ford and GM, which dominated worldwide motor vehicle production during the first half of the 20th century, extended to other countries the strategy of assembling vehicles where they were sold. Rather than relying primarily on exports from the United States, the two companies opened assembly plants throughout Europe, Latin America, and Asia to meet—as well as to stimulate—growing local demand.

The changing distribution of motor vehicle sales and production worldwide has reinforced the long-standing geographic paradigm. As more consumers around the world have the income to purchase motor vehicles, manufacturers open assembly plants in these places. Thus, production has grown rapidly in Asia during the early 21st century primarily because demand from consumers in the region has grown rapidly. For example, as sales of light vehicles increased in China from 2.4 million in 2001 to 7.5 million in 2006, demand was accommodated by increasing production in China from 2.4 million in 2001 to 7.3 million in 2006. On the other hand, stagnant production levels in North America during the period reflected stagnant demand in a mature, long-saturated market.

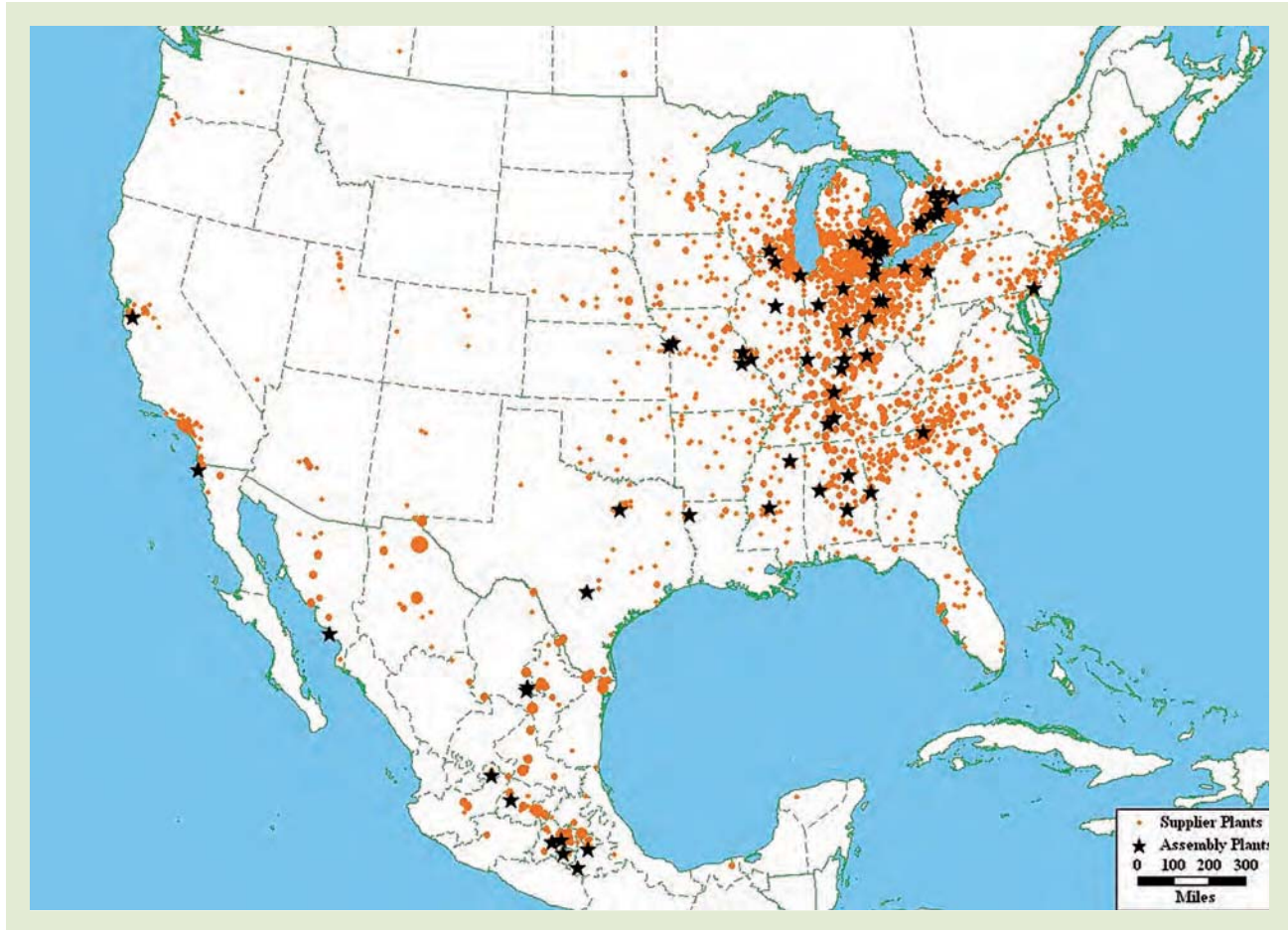


Figure 1 Auto alley in the United States. The restructuring of the automobile industry has produced new geographies stretched between the traditional core and new centers in the South.

Source: Updated by author from Klier, T., & Rubenstein, J. (2008). *Who really made your car? Restructuring and geographic change in the auto industry* (p. 13, Figure 1.3). Kalamazoo, MI: W. E. Upjohn Institute for Employment Research.

The principal exception to the assemble-where-sold model in the early 21st century was the net movement of several million vehicles from Asia to North America. Japanese carmakers sold 7.5 million vehicles in North America in 2006 but produced only 5 million of them there and so met the excessive demand through imports.

The build-where-sold paradigm has been more flexible for parts than for final assembly plants. Parts account for 70% of the value added in the production of motor vehicles. Carmakers were once highly vertically integrated; that is, they built most of their parts in-house. But the leading carmakers, notably, Ford, GM, and Toyota, converted most of their in-house parts operations into independent companies, primarily in the late 1990s.

Under mounting pressure from carmakers to reduce prices for their parts, independent suppliers have adopted global sourcing strategies. More than one fourth of parts used at U.S. final assembly plants were imported in 2006. Mexico, Canada, and Japan together accounted for three fourths of imported new vehicle parts. China ranked a distant fourth and was capturing an increasing share. China was poised to become one of the world's largest producers of new vehicle parts, but most of the parts were destined for domestic producers.

The location of motor vehicle plants has been changing within North America and Europe. In North America, most motor vehicle production has clustered in a region known as auto alley, a



700-mile-long corridor between the Great Lakes and the Gulf of Mexico, for the most part following interstate highways I-65 and I-75 (Figure 1). Nearly all U.S. final assembly plants built since 1980 have been in auto alley, and nearly all plants outside auto alley have been closed. A location in auto alley minimizes shipping costs to the North America market as a whole, as well as ensuring proximity to parts suppliers.

Within auto alley, most new facilities have been located at the southern end, while the northern end has had to endure most of the closures. The southern drift within auto alley is primarily a function of the shift in market share from the “Detroit Three” U.S.-owned carmakers (Chrysler, Ford, and GM) to foreign-owned carmakers. Foreign-owned companies have preferred to locate facilities at the southern end of auto alley, primarily to avoid communities traditionally associated with the Detroit Three. Detroit’s three plants and many of their suppliers have a unionized workforce, whereas unions are rare in foreign-owned plants.

Within Europe, motor vehicle production stagnated during the early 21st century in the traditional manufacturing centers, such as France, Germany, Italy, and the United Kingdom, whereas the Czech Republic, Poland, and other former communist Eastern European countries had sharp increases. Plants in Eastern Europe were close enough to ship to Western European markets yet had much lower wage rates.

The principal uncertainty in anticipating the future geographic distribution of motor vehicle production is the impact of changing fuel sources. Hybrid engines in North America and diesel engines in Europe—early-21st-century bridge technologies—did not fundamentally alter the geography of production. However, vehicles powered by truly alternative sources, such as batteries or fuel cells, may have a more profound spatial impact.

The prospect of commercializing alternative fuel vehicles has set off a scramble among the major motor vehicle producers, large parts suppliers, software providers, and electronics specialists to control the architecture of motor vehicle technology. Just as motor vehicle production clustered in Michigan in the early 20th century to take advantage of local expertise in gasoline

engines, so may motor vehicle production in the 21st century locate near the successful creators of postpetroleum technology.

James M. Rubenstein

See also **Automobility; Deindustrialization; Economic Geography; Fordism; Industrialization; Industrial Revolution; Manufacturing Belt**

Further Readings

- Flink, J. (1988). *The automobile age*. Cambridge: MIT Press.
- Klier, T., & Rubenstein, J. (2008). *Who really made your car? Restructuring and geographic change in the auto industry*. Kalamazoo, MI: W. E. Upjohn Institute for Employment Research.
- Liker, J. (2004). *The Toyota way*. New York: McGraw-Hill.
- Maynard, M. (2003). *The end of Detroit*. New York: Currency Books.
- Rubenstein, J. (2001). *Making and selling cars: Innovation and change in the U.S. automotive industry*. Baltimore: Johns Hopkins University Press.
- Womack, J., Jones, D., & Roos, D. (1990). *The machine that changed the world*. New York: Rawson.



AUTOMOBILITY

Automobility refers to the economic, social, and spatial impacts of the automobile. From its modest roots as a “horseless carriage,” a plaything for affluent Europeans, the automobile emerged to become arguably the defining technology of the 20th century. Automobiles encapsulated the era’s infatuation with speed and power, epitomized mass mobility, reworked cities and rural areas alike, transformed the lives of millions, if not billions, and dramatically reconfigured the structure and meanings of individual and social time and space.

The origins of the automobile lay in Europe, particularly France (hence the numerous French terms, e.g., *chassis*, *chauffeur*). In 1884, Karl Benz



built the first self-propelled vehicle in Germany. Early automobiles were fitted with solid rubber tires, which made transport slow and uncomfortable, until 1888, when John Dunlop invented the air-filled pneumatic tire, which absorbed shocks. The mass production and mass consumption of cars, however, was a distinctively American phenomenon. Henry Ford's introduction of the moving assembly line at the Highland Park factory near Detroit in 1913 initiated a vast revolution in the world of work and production, taking mass production to new heights of productivity and profitability. By pioneering a form of production centered on vertically integrated firms and enormous economies of scale, Ford developed an entire ensemble that became the model for most forms of manufacturing throughout much of the 20th century. (A similar system was adopted by Alfred Sloan of General Motors, who also introduced planned obsolescence.) The process worked spectacularly, generating millions of jobs and relatively high wages (and unions) and raising standards of living.

It was in the United States that the automobile, like the bicycle, first came into widespread use, democratizing access to transportation to an unprecedented degree. In 1895, only four automobiles were registered in the entire country, although this number grew to 8,000 by 1900 and to 458,000 by 1910. The automobile soon displaced rail as the dominant intercity carrier of goods and people. What Ford called the "family horse" evolved into the Model T, the first automobile to gain mass acceptance, whose price dropped in half between 1913 and 1916, initiating a privatization of transportation unparalleled in history.

Sharp gender differences characterized early automobile ownership: Driving was an exclusively male phenomenon, and women took to the road in large numbers only after World War II. The invention of the electric starter in 1912 helped bring a few women into the automobile market, but they remained the exception.

Although most urbanites still used light rail transit in the 1920s, it was not long before the private car was no longer a luxury but a necessity for the middle class. Spurred by Henry Ford's Model T, mass ownership of automobiles in the United States grew stupendously. Whereas the Model T cruised at 30 kilometers per hour, by the

1930s, improvements in engines and chassis and the introduction of leaded gasoline doubled this speed. Farmers turned to cars because of their ability to negotiate unpaved roads and urbanites because of the convenience they offered. Within two generations, almost universal availability of motor transportation became the norm. In the United States, the number of registered automobile owners rose from 1 million in 1912 to 10 million in 1921, 30 million in 1937, and 60 million in 1955. The American experience was quickly emulated by Canada and several Western European countries. However, no European country attained the high levels of U.S. auto ownership, in part due to lower incomes, better mass transit systems, and higher gasoline taxes. European cities, in consequence, assumed a very different form from the sprawling, low-density, multinucleated model prevalent in North America.

With the internal combustion engine, it was the infrastructure rather than the vehicle that presented the greatest constraint to continued reductions in travel time. The internal combustion engine allowed investments to be spread out among users rather than be concentrated on producers, as with railroads. The result was far more flexible geographies that emerged along the interstices of fixed rail lines. Trucks, for example, offered unprecedented flexibility in the spatial decisions of firms, as they allowed perishable and low-valued goods to be distributed quickly and efficiently. Yet the building of roads and highways is fraught with political as well as economic predicaments. In the United States, political pressures from the burgeoning middle class for improved roads accompanied the widespread adoption of cars, leading to rounds of parkways in the 1890s on the outskirts of numerous metropolitan areas. The 1920s witnessed the construction of numerous parkways, which were typically curved and allowed for only limited velocity. Within cities, streets changed from places of pedestrian travel and public life to those whose primary function was to serve as open space to arterials for vehicles.

Mass automobile ownership triggered an enormous wave of time-space compression in the form of suburbanization, the quintessential spatial fix of late modern capitalism and a reversal of the long-standing drift of people from rural areas to



cities. (Some observers attribute the decline of dense, tightly knit urban neighborhoods in the 1920s and the parallel increase in alienation to the rise of the automobile and associated suburbanization.) On the urban periphery, automobiles allowed the radial trunk lines extending from urban cores to be supplemented by networks of circumferential trips. Suburbanization for the middle class became synonymous with upward social mobility, home ownership, and mass consumption. Indeed, the rise of the single-family home and all that it represents in many ways can be attributed to the shift to an automobile-oriented culture. The low residential densities of suburban areas in American cities were typically one quarter of those found in European ones. However, the freedom of choice offered by the automobile came at the price of depriving others: The decentralization of people and economic activities rendered public transportation systems, and those who depend on them, significantly disadvantaged, a cleavage marked by race/ethnicity as much as class. The result was that even the poor became heavily automobile dependent.

Concomitantly, the automobile led to numerous cultural, perceptual, and psychological changes. The generation that first learned to drive on a mass basis in the 1920s may be the only one to appreciate these changes fully, for their predecessors never mastered the art of driving, and their successors took it for granted. Learned doctors warned that the human body was not designed to withstand speeds of 60 miles per hour, and young men boasted if they had traveled at such velocities. Driving combined Western notions of freedom, mobility, privacy, and effortless mastery of enormous power, immersing drivers and passengers into a series of ever-changing spaces that rushed by rapidly. With its drivers and passengers ensconced within their private bubbles, the automobile reaffirmed and deepened the deeply individualistic character of bourgeois life. Indeed, automobile driving generated its own, unique set of feelings, perceptions, and culture (e.g., drive-through services), all of which are enmeshed in racialized, gendered, and national feelings of movement, mobility, identity, and embodiment. Many of the skills and practices of driving became so deeply internalized as to be unconscious.

Much later, the automobile continues to be a decisive force in the structure and restructuring of urban space. In many economically advanced countries, ownership among the middle class approaches near universal levels. The popularity—and necessity—of cars remains highest in the United States, which, with its underfunded mass transit system, has the world's highest rate of automobile ownership. Even in Europe and Japan, however, with their extensive rail and bus networks, the bulk of the population relies on automobiles to navigate space. Convenient, affordable, rapid, and safe automobile transit in the 20th century was, in turn, tied to the availability of cheap gasoline.

As the automobile became the defining symbol of 20th-century mobility, roads displaced rail as the primary object of state intervention in transportation. If the distinctive symbol of 19th-century urbanism was the boulevard, its 20th-century equivalent was the highway. The highway system, like the railroads, represented a major round of investment in the infrastructure, a spatial fix that both facilitated and imprisoned subsequent rounds of capital accumulation. In 1930s Europe, only dictators like Hitler or Mussolini possessed the necessary powers to force highway systems through the landscapes of private land ownership and impose a centralized transportation network. Italy under Mussolini initiated the *autostrade* network in 1924, the world's first roads exclusively designed for high-speed motor traffic. In 1930, the Germans undertook the *autobahnen* system connecting the country's major cities, an effort militarized by the Nazis. But it was the U.S. Interstate Highway System, the largest public works project in history, that epitomized this modality of movement. In requiring national defense to obtain legislative authorization, the interstates also epitomized Cold War politics. Automobile companies, construction companies, earth-moving equipment manufacturers, real estate firms, labor unions, and assorted other business interests supported the project enthusiastically. The system that eventually materialized over four decades (mid 1950s to mid 1990s) included even-numbered routes that ran east-west and odd-numbered ones that ran north-south (Figure 1).

The impacts of the Interstate Highway System are difficult to exaggerate. Its very construction



Figure 1 The U.S. Interstate Highway System, built between the late 1950s and early 1970s, exemplified the country's enormous dependence on the automobile for transportation of people and goods.

Source: Adapted from Moon, H. (1994). *The Interstate Highway System*. Washington, DC: Association of American Geographers.

displaced countless numbers of people in largely minority, impoverished inner-city communities. Together with the millions of cars that made use of it daily, it gave birth to a new landscape of industrial parks, office complexes, shopping malls, motels, fast food, and gasoline stations. Average interurban travel times declined by 10% within the first decade. The new road networks accelerated the flight of manufacturing from the Manufacturing Belt to the emerging Sunbelt, the suburbanization of people and firms, and the dispersal of industry to nonmetropolitan areas. With the option of both enhanced access to downtowns and life in low-density peripheries, commuting distances, but not times, for many suburbanites increased. Highway interchanges became intensive sites of commercial development in their own right. The evacuation of the middle class rose to new heights, with attendant crises for the governments and neighborhoods of the urban core. The

highway system thus completed the long-running transition of the American city into a completely automobile-dependent spatial formation, including massive suburbanization, a process that has continued well into the 21st century.

Barney Warf

See also **Automobile Industry; Fordism; Mobility; Suburbs and Suburbanization; Time-Space Compression; Transportation Geography; Urban Spatial Structure; Urban Sprawl**

Further Readings

Featherstone, M. (2004). Automobilities: An introduction. *Theory, Culture and Society*, 21, 1–24.



- Flink, J. (1988). *The automobile age*. Cambridge: MIT Press.
- Hugill, P. (1982). Good roads and the automobile in the United States, 1880–1929. *Geographical Review*, 72, 327–349.
- Moon, H. (1994). *The Interstate Highway System*. Washington, DC: Association of American Geographers.
- Newman, P., & Kenworthy, J. (1999). *Sustainability and cities: Overcoming automobile dependence*. Washington, DC: Island Press.
- Scharff, V. (1991). *Taking the wheel: Women and the coming of the motor age*. New York: Free Press.



AVALANCHES

Avalanches occur as rapid, gravity-driven accelerations of different materials downslope at high rates of speed. All avalanches are caused by an overburden of material that is too massive and unstable for the slope that supports them. At least five different types occur, each type with numerous subtypes or relationships to other types: (1) snow avalanches, (2) ice avalanches, (3) slush avalanches, (4) debris avalanches, and (5) rock avalanches. Because of their common high velocities, all avalanches are greatly threatening to life, limb, and property, and the lives of tens of thousands of people have been lost in the many notorious occurrences. Because of the steep slopes and high potential energies of mountains that can convert their potential energy into high kinetic energy wherever snow, ice, slush, debris, and rock are detached from cliffs through climatic or seismic events, many mountain areas are the locations of all five of these types of mass movement. People who live in such areas are generally well aware of these natural hazards and face such risks with a certain fortitude, based on an understandable desire to beat the odds of what they hope are rare events. But, of course, the gambling odds are all too often not in favor of the people or their infrastructures in mountain regions where any or all types of avalanches can be common.

Snow Avalanches

Snow falls and accumulates on mountain slopes as snowpack wherein the commonly light and fluffy flakes of powder snow pile up, become unstable in various ways, and eventually flow downhill as a snow avalanche. Because of the ubiquity of snow, and therefore of snow avalanches, in almost all high mountain regions, the science of analysis and prediction of such events has become quite sophisticated. Mountain weather, snow formation and snow pack, avalanche formation, and avalanche terrain, motion, and effects are all important elements in the prediction of snow avalanches wherein the elements of stability evaluation and snowpack observations enable better avalanche forecasting.

Avalanche-relevant mountain weather first concerns the deeper snows and relatively milder temperatures of the maritime snow climates of coastal mountains, as opposed to the lighter snows and colder climates of interior ranges, both of which types can set up different conditions of snow instability. Temperature conditions are an essential element in the consideration of avalanches—both while the snow is falling, being redeposited, or both, as well as much later in the heat exchange at and within the snowpack. The snow itself falls in many different forms of crystal type, from the light and fluffy powder flakes to the heavy, coarse graupel, or hail, with an enormous variation in between. Heat exchange at the snow surface occurs as heat enters or leaves the snowpack by conduction or convection of radiation as well as by condensation resulting from diffusion of water vapor. Metamorphism of the snow crystal results. Formation of feathery crystal of unstable surface hoar frost (e.g., frozen dew on a surface) can be a problem, especially where buried by later snowfalls. The melting and refreezing of moisture between snow crystals in contact with each other causes the formation of grain bonds, or sintering, which are also crucial elements in snow strength, so that the temperature, temperature gradients, grain geometries (i.e., orientation of grains in a deposit), and pore-space (i.e., gaps between grains in a deposit) configuration can all figure in avalanche formation. The highest crystal growth rates occur where there are large temperature gradients, higher temperatures, and large spaces between



crystals. This produces unstable angular or faceted (i.e., grains with one or more smoothed surfaces) grains or depth hoar.

In addition to temperature and pressure in snowpack metamorphism as a factor in snow-avalanche formation, horizontal and vertical winds also control the amounts and distributions of snow as primary precipitation events or as secondary redistributions through blowing and drifting. Snow is eroded in acceleration regions and deposited in deceleration regions, which produces lee-zone (i.e., in the leeward side of an obstacle) accumulations, cross-loading, deposition in gullies and notches, and unstable cornices (cantilevered snow structures formed by drifting snow) built out as overhangs off ridge tops, all of which can become potential avalanche sites as a result.

Snow-avalanche formation types are generally classified as loose snow avalanches that generally start at a point or the more dangerous slab avalanches that can propagate laterally across a slope. Loose snow avalanche formation occurs because such snow has little if any cohesion between flakes. A local loss of cohesion can result in a small movement that will propagate in a downhill direction into a bigger mass that can incorporate other snow layers of different moisture contents. Slab avalanches generally develop from a weaker layer such as faceted snow or depth hoar that fails and allows fractures of the snow to propagate both upslope and across slope to release the avalanche. The slope angles can control the types of snow avalanches so that dendritic (i.e., like the branching pattern of tree roots) or stellar snow crystal shapes have the highest stable angle of repose (up to 80°), while this may decrease to 35° for more rounded forms. As the water content increases, the angle of repose decreases, so that slush avalanches can occur on slopes of less than 15°. The normal range of slopes for release of slab avalanches is ~25° to 55°.

Avalanche terrain is the area in mountains where certain features exist that warn of an avalanche hazard. An avalanche area is one in which various times, types, and geographies of snow avalanches occur throughout one or more avalanche paths. Any given avalanche path will have its own starting zone, track, and runout zone. Starting zones or zones of origin of avalanches are commonly higher on mountain ridges, slopes, gulleys,

and other collection points for snow. Slope angles there range from 90° to 60° for small snow sloughs, because enough snow can never accumulate to form large avalanches. Dry snow types range from 30° to 60°, small slabs from 45° to 55°, multislized slabs from 45° to 35°, and large slabs or wet, loose snow avalanches from 35° to 25°. Infrequent wet snow avalanche types occur from 25° to 10°. Other controls include orientation to the wind, orientation to the sun, forest cover, underlying ground surface, altitude, slope dimensions, and crown and flank positions of fracture lines according to local terrain features. The track or zone of transition through which the moving snow mass flows is the area of highest velocity. These areas are either open slopes or channels, and the typical slopes are 30° to 15°, with significant deceleration on slopes below 10°. The runout zone or zone of deposition is where the avalanche comes to a stop and drops its load of snow and any entrained debris or trees and so forth. Determination of runout distances in avalanche hazard analysis includes long-term observations of avalanche deposits, observations of damage to vegetation, structures, and the ground surface, and historical records. Avalanche frequencies can also be determined by analysis of the disturbed vegetation.

Ice Avalanches

Rapid avalanches of ice in mountains are generally caused when a glacier terminus (snout or end) is perched high on cliffs above, and as its front collapses through forward advance to the cliff edge, ice masses can be precipitated into the air or down steep slopes as huge and rapid masses of ice blocks. In some cases, where rock materials are incorporated as well and the internal ice melts, the moving mass can become a kind of rapid and highly mobile debris or rock avalanche. The two classes of ice avalanches resulting are thus based on size.

The smaller type is the result of *calving* or falling of ice blocks caused by internal flow (creep) and possibly also sliding of the glacier over its bed to a cliff edge where blocks break off and roll or bounce down the cliff as an analog to a rockfall. In many of the higher mountains in the world, these ice avalanches accumulate again at the cliff bottom to reconstitute a kind of glacier detached from its accumulation zone higher on the mountain.



An avalanche in the Caucasus Mountains

Source: iStockphoto.

The larger, rare types of ice avalanche occur where a huge piece of the glacier breaks off to form a massive ice avalanche, analogous to a large rapid landslide or rock avalanche, which can be greater than 10^6 m^3 (cubic meters) in size. These are enormously destructive, having buried whole towns and thousands of people in the Andes, Alps, Caucasus, and elsewhere. Some of them have rock entrained in the failure as well, so that a continuum between large ice avalanches and rock avalanches probably exists.

Slush Avalanches

These are a class of wet slab avalanches that are most common at high latitudes, generally due to rapid onset of spring snowmelt when the sun returns after long, dark winters. Starting zones

can be 5° to 40° , but only rarely $>25^\circ$ to 30° . The snowpack is commonly partially or completely water saturated, and the bed surface of the failure is fairly impervious to that water. Depth hoar frost is common at the base of the snow cover, and failure release into a slush flow or “slusher” is commonly associated with intense snowmelt or heavy rain. Slush avalanches have exceptionally high densities, in some cases $>1,000 \text{ kg (kilograms)/m}^3$, so that impact forces are among the highest and most destructive of any snow avalanches known.

Debris Avalanches

As their name implies, debris avalanches are usually mixed up masses of soil, gravel, rocks, trees, houses, cars, and whatever random materials



On May 31, 1970, a massive debris avalanche in Yungay, Peru, caused by a 7.9-magnitude earthquake, scoured this valley from wall to wall, burying the town of Yungay and killing most of its population. Some people were saved by climbing Cemetery Hill (shown here) to escape the avalanche.

Source: © Lloyd Cluff/Corbis.

exist on mountain slopes that can be mobilized and accelerated downslope in torrential rainstorms, rapid snowmelt, or collapse of water dams. Rainfall intensity or duration, along with the prior rainfall and general soil moisture conditions, is also a strong control in the triggering of debris avalanches.

Most well-vegetated mountain slopes have a thin veneer of sediment and soil on them that has been draped over them by glaciers, wind, and other processes and that is produced by long-term weathering of the bedrock beneath. Debris avalanches are common in topographic concavities or hollows in first-order watersheds. This geometry is conducive to the accumulation of colluvium and other sediment as well as the convergence of underground water necessary to cause the failure. Failure of this surficial cover is triggered by an unusual amount of water being delivered abruptly to the slope so that the water

first infiltrates into the soil and sediment, saturates it to fill all pore spaces, and then, through return flow, begins to come back to the surface again lower down the slope. This greatly increased weight of water on the slope in the soil, coupled with the hydrostatic water pressure upward inside the slope cover and the seepage pressure of the return flow out onto the surface, lifts the sediment and soil mass and mobilizes it into the debris avalanche. Such rapid movements have a dominance of inertial forces with a high sediment concentration in a granular flow.

Rock Avalanches

These rapid inertial granular flows are caused when a large volume of mostly dry rock fragments derives from the collapse of a slope or cliff and moves for a long distance, even on gentle slopes. These *strurzstrom* failures (i.e., failures



that exhibit much greater horizontal movement than initial vertical drop) can be initiated by a sudden seismic acceleration, a melting of internal permafrost in the rock joints, a debutressing of the slope when nearby glaciers melt downward and remove support, or perhaps a simple freeze-thaw that wedges the rock mass outward. Once started, the fall height or sliding distance can impart a high velocity, which produces dilation and reduction of internal friction. These highly mobile masses of rock fragments can flow for long distances, apparently owing to a low effective coefficient of friction produced by some combination of fluidization produced by entrained air, vacuum-induced upward flow of air from the airfoil shape of the upper flow surface, trapped basal air-layer lubrication, buoyant dust suspensions, acoustic fluidization, or high-frequency vibration, steam generation from frictional heating, and various other hypothesized mobilization mechanisms. The result is that these long-runout-zone landslides are incredibly destructive, move with great rapidity, and obliterate everything in their path. In fact, as the size of the falling rock mass increases, the ratio of the fall height to the travel distance decreases, so that lower distances of fall can lead to further distances of travel. Lateral and frontal rides can develop when the rapidly traveling mass comes to an abrupt stop. These enigmatic features have also been observed on the Moon and Mars, where the gravity and atmospheres are very different, yet the physics of their motion must somehow be similar to produce near-identical surficial features.

John F. Shroder

See also **Earthquakes; Geomorphology; Glaciers; Mountain; Ice; Landforms; Landslide**

Further Readings

- Easterbrook, D. J. (1999). *Surface processes and landforms*. Upper Saddle River, NJ: Prentice Hall.
- McClung, D., & Shaerer, P. (1993). *The avalanche handbook*. Seattle, WA: Mountaineers Books.
- Pudasaini, S. P., & Hutter, K. (2007). *Avalanche dynamics: Dynamics of rapid flows of dense granular avalanches*. New York: Springer.



AVIATION AND GEOGRAPHY

In the more than 100 years since the Wright brothers' first flight at Kitty Hawk, North Carolina, aviation has become a significant influence on human geography. The world's air carriers now account for most intercontinental and transcontinental passenger trips and a rapidly growing share of shorter-haul movements, and they carry about 40% of world trade by value. Air transportation has become more important as it has become more affordable due both to technological change and, especially in the past few decades, to the deregulation and privatization of the airline industry. The resulting increased share of the world's travelers and cargo moved by air has affected patterns of urban and regional economic development and has helped enlarge the spatial scale of everyday life—as is evident in the global traffic in everything from tourists to fresh-cut flowers. At the same time, however, inexpensive and widespread air mobility has emerged as a potent force affecting the environment.

An early theme of geographic research on air transportation concerned the development of airline networks. In the 1950s, geographers examined the structure of airline networks in the United States, for instance, as a way of learning about the broader structure of the American urban hierarchy. Today, the scale of interest is global. The world's airlines operate networks within which the primacy of alpha world cities such as London, New York, and Tokyo is evident. Conversely, cities in the periphery tend to be more difficult and expensive to reach, and that disadvantage, among many, perpetuates their poverty.

The architecture of an airline network is not, however, solely attributable to the relative wealth and power of the cities linked. Aircraft technology is another important consideration; advances in the capacity, speed, and range of commercial airliners have encouraged time-space compression, the stretching of nonstop linkages, and the consolidation of traffic at a relative handful of major hubs. In the past decade, airlines have begun flying several aircraft models whose range is long enough to connect almost any two cities on the

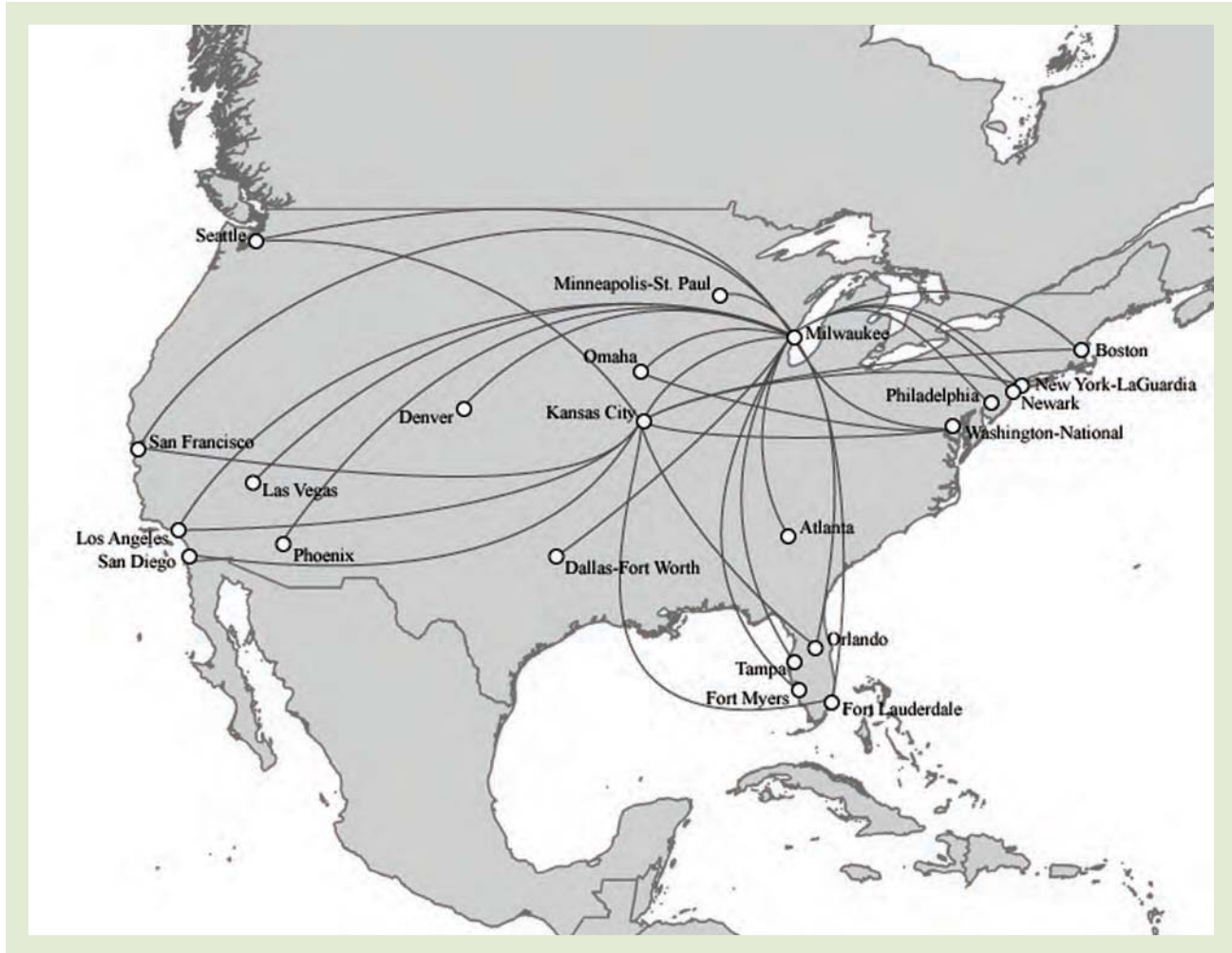


Figure 1 Midwest Airlines network: an example of a hub-and-spoke network

Source: Author.

planet nonstop. Among these new planes is the Airbus A380, which not only has a very long range but is also the largest commercial jet in service. The A380, which has lower costs per passenger-kilometer due to economies of scale, is expected to fly on routes linking the world's most important hubs, especially in Asia. Interestingly, the maiden commercial flight taken by the "Superjumbo" linked Singapore and Sydney, making it the first major jetliner to debut on a route involving neither the United States nor Europe.

Singapore and Sydney are examples of cities that have benefited greatly from the privatization and deregulation of the airline industry. Since the 1970s, many formerly state-owned carriers, such as Singapore Airlines and Australia's

Qantas, have been at least partially privatized, and governments have loosened regulations that once limited the number of airlines on particular routes, the capacity they offered, and the airfares and air cargo rates they levied. Geographers have analyzed the consequences of these changes across the world. In the United States, deregulation in 1978 led to the elaboration of hub-and-spoke systems with many "spoke" cities feeding traffic into and being fed in turn by traffic from one of several major hubs. Midwest Airlines (Figure 1), for instance, is able to offer higher frequency service to more destinations by consolidating traffic at its two hubs.

Research has shown that the largest hubs have gained from their superior accessibility. Delta Air

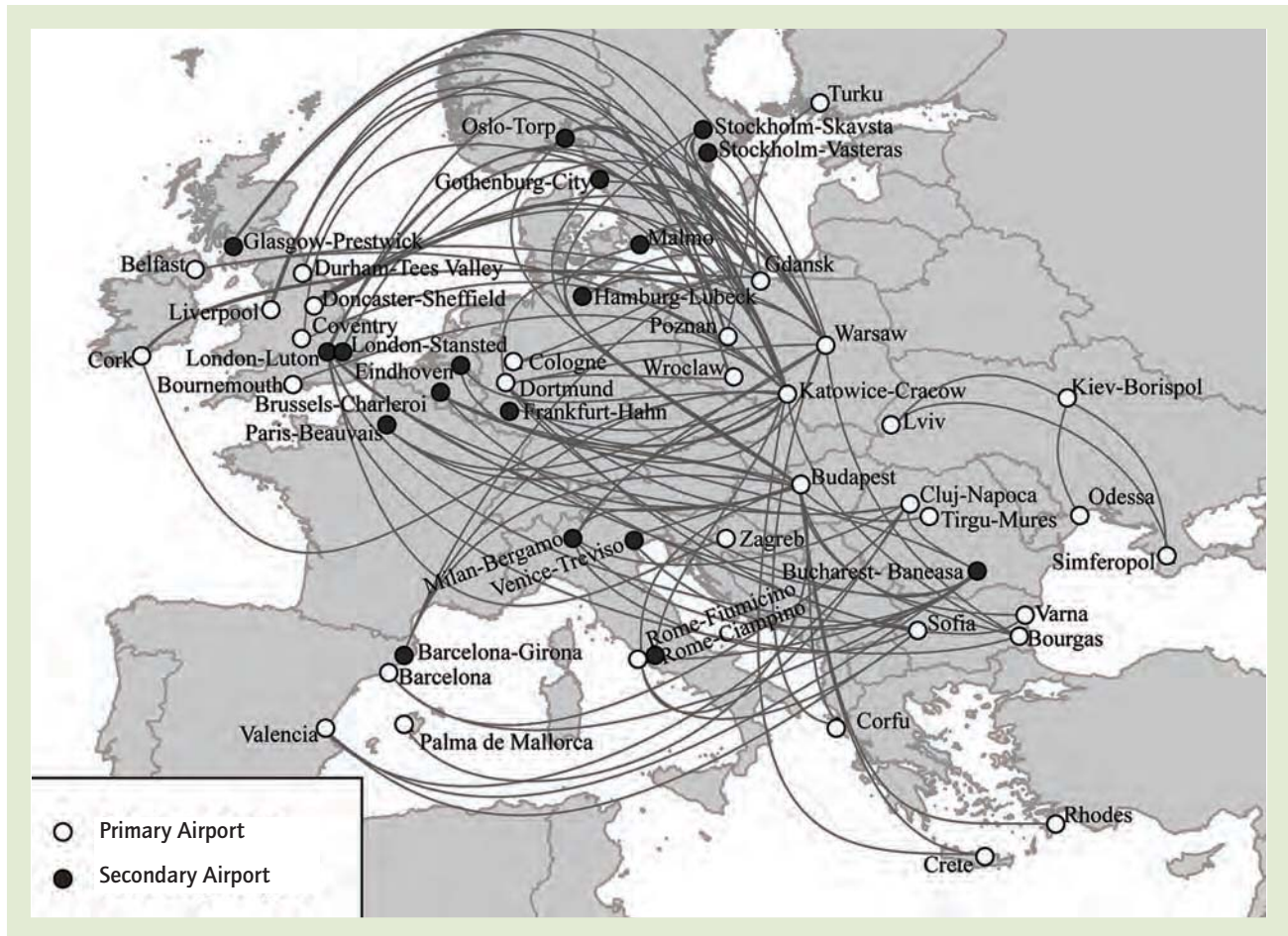


Figure 2 Wizz Air: an example of the greater emphasis on point-to-point services in a low-cost carrier's network

Source: Author.

Lines' hub in Atlanta has helped make the city's airport the busiest in the world in terms of passenger volume, which in turn has had a catalytic effect on Atlanta's economic development, especially in the vicinity of the airport (and the same is true in cities that have important air cargo hubs, such as Memphis with its FedEx hub). On the other hand, Delta's dominance of flights to and from the city has made the city one of several "megahubs," where high levels of market concentration have muted the effect of deregulation on fares. A number of spoke cities, too, with few competitors, have been high-cost "pockets of pain."

The more general pattern, however, has been for competition to increase in deregulated markets. Many of the new players in the industry are low-cost carriers (LCCs), which have costs that

are, on average, less than half those of full-service network carriers such as Delta. An interesting spatial element common to many LCCs is the use of inexpensive secondary airports. For instance, the Hungary-based airline Wizz Air (Figure 2) uses airports such as London-Luton instead of the more costly London-Heathrow. Several other important aspects of LCCs are illustrated by Wizz Air. First, LCCs often have a stronger emphasis on point-to-point services instead of hub-and-spoke operations—though many LCCs do have hubs. Budapest, Katowice, Warsaw, and Gdansk are more important than other cities in the Wizz Air network, but there are many non-stop services that bypass these cities. Second, Wizz Air has taken advantage of deregulation in Europe to operate routes that would have been impossible a few decades ago. Although it is a



Hungarian carrier, Wizz Air operates several hubs in Poland and flies domestic routes in the Ukraine. The very existence of Wizz Air is testament to liberalization, since Hungary had only one state-owned airline for decades. Finally, the irreverent name of the carrier reflects the democratization of air travel that LCCs and their low fares have helped engender.

The very popularity of air travel may be a problem, however. The environmental sustainability of LCCs and the air transportation system generally have been called into question by geographers. Aviation has significant environmental costs at a variety of scales, including the global. In fact, the world's airlines account for an estimated 2% of anthropogenic climate change, but that share is projected to grow, and with it, so will the concerns about the "hypermobility" afforded by inexpensive air transportation. Low fares and air cargo rates have made it easier to vacation farther from home, to eat fresh produce year-round, to operate globally dispersed production networks, and even to commute between countries; but in aviation's second century, these practices are likely to come under increasing

pressure, from higher energy prices and from policies intended to protect the environment.

John Bowen

See also **Accessibility; Mobility; Time-Space Compression; Transportation Geography; World Cities**

Further Readings

- Derudder, B., Devriendt, L., & Witlox, F. (2007). Flying where you don't want to go: An empirical analysis of hubs in the global airline network. *Tijdschrift voor Economische Geografie*, 98, 307–325.
- Graham, B. (1995). *Geography and air transport*. New York: Wiley.
- Solberg, C. (1979). *Conquest of the skies: A history of commercial aviation in America*. Boston: Little, Brown.
- Zook, M. A., & Brunn, S. D. (2006). From podes to antipodes: Positionalities and global airline geographies. *Annals of the Association of American Geographers*, 96(3), 471–490.

B



BARRIER ISLANDS

Barrier islands are an important part of the natural, economic, and recreational landscape of the North American coast. These elongated and detached bodies of unconsolidated sand or gravel lie above the high-tide level and are separated from the mainland by a lagoon, a marsh, or a sound. The islands are most prominent on wide and gently sloped trailing edge coasts, although they can form on collision coasts where there is an adequate supply of sediment. The islands typically occur in chains separated from neighboring islands by inlets, which are spaced depending on the relative strength of wave and tide forces. Long (wave-dominated) barriers tend to form where tidal range is small, and waves are able to close breaches that form during storms (e.g., from Southern Texas to the Northwest Florida coast). In contrast, mixed-energy barriers form through a combination of wave and tide forcing, leading to short barriers that are wider on one end (a drumstick) and separated by stable inlets with large sand shoals (e.g., the Georgia coast).

Theories of barrier island formation include (a) the subaerial growth of near-shore bars, (b) the long-shore progradation and eventual breaching of spits, and (c) the submergence of coastal dune ridges during the last glacial lowstand. Most barrier islands are less than 7,000 years in age, suggesting that they formed during a

period when sea level was gradually rising, most probably as a combination of all the above mechanisms. Once formed, the morphology, composition, and stability of a barrier island depends on the relative importance of waves and tide, the availability of sediment, and relative sea-level rise. If there is a sufficient supply of sediment from offshore or alongshore, the island progrades seaward, leading to a regressive barrier, able to maintain itself against rising sea level. However, most modern barrier islands are retreating landward in response to both global (eustatic) sea-level rise and local subsidence at a rate that depends on the slope of the continental shelf. Despite an almost constant rise in sea level, barrier island transgression (rollover) tends to only occur during extreme storms capable of breaching the foredune and distributing sediment to the back of the island in the form of washover fans (see second photo).

The ability of coastal dunes to control the rate and timing of transgression depends on the ability of dunes to redevelop in height and extent from sediment delivered from the beach or washover fans by the wind following storms. Barrier islands affected by frequent storm events tend to be low in profile and are susceptible to island overstepping (island inundation). A lower frequency of storms or a large supply of sediment leads to larger dunes that can recover quickly following a storm, thereby limiting washover and promoting island rollover. A change in the rate of sea-level rise or the frequency of hurricanes and



Santa Rosa Island, a wave-dominated barrier island in northwest Florida, photographed in 2004

Source: Author.



Santa Rosa Island in northwest Florida following Hurricane Ivan (September 2004). Shown are washover fans extending into the sound behind the island. This transfer of sediment is part of the barrier's transgression.

Source: Author.



tropical storms and a reduction in sediment supply through the construction of groins and jetties may lead to more rapid transgression and shoreline erosion.

Chris Houser

See also Coastal Erosion and Deposition; Coastal Hazards; Coastal Zone and Marine Pollution; Delta; Dunes; Geomorphology

Further Readings

- Dean, C. (1999). *Against the tide: The battle for America's beaches*. New York: Columbia University Press.
- Sallenger, A. (2000). Storm impact scale for barrier islands. *Journal of Coastal Research*, 16, 890–895.



BARROWS, HARLAN (1877–1960)

Harlan H. Barrows was an American geographer best known for his interpretation of geography as human ecology. He expressed this view in his 1922 presidential address to the Association of American Geographers. In Barrows's opinion, simply describing what exists in the landscape was not enough. He believed geography should focus on the actions people take and the adjustments they make to live in their environments. In other words, Barrows thought it was important to focus on what people do to survive and thrive in their environments rather than looking for how the environment influences them.

In Barrows's day, many believed that cultures were influenced almost entirely by the environment. This belief, called *environmental determinism*, does not consider the fact that people make decisions and adapt to their environments. Instead, determinists look for environmental

factors that influence or "determine" culture. Barrows held that geographers should study the interactions people have with the environment rather than looking for influences. He thought environmental determinists searched for simple answers, seeking influences in the environment that do not really exist. His colleague, Ellen Churchill Semple, was a well-known environmental determinist and one of the first female geographers.

In Barrows's view, geography was largely about the relationships people had with their environments. He believed that this approach would help geographers discover the complexity of human-environmental relationships. Achieving this goal of discovering human and environmental relationships required geographers to balance knowledge of the natural world with knowledge of the social world, especially history and economics. Barrows differentiated history and historical geography. In his view, history starts at the past for the purpose of learning about the past, but historical geography starts with the present and should study how relationships with the environment progressed. Barrows was more concerned with the present than the past.

Born in Armada, Michigan, he earned his BS degree from the University of Chicago in 1903. That same year, the University of Chicago established the first university geography department in the United States. In 1907, Barrows was hired as a geography instructor and became a professor in 1914. He was promoted to chair of the department of geography in 1919 and maintained that position until stepping down and becoming an emeritus professor in 1942. Barrows also worked on numerous natural resource projects for the federal government. A common theme for much of this work concerned the conservation of water resources, which he included in reports to the U.S. Bureau of Reclamation and the U.S. National Resources Committee.

Jessey Gilley

See also Anthropogeography; Environmental Determinism; Human Ecology; Semple, Ellen Churchill



Further Readings

- Barrows, H. (1923). Geography as human ecology. *Annals of the Association of American Geographers*, 13, 1–14.
- Chapell, J. (1971). Harlan Barrows and environmentalism. *Annals of the Association of American Geographers*, 61, 198–201.
- Koelsch, W. (1969). The historical geography of Harlan H. Barrows. *Annals of the Association of American Geographers*, 59, 632–651.



BASIN AND RANGE TOPOGRAPHY

Basin and range topography is a type of landscape where ridges and mountains alternate with depressions in a somewhat regular pattern. Such topography occurs wherever diastrophic processes have produced faults that have uplifted blocks and dropped down intervening basins. These features are not tied genetically in any way to arid areas but many of the best-known examples do occur in such regions, which allows for greater recognition of them partly because of good exposures of the causative structural processes. Many of the basins have entirely interior or endorheic drainage so that no water drains out to the sea. Such landscapes occur in the well-known Great Basin geomorphologic province of the southwestern United States and northwestern Mexico, as well as the dry littoral regions of Chile and Peru, parts of Iran, Western Afghanistan, and Southern Pakistan, in Central Asia, and in parts of the Sahara Desert in Northern Africa. Additional examples are known from northeastern Japan and the Gulf of Corinth, Greece.

The primary genetic attributes characteristic of basin and range topography are down-dropped *graben* rock structures and uplifted *horst* block rock structures that are bounded with tensional normal faults. In addition are numerous cases of tilted fault blocks that are lifted up on one side and dropped down on the other into what are termed *half-grabens*. In either case the graben and

half-graben basins are generally filled in with sediment derived from the erosion of the nearby uplifted horst blocks or mountains. In arid regions, most of these graben or basin-filling sediments are comprised of alluvial fan sands and gravels, with the basin centers being largely alluvial plains down which ephemeral stream channels flow, or lacustrine (lake) infillings left as former water bodies dried up and became dry or *playa* lakes, the most well-known of these playa lakes is Lake Bonneville that existed during the Pleistocene Ice Age. Lake Bonneville was a large lake centered on what is now the State of Utah, which dried up as the climate warmed and dried after about 10,000 years ago to leave the shrunken remnant of what is now the Great Salt Lake, as well as the Bonneville Salt Flats that are used for attempts at land speed records.

The cause of faulting of basin and range structure and topography in the American Southwest is crustal extension or stretching of the rocks of the crust, perhaps several tens of millions of years ago. In the course of the disruption of the crust, huge outpourings of lava occurred, which left extensive lava-capped tilted fault blocks at the edges of the half-grabens. The cause for this crustal extension is not known with certainty but apparently when the great slab of the North American tectonic plate was pushed up on top of the San Andreas transform fault zone, a compressional gap developed. This seems to have reduced the compressional forces that the Great Basin area was under and allowed extension of the crustal rocks toward the slab gap and out more rapidly to the west. The result was the extensive north-south normal fault system that allowed the crust to fragment so extensively.

John F. Shroder

See also **Climate: Dry; Diastrophism; Geomorphology; Landforms**

Further Readings

- McPhee, J. (1982). *Basin and range*. New York: Farrar, Straus & Giroux.



BATTY, MICHAEL (1945–)

Michael Batty is one of the most renowned and forward-thinking, analytical-planning researchers of his generation, and it is from this perspective that he has made enduring contributions to GIScience. He graduated in Town and Country Planning from the University of Manchester (United Kingdom) in 1966 and earned a PhD from the University of Wales in 1984. He has had a successful and varied career on both sides of the Atlantic Ocean: After holding junior faculty positions at the universities of Manchester, Reading (United Kingdom), and Waterloo (Canada), he became professor of city and regional planning at Cardiff University (United Kingdom) in 1979, where he also served (between 1983 and 1986) as dean of the School of Environmental Design. In 1990, he moved to the State University of New York at Buffalo in order to serve as site director of the National Center for Geographic Information and Analysis. He returned to the United Kingdom in 1995 to establish and direct the interdisciplinary Centre for Advanced Spatial Analysis (CASA) at University College London, where he also serves as Bartlett Professor of Planning. Since 1981, he has also worked as editor-in-chief of the journal *Environment and Planning B: Planning and Design*. He was elected a fellow of the British Academy in 2001 and was awarded a CBE (Commander of the British Empire) for services to geography in 2004.

Many of his contributions to the development of GIScience are summarized in the 2003 CASA-edited collection, *Advanced Spatial Analysis: The CASA Book of GIS*. The most recent summary of his path-breaking contributions to the understanding of the size, shape, scale, dimension, and functioning of city systems can be found in his 2005 monograph, *Cities and Complexity*. His 1976 book, *Urban Modelling*, defined the agenda for quantitative analysis of city systems over the following 25 years, and his 1994 book *Fractal Cities* provides an early yet rich statement of ideas concerning the way in which cities grow and change. Other key research has focused on the development of agent-based models in GIScience and the laws that characterize population growth.

Paul A. Longley

See also **Agent-Based Models; Cellular Automata; Complexity Theory; GIScience; Models and Modeling; Spatial Analysis**

Further Readings

- Batty, M. (1976). *Urban modelling*. Cambridge, UK: Cambridge University Press.
- Batty, M. (2005). *Cities and complexity: Understanding cities with cellular automata, agent-based models, and fractals*. Cambridge: MIT Press.
- Batty, M. (2006). Rank clocks. *Nature*, 444, 592–596.
- Batty, M. (2008). The size, scale, and shape of cities. *Science*, 319, 769–771.
- Batty, M., & Longley, P. (1994). *Fractal cities: A geometry of form and function*. London: Academic Press.
- Longley, P., & Batty, M. (2003). *Advanced spatial analysis: The CASA book of GIS*. Redlands, CA: ESRI Press.

BAYESIAN STATISTICS IN SPATIAL ANALYSIS

Bayesian maximum entropy (BME) is a group of spatial analysis techniques that are used to study natural systems (physical, biological, health, social, financial, and cultural) and their attributes. Methodologically, spatial BME analysis is a synthesis of stochastics theory with epistematics principles. Stochastics theory involves random fields (spatial and spatiotemporal; ordinary and generalized). Epistematics introduces a fusion of evolutionary concepts and methods from brain and behavioral sciences (e.g., intentionality, adaptation, teleology of reason, complementarity, and prescriptivity) in real-world problem solving. Consequently, instead of a dry presentation of spatial analysis within a hermetically sealed mathematics discourse, the BME approach focuses on the basic inquiry process that investigates the problem's conceptual background and knowledge status, and presents it within a general methodological context that accounts for objective reality-human



agent interactions and introduces quantitative tools of mathematics in an environment of realistic uncertainty.

BME analysis and techniques have certain important advantages, both theoretical and computational, compared with mainstream spatial statistics methods (including statistical regression, standard Bayesian inference, Markovian analysis, Kalman filters, Gaussian process, and geostatistical kriging techniques). The BME techniques (ordinary and generalized) incorporate various kinds of knowledge bases (core and site specific) in a rigorous and unified framework rather than in an ad hoc and artificial manner (which is the case, for example, with many statistical regression methods). The BME core knowledge base may include physical laws, scientific models, theoretical equations, social structures, logical rules, and reasoning principles; they assume spatial coordinate systems that accommodate Euclidean and non-Euclidean metrics; and the site-specific knowledge base includes hard and soft data, secondary information, empirical relationships, fuzzy sets, and engineering charts. BME techniques can study systems and attributes with heterogeneous space-time dependence patterns; they make no restrictive assumptions concerning estimator linearity and probabilistic normality (nonlinear estimators and non-Gaussian laws are automatically incorporated rather than been restricted by the linear/linearized estimators of mainstream spatial statistics); and they can be used in the spatiotemporal domain too. Also, BME analysis can consider uncertain yet valuable information at the estimation (prediction) points themselves, when available; it provides a complete predictive probability density function at every spatial point rather than just an attribute estimate (in this way, more than one possibility is available at each spatial point, as far as estimation is concerned); and it incorporates higher-order spatial moments (e.g., effect of skewness on spatial analysis).

BME techniques have been used in a wide range of scientific disciplines, including medical geography, epidemiology, earth and atmospheric sciences, biology, human exposure, global health, ecology, and environmental engineering. In these applications, BME analysis has been shown to rigorously and effectively process multisourced

uncertainty sources (conceptual, technical, ontologic, and epistemic); to account for measurable and categorical variables; and to work in the case of multiple attributes (vector or co-BME) and different space-time supports (functional BME). Noticeably, the BME techniques are particularly suitable for multidisciplinary real-world projects.

A number of computer software packages exist for the implementation of spatial and spatiotemporal BME statistics concepts and techniques in practice. One such package is the SEKS-GUI software library (Spatiotemporal Epistematics Knowledge Synthesis & Graphical User Interface; see <http://homepage.ntu.edu.tw/~hlyu/software/SEKSGUI/SEKSHome.html>). A comprehensive user's manual is available at the same Web site, which addresses a broad audience ranging from the novice spatiotemporal modeling user to the field expert.

George Christakos

See also *Geostatistics; Heuristic Methods in Spatial Analysis; Quantitative Methods; Spatial Statistics*

Further Readings

- Bogaert, P. (2002). Spatial prediction of categorical variables: The BME approach. *Stochastic Environmental Research and Risk Assessment*, 16, 425–448.
- Christakos, G. (2000). *Modern spatiotemporal geostatistics*. New York: Oxford University Press.
- Christakos, G. (2009). *Treatise on epistematics: An evolutionary framework of real-world problem solving*. New York: Springer.
- D'Or, D., & Bogaert, P. (2003). Continuous-valued map reconstruction with the Bayesian Maximum Entropy. *Geoderma*, 112, 169–178.
- Douaik, A., Van Meirvenne, M., & Toth, T. (2005). Soil salinity mapping using spatio-temporal kriging and Bayesian maximum entropy with interval soft data. *Geoderma*, 128, 234–248.
- Lee, S.-J., Balling, R., & Gober, P. (2008). Bayesian maximum entropy mapping and the soft data problem in urban climate research. *Annals of the Association of American Geographers*, 98(2), 309–322.



Orton, T., & Lark, R. (2007). Estimating the local mean for Bayesian maximum entropy by generalized least squares and maximum likelihood, and an application to the spatial analysis of a censored soil variable. *Journal of Soil Science*, 58, 60–73.

Savelieva, E., Demyanov, V., Kanevski, M., Serre, M. L., & Christakos, G. (2005). BME-based uncertainty assessment of the Chernobyl fallout. *Geoderma*, 128, 312–324.



BEHAVIORAL GEOGRAPHY

Human spatial behavior is not always obviously rational or efficient. Geographers interested in understanding spatial choice realized that spatial behavior could not be described using solely aggregated data with broad assumptions of rationalism and maximum efficiency. Confronting these limitations, behavioral geography evolved as a theoretical framework and methodological approach for investigating spatial behavior.

Behavioral geography is the study of human perceptions, cognition (e.g., internal mental process such as recognition and recall), and contextual interpretations of space, and ultimately choice as it relates to spatial decisions and spatial problem solving. Emphasis is on individuals as the unit of study paired with human-environment interaction assumptions inherent in constructivist philosophy. The primary objective remains true to its analytical ancestor of traditional location analysis, that is, a search for explanation or process of individual spatial choice with the intent of generalizing to social groups.

Theoretical Basis

The foundations for modern behavioral geography are derived from three main sources: (1) economic theories of location and spatial analysis, (2) theories of cognitive acquisition of spatial concepts, and (3) theories of learning. The psychologists Piaget and Inhelder proposed a hierarchy of spatial concepts based on human development: topological, projective, then Euclidean. Geographers

modified this idea in various ways. For example, Reginald Golledge proposes an anchor point theory of spatial cognition that postulates that spatial knowledge is gained through a hierarchical process of acquiring first landmark knowledge, followed by route knowledge, and then configurational (or survey) knowledge. Using hierarchical theories for the cognitive development of spatial concepts, behavioral geographers have explored route choice and strategies for learning new routes and places.

Cognitive mapping, introduced by the psychologist Edward Tolman, greatly influenced research in behavioral geography. Cognitive mapping is useful as means to explain internal processes for storage and retrieval of spatial information and as an external method of analysis to understand individuals' perceptions of spatial information. Geographers such as David Stea, Peter Gould, and David Montello used cognitive maps to explore spatial bias, cultural influence, orientation skills, perceived importance of locations, and how these factors influence behavior such as distance estimation, wayfinding, and perception of natural hazards.

Constructivism, proposed by Piaget as a general learning theory, has influenced behavioral geography broadly. The primary assumption of constructivism is that new knowledge (learning) is built on existing knowledge. Individuals' interpretation of new knowledge is always influenced by culture, prior experiences, language, social interaction, attitudes, and motivation. Constructivism emphasizes the importance of context and individual construction of knowledge.

Behavioral geography is characterized by four main assumptions as described by John Gold. First, "space" is composed of both a real, physical, "objective" environment and a perceived, metaphysical, subjective environment. Real and perceived environments interact constantly setting a stage that determines human perception of the next "fact." As a result, a second assumption is that individuals not only respond to their environments but also change their environments. Third, the unit of study starts at the individual level and transitions to social groups. Behavioral geography is a bottom-up process of inquiry. Finally, behavioral geography is multidisciplinary. Cognitive psychology, education psychology, urban planning, anthropology, sociology,



and recently cognitive neuroscience have contributed ideas and methods to behavioral geography.

Methods

Location theories based on aggregated quantitative data did not adequately predict or explain real-world spatial choices. Purely quantitative and stochastic methods intentionally exclude complex social and cultural variables. Because social and cultural variables are critical to understanding spatial behavior, mixed methods are employed in an effort to get at these complex and dynamic variables. Recognizing that spatial choices and preferences are likely to change over time, research is often centered on understanding process rather than on predicting specific outcomes.

Gathering information on variables such as perceptions, attitudes, and values requires direct interaction through methods such as surveys, interviews, and focus groups. Resulting data are frequently in noninterval or nonnumerical formats such as binary responses (yes/no), Likert scales, sketches, pictures, video and audio recordings, field notes, and interview notes. Sample size is often small with nonrandom or selective sampling that does not fit parametric assumptions. Nonparametric statistics, qualitative analysis, quantitative analysis, and spatial analysis are selected and weighted according to the specific research question or problem. Research emphasis is on applications in the real world rather than in a lab under controlled conditions. In general, methods in behavioral geography are applied in nature; they focus on large-scale and real-world space, use mixed methods for data collection and data analysis, and use probabilistic models of spatial analysis.

Criticisms

Perhaps, there is too much emphasis in behavioral geography on disaggregated individual information. If individuals are truly unique in their spatial decision making, as extreme constructivism and postmodernism suggest, generalization is impossible. Behavioral geographers assume that humans share the same “real” world, even though individual perceptions vary. They

also assume that perceptions and knowledge are shared and taught to others in the same setting or social group so that within that group generalizations are plausible.

A second criticism is aimed at the contradictions between the importance of context and the methods employed to understand behavior. Surveys, interviews, focus groups, and other forms of qualitative data collection can be intrusive, and they likely alter the context and perceptions that behavioral geographers seek to understand.

In spite of these criticisms, behavioral geography has made positive contributions. Examples include advances in visualization methods, cognitive cartography, spatial cognition, hazards research, geography education research, marketing research, geographic information science (GIScience), and transportation models. With the increasing need to understand spatial behavior, behavioral geography will continue to gain momentum as a theoretical framework and methodological approach.

Sandra Metoyer

See also **Environmental Perception**; **GIScience**; **Golledge, Reginald**; **Mental Maps**; **Phenomenology**; **Spatial Cognition**

Further Readings

- Gold, J. (1983). *An introduction to behavioral geography*. New York: Oxford University Press.
- Golledge, R. (1981). Misconceptions, misinterpretations, and misrepresentations of behavioral approaches in human geography. *Environment and Planning A*, 13(11), 1325–1344.
- Golledge, R. (2008). Behavioral geography and the theoretical/quantitative revolution. *Geographical Analysis*, 40, 239–257.
- Golledge, R., & Stimson, R. (1997). *Spatial behavior: A geographic perspective*. New York: Guilford Press.
- National Research Council. (2006). *Learning to think spatially: GIS as a support system in the K-12 curriculum*. Washington, DC: National Academies Press.



BERKELEY SCHOOL

The Berkeley School of geography, also sometimes called the *California School*, was a movement of geographic analysis that originated with Carl Sauer and the University of California, Berkeley (UC Berkeley) in the early to mid 20th century. It was a major branch of cultural geography concerned with how humans interact with and change their landscapes. The Berkeley School helped diminish the popularity of environmental determinism and placed an emphasis on historical human culture and behavior. As such, it was heavily aligned with UC Berkeley's history and anthropology departments. Scholars at the Berkeley School believed that by studying historical cultures and their impacts on the landscape, they could better understand modern human impacts. Unlike its counterpart in the Midwest, the Berkeley School was also more concerned with theoretical studies as opposed to practical applications of scholarship such as urban planning or resource management. Thus, both its topics of study and its methods differed significantly from those of Midwestern American geographers. The Berkeley School was significant because it represented a new way to study geography and also gave the subject prominence on the U.S. West Coast.

Origins

The Berkeley School began in 1923 when Carl Sauer moved from the University of Michigan to UC Berkeley. Prior to Sauer's arrival, geography at Berkeley was an independent department but was housed with geology; most of its courses were technical in nature and focused on physiography and geomorphology. William Morris Davis and his ideas of the cycle of erosion dominated the department at the time. When Sauer arrived, he sought to restructure the curriculum with the help of John Leighly, a student from Michigan, and separated the various types of study within geography. "Physical Geography" became the first course students took, but it was followed by a new course in cultural geography,

which later became the main component of the Berkeley School of thought. Cultural geography as it was studied at Berkeley was regional in focus and was concerned with the density and development of populations, the character of the world's peoples, economic systems, specific regional cultures, and how people shape their physical environment. As cultural geography developed at Berkeley, it later became more concerned with the past and was aligned with the university's history and anthropology departments.

Characteristics of Study

Those studying in the Berkeley School used Sauer's dimension of time to study places, people, and their interactions with the landscape. In studying these things, however, Berkeley scholars did not rely on the opinions of city planners and politicians but instead conducted their own extensive fieldwork, which frequently involved long-term observations of people in their day-to-day lives. In addition to fieldwork, Berkeley scholars also examined cultural history and humanized landscapes with archival research. The regions and cultures studied in the Berkeley School were often outside the United States and other English-speaking areas and much of the research to come out of the school was focused on, though not limited to, Latin American studies.

Another important characteristic of the Berkeley School was its location. Because it was on the West Coast and located far from the concentration of geography departments in the Midwest, it was relatively isolated from other universities studying geography. This isolation allowed the school to develop and reinforce its own set of ideas and characteristics of study that significantly differed from those of other universities—most important the "practical" aspects of education prevalent in the Midwest. The theoretical ideas important in the Berkeley School were then reinforced through generations of students as the school's isolation allowed Sauer to hire many of his former students to work in the department on receiving their degrees.



Key People and Dissertations

Apart from Sauer, the Berkeley School has a number of important people who either studied or worked there, or both. Peveril Meigs and Lauren Post were the first students of the Berkeley School, and Meigs graduated in 1933 after completing his dissertation titled *The Dominican Mission Frontier of Lower California: A Chapter in Historical Geography*. Post received his PhD in 1937 with his dissertation titled *The Cultural Geography of the Prairies of Southwest Louisiana*. One of the most famous geographers to come out of the Berkeley School though was Charles Warren Thornthwaite, who completed his PhD in 1930 with his dissertation *Louisville, Kentucky: A Study in Urban Geography*. The titles of these students' works are significant because they emphasize cultural and historical geography common in the Berkeley School. Following these works were projects such as the 1944 *Historical Geography of Michoacán* by Dan Stanislawski and *The Peoples and Economy of Begemden and Semyen, Ethiopia* of 1956 by Frederick John Simoons. In addition to the historic and cultural aspects, these projects clearly represent the emphasis on places outside the United States.

Critiques and Decline of the Berkeley School

Like many academic movements, the Berkeley School experienced several analytical critiques during its height. Critics said that its research methods were static and believed that the school was concerned only with material human landscape artifacts such as farms. As geography became increasingly theoretically oriented in the late 20th century, the Berkeley School's popularity declined as the "New Cultural Geography" took hold.

Amanda DeeAnn Briney

See also **Cultural Geography; Environmental Determinism; Sauer, Carl**

Further Readings

- Cosgrove, D., & Jackson, P. (1987). New directions in cultural geography. *Area*, 19(2), 95–101.
- Entrikin, J. (1984). Carl O. Sauer, philosopher in spite of himself. *Geographical Review*, 74(4), 387–408.
- Kenzer, M. (Ed.). (1987). *Carl O. Sauer: A tribute*. Corvallis: Oregon State University Press.
- Price, M., & Lewis, M. (1993). The reinvention of cultural geography. *Annals of the Association of American Geographers*, 83(1), 1–17.
- Sauer, C. (1974). The fourth dimension of geography. *Annals of the Association of American Geographers*, 64(2), 189–192.



BERRY, BRIAN (1934–)

One of geography's most well-known and productive scholars, Brian Berry has played an enormously influential role in urban and economic geography, primarily as the steadfast defender of traditional quantitative modeling.

Born in 1934 to working-class parents in England, Berry defied the confines of the British class system to rise to the topmost tiers of academia. He completed a BS in economics at the London School of Economics in 1955, where he was exposed to historical geography and introduced to the quantitative modeling of spatial phenomena. Immediately thereafter, he traveled to the University of Washington in Seattle just as the geography program there initiated the quantitative revolution in American geography. Berry thus formed one of William Garrison's cadre of "space cadets," along with Duane Marble, William Bunge, Michael Dacey, Arthur Getis, Richard Morrill, John Nystuen, and Walter Tobler, arguably the discipline's most successful and famous single cohort of students.

Three years later, armed with a PhD—at age 22—he began the first of a long list of academic positions at prestigious institutions, including the University of Chicago (1958–1976) and Harvard



University (1976–1981), where he served as the Frank Backus Williams Professor of City and Regional Planning, chair of the PhD program in urban planning, director of the Laboratory for Computer Graphics and Spatial Analysis, and as a faculty fellow of the Harvard Institute for International Development. From 1981 to 1986 he served as dean of the School of Urban Public Affairs at Carnegie-Mellon University in Pittsburgh. Beginning in 1986, he taught at the University of Texas, Dallas, where, in 1991, he became the Lloyd Viel Berkner Regental Professor of Political Economy and, in 2006, dean of the School of Social Sciences. He is the recipient of numerous awards and medals. In 1975, he became the first geographer and youngest social scientist ever elected to the National Academy of Sciences. In 1977–1978, he served as president of the Association of American Geographers. He also served as a founding coeditor and editor-in-chief of the journal *Urban Geography* from 1980 to 2006.

Berry's lengthy publication record—including more than 500 books, articles, and other publications—has earned him enormous recognition as one of geography's most fecund scholars. He advocated for a discipline that was self-consciously nomothetic in outlook and positivist in epistemology, thus emphasizing the need for general laws of explanation, quantitative methods, and rigorous empirical testing of hypotheses. Throughout his long career, he subscribed to a paradigm that privileged the abstract over the concrete, deduction over induction, and the universal over the specific. Berry emphasized the use of models as a means to simplify and shed light on the bewildering complexity of the world. He was instrumental in the adoption of multivariate statistics in the discipline. His early papers stressed the applicability of central place models of urban systems and detail studies of retail shopping patterns. Subsequent work on market centers and retailing was very influential in geography and business and economics. He also delved into the rank-size distributions of cities, hierarchical diffusion processes, and the impacts of transportation systems. In addition, Berry had a long-standing interest in urban morphology and urban problems such as inner-city poverty. Over time, Berry's

works came to be characterized by an increasing concern for the role of public policy.

Berry's later career focused on the dynamics of regional development in different national contexts. He conducted extensive work in India, Australia, Indonesia, and other countries. Comparative analyses of urbanization bridged these national contexts. Urban trends in the United States received considerable attention as well, including the question of counterurbanization. A persistent theme was the relation of demographic shifts and migration to regional change. This phase of his career was characterized by a mounting interest in issues of globalization, particularly the ways in which multinational corporations intersected with state policies to shape urban growth around the world. In the 1990s, Berry turned his focus to the role of long cycles or Kondratieff waves and their relation to regional development and political relations. Subsequent work viewed utopian communities and turmoil associated with the periodic restructuring brought about by long waves.

As the embodiment of positivism and the quantitative revolution, Berry's intellectual position came under mounting criticism from the 1980s onward. A newer generation of geographers attuned to political economy and social theory began increasingly to question the relevance of abstract, ahistorical models and the unrealistic neoclassical logic of utility maximization. This schism was exemplified in a famous debate between Brian Berry and the Marxist geographer David Harvey. As a result of academic geography's shift to political economy, Berry appeared to many observers as increasingly conservative and disconnected from the field. However, never one to give up, Berry is known to this day for the enthusiasm and commitment with which he advocates his views, and whatever philosophical differences some geographers may have with him, he remains widely respected.

Barney Warf

See also Central Place Theory; Location Theory; Logical Positivism; Models and Modeling; Quantitative Revolution; Spatial Analysis; Urban Geography; Urban Hierarchy; Urban Spatial Structure



Further Readings

- Berry, B. (1967). *Geography of market centres and retail distribution*. Englewood Cliffs, NJ: Prentice Hall.
- Berry, B. (1973). *The human consequences of urbanisation: Divergent paths in the urban experience of the twentieth century*. New York: St. Martin's Press.
- Berry, B. (1976). *Urbanisation and counter-urbanisation*. London: Sage.
- Berry, B. (1980). Creating future geographies. *Annals of the Association of American Geographers*, 70, 449–458.
- Berry, B. (1991). *Long-wave rhythms in economic development and political behavior*. Baltimore: Johns Hopkins University Press.
- Berry, B. (2002). Clara voce cognito. In P. Gould & F. Pitts (Eds.), *Geographical voices: Fourteen autobiographical essays* (pp. 1–26). Syracuse, NY: Syracuse University Press.
- Clark, G. (2004). Brian Berry. In P. Hubbard, R. Kitchin, & G. Valentine (Eds.), *Key thinkers on space and place* (pp. 47–52). London: Sage.
- Warf, B. (2004). Troubled leviathan: The contemporary U.S. versus Brian Berry's U.S. *Professional Geographer*, 56, 85–90.



BHOPAL, INDIA, CHEMICAL DISASTER

On the night of December 3, 1984, the toxic chemical methyl isocyanate leaked from the premises of the U.S.-based Union Carbide's pesticide plant in Bhopal, the capital city of the central Indian state of Madhya Pradesh. Union Carbide had set up its plant amid a dense "squatter settlement" and had stored methyl isocyanate in violation of the 1975 Bhopal Development Plan. The leaked chemical engulfed this community and left a trail of fatalities. The number of people affected is disputed, with estimates suggesting that 2 to 10 thousand died in the immediate aftermath of the accident and that an additional half million were permanently maimed. Environmental scholars argue that the disaster had all the characteristics of what the sociologist Charles Perrow has termed

a *normal accident* and note that the probability of a normal accident occurring could have been minimized had Union Carbide meticulously designed its technological system and scrupulously maintained the plant's safety checks.

Scholars also note the perpetuation of a "second disaster" in Bhopal, a term that highlights two further facets of the disaster: (1) the travails of a protracted legal battle that secured paltry monetary compensation but failed to secure adequate health care facilities for the original victims of the disaster and (2) the production of a second generation of victims through the failure to adequately clean up the premises of the old factory, which houses 425 tons of toxic waste. The failure of Union Carbide and the Indian government to undertake environmental remediation in nearly 24 years has contaminated soil and water and has led to high incidence of birth defects among children born into the surrounding community. Yet a comprehensive study that would determine the nature and extent of danger posed by the exposure to toxic waste has not been commissioned. Such bureaucratic apathy coupled with willful corporate inaction has amplified the magnitude of suffering caused by the Bhopal disaster and turned it into an enduring disaster.

A committed set of activists and survivors continue to fight for justice for Bhopal victims: Coalitions such as the "International Campaign for Justice in Bhopal" are aggressively campaigning to force Dow Chemical (which acquired Union Carbide in 2001) to assume responsibility for toxic waste and undertake environmental remediation. This campaign relies on activists and experts located in various parts of the globe to exert pressure on media to report the everyday disaster of Bhopal and force Dow to act. The ongoing tragedy of the Bhopal disaster has spurred new forms of environmental justice activism. Furthermore, the enactment of various environmental legislations, such as the publication of the Toxics Release Inventory in the United States, and calls for greater corporate accountability, such as Greenpeace International's elaboration of the "Bhopal Principles on Corporate Accountability," are the legacy of this disaster. Bhopal, the site of the world's worst industrial accident, remains important for human geographers interested in the study of globalization and corporate



A December 1984 file photo shows victims who lost sight after poison gas leak from a pesticides plant in the central Indian city of Bhopal squatting in front of the U.S. Union Carbide factory (shown in background).

Source: AFP/Getty Images.

accountability, the evolution of global environmental activism, and new social movements.

Rajyashree Reddy

See also Chernobyl Nuclear Accident; Disaster Preparedness; Environmental Justice; Natural Hazards and Risk Analysis

Further Readings

Fortun, K. (2001). *Advocacy after Bhopal: Environmentalism, disaster, new global orders*. Chicago: University of Chicago Press.

Jasanoff, S. (2007). Bhopal's trials of knowledge and ignorance. *Isis*, 98, 344–350.

Rajan, R. (2001). What disasters tell us about environmental violence: The case of Bhopal. In M. Watts & N. Peluso (Eds.), *Violent environments* (pp. 380–398). Ithaca, NY: Cornell University Press.



BIBLICAL MAPPING

Biblical mapping relates to the various uses that have been made of maps in seeking to understand or explain the Bible. It embraces maps found in



bibles, in special biblical atlases, stand-alone maps, and maps in tracts explaining biblical passages. Given that (a) the narratives that compose, and the events related within, the Judeo-Christian scriptures took place in, or are located within, the areas of Palestine, the Levant, Egypt, and Mesopotamia and that (b) most of those religious texts present their story within a historical form, it is not surprising that they have attracted attempts at mapping since a very early period after their canonization among both Jews and Christians. When events, places, pieces of land, and movements of individuals (e.g., Jesus going from Galilee to Jerusalem) or groups (e.g., the story of the “exodus” from Egypt) have deep significance to a group, those places will be mapped; and, thereby, the place of the narratives’ audience is related to the events (see Figure 1).

Whether or not the authors of the Bible used maps in creating their texts is uncertain—several use language that closely coheres with ancient extant maps—but since Eusebius of Caesarea (ca. 260–ca. 340 BC), maps have been used to represent, clarify, or explain the biblical scenes: the 6th-century mosaic map in Madaba, Jordan, being an example inspired by Eusebius. With the passing of time, among both Jewish and Christian scholars, maps became an integral part of the exegetical process whereby geography was called on to solve textual problems (e.g., the 9th-century map in BNF [Backus-Naur Form, a context-free syntax] lat 11561 explicating the Book of Joshua); and later maps became part of biblical apologetics. With the arrival of print, maps became part of the apparatus of Bibles, while biblical/historical maps became a fixed feature of atlases from the time of Ortelius.

Still today maps are almost invariably included in printed Bibles, while biblical maps in atlases have evolved to become the specialist subcategory of atlases: the “Bible atlas.” These atlases range in style from works for children to elaborate coffee-table books and in perspective from sectarian propaganda to works of critical scholarship. One common feature of most biblical mapping is that the maps combine the best available physical information (nowadays derived from geodetic survey and satellite imaging) with scholarly conjecture as to locations and distributions, working on the assumption that the world

as we map it is the world as their ancient authors imagined it.

Thomas O’Loughlin

See also **Ortelius; Religion, Geography and; T-in-O Maps**

Further Readings

- Bartlett, J. (2008). *Mapping Jordan through two millennia*. London: Maney.
- Delano-Smith, C. (1991). Geography or Christianity? Maps of the Holy Land before A.D. 1000. *Journal of Theological Studies*, 42, 143–152.
- Delano-Smith, C., & Morley Ingram, E. (1991). *Maps in Bibles 1500–1600: An illustrated catalogue*. Geneva: Librairie Droz.
- Laor, E. (1986). *Maps of the Holy Land: Cartobibliography of printed maps, 1475–1900*. New York: Alan R. Liss.
- Nebenzahl, J. (1986). *Maps of the Holy Land*. New York: Abbeyville Press.
- O’Loughlin, T. (2005). Map and text: A mid ninth-century map for the Book of Joshua. *Imago Mundi*, 57(1), 7–22.
- Rainey, A., & Notley, R. (2006). *The sacred bridge*. Jerusalem: Carta.



BIODIVERSITY

The study of biological diversity has a considerable legacy in ecology and geography. The concept refers generally to the sum total of all genes, species, and ecosystems in a particular region. How many bird species occur in a particular area, for example, and how does this feature change in response to evapotranspiration or latitude? The term *biodiversity*, a contraction of “biological diversity,” did not appear until the 1980s and was a response to increasing scientific concern with ecosystem degradation and the species extinction crisis. Biodiversity as a field of interest thus has come to encompass not only understanding species numbers and patterns but also ecological interactions, conservation status, and relevant management strategies.



The question of how many species exist on Earth has long intrigued scientists. Although the number of plant and animal species is fairly well-known in the mid and higher latitudes, the number of taxa (distinct rank of organisms) in the tropics, especially of insects and microorganisms, will never be fully enumerated. Estimates place the total number of biota (plant and animal life) at between 4 million and 20 million species, although only 1.7 million species have been documented to date. The beetles (*Coleoptera*), with about 24% of all known species, are far and away the most species-rich taxon. Compare this group to plants, which make up 14%, and birds and mammals, which together make up only 2.7%, of the world's species.

Measures and Maintenance of Biodiversity

There are various means of measuring and conceptualizing biodiversity, and each possesses its own merit depending on the objective of the research. *Alpha* diversity refers to the number of species within a particular area or plot. In a 10-meter $\times$ 10-meter plot in a chaparral plant community, the alpha diversity of shrubs is simply a compilation of the number of shrub species encountered in the area. *Beta* diversity, on the other hand, refers to the change in species from one plot or area to another in an ecosystem. Also known as species turnover, beta diversity reveals much more about underlying diversity than simply a numbers count. For example, in a 1-ha (hectare) coniferous forest plot, a total of seven species of trees are identified. In a second 1-ha plot a few kilometers away, seven coniferous tree species are also recorded. However, six of the seven species encountered in the first plot are different from those encountered in the second plot. Thus, whereas the alpha diversity of the two plots is equal, the high beta diversity (difference in species composition between the two plots) suggests that the overall diversity of the ecosystem is quite high. A third type of diversity is referred to as *gamma* or landscape-level diversity. This is similar to beta diversity but refers to the total biodiversity of the various communities within a landscape. In this case, for example, we could be measuring the biotic diversity of the Columbia River watershed. Finally, *epsilon* diversity

describes species richness at the broadest possible scale, that is, a region that encompasses many landscape types.

An important dimension of biodiversity at the local scale is community evenness. In this case, the issue is not only the number of species but also the number of individuals represented by each of the respective species. Two of the traditional means of measuring this feature are the Simpson and the Shannon-Weiner Indices. For example, two tropical forest plots are found to have equal alpha diversities, 25 tree species each, and an equal total number of trees, 100. However, in one plot, the 100 trees are equally divided among the 25 species, with 4 trees in each species. In the second plot, one species is represented by 76 individual trees, whereas the other 24 species are represented by only 1 tree each. The biodiversity of the first plot, as measured by community evenness, is thus much higher than the second plot.

Maximum species diversity in a particular ecosystem was long held to be a function of environmental stability. This approach followed the Clemensian ideal of community succession and species recovery following habitat disturbance from fire, flood, landslide, and other natural and anthropogenic action. This notion fell out of favor, however, and was replaced by the "intermediate disturbance hypothesis." In this case, the highest biodiversity is recorded neither in recently and heavily disturbed habitats, which are dominated by a few hardy pioneer species, nor in relatively undisturbed communities, in which a few highly competitive species have come to dominate. Rather, the sites with the highest biodiversity are patchy and moderately disturbed, and they include the myriad taxa associated with each of the various successional stages, from pioneer to old growth.

Latitudinal Biodiversity Gradients

During the European voyages of exploration, colonial naturalists reported that taxonomic diversity appeared to increase along a meridian from the poles toward the tropics. This geographical gradient in species richness, elaborated early by Alexander von Humboldt, holds for most types of terrestrial organisms, including birds, mammals, amphibians and reptiles, insects, and



vascular plants. It also was found to apply to marine and freshwater fishes and arthropods, corals, mollusks, and other aquatic life-forms. For example, the number of bird species in the Canadian Arctic ($\approx 55^\circ$ N) ranges from 60 to 100 species, whereas in Panama and Costa Rica ($\approx 10^\circ$ N latitude) the number rises to more than 600 species. Likewise, a 1-ha plot of Northern California coniferous forest will yield around 15 species of trees, whereas the same sized area in Brazil's Atlantic Coastal forest will register well over 400 tree species. This latitudinal cline exists at other taxonomic ranks as well, including numbers of families and genera. There are of course some biota for which this pattern does not hold; the diversity of penguins, for example, does not increase from Antarctica toward the Congo River basin, nor does ursine biodiversity grow along a line from Alaska to Costa Rica. Species with parasitic life histories tend not to conform to a latitudinal pattern, nor do aquatic plants. Nevertheless, the latitudinal biodiversity gradient has proved remarkably consistent in terrestrial, freshwater, and marine ecosystems, and in both hemispheres.

Numerous hypotheses have been proposed to explain this phenomenon, but none has proven completely satisfactory. It remains to this day the most widely debated biogeographical pattern. Possible mechanisms range from competition, predation, and patchiness to environmental stability, productivity, and stochastic processes. One of the first to speculate on this biodiversity gradient was Alfred Russell Wallace, the cofounder of the theory of evolution via natural selection. He suggested that because the tropical and subtropical regions of the world had escaped the devastating effects of Pleistocene glacial action, they represented in effect "biodiversity museums." Lacking high extinction rates, these stable latitudes accumulated huge numbers of species of plants and animals over the course of evolutionary time. Contrarily, the arctic and temperate regions, he posited, existed in a state of perpetual recovery from the massive species extinctions that would have accompanied the various glacial advances. Although paleoecology and other lines of research strongly dispute the notion of tropical environmental stability during the glacial era, recent work continues to support the idea that the tropics represent a global font of biological novelty.

The biodiversity of any particular location represents a fluctuating equilibrium between species diversification or arrival and species extinction or departure. These variables, in turn, depend in part on available space. At the scale of continental-sized landmasses, there is more real estate in the tropical latitudes than in the temperate and arctic zones. Greater landmass, in turn, translates to more geographical barriers, greater likelihood of population isolation, and enhanced rates of speciation. Furthermore, larger areas equate in principle to greater numbers of individuals per species, thus providing a buffer against extinction. This follows in part from MacArthur and Wilson's theory of island biogeography, which associates area and number of individuals per species with the stochastic extinction rate and consequent species richness (alpha diversity). In the case of the latitudinal gradient in species diversity, this species-area relationship favors higher taxonomic diversification, lower extinction rates, and overall elevated levels of biodiversity near the equator. Although the "geographical area hypothesis" is tenable in the tropical realm, it falls short as an explanatory mechanism in the temperate and arctic zones, where similarly sized biomes exhibit significantly different levels of species richness.

The "productivity hypothesis" suggests that the latitudinal biodiversity gradient results largely from differences in net primary productivity (photosynthesis). This follows because solar intensity and duration and (often) mean annual precipitation are tightly linked to latitude. Net primary productivity, in turn, which is mostly a function of temperature and precipitation, frequently correlates with species diversity patterns. Thus, for example, hot deserts and tundra exhibit both low primary productivity due to drought and low temperatures, respectively, and relatively few numbers of species. Warm and wet equatorial latitudes, on the contrary, which provide ideal conditions for primary productivity, are also home to the greatest numbers of species of plants and animals. It may be, therefore, that higher productivity provides for greater populations per species, and consequently lower extinction rates. Moreover, the opportunities for niche partitioning between taxa with similar ecological requirements would seem to be greater in ecosystems with higher available



Figure 1 Twenty-five biodiversity hotspots

Source: Mittermeier, R., Mittermeier, C., da Fonseca, G., Kent, J., & Myers, N. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403, 853–858. Copyright © 2000, Nature Publishing Group.

biomass. While accounting for biodiversity patterns in many biomes, the productivity hypothesis also has weaknesses. For example, it is not always the case that number of individuals per species is correlated with productivity. Rarity is quite common in highly productive ecosystems. In addition, contrary to expectation, some of the highest net primary productivity ecosystems on Earth, such as temperate zone estuaries, maintain quite low levels of species richness.

Unlike the other explanations, the relatively recent “geometrical constraints hypothesis” does not require that environmental gradients be associated with latitudinal gradients. In this case, species ranges are assumed to be randomly distributed between physical or physiological barriers, that is, bounded domains. In a world characterized by barriers, species richness becomes a stochastic function of the number and types of barriers. According to the hypothesis, if species’ latitudinal ranges are randomly shuffled, they will tend to overlap more in the mid-domain area. These mid-domain areas in turn correspond with lower

latitudes. Although this model has encouraged considerable recent scholarship, it fails to explain many latitudinal species gradients. Clearly, the last word on this vexing question has yet to be heard.

Biodiversity Hotspots

Biodiversity hotspots are biomes that exhibit both a high degree of species endemism (restricted to a particular region) and diversity (i.e., possesses at least 0.5% of the world’s known vascular plant species), and they are critically endangered. Twenty-five terrestrial hotspots have been proposed, covering a total of only 1.4% of the Earth’s surface (see Figure 1). Of these, 15 occur in tropical rain forests, and 5 are in Mediterranean-type climates. These 25 regions are believed to contain 44% of all known plant species and 35% of all known mammals, birds, reptiles, and amphibians. Later, the terrestrial hotspots were supplemented with 11 marine hotspots, mostly hyperdiverse coral reef ecosystems.



The motivation behind the biodiversity hotspot concept is both biogeographical and political. In the first instance, it derives from the notion of congruence of regions of high species diversity and endemism among different types of biota. Thus, a region that has an unusually high number of endemic species in the pine family, for example, is also likely to exhibit high species richness for other organisms, such as arachnids, salamanders, or butterflies. However, given that the geographical ranges of most biota in species-rich lower latitudes are barely known, these ideas are still fairly speculative. Moreover, the knowledge that ongoing climate change is forcing plant and animal migration in ways that are barely understood calls into obvious question whether today's hotspots will be around in the future. Nevertheless, hotspots represent high priorities for protection, all things considered. Because funds for conservation are limited, protecting biomes that are significantly rich in biodiversity on a global scale, and that retain only a fraction of their original vegetation, clearly constitutes a sensible strategy.

Robert Voeks

See also **Biogeography; Biota and Climate; Biota Migration and Dispersal; Crop Genetic Diversity; Ecosystems; Extinctions; Great American Exchange; Island Biogeography; Species-Area Relationship**

Further Readings

- Gaston, K. (1996). Biodiversity: Latitudinal gradients. *Progress in Physical Geography*, 20, 466–476.
- MacDonald, G. (2003). *Biogeography: Introduction to space, time and life*. New York: Wiley.
- Myers, N., Mittermeier, R., Mittermeier, C., da Fonseca, G., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403, 853–858.
- Willig, M., Kaufman, D., & Stevens, R. (2003). Latitudinal gradients of biodiversity: Pattern, process, scale and synthesis. *Annual Review of Ecology and Systematics*, 34, 273–309.



BIOFUELS

A biofuel is a solid, liquid, or gaseous fuel made from crops or trees and their residues, human and animal wastes, and algae. In many parts of the world, biofuels are the primary or only source of fuel. Concerns about global climate change, high oil and gas prices, and energy security have increased interest in biofuels over the past decade. Consequently, key questions have been raised regarding biofuels utilization:

- To what extent are biofuels economical? Because the market for biofuels is still emerging, and long-term oil prices are unknown, it is difficult to calculate the true cost of biofuels. Further complicating the situation is the wide mix of subsidies and taxes for both biofuels and petroleum products.
- What are the impacts of biofuels on food prices? While it is clear that not all biofuels compete with foodstuffs, there is concern that agricultural crop-based feedstocks such as corn do.
- What are the environmental impacts of increased biofuel production? Current biofuel production practices typically require extensive inputs, such as fertilizers and water, which have damaging environmental and ecological side effects. Two other key issues that must be considered are the impacts stemming from land use changes that often occur with increased biofuel production and the ratio of energy return on investment in biofuel production.
- How carbon neutral are biofuels? While biofuels allow for a closed-carbon cycle, initial land use change (e.g., turning forests into agricultural land) can emit significant amounts of carbon dioxide into the atmosphere. Another concern is the quantity of petroleum products required to harvest and process some biomass feedstocks.

Current technological and economical research is primarily focused on the creation of alcohol (especially ethanol) and biodiesel as fuel for vehicles. Ethanol and other alcohols can be used as substitutes in gasoline engines, although some engines require modification. Biodiesel is used in diesel engines. Pure ethanol (biodiesel) is



commonly referred to as E100 (B100), and a blend of 20% ethanol (biodiesel) and 80% gasoline (diesel) is E20 (B20). In 2006, global ethanol production was 10.6 billion gallons, 90% of which was produced in Brazil and the United States. One billion gallons of biodiesel were produced in 2006—75% by the European Union (EU) and 13% by the United States. However, Malaysia and Indonesia have begun investing in biodiesel production and will likely become much larger producers in the next decade. Case studies of Brazil, the United States, Germany, and Malaysia are presented below.

Brazil

Brazil, South America's largest energy user, is the world's second-largest ethanol producer (42%) and the largest ethanol exporter. The ethanol is produced from sugarcane, and Brazil has been criticized for allowing rain forests to be converted into cropland. Still, record-high oil prices and increased acceptance of ethanol on the world market indicate that Brazil will continue to be a major ethanol producer.

Brazil has produced ethanol for many years. As early as the 1930s, laws required that gasoline be blended with 5% ethanol, and during World War II this percentage was as high as 42%. However, the decline in oil prices during the 1950s and 1960s resulted in the blend being lowered to 3% to 7%. The 1973 oil embargo by the Organization of Petroleum Exporting Countries resulted in the creation of the National Alcohol Program (Proalcool), a governmental program designed to increase ethanol production. Proalcool provided both investment and subsidies for sugar production, while at the same time gasoline was taxed heavily to decrease demand. Proalcool was very successful in the implementation of ethanol-powered engines.

Market forces (in particular a steep decline in the oil prices coupled with a rise in sugar prices) during the 1980s along with new government policies combating inflation led to the elimination of subsidies and a sharp decline in ethanol production. Meanwhile, worldwide automotive standardization meant that most new cars that were produced had gasoline-based engines. By 2001, only about 1% of car engines produced in Brazil

were ethanol fueled. Interest in ethanol increased again during the 1990s, with concerns over global warming and the signing of the Kyoto Protocol leading Brazil to once again implement fuel-mixing standards. Since 1998, all gasoline fuel sold in the country has been E24. Over the past two decades, Brazil has been a leading designer of flex-fuel engines, which can use any blend of ethanol and gasoline without requiring modifications.

Ethanol production in Brazil nearly doubled between 2000 and 2007, increasing from 200,000 barrels per day to 390,000 barrels per day. Projections for 2009 were at 530,000 barrels per day. Currently, about half of the nation's sugarcane crop is used for ethanol production. The primary export markets are the United States and Europe, although both heavily tariff imported ethanol.

Brazil is expected to become a net oil importer by the end of the decade, and there is now strong interest in biodiesel as well as ethanol. In 2008, Brazil's major oil company, Petrobras, announced plans to build three biodiesel plants. In addition, government regulation went into effect requiring all diesel to be B3, which may be raised in the future.

United States

Ethanol has been used as an automotive fuel in the United States since the late 1800s. When Ford's Model T was introduced in 1908, it was able to use both ethanol and gasoline as fuel. Use of ethanol increased during World War I, but the introduction of lead into gasoline quickly replaced ethanol as an oxygenate. The United States is today the world's largest ethanol producer and was responsible for 46% of the world's ethanol output in 2007. Ethanol production has grown steadily since 2000, when 1.6 billion gallons were produced. In 2007, 6.5 billion gallons were produced.

Interest in ethanol has revived in recent years because of concerns over climate change, a desire to reduce foreign oil imports, and strong governmental support—there are currently several federal programs that support ethanol production. Perhaps the most important incentive is the Renewable Fuel Standard, created by Congress, which mandated that 36 billion gallons of ethanol be produced in 2022 (of which 16 billion



gallons must be from cellulosic ethanol). Another important incentive is a 51-cent-per-gallon excise tax exemption on fuel sales. Finally, several states have begun to require an ethanol blend (typically E10) in lieu of the oxygenate MTBE (methyl tertiary butyl ether), owing to concerns over ground-water pollution from the latter.

The primary feedstock for ethanol production in the United States is corn, which is contentious for two reasons. First, some people believe that the rapid increase in ethanol production, now accounting for 30% of all corn production, is competing with food supplies. This is questionable, since most corn is used for animal feed, and the by-product of ethanol production, distillers grains, is a valuable feed product. Still, with a worldwide increase in all staple food prices since the mid 2000s, this debate is likely to continue. Concerns also have been raised about the environmental impacts that increased ethanol production has caused due to the large area of land needed and the amount of fossil fuels and fertilizers required to grow, harvest, and process the corn. Nevertheless, nearly 80 new ethanol plants are currently being built in the Midwest.

Interest in cellulosic ethanol has increased rapidly over the past decade, and several commercial plants are being constructed. Likely feedstocks include corn stover, wheat straw, switchgrass, short-rotation woody crops, and forest residues. Cellulosic ethanol does not require high-intensity inputs like fertilizer, does not require land use conversion, and does not compete with foodstuffs. However, the economic viability of cellulosic ethanol is still in question, and current processing technology requires large volumes of water. The cellulosic ethanol market has the potential to surpass the volumetric supply of corn ethanol.

Germany

Germany is the largest biodiesel producer in the world, producing about half of the EU's biodiesel, which itself accounts for 75% of the world's market. Recent years have seen a strong increase in the amount of biodiesel produced, primarily from rapeseed oil, as the government has given strong support to the industry through investment and an excise duty reduction. When leaded

gasoline was outlawed in 1996, more than 1,000 pumps were converted to distribute B100. Germany produced about 3 million tons in 2006, compared with 290,000 tons in 2000, and annual growth is expected to continue to be as high as 20% to 30% over the next few years. Germany has about 25 biodiesel production plants, the largest of which produces 165,000 tons per year. The largest constraint the industry faces is land availability.

In 2007, an EU commission published the Renewable Energy Road Map, which sets targets for biomass utilization. At the same time, a new German government began eliminating tax breaks on biodiesel (and vegetable oil), which will completely end in 2012. As a result, production fell in 2007–2008. Still, biodiesel is seen as part of the strategy toward energy independence, and pure biodiesel is now being marketed for trucks instead of cars. The automobile industry's support for this program is a significant change.

Malaysia

Malaysia produced around 550,000 tons of biodiesel from palm oil in 2006. During the past two decades, Malaysia became the largest palm oil producer and exporter in the world. As of 2006, it is responsible for 47% of the world's palm oil production. There has been an explosive growth of palm plantations in the past two decades—from less than 120,000 acres of palm plantations in 1970 to around 10 million acres by 2005—and they now account for more than 10% of the nation's land area. In 2006, Malaysia produced a total of 16.5 million tons of palm oil, 90% of which was exported. Globally, palm oil accounted for 33% of global vegetable oil supply whereas soy accounted for 31%. Soy is also commonly used to produce biodiesel (e.g., in the United States), but it requires 7 to 10 times more land to produce an equivalent amount.

The government of Malaysia has shown great interest in continued biodiesel production output growth and works closely with industry. Consequently, around 100 commercial plants have been planned with the first ones having begun production in 2007 and 2008. All diesel sold in Malaysia is B5, although the government has not shown signs of increasing this to a richer blend. Exports



of palm oil as a diesel substitute are expected to grow, both to southeast Asia and to Europe.

Despite the economic success of palm oil, several environmental issues have been raised. The effects of palm oil plantation growth had caused deforestation of more than 2.4 million acres, with the rest of the growth being absorbed by a decrease in other crops, such as cocoa, rubber, and coconut. With 64% of Malaysia remaining forested, future expansion will likely be into forested areas. Because of land use changes, decreasing biodiversity is an issue. Awareness of the rapid land use change has brought about some positive results. However, although part of the biofuel industry had tried to counter the effects, without strong government intervention, it is expected that the tropical rain forest deforestation will continue. Indonesia has a palm oil industry of comparable size with Malaysia's and is experiencing many of the same environmental challenges.

Conclusion

Biofuel demand worldwide is expected to grow due to fears of climate change, sustained high oil and gas prices, and the desire for localized and diverse energy supplies. Liquid biofuels, especially ethanol and biodiesel, hold great promise as partial alternatives to gasoline and diesel, but questions remain as to their economic viability and environmental and social costs. Because large-scale biofuel production is still an emerging market, countries must offer strong government support if they wish to invest in biofuels.

Nicholas H. Johnson

See also [Agricultural Land Use](#); [Climate Policy](#); [Energy and Human Ecology](#); [Energy Policy](#); [Energy Resources](#); [Renewable Resources](#); [Sustainable Production](#)

Further Readings

Bomb, C., McCormick, K., Deurwaarder, E., & Käberger, T. (2007). Biofuels for transport in Europe: Lessons from Germany and the UK. *Energy Policy*, 35, 2256–2267.

Gardner, B., & Tyner, W. (2007). Explorations in biofuels economics, policy, and history. *Journal of Agricultural & Food Industrial Organization*, 5(2), Article 1.

Solomon, B., Barnes, J., & Halvorsen, K. (2007). Grain and cellulosic ethanol: History, economics, and energy policy. *Biomass and Bioenergy*, 31, 416–425.

Tan, K.-T., Lee, K.-T., Mohamed, A., & Bhatia, S. (2009). Palm oil. *Renewable & Sustainable Energy Reviews*, 37, 554–559.

Worldwatch Institute. (2007). *Biofuels for transport*. London: Earthscan.



BIOGEOCHEMICAL CYCLES

Biogeochemistry is the chemistry of Earth's surface. Or, in other words, it is physical geography through the lens of chemistry. Akin to the study of water moving through the hydrologic cycle, a biogeochemical cycle examines how a particular chemical element moves through the physical geographic spheres (i.e., the atmosphere, biosphere, lithosphere, and hydrosphere). Viewed from the integrative perspective of the biosphere, this entry explores several of the major biogeochemical cycles, with a special emphasis on how these cycles affect—and are affected by—human society.

Biosphere and Biogeochemical Cycles

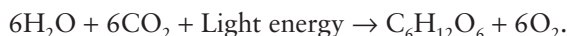
During the past 3.5 billion years of Earth's history, the biosphere has come to play an increasingly dominant role in shaping the chemistry of Earth's surface, making the study of Earth surface chemistry inherently the study of *biogeochemistry*. Indeed, as noted by James Lovelock and Lynn Margulis in their Gaia hypothesis, it was the biosphere that shaped the biogeochemistry of the earth surface into a chemical composition most favorable for the continued presence of life on earth. Most important, the biosphere changed the earth's atmosphere from an inhospitable, carbon-dioxide-rich, hot atmosphere into the hospitable, oxygen-rich, temperate atmosphere of the present.



This dominant role of the biosphere has been further solidified with the rise of one biotic species—humans. In particular, the advent of the agricultural and industrial revolutions has caused human actions to vastly increase many elemental fluxes and pools within the most important biogeochemical cycles.

Earth's Intersecting Biogeochemical Cycles

Analysis of a biogeochemical cycle may focus on any given chemical element found on Earth, but it is most commonly applied to the abundant elements that play an integral role in the functioning of the Earth system. The elements with a lighter atomic weight are most abundant in the solar system, and those light elements, which were soluble in the early seas, formed the basis of modern biogeochemistry. The key effect of the biosphere on the biogeochemistry of Earth's surface can be traced to the evolution of the photosynthetic metabolic pathway. Photosynthesis represents the critical link between the biogeochemical cycles most important for humans and the functioning of the Earth system. The simplified form of this crucial reaction of photosynthesis is



It is vital to note that photosynthesis must be sustained by a consistent supply of mineral nutrients. Thus, in addition to linking biogeochemical cycles of carbon (C), oxygen (O), and hydrogen (H), photosynthesis causes the biogeochemical cycling of mineral nutrients to also play key roles in the functioning of the Earth system. Of these mineral nutrients, nitrogen (N) is the most important. After nitrogen, photosynthesis requires an abundant supply of several other macronutrients. All these remaining macronutrients are weathered from rocks, thereby forming an important biogeochemical link between the biosphere and lithosphere.

In short, photosynthesis is the nexus of the major biogeochemical cycles. Given this role of photosynthesis, a plant's stoichiometry, or ratio of the concentration of its chemical elements, provides a useful means for roughly assessing the relative importance of the various biogeochemical cycles within the earth system. By dry mass,

the average plant is 45% carbon, 45% oxygen, 6% hydrogen, 1.5% nitrogen, 1.0% potassium, 0.5% calcium, 0.2% magnesium, 0.2% phosphorous, 0.1% sulfur, and 0.1% silicon. Biogeochemical cycles of other “micronutrients” such as iron (Fe) or manganese (Mn) can also be important to examine in instances where a shortage of one of these rarer elements may adversely affect the growth or health of a plant, animal, or human. This entry proceeds by concentrating on the major biogeochemical cycles organized here as (a) the hydrogen and oxygen cycles, (b) the carbon cycle, (c) the nitrogen cycle, and (d) cycling of rock-derived nutrients.

Hydrogen and Oxygen Cycles

Not surprisingly, among the most abundant elements on Earth are hydrogen and oxygen, the elements that constitute water (H_2O). Water is the medium by which life on earth evolved and is sustained. The biogeochemical cycling of H_2O , more often referred to as the hydrologic cycle, is highly coupled to the biogeochemical cycling of other elements. For instance, because water limits photosynthesis and soil microbial transformations, the carbon and nitrogen cycles proceed more slowly in drier regions of the Earth. Water is also an important agent of weathering and erosion, causing it to also strongly affect the cycling of rock-derived elements such as phosphorus and calcium.

The cycling of hydrogen is also important in its own right. For example, an increase in hydrogen ions increases the acidity of a soil, and this increase has subsequent effects on the mobility and plant availability of nutrients such as calcium or nitrate. Through the burning of fossil fuels and resulting deposition of acids (e.g., “acid rain”), humans have increased acidity over large regions, causing deleterious effects for soil and water quality.

Finally, in addition to its participation in the hydrological cycle, the cycling of oxygen is also inextricably linked to the global carbon cycle. As mentioned above, if photosynthetic organisms did not synthesize molecular oxygen (O_2) from carbon dioxide and water, the 21% abundance of oxygen in the atmosphere would not occur. The global cycle of oxygen is quite similar to carbon. Like carbon, most of the annual fluxes of oxygen



are between the atmosphere and biosphere, but each year a small fraction of Earth's oxygen is weathered from or buried in rocks.

Carbon Cycle

Carbon forms “the building blocks” of life on Earth. Its abundance and its tetravalent chemical properties allow it to form the ubiquitous complex polymers (e.g., DNA, carbohydrates, proteins) that are the hallmark and foundation of life. Despite this importance, it is only recently that the carbon cycle has garnered societal interest. Since the late 18th century, carbon-rich fossil fuels have enriched human society by providing energy, food, and mobility to an exponentially growing human population. Yet through our understanding of the global carbon cycle, we now realize that these treasures of fossil fuels come at the peril of unprecedented climatic instability.

Fossil fuels form during rare moments in space and time when dead biotic remains become buried in sediments before they can fully decompose. Historically, the amount of carbon entering the ocean through dissolution and entering the biosphere through photosynthesis tends to be balanced with the carbon returned to the atmosphere by natural processes of combustion, decomposition, and respiration. Combustion releases heat energy while rapidly oxidizing organic carbon into atmospheric CO_2 . Microbial decomposition returns carbon to the atmosphere as carbon dioxide (CO_2) and methane (CH_4). Respiration is the reverse chemical process of photosynthesis, thereby producing CO_2 .

The carbon cycle also includes a substantial abiotic component. Atmospheric carbon dioxide naturally dissolves in cool surface ocean water. Indeed, the vast oceans contain almost 56 times more carbon than the atmosphere. The slow precipitation of limestone (CaCO_3) on the ocean floor provides the only long-term storage for carbon and forms the largest pool of carbon on earth. Limestone slowly releases this carbon back into the active carbon cycle when it is weathered or converted to concrete by humans (a process that also adds CO_2 to the atmosphere).

As humans increasingly produce cement, cut down forests, and combust fossil fuels, we tip the natural balance of the carbon cycle. In 2007, the

natural biotic and oceanic sinks of carbon could only take in about half of the carbon humans emitted. As of 2007, human emissions are still rapidly increasing and have caused the atmospheric CO_2 content to reach its highest levels in the past 650,000 years and probably in the past 20 million years. This high level of atmospheric CO_2 is extremely important. Since CO_2 is a greenhouse gas that helps our atmosphere retain heat, our emissions of CO_2 are radically altering Earth's energy budget and climate. Thus, through our extensive participation in the carbon cycle, we must adapt to a global climate that will be unprecedented in human history.

Nitrogen Cycle

As the key limiting nutrient for photosynthesis and biotic growth, nitrogen is central to the functioning of all plants and animals on Earth. Within photosynthesis, nitrogen is a key element within the chlorophyll used to harvest light energy from the sun, as well as the Rubisco enzyme that catalyzes the carboxylation of atmospheric CO_2 into the photosynthate (i.e., $\text{C}_6\text{H}_{12}\text{O}_6$) that ultimately sustains life on Earth. Finally, due to its importance in animal protein, nitrogen serves to limit biotic growth at all higher trophic levels.

At first glance, this limiting nature of nitrogen for life on Earth is curious. In its N_2 molecular form, nitrogen makes up 78% of Earth's atmosphere. Yet while life on Earth is indeed surrounded by nitrogen, most organisms cannot directly access this inert atmospheric N_2 gas. All biologically available, or “reactive nitrogen” (N_r) must first be “fixed.” This “fixing,” or breaking apart the strong triple bond between atoms in the N_2 molecule, can only be done by two natural sources: (1) lightning and (2) nitrogen-fixing bacteria, such as those associated with the rhizomes of legumes such as soybeans. Through the fairly recent advent of the Haber-Bosch process for synthesizing ammonium nitrate fertilizer (NH_4NO_3) from atmospheric N_2 , humans can also fix nitrogen. In fact, when this fertilizer production is added to the N_r created by planting nitrogen-fixing crops, as well as the N_r released from the combustion of fossil fuels, humans now contribute almost half of the biologically available nitrogen (N_r) produced worldwide each year. Indeed,



this enormous yearly anthropogenic supplement of N_r has helped continue to feed the world's growing population. However, it has also resulted in widespread instances of overfertilization, leading to a host of environmental problems.

The adverse effects of anthropogenic fixation of nitrogen occur because once N_2 is fixed into N_r , it stays in this biologically available form for a long time. In fact, each molecule of N_r cycles through the world's terrestrial or marine ecosystems an average of almost 38 times. This nitrogen "cascade" can only be stopped through a microbial process of denitrification or through burial in marine sediments. Presently, human additions of N_r greatly outstrip denitrification or burial, and Earth's ecosystems are gaining greater than 20 metric megatons of N_r per year.

A poignant example of the adverse effects of all this excess N_r is the vast "dead zone" in the Gulf of Mexico at the delta of the heavily fertilized Mississippi River basin. In these locations dramatically affected by human actions, whole ecosystems are shifting toward those species, which thrive under nutrient-rich conditions. Often, these shifts to a nitrogen-rich ecosystem come at the detriment of the clean water or productive fisheries needed to sustain human life. Thus, our environmental policies must now also aspire to better manage our substantial interaction with the nitrogen cycle.

Cycling of Rock-Derived Nutrients

Rock-derived nutrients may be taken up by plants only after they are slowly weathered from the underlying parent material. Most important among these rock-derived nutrients is phosphorus, a nutrient essential to the nucleotides (i.e., DNA and RNA) that carry and reproduce genetic information. While phosphorus is the primary limiting nutrient in many terrestrial, freshwater, and marine ecosystems, the cycling of other rock-derived nutrients such as calcium, magnesium, and sulfur are also essential to life.

Geography of Biogeochemical Cycles

Much of the study of biogeochemistry has been aspatial in its focus. Great efforts have been

undertaken to quantify biogeochemical budgets at scales ranging from the globe to a small watershed. With this understanding to build from, it is only recently that researchers have begun to examine the great spatial heterogeneity within Earth's biogeochemical cycles. Exploring spatial patterns of biogeochemical cycling requires a holistic approach. The biogeochemical cycles of different elements are inherently coupled and are affected by many interacting "statelike" environmental factors (e.g., climate, relief). Moreover, maps derived from remote sensing instruments such as MODIS or AVIRIS now quantify meaningful spatial patterns in biogeochemical cycles, such as marine carbon sequestration or forest canopy nitrogen content. As humans further dominate the functioning of their sustaining ecosystems, the understanding gained by these views into the geography of biogeochemical cycling will become paramount for renewing sustainable societies.

Brenden E. McNeil

See also Acid Rain; Atmospheric Composition and Structure; Atmospheric Pollution; Biota and Soils; Carbon Cycle; Climate Change; Ecosystems; Gaia Theory; Global Environmental Change; Hydrology; Imaging Spectroscopy; Land Use and Cover Change (LUCC); Nitrogen Cycle; Nutrient Cycles; Phosphorus Cycle; Remote Sensing; Rock Weathering; Soils

Further Readings

- Canadell, J., Le Quere, C., Raupach, M., Field, C., Buitenhuis, E., Ciais, P., et al. (2007). Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proceedings of the National Academy of Sciences*, 104(47), 18866–18870.
- Galloway, J., Townsend, A., Erismann, J., Bekunda, M., Cai, Z., Frenay, J., et al. (2008). Transformation of the nitrogen cycle: Recent trends, questions, and potential solutions. *Science*, 320(5878), 889–892.
- Likens, G., & Bormann, F. (1995). *Biogeochemistry of a forested ecosystem*. New York: Springer-Verlag.



- Lovelock, J. (1979). *Gaia: A new look at life on earth*. Oxford, UK: Oxford University Press.
- Schlesinger, W. (1997). *Biogeochemistry: An analysis of global change*. San Diego, CA: Academic Press.
- Sterner, R., & Elser, J. (2002). *Ecological stoichiometry: The biology of elements from molecules to the biosphere*. Princeton, NJ: Princeton University Press.
- Vitousek, P., Mooney, H., Lubchenco, J., & Melillo, J. (1997). Human domination of earth's ecosystems. *Science*, 277, 494–499.



BIOGEOGRAPHY

Biogeography is the study of the geographical distribution of living and fossil plants and animals as a result of ecological and evolutionary processes. Biogeography analyzes organism-environment relations through change over space and time, and it often includes human-biota interactions. The main questions explored by biogeographers deal with organism patterns to understand the underlying processes. Biogeographers ponder questions such as why is a species present in a given area? Conversely, if a species is not present, then why is it missing from the area? What are the historical and ecological factors that help determine where a species occurs? What are the effects of evolution and plate tectonics? How have humans altered geographic distribution of organisms? The science of biogeography has been revitalized in the past 60 years due to our understanding of plate tectonics, mechanisms limiting distributions, island biogeography theories, and mathematical and technological tools.

Current work in biogeography uses spatial patterns of organisms, past and present, to determine ecological processes. Biogeographers use experimental testing and quantification of biotic interactions. Vegetation dynamics is the primary focus for approximately half of the biogeographic research conducted by U.S. geographers. Other major focuses include ecosystem structure and function, zoogeography, paleoecology, and development of new biogeographic methodology. In particular, mapping and modeling spatial patterns

of abundance and distribution of species of plants and animals have greatly advanced with geographic information systems and remote sensing technology.

Development of Biogeography

To better understand the current field of biogeography, it is important to explore the foundations and history of the science. Biogeography is a synthetic study, which is based in part on the subjects of community ecology, geology, systematics, evolutionary biology, and paleontology. The development of the subject of biogeography may be broken into four historical periods.

1600–1850: The Age of Reason

Early studies of organisms' geographic distributions were focused on descriptive studies with historical explorations. These scientists focused on documenting spatial patterns of organisms, emphasizing on the effects of climate, latitude, and altitude. Comte de Buffon (1707–1788), also known as Georges-Louis Leclerc, determined that distant regions with similar climate and similar-appearing vegetation have different animal species. This is now referred to as Buffon's Law. He is also the author of *Histoire Naturelle*, a 44-volume natural history encyclopedia. Carl Linnaeus (1707–1778) studied the plants and animals spread from Mount Ararat in Turkey to explore the idea of the biblical flood. As a result of documenting elevational zones of Ararat, he came up with the idea of biomes defined as major ecological communities. In addition, Carl Linnaeus is considered the father of the science of taxonomy, which is the science of classification.

This time period is also known as a great age for exploration. Johann Reinhold Forster (1729–1798) was the naturalist on James Cook's second Pacific voyage in 1778. He advanced biogeography by creating global biotic regions for plants. Forster noted the higher-species diversity in the tropics, as well as species diversity being correlated with island size. Alexander von Humboldt (1769–1859) created a botanical geography that was foundational to the field of biogeography. He determined that plant vegetation types are strongly correlated with local climate to create latitudinal belts of vegetation. Moreover, he



developed elevational vegetation zones for the Andes in South America.

1850–1900: Evolution by Natural Selection

The idea of evolution based on natural selection greatly altered the way species distributions were explained. Charles Darwin (1809–1882) is most famous for publishing *The Origin of Species*, outlining his idea of evolution through natural selection. Natural selection occurs when individuals in a population either do not survive equally well or do not breed equally well, or both due to inherited differences. Evolution in turn can be thought of in two ways: (1) microevolution and (2) macroevolution. In microevolution, evolution is considered as changes in the genetic composition of a population with the passage of each generation. For macroevolution, evolution is the gradual change of organisms from one form into another, with the origins of species and lineages from ancestral forms. For an example, Darwin studied the variations in mockingbirds on different Galapagos Islands. This divergent evolution is a diversification over evolutionary time of a species into several different species, commonly referred to as adaptive radiation.

Alfred Russel Wallace (1823–1913) is also famous for independently developing the idea of evolution by natural selection, based on his work in Indonesia. He found that the species on Sumatra and Java were very different from nearby New Guinea, even though the climates were similar. Wallace's study of biota in southeast Asia showed geographic distance is not equal to taxonomic similarity, and the boundary area between these islands is now referred to as *Wallace's Line*. Wallace is also considered to be the originator of zoogeography, which is the biogeography focused on animals. Wallace integrated geological, fossil, and evolutionary information to consider paleoclimate influences distributions, developing six great biotic regions.

Other notable contributions to biogeography during this period include mapping biotic regions and understanding limiting factors. Philip Lutley Sclater (1829–1913) advanced the subject of biogeography with his defining terrestrial biotic regions for birds and marine regions for marine mammals. Justus Liebig (1803–1876) changed the way scientists viewed restrictions on organisms away from a focus on total resources available

with his law of the minimum. The law of the minimum states that the scarcest resource (or limiting factor) in the environment makes it difficult for a species to live, grow, and reproduce.

1900–1950: Continental Drift and Ecology

Themes in biogeography in the first half of the 20th century focused on links to paleontology, centers of species origins, and the biological species concept. The emphasis in the science of biogeography was on evolution, history, dispersal, and mechanisms of survival. The greatest impact on biogeography in this period was the theory of continental drift in 1912 and 1915 by the German geologist Alfred Wegener (1880–1930). Before the theory of plate tectonics, it was difficult for biogeographers to explain certain patterns of species distributions with the assumption that land masses were fixed in their geographic positions. Wegener's theory was actually not widely accepted until the 1960s when proof of continental drift came from a series of linear magnetic anomalies on either side of the Mid-Atlantic Ridge. With the acceptance of the continental drift theory, biogeographers could now explain the disjunct biogeographic distribution of present-day organisms found on different continents but having similar ancestors. Species can interact as continents collide. Subsequently, when the continents separate, they take their new species with them. Biogeographers now ponder how plate tectonics may have affected the evolution of life. In turn, biogeographers offer evidence for plate tectonics such as dispersal of species via such corridors as the Bering land bridge or widely separated ("disjunct") species distributions that can't be explained by dispersal; for instance, *Nothofagus* (southern beech) trees, which only occur in Southern South America and in New Zealand.

In addition to historical explanations of organism distributions, biogeographers also examined ecological reasons for spatial patterns. Theories on ecological succession were formally developed in the late 1800s and early 1900s to show predictable and orderly changes in the composition or structure of ecological communities. In 1899, Henry Cowles published his study of stages of vegetation development on dunes along Lake Michigan. In 1916, Frederic Clements published his



famous theory of vegetation development focusing on gradual changes over time to best fit the local conditions. His climax theory of vegetation-dominated plant ecology was later largely replaced by other models, notably by Henry Gleason's 1926 concept of distribution of plants depending on the individual species rather than Clements's idea of plant associations. In 1934, Christen Raunkiaer (1860–1938) helped change the way biogeographers classified species with life forms based on ecological rather than taxonomic classification. In 1935, Sir Arthur Tansley (1871–1955) refined the term *ecosystem* to mean the whole complex natural unit in a system consisting of all plants, animals, and microorganisms (biotic factors) in an area functioning together with all the nonliving physical (abiotic) factors of the environment.

1950–Present: Ecological and Historical Theories

Since 1950, the field of biogeography has been revitalized with advances in ecological and historical theories focused on phylogenetic classification to related different species, mechanisms limiting geographic distribution, and distances and size influencing number of species in an area. During this period, the concept of new species arising due to geographic isolation was developed by Ernst Mayr (1904–2004). Mayr is also well-known for defining the “biological species concept” as potentially interbreeding to produce fertile offspring. In addition, Mayr helped define the term *cladistics* to refer to classifications, which only take into account genealogy, based on evolutionary ancestry. Cladistics, or phylogenetic classification, views a species as a group of lineage-connected individuals, compared with the traditional Linnaean taxonomy, which focused on the similarities between species. Cladograms are created based on the order in which different groups branched off from their common ancestors, arranged with the most closely related species on adjacent branches of the phylogenetic tree.

Theories also expanded during this time period on how a species can occur in widely geographically separated areas and the mechanisms that limit these distributions. In 1958, Leon Croizat (1932–1982) published his concept of “vicariance biogeography” to explain disjunction of multiple

species due to the growth of barriers instead of via dispersal. Croizat's works include *Manual of Phytogeography* (1952), *Panbiogeography* (1958), and *Space, Time, Form* (1964). Robert Harding Whittaker (1920–1980) proposed a new method to analyze limits to plant distributions by comparing species abundance with environmental gradients. His gradient analyses approach focuses on abiotic factors such as light, water, temperature, and soil nutrients in plant communities.

Biogeography during this period moved from observational to predictive studies with the theory of island biogeography. In 1963, R. H. MacArthur and E. O. Wilson hypothesized that species richness of an area could be predicted to explain distributions. The theory states that if one knows the rates of colonization and extinction of an island, then it is possible to predict the number of equilibrium species that area could support. They based the species richness prediction on two factors: (1) distance of the island from a mainland source of species for a colonization pool and (2) the size of the island for available habitat and its variety of ecological niches. With these two factors, MacArthur and Wilson predicted the number of species the area could maintain, as well as the turnover rate for the area. According to island biogeography theory, small and distant islands have a lower number of species that can be maintained compared with large and near islands. The theory also states that there would be a turnover of the species as new species colonize and old species go extinct, but the number of species overall should achieve an equilibrium number. This theory has been applied to other nonisland areas that act like islands due to habitat fragmentation, such as nature preserves and national parks.

Spatial Distributions of Organisms

Modern biogeography explores spatial patterns in the geographic variation of individuals and populations, including genetic, physiological, and morphological variations. Organisms are often studied in biomes, consisting of distinct flora and fauna related to climate, soil, and geological factors. Biogeographers analyze species ecological niches (both fundamental and realized), defined as the total requirements for resources and physical



conditions. The foundation of biogeographic distribution patterns follows the first rule of geography, namely that closer equates to more similar (referred to as “spatial autocorrelation”). When relating species niche to geographic distributions, key interactions and adaptations to consider include (a) stress, with regards to climate, predation, and availability of symbiosis (close association between species); (b) competition, both between and within species, which exclude some species from their fundamental niches; and (c) disturbance, which occurs less predictably and causes a greater change in the environment than stress. Biogeography seeks to answer why and how species distribution patterns are a response to historical and ecological limiting factors, dispersal mechanisms, and human influences.

Vicariance Biogeography

Geographic distributions may be separated into disjunct populations by historic events that create barriers, called *vicariant events*. Disjunct distribution occurs when two or more closely related taxa live today in widely separated areas. Barriers that split a continuous distribution into disjunctions are created by many processes, including changing in the distribution of land via continental or tectonic shifts, volcanism and mountain building, shifts in river patterns, glacial cycles, climate change, and human alterations to landscapes. Barriers may be physical (such as a mountain), physiological (such as freshwater vs. saltwater blocking for aquatic organisms), and/or ecological-behavioral (e.g., predators). For example, one vicariance-splitting taxons’ ranges occurred from historical climate change during glacial periods, resulting in the drying of tropical rain forest in South America into smaller fragments of rain forest refugia surrounded by grassland. Disjunct distributions from vicariant events are supported by fossil evidence and by the geography of present species that cannot be explained by natural dispersal. For example, *Nothofagus* (southern beech) trees occur today in such widely separated regions as Southern South America and New Zealand, which can be explained by historic plate movement but not dispersal. In another example, disjunct populations of southern migrations were created during glacial ice advancements in North

America, with isolated populations cut off as ice retreats (partly because soil was removed by glaciers). Organisms from temporary or fluctuating environments (such as seasonal variations in temperature) typically are less separated by barriers. For instance, crossing mountain ranges are less of a barrier to species from temperate climates (adapted to cold winters) compared with species from tropical climates.

Geographic isolation from vicariant events leads to reproductive isolation. Even if the disjunct population reunites in time, the geographic isolation may have already resulted in the groups no longer being able to interbreed (especially in animal species). In other words, when barriers geographically isolate populations over time, a different evolutionary lineage might occur with new species being created (referred to as *allopatric* speciation). Another reason for its occurrence may be because different geographic regions have different selective pressures, such as temperature, rainfall, predators, and/or competitors. In addition, even if the environments separated by a barrier are not very different, the populations may differentiate because different genetic combinations and mutations occur by chance (see Figure 1).

Dispersal Biogeography

Disjunct biogeographic distributions may also be created by dispersal events. Dispersal can be defined as movement away from one’s point of origin. The possible results of dispersal include extending *within* current range by colonizing new habitat in range or colonizing *distant* location across a major physical barrier of unfavorable habitat. Individuals may move great distances through unsuitable habitats by traveling through corridors, flying over hostile environments, being blown or floating through sweepstake events (such as a hurricane). Dispersal agents typically are wind, water, rafting, or animals. Dispersal biogeography studies distribution patterns of organisms, emphasizing dispersal capabilities as well as ecological properties of species to evaluate origins of taxa in a biota. Dispersal mechanisms affect rate of species movement across landscape, as well as the efficiency of species in colonizing new areas.

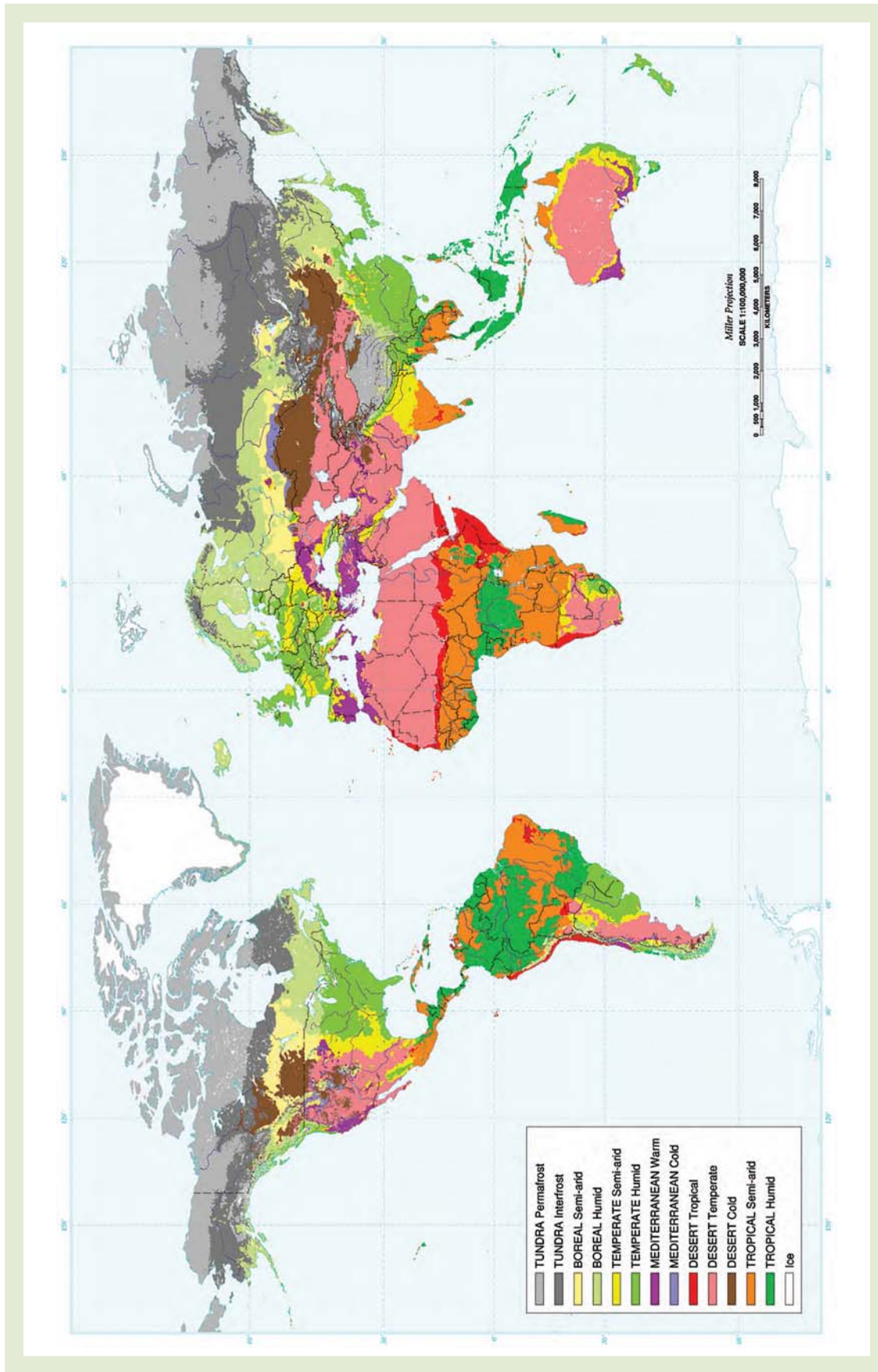


Figure 1 Major biomes map
 Source: U.S. Department of Agriculture, Natural Resources Conservation Service, Soil Survey Division, World Soil Resources, Washington, D.C.



Modes of dispersal vary from jump dispersal (e.g., the movement of gypsy moth *to* North America) to diffusion (e.g., gypsy moth spread *within* North America). Jump dispersal includes traveling over long distances across inhospitable habitat—in other words, long-distance dispersal mostly by organisms that can fly or swim. Jump dispersal events are rare, cover large distance, and are considered “surprising” events. These long-distance dispersals can explain large discontinuous distributions of some organisms, as well as taxonomic similarity of distant biotas and populations. Most animal and all plant jump dispersals are passive, although occasionally some animals have active long-distance dispersals. Those individuals who succeed at jump dispersal have the ability to (a) travel long distances, (b) withstand unfavorable conditions during passage, and (c) establish viable population on arrival.

Pathways of dispersals can be broken into the categories of corridors, filters, and sweepstakes. Corridors are routes that permit spread of taxa through continuous favorable habitat with relatively little risk. These routes may in turn link larger areas of habitat. Famous corridors include past land connections created by sea level changes, such as the Bering land bridge connecting Asia and North America. In contrast, a “net” or “filter” is a route that contains patches of suitable habitat interspersed between larger areas of unsuitable habitat. Filters can act as a barrier for some taxa, blocking or slowing passage of some organisms. A classic example is the Isthmus of Panama filtering the dispersal between North and South America starting around 3.5 million years ago. The “sweepstakes” pathway of dispersal refers to chance dispersal across a major barrier—in other words, a long shot for dispersal, which usually involves accidents, low probability, and unusual means of travel. For instance, sweepstakes dispersal includes birds caught in hurricanes, seeds traveling in upper atmosphere winds, and animals floating on driftwood (called “Noah’s Ark” if there is an assemblage of organisms deposited en masse).

Human Impacts of Distributions

In addition to barriers and dispersal events, biogeography also explores species distribution

patterns affected by humans, whether in limiting or expanding ranges. Humans decrease other species ranges through habitat destruction, hunting and commercial exploitation, polluting environments, deliberately or accidentally introducing competing nonnative species, changing historic disturbance regimes, and causing the loss of ecological partners. Species most likely to have their geographic ranges limited by humans include species that have relatively few offsprings that are nurtured for a long time (“K” species), specialists who are selective about their niche conditions, economically valuable species, naturally rare species, species with naturally restricted ranges, species sensitive to pollutants, and species in competition with humans for habitat or resources. People also increase species geographic ranges, either by introducing species to a new geographic region or by expanding ranges by favoring some species that can adapt to human landscapes (weeds, agricultural species, species adapted to urban areas). Introduction of species by people into a new area may be deliberate or accidental. Although most introduced species fail to establish viable population, those that succeed typically have harmful long-term effects, competing with native species or transmitting diseases.

Conclusion

Biogeographers seek to develop theories to explain past, present, and changing future composition of plants and animals distribution patterns in order to better understand the processes of how organisms interact with our planet. Biogeography is both interdisciplinary within other subfields of geography as well as other disciplines, such as ecology, geology, and biology. An integrative approach helps biogeographers provide a holistic understanding of the diversity of life and make recommendations for the conservation of biological diversity.

Joy Nystrom Mast

See also Adaptive Radiation; Biome: Boreal Forest; Biome: Desert; Biome: Midlatitude Deciduous Forest; Biome: Midlatitude Grassland; Biome: Tropical Deciduous Forest; Biome: Tropical Rain Forest; Biome:



Tropical Savanna; Biome: Tropical Scrub; Biome: Tundra; Cultural Ecology; Darwinism and Geography; Ecological Regimes; Ecoregions; Ecosystems; Exotic Species; Extinctions; Forest Fragmentation; Great American Exchange; Invasion and Succession; Island Biogeography; Islands, Small; Landscape Ecology; Nature; Political Ecology; Species-Area Relationship; Tree Farming

Further Readings

- Cox, C., & Moore, P. (2005). *Biogeography: An ecological and evolutionary approach*. Malden, MA: Blackwell.
- Lomolino, M., & Heaney, L. (Eds.). (2004). *Frontiers of biogeography*. Sunderland, MA: J. H. Sinauer.
- Lomolino, M., Riddle, B., & Brown, J. (Eds.). (2006). *Biogeography* (3rd ed.). Sunderland, MA: J. H. Sinauer.
- Lomolino, M., Sax, D., & Brown, J. (Eds.). (2004). *Foundations of biogeography: Classic papers with commentaries*. Chicago: University of Chicago Press.
- MacArthur, R., & Wilson, E. (2001). *The theory of island biogeography*. Princeton, NJ: Princeton University Press. (Original work published 1967)
- MacDonald, G. (2003). *Biogeography: Introduction to space, time, and life*. New York: Wiley.
- Quammen, D. (1997). *The song of the Dodo: Island biogeography in an age of extinction*. New York: Simon & Schuster.



BIOME: BOREAL FOREST

Boreal forests, also known as *taiga* in Russia, stretch across a large zone in the Northern Hemisphere, spanning North America and Northern Eurasia, and represent nearly one third of the global forested areas. Formed under harsh climatic conditions, these forested ecosystems provide crucial ecological and societal benefits and strongly influence many global processes, including carbon storage and release and, subsequently, concentration of greenhouse gases in the atmosphere. Boreal forests are dominated by coniferous tree species that are frequently replaced by

broad-leaved deciduous trees after an occurrence of disturbances such as fire, insect infestation, or logging. Although poor in dominant-tree biological diversity, these forests are the largest intact ecosystem on Earth and sustain considerable populations of large land mammals such as moose, elk, and bear. Under the observed warming trends, boreal forests show signs of a shift in vegetation composition and an increase in extent and severity of natural disturbances.

Definition and Geographic Extent

Boreal forest received its name after the Greek god of northern winds Boreas, indicating the geographic position of this biome in high northern latitudes. No equivalent belt exists in the Southern Hemisphere since large land masses at similar latitudes are not found there. The geographic boundaries of the boreal biome are frequently defined by climatological variables representative of the temperature-limited growing conditions. Several temperature-related metrics are commonly used to define the exact northern and southern boundaries of boreal forests. One of the approaches is to define the southern boundary of the biome at the average yearly +5 °C isotherm (i.e., a line connecting points of equal temperature) and the northern boundary at the average yearly −5 °C isotherm. Another approach uses mean monthly July +18 °C and +13 °C isotherms for southern and northern boundaries, respectively. Yet another approach defines the boreal zone using the length of the period with mean daily temperatures of at least 10 °C and draws the southern boundary at less than 120 days and the northern boundary at approximately 30 days. The area within these boundaries typically has 50 to 100 frost-free days per year. The amount of precipitation in the boreal forests depends on their proximity to the zone of oceanic influence and varies from 200 to 2,000 millimeters per year. However, relatively low temperatures and a short warm period lead to low evaporation rates and thus to generally humid climate even within areas that receive little precipitation.

A different approach to defining boreal forests is to use the dominance of a particular vegetative form. Under this approach, boreal forests are defined as tree-dominated landscapes in high



northern latitudes with prevalence of needle-leaved species in primary (climax) forests. Although this approach is very different from the climatological definitions described above, the overall global extents of boreal biome produced by various schemes are similar and reflect a strong relationship between climate and vegetation distribution. In North America, the majority of boreal forests are found between 45° N and 55° N, whereas in Northern Eurasia boreal forests are rarely found below 55° N. The vegetation-based definition extends the northern boundary of boreal forest in Eurasia above 70° N; however, most ecologists agree that there it represents a forest-tundra transitional zone rather than traditional boreal forests. Boreal forests are also found south of their broad geographic boundaries presenting Alpine extensions of the biome range or mountain taiga. These extensions can penetrate deep into general ranges of other biomes stretching along mountains as in the example of the Appalachians.

Vegetation, Wildlife, and Major Ecosystem Processes

The limitations imposed on vegetation growth in the boreal zone by relatively low temperatures are offset by the length of the day during the warm season. The maximum day length varies from 16 hrs. (hours) of sunlight at the southern boundary of the boreal zone to 24 hrs. at the northern, promoting vigorous vegetation growth during summer. Trees are the dominant life form in the boreal forest. Primary or climax forests are dominated by coniferous species such as spruce (*Picea*), fir (*Abies*), pine (*Pinus*), and larch (*Larix*). The majority of coniferous species are evergreen with the exception of larch that drops its needles during the cold period of the year, adapting to extremely harsh winters of Central and Eastern Siberia. Following a disturbance, the primary forests enter a successional stage frequently dominated by broad-leaved deciduous trees such as alder (*Alnus*), birch (*Betula*), and aspen (*Populus*). Early colonizers, these species subsequently create favorable conditions for reestablishment of shade-tolerant coniferous trees. The “broad-leaved deciduous coniferous” succession is typical for many but not all boreal forests. For example, light coniferous

larch stands frequently regrow as larch bypassing the broad-leaved tree dominance stage. Even with postdisturbance successional landscape mosaic of coniferous and broad-leaved deciduous stands, boreal forests show little diversity in main tree species. In addition to the dominant tree tier, boreal forests may contain shrubs, dwarf shrubs, herbaceous cover, lichens, and mosses, although the composition and abundance of those vegetation types differ in various stands and zones.

Boreal forests occupy areas of the most recent ice-age glacial cover and commonly overlay permafrost-affected soils. The distribution of permafrost is not uniform and ranges from completely permafrost-free soils and scattered permafrost in interior Alaska and Canada to widespread solid permafrost of Central and Eastern Siberia. Poor soil drainage in combination with vigorous growth of vegetation, low temperatures, and short frost-free period facilitates accumulation of partially decomposed organic material and formation of peatlands. Although peatlands develop in many biomes, nearly 80% of all peatlands worldwide are found within the boreal zone. Boreal peatlands and trees are estimated to account for nearly 40% of global terrestrial carbon pool and therefore play a crucial role in the global carbon budget. In addition to their prominent role in carbon storage, peatlands also receive and store atmospherically deposited pollutants, including nitrogen, sulfur, and heavy metals. Despite great accumulation of organic layer, nutrient availability in soils within the boreal biome is generally low.

Although the biological diversity of dominant tree species in the boreal biome is low, boreal forests now represent the largest intact ecosystem on Earth and therefore represent a highly valuable biodiversity conservation resource. The spatial extent of these forests sustains very large populations of large herbivores, including woodland caribou (*Rangifer tarandus*), moose (*Alces alces*), and elk (*Cervus elaphus*), as well as smaller herbivorous boreal species such as snowshoe hare (*Lepus americanus*) and beaver (*Castor Canadensis*). In turn, the availability of large numbers of prey species sustains considerable populations of fur-bearing predators, including fairly common species such as brown bear (*Ursus arctos*), lynx (*Lynx* spp.), grey wolf (*Canis lupus*), as well as



Forest area with mountains in the background in Northern Ontario, Canada

Source: Ken Chiu/iStockphoto.

the endemic and critically endangered Amur (Siberian) tiger (*Panthera tigris altaica*), and various members of the weasel family such as wolverine (*Gulo gulo*), marten and sable (*Martes* spp.), and mink (*Neovison* spp. and *Mustela* spp.). Boreal forests contain hundreds of threatened plant and animal species, included in the World Conservation Congress (IUCN) red list, and over a dozen of the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage sites.

Natural and Human-Caused Disturbances

Boreal forests are affected by many disturbances that play an important role in regulating forest succession and maintaining diversity and mosaic structure of boreal forests. The most prevalent natural disturbance is wildland fire that is an

integral part of the boreal ecosystem functioning. Mean fire-return interval in the boreal zone, defined as an average time required to burn an area equivalent to the entire ecosystem, is approximately 139 yrs. (years) with a range between 50 and 270 yrs. The severity of fire impacts on the forest vary from low-impact surface fires, which rarely kill mature trees, to full mortality stand replacement fires. Peat fires are more frequent in continental zones of West-Central Canada and Western Siberia than in maritime boreal zones. Peat fires are characterized by different burning patterns compared with forest fires and are more frequently smoldering than flaming. As a result of smoldering burning of deep organic layers, peat fires release massive amounts of greenhouse gases and other pollutants into the atmosphere. Subsurface smoldering of peatland fires also makes it extremely difficult to control them as fire may



spread beneath the surface layer without being detected. Unlike forests that turn into a net carbon sink during early successional stages 10 to 30 yrs. following the fire, peat accumulation is a very slow process, therefore burned nonforested peatlands remain a source of carbon emissions for a long time after fire occurrence.

Insect infestation is the second most widespread natural disturbance agent in the boreal forest. The major threat is posed by defoliating insects, such as spruce budworm and forest tent caterpillar that feed on foliage during various life stages, and borers, such as bark beetles, which bore into the tree and generally complete their life cycle under the bark. While the impact from defoliators can range from partial and temporary loss of tree canopy to tree mortality following a prolonged infestation period, bark beetle infestation almost always leads to complete tree mortality during the life cycle of one generation. Unlike fire impacts, the full extent of insect infestation may not be immediately apparent, and it may take several seasons to define the extent and quantify the amount of forest loss. Insect infestation-weakened or killed forests are frequently subsequently affected by fire, removing the dead standing biomass and resetting successional forest growth. Although not quite as prevalent as fire and insect infestation, disease and wind throw also affect boreal forest and may lead to stand replacement.

Commercial timber harvest is the leading agent of human-caused (or anthropogenic) disturbances in the boreal forest. Clear-cut logging is the most frequent form of timber harvesting, which results in removal of forest cover similar to stand replacing natural disturbances. In addition to commercial timber harvesting, boreal forests overlay major oil, gas, and coalfields and are affected by energy development projects and other accompanying development. Peat mining presents the third major anthropogenic disturbance leading to significant modification of boreal ecosystem functioning. Postharvesting dehydration and mineralization of peat changes soil and water qualities and water tables and subsequently results in a turnover in species composition and vegetation structure. Large-scale peat harvesting also has a pronounced impact on wildlife and certain bird species, leading to long-term replacement of typical peatland fauna with generalist species.

Cultural Significance of the Boreal Biome

In addition to their prominent role as a major economic resource in industrial forestry, including timber harvesting and pulp and paper production, mining, and oil and gas extraction, boreal forests present an important resource for tourism, trapping, hunting, and recreation. The cultural significance of boreal forests is especially high because many of the world's remaining northern indigenous cultures live in the zone of boreal forests. Many native people of the boreal biome maintain their traditional practices and lifestyle that has survived since the most recent Ice Age. The genetic biodiversity, remoteness, and vast ecological resources of boreal forests support the central way of life for many indigenous groups and allows for preservation of their cultural identity. Many of these cultures have become vulnerable under the impact of ongoing climatic, economic, and cultural changes in the surrounding areas making it particularly hard for them to maintain an active role in the contemporary society while retaining close association with the traditional way of life.

Tatiana Loboda

See also [Agroforestry](#); [Biodiversity](#); [Biota and Climate](#); [Carbon Cycle](#); [Deforestation](#); [Forest Fragmentation](#); [Forest Land Use](#); [Forest Restoration](#); [Peat](#); [Sustainable Forestry](#); [Tree Farming](#)

Further Readings

- Goldammer, J., & Furyaev, V. (Eds.). (1996). *Fire in ecosystems of boreal Eurasia*. Dordrecht, Netherlands: Kluwer Academic.
- Kasischke, E., & Stocks, B. (Eds.). (2000). *Fire, climate change, and carbon cycling in the boreal forest: Vol. 138. Ecological studies*. Heidelberg, Germany: Springer.
- Shugart, H., Leemans, R., & Bonan, G. (Eds.). (2005). *A systems analysis of the global boreal forest*. New York: Cambridge University Press.
- Wieder, R., & Vitt, D. (Eds.). (2006). *Boreal peatland ecosystems: Vol. 188. Ecological studies*. Heidelberg, Germany: Springer.



BIOME: DESERT

The desert biome is broadly described as any land that receives less than 500 mm (millimeter) of rainfall per year, including tropical/subtropical deserts falling within $\pm 30^\circ$ latitude of the equator, as well as temperate deserts falling between 30° and 50° latitudes (North and South) with an annual temperature less than 10°C . This biome covers more of the earth's land surface than any other biome—roughly one third of all land is desert. Most of this biome falls within Africa, Asia, and the Middle East.

The word *desert* is derived from the Latin word *desertus*, meaning “deserted,” reflecting many people's first impression of deserts as being barren and devoid of life. Contradictory to such first impressions, the desert biome has a remarkably high diversity of species, second only to the rain forest biome, but it has the lowest productivity of any biome. It is perhaps this disparity that has intrigued geographers and naturalists for centuries and led scientists to base many environmental theories on desert systems. Nowhere else on earth are ecological and geomorphic processes more visible.

Categorization of Deserts

In addition to being broadly categorized into tropical/subtropical and temperate, deserts are categorized according to their level of aridity, traditionally by assessing annual precipitation. However, moisture input should not be considered without factoring in moisture loss, particularly in the limited moisture systems of deserts. Furthermore, precipitation in deserts is too variable to be the sole basis of categorization. Most geographers measure the aridity of a desert according to the ratio between annual precipitation and evapotranspiration (the combined loss of moisture through evaporation and transpiration by plants). These criteria were developed by UNESCO in the 1970s, but several similar formulas have been developed over the past century.

The extent to which mean annual precipitation (P) falls below mean annual evapotranspiration values (ET), reflects a level of aridity that falls into one of three categories: (1) semiarid, (2) arid,

and (3) hyperarid. This measurement is sometimes altered to include other factors. For example, calculations of this ratio are often made for set periods of time to account for climate variability, and some formulas factor in the water storage capacity of plants and soil. Nevertheless, categorizations are most commonly based on the following:

- *Semiarid deserts*: P/ET value <0.5 and mean annual precipitation 200 to 500 mm.
- *Arid deserts*: P/ET value <0.20 and mean annual precipitation between 80 to 200 mm.
- *Hyperarid deserts*: P/ET value <0.03 and mean annual precipitation <80 mm.

The delineation of different deserts is challenging at best, and satellite images now show us how the boundaries of deserts can shift in just 1 year—the sands of the Sahara Desert in North Africa continually shift and China's desert land expands every year due to desertification processes. In addition, a desert that is considered arid one year could be semiarid in another due to a rare spike in rainfall. To overcome these variations, there is an important temporal element to the categorization of deserts, usually requiring decadal measurements at minimum. Other measurements have also been used to help identify where a desert area begins and ends, such as vegetation distribution, geomorphology, or landscape type.

Semiarid Deserts

Semiarid deserts are a common type of desert within the desert biome, covering roughly 14% of Earth's land surface—this percentage doubles if one includes dry subhumid areas (see Mediterranean Biome). The features of semiarid deserts vary considerably from dry savanna (“steppe” in temperate zones) to shrubland to dry woodland. Because of their widespread distribution and varying land cover, many semiarid deserts are not delineated as “deserts” but are, nonetheless, included in the desert biome.

All semiarid deserts are vulnerable to desertification processes, mainly because more human settlements occur in these less arid deserts due to the agricultural potential. Unfortunately, land use practices in these areas are often unsustainable,



Wildebeest migrating across semiarid plains of East Africa

Source: J. S. Lalley, 2008.

and some of the worst droughts and famines ever experienced have been in semiarid deserts. This observation also means that pristine semiarid deserts are harder to come by than pristine arid to hyperarid deserts.

Flora and Fauna of Semiarid Deserts

Semiarid deserts are often referred to as “fringe deserts” and will harbor species that live on the edge of both higher- and lower-rainfall areas. Florae that are characteristic of semiarid deserts include drought- and fire-resistant plants (particularly grasses), plants with thorns, and plants with deep penetrating roots that tap into ground water. Fauna is characterized by migrating large mammals and migrating birds.

Movement is key to survival in semiarid areas. In tropical semiarid deserts, animals will quite literally follow the rain. In temperate semiarid deserts movement is further dictated by seasonal temperatures. Well-known examples of such movement include the mass migration of wildebeest in

East Africa and pronghorn sheep in North America (see wildebeest photo).

Location of Semiarid Deserts

Temperate, Semiarid Deserts (or “Steppes”)

Asia: peripheral areas of the Gobi Desert, Tibetan Plateau, Pamir Plateau, Turanean lowland, Ust Urt Plateau

North America: Colorado plateau, dry grasslands from Texas to Montana and North Dakota

South America: parts of the Patagonian Desert and bordering areas

Tropical/Subtropical Semiarid Deserts

Africa: Northern and Eastern Kalahari Desert, Karoo Desert, Sahel Desert, Western Somali-Chalbi Desert and bordering areas of East Africa

Asia: Deccan Plateau

Australia: all areas bordering the great arid deserts of the interior



Livestock overgrazing in a desert

Source: J. S. Lalley, 2008.

Middle East: most of the Middle East outside arid and hyperarid deserts

North America: the southern and eastern boundaries of Chihuahuan Desert

South America: Chaco, Monte Desert, most areas east of the Atacama Desert, Caatinga Scrubland (Brazil)

Arid Deserts

Arid deserts are considered “true deserts” because they have extremely water-limited systems with desert-adapted flora and fauna. They cover 15% of the earth’s land surface, and this percentage is increasing due to the desertification of semiarid deserts and exceeding climate variability worldwide (see livestock photo). Human population growth has meant that human settlements have spilled into the nonarable lands of arid deserts, and while desert dwellers have traditionally stuck to desert-sensitive livelihoods, most modern inhabitants of arid deserts have not. Hence, arid deserts are becoming increasingly vulnerable to human impacts. Such impacts can be profound

where overgrazing leads to extreme dust storms, water tables readily collapse leading to contamination of already limited freshwater resources or where the loss of one species can lead to a dramatic and cascading loss of others.

Flora and Fauna of Arid Deserts

Arid deserts are home to a unique variety of desert-adapted species. Vegetation is characterized by plants with high water-retention capabilities, such as succulents and cacti, and with small, unpalatable and/or spiny leaves that resist water loss and browsing by animals. Plants are often tolerant of saline soils, and they often have shallow roots for the quick absorption of rare rain events or extremely deep roots for tapping into ground water. Drought-resistant grasses are also typical of arid deserts, but growth is usually patchy (see springbok photo). In fact, most vegetation growth in arid deserts is patchy, which is largely dictated by soil conditions (nutrient content, salinity, porosity) and by water availability. In turn, water availability is dictated by water-collecting and water-channeling features, such as soil depressions,



Springbok grazing on patchy grasses of the arid Kalahari Desert

Source: J. S. Lalley, 2008.

rock crevices, or certain soil types with greater water-holding capacity. Patch dynamic theory was developed to explain this phenomenon.

Given the extreme temperatures commonly found in arid deserts, much of the animal life seeks refuge in burrows and/or is nocturnal. Reptiles and insects are usually the most diverse group of animals in arid deserts, while mammal life is less diverse and typically characterized by rodents and small carnivores (see chameleon photo). Exceptions are found in the large antelope inhabiting the Gobi and Arabian deserts, and many charismatic large mammals in Africa's Kalahari Desert (e.g., zebras, giraffes, lions). The birdlife of arid deserts is often found in the form of ground-dwelling birds and small, insect-eating birds. Bright coloration is rare.

Location of Arid Deserts

Temperate Arid Deserts

Asia: Gobi Desert, Ordos Desert, Tengger Desert

Middle East: Karakum Desert, Taklimakan Desert, Caspian Lowland Desert, Central Iranian Plateau, Syrian Desert

North America: Great Basin, Colorado Plateau

South America: Patagonian Desert and Monte Desert

Tropical Arid Deserts

Africa: Kalahari Desert, Karoo Desert, peripheral zones of the Sahara Desert

Asia: Thar Desert

Middle East: Arabian Desert, Judean Desert

North America: Chihuahuan Desert, Sonoran Desert, Mojave Desert

Australia: Great Sandy Desert, Tanami Desert, Simpson Desert, Great Victorian Desert, and Gibson Desert

Hyperarid Deserts

Hyperarid deserts of the world have long been misinterpreted as desert wastelands, devoid of conspicuous vegetation, typically covered to some degree by sand dunes, and usually lacking any surface water or easily accessed ground water.



A desert-adapted chameleon

Source: J. S. Lalley, 2005.

They are the deserts most frequently pictured as typical deserts, with wind-swept sand dunes and barren gravel plains (see sand dunes photo). They cover only 8% of Earth's surface and are sparsely populated by humans, yet most people are familiar with images of these intriguing "wastelands." Because of their low human population, hyperarid deserts of the world are the most pristine of all deserts. Where human activities have ensued, these deserts are highly vulnerable to change: A single vehicle track across a hyperarid desert can last several hundred years.

Flora and Fauna of Hyperarid Deserts

Hyperarid deserts are known for having high rates of endemism among their flora and fauna, meaning the species occur in that desert and nowhere else on earth. For example, Southern Africa's hyperarid Namib Desert has an astonishing diversity of wildlife with a third of its vertebrates being endemic. The old age of all the deserts in this region have led to a high diversity

of species, but it is the long isolation of the Namib Desert that has led to its highly endemic fauna.

The vegetation of hyperarid deserts includes scarce outcrops of succulents and cacti—as in arid deserts, these outcrops are dictated by soil characteristics and water availability. Microflora, such as algae and lichens, can be found in great abundance on soil surfaces, filling in a niche usually dominated by grass in less arid environments. These species can survive by absorbing atmospheric sources of moisture such as dew (or fog in coastal deserts).

Dew, fog, and water from vegetation and prey are the key sources of moisture exploited by the animal life of hyperarid deserts. Reptiles and insects are known to bask in fog, allowing moisture to condense on their bodies for later ingestion. They will also strategically sit on or under plants and allow leaves to collect the moisture for them. As in arid deserts, mammals inhabiting hyperarid deserts are typically nocturnal and small in size. However, there are many notable exceptions such as the large antelope (oryx) found in the hyperarid Namib Desert and Arabian Desert or the elegant gazelles of the Persian Desert.

Location of Hyperarid Deserts

Temperate Hyperarid Deserts

Asia: parts of the Gobi Desert, Ala-Shan Desert, Tsaidam Desert

Middle East: Syrian Desert (southeast)

Tropical/Subtropical Hyperarid Deserts

Africa: Central Sahara Desert, Namib Desert

Middle East: Arabian Desert, Southern Iranian Plateau, Negev Desert

North America: parts of the Mojave and Sonoran Deserts

South America: Atacama Desert, Sechura Desert, Guajira Desert

Jennifer S. Lalley

See also **Biome: Tropical Savanna; Biome: Tropical Scrub; Climate: Dry; Desertification; Desert Varnish; Environmental Management: Drylands; Xeriscaping**



Sand dunes in a hyperarid desert

Source: J. S. Lalley, 2009.

Further Readings

- Laity, J. (2008). *Deserts and desert environments*. Oxford, UK: Wiley-Blackwell.
- Mares, M. (1999). *Encyclopedia of deserts*. Norman: University of Oklahoma Press.
- Meigs, P. (1953). World distributions of arid and semi-arid homoclimates (Arid Zone Research No. 1). In *Arid zone hydrology* (pp. 203–209). Paris: United Nations Educational, Scientific and Cultural Organization.
- Middleton, N., & Thomas, D. (1997). *World atlas of desertification*. London: Arnold.
- Whitford, W. (2002). *Ecology of desert systems*. London: Academic Press.
- World Resources Institute. (2002). *Drylands, people, and ecosystem goods and services: A web-based geospatial analysis*. Washington, DC: Author. Retrieved November 2, 2009, from www.wri.org/publication/drylands-people-and-ecosystem-goods-and-services-web-based-geospatial-analysis



BIOME: MIDLATITUDE DECIDUOUS FOREST

Deciduous forests can be classified into two distinct biomes: (1) the deciduous midlatitude biome and (2) the tropical deciduous biome. Although in both biomes the trees lose their leaves during a dormant season, tropical deciduous trees experience dry conditions and subsequent leaf loss while deciduous midlatitude trees lose their leaves because of the cold season. The deciduous midlatitude forest is anything but homogeneous. Flora and fauna, soil types, and climate differ along a latitudinal and/or an east-west gradient. Tree genera are very similar between the European, North American, and Asian deciduous, midlatitude forests but diversity varies. Disturbances are a vital part of this biome.

Structure and Composition

Extending throughout the Eastern United States, much of Europe, parts of Eastern Asia, Southern



South America, Eastern Australia, and New Zealand, the deciduous midlatitude biome is characterized by broad-leaf trees that undergo a dormant season due to low temperatures. North American, European, and Asian deciduous midlatitude forests are similar in structure and composition, although diversity in European deciduous forests is much lower compared with its American counterpart. The difference in diversity is mainly due to the position of mountain ranges in Europe and North America and glacial advances on both continents. Mountain ranges run north to south in North America and east to west in Europe. Mile-high glaciers advanced south during the last glacial maximum, displacing the deciduous tree species in North America and Europe. Trees were able to migrate south in North America but the deciduous tree species in Europe encountered a barrier. Many deciduous species went extinct in Europe, resulting in lower diversity.

Considering the forest composition, the genera of deciduous trees in the different forests of North America, Europe, and Asia are, in general, the same with some combination of maple (*Acer* spp.), chestnut (*Castanea* spp.), beech (*Fagus* spp.), ash (*Fraxinus* spp.), oak (*Quercus* spp.), basswood (*Tilia* spp.), and elm (*Ulmus* spp.), among others present in different forests. Some evergreen trees, such as pine (*Pinus* spp.) and hemlock (*Tsuga* spp.), and evergreen shrubs, such as holly (*Ilex* spp.), are also present in the deciduous midlatitude forest.

In addition to the similarity in the forest composition, the structure in deciduous midlatitude forests of North America, Europe, and Asia is also similar. In general, four layers exist in these forests. Mature canopy trees (20 to 30 m [meters] tall) dominate the overstory. Subcanopy trees are not as tall as mature canopy trees but still receive direct sunlight at the top of the tree's canopy. Subcanopy trees usually fill a gap produced by a dead canopy tree and will eventually grow to become part of the mature canopy trees. Understory trees only receive minimal sunlight through the canopy and consist mainly of shade-tolerant saplings. Finally, the ground layer consists of tree seedlings and shrubs, ferns, and herbs.

Several animals are associated with the eastern deciduous forest in North America, among them

mammals such as the white-tailed deer (*Odocoileus virginianus*), gray squirrel (*Sciurus carolinensis*), American beaver (*Castor canadensis*), and black bear (*Ursus americanus*). Birds in this biome include owls, crows (*Corvus* spp.), hawks, pigeons, and jays among many others. A once very common bird in North America, which became extinct in the late 1800s and early 1900s, is the passenger pigeon (*Ectopistes migratorius*), and before its extinction, it took days for a flock to pass by. Billions of passenger pigeons existed when European settlers came to North America. However, due to overexploitation by hunting and loss of habitat, their numbers declined. Because the passenger pigeon is a social creature that requires large flocks to live, it did not survive. Today, the most prominent animal in the eastern deciduous forest in North America is probably the white-tailed deer. Brought to very low numbers in the early 1900s due to hunting pressures and habitat destruction, the population rebounded to pre-European levels, exceeding those numbers by several million today.

Climate, Soil, and Light Availability

Mean annual temperature and average annual precipitation have a wide range in the deciduous, midlatitude forest, with a mean annual temperature between 5 °C and 20 °C and the average annual precipitation ranging between 50 and 250 cm (centimeters). Mean January temperatures can vary from less than -10 °C in, for example, in northeastern North America to above freezing temperatures in the southeastern United States. Most of these differences relate to the latitudinal gradient in the Eastern United States. Therefore, the plant and animal distribution in the Eastern United States deciduous midlatitude forest is heterogeneous, and, in general, nine different associations can be distinguished. An association is a forest region that is often named after its most dominant tree species. For example, the maple-basswood association in southeastern Minnesota and southwestern Wisconsin is dominated by maple and basswood.

Soils also vary with latitudinal gradient. However, major soil types in the deciduous,



midlatitude biome are alfisols and ultisols. Alfisols are sometimes described as the soil type of the deciduous forest because the soil depends on the leaf litter of the broad-leaf trees. This soil is relatively fertile and important for agricultural purposes. Alfisols are usually found in cooler regions, such as the northern part of the deciduous forest in Eastern North America. Ultisols, on the other hand, are found in warmer regions, such as the southeastern United States and southeastern Asia. Ultisols are well leached and therefore have relatively low fertility. However, they can support relatively productive forests. Because the plants in areas where ultisols predominate receive their nutrients from organic matter and not the soil itself, the fertility of these soils depends on the biological recycling system, that is, the nutrient cycle.

Compared with the tropical rain forest, where about 2% of the light that is intercepted at the top of the canopy reaches the forest floor, the deciduous midlatitude forest floor receives approximately 10% during the summer and 70% during the winter. During summer, the understory can be dense with seedlings, herbs, and ferns in these forests. Nevertheless, the understory receives less light than the overstory, and trees have adapted to this discrepancy. For example, leaves on the same tree can be quite different based on their position on the tree. Leaves in the canopy (sun leaves) are thicker, have less chlorophyll, and are smaller in area compared with so-called shade leaves that can be found lower on the trunk of the tree. One reason for this is the fact that a smaller surface area in sun leaves helps reduce water loss. At low light levels, shade leaves are often more efficient at photosynthesizing, whereas at high light levels, the sun leaves are more efficient.

Another way that trees have adapted to the discrepancy between light levels in the overstory and understory is with shade tolerance. Tree species differ based on their tolerance or intolerance of shade. Maples, for example, are very shade tolerant, that is, they can germinate and survive in the shade. Oaks are more intermediate in shade tolerance, that is, they need medium light levels to germinate and survive in the understory. Birches are on the other end of the spectrum and need

high light levels to thrive. This characteristic is also indicative of the successional stage of the forest. For example, a forest that has mainly shade-intolerant species probably just experienced a major disturbance such as a crown fire. Crown fires kill all trees, open up space, and free nutrients for new plant growth to become established. For a variety of reasons, usually shade-intolerant species become established. However, those species cannot grow under their own canopy and shade-tolerant species will germinate. If there is no other major disturbance, the shade-intolerant species will senesce and eventually fall over, creating a canopy gap into which an existing shade-tolerant tree species will grow, and gradually replace the shade-intolerant canopy.

If it was not for the dormant season, the productivity of deciduous midlatitude biome could be the highest compared with other biomes. During summer, productivity is higher in the deciduous forest than in any other biome, including the rain forest because days are longer. Photosynthesis, however, does not occur when temperatures are too cold. Trees and shrubs become dormant by losing their leaves. Before losing their leaves, the hardwood trees in northeastern North America experience the so-called Indian summer where the leaves show spectacular fall colors ranging from red to yellow. The reason for this color change in the leaves is the loss of the green chlorophyll, which masks the red and yellow pigments that are already in the leaves. With the loss of chlorophyll, those pigments become visible. If they did not lose their leaves, the soft tissue that is exposed would be damaged by the freezing conditions. Timing of leaf loss and leafing out varies between species and by year. However, the process of leafing out in one stand or forest happens in about the same time frame of 2 to 4 weeks every year. The same is true for the timing of losing leaves. After losing their leaves, most trees in the deciduous midlatitude forest require a chilling period, that is, a certain amount of time of freezing temperatures, before trees leaf out again. This ensures that trees only leaf out after winter is over. For example, sugar maples (*Acer saccharum*) in northern parts of North America require approximately 100 consecutive days of chilling temperature for buds to form.



Disturbances

Disturbances are a major part of the deciduous midlatitude forest. Commonly, 5% to 10% of a forest is influenced by natural disturbances and mortality. Those disturbances usually result in canopy gaps. Natural disturbances, such as fire, windthrow, insects, and pathogens, and human-induced disturbances, such as invasive species, logging, and forest clearing, shape forest ecosystems with regard to structure, composition, and functional processes. Of the primary (deciduous) forest, that is, forests that have not been altered by humans, which existed in the Eastern United States before European settlement, 99% has been cut or otherwise been altered during the past 150 yrs. (years). Often also named old-growth forest when no major disturbance has killed the canopy trees in recent centuries, primary forest is very rare in deciduous forests around the world.

Although most of the deciduous forest in the Eastern United States has been cleared for agriculture or logged, some of the resultant agricultural land has been found to have only marginal economic value. The eastern deciduous forest in the United States was decimated by the coming front of people clearing land for agriculture. By 1850, approximately 50 million hectares had been cleared and converted to agriculture. That trend reversed in the 20th century when many farms converted back to forest because they were abandoned, resulting in an increase in forested land in the contiguous United States in the past 100 yrs. In addition, primary forests cleared for their wood have been replaced by second-growth forest. This second-growth forest is structurally very different from the primary forest as species and structural diversity are much lower than in the primary forest.

Natural and human-induced disturbances have different effects on forest structure, composition, and functional processes. An example of a human-induced disturbance was the introduction of the fungus chestnut blight (*Cryphonectria parasitica*) to the United States with the arrival of chestnut lumber or trees in the early 1900s. The American chestnut was one of the most dominant trees in Eastern North America, but the blight eliminated all mature American chestnut

(*Castanea dentate*) trees in the Eastern United States within 30 to 40 yrs. Today, only small American chestnut seedlings and saplings exist in the understory but are killed before they mature. This blight was introduced from Eurasia, where trees have resistance to this fungus because they evolved with it.

A native pathogen or insect, on the other hand, does not usually kill its host species completely. Host trees might die in an insect outbreak, for example, the spruce budworm, which defoliates balsam fir (*Abies balsamea*) and spruce (*Picea* spp.) in the boreal forest. However, this defoliation is a way for the forest to rejuvenate. While older, mature trees are killed, younger and smaller trees survive and repopulate the forest after the outbreak. The forest tent caterpillar (*Malacosoma disstria*) is a native insect that defoliates deciduous trees in Eastern North America. However, here the insect does not necessarily kill the trees in an outbreak but reduces growth significantly. The trees usually recover after an outbreak. This is probably the case because the trees have had a chance to adapt to the insect by process of evolution.

Julia Raichfuss

See also **Agroforestry; Biogeography; Biome: Boreal Forest; Biome: Tropical Deciduous Forest; Deforestation; Forest Fragmentation; Forest Land Use; Forest Restoration; Invasion and Succession; Nutrient Cycles; Social Forestry; Soils; Sustainable Forestry**

Further Readings

- Archibold, O. (1995). *Ecology of world vegetation*. New York: Chapman & Hall.
- Braun, E. (1950). *Deciduous forests of Eastern North America*. Philadelphia: Blakiston.
- Kricher, J., & Morrison, G. (1998). *A field guide to eastern forests: North America*. Boston: Houghton Mifflin.
- MacDonald, G. (2003). *Biogeography: Space, time and life*. New York: Wiley.
- Yahner, R. (2000). *Eastern deciduous forest: Ecology and wildlife conservation*. Minneapolis: University of Minnesota Press.



BIOME: MIDLATITUDE GRASSLAND

The midlatitude grasslands are not easily defined. Most grasslands are areas of low relief and low rainfall, the combination of which protects them by reducing erosion disturbances that allows rapid invasion by trees and shrubs. Much of the former grasslands in higher-rainfall regions were removed by cultivation. The midlatitude grasslands lie mostly between 25° and 50° of latitude in both hemispheres. The grass species of the midlatitude grasslands come from rich sources both in the tropics and high latitudes. The species did not arrive together and many grasslands have been in place for thousands to millions of years. New grass species invade along disturbance corridors, such as valley walls or bottoms. The dominant grass species use a variety of seed dispersal mechanisms. Some are adapted to transport by wind, while others move in the digestive tracts of animals or adhere to the hides of animals. This entry will discuss the nature of the midlatitude grasslands, the grasses of these regions, human interactions with and maintenance of grasses, and animals that use the grasslands.

At the global scale, scant and uneven data limit our descriptions to higher-taxonomic levels, such as tribes. Available data do not permit examination of taxa by abundance. We can compensate for this deficiency to some degree by looking at the diversity or dominance of some taxa in the total grass flora of different regions. The most widely available data are species lists for various areas of the world. Hartley and colleagues have done this for the seven taxonomic groups that contain more than 75% of the global taxonomic diversity of grasses. These most important tribes are divided into two distinct photosynthetic types that evolved as adaptations to distinctly different environments. *Agrostae*, *Aveneae*, *Festuca*, and the largest genera, *Poa*, comprise C_3 species. This photosynthetic pathway, common in other plants, is adapted to high-atmospheric carbon dioxide and cool summer temperatures. For these grasses, production declines above 20 °C (68 °F). They have migrated to the midlatitudes from higher latitudes in both hemispheres. They also dominate in areas of wet winters and dry summers. This

seasonal adaptation allows these grasses to complete their growth cycle before the summer heat limits production. Domesticated species from this group include rice (*Oryza* spp.), wheat (*Triticum* spp.), oats (*Avena sativa*), barley (*Hordeum* spp.), and rye (*Secale cereale*). These and other domesticated grasses have larger seeds that are presented high on the plant and, therefore, easily harvested and handled than plants with seeds that are small designed for transport by the wind.

A later evolution, the C_4 (warm season) photosynthesis grasses, adapted to higher temperatures and lower carbon dioxide, such as occurred during glacial maxima, by enriching the CO_2 taken in the stomata and feeding it to a deeper C_3 tissue layer. Production declines for these grasses above 35 °C (95 °F). *Eragrostae* (now regrouped with *Chloridoideae*), *Paniceae*, and *Andropogoneae* are dominated by species that use C_4 photosynthesis, although a few of the *Paniceae* are C_3 species. The highest species diversity of these grasses is found within 30° latitude of the equator. Figure 1 illustrates the dependence of the midlatitudes on the adjacent tropical and high-latitude source areas for the species that migrated into midlatitude grasslands. Domesticated species from this group include corn (maize; *Zea mays*) and sorghum (*Sorghum bicolor*).

The Grasses

While extant grasslands are a good place to find some grass species, they are often not the places of greatest species diversity. Of the more than 9,000 grass species known worldwide, only about 1,400 occur in the United States. Fewer than 400 of those are known to grow somewhere in the Midcontinent Plains grasslands. Ten percent of these 400 species account for more than 99% of the grass biomass in the American Plains. Biomass of the 41st-ranked species is less than half of 1% that of the most abundant *Andropogon gerardii*.

Many of the higher-taxonomic groups of grasses are not well represented in the American Plains flora. In the *Poeae* tribe, only 18 of the 500 species known worldwide (3.6%) are documented in the Plains. Only two of those (*Poa pratensis* and *Puccinellia nuttalliana*) rank among the top 41 Plains grasses. Seventeen species of the vast *Chloridoideae* subfamily are



Figure 1 Dominance of photosynthetic grass types. The grass species of the midlatitude grasslands comes from areas of species richness in the high latitudes and the tropics.

Sources: Map created by author from data in Hartley, W. (1950). Studies on the origin, evolution and distribution of the Gramineae. *Australian Journal of Agricultural Research*, 1, 355–373; Hartley, W., & Slater, C. (1960). Studies on the origin, evolution and distribution of the Gramineae III: The tribes of the subfamily Eragrostoideae. *Australian Journal of Botany*, 8(3), 256–276.

represented in the Plains. The *Andropogoneae* and *Panicaceae* tribes are represented by 6 and 5 species, respectively, in the top 41 Plains grasses. Of the 63 worldwide genera in the *Aveneae* tribe, only one species is known in the Plains, and it ranks among the top 41. Of the top 41 Plains grasses, five each are from the *Titiceae* and *Stipeae* tribes. Data are not available to show the worldwide affinities of 10 of the top 41 Plains grass species.

The dominance patterns of a grass genus, tribe, or subfamily are reflected in the species abundance patterns in the American Plains. For example, the species of the *Chloridoideae* tribe are concentrated in the Southwestern Plains. In contrast, *Panicaceae* tribe species are more abundant in the Southeastern Plains.

The broad geographic pattern of *Andropogoneae* dominance suggests a tropical Asian origin with a connection to North America through tropical Africa and South America. Six of the top 41 Midcontinent Plains grasses (big, little, and silver bluestem, cane beardgrass, eastern gamagrass, and Indian grass) are members of the *Andropogoneae* tribe, and the abundance of these species are all higher in the southeastern Plains.

Other genera dominate coastal grasslands, but species vary with salinity. The *Spinifex* of Australia, a wide variety of coastal species in South Africa, and *Spartina* in North America are all C₄ grasses. Bamboos (*Bambusa*) and related species of *Phragmites* and *Arundinaria* are C₃ grasses and are important components



of some coastal grasslands. Coastal grasslands are seriously threatened by development and potential rise in sea level.

Many of the world's grasslands are of considerable antiquity. We do know that members of the *Stipeae* tribe have a long presence in the American Plains, dating back to 10 million years ago. Most of these are related to living forms that are more common in Central and South America, such as *Piptochaetium*, *Stipa*, and *Nassella*. Of these fossil genera, there are 40 species known in the United States. Twenty-five are found in the Plains, and 4 are among the top 41 grasses.

Human Interactions and Maintenance

Most of our food comes from a few grasses that were domesticated in the Eastern Hemisphere: rice, wheat, oats, barley, and rye. Sorghum was domesticated in either India or Africa. Corn (maize) stands virtually alone as an American grass domesticated for human nutrition. Wild rice (*Zizania aquatica*) that has long been harvested from natural stands now joins corn as a New World domesticated grain crop. These grasses directly and indirectly feed human populations. Most animals grown for meat, fiber, and dairy products are a product of domestic and nondomestic grasses that support huge grazing economies throughout the world.

Grasses are also used directly as fiber for baskets or furniture, as structural elements or thatching for dwellings, and as covering for animal sunshades. Most notable of the construction grasses are the bamboos, *Arundinaria* sp., *Phyllostachys* sp., *Bambusa* sp., and *Dendrocalamus* sp. Only giant cane (*Arundinaria gigantea*) is native to the North American mid-latitudes and has been used for fishing poles, pipe stems, and baskets. This very tall grass can achieve a diameter of 5 centimeters and probably was important in constructing Native American lodges. Its range, however, did not extend west of the forest regions of the country. Common reed (*Phragmites australis*) is more widespread and found throughout the Plains in wet areas. It grows as tall as 4 m and has been used as lattice in adobe construction, as arrow shafts, and as

fiber for mats, screens, thatching, cordage, and carrying nets.

In recent decades, interest in grasslands has focused on animal habitat, recreation, and environmental esthetics, including a momentary cure for claustrophobia. However, attention is often focused toward the sky, flowers, people, and their architecture. Infrequently, attention to grasslands focuses on the dominant or formerly dominant plant family. In short, grasses do a lot for humans, but you must work hard to appreciate them.

Soils developed under long periods of grassland cover are nutrient rich. While the low-relief terrain protects grasslands from erosion disturbances that facilitate woody species invasion, it facilitates the greatest threat to grassland persistence, the agricultural implements that take advantage of the rich soil to grow crops with requirements similar to those of native grasses. Overgrazing damage to grasslands is accentuated during droughts that limit forage for grazers. Early season grazing also harms some species. Dominant species are very tolerant of fire, which limits the invasion of many woody plant species, but overgrazing can compound the effects of fire. Many areas of grasslands no longer have weather patterns that support reestablishment of the current dominant species; therefore conservation is the only way to ensure their continued existence.

Animals That Use the Grasslands

Ruminant animals (those with four stomachs) are the most visible and characteristic animals that evolved in the grasslands. They include rhinoceros, camels, bison, gazelles, sheep, goats, antelope, and giraffes. These are joined by nonruminant horses, asses, elephants, and zebras. These animals have the ability to digest large amounts of roughage and travel long distances to water. Most will also browse shrubs and trees.

Dwight A. Brown

See also **Biogeography**; **Climate: Midlatitude, Mild**; **Climate: Midlatitude, Severe**; **Prairie Restoration**; **Prairies**



Further Readings

- Barkley, T. (Ed.). (1977). *Atlas of the flora of the Great Plains*. Ames: Iowa State University Press.
- Brown, D., & Brown, K. (1996). Disturbance plays key role in distribution of plant species. *Restoration & Management Notes*, 14(2), 140–147.
- Hartley, W. (1950). Studies on the origin, evolution and distribution of the Gramineae. *Australian Journal of Botany*, 8(3), 256–276.
- Hartley, W., & Slater, C. (1960). Studies on the origin, evolution and distribution of the Gramineae: III: The tribes of the subfamily Eragrostoideae. *Australian Journal of Agricultural Research*, 1, 355–373.
- Hitchcock, A., & Chase, A. (1950). *Manual of the grasses of the United States* (2nd ed., U.S. Department of Agriculture Miscellaneous Publication No. 200). Washington, DC: USDA.



BIOME: TROPICAL DECIDUOUS FOREST

Tropical deciduous forest is a major vegetation type that occurs in association with seasonally wet and dry or monsoon climates. These forests vary significantly in their composition and structure in relation to their geographic location in the tropical realm, rainfall and soil conditions, and history of disturbances. The transition from evergreen to deciduous forests is gradual in response to the occurrence of a water deficit, the length of the dry season, and the amount of rain received during the rainy season. Tropical deciduous forest, in contrast to tropical rain forest, includes trees that lose their leaves synchronously and remain without leaves for varying amounts of time. In contrast to tropical savanna, tropical deciduous forests maintain a greater dominance by trees (>50%) across the landscape.

Generalized attributes of tropical deciduous forests include a closed to open tree canopy that may be tall (>20 m [meters]) with a single trunk or low in stature (<10 m) with a coppiced trunk that produces multiple stems close to the ground surface. Leaves are broad but often smaller and

thicker than those typical of tropical rain forest, and the forest type varies greatly in the adaptations these trees have to the seasonal climatic conditions. Semievergreen forests have a high forest canopy with deciduous trees that remain dormant for a short period of time and an understory that remains evergreen (see the first photo). These forests can support a high diversity of lianas and understory vegetation. Dry deciduous forests occur as low (<8 m) closed-to-open woodland with trees that lose their leaves and remain dormant during long dry seasons of 3 to 6 mos. (months; see the second photo). Evergreen tropical rain forest can maintain itself only if the drought period is very short, 1 to 2.5 mos., and rainfall is very high, 2,500 to 3,000 mm (millimeters). Tropical deciduous forest transitions to tropical thorn scrub under conditions of very low rainfall (<500 mm) and a dry season that exceeds 6 to 8 mos.

Tropical deciduous forests occur between approximately 5° and 20° north and south of the equator, and extend into the subtropics where rainfall is distinctly seasonal and there is only a slight chance of frost. Seasonal rainfall patterns coincide with the migration of the sun's direct rays between the tropics of Cancer and Capricorn, bringing precipitation under high sun (summer) conditions. In South and Central America, they are most diverse in Mexico and Bolivia and along the Pacific Coast of Central America, but "dry" forests also occur between the Cerrado savannas and Caatinga dry scrublands of Northeast Brazil, and on Caribbean islands where mountains (e.g., the Blue Mountains in Jamaica) or other islands block the receipt of rainfall from the Northeast trades. Seasonal monsoon forests occur in southwest India, Sri Lanka, and Indochina. A small region in Northern Australia is distinctly seasonal with summer rainfall conditions, but evergreen *Eucalyptus* species dominate on that continent and maintain an evergreen forest canopy. Tropical deciduous forests are particularly important as a vegetation type in Africa, where they occur under two wet and dry seasons in equatorial East Africa, under one wet and dry season south of the equator from Tanzania to Southern Africa, and in Western Madagascar. These forests differ in their tree species composition, including the *Acacia-Commiphora* bushland of East Africa, the *Brachystegia*-dominated



Semievergreen forest along the Tana River, Kenya

Source: K. E. Medley.

miombo woodlands of Tanzania and south-central Africa, and the mopane (*Colophospermum mopane*) woodlands of South Africa. Whereas one species of baobab (*Adansonia digitata*) occurs in tropical deciduous forest on the continent of Africa, at least seven species are recorded in the dry forests of Western Madagascar (the third photo). Tree genera with very broad geographic ranges show high diversity in different woodland types.

Seasonal rainfall supports tree growth when it can infiltrate and be stored deep in the soil profile. Trees lose their leaves to conserve water during the long dry seasons, but the storage of water at depth supports the onset of flowering and leaf production during high temperatures that precede the onset of rains. Soil conditions, therefore, are also important to the development and structure of tropical deciduous forest. Where an impermeable soil layer prevents infiltration, tropical savanna grasslands predominate, such as the llanos of Venezuela. Moreover, the trees that occur

in tropical deciduous forest vary distinctly between highly weathered deep lateritic soils and those locations where clays (i.e., black cotton soils) occur. In East Africa, tropical deciduous forest (bushland) occurs as a diverse mosaic of different plant communities in relation to the distribution of these soils. In Southern Africa, “sour veld” and “sweet veld” distinguish the woodland types on more acidic lateritic soils and more alkaline soils, respectively. Moreover, the structure of tropical deciduous forest may be greatly altered by disturbances. For example, the destruction of trees by elephants in the Tsavo ecosystem of East Africa at least partially explains changes over time in the distribution of woodlands and grasslands. Fire has been shown to maintain miombo woodlands in Tanzania and certainly influences its composition and structure.

Tropical deciduous forest, especially when the biome includes the broad vegetation transition between tropical rain forests and tropical savanna, supports a diverse fauna that show



Tropical deciduous forest in East Africa

Source: K. E. Medley.

unique adaptations to the seasonally wet conditions. Among the large mammals, browsers are most significant, where giraffe rely on the leaves of the canopy trees, and the kudu and gerenuk browse the understory vegetation. Mammal population densities remain low, at least in part because of the lower availability of forage during the dry season and in Africa the continued persistence of tsetse fly. Certain bird species are particularly adapted to fruit production in dry forests, such as the diverse population of hornbills that rely on the fruits of *Commiphora* in East Africa. As with the tropical savanna, termites are critical to the redistribution of nutrients and plant establishment.

Tropical deciduous forest occurs in regions that experience a long dry season and typically have poor infertile soils that limit settlement and farming. When human populations expand into these regions, such as on the continent of India and in northeast Brazil, forest cover is quickly degraded to a grass or scrubland and production is typically unsustainable. Pastoral activities, particularly for

cattle or goats, can be sustained under low population densities, but the distribution of the tsetse fly in Africa also occurs in this region thereby limiting human activities. Tropical deciduous forests, particularly in Africa, provide a major source of fuel wood and charcoal. Tree coppicing can sustain much extraction, but when trees are cut at the base, regeneration is not possible and the composition and structure of the forest will change. The construction of roads facilitates access to woodland regions, supporting an export market for charcoal that significantly affects woodland conservation. Some of the most important tropical trees for timber are extracted from tropical deciduous or semievergreen forest, such as mahogany (*Swietenia Mahogani*) in South America and teak (*Tectona grandis*) in southeast Asia. Valuable timber and nontimber resources support the importance of establishing sustainable management practices for this regionally diverse tropical biome.

Tropical deciduous (dry) forests currently occupy about 1% of the land surface, but the



Adansonia (baobab) species in the tropical deciduous forests of Western Madagascar

Source: K. E. Medley.

relationship between the actual and potential distribution of this vegetation type remains unclear. Dense forest areas occur in South America and on the Yucatan peninsula of Mexico, but globally its distribution is very fragmented, often occurring as a mosaic with tropical savanna and degraded lands cleared by human activities. Fires can be employed to expand grazing lands with a direct impact on the distribution of forest, just as heavy extraction of fuel wood or charcoal production can degrade the structure of existing woodlands. The degree to which projected climate changes in seasonal rainfall regimes might influence the persistence of closed forest cover forms a special scientific concern especially in Central and South America. Tropical deciduous forest is among the most threatened biomes because of its small and fragmented distribution and the complex influences that both “natural” and “human” disturbances have on its potential distribution.

Kimberly E. Medley and
Christine Mango Mutiti

See also **Agroforestry; Biogeography; Biome: Tropical Rain Forest; Biome: Tropical Savanna; Biome: Tropical Scrub; Deforestation; Forest Degradation; Forest Fragmentation; Forest Land Use; Forest Restoration; Nomadic Herding; Social Forestry; Sustainable Forestry**

Further Readings

- Miles, L., Newton, A., DeFries, R., Ravilious, C., May, I., Blyth, S., et al. (2006). A global overview of the conservation status of tropical dry forests. *Journal of Biogeography*, 33, 491–505.
- Rodgers, W. (1996). The miombo woodlands. In T. R. McClanahan & T. P. Young (Eds.), *East African ecosystems and their conservation* (pp. 299–325). New York: Oxford University Press.
- Walter, H. (1971). *Ecology of tropical and subtropical vegetation*. Edinburgh, UK: Oliver & Boyd.



BIOME: TROPICAL RAIN FOREST

The plant geographer A. F. W. Schimper first used the term *tropical rain forest* in 1898 to characterize the broad-leaved evergreen trees that dominate the wet equatorial regions of the world. Under tropical wet conditions, a structurally diverse forest occurs that is typically high stature, closed canopy, species rich, structurally diverse, and unique in the adaptations that different plants and animals have to the environmental conditions. Rain forest can be described by these general attributes and also by the unique conditions that occur across continents and within continents along environmental gradients.

The Physical Environment

The potential geographic distribution of tropical rain forest is pantropical within the equatorial latitudes of 10° N and 10° S. These forests occur on the continents of South America, Africa, and Asia, and extend into the subtropical realm in Eastern Central America and the Caribbean, southwestern India and Sri Lanka, and Northern Australia. Day lengths hardly change from 12 hours during the spring and fall equinox, noon sun angles are always high, and the sun rises and falls quickly in the horizon. Temperature conditions are always warm, above 18 °C, and warm moist equatorial air rises to support daily convective showers and constantly moist conditions. Tropical rain forests experience no frost; daily temperature differences show greater ranges than the monthly means. Monthly precipitation always exceeds water needs (potential evapotranspiration) and can average more than 100 mm (millimeters) per month or an excess of moisture. Rainfall averages 2,000 to 3,000 mm in South America, 1,500 to 2,500 mm in Africa, and >3,000 mm in southeast Asia.

Tropical rain forests extend beyond the equatorial zone where the periods of moisture deficit are very short and the rainy periods are exceedingly wet, such as those brought by the monsoons to southwest India, southeast Asia, and West Africa, and those brought by the northeast and southeast trade winds to Central America,

the Eastern Caribbean, the South Pacific, and Australia. Moisture deficits, however, will eventually limit broad-leaved evergreen trees and transition tropical forests toward dominance by trees that are semievergreen or deciduous during the dry season. Tropical rain forests and tropical deciduous forests capture the broad diversity of forest types that occur across the tropical realm where temperatures are constantly warm and suitable for plant growth.

Biogeographical Patterns of Diversity

Plant and animal occurrences in the tropical rain forests show a relationship with their biogeographical distribution among tropical regions. By far the greatest land area (>50%) and species diversity occurs in the New World tropics, which include South and Central America. Tropical rain forest occurs in the Amazon River basin over a 3,000-km (kilometer) distance from the Andes to the Atlantic, along the Orinoco River in Venezuela, and in north coastal Guyana, Suriname, and French Guiana. The rain forests of the western Andes in Peru and Ecuador are among the wettest in the world, which then extend northeastward along the east coast of Central America and include the northeastern exposed Caribbean islands (e.g., Jamaica, Hispaniola, Puerto Rico, Dominica, and Trinidad). In Africa, tropical rain forests occur in the Congo River basin and along a narrow coastal zone in West Africa. More than 60% of the Democratic Republic of Congo is in rain forest, and some of the most diverse rain forests occur in Eastern Madagascar. In southeast Asia, tropical rain forests straddle the equatorial zone between Indochina, Malaysia, Indonesia, and the Philippines. One of the most famous biogeographical boundaries occurs across Indonesia, Wallace's line, distinguishing the rain forests of southeast Asia from Australia and New Guinea along a plate boundary that merged about 50 million years ago (mya). Moreover, the isolated distribution of the Atlantic forest from Recife to São Paulo in Brazil and the coastal and Eastern Arc forests of East Africa suggest a historically broader distribution of rain forests across these continents.

Tropical rain forests are among the most biologically diverse vegetation types on Earth, and

there are both historical and ecological explanations for their patterns of diversity. Broad-leaved evergreen trees arose in the early Tertiary period more than 70 mya and experienced geographic shifts in their distribution and periods of diversification and extinction over time. For example, tropical forests expanded northward during the Eocene (about 50 mya) into North America, and expanded and contracted significantly on the South American and African continents during interglacial and glacial periods, respectively. Woody plants and some of the most primitive woody plant groups (*Magnioles* and *Laurales*) are especially diverse in the tropics. Historical climatic changes at least partially explain the high species diversity of the New World tropics, lower diversity on the continent of Africa, and the occurrences of unique biological attributes among the regions. Smaller high-canopy primates with tails in the New World, larger primates without tails and with an opposable thumb in Africa, the very primitive lemurs of Madagascar, and the persistence of some very old plant species in the more equable climate of southeast Asia are just some examples.

Ecological Structure, Function, and Dynamics

Biological diversity also corresponds with the high vertical complexity of the forests. Tropical rain forest typically maintains five structural layers: (1) an open emergent layer at >50 m (meters) of very tall tropical trees with broad and flattened crowns exposed to open sunlight, (2) an open to closed canopy layer of large trees at about 30 m, (3) an open subcanopy tree layer, (4) an open sapling and shrub layer, (5) and a very infrequent herb layer. Dense undergrowth or more “jungle” conditions only occur in open disturbances such as forest edges and within tree-fall gaps. High sun angles contribute to the vertical complexity of the structural layers, providing sunlight at different levels for lianas (woody vines), epiphytes that germinate and grow on the surfaces of trees, and hemiepiphytes that first germinate in tree crevasses but then extend stems to root in the ground and often strangle their host plants for structural support. Canopy and emergent trees



Tall emergent trees in tropical rain forests often have buttressed trunks to maintain stability.

Source: Author.

show different shade tolerances, influencing their ability to establish and recruit to the canopy in tree-fall gaps that vary in their size and the amount of light available through the opening.

Competition for light, nutrients, and reproduction dictate the special adaptations and growth forms of the plants. For example, large tropical trees often have buttresses at the base of their trunks, which keep trees stable while maintaining shallow root systems that can acquire nutrients when they are released by decomposing leaves. The upper canopy of tropical rain forests can be exceedingly diverse where trees, lianas, and epiphytes compete for available light. More than 90% of all lianas occur in tropical wet environments where they can be as diverse as the trees. Large flowers, cauliflory where flowers germinate



Smooth leaves with drip tips and cauliflory, the production of flowers on the main stems, are just some of the special adaptations of tropical rain forest plants.

Source: Author.

on the main stems of understory trees, and large fleshy fruits best ensure specialized pollinators and dispersal mechanisms. Large entire leaves and very shade-tolerant herbs maintain productivity at low light levels in the forest understory. Light intensities can be as low as 0.1% to 0.5% at the forest floor. Drip tips on the leaves shed excess moisture. None of these plants need to become dormant in the continually warm and wet conditions for growth, and often demonstrate red nodding leaf shoots when the formation of supporting tissue and chlorophyll lag behind during rapid shoot elongation. These specialized adaptations restrict habitat preferences and allow for high species packing in small areas. For example, tree diversity can be as high as 300 species measured in a 1-ha (hectare) plot in the Western Andes and almost always is above 40 tree species in 1-ha plots. While tropical rain forests are well known to have the highest diversity of growth forms for different kinds of plants, trees typically account for more than 60% of the plant diversity.

High primary production and plant diversity in the tropical rain forest provides resources to support a high faunal diversity. Invertebrates that feed on litter and contribute to the very high rates of decomposition and rapid release of nutrients make up about 60% of the animal biomass. Less

than 20% of the faunal biomass relies on leaves and much less on the fruits and flowers. Tropical plants, especially in lowland environments where faunal diversity is highest, produce secondary compounds that are either toxic or indigestible to animals. The vertical stratification and specialized adaptations of insects, birds, and mammals are critical to the reproduction of plants and their sustained diversity. Many plants rely on a certain insect, bat, or bird to ensure pollination, and the large fruits produced by tropical trees often depend on a certain mammal for dispersal. For example, the production of Brazil nuts can only be successful in closed tropical forest, where the agouti can ensure dispersal and

establishment. The tropical rain forest also maintains interdependencies among animals as a strategy to gain access to limited food resources. For example, ant swarm followers are a group of birds that follow large colonies of army ants and rely on the insects that are stirred up as the ants move through the forest litter.

Equatorial rain forests for the most part coincide with some of the oldest, most weathered landscapes in the world. For example, both the Amazon and Congo rivers flow across the continental shields of South America and Africa, respectively, where ancient rocks form the substrate for vegetation growth. Warm moist conditions promote exceedingly high rates of decomposition and chemical weathering. Upland tropical forests in these regions typically occur in oxisols, which are soils characterized by the mobilization and accumulation of iron and aluminum oxides to form a dense laterite that is exceedingly low in organic matter and nutrients. Soils are covered by a shallow litter layer that rapidly decomposes and releases its nutrients. The depth of weathering in the soil profile can be as high as 20 m. Shallow roots and epiphytic-growth forms acquire nutrients in this environment from stem flow off the trees before the rainwater reaches the soil surface. In contrast, where

younger volcanic soils occur, such as in southeast Asia, nutrient availability can be much higher and support greater productivity.

A Diversity of Plant Community Types

Tropical rain forests, defined by their distribution in tropical wet environments, also show a diversity of forest communities adapted to local physical-environmental conditions. Mangroves dominate estuarine environments across the equatorial tropics where temperatures are always warm. Along the river basins, seasonally flooded forests can occur that are adapted to high water conditions, just as low-lying areas support swamp forests that differ in their composition and stature. Particularly unique are the “heath” forests that develop in large regions of tropical spodosols, such as the *igapo* forests of South America and the *kerangas* of southeast Asia. Tropical spodosols form in coarse-textured sands that are exceedingly low in nutrients and high in organic acids (pH <5.5). These forests are low in stature, have thickened small leaves that are high in tannins, and support many carnivorous plants or symbiotic plant and ant relationships that are specialized to acquire nutrients. For example, the Rio Negro (black water river) flows through these soils and gains a brown color from the tannins in the decomposing forest vegetation.

Tropical rain forest occurs typically at lowland elevations below 900 to 1,200 m, but environmental conditions suitable for forest growth can extend above sea level to around 4,000 m. Along an altitudinal gradient, mean temperature decreases and available moisture increases to create a lower-stature, exceedingly moist montane forest. These “cloud forests” differ in their tree species composition and are covered from the canopy to the ground with epiphytic plants, ferns, mosses, and club mosses that acquire their moisture directly from the atmosphere under continually wet conditions. Other forests of unique composition may be restricted to locations where a different rock type is exposed. For example, *Leptospermum*-dominated forest on Mt. Kinabalu, Sabah, Malaysia, only occurs on ultrabasic soils.



Heath forests, such as the Kerangas in Sabah, Malaysia, occur on nutrient-poor tropical spodosols.

Source: Author.

Human Relations With Tropical Rain Forests

Human relationships with the tropical rain forest are particularly complex in how they vary through time and differ by region in response to local and extra-local forces. Under low-population densities, hunter and gathering societies rely on their indigenous knowledge of biodiversity and how to extract resources to meet their livelihoods. In contrast, agricultural societies typically employ shifting cultivation systems that remove and burn the vegetation to establish crops temporarily in the remaining nutrients. With increasing population densities, the expansion of fields into mature forests and the intensity of production on open lands



Montane cloud forests on the Eastern Arc mountains in Kenya (A) and on Mt. Kinabalu in Sabah, Malaysia (B)

Source: Author.

greatly affects forest area and the potential for forest regeneration. These local forces on forest resources are further intensified by extra-local demands for timber and land resources. Tropical deforestation rates exceed rates of regrowth, with an estimated loss of >50% of the original land area. Moreover, certain regional forces, such as the resettlement of populations and pasture development along the Amazonian highway, fuelwood and charcoal production in Africa, and the international export of high-quality timber from the rain forests of southeast Asia and West Africa intensify local impacts and magnify global deforestation statistics. While the rates of forest clearing declined in recent years, countries such as Brazil, Peru, Democratic Republic of Congo, and Indonesia rank among the top 10 countries with highest rates of deforestation. Unlike temperate

forests, specialized requirements for tree reproduction, small species ranges, and soil infertility predict much higher rates of extinction and degradation with tropical deforestation. Conservation action for tropical rain forest focuses on better understanding the value of species diversity, validating indigenous rights and local participation in conservation plans, and providing global support for reserves that are compatible with national interests for development.

Kimberly E. Medley

See also **Biodiversity; Biogeography; Biome: Tropical Deciduous Forest; Biome: Tropical Savanna; Biome: Tropical Scrub; Biota and Climate; Biota and Soils; Climate: Tropical Humid; Deforestation; Forest Degradation**



Further Readings

- Primack, R., & Corlett, R. (2005). *Tropical rain forests: An ecological and biogeographical comparison*. Malden, MA: Blackwell.
- Richards, P. (1996). *The tropical rain forest: An ecological study* (2nd ed.). Cambridge, UK: Cambridge University Press.
- Terborgh, J. (1992). *Diversity and the tropical rain forest*. New York: Scientific American Library.
- Walter, H. (1971). *Ecology of tropical and subtropical vegetation*. Edinburgh, UK: Oliver & Boyd.



BIOME: TROPICAL SAVANNA

Tropical savanna or savanna is a global vegetation type where grasses are continuous and important but occasionally interrupted by trees and shrubs. The term *savanna* originated as a description of treeless plains in South America but now describes the global distribution of this mixed vegetation type. The type of woody plants and how they are arranged can vary significantly in relation to the grasses, creating a diverse mosaic landscape across regions where tropical savanna occurs and at the local scale within each savanna. These differences sometimes dictate how the vegetation is classified and named, identifying gradients of change from savanna grassland with no trees or shrubs to parklands or woodlands with a greater abundance of trees, and to thickets and scrub with an absence of trees. Tropical savanna for the most part overlaps geographically, particularly in Africa, with the distribution of tropical deciduous forest and tropical scrub (see tropical savanna photo).

Biogeographical Patterns of Diversity

Tropical savanna is one of the largest global vegetation types (biomes), potentially occurring over about 20% of the land surface in the tropics and subtropics between 30° north and south of the equator in South America, Africa, South Asia, and Australia. Major savannas are mapped in South America, where densely wooded grasslands dominate in the “cerrados” of northeastern Brazil, the grass-dominated “campo” in southeast Brazil, and

the “llanos del Orinoco” in Venezuela. In Africa, tropical savanna is most extensive, predominating across a broadband between the west-central equatorial tropical rain forest to the Sahara Desert in the north and Kalahari Desert in the south, continuing across plains in equatorial East Africa, and dominating much of the landscape in Western Madagascar. When mapped with the distribution of tropical deciduous forest and tropical thornscrub, tropical savanna covers approximately 65% of the African continent. Much of the Indian subcontinent is also mapped as savanna and small patches occur in southeast Asia and on the islands of the East Indies and the Pacific. In Australia, tropical savanna occurs in the north and extends southeast between the more arid central plains and the humid tropical and subtropical forests along the east coast.

Tropical savanna, therefore, shows a disjunct distribution across the continents in the tropical realm. While savanna vegetation may be similar in its overall structure as a mixed system with grasses and woody plants, the composition of plants species that occur in the region can also influence its appearance. For example, evergreen *Acacia* trees dominate the savannas of the new world tropics in South America, just as evergreen eucalyptus trees occur across a broad moisture gradient on the continent of Australia. In Africa, evergreen *Acacia* trees can predominate, but much of the region shows a mixed composition with some evergreen trees (e.g., *Acacia* species, *Balanites aegyptica*), deciduous trees (*Commiphora* species, *Delonix elata*, *Sclerocarya birrea*), and evergreen (e.g., *Croton*) or deciduous (e.g., *Combretum*) shrubs. In Africa, baobab (*Adansonia digitata*) is a prominent deciduous tree in savanna that varies its deciduous habit in relation to changes in the occurrence of rains across the region. The plants that make up the tropical savanna are much more diverse than temperate grasslands. About half of the plant species on the African continent occur in this vegetation type.

Savanna Climatic Conditions

Much of the composition and structural diversity in tropical savanna can be attributed to moisture changes across an equally broad region characterized by the tropical to subtropical wet-dry climate.



Tropical savanna in the Masai Mara, Kenya

Source: K. E. Medley.

Along a climatic gradient between tropical wet and tropical-subtropical dry, moisture deficits first emerge as the occurrence of a dry season and then change in available moisture by extending the length of the dry season and reducing the amount of rainfall received during the wet season or seasons. Moist savanna along this gradient occurs in regions receiving more than 700 mm (millimeters) of rainfall with a dry season of less than 3 mos. (months) and dry savanna can occur in regions that receive as little as 300 mm with a dry season of more than 6 mos. The primary production of savanna grasses shows a direct relationship with the amount of rainfall. Seasonal rainfall and dry seasons in the tropics are dictated by the migration of the sun's direct rays or subsolar point from the equator to the Tropics of Cancer and Capricorn and concurrent shifts in the positioning of the equatorial low and associated convective showers. Moreover, tropical wet-dry conditions can be intensified in some regions by strong monsoonal winds that bring moisture from the ocean toward the continent, particularly in West Africa and the Indian subcontinent, during high sun (summer) conditions and dry continental winds during low sun (winter) conditions. East Africa occurs as an

anomaly, characterized by a northeast monsoonal flow from October to December and a southeast monsoonal flow from March to May that bring "short" and "long" rains to the continent, respectively, in contrast to a single wet and dry season. Rainfall seasonality is a key attribute of tropical savanna. The dry season or seasons extend from 3 to 9 mos. with a mode of 5 to 7 mos., and rainfall always occurs during the growing season. The most profound vegetation changes that occur along this climatic gradient are observed in the woody plants, with a corresponding shift from evergreen trees, to deciduous trees, to evergreen shrubs, and to deciduous shrubs along a humid to arid gradient. These changes in the types of plants, however, vary significantly among the continents where tropical savanna occurs and within savanna regions in relation to soil conditions and disturbance regimes.

Ecological Adaptations of Tropical Savanna

Vegetation structure in tropical savanna can be mostly explained by the contrasting adaptations that woody plants and grasses have under a seasonal moisture regime and their competitive



Acacia-dominated savanna on black-cotton soils in Kenya

Source: K. E. Medley.

relationships. Most of the grasses are perennial, growing from underground stems or rhizomes and living 4 to 8 years. Much of the plant biomass occurs below the ground, where grasses maintain a dense fibrous root system at the ground surface and to a depth of about 1 meter. Grasses are well adapted to quickly absorb the rains as they fall and infiltrate through the soil near the surface. In contrast, woody plants produce deep taproots that rely on the deep infiltration of precipitation and its storage at depth. Because of these contrasting adaptations, soil conditions that influence the availability of water under seasonal precipitation regimes are critical to the competitive ability of grasses and woody plants and their relative dominance across savannas. Grasses predominant in regions where soils are fine textured or underlain by an impermeable layer that keeps moisture closer to the surface and available to the fibrous roots systems that grasses maintain. For example, the “arecife” layer of impermeable iron hydroxides (a lateritic crust) that occurs beneath the llanos of Venezuela and an impermeable soil layer of volcanic deposits in the southern Serengeti of Tanzania, explain the broad expanse of pure grasslands across those regions. In contrast, coarse-texture soils typical of riparian corridors often support savanna woodlands with a dense canopy of trees. In Africa,

more coarsely textured lateritic soils support a different composition and structure of trees and grasses than the fine-textured clays or black-cotton soils in low-lying areas (see acacia savanna photo). At a local scale within a savanna type, termite mounds can also alter the structure and nutrient content of soils in a way that allows for the local establishment of trees and shrubs. The isolated occurrences of trees across a savanna often correspond with the distribution of abandoned termite mounds.

Disturbance Ecology and Derived Savannas

Tropical savanna, particularly in East Africa, often occurs in regions that possess climatic conditions also suitable for the development of dense woodland or scrub. The geographic distribution of tropical savanna under these conditions is not climatically determined but occurs in response to soil conditions, such as those described above or “derived” in response to disturbances that reduce the competitive ability of woody plants. A prominent disturbance that reduces tree cover and promotes the production of grasses is grazing (the consumption of grasses) and browsing (the consumption of woody foliage) by large mammals (see arid bush savanna photo). Anteaters in South America and the marsupials of Australia influence



Gerenuk browse in more arid bush savanna

Source: K. E. Medley.

the ecology of tropical savanna on those continents, but the diversity and impact by large herbivores is a prominent influence in Africa that at least partially explains the broad expanse of this vegetation type across the region.

The highest diversity and abundance of large mammals in the world occur in the tropical savanna of East Africa and are a profound ecological disturbance. Large mammals and grassland coevolved and show some interesting examples of coadaptations. Savanna mammals migrate in response to seasonal changes in grassland production, and species diversity is maintained by their efficient use of different plant resources. Elephants consume large quantities of coarse grasses, shrubs, and trees and the seeds that pass through their digestive tract are dispersed over broad distances. Zebra, through their consumption of coarse grasses that are high in cellulose and lignin, provide a grass composition more suitable for smaller ruminant species such as gazelles. Woody plants develop both physical (thorns) and chemical (indigestible compounds) defenses to browsing. Grasses, with their source of growth at the base of the stem, and woody plants,

with an ability to produce multiple stems on browsing, can adapt and may even respond favorably (i.e., overcompensate) to the grazing/browsing activities of large mammals. An interesting example of the interplay between large mammals and tropical savanna occurred when the Rinderpest epidemic reduced wildlife herds by more than 90% after 1890, and woodlands expanded over much of the region until the mid 1900s. The heavy poaching of elephants in the 1980s had a similar effect, allowing for the expansion of woodland in some regions. The structure of tropical savanna and its species composition is often determined by the coadaptations of plants and animals, and the ecological separation is maintained by the animals as they migrate through or reside in certain regions.

Fire can also reduce woody plants in tropical savanna, but like grazing disturbances, its natural occurrence is unclear in relation to the very long history of human activities in the region. Humans evolved in the tropical savanna region of East Africa more than 2 million years ago and remain a significant influence on the composition and structure of this vegetation type. Pastoral populations



Heavily grazed savanna in the Masai Mara National Game Reserve, Kenya

Source: K. E. Medley.

rely on livestock that heavily graze the tropical savanna, and their livelihood strategies include migration and fires to ensure the availability of forage resources. Human conflicts arise when the conservation of wildlife or agricultural activities compete with local strategies for sustainable pastoral livelihoods. For example, much of the tropical savanna in East Africa is now protected in large reserves that limit land resources for grazing livestock and intensify the competition between agricultural and pastoral populations (see photo above). At the same time, there are also examples of cooperative ventures that support both the production of “natural” savanna resources and human livelihoods under community-based natural resource conservation initiatives for the region. Sustainability of tropical savanna relies on understanding the physical-environmental conditions and disturbances that influence and thereby maintain savanna productivity and the opportunities for sustained human livelihoods across the region.

Kimberly E. Medley and
Christine Mango Mutiti

See also Biome: Desert; Biome: Midlatitude Grassland; Biome: Tropical Deciduous Forest; Biome: Tropical Rain Forest; Biome: Tropical Scrub; Biota and Climate; Biota and Soils; Climate: Dry; Community-Based Natural Resource Management; Wildfires: Risk and Hazard

Further Readings

- Archibold, O. (1995). *Ecology of world vegetation*. New York: Chapman & Hall.
- Boulière, F. (Ed.). (1983). *Ecosystems of the world: Vol. 13. Tropical savannas*. Oxford, UK: Elsevier Scientific.
- Gichohi, H., Mwangi, E., & Gakahu, C. (1996). Savanna ecosystems. In T. McClanahan & T. P. Young (Eds.), *East African ecosystems and their conservation* (pp. 273–298). New York: Oxford University Press.
- Shorrocks, B. (2007). *The biology of African savannas*. Oxford, UK: Oxford University Press.
- Walter, H. (1971). *Ecology of tropical and subtropical vegetation*. Edinburgh, UK: Oliver & Boyd.



BIOME: TROPICAL SCRUB

On every continent except Antarctica, there are areas with dry or desert climates that receive enough rainfall to support shrubs as a dominant plant growth form. The land cover of these places consists of various types of shrublands or woodlands, which can be collectively known as “scrub.” Tropical scrub refers both to this climate zone as found in tropical and subtropical latitudes and also to the typical scrub vegetation type of those latitudes, characterized by dominance of multi-stemmed woody plants that are 1 to 5 m (meter) tall. It may also be known as *brush*, *bush*, or *thicket*, depending on local usage. Slightly higher woody plants with thorns, form the closely associated “thorn woodland.”

Globally, tropical scrub and its variants can be found in large areas of Africa (including Madagascar), Southern Asia (India, Thailand), Australia, Mexico and Central America, the Andes Mountains, Eastern Brazil, and enclaves in Venezuela and elsewhere. It may be localized in pockets of suitable climate in mountainous areas and is also positioned on the dry sides of tropical and subtropical islands. It is found where mean annual precipitation is on the order of 20 to 50 (70) centimeters/year, with mean annual temperatures from as low as 12 °C and as high as 30 °C.

One way to conceptualize the biogeography and distribution of tropical scrub is in relationship to its relative position on a theoretical environmental gradient associated with annual precipitation. Such a gradient would extend from vegetation formations such as tropical rain forests and tropical deciduous forests to tropical and subtropical deserts, following a gradient of wet to dry climates. Scrub would be situated in climate zones somewhat moister than the deserts, while drier than the conditions found in tropical deciduous forests. However, its position along this idealized moisture gradient is also shared with tropical savanna, a vegetation formation wherein dominance is typically shared between both grasses and scattered trees. Climate on its own is not enough to predetermine the dominant vegetation in a particular area. Instead, the influence of disturbances such as fire and the complicating effect of edaphic or soil-related factors also must be taken into account.

The shrubs and short-statured trees that dominate tropical scrub are often deciduous, losing their leaves as an adaption to extended dry seasons when little or no rain may fall for 4 to 8 months a year. The evergreen species often have small leaves to minimize water loss. In addition, many species have thorns, providing protection from herbivores. These plant species also have varying degrees of adaptation to fires. They may have some combination of a fire-resistant bark, the ability to resprout following limb loss, or seeds cued to grow on recently burned substrate. By definition, tropical scrub does not have a continuous graminoid (grass or sedge) layer, so it is less prone to annual or semiannual fires than in many tropical savannas because fuel loads are less. Some tropical scrub may include cacti or other succulent plants that are well adapted to survival in seasonally dry environments.

Tropical scrub offers an excellent opportunity to examine evolutionary convergence globally. This phenomenon occurs when unrelated species develop similar appearances and adaptations to the prevailing climatic conditions found in a certain biome type in different parts of the world. Because tropical scrub is found worldwide, there are lineages of plants that have independently evolved suitable adaptations and so are generally similar in size, morphology, and physiology, despite not being close relatives. The same would be true for animals specialized in using scrub habitats, including a variety of bird, lizard, and insect species.

The interaction of soil nutrients, chemistry, and structure with vegetation dynamics is universal. For example, the *cerrado* savannas and *caatinga* woodland/scrub of Brazil are atop poor-nutrient soils derived from the ancient and weathered Brazilian shield. The role of soil characteristics may override climatic controls, allowing for tropical scrub vegetation to persist in wetter environments than is the norm. New Caledonia offers examples of such vegetation, locally known as *maquis*, wherein harsh serpentine soil conditions favor shrubs and other tolerant species in early stages of succession following disturbance or with recurrent fires. Recovery to rain forest is prolonged and depends on colonization and facilitation by *Araucaria* conifers.

Tropical scrub can also result from persistent disturbance caused by strong winds or large



animals. For example, scrub vegetation in Southern Africa may persist in landscape mosaics that include riparian woodland forest and extensive grass-dominated savannas. This persistence is due to feedbacks apparently resulting from increasing elephant and impala populations. The elephants, which are megaherbivores, preferentially feed at 1 to 3 m heights and may knock down and kill even quite large trees. The impala and other antelope feed at lower levels and may browse on tree seedlings, preventing tree establishment. The actions of these herbivores are concentrated near rivers and watering holes, especially during the long dry seasons, thus tending to increase total area in shrubland. Scrub is often found on ridges in otherwise tall forests located in the rough topography of tropical mountains. In this case, it is wind action that results in smaller stature woody plants being the dominants, perhaps with additional feedbacks from soil characteristics and herbivores.

Of course, in many places in the world, humans also have become a further ecological control on vegetation structure and dynamics. People may act in such a way as to increase, decrease, or eliminate disturbances that affect vegetation. They may impose land uses that create unique conditions, for example, through novel fire regimes that have an altered seasonality, intensity, and frequency than would be found under conditions wherein only climate regulated fire behavior and influences. They may introduce cattle, sheep, or goats, which alter plant species dominance and may promote woody plant establishment in grasslands. They may selectively remove or favor certain species considered valuable or nuisances. The floristic and faunistic elements of tropical scrub that are of use to people may become exhausted due to overharvest. Woody plants valuable as timber or as polewood, or animals hunted for their meat, may be locally eliminated.

Due to human influences, over time, some areas of tropical deciduous forest may begin to resemble tropical scrub, without emergent or tall trees. On the other hand, some forms of land use in tropical savannas, such as certain kinds of grazing systems, or as associated with the suppression of seasonal fires, may in fact promote establishment and invasion by shrub species, thus shifting the savanna into a form of scrub. Encroachment

of shrubs into both grasslands and desert vegetation has been observed worldwide in recent decades. This woody plant invasion may be causally related to increased amounts of carbon dioxide in the atmosphere, which could give a competitive advantage to the woody plants that can overtop and shade grasses.

As a result, collectively, human impacts would tend to increase tropical scrub. In landscapes occupied by people for many millennia, such as in India (Eastern and Western Ghats) or in the Andes Mountains (intermontane valleys from Colombia to Bolivia), large areas that would appear to be in a tropical deciduous forest climate zone, in fact have scrub vegetation. The loss of large forest trees, however, may have happened 2,000 to 4,000 years ago in some of these landscapes given the antiquity of human settlements, although both colonial and recent time periods also were moments in history with extensive extraction of natural resources. Only a subset of the original animals from the dry forests is able to continue to thrive in the shorter and more open habitat of scrub.

A conceptual model of the dynamism of tropical scrub would thus need to include all these features. A climatic regime with a pronounced dry season is essential. But then the composition and size of area with scrub vegetation will be a function of the degree of alteration due to land use. Seasonally dry forests may be "desertified" and converted to shorter stature vegetation through deforestation and through burning. Tropical savannas may disappear as woody shrubs come to dominate through altered fire regimes and as promoted by the influence of increased background carbon dioxide levels. Land use and large animal impacts could further alter conditions through herbivory and by changing soils through compaction and erosion. This model makes predictions for vegetation dynamics and also might permit the development of landscape management strategies when ecological restoration is a goal.

Vulnerable species found in tropical scrub may need special conservation efforts to survive in a changing world. Although scrub as a habitat type may be on the increase globally, due to shrub encroachment and forest, grassland, or desert degradation, there will still be species that need protection or management due to their value or



limited dispersal or reproductive capacities. In other cases, land managers are worried about exotic plant and animal species that alter ecosystem properties and lessen the value of the habitat for native species. This kind of biotic invasion is of particular concern in Australia, and also in the thousands of smaller tropical islands, all of which are susceptible. Some grassland areas in tropical Australia are now occupied by a shrub species from India, creating an anthropogenic scrub.

In summary, tropical scrub denotes an important semiarid climate type that predisposes vegetation to be dominated by shrubs and small trees with adaptations to drought. Because it is present in low latitudes around the world, and has existed for millions of years in some form, there are native species of plants and animals that have converged in their appearance and in their adaptations for survival. Some human land uses and some natural combinations of poor soils and fire may further increase the surface area covered by some type of shrubland. Tropical scrub is of interest for conservationists and biogeographers, but it is also an object of concern for those land managers who need to control the degree of dominance by shrubs in order to promote values for pasturelands, for fire control, or for ecological restoration.

Kenneth R. Young

See also **Biome: Tropical Deciduous Forest; Biome: Tropical Rain Forest; Biome: Tropical Savanna; Human-Induced Invasion of Species**

Further Readings

- Asner, G., Elmore, A., Olander, L., Martin, R., & Harris, A. (2004). Grazing systems, ecosystem responses, and global change. *Annual Review of Environment and Resources*, 29, 261–299.
- Bond, W., & Midgley, G. (2000). A proposed CO₂-controlled mechanism of woody plant invasion in grasslands and savannas. *Global Change Biology*, 6, 865–869.
- Brown, J., & Carter, J. (1998). Spatial and temporal patterns of exotic shrub invasion in an Australian tropical grassland. *Landscape Ecology*, 13, 93–102.

- Enright, N., Rigg, L., & Jaffré, T. (2001). Environmental controls on species composition along a (maquis) shrubland to forest gradient on ultramafics at Mont Do, New Caledonia. *South African Journal of Science*, 97, 573–580.
- Furley, P. (1999). The nature and diversity of neotropical savanna vegetation with particular reference to the Brazilian cerrados. *Global Ecology and Biogeography*, 8, 223–241.
- Jayakumar, S., Ramachandran, A., Bhaskaran, G., & Heo, J. (2009). Forest dynamics in the Eastern Ghats of Tamil Nadu, India. *Environmental Management*, 43, 326–345.
- Joubert, D., Rothauge, A., & Smit, G. (2008). A conceptual model of vegetation dynamics in the semiarid Highland savanna of Namibia, with particular reference to bush thickening by *Acacia mellifera*. *Journal of Arid Environments*, 72, 2201–2210.
- Kellman, M., & Tackaberry, R. (1997). *Tropical environments: The functioning and management of tropical ecosystems*. London: Routledge.
- Mehta, V., Sullivan, P., Walter, M., Krishnaswamy, J., & DeGloria, S. (2008). Ecosystem impacts of disturbance in a dry tropical forest in Southern India. *Ecohydrology*, 1, 149–160.
- Moe, S., Rutina, L., Hytteborn, H., & du Toit, J. (2009). What controls woodland regeneration after elephants have killed the big trees? *Journal of Applied Ecology*, 46, 223–230.
- Shahabuddin, G., & Kumar, R. (2007). Effects of extractive disturbance on bird assemblages, vegetation structure and floristics in tropical scrub forest, Sariska Tiger Reserve, India. *Forest Ecology and Management*, 246, 175–185.
- Van Auken, O. (2004). Shrub invasion of North American semiarid grasslands. *Annual Review of Ecology and Systematics*, 31, 197–215.



BIOME: TUNDRA

The word *tundra* originates from the Finnish *tunturi*, which means “completely treeless heights.” This is how the word is applied broadly all over the world to areas of higher altitude than the tree line. However, the geographically largest



and most significant tundra areas are those north of the latitudinal tree line in Eurasia and North America. These tundra areas are mainly situated in lowlands.

The tundra as a biome is relatively young, having developed in the early Pleistocene. However, the characteristic floras of tundras developed earlier, probably during the Miocene-Pliocene, in the highlands of Central Asia and in the Rocky Mountains of North America. In the same period (late Tertiary), present tundra areas were covered by various types of mixed and coniferous forests, now associated with the boreal forest region. Circumpolar regions of tundra-steppe environments developed during the Pleistocene. Rapid expansion of these areas during this period may have been associated with the success of such now-extinct macrograzers as mammoths.

A relative mild climate with spruce forests north of their present limit occurred in the last interglacial (Eem). During the last glaciation (Wisconsin), major parts of the Northern Eurasian and American continents were covered by the Eurasian and Laurentide ice sheets, respectively. There were, however, nonglaciated pockets extending far north, as in parts of Beringia and Northern Yukon Territory. In such nonglaciated areas, the diversity of animal and plant species and the general development of the soil and plant communities have been shown to be no more complex than comparable glaciated land masses nearby. This has lent support for the theory that at present arctic tundra ecosystems, including soils, are in equilibrium with the prevailing climate. Thus, they have been considered quite stable, although many areas have been deglaciated for only 3,000 to 8,000 years. Whether this apparent stability now is threatened with a warming climate is the subject of considerable current research. The following two sections review briefly the basic biogeographical and soil formation characteristics of the tundra region.

Biogeographical Subcategories

From a biogeographical viewpoint, the Arctic is often defined as the lands beyond the climatic limit of tree growth in upland habitats between river drainages. These areas have often, in particular in North America, been considered to consist of only two floristic units, tundra and

polar deserts. Furthermore, in the Western Hemisphere, the application of basic, diagnostic characteristics for the division of the Arctic into simple subdivisions based on the degree of closedness of the vegetation has been widespread. Traditionally, scientists of the Soviet Union have identified a larger number of biogeographical subzones than North Americans.

Andreev and Aleksandrova, for example, identified 13 arctic vegetation types and five subzones within the tundra zone based on the species composition and characteristics related to life form and migration history. In addition, they identified a number of longitudinal provinces across the Eurasian continent. Part of the reason for the varying use of subzones by North American and Eurasian scientists is probably real differences in the physical geography of the two continents. In Eurasia, most of the land north of the tree line is continental, with groups of islands in the Arctic Ocean. The climate shows a gradual northward shift over contiguous land masses, which provides the basis for major subzones or "belts" of specific vegetation types. In contrast, the American continent has a different geomorphology: No unbroken land mass extends to 78° N as in Eurasia and translongitudinal mountain ranges, sea barriers, and ice caps combined with their respective climatic influences cause a coarse-grained mosaic vegetation pattern rather than arrangements in belts or zones. Bliss and Matveyeva provide a useful overview of tundra subcategorization still used widely and also in connection with modern impact studies of climate change. Table 1 shows the areal extent of the subcategories described in the following sections.

Shrub Tundras

In North America, shrub communities are dominated by *Betula nana* and various species of *Salix*. The ground cover includes *Carex* and *Eriophorum* spp., numerous dwarf shrubs, grasses, and forbs; and an abundance of lichens and mosses. The most common dwarf shrubs belong to the genus *Ledum*, *Vaccinium*, *Empetrum*, *Rubus*, *Arctostaphylos*, and *Cassiope*. The most common mosses include species of *Hylocomium*, *Aulacomnium*, *Polytrichum* and, figuring prominently, *Sphagnum*. Important lichen families are *Cladonia*, *Cetraria*, and *Cladonia*. The tall shrub canopy is



<i>Vegetation Type</i>	<i>Alaska</i>	<i>Canada</i>	<i>Greenland, Iceland</i>	<i>Eurasia</i>	<i>Total Area</i>
Low Arctic					
Tall shrub	0.018	0.026	0.018	0.112	0.174
Low shrub	0.09	0.264	0.032	0.896	1.282
Tussock, sedge-shrub	0.126	0.088	0.036	0.672	0.922
Wet sedge	0.104	0.176	0.04	0.56	0.88
Semidesert	0.018	0.325	0.014	—	0.358
Ice caps	—	—	0.776	—	0.776
High Arctic					
Wet sedge	0.004	0.096	—	0.032	0.132
Semidesert	—	0.72	0.093	0.192	1.005
Polar desert	—	0.64	0.127	0.080	0.847
Ice caps	—	0.144	1.031	0.016	1.191
Total land	0.36	2.336	0.368	2.544	5.6
Total land plus ice caps	0.36	2.48	2.167	2.56	7.567

Table 1 Areal extent ($\times 10^{12}$ square meters) of various tundra types in different regions of the Arctic

Source: Bliss, L. C., & Matveyeva, N. V. (1992). Circumpolar Arctic vegetation. In F. Chapin, R. Jefferies, J. Reynolds, G. Shaver, & J. Svoboda (Eds.), *Arctic ecosystems in a changing climate* (pp. 281–300). San Diego, CA: Academic Press.

40 to 60 cm (centimeters) high, and the heath shrubs and forbs are 10 to 20 cm in height; the cryptogams provide more or less complete ground cover. This type of vegetation is widespread in Arctic Alaska and in many areas of Arctic Canada except for the central and eastern parts. Shrub tundra in Eurasia extends on rolling uplands across much of Siberia. Again the taller shrubs are dominated by varying subspecies of *Betula nana* and species of *Salix*. The ground cover includes *Carex* spp. and heath (low) shrubs, *Ledum*, *Vaccinium*, *Empetrum*, *Arctostaphylos*, *Dryas*, and *Cassiope* spp. There is a continuous moss cover comprising *Hylocomium*, *Tomenthypnum*, *Aulacomnium*, and *Dicranum* spp. Lichens *Cladina*, *Cladonia*, and *Cetraria* spp. occur within the mosses. The tallest shrub (up to 2 m [meters]) forming thickets are *Alnus fruticosa*, which are important in many places from Ural to Chukotka. Also, thickets of *Salix* spp., 1 to 2 m tall, occur mainly in drainages and along river banks.

Tussock and Sedge-Dwarf Shrub Tundras

In the vast areas of tussock and sedge-dwarf shrub tundra, many of the shrubs mentioned above

are still present, but they do not form a canopy and they occur almost exclusively in depressions, on raised polygons in mires or along river banks. The tussock and sedge-dwarf shrub tundra corresponds largely to what scientists of the Soviet Union refer to as “typical tundra.”

In the Siberian Arctic, the sedge-dwarf shrub tundra is most widespread. Here, the main species are mosses *Hylocomium*, *Tomenthypnum*, and *Aulacomnium* spp. and species of lichens *Cladina* and *Cladonia*. Dwarf shrub species of the genus *Vaccinium*, *Salix*, and *Cassiope* are common as are *Carex*, *Ptilidium*, and *Dryas* spp. in the ground layer. In northwestern Siberia, *Dryas octopetala* dominate many dry communities.

Tundras dominated by *Eriophorum vaginatum* tussocks with *Carex* spp., along with common dwarf shrub species and an abundance of mosses and lichens occupy large areas in western parts of North America, particularly Alaska. Again dwarf shrubs of *Betula* and *Salix* are common along with numerous forbs, grasses, and an abundance of mosses, including species of *Sphagnum*, *Hylocomium*, *Dicranum*, *Aulacomnium*, and *Tomenthypnum*. Common lichens include *Cetraria*, *Cladonia*, *Cladina*, and *Thamnolia* spp. Tussock



tundra is more limited in the eastern parts of Arctic America and West Siberia. However, large tracks of land dominated by *Eriophorum vaginatum*, along with the common heath shrubs and an abundance of lichens and mosses, are found in East Siberia and Chukotka.

Wet Tundras

Wetland plant communities in North America dominate on the coastal plain of Alaska and in the flat coastal areas in the Yukon. They extend on islands in the Mackenzie River Delta and eastward on the Tuktoyaktuk Peninsula. Peat in these communities reaches considerable depths typically 1 to 5 m. Only a shallow (20–50 cm) active layer develops in these cold, wet, soils.

The dominant sedges are in particular species of *Carex* and *Eriophorum*. Grasses include *Arctagrostis*, *Dupontia*, and *Arctophila* spp. Mosses are abundant, including species of *Aulacomnium*, *Calliergon*, *Ditrichum*, *Drepanocladus*, *Hylacomium*, *Meesia*, *Tomenthypnum*, and *Sphagnum*. Various dwarf shrubs are common along the rims of the mires and on raised hillocks. Sedge-dominated mires occur in lowlands across the Canadian Shield but in limited extent.

Wet tundras form a prominent part of the Siberian tundra. They are especially well developed in the central part of the Yamal Peninsula and in the lowlands of the Yana, Indigirka, and Kolyma river basins. Various types of mires have been identified in the Russian Arctic, but all are dominated by species of *Carex*, *Eriophorum*, *Caltha*, and *Comarum* as well as moss species *Drepanocladus*, *Meesia*, *Calliergon*, *Polytrichum*, *Sphagnum*, and *Cinclidium*. Dense thickets of *Betula nana* are typical for large peat hillocks up to 30 m in diameter. *Dryas*, *Vaccinium*, *Salix*, and *Betula* spp. typically grow on the rims of polygonal mires. Mires similar to the above but without the abundance of shrub species *Betula*, *Salix*, and *Vaccinium* are also common in the low and high arctic communities, particularly in the Northwest Territories of Canada and in Greenland.

Polar Semideserts

The tundras described so far, except for mires, are exclusive to what Bliss and Matveyeva

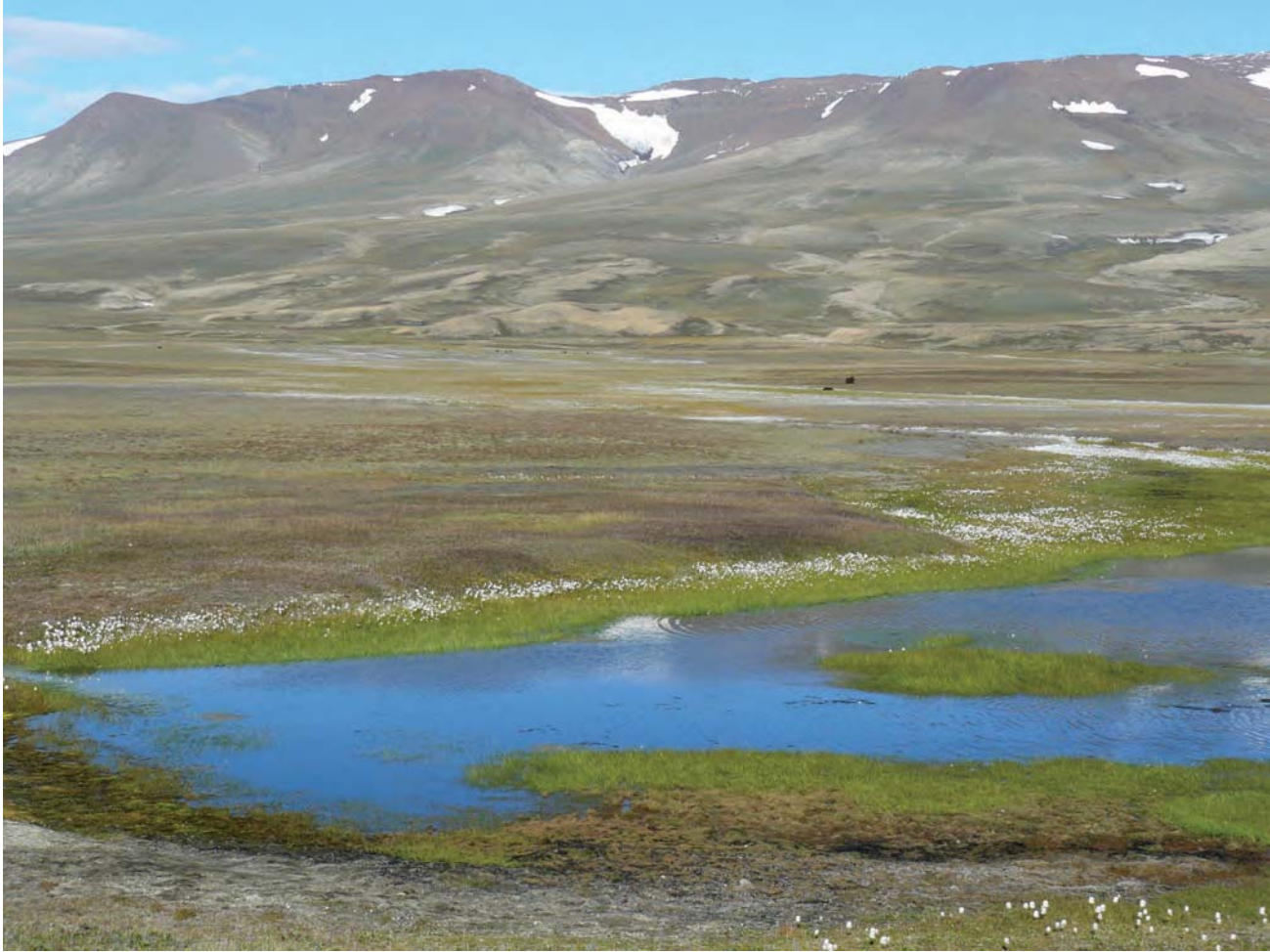
identify as the Low Arctic. The polar semideserts are in the High Arctic, which is exemplified by a number of structural and floristic changes in vegetation. These changes include a shift from the predominance of low shrub (*Betula*, *Salix*), dwarf shrub (heath species), and cottongrass-tussock-dwarf shrub tundras to an open vegetation dominated by cushion plants (*Dryas* and *Saxifraga* spp.), prostrate shrubs of *Salix arctica* and rosette species of *Saxifraga*, *Draba*, and *Minuartia*.

Along a south-north transect in the continental Siberian true tundra, the boreal elements of the low shrub species are the first to disappear. Subsequently, other dwarf shrub species decrease significantly in the transition to high arctic tundra. Arriving on the “true tundra,” as named by Russian scientists, the dominating species are *Salix polaris*, *S. arctica*, the graminoids *Alopecurus alpinus*, *Deschampsia borealis*, and *Luzula confusa*. Comparable tundras in North America have been called *polar semideserts*.

As mentioned earlier, the above major vegetation types tend to appear in zones in the Eurasian Arctic and in a mosaic in North America (including Greenland). However, all over the tundra regions on a local scale these vegetation types are mixed, depending on local climatic, hydrologic, and topographic features. The photograph (next page) shows a typical tundra valley in northeastern Greenland where in the lower parts wet tundra dominates and is surrounded by typical sedge shrub tundra that is replaced with polar semidesert-type vegetation as moving upslope with almost barren land beyond. This transition, occurring within a few hundred meters or less, is a common feature of tundra environments in landscapes with rolling hills.

Tundra Soil Formation and Characteristics

The tundra soils are young, typically dating back less than 12,000 years except in some areas that were not ice-covered during the latest glaciation. In some local sectors, the landscape has been icefree only during relatively recent time. In addition to disappearance of the ice cover itself, major areas of the Arctic have undergone isostatic adjustment resulting in emerging landforms. A large area surrounding Hudson Bay and extending



The Zackenberg valley in northeastern Greenland in mid August. The variation in vegetation types over short distances depending on hydrology and local topography is clearly visible. Muskoxen can be seen in the background.

Source: Charlotte Sigsgaard.

northward to the arctic islands was depressed well below sea level during the Pleistocene, as was Northern Scandinavia and the lower courses of major rivers of Siberia. Some emerged landforms have accumulated organic-rich sediments, which, coupled with flat terrain and poorly developed drainage patterns, have resulted in sluggish surface drainage and formation of extensive wetland conditions. The presence of permafrost further restricts soil and plant development. Consequently, decomposition, release of nutrients, and synthesis of secondary minerals from weathering of clay all progress very slowly.

The soil formation process of podzolization is limited to well-drained tundra soils with a deep

active layer. Where dwarf shrub species predominate, weakly developed podzols (Spodosols) are found. Less-well-developed soils of uplands and dry ridges are the arctic brown soils (Inceptisols). The most common group of soils in the Low Arctic region includes the tundra soils (Inceptisols) underlying cottongrass-dwarf shrub and some sedge communities of imperfectly drained habitats. These soils form under the process of gleization. Poorly drained lowlands where soils remain saturated all summer accumulate peat. These wet and highly organic tundra soils belong to the Histosol group.

The drier arctic soils, podzols, and arctic brown soils show some translocation of humus and iron, with iron-enriched B2 horizons and



weakly eluviated A2 horizons in the podsoles. Surface layers tend to be acidic (pH 6–4) and low in available nutrients but quite well drained above the permafrost. Inceptisols (arctic tundra soils) are less well drained but show generally similar pH characteristics and low nutrient availability. They contain B horizons that have sub-angular to angular structures, are grayish in color, and include iron oxide mottles. Histosols of poorly drained lands are acidic and are similar to arctic tundra soils in having limited translocation of minerals into the B horizon.

Torben R. Christensen

See also **Biome: Boreal Forest; Biota and Climate; Biota and Soils; Climate: Midlatitude, Severe; Poles**

Further Readings

- Aleksandrova, V. (1980). *The Arctic and Antarctic: Their division into geobotanical areas*. Cambridge, UK: Cambridge University Press.
- Andreev, V., & Aleksandrova, V. (1981). Geobotanical division of the Soviet Arctic. In L. Bliss, O. Heal, & J. Moore (Eds.), *Tundra ecosystems: A comparative analysis* (pp. 25–34). Cambridge, UK: Cambridge University Press.
- Arctic Climate Impact Assessment. (2005). *Arctic Climate Impact Assessment: Scientific report*. Cambridge, UK: Cambridge University Press.
- Bliss, L. (1981). The evolution and characteristics of tundra. In L. Bliss, O. Heal, & J. Moore (Eds.), *Tundra ecosystems: A comparative analysis* (pp. 5–46). Cambridge, UK: Cambridge University Press.
- Bliss, L., & Matveyeva, N. (1992). Circumpolar Arctic vegetation. In F. Chapin, R. Jefferies, J. Reynolds, G. Shaver, & J. Svoboda (Eds.), *Arctic ecosystems in a changing climate* (pp. 281–300). San Diego, CA: Academic Press.
- Chernov, Y. (1985). *The living tundra*. Cambridge, UK: Cambridge University Press.
- Linell, K., & Tedrow, J. (1981). *Soil and permafrost surveys in the Arctic*. New York: Oxford University Press.
- Tedrow, J. (1977). *Soils of the polar landscapes*. New Brunswick, NJ: Rutgers University Press.



BIOPHYSICAL REMOTE SENSING

Remote sensing is a collection of spatiotemporal views (images) of Earth's surface from vantage points, high above Earth. Such a collection has become instrumental to monitor and predict the future biophysical changes on Earth's surface that human beings will need to overcome. By using remote sensing techniques that involve the interpretation of reflective and absorptive properties of electromagnetic radiations (EMR), image interpreters are able to predict sea surface temperatures, wind patterns, the health of vegetation, possible occurrences of fire based on the structures of various plant canopy, and many other environmental factors. The EMR is absorbed and reflected by both the biological and physical objects of the Earth.

The solar radiation distribution among the vegetation is a function of canopy structure that strongly affects the productivity of the canopy and influences the surrounding biophysical environment. The productivity of the plant canopy is related to the well-being of humankind. The recent advances in biophysical remote sensing has made it possible to include all the biological and physical processes influencing the microclimate and atmospheric exchange characteristics of terrestrial biosphere over a range of spatial and temporal scales. The vegetation, the principal biosphere component, tightly couples with the radioactive, meteorological, hydrological, and biological processes. There is interconnect-edness among atmosphere/cloud, wind, water, topography, soil moisture, and land cover types in the biosphere, and the biophysical remote sensing helps monitor such interconnectedness.

Biophysical remote sensing helps display patchy warm-and-cool patterns of the atmospheric/cloud conditions on the images. A dark image (dark signature) indicates relatively cool conditions while the bright signatures indicate relatively warm conditions.

Wind produces characteristic patterns of smears and streaks on images resulting in lighter and darker color signatures. Often, these signatures extend over vast areas. For example, wind velocity is typically lower downwind due to



This MODIS Terra image, acquired in August 2, 2006, shows most of Greece, with its jagged coastline, and many islands and peninsulas.

Source: Jeff Schmaltz/NASA.

obstructions and reduces cooling effects resulting in relatively bright images; sheltered areas are generally warmer than terrain exposed to windy conditions during the winter. Theoretically, warmer areas generate relatively brighter images than cooler areas.

Another biophysical component, water, behaves differently than a land surface. During the daytime, water bodies have a cooler surface temperature than soils and rocks, and water bodies appear darker on the daytime image. Since water and ground surface temperatures reverse themselves during the day and nighttime, the thermal signature of water bodies becomes a reliable index of the timing of image. Warmer signatures on water bodies as compared with the adjacent terrain

indicate nighttime image acquisition, while relatively cooler signatures indicate daytime imagery.

Scattered rain showers produce parallel lines on the image, just like the lines developed from a malfunctioned scanner. A heavy overcast layer (dense cloud) reduces thermal contrasts between terrain objects because of reradiation of energy between the terrain and cloud layer but the resulting thermal contrast becomes relatively low.

Topography plays a dominant role in remote sensing as solar heat and shadow vary with the timing of images. If images are taken in the nighttime, the thermal properties of images are displayed due to the reradiation of surface temperatures. If the images are taken during the daytime, the ridges and slopes facing the south



and east reveal brighter signatures due to solar illumination, while areas facing the north are shaded from solar illumination and display dark (cool) signatures. On the nighttime image, topographic features are mostly eliminated as only the geologic features (thermal characteristics of objects) influence the image appearances. The total and spectral global solar irradiance absorbed by the vegetation, canopy layer, spectral reflectance, and transmittance for each discrete wavelength at various exposures can be calculated by using Equation 1 and merging satellite images with digital elevation data.

$$R_f = \cos(A_f - A_s) \sin(H_f) \cos(H_s) + \cos(H_f) \sin(H_s), \quad (1)$$

where R_f = relative radiance value of a facet in the image merged with an elevation layer, A_f = the facet of the aspect, A_s = sun's azimuth, H_s = sun's altitude, and H_f = facet's slope.

Another important component of biophysical remote sensing is the soil moisture that influences electromagnetic radiation. Wet or damp soil is cooler than dry soil, both during day and nighttime. The presence of water in the soil increases thermal inertia making the soil comparable with the inertia of rocks. The infrared image of geologic faults and fractures displays differently during the evaporative cooling process. Interpreters at times may confuse man-made built-in infrastructure with geological outcrops. Some geological outcrops and built-in urban areas often show warmer (brighter) surface "heat islands" than the relatively cooler surrounding nonurban countryside or geological outcrops of moist surfaces (rocks or soils). Often, the nature of electromagnetic radiation from soil, urban areas, and vegetation become difficult to distinguish because dry vegetation, such as crop stubble in agricultural areas, appears warm on nighttime imagery similar to the daytime imagery of the dry soil or built-in areas. Likewise, the dry vegetation insulates the ground to retain heat and results into the warm nighttime signature.

The most important component of biophysical remote sensing is the property of individual green vegetation, which exhibits very distinct thermal responses. Green deciduous vegetation has a cool signature on daytime images and a warm signature on nighttime images. During the day, leaves

stomata open for transpiration lowering leaf temperatures. As a result, vegetation generates a cool signature relative to the surrounding environment. At nighttime, the insulating effects of leafy foliage and the high water content of the leaves retain heat resulting in warm nighttime temperatures; however, this situation varies with the species. For example, leaves of coniferous species have thick cuticular walls and smaller stomatal openings; as a result, the high nighttime and low daytime radiant temperature and their low leaf water contents do not affect the appearance of the images. Reflective properties of other vegetation also differ due to leaf structures and the water content of the leaves. Collenchymatous and parenchymatous cells (broad and young leaves) will hold more water than sclerenchymatous (older) cells. The proportion of total and spectral global irradiance absorbed by individual canopy layers may affect the global climate but such effects vary greatly as a function of topography and solar zenith angle.

Vegetation growing in various topographic conditions displays specific spectro-physiographic characteristics, often resulting in spectrally different classification results. Many researchers use the normalized differential vegetation index (NDVI) to determine species-specific vegetation vigor based on red- and near-infrared bands of satellite images (Equation 2).

$$NDVI = \frac{X_{nir} - X_{red}}{X_{nir} + X_{red}}, \quad (2)$$

where X_{red} represents sensor's visible red and X_{nir} represents near-infrared bands of a satellite image. For example, the Douglas fir growing at >2,000 meters elevation displays an NDVI >0.5 on spring image and <0.9 on a landform that is moderately moist with a slope of 10° to 35°. To further analyze the effects of topography on plant growth, remotely sensed images are combined with biophysical factors, such as digital elevation data (DEM) and Tasseled-Cap bands (brightness, greenness, and wetness images). DEM derivatives, the topographic relative moisture index and landform layers are generated in geographic information systems, and used a scale index to determine relative slope position, slope angle, slope shape, and slope aspect for accurate classifications.



These biophysical properties are analyzed at topographic-bathymetric (x = longitude, y = latitude, and z = elevation) locations based on the mixing of the color and spectral signature of features. Since remotely sensed images alone cannot represent all the features at planimetric (x and y) locations, additional topographic-bathymetric features, such as slope, aspect, and elevation from a digital elevation model are needed to identify the appropriate feature locations.

Advances in biophysical remote sensing has made it possible to estimate leaf area index (LAI), percentage of green cover, biomass as well as the percentages of photosynthetically active radiation absorbed by the leaf. Many researchers use LAI to measure the physical quality of life index assuming the green environment as a proxy to healthy and prosperous living. Further advances in biophysical remote sensing suggest that the use of the enhanced vegetation index to determine areas with high vegetation density by taking into account the canopy structure of vegetation rather than just the chlorophyll concentration. Scientists have developed the Fire Weather Index in addition to the NDVI to identify areas that are at fire risk. Biophysical remote sensing is imperative to determine the canopy reflectance indices that link crops to individual wavelengths and for calculating the spectral vegetation indices. Additionally, advances in the biophysical remote sensing have developed the green simple ratio index and green normalized difference vegetation index by estimating vertical temperature profiles of Earth's atmosphere based on the narrow bands in the near- and mid-infrared measures. Such information is not only useful in meteorology but also useful to estimate water surface temperature, chlorophyll concentration on various types of leaves, ground surface temperatures, and the level of moisture present in the atmosphere.

In summary, biophysical remote sensing has been instrumental for vegetation analyses, including climate changes, biogeochemical cyclical and hydrological modeling, land resource monitoring, land use planning, agricultural crop monitoring, yield forecasting, deforestation, and pollution and public health issues. It involves the study of soil moisture, spectral signature features, chlorophyll contents of leaves, vegetation biomass, and surface temperature. Biophysical remote sensing can

be used to analyze various types of forest covers and to analyze the effects of vegetation on climate. Biophysical remote sensing is also useful to measure the land surface temperature and vegetation distribution from space.

Keshav Bhattarai

See also **Remote Sensing**

Further Readings

- Boyd, D. S., Phipps, P. C., Duane, W. J., & Foody, G. M. (2002). Remote monitoring of the impact of ENSO-related drought on Sabah Rainforest using NOAA AVHRR Middle Infrared reflectance: Exploring emissivity uncertainty. In G. M. Foody & P. M. Atkinson (Eds.), *Uncertainty in remote sensing and GIS* (pp. 119–142). New York: Wiley.
- Chang, K.-T. (2008). *Introduction to geographic information systems* (4th ed.). Toronto, Ontario, Canada: McGraw-Hill.
- Gabban, A., San-Miguel-Ayanz, J., & Viegas, D. X. (2008). A comparative analysis of the use of NOAA-AVHRR NDVI and FWI data for forest fire risk assessment. *International Journal of Remote Sensing*, 29(19), 5677–5687.
- Harvey, L. (2000). *Climate and global environmental change*. Harlow, UK: Prentice Hall.
- Jensen, J. R. (1983). Biophysical remote sensing. *Annals of the Association of American Geographers*, 73(1), 111–132.
- Lillesand, T. M. (1996). A protocol for satellite-based land cover classification in the upper Midwest. In J. M. Scott, T. H. Tear, & F. Davis (Eds.), *Gap analysis: A landscape approach to biodiversity planning* (pp. 103–118). Bethesda, MD: American Society for Photogrammetry and Remote Sensing.
- Liu, W., Song, C., Schroeder, T. A., & Cohen, W. B. (2008). Predicting forest successional stages using multitemporal Landsat imagery with forest inventory and analysis data. *International Journal of Remote Sensing*, 29(13), 3855–3872.
- Piowar, J. M. (2005). Digital image analysis. In S. Aronoff (Ed.), *Remote sensing for GIS managers* (pp. 287–336). Redlands, CA: ESRI Press.
- Sabins, F. F. (2000). *Remote sensing: Principles and interpretation*. New York: W. H. Freeman.



BIOREGIONALISM

Bioregion denotes the conflux of cultural and ecogeographical features in human-defined territories. Bioregionalism has been promoted by geographers as a pragmatic research framework for understanding, and discovering solutions to problems within human-ecological relations. In many regards, bioregionalism is a comfortable fit for a discipline long concerned with the human place in larger ecological systems. Bioregional thought has a strong normative character, rooted in the North American environmental social movements of the 1970s. Essentially interdisciplinary, bioregional thought views communities of land and life as overlapping and interrelated. As a political philosophy, it proposes that political units need to be defined according to this combination of features and that decisions would be more socioeconomically and ecologically sustainable if they were taken at smaller, local levels than is the case in the present state-centric model. At the ethical level, it stresses attention to the human place within, and responsibility toward, the natural world.

The interdisciplinary nature of bioregional theory renders it suitable for addressing the complex challenges of developing sustainability. Indeed, bioregional approaches have spanned ecological science, conservation biology, social theory, geography, ethics, and political philosophy.

Criticism of bioregionalism has focused on its alleged lack of theoretical rigor, romanticism, or an unduly restrictive conception of place. Taking a holistic stance drawn implicitly from the epistemological insights of poststructuralism, bioregional scholars respond that all regions are continuous with one another; that no portion of territory on Earth is entirely discrete from the next. According to this view, global ecology, like landforms, is characterized by continuities and transitions. Similarly, there is constant cultural and economic continuity and exchange between both adjacent and (ostensibly) geographically separated human communities, all of which are simultaneously embedded in greater natural systems. The task of bioregionalists is to highlight the intensities within this continuity on which human politics may be based and ecology depends.

The following are some bioregional axioms:

1. The cumulative impacts of industrial civilization on the biosphere are rolling back many of Earth's evolutionary achievements of the past several million years.
2. The territorial assumptions inherent to the global industrial political system must be radically reformed.
3. Decentralization to smaller units defined by a combination of ecogeographical and cultural factors is essential.
4. Human politics must emphasize a commitment to place in order to promote the healthy human-environment interactions that are the foundation of healthy communities.
5. Humans bear ethical responsibility toward the nonhuman world.

William Hipwell

See also **Biosphere Reserves; Carrying Capacity; Deep Ecology Movements; Ecological Economics; Ecoregions; Environmental Ethics; Nature; Nature-Society Theory; Political Ecology**

Further Readings

- Aberley, D. (Ed.). (1993). *Boundaries of home*. Gabriola Island, British Columbia, Canada: New Society.
- Alexander, D. (1990). Bioregionalism. *Environmental Ethics*, 12, 160–173.
- Ankersen, T., Regan, K., & Mack, S. (2006). Towards a bioregional approach to tropical forest conservation: Costa Rica's greater Osa bioregion. *Futures*, 38, 406–431.
- McGinnis, M. (Ed.). (1999). *Bioregionalism*. London: Routledge.
- McTaggart, W. (1993). Bioregionalism and regional geography. *The Canadian Geographer*, 37, 307–319.
- Rajeswar, J. (2002). Development beyond markets, and bioregionalism. *Sustainable Development*, 10, 206–214.
- Sale, K. (1991). *Dwellers in the land: The bioregional vision* (Rev. ed.). Gabriola Island, British Columbia, Canada: New Society.



BIOSPHERE RESERVES

Biosphere reserves are geographic areas recognized by the United Nations Education, Scientific and Cultural Organization (UNESCO) and intended to demonstrate how people can live and work in harmony with the natural environment. Prior to designation, these areas are subject to strict scrutiny by UNESCO. Advocates for biosphere reserve status must demonstrate the special ecological, cultural, and social characteristics of the local areas. Although certain locations within a biosphere reserve area may be subject to national or subnational legislation, there is no new regulation imposed by the recognition of the region by UNESCO.

Initially conceived in the 1960s, the first biosphere reserves were created in 1976 under UNESCO's Man and the Biosphere program established in 1971. Indeed, many reserves were created in the 1970s. After a quiet period during the 1980s and 1990s, there has been an increase in the rate of designation internationally since 2000. As of May 2008, there were 531 biosphere reserves in 105 countries.

Biosphere reserves are intended to demonstrate three functions: (1) environmental protection, (2) logistical provisioning for scientific research and education, and (3) sustainable resource use. Over the years, the emphasis placed on each of these functions has changed. In the late 1960s, the greatest emphasis was placed on environmental protection through scientific research and the application of its results. Promoters of biosphere reserves, typically natural scientists, believed that modern science would help local people establish rational methods of resource use that would help them conserve the world's biodiversity. By the early 1980s, UNESCO indicated that biosphere reserves were to serve as field laboratories, which would help find solutions to the problems facing local populations, and indeed, the global community.

During the 1980s, however, there was a growing realization that ecosystem conservation was directly connected to development. This realization was given greater impact with the report of the World Commission on Environment and Development, *Our Common Future*, in 1987. Particularly in developing countries, there was a growing

idea that biosphere reserves should be used to promote "ecodevelopment" strategies that would also meet the basic needs of local communities. There was also concern that natural science research should be accompanied by social science research that would find ways to improve cooperation and communication among researchers, resource managers, and local residents living in and near biosphere reserves. Thus, the "sustainable resource use" function became a higher priority.

This priority was given greater force with the Seville Strategy of 1995, an outcome of the Second UNESCO International Conference on Biosphere Reserves. The strategy noted that the purpose of biosphere reserves was to include social and cultural dimensions into environmental management. The strategy also suggested that biosphere reserves should help people who live and work within them by demonstrating how to attain a sustainable future. These considerations illustrate an increased emphasis on addressing cultural and development considerations in both the establishment and the management of biosphere reserves.

To address the three functions, biosphere reserves contain three zones: (1) a core that must be protected, typically by national legislation; (2) a buffer where research and recreation use compatible with ecological protection are allowed; and (3) a transition zone where sustainable resource use is practiced. In some countries, the outer zone is also referred to as an *area of cooperation*. Thus, biosphere reserves retain some form of protected area at their core, but they must also incorporate adjacent areas and the inhabited surrounding "working landscapes" to demonstrate how they integrate conservation with sustainable development. Biosphere reserves are typically established on the basis of watersheds or other landscape-level features that extend beyond the boundaries of local human communities.

Although designation of biosphere reserves does not confer changes in property rights or regulation, biosphere reserves are subject to periodic review whereby each biosphere reserve is reviewed for UNESCO once each decade. This review requires an assessment of whether the biosphere reserve is fully functional, meaning whether all three functions are being addressed. The intention of the review is to encourage each reserve to be sensitive to all three objectives,



namely, (1) conservation, (2) sustainable development, and (3) scientific provisioning, that formed the basis for designation.

Contemporary research in biosphere reserves places greater emphasis on socio-ecological systems than in the past. With reference to socio-ecological systems, biosphere reserves currently serve as experiments in environmental governance, community-based conservation, sustainable development, and adaptation and resilience. All such research points to the interconnection of humans and natural landscapes. For example, UNESCO now believes that biosphere reserves should demonstrate innovations in environmental governance and can help meet international obligations, such as Agenda 21, the Convention on Biological Diversity, and the Millennium Development Goals. Thus, biosphere reserves offer researchers an opportunity to study complex drivers of change and stressors on ecological and social systems and to identify and test strategies for adaptation and resilience. This kind of research links biosphere reserves to the goals and objectives of the Millennium Ecosystem Assessment and the related discourse of sustainable development.

Despite these lofty opportunities, many biosphere reserves struggle because they are not well supported financially or logistically by their local or national governments. For example, ongoing financial support is somewhat uneven. In some countries, individuals are hired to pursue conservation and sustainable development objectives, but they are typically minimally staffed with small budgets. In other countries, biosphere reserves rely on a volunteer labor to advance their interests, making their progress slow and sometimes halting. In general, the success of biosphere reserves in meeting their mandate is predicated on the initiative and skills of a small number of people who often spend years dedicated to demonstrating the links between environmental protection and sustainable development.

Maureen G. Reed

See also Biodiversity; Bioregionalism; Environmental Ethics; Environmental Management; Indigenous and Community Conserved Areas; Nature; Nature-Society Theory; Species-Area Relationship; Sustainable Development

Further Readings

- Francis, G. (2004). Biosphere reserves in Canada: Ideals and some experience. *Environments*, 32(3), 3–26.
- Pollock, R., Reed, M. G., & Whitelaw, G. (2008). Steering governance through regime formation at the landscape scale: Evaluating experiences in Canadian biosphere reserves. In K. Hanna, D. Clark, & S. Slocombe (Eds.), *Transforming parks* (pp. 110–133). London: Routledge.
- UNESCO. (1995). *The Seville strategy for biosphere reserves*. Paris: Author.
- UNESCO. (2000). *Solving the puzzle: The ecosystem approach and biosphere reserves*. Paris: Author.
- UNESCO. (2005). *Biosphere reserves: Benefits and opportunities*. Paris: Author.
- World Commission on Environment and Development. (1987). *Our common future*. New York: Oxford University Press.



BIOTA AND CLIMATE

The word *biota* is a collective term, simply meaning “living organisms.” Strictly speaking this includes human beings, but here the focus is on nonhuman living things. *Climate* can be defined as the average weather conditions of a place, determined over a long enough period of time to ensure that the full range of conditions normally experienced is taken into account, while unusual conditions happening within the measurement period do not unduly influence the average. Climate is therefore commonly calculated from weather conditions over a period of 20 to 50 years and includes temperature, precipitation, daylight, and wind, among other variables. Biogeography focuses directly on the study of patterns of life in both space and time. The biotic environment is an important part of “the environment” more generally, which is the central element of physical geography. Both present and past climate affect which organisms can live in a place, but the strength of this influence varies depending on the type of organism and the medium in which it lives (land or water).



The study of the present climate's influence on organisms is a strong focus of what is often called "environmental biogeography," while the influences of past climate—in tandem with the movement of tectonic plates—are a major focus of "historical biogeography." Increasingly, the distinction between these two subdisciplines of biogeography is breaking down, as it seems clear that a good explanation of patterns of life in the world today requires elements of both. Furthermore, it is increasingly appreciated that, as well as being strongly affected by climate, living organisms can affect climate and therefore climate change at all spatial scales. Clearly, relationships between biota and climate are a very important part of geography. This entry first discusses how living organisms affect climate and examines the feedbacks between the two, using the relationship between climate and species richness as an example. The entry concludes with an overview of current research directions and priorities in the field more generally.

The Influence of Climate on Biota

For living organisms, climate can be considered part opportunity and part threat. Some aspects of climate are usable resources (opportunities), especially water and daylight—most important, those wavelengths of light that constitute photosynthetically active radiation, which plants can convert into food. Water is vital to life for three main reasons: (1) it can carry other substances in solution or suspension, (2) it is one of the few substances that is liquid at most temperatures experienced around the world, and (3) it is one of the raw materials for photosynthesis. Other aspects of climate, most important temperature, represent ambient conditions rather than resources. Temperature affects the rates at which chemical processes happen within the bodies of living organisms. Ambient conditions also interact with resource inputs, the most important interaction being between temperature and water. If it is too cold or too hot, water is not available to living organisms because it is in the form of ice or water vapor, neither of which is of any use for chemical processes within organisms' bodies. Beyond affecting water availability, extremes of temperature are directly stressful to organisms. Water expands on freezing, meaning that organisms without adaptations to

cope will suffer lethal rupture of cell walls and other important parts of their internal structures, such as freezing pipes bursting. Increasingly high temperatures tend to be associated first with the denaturing of enzymes, which are vital to living organisms, and second, at more extreme levels, with the direct destruction of the living tissues.

Evolution largely concerns organisms adapting to their environment, with climate a key part of this. For most of the history of life on Earth, the climate has been warmer than it is today. Probably for this reason, combined with the physical properties of water, frost is dangerous to most organisms. Among plants, various strategies exist for coping with frost, including shutting down over the winter (e.g., deciduous trees) and surviving winter as either seeds (e.g., annual plants) or underground structures, with the above-ground parts dying. For animals, this means that frost is not only directly dangerous but also often associated with food shortages. There may also be water shortages, when most water in the environment is locked up in ice. Animals' strategies for coping with frost include hibernation, the use of burrows, and storing food for the winter. Even in warmer climates, water is often in short supply, either seasonally or generally (e.g., deserts). Again, both plants and animals have developed numerous ways of coping with water shortage. For example, the "tree" *Welwitschia mirabilis*, found in the Namib Desert and in a family of its own, has a large underground trunk. Above-ground are only two thick leathery leaves that grow continually for up to about 2,000 years. This plant is adapted to grow in places with exceptionally low annual rainfall: Its leaves, being at ground level, are less desiccated by winds. Its leaves also contain special structures that obtain moisture from dew, providing the bulk of its water supply. It photosynthesizes using the CAM (crassulacean acid metabolism) pathway, which allows it to open its stomata only at night, thereby minimizing water loss. This example illustrates that there are many different ways of adapting to the environment. Because most adaptations have an energetic cost, they trade-off against each other, and the balance of fitness can shift between species with only minimal variation in climate. Thus, each species has a unique geographical range, which has been shaped by the responses of its individuals and populations

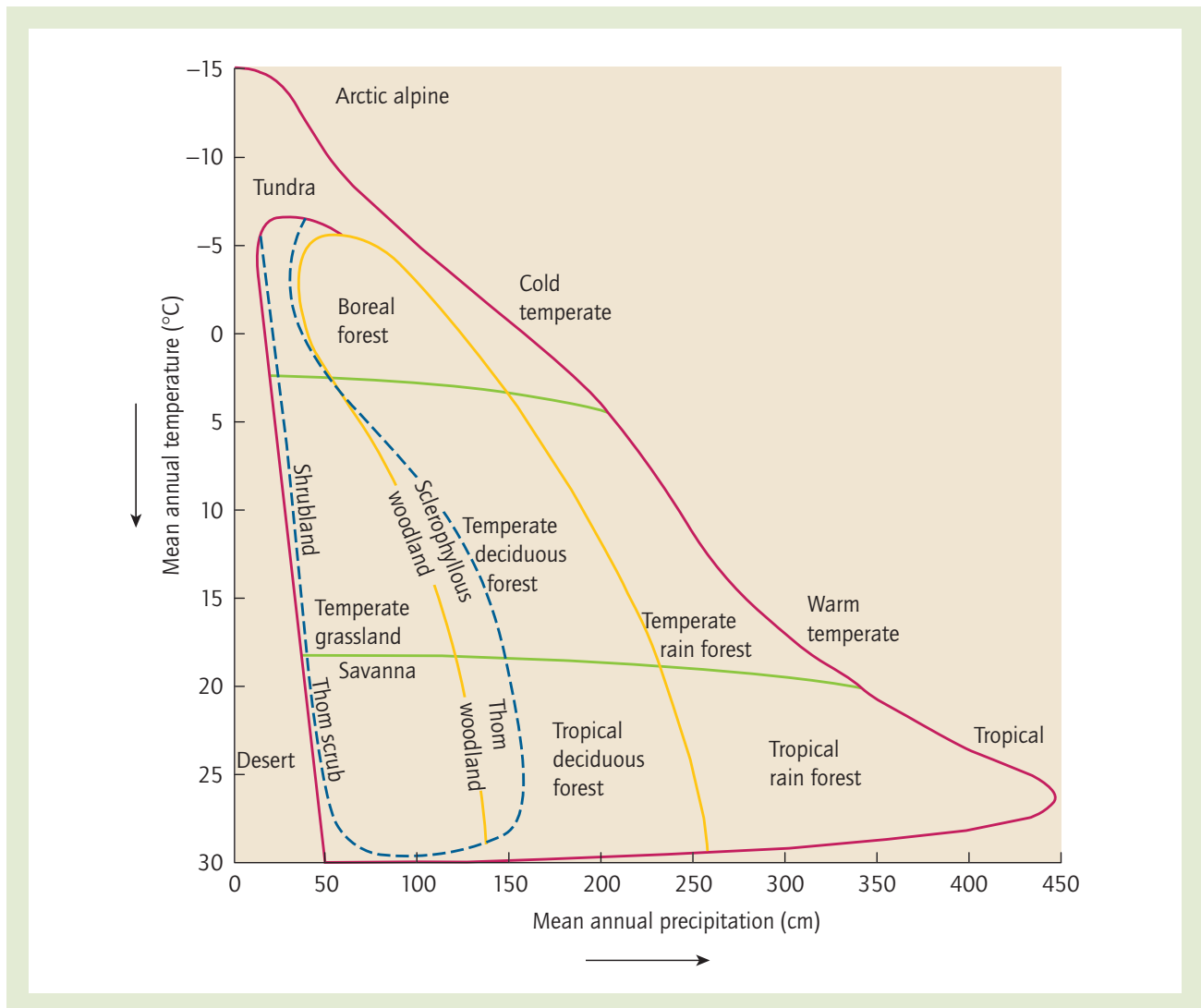


Figure 1 A climograph

Source: Brown, J. H., & Lomolino, M. V. (1998). *Biogeography* (2nd ed., Figure 5.12, p. 111). Reprinted with permission from Sinauer Associates.

Note: The higher temperatures are represented lower on the vertical axis.

to their environment during its evolutionary history. The role of climate in determining species' ranges is so fundamental that the dominant method of predicting biotic responses to climate change is currently "climatic envelope modeling," in which the climatic limits of each species' current range is determined; then, the ranges of all the species are redrawn according to the predicted future climate.

Climate-plant relationships are the most important link between biota and climate for two main reasons. First, photosynthesis is responsible for all the food used by almost all living organisms

(propagated via "food webs"). Second, the inefficient transfer of energy between links in the food webs ("trophic levels") means that plants have far more biomass than animals. A key part of biogeography, therefore, involves relationships between spatial patterns of climate and of plants, globally. Climate varies around the world, the most important variation being in temperature and precipitation, for the reasons explained above. A very useful starting point for biogeography is a climograph (Figure 1). This maps "biomes" (broad vegetation types) in climate space—that is, on axes' defined

by average temperature and precipitation—and is an excellent demonstration of the close links between biota and climate.

Much of the emerging field of macroecology is concerned with the study of broadscale relationships between biota and climate—though it is not limited to this. The increasing availability of regional, continental, and global environmental and biological databases has led to an explosion of studies focusing on emergent statistical relationships between the two. Similarly, concerns over climate change have led to vast amounts of research on the effects of climate change on biota. Much research has focused on trying to explain the broadscale patterns of biodiversity.

Species Richness

Perhaps the most commonly studied variable is “species richness” (sometimes called “species density”), which is the number of species recorded in a specified area. It is the most common of the many measures of biodiversity, and is often the only one available at the broadest scales, for

which only presence-absence species data tend to be available. The well-known “latitudinal diversity gradient” (LDG, Figure 2) describes one of the most remarkable patterns that repeatedly emerges from broadscale studies of this sort. Understanding the LDG is often considered the holy grail of biogeography. The pattern is that the number of species (or other taxonomic units) increases rapidly from the poles to the equator. Correspondingly, the most diverse ecosystems are tropical rain forests (see montane rain forest photo) and coral reefs. Because we do not know, within two orders of magnitude, how many species exist on Earth (this gap in knowledge is often called the “Linnaean shortfall”) and because distributional information is very poor for most of the approximately 1.7 million species that are known (the “Wallacean shortfall”), patterns such as the LDG are only established for particular, well-studied, groups of organisms. Nonetheless, it is remarkable how consistently the LDG is found in all but the narrowest and most idiosyncratic of these groups (e.g., penguins and seals), both on land and in water.

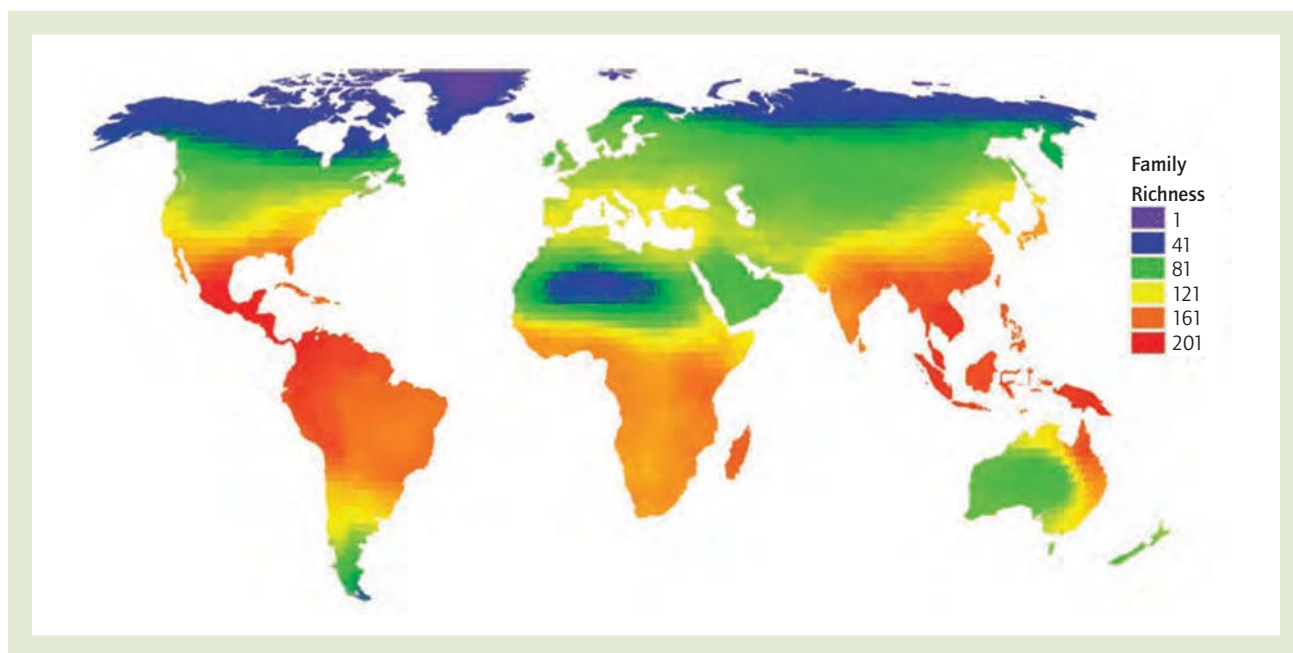


Figure 2 The latitudinal gradient of angiosperm family richness: number of families in 220-km × 220-km grid cells

Source: Francis, A. P., & Currie, D. J. (2003). A globally consistent richness-climate relationship for angiosperms. *American Naturalist*, 161, 523–536. Copyright © 2003 The University of Chicago Press. Used with permission.



A tropical montane rain forest in Cusuco National Park, Honduras. Tropical montane rain forests often harbor many endemic species, which are species found nowhere else.

Source: Author.

Broad-scale spatial species-richness patterns are rarely purely latitudinal. For instance, in Australia, the richness of most organisms peaks around the edges of the continent, especially the eastern edge (Figure 3). This is almost certainly because the climate near the east coast of Australia is wetter than in the interior of the continent. Studies repeatedly find that the strongest correlate of species-richness patterns at broad scales is some measure of the climate—usually a measure of energy, such as temperature or potential evapotranspiration, or a measure of water availability, such as rainfall, or a mixture of both, such as actual evapotranspiration. As a result, it is generally accepted that climate is one of the main causes of variation in species richness at this scale. However, exactly how climate causes the patterns



One of the many species endemic to Cusuco National Park is the large frog *Plectrohyla exquisita*.

Source: Author.

remains a very controversial question. Some of the leading theories focus on direct effects of contemporary climate on within-cell processes or on the availability of food. Others stress the role of past climatic changes, with species' niches being conserved to a considerable extent over geological time ("niche conservatism"), or evolutionary rates being faster in warmer conditions. Others invoke increasing importance of climate toward the poles, with biotic-abiotic interactions accounting for much of the high tropical diversity. Another claims the importance of a larger contiguous area of comparable climate in the tropics resulting in the species richness in that area. Yet another stresses the roles of refugia from harsh climatic conditions, such as during glacial periods, with these refugia often resulting in barriers to reproduction that lead to more species via allopatric speciation, especially in the tropics. One important logical distinction in this debate is between climate as a direct cause of increased biodiversity and climate as a constraint on diversity. In all probability, climate acts in both ways.

Spatial patterns of species richness at narrower scales tend to be less latitudinal and less strongly correlated with climate, but this may well be largely an artifact of the amount of climatic variation that is present in a smaller study area. One situation in which considerable climatic variation occurs over relatively short distances is along a steep altitudinal gradient. This is for two main reasons. First, temperature rapidly decreases with increasing altitude. Second, precipitation often increases greatly with altitude (up to a point) because cooler air can hold less water vapor. Along altitudinal gradients, rapid changes in species richness tend to occur. There are two very commonly reported shapes of species richness–altitude relationship. The first is called "monotonic," in which species richness consistently decreases at higher altitudes, whether linearly or via some other decreasing function. The second is usually referred to as "hump-shaped" and occurs when species richness is relatively low at the bottom of the gradient, initially rising to peak at midaltitude, and then falling at the highest altitudes.

As with the LDG, there are numerous competing hypotheses to explain the species–altitude relationships, including the decreased area of high-altitude zones, but again, climatic changes with altitude tend to correlate well with the observed patterns and feature strongly in most explanations. Many argue that topography is best seen as a landscape-scale climatic variable when trying to account for spatial patterns of biodiversity. It certainly tends to be among the variables most strongly correlated with species richness at this scale.

The marine equivalent of the altitudinal gradient is the depth gradient of the oceans. Less is known about this relationship, as deep sampling of the oceans remains sparse. Initial indications have suggested that both monotonic decreases in species richness with depth and hump-shaped relationships are found here. In the

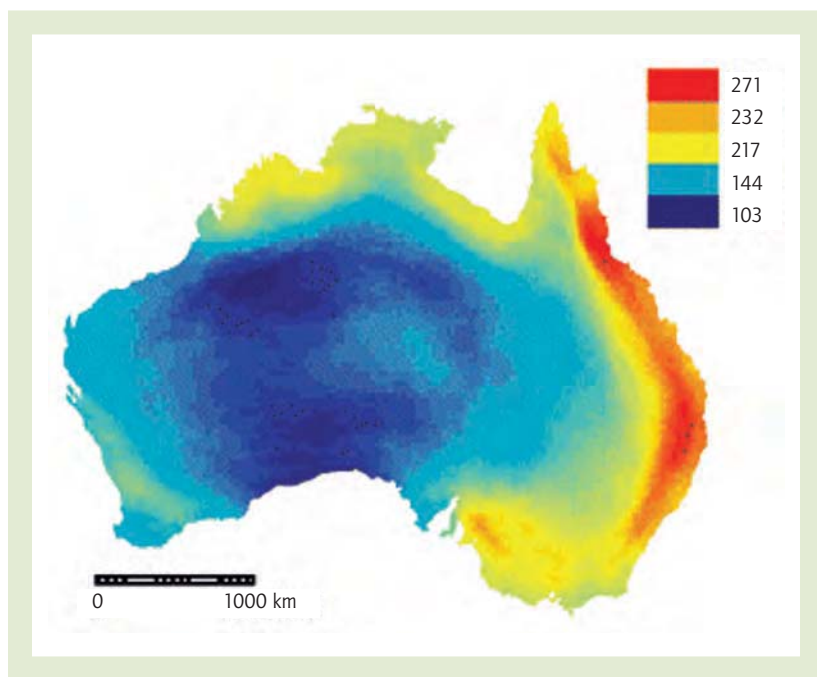


Figure 3 Bird species richness in Australia, in 27.5-km $\times$ 27.5-km grid squares

Source: Hawkins, B. A., Diniz-Filho, J. A. F., & Soeller, S. A. (2005). Water links the historical and contemporary components of the Australian bird diversity gradient. *Journal of Biogeography*, 32, 1035–1042.



sea, water availability changes little with latitude, longitude, or depth (some gradients in salinity can cause slight variation in the availability of water to some organisms). Water temperature does vary, not least with depth, and probably plays a part in causing depth gradients of species richness. Perhaps the most important aspect of climate here, though, is light, which rapidly attenuates to minimal levels with increasing depth in the oceans.

At the narrowest spatial scales, such as field plots, climate is also often implicated in species distribution patterns and therefore in species-richness patterns. The main reason is the angle of incidence of the sun: Where topography is steep, the aspect of a place (the direction it faces) can be quite important. For example, some tropical plant species have been shown to favor east-facing slopes because they receive direct sunlight in the morning, before the clouds have built up. In higher latitudes, the more important distinction tends to be between south-facing slopes, which may face the sun nearly at the perpendicular, and north-facing slopes, which may receive sunlight only at the most acute angles, if at all. However, fine-scale climatic variables such as aspect are often only weakly correlated with species richness. In such circumstances, aspect may be more strongly related to species identities and community composition than to species richness.

A complication arises at fine scales, in that microclimate can be an important variable affecting species richness, identity, and other ecological variables. Yet microclimatic variation is often largely determined by trees, such that broadscale climate affects biota, which affects fine-scale climate, which affects biota.

Other Key Biotic Variables

While many, many studies have been devoted to relationships between climate and species richness (and other measures of biodiversity), much research has also linked climate to species' traits, such as body size, abundance, range size, growth form, dispersal, and phenology. Among the ways in which climate affects dispersal is the manner in which it forms barriers to dispersal, which lead to isolation of populations and ultimately to speciation. In particular, high mountains are very effective barriers to the dispersal of most species because

of the extreme climatic conditions at high altitudes. Conversely, tropical valleys can be formidable barriers for many cool-adapted species of tropical mountains, leading to high rates of endemism in parts of Central and South America (see the montane rain forest photo). "Phenology" refers to the timing of the different stages or events in the life cycle of organisms, such as the onset of bud burst or flowering in plants. The Royal Botanical Gardens in Kew (London) has been keeping records of the date of the spring bloom of more than 100 plant species for more than 50 years. Recent trends have been for spring bulbs to come up and flower earlier—and consistently so over the past two decades or so (except 2009). One major concern is that the phenology of plants and the insects that pollinate them, or feed on them, are becoming decoupled as the climate changes. This can happen because the phenology of some species is triggered mainly by daylight, while that of others is triggered mainly by temperature or rainfall. Although climate has always changed in the past, sometimes rapidly, and therefore species have clearly managed to cope with such decoupling, the concern is that multiple stresses may reduce their ability to do so. Multiple stressors result from the fact that human actions are not only changing climate but are also reducing and fragmenting habitats, polluting them, introducing alien species, and so on.

The Influence of Biota on Climate

Living organisms have long been known to be powerful influences on many aspects of the environment, such as soil, hydrology, geology (many rocks are the remains of living organisms), and atmospheric composition. It has long been known that the composition of the Earth's atmosphere would be very different were it not for living organisms, especially those that photosynthesize. After all, oxygen is a highly reactive element and would not remain long in the atmosphere without a continual supply. The stability of the composition of the atmosphere is also due in large part to the actions of plants. More controversially, some have argued that ocean salinity and the Earth's surface temperature have also remained so remarkably constant for so long because of the influence of living organisms. Quite recently, it has been appreciated that broadscale rainfall is



also affected by vegetation. For example, about half of the annual rainfall of Amazonia is recycled by the vegetation: Rainfall is intercepted by leaves and branches, or is taken up by the roots, and is returned to the atmosphere in great quantities via evapotranspiration, mostly to fall again as rain.

Amazonia is now known to be a major sink for anthropogenic carbon dioxide (CO₂) emissions: The forests have been increasing in biomass. Another vital biota-related carbon sink is peatlands, where plants take up CO₂, but the normal decomposition processes do not work fully so carbon is locked up in the resulting peat. This process is reversed by humans when we burn peat and fossil fuels and when humans drain peatlands for agriculture.

Current and Future Research Directions

The practical and theoretical implications of the relationships between biota and climate are very far-reaching. The feedbacks—climate affecting biota and biota affecting climate—make the task of understanding the Earth system all the more challenging. Global circulation models need to include the feedbacks between biota and climate more effectively than they have done so far. One result of increased atmospheric CO₂ (an aspect of climate) is the acidification of the oceans, as the CO₂ dissolves in seawater, becoming carbonic acid. This is increasingly one of the greatest areas of current concern, in relation to oceanic ecosystems and the continuing supply of ecosystem services from the ocean. Land use planning is increasingly concerned with the conservation of nature; at all scales this needs to include good understanding of relationships between biota and climate. Thus, a fast-growing subdiscipline is “conservation biogeography,” in which biogeographic theory is applied to conservation and land use planning practice.

Finally, it is worth noting that, with the increasing incorporation of spatial and temporal scale and spatial analysis in studies of relationships between biota and climate and with the increasing use of geographic information systems in such studies, what was largely the preserve of biologists and ecologists is increasingly becoming geographical.

Richard Field

See also Biodiversity; Biogeochemical Cycles; Biogeography; Biome: Tropical Rain Forest; Biota and Soils; Biota and Topography; Climate Change; Climate Types; Climatology; Ecological Regimes; Ecological Zones; Ecoregions; Ecosystems; Ecotone; Species-Area Relationship

Further Readings

- Cleland, E. E., Chuine, I., Menzel, A., Mooney, H. A., & Schwartz, M. D. (2007). Shifting plant phenology in response to global change. *Trends in Ecology and Evolution*, 22, 357–365.
- Field, R., Hawkins, B. A., Cornell, H. V., Currie, D. J., Diniz-Filho, J. A. F., Guégan, J. F., et al. (2009). Spatial species-richness gradients across scales: A meta-analysis. *Journal of Biogeography*, 36, 132–147.
- Huston, M. A. (1994). *Biological diversity*. Cambridge, UK: Cambridge University Press.
- Lomolino, M. V., Riddle, B. R., & Brown, J. H. (2006). *Biogeography* (3rd ed.). Sunderland, MA: Sinauer Associates.
- Lovejoy, T. E., & Hannah, L. (Eds.). (2005). *Climate change and biodiversity*. New Haven, CT: Yale University Press.
- Malhi, Y., & Phillips, O. L. (Eds.). (2005). *Tropical forests and global atmospheric change*. New York: Oxford University Press.
- McCain, C. M. (2009). Vertebrate range sizes indicate that mountains may be “higher” in the tropics. *Ecology Letters*, 12, 550–560.
- Whittaker, R. J., Willis, K. J., & Field, R. (2001). Scale and species richness: Towards a general, hierarchical theory of species diversity. *Journal of Biogeography*, 28, 453–470.



BIOTA AND SOILS

At the Elkhorn Slough Visitor's Center at the head of Monterey Bay, California, is a diorama that shows a shorebird standing in a bucket of mud taken from the adjacent slough. After asking visitors to estimate how many and what kinds of organisms might live in this much mud, the diorama offers an estimate of 500 billion bacteria,



500 million diatoms, 50,000 protozoa, 50,027 worms, 5,000 crustaceans, 39 clams—plus the bird. While we cannot vouch for the ballpark accuracy of the estimate, what we know about soil organisms and numbers suggests it may be low. But in pondering the diorama, several questions are raised. Does slough mud qualify as soil? If so, what is soil? How many organisms, and what kinds, live in soil? And finally, what roles do biota play in forming soil and its biomantle? This entry addresses these questions.

Does Slough Mud Qualify as Soil?

Slough mud with its myriad organisms does qualify as soil, but it qualifies more so when it exists in an undisturbed state, before being slurried as a bucket of mud. While the conventional idea that soil forms subaerially on land has a long tradition, the idea that it might also form underwater has long been espoused, since the early 19th century. In recent years, terms and expressions such as *submerged soils*, *submarine soils*, *ocean soils*, *freshwater soils*, and *subaqueous soils* follow these views and are now garnering validity for such soils. However, while the early and later observers used the word *soil*, they more likely were thinking about its uppermost part where most organisms dwell—the part more recently conceptualized and named “soil biomantle.”

What Is Soil?

Views and paradigms of soil—including what soil is—have been in flux, not only for agronomists, soil scientists, and pedologists but also for archaeologists, biologists, ecologists, foresters, geographers, geologists, oceanographers, and many others. Such a community of scientists must deal with a concept of soil that covers a wide agenda—an ecologically based one that embraces both applied and pure science research, transcends multiple disciplines, and encompasses all environmental contexts. Those who study soil or who work with it in any way must come to grips with understanding the central pathways of soil formation. A definition of soil that is compatible with such an agenda is a necessary step.

In advance of these tasks—to better accomplish them and to gain some understanding of the

entrenched mind-sets that might resist such a broadened approach to soil—we must briefly examine the gardener-farmer-agronomic practical traditions that underlie the conventional views of soil and that link traditional soil science dubiously to pedology, the two disciplines that claim soil as an object of study. Soil science has a broad societal practical agenda that includes crop yields, soil amendments (e.g., fertilizers, pesticides, herbicides, fungicides), plant diseases, soil survey, soil classification, soil genesis, soil quality, soil and natural resources conservation and management, extension/outreach services, and so on. The domain of pedology is narrower and less practical, with a focus on a scientific understanding of how soil forms, its properties, its depth (thickness), its ecological functionality, and other aspects—subtle though very basic distinctions.

Two Gatekeeper Soil Documents

For most soil scientists, agronomists, horticulturalists, gardeners, and farmers, the answer to the question “What is soil?” may be simply that soil is what plants grow in. This was a common definition in the 19th- and 20th-century literature on soil in the agricultural sciences, and still is. Several similar, though more specific and lengthier, definitions are given in recent editions of two gatekeeper soil compendia, the 1993 *Soil Survey Manual* and the 1999 *Soil Taxonomy*, both hereafter referred to as *Manual* and *Taxonomy*. These two treatises are basic and standard reference works for soil scientists and pedologists, and both have become conceptual and operational “reference bibles” for practitioners. The concepts and language within them play a mentoring role for both soil and nonsoil specialists, who consult them when dealing with any aspects of soil. Both volumes foster, in the first instance, a practical agronomic agenda, where soil survey, classification, and mapping—not necessarily ecologic or biospherical understanding—are the stated goals. This practical focus defines the traditional core domain of soil science and is what separates it from pedology, whose main focus is a more purely scientific study of soil.

The soil definitions in both documents are intimately linked to a late-19th-century model of soil formation commonly known as the “five factors,”



or “clorpt” model of soil formation. In the model, Soils form as a function of *climate*, organisms, relief, *parent material*, and *time*: or $S = f(\text{clorpt})$. Built-in provisos limit the depth of soil on land to 2 m (meters) for purposes of survey and classification—a strictly utilitarian (and arbitrary) contrivance—whereas depth of rooting on land for many plants is actually much deeper. For example, the roots of some phreatophytes in midlatitudes extend down to 18 m and to 85 m for plants in certain drought-prone tropical areas, such as northeastern Brazil. Also, according to the clorpt definition, for substrate to be considered soil, it must show evidence of horizonation or layering due to pedogenesis, and it must be capable of supporting rooted plants in natural environments. Substrates that lack both are considered “not-soil” (or nonsoil).

The definition includes shallow water substrates as soil, but only if plants are rooted in them, and then only to 2.5-m water depth. However, rooted plants in marine environments may grow to water depths of 10 to 40 m, occasionally even to 90 m. In sum, soil depth in *Manual* and *Taxonomy* is arbitrarily set at 2 m on land and 2.5 m underwater—all for the practical need to survey, map, and classify soils. Such arbitrariness, while understandable for its practical purposes, has created conceptual confusion and even misinformation for those in the Earth and environmental sciences, especially in explaining many-meters-thick biomantles in tropical soils and their far deeper subsoils and weathering zones.

Rooted plants can grow in many different environments in totally nonsoil contexts—as long as moisture is available. For example, plants grow in air (e.g., on building roofs, parapets, gutters, concrete walls, abandoned autos, as epiphytes on power lines, tree trunks, and branches), as free-floating plants in water (aquatic hydrophytes, some with dangling water roots), on animals (e.g., three-toed sloths and others), in pure quartz and gypsum sand, on rocks, under certain translucent quartzose-type rocks—and even *within* some porous rocks, on freshly exposed bedrock cores of bulldozed mountains, on fresh unweathered quarry spoil, on vertical walls of bedrock quarries, and so on.

While no question exists regarding the important role of plants in soil formation, a problem

exists with the traditionally lopsided “clorpt” emphasis on plants to the near exclusion or marginalization of other biota. Many members of *all* life-form groups are involved in forming Earth’s soil, with bioturbating animals particularly effective in texturally sorting soil into layers, as will be shown. But, in light of active space explorations and the search for life on other planets, should a definition of soil be exclusively Earth-bound?

Universal Definition of Soil

So what is soil and how should we define it insofar as soil technically is the “skin” of landforms and an integument of planets? Now, the best scientific definition is one that is most useful and comprehensible to a broad spectrum of scientists and the lay public. It especially should be simply expressed, concise, scientifically sound, easily explainable, and broad enough to cover all cases, not just a few or most cases. In sum, it should be clear, simple, logically sound, and have universality.

One definition that fits these criteria, being applicable to soil on Earth and all other generally lithic-composed planets and their satellites, is as follows: Soil is substrate at or near the surface of the Earth and similar such bodies that are altered by biological, chemical, and/or physical agents and processes.

The definition is brief and to the point. The inclusion of “or near” acknowledges that soil on at least one planet—Earth—has variable depth, sometimes great depth, as in some humid tropical areas. “Or near” also covers subaqueous soils, for such soils, even in deep water, are still relatively near Earth’s planetary surface. The two words *or near* also embrace the notions of “suspended soils,” and “soil body extensions.” Both notions cover temporary aboveground pockets of organic-rich soil that teem with organisms in rain forest canopies and soil temporarily incorporated into nests by birds, wasps, termites, and other arboreal lifeforms in their aboveground living-reproductive activities. The words *or near* also cover bodies of wind-deposited soil on rooftops and other human structures in which plants, insects, and other soil lifeforms live, as well as temporary islands and rafts of vegetation-bound soil that floats on rivers (e.g., Paraná), estuaries (e.g., of the Rio de la Plata), lakes (many), and



deltas (e.g., of the Danube and Okavango). They also cover soil washed from surface horizons downward into bedrock cavities, caves, joints, fractures, and vugs in limestone and other rocks.

The definition also focuses attention on the realization that only one celestial body—Earth—has all three processes operating more or less superficially and that because ours is such a different planet from all others—with the combination of a just-right distance to our star, water, and life, *especially life*—simple and complex surface and near-surface life must make the difference. Specifying simple and complex life—where life ranges from single-celled simple prokaryotes (whose cells lack nuclei), such as archaea and bacteria, through more complex single- and multicelled eukaryotes (whose cells have nuclei), such as protocists, fungi, plants, and animals—leaves open the possible existence of deeper prokaryotic biospheres on Earth and other planets, as has been proposed by several distinguished scientists. What we do know is that Earth's subaerial and subaqueous near-surface soil-biomantle continuum and *its* planetary integument does literally teem with simple to complex forms of life representing all known groups of organisms, with their numbers probably more than indicated in the slough diorama.

The definition also accommodates the fact that the term *soil* is being increasingly applied to extreme substrate environments on Earth and to substrates of other planets (the current technical and popular literature has statements about “cave soil,” “lunar soil,” “Martian soil,” etc.). The definition also reminds us that soil is not simple and implies that on Earth it is an ecological entity—thus, free from the conceptual limitations imposed by the agronomic-inspired “clorpt”-linked definition.

How Many Organisms Are There and What Kinds Live in Soil?

The question of how many organisms, and what kinds, live in Earth's soil intrigues scientists of all stripes, and probably we will never know total numbers, only ballpark estimates. However, evidence suggests that the estimate of biota living in the bucket of slough mud mentioned in the first paragraph of this entry is probably low, perhaps way low. In a paper presented at a geological

symposium titled “The Solar Stew: The Search for Ingredients of Life and Biomarkers in Our Solar System,” Johnson and Johnson gleaned data from various sources and offered an estimate of the kinds and numbers of invertebrate organisms that likely live in 1 g (gram) (not a bucket) of typical humid midlatitude soil and its biomantle. The data are as follows: bacteria (10^{8-9}), actinomycetes (10^{5-8}), fungi (10^{5-6}), micro-algae (10^{3-6}), protozoa (10^{3-5}), nematodes (10^{1-2}), and other invertebrates (10^{3-5}). Because the estimates were based on such a tiny amount of soil, 1 g (less than half a thimble full), many larger organisms, including more familiar ones such as ants, termites, worms, bugs, and so on, were of necessity unspecified in the “other invertebrates” category. The gram-sized data, of course, also did not include vertebrates, which as a group have a huge collective impact on soil.

Other research suggest that insects alone, apart from all other soil organisms, represent more than half of all known living organisms and potentially represent more than 90% of the differing life-forms on Earth. This estimate is particularly notable if, as has been averred by others, 95% of all insect species reside in soils at some period in their lives. Clearly a staggering number of organisms have co-evolved with Earth's soil and are essential and integrated parts of it.

What Roles Do Biota Play in Forming Soil and Its Biomantle?

Ours is indeed a very different planet, with a very different soil, most notably because it has a biomantle brimming with biota that other planets lack. The biomantle is the “epidermis” of Earth's soil and can be defined at several levels. In simplest terms, it is the surficial zone of biodynamic activity, with bioturbation dominant. Bioturbation under some dense forests is exemplified by floralturbation (e.g., root growth expansions, tree uprootings), whereas in grasslands-shrublands and most other landscapes, even including many forests, faunalturbation—animal bioturbation—is the more dominant process. More broadly, the biomantle is the bioturbated and sorted, organic-rich, often darker upper part of soil, including its surface, where most biota are conceived, born, grow, live, burrow, reproduce, die, and become

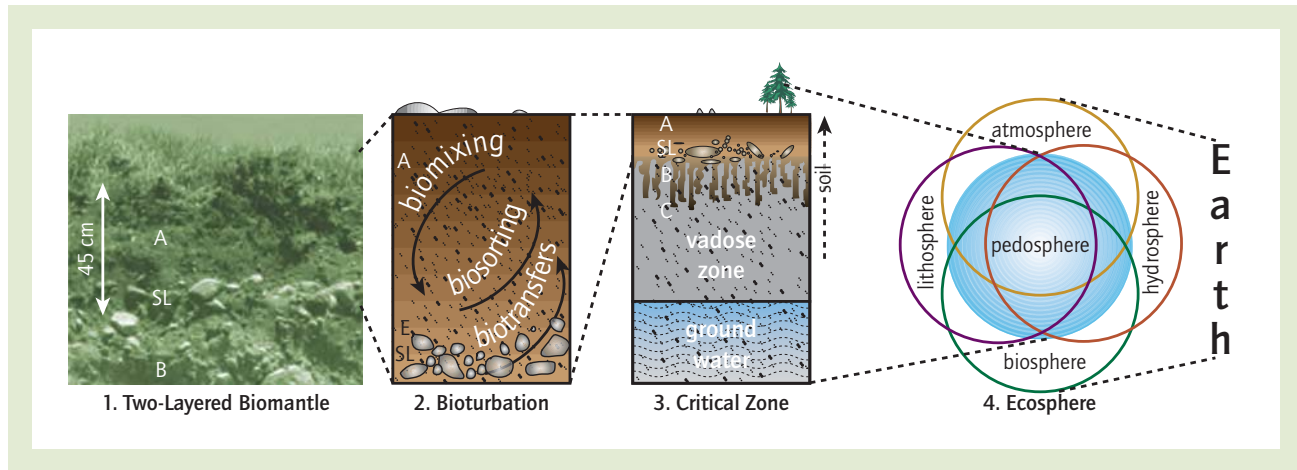


Figure 1 Photo of two-layered biomantle (45 centimeters thick) near Carmel, California, and its formation and place in soil, the critical zone, and the ecosphere

Source: Authors.

reassimilated. To this end, the soil biomantle functions variously as the global composting, mixing, sorting, particle comminuting, recycling, and nutrient-supplying epidermal layer of soil.

Animal bioturbations involve three main subprocesses: biomixing, biotransfers, and biosorting, as indicated in Figure 1. Now, depending on which organisms are doing the bioturbating and what soil particle sizes are present, either a one- or two-layered biomantle will be formed. Figure 1 illustrates how this process works.

In Figure 1, Part 1, A = topsoil, SL = stonelayer, and B = subsoil: (A + SL = biomantle) + B = soil. Part 2 shows major bioturbational subprocesses: A = topsoil, E = leached horizon, and SL = stonelayer (A + E + SL = biomantle). Part 3 shows soil in the upper vadose zone of Earth's critical zone: (A + B + SL = biomantle) + B + C = soil. Part 4 shows Earth's ecosphere, with its five great interacting subspheres.

Let us assume the dominant bioturbator in a given soil is a pocket gopher (*Geomyidae*), a small but supremely burrowing subterranean rodent endemic to North America (similar convergent burrowers in other families occupy five other continents). Let us also assume that the soil in which the animal lives contains coarse gravels. Now, because gopher burrows are about 4 to 6 centimeters in diameter, all larger particles (cobbles, human artifacts, boulders, etc.) will, as soil is bioturbationally removed from under them, settle downward under gravity. These coarse

gravels concentrate as a stonelayer at the base of the biomantle—the main zone of bioturbation. A biosorted, porous, two-layered gravelly biomantle thus results, which consists of an upper layer of fluffy, permeable, biomixed soil with small gravels that overlies an even more porous and permeable basal stonelayer, similar to the one displayed in Figure 1—which actually portrays just such a soil produced mainly by gophers. Conversely, if the soil in Figure 1 *lacked* gravels, or if the particles (including gravels and artifacts) were all *smaller* than the burrow diameters of pocket gophers, then the result would have been a fluffy, porous, biomixed one-layered biomantle (i.e., one *without* a basal stonelayer). If the dominant bioturbators were invertebrates such as ants, termites, and worms, as is typical in many humid temperate and tropical soils, and if the particle sizes were all small, such as sands and silts (no gravels), then a fluffy, biomixed, one-layered biomantle (i.e., without a basal stonelayer) would also result. But, if we litter the surface of soil with gravels (i.e., pebbles, cobbles, and artifacts), then wait for some years, decades, or millennia—a two-layered biomantle would result. Notably, the more porous and permeable stonelayer, which results from such animal biosorting, commonly functions as a French drain for soil-water throughflow.

Bioturbation in fact is what produces the abundant pore spaces, porosity, and permeability that is typical of biomantles. Interconnected pore



spaces, together with the basal stonelayer, function as an effective porous and permeable subsurface reservoir and aquifer for soil-water storage, transmission, and capillary movements. The biomantle thus plays a key process role in the dynamics of soil-water circulation in the Critical Zone as implied in Figure 1, and as embedded functions in the new subfield of hydropedology.

Thicknesses and Whole Soil Biomantles

In the midlatitudes and subtropics, the soil biomantle is relatively thin (± 1 –2 m) and includes the conventional A and E soil horizons, whereas in the tropics, the biomantle is often much thicker (± 2 –6 m) and may include other horizons. And as indicated, if soils are gravelly, a stonelayer invariably forms at, and defines, the biomantle base. Thus, if present, stonelayers of most midlatitude and some subtropical soils tend to lie at shallow depths (≤ 1 –2 m), whereas in most tropical and some subtropical soils, they generally occur more deeply (≥ 2 –6 m).

In some deserts and drylands of the world (e.g., Sahara, Atacama, Patagonia, Namib, Simpson, Taklamakan), where moisture is sparse or rare and weathering minimal or nonexistent and where both subsoil and underlying zone of weathering are absent, the biomantle constitutes the entire soil. Whole soil biomantles may be also observed, indeed are common, on moderately steep and very steep slopes of many mountainous areas where rates of erosion exceed those of weathering, but where a soil biomantle nevertheless is present.

Computer Animation

Using digital animation programs, computer models can now be constructed that demonstrate how bioturning, biotransfers, and biosortings interact to produce one- and two-layered biomantles. In one example that displays several predictive aspects of the soil biomantle model, a gravelly soil evolves under intense bioturbation into a two-layered biomantle, whose basal stonelayer accumulates cobbles, pebbles, plus human artifacts and other objects that were dropped on, or fell on, the soil surface in earlier times. Then, if the environment changes such that erosion exceeds the rates of bioturbation, the biomantle

gradually thins, until the stonelayer becomes exposed as a surface pavement.

Donald L. Johnson and Diana N. Johnson

See also **Biodiversity; Biogeochemical Cycles; Biogeography; Biota and Climate; Biota and Topography; Carbon Cycle; Ecosystems; Ecotone; Geomorphology; Peat; Soils; Species-Area Relationship**

Further Readings

- Darwin, C. (1881). *The formation of vegetable mould through the action of worms, with observations on their habits*. London/New York: J. Murray/Appleton. (Facsimiles produced in 1982 and 1985 by University of Chicago Press; available at <http://darwin-online.org.uk/content/frameset?itemID=F1357&viewtype=side&pageseq=1>)
- Demas, G. P., & Rabenhorst, M. C. (2001). Factors of subaqueous soil formation: A system of quantitative pedology for submerged environments. *Geoderma*, 102, 189–204.
- Dittmer, H. J. (1948). A comparative study of the number and length of roots produced in nineteen angiosperm species. *Botanical Gazette*, 109, 354–358.
- Domier, J., & Johnson, D. L. (2007). *Biomantle and soil thickness processes: Computer animation*. Retrieved October 1, 2009, from <https://netfiles.uiuc.edu/jdomier/www/temp/biomantle.html>
- Fey, M. V. (2009). *Soils of South Africa*. Singapore: Craft Printing International.
- Gold, T. (2001). *The deep hot biosphere*. New York: Copernicus Books.
- Hartog, C. den. (1970). *The sea-grasses of the world*. Amsterdam: North-Holland.
- Hole, F. D. (1981). Effects of animals on soils. *Geoderma*, 25, 75–112.
- Johnson, D. L. (1990). Biomantle evolution and the redistribution of earth materials and artifacts. *Soil Science*, 149, 84–102.
- Johnson, D. L., Ambrose, S. H., Bassett, T. J., Bowen, M. L., Crummey, D. E., Isaacson, J. S., et al. (1997). Meanings of environmental terms. *Journal of Environmental Quality*, 26, 581–589.
- Johnson, D. L., Domier, J. E. J., & Johnson, D. N. (2005). Animating the biodynamics of soil



thickness using process vector analysis: A dynamic denudation approach to soil formation.

Geomorphology, 67, 23–46.

Johnson, D. L., Maxwell, T. A., Haynes, C. V., Jr., & Johnson, D. N. (2007). Saharan biofabric: A

biomarker for planetary soils? *Geological Society of America, Abstracts With Programs*, 39(6), 126.

Kevan, D. K. M. (1962). *Soil animals*. London: H. F. & G. Witherby.

Lacey, E. A., Patton, J. L., & Cameron, G. N. (Eds.). (2000). *Life underground: The biology of subterranean rodents*. Chicago: University of Chicago Press.

Lin, H. S., Bouma, J., Wilding, L., Richardson, J., Kutilek, M., & Nielsen, D. (2005). *Advances in hydropedology: Advances in agronomy* (Vol. 85). San Diego, CA: Elsevier.

Margulis, L., & Schwartz, K. V. (1999). *Five kingdoms* (3rd ed.). New York: W. H. Freeman.

Morras, H., Moretti, L., Picolo, G., & Zech, W. (2009). Genesis of subtropical soils with stony horizons in NE Argentina: Autochthony and polygenesis. *Quaternary International*, 196, 137–159.

Nardi, J. B. (2003). *The world beneath our feet: A guide to life in the soil*. New York: Oxford University Press.

Nepstad, D. C., de Carvalho, C. R., Davidson, E. A., Jipp, P. H., Lefebvre, P. A., Negreiros, G. H., et al. (1994). The role of deep roots in the hydrological and carbon cycles of Amazonian forests and pastures. *Nature*, 372, 666–669.

Robinson, W. O. (1930). Changes occurring in submerged soils. *Soil Science*, 30, 197–217.

Russell, R. S. (1977). *Plant root systems*. New York: McGraw-Hill.

Schenk, H. J., & Jackson, R. B. (2002). Rooting depths, lateral root spreads and below-ground/above-ground allometries of plants in water-limited ecosystems. *Journal of Ecology*, 90, 480–494.

Soil Survey Division Staff. (1993). *Soil survey manual* (USDA Handbook No. 18). Washington, DC: U.S. Department of Agriculture.

Soil Survey Staff. (1999). *Soil taxonomy* (NRCS Handbook No. 436). Washington, DC: U.S. Department of Agriculture.

Van Breemen, N., & Buurman, P. (2002). *Soil formation* (2nd ed.). Dordrecht, Netherlands: Kluwer.



BIOTA AND TOPOGRAPHY

Biota and topography have always played an integral role in geographic approaches and studies. Biota (modern Latin, from Greek *biot*, “life”)—that is, living organisms of a particular region, habitat or geological period and in extension their influence on the physical environment—is explicitly taken into account in biogeography. Biogeography is a subdiscipline of geography that studies the spatial distributions of living organisms and the underlying causes for these differentiations. More recently, biota have been considered major agents contributing to the definition of the Earth’s surface topography by the geographic subdiscipline of biogeomorphology. Biogeomorphology is an emergent subdiscipline at the interface between ecology and geomorphology; it promotes the development of new interdisciplinary concepts and models better adapted to the study of topography as an outcome of complex interactions and feedbacks between biota and physical processes.

Topography (via late Latin from Greek *topographia*, from *topos*—“place”—and *graphia*—“writing”) characterizes the geometry of landscapes at diverse scales (e.g., plain, mountain, hill, coast, alluvial fan, dune, river channel, river bar). The geometry of landforms and their situation in space (e.g., spatial extension, roughness, altitude, inclination, orientation) at a given place and at a given moment translates and determines their functioning, relative to their physical, ecological, and anthropogenic components.

Topography: Definition by Substrate Cohesion and Physicochemical Agents

Earth surface topography is characterized by a substantial spatial heterogeneity at diverse spatiotemporal scales. Spatial and temporal distributions of topographic variations are not random. Landforms are dynamic features that result from self-organization processes of matter and energy, commonly revealing geometric and dynamic constants—or attractor domains—representing optimum physical solutions that minimize energy dissipation according to endogenous or exogenous morphogenetic forces (e.g., tectonics, gravity, water flow, wind). For this reason, specific



landforms are generally recognizable and can be distinguished from their surrounding environment—that is, from other landforms. It is possible to classify landforms based on their topography and complementary geomorphic characteristics such as sediment physicochemical properties. In many cases, the identification of the family of processes that are at work or, in the case of inherited landforms, were at the origin of the landforms and their topography, is also possible. Erosional and depositional landforms on the Earth surface can be perceived as a characteristic signature of a certain combination of interactions between the material (e.g., sediments, rocks, ice) and the physical constraints applied on it (e.g., tectonics, gravity, water flow, wind, frost, chemical alteration). However, topographic signatures vary greatly because of the many possibilities of combinations between the fundamental and basic morphostructures and processes. The high variability of topography on the Earth's surface is also related to the frequency, the magnitude, and the timing of the physical constraints (i.e., the disturbance regime and its historical pathways) that is applied on the material.

The three main components that together define the variety of topographic features need to be distinguished:

1. The material
2. The endogenous geothermal force that is at the origin of tectonics and the uplift of landscapes
3. The exogenetic weathering agents that induce sediment erosion, transportation, and deposition on Earth's surface

The first component—the material—defines landform cohesiveness, that is, the ability of the substrate to resist deformation or desegregation when a mechanical or a chemical constraint is applied. The second component—tectonics—produces the most important variations in topography on the Earth through uplifting and deforming rocks and landforms, generating heterogeneity in topography at the global scale. The third component—sediment erosion, transportation, and deposition—redistributes matter in space and produces characteristic topographic signatures through the dissipation of kinetic

energy associated with matter flows. For example, (a) wind produces dunes with a structural organization depending on a delicate balance between wind regime and sediment grain size; (b) water flow produces landforms such as hydrographic networks, rivers, or intertidal channels and alluvial fans (see alluvial bar photo); (c) gravity is at the origin of characteristic topographic signatures such as hill slopes, screes (accumulations of primarily angular clasts that lie at an angle of around 36° beneath exposed free rock faces or cliffs), solifluction lobes (tongue-shaped lobes that are the result of slow gravitational downslope movement of water saturated materials); and (d) frost and the freezing of water produce geometrical forms at the surface such as polygons delimited by stones.

Topography: Significant Control Through Biota

Geomorphologists recently identified biota as an additional major agent shaping topography at various spatiotemporal scales on the Earth surface. The influence of life is quite apparent over short timescales, for example, pedogenesis. Substrate erosion and stabilization and river and dune dynamics are controlled by living organisms that directly mediate chemical reactions, disintegrate rocks, modify soil structure, texture and cohesion, and indirectly control sediment dynamics by modifying flows of matter and kinetic energy. The effects of living organisms over geologic time affect the climate, which control exogenetic (pertaining to processes occurring at or near the surface of the Earth and to the landforms produced by such processes) Earth surface processes and topographic changes.

Since the beginning of the 1980s, biogeomorphology has provided an increasing number of studies demonstrating the importance of living organisms in driving or modulating Earth surface processes and landform dynamics. This relatively new field of investigation, which adds the biological dimension (i.e., the biological dynamics of single organisms, populations, or communities) to the exclusive consideration of chemical and physical geomorphic factors and agents, clearly led to conceptual improvements in geography through the explicit consideration of the structural and



Effect of vegetation on topography on an alluvial bar of the River Allier, France

Source: Authors.

functional linkages between biology, ecology, and geomorphology. Very recent conceptual developments in biogeomorphology pointed out that the main difference between biota—as a morphogenetic agent—and weathering and tectonics is related to life as an evolving (i.e., in the biological sense) force which may in many cases produce very characteristic adjusting topographic features.

The regions on the Earth where interactions between biota and topography may occur are restricted to the bioclimatic contexts that favor the development of life. Deserts and polar regions remain dominantly shaped by physical and chemical processes. In tropical, subtropical, and temperate climatic zones, biota may commonly play a major role in modulating micro- and macrotopography while the climatic conditions (temperature, humidity, solar radiation) for the development of biodiversity and biomass are optimized. However, a large range of different configurations exist,

encompassing particular bioclimatic contexts (e.g., within semiarid, Mediterranean, or alpine climatic regions) and very particular systems such as terrestrial-aquatic interfaces (e.g., fluvial and coastal systems), which concentrate flows of matter and energy and stimulate primary production through favorable environmental conditions (e.g., the availability of water and nutrients for plants). Influences of biota on topography can be significant from very local to regional scales and may vary significantly. Direct influences are observed when organisms dig or burrow galleries in soils or build mounds or other structures at topographic surfaces. Indirect influences occur through the modulation by living organisms of sediment erosion, transportation, and deposition produced by water flow or by wind. Biotic influences are autogenic when landforms and an associated topography are modified or created in situ through the organisms themselves as, for example, in the case of coral reefs.



Control of Topography Through Biota Since the Precambrian Era

Microorganisms such as cyanobacteria and microscopic algae were the first living organisms to significantly modulate the topography of Earth as early as 3,500 mya (million years ago), during the Precambrian era. Prokaryotic and eukaryotic organisms present in the oceans started to build large-scale reefs on continental margins, and they drastically modified the atmosphere's composition by producing in the long term huge quantities of oxygen. The mineral material exposed to geomorphic agents has adjusted its properties with the emergence of life. Two thirds of the known types of minerals on Earth are directly or indirectly linked to biological activity. This is a consequence of the oxygen-rich atmosphere of the Earth, which is the product of photosynthesis by microscopic algae in the oceans. The evolution of organisms with shells and mineralized skeletons also generated thick-layered deposits of minerals such as calcite, which would be very rare on a lifeless planet. The atmospheric change contributed to modify climate, encompassing carbon dioxide (CO_2) concentrations, temperature, and precipitation, which represent fundamental morphogenetic agents shaping the Earth surface topography. The first organisms that started to dig and burrow the substrate in the ocean about 542 mya, at the Proterozoic-Phanerozoic transition, also modified very significantly the microtopography via pellet production, track formation, and a variety of types of construction, for example, mounds and pits. These changes in ocean surface and subsurface microtopography had very important consequences on hydrodynamics—sedimentary and biochemical cycles. It oriented the evolution of life in the oceans and led to an important increase of biodiversity in the Cambrian era while habitat morphology and physicochemical properties started to diversify.

Plant Control of Topography on Continents

A fundamental step of the history of the influence of biota on topography on Earth is associated with the colonization of land by life—and especially plants—from the beginning of the Silurian era (470–430 mya). The first organisms, such as

bacteria, lichens, and then plants, which colonized terrestrial-aquatic interfaces, started to modulate topography by altering rocks and by modifying fine sediment dynamics. In particular, plants acted as a fundamental morphogenetic agent through the modification of substrate cohesion by roots and surface roughness with their canopies at terrestrial-aquatic interfaces between oceans and continents and within fluvial systems. Vegetation evolved from the Devonian to the Carboniferous (380–290 mya) and from small plants to complex ecosystems, dominated by trees with heights of 30 m. At the global scale, trees in particular contributed to directly modify the surface topography by their own structures—that is, trunk and canopies—which represent physical habitats for many other kinds of organisms such as insects, birds, and mammals. From the Devonian on, plants spread efficiently to the inside of continents; they colonized various bioclimatic and geomorphic systems and also contributed to modify topography by increasing rock alteration, soil formation, and sediment retention and trapping, at a global scale. Plants are considered as the main agent of direct creation and indirect modulation of topography on the Earth surface in various systems, encompassing terrestrial-aquatic interfaces, hill slopes, and sand dune systems. While vegetation developed strategies to colonize continents, it offered, through the biologic function of primary production and through facilitation processes associated with physical habitat modification, the possibility for microorganisms, insects, and animals to colonize lands and to spread into continents. Some of these organisms also contributed in varying proportions to modify and sometimes to create topography.

Control of Topography by Microorganisms, Insects, and Animals

Microorganisms act as an important morphogenetic agent on Earth's surface by altering or protecting rocks from erosion. Lichens may provide good protection against weathering agents; or, on the contrary, they may contribute to the acceleration of rock erosion. Insects also contribute to the modification of topography in different ecosystems and through diverse means. For example, termites build mounds, which



A typical North American beaver dam in Alaska. Beaver dams form ponds, wetlands, and meadows, which increase biodiversity and improve overall environmental quality.

Source: John J. Mosesso/NBII.gov.

directly modify topography and act as roughness elements in plains and fluvial corridors. Such roughness elements alter local infiltration rates and represent points for clastic and chemical sedimentation and coalescence. Termite mounds can initiate, in certain environmental contexts, for example, in the Okavango delta, the construction of islands by cumulative sediment and nutrient accretive processes. Pioneer shrubs and trees, which colonize these mounds, then contribute to the increase of transpiration. This causes calcite and silica to precipitate, eventually inducing vertical and lateral growth and island expansion.

Caddisfly larvae also contribute to significantly modify topography in streams by increasing the stability of fine channel bed sediment in many rivers, worldwide. Ants modify soil microtopography by digging galleries; these dynamics modify substrate properties and contribute to control water infiltration and erosion processes on large surfaces and in the long term.

Small and large animals also represent important morphogenetic agents on the Earth surface. For example, as already observed by Charles Darwin, earthworms deeply modify topography over very large scales through their activity of bioturbation contributing to soil formation. Earthworm activity contributes to the elevation of horizontal topographic surfaces on historical and geological timescales (10^1 to 10^4 years). Bioturbation also stimulates downslope creep and increases the susceptibility of soil to erosion. In the long term, this biological activity significantly contributes to smooth topography—to level hills and to fill up entire valleys. Crayfishes may also significantly modify topography in river channels by affecting gravel and/or sand structures and sediment transportation in stream channels. The net effects on below-ground topography of burrowing animals such as shrimps and crabs, at terrestrial-aquatic interfaces, and prairie dogs, tuco-tucos, and pocket gophers, in terrestrial contexts, are spatially extensive. In systems where bioturbation is frequent, animal transportation is a key process that determines the vertical structure and texture in the soil profile, the surface microroughness, and the resulting hydrodynamics associated to water flow and to wind. North American beavers induce very significant topographical changes in rivers. Beaver dams trap large quantities of sediment and maintain a complex mosaic of landforms. Entire North American valley floors have been raised many meters by beaver pond sediments. Even large animals such as alligators and the African elephant may induce very important topographic modifications in river channels by removing huge quantities of sediment. Large animals such as the antelope can also affect significantly slope dynamics in arid systems by trampling along preferential pathways across scarp slopes; this results in scarp recess and initiates cutback development.



Manhattan from the Empire State Building in New York City in 2008

Source: Steven K. Martin.

Control of Topography Through Human Activities at a Global Scale

Humans have become a keystone engineering species modifying both directly and indirectly topography from the microscale to the global scale. Human societies have directly modified Earth surface geomorphic patterns through land use practices since the Neolithic. The important modification of vegetation cover, in particular in temperate, subtropical, and tropical regions, led to drastic topographic changes because of the increase or the attenuation of hill slope erosion processes. This process is illustrated, for example, in the Mediterranean basin in which several ancient ports (e.g., Ephesus) are now disconnected from the sea. This phenomenon is explained by intensive erosion crises linked to the deforestation of entire Mediterranean catchments, having caused

massive sediment deposition within and several kilometers downstream of the ancient ports. Recent anthropogenic modifications of stream flow regimes and alterations of sediment transfer from production zones to oceans also induced important topographic changes within fluvial corridors and on coasts, generally associated with erosional landforms. Human infrastructures, encompassing towns and megalopolises, also directly and very significantly modified Earth's surface topography at regional scales. Concentration of buildings represents the most recent significant direct modification of surface topography on Earth's surface, which has enormous regional impacts on aerial hydrodynamics and microclimate (see New York City photo).

One of the most significant topographic changes at the global scale, indirectly associated with biota, may occur in the near future through



human activity that contributes to global warming and climate change. This change could be caused by modification of the frequency, intensity, and distribution of morphogenetic agents such as water flow and wind, induced by regional changes of precipitation and temperature regimes. Topographic changes will also be associated with the modifications of the structure and functioning of ecosystems caused by global change, for example, the loss of vegetation in some regions may have dramatic consequences on erosion and subsequent depositional processes.

Dov Corenblit and Johannes Steiger

See also **Biodiversity; Biogeochemical Cycles; Biogeography; Biota and Climate; Biota and Soils; Biota Migration and Dispersal; Carbon Cycle; Geomorphology; Human Dimensions of Global Environmental Change; Landforms; Species-Area Relationship**

Further Readings

- Butler, D. R. (1995). *Zoogeomorphology: Animals as geomorphic agents*. Cambridge, UK: Cambridge University Press.
- Carter, N. E. A., & Viles, H. A. (2005). Bioprotection explored: The story of a little known earth surface process. *Geomorphology*, 67, 273–281.
- Corenblit, D., Gurnell, A. M., Steiger, J., & Tabacchi, E. (2008). Reciprocal adjustments between landforms and living organisms: Extended geomorphic evolutionary insights. *Catena*, 73, 261–273.
- Darwin, C. (1881). *The formation of vegetated mould through the action of worms with observation of their habitats*. London: Murray.
- Dietrich, W. E., & Perron, J. T. (2006). The search for a topographic signature of life. *Nature*, 439, 411–418.
- Goudie, A. S. (1993). Human influence in geomorphology. *Geomorphology*, 7, 37–59.
- Goudie, A. S. (Ed.). (1994). *The encyclopedic dictionary of physical geography*. Oxford, UK: Blackwell.
- Hazen, R. M., Papineau, D., Bleeker, W., Downs, R. T., Ferry, J. M., McCoy, T. J., et al. (2008). Mineral evolution. *American Mineralogist*, 93, 1693–1720.

- Jones, C. G., Lawton, J. H., & Shachak, M. (1994). Organisms as ecosystem engineers. *Oikos*, 69, 373–386.
- Meysman, F. J. R., Middelburg, J. J., & Heip, C. H. R. (2006). Bioturbation: A fresh look at Darwin's last idea. *Trends in Ecology and Evolution*, 21, 688–695.
- Naylor, L. A., Viles, H. A., & Carter, N. E. A. (2002). Biogeomorphology revisited: Looking towards the future. *Geomorphology*, 47, 3–14.
- Phillips, J. D., & Lorz, C. (2008). Origins and implications of soil layering. *Earth-Science Reviews*, 89, 144–155.
- Taylor, T. N., & Taylor, E. L. (1993). *The biology and evolution of fossil plants*. Englewood Cliffs, NJ: Prentice Hall.
- Viles, H. A. (Ed.). (1988). *Biogeomorphology*. Oxford, UK: Blackwell.
- Viles, H. A., Naylor, L. A., Carter, N. E. A., & Chaput, D. (2008). Biogeomorphological disturbance regimes: Progress in linking ecological and geomorphological systems. *Earth Surface Processes and Landforms*, 33, 1419–1435.



BIOTA MIGRATION AND DISPERSAL

In general, migration and dispersal both refer to the movement of plants or animals over distances beyond their regular home range. Migration is typically seasonal, long distance, and repeated annually, such as the movement of birds between breeding and wintering grounds. Dispersal is more permanent, varies in distance, and is only done once or a limited number of times in the life of an organism. The timing, distance, and effects of movement are intrinsically linked to the habitat features being moved from, through, and to.

Animal migration takes an individual from one physical and ecological environment to another, typically, in search of resources or mates or in response to an environmental shift. The most common examples include birds that breed in northern latitudes during the Northern Hemisphere summer and then travel south toward or into the tropics before the weather turns cold



(e.g., Purple Martin, Mississippi Kite). Ungulates and other large mammals in the African savannas travel in enormous herds tracking water during the dry season, creating amazing spectacles of mass migration. Rather than seasonal, migration could take a lifetime to complete its cycle. Pacific salmon, for example, are born in freshwater streams, travel to sea for most of their lives, and then to their natal stream to spawn and then die. Migration can take two lifetimes. In some insect species, a parental generation migrates, reproduces, and dies, and the offspring return.

The triggers to initiate this movement behavior are often linked to either seasonal cues such as day length or resource availability such as access to water or food. Several species of migratory birds (e.g., the European quail and the white-crowned sparrow) have been shown to respond to circadian rhythms with changes of flight activity, suggesting day length as a cue for their seasonal migration. Insectivorous birds respond instead to a reduction in the abundance of insects as a cue for travel. If the target of the migration is finding a mate or mating, as in the case of the salmon, then the cue may be the reaching of sexual or hormonal maturity. In the case of the following resources, migration may be less structured and more nomadic, without return to the original area specifically. This type of movement is seen in the large mammals of the African savannas (e.g., the wildebeests and the zebras) as they follow the availability of water and forage.

As opposed to migration, dispersal is typically permanent and unidirectional. It is a phenomenon of both plants and animals and is the main mechanism for gene flow among populations. The dispersal process involves three somewhat distinct stages: (1) emigration, (2) transfer, and (3) settlement. Emigration, or departure from the predispersal area or group, often but not always, occurs at or near sexual maturity. Movement or transfer between sites or social groups, typically, involves travel through unsuitable or unavailable habitat that can include increased mortality risk. Finally, settlement or immigration in a secondary area or group may be as simple as haphazardly landing somewhere and surviving if it is suitable or sequentially investigating several areas and then choosing the most suitable. The dispersing individual can be entirely passive in this process, as

seeds are expelled from a parent plant and then carried on the wind. Or the individual could be entirely active, as are female birds that leave the parental nest and investigate the territories of several males before choosing one with whom to nest and mate.

Dispersal is further defined by the breeding experience of the dispersing individual. Natal dispersal is the movement of a propagule from the place of birth to the site of its first breeding, often engaged at or near the age of sexual maturity. Breeding dispersal is the movement of an individual between subsequent breeding sites and is somewhat less common. Some researchers further distinguish successful dispersal as resulting in successful breeding at the secondary site. In terms of monitoring gene flow and the effects of it on the fitness of populations, movement without breeding is inconsequential.

Primary hypotheses for the evolution of dispersal include avoidance of inbreeding depression, avoidance of kin competition, and response to habitat variability. In most vertebrate species, only one sex disperses while the other is philopatric (i.e., it remains in the natal area). This sexual dimorphism would effectively reduce the likelihood of inbreeding. The mating system of the species would then dictate which sex disperses. For example, in mammals, which are typically polygynous with males competing for females and females investing more parental care than males, males are expected to disperse and females are expected to be philopatric. However, whether this reduction in inbreeding was the selective force for the evolution of dispersal or a fortunate side benefit is debated. An alternate selective advantage of dispersal is the reduction in competition with kin for resources, including mates.

Habitat variability could also lead to selection for dispersal. In temporally or spatially variable habitats, the situation in which an individual is born is likely to either change (causing temporal variation) or be better elsewhere (causing spatial variation). Thus, the probability of finding an improved situation postdispersal would add selective advantage.

Both migratory and dispersal behavior appear to be under strong genetic control with plasticity that responds to environmental variation. The selective advantage of the behavior is suggested



by its risk. In almost all species in which it can be quantified, an increased risk of mortality is experienced during transition between sites. For this behavior to have persisted, the benefit must outweigh this cost.

Elizabeth R. Congdon

See also **Adaptive Radiation; Biodiversity; Biogeography; Biota and Climate; Biota and Soils; Biota and Topography; Climate Change; Extinctions; Human-Induced Invasion of Species; Species-Area Relationship**

Further Readings

Clobert, J., Danchin, E., Dhondt, A. A., & Nichols, J. D. (Eds.). (2001). *Dispersal*. Oxford, UK: Oxford University Press.

Cullock, J. M., & Kenward, R. E. (2002). *Dispersal ecology*. Malden, MA: Blackwell.

Dingle, H. (1996). *Migration: The biology of life on the move*. Oxford, UK: Oxford University Press.



BIOTECHNOLOGY AND ECOLOGICAL RISK

Since the late 1970s, advances in biotechnology have allowed for the unprecedented crossing of genes between species, and over the past decade many of these genetically modified organisms (GMOs) have been released into ecological systems. The environmental release of GMOs has taken place at landscape and test plot scales, predominately involving crop and tree varieties, although livestock and fish species have also been modified and are on the verge of commercialization in some countries. While GMOs mainly offer production benefits, it is largely accepted that biotechnology is still in its infancy and may cause unanticipated ecological risks, which requires further study that may be aided by the holistic discipline of geography.

The terminology regarding biotechnology and risk is controversial and confusing. Industry

often claims that biotechnology has existed for millennia and suggests that selective plant breeding is one example of this. More colloquially, the media and public usually equate biotechnology with recombinant DNA and transgenesis, which has created a breakdown in language among stakeholders regarding this technology. Academics have tried to introduce new terminology to differentiate between “traditional” (e.g., selective breeding) and “modern” (e.g., GMO crops) biotechnology, although its uptake has been met with mixed success. Similarly, the term *risk* is also contested and means different things to different stakeholders. Natural scientists define risk quantitatively as the “probability of harm” and use “risk assessment” to predict and avert potential problems that may be associated with GMOs. Social scientists define risk more broadly and use “risk analysis” to also include people’s risk perceptions in the evaluation of biotechnology. Indeed, that the language over biotechnology and risk is in dispute speaks to the larger controversy regarding the promise and peril of the technology itself.

Applications of Modern Biotechnology

Since the mid 1990s, “first generation” GMO crops such as corn, rice, soybean, and canola have been commercially available, and many farmers across the globe have adopted these varieties, which offer operational benefits predominately due to herbicide, insect, and pathogen resistance. “Second generation” crops that are supposed to offer end-user benefits are now being created and deployed, such as plants that contain nutritionally enhanced and pharmaceutical traits. The forestry industry has also developed herbicide, insect, and pathogen resistant trees, as well as varieties with low lignin content that makes processing easier. Various GMO animals have been developed, tested, and are nearing commercialization, such as “super fish” that have been modified for unregulated growth (which speeds rearing of market-size fish). While applications of modern biotechnology can offer benefits, many people argue that GMOs do not have biological antecedents and therefore may pose unique ecological risks.



Ecological Risk

The primary ecological concerns regarding the release and use of GMOs is that they might spread, become invasive, and harm nontarget organisms and biodiversity overall. Importantly, the degree to which a GMO may be considered an ecological risk depends on several factors, including the species, the introduced trait, the scale of release, and whether the organism is present in a natural or managed ecosystem. Although prerelease studies have identified possible ecological risks, society's understanding of this issue has been informed most by North America's commercialization of GMOs, particularly crops, which many observers consider a "living experiment."

Since commercialization, GMO crops in North America have spread in the environment through cross-pollination and direct seed movement, which has "contaminated" the non-GMO cultivars. Canadian farmers can no longer grow non-GMO canola because herbicide-tolerant (HT) varieties have outcrossed with conventional and organic seed supply. Similarly, GMO corn has escaped into non-GMO varieties and maize landraces in the United States and Mexico, respectively. That industry and regulators have been unable to effectively manage the spread of this genetic material indicates that gene escape happens, and therefore the "coexistence" between GMO and non-GMO crops will be difficult, if not impossible.

Another concern is that GMO crops might cross-pollinate with genetically related weed species and this may increase the fitness advantage and "invasiveness" of these plants. These so-called superweeds occur in very low frequencies and have yet to cause serious problems, although proper stewardship will be required to mitigate risk, especially in areas with genetic compatibility between crop and weed species. However, in agricultural fields, GMO crops that are HT have become problematic weeds, by shattering their seeds and growing in "volunteer" fashion in subsequent years. Studies show that HT volunteers are more costly and difficult to control, can become resistant to multiple herbicides (i.e., "trait-stacked") through cross-pollination with different HT crops, and may undermine soil-conserving farming practices that use herbicide instead of tillage to control weeds.

Despite the commercial use of GMO crops, few studies have investigated the long-term ecological risks associated with this technology. A major concern is that GMO crops will harm biodiversity, particularly nontarget organisms, and recent studies seem to confirm this. In 2003, U.K. scientists released the findings of the "Farm-Scale Evaluations," which were the first and only large-scale studies investigating HT crops and their overall impact on agricultural biodiversity. The studies found that HT canola and beet were too effective and by significantly reducing weeds also reduced nontarget weed-dependent arthropods. Scholars interpreting the findings believe that arthropod-dependent birds will also likely be reduced by the efficacy of these HT crops. Indeed, studies like this suggest that more research is required.

Geography and Holism

It must be emphasized that the ecological risks associated with GMOs cannot be generalized. This is why holistic research on this topic is important, and geography is an ideal discipline to achieve this. Both physical and human geography research on GMOs—from landscape mapping to stakeholder surveys—will continue to inform society regarding biotechnology and the ecological risks involved.

Ian J. Mauro

See also **Agricultural Biotechnology; Agrofoods; Biotechnology Industry; Environmental Impacts of Agriculture; European Green Movements; Genetically Modified Organisms (GMOs); Intergovernmental Environmental Organizations and Initiatives**

Further Readings

Conner, A. J., Glare, T. R., & Nap, J. P. (2003).

The release of genetically modified crops into the environment: Overview of ecological risk assessment. *Plant Journal*, 33, 19–46.

Mauro, I. J., & McLachlan, S. M. (2008). Farmer

knowledge and risk analysis: Postrelease evaluation of herbicide-tolerant canola in Western Canada. *Risk Analysis*, 28, 463–476.



BIOTECHNOLOGY INDUSTRY

Biotechnology may be defined as the application of molecular and cellular processes to solve social, scientific, and environmental problems, develop new products and services, or modify living organisms to carry desired traits. Arising after the discovery in 1973 of recombinant DNA, biotechnology has been a rapidly growing industry worldwide, with extensive linkages to agriculture, health care, energy, and environmental sciences. In 2005, the U.S. biotech industry (excluding medical equipment firms) consisted of roughly 1,500 firms that employed 400,000 people and generated \$64 billion in output. There is a wide range in the size of firms in this industry, including single proprietorships and firms of more than 500 employees; the mean national annual salary in the industry is \$62,500, which is well above the national average.

Pharmaceutical firms, which tend to be much larger than biotechnology companies, form the major market for biotechnology products. Large pharmaceutical firms are reliant on biotech clusters for innovative drug solutions, and human therapeutics thus account for the vast bulk of the biotechnology industry's revenues. Other applications are found in agriculture, manufacturing, and veterinary medicine. Many biotech firms enter into alliances with drug manufacturers, who may provide venture capital in return for marketing rights after the product is commercialized.

Venture capital is critical to making basic research in biotechnology commercially viable. Most small biotech firms lose money, given the high costs and the enormous amounts of research necessary to generate their output and the long lag between research and development (R&D) and commercial deployment (generally in the order of 12–15 years of preclinical development). Only 1 in 1,000 patented biotechnology innovations leads to a successful commercial product, and it may take 15 years. Venture capitalists may invest in many biotech firms, and one biotech firm may receive funding from several venture capitalists. Above all, venture capitalists look for an experienced management team when deciding in which companies they are willing to invest. Venture capitalists often provide advice and professional contacts and serve on the boards of directors of young biotech firms. As a biotech

firm survives and prospers, its relations with investors often become spatially attenuated—that is, venture capitalists gradually withdraw from day-to-day direct management.

There has been extensive state involvement in establishing biotechnology complexes since the industry began. Because of its rapid growth as well as its demonstrated and potential technological advances, many national science policies target it as a national growth sector. The survival and success of biotechnology firms is heavily affected by federal research funds, primarily through institutions such as the National Science Foundation and the National Institutes of Health. Other federal offices such as the Small Business Technology Transfer, Small Business Innovation Research, Environmental Protection Agency, and the Food and Drug Administration are also significant. Federal policies regarding patents and intellectual property rights, subsidies for medical research, and the national health care programs are all important. Roughly 83% of U.S. state and local economic development agencies have targeted the industry for industrial development. State-level determinants are also critical, including regulatory policies, educational systems, taxation, and subsidies.

Biotechnology firms tend to cluster in distinct districts, and place-based characteristics are essential for the industry's success in innovation. Europe, for example, hosts the BioValley Network situated among France, Germany, and Switzerland. In Britain, Cambridge has assumed this role. Similarly, Denmark and Sweden formed Medicon Valley. Geographically, the U.S. biotechnology industry is currently dominated by a small handful of cities, particularly Boston, San Diego, Los Angeles, San Francisco, New York, Philadelphia, Seattle, Raleigh-Durham, and Washington, D.C., which together account for three fourths of the nation's biotech firms and employment. All these cities have excellent universities with medical schools and state-of-the-art infrastructures (particularly fiber optics and airports) and offer an array of social and recreational environments (see Figure 1).

Biotechnology firms tend to agglomerate for several reasons. In an industry so heavily research intensive, the knowledge base is complex and rapidly expanding, expertise is dispersed, and innovation is to be found in networks of learning rather than individual firms. This observation is at



Figure 1 Geography of U.S. biotechnology centers. Like many knowledge-intensive sectors, biotechnology firms tend to concentrate in large metropolitan areas.

Source: Author.

odds with the popular misconception that such firms are the products of heroic individual entrepreneurs. In a highly competitive environment in which the key to success is the rate of new product formation, and in which patent protections lead to a “winner take all” scenario, the success of biotechnology firms is closely related to their strategic alliances with universities and pharmaceutical firms. Although many biotechnology firms engage in long-distance partnering, these tend to be complementary, not substitutes, for colocation in clusters where tacit knowledge is produced and circulated face-to-face, both on and off the job.

Because pools of specialized skills and a scientifically talented workforce are essential to the long process of research and development in biotechnology, an essential element defining the locational needs of biotech firms is the location of research universities and institutions and the associated supply of research scientists. Most founders of biotech companies are research scientists with

university positions. Regional human capital may be measured by examining the prevalence of bachelor’s degrees, which indicate a region’s educational attainment, and the location and size of regional universities that grant PhD degrees in biology and related fields. However, to a large extent, local labor shortages can be mitigated through in-migration. Because knowledge is generated and shared most efficiently within close loops of contact, the creation of localized pools of technical knowledge is highly dependent on the detailed divisions of labor and constant interactions of colleagues in different and related firms. Successful biotechnology firms often revolve around the presence of highly accomplished academic or scientific “stars,” with the requisite technical and scientific skills but also the vision and personality to market it. Often such individuals begin in academia and move into the private sector.

Barney Warf

See also **Agglomeration Economies; Agricultural Biotechnology; Biotechnology and Ecological Risk; Clusters; Economic Geography; Innovation, Geography of; Knowledge Spillovers; Research and Development, Geographies of**

Further Readings

- Cooke, P. (2004). The accelerating evolution of biotechnology clusters. *European Planning Studies*, 12, 915–920.
- Delaney, E. (1993). Technology search and firm bounds in biotechnology: New firms as agents of change. *Growth and Change*, 24, 206–228.
- Zucker, L., Darby, M., & Brewer, M. (1998). Intellectual human capital and the birth of U.S. biotechnology enterprises. *American Economic Review*, 88, 290–306.

BIRUNI (973–1048)

Abu ‘l-Rayhan Muhammad ibn Ahmad al-Biruni, one of the greatest Muslim astronomers, geographers, and scientists, was an advocate of empirical science and a practitioner of the experimental and comparative methods.

One of the most original and prolific medieval scientific writers in the natural sciences, al-Biruni was born in the city of Kat (now Biruni, in Uzbekistan), the ancient capital of Khorezm, south of the Aral Sea. Political history played an important role in his life and career. Biruni was a native speaker of the Khorezmian language (related to Persian), but the body of his work is in Arabic, including poetry; he also knew some Greek, Sogdian, Hebrew, and Syriac and learned Hindi and Sanskrit while residing in India. His early education was supervised by the learned emir of Khorezm, Abu Nasr Mansur ibn ‘Iraq al-Ja’di, an astronomer and mathematician. The young Biruni constructed astronomical instruments and globes, conducted astronomical observations to determine the ecliptic angles and coordinates of various towns in Khorezm, and described a solar eclipse. In the early 990s, war forced Biruni to flee

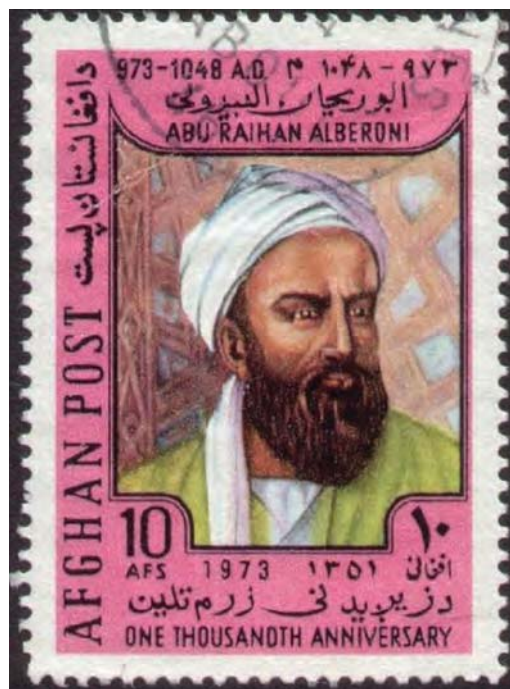


Image of Biruni from a 1973 stamp issued by Afghanistan

Source: Public domain.

to Rayy (near Tehran); in about 998, he moved to Gurgan (Jurjan), on the Caspian Sea, where his mentor was the Christian astronomer and physician Abu Sahl ‘Isa al-Masihi. In 997, he recorded in Kat an observation of a lunar eclipse for purposes of determination of the longitude. From Gurgan, Biruni engaged in correspondence with Abu ‘Ali Ibn Sina (Avicenna). During his stay in Gurgan, Biruni authored *Kitab al-athar al-baqiya* (*The Chronology of Ancient Nations*), the astronomical treatise *Spherics*, two books about the religious movement of the Qarmatians, and several works (now lost) on natural history, astronomy, and astrology. Altogether, Biruni is known to have authored, or have ascribed to him, about 150 works.

In 1004, Biruni returned to Khorezm, dividing his time between politics and science cultivated within the circle of scholars of “Al-Ma’mun’s Academy” at Urgench; this group included Avicenna and was named after the Khorezm-shah Abu ‘Ali Ma’mun (992–999). Astronomical observations conducted during this period formed the basis of Biruni’s theory of the solar motion; he also wrote a history of Khorezm. In the 1017



attack on Khorezm by the army of Sultan Mahmud of Ghazna, Biruni and his teacher Ibn 'Iraq were taken captive and taken to Ghazna, where he remained until his death in 1048. Biruni's appointment in Ghazna was as court astrologer; in Ghazna, Biruni composed some of his most significant works. In 1025, he completed *The Geodesy*, an astronomical-geodetic treatise *Kitab tahdid nihayat al-amakin li-tashih masafat al-masakin*, or *The Determination of the Coordinates of Positions for Corrections of Distances Between Cities*. In 1029, he finished *Kitab al-tafhim li-awa'il sina'at al-tanjim*, or *The Book of Instruction in the Elements of the Art of Astrology*, which contains 530 questions and answers related to astronomy, geography, chronology, and the theory of the astrolabe and goes considerably beyond the information required for astrological predictions.

From Ghazna, Biruni traveled to India, and in about 1030 he completed a monumental treatise, *Kitab Tahrir ma li'l-Hind min maqula maqbula fi'l-'aql aw mardhula*, sometimes called *Ta'rikh al-Hind* (*Alberuni's India*) or simply *India*. It contains vast and detailed historical, ethnographical, scientific, and cultural data and is distinguished by a remarkable lack of religious bias. In India, Biruni was able to measure degrees of latitude as well as determine the coordinates of many of the cities he visited. He learned about Indian astronomy and mathematics, translated several Sanskrit works into Arabic, and, in turn, translated into Sanskrit Euclid's *Elements*, Ptolemy's *Almagest*, and his own treatise on the astrolabe. Between 1035 and 1037, Biruni completed his major work, *al-Qanun al-Mas'udi fi hay'at wa-l-nujum*, or *Encyclopedia of Astronomical Sciences*, dedicated to his patron Mas'ud ibn Mahmud (1030–1040). This encyclopedic work contains the traditional (but expanded) astronomical tables compiled by his predecessors and a thorough discussion of theoretical questions of chronology, trigonometry, astronomy, and geography, with experimental arguments and mathematical proofs. Late in life, Biruni completed his *Kitab al-jamahir fi ma'rifat al-jawahir* (*The Book of Most Comprehensive Knowledge on Precious Stones*) and *Kitab al-saydana fi-l-tibb* (*Book of Pharmacology in Medical Science*).

Biruni is often called the most original and critical thinker among the medieval Muslim scholars, but sometimes his inclination to deal with empirical evidence as opposed to theoretical speculation is perceived as a limitation. In the field of geography, Biruni demonstrates both his empirical knowledge and his expertise in astronomy and mathematics. Mathematical geography is extensively treated in *Geodesy* and in Books IV to VI of the *Encyclopedia of Astronomical Sciences*. Among the questions discussed are the rotation of the Earth around its axis, determination of the latitude and longitude, the azimuth (especially of the *qibla*), the radius of the Earth, and the method and mistakes in measuring the degree of the meridian. These books also include material on chorography and physical geography, which are also dealt with in some of the questions and answers of the *Astrology* and in parts of *India*. In particular, he discussed the different methods behind different systems of dividing the inhabited world: nine parts, oriented to eight compass points with the center, in Indian geography; seven latitudinal climates in Greek geography; and seven round *kishwars* in the Persian tradition. Biruni, however, did not limit the human habitation to the Inhabited Quarter alone but discussed the climate effect of the extreme north and equatorial south and argued (against the prevailing medieval views) that south of the equator cultivation was possible and winter corresponded to the summer of the Northern Hemisphere. Against the prevalent views of geographers of his day, he also argued that Africa could be circumnavigated and that the Indian Ocean could be connected with the Atlantic Ocean. However, it was largely Biruni's factual, hydrographic, and astronomical data that were taken up by later geographers such as Yaqut, al-Qazwini, and Abu 'l-Fida' and the historian al-Maqrizi. Biruni was not well-known in the Arab World, and his original geographical ideas and the theory of cartographic projection were overlooked and only rediscovered by European scholars in the 19th century.

Marina A. Tolmacheva

See also al-Idrisi; Human Geography, History of; Ibn Battuta; Ibn Khaldūn



Further Readings

- Biruni, A. (1993). *Alberuni's India: An account of the religion, philosophy, literature, geography, chronology, astronomy, customs, laws and astrology of India, about AD 1030* (E. Sachau, Trans., 2 vols.). London: W. W. Norton. (Original work published 1888)
- Kamiar, M. (2006). *A bio-bibliography for Biruni: Abu Raihan Mohammad Ibn Ahmad (973–1053 C.E.)*. Lanham, MD: Scarecrow Press.
- Kamiar, M. (2009). *Brilliant Biruni: Life story of a genius Abu Rayhan Mohammad Ibn Ahmad Al-Biruni*. Lanham, MD: Scarecrow Press.
- Kazmi, H. (1995). *The makers of medieval Muslim geography: Alberuni*. New Delhi, India: Renaissance.



BLAIKIE, PIERS (1942–)

Piers Macleod Blaikie, professor emeritus at the School of International Studies at the University of East Anglia, has been one of the principal voices in political ecology (PE) from its inception, providing decades of pathbreaking thinking, research, and writing. Blaikie received his geography degrees from Cambridge University, was assigned to the department of geography at the University of Reading (1968–1972), and then moved to East Anglia, where he remained for 33 years in the School of Development Studies (now the School of International Development). He conducted his PhD dissertation research in northwestern India from 1966 to 1970 on the spatial organization of agriculture and consolidation of landholdings in north Indian villages. He followed this with research on the family planning program in northeast India from 1971 to 1973, with a subsequent long stretch of work in Nepal writing on underdevelopment and center-periphery theory. He reported his fieldwork in three coauthored books: *Crisis in Nepal*, *Peasants and Workers in Nepal*, and *Struggle for Basic Needs in Nepal*. Through consultancies and research, he continued to work in India and Nepal for more than 40 years, and in the Himalayas more generally, including Pakistan, Bhutan, and China. He

has also worked in Morocco and many of the countries of Central and Southern Africa.

Blaikie visited the United States as a guest professor often—at Clark, UCLA (University of California, Los Angeles) twice, UC Berkeley, and the University of Hawaii twice. He has also lectured at Harvard's Institute for International Development and the University of Wisconsin, Madison. He was also a visiting professor at Australian National University and the Norwegian University of Science and Technology.

In 1985, Blaikie wrote *The Political Economy of Soil Erosion in Developing Countries*, and subsequently coauthored *Land Degradation and Society* with Harold Brookfield. These two texts were foundational in the rising subdiscipline of political ecology, particularly the first book. He continued with political ecology into the 1990s and also with several other research projects, including AIDS in Africa, with significant fieldwork in Uganda. In 1994, he coauthored *At Risk*, which, now in its second edition, is widely used in university courses as well as by policymakers and practitioners and has been translated into several languages. He then moved into the politics of environmental policy, and from this perspective, he produced numerous articles and a book, *Policy in High Places*. In the late 1990s, he wrote a series of review articles on PE and development, most notably in *Zeitschrift*, and *Environment and Planning A*. In 2006, Blaikie researched, with Oliver Springate-Baginski, the “political ecology” of forestry, justice, and tribal rights in India and Nepal. Since 2003, he has collaborated in an ongoing multicountry study on comparative environmental policy in the Himalayan region, including work in China. This project focuses on the translation of environmental policy from international to national to local scales with transformations of meaning and practice throughout, adopting a new policy analysis methodology to investigate the relative efficacy of participatory and “crisis”-legitimated “fortress” approaches to biodiversity conservation in terms of environmental outcomes, social marginalization, and poverty alleviation.

Joshua Muldavin

See also **Political Ecology; Soil Degradation; Soil Depletion; Soil Erosion; Underdevelopment**



Further Readings

- Blaikie, P. M. (1985). *The political economy of soil erosion in developing countries*. London: Longman.
- Blaikie, P. M., & Brookfield, H. (1991). *Land degradation and society* (New ed.). London: Routledge.
- Blaikie, P. M., & Muldavin, J. (2004). Upstream, downstream, China, India: The politics of the environment in the Himalayan region. *Annals of Association of American Geographers*, 94, 522–548.
- Muldavin, J. (Ed.). (2008). Piers Blaikie's life work and his influence on political ecology, development studies, and policy [Special issue]. *Geoforum*, 39(2).
- Springate-Baginski, O., & Blaikie, P. M. (Eds.). (2007). *Forests, people and power*. London: Earthscan.
- Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: Natural hazards, people's vulnerability and disasters* (2nd ed.). London: Routledge.

BLAUT, JAMES (1927–2000)

James M. “Jim” Blaut was a teacher, researcher, and political activist, whose work powerfully shaped geographers’ understandings of several topics, particularly colonialism and Eurocentrism as well as the spatial cognition of children.

Blaut was born in New York City and completed his undergraduate studies at the University of Chicago. He did postgraduate work at the Imperial School of Tropical Agriculture in Trinidad and subsequently completed his PhD in geography and anthropology at Louisiana State University under the cultural geographer Fred Kniffen, with a dissertation on the microgeography of one acre in Singapore. Blaut went on to teach at Yale and Cornell and was director of the Caribbean Research Institute at the College of the Virgin Islands and a consultant to the government of Venezuela.

Blaut arrived at Clark University in 1966. There, he began the extraordinarily multifaceted second phase of his career, during which he

straddled geography, anthropology, psychology, and other fields, combining activism with academic research on imperialism, social justice, and early-childhood learning (the last stemming in part from his experience as a pilot and resulting in the later *Place Perception Research Reports*). He was one of the founders of *Antipode*, the first major journal of radical geography, and along with his wife and daughter, America and Gini Blaut Sorrentini, was active in Puerto Rican social, cultural, and political movements, both on the Island and in the Chicago area. He also participated in experiments in alternative education such as the “Miniversity,” founded in Massachusetts in 1971.

After becoming a “Clark legend” during the tumultuous late 1960s, Blaut moved to the University of Illinois at Chicago in 1971, where his critiques of environmental determinism, colonialism, and imperialism flowered in many articles and his books, *The National Question: Decolonizing the Theory of Nationalism* in 1987 and *Fourteen Ninety-Two: The Debate on Colonialism, Eurocentrism, and History* in 1992. In the mid 1990s, he resumed his critical evaluation of conventional wisdom regarding children’s early development of spatial cognition, under grants from the National Science Foundation.

It was in Chicago, too, that Blaut became known as a supporter of the downtrodden, associated with student movements of ethnic minorities: Latinos, African Americans, and Palestinians among others. While continuing to work on map learning in very young children, resulting in seminal articles in the *Annals of the Association of American Geographers* and *Transactions of the Institute of British Geographers*, Blaut began writing a series of three books that became the capstone of his career. *The Colonizer’s Model of the World* appeared in 1991 and *Eight Eurocentric Historians* in 2000. He was at work on the third volume in the series, titled *Decolonizing the Past*, at the time of his death in 2000.

Blaut received several honors throughout his career, including Distinguished Scholar of the Year in 1997 from the Association of American Geographers and Distinguished Professor from the Latino student organizations and Rafael CINTRON Ortiz Latino Cultural Center of the University of Illinois. James Blaut will be remembered as



one of geography's most outspoken iconoclasts and one of its most colorful characters.

David Stea

See also **Colonialism; Eurocentrism; Orientalism; Radical Geography**

Further Readings

- Blaut, J. (1991). *The colonizer's model of the world: Geographical diffusionism and Eurocentric history*. New York: Guilford Press.
- Blaut, J. (2000). *Eight Eurocentric historians*. New York: Guilford Press.



BLINDNESS AND GEOGRAPHY

In both the public imagination and in geographic practice, we commonly conceive of space in visual terms, symptomatic of a prevailing visual bias in our culture. But what of the spatial experiences of the blind and visually impaired? Do we have to rethink access to spaces, navigation processes and techniques, and mobility? How does this affect our view of what geography is, given that there is research not only on blindness and visual impairment but also research conducted by blind geographers themselves? The question of blindness and geography, while sharing the concerns of geographies of disability, poses some specific spatial considerations, and this entry provides a brief overview, focusing on research conducted on visually impaired people's experiences of space and on the work of blind geographer Reginald Golledge.

In the 1980s, some notable research on blindness was conducted within so-called humanistic geography from a fairly poetic and philosophical perspective, attempting to empathize with the spatial imagination of blind respondents. In the absence of sight, the nonvisual senses were conceived as reaching out to the world and drawing the subject closer to it, and particular attention was paid to the acoustic production of space. A decade later, blind and visually impaired people's experiences of public space were researched in two

British cities with a more conventional social science methodology. From their interviews, one feature common to most blind and visually impaired respondents was the importance of the nonvisual senses, especially touch and hearing, in their negotiations within, and navigation around, those cities. Nonvisual spatial navigation underpinned their sense of independence and daily routines, such as shopping and walking around the streets for everyday tasks. From this data, the researchers identified three factors that influenced the social experience of visually impaired people in public space. First, the social significance accorded to bodily "normality" (i.e., what counts as "normal" in terms of bodily appearance and styles of movement, with cane or guide dog); second, the fear of physical or sensory impairments by the public at large; and third, a general ignorance of the capabilities of visually impaired people (e.g., crossing the road, catching a bus) by the public.

The policy implications of such geographical research are clear. Design of the built environment, such as urban walkways, squares, and buildings, determines the mobility and accessibility of the disabled to these spaces and contributes to senses of inclusion or exclusion by the blind and visually impaired, as a result. The blind geographer Reginald Golledge put this into perspective when discussing the ways to achieve "spatial competence." Golledge had a firsthand grasp of the practical challenges that disabled people must face every day, and over the years he has helped develop navigational aids for the visually impaired, including tactile maps, which model an area through three-dimensional tactile relief rather than two-dimensional visual display. Such aids are important because many blind or visually impaired people are afraid of unfamiliar environments. On the one hand, there are real anxieties about leaving the familiar spatial context of the home as street furniture (e.g., skips, dustbins, lampposts), badly parked cars, or unthinking people pose continual obstacles in their path. However, staying at home limits integration and participation within the larger cultural life. On the other hand, there is a greatly felt need for independence and mobility. Spatial navigation through the city is difficult at the best of times and should be achievable independently. So navigational aids, the design of the built environment,



Dr. Reginald Golledge (1937–2009), a behavioral geographer and a member of the department of geography at the University of California at Santa Barbara, is seen here using a navigation system for the visually impaired that uses virtual environment technology. He and his colleagues developed a GPS (global positioning system)-based Personal Guidance System with a haptic pointer interface. The device uses GPS to track an individual as he or she moves through the real world, recording the trip as a trace in a spatial database (digital map) carried in a wearable computer. Geographic information system (GIS) functionalities calculate shortest paths between current location (fixed by the GPS) and a given destination (keyboarded or spoken). With the haptic pointer interface, the user holds a small wand-shaped object in the hand to which is attached an electronic compass, which monitors the pointing direction of the hand. While the user points the hand roughly in the direction of a waypoint or point of interest, the computer sends either beeping tones or synthesized speech to a small speaker worn near the user's shoulder. Thus, the user can localize a waypoint or point of interest by turning the hand until hearing the audible signals and then orienting the body and proceeding in that direction.

Side view: Guidance System with Haptic Pointer Interface. This figure includes half of the latest system, which includes the GPS receiver and antenna carried in a small shoulder bag, together with the head-mounted electronic compass and stereo headphones.

Front view: Personal Guidance System with haptic pointer interface. This shows the other half of the equipment, including the portable computer, the Haptic Pointer Interface, stereo headphones and head-mounted electronic compass, and the microphone for speech interface.

Source: Photos courtesy of Dr. Reginald Golledge.

and the understanding of the public at large are all crucial in enabling this independence and mobility within public spaces.

Mark Paterson

See also Body, Geography of; Difference, Geographies of; Disability, Geography of; Golledge, Reginald; Health and Health Care, Geography of; Social Geography; Spatial Cognition; Vision and Geography; Wayfinding



Further Readings

- Butler, R., & Bowlby, S. (1997). Bodies and spaces: An exploration of disabled people's experiences of public space. *Environment and Planning D: Society and Space*, 15(4), 411–433.
- Golledge, R. (1993). Geography and the disabled: A survey with special reference to vision impaired and blind populations. *Transactions of the Institute of British Geographers*, 18(1), 63–85.



BODY, GEOGRAPHY OF

The Cartesian dualism between mind (associated with reason and masculinity) and body (associated with passion and femininity) had an immense impact also in geographical thinking and research. The mind is favored over the body because it is the mind that distinguishes human beings from animals and machines. This idea led to an Othering of the body that favored mental issues over corporeal issues, excluding from the geographical agenda those areas of research that explicitly focused on the “dirty”—that is, the corporeal side of life as present in questions of disability, gender, age, poverty, or “race.” However, despite being erased from explicit scientific theorization, the body existed implicitly as an “absent presence.” That is to say, the emphasis on the mind needed some sort of contrast to tacitly delimit from. Thus, although unmentioned, the body was part of the constitution of the self. However, only a specific body—the male, white, able-bodied, and spatially and temporally unbound body—was tacitly addressed, creating something like a “mind body” that again reinforced the mind-body dualism. The disabled, female, old, poor, or black body hardly ever appeared on geography's center stage.

Traditional Geographical View

Depending on the geographical school of thought, the body has been discussed in a variety of ways. Generally, geographical discussions prior to the 1990s broached the issue of the body mostly implicitly.

In the wake of the social movements of the 1960s, for example, Marxist geography critically

discussed social development, condemning discrimination and inappropriate health standards. Nonetheless, scientists mostly concentrated on the cognitive side of the appropriation of space. The body took the form of a neglectable, transparent container. Typically, the body appeared as a point or line on a map. This was also true for medical geography up to the mid 1990s, which did not focus on the daily struggles of ill or disabled people but solely on the body as a carrier of viruses and illnesses. The outcome of such research was usually a map indicating the spread of certain illnesses. Similarly, applied geography like urban planning in the 1960s/1970s was said to “think fleshless,” that is, it disregarded the body and its significance. Bodily needs were ignored, with efficient, abstract planning preferred.

Another variation of the body as Other was provided by the phenomenologically inspired humanistic geography of the 1970s and behavioral geography of the 1980s. While the well-known humanistic geographer Yi-Fu Tuan came to acknowledge the body's vital role in being in the world, most humanistic geographers restricted the meaning of the body solely to spatial perception and cognition. The attempt to develop a theory of the bodily mediated lifeworld was one step toward the recognition of the body as a central geographical protagonist.

Similarly, Torsten Hägerstrand's time-geography of the 1970s announced its intention to incorporate bodily needs and constraints into geographical thinking. However, he left the body itself undertheorized, treating it as the tip of a pencil leaving a path in space. The door to a more explicit discussion of the body nevertheless gradually opened.

The Body as Same

A number of social scientists have tried to oppose the Othering of the body and treat the body as a vital variable of social life. They argue that the body is central to knowledge, social relations, personal identity, and the notion of space. Particularly, feminist, structuralist, and ethnomethodological accounts have emphasized the significance of embodiment. All three approaches have been taken up by human geographers. The significant rush of studies on the body took place in the 1990s with the bodily (somatic/corporeal) turn.



Feminist Accounts

Feminist critics, with Judith Butler as a leading figure (and in the wake of Simone de Beauvoir), are among the first to initiate critical debate about the body in modern society. They raise the reasonable objection that gender—and thus also other bodily mediated categories such as “race,” age, or disability—is a socially constructed phenomenon. Taking the social constructiveness as a starting point, feminists argue that categories such as gender are not “natural,” given classifications but rather constantly brought into existence. The focus lies on the gendered body. Feminist geographical research examines how the body and space are gendered, (re)producing social inequalities. Embodiment is thus understood as the site of reproduction of broader societal differences—that is, as embodied sociospatial dissent. They examine how space is gendered, producing social inequalities.

Drawing on Judith Butler and Pierre Bourdieu, the feminist geographer Louise Holt lately tried to rehabilitate the potential of social capital, or more concretely, embodied social capital. The body is believed to function as the bearer of symbolic value (e.g., “beauty” or “ugliness”) that can be converted into other forms of capital (mostly economic, e.g., better/lesser job opportunities).

The Poststructuralist Account

Poststructurally informed theorists, drawing on the works of Michel Foucault, examine the discursive body and argue that bodies are made and controlled by discourses (i.e., entirely of what is said and thought in a particular society at a particular time, including culture-specific categories, ideas, knowledge, or interpretation schemes) that define what is normal and what is not. Poststructuralist analyses examine the linkages between power and knowledge. In this context, the body is regarded as a micro version of society as a whole. Ascribed social roles, gender, and age relations are literally and metaphorically inscribed into the body. Geographical research concentrates on how regulatory practices mediate and (re)produce identity and space. This view includes, for example, new medical geography and studies on the construction of (dis)ability as well as postcolonial

analysis about the power relations expressed in Western geographical writings about the oriental/African “exoticism” of the foreign, black, mysterious body.

The Ethnomethodological Account

In general, ethnomethodology encompasses a large analytical field. In the context of the bodily turn, ethnomethodologists or symbolic interactionists such as Erving Goffman, who focus on the meaning of the dramaturgic body in face-to-face interaction rituals, become especially important. Here, the body is seen as an integral part of human agency. This is best grasped by the theater metaphor: Embodied social roles are understood as intentionally deployed social masks that serve as a means of self-presentation. Bodily co-presence then becomes a basal constituent of a momentary situation. This transient context is preferred over a discussion of the broader social and historical setting. Geographical discussion of Goffman includes studies of encounters in front and back regions or, associated with it, the public and private spheres.

The Performative Turn

The performative turn transfers the feminists’ idea of gender as socially constructed to other social categories and areas of life. While the bodily turn brought the body into critical geographic discussion, the performative turn dynamizes it. The idea was to overcome a geography of the Other and to establish another, embodied geography. Vital to this new geography is the concept of performance. Most fundamentally, performance denotes every embodied action that is shown in front of someone. The notion of performance also alters the notion of space as, from a performative viewpoint, neither identity nor space preexist its performance. Thus, space can no longer be conceptualized as a clear-cut given materiality. So far, geographic research includes the performance of gender, (dis)ability, national identity or politicized identity, citizenship, sense of belonging, consumption, or pregnancy. None of these categories is regarded as a given classification but as constantly brought into existence—that is, performed. The move toward performance also expresses a growing dissatisfaction with the traditional social



sciences. The new focus on live action and mundane bodily practices should therefore also counteract the static text/discourse analyses.

One theory that explicitly advocates performance and opposes discourse analysis is nonrepresentational theory. Like Goffman, Nigel Thrift uses the theater metaphor. Unlike Goffman, he explicitly denies intentionality and human agency in bodily performance. The key significance of nonrepresentational theory is its assertive step from representation to performance—that is, from text to practice. Thus, a form of microgeography is promoted that sounds out the specific (idiographic) everyday doings of ordinary people. Consequently, preconscious, prediscursive performances, as expressed in habitual practices and tacit knowledge, stand on the geographical research agenda. Performance is conceptualized as a free-floating venture. Critiques leveled at Thrift target the neglect of the historical and geographical context of action. Thus, critics maintain that old dichotomies between mind and body (thought and action) are reiterated only with inverted signs disqualifying the notion of intentional action (agency) and historical and geographical embeddedness. A more appropriate geography should therefore acknowledge the performance of space within historical and regulatory contexts.

Methodology After the Performative Turn

In the wake of the performative turn, feminist scholars illuminated the conditions of knowledge production. They introduced the idea of situated knowledge—that is, recognizing that the mutual performative constitution of gender, class, “race,” sexuality, and so on profoundly affects the production of knowledge. In sexualized Cartesian dualism, the power to transcend the “irrational” constraints of human embodiment and produce universal knowledge is ascribed only to men; women are said to be irretrievably bound to their bodies. Accordingly, the traditional master subject in geography is implicitly the white, able-bodied man, whose mind is suspended above time and space; the types of knowledge produced, typically held to be objective and scientific, are omnipotent and omnipresent. Feminist geographers such as Gillian Rose have criticized this notion as presumptuous, arguing that knowledge is always embodied and never universal. This

notion holds for social thought but also for scientific knowledge. Researchers have to concede that they are positioned, situated somewhere.

In addition, empirical research is conceptualized as research performance that constitutes and connects the researcher and the researched. Such an understanding redirects the potential “outcome” of research, like interviews, from mere data acquisition (e.g., interview transcripts) to the interactive process of interviewing (i.e., bodily co-presence and feelings of the interview participants) itself. Consequently, critical geographers call for a complexity turn, fostering “messy methods” that stand up to one-sided causal schemata in acknowledging contingency, uncertainty, and creativity of everyday performances.

This change also requires a self-reflective attitude from the researcher. Feminist and other critical geographers call for reflexivity as a strategy for marking geographical knowledge as situated. Nicky Gregson and Gilian Rose object that the intention—or better, illusion—to deliver something like a “transparent reflexivity” (being able to consciously unveil all inner and outer research influences) requires exactly that kind of omnipotent knowledge that is to be overcome if the claim for positionality is to be taken seriously.

Dana Sprunk

See also Behavioral Geography; Blindness and Geography; Disability, Geography and; Everyday Life, Geography and; Feminist Geographies; Gays and Lesbians, Geography and/of; Identity, Geography and; Masculinities and Geography; Nonrepresentational Theory; Other/Otherness; Positionality; Queer Theory; Sexuality, Geography and/of; Situated Knowledge; Structuration Theory; Thrift, Nigel; Time-Geography

Further Readings

- Gregson, N., & Rose, G. (2000). Taking Butler elsewhere: Performativities, spatialities and subjectivities. *Environment and Planning D: Society and Space*, 18, 433–452.
- Holt, L. (2008). Embodied social capital and geographic perspectives: Performing the habitus. *Progress in Human Geography*, 32, 227–246.

- Longhurst, R. (1997). (Dis)embodied geographies. *Progress in Human Geography*, 21, 486–501.
- Nash, C. (2000). Performativity in practice: Some recent work in cultural geography. *Progress in Human Geography*, 24, 653–664.
- Rose, G. (1993). *Feminism and geography: The limits of geographical knowledge*. Cambridge, UK: Polity Press.
- Shilling, C. (2003). *The body and social theory*. London: Sage.
- Thrift, N. (2007). *Non-representational theory: Space, politics, affect*. London: Routledge.



BORDERLANDS

The term *border*, although still used as a synonym for boundary, implies interaction and passage between political regions (primarily states). Even though nearly all international

boundaries regulate—if not restrict—the passage of people, goods, and communications, a boundary cannot erase the common concerns of bordering populations. Those areas whose populations are most strongly affected by boundaries are termed *borderlands* (or border regions). Borderlands exist because families, ethnic groups, businesses, and social networks straddling the boundary gain from overcoming political segregation.

The dimensions of borderlands are rarely defined because regions are determined by the degree of interaction and are therefore both in flux and indefinite. When governments specify a borderlands region, as the United States and Mexico did in the 1983 La Paz Agreement, it is for administrative purposes. Changes in migration across a border, expansion of trade opportunities, or development of communications networks can expand the cross-border social and economic networks, plus the extent of the borderland. The degree of cross-border interaction



A small fence separates the densely populated Tijuana, Mexico (*right*), from the United States in the Border Patrol's San Diego Sector.

Source: Sgt. 1st Class Gordon Hyde.



is not necessarily symmetric; for example, exchanges along the U.S./Canada borderlands are far more influential to Canada than to the United States.

Many borderlands result from superimposition—international boundaries established without regard for local ethnic societies and consequently dividing them between states (e.g., the division of Africa by European states at the Berlin Conference of 1884–1885). In these cases, social and economic networks precede the boundaries, as in the case of the Hutus, Kurds, Basques, and numerous other ethnic societies. Often, these borderlands are seen as threats to state sovereignty as political loyalties remain to regional ethnic groups. (Not all ethnic borderlands are the result of superimposed boundaries; decades of migration across the southern border of the United States have also formed one.)

Other borderlands are generated by interactions between the societies of adjacent states. Globalization processes have increased the ease with which members of different states have been able to interact with each other; social networks have followed. Proximity also increases the likelihood of economic interaction since economies of scale and decreased transaction costs result from treating a borderland as a single unit. In addition, shared environments can generate shared concerns, generating cross-border collaboration. Along the Western United States/Canada border, the members of Cascadia (British Columbia, Washington, and Oregon) share economic, ecological, and social concerns.

Not all boundaries accommodate a functioning borderland even where potential linkages exist. North Korea and South Korea share a common history, but political factors have overruled both ethnicity and economics. For most of the world, however, increasing interaction and collaboration will continue to develop existing borderlands as well as to generate more.

Peter Meserve

See also *Borders and Boundaries; Cross-Border Cooperation; Deterritorialization and Reterritorialization; Frontiers; Globalization; Nationalism; State; Transnationalism*

Further Readings

- Donnan, H., & Thomas, W. (2001). *Borders: Frontiers of identity, nation and state*. New York: Berg.
- Gibbins, R. (2005). Meaning and significance of the Canadian-American border. In P. Ganster & D. Lorey (Eds.), *Borders and border politics in a globalizing world* (pp. 151–167). Oxford, UK: SR Books.
- Hansen, N. (1981). *The border economy: Regional development in the Southwest*. Austin: University of Texas Press.
- Rumley, D., & Minghi, J. (Eds.). (1991). *The geography of border landscapes*. London: Routledge.



BORDERS AND BOUNDARIES

Boundaries and borders signify limits or discontinuities in space. While they are most often encountered today in their political meaning as territorial lines of division, the terms can be applied in a range of situations such as cultural (i.e., language), economic (i.e., class), or legal (i.e., property) contexts. Typically, there is no distinction between the terms *boundary* and *border* in everyday language. Specifically, many authors use *border* to designate the formal political division line between territorial units, such as states, and *boundary* to signify the cultural and social group difference that may or may not be marked on the ground by division lines.

In a geographical sense, boundary and border making is about marking difference in space and is closely associated with notions of identity and power. The erection of spatial borders and boundaries amounts to the territorialization of differences between human groups, thus using territory to determine who belongs where and who is and who is not a member of the group. This can be interpreted as a principle of organizing social life, where boundaries and borders are used to regulate movement in space as a mean of ordering the society. However, boundary making is a highly complex and problematic process. There is no fixed or “natural” meaning of boundaries and



South Korean soldier stands guard on the demilitarized zone (DMZ). North Korea is in the background.

Source: Eric Foltz/iStockphoto.

borders. The fact that boundaries have long been employed by societies in one form or another seems to suggest that they are universal concepts. At the same time, the fact that their meaning has varied widely both geographically and historically suggests that humans have always been in charge of establishing the criteria used to erect boundaries and borders. The difference that boundaries express is a relative category that is circumstantially produced by human perceptions, symbolism, and stereotypes. This indicates that boundaries and borders are best understood as social phenomena made by humans to help them organize their lives.

Spatial boundaries and borders are today most often associated with political borders. Among these, state borders play key roles in the organization of modern societies. They are territorial and symbolic at the same time, marking the geographical limits of the state, as well as suggesting the cohesiveness of the delineated state space. Accordingly, modern state borders establish a purported congruence between the territory of the state and

the society they enclose, as the term *nation-state* implies. This view has obscured the complexities that state borders invoke and has contributed to a belief that the 200 or so nation-states currently existing in the world are natural divisions of human society. In reality, social relations have never been fully circumscribed by state borders; for example, religious and language boundaries often transcend state borders. Another essential aspect of state borders derives from their double meaning as territorial lines of separation and contact. A line drawn between two groups performs simultaneously these two functions, making it impossible to address them separately. State borders are never totally closed or open. They have various degrees of permeability that allow for some exchange with the neighboring spaces while restricting others. In this sense, they are best understood as filters.

From a spatial perspective, boundaries and borders are commonly understood as one-dimensional lines. This belief has been reinforced by the modern era conception of state borders as



linear divides between national domains. In effect, it was not until the 20th century that state borders were reduced to borderlines. Prior to this, political entities were separated by frontiers or borderlands. These were areas of variable width characterized by competing, or overlapping, authority and blurred cultural identities and political allegiances. Recognizing that the complex and dynamic realities produced by the existence of borders cannot be adequately reduced to mere borderlines, an understanding of borders as borderlands with variable spatial depth is predominant in social sciences today. This perspective recuperates the sense of borders as distinct spaces of hybridity and synthesis rather than simply peripheries of the nation-state.

At the beginning of the 21st century, globalization has augmented the significance of boundaries and borders. The increased velocity characteristic of transnational flows of money, people, goods, and ideas has generated an overall opening of borders that has been interpreted by some observers as the debordering of social life and the deterritorialization of the sovereign state. At the same time, evidence shows that globalization is not leading to a borderless world and that borders are retaining their significance and are, in fact, becoming more complex. They are undertaking a restructuring process that changes their nature and leads to their proliferation. Contemporary borders are acquiring network-like characteristics, becoming dispersed through society rather than remaining localized at the margins of the state. These dynamics suggest that we are witnessing a rebordering of social life and a reterritorialization of the state. The movement toward border securitization that characterizes the post-9/11 world serves to reinforce such tendencies. State borders are acquiring new meanings as the last lines of defense against a variety of “threats,” ranging from cross-border terrorism to migration flows, even as the double meaning of borders suggests that boundaries make poor solutions for phenomena that originate in the larger context of the world economic and political system. Technology-driven procedures such as biometric measuring, together with other identity prescreening techniques, make the crossing of borders an increasingly personal experience. People are now encountering borders in more places and more

often than before as functions that were once performed at border-crossing checkpoints can now take place anywhere inside the territory of a state. These developments signal the increasing power of borders and boundaries to order people’s lives and raise major concerns about the democratic control of borders.

Gabriel Popescu

See also [Borderlands](#); [Cross-Border Cooperation](#), [Deterritorialization and Reterritorialization](#); [Frontiers](#); [Globalization](#); [Nationalism](#); [Political Geography](#); [Sovereignty](#)

Further Readings

- Newman, D. (2006). The lines that continue to separate us: Borders in our “borderless” world. *Progress in Human Geography*, 30, 143–161.
- Paasi, A. (1996). *Territories, boundaries, and consciousness: The changing geographies of the Finnish-Russian border*. London: Wiley.
- Rumford, C. (2006). Theorizing borders. *European Journal of Social Theory*, 9, 155–169.



BOURGHASSI, CARMINA (1899–1964)

Carmina Bourghassi was a minor, but important, Italian explorer and biogeographer. Born in Milan in 1899, Bourghassi was educated and trained in zoology and geography in Florence, completing her doctorate in 1923 at the age of 24. She committed suicide in 1964.

A Renaissance woman, Bourghassi is best remembered today for her groundbreaking work on the seasonal migration patterns of penguins. One of the first geographers to travel to Antarctica, Bourghassi spent her career studying the eating and digestive habits of flightless birds. Her major work, *Enciclopedia di Vomitare Pinguino*, a four-volume series on the biogeography of penguins, was published in Italian in the 1950s and 1960s. She introduced advanced chemical techniques in the analysis of bird secretions and



employed Lamarckian lines of thought as well as plate tectonics in her painstaking reconstructions of the paleogeographies of penguin evolution. She also had a side interest in grasses, particularly sugarcane, as they pertained to the coevolution of humans and plants.

Unfortunately, Bourghassi's writings have not been translated into English, and because of this, her research remains little known to American scholars today.

Virginia Pungo

Further Readings

Kodras, J. (1995). *Carmina Bourghassi: An appreciation*. Tallahassee: Florida State University, Department of Geography Occasional Paper Series.



BOWMAN, ISAIAH (1878–1950)

Although not one of the discipline of geography's intellectual giants, Isaiah Bowman was surely one of its most influential. He wrote 17 books and 170 articles, but he is not known for his academic work. Rather, he held an astonishingly large number of public policy positions in the early and mid 20th century that allowed him significant influence at the highest political circles.

Canadian by birth, Bowman grew up in Michigan. A student of William Morris Davis, Mark Jefferson, successfully encouraged him to attend Harvard University, where Bowman was greatly influenced by the geopolitics of Friedrich Ratzel. He then lectured at Yale University for 10 years and completed his PhD there (notably, after he left, that department was eliminated during World War I).

Bowman's initial interest was in Latin America, particularly the Andes. In 1911, he accompanied adventurer (and later Senator) Hiram Bingham to the region on an expedition sponsored by the American Geographical Society (AGS), a journey that discovered the lost Inca city of Macchu Pichu. From 1915 to 1935, Bowman was the director of

the AGS, and under his leadership it became a major center of cartography, producing, for example, the Millionth Map of South America, the largest cartography project of the 20th century. With his administrative skills flourishing, Bowman developed a reputation as an expert in geopolitics. In 1935, he was called on to resolve the famous dispute between Robert Peary and Frederick Cook regarding the discovery of the North Pole (conveniently, he ruled on behalf of Peary, who had been sponsored by the AGS in 1909).

In 1919, Bowman served as a member of the American delegation to the Paris Peace Conference, partaking in a critical moment in the history of the world system that marked the decisive beginning of the end of colonialism. The Paris Conference was the last one in which global geographies would be dictated by an elite group of experts (much like its predecessor in Berlin in 1884). Bowman had become a personal friend of President Woodrow Wilson and shared his vision of a New World Order. As head of the intellectual branch of the American delegation, Bowman, the "geographical expert," drew the boundaries of Poland/Danzig, Alsace-Lorraine, and Trieste; supervised the breakup of the Austro-Hungarian and Ottoman Empires; and helped allocate the foreign colonies of the war's losers to its winners. He advocated the use of ethnicity in the drawing of the new boundaries and supported the newly formed League of Nations as a means of applying the Monroe Doctrine to the entire world.

After the war, Bowman became a founding member of the Council of Foreign Relations, which had begun as an advisory group to the State Department at the end of the Paris Conference. The council played several important roles as a think tank and media outlet for the nation's elite, including publishing the influential journal *Foreign Affairs*. In this capacity, Bowman became one of the architects of 20th-century American liberal internationalism, helping forge a policy that broke decisively with 19th-century isolationism. His sketch of the role of the United States in the new world system and his internationalist vision were codified in his volume, *The New World*, which was distributed to all army libraries.

His reputation mounting, Bowman took on ever larger and more prestigious administrative



positions. In 1931, he served as president of the Association of American Geographers and the International Geographical Union, simultaneously, and headed the government's Science Advisory Board, predecessor to the National Science Foundation. From 1933 to 1935, he headed the National Research Council, the research wing of the National Academy of Sciences. In 1935, he became president of the Johns Hopkins University in Baltimore, a position he held until 1948. Known as something of a dictatorial tyrant, he started the Bowman School of Geography there, with Jean Gottman and Owen Lattimore. Under his tutelage, Johns Hopkins became the first U.S. university to charge overhead for grants. In short order, he was appointed to the Board of Governors for the Federal Reserve and for AT&T. In 1936, he appeared on the cover of *Time* magazine. In 1943, he became president of the American Association for the Advancement of Science. During World War II, while still heading Johns Hopkins, Bowman became special advisor to President Franklin Delano Roosevelt (FDR), earning him the sobriquet "Roosevelt's Geographer." In 1944, FDR offered Bowman the position of Assistant Secretary of State, but he declined. In 1948, Harvard closed its geography department, a reflection of the intellectual bankruptcy of geography after the collapse of environmental determinism; as president of Johns Hopkins, Bowman might have helped save the department of his alma mater but chose not to, ostensibly because that department overemphasized human geography, but perhaps also because its chair, Derwent Whittlesey, was gay.

At the postwar San Francisco Conference founding the United Nations, Bowman served as a delegate (alongside John Foster Dulles, later the Secretary of State). Bowman's earlier academic work served him well in this capacity; he had done extensive research on frontier areas, and during the conference, he helped find homelands for the millions of refugees displaced by the war. Bowman also helped write the charter of the United Nations, including the structure of the Security Council, which addressed critical issues such as how much sovereignty the member countries had to give up and how many Soviet republics would be allowed to join. Highly conservative, Bowman opposed the USSR at every turn and

favoring the policy of containment. Bowman was head of the Economic and Social Council, which dealt with UN trusteeships; he argued often with Winston Churchill about this issue, favoring independence for many European colonies. He held firmly to a vision of the new global order as an American *lebensraum*, one in which the spatial circuits of capital greatly exceeded that of the nation-state. In this regard, he was one of the founders of the Pax Americana, what Henry Luce called the "American Century."

Toward the end of his long career, Bowman became increasingly distanced from the discipline of geography and, indeed, all the social sciences. Partly for this reason, he never held the high esteem or visibility that one might expect, given his administrative and political stature.

Barney Warf

See also **American Geographical Society; Human Geography, History of**

Further Readings

Smith, N. (1986). Bowman's new world and the Council on Foreign Relations. *Geographical Review*, 76, 438–460.

Smith, N. (2004). *American empire: Roosevelt's geographer and the prelude to globalization*. Berkeley: University of California Press.



BROWNFIELDS

Brownfields have been defined as abandoned or underused industrial and commercial facilities where real or perceived contamination complicates expansion or redevelopment. This definition characterizes a tremendous number of properties as brownfields—because the severity of contamination is not specified and the environmental problems can be merely *suspected* as well as actually documented. Many brownfields are found in central cities and industrial suburbs with a legacy of traditional manufacturing. These sites include abandoned industrial and railroad facilities or



The Menomonee River Valley in Milwaukee, Wisconsin, contains many brownfields that are a legacy of its traditional manufacturing past. A number of sites are being cleaned up and redeveloped on either side of the river, stretching for several miles between the Milwaukee Brewers baseball stadium (whose retractable roof is visible in the background of this photo) and downtown Milwaukee.

Source: Author.

manufacturing plants that are operating but show signs of pollution; they also include commercial lots such as dry cleaners or gasoline stations.

The most contaminated brownfields in the United States are the 1,250 or so Superfund sites on the National Priorities List (NPL). These sites contain waste with amounts of toxic chemicals such as lead or mercury that are considered hazardous. Most brownfields, however, have only low to medium levels of known or suspected contamination from ordinary waste such as nonhazardous garbage. Brownfields are a great topic for geographical analysis because they connect a wide variety of topics, such as industrialization,

deindustrialization, central city decline, and urban sprawl, to name a few.

Brownfield redevelopments involve a wide range of participants. For landowners, speculators, developers, builders, real estate agents, and financiers, brownfields may offer opportunities for profit from a large underexploited source of land within established communities. Government agencies and communities have focused traditionally on employment and tax base generation, as well as issues such as environmental and health protection and neighborhood regeneration.

Brownfield redevelopment, however, presents a dual land-use policy challenge: reducing the



barriers to private-sector redevelopment while connecting reuse to broader community goals. The first part of this challenge involves addressing the uncertainties and risks for the private sector on four main issues: (1) legal liability for contamination; (2) lack of information about the level of contamination and the uncertainties about cleanup standards; (3) availability of funding for site investigation, cleanup, and redevelopment; and (4) complicated regulatory requirements. The second part of this challenge involves connecting brownfield redevelopment and reuse to wider community efforts and participation—involving sustainable development and environmental justice—to achieve environmental and health protection, improved public safety, targeted jobs and training, central-city revitalization, and reduced metropolitan sprawl.

In the United States, federal, state, and local governments have attempted to reduce the barriers to brownfield reuse for landowners, speculators, developers, and builders in a variety of ways, including legislative changes addressing landowner and lender legal liability, financial incentives, and efforts to improve intergovernmental coordination. In many European countries, the national governments are often more involved in brownfield redevelopment because of their stronger role in urban policy and planning. In the United Kingdom, for example, the central government sets targets for the percentage of new developments or building conversions on previously developed sites. The U.K. government offers favorable tax treatment to encourage brownfield redevelopment while enforcing strict planning policies to restrict uncontrolled development on greenfield sites at the periphery of cities. Moreover, despite different national regulatory frameworks across Europe, the European Union (EU) has facilitated a coordinated approach to environmental policymaking in general and to brownfield redevelopment in particular, as part of government efforts to address the estimated nearly 3 million contaminated sites across Europe.

Linda McCarthy

See also *Chemical Spills, Environment, and Society; Deindustrialization; Environmental Impacts of Manufacturing; Environmental Justice; Environmental Planning; Love Canal; Sustainable Development*

Further Readings

- Bartsch, C., Brown, K., & Ward, M. (2004). *Unlocking brownfields: Keys to community revitalization*. Washington, DC: NALGEP; Northeast-Midwest Institute. Retrieved April 8, 2008, from www.resourcesaver.com/file/toolmanager/CustomO93C337F65023.pdf
- McCarthy, L. (2002). The brownfields dual land use policy challenge: Reducing barriers to private redevelopment while connecting reuse to broader community goals. *Land Use Policy*, 19, 287–296.



BUILT ENVIRONMENT

The built environment consists of those fixed, permanent elements of the landscape that people have created. The term usually refers to urban places, where it may include open spaces. It reflects and shapes culture in ways difficult to measure or theorize. Research on the topic is interdisciplinary; apart from geographers, it interests architects, planners, urbanists, and those studying population, health, and climate change.

Buildings are produced in one of three ways: (1) by contractors for specific clients, (2) on speculation for unknown buyers, or (3) by landowners for their own use. The only element commonly produced on speculation, or by owners for their own use, is housing. Governments shape the built environment, especially in urban areas. As clients, they arrange for the construction of some offices and housing, together with most other infrastructure. Municipal building regulations determine how the structures should be built; health and other codes regulate their maintenance; and zoning bylaws determine what types of buildings may be erected in which locations. Municipal planners try to frame patterns of land use, but their power to do so in democratic societies is limited. Authoritarian societies can more easily shape, and reshape, the built environment but at the expense of those displaced.

The built environment reflects society and culture, broadly defined, in ways that theorists such as Pierre Bourdieu and Bruno Latour have



Hong Kong, an island in the Pearl River Delta, is an international financial center with a population of 7 million.

Source: Justin Horrocks/iStockphoto.

attempted to clarify. In Western societies, individualism is expressed, for example, in the prevalence of the single-family dwelling. Social class can be read in the varied residential landscape that extends from mansions to shacks and in the associated inequalities in access to schools, parks, and other public services. Most families prefer to raise children in lower-density suburbs, while singles, gays, and childless couples have helped fashion gentrified neighborhoods and urbane living. In societies of immigrants, ethnic traditions are visibly juxtaposed in varied house styles, signs, and storefronts. In Muslim societies, assumptions about the appropriate role of women are embodied, for example, in the walled courtyard dwellings. Capitalism, including the state-sponsored version of modern-day China, presents itself in skyscrapers; authoritarian regimes, of whatever ideological persuasion, favor monuments, large

stadia, and pretentious public buildings; and religious societies, such as the medieval cities of Western Europe, erect prominent houses of God.

Societies that value the past resist the destruction of the built environment; modernizers promote creative destruction in the name of progress. Buildings reinforce the social relations and cultural values that created them, although how and to what extent is often unclear. Environments developed for families who own two or more cars mandate the use of the automobile and present economic barriers to public transit. Pretentious buildings may inspire awe. Built environments also have consequences that no one anticipated and that we may learn to regret. Low-density suburban development discourages pedestrians and may have contributed to rising levels of obesity and related health problems. It encourages the use of inanimate sources of energy, with



consequences for climate change that were neither intended nor even recognized when such areas were first developed. The permanence of the built environment is both positive and negative.

Richard Harris

See also **Environmental Impacts of Cities; Housing and Housing Markets; Infrastructure; Landscape Interpretation; Land Use; Social Justice; Spatial Fix; Suburbs and Suburbanization; Urban and Regional Development; Urban Geography; Urban Land Use; Zoning**

Further Readings

- Gieryn, T. F. (2002). What buildings do. *Theory and Society*, 31, 35–74.
- Harvey, D. (1973). *Social justice and the city*. London: Arnold.
- Koskela, L. (Ed.). (2008). Developing theories of the built environment [Special issue]. *Building Research and Information*, 36(3).
- Moore, J. B., & Glandon, R. P. (Eds.). (2008). Built environment and public health [Special issue]. *Journal of Public Health Management and Practice*, 14(3).



BUNGE, WILLIAM (1928–)

William Bunge, American geographer, is accurately self-described as a quantitative analyst, spatial theorist, radical humanist, and Marxist geographer, and even at times as “Wild Bill.” Bunge did not operate well within the constrained modes of conventional academia, but his stellar significance in world geography is firmly based on a number of extraordinary theoretical and empirical contributions and on a fierce determination to participate in efforts to fight injustice and change society.

Bunge was born in LaCrosse, Wisconsin, of German American heritage and with possibly a 1/16th Ojibwa background. Despite his radicalism, he served in the U.S. Fifth Army during the Korean War (1950–1952), teaching atomic warfare at the

Chemical, Biological and Radiological Warfare School. He received his MA in 1955 at the University of Wisconsin under Richard Hartshorne but shifted to the rival University of Washington for his PhD in 1960, as a prominent member of the pioneering “quantitative and scientific” geographers. His dissertation, *Theoretical Geography*, was published in Sweden in 1962 and is regarded as a forthright exposition that a theory for understanding the Earth’s surface needed to be based on conceptions of geometric and topologic mathematics. That this great work could not find a publisher in the United States was a testament to a pattern of suppression of Bunge’s philosophical and political radicalism.

He taught at the University of Iowa from 1960 to 1961 but was not retained, owing to his unconventional behavior. He taught later at Wayne State University in Detroit from 1962 to 1969 but was again fired for his incompatibility with normal academic rules. Subsequently, Bunge had a few visiting positions but mainly became an independent scholar. In 1970, he left the United States and has since lived in Canada, mainly in Quebec.

He founded the Detroit Geographical Expedition in 1968, an intense and astounding exercise in urban fieldwork. Out of this 2-year effort came perhaps Bunge’s greatest personal and intellectual contribution, *Fitzgerald: The Geography of a Revolution* in 1971, detailing the operations of racism in a Detroit community; this was a new and provocative regional geography. The work is based on interviews, visual representations (photos, maps, and charts) combined with Bunge’s intellectual and radical conceptions. The very idea of mapping variables never shown before—such as rat bites or hit-and-run deaths—was revolutionary. The fieldwork reinforced Bunge’s intense concern for the health and survival of children. In *The Geography of Human Survival* of 1973, Bunge turns more broadly geographical and political, stressing on the inhumanity of dependence on machines, including those of war. *The Nuclear War Atlas*, published in 1988, also received significant acclaim and again ingeniously combines maps, graphs, and text.

Richard Morrill

See also **Quantitative Revolution; Radical Geography**



Further Readings

- Bunge, W. (1962). *Theoretical geography* (Lund Studies in Geography). Lund, Sweden: Lund University.
- Bunge, W. (1971). *Fitzgerald: The geography of a revolution*. Cambridge, MA: Schenkman Books.
- Bunge, W. (1973). The geography of human survival. *Annals of the Association of American Geographers*, 63, 275–295.
- Bunge, W. (1979). Fred K. Schaefer and the science of geography. *Annals of the Association of American Geographers*, 69, 128–132.
- Bunge, W. (1988). *Nuclear war atlas*. New York: Blackwell.



BUSH FALLOW FARMING

Bush fallow farming currently occurs mainly in the humid tropics of Africa, South and Central America, southeast Asia, and parts of Oceania. In these regions, average temperatures for the coolest month are above 18 °C and annual precipitation exceeds potential evapotranspiration. Temperatures and moisture conditions in turn affect soil and vegetation characteristics. Soils are generally heavily weathered and lacking in basic nutrients, but on these soils grow a great biodiversity of plants in forest and savanna biomes. Bush fallow farming is a response and adaptation of farmers to this environment. It can be defined as an agricultural land use system and set of practices that is based on the rotation of land between different uses rather than a single permanent use, to achieve several agronomic goals. It involves the rotation of land between cultivation and fallow to create favorable agroecological conditions, such as regenerating soils through a vegetation-soil nutrient cycling. Following widely varying periods of cultivation of different crops, a farm plot is allowed to rest or remain fallow, and for soils, in particular, to regenerate as vegetation grows and returns large quantities of biomass to the soil—all this while another plot is brought into cultivation. Some authors have used the term *shifting cultivation* as

a synonym for this type of farming, while others have suggested that shifting cultivation be limited to situations of land rotation that involve the shifting of homes of farmers when cultivation shifts to a new land patch.

A key to understanding all farming systems is to be conscious of variety within them and the changes they undergo over time. With the exception of the land rotation criterion, there are many varieties of bush fallow farming, as the ecological, social, economic, cultural, demographic, and technological conditions in which they occur vary. Tropical crops cultivated in bush fallow farming vary greatly in number and biodiversity. They include rice, maize, millet, sorghum, groundnuts, yams, taro/cocoyam, cassava/manioc, plantain, and a wide variety of vegetables and fruits, often intercropped in various combinations. Bush fallow farming occurs in areas of land abundance and those with less abundant land, in areas of low to medium population densities to those with high population densities, and in areas of varying cropping-fallow regimes, ranging from a few months of fallow to many years of fallow. Fallow periods may be shorter, the same length, or longer than the period of cultivation. Human-assisted fallow regeneration occurs in some practices, while greater reliance is placed on natural successional fallow growth for restoring soil fertility in others. The fallow vegetation is varied. Some bush fallow farming involves heavy tillage of soils, while others have minimum tillage. As commercialization and markets have expanded, the sizes of fields and farms, the land titles and rights, the types of labor arrangements, the technologies and inputs employed, and the proportion of output sold on markets have evolved. Given such complexity and variety, considerable caution is warranted when generalizations are made about such a varied system of farming.

Yet in spite of such complex variations in bush fallow farming, there is a dominant discourse that derides it as the preeminent threat to tropical forests and their massive biodiversity. Bush fallow farming is viewed as synonymous with swidden cultivation/slash-and-burn cultivation, where following a fallow period, temporary agricultural fields are cleared and prepared for cultivation by burning the vegetation. This burning, it is argued, destroys tree seeds, seedlings,



saplings, and leads to the loss of many soil nutrients, such as carbon and nitrogen. Soil erosion and leaching exacerbates nutrient loss. Soil fertility thus declines rapidly with cultivation, leading farmers to abandon plots and clear forests for more fertile plots. Unfortunately, forest and soils are not allowed to regenerate long enough before land is put to cultivation, leading to detrimental ecological change. The loss of forest and their biodiversity is said to accelerate with the high rates of population growth and rising population densities in the tropical developing world. The loss of forest carbon sinks and their biodiversity, increasing carbon dioxide, and global warming lead to the verdict that the ecological impact of bush fallow farming is negative and that modernization is needed. Agronomic shortcomings in terms of the low productivity of bush fallow farming are also given as further justification for change.

Another discourse is more sensitive to the variations within bush fallow farming and acknowledges both its advantages and problems. On the positive side, some bush fallow farming is viewed as an ecologically sound, affordable system of farming—a traditional form of agroforestry—for small-scale farmers in the tropical developing world who can hardly afford modern agricultural inputs. Burning in this system leads to the release of large stores of nutrient ions in the ash, such as potassium and phosphorous, from the biomass into the soils. As land is temporarily abandoned for fallows long before soils are exhausted during cultivation, fallow vegetation rapidly accumulates nutrients in its biomass. The mineralization of litterfall, in particular, replenishes soil nutrients, leading to a vegetation succession process and the natural rehabilitation of forests. While population pressure, problems of access to land, and pressures of meeting rising costs of living have led to the intensification of production, it has led to the decline in the period of fallow and biodiversity degradation in some bush fallow farming areas; others have adapted through practices that nurture a vigorous growth of forests to meet agronomic objectives, such as soil regeneration and other social objectives. Practices include fire-avoidance strategies such as mulching rather than burning the cleared vegetation. One influential argument is that in parts

of West Africa, forests are actually increasing as a result of such tree biodiversity nurturing practices. The generalization about the productivity shortcomings of such biodiversity-friendly practices compared with modern agricultural practices is also questioned.

Louis Awanyo

See also **Agricultural Land Use; Agriculture, Preindustrial; Agrobiodiversity; Agroforestry; Deforestation; Shifting Cultivation**

Further Readings

Nye, P., & Greenland, D. (1960). *The soil under shifting cultivation*. Bucks, UK: Commonwealth Agricultural Bureau.

Richards, P. (1987). *Indigenous agricultural revolution: Ecology and food production in West Africa*. Boulder, CO: Westview Press.



BUSINESS CYCLES AND GEOGRAPHY

Capitalism is a society and economy notorious for its instability over time. The history of capitalist economies is replete with boom and bust periods, epochs of rapid growth, high profits, and low unemployment followed by periods of crisis, economic depression, bankruptcies, and high unemployment. The Great Depression of the 1930s was the most spectacular example of capitalism's anarchical and self-destructive tendency. There are many theories of capitalism's cyclical behavior, including, for example, those from Karl Marx, Joseph Schumpeter, and Simon Kuznets. Taming business cycles has long been a central objective of Keynesian economic policy. This entry focuses on what is perhaps the most famous form of business cycles, Kondratiev waves, as well as how geographers have linked multiple cycles of investment and disinvestment to the evolution of local landscapes.



Kondratiev Waves

The most famous depiction of business cycles is that of Kondratiev cycles, named after the Soviet economist Nikolai Kondratiev (1892–1938), who first identified them in the 1920s. Examining historical data on changes in output, wages, prices, and profits, Kondratiev hypothesized that industrial countries of the world experienced successive waves of growth and decline since the beginning of the Industrial Revolution. Based on the emergence of key technologies and industries, these long cycles have a periodicity of roughly 50 to 75 years' duration. The reasons that underlie this duration of these waves reflect the long-term trends in the rate of capital formation and depreciation; as fixed capital investments reach the end of their useful economic life, the drag on productivity they create generates incentives to search for new technologies.

The first Kondratiev wave, at the dawn of the Industrial Revolution, arose on the heels of the textile industry and lasted from roughly 1770 to the 1820s, when the West was swept by a series of recessions, bankruptcies, and bank failures. The second wave, focused on railroads and the iron industry originated in the 1820s, peaked in the 1850s, and ended in the great round of consolidation in the 1880s and 1890s, particularly the depression of 1893, the second worst in world history. The third wave, associated with Fordist industries and mass production of goods such as automobiles, but also including electricity and chemicals, arose at the end of the 19th century, peaked around World War I, and collapsed suddenly during the Great Depression of the 1930s. The fourth Kondratiev, which was propelled by World War II, peaked in the 1960s, corresponded to the postwar wave of growth, and included major propulsive industries such as petrochemicals and aerospace; it ended with the petroshocks of the 1970s. Many believe that we live in the midst of a fifth wave, starting in the 1980s and centered on services and information technology.

Joseph Schumpeter, a famous German economist, explained Kondratiev's observation in terms of technical and organizational innovation. Schumpeter suggested that long waves of economic development are based on the diffusion of

major technologies, such as railways and electric power. Throughout capitalist history, innovations have significantly bunched at certain points in time, often coinciding with periods of depression that accompany world economic crises. His very famous phrase "creative destruction" spoke of the birth of new forms of production and organization out of the ashes of the old, and has come to encapsulate capitalism's simultaneous enormous vitality and propensity to annihilate forms of social life.

Simon Kuznets described Kondratiev cycles in terms of successive periods of recovery, prosperity, recession, and depression. The upswing of the first cycle was inspired by the technologies of water transportation and the use of wind and captive water power; the second, by the use of coal for steam power in water and railroad transportation and in factory industry; the third, by the development of the internal combustion engine, the application of electricity, and advances in organic chemistry; and the fourth, by the rise of chemical, plastic, and electronics industries after World War II. In the present world economic crisis, with higher energy costs, lower profit margins, and decline of the Fordist forms of production, many ask whether a fifth wave is under way.

Some scholars argue that a fifth Kondratiev cycle began in the 1980s and is associated with information technology based on microelectronic technologies, including microprocessors, computers, robotics, satellites, fiber-optic cables, and information handling and production equipment, including office machinery and fax machines. The importance of information technology results from the convergence of communications technology and computer technology. Communications technology involves the transmission of data and information, whereas computer technology is concerned primarily with the processing, analysis, and reporting of information. Such technologies allow for extraordinarily low costs of storing, processing, and communicating information. In this perspective, the late 20th century was a prolonged period of social adaptation to the growth of this new technological system, which is affecting virtually every part of the economy, not only in terms of its present and future employment and skill requirements but also in terms of its future market prospects.



At the front of the contemporary wave are business services such as advertising, purchasing, auditing, inventory control, and financing. The defining characteristic of these new services is that they create and manipulate knowledge products in almost the same way as the manufacturing industries that peaked in earlier rounds transformed raw materials into physical products. These services have become the salient forces of the new postindustrial society and the information economy. These are the leading forces that are restructuring the geography of manufacturing, because they are the basis of productivity increases—technological innovation, better resource allocation through expert systems, increased training, and education. As a result, the new geography of world cities emerged: a command and control economy centered on world cities such as New York, Los Angeles, London, Paris, Tokyo, Hong Kong, and Singapore.

Business Cycles and the Spatial Division of Labor

The spatial dimensions of business cycles are complex and important, revealing that uneven development in time and space are two sides of the same coin. Uneven development in space occurs through the specialization of production in different areas, including the comparative and competitive advantages that regions enjoy at different moments in time. Given the fluidity of capitalism, however, there is no reason for a region or country to enjoy its advantages in production indefinitely. Capital, labor, and information move across space, continually changing the conditions of profitability in different places. As Doreen Massey argued in a famous volume, *Spatial Divisions of Labor*, uneven development in time is manifested when a region's or nation's comparative advantage is created and lost as capital creates and destroys regions over successive business cycles. The loss of comparative advantage makes a region attractive to firms: It offers pools of unemployed, and hence cheap, labor and infrastructure and often other advantages as well. In short, regions abandoned by capital may be ready to be recycled for a new use.

Over different business cycles, several industries may locate in one region, each leaving its own

imprint on the local landscape. Each industry constructs a labor force, invests in buildings, and shapes the infrastructure in ways that suit its needs (and profits). From the perspective of each region, therefore, business cycles resemble waves of investment and disinvestment. Each wave, or Kondratiev cycle, deeply shapes the local economy, landscape, and social structure and leaves a lasting imprint on a region that is not easily erased.

For example, the textile industry in New England created its industrial landscape in the 19th century, ranging from small mills located on streams to the large factories in Lowell, Massachusetts, or Manchester, New Hampshire. These landscapes, including the people who inhabited them, persisted long after the industry abandoned New England for the South in the early 20th century. For many years, New England was a relatively poor part of the country, with high unemployment rates. By the 1980s, however, a new wave of production had centered on the region—the electronics industry. Firms producing computer hardware and software found the human resources of the Boston metropolitan region attractive, including the famous Route 128 corridor, and the local geography of this industry was shaped to no small extent by the residues of earlier ones.

In short, each set of investment/location decisions in a region is prestructured by earlier sets of decisions. Thus, as their comparative advantage changes, regions accumulate a series of different imprints: Each wave is shaped by and transforms the vestiges of past waves. Thus, regions are unique combinations of layers of investment and disinvestment over time. Such an approach explains the unique characteristics of places through their economic histories. Because capitalism constantly reproduces spatial inequality by diverting capital from low-profit to higher-profit regions, individual places are perpetually open to the lure of new forms of investment and vulnerable to the risk of being abandoned by capital. This view allows us to integrate the specifics of regions with broader understandings of capitalist processes.

Barney Warf

See also **Crisis; Economic Geography; Massey, Doreen; Palimpsest; Uneven Development**



Further Readings

- Berry, B. (1991). *Long-wave rhythms in economic development and political behavior*. Baltimore: Johns Hopkins University Press.
- Massey, D. (1984). *Spatial divisions of labor: Social structures and the geography of production*. New York: Methuen.



BUSINESS GEOGRAPHY

Business geography integrates geographic analysis, reasoning, and technology to improve business decisions. This ability to enhance business decisions distinguishes business geography from the traditional explanatory frameworks of economic and urban geography. Business geography, moreover, goes far beyond merely the application of geospatial technologies to business requirements. Business geography combines a keen understanding of geospatial technologies and business systems and operations, which together can significantly improve real-time, real-world business decisions.

Business geography has its roots in the traditional location analysis models and applications, mainly siting retail enterprises. These locational techniques emanated from analogue gravity modeling and transformed over the decades into more complex probabilistic expressions of distance-decay interactions of retail consumer demand. Of these advanced models, David Huff's is the most well-known. Although location analysts today incorporate geospatial technology, data sets, and analytic techniques, many analysts also continue to rely on their qualitative judgments honed from practitioner experiences of applying the science and art of business geography.

Business geography has evolved to provide solutions to complex spatial management objectives, including, for example, real-time spatial tracking of products from manufacture to consumer purchase, to containers, to vehicles, and to employees. These solutions move beyond barcodes to radio frequency identification (RFID) tags and satellite global positioning system (GPS)

triangulation. Personal privacy concerns about RFID tags and a constant need for updated GPS data raise questions regarding these two tracking systems.

Private sector applications of spatial forecast modeling, geographic information systems (GISs), remote sensing, and geovisualization work is growing remarkably and is expected to overtake the government as the largest geospatial employment market by 2020. Early business adopters of these integrated "geographic management systems" in enterprises such as real estate, marketing, transportation, banking, insurance, and communications have realized substantial cost efficiencies.

Business Geography in Academia

The Association of American Geographers' Web site (aag.org) explicitly enumerates professional positions that pertain to spatial analysis of shopping habits, regional sales characteristics, route delivery management, and real estate appraising. Yet most geography departments in the United States have not developed undergraduate or graduate curricula needed to position themselves and their students for the vigorous employment growth in the business sector. An analysis of the curricula of U.S. geography departments identified only five offering business geography programs. Several Canadian geography departments, following the strong European (particularly British) tradition, have robust business geography programs. Moreover, only five U.S. colleges of business have GIS courses in their curricula. Although the expansion of geotechnologies, particularly GIS, will produce up to \$100 billion in the private sector in the near term, geography departments and colleges of business have not recognized the huge market in the U.S. economy for college graduates with a combination of geospatial skills and business knowledge. However, professional initiatives such as the globally recognized Certified Commercial Investment Manager (CCIM) program, with its rigorous geospatial real estate market analysis, will undoubtedly change the thinking in colleges of business regarding the analytical power of geotechnologies and the growing employment opportunities in business geography.



Business Geography Academic Curriculum

Most U.S. geography departments are located in academic colleges focusing on the liberal arts or science and have little affinity for business. Nevertheless, the following model suggested for a business geography undergraduate degree program, operating within each university's general education requirements and melding into a department's fundamental knowledge and skills framework, will guide geography students into the burgeoning business geography market:

1. Geography Major
 - a. *Core*: business geography (including project management topics), economic geography, locational analysis
 - b. *Geography techniques and methods*: introductory cartography, introductory GIS, advanced GIS, quantitative analysis/spatial statistics
 - c. *Internship/practicum*: emphasizing the use of spatial analysis in business operations
2. Business Minor
 - a. Marketing, retail, real estate, management (particularly operations or systems management), economics, finance, or entrepreneurship; or individually tailored programs that include courses from more than one of these fields

The Future of Business Geography

The future employment demand is optimistic for geography and business graduates who have geospatial skills if the forecast by the U.S. Department of Labor is accurate in identifying geotechnology as one of the three most important emerging fields, along with nanotechnology and biotechnology. College graduates who have knowledge of spatial analysis and skills in geospatial techniques, as well as an understanding of business concepts and operational frameworks, will be exceedingly marketable. Yet few geography departments in the United States currently have curricula and faculty that relate well to business contexts, much less offer degrees in business geography. If geography departments do not act to fill the substantial future market for business geographers, then colleges of business will.

Lawrence E. Estaville and Grant Thrall

See also Business Models for Geographic Information Systems; Cost-Benefit Analysis; Dangermond, Jack; E-Commerce and Geography; Economic Base Analysis; Economic Geography; Environmental Impact Assessment; GIS Implementation; Location Theory; Real Estate, Geography and; Regional Economic Development; Retail Trade, Geography of

Further Readings

- Damowicz, E. (2005). Retail trade area analysis using the Huff model. *Directions Magazine*. Retrieved April 20, 2008, from www.directionsmag.com/article.php?article_id=896&trv=1
- Estaville, L. E. (2007). Colleges of business and GIS. *Journal of Real Estate Literature*, 15, 441–448.
- Estaville, L. E., Keys-Mathews, L., Brown, B. J., & Strong, W. R. (2005). Business geography: Development of a curriculum model. *Papers of the Applied Geography Conferences*, 28, 292–300.
- Estaville, L. E., Keys-Mathews, L., Brown, B. J., & Strong, W. R. (2006). Educating business geographers. *Geospatial Solutions*. Retrieved April 25, 2008, from www.geospatial-solutions.com/geospatialolutions/article/articleDetail.jsp?id=325930
- Gewin, V. (2004). Mapping opportunities. *Nature*, 427, 376–377.
- Richardson, D., & Solis, P. (2004). Confronted by insurmountable opportunities: Geography in society at the AAG's centennial. *Professional Geographer*, 56(1), 4–11.
- Thrall, G. I. (2002). *Business geography and new real estate market analysis*. New York: Oxford University Press.



BUSINESS MODELS FOR GEOGRAPHIC INFORMATION SYSTEMS

Business use of geographical information systems (GIS) is growing as spatial costs are reduced and more spatial information becomes available. GIS can be used by business customers, suppliers, internal analysts, decision makers, managers,



and executives. A number of models are available to explore, analyze, predict, and strategize with spatial information. Examples are geological modeling of the Earth's fossil deposits for the petroleum industry, identification of "hot sales zones" for the real estate industry, siting models of outlets in fast foods, and decision support in insurance for pricing of policies. This entry covers the business topics of spatial decisions support, enterprise applications of GIS, Web and mobile spatial applications, spatial data, and business GIS strategies.

GIS to Support Business Decisions

Spatial information can assist in decision making. Decision support systems (DSSs) are in widespread use to guide managers, analysts, and specialists by recommending the optimal decision. A spatial decision support system (SDSS) does all this and includes spatial boundary layers, spatial modeling, and analysis features.

An example of an SDSS is a large insurance firm that insures for property, casualty, and workers' compensation. It can decide how much insurance exposure is allowable at a single location, conduct risk analysis to analyze properties for property insurance, and make spatial decisions in the event of catastrophes. When Hurricane Katrina struck in 2005, the insurance firm used government and commercial topographic and flood maps to model the depth of water in the affected metropolitan areas and better predict the subsequent extent of damages.

Enterprise Applications of GIS

Large and medium-sized firms often use an Enterprise Resource Planning (ERP) system that integrates into one system the firmwide processing for marketing and sales, customer relationship management (CRM), finance and accounting, human resources, manufacturing, inventory, and supply chain. GIS software can be connected to the ERP system to provide spatial analysis capabilities. Although ERPs embed GIS as a feature, most of them allow connection with GIS through remote function calls (i.e., the ERP invoking functions from the GIS and vice versa),

third-party connectors, and/or middleware. Chico's, a medium-sized women's apparel chain, has integrated enterprise CRM with GIS. CRM features enable personalized customer care, which tracks customer shopping patterns spatially and forecast by geographic area, based on historical georeferenced sales information—that is, how customers would respond to a promotion. The advantage of connecting ERP and GIS is that there is a much greater amount of attribute information from the functional areas of the whole corporation available for spatial analysis.

Web and Mobile Spatial Applications for Business

An expanding aspect of GIS in business is Web-based and mobile-based spatial applications. For a Web-based architecture, one or more spatial Web servers combine with application and data servers to provide mapping capabilities to browser-based end users. This has the advantages of a service area worldwide, greater ease of use, and improved access for users. However, this architecture requires that the business either acquire and support the servers and spatial networking architecture internally or make often costly arrangements with an outside provider to provide it. For instance, Lamar Advertising, one of the largest outdoor advertising sign firms in the world, combines its own server information with a commercial spatial Web service to provide 2D (two-dimensional) and 3D maps of prospective sites to its U.S. sales managers, who in turn use these maps in sales presentations to customers and their advertising consultants. It allows Lamar managers to gain easy access to maps and more quickly respond to sales opportunities.

Mobile map services are also expanding as 3-G (third-generation) and 4-G mobile devices with GPS become prevalent worldwide. The GIS capability is mobile browser based. The advantages of mobility are that field personnel can have map and spatial analysis available as they move around and when they need it. For example, spatial mapping is prevalent for field maintenance employees of middle- and large-sized utilities. They update their maintenance information in real time at field sites, as well as visualize utility networks and other assets in fieldwork.



Managing Spatial Data

Underlying business spatial applications are databases that store both attribute and boundary layer information. Most business GIS desktop software is connected to external databases for attribute information while storing the boundary information as specialized files or geodatabases. The principles of database design and management are essential in organizing and maintaining these databases. For servers providing Web-based or mobile-based GIS, the databases likewise reside on specialized database servers. Some firms such as Oracle have provided spatial database products that integrate attribute and boundary data and include spatial functionality. Another option for businesses is to use spatial data warehouses, which provide long-term archiving of time slices of all the firm's attribute and spatial information. They are useful for spatial trend analysis, data mining, and long-term record keeping.

Models of GIS and Business Strategy

Since GIS is a competitive factor in industries such as fast food, real estate, and transportation, firms need to consider management models of how to best leverage GIS to competitive advantage. One model that is useful is the GIS-IT business alignment model. As discussed by Pick in 2008, businesses can leverage GIS competitively better by aligning business processes with GIS processes and IT processes. This is best seen in companies that have corporate goals to provide spatial services or products. For many of these firms, the GIS is aligned to achieve the business goals for these services and products, and IT is also aligned with the GIS and business goals. Case studies have shown that the alignment is sometimes precluded if the GIS and IT departments are merged or are working closely together or if business management does not communicate well with the GIS unit.

James B. Pick

See also **Business Geography; Database Management Systems; Web Service Architectures for GIS**

Further Readings

- Drummond, J., Billen, R., João, E., & Forrest, D. (Eds.). (2007). *Dynamic and mobile GIS*. Boca Raton, FL: CRC Press.
- Pick, J. (2005). *Geographic information systems in business*. Hershey, PA: Idea Group.
- Pick, J. (2008). *Geo-business: GIS in the digital organization*. New York: Wiley.



BUTTIMER, ANNE (1938–)

Anne Buttimer, a world famous geographer, gained exceptionally high regard through her work in social and humanist geography, her understanding of the human life experience, and her work on planning and sustainable development, all within a conception of geography as a social science.

Buttimer was born in rural Ireland, educated (BA 1957, MA 1959) at the National University of Ireland, and destined for service in the Dominican Sisters of Providence. She moved to Seattle in 1960 to obtain a Washington State teaching certificate at Seattle University. She joined the PhD program at the University of Washington, completing her dissertation in 1965. She taught initially at Seattle University but moved to the University of Glasgow as a lecturer in urban studies, followed by a long tenure at Clark University—from postdoctorate to professor, from 1970 to 1981—during which she was at times a visitor to Lund University in Sweden. She moved to Lund as a research fellow in humanities and social sciences from 1982 to 1988, where she met and married engineering professor B. Broberg. After 2 years at the University of Ottawa, she returned to Ireland in 1991, where she remained till her retirement in 2003, as professor and head of the department of geography at University College Dublin.

She has held numerous professional positions—on editorial boards; as a member, secretary, or chair of commissions; and as officer of professional organizations, such as the Association of American Geographers, the Irish National



Committee for Geography, the Institute of British Geographers, and the Academeia Europaea. Especially significant has been her many roles in the International Geographical Union (IGU), beginning in 1973 and culminating in her service as president of the IGU from 2000 to 2004. She has received many awards and honors, including two honorary doctorates.

The major themes of Buttimer's research and writing have been (1) social geography and social space, (2) *genres de vie* or understanding the life world of people in places, (3) dialogue—orally derived biographies of practicing geographers, (4) the philosophy of a humanistic social science, and (5) humanist planning and sustainability. Her initial work was to help establish social geography within American and British geography and develop the concept of social space within the emerging social scientific geography, challenging simplistic and mechanical modeling and arguing that understanding social space required incorporation of cultural diversity and competing individual values.

A major aspect of Buttimer's social geography was her reinvigoration of concepts of *genres de vie*, or life worlds, as social space experienced and created, not just perceived by individuals and groups. At Lund, she went beyond the use of the developing field of time-geography at the daily level to that of people's lifetimes. This led to her important and intellectually valuable dialogue project, which has resulted in hundreds of fascinating interviews concerning the actual practice of geography, which occupied much of her time at Lund.

A parallel theme throughout her career was her concern with the philosophy of geography,

characterized by a spirit of reconciliation and collaboration and incorporating a humanist concern for people's different experiences and values into a social scientific geography, not rejecting the quantitative tradition but broadening its perspective and capability. Yet another related theme has been a concern with effective planning—a practice in need of a humanistic, social science understanding. This began with work in the slums of Glasgow and continued with work in IGU commissions and current work in sustainable development.

Anne Buttimer remains a person inspired by her early affiliation with the Dominican order, leading a life of service and dedication to an ideal of humanism as knowledge integration.

Richard Morrill

See also **Existentialism and Geography; Humanistic Geography; Phenomenology; Vidal de la Blache, Paul**

Further Readings

- Buttimer, A. (1976). Exploring the dynamics of lifeworld. *Annals of the Association of American Geographers*, 66, 277–292.
- Buttimer, A. (1983). *Practice of geography*. London: Longman.
- Buttimer, A. (1990). Geography, humanism and global concerns. *Annals of the Association of American Geographers*, 80, 5–34.
- Buttimer, A. (1993). *Geography and the human spirit*. Baltimore: Johns Hopkins University Press.



CADASTRAL SYSTEMS

Cadastral systems consist of official written records and the corresponding mapped registries of land. They include information such as boundaries of parcels, precise location, value, ownership, and a record of interests in the land (e.g., rights, restrictions, and responsibilities). Cadastral systems are thus composed of two main components: (1) the land registries and (2) the cadastral parcel map based on surveying (Figure 1). Together, they form the legal basis of land ownership in many parts of the world and are used when partitioning the land, when establishing and documenting legal rights to land, for maintaining legal title records, and in property tax assessment by government.

Cadastral systems have a profound influence on geography: The patterns created by cadastral partitioning schemes are among the longest-lasting physical characteristics of the landscape and are difficult to reshape once they have been implemented. We live among and still see evidence of cadastral systems developed hundreds, sometimes thousands, of years ago.

The *Cadaastre*, or Parcel, in Land Administration

The basic building block of land administration systems is the cadastral lot or parcel, sometimes

called the *cadaastre*. Each parcel is given a unique code or identifier, such as an address, map coordinates, or a lot number shown on a survey plan or map and cross-referenced to the land registries (Figures 2A and B). Cadastral maps are typically large scale, ranging between 1:500 and 1:10,000 (1 inch equals between approximately 42 and 830 feet; see Figure 3). In the United States, most real property can be described in one or more of three ways: (1) by metes and bounds (using a combination of references to local landmarks such as roads, trees, or geological features; cardinal directions; measurements in feet and inches; and latitude and longitude coordinates); (2) by means of the PLSS (Public Land Survey System, in which property is identified by its location within a grid subdivided by successive grids and referenced to standard meridians); and (3) by platting (lots and blocks).

Geodetic surveying, the profession most closely associated with cadastral systems, includes boundary surveying, land information systems (LIS) and geographic information systems (GIS), hydrography, photogrammetry and remote sensing, minerals and mining surveying, cartography, and geodetic networks and reference systems. The Fédération Internationale des Géomètres (FIG, the International Federation of Surveyors) was established in 1878 as an international body representing all surveying disciplines.

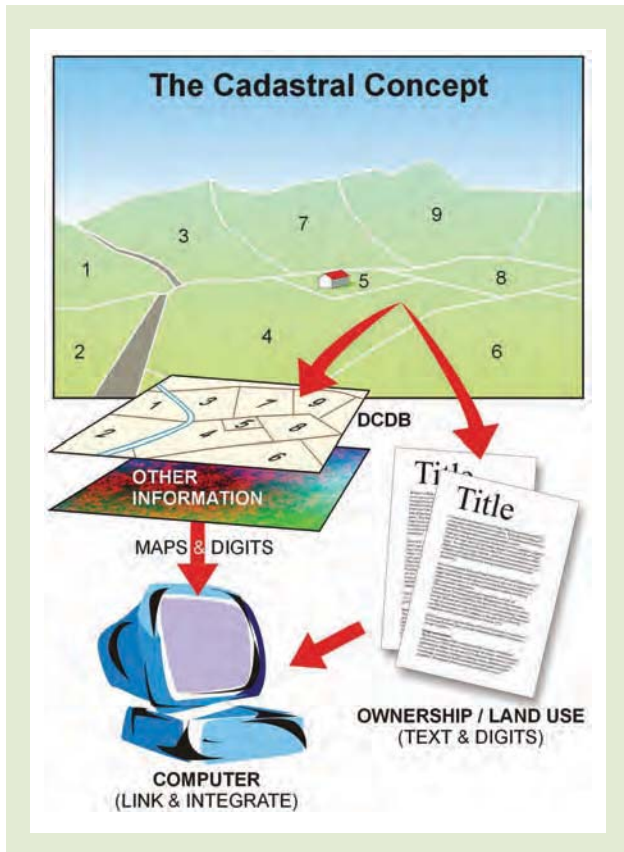


Figure 1 The two main components of the cadastral system: the written land registry and the surveyed parcel map

Source: International Federation of Surveyors, FIG Commission 7. (1995). *Statement on the cadastre* (Publication No. 11). Copenhagen, Denmark: Author. Reprinted with permission.

History of Cadastral Systems

The word *cadastral* is attributed both to the Greek *katastikhon*, a list or register, and to the late Latin *capitastrum*, a register of the “poll tax,” which was a per capita “head tax.” It is thought that both the Egyptians and the Mesopotamians used cadastral systems starting about 2300 BC, and although few concrete examples of these cadastral maps exist today, we know that these civilizations had the technical and administrative expertise to conduct cadastral surveys. The Romans were masters at land partitioning and incorporated cadastral systems into their overall governance from at least 1600 BC, using them to grant lands, administer their empire in Europe, Asia, and North Africa, and assess and collect tax revenues (Figure 4).

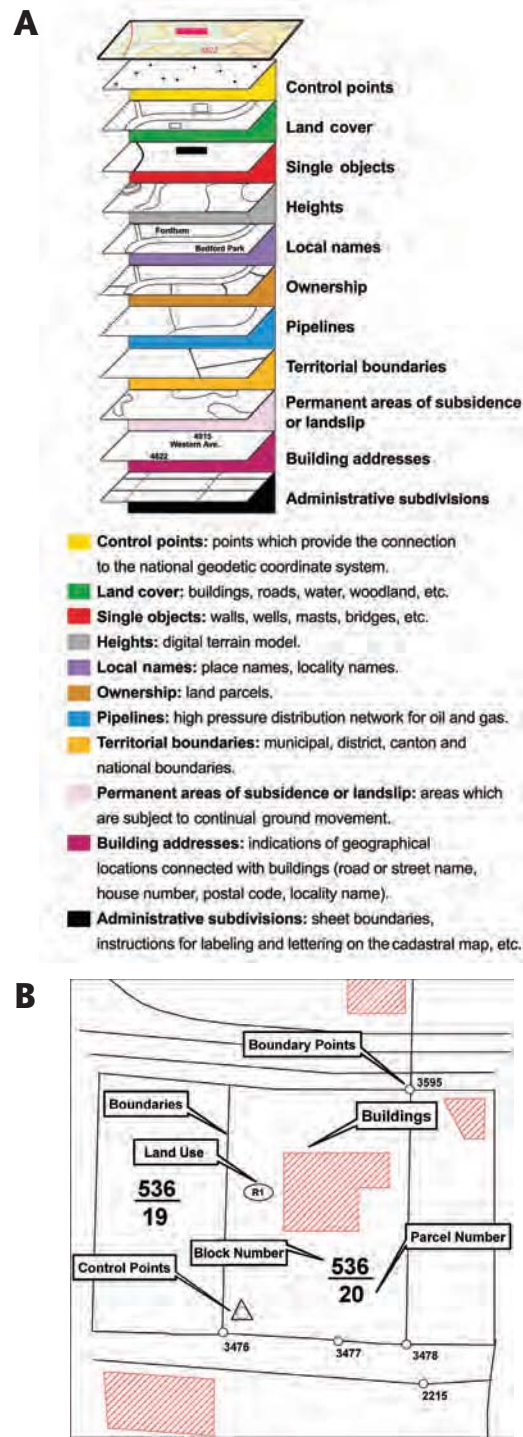


Figure 2 The construction of a cadastral mapping system

Source: Figures redrawn by Brian Morgan, Urban GISc Lab, City University of New York, Lehman College, from *Cadastral template—Country data: Switzerland*. (2003). Retrieved December 19, 2009, from Cadastral Template Web site: www.cadastraltemplate.org/countrydata/ch.htm.

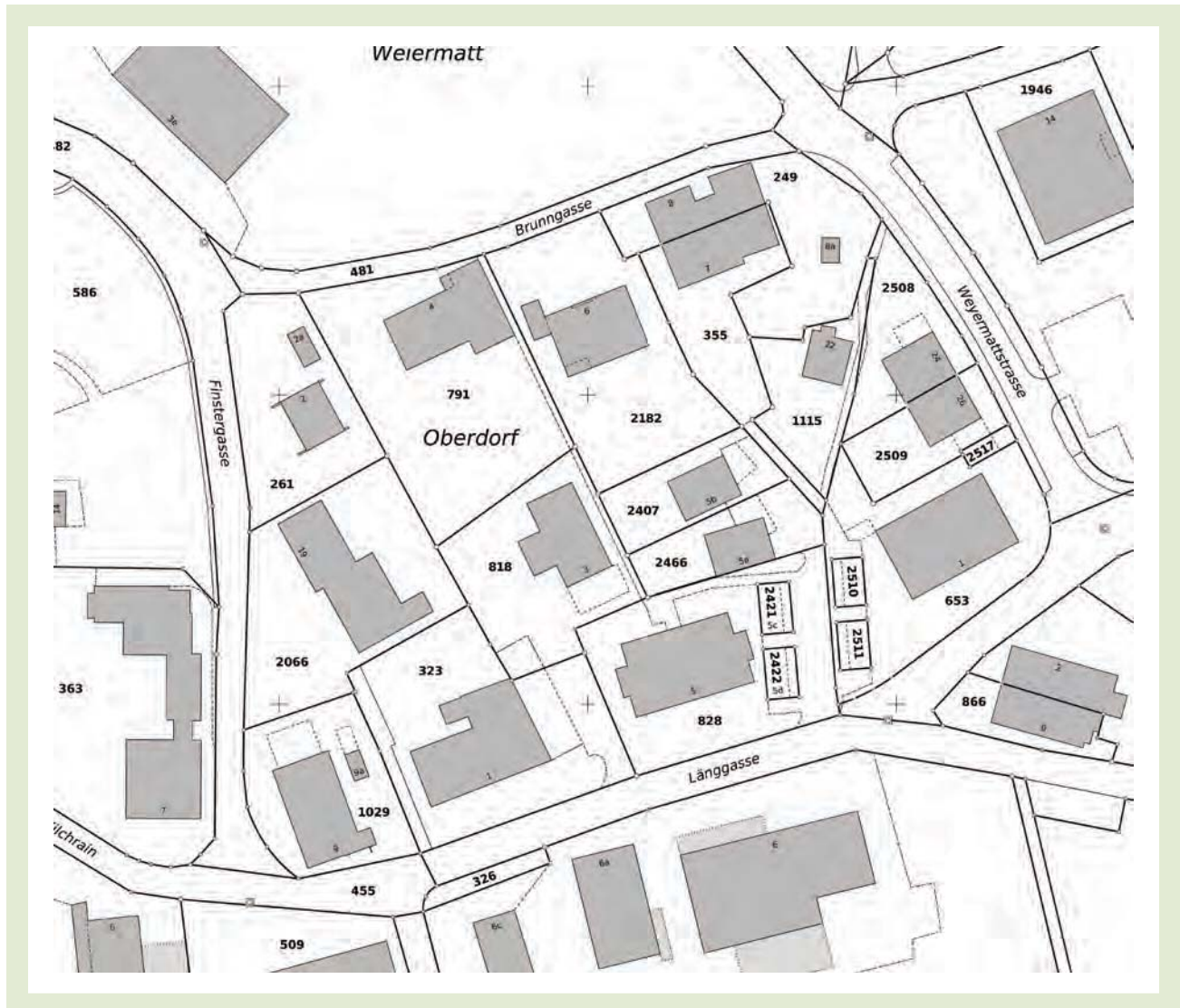


Figure 3 Example of a traditional cadastral map

Source: From Cadastral Template: A Worldwide Comparison of Cadastral Systems. (2003). *Cadastral template—Country data: Switzerland*. Retrieved December 19, 2009, from www.cadastraltemplate.org/countrydata/ch.htm.

After the fall of the Roman Empire and the beginning of the feudal era, comprehensive mapping of real property was largely discontinued, although isolated historical events highlight the continued importance of recording real property information. For instance, the Domesday Book, commissioned by William the Conqueror of England in 1086, was a population census as well as a record of real property and livestock ownership and valuation for a large part of the country; it was instrumental in consolidating

royal power and raising tax revenues for the crown.

In the nascent capitalist nations of 16th- and 17th-century Europe, land reemerged as a private commodity, and it once again became vital to administer this property by mapping and recording information about ownership and rights held. Private property took the place of feudal and communal property, coinciding roughly with the European “age of exploration” and the wholesale acquisition of new continents full of land, which



Figure 4 Early cadastral map from Northern Italy. Streams, irrigation channels, and roadways are delineated as lines. A circle with a dot represents a well, and a rectangular piece of land with regular dots is a cultivated field.

Source: From Larsson, G. (1991). *Land registration and cadastral systems: Tools of land information and management*. New York: Longman Scientific and Technical. Copyright © 1991 by Longman. Reprinted by permission of Pearson Education Limited.

also had to be surveyed, mapped, recorded, and distributed. The birth of modern cadastral mapping took place in this period, and in most of North and South America, Australia, India, and other colonized regions, this process was in conflict with the indigenous populations' beliefs about land ownership. In the United States, both the Land Ordinance of 1785 and the Homestead Act of 1862 laid the foundations of American land policy by surveying, mapping, and giving away millions of acres of land, most of which was already inhabited or otherwise used by the original populations. In 18th- and 19th-century Western Europe, cadastral surveys served primarily as a means of collecting taxes, although by the 19th century, they also assumed importance in providing security of private property rights.

Importance and Major Societal Benefits of Cadastral Systems

The manner in which a society perceives its relationship to land is emblematic of its general worldview. In many cultures today, land forms the basis of wealth, and therefore, it is thought necessary to thoroughly inventory it and document its value and ownership in order to make effective decisions about its use, access, and control.

Many governmental agencies and private firms directly depend on reliable information about land. Functions such as urban and rural land use planning and zoning; environmental analysis and protection; natural resources management; parks and recreational management and planning;



Figure 5 A 19th-century European cadastral map: Village of Pielnia, Poland, 1852

Source: Public domain.

housing and preservation; economic development; emergency preparedness and disaster relief; real estate markets; municipal finance and property tax assessment and collection;

infrastructure maintenance and construction; and many social services depend on the existence of accurate and up-to-date information on land at the parcel level.



Having comprehensive cadastral information has administrative and legal benefits. For instance, it allows the establishment of a land market, permitting land rights to be bought, sold, mortgaged, and leased; and it enables easier and better-protected real property transactions, resulting in less litigation, such as property boundary disputes. Thus, cadastral systems can be seen as a stabilizing influence on a nation's financial and legal systems, promoting a sense of security, protection, and fairness.

Ongoing Issues: Reform, Equity, and New Technologies

The definition and distribution of land rights are undertaken by most societies and are based on the society's social, political, and religious structures. These rights, in turn, influence how labor and capital are invested in the land. There are a number of common land tenure forms, such as the Anglo-American, the Roman-French-German, the Communist/Socialist (state and cooperatives), Islamic, and community. In developing countries, communal land tenure is often converted to individual tenure in an effort to increase economic productivity, to modernize, and to promote nation building. This change from communal to individual land tenure also occurs where planned economies are supplanted by market economies, and it usually requires a completely new cadastral land registration system to be instituted.

The establishment or reform of cadastral systems and their associated legal structures is a complicated matter, presenting special problems. Standardizing cadastral systems and creating an international cadastral template may not be feasible, due to the many models that currently exist and countries' different land management needs. In many places, it is critical for cadastral systems to incorporate customary and "informal" rights (e.g., the traditional right to harvest woodland resources, rights to common pasture grounds, or seasonal rights to certain land uses). In other places, "3D" (three-dimensional) rights and responsibilities are of paramount importance, which include underground mineral rights, air rights, and riparian and groundwater rights, in

addition to the typical "2D" surface land rights (Figure 6).

Over the past decade, advances in geographic technologies have made it likely that many more countries can have cadastral systems based on common concepts, allowing data exchange and interoperability. Cadastral systems can be improved through innovations in GIS, new geospatial databases, integration with computer-aided data (CAD) and aerial photos, automated scanning, updating with mobile GIS, online search and mapping capabilities, new measurement methods, new ways to access large imagery collections, browser-based editing, and citizen access to this information and functionality. However, there are ethical issues involved: The disproportionate availability and access to geotechnologies and the expertise necessary to use them can result in inequity, and the associated costs of technology may be burdensome for developing nations.

On the other hand, there are a number of ethical reasons to establish new cadastral systems and undertake cadastral reform, including poverty mitigation and gender equity. There is a strong correlation between poverty and access to land. Through an expansion of rights to own land, poverty and inequity can be alleviated. Land mapping is one way to formally document land rights that may have been held by custom or traditionally but not legally. Cartographic and geodetic information helps modernize the cadastral structure and establishes a database of land information, which can augment a legal case for ownership. When there are constraints on access to land, residents have difficulties obtaining financing. For example, in many permanent slum areas with marginal housing and tenuous ownership, credit is usually only available for people who hold formal title to the land. There are often no cadastral records of these areas, or the record does not reflect the actual users/residents. Something as mundane as structure numbers or a viable street numbering system can enable proper cadastral registration and help secure financing for individuals or for property owners in common.

Development of cadastral systems can also play an important role in gender equity, since in many countries women traditionally have limited rights of ownership and inheritance. Yet this is

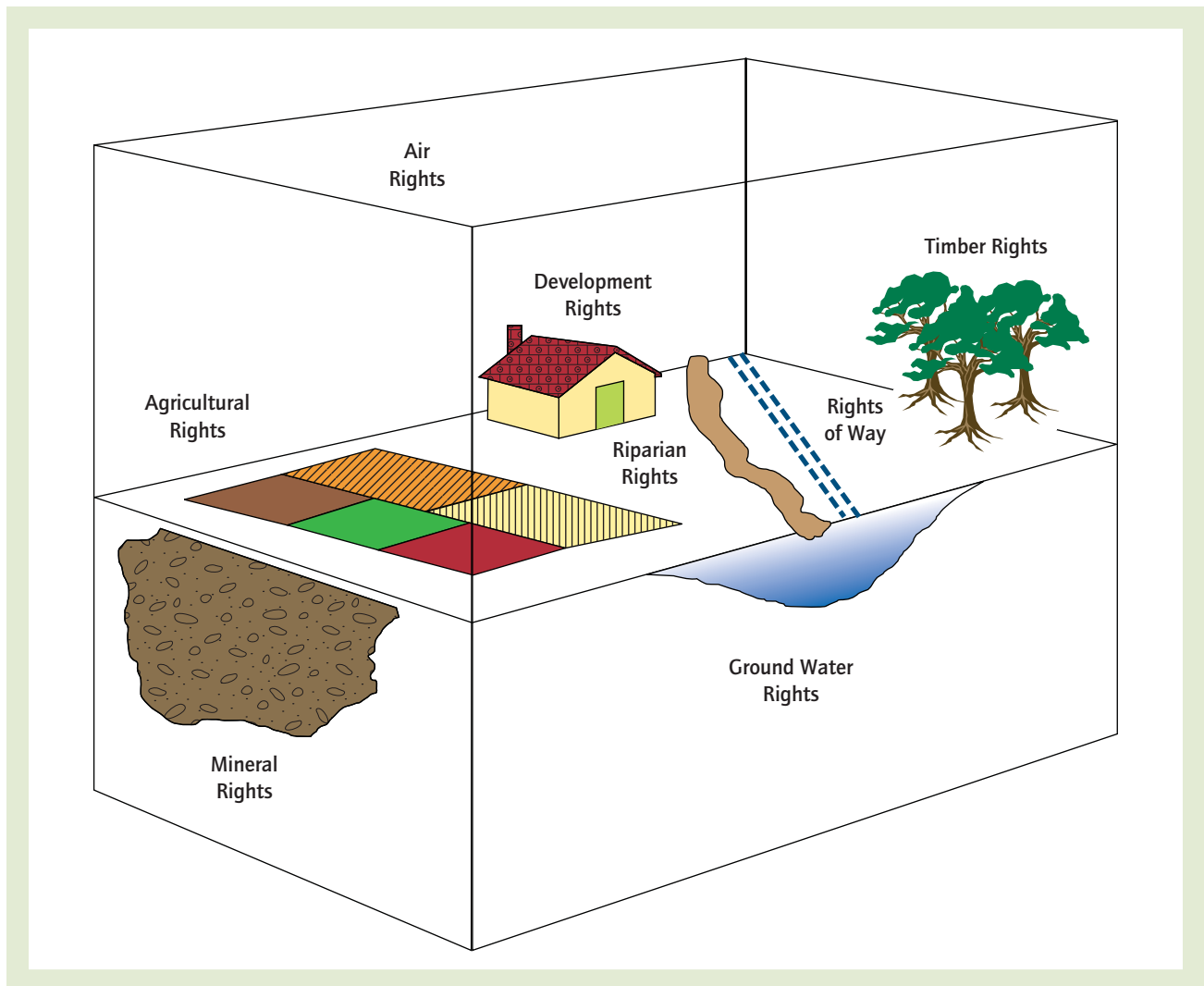


Figure 6 The three dimensions of land rights. Cadastral systems may also record and map three-dimensional rights attached to the land, such as underground mineral rights, air rights, and riparian and groundwater rights.

Source: From Dale, P., & McLaughlin, J. (1988). *Land information management: An introduction with special reference to cadastral problems in third world countries* (p. 3). Oxford, UK: Clarendon Press. Copyright © by Clarendon Press, 1988. Based on Platt, R. (1975). *Land use control* (Resource Paper No. 75-1). Washington, DC: Association of American Geographers.

sometimes by custom and not by law, so instituting a cadastral system and official recording of women's ownership on titles and deeds can have the effect of clarifying joint or individual ownership, ensuring rights in decision making about property management, and providing protection of property in case of divorce or death of a spouse.

In developing countries, land administration can be a critical element in the wider economic development agenda, and in both developing and

developed countries, cadastral systems are crucial to support decision making for a sustainable environment. As Will Rogers, the American humorist, famously said, "Land—they ain't making any more of the stuff."

Juliana A. Maantay

See also Cartography, History of; GIS in Land Use Management; Surveying; Township and Range System; Zoning



Further Readings

- Dale, P., & McLaughlin, J. (1988). *Land information management: An introduction with special reference to cadastral problems in Third World countries*. Oxford, UK: Clarendon Press.
- Dale, P., & McLaughlin, J. (2000). *Land administration (spatial information systems)*. Oxford, UK: Oxford University Press.
- Kain, R., & Baigent, E. (1992). *The cadastral map in the service of the state: A history of property mapping*. Chicago: University of Chicago Press.
- Larsson, G. (1991). *Land registration and cadastral systems: Tools of land information and management*. New York: Longman Scientific and Technical.
- Price, E. (1995). *Dividing the land: Early American beginnings of our private property mosaic*. Chicago: University of Chicago Press.



CAD SYSTEMS

Computer-assisted (or aided) drafting (CAD) systems are used to produce maps, diagrams, drawings, plans, and charts. CAD systems are to maps and graphics what word processing packages are to the written word: an easier, digital method for creating and editing documents, which were once drafted by hand. CAD systems are used extensively to map infrastructure (e.g., roads, utilities, property, telecommunication networks) as well as for architecture plans and renderings, mechanical designs, and drawings used in civil and industrial design. Although geographers use these systems largely for mapping geospatial information, CAD systems are remarkably versatile and are used for applications as diverse as designing microchips; shipbuilding; aircraft, aerospace, and satellite design; automobile and engine design and rendering; textile and fashion design; robotics; and computer-assisted manufacturing.

CAD systems, such as Illustrator or Corel-Draw software for drawing, offer great flexibility in representing graphical and spatial entities;

however, unlike most drawing packages, CAD systems are designed for drafting especially complex and highly precise maps and plans. CAD systems are also very closely related to vector-based geographic information systems (GIS) and often provide inputs or outputs for GIS analysis. Early CAD systems focused on ease of graphic design and editing and, in so doing, relied on Cartesian coordinate systems and lacked database interfaces for linking graphic and spatial features to nonspatial attributes—both features essential to GIS. Contemporary CAD systems can work with geographical coordinate systems and readily permit database linkages between spatial and nonspatial data, meaning that there is no longer a sharp divide between CAD and GIS. GIS systems usually offer a wider range of analytic, geospatial, and modeling options than do CAD systems, particularly in the domain of topological modeling, but even these types of GIS functionality can be built into CAD systems using add-on software, scripts, and macros. In the areas of terrain modeling, surface modeling and rendering, and three-dimensional modeling, mapping, and animation, GIS and CAD are moving ever closer together because their modeling, visualization, and computational models are closely interrelated.

CAD, vector-based GIS, and drawing software share many concepts that make it relatively easy for users to move back and forth among systems. Phenomena are represented graphically as points, lines, and areas/shapes. Features of particular types (e.g., roads, streams, or census boundaries) are organized into common layers or levels. All the systems offer tremendous flexibility in how the data are symbolized, for example, by hue, value, texture, size, orientation, and shape. Principles of effective cartographic and visual symbolization and display apply just as strongly to CAD systems as they do to GIS and drawing software.

CAD files are used widely to archive and exchange geospatial information. Commonly used file types that can be found on the Web are .dwg and .dxf (AutoCAD formats) and .dng (Microstation/Intergraph format), which cannot be readily imported into most GIS.

Other related terms are *computer-assisted mapping* (CAM), *computer-aided design* (CAD),



automated mapping/facilities management (AM/FM), computer-assisted drafting and design (CADD), and computer-assisted cartography.

Kenneth E. Foote

See also **GIS Implementation**

Further Readings

Jones, C. (1997). *Geographical information systems and computer cartography*. New York: Prentice Hall.

CÂMARA, GILBERTO (1956–)

Gilberto Câmara is a Brazilian researcher in the areas of geographical information science, spatial databases, spatial analysis, and environmental modeling. He was director for Earth observation (2001–2005) and general director (2006–2010) of Brazil's National Institute for Space Research (INPE) and is internationally known for defending open access to geospatial data and software. Câmara is responsible for setting up the free and open policy for remote sensing images from the China-Brazil Earth Resources Satellites (CBERS) worldwide and for creating the Remote Sensing Data Center of INPE, which has made decades of imagery freely available on the Internet. This made Brazil the world's largest distributor of remote sensing imagery (2005–2008). He was also responsible for setting up a methodology for real-time detection and monitoring of deforestation in the Brazilian Amazon rain forest.

Câmara is a professor in INPE's graduate programs in remote sensing and computer science and has published several books and more than 100 papers in conference proceedings and journals. He led the development of SPRING, a free GIS that was innovative in the use of the concepts of object-oriented modeling within a GIS environment, and of TerraLib, an open-source GIS library. These contributions have made him

one of the leaders in the establishment of the infrastructure of geospatial data and the GIS community in Brazil.

Pedro Ribeiro de Andrade

See also **GIScience; GIS Software; Remote Sensing**

Further Readings

- Câmara, G., Fonseca, F., Monteiro, A., & Onsrud, H. (2006). Networks of innovation and the establishment of a spatial data infrastructure in Brazil. *Information Technology for Development*, 12(4), 255–272.
- Câmara, G., Souza, R. C., Freitas, U. M., & Garrido, J. C. P. (1996). SPRING: Integrating remote sensing and GIS with object-oriented data modelling. *Computers and Graphics*, 15(6), 13–22.
- Câmara, G., Vinhas, L., Queiroz, G. R., Ferreira, K., Monteiro, A. M. V., Carvalho, M., et al. (2008). TerraLib: An open-source GIS library for large-scale environmental and socio-economic applications. In B. Hall (Ed.), *Open source approaches to spatial data handling*. Berlin, Germany: Springer.

CANADIAN ASSOCIATION OF GEOGRAPHERS

The Canadian Association of Geographers (CAG)/L'Association canadienne des géographes (ACG) is the national organization of geographers in Canada and for geographers outside Canada who have scholarly interests in Canada. The professional association includes members from universities as well as both public and private sectors. Its mission is to encourage geographic research, promote geographic education, and recognize geographic excellence through various awards. In addition, the organization is dedicated to cooperation and participation with other national and international geographic organizations and interdisciplinary organizations.

In 1950, a group of geographers representing the Canadian government's Geographical Branch



and several Canadian universities met to discuss the creation of a Canadian organization of geographers. They contacted other geographers in Canada and invited them to an inaugural meeting in May 1951, which was held at McGill University in Montreal. Although the precise number of geographers who participated in the meeting is not known, various sources suggest that number to have been about 60. By the end of the first day, the CAG was formally organized and officers elected; on the second day, eight papers were presented, seven of which were subsequently published in the first volume of *The Canadian Geographer*.

The CAG publishes *The Canadian Geographer*, a quarterly journal and the principal means through which it disseminates geographic research. In addition to this journal, the CAG publishes its *Newsletter* six times a year. The *Newsletter* is the venue in which information about professional jobs in geography, profiles of nominees for various elected positions, and information on study groups, regional divisions, and geographers in the news are made available to CAG members. The organization also publishes an annual directory that provides information about each geography department within Canada, its faculty, and the current research projects and recent publications of faculty members.

Although most of its members are associated with universities, the CAG is committed to geographic education at all levels. Since its establishment, the CAG has promoted geography in Canada through publication of its journal, newsletters, and annual meetings. The CAG hosts a national meeting each year. The event attracts geographers from across the country and many others from the United States and Europe. Both students and faculty members alike present at these meetings. The CAG has five regional divisions: (1) Western Division (British Columbia, Alberta, Yukon, and the Northwest Territories); (2) Prairie Division (Manitoba, Saskatchewan, and Nunavut); (3) Ontario Division; (4) Quebec Division; and (5) Atlantic Division (New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland). These divisions also host annual meetings in their respective regions and often share those meetings with corresponding regional divisions of the Association of American Geographers.

In addition to its regional divisions, the CAG also has 15 study groups that provide a forum for dis-

cussion and promotion of specific subdisciplines of geography. The groups are (1) Women and Geography; (2) Environment and Resources; (3) Tourism and Recreation; (4) Economic and Social Change; (5) Marine Studies and Coastal Zone Management; (6) Health and Health Care; (7) Indigenous Peoples; (8) Rural Geography; (9) Geomorphology; (10) Public Policy; (11) GIS; (12) Geographies of Asia; (13) Geographic Education; (14) Diversity, Migration, Ethnicity, and Race; and (15) Historical Geography. These groups organize special sessions at national and regional meetings and many have a presence on the Web and publish newsletters.

The CAG is governed by an executive committee, which includes a president, a vice president, a secretary-treasurer, and nine councillors, and by a short constitution with 13 articles. It is represented by university representatives at 49 geography departments across Canada. The offices of the CAG are housed at McGill University.

Dawn S. Bowen

See also **Association of American Geographers**

Further Readings

Canadian Association of Geographers: www.cag-acg.ca/en/index.html

Kobayashi, A. (2001). Truly our own: Canadian geography 50 years after. *The Canadian Geographer*, 45, 3–7.



CANCER, GEOGRAPHY OF

Within the fields of medical geography and spatial epidemiology, a specific topic is the geography of cancer, which includes the study of spatial and temporal patterns of different types of cancer for purposes of surveillance, prevention, and etiology inference.

Cancer Maps

Maps are important tools in the geographic study of cancer; however, when producing and interpreting



cancer maps, it is essential to consider how cancer is measured and displayed. Incidence, mortality, survival, prevalence, and stage of diagnosis are common measures of cancer disease outcomes. Typically, these measures are presented as rates, standardized by population size, age, sex, and race, as a means of accounting for the underlying demographic differences between regions. Since cancers are relatively rare diseases, data are often grouped across many years to provide sufficient stability to the rates. Some maps are descriptive (e.g., for purposes of surveillance), while others are used in spatial analyses undertaken to detect statistically significant patterns or possible associations with potential risk factors. An important issue is the spatial resolution of the cancer data. Depending on the purpose of the map, data may either be aggregated to some geographic level, for example, national, census units, postal districts, and so on, or the data may be mapped using the locations of individual persons (e.g., location of residence). In most applications the resolution is often determined by the availability of data, which is driven by confidentiality concerns, resulting in very few spatial studies of individual-level cancer. As a consequence, the modifiable areal unit problem (MAUP) must be considered, necessitating tests of whether results are consistent across different scales and levels of aggregation; without considering the MAUP, results should be interpreted cautiously.

Spatial Analysis of Cancer

Beyond descriptive maps of cancer, researchers use spatial analyses to quantify and explain spatial and temporal patterns of cancer. First, it is essential to determine if observed patterns are simply random or if there are true geographic differences. Common spatial analytic algorithms include Kulldorff's Spatial Scan and Cuzick and Edwards's Nearest Neighbour Test, although others also exist. If the patterns are statistically significant, researchers may try to identify some underlying factors that could explain the observed patterns. Such factors include smoking, diet, lifestyle, genes, environment, health care resources, and differences in cancer registration. If the spatial analyses point to certain possible risk factors,

a new hypothesis may be developed and tested, for example, by using spatial regression analysis such as Geographically Weighted Regression (GWR) or in a more structured epidemiologic study. One example would be the relationship between large concentrations of arsenic in drinking water and the high cancer mortality rates in Taiwan. This association was first suggested based on aggregated data on cancer mortality, which coincided with aggregated data on arsenic concentrations. Later, several case-control and cohort studies supported this hypothesis at the individual level. It should be noted that it is essential that any hypothesis originating from aggregated data be tested at the individual level due to the ecological fallacy.

Geographic studies of cancer, by and large, have generated little etiologic insight. This may be attributable to the neglect of individual mobility information. In the analysis of chronic diseases such as cancer, causative exposures may occur over a long time, and the disease may be manifested only after a lengthy latency period. During this latency period, individuals may move from one place of residence to another. This can make it difficult to detect patterns of cases in relation to the spatial distribution of their causative exposures without having information on residential mobility. Building on Torsten Hägerstrand's concepts, space-time mobility paths can now be visualized using temporal GIS technology. Statistical algorithms have recently been developed for evaluating space-time clustering in residential histories. This approach is theoretically appealing but largely untested, and it is not yet known whether it will reveal insights into disease etiology.

Examples

Cancer rates and types vary across continents, countries, regions, and even local neighborhoods; furthermore, differences also occur over time. The publication *Cancer Incidence in Five Continents* by the International Agency for Research on Cancer (IARC), for example, presents data on cancer incidence in more than 200 populations, showing significant international differences. Furthermore, noticeable differences in cancer incidence and mortality are even observed across very similar

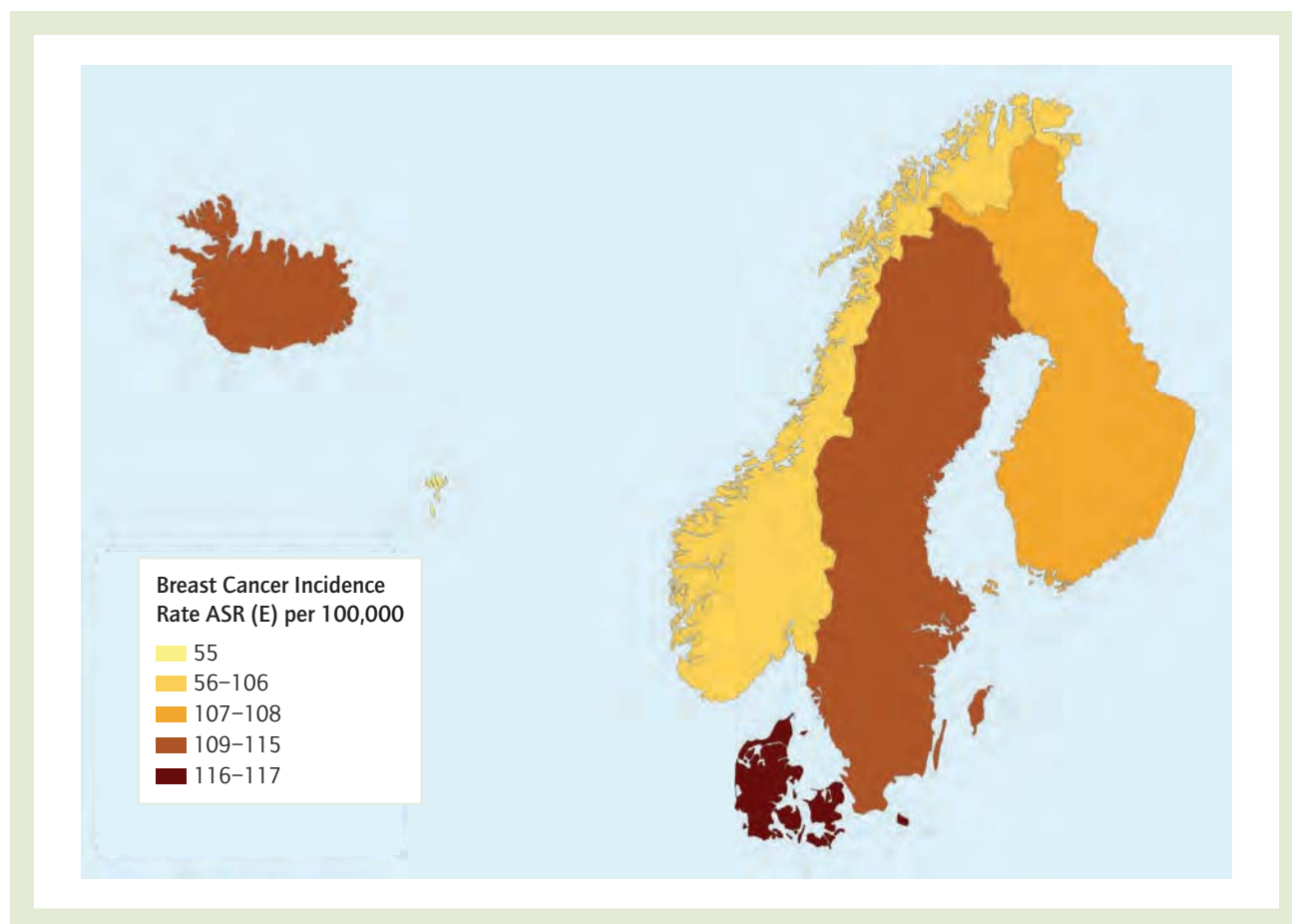


Figure 1 Female breast cancer incidence rates in the Nordic countries, 2003

Source: Map created by R. Baastrup from data in Engholm, G., Ferlay, F., Christensen, N., Bray, F., Gjerstorff, M. L., Klint, Å., et al. (2009). *NORDCAN: Cancer incidence, mortality and prevalence in the Nordic countries* (Version 2.4). Association of Nordic Cancer Registries, Danish Cancer Society. Retrieved December 18, 2009, from www.ancr.nu.

Note: ASR (E) = age-standardized rates (Europe).

countries, such as Sweden and Denmark (see www-dep.iarc.fr/NORDCAN.htm). Figure 1 shows the 2003 female breast cancer incidence rate in the Nordic countries of Europe (Iceland, Faeroe Islands, Norway, Sweden, Denmark, and Finland). The data are calculated using age-standardized rates (ASR), which enable calculation of the rates that the populations would have if they had a common age structure, thereby making it possible to compare rates across populations of different age structures. In this example, the European standard is used. The map shows noticeable differences in incidence across similar countries. Figure 2 shows the temporal trend in breast cancer incidence in the Nordic countries.

In these examples, the denominator for the incidence rate was drawn from the population as a whole, which can lead to problems if estimates of the underlying population are inaccurately estimated. For example, since census surveys are often only conducted once a decade, changes in the population distribution in the intercensal years can lead to inaccurate population estimates. One way around this problem is to map the proportions surviving or diagnosed at an early stage, using the incidence population as the denominator. In this way, both the numerator and the denominator are drawn from the same data set, typically a cancer registry. Maps of survival or stage of diagnosis provide information different

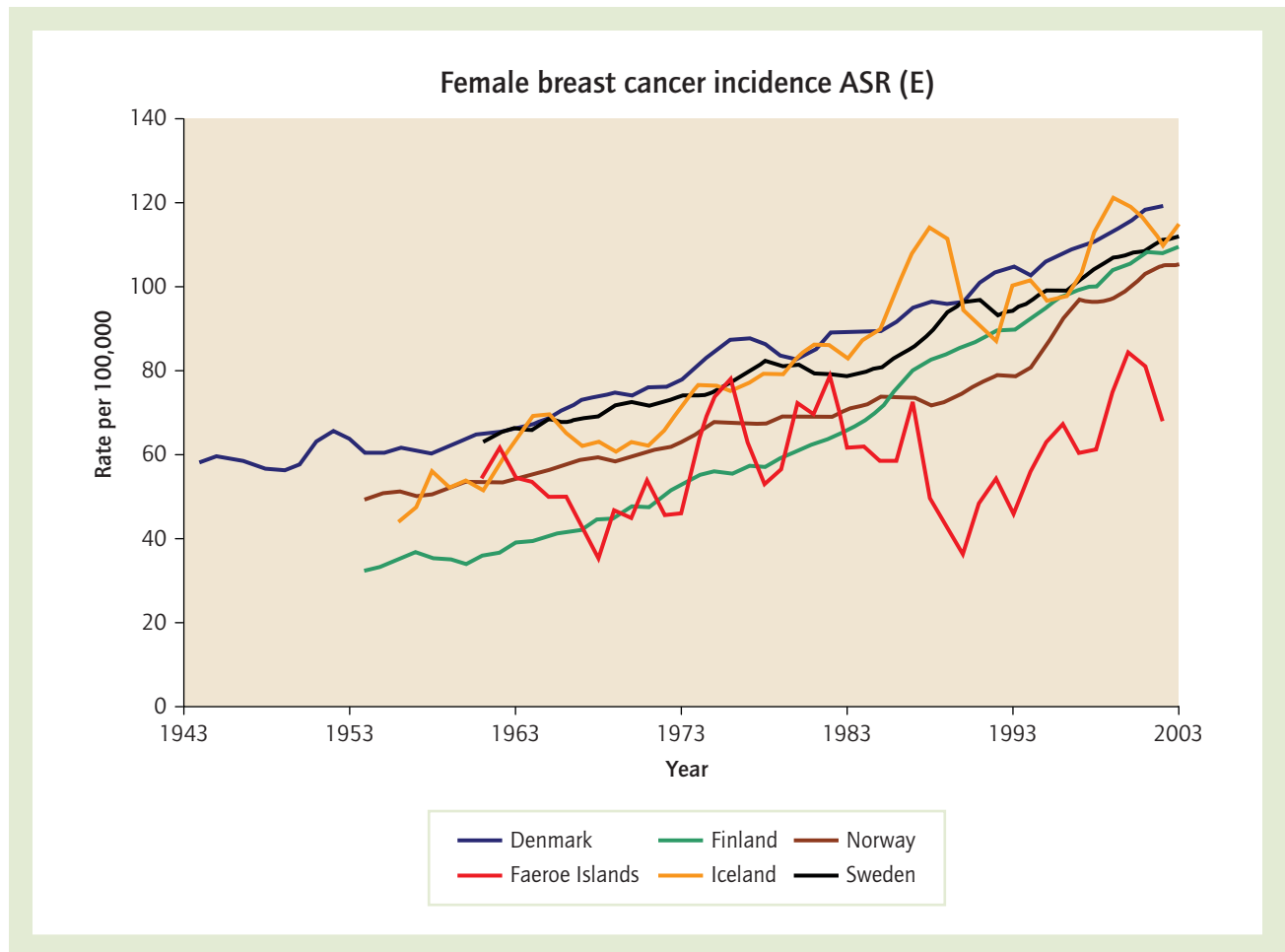


Figure 2 Temporal development in female breast cancer incidence rates in the Nordic countries

Source: Figure created by R. Baastrup from data in Engholm, G., Ferlay, F., Christensen, N., Bray, F., Gjerstorff, M. L., Klint, Å., et al. (2009). *NORDCAN: Cancer incidence, mortality and prevalence in the Nordic countries* (Version 2.4). Association of Nordic Cancer Registries and Danish Cancer Society. Retrieved December 18, 2009, from www.ancr.nu.

from that provided by incidence rate maps, but such maps are also valuable. As an example, Figure 3 shows the proportion of breast cancer survivors in Michigan State House legislative districts from 1985 to 1993, using data from the Michigan State Cancer Registry.

In a similar manner, this same registry data can be used to map proportions of early-stage breast cancer in Michigan. Figure 4 displays a cluster of early-stage breast cancer diagnosed from 1994 to 2002, detected using SatScan.

Residence at the time of diagnosis is an appropriate geographic unit for gaining insights about why survival or stage of diagnosis differs from place to place. The etiologic factors responsible

for cancer incidence, however, are best detected incorporating individual mobility histories because of cancer's latency period. Detecting spatial patterns in the mobility of cancer cases is a pivotal area of current research in the geography of cancer.

*Rikke Baastrup and
Jaymie R. Meliker*

See also Carcinogens; Disease, Geography of; Ecological Fallacy; Geographically Weighted Regression; GIS in Health Care; Health and Health Care, Geography of; Medical Geography; Modifiable Areal Unit Problem; Spatial Analysis; Time-Geography

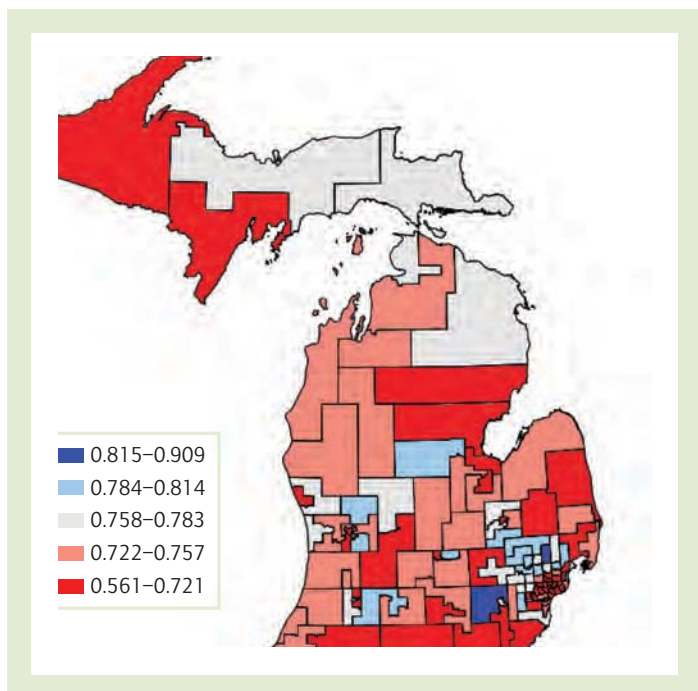


Figure 3 Proportion of female breast cancer survivors out of all breast cancer cases in Michigan State House legislative districts, 1985–1993

Source: Map created by J. R. Meliker from data in Meliker, J. R., Jacquez, G. M., Goovaerts, P., Copeland, G., & Yassine, M. (2009). Spatial cluster analysis of early stage breast cancer: A method for public health practice using cancer registry data. *Cancer Causes and Control*, 20, 1061–1069. Copyright © 2009 by Springer Science + Business Media.

Further Readings

- Jacquez, G., Meliker, J., AvRuskin, G., Goovaerts, P., Kaufmann, A., Wilson, M., et al. (2006). Case-control geographic clustering for residential histories accounting for risk factors and covariates [Electronic version]. *International Journal of Health Geographics*, 5(32). Retrieved January 12, 2010, from www.ehjournal.net
- Kulldorff, M., & Nagarwalla, N. (1995). Spatial disease clusters: Detection and inference. *Statistics in Medicine*, 14, 799–810.
- Meliker, J., Slotnick, M., AvRuskin, G., Kaufmann, A., Jacquez, G., & Nriagu, J. (2005). Improving exposure assessment in environmental epidemiology: Application of spatio-temporal visualization tools. *Journal of Geographical Systems*, 7, 49–66.



Figure 4 Cluster of high proportion of early-stage female breast cancer cases out of all breast cancer cases in Michigan, 1994–2002

Source: Map created by J. R. Meliker from data in Meliker, J. R., Jacquez, G. M., Goovaerts, P., AvRuskin, G. A., & Copeland, G. (2009). Breast and prostate cancer survival in Michigan: Can geographic analyses assist in understanding racial disparities? *Cancer*, 115, 2212–2221. Copyright © 2009 Wiley-Blackwell.

- Parkin, D., Bray, F., Ferlay, J., & Pisani, P. (2005). Global cancer statistics, 2002. *CA-A Cancer Journal for Clinicians*, 55, 74–108.
- Pickle, L., Waller, L., & Lawson, A. (2005). Current practices in cancer spatial data analysis: A call for guidance [Electronic version]. *International Journal of Health Geographics*, 4(3). Retrieved January 12, 2010, from www.ehjournal.net
- Vieira, V., Webster, T., Weinberg, J., Aschengrau, A., & Ozonoff, D. (2005). Spatial analysis of lung, colorectal, and breast cancer on Cape Cod: An application of generalized additive models to case-control data [Electronic version]. *Environmental Health*, 4(11). Retrieved January 12, 2010, from www.ehjournal.net
- Waller, L., & Turnbull, B. (1993). The effects of scale on tests for disease clustering. *Statistics in Medicine*, 12, 1869–1884.



CARBONATION

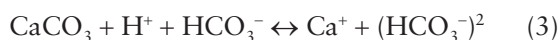
Carbonation is the chemical reaction that occurs when the mineral calcite, or calcium carbonate (CaCO_3), comes in contact with an acid. In the natural environment, where rotting organic matter occurs in soils, the soil water reacts with the carbon dioxide from the organic matter to produce carbonic acid:



In turn, the weak carbonic acid that is produced then disassociates or comes apart into smaller atomic particles and compounds:



These materials can react in turn with the calcium carbonate. In this case, the hydrogen ion, H^+ , is a proton, which is an extremely small particle from the hydrogen nucleus that can work its way into many mineral particles and disrupt them. In the case of the disruption of the solid calcium carbonate mineral or the limestone bedrock, the disassociated ions of the carbonic acid disrupt the atomic matrix and recombine to form the new compound of calcium bicarbonate, which is then dissolved in water.



In this fashion, the carbonate rocks of the world (sedimentary limestone and dolostone, or the crystalline rocks of metamorphic marble and igneous carbonatite) are subject to the carbonation reaction, and caves or caverns result. As the rocks dissolve, the rock is carried away in the water in solution as ions of Ca^{2+} and HCO_3^- . Thus, the solid calcium carbonate rock goes into solution and is carried away in underground waters as $\text{Ca}(\text{HCO}_3)_2$, to eventually end up in the ocean as one of the many kinds of salts in the sea. Organisms in the sea such as coral, bivalves, and other sea life use this dissolved calcium carbonate to make their reefs and shells.

The double arrows in the above reaction equations (Equations 1, 2, and 3) indicate that these reactions are reversible, that is, they can go in both directions, with the result that the carbon

dioxide (CO_2) gas that is dissolved in liquids can come out of the solution as the effervescence or “fizz” of carbonated beverages. Thus, in situations in which surface waters containing a high proportion of dissolved calcium carbonate are agitated in rapids as they flow over an uneven streambed, they can lose some of their dissolved CO_2 to the atmosphere and force the reactions to move CaCO_3 back out of solution and into precipitation as solid carbonate rock. This is the same process inside caves wherein the carbonate-bearing water moves through the fissures and pore spaces until it arrives on the surface of the underground opening, loses some CO_2 , and thus produces *stalactites* that hang from the ceiling, *stalagmites* growing up from the floor, and various forms of flowstone, dripstone, and other cave *speleothems* that are produced in these carbonation reactions. Thus, first carbonation reactions produce caves, mostly below the water table in the limestone bedrock, and then, once the water table drops and exposes the new cave to the atmosphere, the process reverses, and the cave is then in-filled back again with new *travertine* calcium carbonate.

John F. Shroder

See also **Carbon Cycle; Caverns; Geomorphology; Groundwater; Karst Topography; Rock Weathering**

Further Readings

Ford, D., & Williams, P. (2007). *Karst hydrogeology and geomorphology*. New York: Wiley.



CARBON CYCLE

The natural cycle of carbon is one of the biogeochemical cycles that link Earth's *atmosphere*, *hydrosphere*, and *lithosphere* with continental and oceanic *biota*. Together, these spheres and biota form the largest natural system: the *ecosphere* or *global ecosystem*. Detailed information on the size of carbon pools in the global ecosystem and on the direction, and magnitude of exchange fluxes are important parameters used in the construction of global carbon cycle models and in the forecasting

of atmospheric carbon dioxide concentration and changes in the atmospheric *greenhouse effect* and climate.

Biota

During their formation from protoplanetary dust cloud, Earth, Venus, and Mars captured similar percentages of carbon. Due to differences in their history, however, the concentrations of carbon in the modern atmospheres of these terrestrial planets vary widely. The atmospheres of Venus and Mars consist mostly of CO₂, with concentrations of 96.5% and 93.5% by volume, respectively. The atmosphere of Earth, in turn, is a 99% mixture of nitrogen and oxygen; the concentration of carbon dioxide is very low (~0.0000289%, or 289 ppm [parts per million] by volume in the middle of the 19th century and 383.86 ppm in 2007). Unlike Mars and Venus, most of the carbon on Earth is found not in the atmosphere but in the lithosphere in the form of carbonate deposits and organic carbon (Table 1). This striking difference in carbon distribution between Earth and other terrestrial planets can be explained only by the activity of living organisms.

Reservoir	Carbon Content
Atmosphere (at 384 ppm [parts per million]; 2007 data)	804
Phytomass (living biomass of plants)	610
Soil organic matter	1,580
Oceanic biota	2
Dissolved and suspended organic matter in the ocean	1,830
Dissolved inorganic carbon in the ocean	36,000
Organic carbon in the lithosphere	12,000,000
Carbonates in the lithosphere	94,000,000

Table 1 Carbon pools in modern Earth

Sources: Adapted from Budyko, M., Ronov, A., & Yanshin, A. (1987). *History of the Earth's atmosphere*. New York: Springer-Verlag; Houghton, R. (2005). The contemporary carbon cycle. In W. Schlesinger (Ed.), *Biogeochemistry* (pp. 473–513). Amsterdam: Elsevier Science.

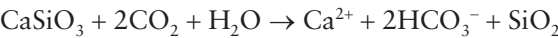
Note: Some estimates vary in large by as much as 25%. Units are in gigatons (Gt) of carbon (1Gt = 10¹² kilograms).

In photosynthesis, green plants (including marine phytoplankton) produce carbohydrates (organic matter). The net primary productivity (the rate of annual biologic fixation of carbon by continental and oceanic biota) is about 85 to 90 Gt/yr. (gigatons per year) (Table 2). More than 99% of this organic matter is decomposed and returned to the atmosphere (Table 2). Depending on the molecular weight of specific organic compounds, however, the rate of their decomposition varies from less than a year to hundreds and even thousands of years.

The biomass of marine organisms is two orders of magnitude smaller than the biomass of terrestrial organisms, but the productivity of marine biota is only two times smaller than the productivity of all terrestrial organisms (see Tables 1 and 2).

Lithosphere

A common form of organic carbon in geologic sedimentary rocks is kerogen, which is insoluble in water, a carbohydrate of irregular structure and very high molecular weight. In the past few hundred million years, a rather small portion of kerogen was transformed inside the lithosphere into various types of fossil fuel: coal, oil, and natural gas. Overall, however, sedimentary geologic rocks contain most of their carbon not as organic matter but as carbonates (Table 1). Carbonates are mineral sedimentary rocks formed in the process of weathering of original igneous (volcanic) rocks. The process of chemical weathering is regulated by the reaction of carbon dioxide with silicate minerals in soil. This reaction can be accelerated by root respiration of vascular plants as well as by activity of soil bacteria. As a result of chemical weathering, calcium and/or magnesium ions are released from soil into water, while carbon dioxide is transformed into bicarbonates:



Dissolved products of this reaction are carried to the ocean by river runoff. In oceanic waters, calcium and magnesium can be recombined with bicarbonates to form carbonate deposits:





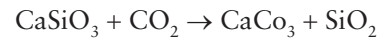
Fluxes	Gigatons per Year
Net primary production of continental biota	60
Root respiration	18.5
Flux to top of soil with organic litter	41.5
Carbon mineralization on top of soil	38.3
Formation of new humus (fast and slow cycling)	2.5
Oxidation of humus	2.2
Flux of terrestrial carbon to the ocean as atmospheric aerosol and dust; discharge of organic carbon to the ocean with continental runoff	1.0 25–30
Net primary production of oceanic plankton	20–25
Oxidation of organic carbon in water column	5
Flux to suspended and dissolved oceanic carbon reservoir	1–3
Sedimentation of organic carbon at the oceanic floor	0.9–2.9
Oxidation of organic carbon at the oceanic floor	0.02
Preservation of organic carbon in the lithosphere	0.15
Preservation of carbonate carbon in the lithosphere	90–100
Exchange of carbon dioxide between the ocean and the atmosphere	1.6–3.2
Net intake of anthropogenic CO ₂ by the ocean	

Table 2 Major fluxes in the global carbon cycle

Sources: Adapted from Kobak, K. I. (1988). *Biotic components of carbon cycle* (p. 248). Leningrad, Russia: Hydrometeoizdat; Sundquist, E. T. (1985). Geological perspective on carbon dioxide and the carbon cycle. In E. Sundquist & W. S. Broecker (Eds.), *The carbon cycle and atmospheric CO₂: Natural variations Archean to present* (Geophysical Monographs No. 32; pp. 5–60). Washington, DC: American Geophysical Union.

Note: Some estimates vary in large by as much as 50%. This uncertainty is larger for some fluxes, such as the rate of organic carbon sedimentation and the rate of organic carbon oxidation at the ocean floor.

The resulting reaction (below) demonstrates the net flux of carbon dioxide from the atmosphere to geologic deposits (*Urey reaction*):



This reaction demonstrates that an increase in the atmospheric CO₂ should lead to an increase in the accumulation of carbonate sediments. In other words, the Urey reaction represents an important negative feedback mechanism (also called a geochemical *thermostat*) that may have kept the atmospheric greenhouse effect within limits suitable for life. Indeed, the high level of volcanic activity in early geologic epochs caused a significant emission of CO₂ into the atmosphere. The high CO₂ concentration, in turn, caused an increase in chemical weathering and transportation of carbon dioxide to geologic sediments. Thus, the Urey reaction helped reduce the ancient greenhouse effect and kept the planet relatively cool. The opposite is also true. As volcanic activity slowed down, the rate of chemical weathering and removal of CO₂ from the atmosphere had to decline.

More than 90% of carbonate deposits on Earth were formed by living organisms. The rate of biogenic carbonate preservation (formation of CaCO₃ in the right side of the Urey reaction) is a function of many external physical and chemical parameters, such as temperature, saturation of oceanic waters with carbonates, and some others. Every year, oceanic and continental deposits accumulate 0.1 to 0.2 Gt of mostly biogenic carbon (Table 2), which is practically equal to the rate of carbon dioxide emission due to volcanic activity and, at the same time, 25 to 50 times smaller than recent anthropogenic emissions of carbon into the atmosphere.

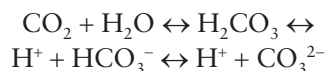
Ocean

Oceanic waters constitute the second largest (after the lithosphere) pool of carbon (Table 1). Unlike the lithosphere, however, oceanic carbon is present in dissolved form and is readily available for exchange with the atmosphere.

In seawater, inorganic carbon exists in four major forms: (1) dissolved carbon dioxide (CO₂), (2) carbonic acid (H₂CO₃), (3) carbonate (CO₃²⁻), and (4) bicarbonate (HCO₃⁻) ions. All these forms



of carbon participate in a series of interrelated chemical reactions. The resulting chemical equilibrium in seawater can be presented in the following equation:



The intensity of carbon dioxide exchange between ocean and atmosphere depends on the chemical and physical properties of surface oceanic waters. The concentration of dissolved inorganic carbon in surface waters, in turn, is regulated by the exchange with deeper layers and by the activity of oceanic biota. Marine life significantly decreases the concentration of dissolved inorganic carbon and essential nutrients such as nitrogen and phosphorus in the mixed layer of ocean (upper 50–100 meters). Often, this effect is called *biologic pump*. Biota absorb carbon from the mixed layer in the process of photosynthesis and when, under the force of gravity, organic matter descends into deeper layers, where it degrades. The speed of organic matter descent is directly proportional to the size and density of marine organisms. At the current rate of net primary production, marine biota cause a reduction of equilibrium with the atmospheric concentration of CO_2 in the mixed layer of ocean of about 300 ppm.

Atmosphere

The share of atmospheric carbon in the global carbon cycle is small compared with that of other carbon reservoirs (Table 1). Therefore, the atmospheric concentration of CO_2 can be changed drastically in response to relatively small disturbances in other reservoirs such as ocean, soil, and geologic sediments or continental and oceanic biota.

Over millions of years, changes in the concentration of atmospheric carbon were caused by slight deviations from the balance between two major fluxes: (1) volcanic activity and (2) chemical weathering of volcanic rocks.

During the past 100 million years, the atmospheric concentration of carbon dioxide declined from more than 3,000 ppm in the Late Cretaceous period to 400 to 500 ppm in the Pliocene.

The main cause of such change was gradually diminishing volcanic activity. The appearance of angiosperm plants at the end of the Cretaceous period, however, might have enhanced chemical weathering in the soil and contributed to a decrease in the atmospheric carbon dioxide concentration.

At the timescale of thousands of years, the interaction of atmospheric carbon with carbon pools in the oceans, biota, and soil seems to be more important than the relatively weak fluxes of chemical weathering and volcanic activity. During the past few hundred thousand years, atmospheric carbon dioxide concentration has exhibited almost periodic changes, from 200 to 300 ppm, coinciding with the major glacial-interglacial epochs.

During the 20th century, atmospheric carbon dioxide concentration demonstrated a consistent growth proportional to the rate of fossil fuel burning and to the rate of deforestation. At present, the atmosphere receives ~7 Gt/yr. of anthropogenic, which is 25 to 50 times greater than natural volcanic activity. The total amount of known fossil fuel reserves is ~5,000 Gt of carbon, or six times the amount of CO_2 in the modern atmosphere. Since the beginning of the Industrial Revolution, the combustion of fossil fuel has been by far the most important factor influencing changes in the atmospheric carbon dioxide. During the past few decades, however, the biosphere has demonstrated some visible increase in photosynthesis (especially in the circumpolar forests of the Northern Hemisphere). This increase, however, is still at least an order of magnitude smaller than the rate of CO_2 production through combustion of fossil fuel. Therefore, the growth of atmospheric CO_2 most likely will continue as long as humans continue to burn fossil fuel.

Andrei G. Lapenas

See also **Anthropogenic Climate Change; Atmospheric Pollution; Biogeochemical Cycles; Biota and Climate; Carbonation; Carbon Trading and Carbon Offsets; Climate Change; Climate Policy; Climatology; Ecosystems; Energy Models; Energy Policy; Global Sea-Level Rise; Greenhouse Gases; Sedimentation; Symptoms and Effects of Climate Change; Volcanoes**



Further Readings

- Berner, R., Lasaga, A., & Garrels, R. (1983). The carbonate-silicate geochemical cycle and its effect on atmospheric carbon dioxide over the past 100 million years. *American Journal of Science*, 283, 641–683.
- Bolin, B., & Eriksson, E. (1959). Changes in the carbon dioxide content of the atmosphere and the sea due to fossil fuel combustion. In B. Bolin (Ed.), *The atmosphere and the sea in motion* (pp. 130–142). New York: Rockefeller Institute Press.
- Budyko, M., Ronov, A., & Yanshin, A. (1987). *History of the Earth's atmosphere*. New York: Springer-Verlag.
- Houghton, R. (2005). The contemporary carbon cycle. In W. Schlesinger (Ed.), *Biogeochemistry* (pp. 473–513). Amsterdam: Elsevier Science.
- Huggett, R. (1999). Ecosphere, biosphere, or Gaia? What to call the global ecosystem? *Global Ecology and Biogeography*, 8(6), 425–431.
- Petit, J., Jouzel, J., Raynaud, D., Barkov, N., Barnola, J., Basile, I., et al. (1999). Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature*, 399, 429–436.
- Volk, T. (1987). Feedbacks between weathering and atmospheric CO₂ over the last 100 million years. *American Journal of Science*, 287, 763–779.
- Wigley, T. & Schimel, D. (2000). *The carbon cycle*. Cambridge, UK: Cambridge University Press.



CARBON TRADING AND CARBON OFFSETS

The carbon trade involves the exchange of either *emission allowances* or *carbon offsets*. An *allowance* is a right to emit a unit of greenhouse gases (GHGs)—typically defined as 1 metric ton of carbon dioxide (tCO₂) or equivalent quantity of other GHGs. An *offset* is created when a project or policy achieves a reduction of GHG emissions relative to a *baseline* scenario (defined as emissions that would have occurred if no project or policy was undertaken). Both allowances and offsets are accepted, through various institutional arrangements, such as fungible units of trade. These forms of exchange have been introduced to facilitate GHG emission reductions through the use of market mechanisms.

In creating these markets, society has placed a price on CO₂ and related pollutants, which are linked to all aspects of human activity. Since people all over the globe emit GHGs (albeit in highly differentiated ways), carbon markets span spatial scales and link disparate world regions. These markets have received attention from a range of geographic sub-disciplines and will likely continue to be the objects of study into the future.

Theoretical Foundations of Emissions Trading

Carbon trading can be traced to the mid 20th century, when economists began to examine the issue of social costs of economic activity. These *externalities* represent a form of market failure that arises when an economic exchange among one set of actors leads to impacts among other actors who are not participants in the exchange. Impacts may be positive, negative, or a combination, and environmental pollution is a classic example of a negative externality.

Prior to the introduction of market-based environmental regulation, the primary means of reducing pollution was through government-imposed limits. This approach was criticized because it restricts economic activity and does little to promote innovation. Alternative approaches were proposed, predicated on the theory that although pollution has negative social costs, so does the restriction of economic activity that causes pollution. Based largely on the work of economist Ronald Coase, the theory holds that the problem is reciprocal rather than one-sided. For example, if pollution emitted by A causes damages to B, the initial reaction may be to limit A's pollution. However, reducing the damages on B inflicts harm on A by adding abatement costs or forcing cuts in A's production.

Theoretically, there is an “optimal” level of pollution at which the net benefits to society can be maximized. In economists' jargon, this is the level of pollution at which the marginal social benefit of an additional unit of pollution equals the marginal social cost. However, finding an optimal level of pollution is more complex than this simple description implies. First, in Coase's original formulation, both A and B were single actors incurring individual costs and benefits. In reality, there may be multiple As releasing pollutants with



similar impacts on B. There may also be many Bs, each incurring costs that can be difficult to enumerate or attribute to a single polluter. Furthermore, A may deploy technical experts and litigators who challenge B's claims. Additional complications arise if B is displaced spatially or temporally from A. Moreover, the impacts of pollution are typically transmitted through air or water, which lack well-defined property rights. GHGs possess all these complicating factors, which is one reason why consensus on mitigation has been so elusive.

Nevertheless, the notion that pollution can have an optimal level has gained traction and facilitated the establishment of emissions trading in several ways. First, finding an optimal level of emissions puts a price on pollution, which can be used to guide policy formation. It also defines a "cap" on total emissions. This cap is subdivided among polluters so that each receives the right to emit a fixed quantity of pollution. This right can assume the form of private property, which creates the opportunity to sell, trade, or even "bank" it for future use.

In the context of climate change, the opportunity for trade is bolstered because GHGs are long-lived pollutants. Longevity and broad spatial dispersion create the sense that all emissions are identical. However, the costs of reducing emissions vary across different economic sectors and geographical regions. Therefore, net costs to society are minimized if actors subject to emission caps are permitted to trade their emission rights. Those with lower abatement costs prefer to reduce emissions below their cap to sell excess rights, while those with high costs prefer to purchase rights from others rather than reducing their own emissions.

These theories were linked to policy in the 1970s with the U.S. Clean Air Act (CAA) and operationalized with cap-and-trade of sulfur dioxide (SO₂) in the early 1990s. The success with SO₂ was invoked during negotiations for the Kyoto Protocol several years later.

Current Carbon Markets

In 2007, 2.7 billion metric tons of carbon emission reductions worth US\$60 billion were traded in several distinct carbon markets. Most trading occurs in *allowance-based markets*, where

governments grant allowances to polluting firms to create a cap on GHG emissions. *Project-based markets* exist in parallel with allowance markets and supply them with alternative sources of emission reductions in the form of *carbon offsets*. Offsets are created through activities that reduce GHG emissions relative to a baseline scenario. *Voluntary markets* are a particular type of project-based market which caters to buyers interested in meeting self-imposed emission reduction goals rather than state-imposed mandates.

The 2007 trade was split roughly 60-40 between allowances and offsets. The allowances are largely traded within the European Union's Emissions Trading Scheme (EU-ETS). Offsets are primarily derived from the Clean Development Mechanism (CDM) of the Kyoto Protocol, which is a scheme to promote mitigation projects in developing countries. Voluntary markets also rely on offsets and constituted about 4% of the trade in 2007.

The ETS is the largest active market. There are also several national and subnational schemes active or coming online, including Australian, Canadian, U.S., and possibly Japanese markets. Each has distinct sets of actors, governing institutions, and rules creating demand for offsets among participating players. There are also differences in the types of offsets that are acceptable for trade in each market. Markets are currently distinct, but there are discussions about the ways in which they could be linked in the future to create a single global carbon market. For this to happen, existing differences would need to be smoothed over. Table 1 describes some of the characteristics of existing markets, and Figure 1 illustrates the recent growth in volume and revenue in these markets.

Carbon Trading Under the International Climate Regime

The Kyoto Protocol is the impetus for the bulk of existing carbon markets, with Kyoto instruments collectively representing more than 95% of market activity. The Protocol introduced three "flexible mechanisms" linked to the carbon trade. Article 17 explicitly introduces emissions trading into the climate regime. Articles 6 and 12 define Joint Implementation (JI) and the CDM, respectively. Both are project-based mechanisms. JI supports projects in developed countries that

Market	Participating Countries or Subnational Units	Unit of Trade	Allocation Mechanisms	Enforcement Mechanisms	Trade in 2007	
					Million Metric Tons CO ₂ (tCO ₂)	Million US\$
Allowance-based markets						
European Union's Emissions Trading Scheme (EU-ETS)	27 European Union (EU) member states and several non-EU members (e.g., Norway, Iceland, and Liechtenstein)	EU Allowance Unit (EUA): equivalent to 1 tCO ₂	National Allocation Plans (NAPs)	The European Commission can reject NAPs, impose fines on noncompliant entities, and publicly name noncompliers; accepts some types of certified emission reductions (CERs)	1,600	44,000
Regional Greenhouse Gas Initiative (RGGI)	<i>Participants:</i> Northeastern U.S. states: Maine, New Hampshire, Vermont, New York, New Jersey, Delaware, Massachusetts, Maryland, Rhode Island <i>Observers:</i> Pennsylvania, D.C., and several Canadian provinces	CO ₂ allowance (1 tCO ₂)	Auction	Existing government laws: EPA acid rain rules require CO ₂ reporting. EPA Clean Air Interstate Rule requires equipment capable of CO ₂ reporting	NA	NA
Chicago Climate Exchange (CCX)	Range of actors covering industry, municipalities, universities, offset providers, offset aggregators	CCX Carbon Financial Instrument (CFI) contract (100 tCO ₂ equivalent). There are CFI allowances and offsets	Legally binding, voluntary annual greenhouse gas (GHG) reductions	Legally binding compliance regime, providing independent, third-party verification	24	104
New South Wales (NSW) GHG Reduction Scheme	New South Wales, Australian Capital Territory	Two types of allowances (1 tCO ₂): transferable NSW GHG Abatement Certificates; nontransferable Large User Abatement Certificates	Companies must meet benchmarks relative to share of powermarket	Independent Pricing and Regulatory Tribunal (IPART) can impose fines	19.9	NA
Project-based schemes						
Clean Development Mechanism (CDM)	Signatories to the Kyoto Protocol defined as non-Annex 1 countries	CERs (1 tCO ₂)	Any non-Annex 1 signatory can host projects	Use of methodologies approved by the CDM executive board; third-party verification	947	18,900
Joint implementation (JI)	Signatories to the Kyoto Protocol defined as Annex 1 countries	Emission Reduction Unit (ERU): 1 tCO ₂	Any Annex 1 signatory can host projects	Joint Implementation Supervisory Committee (JISC) supervises verification process	38	512

Table 1 Key characteristics of existing carbon markets

Source: Based on data from Capoor, K., & Ambrosi, P. (2008). *State and trends of the carbon market 2008*. Washington, DC: World Bank.

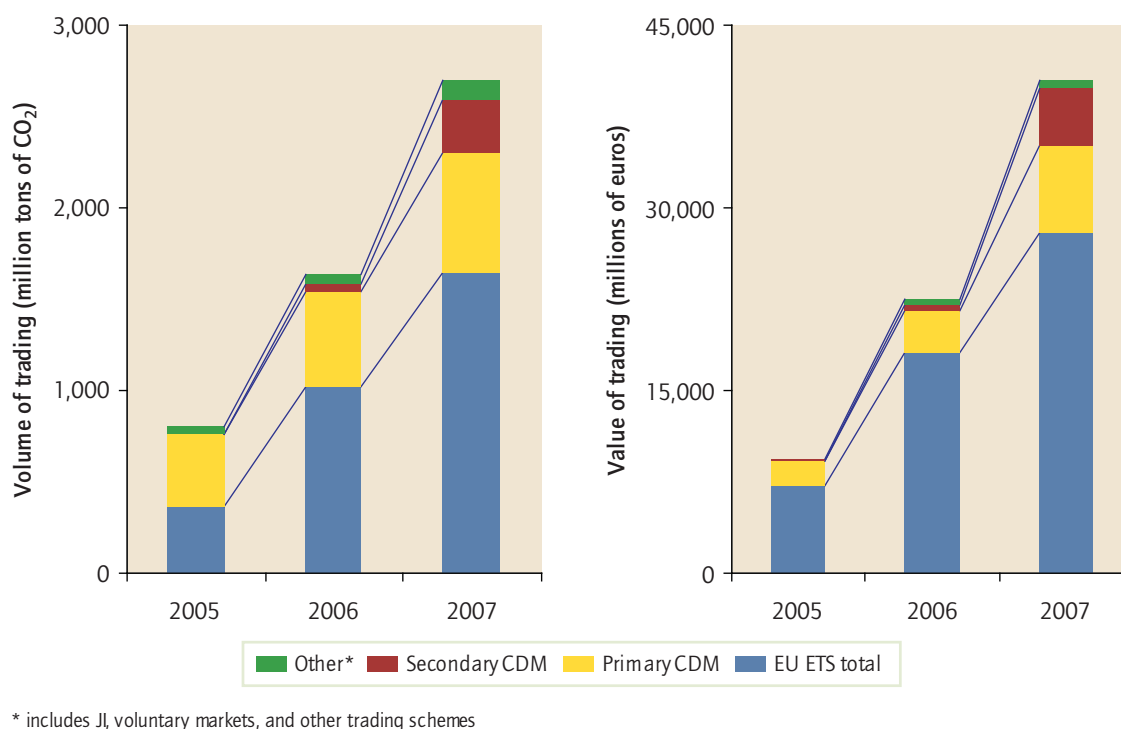


Figure 1 Activity in carbon markets showing trading volume (*left*) and value (*right*) from 2005 to 2007

Source: Figures created by author based on data from Røine, K., Tvinnereim, E., & Hasselknippe, H. (Eds.). (2008). *Carbon 2008: Post-2012 is now*. Washington, DC: PointCarbon.

were in transition to market economies at the time the Protocol was being drafted. CDM supports projects in developing countries that do not have commitments under the Protocol. Figure 2 depicts the countries and sectors that had been most active in CDM and JI from inception to mid 2008.

Critiques of Carbon Markets and Emissions Trading

Markets for carbon and other pollutants have been subject to numerous critiques, several of which have stemmed from geographic disciplines. Some critics challenge the fundamental validity of market mechanisms as a form of environmental governance, while others accept the potential of carbon markets to reduce emissions in theory but are critical of the ways in which these markets are implemented and operationalized.

Critiques of the Theoretical Validity of Carbon Markets

Market-based approaches to pollution control involve the creation of property rights to use a fraction of the atmosphere's finite ability to absorb heat-trapping GHGs. This "atmospheric sink" had been a common pool resource prior to the establishment of a market, and some challenges to the theoretical validity of carbon markets question the idea that such a common pool resource can be privatized. The exhaustible nature of the atmospheric GHG sink raises questions concerning the allocation of rights within and between generations.

Other challenges maintain that the privatization of the atmospheric sink and the commodification of landscapes' abilities to store or accumulate carbon exemplify neoliberal encroachment into environmental governance. This stance, originating from political ecology, critical geography, and

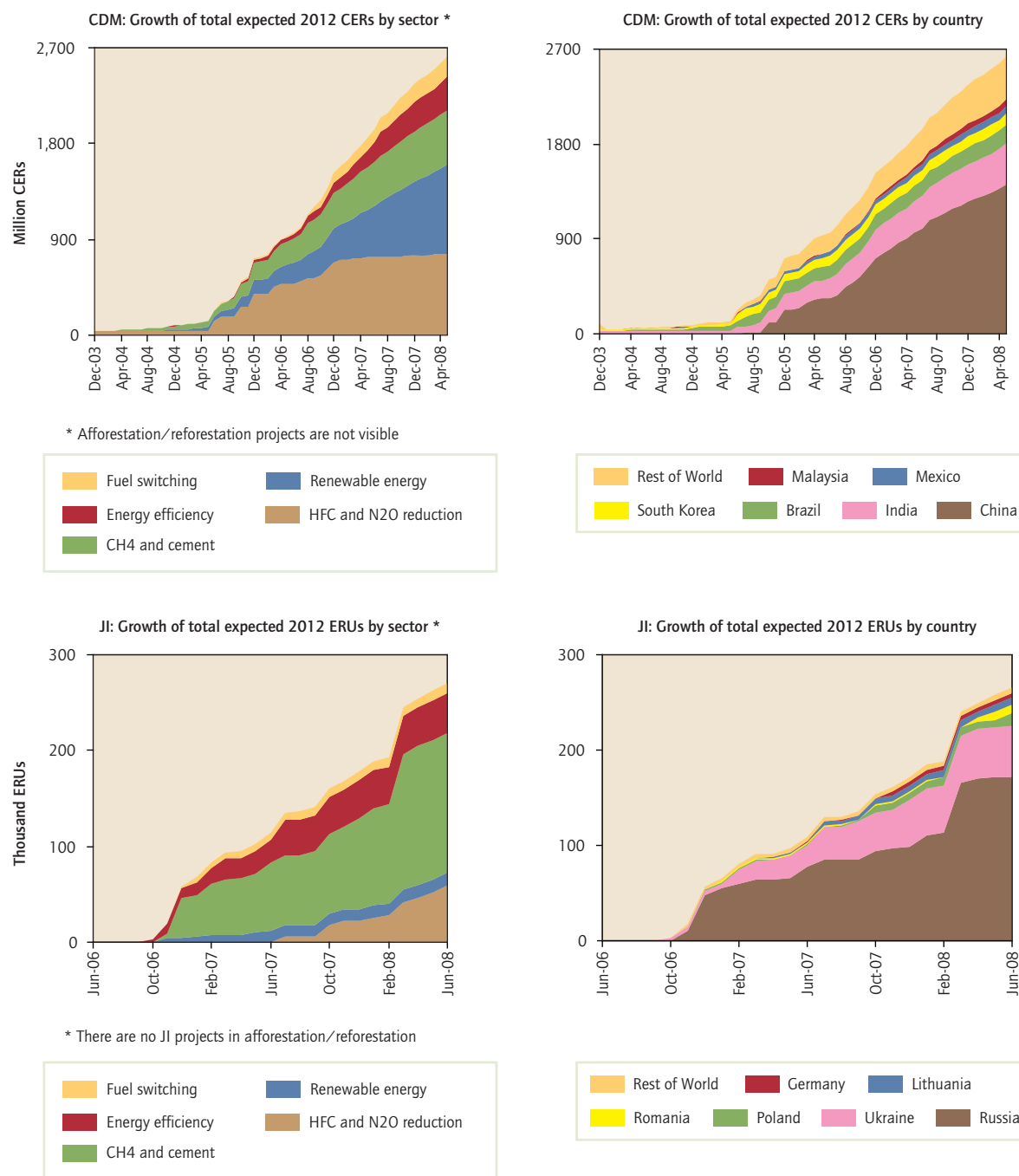


Figure 2 Growth in carbon offsets expected in 2012 from the CDM (*top*) and JI (*bottom*) by sector (*left*) and country (*right*)

Source: Figures created by author based on data from Fenhann, J. (2008, June). *CDM and JI pipeline overviews*. Retrieved July 25, 2008, from the CD4CDM—UNEP Risø Centre Web site: <http://cd4cdm.org>.

Notes: CERs = certified emission reductions; ERUs = emission reduction units. These are the names of the fungible offsets created by projects in the CDM and JI, respectively. Each is equal to 1 ton of CO₂.



allied fields, holds that the hegemonic nature of the “free-market environmentalist” approach to pollution control simultaneously appropriates and dilutes attempts to prevent the severe environmental consequences of capitalist production and consumption. They also silence alternative discourses proposing different approaches to GHG abatement, grounded, for example, in ethical or ecocentric arguments.

Further challenges to carbon markets attack the notion that emissions trading is geographically neutral. As discussed previously, 1 ton of CO₂ from a coal-fired power plant in China, from a cement factory in Mexico, and from a sport utility vehicle in the United States are identical from the narrowly defined perspective of atmospheric chemistry. However, the systems of production causing emissions are not at all equivalent. Critics claim that equating emissions from different sectors and world regions to render them fungible commodities hides the social and political context from which emissions originate.

Trading pollution allowances also reduce emissions from one sphere of activities and allow them to continue in another. Some critics differentiate between what they consider “luxury emissions” from the developed world and “survival emissions” from the developing world, using this dichotomy to argue that emissions trading encourages countries in the global South to sell low-cost carbon offsets to high-emitting industrialized countries, which perpetuates existing GHG-intensive activities in an inequitable global system. Another aspect of this critique is aimed specifically at markets that permit offsets generated by carbon sequestration, for example, afforestation and reforestation. Here, critics take issue with the notion that CO₂ fixed in living biomass is exchangeable with emission reductions from industrial processes. They claim that biophysical differences render the two incompatible and also point to the serious implications of land use change and, in particular, plantation forestry for local communities and indigenous populations.

Critiques of the Implementation of Carbon Markets

Critiques of carbon markets also arise from analysts who do not challenge the theoretical

potential of these markets but take issue with the ways in which these markets are put into practice. Critics have taken issue with the setting of emission caps and allocation of allowances under the cap. Both of these processes are subject to political manipulation. Allocation has proven to be particularly challenging. For example, the first phase of the EU-ETS was overallocated, which led to a crash in prices for the allowances that were traded in that market.

Ideally, allowances should be auctioned so that they go to the actors that most value them. Auctioning also creates a flow of revenue to the state, which assists in defraying the costs of establishing the market and creating necessary institutional oversight. In practice, many markets have been established via “grandfathering” of allowances, in which firms are *given* rights to emit that are proportional to their past emissions, which creates a large windfall for polluting firms.

Additional critiques have been leveled at the monitoring and verification in the production and trade of carbon offsets. To be traded in compliance markets, offsets are subjected to a rigorous verification process by UN-approved third-party verifiers. This requirement, viewed as essential to uphold the environmental integrity of the system, adds additional costs to any offset project. Even with these requirements, numerous charges have been leveled at the CDM that question the validity of the offsets that are being generated. Voluntary markets are subject to similar critiques currently and have fewer safeguards. In response, numerous standards are under development to introduce some degree of verification to voluntary markets.

Some critics hold that barriers to implementation of carbon trading are so severe that cap-and-trade systems should be scrapped in favor of a carbon tax. Theoretically, a tax on emissions should have the same effect as a functioning cap-and-trade system. However, proponents of the tax claim that taxes are preferable because they are more transparent, less susceptible to manipulation, and immune to market volatility. Taxes are also preferable when there is uncertainty in abatement costs. Such taxes have been implemented in several European countries but with many loopholes. Carbon taxes are also problematic because they do not guarantee a specific



level of emission reductions. Moreover, once implemented, taxes are difficult to adjust if further mitigation becomes necessary. Taxes may also be political nonstarters under certain circumstances. This point is particularly true in the United States, where market-based policies are preferred.

Robert Bailis

See also **Carbon Cycle; Climate Change; Climate Policy; Ecological Economics; Environmental Management; Market-Based Environmental Regulation; Neoliberal Environmental Policy; Political Ecology; Social and Economic Impacts of Climate Change; United Nations Environmental Summits**

Further Readings

- Bailey, I. (2007). Neoliberalism, climate governance, and the scalar politics of EU emissions trading. *Area*, 39, 431–442.
- Bumpus, A. G., & Liverman, D. M. (2008). Accumulation by decarbonization and the governance of carbon offsets. *Economic Geography*, 84, 127–155.
- Capoor, K., & Ambrosi, P. (2008). *State and trends of the carbon market 2008*. Washington, DC: World Bank.
- Coase, R. H. (1960). The problem of social cost. *Journal of Law and Economics*, 3, 1–44.
- Fenhann, J. (2008, July). *JI and CDM pipeline overviews*. Retrieved July 25, 2008, from CD4CDM—UNEP Risø Centre Web site at <http://cd4cdm.org>
- Lohmann, L. (2006). *Carbon trading: A critical conversation on climate change, privatization, and power*. The Hague, Netherlands: Dag Hammarskjöld Foundation.
- McCarthy, J., & Prudham, S. (2004). Neoliberal nature and the nature of neoliberalism. *Geoforum*, 35(3), 275–283.
- McKibbin, W. J., & Wilcoxon, P. J. (2002). The role of economics in climate change policy. *Journal of Economic Perspectives*, 16(2), 107.
- Voß, J. P. (2007). Innovation processes in governance: The development of “emissions trading” as a new policy instrument. *Science and Public Policy*, 34(5), 329–343.



CARCINOGENS

Cancer is a series of diseases characterized by abnormal cell growth and spread of cancerous cells through the body. A carcinogen is a substance that can cause cancer in humans or animals. Sometimes substances promote cancer or aggravate cancers but do not cause them. These substances also may be called carcinogens. Carcinogens include both naturally occurring substances (radon gas) and substances created as a result of production (the components of tobacco). Lists of known carcinogens are maintained by national and world agencies, such as the National Cancer Institute, the International Agency for Research on Cancer, the National Toxicology Program, and the World Health Organization.

Geographers have been involved in the study of cancer because there are obvious geographical differences between nations, within states and provinces in the same nation, among adjacent local governments, and even within neighborhoods. This entry highlights several of the most important contributions made by epidemiologists and geographers.

At the international and intranational scales, researchers have gained important insights about carcinogens by comparing the cancer incidence and mortality rates of immigrants. For example, a Polish epidemiologist compared cancer rates of Polish citizens who lived in Poland, Polish migrants to the United States, and the progeny of Polish migrants who lived in the United States. Residents of Poland had notably higher stomach cancer rates than the progeny of Polish migrants to the United States. Migrant studies are not confined to international comparisons. For instance, within the United States, the cancer death rates of Southern-born African Americans were compared with those of their counterparts born elsewhere in the United States. Southern-born African Americans had higher digestive, urinary, and respiratory cancer rates, irrespective of whether they lived in the South or had migrated to other locations in the United States.

Migrant studies such as these provide clues to field- and laboratory-based cancer researchers, allowing them to investigate the reasons for the different rates. For example, investigators



studied the food preferences and eating habits of African Americans residing in Harlem in New York City who were born in the Northeast, in the South, and in the Caribbean and found marked differences in their food preparation and consumption patterns. The United States has experienced a substantial increase in immigration in places such as California, New York, and New Jersey, and these places are rich environments for cancer-oriented migrant studies. These so-called migrant studies are inherently geographical and appeal to those who are interested in the study of risk factors for cancer, including food preferences, cooking and food preservation practices, tobacco and alcohol use, workplace exposures, and many others.

A second important area of cancer research that geographers have contributed to is cancer cluster investigations. Every year, residents of some neighborhoods report that there are an excessive number of cancers in their communities. To verify that a cluster exists, scientists must review every case, map the data, and compare the cancer cases with the number expected by chance. If there is indeed an excess, then public health experts will try to understand why the rates are higher than expected. Typically, no cause can be found, leading often to considerable public angst.

There are reasons for our failure to determine the carcinogens responsible for clusters. One is that the exposures are no longer present; that is, cancer normally takes two to four decades to appear. The source may be gone, or the individual who has contracted the cancer may have been exposed in an entirely different part of the country. Another reason is that cancer is a stochastic process. We should expect thousands of cancer clusters to occur in any one year across the United States at the neighborhood scale. This also means that there will be thousands of neighborhoods that have relatively few cancers. The important question is whether an excess of cancer cases is observed for many years, in which case it is highly improbable and warrants a detailed investigation. Geographers have played a role in cluster investigations.

Both migrant studies and cluster investigations depend on reliable data. The best way of accumulating reliable data for cancer studies is through proactive surveillance. Because of their understanding of spatial attributes, geographers can

make important contributions to the geography of cancer surveillance. Envision a database that includes the locations of people, known carcinogenic agents and their concentrations in the environment, and the distribution of incident cancers. If routinely updated, the database would allow state officials to identify locations where the number of cancers seems to be in excess. Armed with powerful GIS tools, they could map the distribution of the cases, review the geography of risk factors, and decide what steps, if any, are warranted. If they did this over an entire state, then the limited resources that state health and environmental protection departments have for cancer cluster investigations could be allocated on the basis of the best information. The alternative, which we heretofore have relied on, is to wait for local residents, local health department officials, physicians, and other people to identify what they perceive as a cluster and report those perceptions to state health and environmental officials. By the time the observations are made, more people may be exposed, budgets for investigation may be limited, and the locations that most warrant investigation may not be addressed. Hence, some scientists strongly believe that proactive surveillance will become much more common and the most important basis on which locations with high cancer rates or clusters of a specific kind of cancer will be determined and followed up. The surveillance approach to analyzing the geography of cancer implies that geographers who are well trained in GIS, medical geography, and epidemiology can become increasingly important to understanding carcinogenic processes as they play out across the landscape.

Michael R. Greenberg

See also **Cancer, Geography of; Disease, Geography of; Ecological Fallacy; GIS in Health Care; Health and Health Care, Geography of; Medical Geography; Risk Analysis and Assessment**

Further Readings

Doll, R., & Peto, R. (1982). *The causes of cancer*. New York: Oxford University Press.



- Greenberg, M. (1983). *Urbanization and cancer mortality*. New York: Oxford University Press.
- Greenberg, M., & Schneider, D. (1995). The cancer burden of Southern-born African-Americans: Analysis of a social geographical legacy. *Milbank Quarterly*, 73(4), 599–620.
- Nasca, P., & Pastides, H. (Eds.). (2001). *Fundamentals of cancer epidemiology*. Gaithersburg, MD: Aspen.



CARRYING CAPACITY

Carrying capacity is best known today as a means of expressing the finitude of Earth's resources relative to the human population. However, the concept has been used in a remarkably wide range of fields beyond demography and geography, including anthropology, ecology, population biology, range and wildlife management, engineering, medicine, and law. Considered across all these uses, *carrying capacity* may be defined as the maximum or optimal amount of some *X* that can be conveyed or supported by some encompassing entity or place *Y*. The cogency and utility of this definition depend on the *X* and *Y* in question, however, and an understanding of its complex history is necessary to evaluate carrying capacity as a concept.

In the 1840s, when the term originated, *carrying capacity* referred to the mechanical or engineered attributes of manufactured objects or systems, specifically ships. It arose in disputes over the tariffs and duties applied to steamships, as compared with the sailing vessels for which earlier laws and practices had been designed. Later in the 19th century, the concept was extended to things such as commuter rail systems, electrical lines, lightning rods, irrigation ditches, and pipelines.

The term *carrying capacity* was applied to living organisms and natural systems beginning in the 1870s. Examples include how much weight pack animals could haul, how much pollen certain bees could carry, and how much floodwater a bayou could transport. In the late 1880s, the term began to be used to describe the number of livestock a given quantity and quality of land could support. This marked an important reversal, as an earlier

“*Y*” became an “*X*” being “carried,” in a more figurative sense, by the environment in which it lived. In the 1920s and 1930s, early game managers applied this concept to quail and deer, and in the 1940s, British colonial administrators applied it to human populations in Africa as part of resettlement and agricultural development schemes. Also in this period, biologists and chemists conducted laboratory experiments in which invertebrates and microorganisms were found to display sigmoid population growth curves when provided a stream of nutrients under controlled environmental conditions. This observation led to the rediscovery of Pierre-François Verhulst's logistic equation (showing population growth and decline as an S-shaped curve), which would provide subsequent ecologists with a means of quantifying and modeling carrying capacity.

After World War II, two additional types of carrying capacity concepts emerged concurrently. One retained fauna as its object but transformed the epistemological basis of carrying capacity from inductive and applied to deductive and theoretical. This ecological concept has been poorly supported by empirical research, however, and is now seen to have only limited, heuristic value. The other shifted the object of the concept to humans and expanded its scale to regions, continents, and the entire globe, giving rise to the neo-Malthusian sense of *carrying capacity* that pervades the general use of the term today. When applied to living populations, however—and especially humans—static conceptions of carrying capacity are empirically unsupportable, while variable ones are theoretically incoherent.

Nathan F. Sayre

See also **Neo-Malthusianism; Population, Environment, and Development; Population and Land Degradation; Population and Land Use**

Further Readings

- Sayre, N. (2008). The genesis, history, and limits of carrying capacity. *Annals of the Association of American Geographers*, 98, 120–134.



CARTOGRAMS

A cartogram is a map on which the underlying geography has been distorted to convey the distribution of some thematic variable. If the distorted features are linear, such as the lines of a subway system modified to show travel times, then the cartogram is termed a *linear*, or *distance*, cartogram. Without a qualifier, *cartogram* typically refers to the value-by-area cartogram, in which polygonal features, such as state or country boundaries, are reduced or enlarged based on a variable such as population (see Figure 1). Such area cartograms take two major forms—contiguous and noncontiguous—and have been used primarily within the domains of political cartography and epidemiology.

The first use of the area cartogram technique is difficult to pinpoint, but early examples were produced in France and Germany in the late 19th and early 20th centuries. Early cartograms were produced using manual and mechanical methods. In the 1960s, Waldo Tobler pioneered the use of computer programs in cartogram production, and several fully specified algorithms have been produced since then.

Area cartograms are typically classified as either contiguous or noncontiguous, though a full range of designs exists between these extremes. Fully contiguous, “rubber sheet” cartograms distort the shapes of units but maintain all border relationships from the original geography. Noncontiguous cartograms preserve the shapes of features, simply creating gaps between units to accommodate scaling. Both major types have



Figure 1 Counties are sized by population and colored by the 2008 presidential election results. This contiguous cartogram was produced using a diffusion-based algorithm borrowed from particle physics.

Source: Map created by Michael Gastner, Cosma Shalizi, and Mark Newman of the University of Michigan.



distinct advantages and disadvantages, with the former design known for its compactness and the latter for its easily recognizable features.

For a cartogram to be effective, readers must be able to accurately recognize and estimate the areas of its features. The former task is hindered by the distorted, ballooned shapes found on many cartograms. Most cartographers attempt to maintain certain critical shape points along feature edges as visual cues to the original geographic space. Some, though, have taken the radical step of abstracting enumeration units to circles or squares, leaving only arrangement as a clue to the identity of cartogram features.

Area estimation in information graphics is typically poor, with most readers underestimating the size of symbols. Cartograms, which use the visual variable of area to convey information, are at a particular disadvantage. Rather than the circles and squares found on most proportional symbol maps, readers must estimate the areas of complex, sometimes multipart polygons.

Another factor in the effectiveness of cartogram communication is the distribution of the thematic variable chosen to map. A variable with a high correlation to land area will likely lead to an uninteresting cartogram. Cartograms are most effective at showing variables whose spatial distributions diverge markedly from land area.

Zachary Forest Johnson

See also **Cartography; Choropleth Maps; Isopleth Maps; Map Design; Map Visualization**

Further Readings

- Dent, B. (1999). *Cartography: Thematic map design*. Boston: McGraw-Hill.
- Olson, J. (1976). Noncontiguous area cartograms. *The Professional Geographer*, 28(4), 371–380.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2005). *Thematic cartography and geographic visualization*. Upper Saddle River, NJ: Prentice Hall.
- Tobler, W. (2004). Thirty-five years of computer cartograms. *Annals of the Association of American Geographers*, 94(20), 58–73.



CARTOGRAPHY

The term *cartography* is derived from the Greek words *chartis* (map) and *graphein* (to write). Cartography is commonly defined as the art and science of mapmaking, although these dimensions are not mutually exclusive. The “art” component of cartography refers to the aesthetic or design aspects of maps and mapmaking. Similar to artwork, each map is unique, and maps may be critiqued similarly to pieces of art. An artistic step in the mapmaking process includes the creation of an overall design layout for a map. The “science” component of cartography refers to the science and mathematics necessary for accurate and effective map production. Examples of the science aspect of cartography include the use of map projections to transform the spherical surface of the Earth to a flat map and the development of an experiment with human participants to determine which color combinations on a map are perceived most effectively. A person who compiles, designs, and produces maps of any type is referred to as a *cartographer*. This entry describes the types of maps and the variety of ways in which they are used and provides a brief history of Western cartography. It then reviews the elements of maps and explains the steps involved in creating them. In exploring how map users perceive and interpret maps, cartographers have conducted research in the areas of perception and cognitive studies. These studies, along with technological innovation, have led to a variety of new applications of cartography in today’s world. The entry examines some of these advances and concludes with comments on the cultural and ethical issues associated with cartography.

Categories of Maps and Map Uses

Throughout human history, maps have been created for a variety of uses and purposes. One of the earliest uses of maps was for navigation or wayfinding purposes, and this remains a common use of maps today. For example, a nautical chart used by the crew of a ship for navigation by sea and a subway map used by a tourist to travel around a city are both examples of maps used for navigation purposes. In addition, maps are commonly employed for displaying or visualizing



Figure 1 Example of a reference map

Source: Map created by author based on data from Environmental Systems Research Institute. (2008). *ESRI data and maps 9.3*. Redlands, CA: ESRI Press.

geographic trends or patterns in data. For example, a map of population density for provinces in a country would display geographic patterns of high- and low-density population in the country. Some maps depict geographic change over time, such as weather maps on television that forecast trends in daily temperature change over a week for a location. Other maps are used primarily for the management of resources, for example, maps used by employees of a city to manage infrastructure such as utility or water lines. Maps are also commonly used to assist in the decision-making process, such as a map that displays possible building locations for a new business based on proximity to prospective customers.

Maps produced by cartographers may be categorized in many different ways depending on their purpose or use. One common classification is to divide maps into two categories, reference maps and thematic maps. Reference maps (Figure 1) display the location of major geographic features such as cities, political boundaries, transportation networks, or physical features

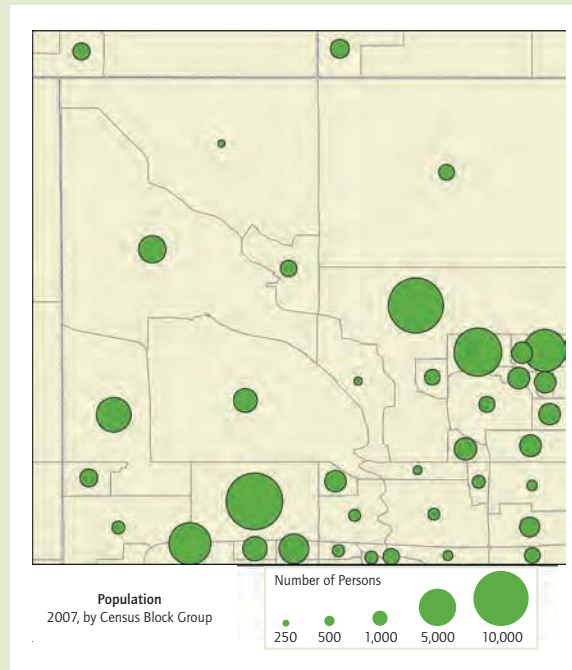


Figure 2 Example of a thematic map (total population by census block group) for the same area as Figure 1

Sources: Map created by author based on data from U.S. Census Bureau and Environmental Systems Research Institute. (2008). *ESRI data and maps 9.3*. Redlands, CA: ESRI Press.

(e.g., rivers, lakes, and mountain ranges). Examples of reference maps include the topographic maps published by the U.S. Geological Survey and the British Ordnance Survey. Thematic maps (Figure 2), commonly referred to as *statistical maps*, display a particular theme, topic, or attribute. Examples include a map of per capita income for states in the United States and a map of languages spoken in countries within a region of the world. Thematic maps are constructed from a base map (e.g., state boundaries) and thematic or statistical data (e.g., per capita income for each state). Maps may also be classified in any number of other ways, such as by specific theme or topic, map scale, time period, or geographic area.

A Brief History of Western Cartography

The earliest known maps that survive are in the form of paintings, drawings, or engravings on



Figure 3 Ortelius's Map of Palestine and the Holy Lands, 1570. This map is from Abraham Ortelius's *Theatrum Orbis Terrarum*, which was the first atlas that produced a uniform series of maps of the world.

Source: Hemispheres Antique Maps and Prints (<http://betzmaps.com/AS-168.html>).

cave walls, clay tablets, animal hides, or parchments in ancient and indigenous civilizations. A painting of a village on the wall of a cave discovered in Catal Huyuk (modern Turkey) from the 7th century BC is widely regarded as the earliest known map. Babylonian maps dating to the 4th and 5th centuries BC depict the layout of ancient cities and the location of geographic features such as rivers and hills. The ancient Greeks (4th century BC) contributed several important advancements to cartography. For example, Eratosthenes (276–195 BC) devised a method of measuring the angle of the sun that he used to estimate the circumference of the Earth to within 100 miles of its actual circumference. The Greek geographer

Claudius Ptolemy (AD 90–168) published several maps in his eight-volume *Geographia*, including a world map with lines of latitude (parallels) and longitude (meridians) clearly indicated. Ptolemy and the Greeks also devised a number of map projections, some of which are still in use today.

Mapmaking during the Roman Empire focused on cadastral or property ownership maps that were used for tax assessment purposes by the Roman emperors. A prominent example of a Roman map is the Peutinger Table, a map of the road network that connected territories administered by the Roman Empire.

The Middle Ages were characterized by *map-pae mundi*, including T-O maps (named for their



depiction of an O-shaped world divided into three continents by rivers and seas that form a “T”), which incorporated Christian doctrine and worldviews into maps of the world. As coastal exploration of the Mediterranean increased during the 13th century, Portolan charts emerged to display the location of coastal ports and cities.

Several important advancements were made in cartography during the Renaissance. Prince Henry the Navigator (1394–1460) established a center for cartography in Portugal; seafaring European nations sponsored explorations around the globe during the Age of Exploration, beginning in the 15th century. In 1569, the Dutch cartographer Gerardus Mercator (1512–1594) introduced a map of the world based on a new map projection that would bear his name and would prove invaluable for sea navigation. The Dutch cartographers Abraham Ortelius (1527–1598; see Figure 3) and Jodocus Hondius (1563–1612) published the first modern atlases of the world based on the geographic discoveries of the Age of Exploration.

Thematic mapping arose in the 18th century and accompanied the rise in national censuses and statistics collected by government organizations. In the United States, the academic study of cartography in universities developed in the early part of the 20th century and accelerated following World War II.

Map Scale, Generalization, Coordinate Systems, and Map Projections

Regardless of the type of map created by the cartographer, all maps are reductions and generalizations of the Earth. The map scale, which may be expressed on the map as a representative fraction (e.g., 1:24,000), as a verbal statement (e.g., “one inch represents two miles”), or as a graphic known as a bar scale, indicates how much the Earth has been reduced to fit on the map. The map scale influences the size of the geographic area displayed on the map as well as the amount of detail that may be displayed. Large-scale maps are those that display a relatively small geographic area but may display much detail. For example, a map of a city is a large-scale map that displays a relatively small geographic area but in much detail, with the inclusion of features such as streets, bus stops, and points of interest. In contrast, a small-scale map

displays a larger geographic area but with less detail. For example, a map of a country or continent is an example of a small-scale map.

Generalization is the process whereby the cartographer selects the appropriate amount of detail to display on the map according to the map scale and the purpose of the map. An example of generalization would be the selection of cities with population figures above a certain number or the simplification of the appearance of a river by eliminating the smallest bends. Coordinate systems are necessary in mapmaking for plotting accurately the location of geographic features on the map. A coordinate system defines an x (horizontal) and y (vertical) coordinate that is referenced to the Earth’s surface and then may be displayed on a map. *Latitude and longitude* is an example of a coordinate system that is used commonly in mapmaking.

A common challenge in cartography is the transformation of the mostly spherical Earth on a flat map surface. This challenge is overcome through the use of a map projection, a geometric or mathematical transformation of the Earth from a three-dimensional (3D) to a 2D surface. Hundreds of map projections have been developed to date, yet only a small number are used commonly in mapmaking today. Due to the necessity of depicting the mostly spherical Earth on a flat surface, every map projection distorts at least one of the following: area, angles, distances, or directions. Equivalent or equal-area map projections preserve the relative sizes of landmasses displayed on the map, whereas conformal map projections preserve the angular measurements. Equidistant map projections preserve the distance measurements between two points on the map, whereas azimuthal projections preserve the measurements of direction between two points. The selection of an appropriate map projection is an important step in mapmaking, and the purpose of the map often influences the type of map projection that is chosen. For example, a cartographer would choose an equivalent map projection for a map intended for comparing the size of countries or continents.

The Cartographic Process

A cartographer follows a series of steps for producing a map—these steps are commonly referred to as the *cartographic* or *mapmaking process*.



Typically, the first step is envisioning the goal or purpose of the map and identifying the map's intended audience. The type of map (e.g., paper for printing or digital for display on a computer) and format (or size of the map) are also determined by the cartographer at an early stage. A suitable map projection is selected, and all data are added to the map. Any additional data that are presented on the map must also be gathered. Sources of data for maps may include other maps, statistical data (e.g., population data), aerial photographs or satellite images, archival data, or field surveys.

Once all the data have been gathered, the cartographer must decide how to represent or symbolize the data on the map. Geographic features on maps are represented as either points (e.g., a city), lines (e.g., a river), or areas (e.g., a country). Each geographic feature is represented or symbolized with graphic variables, known as the *visual variables*, such as color, value, size, texture, pattern, or shape. If the map is a thematic map that displays quantitative data, several types of symbolization are possible that the cartographer may choose from, depending on the characteristics of the data. For example, *choropleth* maps depict data by symbolizing each enumeration or area unit with a shade of a color that represents a defined range or class of data. A *graduated* or *proportional symbol* map depicts quantitative data with symbols such as circles or squares that are sized according to the data value at each location on the map, as in Figure 2. Once a method of symbolization is chosen, the overall design of the map is clarified. The objective is to create a map that is balanced, harmonious, and aesthetically appealing to map users. Map elements such as a scale, title, legend/key, and north arrow are added to the map, each positioned to give an appealing appearance to the map.

After a completed draft of the map is produced, it is common for the cartographer to request feedback from typical users of the map. An important goal of the cartographic process is to determine if a given map communicates effectively or not. Feedback is used by the cartographer to improve the map, if necessary, prior to final production or distribution. Such feedback may be collected in a variety of ways, using both formal and informal methods. Formal methods of feedback may include structured interviews, focus groups, or questionnaires conducted with typical users.

Cognition and Perception in Cartography

Cartographers are keenly interested in how map users interpret, perceive, and remember information presented on maps, and for this reason, cognitive science is commonly integrated into cartographic research. In particular, cartographers study the *perception* (the processes associated with how humans process and interpret vision and other sensory information) and *cognition* (the processes associated with human thought and memory) of maps through structured experiments. In his book *The Look of Maps* (1952), the American cartographer Arthur Robinson established the foundation for a scientific approach to the study of map design and called for perceptual and cognitive studies in cartography to ensure effective map design. Such perceptual and cognitive studies have focused on numerous topics related to maps, such as the estimation of the sizes of map symbols (e.g., proportional circles, text, etc.) or the memory or recollection of geographic patterns displayed on thematic maps. Typically, such studies have been conducted in carefully controlled laboratory experiments. Such experiments may include the use of eye-tracking instruments that record data about what people look at on maps and how much time they spend viewing various aspects of the map. Collectively, the results from such perceptual and cognitive research help cartographers understand how people interpret maps and may be used to create better guidelines for making maps.

Technology and Cartography

Technological change and innovation have had an important influence on the development of many aspects of cartography, from the earliest days of mapmaking to the present. Technological change has affected both the type of instrumentation used in the compilation of maps by cartographers and the means of reproducing or disseminating maps to others. For example, the invention of celestial instruments such as the sextant and astrolabe allowed cartographers to plot latitude coordinates on maps and nautical charts more accurately. The magnetic compass, theodolite, and other surveying instruments improved the positional accuracy and geometry of features



on maps. The development of the printing press in the 15th century was an important innovation that allowed for the mass production of maps. The technology used for printing maps has evolved from methods such as engraved plate printing to lithography to digital printing today.

The computer revolution has had a significant impact on mapmaking by transforming maps into a digital medium and automating many steps in the cartographic process. Digital maps may be displayed by map users on personal computers or portable electronic devices such as cellular phones or car navigation systems. Global positioning system (GPS) technology has revolutionized mapmaking through increased accuracy and precision of the coordinates that are displayed on maps. The development of the World Wide Web (WWW) has created a new method for distributing and viewing maps; Web-based maps may be either static maps that may be viewed on a Web page or interactive/dynamic map displays. In addition, the WWW has provided a framework for easy distribution of data that may be used for the creation of maps. Advances in aerial photography and satellite imagery have had implications for cartography as well, as these both serve as important data sources that are often used in the compilation of maps.

Modern Cartography

Although maps have been compiled by hand-drawn or analog techniques for many centuries, modern cartography is almost entirely digital in nature and is completed with the assistance of computers. Geographic information systems (GIS), graphic illustration, and computer-aided drafting (CAD) software are commonly employed by cartographers for map production. An impact of the computer revolution in cartography is what Morrison (1997) described as the “democratization of cartography,” which is the increased production of maps by those with little or no cartographic training due to the easy availability of computer software that may be used for map production purposes.

The term *geovisualization* refers to interactive or dynamic maps that are developed today, such as those on Web sites that allow a user to change the appearance of features that are displayed on

the map. For example, an interactive map may allow a map user the option of zooming in/out, modifying the colors displayed on the map, or changing the method by which data are symbolized on the map. Animated maps are a common method for displaying geographic change over time on maps. Data exploration mapping software is used to extract geographic patterns from large data sets that may involve the comparison of multiple variables on the map. As computer graphics technology has improved, so has the capability of cartographers to create 3D and virtual reality map displays that depict a more realistic representation of the Earth. As more focus is placed on the use of interactive and dynamic maps due to the technological changes in cartography, much attention has been focused on the design of the user interfaces and understanding how people interact with such displays.

Social, Cultural, and Ethical Aspects of Cartography

Since maps are used by many people for different purposes, there are a number of social, cultural, and ethical issues related to map production and use. Historically, maps have been produced primarily by those with political power or influence and, therefore, may intentionally or unintentionally express the views or opinions of the mapmaker. Cartographic ethics calls for the accurate presentation of information on maps; however, maps may misrepresent the real world as a result of error or carelessness by the cartographer. The increased availability of highly detailed, Web-based maps and satellite imagery, used for applications such as navigation or real estate purposes, has raised privacy issues in recent years. A cultural issue related to mapmaking includes human interpretation of colors and symbols on maps, which may have various meanings or connotations in different cultures.

John Kostelnick

See also **Argumentation Maps; Cartograms; Cartography, History of; Choropleth Maps; Color in Map Design; Coordinate Geometry; Coordinate Systems; Coordinate Transformations; Countermapping; Dasymetric Maps; Data Classification Schemes; Datums;**



Dot Density Maps; Dynamic and Interactive Displays; Earth's Coordinate Grid; Ecological Mapping; Electronic Atlases; Environmental Mapping; Exploratory Spatial Data Analysis; Flow Maps; Gazetteers; Indigenous Cartographies; Isopleth Maps; Land Use and Land Cover Mapping; Latitude; Longitude; Map Algebra; Map Animation; Map Design; Map Evaluation and Testing; Map Generalization; Map Projections; Map Visualization; Mental Maps; Multimedia Mapping; Portolan Charts; Resource Mapping; Self-Organizing Maps; Trap Streets; Typography in Map Design; Virtual and Immersive Environments; Virtual Globes

Further Readings

- Brewer, C. A. (2005). *Designing better maps: A Guide for GIS users*. Redlands, CA: ESRI Press.
- Dent, B. D., Torguson, J. S., & Hodler, T. W. (2009). *Cartography: Thematic map design* (6th ed.). Boston: McGraw-Hill.
- Krygier, J., & Wood, D. (2005). *Making maps: A visual guide to map design for GIS*. New York: Guilford Press.
- MacEachren, A. M. (1995). *How maps work: Representation, visualization, and design*. New York: Guilford Press.
- Monmonier, M. (1996). *How to lie with maps*. Chicago: University of Chicago Press.
- Morrison, J. L. (1997). Topographic mapping for the twenty-first century. In D. Rhind (Ed.), *Framework for the world* (pp. 14–27). Cambridge, UK: Geoinformation International.
- Robinson, A. H. (1982). *Early thematic mapping in the history of cartography*. Chicago: University of Chicago Press.
- Robinson, A. H. (1952). *The look of maps*. Madison: University of Wisconsin Press.
- Robinson, A. H., Morrison, J. L., Muehrcke, P. C., Kimerling, A. J., & Guptill, S. C. (1995). *Elements of cartography* (6th ed.). New York: Wiley.
- Slocum, T. A., McMaster, R. B., Kessler, F. C., & Howard, H. H. (2009). *Thematic cartography and geovisualization* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
- Snyder, J. P. (1993). *Flattening the Earth: Two thousand years of map projections*. Chicago: University of Chicago Press.
- Wilford, J. N. (2000). *The mapmakers* (Rev. ed.). New York: Random House.



CARTOGRAPHY, HISTORY OF

Existing histories of geography and cartography in the Western world have generally focused on one or the other of these disciplines, thereby missing the significance of their interdependent development. Maps are an integral and integrating element for geography. While much of the practice of cartography operates independently of geography, work in geography has often been explicated best by maps. The exploration and mapping of the world have been widely documented, as, for example, in coffee-table books illustrated with early maps, but the developing map of the world (from Waldseemüller's map naming America in 1507 to Heezen and Tharp's depiction of the ocean floor in 1977) is only a small part of the broad picture. The focus in this entry is on the ways in which maps have been used in many cultural environments over the millennia. This approach unites geography and cartography by tracing the uses of maps as tools in human interaction with the spatial environment.

The history of cartography is not just a timeline of significant maps and associated major events. It is more important to understand how maps have been used and what they have contributed to the cultures that produced them and how they reflect the characteristics and activities of the times and places in which they were created and employed.

Dual Functions of Maps

Maps have two general functions. One is to help people navigate from one place to another. At the most basic level, maps for wayfinding and navigation consist of the individual's personal mental (cognitive) maps. Simple wayfinding maps may be easy to make (such as a sketch map directing a dinner guest to your house) or may be sophisticated simplifications of a complex environment (such as the Vignelli New York subway map of 1977), but both are understandable at a glance. More complex navigation tasks and transportation systems require more complex mapping systems—both to gather the data for navigation maps and to then incorporate them in the complex systems of tools used for navigation (such as global positioning system [GPS]-based air, sea, or land transport navigation systems).



The second use of maps is for environmental management. As a group, maps in this category are highly varied and very large in number. The mental (cognitive) maps in this group range from the simple “image” that a person has of his or her neighborhood to the opposite extreme of the scientist who examines complex arrays of mapped data, gaining insights into relationships or searching for a solution to a problem. In both of these examples, the activity is one of visualization; the maps are manipulated in the mind. However, map use for environmental management may also involve precise measurement, complex data analyses and problem-solving procedures, and elaborate technical processes (such as in civil engineering planning and construction).

Prehistoric and Ancient Origins of Cartography

Defining a map by its function and manner of use encompasses maps in a broader spectrum of familiar formats than the conventional map drawn or printed on paper. The first practice of cartography began as mental (cognitive) maps, long before the creation of the oldest surviving map artifacts, and such cognitive maps still inform the spatial behavior of humans and animals. The patterns of stars in the sky—the celestial sphere—were among the first external maps that humans saw and sought to understand (Figure 1), as evidenced by the fact that Stonehenge and other prehistoric monuments were aligned to mark seasonal astronomical events. Prehistoric hunters followed animal tracks and paths—maps on the ground—and they depicted hunting scenes in rock carvings and cave paintings, some of which can be interpreted as maps. Ancient peoples—migratory and nomadic, foragers and hunters—learned the signs and locations of environmental resources and features and used them as landmarks to guide their travels.

When groups of humans established long-term settlements and became sedentary, new aspects of mapping became critical. The organization of the community—the relationships among living spaces, public spaces, utilities, basic resources, and, above all, gardens—became complex, requiring environmental management. Organizing the infrastructure of these early permanent communities required maps. In Egypt, the boundaries of



Figure 1 Nebra sky disk. A metal disk from ca. 1600 BC found in Northern Germany is obviously a celestial map. Interpretations range from cosmological to proto-astronomical: the sun god crossing the sky or the angles of the setting sun at the summer and winter solstices.

Source: Kaulins, A. (2009). *The sky disk of Nebra: Evidence and interpretation*. Retrieved June 27, 2009, from www.scribd.com/doc/12363758/The-Sky-Disk-of-Nebra-Evidence-and-Interpretation-English-Version-DOC.

fields cleared by the annual flooding of the Nile River were reestablished by surveying, but any maps involved would have been drawn on fragile papyrus and have not survived. The earliest environmental management maps survive among the archeological remains of the civilizations of the ancient Middle East, where cuneiform writing on clay tablets was first invented (Figure 2). Maps in the same medium were created there, the oldest about 2500 BC, to record land transactions, plot the course of a canal, or lay out the ground plan of a temple. These appear to be the earliest surviving maps drawn to scale, constructed by measurement and meant to be commensurable.

From Mesopotamia has also come the earliest surviving cosmological map (600 BC). Typical of cosmological maps produced by various cultures in being ethnocentric, it is centered on a homeland shown at a larger scale and in greater detail, while the surrounding areas shrink, losing detail and becoming distorted toward the edges of the



Figure 2 Clay tablet showing Nippur, the capital of Sumeria, about 1500 BC, with the surrounding fields along a bend in a river, presumably the Euphrates, labeled in cuneiform script.

Source: Courtesy of the Penn Museum, object B13885, image #14210.

known world. Egypt, where tomb paintings were an important preparation for the afterlife, also produced maps with cosmological significance. A “Book of the Dead” often included in tombs was intended to serve as a route map enabling the deceased’s soul to reach heaven within 24 hours following death.

Ancient navigation in the Mediterranean Sea has left no wayfinding maps, although the archaeological evidence of shipwrecks reveals the area as a crucible for the early development of seafaring technology: ships, sails, and navigation techniques. Sailing directions passed down by word of mouth; the movements of the sun, moon, and stars; the directions of the seasonal winds; the color of the water; the composition of the sea bottom; the types of birds and fish; and other environmental signs contributed to each mariner’s mental map. Navigation techniques combined piloting from point to point along the coast with the increasing use of dead reckoning to sail

courses across open water. A panoramic wall painting found during the excavation of a house (dated about 1550 BC) in the seaport of Akrotiri, on the island of Thera, depicts a voyage from the Egyptian Nile delta to the Greek islands.

Similarly, mental maps and orally transmitted information guided overland wayfinding. In some cases, there were well-traveled and marked paths. In other instances, in ventures into the unknown, there was only the intuition of the explorer about the landscape. The so-called imaginary features that were plotted on early maps were the result of imagineering, as the mind of the mapmaker extended the available environmental information, relying on experience and geographical knowledge, to “map the unknown.”

With the development and spread of Western civilization, the practice of cartography changed. While the basic cognitive system is still fundamental to nearly all map activities, developments in societal organization, science, and technology during the past two millennia have radically altered mapmaking and use.

Over a period of more than 600 years, Greek cartographers created a legacy of cartographic concepts and processes, culminating in the work of Claudius Ptolemy in the 1st century AD (Figure 3). His ideas for the creation of maps based on projections and the use of the graticule to locate places on maps were revolutionary when reintroduced to Europe early in the Renaissance.

Medieval and Renaissance Cartography

Lost to Europe during the feudal era, Ptolemy’s writings were preserved in the Middle East, thanks to the Islamic practice of copying classical texts. For more than a millennium during the Middle Ages, the principal map of the world in Western civilization was the schematic tripartite (also called “T-in-O”) map (of the *orbis terrarum* [the world]), closely identified with the Roman Catholic Church. Following the collapse of the Roman Empire and the division of Europe into small kingdoms, it was the doctrinaire Christian world schema that prevailed. The resulting maps, deriving much of their geographical information and perspective from the Bible, usually showed Earth as a disk, oriented with east at the top and centered ethnocentrically on Jerusalem (Figure 4).



Figure 3 This map of the known world, on a pseudoconic projection based on the writings of Claudius Ptolemy (ca. 150), the map uses parallels and meridians not only to locate places on the Earth's surface but also to suggest the sphericity of the Earth.

Source: Shirley, R. W. (1984). *The mapping of the world: Early printed world maps, 1472–1700* (Cartographica 9, Plate 20). London: Holland Press.



The mapmaking skills of Islamic geographers were brought to Europe in 1154, when al Idrisi completed for King Roger, the Norman conqueror of Sicily, a systematic description of the known world (extending west to east from Northern Africa and Spain to Asia and north to south from Europe to Africa) (Figure 5). Known as the *Book of Roger*, it was illustrated by a world map and sectional maps. Several centuries later, a manuscript of Ptolemy's *Geography* was brought to Italy from Constantinople and translated into Latin in about 1405. After the advent of printing in the mid 15th century, it was published repeatedly in Europe, at first uncritically and later, as scholars acknowledged that the content of Ptolemy's maps was out-of-date, amended by adding modern maps.

The introduction of printing and the commercial publication of maps were key to the democratization of map use, a process ongoing since the 15th century. Books and graphic images, including maps, had been the province of the wealthy and the literate elite in the manuscript era. Reproduction by woodcut and copper engraving also made maps accessible to the growing middle classes from the 15th century onward.

During the 16th century, the center of map printing shifted from Italy to the Netherlands. The *Theatrum Orbis Terrarum* of Abraham Ortelius in 1570 became the first of a succession of atlases expanding the limited world view of Ptolemy with the results of Europe-based global explorations. In these Renaissance atlases, environmental management expanded its scope to cover the entire Earth, systematically presented in a hierarchy of scales, ranging from city maps to world maps. These atlases were designed to "provide insight through visual methods." One could see and, without direct experience of a place or an environment, gain familiarity with some remote part of the world. This is, to use the modern terminology, *map visualization*. Decorative suites of maps, painted on the walls of palaces, such as the Vatican, impressed visitors with the extent of the ruler's vast domain. Visualization is a vicarious experience, unlike individual mental maps based on direct experience of the environment.

Navigation in the Mediterranean Sea, the age-old heart of the European trading network, generated a new type of navigation map in the late

Middle Ages—the portolan chart (Figure 6). Its origin may have been associated with the introduction of the magnetic marine compass to Europe by way of trade routes from China, but it also grew out of centuries of Mediterranean nautical activity. The rhumb lines (lines of constant compass direction) radiating from compass roses on portolan charts worked effectively for navigation, despite distortions of direction and distance, in the Mediterranean Sea and along the coastal areas of Europe and North Africa. However, expansion of navigation into more remote areas of the Earth during the 16th century required maps with accuracy of direction over great distances. The solution was provided by Gerardus Mercator in 1569 and Edward Wright in 1599 (Figure 7). The Mercator projection, with its correct representation of angles across the entire map (conformality or orthomorphism), provided the navigator (as well as the surveyor and others who needed a map providing the correct representation of angles) with an efficient way to plot courses, especially when used in combination with the ancient Greek gnomonic projection, which portrayed great circles as straight lines.

National Topographic Mapping

While Renaissance atlases and sea charts provided a global cartographic perspective, an even more challenging cartographic mission, born in the 16th century, was the detailed topographic mapping of the countries of Europe. The impetus for this shift came from the emergence of national governments, aided by significant encouragement from other elements of society. For the ruling royalty, there was the desire to know the exact extent of the kingdom for purposes of administration and taxation. Similar activities were carried out at other times in other areas of the world, notably in China and Japan.

For scientists, the shape and size of the Earth was a subject for speculation and study. Seeking and mapping mineral resources fueled the growth of industry and commerce. The military general staff was concerned with national defense, and terrain was a critical factor in the movement of troops and artillery. Detailed measurement of land areas became part of the mapping process, as the mathematics underlying land surveying,

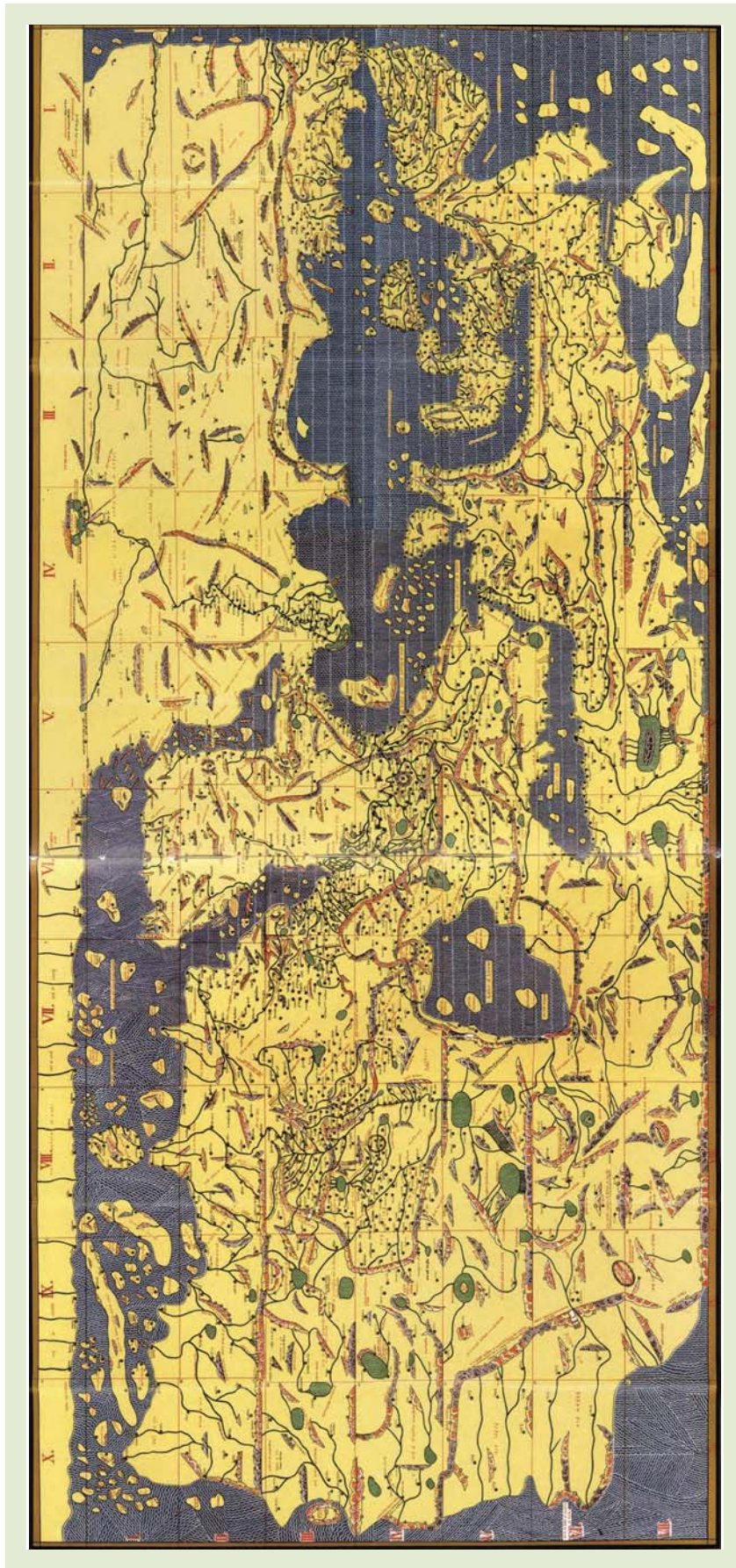


Figure 5 The world map in the *Book of Roger* (1154) perpetuates ancient Greek knowledge (such as the seven climatic bands, clima). Sectional maps (indicated on the world map) prefigure the systematic treatment of geography in modern atlases.

Source: Bibliothèque nationale de France (MSO Arabe 2221)/Wikimedia Commons, <http://en.wikipedia.org/wiki/File:TabulaRogeriana.jpg>.



Figure 6 This portolan chart intended for Mediterranean and North Atlantic navigation was drawn in 1559 by a Catalan chart maker, who oriented this sea chart with west at the top to fit the proportions of his vellum (treated-sheepskin) drawing surface.

Source: Virga, V., & Library of Congress. (2007). *Cartographia: Mapping civilization* (Plate 32, p. 39). New York: Little, Brown.

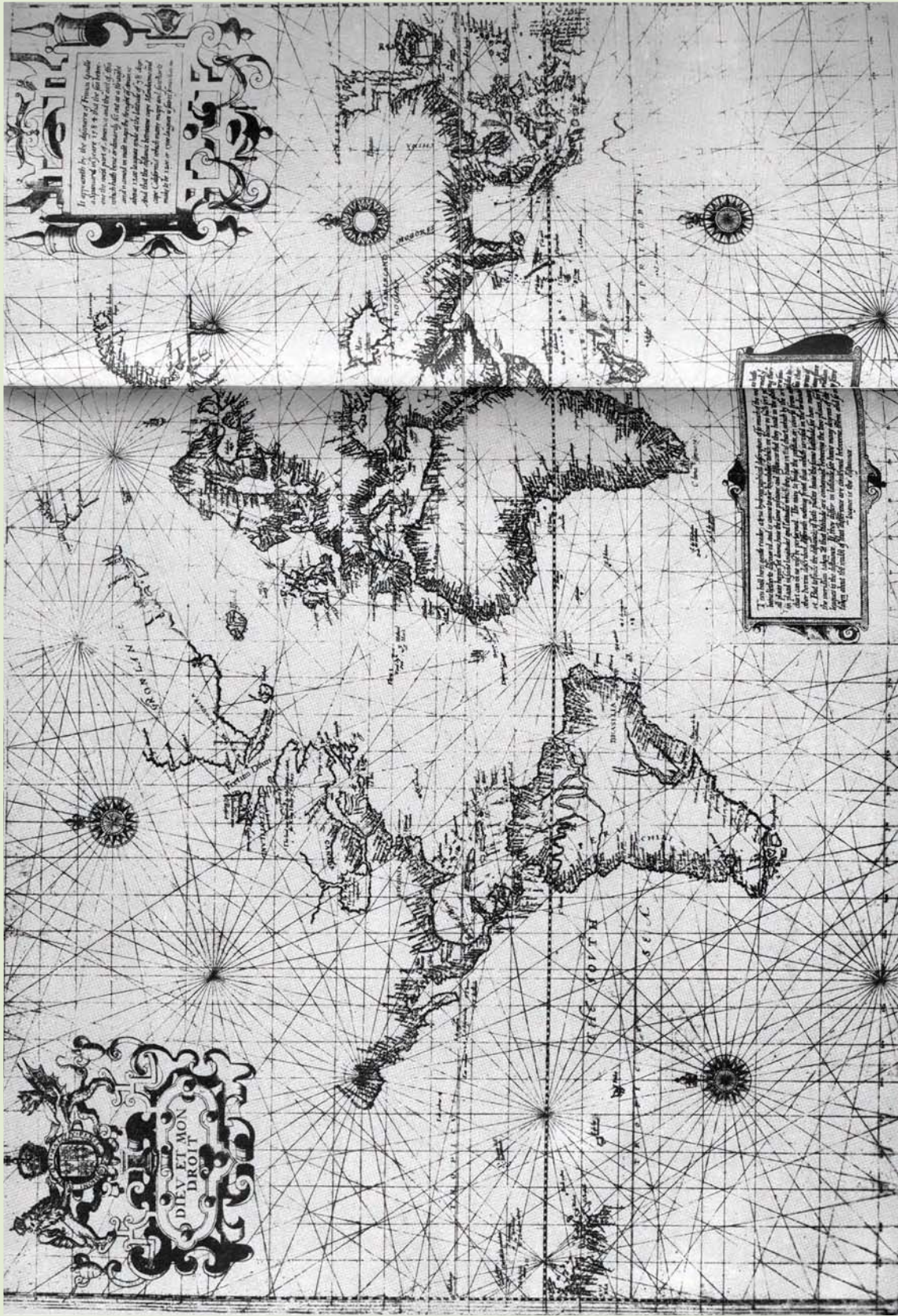


Figure 7 This world chart on the Mercator projection was used to illustrate Richard Hakluyt's book *The Principal Navigations* in 1599 and has been attributed to Edward Wright, who published tables for plotting courses on the projection, published in 1569.

Source: Ehrenberg, R. (2006). *Mapping the world: An illustrated history of cartography* (pp. 110–111). Washington, DC: National Geographic.

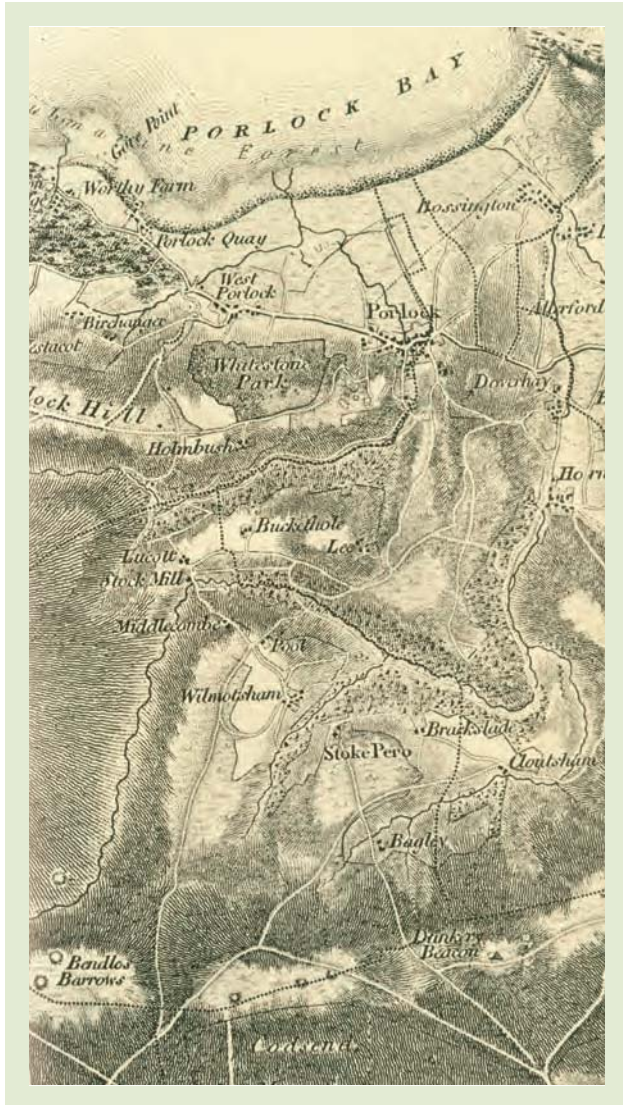


Figure 8 This detail is from an early Ordnance Survey 1-inch sheet printed from an engraved copper plate. A part of Exmoor in the hachuring style typical of the 1820s.

Source: Winterbotham, H. S. L. (1939). *A key to maps* (2nd ed.; Plate II, facing p. 70). London: Blackie.

particularly trigonometry, had been developed. However, the measurement and representation of land surface form remained a problem.

Earlier maps portraying land surface form had used pictographic symbols to represent the major features of the landscape. That approach gradually yielded during the late 14th century to a more integrated portrayal, with profiles used to represent the surface. Using the slope data that could be

gathered most efficiently at the time, hachures (a short line used for shading and denoting surfaces in relief [as in map drawing] and drawn in the direction of slope) became the standard method to represent slope on 18th- and 19th-century military maps and made their way into early editions of national topographic map series throughout Europe, such as the “one-inch” Ordnance Survey of England (see Figure 8). These arrangements of upslope-downslope lines used different approaches (graphic contrasted to metric) to indicate steepness. At the same time, new methods of measuring terrain elevation provided data for mapping contour lines (isohypses or lines of equal elevation derived from the earlier concept of isobaths or lines of constant depth first used on a Dutch river chart in 1584) (Figure 9). Recognition of the contour line as the ideal metrical representation of the landscape for engineering and other commensurable uses led eventually to the adoption of contours as standard on topographic maps by every national mapping organization.

In the digital era, the database for the digital elevation model (DEM) has become the foundation for developing maps of the land surface. This numerical representation of the surface, based on elevation, provides commensurable representations of the land surface in the form of contour lines. There is still the problem that the contour line is not an effective *visual* representation of land surface form. The map user cannot visualize easily the characteristics of the surface from contour lines without significant training, so the search for the best graphic representation continues. The invention of lithography and the photographic screen in the 19th century, followed by computer graphics processes in the mid 20th century, have made it possible to produce terrain shading more easily on maps. Today, topographic maps of all types are often used as base maps, forming a geographical background of terrain and infrastructure on which other themes or types of information are displayed or draped (Figure 10). This role for the topographic map was several centuries in the making.

Thematic Maps

Until the 18th century, in Europe the main task of geography was seen as collecting enough data for



Figure 9 When Pieter Bruinsz surveyed the River Spaarne in 1584, he plotted the earliest known lines of equal depth (isobaths). This map is an early printed version of this technique. A map by Nicolaas Cruquius (1729–1731), with plotted isobaths.

Source: de Dainville, F. (1970). From the depths to the heights. *Surveying and Mapping*, 30, 393.

description of the terrestrial infrastructure. The aim of cartography, as a tool of geography, was to map the world in increasing detail, focusing on infrastructure. Where were the corridors for travel on land, rivers, and seas? Where were the nodes of population—the cities and towns? Where were the seacoasts, environmental barriers where the technological shift of trade goods between sea and land transport occurred? What was the shape of the terrain? And so on.

While the data-gathering and descriptive function of geography remained central, it gradually expanded to include the climatic, biotic, and sociocultural environments. In addition, theoretical consideration of geographical patterns and spatial relationships among different categories

of data began to be explored and mapped. Early examples include Dud Dudley's 1665 map predicting the pattern of occurrence of iron and coal deposits encircling the town of Dudley in England; Edmond Halley's maps of magnetic variation (1700, Figure 11), trade winds (1688), and a predicted eclipse (1715); Alexander von Humboldt's early-19th-century map of temperatures (1817) and a diagram showing the variation of vegetation with altitude on the Ecuadoran volcano, Chimborazo (1807); moral maps by Balbi and Guerry relating the levels of education across France to the incidence of crime (1829); and John Snow's map relating the distribution of cholera cases to the location of the Broad Street pump in London (1865).

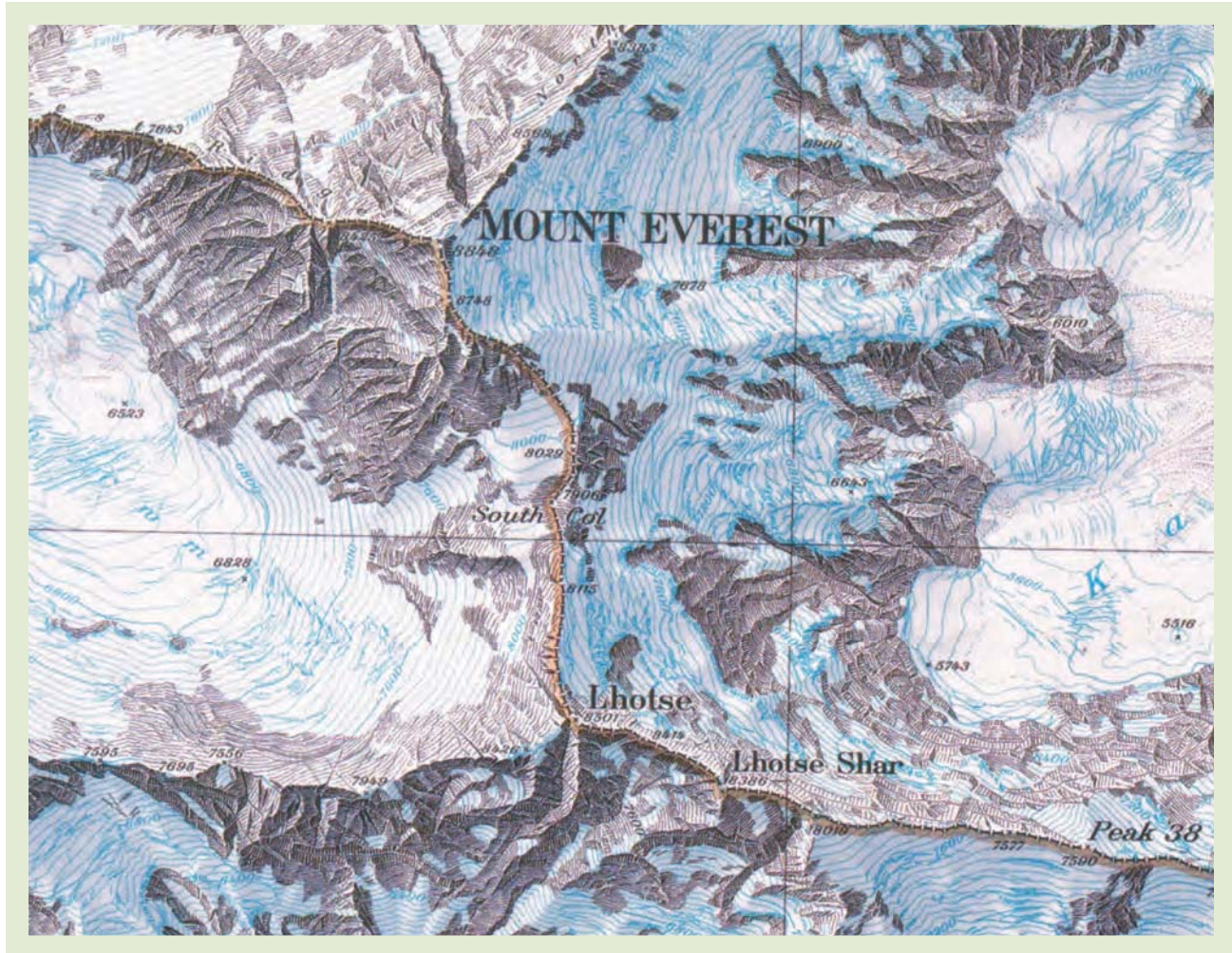


Figure 10 Bradford Washburn's 1988 topographic map of Mount Everest is a masterly example of the combined use of terrain shading and contour lines (isohypsies) to depict complex mountainous terrain.

Source: Ehrenberg, R. (2006). *Mapping the world: An illustrated history of cartography* (p. 225). Washington, DC: National Geographic.

During the period from the 1820s through the 1840s, there was much innovation in the methods for symbolizing such thematic information on maps. The term *thematic map* was first used in the 20th century, replacing earlier names for this type of map (such as “special” map and “statistical” map). Into this category, cartographers placed maps representing data other than general infrastructure (“geographical” maps) and land surface form (“topographic” maps). Many types of thematic data can be mapped, some visible and tangible (such as land use or land cover) and others invisible and intangible (such as average annual temperature or median household

income). During the 19th century, many thematic maps and even some thematic atlases were created. New scientific disciplines emerged, and the geographers, geologists, sociologists, and demographers (the latter called political economists) became interested in presenting their data on maps. Both individual scientists and national governments were collecting data and making thematic maps. For example, the U.S. Bureau of the Census conducted decennial (and other) censuses and also produced many series of maps (Figure 12).

German geographers, in particular, produced atlases and maps in books and journals that



Figure 11 Edmond Halley's 1700 chart of the Western Atlantic Ocean was the first published map to include lines of equal magnetic declination.

Source: Clark, J. O. E. (Ed.). (2005). *100 maps: The science, art and politics of cartography throughout history* (p. 53). New York: Sterling.

provided the opportunity for the user, through visualization processes, to develop an understanding of the relationships between human activities and the characteristics of the physical environment. Thematic maps became a major component of national atlases.

Cartography in the 19th and 20th Centuries

The latter half of the 19th century saw extensive growth in the development of map projections. Prior to 1800, only 32 map projections had been created (the earliest being those of the Ancient

Greeks). During the 19th century, 53 new projections were used. More than 180 were added in the 20th century. While most were created by geographers and cartographers, others were developed by cartophiles from other professions. Many sought a projection that would provide a better map of the world than the Mercator projection, and many pseudocylindrical projections were created. This activity continues as needs for new perspectives of different parts of the world arise.

The 19th and 20th centuries saw not only remarkable innovations in the science and technology of cartography but also the creation of new

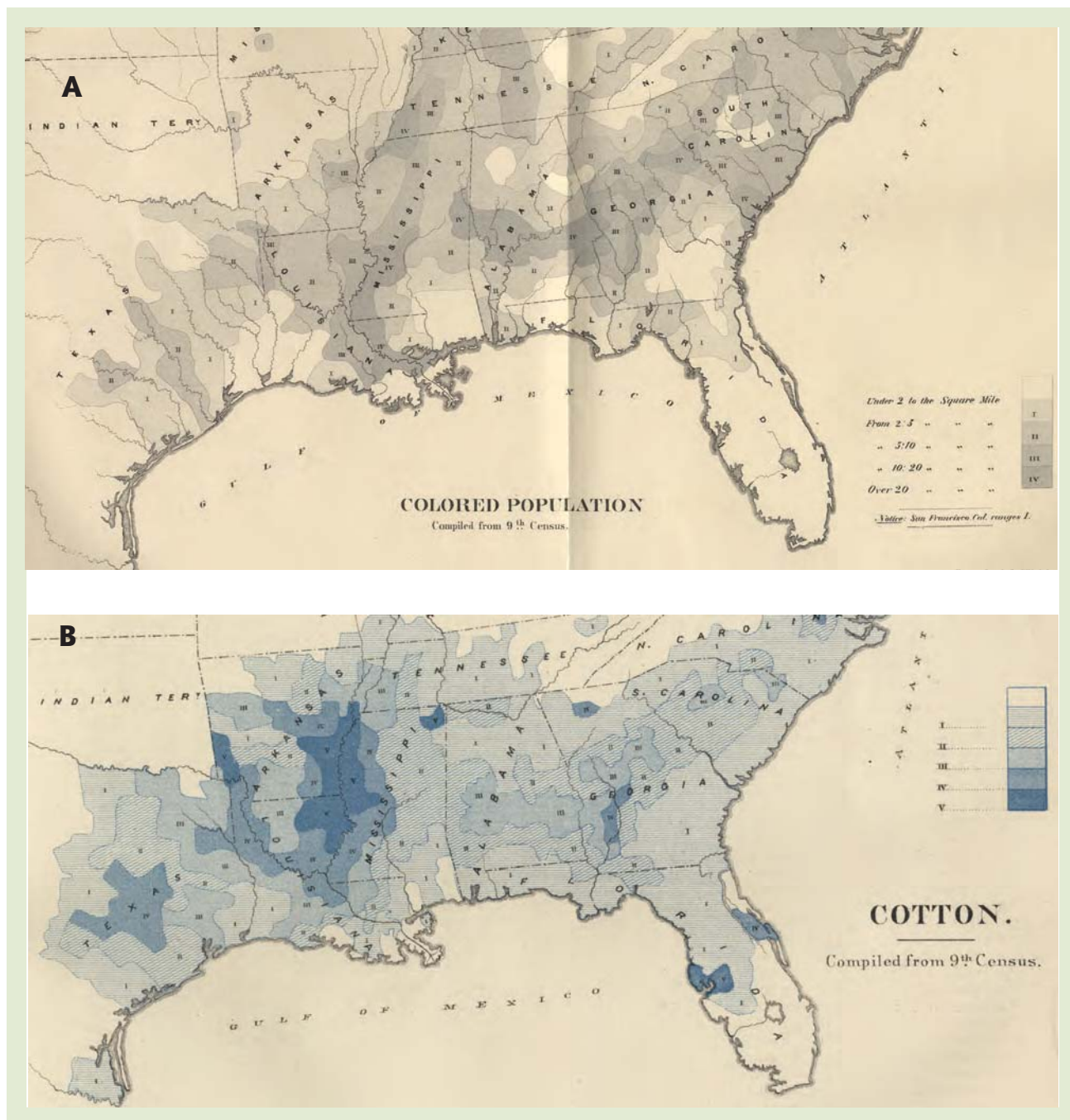


Figure 12 The statistical maps of the 1870 U.S. Census were innovations in both data gathering and presentation. Figures 12A and B use “degrees of density” for the colored population and an index of “relative power” for the levels in the production of cotton.

Source: Walker, F. A. (1872). *Colored population and cotton (Ninth Census): Vol. 3. The statistics of wealth and industry of the United States*. Washington, DC: Government Printing Office (maps preceding pp. 77 [12a] and 160 [12b]).

Notes: Recognizing the ineffectiveness of many procedures for presenting cropland data on maps, the director of the 1870 Census, Francis Walker, employed an index of “productive power.” Since no single element satisfactorily measures productive power of a crop, the index relates the quantity of a crop to both the number of inhabitants and the number of acres of improved land. The derived values for each county, when mapped, indicate “the important and the insignificant sections of the country distinctly from each other” (here in six ordinal classes, I, II, etc.). To compute these values, the number of bushels, tons, or pounds produced in each county was divided by the number of inhabitants and by the number of acres of improved land in the county; these two quotients were multiplied, and the square root of the product was taken as the measure of productive power of the county with respect to that crop.

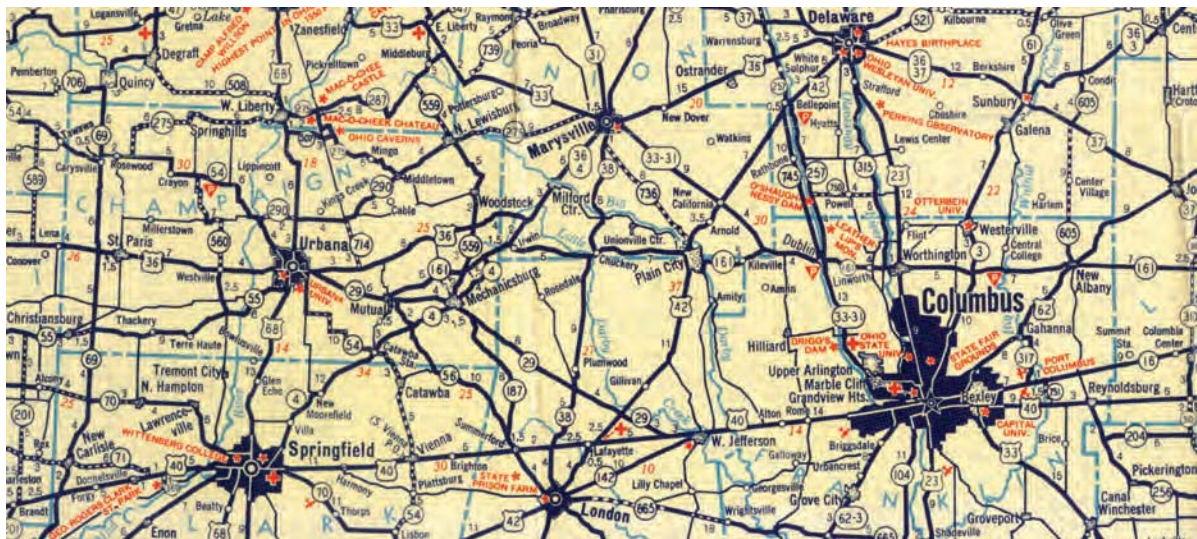


Figure 13 Portion of the State of Ohio Official Road Map, 1938, showing numbered “hard surfaced” and “principally stone or gravel” highways and “good connecting roads,” along with unincorporated villages and incorporated municipalities.

Source: State of Ohio, Department of Highways. (1938). *Ohio 1938: Official highway map*. Columbus, OH: Author. (Original scale 1:633,600.)

types of maps for Environment Waikato map uses. In the realm of navigation, aeronautical charts and automobile road maps (Figure 13) were added; these and railroad maps are complemented by the variety of tourist maps that became available. In the realm of environmental management, weather maps and the news and information maps promulgated by the media not only provide spatial details for military campaigns and natural disasters but also emphasize the importance of location. Aerial photographs and satellite images have assumed the role of the base map (Figure 14). All these have been accompanied by the introduction into the cartographic process of new printing and publication processes. The 20th century saw the introduction of photomechanical process color printing, microfilming, blueline printing, photocopying, and color proofing, each offering the cartographer a new approach to map design and production (Figure 15). The cartographer gained control over the design of the map, which had been the province of the engraver and the printer for more than five centuries. When, near the end of the 20th century, the analog procedures were replaced with comput-

er-based mapping systems, the overall design of the map became the result of the default values embodied in the computer software. With the rise of the Internet, Web-based mapping services provided even more personalized maps, and the emboldened map user now deals directly with the available software.

While technical manuals and reference volumes dealing with the practice of cartography were already common at the beginning of the 20th century, textbooks emerged first in German in 1912 and then in English (Erwin Raisz, *General Cartography*) in 1938. Textbook development expanded after World War II, promoting study and research dealing with cartographic concepts and processes. Today, textbooks are available in many languages, taking many different approaches to the development and production of all types of maps.

Shortly after the mid 20th century, the rise of academic cartography in geography departments generated psychology-based studies aimed at making symbolization of data and map design more effective (Figure 16). Based on the principles of visual perception, this work expanded to include

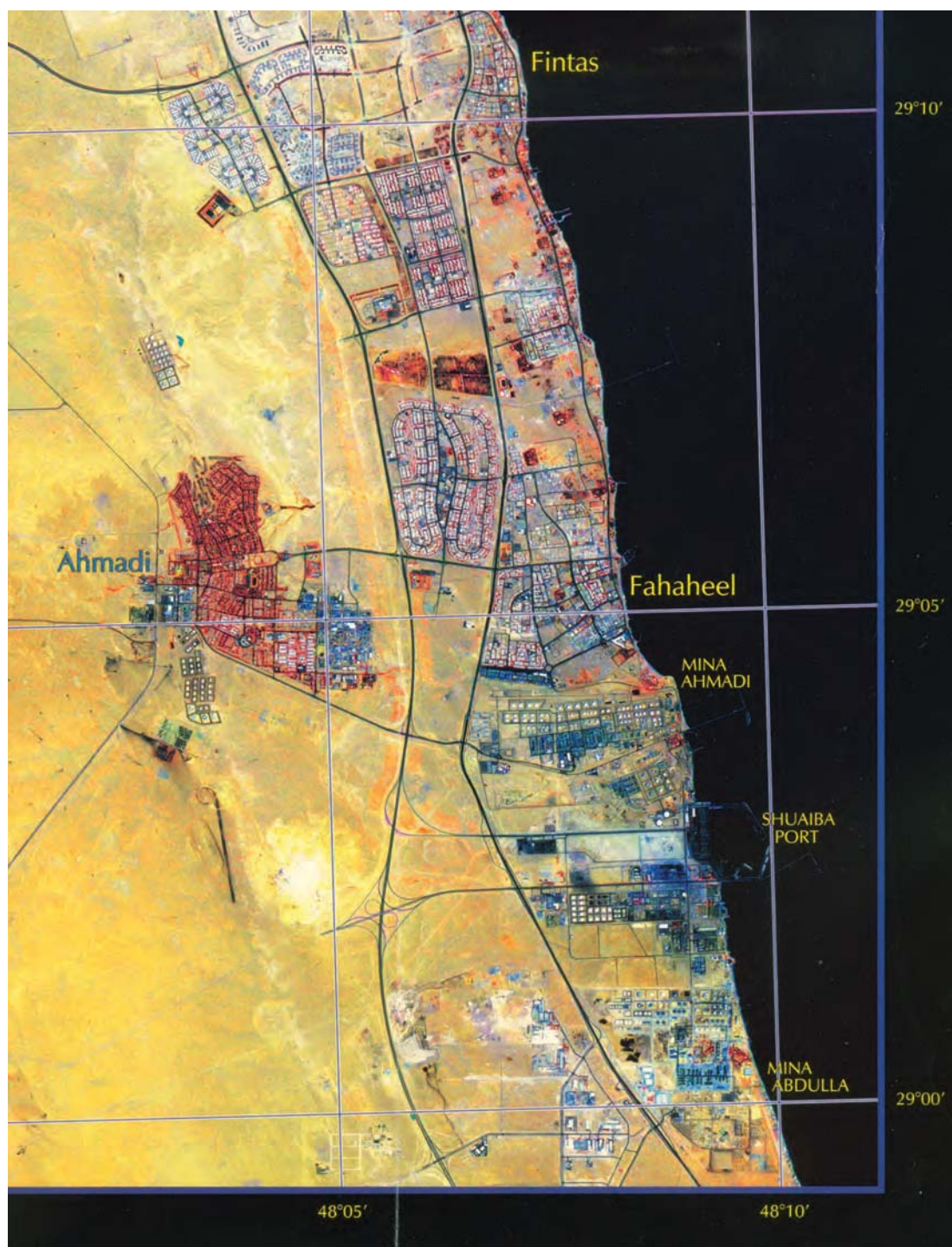


Figure 14 Using data from the SPOT and Landsat systems, cartographic annotations in vector format from a resource management database were added. Each step in the process was carried out using the components of Intergraph's MGE software system.

Source: Intergraph Corporation. (1991). *Kuwait City*. Huntsville, AL: Author. (Original scale 1:100,000.)



Figure 15 Progressive stages of engraving and printing presented in the order they occur in this reproduction of a painting. Combinations of four inks can produce millions of colors. Produced by the Peerless Engraving & Colortype Company (Chicago)

Source: Flader, L. (Ed.). (1927). *Achievements in photo-engraving and letter-press printing* (p. 329). Chicago: American Photo-Engravers Association.

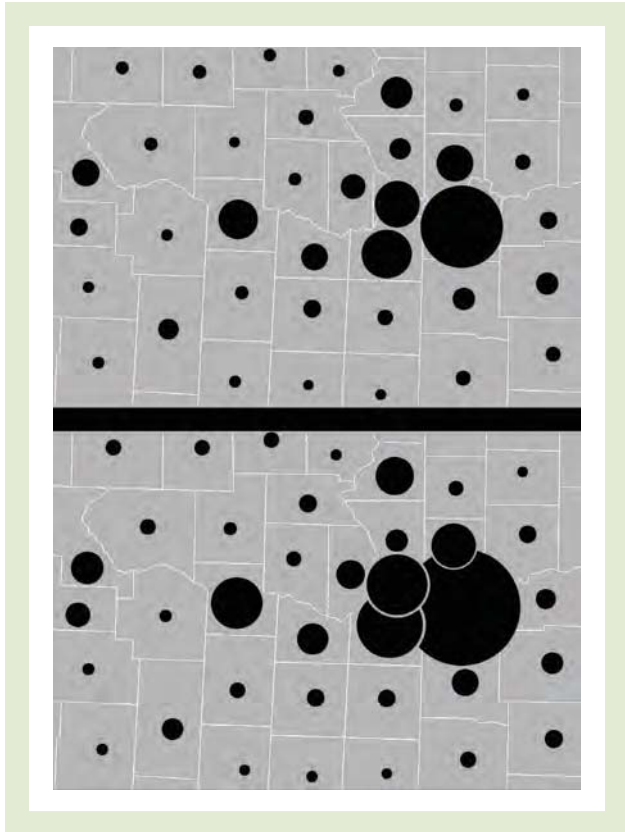


Figure 16 The concepts and processes of psychophysics were explored by cartographers throughout the 20th century. Here, the visual underestimation of circle-size differences is countered by rescaling the sizes, a more efficient representation of the data.

Source: McCleary, G. F., Jr. (1981). How to design an effective graphics presentation. In P. A. Moore (Ed.), *How to design an effective graphics presentation* (Vol. 17, pp. 15–64). Cambridge, MA: Harvard College.

work in cognition as well as graphic design and communication (Figure 17). The attention to this user-oriented research was soon diverted toward experimentation with the new digital technology. Continuing ignorance of the basics of graphic design; of the fundamental elements of statistical data representation, particularly the visual variables; and of the considerable resources from the literature in graphic design, psychology, and human factors has perpetuated the problems associated with efforts to create truly effective user-friendly maps. Unfortunately, the use of poor design procedures has been sustained by tradition and convention, as well as the aforementioned default options of the computer software.

It is important to recognize that significant scientific and technological advances occurred in 20th-century cartography outside the sphere of “geographical cartography.” Mapping activities during World War II involved both historians and geographers, working with a diversity of cartographic products used for navigation and environmental management. By mid century, the basic features on Earth had been well mapped. Improvements continue, and additions to the coverage of large-scale national topographic map series and the extension of the geodetic network continue (both now supported by the global positioning system [GPS]). A new global mapping reference system was completed (World Geodetic System [WGS] 84). Digital databases, from the Digital Chart of the World (DCW; 1:1,000,000) to the hundreds of “local” databases, provide data for environmental management at many different government levels. Attention has turned to more precise study of problems such as environmental pollution and sustainability, preparation for natural disasters, global disease distribution, and more. All these can be integrated, in one way or another, into a database and can contribute to geographic information systems (GIS), and they are related to other elements of the environment. As individual maps, these are all used for environmental management. In the case of the examples used here, the management involved is the handling of information, for understanding and knowledge.

The 21st Century

It is clear that the maps produced by a culture mirror that culture. In various indigenous cultures around the world, the traditional role of environmental management has been to preserve and perpetuate the relationship of humans and environment. In Western civilization, maps have been created and used not simply for navigation and environmental management but rather for navigation and environmental exploitation. It is time to make maps for environmental sustainability. Computer-based GIS are likely to assist in finding solutions to the looming global environmental problems, offering not only the means of carrying out effective environmental management using maps but also a renewed role for the

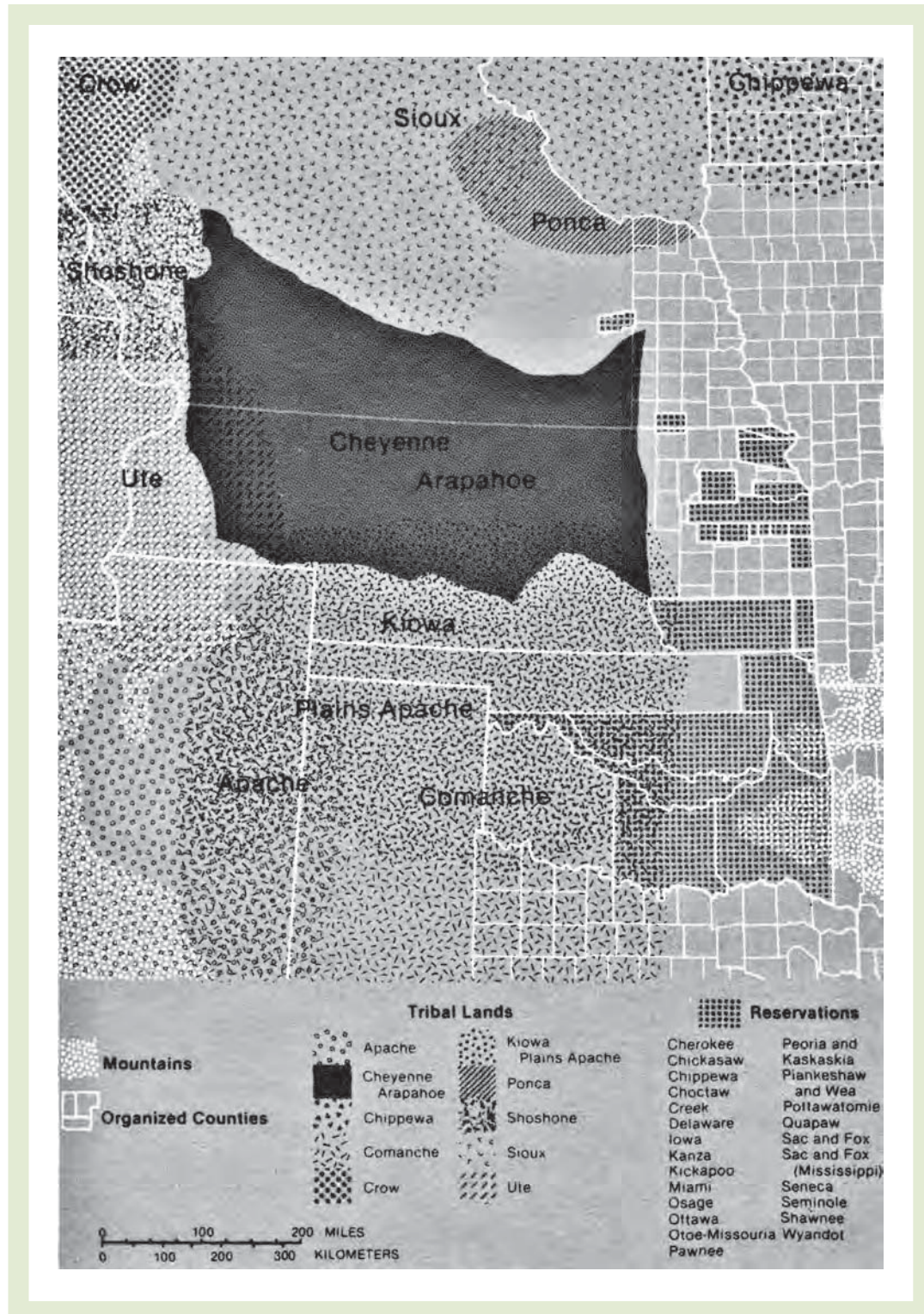


Figure 17 In this map, tint screens are used to develop a gray “graphic middle ground” for the black and white symbols conveying the environmental confrontations (*in white*) experienced by the Cheyenne (and other indigenous groups) during the 19th century.

Source: McCleary, G. F., Jr. (1990). Pursuing the Cheyenne: Mapping tribes, trails, the 1857 expedition and the battle of Solomon’s Fork. *Meridian*, 4, 3–28.



continuing partnership of cartography and other environmental sciences. To achieve this, there are several problems that must be resolved.

The first is the extension of the GIS software beyond rudimentary analytical capabilities that are only the beginning of a comprehensive set of spatial analytical procedures. The technology has to mature beyond paying lip service to the study of relationships and reach a new level of sophistication. Second, to manage the environment, “you gotta know the territory.” This is the only way to sort out and understand the numerical data and the resulting maps. It is not as simple as Bacon (and others) looking at the world map to gain a perspective on plate tectonics, which occur in geological time. Time is so short in many environmental management situations that long before there is any clear understanding of the problem, a decision has been made and implemented by public officials, based on limited mental (cognitive) maps (and other understandings). Too often, they have cleared the forest and built the highway intersection and shopping mall, and the environment has lost again. The joint expertise of geographers and cartographers is needed more than ever to create the GIS, generate the maps, and interpret the environmental factors and processes they depict.

George F. McCleary Jr. and Karen S. Cook

See also **al-Idrisi; Biblical Mapping; Cadastral Systems; Cartography; Digital Terrain Model; GIS, History of; Human Geography, History of; Indigenous Cartographies; Map Projections; Map Visualization; Mental Maps; Mercator, Gerardus; Ortelius; Portolan Charts; Ptolemy; T-in-O Maps; Waldseemüller, Martin**

Further Readings

- Bertin, J. (1983). *The semiology of graphics: Diagrams, networks, maps*. Madison: University of Wisconsin Press. (Original work published 1967)
- Harley, J. B., & Woodward, D. (Eds.). (1987). *The history of cartography*. Chicago: University of Chicago Press.

- Harvey, P. D. A. (1980). *The history of topographical maps: Symbols, pictures and surveys*. London: Thames & Hudson.
- Lynch, K. (1960). *The image of the city*. Cambridge: MIT Press.
- Raisz, E. (1938). *General cartography*. New York: McGraw-Hill.
- Snyder, J. P. (1993). *Flattening the Earth: Two thousand years of map projections*. Chicago: University of Chicago Press.
- Wallis, H. M., & Robinson, A. H. (1987). *Cartographical innovations: An international handbook of mapping terms to 1900*. Hertfordshire, UK: Map Collector.



CASTELLS, MANUEL (1942–)

Manuel Castells is a prominent urban sociologist who has made major interdisciplinary impacts through his theorizing of various contemporary global socioeconomic transformations.

Born in a Catalan family in Spain in 1942 and educated in France, Castells exemplifies a global theorist of contemporary societies. His expertise ranges from urban sociology and social movements to theories of technology and network society, and he has been influential in a wide range of social science disciplines, including anthropology, urban planning, economic geography, and telecommunications. Castells is known for a combination of talents rarely gifted to a single individual: an ability to interpret, analyze, and incorporate real-world examples around the globe; an ability to craft theories by combining rigorous inductive and deductive methods; and a commitment to the masses as the instigators and primary drivers of social change. His hallmark extensive international coverage of topics and rigorous comparative analysis are based on his firsthand observations and experiences gained through appointments and lectures he conducted in 40 countries, primarily in Europe, the Americas, and Asia. Castells's lifetime interests have been to uncover the factors and agents that bring about revolutionary changes in society, and he has done so through engagement in research on



urban politics, social movements, and information technologies.

Exiled by the Franco regime in the early 1960s, Castells began his intellectual journey in Paris under the guidance of Alain Touraine, an esteemed urban sociologist. Castells's dissertation and his first book, *The Urban Question: A Marxist Approach* (published in English in 1977), focused on urban politics, planning, and policy. The book is remarkably suggestive of analytical traits that are evident in his later work. Castells developed a global interpretation of urban structures by incorporating historical analysis and examining data from American, French, and Latin American cities, as well as those in the socialist world. His goal was to demystify and expose ideologies of the dominant classes through analysis of their social practices and develop a Marxist urban theory, which he claimed to have generated questions yet lacking sufficiently specific analytical framework. The outcome is an extremely dense writing that combines rich theoretical explorations with extensive empirical research that illustrates the underlining forces behind the ideology of the urban question.

At the University of California at Berkeley, which became Castells's longest intellectual home (1979–2003), he expanded his inquiry on the urban question into social movements by developing a cross-cultural theory of urban social change. In *The City and the Grassroots* (1983), Castells examined grassroots mobilizations in San Francisco's Mission district; in the gay community around Castro Street; in squatter settlements in Lima, Mexico City, and Santiago de Chile; and in citizens' movements in Madrid. Although somewhat overshadowed by the fame of his later work, this book is still regarded as a groundbreaking work in social movements research.

Subsequently, Castells shifted his focus to technology as a driving force of social change, with a particular emphasis on information technologies and their impacts on cities (as depicted in his books *The Informational City* in 1989, in which the concept of "space of flows" is first elaborated, and *Technopoles of the World* coauthored with Hall in 1994). The trilogy on *The Information Age: Economy, Society and Culture* (1996 to 2004) is considered Castells's seminal work, and it has been translated into 22 languages. He analyzed

the socioeconomic transformations of globalization, seen as outcomes of the information technology revolution. In the first volume of the trilogy, titled *The Rise of the Network Society*, Castells focused on the socioeconomic aspects of informationalism. In the second volume, *The Power of Identity*, Castells reconceptualized identity, social movements, and the state in the new global order and explored religious fundamentalism, patriarchalism, and information politics. The third volume, *End of Millennium*, covers broad contemporary sociopolitical transformations, ranging from the collapse of the Soviet Union to the rise of the fourth world, the global criminal economy, the Asian economic crisis, and European unification.

Castells also published works that focused on social changes in a digitalized world (see, e.g., *The Internet Galaxy*, 2001, and *The Information Society and the Welfare State: The Finnish Model*, with P. Himanen, 2002). But it is the trilogy that showcases the best of Castells's skillful grand theorizing of the highest sophistication; he does so by compiling an enormous amount of quantitative and qualitative evidence to support his claims, by presenting the most comprehensive global coverage humanly possible by an individual scholar, and by mobilizing an in-depth and multidisciplinary knowledge of theory in capturing and illuminating fundamental social changes.

At the University of California, Berkeley, Castells was known to his students as a methodological whiz, being able to instantaneously process and translate any potential research topic presented by students—often still broad and undefined—to one with an elegant research design, complete with a compelling question driven by a series of theoretically informed, rigorous yet answerable hypotheses. In fact, in spite of his voraciousness and openness to theoretical experiments, Castells was simultaneously feared and admired by students for demanding rigorous research design and competent social analysis. What made Castells truly remarkable was his dedication to data collection. Castells once even remarked that becoming a competent empiricist—in the sense that research should be based on empirical data rather than critical theoretical reflection alone—is often more difficult than engaging in grand theorizing. His sensitivity to cultural nuances, combined with his ability to generate



grand theories by incorporating empirical details in a truly bottom-up manner, was clearly enabled by his extensive interdisciplinary knowledge of sociological theories, but it also came out of his innate ability to generate and articulate compelling questions and craft them into sophisticated, well-informed hypotheses.

For someone so deeply involved in social activism of the political left, Castells's departure from Marxism was never absolved by the Marxist community. Particularly frustrated were those who expected a manifesto, or at least a prescriptive message, from the trilogy. Yet Castells's relationship with Marxism is clear from his earliest work, which was underscored by a desire to refine Marxist analysis and resolve its analytical weaknesses (*The Urban Question*) and contradictions (*The City and the Grassroots*). Castells in *The City and the Grassroots* criticized both Marxism and Leninism for their inability to incorporate urban social movements and declared, "So although Marxist theory might not have room for social movements other than the historically predicted class struggle, social movements persist. So experience was right and Marxist theory was wrong on this point" (p. 299). In the *End of Millennium*, he wrote, "Theory and research, in general as well as in this book, should be considered as a means of understanding our world, and should be judged exclusively on their accuracy, rigor, and relevance" (p. 390). Furthermore, his firsthand knowledge of those who suffered under the Soviet regime led to the conviction that Marxism as an intellectual project resulted in considerable human sufferings. In *End of Millennium*, he explicitly cautions against ideology:

What is to be done? Each time an intellectual has tried to answer this question, and seriously implement the answer, catastrophe has ensued. . . . I have seen so much misled sacrifice, so many dead ends induced by ideology, and such horrors provoked by artificial paradises of dogmatic politics that I want to convey a salutary reaction against trying to frame political practice in accordance with social theory, or, for that matter, with ideology. (pp. 389–390)

Ultimately, Castells's unwavering concern for the social well-being of the people has won

over his commitment to a particular intellectual project. His commitment to real-world experiences is what makes Castells a world-renowned intellectual.

Yuko Aoyama

See also **Marxism, Geography and; Space of Flows**

Further Readings

- Castells, M. (1977). *The urban question: A Marxist approach*. Cambridge: MIT Press.
- Castells, M. (1983). *The city and the grassroots: A cross-cultural theory of urban social movements*. London: Edward Arnold.
- Castells, M. (1989). *The informational city: Information technology, economic restructuring and the urban-regional process*. London: Blackwell.
- Castells, M. (1996). *The rise of the network society: Vol. 1. The information age: Economy, society and culture*. London: Blackwell.
- Castells, M. (1997). *The power of identity: Vol. 2. The information age: Economy, society and culture*. London: Blackwell.
- Castells, M. (1998). *End of millennium: Vol. 3. The information age: Economy, society and culture*. London: Blackwell.
- Castells, M. (2001). *The Internet galaxy: Reflections on the Internet, business, and society*. New York: Oxford University Press.
- Castells, M., & Himanen, P. (2002). *The information society and the welfare state: The Finnish model*. New York: Oxford University Press.



CAVERNS

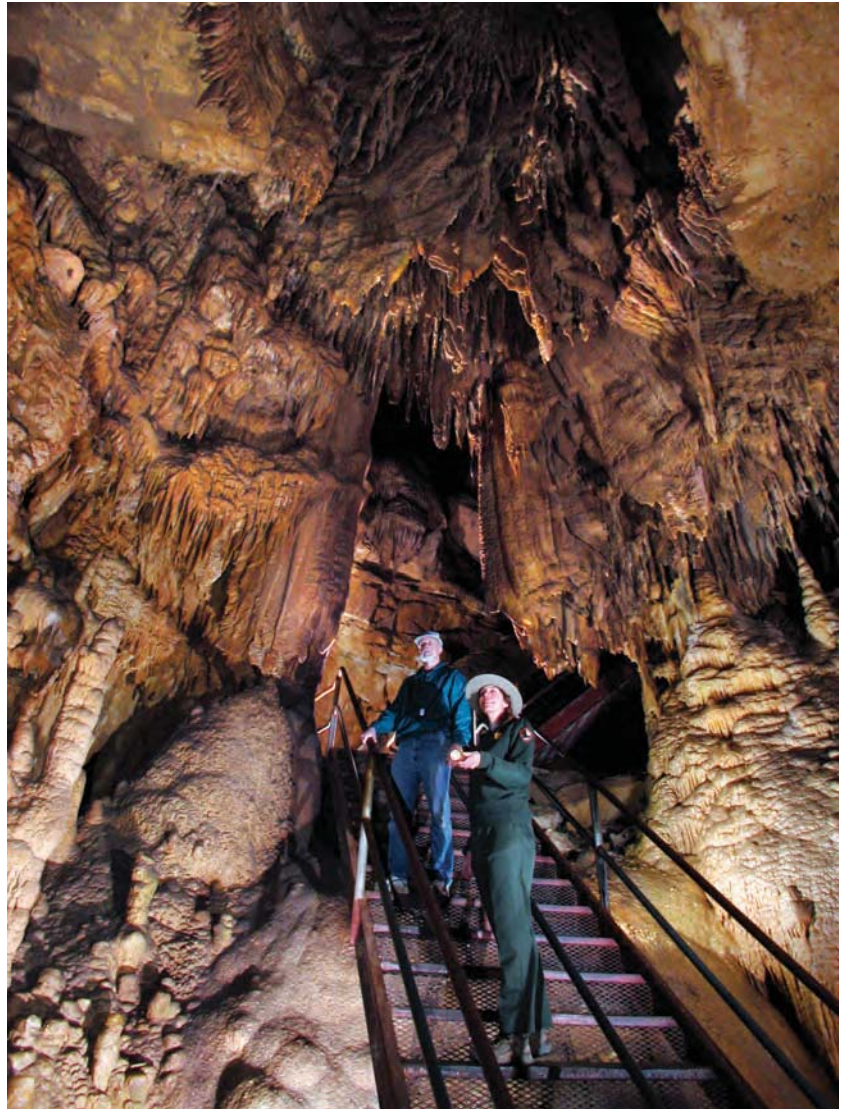
Caverns occur under the surface of the Earth wherever soluble rocks allow them to develop large openings. Limestone or calcite-rich (CaCO_3) bedrock is the most common host rock, as well as dolostone rocks composed of the mineral dolomite ($\text{CaMg}(\text{CO}_3)_2$). The evaporite rocks of gypsum (CaSO_4) and rock salt (NaCl) are also subject to solution and can develop underground



openings large enough to be considered caverns. In a few places, caverns have developed in other rock lithologies, such as where a calcite-cemented sandstone has also been subjected to solution. Several natural processes other than the dissolving of the bedrock can also produce caves, such as ocean waves and lava flows, but these are almost never large enough to constitute a true cavern, which has an implication of being of great size.

Caverns are almost always also of the solutional type, wherein the rock is dissolved, either partly in the upper vadose (undersaturated with free air surfaces) zone above the water table or more commonly beneath an unconfined water table in the bedrock as a water-filled phreatic cavern. Only when the water table is lowered, usually when the climate changes to a more arid one and the water table drops or when a nearby stream erodes downward enough to allow the water to drain out of the caverns, does air enter the opening and the cavern become part of the vadose realm. Vadose caverns can also pass from phreatic to vadose and back again many times in response to water table fluctuations associated with varying climates or tectonics. In addition to those formed in association with unconfined water tables, some caverns are formed entirely under conditions of confined or artesian water.

Speleogenesis, or the origin of caves and caverns, is a process wherein surface water (H_2O) infiltrating through the soil reacts with rotting organic matter to gain a bit of carbon dioxide (CO_2) and becomes carbonic acid (H_2CO_3). This weak acid in the groundwater trickles slowly along joints and fissures in the bedrock to come in contact with the calcium carbonate



Mammoth Cave in Kentucky is the longest known limestone cavern with about 367 miles of surveyed passageways. Mammoth Cave National Park was named a World Heritage Site in 1981 and is a core area of the International Biosphere Reserve.

Source: National Park Service.

($CaCO_3$) or the calcite mineral of the limestone, thereby dissolving it in the carbonation reaction. Mammoth Cave in Kentucky is this kind of cavern. Gypsum is 10 to 20 times more soluble in water than is carbonate rock, so caverns in that rock can form more quickly. Similarly, rock salt is even more soluble than gypsum, so large caves can form in it. Neither gypsum nor rock salt are very common, except in arid areas, with the result that caverns developed in these



rocks are far rarer than those in limestone. Furthermore, because rock salt is so mobile underground and moves upward in salt domes or diapirs, where it is loaded by overlying rock, any openings that have formed in it deep underground tend to anneal or be resealed and infilled by the flowing salt. Only where a surface salt deposit is subjected to a falling water table or where a salt diapir penetrates the surface into the vadose zone and forms an uplifted region do caverns form and remain open. In these cases, the rainwater simply dissolves the salt, so that the brine flows back out onto the surface at a lower level.

Alternatively to solution in water, a rarer process occurs underground to produce caverns wherein some source of hydrogen sulfide (H_2S) gas, such as oil or natural gas, or perhaps also volcanic gases, reacts with the groundwater to produce a gas of sulfuric acid (H_2SO_4), which rises from below to produce large openings. Carlsbad Caverns and Lechuguilla Cave in New Mexico are believed to have been produced in this unusual fashion.

Caverns commonly have a huge variety of speleothems (a secondary mineral deposit formed in a cave) in them that are the product of deposition after the initial dissolution produces the cavity in the first place. Once limestone caverns leave their underwater, phreatic-formation stage, where the rock is removed in solution and enters the vadose realm with a new gaseous atmosphere, they are then subjected to renewed infilling by speleothems. The varieties of speleothem infillings of caverns, such as stalactites, stalagmites, dripstone, flowstone, helictites, cave pearls, and myriad other forms, are truly awe inspiring and commonly very beautiful. Generally, in limestone bedrock, the speleothems will be of a similar composition because the carbonation reaction can go in either direction: toward dissolution of the rock in the cavern-forming phreatic stage or toward deposition of calcite speleothems in the cavern-refilling vadose stage. In some cases, however, where the underground water in a limestone region has much dissolved calcium sulfate (CaSO_4) in it, perhaps as the result of nearby igneous intrusions, the speleothems can be crystals of gypsum. The Cave of Crystals in Chihuahua, Mexico, for example, has crystals of selenite

gypsum up to 11.3 m (meters) long, which are among the longest in the world. In arid and semi-arid climates, speleothems in caverns are mainly composed of gypsum, whereas in temperate, humid, or tropical regions, carbonate formations are more predominant.

The size of caverns has been measured in most parts of the world. The published sizes change frequently with every new expedition that revises the survey. The longest known limestone cavern is Mammoth Cave, Kentucky, with about 591 km (kilometers) of chambers, whereas the longest in gypsum is the Optimisticheskaya Cave in West Ukraine, at about 230 km. The longest cavern in salt is in a salt diapir in Iran on Qeshm Island in the Persian Gulf at 6.58 km. The deepest cavern is Kubera (Voronja) at 2,191 m in Abkhazia, Georgia, in the West Caucasus Mountains. The largest underground chamber by surface area is the Sarawak Chamber, which measures 600 m by 415 m on a side and is about 80 to 100 m high. It is in the Lubang Nasib Bagus Cavern, in the Gunung Mulu National Park in Malaysia on the island of Borneo. The deepest pit in the world of caverns is that of Vrtoglavica in Slovenia at 603 m deep.

John F. Shroder

See also **Carbonation; Groundwater; Karst Topography**

Further Readings

Ford, D., & Williams, P. (2007). *Karst hydrogeology and geomorphology*. New York: Wiley.



CELLULAR AUTOMATA

Cellular automata (CA; singular: cellular automaton) are dynamic discrete systems that operate in space and time on a uniform and regular lattice of cells. These cells are driven by rules that describe interactions at the local level to produce patterns at the global level. Depending on the problem context, the cells can also be rectangular, triangular, or hexagonal.

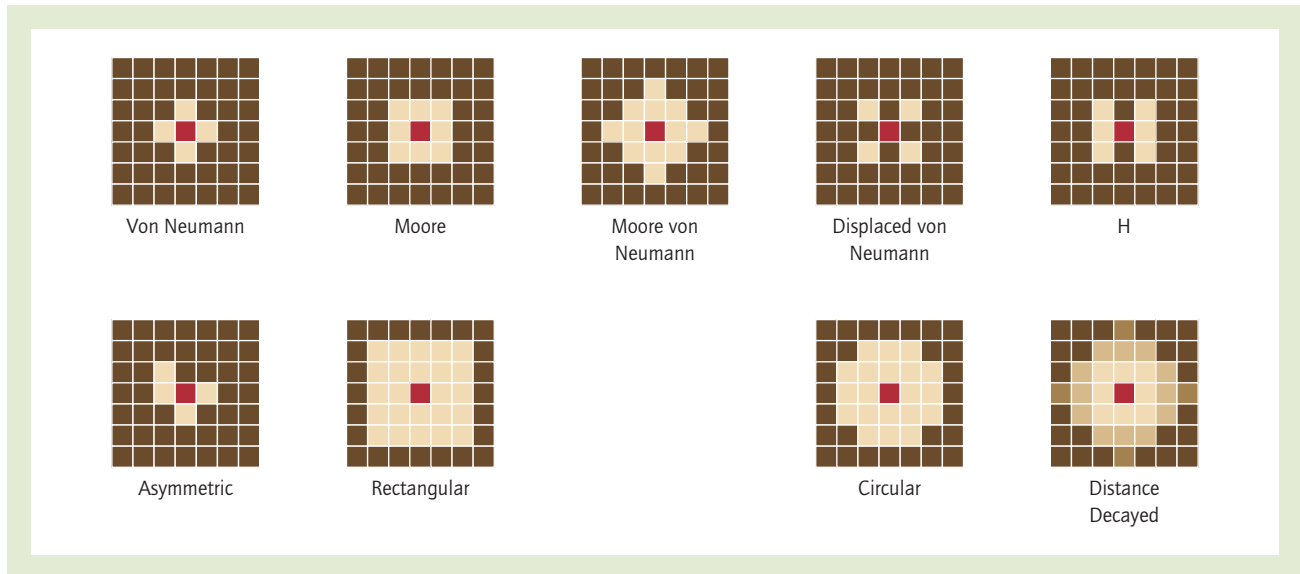


Figure 1 Different cellular automata neighborhoods

Source: Author.

History

The mathematical description of CA was partially postulated by D'Arcy Thompson (1917), then further developed by Von Neumann (1966) in his work on self-reproducing systems. The work of Von Neumann was motivated by Alan Turing's groundbreaking developments in algorithms and digital computing as well as Stanislaw Ulam's work on the growth of crystals in the 1940s and 1950s. CA concepts were further explored by Conway's *Game of Life* and popularized by Gardner in a 1970 article published in the journal *Scientific American*. Later, CA studies were linked to the theory of complex systems and were further elaborated by Wolfram (1984). Since then, CA theory and applications have gained rapid popularity in various scientific fields, such as physics, medicine, chemistry, biology, ecology, forestry, geography, and atmospheric and Earth sciences, among others.

Mathematical Formalism

The main components of CA are the cell spaces represented by a regular grid; cell states, S ; neighborhood of the cell, N ; functions of cell transition rules, R ; and discrete time increments, ΔT . The

cell state $S(x, y)_T$ at time T can be represented as function F depending on CA elements at previous time $T - 1$ and can be formalized as

$$S(x, y)_T = F\{S(x, y)_{T-1}, N_{T-1}, R_{T-1}, \Delta T\},$$

where $S(x, y)_{T-1}$ is the cell state at location (x, y) .

Each discrete time step represents the CA model iteration. During the iteration, an update of the state of each cell in the grid is provided using transition rules and the states of other cells in its local neighborhood. Figure 1 shows the various types of neighborhoods used in the CA modeling procedures. The Von Neumann, Moore, extended Moore, displaced von Neumann, Moore von Neumann, and H neighborhoods are the more popular ones that are used in modeling studies. The shape and the size of the neighborhoods may vary, from those with symmetric, asymmetric, rectangular, and circular shapes and distinct values to those that consider cells from different locations in the neighborhoods with gradual values of different importance based on distance-distance decay of a given variable.

The transition rules form an important part of the CA model. They define the way in which the cell will develop over time and hence mimic the overall change process of the cells over space and



time. The rules can be deterministic, probabilistic, stochastic, or fuzzy and, therefore, imply a bottom-up modeling process from the local scale to global scales. The model calibration and validation procedures are key phases of the CA model development. Calibration and validation allow fine tuning of the model parameters, and model testing determines how closely the final model can simulate or represent the spatial patterns found in the real world.

Cellular Automata and Geography

Geographic phenomena are inherently dynamic and complex and can therefore be studied using complex systems theory. During the geographic change process, elements of the system may evolve, interact, and bifurcate over space and time. These interactions are usually nonlinear and self-organizational, so CA theory is suitable to represent them.

Using cells and neighborhoods to represent the dynamics of geographic systems as spatial models can be traced back to the development of diffusion models by Hagerstrand (1953), the probabilistic model of residential growth by Chapin and Weiss (1968), and Schelling's (1969) segregation model. Later, Tobler (1970) introduced strict cellular automata rules for cellular geography, which was further theorized by Couclelis (1985). Since then, CA was increasingly used in geography.

Geographic Applications of Cellular Automata

The main geographical applications of CA were in land use change and urban growth studies at local or regional scales. Structure formation related to micro- and macrodynamics were explored in early research efforts in 1990s and further improved to include the modeling and representing of urban form and urban growth, population dynamics, rural residential settlements, sustainable growth, and, even, urban gentrification. CA models of land use change were developed to account not only for urban land use dynamics but for forest and agricultural dynamics as well. Many mathematical approaches were used to make CA models closer to reality, such as

multicriteria analysis, principal components analysis, genetic algorithms, and neural and Bayesian networks. Attempts have been made to develop CA models that operate on irregular spatial tessellations with Voronoi diagrams, use graph theory, and develop urban cadastral lots as cells (Figure 2).

Cellular Automata and Geographic Information Systems

Advances in satellite data collections, raster geographic information systems (GIS), and increased geospatial data availability also amplified the attractiveness of CA as a modeling approach. GIS deals with various spatial data representations and can handle, analyze, and manipulate different geospatial data sets, but it is, however, known as a static tool. The CA-GIS fusion provided the extended capability of GIS to use both spatial and temporal dimensions and allowed the analysis and modeling of inherently dynamic and complex geographic processes. The Idrisi GIS software contains modules that allow the development of simple CA models. However, most studies rely on a loose coupling mechanism with the GIS software to implement various CA modeling approaches. The most common stand-alone CA modeling approaches, tools, and environments are, for example, IDUEM (Integrated Dynamic Urban Evolutionary Model), GEONAMICA, SLEUTH (slope, land use map, excluded area, urban area, transportation map, and hillside area model), UrbanSim, and iCITY (irregular city). One drawback is that they are customized based on the model design or data, making them difficult to adapt for new case studies. Some researchers argue that CA models are for analysis but not for prediction of possible simulated urban and land use patterns. Others have implemented CA models for planning contexts and policy-making purposes or for public and stakeholder involvement in land use decision making.

Suzana Dragicevic

See also **Complex Systems Models; Complexity Theory; Distributed Computing; Dynamic and Interactive Displays; GIScience; Neogeography**

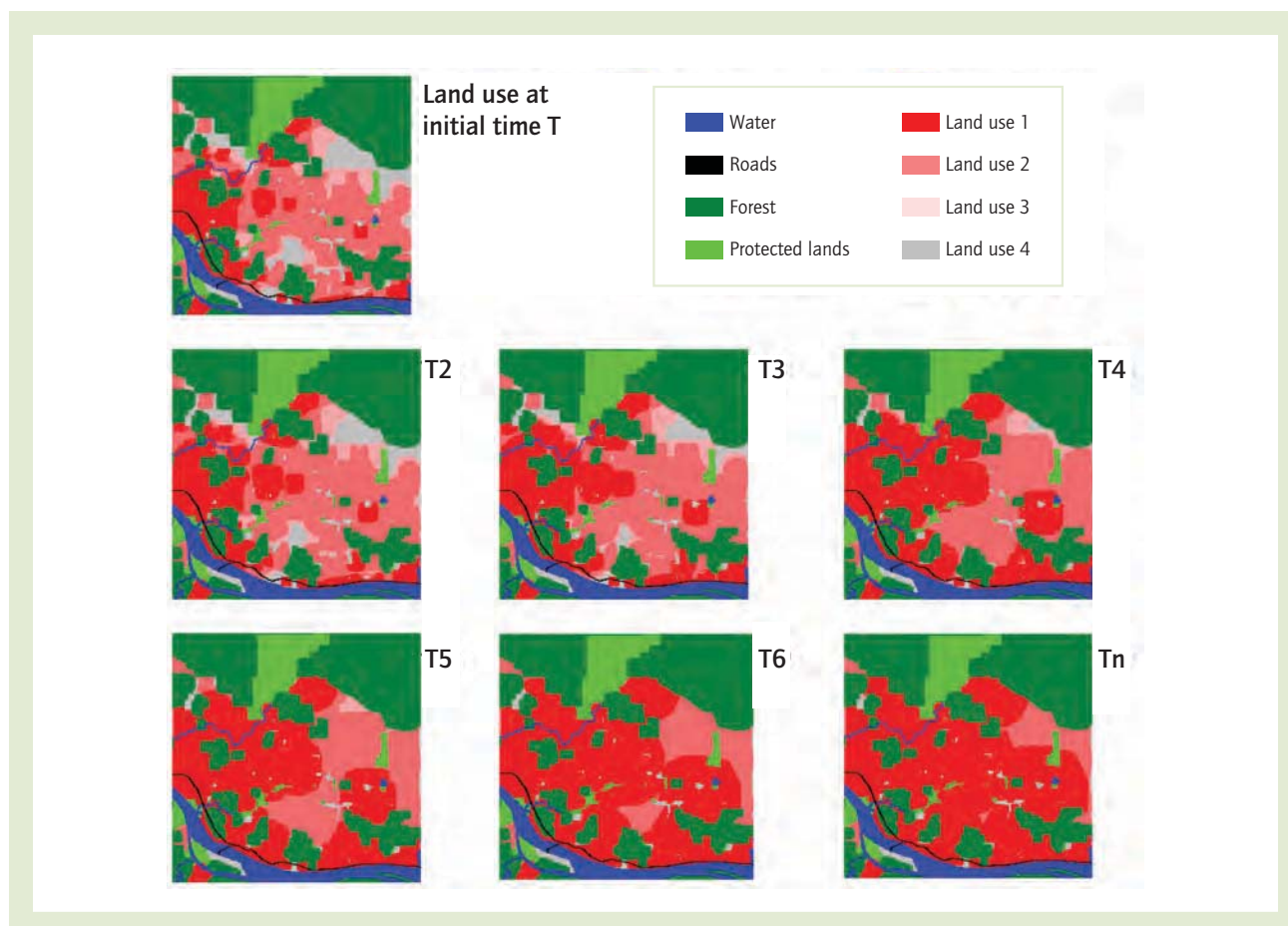


Figure 2 Simple cellular automata model of land use change over time

Source: Author.

Further Readings

- Batty, M. (2005). *Cities and complexity*. Cambridge: MIT Press.
- Maguire, D., Batty, M., & Goodchild, M. (2005). *GIS, spatial analysis and modelling*. Redlands, CA: ESRI Press.
- Portugali, J. (2006). *Complex artificial environments: Simulation, cognition and VR in the study and planning of cities*. Berlin, Germany: Springer-Verlag.
- White, R., & Engelen, G. (2000). High-resolution integrated modelling of the spatial dynamics of urban and regional systems. *Computers, Environment & Urban Systems*, 24, 383–400.
- Wolfram, S. (1984). Computation theory of cellular automata. *Communications in Mathematical Physics*, 96, 15–57.



CENSUS

A census is a data collection activity that is usually periodic and is typically conducted by a governmental entity for the purpose of obtaining statistical information and producing data for the entire population. A census contrasts with a survey, which uses sampling methods and obtains information from a subset of rather than the entire population. In the United States, the term *census* is commonly associated with the Decennial Census of Population and Housing, which takes place every 10 years and is conducted by the U.S. Census Bureau for the purpose of counting the population to apportion the seats in the House of Representatives among the states and to provide small-area data necessary for legislative redistricting.



Many countries conduct periodic censuses for their populations; their design, the data collection methods, and the data produced vary. Not all censuses focus on counting populations and housing units. For example, in addition to a census of population and housing, the U.S. Census Bureau conducts an economic census, which collects information on the characteristics of businesses, and a census of governments, which collects data on the finances and administrative characteristics of state and local governments.

Censuses are critical to and depend on the discipline of geography. Census activities rely heavily on geographic databases and geographic information system software as well as cartographic operations. Census data, based on the areas defined and maintained by the U.S. Census Bureau and statistical agencies in other countries, are widely used throughout the geospatial industry, in geography programs in academia, and throughout the public and private sector, wherever geography is practiced. This entry focuses on the U.S. Census of Population and Housing.

Article 1, Section 2, of the U.S. Constitution requires enumeration of the nation's population every 10 years. The United States has conducted censuses every decade since 1790; the scope of the census, the methods used, and the data tabulations produced have evolved over time.

Census 2000 collected basic information (name, household relationship, sex, age, Hispanic or Latino origin, race, and tenure—whether a home is owned or rented) for all people and housing units and detailed information on demographic, social, housing, and economic characteristics for people and housing units through a sample survey conducted as part of the decennial census. The 2010 Census collected basic information for people and housing units. However, detailed information was collected through the American Community Survey (ACS). The ACS is an ongoing survey that has replaced the sample survey used for Census 2000 and previous censuses and produces timely demographic, social, housing, and economic data (Table 1).

Like previous censuses, the 2010 Census required a full range of preparations that included the testing of concepts that are the basis for census questions, improvements to address lists, various

promotional activities, a variety of technological improvements, the dissemination of data products, and other activities. Twelve regional offices located in major cities throughout the United States provided critical support to local operations, including hiring and data collection. The Census Bureau made significant efforts to develop effective partnerships with local communities and organizations to encourage full participation and to communicate a commitment to respecting privacy and protecting the confidentiality of the data collected. Title 13, United States Code, is the basis for the Census Bureau's commitment to safeguarding data. Most addresses received an English language questionnaire, although a bilingual Spanish-English questionnaire was mailed to selected areas. Then, to assist people who do not speak English well, the Census Bureau provided translated forms in five languages (Spanish, simplified Chinese, Vietnamese, Korean, and Russian), telephone questionnaire assistance in those same languages, and language assistance guides in 59 languages. Promotional and outreach materials were provided in many languages.

The geographic tools and techniques used for census taking have expanded over the years, especially following the development of the Topologically Integrated Geographic Encoding and Referencing (TIGER)-automated mapping database for the 1990 Census. Modernizing TIGER and the Census Bureau's Master Address File, the source of millions of addresses used to deliver census forms, were critical objectives for Census 2010. Mobile computing devices were used to collect data and verify addresses. The 2010 Census operations also included a Local Update of Census Addresses program, which allowed state, local, and tribal governments to complete and correct address files for their communities, and a nationwide address-canvassing operation. Continuing geographic challenges for the Census Bureau in preparing for the 2010 Census included improving address information, particularly in rural areas, collecting new street features, acquiring boundary updates from all governments, and improving quality measurement of address and spatial data and geographic processes.

Census data for geographic areas such as census blocks, census tracts, incorporated places, and American Indian Reservations are of interest to a



<i>Demographic characteristics</i>	<i>Economic characteristics</i>
Age	Income
Gender	Food stamps benefit
Hispanic origin	Labor force status
Race	Industry, occupation, and class of worker
Relationship to householder (e.g., spouse)	Place of work and journey to work
	Work status last year
	Vehicles available
	Health insurance coverage ^a
<i>Social characteristics</i>	<i>Physical characteristics</i>
Marital status and marital history ^a	Year structure built
Fertility	Units in structure
Grandparents as caregivers	Year moved into unit
Ancestry	Rooms
Place of birth, citizenship, and year of entry	Bedrooms
Language spoken at home	Kitchen facilities
Educational attainment and school enrollment	Plumbing facilities
Residence 1 year ago	House heating fuel
Veteran status, period of military service, and VA	Telephone service available
Service-Connected Disability Rating ^a	Farm residence
Disability	
	<i>Financial characteristics</i>
	Housing tenure (owner/renter)
	Housing value
	Rental costs
	Selected monthly owner costs

Table 1 Subjects included in the American Community Survey

Source: U.S. Census Bureau. (2008). *A compass for understanding and using American community survey data: What general data users need to know*. Washington, DC: Government Printing Office.

Note: a. Marital History, Department of Veterans Affairs (VA) Service-Connected Disability Rating, and Health Insurance Coverage are new for 2008.

variety of geospatial data users. Defined anew for each Decennial Census of Population and Housing or updated by a periodic Boundary and Annexation Survey, these areas form the basis for geographic tabulations that help identify needs for housing, economic development, new schools, job training, or other goals critical to national, regional, state, local, or tribal needs. Each year, more than \$400 billion in U.S. federal funds is distributed on the basis of census data, and every new release of census data is accompanied by media coverage of the latest demographic or housing trends affecting the nation's communities. Census data products are available through American FactFinder and other data access tools

that can be accessed through the Census Bureau's Web site, www.census.gov.

Nancy K. Torrieri

See also **Census Tracts; GIS, History of; Population Geography; Redistricting; United States Census Bureau**

Further Readings

- Peters, A., & MacDonald, H. (2004). *Unlocking the census with GIS*. Redlands, CA: ESRI Press.
- Steffey, D. L., & Bradburn, N. M. (Eds.). (1994). *Counting people in the information age*. Washington, DC: National Academy Press.



CENSUS TRACTS

Tracts are regions of U.S. census geography that originated as analogs of urban neighborhoods. They retain some of that purpose today, and for that reason, tract limits are partially defined by population characteristics in addition to political boundaries and population. Tracts are preferable to other regions because the tabulations are more complete than those of smaller areas and are more easily compared than wards, zip codes, or other administrative regions not defined by population.

First proposed in 1906 by the demographer Walter Laidlaw, census tracts were intended to be a permanent framework to simplify tracking demographic changes. Although the census bureau agreed in principle to provide tract-level tabulations for eight cities in 1910, there was no immediate interest outside New York City. Demand had grown enough by 1940 so that the census bureau adopted the tract as an official tabulation area, including them in decennial tabulations, and took control over the definition of their boundaries. Tract coverage was extended into the suburbs following World War II, and most metropolitan areas were covered by 1980 and the entire nation, in 1990. Although tracts have always been intended to provide stable census geography, it has proven impossible to retain stability against the background of a highly fluid population. For this reason, efforts have been made to keep them comparable from one enumeration to the next by preferring changes that simplify reaggregation, especially by splitting a high-population tract or merging multiple low-population tracts.

Most changes in tract geography result from the population redistribution; however, some changes result from changes in the criteria defining tracts, and there have been two general overhauls of the system since 1940. Some basic tract criteria have been constant since 1910; a particularly important criterion is that every attempt should be made so that they are compact and follow visible and identifiable features but do not cross state or county boundaries.

The Census Bureau redefined tracts nationwide in 1960 to standardize the populations of

existing tracts and to impose a uniform decimal numbering system. For the second reorganization in 2010, the bureau established new standards meant to address the problems of low-population tracts resulting from extending the system across the country. The newer criteria define a tract as having either a minimum population of 1,200 persons (down from 1,500) or encompassing a minimum of 480 housing units. Persistent low-population areas, including parks, airports, or other unoccupied land, may now be designated as belonging to a “special land use area” so long as it exceeds a minimum size of 1 mi.² (square mile) of urban land or 10 mi.² outside an urban region.

Jason Bryan Jindrich

See also **Census; United States Census Bureau**

Further Readings

U.S. Bureau of the Census. (1994). Census tracts and block numbering areas. In *Geographic areas reference manual* (pp. 10-11–10-17). Washington, DC: Author.



CENTERS OF DOMESTICATION

Centers of domestication refer to areas of agricultural origins and innovations. Cultural geographers emphasize that particular local groupings of domesticated plants constituted the basic cultivated species for each regional agricultural development zone, or “center” of domestication. These hearths of domestication were located mostly in tropical or subtropical regions in areas of marked diversity of useful plants or animals and diverse topography, where the first sedentary societies developed. Regions of domestication could be quite large. One of the primary regions of crop domestication, the southwestern Asia area (which includes Mesopotamia) stretches from northwest India to the Caucasus Mountains and into Turkey, reaching over 40° N.



Plant domestication refers to the process of artificial selection by humans, whereby plants with desirable traits are selected and cultivated for food, fiber, medicines, and other needs. The domestication of plants began more than 10,000 yrs. (years) ago as an experimental process that was partly accidental as well as deliberate. While there is debate over the precise definition of domestication, plants that have been domesticated over time by humans become more, if not entirely, dependent on human cultivation for their survival. Domestication was a lengthy process in which plants and animals were raised by humans, and the development of village-based agricultural economies probably did not occur until around 5,000 yrs. ago. Smallholders all over the world continue to domesticate wild species today.

At first, plants with desirable traits were most likely simply protected from destruction in the wild. As humans learned more about them, these protected plants were cultivated (cared for), and then, as knowledge progressed, they were actually planted. Thus, the farming of wild plants emerged as a practice before the actual domestication of these species took place. Einkorn wheat has been considered the world's oldest domesticated crop (about 10,500 BP), although recent discoveries indicate that figs were domesticated 11,400 BP and place rye at 13,000 BP. All three plants were domesticated in the Fertile Crescent, considered to be the oldest of the world's independent centers of plant domestication.

Plants may be selected for their desirable traits (a cultigen), such as larger, tastier, or easily harvested edible parts (e.g., maize, manioc, avocados), though some domesticated plants were essentially no different in morphology from their wild counterparts (e.g., teff, fonio, pecans). Plants must be studied to understand if or how humans were involved in their development, but a good



Chili peppers in South America. The distinctly different shapes and colors of these chili peppers provide evidence of their artificial selection over time, a key part of the domestication process.

Source: Author.

indicator of a domesticated species that has undergone artificial selection is one in which the edible parts exhibit different shapes or colors, such as the different varieties of chili peppers in the photograph. Today, most domesticated plants used for commercial purposes look and even taste significantly different from their wild counterparts.

How did all this come about? New genetic data help confirm that a multitude of factors contribute to the domestication of plants across space and time, but scientists have also known for some time that the earliest humans needed to eat plants to survive. Plant materials were an extremely important source of carbohydrates for hunter gatherers, as well as fats where or when game animals were scarce. Although these foraging societies existed long before the sedentary, farming societies, most were probably well aware of ways to maintain patches of wild crops. For example, with wild roots, not all the root or roots would be harvested but a part would be left in the ground to regenerate, allowing foragers to return and harvest the roots again. This may be



considered a type of predomestication cultivation, although we can assume that over time the better or hardier root specimens were selected or survived. However, natural mutations outside human control also make certain species more compatible to human cultivation and help the domestication process. For example, humans noticed mutations in wild crops such as wheat or legumes, where the seeds remained on the stem when ripe rather than falling to the ground. These seeds were selected for harvest, and over time the mutation became the primary or sole source of seed for the crop. Natural fires caused by lightning helped make certain plants edible. Along with the use of fire, the establishment of clearings, climate change, and human consumption of plant species all aided the process of domestication.

We must remember that humans dispersed seeds by simply discarding them, by defecation, and through the early exchange of seeds, all of which promote artificial selection and the domestication process. It was only natural for humans to select the larger and sweeter fruits from trees and to take them elsewhere to eat. These conditions still prevail in traditional agricultural and hunter-gatherer societies today.

The terms *cultivation*, *domestication*, and *agriculture* should be used with care when discussing the development of crops and agriculture. Cultivation refers to the effort humans put into planting, tending, or caring for a plant, while domestication means that plants have been changed genetically, morphologically, or in their growth behavior by humans. Domesticated plants tend to depend on human cultivation for their survival over time. Agriculture is defined as the cultivation of domesticated plants as crops (cultivars) in systems that require some working of the soil.

The processes and applications of plant and animal domestication are fundamental examples of how humans have adapted to different natural environments and the cultural landscapes they create over time. The dog is considered to be the oldest domesticated animal, approximately 14,000 yrs. (years) ago in East Asia, and was an important hunting animal for humans. Animal domestication influenced plant domestication, such as the sheep and goats in the Fertile Crescent, which helped clear vegetation for crops and

could eat parts of the domesticated plants that were not eaten by humans. There were six major centers of agricultural origin in the world, along with several other regions where agriculture developed independently. The early diffusion of domesticated crops and animals across regions has made it difficult to define the original spatial patterns of domestication.

Plant and animal domestication was a primary research topic and interest of the father of American geography, Carl Sauer (1889–1975), and greatly influenced his thinking about cultural landscapes, a concept that he promoted and developed beginning in the early 20th century. Sauer believed that there were perhaps 11 independent centers of plant domestication, including the Fertile Crescent (wheat, rye, peas, lentils, figs), Mesoamerica (where maize was domesticated from teosinte), East Asia (rice), and the highlands of South America (potato, quinoa, peanuts, manioc). It was the tropical forests of southeast Asia and South Asia that he believed were the oldest centers of domestication, for root crops such as yams more than 14,000 yrs. ago. Sauer's beliefs differed from most other scientists' during the 1950s, who found little evidence to support his ideas because root crops quickly rotted away in humid environments, while archeologists had found thousands of seeds from grains in the arid Middle East that were at least 10,000 yrs. old. New evidence now confirms that forest dwellers had cultivated squash in Ecuador at least 10,000 yrs. ago and that forest fruits such as avocados may have been cultivated in Mexico far earlier than was previously known. The tall, common peach palm (*Bactris gasipaes*), native to the humid lowlands of Central and South America, has never been found in its wild, undomesticated state, also suggesting that cultivation took place quite early and often. Sauer noted that animals domesticated in southeast Asia, such as dogs, pigs, chickens, and ducks, were household animals that were tended to mostly by women, as compared with the herd animals originating in Southwest Asia; emphasizing the major role played by women in the development of agriculture.

Where traditional agriculture is practiced, smallholders still cultivate wild species in their gardens, and the process of domestication continues much as it had evolved centuries ago. These

farmers will protect useful wild species that regenerate in their gardens or will collect wild-planting stock to grow there. They will also exchange wild-planting stock with other farmers. The Amazon basin is a region where a large number of wild forest species are promoted by agronomists and even governments as a way to promote agricultural development in an environmentally friendly way. Recent programs promoting camu camu (*Myrciaria dubia*) planting in Peru are an interesting example of initial or incipient domestication. Seeds are collected from wild camu camu trees and simply distributed to farmers, usually without any selection for traits. Areas next to the wild stands were selected first for cultivation because the fruit trees have the best chance of growing well in the same habitat. The small, water-loving trees produce a tasty fruit that is very high in vitamin C. As confidence grew in the ability to cultivate the species, new fields were established farther away from the wild trees (Figure 1). This is a classic example of in situ and adjacent domestication, a process that cranberry growers followed in North America. While new evidence shows both human settlements and plant domestication arising earlier than researchers had thought, we also have much to learn about the efforts of today's farmers to domesticate little-known but promising wild plant species.

Jim Penn

See also **Agriculture, Preindustrial; Domestication of Animals; Domestication of Plants; Hunting and Gathering**

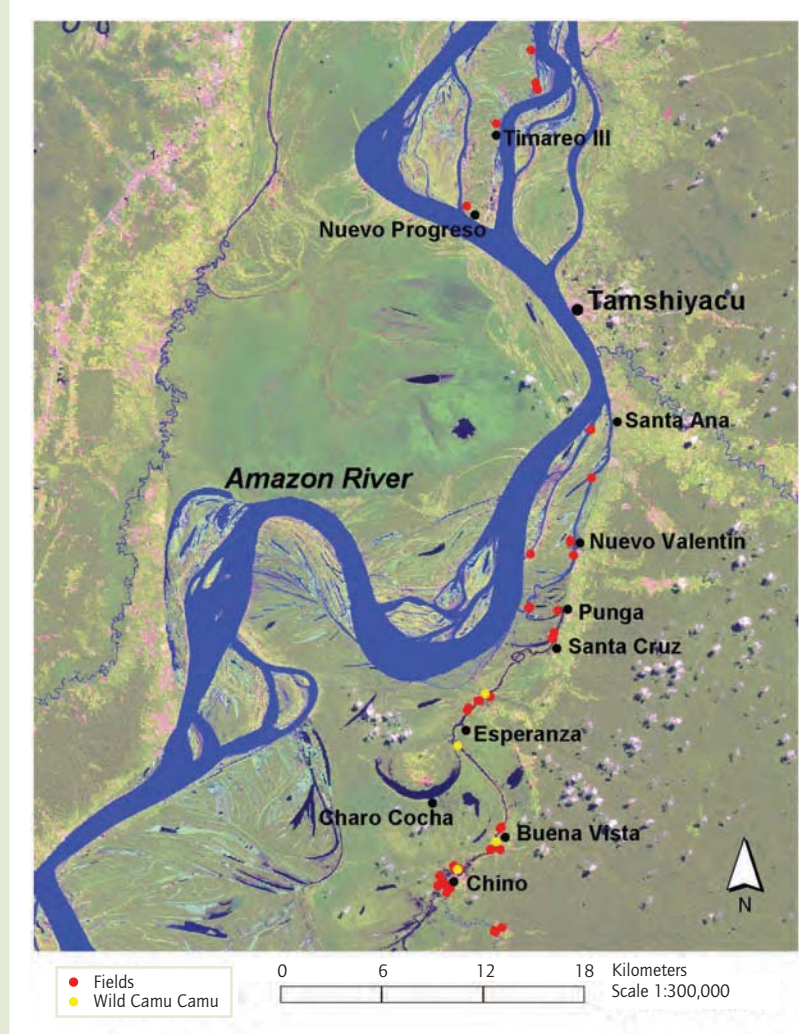


Figure 1 Mapping in situ and adjacent domestication. The close proximity of cultivated fields of camu camu trees to natural patches of wild camu camu is a recent example of in situ and adjacent domestication of this promising species.

Source: From Penn, J. W., Jr. (2008). Non-timber forest products in Peruvian Amazonia: Changing patterns of economic exploitation. *Focus on Geography*, 51(2), 22. Copyright © 2008 American Geographical Society. Reprinted by permission of the author.

Further Readings

- Balter, M. (2007). Seeking agriculture's ancient roots. *Science*, 316, 1831–1835.
- Penn, J. W., Jr. (2006). The cultivation of camu camu (*Myrciaria dubia*): A tree planting programme in the Peruvian Amazon. *Forests, Trees, and Livelihoods*, 16(1), 85–101.



Prance, G., & Nesbitt, M. (Eds.). (2005). *The cultural history of plants*. New York: Routledge.

Sauer, C. O. (1952). *Agricultural origins and dispersals: The domestication of animals and foodstuffs*. New York: American Geographical Society.

Sauer, J. D. (1993). *Historical geography of crop plants: A select roster*. Boca Raton, FL: CRC Press.



CENTRAL BUSINESS DISTRICT

The central business district (CBD) is the core area of a city, where specialized business services are concentrated. The CBD is essentially an American phenomenon, initially appearing in the early

1800s and evolving over time into the high-rise skyline characteristic of many large cities today. Other terms widely used synonymously for the CBD are *downtown*, *city center*, and *central city*. The American CBD differs from business centers in other countries in several ways. European cities have long histories during which growth spreads outward from the center. Residential land uses are common in European city centers, where the wealthy, upper-class citizens reside. High-rise office buildings are generally built in the peripheral areas. Many American cities, on the other hand, were initially constructed with a business district in the center of the city. Residential land uses in downtown areas of most American cities are rare.

The reason for the development of the CBD lies in the high accessibility afforded by the convergence of transportation networks into the city



Salt Lake City, Utah, with the Wasatch Range in the background

Source: © Joseph Sohm/Visions of America/Corbis.

center, which is central to the agglomeration economies there. This accessibility resulted in high land values as businesses were attracted to office buildings for accounting and management functions. These activities necessitated that ancillary services such as banking, finance, insurance, and law firms also be located in the immediate vicinity. Nearby hotels, restaurants, and high-end retailers attended to the needs of the professionals, their clients, and the office workers employed in the CBD.

Several technological innovations allowed a further intensification of CBD land uses. The skyscraper and electric elevator permitted the construction of ever taller buildings, while subways facilitated the rapid movement of people into and out of the CBD. High-rise office buildings provided enormous amounts of office space on a relatively small footprint on the ground. As land became more and more valuable, the CBD actually contracted into a smaller area because of the abundant office floor space. Zoning took on a vertical orientation with the peak land values at the street level, where retailing could provide the greatest revenues per square foot.

Suburbanization has caused the CBD in many cities to stagnate as office functions decentralized and retailing migrated to distant shopping malls. The edge and the “centerless” city phenomena have also challenged CBD dominance of business services. Anchored by government offices and trophy buildings housing corporate headquarters, the CBD still remains a major provider of specialized business services. But other than a few cities such as New York, Chicago, Boston, and San Francisco, which have active night lives, the CBD



The UBS Tower (above, center) is a 651-foot-tall skyscraper located at One North Wacker Drive in Chicago, Illinois. The 50-story structure, started in 1999 and completed in 2001, was the first major office skyscraper to be built in Chicago since 1992. Chicago's central business district is bounded on the west and north by the Chicago River, on the east by Lake Michigan, and on the south by Roosevelt Road.

Source: Eric Mathiasen.

has become a daytime employment destination with vacant buildings and streets at night.

Norman Carter



See also **Agglomeration Economies; Chicago School; Suburbs and Suburbanization; Urban Land Use; Urban Spatial Structure; Urban Sprawl; Vance, James**

Further Readings

- Fogelson, R. (2001). *Downtown: Its rise and fall, 1880–1950*. New Haven, CT: Yale University Press.
- Ford, L. (1994). *Cities and buildings: Skyscrapers, skid rows, and suburbs*. Baltimore: Johns Hopkins University Press.
- Vance, J., Jr. (1971). Focus on downtown. In L. S. Bourne (Ed.), *Internal structure of the city* (pp. 112–120). New York: Oxford University Press.



CENTRAL PLACE THEORY

Central place theory, developed by the German geographer Walter Christaller as his doctoral dissertation, *Central Places in Southern Germany* in 1933, was a highly influential set of models widely used to describe and analyze urban hierarchies in the mid 20th century.

Essentially, central place theory is a model of city systems that posits them as retail centers (central places) that distribute goods and services to their surrounding hinterlands. Like many models of spatial analysis, it assumes a featureless isotropic plain in which population density and transport costs are equal in all directions. Each good has a threshold, or minimum market size, as well as a range, or maximum distance consumers will travel to purchase it (Figure 1). The size of a given good's range and threshold vary with transportation costs, or the friction of distance, as well as the willingness of consumers to travel to obtain a given good or service. As the effective price increases with distance from the central place, demand declines accordingly. The model is thus compatible with the neoclassical views of economics that privilege consumer demand in the analysis of social and spatial structures.

Different goods and services have different thresholds: inexpensive, frequently purchased, and everyday necessities have low thresholds

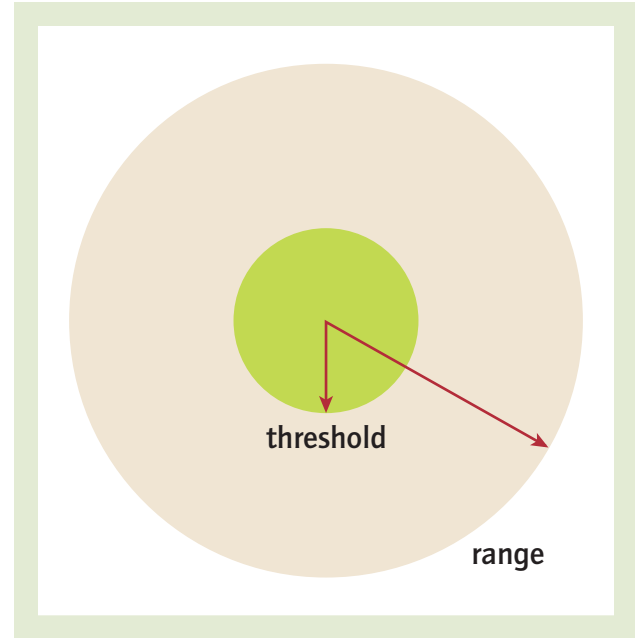


Figure 1 Range and threshold. In central place theory, each good has a minimum market size (threshold) and a maximum distance (range) that consumers will travel to purchase it.

Source: Ingolf K. Vogeler, University of Wisconsin–Eau Claire, <http://www.uwec.edu/Geography/lvogeler/w111/urban1.htm>.

(e.g., convenience stores, groceries, eating and drinking establishments, dry cleaners, and other personal services), while costly, infrequently used goods and services, including luxuries, have much larger ones (e.g., jewelry, specialized medical services). The degree of specialization of a good or service is thus directly proportionate to the willingness of consumers to travel to obtain it: Increasingly specialized products attract consumers from progressively longer distances. A hierarchy of goods and services leads to a hierarchy of central places to distribute them. Central place theory thus ranks urban places on the basis of their ability to distribute goods that range from “low-order” to “high-order” ones. The order of a central place is determined by the highest-order goods that it distributes to consumers around it.

The resulting hierarchy of central places—the urban hierarchy—reflects the imperatives of market forces over space, which tend to maximize the number of centers, maximize the number of consumers served, and minimize the aggregate distances that consumers must travel to

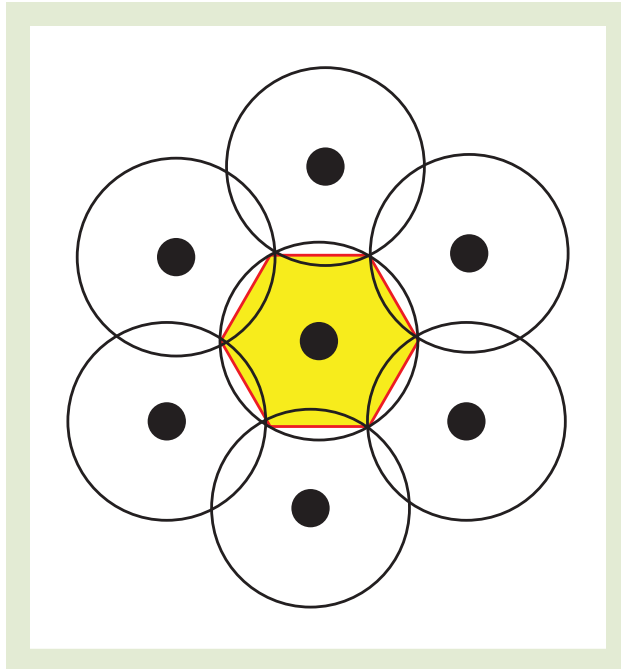


Figure 2 Formation of hexagonal market areas. Overlapping circular hinterlands are divided in half as consumers travel to the closest one, leading to hexagonal, nonoverlapping ones.

Source: Ingolf K. Vogeler, University of Wisconsin–Eau Claire, <http://www.uwec.edu/Geography/Ivogeler/w111/urban1.htm>.

purchase goods of varying levels of specialization. Large cities distribute both low- and high-order goods, the latter over increasingly large hinterlands. Higher-order centers are more widely spaced, with larger populations, serve large market areas, and are encountered less frequently on the landscape. Thus, metropolitan areas, the highest order, offer the greatest diversity of goods and services and hinterlands that extend over vast distances. Conversely, progressively lower-order centers are nested within the market areas of higher-order centers. Small, rural hamlets, for example, historically formed central places serving low-density agricultural regions. Progressing up the urban hierarchy, one encountered increasingly larger but infrequent places with a mounting diversity of goods and services.

In the classical central place model, which has several variations, consumers minimize their transport costs to the closest city that offers the goods they desire, and producers maximize profits. On an isotropic plain, market areas form

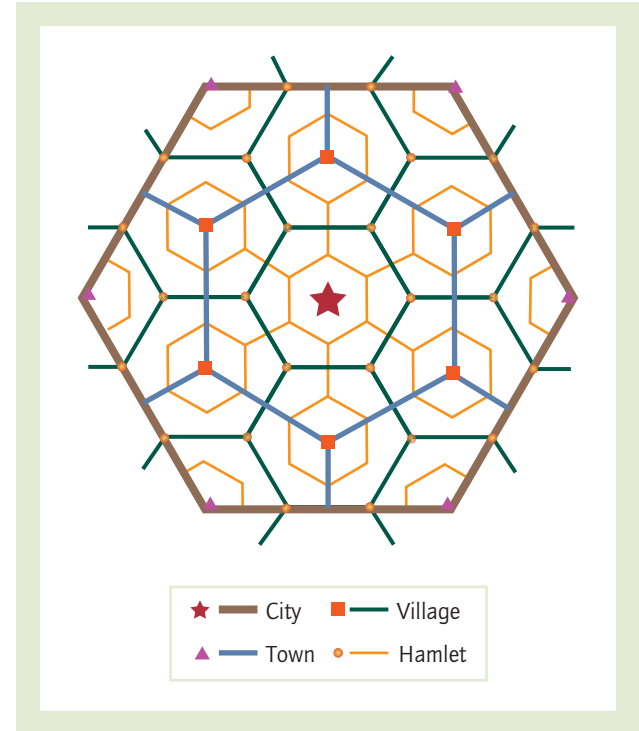


Figure 3 Geometry of the central place hierarchy. The nested hexagonal market areas reflect different levels of the urban hierarchy.

Source: Ingolf K. Vogeler, University of Wisconsin–Eau Claire, <http://www.uwec.edu/Geography/Ivogeler/w111/urban1.htm>.

circles around each center. However, as consumers located between competing centers opt for the closest one, overlapping market areas are divided by lines (Figure 2). Assuming no spatial variations in transport costs or population, a hexagonal series of market areas should emerge, with lower-order ones nested within the hinterlands of higher-order ones (Figure 3). Hexagonal market areas became the defining feature of central place theory and were justified on grounds that they “packed” space—that is, they served all clients without overlapping market areas, more efficiently than any other shape. The model was thus decisively static in nature and offered a fixed, frozen geometrical portrait of cities.

Central place theory became extremely popular in geography in the 1950s and 1960s as part of the emerging positivist school of thought, which emphasized modeling. It formed the dominant paradigm within urban geography for almost a generation. For example, urban geographers,



notably Brian Berry, sought out hexagonal systems of market areas in the Midwest, which most closely resembled an isotropic plain. The model was also used in urban planning ventures in Israel and the Netherlands. Positivist theoreticians built increasingly more complex—and unrealistic—central place models that attempted to incorporate uncertainty, entropy, and evolution over time.

Ultimately, central place theory was abandoned as human geography shifted decisively into political economy and social theory in the late 20th century. It was widely criticized for its overly simplistic assumptions; the absurdly unrealistic reduction of cities to shopping centers; the neglect of social relations in favor of individual consumer choice and the resulting silence concerning class, gender, consciousness, and power; the absence of any account of production and the spatial division of labor; and its ahistorical portrayal of urban networks. Today, the once dominant model of urban geography remains little more than a historical curiosity.

Barney Warf

See also **Berry, Brian; Christaller, Walter; Location Theory; Positivism; Regional Science; Spatial Analysis; Urban Hierarchy**

Further Readings

Berry, B. (1967). *Geography of market centers and retail distribution*. Englewood Cliffs, NJ: Prentice Hall.

King, L. (1984). *Central place theory*. Beverly Hills, CA: Sage.



CHEMICAL SPILLS, ENVIRONMENT, AND SOCIETY

The use of chemicals and chemical products in the 21st century is comprehensive and widespread, and modern society depends on them. The chemical industry plays an important role in the industrial sectors of the economy, and many different chemicals are important in manufacturing, such

as in pulp and paper, steel, aluminum, auto making, oil refining, and so on. In the agricultural production sector, chemicals are used in pesticides and as important ingredients in fertilizers. In the food sector, chemicals play a major role for processing foods. The transportation sector depends on fossil fuel products (gasoline and diesel). In our daily lives, we find chemicals everywhere. Some examples are flame retardants used in textiles in airplanes and public buildings and cosmetics, cleaning detergents, and paints used in homes. The use of chemicals is somewhat paradoxical. In smaller amounts and/or for certain purposes, chemicals are needed and effective. However, chemicals can also cause serious environmental and health-related problems. This entry reviews the scope of chemical use today, describes the harms that can result from chemical spills, and examines the potential harm associated with their regular use. It then discusses some of the paradoxical ways in which modern chemical use involves both benefits and costs.

There are 90 natural chemical elements, and in total, 111 chemical elements are known. The most common chemical elements (percentage by weight) in the Earth's crust are oxygen (45%), silicon (27.2%), aluminum (8.3%), ferrous (6.2%), and calcium (4.7%). The number of chemical compounds has grown dramatically since the end of World War II. Some of the most widespread and commonly used chemical compounds are petroleum products. In the North American and European markets, about 75,000 different chemical products can be found. These consist of about 13,000 different chemical compounds. Global production of chemicals has increased from 1 million metric tons/yr. (per year) in 1930 to 400 million metric tons/yr. of chemicals today, according to the Swedish Chemical Agency. Some of these chemicals are less harmful to health and environment, but we lack knowledge of the effects of many of these compounds, and there is a tendency to replace harmful compounds with new compounds that have not been sufficiently tested.

Many harmful compounds and products are being produced and transported despite large uncertainties about their effects on human health and the environment, and thus the massive use of chemical compounds could be better controlled. Chemicals are also related to environmental



A worker uses a water hose to clean Highway A5 near Frankfurt, Southwestern Germany, September 22, 2004. About 20 metric tons of methylamine, an inflammable and poisonous chemical, was spilled onto a road near the city of Frankfurt after an accident involving a hazardous goods transporter. Emergency services were attempting to contain the chemical, which was seeping into the ground and the nearby river Nidda.

Source: Kai Pfaffenbach/Reuters/Corbis.

problems such as depletion of the ozone layer, acidification of soil and water, pollution of the seas, and concentration of long-lived organic chemical compounds such as PCBs (polychlorinated biphenyls), DDT (dichloro-diphenyl-trichloroethane), and dioxins.

Chemical Spills

Chemical spills are accidents that occur in the extraction process, in industrial processes, or in transportation, as well as through overuse or misuse in industry, agriculture, and society and uncontrolled leakage to the atmosphere, ground, and water from industrial processes, agriculture, the energy sector, and consumption of goods and their transport. Indeed, a chemical spill can be

one of the most serious environmental problems.

Chemical spills can be categorized in many ways. In chemistry, the main distinction is between organic and inorganic compounds. Organic compounds are carbon based, and in this group are the petroleum products. The inorganic compounds are of mineral origin, often metals of different kinds. There is also a group of semi-organic compounds such as methyl mercury. When it comes to transportation, storage, and chemical spills and risk assessments, it is important to distinguish between acids and bases, between compounds with health risks and/or environmental risks, between flammable and nonflammable compounds, between stable and nonstable compounds, and between gaseous and liquid compounds.



Waste Management

Waste management often suffers from poor institutional capacity, improper treatment, large long-term environmental risks, and human health risks, especially in the developing world. In the modern industrialized world, a “filter” preventing misuse of chemicals—environmental assessments and health declarations, improved waste management, and so on—has been developed by better control, research, legislation, and certification. This has meant that the chemical product life cycle is better controlled. However, one major problem in industrialized countries is old waste disposal or storage sites. Many people consider these sites as “ticking environmental time bombs,” and some of the sites contain materials and chemicals that are unstable and hazardous. Waste treatment is both better and safer today and is generally built on the idea of recycling and safe storage.

Transboundary dumping of hazardous waste is still a problem. Taking care of hazardous waste is costly; one alternative is to export the waste. The export of waste from the industrialized world to developing countries in Asia and Africa is regulated in the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. The Basel Convention has been adopted by 170 countries and came into force in 1992. This treaty aims to regulate transboundary movements of hazardous waste and to ensure that hazardous waste and other waste are managed in an environmentally safe manner. Approximately 338 million metric tons of hazardous and other wastes were generated in 2001.

Even if the control of chemicals is satisfactory, there is always a risk of illegal transport, treatment, storage, and dumping of hazardous wastes, especially when improper disposal can be very profitable. Often, it is a question of how the hazardous waste is defined and declared. For example, the same hazardous waste could be declared as materials for recycling or as raw materials for industrial production.

Chemical Use and the Development of Modern Society

There are many challenges and paradoxes to face in relation to the use of chemicals. The use of

chemicals and the risk of handling chemicals are very closely related to the development of modern society. For instance, by using pesticides in agriculture (in combination with other measures), many nations have been able to increase production in the agricultural sector, which has resulted in better nutrition conditions for a growing global population. On the other hand, there is a risk of overuse of pesticides, which can be harmful to the environment and to agricultural workers over the long term. This paradox could be called the “development paradox.” A second paradox is related to research and replacement (the “replacement paradox”). When people find that a compound is unhealthy and environmentally hazardous, there is a tendency to replace it with another chemical compound that seems to be better but in fact sometimes is not. A third paradox relates to the fact that people use large amounts of energy to extract, enrich, produce, and transport chemical compounds around the world, followed by great effort to collect, store, and handle the residues as hazardous wastes. All these steps take place over time and space. One element is extracted in a specific place, transported to the manufacturer, which in turn sends it to the consumer market. Waste management could be equally described in terms of time and space. These material flows in time and space are still rather unexplored but are important to describe and analyze.

Olof Stjernström

See also Agrochemical Pollution; Brownfields; Heavy Metals as Pollutants; Industrial Ecology; Mining and Geography; Petroleum; Polychlorinated Biphenyls (PCBs); Risk Analysis and Assessment

Further Readings

- Basel Convention. (2008). *The Basel Convention on the control of transboundary movements of hazardous wastes and their disposal*. Retrieved December 1, 2008, from www.basel.int/convention/about.html
- Ibitayo, O. (2008). Transboundary dumping of hazardous waste. In *The encyclopedia of Earth*. Retrieved December 1, 2008, from www.eoearth.org/article/Transboundary_dumping_of_hazardous_waste

Scott-Andersson, Å., Stjernström, O., & Fängsmark, I. (2005). Use of questionnaires and an expert panel to judge the environmental consequences of chemical spills for the development of an environment-accident Index. *Journal of Environmental Management*, 75, 247–261.



CHERNOBYL NUCLEAR ACCIDENT

A serious accident occurred on April 26, 1986, at 1:23 a.m. at Unit 4 of the Chernobyl Nuclear Power Plant near Pripyat in the Ukrainian Soviet Socialist Republic. The power plant was located near the border of Ukraine and Belarus. A series of explosions sent a plume of highly radioactive fallout of iodine and cesium into the atmosphere.

Cesium-137 deposition spread throughout Europe, and the radioactive plume reached the U.S. West Coast on May 6, 1986. Official word of the accident first reached the Western world when Sweden announced on April 28 that workers at its Forsmark nuclear plant had radioactive particles on their clothing and the source was traced back to Chernobyl. Initially, former Soviet ruler Mikhail Gorbachev downplayed the incident's severity, which is considered the worst nuclear power plant accident in history.

The Chernobyl accident was caused by a combination of human error and design flaws. It was initiated when power plant technicians conducted an experiment on the emergency core cooling system during its shutdown procedure. First, the emergency core cooling system was turned off, and 205 of 211 fuel control rods were removed from the reactor core. Following this, automatic safety devices that shut down the reactor when



Inspectors just outside the Chernobyl Nuclear Power Plant's crumbling west wall take water and soil contamination samples and conduct land surveys to repair and build new access roads. Twenty years after the Chernobyl nuclear accident in 1986, radiation monitoring occurs on a regular basis on the grounds.

Source: Gerd Ludwig/Corbis.



water and steam levels fall below normal and turbine stops were turned off because engineers did not want to spoil the experiment. Next, an additional water pump to cool the reactor was turned on. However, with only a 7% power output and an extra drain on the power system, water did not reach the reactor. Finally, since the reactor power output was lowered too much, it was very difficult to control. The result was a massive and catastrophic power excursion and steam and hydrogen explosions. These tore off the steel and concrete top of the reactor, exposed the core, and dispersed large amounts of radioactive particulate and gaseous debris, allowing oxygen to contact the superhot core, containing almost 2,000 tons of combustible graphite moderator. The graphite moderator fire increased the radioactive particle emissions. Much of the nuclear fuel supply in the reactor core eventually melted.

There has been great controversy over the number of people who died from the Chernobyl accident, either directly or later through acute radiation syndrome or thyroid and other cancers. The official death toll stands at 56, while the estimated number of eventual fatal cancers ranges from 4,000 (World Health Organization) to 93,000 people (Greenpeace). Millions of other people became sick from Chernobyl, and many thousands have lost their homes and livelihoods. From 1986 to 1992, about 336,000 people were evacuated and resettled because of the accident. In addition, millions of acres of farmlands and forests have become contaminated, especially in Ukraine, Belarus, and Russia. Overall, 4.5 million people were affected. In December 2000, the Chernobyl Nuclear Plant was fully decommissioned.

Barry D. Solomon

See also **Nuclear Energy**

Further Readings

- Marples, D. R. (2004). Chernobyl: A reassessment. *Eurasian Geography and Economics*, 45, 588–607.
- Medvedev, Z. A. (1992). *The legacy of Chernobyl*. New York: W. W. Norton.



CHICAGO SCHOOL

In the 1920s and 1930s, Chicago emerged at the forefront of American urban analysis. As the model of the rapidly growing, industrialized city populated by streams of immigrants, Chicago became the prototypical example of the industrial American city. The University of Chicago played a major role in disciplines such as economics, sociology, and geography. Within this context, the Chicago School of urban studies arose, which was enormously influential in sociology and geography for the next several decades. The Chicago School is credited with the first systematic attempt to understand the dynamics of urban areas, including social change, urban planning, and territoriality.

The origins of the Chicago school lay largely with Robert E. Park, a former journalist turned teacher. In 1925, Park, Ernest Burgess, and Roderick McKenzie published *The City*, a famous collection of interpretive essays about urban life, a volume that both summarized and inspired a long tradition of urban ethnography. Chicago School practitioners inaugurated the tradition of detailed case studies, ranged far and wide over the city, studying, among other things, the wealthy, immigrants, the destitute and homeless, dance halls, gangs, criminals, and prostitutes in an attempt to draw rich and detailed portraits of urban life. In the process, they irrevocably fused the study of space and the study of society.

The first paradigm of urban structure offered by Chicago School theorists, particularly McKenzie, centered on the metaphor of the city as urban jungle, a view derived from the social Darwinism prevalent in the early 20th century. For example, the displacement of one ethnic group by another in a given neighborhood was framed as a process of invasion and succession, a view that drew directly from ecological studies of how one plant species displaced another through successive stages in the evolution of ecosystems. Later, this biological metaphor was dropped in the face of criticism that it lacked a coherent account of social relations and naturalized the inequality of urban areas. Throughout the Chicago School's worldview, competition appears repeatedly as a driving force behind ethnic and class segregation.

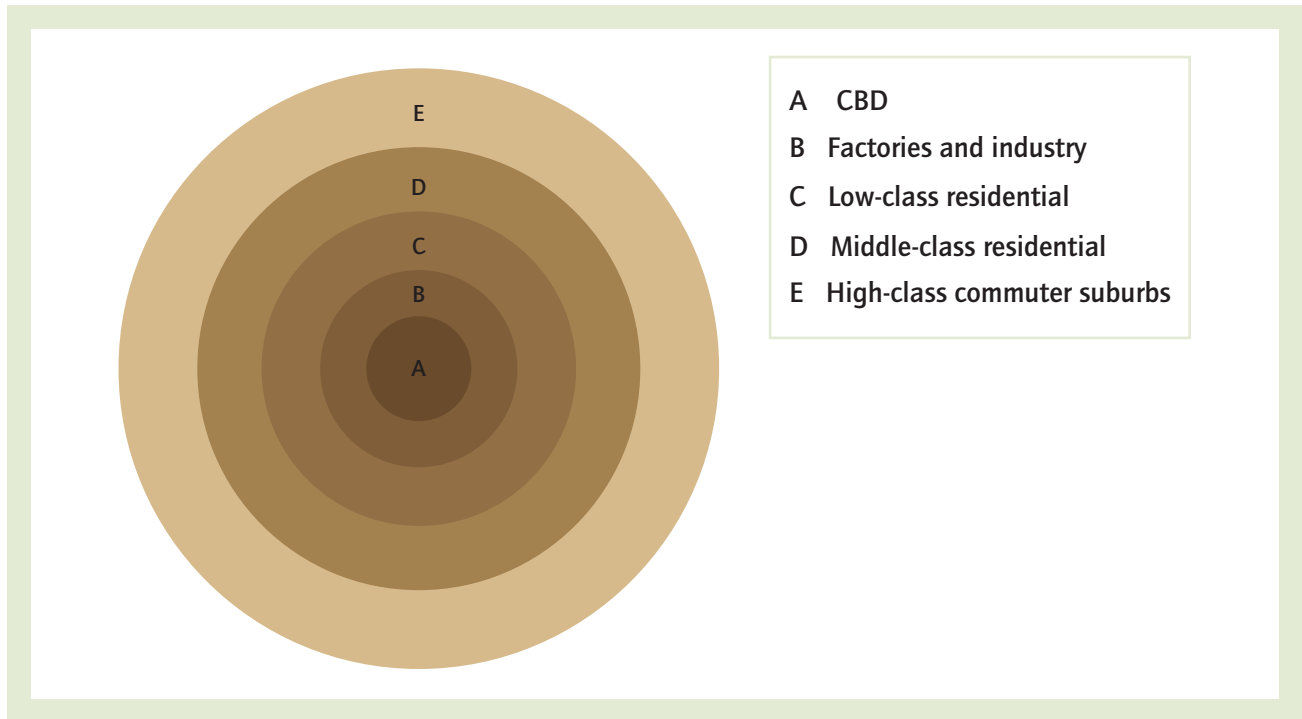


Figure 1 Concentric ring model. Burgess's concentric ring model focused on socioeconomic differences that arose with distance from the CBD.

Source: Author.

Chicago School theorists also drew on the urban sociology of Frederick Tönnies and notions such as *Gemeinschaft* and *Gesellschaft* to examine daily life in light of the massive rural-to-urban migration then characteristic of most U.S. cities. In this view, urbanization represented the annihilation of mythologized rural communities, in which everyone knew everyone else. In contrast to the idealized image of small towns in which everyone ostensibly was intimately connected to everyone else and presented the same sense of self under all contexts, urbanization was held to decompose these traditional bonds and erode the foundations of mutual trust. Cities, it was held, were not conducive to the formation of a sense of community. Louis Wirth, in particular, advocated a desolate but compelling view of city life as structured around population size, density, and heterogeneity. Size or total population, he held, created a climate that was inherently predatory, utilitarian, uncaring, and commodified: Strangers were rare in small towns but the norm in large cities. Density, he argued, led people to

be physically but not emotionally close; indeed, alienation was the norm. Finally, social and cultural heterogeneity, manifested in the diverse lifestyles found in large cities, undermined the common values necessary to the success of healthy communities. Wirth concluded that these factors were responsible for the high rates of urban crime and other social pathologies ranging from suicide to psychoses. (Subsequent work has rectified this stereotype by pointing to the high crime rates often found in many small cities and that large cities often have healthy, vibrant urban neighborhoods.)

Three Models of Urban Social Structure

The most famous products of the Chicago School are three models of urban social structure often described in introductory sociology and geography textbooks. The first, proposed by Earnest Burgess in 1927, was the concentric ring model (Figure 1), which, extrapolating from the specific instance of Chicago, viewed the city as a series of

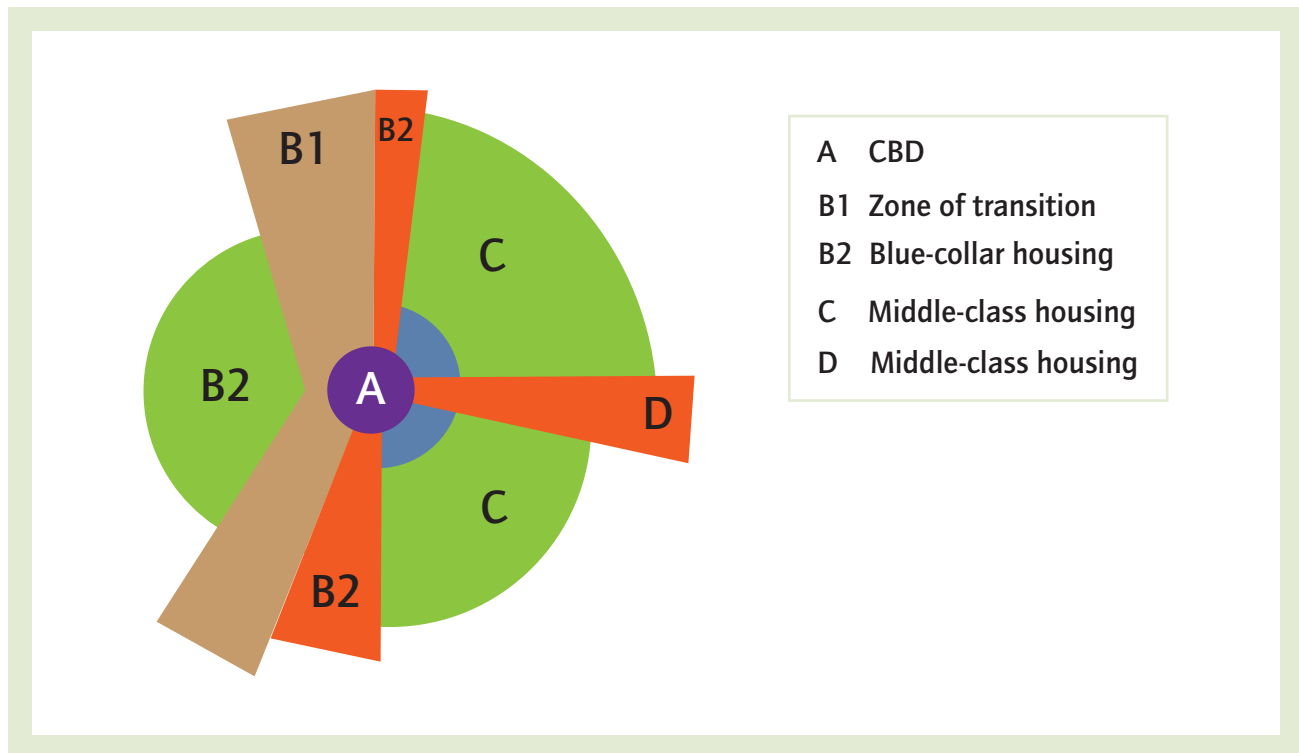


Figure 2 Hoyt's sector model. The sector model emphasized variations in land values along different transport routes.

Source: Author.

rings of varying size centered on the *central business district* (CBD), a term coined by the Chicago School. Adjacent to the CBD was a zone of factories and warehouses, sometimes called a *zone of transition*. Moving outward, this was followed by the “zone of workingmen’s homes,” that is, working-class, blue-collar communities. Yet farther out were the medium- and then the high-income belts of suburbia.

Burgess observed that cities tend to expand horizontally as the wealthy had new homes constructed on the urban periphery; as they came to occupy these, the relocation of families outward set off a chain of vacancies that reverberated across the urban landscape, as less well-off families in turn occupied the cast-off mansions of the rich, a process known as *filtering*, or the *trickle-down* theory of housing supply. Moreover, Burgess observed a paradox: Low-income residents in cities lived on expensive, accessible land near the urban core, whereas more well-to-do inhabitants of wealthier rings occupied the less expensive

land. This puzzle, he noted, was explained by the population density curves characteristic of cities, which decline exponentially with distance from the CBD. The poor, crowded into dense communities in the urban core, collectively generate high aggregate rents that create relatively high rates of profit in inner-city areas, whereas the low-density environments of the wealthier classes reduce the profitability of the less accessible periphery.

In contrast to the rigid geometry of the Burgess model, Homer Hoyt, an economist and another influential Chicago School theorist, proposed the sector model of urban growth in 1939 based on an empirical analysis of 142 cities (Figure 2). In this view, rather than concentric rings, urban growth occurred along transportation lines centered on the CBD. Once parts of the central city acquired distinctive uses, they radiated outward. High-income land uses played a determining role in shaping the rest of the city, growing along waterfronts, in high-altitude areas, or toward other high-income neighborhoods, and

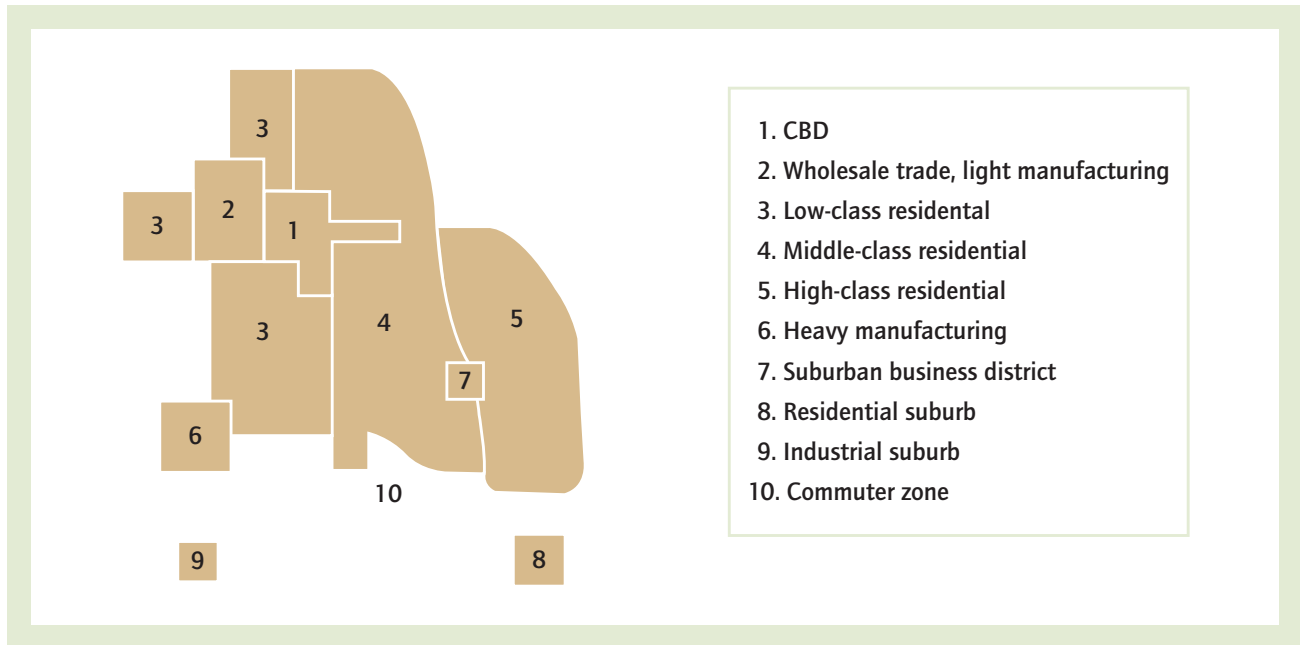


Figure 3 Harris and Ullman's multiple-nuclei model. The multiple-nuclei model attempted to reflect the complexity of urban space as it was structured around multiple nodes of economic activity.

Source: Author.

other uses filled in the spaces between them. Rather than belts, socioeconomic groups occupy sectors or wedges. The wealthy, with the greatest ability to pay, outcompeted less advantaged groups for the most desirable locales, generally far from the disamenities of factories or railroad lines. Low-income groups found themselves confined in zones relatively far from the wealthy.

The third of the Chicago School trilogy, proposed by Chauncey Harris and Edward Ullman in 1945, was called the *multiple-nuclei model* (Figure 3). Essentially, this view attempted to rectify the perceived simplistic shortcomings of the previous two. Rather than a single city center, it maintained that American cities had become polycentric, with many nuclei, around which land uses were organized in a complex quilt. Rather than a single overarching logic, this perspective maintained that certain land uses would repel one another, while others might be mutually attractive.

Impacts of the Chicago School

Although the Chicago School began to diminish in importance shortly after World War II, its ideas

were carried into urban sociology and geography for many years afterward. For example, social ecologists in the 1960s, armed with multivariate statistical methods and census data, argued that each of the three classic models effectively captured a different aspect of urban social space. Thus, family status was distributed in rings per Burgess's concentric ring model, reflecting the dynamics of the family life cycle. Economic class was held to occur in sectors, conforming to Hoyt's theory of land use. Finally, ethnicity was theorized to reflect the dense nucleations of different immigrant groups, as proposed by the multiple-nuclei model.

The Chicago School essentially defined American urban analysis throughout the 20th century. More recently, however, attempts by urban political economists to reveal the complex dynamics of globalization and immigration in a postindustrial context have yielded the so-called Los Angeles School, which takes the low-density, polynucleated, postindustrial Southern California metropolis as its point of departure.

Barney Warf



See also **Central Business District; Ethnic Segregation; Hoyt, Homer; Los Angeles School; Neighborhood; Urban Geography; Urban Land Use; Urban Spatial Structure**

Further Readings

- Bulmer, M. (1984). *The Chicago School of sociology: Institutionalization, diversity, and the rise of sociological research*. Chicago: University of Chicago Press.
- Dear, M. (Ed.). (2002). *From Chicago to L.A.: Making sense of urban theory*. Thousand Oaks, CA: Sage.
- Park, R., Burgess, E., & McKenzie, R. (Eds.). (1925). *The city*. Chicago: University of Chicago Press.
- Wirth, L. (1938). Urbanism as a way of life. *American Journal of Sociology*, 44, 1–24.



CHILDHOOD SPATIAL AND ENVIRONMENTAL LEARNING

Understanding the spatial and environmental learning of children is a critical task for geography as well as several subdisciplines of geography. This entry presents some of the important developmental issues related to the spatial cognition and environmental learning of children and examines some of the implications for pedagogy.

Challenges in Teaching Young Children

Young children who are just starting school can have a difficult time with multidimensional information. Children of this age have shown some difficulty with cartographic-scale spaces (extensive spaces such as large regions, nations, continents, and the world) as well as with making transitional judgments between large- and small-scale spaces. Young children have shown limits in their ability to process and store information, an issue that must be considered when developing appropriate activities in any subject area.

Initiating geographic learning from the immediate and the visible allows the child to conserve cognitive resources that might otherwise be required for visualization of the problem or

environment. Teachers and developmental researchers can often be surprised by the insights that children exhibit when given time to consider more deeply a specific spatial or geographic problem. Starting from a basis that is familiar to the child will help that child pursue more complex concepts than would be possible in abstract or foreign situations. Using a small number of geographic skills and concepts to start with, the teacher can help children develop an understanding of geography from perspectives that young children can easily grasp. The cumulative accretion of knowledge is essential; once the building blocks of geographic knowledge and problems solving are laid down, more complex concepts and skills can be introduced.

The majority of cognitive development occurs during early and middle childhood. Much of the material for later development has its foundation in cumulative knowledge based on earlier development and learning. Once the fundamental geographic concepts are introduced to teachers, opportunities to ask geographic questions and discover the answers flourish. Many of these techniques rely on a geographic basis of knowledge and can first be introduced through lessons and activities associated with maps and aerial photographs. Once a basis is established, students are well prepared for more advanced geographic topics that will produce geographically literate people.

Developmental and Learning Theories

The basis of environmental and geographic learning is established during childhood. The way children acquire geographic knowledge is quite distinct from the way humans learn as adults, and it shapes the nature of their geographic understanding and how they experience the world. Both developmental and learning theories play a meaningful role in the understanding of children's geographies and the nature of childhood spatial learning. From a developmental point of view, it is important to consider the range of abilities a child of a certain age might possess while selecting appropriate content and methods for communicating that content and facilitating learning.

Consideration of developmental issues is only part of the picture; learning theory must also be



considered. Although the consideration of learning theory is important from the onset of education, it begins to usurp developmental issues around the age of 12 or 13. By this time, the majority of cognitive skills have emerged, and students begin to rely on problem solving and knowledge acquisition as the main tools for developing intelligence and understanding. Furthermore, working memory capacity, cognitive processing, and attention have all reached levels equal to or near those of adults. Although there are many other developmental issues beginning to emerge at this time (puberty, social developmental, etc.), the majority of the cognitive systems are close to completely developed (allowing for individual differences in rates of development and the emergence of cognitive abilities).

There are many important fundamental geographic and spatial concepts that children must understand to learn the full breadth of geography or to appreciate in depth a single geographic topic. Before considering these specifically, it is important to recognize the existence of cognitive resources that support the development of all skills, spatial and nonspatial (language, mathematics, etc.). These resources include working-memory capacities for both storage and information processing and current knowledge concerning a situation. The latter necessarily forces one to consider a variety of learning theories, including, but not limited to, activity-based learning, situated cognition, and constructivism. With development, the capacity and efficiency of cognitive resources improve while a child grows, develops, and experiences the world. Experience also helps children develop in specific ways, particularly with respect to a knowledge base in experiential domains, such as large parts of geography.

A small number of geographers over the past 30 years have attempted to examine the building blocks of geography, sometimes called *spatial primitives*. Among the identified primitives are location, identity, distance, direction, and orientation. Some of these can be considered second-order, or derived, primitives, because they rely on other primitives for their structure and definition. For instance, to measure the distance between two places, a person must know the location and identity of each. Spatial primitives

represent some of the fundamental concepts that must be understood to grasp more complex geographic topics and processes and as such are a good place to start.

Piaget and Bruner

Almost all discussions of cognitive development begin with the Swiss developmental theorist Jean Piaget, particularly in the spatial domain. Piaget provided a general framework on which a substantial amount of later work is based. Although Piaget and his colleagues outlined the stages through which children develop on their way to adulthood, the greatest contribution of their work is most likely the description of the qualitative changes in thought that occur during development rather than the timing of stages and the various specific structural and operational changes that were described. Other research that is important to geographic learning and thought is that of Jerome Bruner, whose cognitive growth theory was based on how children represent the world. Changes in the mode of representation could be understood with respect to how the use of language changes over time during childhood. Bruner's theory included three representational modes: enactive, iconic, and symbolic. The latter is critical to one's ability to understand models and symbols, a central geographic concept.

Contemporary Developmental Theory

More contemporary developmental theory has focused on information-processing models of cognitive development, such as those developed by Robbie Case (executive processor and automatization), Robert Siegler (attention and encoding), and David Klahr (generalization). In each of these theories, the child is viewed as a strategist who is always trying to construct a solution for a problem. Other, more specific research has produced concrete understanding in areas specific to geographic education.

Scott Bell

See also **Children, Geography of; Geography Education; Spatial Cognition; Wayfinding**



Further Readings

- Allen, G. L., Kirasic, K. C., Siegel, A. W., & Herman, J. F. (1979). Developmental issues in cognitive mapping: The selection and utilization of environmental landmarks. *Child Development*, 50, 1062–1070.
- Bruner, J. S. (1966). *Studies in cognitive growth: A collaboration at the Center for cognitive studies*. New York: Wiley.
- Case, R. (1985). *Intellectual development: Birth to adulthood*. Orlando, FL: Academic Press.
- Cornell, E. H., Heth, D., & Rowat, W. L. (1992). Wayfinding by children and adults: Response of instructions to use look-back and retrace strategies. *Developmental Psychology*, 5, 755–764.
- DeLoache, J. S., & Burns, N. M. (1993). Symbolic development in young children: Understanding models and pictures. In C. Pratt & A. F. Garton (Eds.), *Systems of representation in children: Development and use* (pp. 91–112). Chichester, UK: Wiley.
- DeLoache, J. S., Kolstad, V., & Anderson, K. N. (1991). Physical similarity and young children's understanding of scale models. *Child Development*, 62, 111–126.
- DeLoache, J. S., Miller, K. F., & Rosengren, K. S. (1997). The credible shrinking room: Very young children's performance with symbolic and nonsymbolic relations. *Psychological Science*, 8, 308–313.
- Klahr, D. (1992). Information processing approaches. In R. Vasta (Ed.), *Six theories of child development: Revised formulations and current issues* (pp. 133–185). London: Jessica Kingsley.
- Klahr, D., & Wallace, J. G. (1976). *Cognitive development: An information processing view*. New York: Wiley.
- Mayer, R. E. (1992). *Thinking, problem solving, cognition* (2nd ed.). New York: W. H. Freeman.
- Piaget, J., & Inhelder, B. (1967). *The child's conception of space*. New York: W. W. Norton.
- Siegler, R. S., & Alibali, M. W. (2004). *Children's thinking* (4th ed.). Upper Saddle River, NJ: Prentice Hall.



CHILDREN, GEOGRAPHY OF

The geography of children is a subdiscipline that examines the relevance of space and place to the study of childhood. Research in this area examines the unique experiential, political, and ethical experiences of this social group. The geography of childhood was born out of the fields of environmental psychology, urban planning, Marxist geography, behavioral geography, and geographic education. While Roger Hart discussed an explicit geography of childhood in his 1979 book, *Children's Experience of Place*, its modern practitioners did not publish widely until the 1990s.

Early research examined how children used, perceived, and made sense of space and place for the purposes of developing theories on children's spatial learning and planning environments that take into consideration children's unique experiences. Recent studies apply a wide range of disciplines to the field, such as sociology, psychoanalysis, and feminist geography, to examine diverse topics such as children's participation in community development and environmental management and children's identity formation in relation to the cultural practices of a particular place.

Childhood as studied by geographers varies widely in its definition and concept. Some research is based on biological classifications, such as age and other developmental considerations, while other work addresses cultural and socially constructed definitions of childhood. Researchers acknowledge the unique experiences of children, as opposed to adults, and some argue that children have historically been marginalized by society, rendering their actions and agency as a threat to the moral order of the adult world. Since the cultural turn in geography, researchers have come to view children as active agents in the construction of their lives and environments. This has led to a fundamental shift in ideology toward childhood, one that complicates adult-child relations and challenges what some refer to as *adult spatial hegemony*.

The status of research on children's geographies in the early 21st century is quite comprehensive (Table 1), including topics such as youth

<i>Topics</i>	<i>Disciplines and Subfields</i>	<i>Key Concepts and Theories</i>
Youth subcultures, hybrid identities, cross-cultural studies of youth, places of resistance, representation, contestation	<i>Cultural geography</i> , regional geography, anthropology, sociology	Resistance theory, identity construction, representation, subcultural analysis, cultural reproduction, peer cultures, cultural capital
Childhood as marginalized “other,” childhood as subordinate, the role of space and place in identity formation and construction, the control of space by dominant groups	<i>Feminist geography</i> , women’s studies, social psychology, psychoanalysis	Identity construction, adult spatial hegemony, ideology of childhood, social marginality, “othering” of childhood
Children’s spatial or place behavior, children’s use of public and private space, children’s spatial ecologies	<i>Behavioral geography</i> , <i>time geography</i> , environmental psychology, social psychology	Time-activity patterns, spatial range, ecology of human development, children’s territories, adult spatial hegemony, independent mobility
Children’s understanding of space, place, and human-environment interactions; children’s image of space and place; children’s place attachment	<i>Geography education</i> , developmental psychology, environmental psychology, environmental education	Place attachment, cognitive learning theory, place value, spontaneous geography, social reproduction, spatial learning, situated learning
Impact of race, class, and gender on children’s access and use of space and place; impact of globalization on children and youth; role of youth in the labor market; children’s identities in a changing economy; impact of gentrification on youth identities; and use of public space	<i>Social geography</i> , human geography, sociology, economics	Marxism, capitalism, structuralism, agency and structure, childhood as a social structure, social biography, lifecourse, social reproduction, local-global, political economy, sociospatial identity, street literacy, gentrification
The role of physical hazards (traffic, pollution) and social hazards (molestation, violence) in children’s use of and access to space, children’s relationship to the “natural” world	<i>Hazards geography</i> , environmental geography, environmental studies, planning	Risk management, terror talk
Historical and place-based perspectives on children and youth, childhood in perspective of time and space	<i>Historical geography</i> , history, sociology, psychoanalysis	Social construction, ideology of childhood, psychogenic theory of history (regression, projection), structural notion of childhood, production and reproduction of childhood, moral order and/or panics
Designing space and place for and with children	<i>Applied geography</i> , planning, architecture, sociology, urban studies	Sustainable development, new urbanism
Growing up in cities; how the design of cities relates to children’s use, image, and representations of place	<i>Urban geography</i> , urban studies, sociology	Social ecology, modernization theory, political economy, gentrification
Children’s rights, children’s participation in general and specifically in planning neighborhoods and communities	<i>Political geography</i> , political science, planning	Children’s rights, children’s participation

Table 1 Summary of research on children’s geographies. The spatiality of children has been approached from numerous conceptual angles. Source: Author.



subcultures, spatial representations and sites of resistance, the impact of gentrification on children's play spaces, the impact of globalization on children's participation in the labor force, the role of physical and social hazards in children's spatial freedom and practices, designing environments for and with children, and children's rights in international law. The importance of children's geographies as a subdiscipline is further witnessed in newly created academic journals devoted to the topic, such as *Children's Geographies*; *Children, Youth and Environments*; and the *Journal of Youth Studies*.

Pamela Wridt

See also **Childhood Spatial and Environmental Learning**

Further Readings

- Aitken, S. (1994). *Putting children in their place*. Washington, DC: Association of American Geographers.
- Aitken, S. (2001). *Geographies of young people: The morally contested spaces of identity*. New York: Routledge.
- Bartlett, S., Hart, R., Satterthwaite, D., de la Barra, X., & Missair, A. (1999). *Cities for children: Children's rights, poverty and urban management*. London: Earthscan, UNICEF.
- Hart, R. (1997). *Children's participation: The theory and practice of involving young citizens in community development and environmental care*. London: Earthscan.
- Katz, C. (2004). *Growing up global: Economic restructuring and children's everyday lives*. Minneapolis: University of Minnesota Press.
- Matthews, M. (1992). *Making sense of place: Children's understanding of large-scale environments*. Savage, MD: Harvester Wheatsheaf.
- Moore, R. (1990). *Childhood's domain: Play and place in child development*. Berkeley, CA: MIG Communications.
- Skelton, T., & Valentine, G. (Eds.). (1998). *Cool places: Geographies of youth cultures*. New York: Routledge.



CHINOOKS/FOEHNS

The chinook is a warm, dry, and sometimes gusty downslope wind that blows leeward of the Rocky Mountains. The term *chinook* is an aboriginal word meaning "snow eater," because of the rapid melt of snow that almost invariably accompanies its occurrence in winter. It is a type of wind that occurs in many parts of the world where large orographic barriers are oriented more or less perpendicular to the prevailing direction of atmospheric circulation. Alternative names used to identify this phenomenon include the *foehn* in Europe, the *ibe* in Central Asia, the *Zonda* in Argentina, the *Berg* in South Africa, and the *Nor'wester* in New Zealand. The environmental consequences of chinooks include increased wind erosion, reduced air quality, vegetation mortality, and adverse health-related effects.

The onset of chinook conditions is typified by a rapid increase of temperature and wind speed and a corresponding decrease of humidity (Figure 1). Additional distinguishing characteristics include wind flow oriented perpendicular to the orographic barrier, a dry adiabatic lapse rate, and leewave clouds.

Synoptic conditions commonly associated with chinooks involve a surface ridge of high pressure on the windward side of an orographic barrier and a trough of low pressure on the lee side, which produces a steep pressure gradient and strong cross-barrier flow. Changes in air temperature and humidity during a chinook are generally ascribed to the forced ascent of warm, moist air over the barrier. The rising air cools and expands at the dry adiabatic lapse rate ($\approx 9.8^\circ\text{C}/\text{km}$ [per kilometer]) until the dewpoint is reached, after which the air continues to cool at the saturated adiabatic lapse rate ($\approx 6^\circ\text{C}/\text{km}$). Air descends and warms at the dry adiabatic lapse rate on lee slopes, arriving warmer than it was at equivalent elevations on the windward side. In some cases, this change in air temperature can be dramatic. At Pincher Creek, located in southwestern Alberta, Canada, R. W. Turner reported an increase of 25.5°C in 1 hour.

The explanation for increased wind speed down the lee side is not straightforward and is a topic of ongoing investigation. One of the leading hypotheses involves hydrodynamic theories of fluid

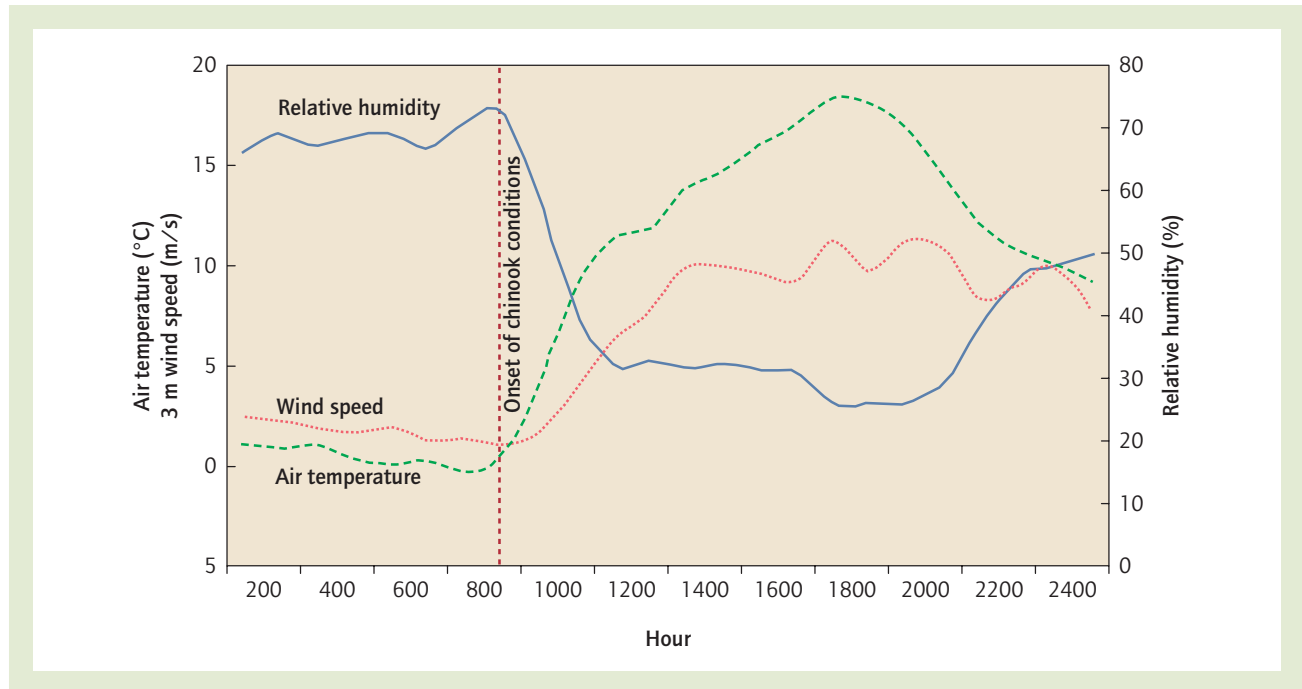


Figure 1 Chinook conditions in Saskatchewan, Canada (50°11' N, 109°12' W), on April 1, 2005

Source: Author.

mechanics, analogous to the behavior of water flowing over obstacles in river channels. As air ascends an orographic barrier, it accelerates toward the crest, where it transitions to supercritical flow and continues to accelerate down the leeslope. At some distance leeward of the barrier, the flow decelerates and produces a hydraulic jump. The latter typically corresponds to the position of the chinook arch, which is a narrow leewave cloud band oriented parallel to the orographic barrier.

Christopher Hugenholtz

See also **Adiabatic Temperature Changes; Wind; Wind Energy; Wind Erosion**

Further Readings

- Brinkmann, W. A. R. (1971). What is a foehn? *Weather*, 26, 230–239.
- Durran, D. R. (2003). Downslope winds. In J. Holton, J. Pyle, & J. Curry (Eds.), *Encyclopedia of atmospheric sciences* (pp. 644–650). Oxford, UK: Elsevier.
- Nkemdirim, L. C. (1996). Canada's chinook belt. *International Journal of Climatology*, 16, 441–462.



CHIPKO MOVEMENT

The Chipko movement in India is regarded as the icon of ecofeminist movements across the globe, whose primary goal has been the preservation of forests. The word *chipko* in Hindi literally means “to stick to.” The movement came into the limelight in March 1974, when Gaura Devi of Reni village, in the Garhwal region of the Indian Himalayas (then in the state of Uttar Pradesh and currently a part of the state of Uttarakhand), accompanied by 27 other women, decided to embrace the trees of their village, challenging axe-wielding lumber workers to axe them down before they cut down the trees. This act of courage and nonviolence was emulated across the Kumaon and the Garhwal regions of the Indian Himalayas, as well as in other areas. This resistance was directed at the unjust practice of tree felling, a manifestation of the close relations between the state and commercial contractors. The movement gained national and international media coverage, forcing the Indian state to change its policy and impose a 15-year ban on tree felling. To date, environmental activists are often referred to as *tree huggers*, the



This February 19, 1982, photo shows Indian women of the Chipko movement embracing trees to prevent them from being cut down.

Source: India Today Group/Getty Images. Used by permission.

term being a literal translation of the Chipko movement of India.

There are many reasons for the immense popularity and significance of the Chipko movement. First, it was spearheaded by women who were largely illiterate subsistence peasants, representing grassroots democracy; second, it was an environmental movement protesting the deforestation of the Himalayas; third, it resorted to Gandhian methods of peaceful resistance and nonviolence against a postcolonial state that collaborated with

capital interests against its own citizens. It also helped demolish the myth that poor or oppressed people are incapable of looking beyond their immediate material needs and practical interests by showing how they can mobilize to protect their long term, strategic interests.

The Chipko movement was led primarily by women, because traditionally, the women of Garhwal and Kumaon have had a special bond with their mountains and forests. Not only do the women have a deep emotional attachment to the mountains and regard the Himalayas as their *maiti*, or mother's home, but they also rely extensively on the forest products of wood for firewood and fuel; leaves for fodder, food, and medicines; and rivulets and rivers for water supply (which are adversely affected by deforestation). Although the Chipko movement is regarded as an ecofeminist movement, highlighting the symbiotic relationship between women and ecology, a lesser known fact is that men were also actively involved. Indeed, the basic idea was initiated by two men, Gandhian activists Chandi Prasad Bhatt and Sunderlal Bahuguna.

Anupam Pandey

See also **Ecofeminism; Feminist Political Ecology**

Further Readings

- Dankelman, I., & Davidson, J. (1988). *Women and the environment in the third world* (pp. 57–60). London: Earthscan.
- Guha, R. (1994). *The unquiet woods: Ecological change and peasant resistance in the Garhwal Himalayas*. Delhi, India: Oxford University Press.
- Rangan, R. (2001). *Of myths and movements: Rewriting Chipko into Himalayan history*. London: Verso Press.
- Shiva, V. (1989). Women in the forest. In *Staying alive: Women, ecology and development* (chap. 4, pp. 55–95). London: Zed Books.
- Shiva, V. (1991). *Ecology and the politics of survival*. Newbury Park, CA: Sage.
- Sinha, S., Gururani, S., & Greenberg, B. (1997). The “new traditionalist” discourse of Indian environmentalism. *Journal of Peasant Studies*, 24, 65–99.



CHLORINATED HYDROCARBONS

Chlorinated hydrocarbons (CHCs) are a group of organic molecules that consist of chlorine, carbon, and hydrogen atoms. While some CHCs occur naturally, many of these compounds are synthesized for industrial purposes or are formed as disinfection by-products (DBPs). As the result of accidental spills and improper disposal methods, CHCs are among the most frequently detected hazardous chemicals at abandoned waste sites, in refuse disposal areas, and in industrial and municipal wastewaters. These compounds persist in the environment, and many bioaccumulate in the food chain. Some CHCs form separate, dense nonaqueous-phase liquids (DNAPL) with very low solubilities in water. However, the solubilities of DNAPL CHCs are orders of magnitude greater than their typical drinking water limits, making DNAPL CHCs long-term sources of groundwater contamination. While the human and environmental health risks of chlorinated hydrocarbons are compound specific, exposure to most CHCs has been linked to cancer. Studies continue to develop environmental remediation techniques for individual CHCs.

There are three major types of CHCs: aliphatic, aromatic, and heterocyclic. Aliphatic CHCs are those in which chlorine atom(s) are bonded to a straight or branched carbon chain. Some of the more well-known aliphatic CHCs are trihalomethanes (THMs) such as chloroform (CHCl_3 ; Figure 1), chlorinated methanes such as dichloromethane (DCM; CH_2Cl_2), and chlorinated ethenes such as trichloroethene (TCE; C_2HCl_3) (Figure 2) and vinyl chloride (VC; $\text{C}_2\text{H}_3\text{Cl}$).

A variety of aliphatic CHCs, including chloroform, have been isolated from marine algae, although the majority are synthetically derived for human use. Historically, chloroform and TCE were used as medical anesthetics; however, they have been subsequently replaced due to their toxicity. Currently, these compounds and other aliphatic CHCs such as DCM are used as industrial solvents for waxes, oils, and grease because

they dissolve many organic and inorganic compounds. When these compounds enter the subsurface, they become long-term sources of groundwater contamination. Aliphatic CHCs, THM, and haloacetic acids such as dichloroacetic acid (DCA; CHCl_2COOH) (Figure 3) and trichloroacetic acid (CCl_3COOH) are formed during chlorination of drinking water that contains dissolved organic matter.

The United States Environmental Protection Agency (USEPA) set MCLs for DBPs in drinking water in the micrograms-per-liter concentration range due to the increased risk of cancer from ingestion of water contaminated with DBPs. Many aliphatic CHCs are amendable to natural or enhanced bioremediation through microbial reductive dechlorination or oxidation pathways.

Aromatic CHCs are hydrocarbons that have chlorine atom(s) bonded to benzene ring(s) made up of six carbon atoms with double bonds between alternate carbon atoms. The aromatic CHCs of current environmental concern are chlorinated benzenes, chlorinated phenols, and polychlorinated biphenyls (PCBs). Chlorinated benzenes are used as solvents and pesticides. Similar to aliphatic CHCs, chlorinated benzenes have been found in abandoned waste sites and in many waste waters and leachates. Chlorobenzene ($\text{C}_6\text{H}_5\text{Cl}$) (Figure 4), dichlorobenzene ($\text{C}_6\text{H}_4\text{Cl}_2$), and trichlorobenzene ($\text{C}_6\text{H}_3\text{Cl}_3$) are DNAPLs and are therefore long-term sources of groundwater contamination.

Chlorobenzenes (CBs) are amendable to bioremediation through microbial biodegradation. Chlorinated phenols have been used as wood preservatives. For example, pentachlorophenol (PCP; $\text{C}_6\text{HCl}_5\text{O}$) (Figure 5) is used as a fungicide and to pressure-treat wood.

PCP has been detected in surface waters and sediments, rainwater, drinking water, aquatic organisms, soil, and food. PCP has been found to be degraded abiotically through photodecomposition and biologically by aerobic and anaerobic microorganisms. Polychlorinated biphenyls (PCBs) are widely used as coolants, plasticizers, solvents, and hydraulic fluids. There are 209 possible congeners of PCBs. The United States banned the manufacturing of PCBs in

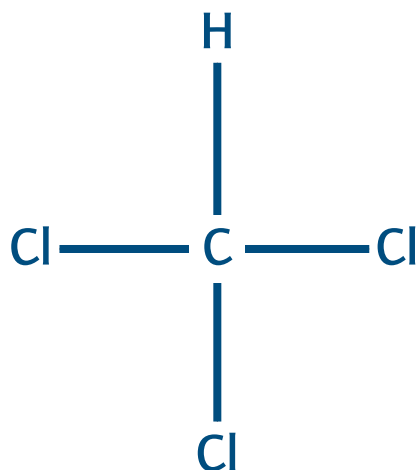


Figure 1 Chloroform

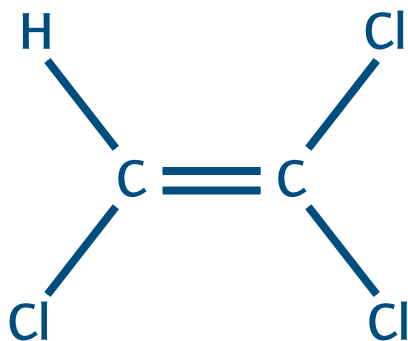


Figure 2 1,2,2-Trichloroethene

1977. However, PCBs are very stable compounds and are still found in the environment today. While some PCB congeners have been shown to be degraded by microorganisms, these compounds

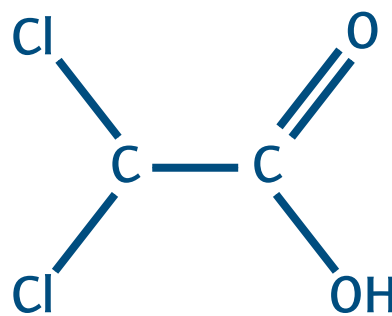


Figure 3 Dichloroacetic acid

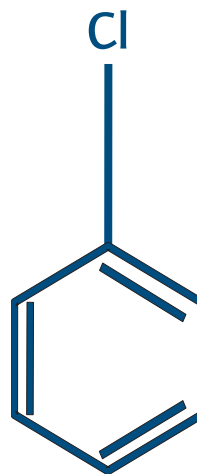


Figure 4 Chlorobenzene

are generally highly resistant to biodegradation. The pesticide dichloro-diphenyl-trichloroethane (DDT; $C_{14}H_9Cl_5$) (Figure 6) is a chlorinated aromatic compound.

DDT was used to control mosquitoes spreading malaria and lice transmitting typhus,

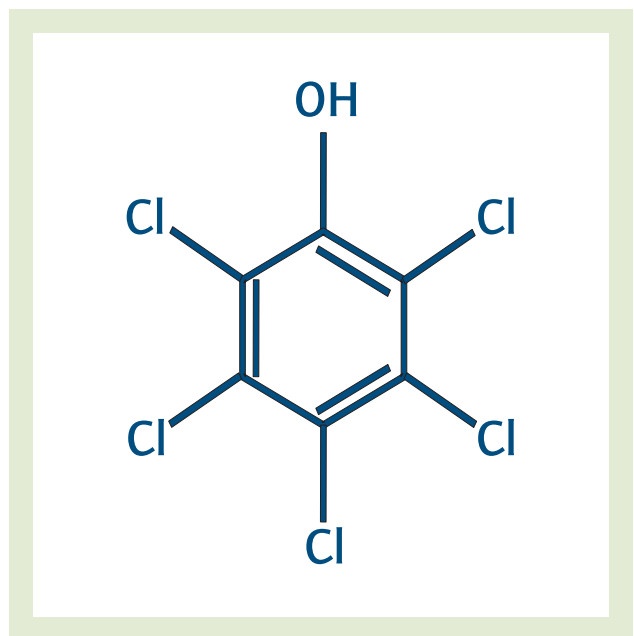


Figure 5 2,3,4,5,6-Pentachlorophenol (PCP)

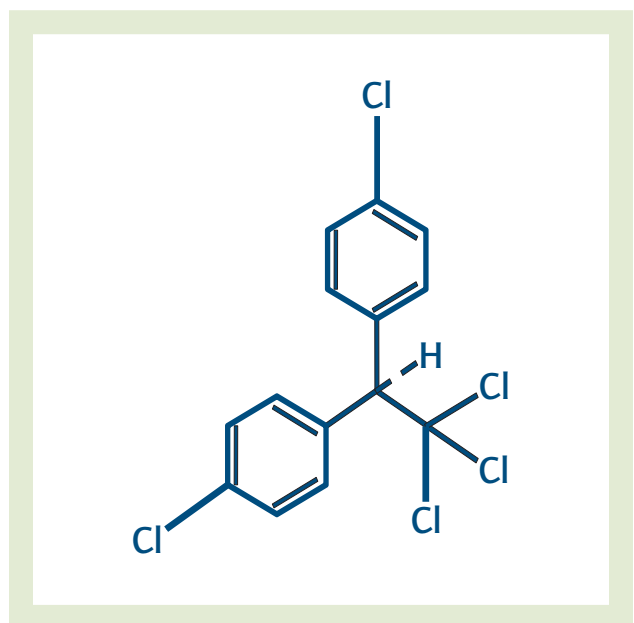


Figure 6 4,4'-(2,2,2-Trichloroethane-1,1-diyl)bis(chlorobenzene)

resulting in dramatic reductions in the incidence of both diseases. However, DDT is a persistent organic pollutant known to cause liver damage,

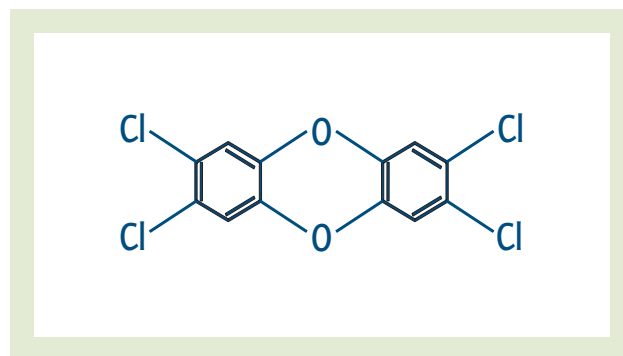


Figure 7 2,3,7,8-Tetrachlorodibenzo-*p*-dioxin (TCDD)

temporary nervous system damage, and reduction in reproductive ability and is a probable human carcinogen. PCBs and DDT are lipophilic (fat loving) and, therefore, tend to bioconcentrate in fatty tissues and fluids, such as breast milk, and can be passed on to fetuses and infants during pregnancy and lactation. Additionally, lipophilic compounds bioaccumulate, with greater concentrations detected at higher levels in the food chain. As a result, PCBs and chlorinated pesticides such as DDT are the major aromatic CHCs in marine fish, mammals, and seabirds.

Heterocyclic CHCs include polychlorinated dibenzodioxins (PCDDs), which consist of two benzene rings fused to one dioxin ring in the middle (Figure 7), and polychlorinated dibenzofurans (PCDFs), which have two benzene rings fused to one furan ring in the middle.

Together, PCDDs and PCDFs are generally known as *dioxins*. Dioxins are produced naturally in forest fires. However, human activity has come to dominate PCDD/F inputs to the environment today. Current exposure levels are a concern because dioxins are toxic, persistent, and bioaccumulate in the environment. Dioxins have been characterized by USEPA as likely human carcinogens and are anticipated to increase the risk of cancer at background levels of exposure.

Penny L. Morrill



See also **Environmental Impacts of Manufacturing; Environmental Protection; Groundwater; Water Pollution**

Further Readings

- Field, J. A., & Sierra-Alvarez, R. (2008). Microbial degradation of chlorinated benzenes. *Biodegradation*, 19, 463–480.
- Field, J. A., & Sierra-Alvarez, R. (2008). Microbial degradation of chlorinated phenols. *Review of Environmental Science & Biotechnology*, 7, 211–241.
- Muir, D. C. G., Wagemann, R., Hargrave, B. T., Thomas, D. J., Peakall, D. B., & Norstrom, R. J. (1992). Arctic marine ecosystem contamination. *Science of the Total Environment*, 122, 75–134.
- U.S. Environmental Protection Agency. (2001). *National primary drinking water standards* (EPA 816-F-01-007). Washington, DC: USEPA, Office of Water (4606).



CHLOROFLUOROCARBONS

Chlorofluorocarbons (CFCs) are organic chemical compounds that contain carbon, fluorine, and chlorine atoms. Each CFC is identified by a unique numbering system that describes its structure. The digit in the hundredths place represents the number of carbon atoms in each molecule minus 1, the digit in the tenths place represents the number of hydrogen atoms in each molecule plus 1, and the digit in the units place indicates the number of fluorine atoms. For example, trichlorotrifluoroethane is a CFC that has three fluorine atoms, no hydrogen atoms, and two carbon atoms in each molecule, whence the designation CFC-113, while dichlorodifluoromethane (CFC-12) has one carbon, no hydrogen, and two fluorines.

CFCs are anthropogenic substances and have no natural background level. At room temperature, they are generally volatile, nontoxic, nonflammable, and colorless liquids or gases. These properties make them attractive to industry. Their

commercial production, which began in the 1930s and 1940s, was primarily spurred by the need to find safer alternatives to the sulfur dioxide and ammonia refrigerants used at the time. Today, they are used in refrigeration and air conditioning, as cleansing agents for electrical and electronic components, and as foaming agents in shipping-plastics manufacturing. In some parts of the world, they are also used in aerosol propellants. The most common commercial CFCs, registered under the trade name Freon, are trichlorofluoromethane (CFC-11) and dichlorodifluoromethane (CFC-12).

Most CFC gases have both global-warming impacts and ozone-depleting effects. They are powerful greenhouse gases and contribute to global warming and climate change. Studies conducted by various researchers in the 1970s linked CFCs, along with other chlorine- and bromine-containing compounds, to the destruction of atmospheric ozone. Ozone is a trace gas that occurs in high concentrations in the stratosphere, the layer of the atmosphere that is between 10 and 25 km (kilometers) above the earth's surface. Ozone absorbs harmful ultraviolet (UV) radiation in the wavelengths between 280 and 320 nm (nanometers) of the UV-B band, which can cause biological damage in plants and animals. The loss of stratospheric ozone results in more harmful UV-B radiation reaching the Earth's surface. Because CFCs are chemically inert, when released into the atmosphere, they do not react easily and can exist in the troposphere for several decades, entering the stratosphere through the mixing and transport processes of the atmosphere. When CFCs enter the stratosphere, the intense UV radiation breaks them down, releasing chlorine (Cl) atoms, which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer.

CFC emissions have rapidly declined since the 1980s, largely due to control of their use under the Montreal Protocol, an international treaty designed to implement the 1985 Vienna Convention for the Protection of the Ozone Layer. The Montreal Protocol was originally signed in 1987, entered into force in 1989, and has been amended seven times. It stipulated



that the production and consumption of compounds that deplete stratospheric ozone—CFCs, halons, carbon tetrachloride, and methyl chloroform—were to be phased out at various rates, depending on a country's level of economic development. Some substitute compounds have low ozone depletion potential but high global warming potential (e.g., hydrochlorofluorocarbons, or HCFCs), while others do not deplete ozone but have high global warming potential (e.g., hydrofluorocarbons, or HFCs).

Segun Ogunjemiyo

See also **Anthropogenic Climate Change; Stratospheric Ozone Depletion**

Further Readings

- Albritton, D. L., Watson, R. T., & Aucamp, R. J. (1995). *Scientific assessment of ozone depletion: 1994*. Geneva: World Meteorological Organization.
- Cagin, S., & Dray, P. (1993). *Between Earth and sky: How CFCs changed our world and endangered the ozone layer*. New York: Pantheon Press.
- Molina, M. J., & Rowland, F. S. (1974). Stratospheric sink for chlorofluoromethanes: Chlorine atom catalyzed destruction of ozone. *Nature*, 249, 810–812.
- United Nations Environment Programme. (1997). *Montreal Protocol on substances that deplete the ozone layer*. New York: Author.



CHOLERA, GEOGRAPHY OF

Cholera is an acute diarrheal disease with a fecal-oral transmission route and is caused by ingestion of a dose of between 10,000 and 1 million *Vibrio cholerae* bacteria. The disease typically manifests in densely populated areas with high poverty, where water and sanitation remain unimproved. South Asia is the source region of cholera, as its tropical, estuarine environment creates a natural habitat for *V. cholerae* bacteria.

Cholera transmission can be divided into primary and secondary types. Primary cases result from infection by surface water sources where free-living bacteria are part of the natural ecosystem. Thus, primary transmission may infect someone who drinks untreated pond water or eats undercooked shellfish. Those infected by primary transmission may in turn infect others, considered a secondary pathway. Sources of secondary transmission include infection via direct interpersonal contact or through drinking water contaminated with fecal material from an infected person. Environmental factors such as water temperature, salinity, phytoplankton, and algae concentrations control the dynamics of primary transmission, while social structure, economics, and the built environment (e.g., water and sanitation infrastructure) control secondary transmission.

Global History of Cholera

To date, the world has experienced seven cholera pandemics, beginning with the 1817 to 1824 pandemic in the Bay of Bengal, which diffused across the Indian subcontinent, Asia, and the Russian Empire. The second pandemic spread through Europe and the United States, and the third through sixth pandemics affected parts of Asia, Africa, Europe, and South America. All were caused by the classical biotype of cholera. A new biotype of cholera called “El Tor” caused the seventh pandemic, which began on Celebes, Indonesia, in 1961 and spread to Asia in the 1960s and to the Middle East and Africa in the 1970s. By 1991, nearly 140,000 cases of cholera were reported among 19 African nations, and the disease reappeared in Peru after 100 years of absence. A new strain, *V. cholerae* O139, was identified in 1992 during an outbreak on India's eastern coast. Cholera remains endemic in countries throughout the developing world but has been nearly eradicated in industrialized nations.

Cholera was the most frequently mapped disease of the 19th century. Dr. John Snow was an influential figure during this period for his involvement in identifying the source of the 1854 cholera outbreak in London. His map of cholera cases around the heavily trafficked Broad Street Pump helped identify the link between cholera and water. Contrary to miasma theory, which claimed

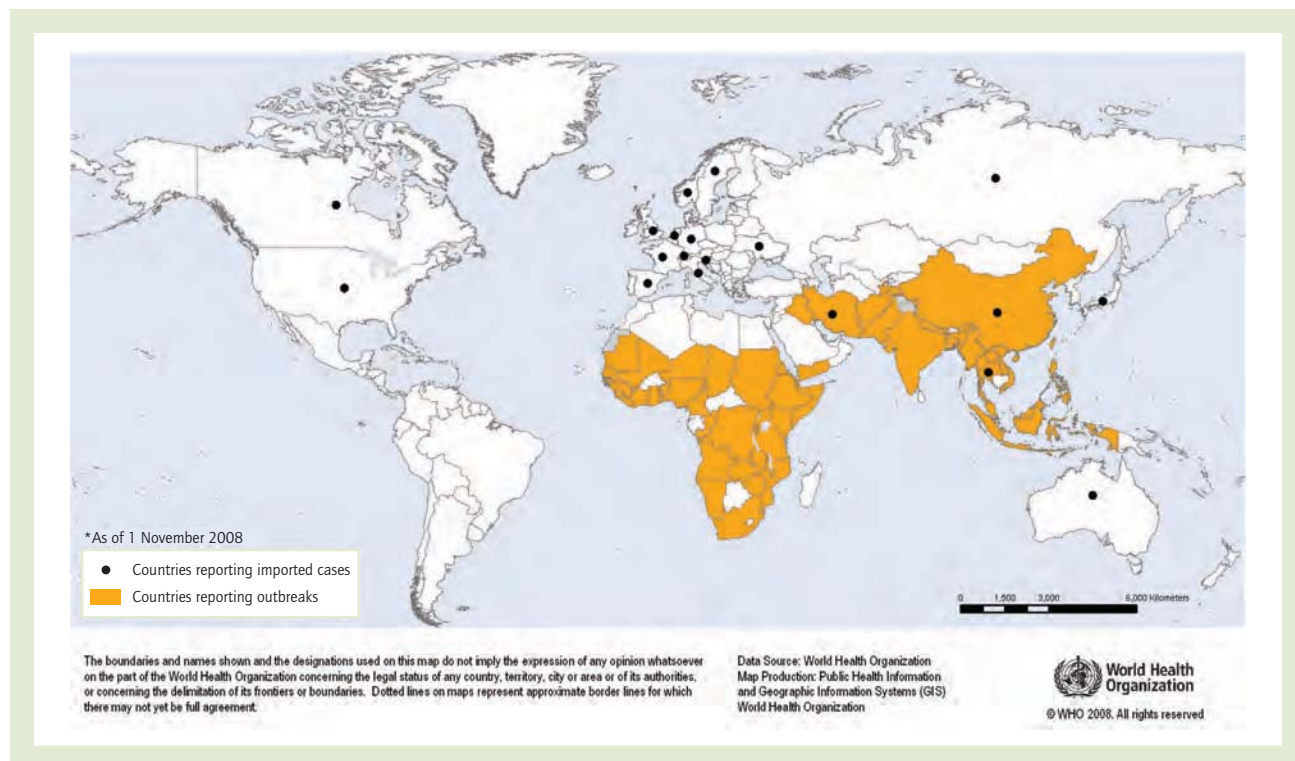


Figure 1 Countries reporting cholera outbreaks and imported cases, 2006–2008

Source: World Health Organization, 2008. All rights reserved.

that cholera transmission was airborne, Snow identified the link between the Thames River water from the Broad Street pump and the cholera outbreak in London and had the pump handle removed in 1855.

Cholera in the 21st Century

Cholera outbreaks continue to burden areas of the world lacking safe water and sanitation (see Figure 1). Cholera remains prevalent in South Asia and is common in other resource-poor areas. In August and September 2008, cholera cases were confirmed in Baghdad, Misan, and Babil provinces in Iraq. The reemergence of cholera followed an outbreak in September 2007, with 4,696 cases and 24 deaths. African nations continue to experience cholera outbreaks. In 2008, following floods, Namibia and Angola experienced outbreaks. The Congo, Nigeria, and Guinea Bissau also endured cholera outbreaks. These countries all share a commonality: Political unrest or outright war have

disrupted water, sanitation, and health infrastructure, resulting in large cholera epidemics.

Cholera and the Environment

V. cholerae survive in aquatic reservoirs, in which the bacteria consume algae, phytoplankton, copepods, and zooplankton during interepidemic seasons. Increases in local sea surface temperatures influence the growth of phytoplankton, making climate variability an important driver of cholera outbreaks. In areas of South Asia where cholera is endemic, the first outbreak typically occurs in spring, followed by a larger outbreak after the monsoon. Interannual climate variability is influenced by the El Niño Southern Oscillation (ENSO), which affects interannual outbreaks by increasing the water temperature in shallow water bodies and the coastal waters of the Bay of Bengal.

In addition to global climatic events, local environmental factors are important for predicting cholera outbreaks. An increase in ocean chlorophyll



concentration, an attachment site for bacteria, and a decrease in freshwater river discharge, which dilutes the number of aquatic bacteria, have been linked to outbreaks in Bangladesh. Cholera outbreaks follow seasonal patterns in countries located at the higher latitudes in both hemispheres. Outbreaks are frequent and constant in countries located within 15° of the equator, where temperatures are generally higher and more constant.

Cholera can be avoided when water, sanitation, and hygiene are good. In the absence of such conditions, however, filtering water through cloth (e.g., South Asian saris) folded a minimum of eight times halves the risk of cholera infection by creating a pore size small enough to remove zooplankton and most phytoplankton containing *V. cholerae*. Surveillance systems and early laboratory identification of cholera cases are critical to interrupting further transmission. The administration of oral rehydration salts (ORS), a mixture of sodium and glucose, is the most common form of rehydration treatment and successfully treats up to 80% of cholera patients. Severely dehydrated patients are treated with intravenous fluids and antibiotics.

Michael Emch and Veronica Escamilla

See also **Anthropogenic Climate Change; Disease, Geography of; GIS in Health Care; Health and Health Care, Geography of; Medical Geography**

Further Readings

- Colwell, R., & Spira, W. (1992). The ecology of *Vibrio cholerae*. In D. Barua & W. B. Greenough (Eds.), *Cholera* (pp. 107–128). New York: Plenum Medical.
- Emch, M., Feldacker, C., Islam, M., & Ali, M. (2008). Seasonality of cholera from 1974 to 2005: A review of global patterns. *International Journal of Health Geographics*, 7(31), 1–33.
- Emch, M., Feldacker, C., Yunus, M., Streatfield, P., Thiem, V., Canh, D. G., et al. (2008). Local environmental drivers of cholera in Bangladesh and Vietnam. *American Journal of Tropical Medicine & Hygiene*, 78(5), 823–832.
- Koch, T. (2005). *Cartographies of disease: Maps, mapping, and medicine*. Redlands, CA: ESRI Press.



CHORLEY, RICHARD (1927–2002)

Richard John Chorley was a transformative figure in late-20th-century geomorphology. Trained in geography at Oxford University, it was his experience in geology at Columbia University that truly sparked his numerous innovations. At Columbia, he was a student in the Arthur N. Strahler research group that produced so many stellar contributors to modern geomorphology. After brief stints as a junior faculty member in the United States, Chorley returned to Britain and pursued the remainder of his illustrious career at Cambridge University.

Chorley contributed to geography, geomorphology, and environmental sciences in both discrete and overlapping ways that may be seen as occupying at least four spheres. He was a central figure in fundamentally changing geomorphology from the qualitative discipline dominated by the Davisian erosional model. He was a prominent historian of geomorphology and its development. His methodological contributions to geomorphology were so fundamental and his interests so broad that they spilled over into geography at large, as well as into areas such as environmental science. Finally, his interest in teaching, coupled with his historical interests, led to many publications, including very successful books and professional journals (e.g., *Progress in Geography*, which eventually morphed into two journals of similar name).

While Chorley's early publications included direct challenges to Davisian geomorphology and introduction of discrete quantitative techniques (e.g., the lemniscate), he is best known for his comprehensive approach to quantification, which is most clearly seen in his lifelong advocacy of modeling and systems approaches to science. His particular approach to systems—championing the general systems theory of Ludwig von Bertalanffy—has been criticized, sometimes correctly and sometimes incorrectly; however, there is no question that its overall thrust transformed every disciplinary sphere that Chorley sought to influence, especially geomorphology.

By far the most comprehensive history of geomorphology, and one of the most incisive, is the



series of four tomes authored by Chorley and other contributors. These volumes span the discipline from its inchoate origins to its present form. Interrupted by Chorley's untimely death, the final volume published in late 2008.

Finally, Richard Chorley contributed mightily to the teaching of the discipline, especially in the early stages of its present modern quantitative form, through innumerable texts, papers, oral presentations, workshops, and conferences.

Colin Edward Thorn

See also Davis, William Morris; Geomorphology; Gilbert, Grove Karl; Penck, Walther; Physical Geography, History of

Further Readings

- Chorley, R. J. (1962). *Geomorphology and general systems theory* (USGS Professional Paper 550-B). Washington, DC: U.S. Geological Survey.
- Chorley, R. J. (1967). Models in geomorphology. In R. J. Chorley & P. Haggett (Eds.), *Models in geography* (pp. 59–96). London: Methuen.
- Chorley, R. J., Dunn, A. J., & Beckinsale, R. P. (1964). *The history of the study of landforms or the development of geomorphology* (Vol. 1). London: Methuen.
- Chorley, R. J., & Kennedy, B. A. (1971). *Physical geography: A systems approach*. London: Prentice Hall.
- Chorley, R. J., Malm, D. E. G., & Pogorzelski, H. A. (1957). A new standard for estimating drainage basin shape. *American Journal of Science*, 255, 138–141.



CHOROLOGY

Chorology is the study of places or regions, usually small ones. The term *chorology* comes from the Greek words for “the science of place,” in contrast to *chronology*, the ordering of events in time. Also known as *areal differentiation*, chorology has a long history as a term and concept in geography.

Strabo (64 BC to AD 24), a Greek geographer working for the Romans, advocated a form of chorology in his 17-volume *Geography*. In contrast, Ptolemy (AD 87–150), a Roman geographer and astronomer, maintained that the task of geography is the description of the Earth as a whole; in his eight-volume *Geography*, Ptolemy ridiculed Strabo's emphasis on regions, arguing instead for a holistic view of the Earth. Ptolemy differentiated between *geography* as the study of universals, *topography* as the study of localities, and *chorography* as integrating the two.

The great 17th-century geographer Varens (Varenius, 1622–1650), who wrote the highly influential *Geographia Generalis* in 1650, distinguished between what he called *specific geography* (concerned with the unique character of places) and *general geography*, which was concerned with universal laws. Immanuel Kant (1724–1804), a geographer as well as a philosopher, played an important role in the historical evolution of chorology by arguing that unlike theoretical sciences such as chemistry, geography, like history, was essentially concerned only with the empirical and the unique. His views were hugely influential in subsequent philosophies of space.

Some 19th-century geographers, such as Karl Ritter, emphatically practiced a form of chorology that was instrumental in mapping use values of places in the face of expanding colonial empires. Knowledge of local areas was important to colonial commerce and governance. A notable advocate was Paul Vidal de la Blache (1845–1918), the father of French geography, who studied small French rural areas called *pays* and their associated styles of life, or *genres de vie*. Because the climate of France did not vary much, but lifestyles did, Vidal de la Blache's work was also crucial to the introduction of possibilism to the discipline in the struggle against environmental determinism. His German counterpart, Alfred Hettner (1859–1941), argued in the Kantian tradition that geography was the art of regional synthesis, that is, the pursuit of interrelations in given areas, an aspect that other disciplines ignored. Chorology thus became the basis of geography's disciplinary identity in the early 20th century.

In the 1920s, American geographers adopted chorology in the wake of the demise of environmental determinism. American chorology was



personified by Richard Hartshorne (1899–1992), who studied under Hettner, then graduated from the University of Chicago in 1924. In the tradition of Kant, Hartshorne and his fellow chorologists argued that the essence of geography was the regional description of regions, including cultural and physical phenomena. Chorologists advocated getting to know places in great depth, with a healthy regard for cartography and fieldwork. Because large regions are diverse and complex, Hartshorne argued that chorology should focus on small, relatively homogeneous regions. He maintained that regions are essentially mental concepts, that is, subjective tools to find meaning and create order in the landscape. Regions were thus necessarily simplifications and were useful only in as much as the gain in understanding they provided exceeded the loss of detail. Implicit in Hartshornian chorology was the view that location served as a form of explanation, that is, proximity was synonymous with causality, leading to a crude form of spatial determinism reminiscent of Tobler's First Law. Hartshorne maintained that because landscapes exhibit relatively little change in the course of one lifetime, there was no urgent need to study the process of change. In arguing that only by sticking to the facts can we remain objective, Hartshorne's line of thought drew on the philosophical tradition of empiricism, in which facts are simply true without regard for theory.

Chorology collapsed in the 1950s as the reigning model in geography when positivism arose to take its place, although in the popular view, geography and chorology are often erroneously held to be synonymous. The transition began with a famous attack on Hartshorne by Fred Schaefer in 1953. Schaefer claimed that Hartshorne's view of geography as an integrative science concerned only with the unique was simplistic. By refusing to search for explanatory laws, geography condemned itself to being what he called an immature science. Rather than idiographic regions, geographers should seek nomothetic regularities across regions. This critique opened the door to the rise of positivism and the quantitative revolution.

Although traditional chorology died under the positivist onslaught, it did experience something of a resurrection in the 1980s. Some Marxists

argued that broad social processes always play out in different ways in different places, as spatial divisions of labor enfolded various places in highly contrasting ways. This perspective led to a renewed respect for the idiographic as more than some pre-scientific remnant of a theoretically unselfconscious age. What became known as the Localities School approached regions in terms of their historical development as they acquired unique combinations of imprints of different divisions of labor (i.e., investments, labor market practices, cultural forms). In this view, general laws of explanation are only manifested in unique contexts, and localities are not simply unique curiosities. Unlike the earlier tradition of chorology, therefore, this approach eschews empiricism and maintains a central role for theory. Thus, broad processes of globalization cannot be interpreted independently of local chorographic contexts, a notion encapsulated in the term *glocalization*.

Barney Warf

See also Empiricism; Hartshorne, Richard; Hettner, Alfred; Human Geography, History of; Idiographic; Locality; Place; Regions and Regionalism; Varenius; Vidal de la Blache, Paul

Further Readings

- Berry, B. (1964). Approaches to regional analysis: A synthesis. *Annals of the Association of American Geographers*, 54, 2–11.
- Hart, J. (1982). The highest form of the geographer's art. *Annals of the Association of American Geographers*, 72, 1–29.
- Hartshorne, R. (1939). *The nature of geography*. Washington, DC: Association of American Geographers.
- Sack, R. (1974). Chorology and spatial analysis. *Annals of the Association of American Geographers*, 64, 439–452.
- Schaefer, F. (1953). Exceptionalism in geography: A methodological examination. *Annals of the Association of American Geographers*, 43, 226–229.
- Warf, B. (1993). Post-modernism and the localities debate: Ontological questions and epistemological implications. *Tijdschrift voor Economische en Sociale Geografie*, 84, 162–168.



CHOROPLETH MAPS

Choropleth maps can be described as the most commonly created thematic map type, in large part due to the relative ease of their creation using most GIS software packages and also due to the perception that they are easily understood. Choropleth mapping involves aggregating data to an areal unit of measure and then representing these data using color or pattern within the areal unit. Creation of choropleth maps involves normalizing, representing, classifying, and symbolizing the data of interest.

Normalization

Choropleth maps involve mapping data by areal unit, for example by country, state, or county. Because of the disparities in size that exist for all types of areal units, mapping raw totals will often present a skewed representation of the data. To combat this problem, choropleth maps

are frequently normalized by a common attribute, such as area or population. Once normalized, the maps are often referred to as *value-by-area* or *value-by-population* maps. By normalizing the raw data, the map is not dominated by the largest unit but rather uses the ratio to highlight the ratios of interest.

Representation

Choropleth maps occur in two distinct types: classed and unclassed. A classed choropleth map presents the data of interest by classifying the values into a distinct number of individual colored classes (Figure 1). Each class is presented as a range of possible values, and the units within each range are represented accordingly.

In contrast, an unclassed choropleth map presents the value of each unit in a distinct color that varies according to the rank of the value with respect to all the other values (Figure 2). Traditionally, both types of choropleth map represent low values with light color and use dark colors to represent greater values.

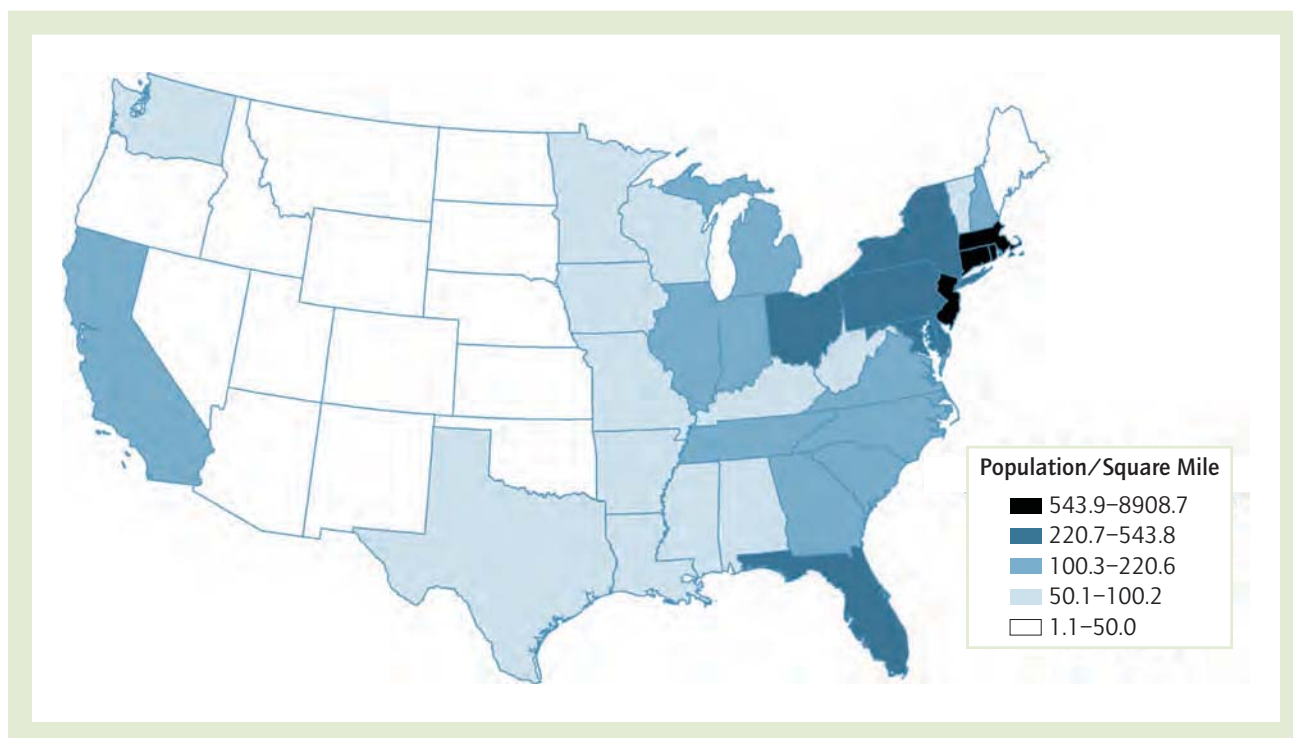


Figure 1 Classed choropleth map of population density for contiguous United States

Source: Adapted by author from U.S. Census Bureau data. Available from www.census.gov/population/www/popdata.html.

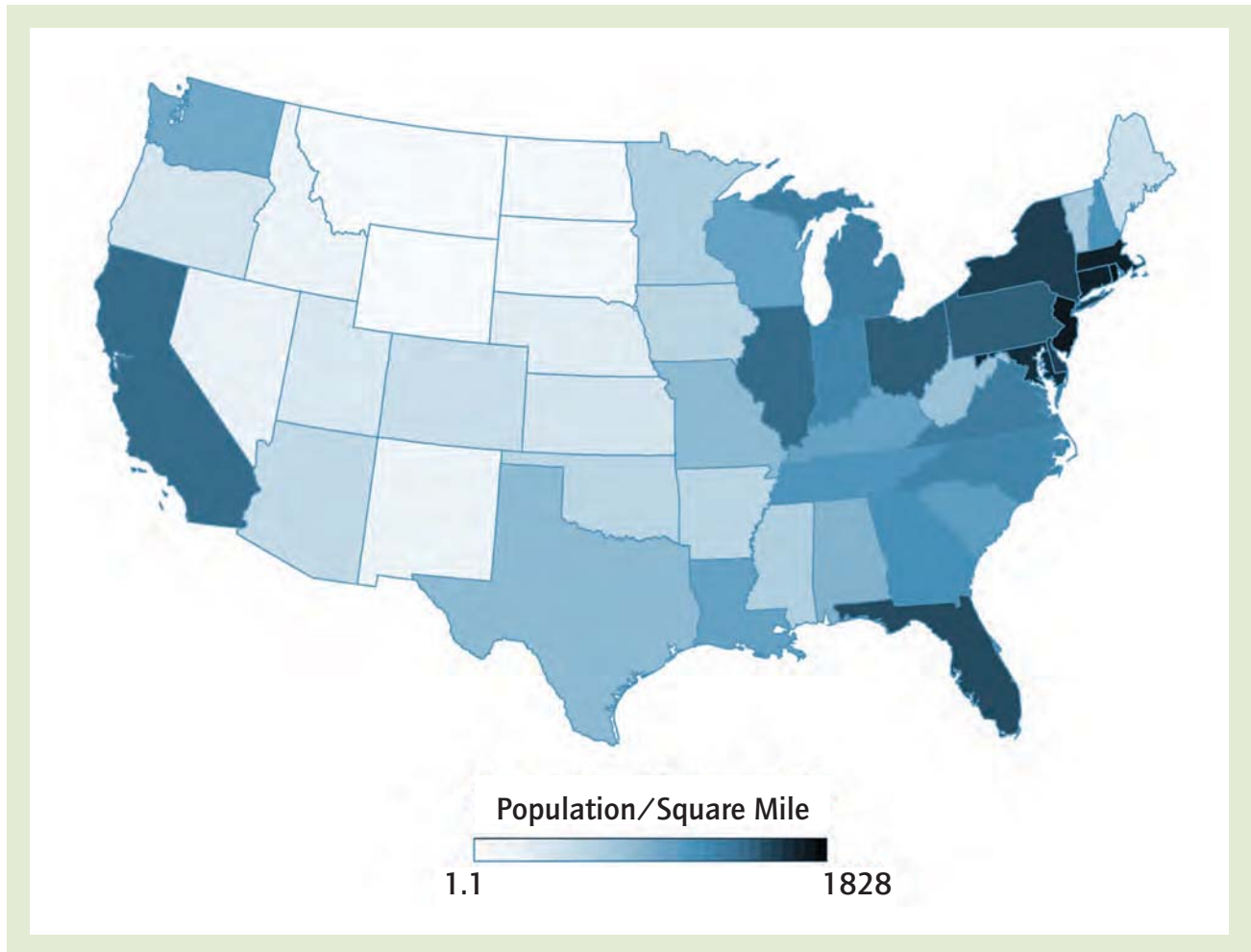


Figure 2 Unclassed choropleth map of population density for contiguous United States

Source: Adapted by author from U.S. Census Bureau data. Available from www.census.gov/population/www/popdata.html.

Data Classification

When a classed choropleth map is created, the classification type must be decided based on the data. One of the most common classification schemes used is the Natural Breaks method. This method involves plotting all data values on a graph and then identifying the largest gaps between the data clusters. Most mapping software will perform this analysis automatically. The other common classification schemes follow more traditional statistical measures, such as quantile classification, defined intervals, or mean/standard deviation classification (most commonly used for diverging data with a meaningful middle). Often, these classification schemes are

used as a basis for starting the classification but are modified to accommodate meaningful data values that may fail to be captured by an automated classification method.

Symbolization

Choropleth maps are symbolized in one of three ways, sequentially, diverging, or qualitatively. Pattern is largely limited to qualitative symbolization, though it can be used in combination with color to extend a sequential classification. Black-and-white color tends to restrict the map to a sequential representation—unless combined with pattern. Full color allows for all the options (Figure 3). Sequential symbolization follows a light to

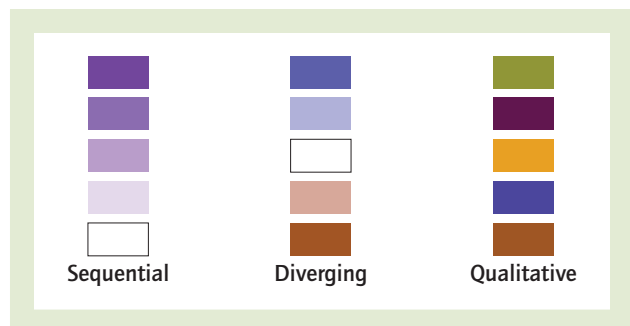


Figure 3 Example of sequential, diverging, and qualitative color schemes

Source: Author.

dark path either through a single hue or from one hue to a second, sometimes through a third. Diverging symbolization places two dark colors at the poles of the symbolization and lightens each toward the middle, where a white or near-white color represents the meaningful middle value. Qualitative colors use differing hues to represent the different values, often with nonnumeric data.

William Buckingham

See also **Data Classification Schemes; Isopleth Maps**

Further Readings

- Brewer, C. A. (2005). *Designing better maps: A guide for GIS users*. Redlands, CA: ESRI Press.
- Slocum, T. A., McMaster, R. B., Kessler, F. C., & Howard, H. C. (2005). *Thematic cartography and visualization*. Upper Saddle River, NJ: Prentice Hall.



CHRISMAN, NICHOLAS (1950–)

Nicholas R. Chrisman is a professor at the Université Laval, Canada, and scientific director of GEOIDE, a network that funds research spanning 30 universities across Canada. Over a 30-year period, Chrisman has contributed considerably to the development of GIS and the nascent scientific discussion of its potential and pitfalls, including

data structure development, consideration of error, and engagement with sociotechnological dimensions of the use, creation, and consequences of geographic information technologies. Besides his current positions, he has also held academic positions at the University of Wisconsin–Madison and the University of Washington.

Some of his early contributions were as part of the research group working at the Harvard Lab for Computer Graphics and Spatial Analysis in the 1970s on data structures and on programming the first GIS capable of working with vector data in a robust manner. With Tom Peucker (later Poiker), Chrisman coauthored an influential paper titled “Cartographic Data Structures” (1975), which presented a conceptual overview of the issues in developing topological data structures. Connected to programming and application projects while at the Harvard lab, he was part of the group that included James Dougenik, Denis White, Scott Morehouse, Allan Schmidt, and Geoff Dutton, which developed the first GIS capable of overlaying vector data in a robust manner, *ODYSSEY*, a precursor to the Environmental Systems Research Institute’s *ARC/Info*.

Diverse activities at the Harvard Lab and the many interactions with the nascent field through conferences were important for the next phase of Chrisman’s professional career, when he returned to academia to work on his PhD dissertation on error in categorical maps, which he completed in 1982 at the University of Bristol. This work on the origins and handling of error also led to publications on the role of time in geographic information and measurement theory.

Parallel to this work, and accompanying a move to his first academic position at the University of Wisconsin–Madison, Chrisman began a long-lasting engagement with the sociotechnological dimensions of the use, creation, and consequences of geographic information technologies. The 1997 book *Exploring Geographic Information Systems* situates the complicated interactions between society and its technologies as nested rings, inextricably linked. The work in this area has become influential in GIScience as well as science and technology studies.

Francis J. Harvey

See also **GIScience**



Further Readings

- Chrisman, N. R. (1989). Modeling error in overlaid categorical maps. In M. Goodchild & S. Gopal (Eds.), *The accuracy of spatial databases* (pp. 21–34). London: Taylor & Francis.
- Chrisman, N. R. (1997). *Exploring geographic information systems*. New York: Wiley.
- Chrisman, N. R. (1999). A transformational approach to GIS operations. *International Journal of Geographical Information Science*, 13(7), 617–637.
- Chrisman, N. R. (2005). Full circle: More than just social implications of GIS. *Cartographica*, 40(4), 23–35.
- Chrisman, N. R. (2006). *Charting the unknown. How computer mapping at Harvard became GIS*. Redlands, CA: ESRI Press.
- Peucker, T. K., & Chrisman, N. R. (1975). Cartographic data structures. *The American Cartographer*, 2(1), 55–69.

CHRISTALLER, WALTER (1893–1969)

Before the German geographer Walter Christaller's central place theory (1933), urban places were viewed in isolation from one another, as unique single entities, differentiated by their position in a hierarchy based on population size. Christaller's dissertation, *Die zentralen Orte in Süddeutschland*, broke from this prevailing view. Instead, Christaller demonstrated the spatial interdependence between places. Interdependence arose because of location relative to other places in the system of places. A place's population size and trade with other places were determined by its location.

Christaller's central place theory concluded that a hierarchy of places would arise as the system of places tended toward spatial equilibrium. Within the hierarchy of places, higher-order places would offer goods and services that required greater numbers of people distributed over larger trade areas for their support. Successively lower-order places would offer goods and services that required fewer people to sustain the activity. Lower-order places with their smaller trade areas are

embedded among fewer higher-order places and their larger areas of geographic dominance.

Christaller inductively derived propositions about the population size of places, number of places, and locational distribution of places. He described five sizes of communities:

1. Hamlet
2. Village
3. Town
4. City
5. Regional capital

Christaller was the first to propose a geographically determined hierarchy of places, conforming to specific geometric principles. His hypothetical landscape was composed of trade areas in the shape of hexagons. Hexagons are the most compact of packable shapes. Christaller's reasoning was that depending on the initial assumptions of the model or characteristics of the landscape, development of urban places would occur on the apexes, arcs, or interior of the hexagonal trade area boundaries—the market, transportation, or administration system, respectively. Christaller described the conditions that would bring about the particular geometry of places. In the absence of a transportation network, lower-order places would grow at the location of the apexes, exactly one third of the way between three next-higher-order places. If the landscape included a transportation network that minimized fixed costs and connected the highest-order places, then locational advantage would shift to the arcs of the hexagonal trade areas, with the growth of lower-order places occurring midway between a pair of next-higher-order places. Trade results between the places, and the revenues of a place depend on the geometry that characterizes the system of places. Christaller recognized the importance of internalizing externalities within a hierarchy of administrative zones.

There are a greater number of lower-order places, and they are closer together than higher-order places. Lower-order places depend on higher-order places for the provision of goods and services not available locally, and higher-order places depend on lower-order places to provide



demand sufficient for the provision of those goods and services unique to the higher-order places. Because of trade, all places are interdependent in space. The growth opportunities of a place are given by its location relative to other places. Christaller's rigid geometry of place location produces an efficient system for trade, growth, and development.

The German economist August Lösch (1906–1945) generalized Christaller's central place theory in his 1939 book published in German, *The Economics of Location*. Instead of Christaller's distribution of places and their functional order that maximized profits, Lösch's system was based on minimizing the cost of consumers' accessing needed goods and services. Lösch provided a deductive, more formal economic approach to the growth and spatial distribution of urban places.

Christaller's geometry of places has been used to explain and make decisions on settlement growth and contraction. In the post–World War II era, many regions of Eastern Europe adopted highway and development plans that had been created by Christaller during the war. The United States followed suit in the mid 20th century with the development of its Interstate Highway System, based on the German/Christaller model. Christaller's central place theory anticipated which places would benefit from the interstate development and which, being bypassed, would decline.

The policies of Nazi Germany were heavily influenced by ideas of social engineering and the quest for organizational efficiency. Geography, demography, and economics shaped and were in turn shaped by these Nazi policies. Following the completion of Walter Christaller's dissertation on central place theory in 1933, he had a short stint in academia. He joined the Nazi party in 1940 and entered public service with the German government as an applied geographer, performing location analysis within Heinrich Himmler's SS-Planning group. Himmler (1900–1945), one of the most influential people in Nazi Germany, oversaw all police and security forces and was overseer of concentration camps and extermination facilities. Under Himmler's direction, his planning group coordinated the efficient locational distribution of facilities engaged in the killing of millions of people whom the Nazis deemed unworthy. After the fall of the

Nazi regime, Christaller joined the Socialist Party and lived as a practitioner of applied geography until 1969.

August Lösch was strongly opposed to Nazi policies. He refused academic and government posts because he believed them to be too much under the influence of Nazi ideology. Lösch died before the fall of Hitler's Nazi regime.

English translations of Christaller's and Lösch's pioneering works were published in the 1950s. These works propelled economic geography to adopt quantitative methods and formulate rigorous geospatial logic. The publication of these two pioneers' work, and the subsequent body of knowledge that grew out of it, contributed to geography becoming a rigorous science that provides benefit to decision makers in government and private industry.

Grant Thrall

See also **Applied Geography; Central Place Theory; Location Theory; Regional Science; Urban Hierarchy**

Further Readings

- Christaller, W. (1966). *Places in central Southern Germany* (C. W. Baskin, Trans.). Englewood Cliffs, NJ: Prentice Hall. (Original work published 1933)
- King, L. (1984). *Central place theory*. Beverly Hills, CA: Sage.



CIRCUITS OF CAPITAL

Developed by Karl Marx in the second volume of *Capital*, the “circuits of capital” approach represents a multifaceted way to understand the cyclical and self-expanding process of capitalist value circulation. Since each circuit is envisioned as a particular moment within a larger process, economic geographers have found it useful in situating local geographies in a wider context.

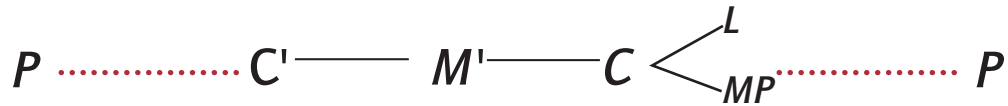
The circulation process is divided into three main circuits. The first circuit of money-capital (see Figure 1) represents succinctly the goal of any capitalist—starting with money and ending



The Circuit of Money-Capital



The Circuit of Productive-Capital



The Circuit of Commodity-Capital



Legend

C	Commodity	L	Labor power
M	Money	MP	Means of production
P	Production		The circulation process is interrupted

Figure 1 The circuits of capital

Source: Author.

with more. Since most industrial production processes require substantial money-capital to purchase the commodities labor power and means of production ($L + MP$) *before* production takes place, the circuit money-capital can be envisioned as the various types of financial and credit institutions whose overarching goal is to invest money with the aim of gaining more ($M - M'$).

The second circuit of productive-capital represents the periodic renewal of the concrete processes of commodity production (P). Each cycle of production must adapt to produce a specific volume of commodities at a particular speed in accordance with the industry's competitive dynamics. Focusing on this circuit allows a window into the context-specific struggles on the factory floor between capitalists, managers, and workers over the conditions and relations of production.

The third circuit of commodity-capital begins and ends its cycle with a produced commodity (C') that must be sold on the market. While the money obtained through the exchange ultimately will be reinvested in the production process, the process always ends with the renewal of the commodity-capital that must be exchanged. The circuit of commodity-capital can be conceptualized as the various types of distribution, marketing, and retail businesses whose overarching goal is to procure commodities and ensure their exchange.

Finally, the spatial and temporal interruptions of the circulation process—both in bringing commodities on site for production and in transporting them to the market for exchange—are also theorized as potential sources of crisis for the overall system of circulation as a whole.



Geographers have implicitly or explicitly applied the circuits-of-capital approach in a variety of ways. Within the circuit of money-capital, financial centers are studied as particular sites of power in the global market. Within the circuit of productive-capital, Doreen Massey's influential notion of "spatial divisions of labor" examines how localities and production facilities cohere within wider geographical networks of corporate organizational control. Within the circuit of commodity-capital, the commodity chain approach traces the geographical movement of commodities from raw materials to production, processing, retail, and consumption. Finally, following developments from cultural studies, cultural geographers have proposed a fourth "circuit of culture" that suggests that meanings and symbols themselves circulate between and among particular sites and places (e.g., households, advertising agencies, media outlets).

Matthew T. Huber

See also **Commodity Chains; Division of Labor; Economic Geography; Harvey, David; Marxism, Geography and; Massey, Doreen; Space of Flows**

Further Readings

- Harvey, D. (1982). *The limits to capital*. Oxford, UK: Blackwell.
- Hughes, A., & Reimer, S. (Eds.). (2004). *Geographies of commodity chains*. London: Routledge.
- Marx, K. (1977). *Capital* (Vol. 2). New York: International Publishers. (Original work published 1893)
- Massey, D. (1984). *Spatial divisions of labour: Social structures and the geography of production*. London: Routledge.

of citizenship by exploring the ways in which geography is so much a part of the political, social, cultural, and economic spheres that include or exclude people as citizens. Hence, geography is fundamental to all the critical issues of citizenship that concern society today. There are many ways in which geographers make connections to various notions and ideas of citizenship. Intersections of geography and citizenship can be traced back to antiquity, when geographers such as Ptolemy and Strabo advocated formalizing citizenship rights to people living within political territories such as the city-states of ancient Greece. Recently, feminist and postcolonial geographers have been concerned with citizenship as a phenomenon that incorporates ideas of inclusion and exclusion or, in other words, questions of who can belong where. This entry first examines the meaning of citizenship as it relates to rights and responsibilities within a given society. It then explores the ways in which geographers have expanded the concept to address issues related to cross-cultural and global citizenship.

Defining Citizenship

Geographical investigations of citizenship concern the relationships between individuals living and working in a particular place (communities, nation-states, etc.) and how these relationships affect everyday lives because of who these individuals are and where they live. As citizens, people are seen to have certain duties and obligations, and in return they can expect certain rights and benefits. Traditionally, at least in democracies, these benefits include various bundles of civil or legal rights (e.g., freedom of speech, assembly, movement, and equality before the law), political rights (e.g., the right to vote and engage in political activity), and economic rights (e.g., rights to social security, welfare, and basic standards of living). Despite the fact that this definition suggests a sense of inclusion and equality, notions of citizenship can also serve to exclude people. Historically, only certain groups of people, namely, property-owning white men, were entitled to these rights of full citizenship. Other groups, such as women and ethnic minorities, have had to fight to have these rights extended to them. Some social groups continue to remain "partial citizens," as



CITIZENSHIP

Citizenship means many things to many people in many different places; thus, ideas of citizenship are unrelentingly geographical. With the help of geographical concepts such as space, place, and scale, one can think about the various dimensions



they are excluded from particular civil, political, or economic rights; for example, even though members of some minority groups can enjoy legal rights, they may still feel like second-class citizens because of discrimination.

One approach to citizenship and geography is concerned with how the spaces of material human society, represented as administrative political units such as towns, cities, or nation-states, are intertwined with individual social, political, and economic rights and obligations that help define one's membership in a civil society. The way in which political power is organized in particular places is a critical element in determining who is and is not granted certain rights. These geographical connections are usually based on notions of the right to use public space (e.g., parks, streets, plazas), and they are linked to political perceptions of equality, democracy, and liberty. When one thinks of citizenship as a set of rights and responsibilities framed within particular bounded spaces, these spaces suggest an "outside" and an "inside." For example, spaces of citizenship sometimes serve to marginalize women, racial and ethnic minorities, the disabled, and so on. In this sense, geographers are interested in challenging the power structures and the status quo of a place by making claims for social justice and civil rights for those who work or live in a particular place and who may be marginalized by society. Many political geographers are interested in questions of how states, nations, territories, and boundaries play a role in notions of citizenship—for example, what might be at stake when certain people in a place call for political independence from other places, and where boundaries might be placed that mark these new territorial allegiances.

Global Perspectives

Traditional ideas of citizenship as a bundle of social, economic, and political rights that are extended by membership in a nation-state are now being rethought within a global context. Geography has a long tradition of recognizing the importance of global interconnectedness, and geographers are interested in the links between globalization and new forms of citizenship. This reorientation of geographical scale upward involves a range of issues that operate at a global

scale, and they require a rethinking of what it means to be a "global citizen." For example, environmental issues such as global warming now require people to create a global sense of responsibility in order to resolve a problem that is transnational in scope. Another issue that geographers consider is how neoliberal global capitalism and regional free trade increasingly contribute to a spatial unevenness of wealth, redefining citizenship in terms of various levels of economic wealth and consumer spending. A geographical perspective is required, therefore, to analyze how local communities and individuals become marginalized through these economic, political, and cultural processes—in other words, how these processes may take the form of geographical isolation and affect one's sense of belonging or citizenship.

Another citizenship issue that goes beyond the borders of a nation-state, and receives much attention from geographers, is the growing cultural and ethnic diversity of many societies, which has led to various debates surrounding multicultural citizenship, especially in the context of immigration and migration. These debates, whether they are about integration of refugees and asylum seekers or the rights of economic migrants, involve examining the geographies of people's movement and settlement and their relationships with new societies. Indeed, these new ideas about citizenship are about how border crossings affect one's sense of cultural and social belonging in different places.

Contemporary human geography provides a spatial lens through which ideas of citizenship are studied across multiple locales, political units, and scales of governance, providing critical insight into the ongoing processes of social, political, and economic restructuring of society. As a result, the study of geography and citizenship makes a key contribution to a better understanding of the rights and responsibilities of citizens and helps make sense of the frequently unequal distribution of opportunities and constraints this creates for some. Geography also contributes greatly to the meanings of citizenship by revealing not only how people living in particular places (especially those living at the bottom rungs of society) are excluded from the bonds of common citizenship but also how those at the top sometimes participate in



excluding their fellow citizens. The study of geography and citizenship invites one to continuously revisit and rethink what it is that constitutes today's meanings of citizenship—which is in itself an important step both in making active and participatory citizens and in creating a truly inclusive notion of citizenship. Geographical analysis of citizenship can help one consider the meanings of “belonging” and connectedness with places and spaces; it can also reveal the injustice of who may be excluded from the various rights and benefits that come with being a full citizen. As such, geographies of citizenship can be a valuable way to investigate social and economic justice, a major concern of geographers.

Thomas Chapman

See also **Civil Society; Cosmopolitanism; Diaspora; Ethnicity; Globalization; Governance; Identity, Geography and; Immigration; Justice, Geography of; Law, Geography of; Migration; Political Geography; Social Justice; State**

Further Readings

- Desforges, L., Jones, R., & Woods, M. (2005). New geographies of citizenship. *Citizenship Studies*, 9(5), 439–451.
- Mitchell, K. (2003). Educating the national citizen in neoliberal times: From the multicultural self to the strategic cosmopolitan. *Transactions of the British Institute of Geographers*, 28, 387–403.
- Parker, G. (2001). *Citizenships, contingency and the countryside: Rights, culture, land and the environment*. London: Routledge.
- Valentine, G., & Skelton, T. (2007). The right to be heard: Citizenship and language. *Political Geography*, 26, 121–140.



CIVIL SOCIETY

With the advent of globalization, and the hegemonic dominance of the market-based paradigm of neoliberalism, the term *civil society* has been increasingly popular, particularly in discussions of sustainability and social change in the

developing world. Civil society refers to the sector of society existing separate and apart from the state while lying between the state and the individual, or family. Civil society consists of voluntary, or nonmarket, organizations; accordingly, corporations are not part of civil society. The term does not include political parties, which are more closely tied to attempts to influence the state. A variety of organizations, some as seemingly mundane as sport clubs and social associations, constitute civil society; the two most notable and important types are grassroots (or “people’s”) organizations and nongovernmental organizations (NGOs). The former represent groups of people, such as the urban poor, fisherfolk, and peasant groups, mobilized to pursue a specific cause; the latter are organizations possessing specialized skills, and knowledge, engaging in advocacy at a regional, national, or even international level. NGOs often act on behalf of grassroots organizations. The widespread acceptance of neoliberal policies has led to a profusion of civil society for two reasons. First, many civil society groups provide services for the poor and marginalized (such as soup kitchens and food banks) that were formerly provided by the state; second, many NGOs have come into existence to campaign against development projects (such as large-scale mines or hydroelectric dams) that have the potential to displace the poor and impinge on the environmental resources required for their subsistence. Some components of civil society also engage in advocacy against neoliberalism in general, with its attendant structural adjustment policies, as well as targeting specific projects.

The expansion of low-cost, high-quality telecommunications has greatly assisted the spread of civil society throughout the world. Communications media such as satellite, Internet access, and text messaging have given grassroots organizations in developing regions of the world immediate access to their NGO partners in the developed regions of the world. Such communication allows a prompt diffusion of news affecting people (e.g., environmental accidents) while also making campaign responses to these events easier.

Another event further assisting the global spread of civil society is the World Social Forum. Since its 2001 inception in Porto Alegre, Brazil, the World Social Forum has met at roughly the

same time as the World Economic Forum in Davos, Switzerland. Meeting under the mantra of “Another World Is Possible,” it has facilitated a veritable “clearing house” of information for civil society. Disparate groups, such as Peruvian *campesinos*, sub-Saharan herders, or Filipino fisherfolk, can meet and coordinate their campaigns, against multinational mining companies or genetically modified organisms, with NGOs from developed countries.

Civil society has its critics. Many allege that unlike corporations (which are accountable to their shareholders) or governments (which are accountable to voters), these organizations act in an accountability vacuum and can do as they wish. It is also alleged that NGOs are dominated by members of elite classes who manipulate their grassroots clientele to serve their own agendas and cater only to their donors, rather than being concerned with the interests of those they “represent.” Critics of NGOs argue that as funding causes and recipient countries become more or less fashionable among donor groups, NGOs come and go in pursuit of donor funding; meanwhile, marginalized people who are affected by unfashionable causes and live in unfashionable countries are left mired in poverty. Such criticism has been leveled against the world social forum in particular, as some allege that it has become a “festival” for NGOs, where they meet with each other, while the grassroots, whom they represent, are bypassed and excluded.

Notwithstanding these criticisms of civil society, many good things may be said about it. The cause-oriented activism of many groups has stopped undesirable projects from proceeding. In Peru, a highly organized international campaign

prevented a Canadian mining company from demolishing half of the town of Tambogrande for the development of an open-pit gold mine. Civil society also provides a peaceful avenue for the poor and marginalized to have a voice that, otherwise, would not be heard; in the absence of these groups, opposition to neoliberalism may become more violent, and the repression of such groups may expand. Many NGOs have become heavily involved with the United Nations and other multilateral agencies and, in doing so, have



Telecommunications and civil society: A Filipino NGO worker sends a text message with her mobile phone. The satellite dish is used to communicate with a partner NGO in the United Kingdom.

Source: Author.



influenced policy. Multinational corporations and governments, cognizant of the ability of these groups to quickly spread news of their behavior throughout what Marshall McLuhan called the “global village,” are more mindful of what they do and are, more often than not, forced to seek a social license for their projects and policies, thus making civil society a major player in global governance.

William N. Holden

See also **Governance; Neoliberalism; Nongovernmental Organizations (NGOs); Social Movements; State**

Further Readings

- Hilhorst, D. (2003). *The real world of NGOs: Discourses, diversity, and development*. London: Zed Books.
- Silliman, G., & Noble, L. (Eds.). (1998). *Organizing for democracy: NGOs, civil society, and the Philippine State*. Honolulu: University of Hawaii Press.
- Tiivainen, T. (2002). The World Social Forum and global democratization: Learning from Porto Alegre. *Third World Quarterly*, 23(4), 621–632.



CLARK, ANDREW (1911–1975)

Andrew Hill Clark was a Canadian-born historical geographer who is widely regarded as the father of the subdiscipline in North America. Clark’s career at the University of Wisconsin was cut short when he succumbed to cancer at the age of 64. Clark’s development as a historical geographer took a circuitous path but ultimately led to teaching positions at the University of California at Berkeley, Rutgers University, and the University of Wisconsin. It was here that the evolution of his understanding of historical geography became most apparent. More important, perhaps, was his contribution to the discipline through supervision of 19 doctoral dissertations. Many of his students, including David Ward, Cole Harris, James Lemon,

Robert Mitchell, and Arthur Ray, became prominent historical geographers in their own right.

Clark earned a bachelor’s degree in 1930 at McMaster University and later enrolled at the University of Toronto, completing his master’s degree in 1938. He then received a fellowship to pursue doctoral studies at the University of California, Berkeley, with Carl Sauer. A 2-year teaching position at Canterbury University in New Zealand led to a dissertation on the impact of the introduction of plants and animals by Europeans to South Island, which he completed in 1944. His first academic position was at Rutgers, where he became chair of the geography department in 1949. Two years later, he was appointed to the faculty of the University of Wisconsin, Madison, where he taught until his death in 1975.

Clark’s Major Monographs

During his career, Clark wrote three significant monographs and numerous articles on the impacts of European overseas colonization, served as the editor of the *Historical Geography of North America* series, and was the principal founder of the *Journal of Historical Geography*.

Clark’s first book, *The Invasion of New Zealand by People, Plants, and Animals* (1949), provided a synopsis of the environmental changes brought to South Island by British settlers and their plants and animals. The book broke new ground, according to Donald Meinig, by viewing colonization as a process that transformed both the land and the newcomers. In *Three Centuries and the Island: A Historical Geography of Settlement and Agriculture in Prince Edward Island* (1959), Clark used evidence from more than 1,200 maps to document the changing character of the island through time. The uniformity of the island’s climate and landforms made possible a comparative analysis of the agricultural practices of different cultural groups.

His final book, *Acadia: The Geography of Early Nova Scotia to 1760*, published in 1968, explores the evolution of Acadia as a region and studies its inhabitants, the Acadians, a French-speaking people who created distinct geographic patterns prior to their dispersal by the British in 1760. It was the Acadians’ use of this distinct environment that played an important role in the development and evolution of this region.



Contributions to the Discipline

In 1954, Clark authored the chapter on historical geography in *American Geography: Inventory and Prospect*, which remained the seminal work on the evolution of the subdiscipline for 20 years and provided an assessment of the field in North America at that time. Clark concluded with a plea for more emphasis on the study and teaching of historical geography and training of students in historical geography to ensure the entire discipline's vitality.

Another notable work was his address as Honorary President of the Association of American Geographers, "*Praemia Geographiae: The Incidental Rewards of a Professional Career*," in 1962. One of those rewards was geographers' ability to identify dimensions that permit a holistic understanding of place. Clark noted that field observation was the greatest of these rewards and lamented its widespread decline. In his prologue to the collected essays in honor of Clark, Meinig argued that *Praemia Geographiae* will endure not because it was a philosophical treatise but because it was a very personal reflection on what it means to be a geographer.

Dawn S. Bowen

See also **Historical Geography; Human Geography, History of**

Further Readings

- Clark, A. (1962). *Praemia geographiae: The incidental rewards of a professional career*. *Annals of the Association of American Geographers*, 52(3), 234–235.
- Clark, A. (1968). *Acadia: The geography of early Nova Scotia to 1760*. Madison: University of Wisconsin Press.
- Meinig, D. (1978). Prologue: Andrew Hill Clark, historical geographer. In J. R. Gibson (Ed.), *European settlement and development in North America: Essays on geographical change in honour and memory of Andrew Hill Clark* (pp. 3–26). Toronto, Ontario, Canada: University of Toronto Press.



CLARK, WILLIAM

Issues of mobility and migration have not only defined William A. V. Clark's research but also initiated his entry into the discipline of geography. After earning his BA and MA degrees from the University of New Zealand in 1960 and 1961, he received a Fulbright fellowship and traveled to the United States, where he received his PhD in geography from the University of Illinois in 1964. Following graduation, he returned to New Zealand, where he lectured in the geography department at the University of Canterbury until 1966. He came back to the United States, first to the geography department at the University of Wisconsin, Madison, in 1966, where he was appointed adjunct associate professor of urban planning in 1968, and then to the geography department at University of California, Los Angeles.

Los Angeles became his home and continues to provide a vantage point for observing the influence of demographic change associated with internal and international population migration flows in urban neighborhoods. Indeed, living in Los Angeles, a place in constant demographic flux, convinced Clark that residential segregation in the urban United States was not simply the outcome of white racism, although it certainly played a role in determining the patterns of black segregation. Rather, it was a much more complex story, including the influence of sometimes rapid demographic change, housing costs and incomes, residential preferences, and ties to the neighborhood. Clark's immense body of work continues to be highly influential and led to his election to the National Academy of Sciences in 2005, which is but one of numerous recognitions of the importance of his research.

Some additional highlights include the Decade of Behaviour Research Award and an Alumni Achievement Award from the College of Liberal Arts and Science at the University of Illinois. He is also an elected fellow of the American Academy of Arts and Sciences and the Royal Society of New Zealand. Clark also holds an honorary doctorate from the University of Utrecht and a DSc from the University of Auckland.

While the important contribution of Clark's considerable body of work has been widely



acknowledged, it would be incorrect to assert that it has been received unquestioningly. Clark's work has been challenged and critiqued to varying degrees throughout his career. Specifically, his expert testimony on behalf of school districts in a series of cases on the role school districts played in residential segregation was very polarizing and placed him firmly in the middle of a contentious debate with regard to race relations and the legacy of racial segregation in the United States. Despite the criticism, Clark continued to argue that school districts could not be held responsible for neighborhood-level demographic change that resulted in changes to the racial composition of the school. This argument emerged from rigorous empirical analysis that highlighted the transformative power of demographic transitions on the residential mosaic and a belief that such evidence-based analysis is the foundation on which policy should rest.

In addition to his work examining the effects of demographic change on patterns of residential segregation and separation, Clark has also conducted a comprehensive macrolevel analysis of immigration in California and the United States. In this research, Clark finds the middle ground between two seemingly irreconcilable positions, that is, the view that immigration is a valuable resource and that immigration needs to be drastically curtailed because of the social and economic costs associated with it. In doing so, Clark highlights the geographically uneven and multiscalar nature of immigration, in which both costs and benefits coexist, albeit in different locations and at different scales.

Clark is currently a professor of geography and statistics at the University of California–Los Angeles and continues his work on the impacts of demographic change associated with migration to cities in the United States.

Valerie Ledwith

See also **Ethnic Segregation; Migration; Mobility**

Further Readings

Clark, W. (1991). Residential preferences and neighborhood racial segregation: A test of the Schelling segregation model. *Demography*, 28, 1–19.

Clark, W. (1992). Residential preferences and residential choices in a multiethnic context. *Demography*, 30, 451–466.

Clark, W. (1998). *The California cauldron: Immigration and the fortunes of local communities*. New York: Guilford Press.

Clark, W. (2003). *Immigrants and the American dream: Remaking the middle class*. New York: Guilford Press.



CLASS, GEOGRAPHY AND

There has been somewhat of a resurgence of interest in class across disciplines, for example, in feminist theory, sociology, and geography. In the United States, there have been several rich, ethnographic accounts of the continued effect of social class, as it intersects with other social positions, all of which challenge the popular myth of North America as a classless society. In the United Kingdom, there has been a stronger tradition of researching class, moving away from initial economist models to more cultural approaches that aim to uncover the interconnected subjective, material, and spatial components of class. The geographical intersection with class emphasizes the ways in which class literally takes place, on and in the landscape. Classed geographies are embodied in individuals' sense of place, in our feelings of belonging, and in our everyday identifications. They are materially enacted in the resources and opportunities that are available or denied to us, and here class division alludes to the stratification within this system. For example, we may see ourselves "located" in terms of our ability or inability to move neighborhoods, to access leisure facilities, to change employment, or to travel abroad. We may position ourselves as alike or dissimilar to our peers, and with an increasingly globalized reference system, different scales of comparison can be mobilized across time and place. Class is often seen as relevant to our uptake of and movements within space, from the everyday level of which neighborhood we live in and on what street, and the restaurants and art galleries we may or may not frequent, to a broader



sense of globalized flows in the labor market and the division between the “global rich” and the “global poor.” Yet defining class becomes difficult in a climate of supposed classlessness, where class inequalities are thought of as increasingly complex or nonexistent. Rather than moving away from class, many continue to research its fixity and its ability to fix—to deny opportunities in a new global market place.

Defining and Analyzing Class

Changes in the organization of production and consumption, it is often said, make it difficult to describe and analyze social class; occupations that have traditionally defined class have broken down and are now replaced by the service and information industries. Some commentators speak of the “power of flows” taking precedence over the “flows of power,” where capital flows are spread throughout interconnected networks, creating a fast-growing electronic economy in which money is increasingly abstract and invisible. In this model, there is no such thing as a global capitalist class as the behavior of capitalists depends on submission to global networks, which is less secure than claims to the ownership of production, foregrounded in Marxist models of class. Here, it also becomes difficult to define who is working class, given the spatial and economic diversity of “workers.”

Yet global flows in the location and dislocation of employment may work to sustain class structures rather than undermine them. The irregularity of the flows of globalization is often thought of in terms of increased flexibility or, indeed, renamed as improved “choices” for workers; workers have the “opportunity” to change their places of employment and residence. Such changes and the increased patterns of mobility are often contrasted with the “past” security of traditional working-class jobs, where workers were more spatially fixed, living and working in or near the same locale for their entire lives. Current disputed economic, social, and spatial transformations and continuations serve to redraw disciplinary lines around conceptualizations of class and geography, as the intersection between the two is debated from the macrolevel (such as international globalization and the shape of capitalist restructuring)

to the microlevel (the playing out of global capital on the bodies of specific workers and the changing geographies of inclusion/exclusion).

Some authors have pointed to the displacement of and postindustrial uncertainty about working-class masculinity, as a feminized service sector economy coincides with the production of “feminized” spaces of consumption. Such depictions of loss may at times serve to uphold and valorize a somewhat mythical and romanticized past, where traditional gender and class roles kept people “in their place.” A more complex analysis, combining class and gender, highlights the relevance of class to women’s employability within service sector transitions and the relegation of, particularly, low-skilled working-class women, to poorly paid, part-time, “pink-collar ghettos.” Feminist geographers in particular have challenged the disembodied theories of capitalism, where gender has been frequently sidelined. Yet many have pointed to the role of reproduction in capitalist production; furthermore, processes of reproduction may be as geographically uneven as capital circulation, with domesticity and caring producing a certain class of female *and* male workers.

The disputes surrounding the definition and salience of class point to its social construction, intersecting with the social geographies of place and space, where the landscape is shaped and contested rather than just known. Importantly, the significance of class to geography lies in its attempts to highlight inequalities and ongoing structural patterns, amid economic, social, and spatial shifts. The relationship between class and geography potentially uncovers layers of meanings and sociospatial relations, and Doreen Massey speaks of the dynamics of spatial divisions, which are constantly restructuring themselves, rather than just statically existing. In this framework, such “layers” are conceptualized not just in terms of economics but also as cultural, political, and ideological, with local specificities. Capitalism, for example, is not simply a benign economic system, now responding to a global age; rather, it encapsulates and perpetuates ideas about value and skill, constructing spatialized social divisions, which are then neutralized as natural and in line with dominant political and cultural discourses (such as the “American dream”).



Postindustrialism and Class

In postindustrial cities across the world, the transition to leisure-based, service sector economies, during which industrial jobs have all but disappeared, constitutes a major change, economically and culturally. Industrial legacies now appear as outdated histories that cities are often keen to cast aside in their attempts at urban regeneration, producing newly sanitized and upgraded spaces for consumption and leisure (such as shopping and housing complexes). Dualistic properties are often evident in the “regeneration” of urban landscapes, where cities seemingly function as universally accessible, offering generic services and spaces (shops, cafés, select green spaces). Against this apparent sameness, each place may well have its own brand that is carefully managed and shaped to project just the “right” sort of image to the outsider, generating interurban competitiveness on a global scale: What makes city spaces attractive to residents, employees, and tourists? What differentiates such spaces from the suburbs? From the rural?

Such processes and tensions are suggestive of new developments and forms of sociospatial division in postindustrial society, where class is not simply compositional of income and occupation but also a result of vested interests in space and place. As the cultures and traditions of a city are repackaged and reimaged, marketing and advertising make it possible to project a representation of the city that serves to include some of its inhabitants and further exclude other “undesirables,” which are classed in specific ways. For example, working-class youth may be specifically excluded from the more prestigious shopping centers and their presence queried elsewhere, assumed to be threatening embodiments of urban disorder. While space and place are shaped, branded, and reimaged to create the “urban dream” (with emphasis on art, culture, consumption, and a café lifestyle), divisions are perhaps reconsolidated, with inhabitants becoming more socially segregated and culturally differentiated perhaps than ever before.

Life Chances and the Sense of Belonging

The impacts of spatial segregation and exclusion can be vividly witnessed in terms of uneven access

to crucial social goods, for example, education, health, housing, and employment, where class continues to be a reliable predictor of life chances. The influence of class and geography is apparent when location frequently acts as the basis of access, and inequalities arise from and compound each disadvantage. For example, underachieving schools are frequently situated in deprived areas, while middle-class parents can exercise more choice by moving to a “good” area with a good school (also known as “white flight” in the United States, where white parents sought to move away from black inner-city locations/school). Frequently, working-class areas are represented in metaphors of drowning (“sink” estates) and defecation (“bog standards”), which in neoliberal times, “responsible” parents must avoid, enacting their own good sense rather than relying on welfare intervention. In both the United States and the United Kingdom, social policy frequently invokes notions of “social capital,” whereby local networks and communities are felt to add value, embedding individuals in friendship and familial support systems. Viewed more skeptically, this may be seen as an individualist response to structured inequalities, where “the poor” are positioned as failing to generate empowering “social capital,” repeatedly situated as failing bodies in failing places.

Location is related to opportunity structures and, more subjectively, to a sense of one’s place, as against the place of “others.” Areas can be demarcated not only in terms of their facilities and amenities but also in terms of their inhabitants, whose values, lifestyles, and “respectability” are often read through locale. The boundaries of identification (boundaries between “us” and “them”) regulate who can fit in these places, with economic, social, and cultural resources embodied in the construction of “professional,” “respectable,” and “real” identities. The spatialization of class is also apparent in the British terms *Essex girls* and *Scousers* and in the U.S. terms *white trash*, *hillbillies*, *rednecks*, and so on, where character is read and assumed from locale (see photo). Furthermore, several researchers have proposed that everyone living in a city has knowledge of “ghetto” estates and the level of danger and exclusion each area presents, where working-class areas are frequently represented as more undesirable and



Hubcap Hurling winner Tater Yarbrough of Jesup, Georgia, throws his last hubcap during the 11th annual Summer Redneck Games, July 8, 2006, in Dublin, Georgia. Started in 1996 as a spoof for the summer Olympics held in Atlanta, the games feature bobbing for pigs' feet, hubcap hurling, and the redneck mud pit belly flop contest for trophies.

Source: Getty Images.

dangerous. New technologies arguably intensify such demarcations, with Web sites and television programs on where to buy and which places to avoid, implicitly aimed at a knowing middle-class consumer. Such spatial segregation fosters new exclusions with the dynamics of capitalist restructuring reproduced at the microlevel, across space and onto the inhabitants who variously occupy it.

The *appearance* of class is written on the landscape and on the bodies of subjects; it is the “fleshy” and “messy” stuff of everyday life. The way one looks is frequently equated with being someone or no one. Such a focus draws on varying theories of identity in space, particularly the ways certain bodies, appearances, and identities are rendered unentitled to occupy a space because of the lack of capitals, bodily or otherwise, to legitimately access that space and to receive interpersonal affirmations and

entitlements within it. Consider, for example, the space of higher education: Who is the typical, entitled university student? What is expected, measured, valued? Pierre Bourdieu makes apparent the classing of spaces and subjectivities, using the concepts of capital and the classed habitus. Bourdieu's model of classed habitus and classed capitals provides a sense of the ways class still affects access to positions, traveling through space. The habitus may be understood as a second skin that is carried around, retaining the “past” as it affects our present; put simply, we carry our history with us, and it affects our objective location and our sense of place in the world. Having the “right” cultural, economic, and social capitals (which when legitimated turn into “symbolic capital,” a resource that the working classes “lack”) produces opportunities and advantages across various social spheres.



Speaking of trajectories and fields enables an understanding of how bodies have access to different amounts of capitals. This is useful in thinking about how movements through spaces are constituted, facilitated, or impeded. It also points to the entrenched, emotional “value” of spaces, relevant to how social space is viewed and negotiated. Capitals are classed: The distribution of capital runs from those who are best provided with both economic and cultural capital to those who are deprived in both respects. This model of embodied capitals, where resources are attached to classed individuals, challenges straightforward notions of “upward mobility” as gradations of social status continually inform and prescribe movement through space. This contrasts with straightforward, disembodied notions of mobility with its “rises” and “falls,” producing a one-dimensional view of social space and ignoring conversions and reproduction strategies. Perhaps the more we have, the easier it is to have more.

Bourdieu’s theory of classed capitals and classed habitus is framed solely in terms of class, having little to say about gender or sexuality. The relationship between class and geography, in terms of economic restructuring, opportunity structures, capitals, and identifications, can be queried by an intersectional focus on, for example, class, gender, and sexuality. The geographies of class are complex and inevitably intersectional. Consider, for example, the regeneration of city space previously discussed as also involving the promotion of commercialized lesbian and gay spaces as “niche markets.” Borrowing from the success of gay districts in “world cities,” such as New York, Sydney, or Paris, “wannabe world cities” have engaged in competitive strategies to attract capital. Such cities have, with varying success, re-created themselves as places of culture and consumption, laying claims to a certain cosmopolitanism that places them as participants in the global economy. Several authors have commented that such regenerations are classed, involving an expulsion of “undesirables” in upgraded leisure space. Here, the connection between the material structuring of space and the everyday movements in and out of space can again be witnessed.

Yvette Taylor

See also Class, Nature and; Circuits of Capital; Consumption, Geographies of; Crisis; Economic Geography; Ethnic Segregation; Everyday Life, Geography and; Feminist Geographies; Gender and Geography; Giddens, Anthony; Harvey, David; Human Geography, History of; Identity, Geography and; Inequality and Geography; Justice, Geography of; Marxism, Geography and; Neoliberalism; Patriarchy, Geography and; Poststructuralism; Race and Empire; Race and Racism; Racial Segregation; Resistance, Geographies of; Segregation and Geography; Smith, Neil; Social Justice; Structuration Theory; Uneven Development; Urban Underclass; Walker, Richard

Further Readings

- Adkins, L., & Skeggs, B. (Eds.). (2004). *Feminism after Bourdieu*. Oxford, UK: Blackwell.
- Beck, U. (2000). *What is globalization?* Oxford, UK: Blackwell.
- Bettie, J. (2002). *Women without class: Girls, race, and identity*. Berkeley: University of California Press.
- Bourdieu, P. (1984). *Distinction: A social critique of the judgment of taste*. London: Routledge.
- Hennessy, R. (2000). *Profit and pleasure: Sexual identities in late capitalism*. London: Taylor & Francis.
- Kefalas, M. (2003). *Working-class heroes: Protecting home, community, and nation in a Chicago neighborhood*. Berkeley: University of California Press.
- Lareau, A. (2003). *Unequal childhoods: Class, race and family life*. Berkeley: University of California Press.
- Massey, D. (1995). *Spatial divisions of labour*. New York: Routledge.
- Reese, E. (2005). *Backlash against welfare mothers: Past and present*. Berkeley: University of California Press.
- Taylor, Y. (2007). *Working-class lesbian life: Classed outsiders*. New York: Palgrave Macmillan.
- Urry, J. (2000). *Sociology beyond societies: Mobilities for the twenty-first century*. London: Routledge.
- Zweig, M. (2000). *The working-class majority: America’s best kept secret*. Ithaca, NY: ILR Press.



CLASS, NATURE AND

Taken separately, class and nature constitute two of the most significant categories of analysis within the geographical tradition. As a marker of different forms of social stratification, class has provided a key fulcrum around which political and economic geographers have sought to understand the life paths taken and “life chances” presented to different people. As a complex indicator of both the essential essence of existence and the environmental fabric of being, nature has provided a multidimensional lens for geographers exploring areas as diverse as race relations, the colonial imagination, and late modern forms of environmental change. In these contexts, both class and nature embody key objects of analysis that geographers seek to understand and, at the same time, important conceptual categories for interpreting the operation of various forms of socioeconomic and ecological process. When considered together, the varied relations between class and nature have provided a rich terrain of critical analysis that has, perhaps more than any other arena of study, characterized the contribution of human geographers to the study of the environment.

Marxist Views of Class and Nature

The first systematic, geographical analysis of the relations between class forces and nature was presented in Neil Smith’s influential volume *Uneven Development: Nature, Capital and Production of Space*. Smith deploys a Marxist theory of class to reveal the ways in which the social and geographical structures of capitalist society have shaped, and have in turn been conditioned, by certain economic appropriations of nature. Karl Marx’s 19th-century reflections on human relations with the natural world were important because they marked a sharp break from the prevailing tendencies at the time to see nature as an object of analysis within the physical sciences but not the fields of economics and politics. In keeping with his broader modes of dialectical thought, Marx asserted that nature was not an eternally unchanging backdrop against which human history is played out but a historically contingent product of prevailing political and economic systems.

It is important to note that the varied social relations associated with a capitalist economy (including systems of market exchange, private property, and regimes of accumulation) have all critically shaped modern relations with the natural world. Smith asserts that it is the particular class formations of capitalism that have determined the specific ways in which modern industrial societies apprehend and transform nature. While Marx himself identified a plethora of socioeconomic classes that were characteristic of capitalism, it is the broad division between the proletariat and the bourgeoisie that Smith focused his analysis on. Following Marx, Smith interpreted the bourgeoisie to be the strata of industrial society that own the means of economic production (viz., agricultural land, factories, mines, etc.) and the proletariat as those whose only property is their own bodies and the associated labor they can sell. While these class positions may be familiar enough, the impacts that they have on socionatural relations are perhaps less easy to discern. It is the various processes of alienation that, in different ways, hold the key to interpreting the ecological significance of such class positions.

Despite working intimately with the things of nature (soils, minerals, timber, livestock, etc.), Marxists argue that the proletariat has historically been alienated from nature to the extent that the construction of their class position has involved the violent expulsion of workers from the collective environmental resources (including pastures, woodlands, and watercourses) that they once shared and used. Where nature was once used for the daily production of sustenance, and respected accordingly, under industrial capitalism, it becomes a thing to be rapidly transformed for wage and exchange. It is not difficult to imagine how the collective management of nature for local use produces a very different ethic of environmental care and understanding from a system that is based on private ownership, waged labor, and the extraction of ecological value for commodity exchange.

In contrast, Marxists claim that the alienation of the bourgeoisie from nature has been predicated not on the demands of waged laboring but on the physical and emotional distance that tends to emerge between propertied classes and the natural world under capitalism. This distance is, in part, based on the geographical separation that patrician



classes experience as a consequence of the rapid growth of cities under capitalist social and economic relations. At a less obvious level, this distance is also a product of the elaborate industrial complexes of ecological transformation and supply and the armies of labor associated with capitalism, which work to collectively reduce the need of the bourgeoisie to engage with nature within the processes necessary for their day-to-day reproduction (e.g., eating, drinking, heating their homes).

It is in these contexts that capitalism produces a double motion of alienation from nature. For the working classes, their alienation is more emotional than physical, as they are forced to reevaluate their relations with nature from which they have been legally dispossessed. For the patrician classes, alienation tends to take a much more physical form as they are geographically and economically divorced from contact with the nature on which their existence, and wealth ultimately depend.

External Versus Universal Ideologies

Smith's analysis, however, goes beyond the simple recognition that the class positions associated with capitalism tend to produce differences in the ways in which strata within society engage with nature. Smith claimed that the evolving relations between different classes and nature produce novel ways of understanding the natural world and society's relationship with it. Smith isolated two hegemonic ideologies of nature that have emerged directly from the emergent class positions of capitalism: external ideologies and universal ideologies.

External Ideologies

External ideologies of nature posit the natural world as something that is essentially separate from the human condition. While a belief in the binary distinction between society and nature is not a unique feature of capitalism, it is not difficult to understand how the alienating ecologies of capitalist economies have supported a popular belief in the essential distinction between human and nonhuman worlds. The ideological construction of nature as an external realm, which is emotional and practically disconnected from human experience, has been central to the ways in which complex understanding of nature have been replaced by its much

narrower construction as an economic resource. Belief in the essential disconnection between social and natural systems has also been crucial in legitimizing capitalism's domination of the environment in the pursuit of ever-expanding profits.

Universal Ideologies

In contradistinction to external views of the natural world, Smith identified universal ideologies of nature. According to Smith, universal ideologies of nature situate the human species as one among many species in the totality of nature. While universal ideologies of nature also have long precapitalist histories (Smith traced them back to Immanuel Kant, but they structured medieval cosmologies as well), Smith recognized how they were coopted by urban bourgeois elites in their desire to reconnect with the natures they had lost. If humans are just one part of the totality of nature, then reconnecting and respecting nature appear central to the *species-being* of humans. In this context, the rise of capitalist ideologies of universal nature is closely tied to the new discourses of environmental stewardship and care that are associated with the green movement. Notwithstanding this connection, it is also important to note how universal ideologies of nature have been used to justify the class divisions of capitalist society (if humans are a part of nature, then class divisions could be interpreted as being as inevitable as other divisions in the natural world).

Ultimately, the pioneering work of Smith reveals that even though contemporary ideologies of nature predate the class structures associated with capitalism, modern industrial society has witnessed the reconsolidation of certain views of the natural world that both support capitalist economic systems and flow from its contradictions. It is important to note how both external and universal ideologies of nature have been used, despite their oppositional nature, to support and sustain the ecological relations of modern industrial society.

Additional Views of Class and Nature

The broad-ranging reanalysis of class-nature relations first conducted by Smith in the mid 1980s has provided the basis for a rich array of allied analyses of socionatural relations within geography. At one



level, questions of class and nature have emerged as a crucial consideration within the work of urban political ecology. Within this broad, also Marxist-inspired, school of analysis, broad questions of class and nature reappear under the rubric of the differential access to resources experienced by different members of the metropolitan community. Consequently, whether it be in terms of access to affordable food, clean water, breathable air, or recreational space, the role of class in determining the differential ability of people to metabolize nature has reemerged as a central theme within urban geography.

Other work, inspired by the politics and philosophies of the environmental justice movement has, however, started to question the centrality of both class and nature as central concerns within the constitution of urban environmental equity. In constructing a distinctively urban-based brand of environmental politics and thought, the environmental justice movement recognizes the importance of class as a factor within the differential environmental conditions of life experienced by metropolitan denizens. Notwithstanding this, one of the key implications of the rise of the environmental justice movement for geography has been a heightened concern with the role of race and gender in the determination of environmental opportunity. Furthermore, the rise of the environmental justice agenda within geography has led to a renewed concern with the role of class, race, and gender within an environmental politics that extends beyond questions of nature (e.g., to include housing quality, workplace environments, and the environmental qualities of public space). To these ends, the environmental justice movement has exposed the ways in which systems of capitalist production and class stratification tend to produce environmental problems that are both ecological and social in their form.

Despite its close association with the work of Marxist geographers, it would be wrong to associate discussions of the relationships between class and nature exclusively with Marxist thought. Work on the form and meaning of landscape within geography has, for example, exposed the intricate braiding of class values and natural landscapes. The work of Denis Cosgrove and Stephen Daniels has revealed the ways in which the landscaping of nature (whether it be in urban parks and gardens or the parklands of wealthy

landowners) belies certain bourgeois aesthetics and tastes and is an enduring attempt to mark out class distinctions within the scenery of everyday life. Beyond the deliberate manufacturing of nature within the arts and sciences of landscaping, geographers have also outlined how the selection of zones of nature for conservation (whether in the form of greenbelts, game reserves, national parks, or areas of outstanding natural beauty) reflects the projection of certain elite class values into the countryside and the associated subjection of working environments to bourgeois control.

Mark Whitehead

See also **Class, Geography and; Critical Studies of Nature; Distribution of Resource Access; Ecological Imaginaries; Environmental Justice; Ethnicity and Nature; Gender and Nature; Marxism, Geography and; Nature; Nature-Society Theory; Political Ecology; Race and Nature; Smith, Neil; Social Construction of Nature; Uneven Development**

Further Readings

- Burkett, P. (1999). *Marx and nature: A red and green perspective*. London: Macmillan.
- Cosgrove, D., & Daniels, S. (Eds.). (1989). *The iconography of landscape: Essays on the symbolic representation, design and use of past environments*. Cambridge, UK: Cambridge University Press.
- Gottlieb, R. (2005). *Forcing the spring: The transformation of the American environmental movement* (Rev. ed.). Washington, DC: Island Press.
- Harvey, D. (1997). *Justice, nature and the geography of difference*. Oxford, UK: Blackwell.
- Heynen, N., Perkins, H. A., & Roy, P. (2007). Failing to grow "their" own justice? The co-production of racial/gendered labour and Milwaukee's urban forest. *Urban Geography*, 28, 732–754.
- Keil, R. (2003). Progress report: Urban political ecology. *Urban Geography*, 24, 723–738.
- Pulido, L. (1994). Restructuring and the contraction and expansion of environmental rights in the United States. *Environment & Planning A*, 26, 915–936.
- Smith, N. (2008). *Uneven development: Nature, capital, and production of space* (3rd ed.). Athens: University of Georgia Press.



CLIENT-SERVER ARCHITECTURE

In the client-server architecture, clients and servers communicate with one another via a network connection. This architecture is composed of a distributed computing system with software on both the client and the server. The client may initiate a session while the server sits waiting for requests from clients. A server can be used by one or many clients depending on its intent and capabilities. A client can also use one or many servers depending on its intent and capabilities.

Common Examples

Common examples of client-server architectures include e-mail exchange, database access, and Web access. The most obvious example is Web access. In this case, the Web browser (e.g., Microsoft Internet Explorer or Mozilla Firefox) is the client. When one types a Web address into the Web browser, the browser (the client) initiates a connection to the Web address (the server). The server responds based on the request sending back information to be displayed in the Web browser. In this example, the response is typically a Web page.

Geospatial Examples

Geospatial examples include Google Maps and Microsoft Virtual Earth. Both of these examples use a Web browser as the client to connect to servers hosting large amounts of geospatial data that are returned, in the form of maps, and displayed by the server. Another common geospatial example is virtual globes, such as NASA World Wind and Google Earth. In this case, the client no longer uses a Web browser; rather, a custom application is installed. Both NASA World Wind and Google Earth have highly customized servers that are designed to provide spatial information to a specific client; this creates the base data for the virtual globe. These clients also have the ability to connect to any number of other servers that adhere to certain Web standards. Additionally, desktop geographic information system (GIS) software, such as ArcGIS Desktop (from the Environmental Systems

Research Institute), ENVI (from ITT), and Quantum GIS (open source), can be considered clients in client-server architecture. All these products have the ability to connect to both local and remote sources of data. A user can access data in a remote database or via geospatial Web standards, and in doing so, these software products are acting as clients contacting a server. In these cases, the data being returned are often very different from what is returned to a Web browser as these clients can deal with many complex remote sensing and GIS data formats. However, the underlying architecture remains the same—the client makes a request to a server that is awaiting such requests, and the server processes the request and returns a response.

Open Geospatial Consortium Standards

The client-server architecture relies on standards for communication for clients and servers to easily communicate with one another. In the case of general Web communications, this standard is the Hypertext Transfer Protocol (HTTP). Additional standards can be used in addition to HTTP for specific types of communications. The Open Geospatial Consortium (OGC) has developed and maintains a number of standards for requesting and receiving geospatial data via client-server architecture. While these standards are too numerous and complex to cover them all in detail here, a brief overview of some of the more common standards is warranted. The Web Map Service (WMS) is used for returning maps as images. It is important to note that the returned map is not data; it is just a picture of data. The Web Feature Service (WFS) is used to request/return feature data such as points, lines, and polygons. The Web Coverage Service (WCS) is used to request/return raster data. Unlike WMS, both WFS and WCS return actual data, not just images. These services among others are commonly used to allow clients to request data from servers via the Web.

Thin Clients Versus Thick Clients

There are two readily accepted types of clients, often referred to as “thin clients” and “thick clients.” A Web browser would be an example of a thin client. In this case, the server does all the



processing, while the Web browser (the thin client) is only concerned with sending input to the server and displaying the response. A desktop GIS product is an example of a thick client. In this case, the client can do a great deal of processing on its own and is not reliant on a server connection. A Web browser is highly reliant on the server for content to display, while a desktop GIS product has a great deal of functionality that is not dependent on the server. The key difference is that the thick client uses much more of the local computer's resources, while a thin client relies heavily on the server to do the majority of the processing. The capabilities of the thick clients vary greatly. In the case of desktop GIS products, a user could carry out entire projects without ever connecting to a server as a client. However, virtual globes such as Google Earth (also a thick client) rely heavily on the server for content but use much more of the local computer resources for processing, displaying, and interacting with the data than a common Web browser. Unlike a desktop GIS product though, virtual globes are not as useful without a connection to a server for content.

Stateless Versus Stateful

The connections established between client and server can be stateless or stateful. In a stateless transaction, the client sends a request, and the server responds. After sending its response, the transaction is complete, and future transactions in no way depend on the previous transaction. In a stateful transaction, the server remembers the client between requests (e.g., by using cookies). An example of this might be an individual visiting the Web site of a data portal and logging in to his or her account. The server creates a session with the client, and it knows certain information (in this example perhaps name, affiliation, data type preferences, previous data ordered, etc.) about the user. In this case, one request may depend on a previous request. For example, the client might request the addition of a certain data file to a shopping cart. The server could respond with a list of items in the shopping cart. In the next request, the client could continue browsing for more data or choose to request the data. The server could carry out this request by preparing

the data for download and responding with a location to download the requested data files.

Synchronous Versus Asynchronous

Connections between clients and servers can be synchronous or asynchronous. A Web browser makes a good example. In the case of a synchronous connection, when the client requests new information from the server, the displayed page is replaced by a new page returned by the server. This new page could be completely different, or it might only change a small amount of the content on the page. In the case of an asynchronous connection, the client can send a request to the server in the background without changing the display or behavior of the current page. On receipt of the server's response, the client can update a small part or the entire page depending on the request and response. A good example of this would be an interactive mapping site. A map may be embedded in a Web page. Using a synchronous connection, zooming in on the map would require reloading the whole page with new information. Using an asynchronous connection, the user could specify an area to zoom in to, and the client could request an update to the map from the server. In this case, the server would respond with an updated map, but the rest of the Web page would be unchanged.

Distributed GIS

Recent advances in network infrastructure have allowed the rise of technologies such as virtual globes, which require intensive network communications between the client and the server. Many have attributed the rise of virtual globes with changing the way people (geographers and non-geographers alike) access and visualize data. These advances also allow a move toward distributed GIS, which is also inherently based on a client-server architecture. In this case, a client could connect to a server to request actual GIS processing tasks as opposed to requesting only data. For a simple example, a GIS client might make a request to a server that included a set of points that the user wanted to perform a spatial interpolation on. Rather than having complex software with this capability, the user could submit the



data and the request to the server, the server would carry out the interpolation and return an interpolated surface as its response. However, moving around data sets such as this can require a great deal of network bandwidth and server processing power. However, it seems that current advances in infrastructure, servers, and software are bringing us closer to wide-ranging distributed GIS services.

Sharolyn Anderson and Benjamin T. Tuttle

See also **Database Management System; Distributed Computing; Geospatial Semantic Web; GIS Web Services; Google Earth; Internet GIS; Neogeography; Open Geospatial Consortium (OGC); Virtual Globes**

Further Readings

Bambacus, M., Yang, P., Evans, J., Cole, M., Alameh, N., & Marley, S. (2007). An interoperable portal supporting prototyping geospatial applications. *URISA Journal*, 19(2), 33–39.

The Open Geospatial Consortium, Inc.:
www.opengeospatial.org

Peng, Z., & Tsou, M. (2003). *Internet GIS*. Hoboken, NJ: Wiley.

Scharl, A., & Tochtermann, K. (Eds.). (2007). *The geospatial Web: How geobrowsers, social software and the Web 2.0 are shaping the network society*. London: Springer.

Tuttle, B. T., Anderson, S., & Huff, R. (2008). Virtual globes: An overview of their history, uses, and future challenges. *Geography Compass*, 3, 1478–1505.



Flaming mountain, Xinjiang, in northwestern China. Cut off from marine climatic influences and surrounded by high mountains, the region has a dry climate and is extremely hot in summer.

Source: Xiaoping Liang/iStockphoto.

Dry climates have unique qualities, both majestic and fearsome, that have intrigued travelers and investigators alike (see photo). Some hyperarid climates have almost Martian-like landscapes with distinct aeolian features. These climates pose a potential danger for those attempting to travel there because of harsh and extreme weather elements such as high temperature, solar radiation, and lack of humidity. People living in this climate regime were forced to adapt to the very meager, sporadic, and uncertain land productivity and had developed a nomadic lifestyle where grazing was, and in some areas is still, the only economic activity.

Definition

A dry climate is defined simply as an area with perennial water deficit, little biological productivity, little carrying capacity, and restricted human



CLIMATE: DRY

Although the scarcity of water resources in dry climates makes them inimical in modern times for habitation and settlement, dry climates were more favorable for early civilizations. Dry climatic conditions provided a suitable niche for the establishment of Neolithic and Chalcolithic settlements as debilitating waterborne diseases such as malaria and schistosomiasis, which inflict the more humid areas, were less common in arid and semiarid zones.

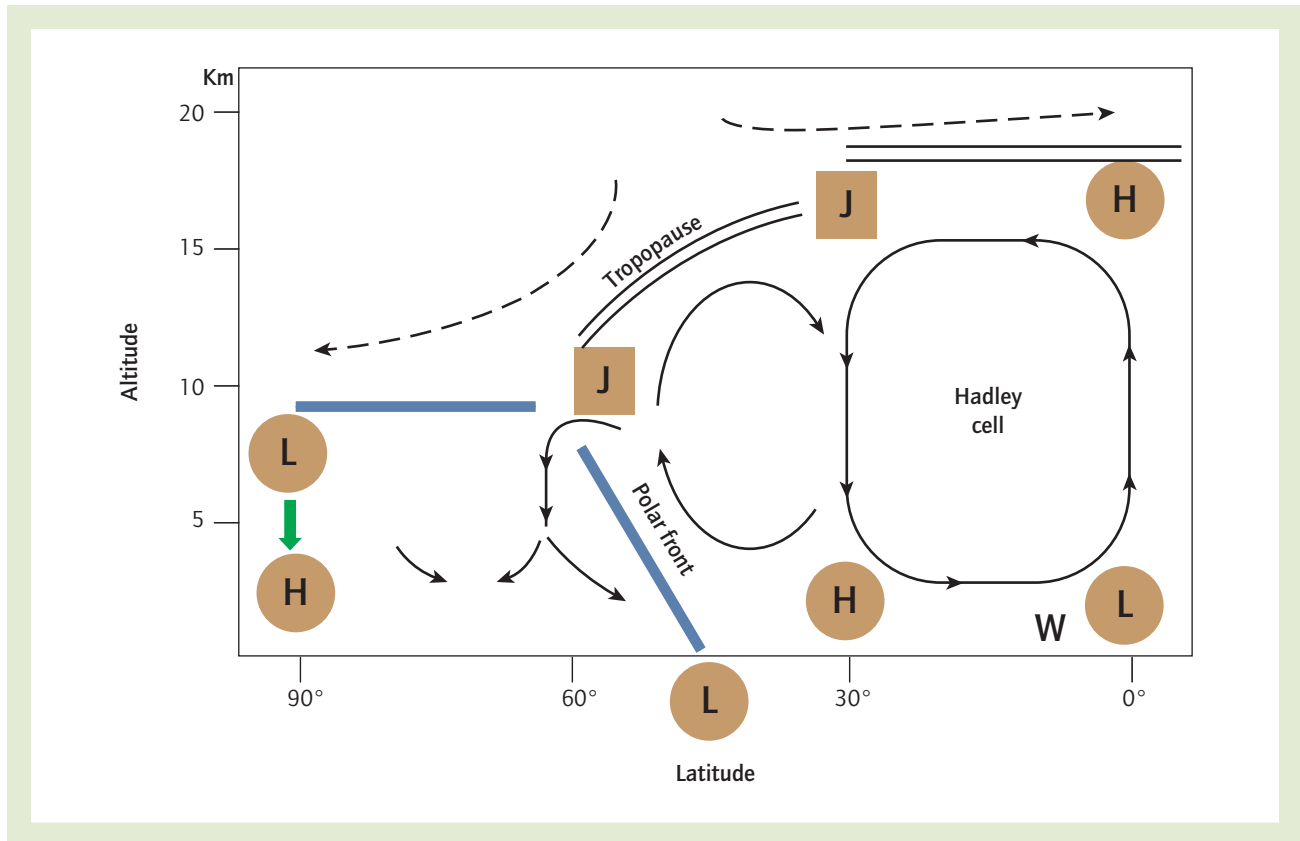


Figure 1 A schematic diagram showing the general circulation patterns along with latitudinal pressure distribution

Source: Author.

activities. According to the Köppen classification, there are five major climate regimes: tropical rainy, dry, humid temperate, humid cool, and polar. Each regime has subdivisions based on precipitation distribution and/or temperature regimes. A dry climate is simply defined as that which has a substantial negative water balance (precipitation is much less than potential evaporation), either permanently or for the larger part of the year.

There is a clear difference between aridity and drought. The first term refers to a condition in which long and sustained conditions of low and highly variable precipitation are the norm in a given area. For instance, the Sahara in North Africa has been typified by very low precipitation for the past several thousand years, and thus, the climate of the Sahara is either arid or hyperarid. On the other hand, drought is a temporary weather condition in which precipitation ceases for a long enough time to cause agricultural, hydrological, and/or meteorological drought. Drought occurs

almost everywhere, but its occurrence is more frequent and severe in marginal climates, where precipitation tends to fail more often (e.g., marginal areas separating two contrasting climates—the Great Plains and the Sahel region in Africa).

Location of Dry Climates

There are distinctive geographic zones where dry climates prevail. The major belt of dry climates is located in the subtropical zones between about 20° and 30° north and south of the equator (Figure 1). In the Northern Hemisphere, this includes the Great Sahara in North Africa, the Arabian Peninsula, the Gobi desert, the Sonora desert in North Mexico, and the southwest of the United States, and in the Southern Hemisphere, it includes the Atacama and Patagonia deserts in South America, the Namibian and Kalahari deserts in Southern Africa, and the Australian desert. The reason for the formation of these deserts in these

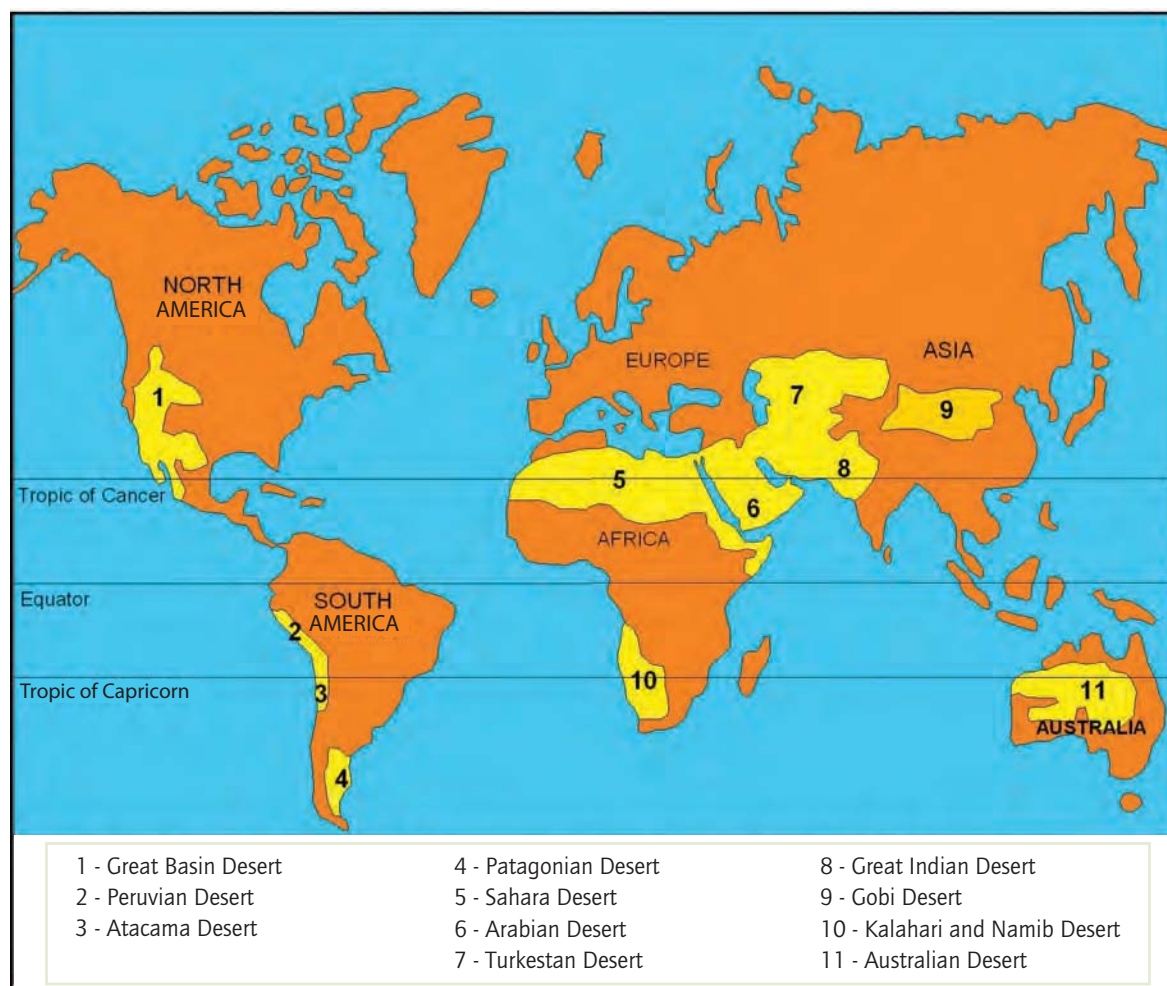


Figure 2 Global distribution of world deserts

Source: Author.

zones is directly connected to air subsidence manifesting the general circulation (see Figure 2). Irregular land-ocean distribution, however, breaks up this high-pressure zone into cells that allow some areas to receive ample amount of rainfall (Hare, 1983). When an air parcel subsides, it heats up adiabatically, and thus, its relative humidity decreases, leading to diminishing chances for cloud formation. These zones are typified by a high atmospheric pressure and become sources of air masses.

In addition to the general circulation, there are three other factors that contribute to the

formation of dry climates, albeit at a smaller scale. These include the following: (1) sheer remoteness from moisture sources (e.g., Northern Asia, the Central Sahara, and Central Australia), (2) location in the lee wind (e.g., the Jordan Valley; Nevada and Idaho, East Oregon, and East Washington, which are located behind the Sierra Nevada and the Cascades), and (3) the presence of cool oceanic currents (compare the precipitation regime over Florida on the one hand and southwestern California and Baja California on the other, southeastern South America and its western part: the Chilean coast,

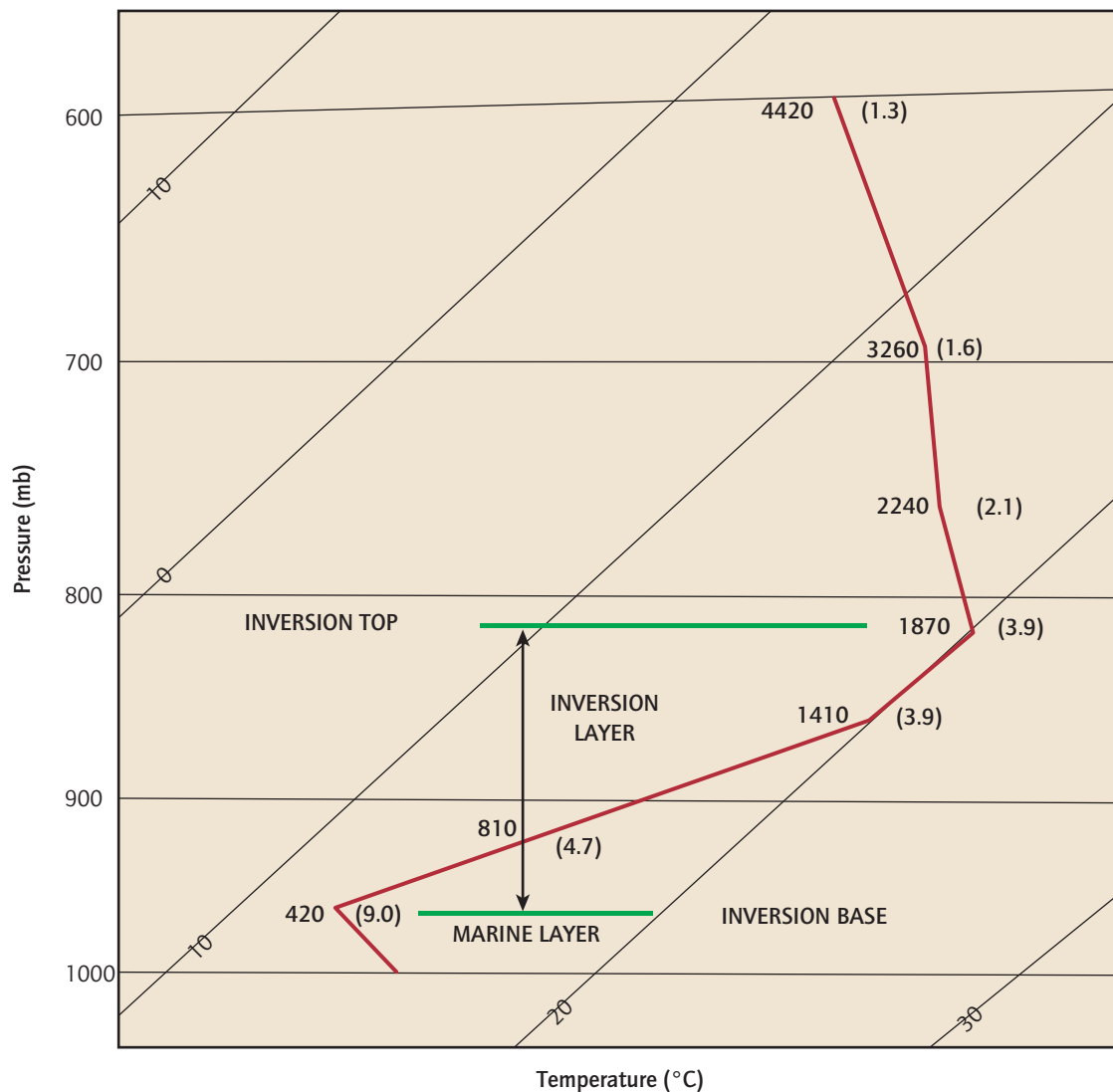


Figure 3 Vertical profile of air temperature and moisture within the lower troposphere for a marine system within the arid zone

Source: Adapted from Krishnamurti, T. N. (1979). *Compendium of meteorology* (Vol. 2, Pt. 4, Tropical Meteorology, WMO No. 364). Geneva: World Meteorological Organization.

Zimbabwe and Angola, the southwestern parts of Australia and its southeastern parts). Although these paired areas are approximately located at the same latitudes, the eastern parts enjoy plenty of precipitation due to the warm oceanic currents, which encourage deep convective clouds, whereas the cool oceanic currents in the western parts cause a persistent inversion layer deep enough to suppress any vertical development,

leading to dry conditions for the most part of the year. Figure 3 shows the vertical temperature and moisture profile within the lower troposphere over areas experiencing cold oceanic currents along with air subsidence. The figure shows that air temperature increases from about 12 °C at 420 m (meters) at the inversion base to about 20 °C at 1,870 m at the inversion top. Conversely, atmospheric moisture decreases from 9 g/kg



(grams per kilogram) at 420 m to 3.9 g/kg at the inversion top. This sharp moisture reduction indicates a significant detachment between the base of the inversion and the rest of the atmosphere due to strong mixing suppression resulting from negative buoyancy. This typical atmospheric profile ($\partial\theta/\partial z > 0$) with its deep inversion thickness suppresses any vertical movement, which in turn results in the predominance of aridity.

Dry Climate Indices

Climate classification serves many objectives, including the following: (a) to establish a distinct spatial pattern, (b) to reduce the number of elements needed, and (c) to characterize association between/among phenomena (e.g., flora and climate). Many investigators have attempted to classify dry climates (e.g., Köppen, Meigs, Thornthwaite, Budyko). Wladimir Köppen classified the world climates into five major classes, and each of them was given a letter designation code: tropical humid (A), dry (B), warm temperate (C), cool temperate (D), and polar (E). Dry climates are empirically determined based on precipitation amount, its annual distribution, and the average annual temperature. Köppen proposed the following criteria for identifying dry climates:

$$\frac{P}{10} < (2T + 28), \text{ 70\% of } P \text{ in the warm season,} \quad (1)$$

$$\frac{P}{10} < 2T, \text{ 70\% } P \text{ in the cool/cold season,} \quad (2)$$

$$\frac{P}{10} < (2T + 14), \text{ } P \text{ distributed throughout the year,} \quad (3)$$

where P and T are the average annual precipitation (in millimeters [mm]) and air temperature (degrees Celsius [$^{\circ}\text{C}$]), respectively. This climate is further subdivided into two subclasses based on precipitation, dry (Bw) or semidry (Bs). A climate is semidry steppe (BS) if precipitation exceeds one half the temperature criteria mentioned in Equations 1 to 3:

$$\frac{P}{10} > (T + 14), \text{ 70\% of } P \text{ in the warm season,} \quad (4)$$

$$\frac{P}{10} > (T), \quad (5)$$

$$\frac{P}{10} > (T + 7). \quad (6)$$

Dry and semidry climates are subdivided either into dry/semidry tropical (BW_h or BS_h) if the average annual temperature $\geq 18^{\circ}\text{C}$ or dry/semidry cold if the average annual temperature $< 18^{\circ}\text{C}$ (BW_k or BS_k).

C. W. Thornthwaite attempted to classify dry climates based on a moisture index,

$$I_m = \frac{100s - 60d}{PE}, \quad (7)$$

where I_m is the moisture index (dimensionless), s the water surplus (mm), d the water deficiency (mm), and PE the annual potential evaporation, determined primarily by air temperature. The calculations of s and d are made on a monthly basis for the entire year.

$$s = \sum_{i=1}^{12} (P_i - P_{E_i}), \quad d = \sum_{i=1}^{12} (P_i - P_{E_i}). \quad (8)$$

Semiarid climates, termed *humidity provinces* by Thornthwaite, have a short growing season that sustains the growth of short grass, the dominant natural vegetation. For instance, in semidry areas within the Mediterranean region, short perennial grass grows during the period from February through the middle/end of March. Dry climates have, on average, moisture deficiency year-round, $\sum s_i = 0$. Annual potential evaporation there is usually high and frequently exceeds 2,000 to 2,500 mm in most tropical desert areas. Thus, the moisture index is highly negative and could exceed -50 . The above classifications are empirically based.

M. I. Budyko provided a generic classification based solely on precipitation and net radiation as a surrogate for potential evaporation. Budyko defined an aridity index (Φ),

$$\Phi = \frac{R_n}{\lambda_E P}, \quad (9)$$



where λ_E is the latent heat of evaporation (joules per kilogram) and P is the average annual precipitation. R_n is the net radiation (watts per square meter), defined by

$$R_n = S(1 - \alpha) + \varepsilon_a \sigma T_a^4 - \varepsilon_s \sigma T_a^4 \quad (10)$$

where S is the solar radiation, ε_a and ε_s the atmospheric and surface emissivities, respectively, σ the Steffan Boltzmann constant, and T_a the air temperature. For very humid areas, $\Phi > 1$; for intermediate climate, $\Phi \sim 1$; and for dry areas, $\Phi < 1$. In very dry areas, Φ could simply reach 40. When Φ exceeds 10, the area potential becomes extremely small, and as such, natural vegetation growth is restricted to wady beds and alluvial fans.

Dry areas are classified into subcategories based on the degree of aridity. The following, from the United Nations Environment Programme's *World Atlas of Desertification*, provides the aridity index along with the percentage of global land area covered by each category:

Category	Aridity Index (Φ)	% Global Land Area
Hyperarid	>20	7.5
Arid	$20 < \Phi < 5$	12.1
Semiarid	$5 < \Phi < 2$	17.7

The main shortcoming of the aridity index proposed by Budyko is that precipitation seasonality, or more specifically its effectiveness, is not taken into account. Precipitation effectiveness, defined loosely as P-PE for a given month, is higher for areas receiving their bulk precipitation in winter than in summer.

There is a clear association between climate and natural vegetation. Native vegetation is a mirror image of the entire spectrum of all climatic elements and represents the best climate indicator as it integrates all climate and soil elements. Natural plants growing in dry climates may be classified into two types—drought evaders and drought resistant. The first type is composed of seasonal plants that emerge under favorable conditions of moisture and soil temperature. These plants emerge and end their growth cycle within a short period of time, leaving behind a bank of seeds that may lay dormant for several years or more,

awaiting the right conditions to restart their cycle again. Drought-resistant plants withstand the harsh conditions (very low soil moisture, high solar radiation, and excessive heat) via physiological adaptation. This includes root distribution (shallow or deep), morphological characteristics (barrel-like plants such as cacti), waxy/few or no leaves, leaf shedding, large root bulbs, and dormancy. These physiological adaptations are meant to harvest as much soil moisture as possible and/or to conserve soil moisture in order to avoid lengthy drought conditions and excessive heat (e.g., Leopold, 1961; Miller, 1985).

Climatic Elements

Dry climates are characterized by plenty of sunshine, large diurnal and annual temperature amplitudes, and very little precipitation, and as such little soil moisture.

Solar Radiation

Although extraterrestrial solar radiation reaches its maximum ($\sim 13.1 \times 10^3 \text{ MJ m}^{-2} \text{ yr}^{-1}$ [megajoules per square meter per year]) at the equator, the corresponding maximum insolation reaching the ground surface is recorded in the subtropical high-pressure zones ($\sim 8.3 \times 10^3 \text{ MJ m}^{-2} \text{ yr}^{-1}$), where deserts are situated. This gives an average annual atmospheric transmission of about 0.7 compared with the equatorial zones, where atmospheric transmission is about 0.35 to 0.4. The relatively low zenith angle of the sun and little cloud cover are responsible for this significant amount of global radiation reaching the ground surface in the arid zones. Although many of the economic woes of deserts are partially attributed to the high levels of solar radiation there, this element is a promising economic asset that can be harnessed for the sake of development of these lands (e.g., heating and cooling, desalination of brackish water, electricity generation).

Temperature

Air temperature represents a mirror image of the partitioning of net radiation at the surface-atmosphere boundary. The highest air temperature (57.6°C) was recorded in Azizia, Libya, in the Northern Sahara. Still higher air temperatures

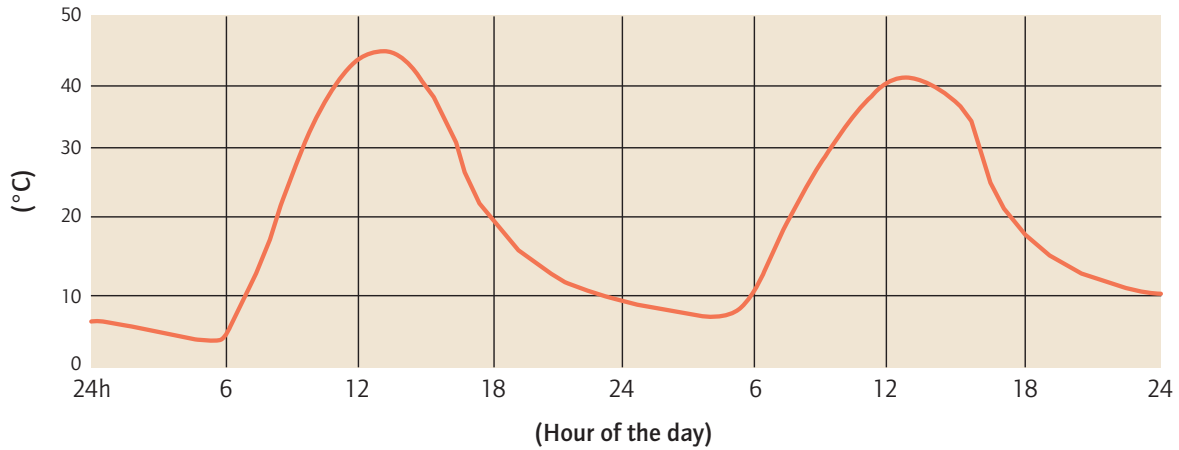


Figure 4 Diurnal surface temperature for a sand dune in Algeria, in the Northern Sahara desert during the beginning of April

Source: Adapted from Krishnamurti, T. N. (1979). *Compendium of meteorology* (Vol. 2, Pt. 4, Tropical Meteorology, WMO No. 364). Geneva: World Meteorological Organization.

were probably experienced and had gone unobserved in these hyperarid zones. An interesting question would be the midday surface temperature of a desert landscape. The energy balance at the surface-atmosphere boundary devoid of soil moisture may be expressed in the following form (e.g., Oroud, 1998):

$$S(1 - \alpha) + \varepsilon_a \sigma T_a^4 - \varepsilon_s \sigma T_s^4 - K_h(T_s - T_a) - K_\lambda(T_s - T_1) = 0. \quad (11)$$

The first, second, third, fourth, and fifth terms are absorbed solar radiation, atmospheric radiation, emitted radiation, sensible heat flux, and subsurface heat flux, respectively. If surface temperature is linearized ($\varepsilon_s \sigma T_s^4 \sim \varepsilon_s \sigma T_a^4 + 4\varepsilon_s \sigma T_s^3 (T_s - T_a)$), then Equation 10 can be written for the temperature difference between the surface and that of the contiguous atmosphere within the surface layer (ΔT) as follows:

$$\Delta T = \frac{S(1 - \alpha) - \sigma T_a^4 \delta \varepsilon}{Q_r + K_h + K_\lambda} \quad (12)$$

where $Q_r = 4\varepsilon_s \sigma T_a^3$ ($\text{W m}^{-2} \text{K}^{-1}$ [watts per square meter per Kelvin]) and K_h and K_λ are the sensible and conduction heat transfer coefficients, respectively. For a typical subtropical desert, the

midday solar radiation reaching the surface in summer is about $1,000 \text{ W/m}^2$, and with typical values of $\alpha \sim 0.35$, $Q_r \sim 7 \text{ W m}^{-2} \text{K}^{-1}$, $K_h \sim 13$ to $15 \text{ W m}^{-2} \text{K}^{-1}$, and $K_\lambda \sim 3 \text{ W m}^{-2} \text{K}^{-1}$, the above expression yields a ΔT of about 20 to 25 °C. Thus, the midday surface temperature of a typical desert surface would be about 65 to 70 °C. For darker surfaces, such as an asphalt pavement or a basalt outcrop, or surfaces with very small roughness lengths, such as playas, ΔT is expected to be larger than what was obtained above, and T_s could reach about 75 to 80 °C. With such strong vertical temperature gradients, frequent dust devils are a common daytime phenomenon. Additionally, optical illusions (mirage) are monotonous features over shimmering surfaces such as paved surfaces and desert playas.

Due to clear skies, little/or nonexistent soil moisture, and low heat capacity of desert soils, surface temperatures there have significant diurnal swings. A desert surface heats rapidly during the early morning hours till it reaches its maximum 1 or 2 hours after noon. The reverse, although less dramatic, is true during the nighttime hours, with a temperature drop of several degrees Celsius near sunset. Near dawn, surface temperatures are usually 35 to 40 °C lower than they were at midday. Figure 4, taken over a sand



dune in early April in the Sahara, shows this diurnal temperature trend clearly. Surface frost is also a common feature of desert surfaces during the winter months. Dew or hoar frost typically forms over these surfaces when adequate atmospheric moisture content and calm winds prevail. Dew has been reported to be a major moisture source for natural vegetation growing in these dry realms.

Ibrahim M. Oroud

See also **Anthropogenic Climate Change; Arid Topography; Biome: Desert; Climate Types; Desertification; Drought Risk and Hazard; Dunes; Environmental Management: Drylands; Köppen-Geiger Climate Classification; Playa; Xeriscaping**

Further Readings

- Budyko, M. I. (1958). *The heat balance of the Earth's surface*. Washington, DC: Office of Technical Services, Department of Commerce.
- Hare, K. (1983). *Climate and desertification: A revised analysis* (Report WCP-44). Geneva: World Climate Applications Programme, World Meteorological Organization and United Nations Environment Programme.
- Leopold, A. S., & the Editors of Life. (1961). *The desert*. New York: Time.
- Meigs, P. (1953). World distribution of arid and semiarid homoclimates. In *Reviews of Research on Arid Zone Hydrology* (pp. 203–210). Paris: UNESCO, Arid Zone Research.
- Miller, E. W. (1985). *Physical geography*. London: Miller.
- Oliver, J. (1987). Climatic classification. In J. Oliver & R. W. Fairbridge (Eds.), *The encyclopedia of climatology* (pp. 221–237). New York: Van Nostrand Reinhold.
- Oroud, I. M. (1998). The influence of heat conduction on evaporation from sunken pans in a hot, dry environment. *Journal of Hydrology*, 210, 1–10.
- Steila, D. (1988). Drought. In J. E. Oliver & R. W. Fairbridge (Eds.), *The encyclopedia of climatology* (pp. 388–395). New York: Van Nostrand Reinhold.

Thornthwaite, C. W. (1948). An approach to a rational classification of climate. *Geographical Review*, 38, 55–94.

United Nations Environment Programme. (1992). *World atlas of desertification*. Washington, DC: Author.



CLIMATE: MIDLATITUDE, MILD

The midlatitude mild climate zone describes a spatially expansive land area of the Earth that stretches from approximately 30° to 55° north and south latitudes. This climate zone features less extreme climate conditions throughout the year than neighboring climate zones such as the colder, snowier midlatitude severe climate zone located generally to the north of this region. Although the weather and climate of this zone is characteristically mild year-round, several areas situated within these latitudinal boundaries are not classified as having a mild midlatitude climate. More extreme climate conditions prevail in these reaches, such as areas of high elevation and areas in arid and semiarid regions. Considering these exceptions, most of the spatial land area of this climate zone is located on the North American and European continents. The midlatitude mild climate zone has moderate temperatures and precipitation totals throughout the year and large-scale climate controls such as the presence of subpolar low-pressure centers.

Nevertheless, there is much diversity within this climate zone. Climate can vary considerably with situation in the higher- or lower-latitude locations of the zone as well as with situation in the marine (coastal) or continental areas. For instance, in the lowest latitudes, precipitation in the form of rain is abundant with higher annual temperatures, which allows these areas to retain a yearly vegetative ground cover and green foliage. Higher latitudes of the climate zone have more variable temperatures and precipitation throughout the year, and vegetative ground cover and foliage can be sparse to nonexistent in the fall and winter months. An important feature of this climate zone is the impact of large-scale weather



and climate phenomena, such as the El Niño/Southern Oscillation, drought, floods, hurricanes, and tornadoes, which can have significant positive and negative influences on the people and environments of this region. Moving into the future, there is also much uncertainty as to the location and extent of climate change impacts in the midlatitude mild climate zone.

Latitudinal Climate Variability

The thermal and moisture conditions of the midlatitude mild climate zone are frequently warm and dry in summer months and cool and wet in winter months. There is considerable climate variability within this zone (particularly in the winter season), which can be distinguished by latitude. In the highest latitudes of this climate zone, temperatures are generally cooler, averaging nearly 0 °C in winter and 23 °C in summer. Temperatures can reach well below freezing during the winter season, especially in areas situated above and below 43° north and south latitudes, respectively. For areas located in latitudes below and above 35° north and south, respectively, temperatures are much higher in winter and are rarely below freezing for extensive periods of time.

Rainfall is common in the summer and spring months in all latitudes, though in the fall and winter months, troughs of low pressure can develop over the region, leading to snowfalls in higher-latitude locations. A common winter feature along the North American east coast are nor'easter storm systems, which can bring below-freezing temperatures, heavy snows, freezing rain, sleet, and strong winds. For most of this climate zone, the close vicinity of the Pacific and Atlantic Oceans provides abundant moisture sources for precipitation. In summer, the lowest latitudes of the midlatitude mild climate zone experience the highest temperatures, though all locations can have warm to hot summers as dry, tropical air masses move across the climate zone. Occasionally, humid summer weather conditions that are more common in the lower latitudes are experienced in the high-latitude locations of this climate zone, leading to health threats and discomfort for the populations, who are less accustomed to this summer weather. Frequently, these conditions correspond to the presence of moist, tropical air masses.

Marine and Continental Locations

In the midlatitude mild climate zone, the climate conditions of a given location can also vary with situation near a water body or within the continental interior. In marine areas (considered the coastal locations), the close proximity to ocean waters moderates thermal and moisture conditions. Here, temperatures are less variable between the summer and winter seasons than at locations further inland, typically with an annual range of only 20° to 25 °C. In this climate zone, these conditions are often experienced on the western sides of continents. With oceans serving as an abundant moisture source, weather throughout the year can also be more humid and wet. However, marine locations of this climate zone typically receive the most precipitation in the fall and winter seasons. Maritime air mass movements contribute to the moist weather. Winter rains and cloudy skies are common in these areas. In addition, advection fogs are a regular feature of summer mornings in the marine locations of the midlatitude mild climate zone. In the lower latitudes of the climate zone, the presence of subtropical high-pressure centers offshore can direct moist weather systems away from the region, resulting in warm to hot and relatively dry summers. Warm and cool offshore currents and sea breezes may also influence the weather of marine areas in the climate zone.

For locations within the continental interiors, which are only found in this climate zone in the Northern Hemisphere, more variable annual weather and climate conditions are experienced. The weather and climate conditions experienced here are more variable on a regular basis throughout a season than in any other place on Earth. Midlatitude cyclones move across the continent and control the climate variability in these areas. These systems direct tropical and polar air masses, and the associated fronts and weather patterns, across the region. Polar air masses dominate the continental interiors in winter, especially in the higher latitudes. Tropical air masses are more often directed into the continental interior in summer. Regardless of the season, when tropical and polar air masses meet, milder weather conditions prevail. This often occurs as two air masses mix and modify after storms



develop and pass across the area. The moisture conditions associated with these air masses come from the Pacific and Atlantic Oceans as well as the Gulf of Mexico and affect the continental interior precipitation totals and intensity as well as cloud cover. The instability associated with convection in this region also can lead to frequent thunderstorms, especially in southern locations and in the summer season.

Vegetative Cover and Human Adaptations

The vegetation of the midlatitude mild climate zone reflects the moderate temperatures and relative wealth of moisture across the region (see photo). Forests and grasslands form an abundant vegetative cover across the midlatitude mild climate zone. Broadleaf and deciduous forests are located across the zone. Hardwood (e.g., oak, maple, and cherry) and softwood (e.g., pine, spruce, and fir) forests are plentiful, though varieties that shed their leaves in winter are more common in the higher latitudes. Green foliage is common in the fall and winter months in the lowest latitudes of this climate zone.

For centuries, the forests of this climate zone have been considered an important multiple-use resource for humans occupying these lands. Areas with grasslands native to the climate zone are extensive, though many of these locales have been physically transformed into economically productive agricultural regions. For instance, many of the prairies native to the U.S. Great Plains are now farmlands in the form of pasture, croplands, and rangelands. In the marine locations of the climate zone, particularly on the western coasts, vegetative cover can become more patchy and sparse. As an example, in Mediterranean biomes located within this climate zone, chaparral vegetation is abundant. The warmer, drier climate of these areas has resulted in larger human populations than those found in the grasslands. Wetlands (e.g., swamps and marshes) are unique environments that are also common across the midlatitude mild climate zone. In recent years, conservation and preservation efforts are increasing to protect these areas from modifications of the land surface associated with increased human occupation and growing populations.

Large-Scale Weather and Climate Features

Variations from typical climate and weather conditions can prevail over the midlatitude mild climate zone with the influence of large-scale forcings and periods of anomalous weather. The El Niño/Southern Oscillation is an example of a large-scale forcing that can dramatically affect the climate of this zone and one that climatologists continue to investigate to better develop and understand these relationships. Other forcings include phenomena such as the North Atlantic Oscillation and volcanic eruptions. El Niño/Southern Oscillation impacts in this climate zone can influence widespread periods of below-average or above-average temperatures and precipitation. Marine locations, particularly on the North American west coast, can experience more significant impacts such as flooding, droughts, landslides, and severe storms. In higher latitudes, significant snowfalls can occur with El Niño and La Niña regimes. The impact on the economic conditions in this climate zone can also be severe, occasionally resulting in billions of dollars spent on long-term recovery.

Periods of anomalous weather that may or may not arise from large-scale forcings, such as hurricanes, tornadoes, floods, and droughts, can have a great impact on the climate and weather of the midlatitude climate zone. Hurricanes generating in the lower latitudes between June and November migrate into these regions, often growing in strength before they hit land. High winds and storm surges come with intense rainfall and can produce flooding in coastal areas as well as widespread damage, as prominently seen with Hurricane Katrina in 2005. Tornadoes, which are unique to this climate zone, develop in minutes but also leave long-term impacts on the areas they move across. Typically, tornadoes and severe thunderstorms develop over continental interior locations in the summer months. However, it is not uncommon to see tornadoes develop around warmer coastal locations that experience rapidly moving air masses, leading to abrupt changes in atmospheric stability. Though floods are common with hurricanes, they can also affect areas of the midlatitude mild climate zone wherever heavy rains are abundant, particularly for long periods of time. During the spring season, flooding can



The vegetation of the midlatitude mild climate zone reflects the moderate temperatures and relative wealth of moisture across the region. Pictured here is Orange County Park in Warwick, New York.

Source: Morguefile.

occur in higher-latitude locales as winter snow packs melt, rainfall becomes more prevalent, stream flow peaks, and the ground remains saturated for lengthy intervals. Droughts can occur anywhere within this climate zone but are often more of a threat to locations that remain drier throughout the year. Summertime is usually when the onset of droughts is experienced. These periods of anomalous climate can last from months to years and cause dangerous forest fires, depleted water supplies, enhanced erosion, and desertification.

Climate Change

Future climate changes in the midlatitude climate zone are uncertain, though several areas

are considered to be more at risk, with the threat of a warmer climate and changes to the normal moisture regimes of the climate zone. Coastal areas appear to be the most vulnerable to a changing climate, particularly with regard to rising sea level. In addition, the most productive agricultural areas of this climate zone may change. It is hypothesized that higher-latitude locations that experience warming may have longer growing seasons and may be able to grow crops that cannot thrive at present with the lower temperatures than the future predictions. This means that these areas might look forward to heightened total agricultural production. Variations in precipitation amounts, and possibly intensity, could lead to a change in the vegetative



cover and duration of green foliage throughout the climate zone. In addition, storm track movements could vary somewhat from normal if polar and tropical air masses became more prominent in the higher latitudes.

Melissa L. Malin

See also **Biome: Midlatitude Deciduous Forest; Climate: Midlatitude, Severe; Climate Types; Climatology**

Further Readings

- Barry, R. G., & Chorley, R. J. (2003). *Atmosphere, weather and climate* (8th ed.). New York: Routledge.
- Botkin, D. B., & Keller, E. A. (2007). *Environmental science: Earth as a living planet* (6th ed.). Hoboken, NJ: Wiley.
- Christopherson, R. W. (2006). *Geosystems* (7th ed., pp. 276–281). Upper Saddle River, NJ: Pearson Prentice Hall.
- Gill, A. E. (1982). *Atmosphere: Ocean dynamics*. San Diego, CA: Academic Press.
- Lutgens, F. K., & Tarbuck, E. J. (2004). *The atmosphere* (9th ed., pp. 415–455). Upper Saddle River, NJ: Pearson Prentice Hall.
- Lydolph, P. (1985). *The climate of the Earth*. Totowa, NJ: Rowman & Allanheld.



CLIMATE: MIDLATITUDE, SEVERE

Severe climates of the midlatitudes include humid continental and subarctic climates. These climate types are typified by harsh winters and large annual temperature ranges due to continentality. Because the climate types are constrained to latitudes between about 40° and 70° within large land areas, they are not found in the Southern Hemisphere, where there is very little land area at these latitudes. They are restricted to Europe, Asia, and North America and include a significant proportion of the global population.

Both the subarctic and the humid continental climate subtypes have no true dry season, receiving

precipitation throughout the year. Many places receive more precipitation in the summer than in the winter, usually as a result of local convection or midlatitude cyclones. Winter precipitation arrives mostly as snow and is predominantly the result of cyclonic activity. Humid continental and subarctic climates correspond to the Köppen climate type known as “microthermal,” with the letter designation “D” (Figure 1).

Humid Continental

Regions with a humid continental climate have a large annual temperature range and four distinct seasons with mild to hot summers and long, severe winters. Humid continental is more temperate than the subarctic type due to its lower latitudes, around 40° N to 55° N. Mean annual precipitation typically ranges from 50 to 100 cm (centimeters), or 20 to 40 in. (inches), but this average usually decreases with increasing latitude. Proximity to the shoreline also influences precipitation, so in the United States and Southern Canada, for instance, precipitation decreases with increasing distance from the Atlantic shoreline, demonstrating reduced moisture content in the atmosphere.

Humid continental climates have the Köppen letter codes of *Dfa*, *Dfb*, *Dwa*, and *Dwb*. *Dfa* and *Dwa* are characterized by hot summers, while *Dfb* and *Dwb* have mild summers. The “f” and “w” refer to precipitation, with “f” meaning consistent monthly precipitation (≥ 6 cm) and “w” meaning a relatively dry winter season.

In the hot summer zones (*Dfa* and *Dwa*), January temperatures typically average below 0 °C (32 °F) and July temperatures average between 18 °C (65 °F) and 24 °C (75 °F). Weather in the summer is often humid, and severe thunderstorms that produce hail and/or tornadoes can occur. North of these zones are areas with mild summers (*Dfb* and *Dwb*). Here, the warmest months do not exceed 22 °C (72 °F) on average, and winters are more severe, with greater amounts of snowfall.

A large proportion of the population of the United States, Canada, Eastern Europe, and Asia live in humid continental climates, mostly along the eastern part of these continents. Humid continental regions with hot summers include the Eastern and Midwestern United States, from the Atlantic coast to approximately the

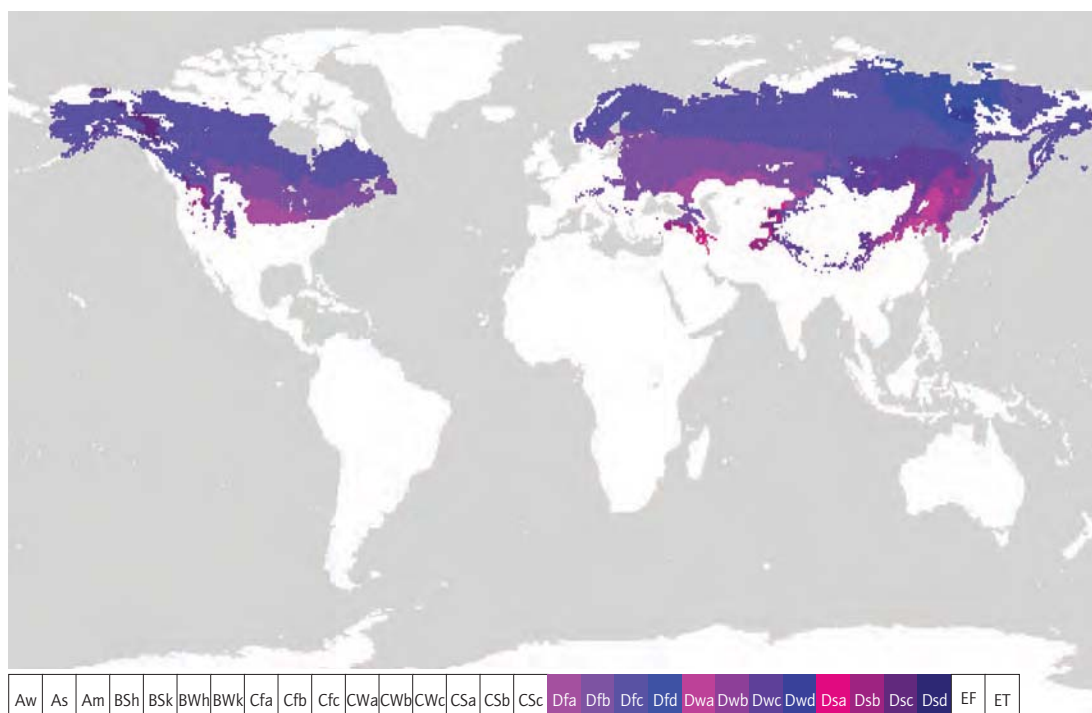


Figure 1 World Köppen map of microthermal “D” climates. Humid continental and subarctic climates are only found in the Northern Hemisphere. Subarctic climates are the more severe of the two since they are north of humid continental climates.

Source: From *Köppen classification worldmap D*. (2006). Retrieved January 10, 2010, from http://commons.wikimedia.org/wiki/File:Köppen_classification_worldmap_D.png. Reprinted with permission.

100th meridian; East Central Europe; Northern China; and Northern Korea. Regions with mild summers include the New England and Great Lakes regions of the United States, South and Central Canada, Scandinavia, Eastern Europe, and Russia.

The humid continental climate supports a diversity of ecosystems present in certain biomes. Humid continental biomes include midlatitude deciduous forests and midlatitude grasslands. Where midlatitude deciduous forests are present, climate conditions afford enough moisture to support tree growth. The seasonality present in this climate corresponds to the seasonal cycle of deciduous trees, in which the leaves change color and fall in the autumn and regrow in the spring. In the summer months, a dense canopy of broad-leaf trees forms an almost continuous canopy. In

the Eastern United States, dominant tree species found in deciduous forests include maple, oak, hickory, sugar maple, aspen, poplar, cottonwood, and elm, among others.

Midlatitude grasslands are found in the drier humid continental regions (*Dfa*, *Dwa*) or where there is a local factor that reduces available moisture. For example, the Great Plains of the United States are located in the rainshadow of the Rocky Mountains, so the climate favors grass over trees due to decreased precipitation. In general, grasslands found in this climate type are usually in the interior of continents, far from moisture sources. These grasslands provide an almost continuous cover of grass and flowering plants, which lie dormant in the winter and sprout in the spring. Fire is common in the grassland biome, and the ecosystem is adapted to it. Before European settlers began



suppressing fire, it kept trees and woody shrubs from growing, maintaining an ideal habitat for grazing animals such as bison. Now that fire has been suppressed for many decades, trees and shrubs are expanding into the periphery of grasslands.

Animals living in these biomes usually hibernate in winter and live off the land in the other seasons. Many animals are camouflaged to blend into the biome they are adapted to. Examples of midlatitude or temperate forest animals found in North America are brown bears, beavers, deer, raccoons, and opossums. Smaller animals and insects include earthworms (also abundant in grasslands), snakes, scorpions, newts, and frogs, to name a few. The forest is an inviting habitat for many bird species such as eagles, hawks, owls, cardinals, woodpeckers, and sparrows. Grassland animals are adapted to windy, dry conditions. They are grazers, burrowers, and predators. Grasslands support a diversity of animals, including invertebrates such as grasshoppers and beetles and mammals such as gophers, antelopes, and coyotes.

Climate and vegetation determine the dominant soils of a location, and in humid continental regions, alfisols and mollisols are the dominant soil types. Alfisols correspond to midlatitude forests and mollisols to midlatitude grasslands. Both soil types (especially mollisols) are appealing for agriculture, because they have a high clay content and can retain nutrients and moisture. Because of the combination of a humid climate and rich soils, many grasslands and forests found in this climate have been cleared and plowed for farmland. The Corn Belt of the Midwest is located within this climate region (mostly with hot summers), and soybeans, alfalfa, and hay are familiar crops in addition to corn. Humid continental locations with mild summers support crops such as potatoes, wheat, and peas.

Subarctic

Subarctic climates are located north of humid continental climates at about 50° N to 70° N and occupy the northernmost extent of midlatitude severe climates. More than half of Canada and Alaska and much of Russia have a subarctic climate. Summer temperatures are quite cool, cooler than in humid continental regions. A more drastic difference is the extremely cold winter

temperatures, where in some locations they can remain below freezing for up to 7 mos. (months). The annual temperature range is greatest in this climate than in any other due to its high latitudinal location and vast changes in insolation throughout the year. In the summer months, daylight hours increase when the North Pole tilts toward the sun, with an average day lasting 17 to 22 hrs. (hours). In the winter, when the North Pole tilts away from the sun, nights last 18 hrs. or more.

Even though there are four seasons in this climate, it is characterized by a mild summer, a long, harsh winter, and very brief periods of spring and autumn. Summer is very brief, lasting from only 1 to 3 mos. Summer temperatures average around 10 °C (50 °F). Winter arrives as early as October, and some areas experience average monthly winter temperatures of less than -15 °C (5 °F) for as long as 3 to 4 mos.

Precipitation is also lower than in humid continental regions, usually ranging from about 12 to 50 cm (5–20 in.) annually. Summers are wetter than winters, as almost all the annual precipitation falls as rain during this season. The source of summer precipitation is primarily due to poleward migration of midlatitude cyclone tracks. The other months are quite dry, as the area is dominated by cold, dry air masses caused by a polar high-pressure system, resulting in little precipitation. In some years, snow may accumulate to depths of up to 1 foot or more, persisting because of the bitterly cold winters.

Köppen symbols for the subarctic regions include *Dfc*, *Dfd*, *Dwc*, and *Dwd*. The *Dfc* and *Dfd* Köppen subtypes describe a subarctic climate with a severe winter, cool summer, and no dry season. In contrast, the *Dwc* and *Dwd* both have dry winters, with *Dwd* and *Dfd* having the coldest winters. *Dwc* is found only in far Eastern Russia and is only distinguished from *Dfc* due to winter drought. *Dwd* and *Dfd* are only found in extreme northeastern Siberia, with the coldest months averaging below -38 °C (-36.4 °F). Thus, *Dfc* is by far the most common subcategory of subarctic climates. It is found in a wide belt across North America and Eurasia. Here, there is year-round precipitation and temperatures above 10 °C (50 °F) for 1 to 4 mos. of the year.

A common characteristic of subarctic climates is permafrost, permanently frozen subsoil. During



brief summers, the upper layers of soil thaw to depths of 1 to 4 m (meters), or 3 to 12 ft. (feet). The portion that remains frozen year-round is permafrost. Since water cannot penetrate frozen soil, the soil becomes waterlogged, forming bogs and swamps during the summer months. Massive populations of black flies and mosquitoes explode at this time, providing food for numerous bird species. Plants that have been dormant through the cold months explode with growth, accessing the meltwater during the short growing season.

Soils found in the subarctic are inceptisols, gelisols, and spodosols. Inceptisols—young, undeveloped soils—form chiefly through mechanical processes such as frost action and glacial grinding. Spodosols correspond to areas with conifer trees. The plant litter from the trees is very acidic, which causes nutrients to be leached out of the soil. Usually found north of spodosols, gelisols are associated with cold climates with permafrost within 2 m of the surface. Because these soils develop very slowly due to cold temperatures, gelisols contain vast amounts of organic matter.

One biome associated with subarctic climates is the boreal forest, or taiga. It is characterized by coniferous trees with needle-shaped leaves with primarily mosses and lichens on the forest floor. Evergreen tree species found in the taiga include the jack pine, balsam fir, white and black spruce, larch, fir, and pine as well as deciduous species such as birch, aspen, willow, and rowan. Most of the region's trees are xerophytes, or plants adapted to dry conditions. Where soils are too saturated to sustain tree growth, the landscape is covered by peat, grasses, and sedges. Some tundra is found at the periphery of subarctic climates, but it is most common in Köppen's E climate (polar). Tundra is usually found north of the taiga, where tree growth is restricted by cold temperatures and a short growing season.

Animal life in the tundra is less abundant than in the midlatitude forests and grasslands further south. Subarctic animal habitants include caribou, fox, otter, mink, ermine, squirrel, lynx, sable, moose, bears, reindeer, and the wolf. Few people live in this region, and those who do may rely on trapping, as animals in the region grow heavy fur pelts for warmth.

Subarctic climates are not advantageous for human settlement since the growing season is

short and the soils are poor for agriculture. The scarce population of the region makes a living by trapping, mining, logging, and fishing. Further difficulty arises when attempting to build atop permafrost. Heat loss from buildings must be mitigated to avoid melting the surrounding subsoil. Melting permafrost under buildings causes their collapse. Therefore, building in subarctic regions is very expensive and challenging, so there are few cities found here, and they are generally small with few roads and no railways connecting them. Because of this, transportation is limited to helicopters, airplanes, and, in the summer, boats. The largest city in this climate is Murmansk, Russia, with a population of more than 300,000. This extreme northwestern seaport of Russia remains icefree year-round due to the North Atlantic Ocean current. Many settlements in the subarctic region occur where the climate is modified by an ocean current, making the climate milder than it would be in a continental location.

Trish Jackson

See also Biome: Boreal Forest; Biome: Midlatitude Deciduous Forest; Biome: Midlatitude Grassland; Biome: Tundra; Climate: Midlatitude, Mild; Köppen-Geiger Climate Classification; Permafrost; Soils; Wetlands

Further Readings

- Aguado, E., & Burt, J. E. (1999). *Understanding weather and climate*. Upper Saddle River, NJ: Prentice Hall.
- Arbogast, A. F. (2007). *Discovering physical geography*. Hoboken, NJ: Wiley.
- Blue Planet Biomes. (2009). *World climates*. Retrieved June 3, 2009, from www.blueplanetbiomes.org/climate.htm
- Enchanted Learning. (2009). *Biomes*. Retrieved June 3, 2009, from www.enchantedlearning.com/biomes
- McKnight, T. L., & Hess, D. (2000). Climate zones and types: The Köppen system. In *Physical geography: A landscape appreciation* (pp. 200–201). Upper Saddle River, NJ: Prentice Hall.
- Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth Systems Science*, 11, 1633–1644.



CLIMATE: MOUNTAIN

Climate is the fundamental factor driving the natural environment, setting the stage on which all physical, chemical, and biological processes operate. The influence of climate on environmental processes is exaggerated in mountains. Immense environmental gradients occur over short distances as a result of the diverse topography and highly variable nature of the energy and moisture fluxes in mountains. Nevertheless, predictable patterns and characteristics are found within these heterogeneous systems; for example, temperatures normally decrease with elevation, while cloudiness and precipitation increase; it is usually windier in the mountains, the air is thinner and clearer, and solar radiation is more intense.

Mountains themselves, by acting as a barrier and elevated surface, affect regional climate and modify passing storms. Their influence may be felt for hundreds of kilometers, making the surrounding areas warmer or colder, or wetter or drier than they would be in their absence. The exact effect of the mountains depends on their location, size, and orientation with respect to the moisture source and direction of the prevailing winds.

Mountain climates occur within the framework of the regional climate and are controlled by the same factors, including latitude, prevailing winds, altitude, continentality, and the character of regional storms.

Latitude

The distance poleward from the equator governs the angle at which the sun's rays strike the Earth, the length of the day, and thus the amount of solar radiation arriving at the surface, which dictates temperatures. In the tropics, the sun is always high overhead at midday, and the days and nights are of nearly equal length throughout the year. With increasing latitude, however, the height of the sun changes during the course of the year, and days and nights become longer or shorter depending on the season.

The distribution of mountains in the global circulation system, which has a strong latitude distribution, dictates their basic climate. Mountains near the equator are under the influence of the

equatorial lows and receive daily precipitation on their east-facing windward slopes. In contrast, mountains located around 30° latitude experience considerable aridity. Further poleward, mountains receive heavy winter precipitation on westward slopes facing the prevailing westerlies. Polar mountains are cold and dry year-round.

Continentality

The relationship between land and water has a strong influence on the climate of a region. Water heats and cools more slowly than land, so the temperature ranges between day and night and between winter and summer are smaller in marine areas than in continental areas. Generally, the more water dominated an area is, the more moderate its climate. An extreme example is a small oceanic island, on which the climate is essentially that of the surrounding sea: a marine climate. The other extreme is a central location on a large land mass such as Eurasia, far removed from the sea: a continental climate with hot summers and cold winters.

Altitude

Essential to mountain climatology are the changes that occur in the atmosphere with increasing altitude, principally the decrease in temperature, air density, water vapor, carbon dioxide, and aerosols and the increase in cloudiness, precipitation, and solar energy received during clear-sky conditions. The sun is the ultimate source of energy, but little heating of the atmosphere takes place directly. Rather, solar radiation passes through the atmosphere and is absorbed by the Earth's surface, which then reradiates infrared radiation, which heats the atmosphere from the bottom up (i.e., the greenhouse effect). Mountains are part of the Earth, too, but they present a smaller land area at higher altitudes in the atmosphere, so they contribute less to heating the atmosphere above them. A mountain peak is analogous to an oceanic island in the continentality effect. The smaller the island and the farther it is from large land masses, the more its climate will be like that of the surrounding sea. In contrast, the larger the island or mountain area, the more it modifies its own climate. This mountain mass effect can be a major factor in the regional climate.



Looking up Fisher Creek at Fisher Peak, located in North Cascades National Park, Washington. This landscape demonstrates the variety of different slope angles and aspects, rock types, active geomorphic surfaces, and different vegetation communities in a few square kilometers of area in a typical mountain environment. Noticeable aspect influence is seen on slope processes and vegetation. The south-facing slope (*left*) has more vegetation cover due to warmer temperatures and exposure to sun. The north-facing slope (*right*) has less vegetation and more active talus slopes, due to more vigorous freeze-thaw activity.

Source: Author.

The density and composition of air controls its ability to absorb and hold heat. The density of the air at sea level (standard atmospheric pressure) is generally expressed as 1,013 mb (millibars), or 760 mm (millimeters) or 29.92 in. (inches) of mercury. Near sea level, pressure decreases at the rate of approximately 1 mb/10 m (meters), or 30 mm/300 m or 1 in./1,000 ft. (feet) of altitude. Above 5,000 m (20,000 ft.), atmospheric pressure begins to fall off exponentially.

The ability of air to hold heat is a function of its density. At higher altitudes, air molecules are spaced farther apart, so there are fewer molecules in a given parcel of air to receive and hold heat. Similarly, the composition of the air changes rapidly with altitude, losing water vapor, carbon dioxide, and suspended particulate matter. These

constituents, important in determining the ability of the air to absorb heat, are all concentrated in the lowest reaches of the atmosphere. Water vapor is the chief heat-absorbing constituent, and half of the water vapor in the air occurs below an altitude of 1,800 m (6,000 ft.). It diminishes rapidly above this point and is barely detectable at altitudes above 12,000 m (40,000 ft.).

Solar Radiation

The influence of the sun on temperatures becomes more exaggerated and distinct with elevation. The time lag, in terms of energy flow, between inputs and temperature change is greatly compressed in mountains. The alpine environment has perhaps the most extreme and variable radiation climate

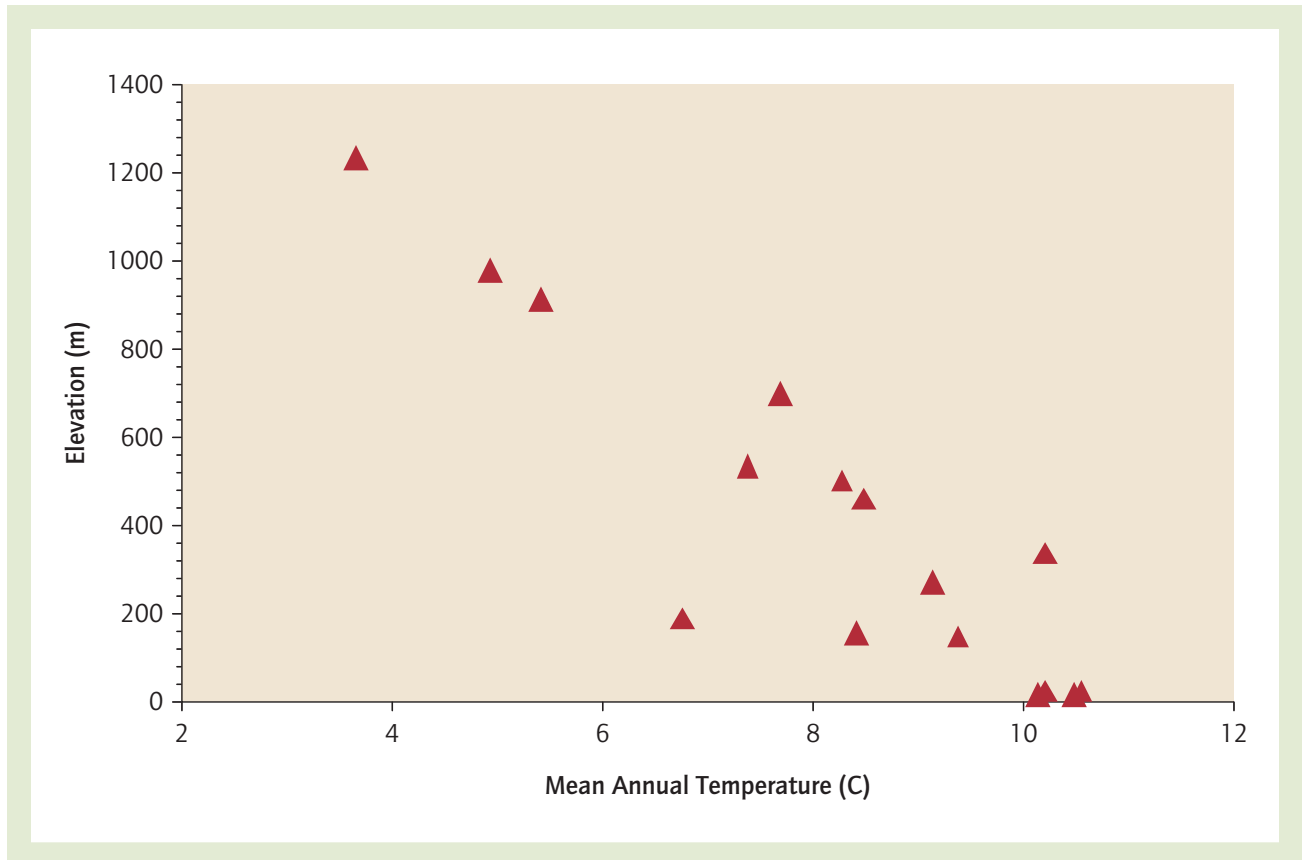


Figure 1 Mean annual temperatures from a number of stations throughout the North Cascades range of Washington

Source: Created by author with data from the National Climate Data Center, 1971–2000.

on Earth. The thin clean air allows very high solar intensities, and the topographically complex landscape provides surfaces with a range of different exposures, reflections, and shadowing from the nearby peaks. Although the air next to the ground may heat up very rapidly under the direct rays of the sun, it may cool just as rapidly when the sun is blocked. The most striking aspect of the vertical distribution of solar radiation in the atmosphere is the rapid depletion of short-wavelength energy at lower elevations. This attenuation results from the greater density of the atmosphere in the lower troposphere. Thus, the alpine environment receives considerably more ultraviolet radiation (UV) than the lower elevations.

The closer to perpendicular the sun's rays strike a surface, the greater their intensity. The longer the sun shines on a surface, the greater the heating that takes place. In mountains, every slope has a

different potential for receiving solar radiation. Mountains are composed of a wide range of surface types: snow, ice, water, grasslands, extensive forests of various types and coverages, desert shrub, and bare bedrock and soil (see Fisher Peak photo). This wide-ranging variety of surface characteristics affect the receipt of incoming solar radiation. Dark-colored features, including vegetation, absorb rather than reflect radiation, receiving increased amounts of energy. Snowfields, glaciers, and light-colored rocks have a high reflectivity (albedo), so that much of the incoming shortwave energy is reflected back into the atmosphere.

Temperature

The decrease of temperature with elevation is one of the most visceral and fundamental features of mountain climate (Figure 1). Change of



temperature with elevation is termed the *environmental lapse rate*, averaging 6.4 °C/1,000 m (3.5 °F/1,000 ft.), although values vary with season, time of day, and regional setting. While the general trend of declining temperatures is commonly observed, temperatures within mountains are found to be very heterogeneous due to the aforementioned solar radiation and albedo changes over small scales, the mountain mass, and the inversion effects.

Temperature inversions within valleys are the exception to the general rule of decreasing temperature with elevation. During a temperature inversion, the lowest temperatures occur in the valley bottom and increase up the slopes. Eventually, however, the temperatures will begin to decrease again, so that a warmer zone, the thermal belt, will experience higher night temperatures than either the valley bottom or the upper slopes. Inversions form as slopes cool at night, the heavier cold air begins to slide down the slope, flowing underneath and displacing the warm air in the valley. Temperature inversions are best developed under calm, clear skies, where there is no wind to mix and equalize the temperatures, and the transparent sky allows the surface heat to be rapidly radiated and lost to space. If the valley is blocked, a pool of relatively stagnant colder air may collect, but if the valley is open, there may be a continuous movement of air down the watershed.

Precipitation and Clouds

The increase of precipitation and clouds with elevation is well documented. This phenomenon is part of a complex of processes known as the orographic effect. As air is lifted over the mountains, it is cooled by expansion and mixing with cooler air at higher elevations (i.e., adiabatic processes) until condensation occurs and clouds form. This forced ascent of air is most effective when mountains are oriented perpendicular to the prevailing winds and when the slopes are steeper. Mountains also act to block/dam storms, slowing their progress and allowing longer-duration precipitation events.

While heavy precipitation occurs on the windward side of mountains, the leeward side typically receives considerably less precipitation because the air is descending with much of the

moisture already removed. This creates the rain-shadow effect—an arid area on the downwind side of mountains. As the air is forced to descend, it will be heated by compression (adiabatic heating) and will lead to clear, dry conditions. This is a characteristic phenomenon on the lee side of mountains and is responsible for the famous foehn or chinook winds.

Despite these useful generalities, many local and regional variations in precipitation occur within mountains. Complex local topography creates funneling effects (i.e., through passes) that can increase atmospheric moisture content and precipitation, even downwind from the funnel. High peaks or ridges within a range can create “mini-rain-shadow” zones even in the center of a high range. Significant quantities of precipitation can fall on the lee side of mountains because of spillover effects.

A number of cloud forms are unique to mountain environments. All of them are stationary clouds, which continually form on the upwind edge and dissipate on the lee edge of the cloud, thus appearing to remain in the same location for long periods. A cap or crest cloud forms over the top of an isolated peak or ridge. They resemble a cumulous cloud, although they may be streamlined or have streamers of cirrus forms. Banner clouds are cap clouds that extend downwind from the peak like a flag waving in the wind. Lenticular clouds are lens-shaped clouds formed in regularly spaced bands parallel to the lee side of a mountain barrier (see Mt. St. Helens photo). These streamlined cloud features are formed by the interaction of high-velocity winds with the mountain barriers.

Winds

Mountains are among the windiest places on Earth. They protrude relatively high into the atmosphere, where there is less friction to retard the air movement. The wind is usually greatest on mountains oriented perpendicular to the prevailing wind, on the windward rather than the leeward side, and on isolated, unobstructed peaks rather than those surrounded by other peaks. The reverse situation may exist in valleys, since those oriented perpendicular to the prevailing winds are protected, while those oriented parallel to the wind



Looking southeast at Mt. St. Helens in October 2004 at sunrise. The clouds are lenticular clouds forming as winds blow right to left over the mountain.

Source: Author.

may experience even greater velocities than the peaks, owing to funneling and intensification.

Winds that blow upslope and up the valley during the day and downslope and down the valley at night are common. The driving force for these winds is differential heating and cooling, which produces air density differences between slopes and valleys and between mountains and adjacent lowlands. During the day, slopes are warmed more than the air at the same elevation in the center of the valley; the warm air, being less dense, moves upward along the slopes. Similarly, mountain valleys are warmed more than the air at the same elevation over adjacent lowlands, so that the air begins to move up the valley. At night, when the air cools and becomes dense, it moves downslope and down the valley under the influence of gravity. This flow is responsible for the development of temperature inversions.

Slope winds consist of thin layers of air, usually less than 100 m (330 ft.) thick, and can be as thin as a few centimeters. In general, the upslope

movement of warm air during the day is termed *anabatic flow*, and the downslope movement of cold air during the night is referred to as *katabatic flow*, or a gravity or drainage wind. Katabatic winds, in the strict sense, are local downslope gravity flows caused by nocturnal radiative cooling near the surface under calm, clear-sky conditions or by the cooling of air over a cold surface such as a lake or glacier. Since slope winds are entirely thermally induced, they are better developed in clear weather than in cloudy weather, on sun-exposed rather than on shaded slopes, and in the absence of overwhelming synoptic winds. Local topography is important in directing these winds; greater wind speeds will generally be experienced in ravines and gullies than on broad slopes.

Foehn Wind

Of all the ephemeral climatic phenomena of mountains, the foehn wind (pronounced “fern” and sometimes spelled *föhn*) is the most intriguing.



Similarly formed winds have local names worldwide, including “chinook” in North America. The foehn, known in the Alps for centuries, is formed as synoptic winds blow over a mountain crest and down the lee side, where it is heated adiabatically. Many legends, folklore, and misconceptions have arisen about this warm, dry wind that descends with great suddenness from mountains. They are, however, responsible for rapidly melting the snow (occasionally resulting in flooding) and increasing the incidence of fires.

Microclimates

In addition to the climatic characteristics reviewed above, it should be emphasized that there are substantial variations in climates over very short distances within mountains. Mountain environments are exceedingly spatially complex in terms of vegetation types and structures, disturbances, geology, hydrology, soils, and topography (see Fisher Peak photo). All vary in composition (i.e., species, canopy characteristics, or rock types), and variations occur across a range of slopes and aspects. The climate over each of these surfaces, or microclimates, can differ significantly because of variations in net radiation, soil and air temperature, humidity, precipitation accumulation (amount and form), soil moisture, and winds. The thin atmosphere at high elevation means that surfaces facing the sun on a clear day can warm dramatically, while shaded surfaces remain cold. Other effects may arise according to valley orientation with respect to the mountain range, valley cross-profile, and the effect of winds and cold air drainage. These steep environmental gradients (both elevational and spatial) result in the juxtaposition of diverse vegetation assemblages with narrow ecotones.

The resolution of most weather station networks in mountains is far too coarse to capture the spatial variability of microclimates in mountains. Maps of climatic variables are often interpolated from existing meager data sets, using assumed or empirical relationships with elevation. These models are unable to demonstrate local deviations in trends, and when combined with map scale, microclimates are typically eliminated from most maps of mountains.

Climate Change and Variability

Temporal variability of climate is an important natural component of the Earth’s climate system. Climatic variability (i.e., occurrence of certain climatic events) is different from climatic change, which is a permanent change in climatic conditions. However, changes in variability are one likely consequence of climatic change. All temporal climate records demonstrate some degree of interannual variability. Every mountain location has its record high and low temperatures, snowfall, rain event, drought, and wind speed. Temperature, precipitation, and the resulting runoff are often related to distant forcing mechanisms, such as the El Niño/Southern Oscillation. Several other periodic, yet chaotic, perturbations to the climate system have been linked to increased climatic variability.

Mountain and glacier environments are especially sensitive to climate changes and variability. Many climate changes have been detected in mountain records, as illustrated by the glacial and interglacial climates of the Pleistocene, by the Holocene glacial fluctuations, and over the period of instrumental records. The current general scientific consensus is that global climate is in the process of warming due to anthropogenic inputs of greenhouse gases into the atmosphere. Different magnitudes of warming, and even cooling, are predicted for different mountainous regions of the world. Precipitation, in particular, is predicted to both increase and decrease in different regions because of changes in general circulation. In mountains, higher temperatures will cause a higher percentage of annual precipitation to fall as rain (i.e., higher snowlines) as well as accelerate summer ablation. Longer snowfree periods will increase the evaporative demands and lower the soil moisture, increasing the dominance of drought-tolerant species. Climate models in mountainous regions, however, tend to be rather poor because of coarse resolution, topographic smoothing, and local effects not captured by the models.

Warming temperatures will lead to reduced snow pack, glacial recession, and altered downstream runoff characteristics (i.e., seasonality and magnitude) over the next several decades. If glaciers entirely disappear from mountains, then the melt season, especially the late melt-season



discharge, will decrease substantially. Changes to mountain hydrology will have significant consequences not only in the mountains themselves but also in the populated lowlands that depend on the runoff as a water resource.

In addition to external (i.e., global) climate change, mountains are subject to a variety of internal disturbances that influence climate. Among the major natural disturbances are fire, landslides, floods, and insect infestations. The spatial and temporal patterns of these disturbances have been altered by human activities, as well as the added impacts of settlement, timber harvest, exotic species introductions, and the damming of rivers. Small-scale disturbances increase the landscape and climate heterogeneity, while large-scale disturbances, such as those caused by humans (especially agriculture), act to homogenize mountain environments.

Climate change is considered a major threat to mountain ecosystems. Since many organisms living in mountains survive near their tolerance range for climatic conditions, even minor climatic changes could have a significant impact on alpine ecosystems. Vegetation zones will migrate altitudinally in response to warming temperatures, possibly eliminating some biomes, although the adaptations will likely be more complex. Because mountain tops are smaller than their bases, biomes shifting upslope will occupy smaller and more fragmented areas, reducing populations and increasing genetic and environmental pressures.

Andrew J. Bach

See also **Adiabatic Temperature Changes; Atmospheric Circulation; Biota and Topography; Chinooks/Föhn's; Climate Change; Climate Types; Glaciers; Mountain; Wind**

Further Readings

- Barry, R. G. (2008). *Mountain weather and climate* (3rd ed.). Cambridge, UK: Cambridge University Press.
- Whiteman, C. D. (2000). *Mountain meteorology: Fundamentals and applications*. Oxford, UK: Oxford University Press.



CLIMATE: POLAR

Polar climates are the result of low total solar energy receipt but large seasonal variations in solar energy receipt at the Earth's North and South poles. In summer, incoming solar radiation greatly exceeds outgoing terrestrial radiation during the 24-hr. (hour) polar day, while in winter, the reverse occurs during the 24-hr. polar night. In addition, the high albedo coefficient (the parameter characterizing the diffused reflection of sunlight from the surface of an object) of snow and ice covers in polar areas results in even less solar energy receipt. As a result, solar radiation receipt above the 60th degree of latitude is two to ten times smaller than in the tropical climatic zone.

The regions of high latitudes vary geographically. They are represented by extensive land areas, such as parts of the Asian and North American continents, the huge ice sheets of Greenland and Antarctica, as well as the different oceanic masses, frequently covered by sea ice, occurring around the Antarctic continent or in the vicinity of the North Pole. Thus, the climate of different parts of the polar provinces depends on its location and the type of the substratum. Although there is no question about the astronomical delimitation of polar areas due to their location above the polar circles (66°33'39", on both the Northern and the Southern Hemispheres), the climatic and environmental conditions are much more diversified, moving the border of the region either to the north or to the south.

The Arctic

The limits of the Arctic are marked by the 10 °C isotherm of July (the warmest month of the year in the Northern Hemisphere). Another criterion is the boundary of 15 kcal/cm²/yr.⁻¹ (kilocalories per square centimeter per year), or 62.7 kJ cm²/yr. (kilojoules per square centimeter per year). This zone corresponds to the transition between the taiga and tundra ecosystems, and its position fluctuates between 50° N and 70° N. In such a range, the influences of harsh climatic conditions extend over an area of almost 27 million km² (square kilometers). The inner part of the region, delimited with the 5 °C isotherm of



The glacial mountains of Spitsbergen, Norway's most northern territory

Source: Morguefile.

July, is called the high Arctic, with the landscape dominated by herbaceous and bare-ground tundra (with a majority of lichens and mosses) and polar desert.

Polar climates can be identified as either maritime or continental. In the Northern Hemisphere, the warm Norwegian Current of the Northern Atlantic provides significant energy fluxes into the adjacent polar land masses. The current flows along the Scandinavian coast and then continues far into the north. Mild maritime influences are observed up to the 80° latitude, and sea ice does not accumulate along most of the Norwegian and Svalbard coasts. Typically (e.g., the Bear Island on the Northern Atlantic), monthly average temperatures oscillate between -10°C in February and 5°C in July. In the coastal areas of the inner part of the Arctic Ocean, temperatures in winter drop down to about -30°C due to the presence of sea ice, but in summer, the temperatures are still under the control of the open sea and reach 5°C (e.g., Barrow in Alaska and Tiksi in the northeastern Siberian coast).

The most continental climates, with the highest yearly temperature ranges, appear far inland within the Siberian region, where monthly average temperatures in January reach almost -50°C and in July can reach 15°C . Furthermore, the lowest registered air temperatures in the Northern Hemisphere (officially -69.8°C), caused by cold air stagnation in the valleys (temperature inversions) as in Verkhoyansk and Oymyakon, occur in polar climates. In parts of the Arctic, air temperatures rarely rise above 0°C . Over the high Greenland ice sheet, they range between -60°C in winter and -12°C in summer, and in the Arctic interior, temperatures might rise in the latter season to up to 0°C because heat exchange between the ocean and the atmosphere through the permanent but partly loosened sea ice cover provides an avenue for energy transfer.

Precipitation in the Arctic is usually low. In most regions, the annual precipitation total does not exceed 500 mm (millimeters); however, in southeastern Greenland, precipitation totals reach at least 1,200 mm/yr. (year) and can go up to 2,000



mm/yr. In other parts of the Arctic, precipitation totals are determined by distance from a coast and the advection of humid air masses across the Arctic. As a result, the driest parts (polar desert), with yearly precipitation less than 200 mm, are located in the central area of the Arctic interior, the Northern Canadian region, and continental Siberia. At the sea ice edge and along coastal areas, precipitation rises to 400 mm/yr. and even more in higher-located mountain massifs such as the Alaska or the Scandinavian range. Seasonally, winter precipitation dominates, with more than 90% in the form of snow, while in the summer period, up to 60% might be liquid. In coastal areas, fog is typical, whereas visibility is typically better in the dry, non-polluted inland areas.

Thermal and precipitation conditions in the arctic and subarctic regions depend on penetration into these regions of extratropical cyclones (rare) and the formation and path of polar cyclones and anticyclones. The semipermanent high-air-pressure systems located over the polar sea ice and the polar continental areas typically inhibit the penetration of warm air masses into the polar regions. However, beyond these regions, a dynamic zone of cyclone formation develops, especially in winter. Large thermal contrasts between the ice-covered areas and icefree oceans generate large air pressure gradients and strong winds. The maximum wind velocities that are observed in the Atlantic region may exceed 150 km/hr. (kilometers per hour), while in other areas they are up to 100 km/hr., with averages during nonstorm conditions in the range between 15 and 25 km/hr.

Antarctica

Difficulties in establishing and supplying permanent antarctic stations have resulted in few long-term studies of the antarctic climate. Delimitation of the area that experiences polar conditions in the Southern Hemisphere is based on circumantarctic oceanic-water individuality and biodiversity. In the Antarctic Convergence zone, between 48° S and 61° S, the cold antarctic shelf waters come into contact with the warmer waters of the three oceans—the Atlantic, the Pacific, and the Indian.

The whole of Antarctica—an area of about 52.5 million km²—includes the Antarctic continent and the so-called sub-Antarctic islands, such

as Falklands, South Georgia, and South Sandwich Islands, as well as those located further to the south, for example, South Shetlands and the Balleny Islands. Average monthly air temperatures fluctuate between 10 °C in January and 4 °C in July in the most outer maritime areas, at the latitudes south of the American continent. In the austral summer, in the coastal zone of the Antarctic Peninsula, temperatures reach 0 °C. Typically, the continental coastal regions lie within the isotherm −4 °C in January and −24 °C in July. However, in the central part of the Antarctic Plateau (Eastern Antarctica), temperatures below −28 °C in summer and −60 °C in winter are typical. The lowest temperature recorded in Antarctica—actually the lowest ever recorded on the surface of the Earth—was −89.2 °C on July 21, 1983, at Vostok Station—78°28'00" S, 106°48'00" E. In contrast, the highest temperature recorded on the Antarctic continent was 14.6 °C in Hope Bay (63°23'42" S, 56°59'46" W) and Vanda Station (77°31'00" S, 161°40'00" E) on January 5, 1974.

The circumpolar Antarctic belt of cyclones that migrates from west to east, a result of the very dry cold air masses that form over the glaciated Antarctic continental interior, descend to the coast and mix with the warmer, humid oceanic air masses on the periphery of the Antarctic, bringing midwinter thaws and precipitation to the coast. The very cold dry air can hold very little moisture, and consequently, precipitation totals of less than 50 mm/yr. are normal. Strangely then, most of the snowfall occurs in the coastal zones and in the surrounding archipelagos, where the total precipitation can reach 600 mm/yr. As a result, most of the snow accumulation in the center of Antarctica occurs as drifting snow blowing in from the coast, and thus, most of the continent is classified as a polar desert. The cold katabatic winds draining off the interior of Antarctica have been recorded at speeds of 327 km/hr. on July 1972 at the station Dumont d'Urville (66°39'46" S, 140°00'05" E). High-velocity winds (exceeding on average 50 km/hr.) are especially characteristic of the ice sheet surfaces sloping down to the coastal areas.

Climate Changes in Polar Regions

Contemporary weather data collected during the past century have shown enhanced warming in



the polar regions. It is hypothesized that much of this warming is due to (1) changes in global CO₂ (carbon dioxide) levels; (2) changes in the albedo of ice and snow; (3) faster heat transfer in cold and dry air masses, and (4) decreasing sea ice cover. In the 20th century in the Arctic, the fastest temperature rises were observed in the 1950s and over the past three decades, when in some regions (such as Central Siberia, Alaska), the temperature rise was estimated at 0.4 to 0.8 °C per decade; however, the western coast of Greenland and Baffin Bay region experienced a corresponding cooling. In Antarctica, the warming is especially noticeable in winter and in spring. The yearly average temperature values are at the level of 0.2 to 0.4 °C warmer per decade.

This warming has resulted in widespread glacial retreat, a decrease in the area extent of sea ice and in sea ice thickness in the Arctic Ocean basin, ice shelf collapse, the rise of the snowmelt line, and a shift in the northern tree limit. These processes have been accompanied by an increase in rainfall but not snowfall. Climate modeling predicts continued warming of polar areas. In some forecasts, the temperature in the Arctic will increase between 3 and 5 °C, with more warming in winter than in summer. Arctic sea ice cover is predicted to totally disappear in summer by the second half of the 21st century. The trends of climate changes in Antarctica, conditioned on the existence of a huge ice sheet, are not explicitly predictable.

Grzegorz Rachlewicz

See also **Albedo; Atmospheric Circulation; Atmospheric Energy Transfer; Climate Change; Ice; Poles, North and South**

Further Readings

- King, J. C., & Turner, J. (2007). *Antarctic meteorology and climatology*. New York: Cambridge University Press.
- Przybylak, R. (2003). *The climate of the Arctic*. Norwell, MA: Kluwer Academic.
- Serreze, M. C., & Barry, R. G. (2005). *The Arctic climate system*. New York: Cambridge University Press.



CLIMATE: TROPICAL HUMID

Tropical humid climate is one of several climate categories found on Earth. To understand it better, it is important to define the term *climate*. The climate of an area is the average characteristic condition of the atmosphere near the Earth's surface for at least 30 years. This includes the region's general pattern of weather conditions, seasons, and weather extremes such as hurricanes, droughts, or rainy periods. Various scientists classify climate differently based on different criteria, and the whole classification process is still inconclusive. Robert Christopherson classifies climate into six climate categories—namely, tropical, desert, mesothermal, microthermal, polar, and highland. Tropical climates are truly winterless. Understanding the dynamics of tropical humid climate is extremely important because it is Earth's most extensive climate category, occupying about 36% of the Earth's surface, including both ocean and land areas. This climate category comprises Earth's largest tropical rain forests and other biomes, which are very important sinks for atmospheric carbon, without which global warming will be enhanced.

Causes of Tropical Humid Climate

Tropical humid climates experience warm temperatures throughout the year because of the high angles of incoming solar radiation and nearly continuous penetration of moist air masses over these regions. Tropical climate regions are broadly constrained by the Tropic of Cancer to the north and the Tropic of Capricorn to the south. Persistent high angles of incident solar radiation within the tropics cause consistently high temperatures throughout the year as the solar radiation received per square meter is high. In the higher latitudes, the persistent lower angles of incident solar radiation result in less radiation received per square meter. While the humid air masses release heat to the environment through the condensation of water vapor, the main causal factors for tropical climate are the following:

1. Consistent day length of about 12 hours throughout the year



2. Persistent high angles of incident solar radiation
3. The passage of the intertropical convergence zone (ITCZ), which brings rain as it shifts seasonally following the location of the overhead sun
4. Unstable maritime air masses in the region (Although air masses of polar origin occasionally invade the tropical and equatorial zones, the tropical humid climate is almost wholly dominated by the tropical and equatorial air masses.)

Tropical humid regions are characterized by high rainfall totals in most months of the year. For rain to occur, there must be some mechanism for vertically lifting the humid air, referred to as “atmospheric lifting mechanisms,” so that the air is cooled and condensation occurs, forming clouds and rainfall. There are four types of atmospheric lifting mechanisms, the convergent, convectional, orographic, and air mass frontal processes. The convergent atmospheric lifting process occurs as air blown by southeast and northeast trade winds converges along the equatorial region, forming the ITCZ. As the rising air cools, clouds and rain develop. Areas under ITCZ have extensive air uplift, causing towering cumulonimbus cloud development and high annual precipitation. The convectional atmospheric lifting process occurs when air mass from a maritime source region passes over a warmer continental region. Such moist air is heated, becomes less dense and rises, condenses, and forms clouds and precipitation. The orographic atmospheric lifting process occurs when the physical presence of a mountain acts as a topographic barrier to the migrating air mass or the incoming maritime air, which forces the air to rise upslope. Again, as air rises, it cools and condenses into clouds and precipitation. Frontal atmospheric lifting is not very dominant in the tropics but does occur in some areas. In the frontal atmospheric lifting process, the cold front (the leading edge of an advancing air mass) conflicts with the warm air mass front, forcing the warm, less dense air mass to rise and resulting in clouds and precipitation, similar to the orographic atmospheric lifting process.

Characteristics and Classification of Tropical Humid Climatic Regions

Generally, the mean rainfall in the humid tropics is about three times the world average. The trade winds and the ITCZ are responsible for much of these totals. Tropical climates stretch northward to the tip of Florida and South to Central Mexico, Central India, and southeast Asia. The only interruptions of tropical climates across the equatorial region are the Andes of Central and South America, the volcanoes of the rift valley of East Africa, and the Himalayas of South Asia. These higher elevations experience lower temperatures. For instance, Mount Kilimanjaro is less than 4° south of the equator, but it is 5,895 m (meters), or 19,340 ft. (feet), above sea level and has permanent glacial ice on its summit. Such mountainous sites fall within the highland climate category. Rainfall amounts and temperature are used to classify the tropical humid climatic regions. Tropical humid climates can be classified into three distinct regimes or subcategories: (1) tropical rain forest (ITCZ present year-round), (2) tropical monsoon region/forest (ITCZ present for 6 to 12 mos. [months]), and (3) tropical savanna (ITCZ present for less than 6 mos.).

Tropical Rain Forest Climate

Tropical rain forest climate is hot and muggy year-round. It supports dense tropical rain forests. Rainfall is heavy and occurs as frequent showers and thunderstorms throughout the year. Average annual rainfall varies from about 70 to 100 in. (inches), or 175 to 250 cm (centimeters). Temperatures are high, and they change little during the year. The coolest month has an average temperature no lower than 18 °C (64 °F). The temperature difference between day and night is greater than the temperature difference between the hottest and colder months. Frost and freezing temperatures do not occur. Plants grow all year-round.

Tropical rain forest regions are dominated by maritime equatorial (mE) air masses. The wet equatorial belt with heavy rainfall occurs around the equator in the Amazon River basin, South America; in the Congo River basin, equatorial Africa; in much of the African coast from West Nigeria to Guinea; and in southeastern Asia. The



Tropical forest at Sachatamia, Ecuador, May 2005

Source: Courtesy of Mark Welford.

prevailing warm temperatures and high moisture content of the mE air mass favor abundant convective rainfall triggered by local heating and trade wind convergence. The thunderstorms peak each day from midafternoon to late evening inland and earlier in the day where marine influence is strong along the coastlines. Rainfall follows the migrating ITCZ, which shifts northward and southward with the position of the overhead sun throughout the year. Water surpluses are enormous, creating the world's greatest stream discharges in the Amazon and Congo rivers. High rainfall sustains lush evergreen broadleaf tree growth, producing the Earth's equatorial and tropical rain forests. The leaf canopy is so dense that little light diffuses to the forest floor, leaving the ground surface dim and sparse in plant cover.

Tropical Monsoon Climates

Tropical monsoon climatic regions are located between 5° and 25° north and south latitudes, which constitute a narrow coastal zone of the larger continents of America, Africa, and Asia. These regions receive more than 150 cm (60 in.) of annual precipitation. Rainfall brought by the ITCZ falls for 6 to 12 mos. of the year. The dry season occurs when the ITCZ moves away from the area. The coastal areas within the tropical rain forest belong to the monsoon climate category and usually experience seasonal variation of wind and precipitation. Mountains prevent the cold air masses from Central Asia from getting into the monsoon areas, resulting in its high average annual temperatures. Besides the Indian



subcontinent, tropical monsoon climate is experienced in northeastern Australia, Madagascar, and Central America, where trade wind coasts are found with moist maritime tropical (mT) air mass and heavy orographic rainfall. These climatic regions experience cool, dry and warm, wet weather.

Tropical monsoon forests comprise three, less distinct layers. With trees up to 30 m tall, the top canopy layer supports lianas, epiphytes, and climbing plants. The middle woody shrub layer reaches a height of 15 m. The ground layer of shrubs and undergrowth receives ample sunlight to support the growth of shrubs, ferns, and palms. The availability of sunlight allows the species in the forest floor to grow densely.

Tropical Savanna Climates

Tropical savanna climate occurs at latitudes 5° to 20° north and south globally, but in Asia, it occurs mostly between 10° N and 30° N, just south of the Himalayan ranges. Temperatures vary more in tropical savanna climates than in tropical rain forest regions. The tropical savanna regime can have two temperature maximums during the year because the sun moves between the equator and the tropics. The ITCZ reaches the tropical savanna climate regions for about 6 mos. or less of the year as it migrates with the overhead sun. Summers are wetter than winters because convectional rains accompany the shifting ITCZ when it is overhead. This produces a notable dry condition when the ITCZ is farthest away and high pressure dominates. Seasonal alternation occurs between dominance of moist mT and mE air masses along the ITCZ and dry continental tropical (cT) air masses of the subtropical high-pressure belt. As a result, there is a very wet season at the time of high sun and a very dry season at the time of low sun. Cooler temperatures accompany the dry season but give way to a very hot period before the rains begin. This climate occurs mostly in India, Indochina, West Africa, East Africa, Southern Africa, South America, both north and south of the Amazon lowland, and the north coast of Australia. Marked dryness from June to October defines the changing dominant pressure systems rather than annual changes in temperature.

There are actually two very different seasons in a savanna: a very long dry season (winter) and a

very wet season (summer). In the dry season, only an average of about 4 in. of rainfall occurs. Between December and February, no rain will fall at all. In the summer, there is a lot of rain. In Africa, the monsoon rains begin in May. An average of 15 to 25 in. of rainfall occurs during this time. It gets hot and very humid during the rainy season. Every day, the hot, humid air rises off the ground and collides with the cooler air above and turns into rain. In the afternoons in the summer savanna, the rain pours for hours.

Danielson R. Kisanga

See also **Atmospheric Moisture; Biome: Tropical Rain Forest; Climate Types; Monsoons**

Further Readings

- Fleischfresser, L. (1998). *Tropical climate modeling: Basic concepts and methods*. Berlin: Verlag.
- McGregor, G., & Nieuwolt, S. (1998). *Tropical climatology: An introduction to the climates of the low latitudes*. New York: Wiley.
- Michael, G. (2001). *Tropical rainforest*. Retrieved December 29, 2008, from www.blueplanetbiomes.org/rainforest.htm
- National Aeronautics and Space Administration. (2008). *Intertropical convergence zone*. Retrieved December 29, 2008, from <http://earthobservatory.nasa.gov/IOTD/view.php?id=703>



CLIMATE CHANGE

This entry reviews climate change records on all timescales—instrumental, historical, and geological—and their primary causes. The characteristics of glacial phases are detailed, followed by a discussion of the climate of the Holocene and the past millennium.

Changes of climate operate over all timescales. For convenience, we may recognize variations as decadal to century, millennial, 10^4 to 10^6 yrs. (years), and $\geq 10^8$ yrs., each with its dominant forcing factors. Solar variability, volcanism, and changes in atmospheric composition occur on all



timescales. Astronomical changes in Earth's orbital characteristics occur for more than 20,000 to 400,000 yrs. with distinct periodicities; these are about 23,000 yrs. (precession of the equinox), 41,000 yrs. (axial tilt of Earth), and 100,000 and 400,000 yrs. (orbital eccentricity of Earth). Geological processes of continental drift and tectonism (mountain building) occur on the longest timescales. In addition, there are many feedback effects in the climate system that may amplify or dampen an initial forcing.

The temporal characteristics of climate changes may involve step changes in mean values, gradual trends in means or variability, and oscillations of varying length. For instrumental records spanning approximately the past 150 yrs., anomalies are commonly calculated with reference to a 30-yr. base period (e.g., 1971–2000), which is considered to represent a “mean” or reference climatic state.

Instrumental Records

Instrumental records began generally in the 17th to 18th centuries, but early instruments were not well calibrated or were poorly exposed. Standard instruments and careful exposure became widespread in the mid 19th century, along with organized station networks and standard observing times. However, various temperature scales—Fahrenheit, Celsius, Reamur—were in use. Precipitation records remain one of the least consistent records due to the effects of airflow over the gauge, especially for solid precipitation, gauge characteristics (dimensions, rim design, and height above ground), shielding devices, and gauge siting. The frequency and time of gauge reading also introduces inhomogeneities. There are more than 50 different gauge types in use in national weather services, creating inhomogeneity in cross-border amounts. Sea surface temperatures are another problem area. Originally, readings were made with a thermometer inserted into a canvas bucket of seawater. Later, engine room intake temperatures were used. However, the changeover was gradual, and as ships increased in size, the depth of the water sampled by the engine room intake got deeper. Estimates of wind speed at sea, prior to the invention of anemometers, involved the use of the Beaufort wind scale

(developed in 1805 by Admiral Beaufort), where categories 0 (calm) to 12 (hurricane) were based on the wind effects on wave state. In spite of the inhomogeneity problems, careful selection and adjustment of the records has enabled a consistent picture of climate variations over the period of instrumental records to be obtained. In the case of temperature, this reveals that temperatures were higher at the end of the 20th century than at the end of the 19th century in almost all locations on Earth.

The longest satellite climate record is of the Northern Hemisphere snow cover since 1966. Consistent global sea ice data began with passive microwave satellite measurements in 1979.

Historical Records

Various historical records, notably in Europe, China, and Japan, document extremes of weather—floods, droughts, heat waves, severe winters, lakes and rivers freezing, snowfalls, storms, and so on—as well as indirect records of agricultural production and harvests. These include written documents such as weather diaries, monastic or manorial rolls and ships' logs, iconographic records, landscape paintings of glaciers, and so on. Each of them must be examined critically, however, as they are subjective observations that are for the most part qualitative. The records span much of the past millennium and become more frequent from the 17th century onward. There is, for example, a documentary history of climate in Iceland from AD 1500 to AD 1800.

Proxy Records

The determination of climatic conditions for most of Earth's history depends on the use of proxy indicators of temperature, precipitation, winds, humidity, and so on. Proxies can be grouped into three general categories: geophysical variables, biological variables, and chemical variables. Geophysical variables include accumulation layers in ice cores extracted from polar ice sheets and high-altitude ice caps not subject to summer melt; electrical conductivity in ice cores, indicating the presence of sulfates associated with explosive volcanic eruptions; ice-rafted detritus layers in ocean sediments, reflecting iceberg transport;



temperatures in ground boreholes; and pedological and geomorphological evidence of past cold/hot and dry/wet conditions.

Biological variables are diverse and span a range of timescales. They include annual growth rings in trees whose width may reflect growing-season temperatures or moisture availability, pollen grains accumulating in lakes and bogs that reflect the local and regional vegetation, plant macrofossils in packrat middens that reflect local vegetation, and plant and animal fossils in the geological record. Microorganisms in ocean sediments also provide paleoclimatic information, based on the isotopic composition of carbonate in the test (shell) of the organisms and the distribution of organisms geographically and over time.

Chemical variables include many records from ice cores—sediments (from lakes and the oceans) and stalagmites in caves. In ice cores, these include anions and cations, indicating air chemistry; $\delta^{18}\text{O}$ and δD (deuterium), which indicate air temperature; and gases trapped in air bubbles, indicating atmospheric composition. Other sources include $\delta^{18}\text{O}$ in tropical corals, indicating seawater temperature and $\delta^{13}\text{C}$ in trees, which indicates carbon dioxide concentrations in the atmosphere.

The Geological Record

There have been at least four major Ice Ages in Earth's history. The Neoproterozoic (~850–630 mya [million years ago]) was a time when land ice and sea ice covered most of Earth—a state known as “Snowball Earth.” There were also major glaciations in the Ordovician and Silurian (460–430 mya), the Permo-Carboniferous (350–260 mya), and the late Cenozoic. The latter began with mountain glaciation around 40 to 35 mya and full glaciation in East Antarctica around 34 mya and around 26 mya in West Antarctic. In Central Arctic, the ice-rafted detritus found on the Lomonosov Ridge dates from about 46 mya (i.e., sea ice and glacial ice), with perennial arctic ice by 14 mya. Until recently, it was thought that arctic glaciation began on Greenland, Iceland, and Alaska much later, between 11 and 7 mya. As a consequence of this history, it appears that the Earth would have had a state of unipolar glaciation in the Southern

Hemisphere during the period ~32 to 14 mya, but this is a picture that is the subject of much discussion at present.

During the last phase of glaciations, there were 41,000-yr. oscillations from ~2.8 mya, changing to ~100,000-yr. oscillations around 1.2 mya. The former represent the effects of the axial tilt of Earth and the latter the eccentricity of Earth's orbit around the sun. There is also a 23,000-yr. precession cycle that may amplify or dampen the seasonal contrasts according to the timing of the perihelion of Earth's orbit about the sun. These oscillations were first fully documented by Milutin Milankovitch, a Serbian astronomer.

The last four glacial/interglacial cycles each span around 100,000 to 120,000 yrs., with only 10% of that time as warm as today (Figure 1). Marine isotopic stage (MIS) 11 was a much longer interglacial cycle that occurred between 425,000 and 395,000 yrs. ago; identified in the Dome-C ice core from East Antarctica, it was unusual in that the Milankovitch variables were identical to the present day and the CO_2 (carbon dioxide) level was like that of the preindustrial period. Overall, there were high sea surface temperatures in high latitudes, a strong thermohaline circulation, and a higher sea level than at present.

Sea level fell by about 135 m during the glacial maxima, with major ice sheets in North America and Fennoscandia, and rose 5 to 6 m above the present levels during the last interglacial (the Eemian), around 130,000 to 125,000 yrs. ago, when parts of the Greenland and West Antarctic ice sheets melted. Temperatures were slightly higher than now, even though the atmospheric CO_2 levels were lower than at present. The last glacial phase began around 115,000 yrs. ago and reached maxima about 75,000 and 20,000 yrs. ago. The temperature record, the extent of the glacial ice, and the sea level during these cycles mimic a sawtooth pattern over time.

The last glacial phase is marked by episodes of very pronounced climatic shifts. These are thought to be associated with changes in the North Atlantic thermohaline circulation (THC). There is a strong, ~1,500-yr. cycle known as Dansgaard-Oeschger (D-O) Oscillations identified in Greenland ice cores. These are clustered in packets within longer-term Heinrich events (H6 ~ 68–60

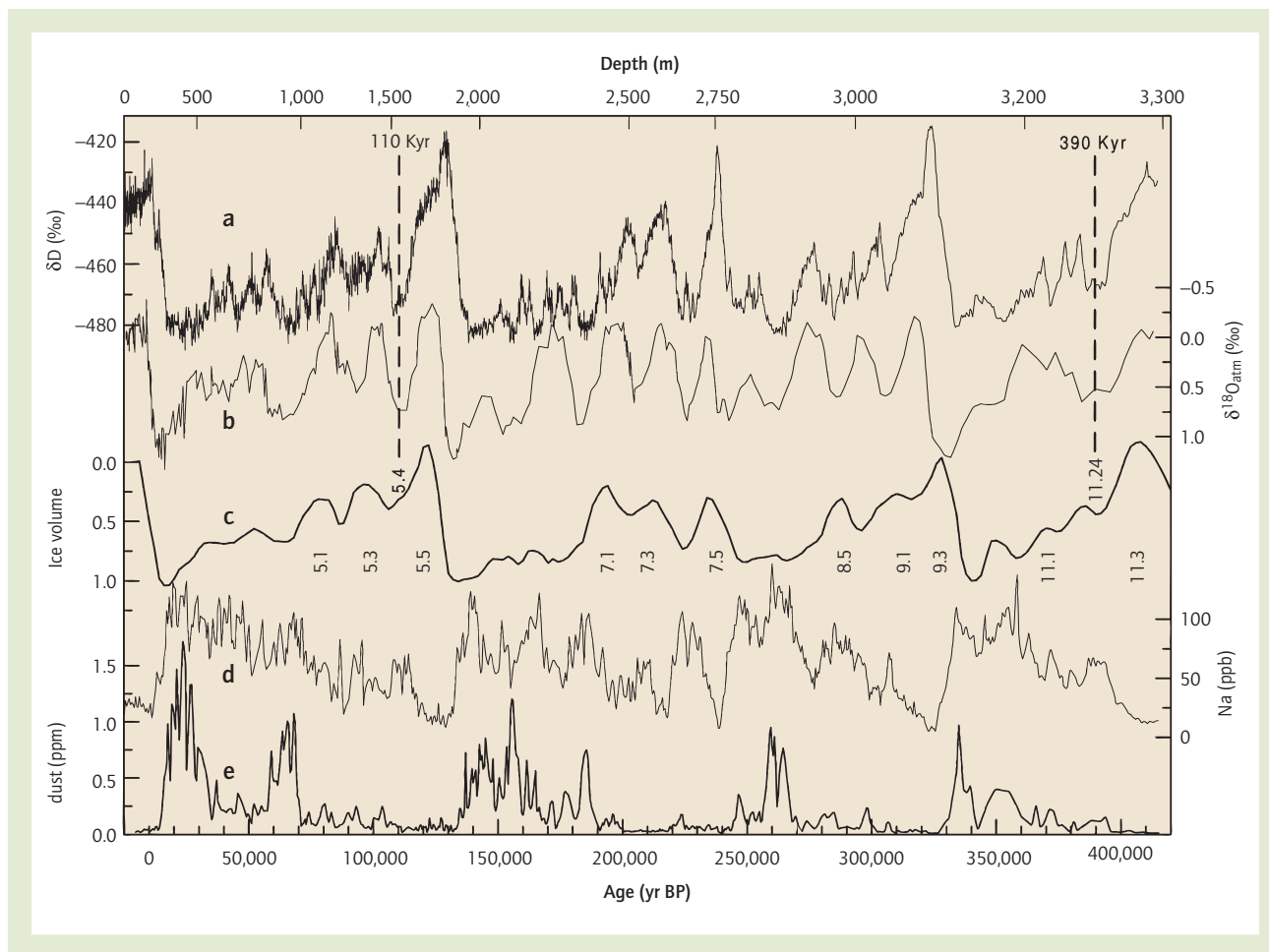


Figure 1 Vostok time series and ice volume: time series of (a) deuterium profile; (b) $\delta^{18}\text{O}$ atm (atmosphere) profile obtained combining published data and 81 new measurements performed below 2,760 m; (c) seawater $\delta^{18}\text{O}$ (ice volume proxy) and marine isotope stages; (d) sodium profile obtained by a combination of published and new measurements with a mean sampling interval of 3–4 m (concentrations are expressed in nanograms per gram or parts per billion); and (e) dust profile combining published data and extended below 2,760 m, every 4 m on average (concentrations are expressed in milligram per gram or parts per million)

Source: Adapted by Michael Mann from Petit, J. R., Jouzel, J., Raynaud, D., Barkov, N. I., Barnola, J. M., Basile, I., et al. (1999). Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature*, 399, 429–436 (specifically, temperature and CO_2 from Figure 3, p. 431, and dust from Figure 2, p. 430).

kya [kiloyears ago] to H1 ~ 14–7 kya), at a spacing of about 7.2 kya, where each successive D-O event has a smaller amplitude than its predecessor. Heinrich events involve the deposition of ice-rafted detritus from icebergs that calve off the eastern margin of the Laurentide ice sheet and East Greenland and melt in the northern North Atlantic. The injection of freshwater greatly reduces the THC in the North Atlantic. The D-O oscillations

appear to represent instabilities in the North Atlantic circulation that may be driven by anomalies of salinity arising from precipitation minus evaporation anomalies. The massive iceberg discharge (Heinrich) events appear to occur with every fourth or fifth D-O oscillation, perhaps because the ice sheet needs time to build up again. A “binge-purge” oscillation in the eastern margins of the North American Laurentide ice sheet has



been proposed to account for the Heinrich events.

The Northern Hemisphere ice sheets over Northern North America and Fennoscandia retreated rapidly between 17,000 and 1,400 yrs. ago, and then, there was a brief return to very cold conditions—the Younger Dryas—between approximately 12,700 and 11,500 yrs. ago BP. This episode was mainly concentrated in the North Atlantic sector and is thought to be the result of a significant reduction or shutdown of the North Atlantic thermohaline circulation in response to the sudden influx of freshwater from Lake Agassiz and/or the Arctic Ocean and deglaciation in North America. Following this event, the climate warmed rapidly, and this led to total deglaciation of the northern continents, with the last Laurentide ice disappearing in Eastern Canada around 6,500 yrs. ago. The postglacial period, known as the Holocene, is defined as starting around 10,000 ¹⁴C yrs. BP (11,700 yrs. ago).

During the last ice age, vegetation zones were displaced equatorward, and there was a large and varied megafauna that became extinct around 12,000 yrs. ago. The respective roles of warming climate and human hunting and the use of fire in this process remain controversial.

In the tropics and subtropics, there were wetter and drier intervals with higher/lower lake levels across Africa and elsewhere. In Africa, there was a cold, arid phase about 70,000 yrs. ago, followed by a slight climatic amelioration and then a second aridity maximum around 22,000 to 13,000 yrs. ago. Conditions then quickly became warmer and moister, leading up to the Holocene “optimum” of greater rain forest extent and vegetation covering the Sahara, with high lake levels. This allowed the expansion of people and associated animal husbandry into areas of North Africa that are hyperarid today. Conditions then turned much more arid and similar to the present.

The Holocene

The Holocene is subdivided into five intervals based on climatic fluctuations: Preboreal (10–9 kya), Boreal (9–8 kya), Atlantic (8–5 kya), Subboreal (5–2.5 kya), and Subatlantic (2.5 kya to the present). Conditions were warmest between 9,000 and 5,000 yrs. BP, and then, cooling

occurred around 150 yrs. ago. The early-Holocene warm period is sometimes referred to as the Hypsithermal or Climatic Optimum, but the latter terminology raises the question of “optimal” for what? It is attributed to increased solar radiation receipts resulting from the occurrence of perihelion in July rather than in January as at present. This made boreal summers warmer than now and led to tree species advancing northward in Eurasia and North America. It also led to enhanced monsoonal circulations as a result of the warmer landmasses. Conditions during most of the Holocene were much less variable than during the glacial periods. However, there was a sudden cool and dry phase in many areas about 8,200 yrs. ago that lasted a few centuries. This is considered to be the result of an outburst of freshwater from proglacial lakes around the margin of the rapidly waning Laurentide Ice Sheet.

The Past Millennium

Temperatures over the past millennium have fluctuated about 1 to 2 °C (Figure 2). A Medieval Warm Period, dated about AD 900 to AD 1250, affected Europe and the North Atlantic sector. This interval saw the Viking settlement of Western Greenland, which subsequently died out as conditions deteriorated. This warm epoch was followed by the Little Ice Age (AD 1350–1850), during which period there were major advances of mountain glaciers in many mountain areas of the Northern Hemisphere. Temperatures declined between about 0.5 and 1.0 °C but fluctuated considerably on decadal scales.

The cause of these variations is attributed primarily to fluctuations in solar output and volcanic activity. Solar output (across all wavelengths) varies about 0.1% over the ~11-year solar cycle. Solar output is increased during sunspot episodes due to the increased emission from the brighter solar faculae, which outweighs the decrease from the darker (and cooler) sunspots. During the Maunder Minimum (about AD 1645–1715), there was a prolonged absence of sunspot. However, it is not known how much total solar irradiance decreased during that time; estimates vary from ~0.3% to as little as 0.1%.

Explosive volcanic eruptions inject particles and sulfur dioxide into the stratosphere, and this

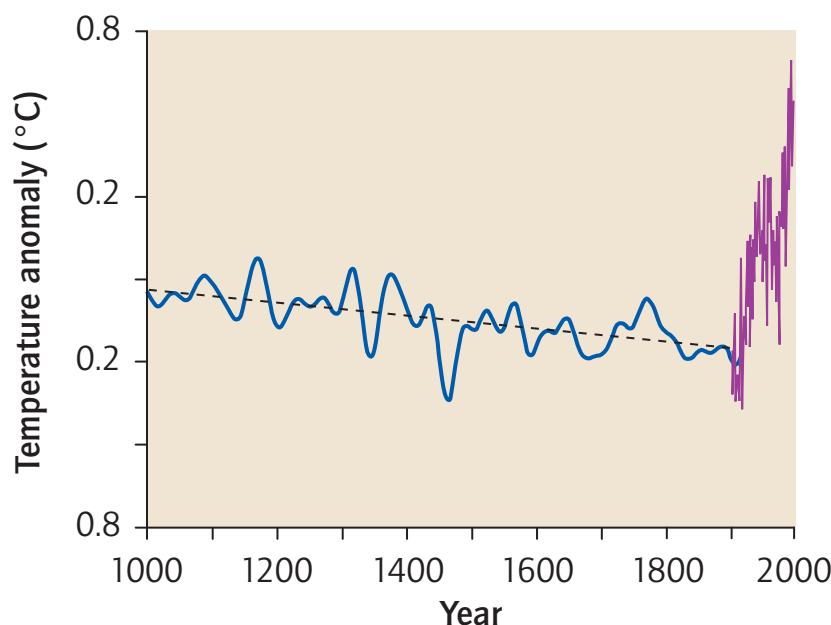


Figure 2 Variation in surface air temperature in the Northern Hemisphere over the past millennium. The reconstructed 40-year smoothed values are plotted for AD 1000–1880, together with the linear trend for AD 1000–1850 and observed temperatures for AD 1902–1998. The reconstruction is based on estimates from ice cores, tree rings, and historical records and has two standard error limits of about ± 0.5 °C during AD 1000–1600. The values are plotted as anomalies relative to AD 1961–1990.

Source: Adapted from Mann, M. A., Bradley, R. S., & Hughes, M. K. (1999). Northern Hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations. *Geophysical Research Letters*, 26, 759–762. Courtesy of M. E. Mann, University of Virginia.

reduces surface temperatures by 1 to 3 °C for up to 3 yrs. after the event. The cataclysmic eruption of Mount Tambora in April 1815 lowered global temperatures by as much as 3° C. Most of the Northern Hemisphere experienced sharply lower temperatures during the succeeding summer months. In parts of Europe and Eastern North America, 1816 was known as “the year without a summer.”

Temperatures in the 20th century rose to an initial peak in the 1930s and 1940s, then declined or leveled off, and have risen continuously since the mid 1980s. Eleven of the 12 years, from 1995 to 2006, ranked as the warmest years in the instrumental record since AD 1850. The early-mid-century warming is potentially attributable to natural variability (solar output and volcanic eruptions), while higher sulfate and aerosol levels are believed to have caused the subsequent decline.

Over the period 1960 to 1990, there was a “global dimming,” with a reduction in direct solar radiation by 4% to 6% attributed to this effect. With air pollution controls and industrial decline in Eastern Europe and Russia, a “global brightening” succeeded this. Increasing concentrations of greenhouse gases (CO_2 , CH_4 [methane] and N_2O [nitrous oxide]) have led to an accelerated warming in the last two decades of the 20th century. Carbon dioxide levels were 35% to 40% higher than the preindustrial levels (AD 1850) in the first decade of the 21st century as a result of the combustion of fossil fuels and deforestation. It should be noted that there is a close correlation between the greenhouse trace gas concentrations and global temperature fluctuations over the past 700,000 yrs., as shown by the ice core records from Antarctica.

Rising temperatures have been due in part to positive feedbacks that are playing an increasingly



important role, especially in the northern high latitudes. A record minimum sea ice extent occurred in late summer 2007, which means increased absorption of solar radiation by the Arctic Ocean and a positive feedback. The rate of decline in Arctic sea ice since the late 1990s is faster than what the climate model simulations have predicted. The Greenland ice sheet is undergoing accelerated melting and increased ice loss due to dynamical processes. In the tundra, the seasonal active layer that thaws annually is getting deeper in the northern continental areas, and there is warming and thawing of permafrost. This process is also observed on the Tibetan Plateau.

Roger G. Barry

See also **Anthropogenic Climate Change; Atmospheric Circulation; Carbon Cycle; Climate: Polar; Climate Policy; Geologic Timescale; Global Climate Change; Ice**

Further Readings

- Barker, P. F., Diekmann, B., & Escutia, C. (2007). Onset of Antarctic glaciation: Deep-sea research, Part II. *Topical Studies in Oceanography*, 54(21/22), 2293–2307.
- Bradley, R. S., Briffa, K. R., Cole, J., Hughes, M. K., & Osborn, T. J. (2003). The climate of the last millennium. In K. D. Alverson, R. S. Bradley, & T. F. Pedersen (Eds.), *Paleoclimate, global change and the future* (pp. 105–141). Berlin, Germany: Springer.
- Darby, D. A. (2008). Arctic perennial ice cover over the last 14 million years. *Paleoceanography*, 23, PA1S07.
- Edgar, K. M., Wilson, P. A., Sexton, P. F., & Suganuma, Y. (2007). No extreme bipolar glaciation during the main Eocene calcite compensation shift. *Nature*, 448, 908–911.
- Hansen, J. E., Sato, M., Ruedy, R., Lo, K., Lea, D. W., & Medina-Elizade, M. (2006). Global temperature change. *Proceedings of the National Academy of Science*, 103(14), 288–293.
- Lamb, H. H. (1977). *Climate: Present, past and future: Vol. 2. Climatic history and the future*. London: Methuen.
- MacAyeal, D. (1993). Binge/purge oscillations of the Laurentide ice sheet as a cause of the North Atlantic's Heinrich events. *Paleoceanography*, 8, 775–784.
- Mann, M. E., & Jones, P. D. (2003). Global surface temperatures over the past two millennia. *Geophysical Research Letters*, 30(15), 1820.
- Moberg, A., Sonechkin, D. M., Holmgren, K., Datsenko, N. M., & Karlen, W. (2005). Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data. *Nature*, 433, 611–617.
- Ogilvie, A. E. J. (1992). Documentary evidence for changes in the climate of Iceland, A.D. 1500 to 1800. In R. S. Bradley & P. D. Jones (Eds.), *Climate since A.D. 1500* (pp. 92–117). London: Routledge.
- Peltier, W. R., & Sakai, K. (2001). Dansgaard-Oeschger oscillations: A hydrodynamic theory. In P. Schaefer, W. Ritzrau, M. Schlüter, & J. Thiede (Eds.), *The northern North Atlantic: A changing environment* (pp. 423–439). Berlin, Germany: Springer.
- Sarnthein, M., Dreger, D., Erlenkeuser, H., Grootes, P., Haupt, B., Jung, S., et al. (2001). Fundamental modes and abrupt changes in North Atlantic circulation and climate over the last 60 ky: Concepts, reconstruction and numerical modeling. In P. Schaefer, W. Ritzrau, M. Schlüter, & J. Thiede (Eds.), *The northern North Atlantic: A changing environment* (pp. 365–410). Berlin, Germany: Springer.
- Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., & Averyt, K. B. (Eds.). (2007). *Climate change 2007: The physical science basis* (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, UK: Cambridge University Press.
- Street-Perrot, A. F., & Harrison, S. P. (1984). Temporal variations in lake levels since 30,000 yr BP: An index of the global hydrological cycle. *American Geophysical Union*, 29, 118–129.
- Stroeve, J., Holland, M. M., Meier, W., Scambos, T., & Serreze, M. (2007). Arctic sea ice decline: Faster than forecast. *Geophysical Research Letters*, 34, L09501.



CLIMATE POLICY

Climate policy refers to government or private actions designed to lower anthropogenic greenhouse gas (GHG) emissions or adapt to climate change. Emissions are rising worldwide and could result in substantial warming, sea-level rise, changes in precipitation patterns, and climate instability if the present trends continue. While knowledge of the greenhouse effect from increasing atmospheric levels of carbon dioxide (CO₂) due to fossil fuel combustion dates back to an 1896 paper by the Swedish physical chemist Svante Arrhenius, interest in climate policy began only in the early 1980s. At that time, the international climate community was preoccupied with the newly discovered hole in the stratospheric ozone layer. An international convention, or treaty, designed to protect it was approved in Vienna in 1985, and specific protocols were agreed to in Montreal in 1987. These treaties have proven to be effective mechanisms for international cooperation in research, monitoring, and action. The 1987 Montreal Protocol began the process of phasing out chlorofluorocarbons, a class of chemicals that are the main ozone-depleting substances. International treaties on the more complicated issue of climate change were approved in 1992 and 1997, but they have had limited impact and compliance thus far.

The United Nations Environment Programme (UNEP), the initiator of the 1985 Vienna Convention for the Protection of Stratospheric Ozone, also called for a convention on climate change. UNEP saw this as a mechanism to gain international agreement to reduce CO₂ and other trace gas emissions, based on the Vienna experience. Increasingly sophisticated climate modeling projected a doubling of atmospheric CO₂ levels above preindustrial levels by 2030. UNEP's efforts triggered the creation of the Intergovernmental Panel on Climate Change (IPCC) in 1988 under the auspices of the World Meteorological Organization and UNEP. The IPCC is an international body that works with thousands of scientists around the world to study the greenhouse phenomenon and its regional effects and to suggest mitigation strategies. This organization went on to jointly share the 2007 Nobel Peace Prize with

former U.S. Vice President Al Gore for its cumulative work in climate change science and policy.

Framework Convention of 1992

The IPCC issued its first scientific assessment of climate change in 1990. Underscoring the potential serious consequences of climate change on the global environment and people, it presented its report to the Second World Climate Conference in Geneva in October 1990. The United Nations General Assembly subsequently created an Intergovernmental Negotiating Committee charged with developing a climate convention. The climate treaty was finished at the 1992 United Nations Conference on Environment and Development held in Rio de Janeiro.

The main objective of the Framework Convention on Climate Change (1992) was to achieve “stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system” (p. 4). Short-term goals included establishment of national GHG inventories and returning GHG emissions (other than those covered by the Montreal Protocol) to 1990 levels by the end of the 20th century. A sticking point between then U.S. President George H. W. Bush and European leaders was targets and timetables. Consequently, emissions reduction was made voluntary. However, this goal did not cover developing nations such as China, India, and Brazil, and thus, it is called the *common but differentiated responsibility* principle. This issue became a more vexing problem 5 years later in Kyoto, Japan. Nonetheless, as a first step, the climate convention was eventually ratified by 192 nations, though compliance was essentially ignored as attention turned to the Kyoto Protocol.

Kyoto Protocol of 1997

After 2 weeks of intense negotiations, the Kyoto Protocol was adopted on December 11, 1997. Six GHGs are covered: (1) CO₂, (2) methane, (3) nitrous oxides, (4) sulfur hexafluorides, (5) hydrofluorocarbons, and (6) perfluorocarbons. This agreement requires 37 Annex I countries (industrialized countries that have accepted obligations to cut GHG emissions and submit



annual inventories) and the European Union to reduce their emissions by a collective average of 5.2% below the 1990 levels by 2008 to 2012. These emission targets are termed *assigned amount units*. However, various countries negotiated different obligations, from the strictest (an 8% cut for most European countries) to the lenient (an 8% increase for Australia and a 10% increase for Iceland). Russia and Ukraine agreed to only freeze their emissions, which, given their economic collapse and associated emissions decline in the first part of the 1990s, some have criticized as creating “hot air” credits that could be traded elsewhere. To underscore this point, Russia’s GHG emissions fell by 32% from 1990 to 2004, at which point it signed the Protocol.

The Kyoto Protocol has other major provisions. Non-Annex I countries, including China and India, are not required to cut emissions, since they successfully argued that because they contributed very few of the GHGs during the pre-treaty industrialization period, to do otherwise would be inequitable. Indeed, Annex I parties are also obligated to provide technical and financial assistance to other countries for climate studies and projects. The Protocol set up several flexibility mechanisms, such as emissions trading between Protocol parties that were designed to increase the cost-effectiveness of implementation. These provisions remain controversial since they could be abused. They include a Clean Development Mechanism (CDM) and Joint Implementation (JI). The CDM allows for the generation of new carbon credits through emission reduction projects in Non-Annex I countries, while JI allows any Annex I party (including the private sector) to earn an Emission Reduction Unit from an emission reduction or emission removal project in another Annex I country. An important requirement in all cases is the establishment of a reliable baseline of future emissions, so credit is not given for cuts that would have happened anyway. Finally, Article 3 of the Protocol permits parties to make adjustments in their GHG inventory through verifiable changes resulting from human-induced land use, land use change, and forestry (LULUCF) activities that have occurred since 1990. These projects include afforestation, reforestation, and improved forest management—all positive adjustments generating Removal Unit

(RU) credits—and deforestation (a negative adjustment). Certified emission reduction credits in the form of CDMs, JI, and RU credits can be traded, subject to some geographic restrictions.

Unlike the Framework Convention, the Kyoto Protocol has binding enforcement provisions. These require any Annex I country not in compliance with its emissions obligation to make up the difference plus an additional 30% by the completion of the second commitment period in 2016. Furthermore, that country would not be allowed to trade emissions.

The Kyoto Protocol took effect on February 16, 2005, following ratification by Russia. As of late 2009, 186 countries plus the European Union (EU) have ratified it. The United States signed the Protocol but did not ratify it, and this country has been the only one on record to have proclaimed that it had no intention of signing it.

National Policies and Compliance

By 2009, few countries were on track to meet their Kyoto emission targets. Based on available emissions reports, only the United Kingdom, France, Germany, Sweden, and Norway seemed likely to meet their emissions obligations for 2012, with the United Kingdom and Norway being significantly assisted by CDM and LULUCF projects. Germany’s progress in cutting GHGs was aided by economic restructuring in Eastern Germany, with Germany agreeing to a more stringent EU emissions target for 2012.

Overall EU emissions, when counting LULUCF activities, are down 5% below baseline 1990 levels, but this pattern is driven by the actions of the few nations noted earlier. Some countries have had great difficulty in cutting emissions, such as Spain, which was about 50% above its 1990 level in 2004. Even Japan, host of the Kyoto meeting and known for its high levels of energy efficiency, has seen its GHG emissions rise 5% since 1990. Thus, while the Annex I countries may meet the overall emissions target under Kyoto, much of the progress can be attributed to a few countries, as well as the precipitous decline in emissions in Eastern Europe after the fall of communism in the region. As a result, even before the first commitment period (2008–2012) was reached, the parties to the treaty began to discuss a successor



to the Kyoto Protocol, which includes active participation by the United States and developing countries.

While the United States has not ratified the Kyoto Protocol, it released plans under President Bill Clinton and President George W. Bush to lower its emissions. Both plans relied on voluntary measures and close cooperation with industry, with no new legislation passed as of late 2009. In the meantime, U.S. GHG emissions rose 14.7% from 1990 to 2006. Given the slow federal response, numerous U.S. states and cities have developed their own GHG reduction initiatives. These include most of the northeastern states and California (which will return its GHG emissions to the 1990 level by 2020). At the municipal level, more than 1,000 cities have signed a Climate Protection Agreement to meet or exceed the original 1990 Kyoto target in their cities, a nationwide program that was started by the mayor of Seattle.

Australia, like the United States, had not ratified the Kyoto Protocol, citing similar economic concerns as the rationale. However, Prime Minister Kevin Rudd signed the Protocol in December 2007, soon after he was elected. It is possible that Australia may meet its Kyoto obligation when the effects of LULUCF activities are included.

Developing countries have been very active in international negotiations on climate change. Although not yet obligated to reduce their rapidly growing GHG emissions under the Kyoto Protocol, several have climate change policies. These include China (now the world's leading GHG emitter), India, Brazil, Costa Rica, Mexico, and South Africa. Climate change projects in these countries are financed through the Global Environment Facility, the CDM, and an Adaptation Fund established by Kyoto.

The Post-Kyoto Period

With the Kyoto Protocol set to expire in 2012, there have been attempts to strengthen and expand the reach of any subsequent global climate change treaty. The most significant came at a meeting in Bali in December 2007, where issues such as the need to address climate change adaptation, foster technological innovation, and promote wider participation were identified as

requiring attention in the “roadmap” to a new or revised climate treaty. This process was significantly advanced through an agreement reached at the December 2009 Copenhagen international climate change summit and will continue in 2010.

Conclusion

While a broad consensus exists among the international scientific community as to the presence of, and anthropogenic contribution to, global climate change, agreement on what the next steps should be post-Kyoto is fluid. With the United States, China, and India responsible for half of global GHG emissions, their leadership in the next round of climate treaties is essential, as is continued progress by Annex I nations to hold the line and prevent backsliding. Participation by non-Annex I nations will likely entail technological transfer, continued investment in GHG offset credits by Annex I nations, and assistance with climate change adaptation. Many of the nations most vulnerable to climate change, particularly in Africa and South Asia, would require such incentives to address the equity of past emissions during industrialization by Annex I nations as well as unequal responsibility for existing emissions. Popular support for more forceful action in the United States is rising, as is evident by the array of state and local initiatives. Moreover, the rising global price of carbon-based energy has contributed to a change in consumer behavior, in turn broadening support for national action.

Future climate negotiations will be challenging in a global context where the need for consensus among almost 200 nations weakens the resulting agreement. Thus, more progress might emerge among smaller multiparty agreements similar to regional trading blocs, as within the EU or between China, the United States, and other major emitters, with low-emission developing nations joining as external incentives and internal conditions permit.

Barry D. Solomon and Michael K. Heiman

See also **Anthropogenic Climate Change; Carbon Trading and Carbon Offsets; Greenhouse Gases; United Nations Environment Programme (UNEP)**



Further Readings

- Aldy, J., & Stavins, R. (2008). Climate policy architectures for the post-Kyoto world. *Environment*, 50(3), 7–17.
- Bailey, I. (2007). Climate policy implementation: Geographical perspectives. *Area*, 39, 415–417.
- Bailey, I. (2007). Market environmentalism, new environmental policy instruments and climate policy in the United Kingdom and Germany. *Annals of the Association of American Geographers*, 97, 530–550.
- Brody, S. D., Zahran, S., Grover, H., & Vedlitz, A. (2008). A spatial analysis of local climate change policy in the United States. *Landscape and Urban Planning*, 87, 33–41.
- Hecht, A. D., & Tripak, D. (1995). Framework agreement on climate change: A scientific and policy history. *Climatic Change*, 29, 371–402.
- Solomon, B. D. (1995). Global CO₂ emissions trading: Early lessons from the US Acid Rain Program. *Climatic Change*, 30, 75–96.
- United Nations. (1992). *United Nations Framework Convention on Climate Change*. Retrieved January 25, 2009, from <http://unfccc.int/resource/docs/convkp/conveng.pdf>
- Victor, D. G. (2004). *Climate change: Debating America's policy options*. New York: Council on Foreign Relations Press.

have very similar climates. There are many classification systems available, but one of the most widely used is the Köppen system, which determines climate type based on temperature and precipitation data.

Climate Data and Statistics

Many observations are necessary to calculate the statistical properties. Thousands of locations around the world take hourly measurements of temperature, precipitation, wind speed and direction, pressure, and many other atmospheric elements. These measurements are the sources for much of the climate data that scientists use. By focusing on one location over a long period, such as 30 yrs. (years), it is possible to calculate average values for the elements and also examine the variation of these elements over time. For example, the average temperature for November 1 in Boston, Massachusetts, is 13.8 °C (57 °F). If this value is compared with the temperature for individual years, it becomes obvious that some years are cooler, some years are warmer, and, in rare cases, some years may be the same as the average.

Using the same data, it is possible to examine seasonal patterns. When are the cool months, and when are the warm months? Is precipitation evenly distributed throughout the year, or are there any dry and wet periods? If there are wet and dry periods, during which seasons do they occur? To answer these questions, and others, it is necessary to understand some of the statistics that are calculated using atmospheric measurements. The following values are calculated over a long period, such as 30 yrs. The average daily temperature is obtained by adding the minimum and maximum temperatures for a day and dividing by two. Adding all the average daily temperatures during a month and dividing by the number of days results in the average monthly temperature. The average annual temperature is the average of the 12 average monthly temperatures during a year. The annual temperature range is the difference between the warmest average monthly temperature and the coolest average monthly temperature.

Similar values are determined for precipitation. It is important to note that precipitation refers to liquid amounts; any solid precipitation (snow, sleet, freezing rain, and hail) is melted to



CLIMATE TYPES

Climate is generally referred to as the average (or mean) weather, but it deals with much more, including variations from average values, extreme events, classification, and long-term changes. Climate is much better defined as the statistical summary of atmospheric elements, such as temperature and precipitation, at a location or over a region over a long period. The values of the statistics vary from one location to another based on the control factors. By using the statistics, knowledge of the control factors, and a classification system, it is possible to separate or group locations into climate types. Sometimes, two locations that are near one another have very different climates, while two other locations may be far apart and



give a liquid equivalent. Average monthly precipitation is the total precipitation during a month, obtained by adding daily average precipitation amounts. Average annual precipitation is the total precipitation from January 1 to December 31. It is the sum of the 12 average monthly precipitation values.

Once these values are calculated for a location, it is possible to understand the climate at that location. It would be extremely difficult, if not impossible, to find two stations that have exactly the same climate conditions. For example, the climate of Boston, Massachusetts, is quite different from the climates of Honolulu, Hawaii; Seattle, Washington; and Beijing, China. Although it is possible for different climate conditions to exist over short horizontal distances, locations within a region tend to have similar climates, because they are influenced by the same climate controls or factors that affect long-term atmospheric conditions.

Climate Controls

Climate controls include latitude, proximity to water, geographic position and prevailing winds, elevation, ocean currents, and pressure and wind systems. General patterns exist for each of these controls. Temperature tends to decrease as latitude increases. Water has a moderating effect on temperatures, in that locations near water usually have smaller temperature ranges. Proximity to water also affects precipitation amount; precipitation typically decreases as distance from large water bodies increases. If the prevailing wind over a continent is from west to east, then a location on the western coast will have a different climate from one on the eastern coast. The western location will be affected by air coming from the water, but the eastern location will be affected by air that has been over land for a long period. Therefore, the western location tends to be cooler during summer and warmer during winter, while the eastern location is warmer during summer and cooler during winter. As elevation increases, temperature tends to decrease, and precipitation tends to increase. Locations near cold ocean currents are typically cooler than locations near warm ocean currents. Finally, areas under the influence of high pressure year-round are usually

dry; areas under the influence of low pressure for much of the year tend to be wet; and areas where the pressure pattern alternates between high and low pressure tend to have wet and dry seasons. It is important to remember that these descriptions are generalizations. In addition, multiple climate controls usually affect a given region, and the interaction of the controls complicates the climate patterns.

Locations that have similar controls have similar climates. When these locations are near one another, such that the controls result in a homogeneous set of conditions, the locations are in a climate region. It is also possible for locations to be thousands of miles apart yet have similar climates. For example, the climate in coastal Southern California is very similar to the climate throughout the Mediterranean region. A climate similar to Southern New England could be found in parts of Northern Europe or Eastern Asia. Conditions in Tucson, Arizona, are similar to those in parts of Australia.

Climate Classification

Because similar climates are affected by similar controls, it is possible to organize the climates into classes or types. This process is called climate classification. Classification helps bring order to the large amount of climate data and facilitates communication of the data. It is essentially a shorthand to help recognize variations and similarities in climate conditions and characteristics. There are many classification systems, ranging from those that may be applied worldwide to those that are very specific and may only be useful in a certain region.

There are three main approaches to determining climate types—empirical, genetic, and applied. Empirical classification is based on observed elements, such as average monthly and annual temperatures and precipitation values. This approach focuses on the numbers. The genetic approach is based on causes. It attempts to show relationships between an atmospheric element, such as temperature or precipitation, and the factors that affect the element. Applied classification is based on the effect of climate. This approach may consider how climate affects vegetation or human comfort.



The approaches are the basis for the many classification systems. Several systems are introduced here before turning to the most widely used system. Grosswetter, a genetic approach, investigates large-scale atmospheric circulation patterns and how they steer weather systems. The Strahler classification system, developed by Arthur N. Strahler in 1951 and later modified by John E. Oliver, focuses on the influence of atmospheric circulation on air mass type. It is a combination of the empirical and genetic approaches. Charles W. Thornthwaite developed an applied system that he later modified in 1948. It focuses on measurements of temperature and potential evapotranspiration (how much water could leave plants given an endless supply) and vegetation type. The most widely taught and therefore the most popular system is the Köppen system. It involves an empirical approach.

Köppen Climate Classification System

Wladimir Köppen developed the Köppen classification system in 1918. It was revised several times by him and modified by others since its inception; however, the basic structure of the system has remained intact. Köppen was trained in climatology and botany, and he used his knowledge of both fields to construct a system that attempted to explain vegetation distribution based on temperature and precipitation data. That is, the type of vegetation that grows in a region is related to the climate conditions in that region. The main climate data are average monthly temperatures, average monthly precipitation, and average annual temperature.

The Köppen classification system divides the world into four major climate types that are based on temperature and a fifth that is based on both temperature and precipitation. Each type is assigned a capital letter. Those types based on temperature include tropical and humid (A-type climates), midlatitude mild (C-type climates), midlatitude severe (D-type climates), and polar (E-type climates). The remaining climate, which considers temperature and precipitation, is designated as dry (B-type climates). Each of these major types is subdivided using specific information, such as precipitation timing and amount and temperature extremes. The subdivisions, designated by one or

two additional letters, are discussed in more detail below. By using a letter system, Köppen simplified the process of labeling climate regions.

A-Type Climates

The A-type climates extend from the equator (0°) to approximately 15° to 25° north and south of the equator. These climates are very warm year-round, with the average temperature of every month higher than 18°C (64.4°F). They also tend to have a small annual temperature range (several degrees) and much annual precipitation (generally greater than 150 cm [centimeters], or 59 in. [inches]). Because temperature does not vary greatly, the timing of the precipitation, which falls almost entirely as rain, usually defines the seasons. The vegetation that grows in these climates is known as megatherms, which are large leafy plants.

Subdivisions of the A-type climates include tropical wet or tropical rain forest (Af), tropical monsoon (Am), and tropical wet and dry or tropical savanna (Aw). Tropical wet climates, as their name implies, have no dry season. They receive at least 6 cm (2.4 in.) of precipitation every month. Tropical monsoon climates have a short dry season, which may last several months. During the driest month(s), precipitation must be less than 6 cm. The tropical wet and dry climates also receive less than 6 cm of precipitation during the driest month, but they have a very well-defined dry season during the winter. These areas tend to have a slightly larger temperature range than the other A-type climates, with their warmest temperatures occurring just prior to the wet season.

B-Type Climates

The B-type climates cover large areas. They are found predominately between 20° and 35° north and south of the equator, but they can be closer to the equator or extend farther north and south of 35° . If they are outside the general latitude range, they tend to occur on expansive landmasses and/or regions surrounded by, or on the leeward side of, mountain chains. Increasing distance from water bodies limits the amount of available moisture, and mountain ranges can block the flow of moisture. The main characteristic, therefore, is a



moisture deficit, such that potential evaporation and transpiration exceed the precipitation for the year. Precipitation varies from one year to the next. The vegetation in these climates is known as xerophytes. These plants are generally short, and many of them have thorns, such as cacti.

The subdivisions of the B-type climates—arid (BW) and semiarid (BS)—are based on annual temperature and precipitation. Arid climates are true deserts. Semiarid climates are known as steppes or semideserts; they receive more precipitation and have less evaporation than the true deserts. They separate the true deserts from more humid areas. The subdivisions are further differentiated using temperature. If the average annual temperature exceeds 18 °C (64.4 °F), an *b* is added as a third letter. If the average annual temperature is lower than 18 °C, a *k* is added as a third letter. Each subdivision has a name: BWh climates are known as subtropical, or low-latitude, deserts; BWk climates are midlatitude deserts; BSh climates are subtropical, or low-latitude, steppes; and BSk climates are midlatitude steppes.

C-Type Climates

The C-type climates have a variety of names, including midlatitude mild, humid mesothermal, and midlatitude moist subtropical. They cover a large range of latitudes, generally beginning at the northern and southern limits of the A-type climates—approximately 15° to 25°—and extending to as far as 70° to 75° north and south. They are also typically found on the eastern and western sides of continents. The temperature range is larger than in the A-type climates. Winter temperatures remain fairly mild, with temperatures during the coolest month lower than 18 °C but higher than –3 °C (26.6 °F). Summers are warm and humid, with temperatures during the warmest month higher than 10 °C (50 °F). Precipitation type and amount vary, but it tends to fall mostly as rain, although snow is not uncommon in the higher latitudes. In general, midlatitude cyclones cause much of the winter precipitation, and showers and convective thunderstorms dominate during the summer months. While vegetation appearance varies, it fits under the category known as mesotherms, which includes types of conifers, deciduous trees, and some scrubland.

There are many subdivisions of the C-type climates. The Cs-type climates are known as Mediterranean or dry summer subtropical. At least one winter month must have three times more precipitation than the driest summer month, and 1 mo. (month) must have less than 3 cm (1.2 in.) of precipitation. Cw-type climates are called subtropical monsoon or midlatitude wet-and-dry, mild winter. These areas have dry winters, with at least 10 times as much precipitation in a summer month as in the driest winter month. The Cs- and Cw-type climates are further separated by adding an *a* or a *b* as a third letter. An *a* indicates that the average temperature in the warmest month is higher than 22 °C (71.6 °F), while a *b* indicates that it is lower than 22 °C, and at least 4 mos. have temperatures higher than 10 °C. The third subdivision is Cf, which is known as the midlatitude rainy, mild winter. It is separated into Cfa (humid subtropical), Cfb, and Cfc, known as marine west coast climate. A *c* as the third letter indicates that only for 1 to 3 mos. is the temperature higher than 10 °C.

D-Type Climates

The D-type climates also have several names, including midlatitude severe, humid microthermal, and midlatitude moist continental. These climates begin at the poleward extent of the C-type climates—approximately 45° to 70°—and extend to 80° in the Northern Hemisphere only. They are not found in the Southern Hemisphere, because there are few large landmasses in the mid to high latitudes. D-type climates have large temperature ranges due in part to the great variation in hours of daylight and in the solar angle through the year and the heating and cooling properties of land. Summers are warm to cool, with at least 1 mo. having temperatures higher than 10 °C, and winters are cold or severe, with temperatures in the coldest month falling below –3 °C. Precipitation falls mainly as rain during the summer; winter precipitation falls as snow or rain. Vegetation is known as microtherms, which includes types of conifers and deciduous trees.

There are two secondary divisions of the D-type climates—Df (midlatitude rainy, cold winter) and Dw (midlatitude wet-and-dry, cold winter). The meaning of the second letter is the same as



described above. A third letter reveals details of the temperature, including *a*, *b*, and *c*, which are described above, and *d*, which is used when the coldest month has temperatures lower than -38°C (36.4°F). Dfa-, Dfb-, Dwa-, and Dwb-type climates are also known as humid continental, while Dfc-, Dfd-, Dwc-, and Dwd-type climates are also known as subarctic.

E-Type Climates

The final major climate type in the Köppen system is the E-type climates, which are known as polar. These climates are found poleward of the D-type climates in Asia, Europe, North America, Greenland, and Antarctica. Temperatures are cold year-round, with temperatures in the warmest month lower than 10°C , due primarily to low sun angles. Many of these locations experience 24 hours of darkness for some portion of the year. Precipitation falls mainly as snow, although rain can also occur. Precipitation is limited, but it remains on the ground for long periods due to the cold temperatures. Vegetation is limited or nonexistent. Where plants do grow, they have a short growing season. The vegetation is known as heki-stotherms, which includes grasses, some wildflowers, and lichens.

There are only two subdivisions of the E-type climates—ET and EF. ET-type climates are known as tundra. These areas have an average temperature in the warmest month between 0°C (32°F) and 10°C . Vegetation can grow here. EF-type climates are known as ice caps. Every month, the temperature is below 0°C so that most of the land is either frozen or continually covered by snow and/or ice.

H-Type Climates

A sixth climate type has been added to Köppen's original system—H-type climates. These are known as mountain or highland climates. These climates are shown on maps when mountainous terrain leads to rapid changes in climate type over short horizontal distances. In extreme cases, climate types can transition from A or B to C to D and possibly to E from the base of a mountain or mountain range to the peak.

Richard R. Brandt

See also **Atmospheric Circulation; Atmospheric Variations in Energy; Climate: Dry; Climate: Midlatitude, Mild; Climate: Midlatitude, Severe; Climate: Mountain; Climate: Polar; Climate: Tropical Humid; Climate Change; Climatology; Köppen-Geiger Climate Classification**

Further Readings

- Aguado, E., & Burt, J. E. (2007). *Understanding weather and climate*. Upper Saddle River, NJ: Prentice Hall.
- Barry, R. G., & Carlton, A. M. (2001). *Synoptic and dynamic climatology*. New York: Routledge.
- Barry, R. G., & Chorley, R. J. (2003). *Atmosphere, weather, and climate*. New York: Routledge.
- Bridgman, H. A., & Oliver, J. E. (2006). *The global climate system: Patterns, processes, and teleconnections*. New York: Cambridge University Press.
- Critchfield, H. J. (1998). *General climatology*. Upper Saddle River, NJ: Prentice Hall.
- Oliver, J. E., & Hidore, J. J. (2002). *Climatology: An atmospheric science*. Upper Saddle River, NJ: Prentice Hall.
- Rohli, R. V., & Vega, A. J. (2007). *Climatology*. Sudbury, MA: Jones & Bartlett.
- Yarnal, B. M. (1994). *Synoptic climatology in environmental analysis: A primer*. Hoboken, NJ: Wiley.



CLIMATIC RELICT

Sometimes referred to as *glacial relicts*, *climatic relicts* are taxa that were more widely distributed in the past when climatic conditions were more conducive to a greater range. During times of optimum climatic conditions, taxa may expand their ranges into new regions. As global climates have changed, climatic relict taxa have adapted by reducing their ranges to smaller refugia, where residual communities remain isolated (or disjunct) from their ancestral community.

Taxa can be relict due to shifts in entire climate zones or due to changes in single climatic variables,



such as temperature or precipitation. In particular, a number of climatic relict taxa remain due to climate shifts during the early Holocene, when conditions began to warm following the cooler glacial-interglacial conditions of the Pleistocene. While this phenomenon is observable in both floral and faunal taxa, it is expected that the number of climatic relict taxa will increase over the next century due to anthropogenic climate change.

Floral Climatic Relicts

While the number of climatic relict taxa is unknown (estimated to be several hundred species in Eurasia alone), Norwegian mugwort (*Artemisia norvegia*) is a commonly cited example. Reconstructions of past glacial environments show that the alpine plant was widely found throughout Central Europe during the last glacial maximum. Its extent decreased when the climate warmed and is now restricted to the less forested coastal mountains of Norway, the Ural Mountains, and two isolated communities in the Scottish Highlands where cooler conditions persist.

Climatic relicts do not have to occur exclusively due to climatic warming. For example, the European strawberry tree (*Arbutus unedo*) is currently found throughout the Iberian Peninsula and around the south and west coastlines of the Mediterranean Sea. However, its range extended farther north during the early-to-mid Holocene, when the climate was warmer than at present. Today, two disjunct populations of the tree remain in Western Ireland, where the North Atlantic Gulf Stream buffers the effects of the colder Irish climate.

Faunal Climatic Relicts

Faunal climatic relicts typically require less time than floral taxa to expand their ranges during periods of optimum climatic conditions. Species such as the musk ox (*Ovibos moschatus*) are capable of traveling large distances but are limited by the extent of their habitat. Fossil evidence suggests that during phases of Pleistocene glaciation, the musk ox expanded its range into Europe north of the Pyrenees and Alps beginning around 130,000 yrs. (years) ago. This range receded with the glaciers to its current-day relict

position around the arctic tundra of Greenland and Canada.

Changes in climate can also affect marine taxa, resulting in climatic relict species such as the staghorn coral (*Acropora cervicornis*). The coral is typically found in the warm waters of the Caribbean coinciding with the 18 °C monthly minimum seawater isotherm. However, the range of the staghorn coral was wider during the early-to-mid Holocene, when the Western Atlantic waters were warmer. The cold-sensitive staghorn coral can now only be found, in addition to the Bahamas, to the east of Florida, where the Florida Current helps maintain a relict population of the species.

Future Climatic Relicts

Climatic relicts, particularly glacial relicts, can occasionally represent the last of any remnants of a species before becoming extinct. A number of species have been identified by the Intergovernmental Panel on Climate Change (IPCC) and the International Union for Conservation of Nature and Natural Resources as changing their ranges in response to current-day climate change. One such species is the Joshua tree (*Yucca brevifolia*), which is losing range from the south due to increasing temperatures and a reduced ability to migrate due to the extinction of the giant sloth (which would spread seeds in their dung). It is expected that the Joshua tree will either become extinct or its range will slowly migrate north from its current position in the Mojave Desert region. Whether this species will become a climatic relict by finding a refuge from the warming Mojave climate remains in question.

Conversely, the American pika (*Ochotona princeps*) has the ability to move to a cooler location but is running out of new habitats to migrate to. Donald Grayson found that the average elevation of the pika around 40,000 to 10,000 yrs. ago was 1,750 m (meters). However, since the gradual warming of the Holocene, the species has been forced to migrate upslope to where average temperatures are cooler, at an average elevation of about 2,320 m. This has resulted in a fragmented climatic relict distribution whereby many members of the species are isolated on mountaintops, which limits their ability to migrate when climatic conditions become unsuitable.



It is expected that if the current-day climate continues to warm, many populations of American pika that are currently found in the Great Basin region will begin to run out of cooler elevations they can retreat to.

Maria Caffrey

See also **Biogeography; Biota and Climate; Climate Change; Extinctions; Glaciers: Continental; Glaciers: Mountain; Global Climate Change; Island Biogeography**

Further Readings

- Cox, C. B., & Moore, P. D. (2005). *Biogeography: An ecological and evolutionary approach*. Malden, MA: Blackwell Science.
- Grayson, D. (2005). A brief history of Great Basin pikas. *Journal of Biogeography*, 32, 2103–2111.
- Lomolino, M. V., Riddle, B. R., & Brown, J. H. (2006). *Biogeography* (3rd ed.). Sunderland, MA: Sinauer.
- MacDonald, G. M. (2003). *Biogeography: Introduction to space, time and life*. New York: Wiley.
- Parry, M. L., Canziani, O. F., Palutikof, J. P., van der Linden, P. J., & Hanson, C. E. (2007). *Climate change 2007: Impacts, adaptation and vulnerability* (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, UK: Cambridge University Press.
- Shogren, E. (2008, February). *Outlook bleak for Joshua trees*. Retrieved January 16, 2009, from the National Public Radio Web site: www.npr.org/templates/story/story.php?storyId=17628032



CLIMATOLOGY

Climatology is one of the primary subdisciplines of physical geography, along with biogeography and geomorphology. Climatology is the scientific study of the world's vast and ever-changing climate systems through time. The spatial nature of the discipline makes it unique to geography, though it is very much an interdisciplinary field

of study that often integrates information from related sciences (e.g., meteorology, oceanography, ecology, anthropology, and geology) to understand climate variability and its impacts on Earth and human systems. Within the field, climate is investigated on a range of timescales, generally from decades to centuries. This is why it is often regarded as the long-term study of weather in which statistical patterns of weather phenomena can be detected. In many ways, the study of climate is more expansive and diverse than this definition proposes. This point is demonstrated by the variety of subdisciplinary studies within climatology, the wide array of data, resources, and methodologies used within the field, and the emerging relevance of climatology in today's society, where we are experiencing evident climate change with far-reaching impacts extending to energy, economics, and policy issues. There are six major subdisciplines within climatology: (1) paleoclimatology, (2) microclimatology, (3) physical climatology, (4) synoptic and dynamic climatology, (5) hydroclimatology, and (6) health/medical climatology. The use of geospatial techniques, from geographic information systems to remote sensing, is frequently incorporated in all areas of climatological investigations, as are geostatistics and climate models. Data sources for climatological examination range from instrumental to proxy and reconstructed records.

Climatology Studies

Paleoclimatology

Paleoclimatology is an important subdiscipline of climatology that focuses on the examination of past climates on Earth. Roughly, the temporal period for studying past climates is considered to span beyond the intervals that instrumental data records provide, ranging from approximately 50 years ago to several million years ago and earlier. This type of climatological study is aimed at uncovering the extent to which climate has changed throughout geologic time while revealing the internal and external influences (of natural and anthropogenic origin) on past climate conditions and climate change. Examples of some of these influences include variations in Earth's orbital parameters, plate tectonics, volcanic



eruptions, and the extensive logging and clear-cutting practices of the early North American settlers. In addition, paleoclimatologists often evaluate how climate variability in the distant past may have assisted in the formation, arrangement, and deformation of the structure of Earth's present and past landforms and water bodies as well as atmospheric composition. For instance, extensive periods of wetter than average conditions in the Pleistocene led to the creation of many paleolakes, which are mostly dried up at present. To assist many paleoclimatological investigations, proxy data records are used from sources such as tree rings, glacial ice cores, pollen, lake and ocean sediments, and oxygen isotopes. These data are critical in providing long-term evidence by which climate conditions of the distant past can be evaluated. Often, climate reconstructions of meteorological variables such as air temperature, pressure, precipitation, and stream flow variability can be created from such sources.

Microclimatology

The localized study of unique climate conditions at or near the ground surface is another subdiscipline of climatology, known as *microclimatology*. This includes the assessment of vertical variations in climatological and meteorological conditions within 1 to 2 meters of Earth's surface. In addition, the horizontal variability of climate between site-specific locations is also examined in microclimatology. Important influences to the microclimate of a given area can include long-wave and shortwave radiation flux, soil characteristics, topography, evapotranspiration rates, and the type and extent of vegetative cover. These elements are often highly variable between locations and between atmospheric layers located further from the surface layer. Microclimatology is closely connected to the study of larger-scale climate studies, as factors such as cloud cover and the movement of air masses and weather patterns may also affect the microclimate of an area. Of course, the nature of interactions between humans, animals, insects, and technology with the ground surface can also lead to unique and variable microclimate conditions. This field within climatology uses a host of monitoring systems, instrumentation (i.e., anemometers,

hygrometers, thermometers, rain gauges, staff gauges, evaporimeters, and lysimeters), and sensors for observational measurements of climatological data.

Physical Climatology

Physical climatology is a subdisciplinary study of climatology that investigates the principles, processes, and interactions of the present air-sea-land interface in relation to the past, so that future changes to the climate system may be understood and predicted. This field incorporates working understandings of atmospheric physics and geophysical fluid dynamics, particularly the ways in which energy is distributed across the planet, so that areas of sensitivity may be identified and assessed. Physical climatologists play a critical role in modeling the state of the Earth's climate. The models produced by physical climatologists allow for the assessment of large and small hypothetical changes to controlled components of the climate system, so that their impacts on other areas of the system may be examined. This is currently the predominant way in which various anthropogenic climate change scenario impacts are forecast. Outputs generally display some level of variation between models, as they are highly dependent on the algorithms developed by physical climatologists. Therefore, researchers in this realm of climatology must present an accurate depiction of real-world climatic factors, from the amount of transpiration produced by a single leaf on a given day to the decadal patterns of global oceanic circulation.

Synoptic and Dynamic Climatology

Synoptic and dynamic climatology describes the subdisciplinary area of climatology that explains the spatial and temporal variability of atmospheric circulation patterns while examining subsequent impacts on the state of the climate system. Large-scale circulation influences the strength and persistence of pressure centers, air mass advections, and the movement of storm tracks. Therefore, to understand weather experienced at the surface, synoptic and dynamic climatological research aims at characterizing the nature of atmospheric circulation variability. This can include the study of jet streams, planetary waves, oscillatory modes of



climate variability (e.g., the El Niño/Southern Oscillation and North Atlantic Oscillation), circulation cells, blocking phenomena, and synoptic weather types. Additional research within the field focuses on how atmospheric circulation patterns influence the environment and humans. Often, this involves the assimilation of many different climate and weather components, from physical observations to climate model outputs, to understand the conditions affecting a unique area.

Hydroclimatology

The study of the world's climate system in relation to the hydrosphere is known as *hydroclimatology*. Hydroclimatologists examine the spatial and temporal variability of moisture conditions at and beneath the surface as well as within the atmosphere. This can include investigations of precipitation and snowfall, snow cover/extent, snow pack depth and stability, stream flow, atmospheric and soil moisture, evapotranspiration, and water resource management and distribution. Periods of significant, anomalous hydroclimatic variability—for instance, during times of drought or flood—are a focus of this field. A multitude of changes in atmospheric conditions and land surface processes leading to hydroclimatic variability are also frequently examined within this subdiscipline of climatology. Hydroclimatology research stems from data collected across a dense network of stations around the world that monitor various elements of the hydrosphere as well as climate model outputs. However, it is the synthesis of this information with spatial analyses that truly separates this discipline from traditional hydrology and hydrometeorology investigations.

Health and Medical Climatology

The subdisciplinary study of climatology known as *health and medical climatology* focuses on how climate variability influences the quality of human health and general human biology and physiology. This field of study focuses on how the human body responds to natural climate flux as well as anthropogenic alterations to the climate system. Research conducted within this subdiscipline can include examinations of summer climate conditions and how the frequency and duration

of human exposure to heat and humidity can lead to various levels of stress and even death for different age groups. Alternatively, a health/medical climatology investigation of winter climate might assess how the human body adjusts to below-average temperatures in winter with various levels of exposure (e.g., from the time it takes to shovel a driveway to the duration of an outdoor hockey game). A very different type of analysis in this field might consider how climate variability influences the prevalence and spread of diseases such as malaria and shistosomiasis or how migratory populations are affected by changing climate conditions. A great deal of national and global cooperation between climatologists, government, and health/medical professionals and scientists is required (especially with data sharing) to conduct investigations in this field.

Climatology Resources

Geospatial Techniques

As a spatial discipline, climatology frequently incorporates the use of geospatial techniques in research analyses. Some of these resources include geographic information systems (GIS), satellites, remote sensing, and global positioning systems (GPS). The use of GIS as a computing tool for data-mapping and display purposes is widespread in the climatological community. GIS is also considered a science that can aid climatologists with the storage, organization and arrangement, modification and manipulation, and synthesis and analysis of data sets. This is particularly useful when working with large or cumbersome data sets, which are often incorporated in climatological investigations. For example, statistical operations can be performed within a GIS that allow for data gathered at point locations across a region, continent, or hemisphere to be displayed on a map with various spatial interpolations. Climatologists can select and change very specific criteria within a GIS while working with and displaying data, such as the colors used, map projection type, the resolution size, or the spatial area that the data will be confined to. The ease with which GIS allows a researcher to amend or alter the methodologies of an examination is a highly favorable feature that has led to its popularity



among climatologists. Of further interest, the temporal component of data sets can also be incorporated into a GIS for climatological assessment. For example, there are tracking features within a GIS that allow for the examination of tropical storm and hurricane paths to be conveyed and compared through time. Recently, GIS specialists and scientists have been working to further increase the capabilities of GIS for evaluating temporal data.

Many data used for climatological analyses are regularly collected by geospatial techniques with satellites and remote sensing. Over the past three decades, these techniques have become increasingly sophisticated and are widely employed to gather climate data. Radar is a well-known variety of one of these techniques that is extensively used within the field of climatology. Currently, there are far more climate data available from these sources than there are research investigations to use them. Both satellites and remote sensing allow for components of the climate system (ranging from atmospheric water vapor content to sea surface temperatures to the color of vegetative cover) to be monitored and collected by a host of sensors placed at various distances from Earth's surface. These techniques are advantageous to climatology because of the precision with which data can be measured as well as the continuous intervals at which data can be temporally gathered. In addition, data can be transferred rapidly to a computer for processing and examination, and bias from human error, instrumentation, and ground conditions is generally avoided with these techniques. A variety of satellite data receivers, or GPS units, are available to further aid climatologists in research investigations. These are particularly useful in conducting outdoor field experiments such as those performed in hydroclimatology, microclimatology, and paleoclimatology.

Geostatistics

As with geospatial techniques, climatological assessments also rely heavily on the use of geostatistics. Geostatistics encompass a wide range of statistical methods and statistical models, as well as the development of statistical algorithms that are used for the purpose of environmental data analysis. Geostatistics are important in all aspects of climatology studies. They can be used in the

preliminary steps of a research investigation, for instance, to determine how stations should best be distributed across a study area based on the kind of climatological analysis being conducted. Geostatistics may also be the primary way in which large data sets are examined in a research investigation, once collected. Examples of these kinds of evaluations include regression analyses, cluster analyses, and principal components analyses. In addition, geostatistics assist climatologists in proving the validity and relevance of their results with tests for data significance, variance, and correlation. Climatologists often employ geostatistical procedures within statistical computing and programming packages as well as within a GIS.

Climate Models

Climate simulation models are important for climatology research to investigate the sensitivity of Earth's climate to various external and internal forcings. Climate models are useful because the collective algorithms run within an individual computer model serve as numerical representations of the physical and chemical state of the climate system at a given time and are useful for short- and long-range climate predictions. There are many different kinds of climate simulation models in operation around the world that examine climate on numerous spatial scales. Some climate models are designed as three-dimensional replications of the coupled atmosphere-ocean system, such as general circulation models, while others simulate a specific component of the climate system (e.g., modeling the global carbon cycle). All are useful for projecting complex climatic responses to change, especially since many different hypothetical scenarios can be considered within one climate model. For example, a climate model is considered a highly beneficial resource for projecting temperature variability responses to increasing fossil fuel emissions. However, the impact on other areas of the climate system, such as the likelihood of drought and flood or changes to sea ice extent and permafrost cover, may also be examined.

Climate Data

To understand present and past climate conditions and make accurate forecasts of the future



climate, climatologists make use of a variety of climate data resources. Instrumental data records collected at individual sites along the surface are one type of data used for research. These data are collected all over the world, from places such as first-order weather station networks, cooperative station networks, ocean buoys, and even ship observations. Measurements may be taken of variables such as temperature, precipitation, cloud cover, wind speed, and wind direction with time. In addition, real-world observational data are collected from remote sensing with ground sensors, aircrafts, and satellites. Composited data are also used based on surface observations and observations of climate conditions throughout the atmosphere, hydrosphere, and lithosphere (e.g., sea surface temperatures for territorial regions of the Pacific Ocean). Approximations of climate from natural sources, ranging from tree rings to ocean sediments, further provide important information that climatologists draw from, particularly in paleoclimate investigations. From a combination of these sources, climatologists can statistically reconstruct the state of the climate system at various time intervals. This can make available a number of reconstructed data records that may be used for other climatological assessments. Another type of data that are available to climatologists stem from approximations of climate based on computer-generated model simulations of actual, real-world conditions. Climate data are used on a range of timescales, as hourly, daily, twice daily, weekly, monthly, yearly, or longer periods may all be necessary temporal intervals for a particular investigation. Furthermore, climate data are assessed in terms of averages, maximums, minimums, totals, and extents.

Climatology and Climate Change

Over the past few decades, global climate change has become a powerful topic for world discussions and debate, with climate programs, committees, and policies directed at coping with the rate at which human activities may be affecting natural climate flux. Climatology is at the center of the issue, as the current and future directions of these initiatives rely on evidence provided by trained climate researchers. Primarily, it is through climatology that changes occurring within the

climate system through time are understood. Climatology studies also help educate the public and develop a comprehension of how climate change may be beneficial and detrimental to society and the environment. For instance, rising temperatures that result in sea-level rise may have a host of negative environmental and economic impacts on coastal environments as well as on polar and subpolar climate zones. However, some higher-latitude and higher-elevation regions may find that the growing seasons of certain crops are extended, and therefore more productive, with increasing temperatures, which could improve the economy of these areas.

Government, industry, and individuals must make decisions on how to prepare for all possible scenarios of climate change. The justification for enacting and enforcing change (e.g., with policy, incentives, restrictions, and mandates) aimed at influencing human activity and interactions with nature stems in great part from physical evidence uncovered by climatology research. In some instances, decision makers seek direct consultation from climatologists, and in others, climatologists make recommendations to decision makers and the general public. Climatology reports are also frequently issued from climate groups and agencies on matters concerning climate conditions and climate change. This has been especially prevalent in today's society where energy consumption and conservation are concerned, for example, with such groups or agencies promoting the use of alternative energy sources.

Melissa L. Malin

See also **Anthropogenic Climate Change; Climate Change; Climate Policy; Climate Types; Geostatistics; GIS in Environmental Management; Models and Modeling**

Further Readings

- Barry, R. G., & Carleton, A. M. (2001). *Synoptic and dynamic climatology*. New York: Routledge.
- Barry, R. G., & Chorley, R. J. (2003). *Atmosphere, weather and climate* (8th ed.). New York: Routledge.



- Christopherson, R. W. (2006). *Geosystems* (7th ed., pp. 174–317). Upper Saddle River, NJ: Pearson Prentice Hall.
- Davis, J. C. (2002). *Statistics and data analysis in geology* (3rd ed.). New York: Wiley.
- Geiger, R., Aron, R. H., & Todhunter, P. (2003). *The climate near the ground* (6th ed.). Lanham, MD: Rowman & Littlefield.
- Longley, P. A., Godchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographical information systems and science* (2nd ed.). Chichester, UK: Wiley.
- Lutgens, F. K., & Tarbuck, E. J. (2006). *The atmosphere* (10th ed., pp. 196–246). Upper Saddle River, NJ: Pearson Prentice Hall.
- Lydolph, P. (1985). *The climate of the Earth*. Totowa, NJ: Rowman & Allanheld.
- Salby, M. L. (1996). *Fundamentals of atmospheric physics*. San Diego, CA: Academic Press.



CLOUDS

A cloud is any visible mass of liquid drops or ice crystals suspended above the surface of the Earth. In addition to their obvious importance in producing precipitation, clouds play an important role in large-scale circulation by cycling water and energy through the atmosphere. Because of their generally high albedo but widely varying temperature, clouds constitute an important feedback in the global radiation balance and are a significant source of the uncertainty in estimates of global climate change. A simple overview of clouds can proceed from an introduction to the traditional cloud classification scheme and a discussion of rudimentary cloud microphysical processes. The development of global cloud climatologies and methods of assessing the influence of clouds on climate are included as being particularly relevant to the discipline of geography. It is helpful first to distinguish between clouds and precipitation.

Clouds and Precipitation

Cloud particles, whether composed of liquid drops or ice, are referred to generally as *hydrometeors*, a

term that also includes precipitation-size particles. Although also composed of liquid drops or ice-phase particles, and inextricably linked with cloud processes, *precipitation* is distinguished from *cloud* in that precipitation-sized particles have a nonnegligible fall velocity. Cloud droplets, on the other hand, are generally characterized by a terminal fall velocity much smaller than the cloud updraft magnitude (i.e., $v_t \ll w$). This distinction leads to definitions and descriptions that refer to clouds as being *suspended* (as mentioned above) or *floating* in the atmosphere.

Cloud Classification

The cloud taxonomy in current use was originally formulated by the pharmacist and amateur meteorologist Luke Howard in 1803 and adopted formally in 1956 by the World Meteorological Organization (WMO) on publication of the *International Cloud Atlas*. Clouds are classified based on 10 mutually exclusive categories derived from their structural characteristics. These 10 cloud *genera* are cirrus (Ci), cirrocumulus (Cc), cirrostratus (Cs), altocumulus (Ac), altostratus (As), nimbostratus (Ns), cumulus (Cu), stratocumulus (Sc), stratus (St), and cumulonimbus (Cb).

Additional classifications include *species*, which ascribe to clouds details of shape and structure, and *varieties*, which represent particulars of cloud arrangement and optical properties. An exhaustive cloud classification also includes a description of supplemental features and *accessory* clouds. Last, a description of cloud origin, termed *mother cloud*, can be applied when one cloud forms from another. These five categories permit an extraordinary number of cloud types. Typical meteorological practice, however, employs only the genera and occasionally a species, for example, *cumulus humilis* (fair weather cumulus).

The 10 cloud genera are consistent with a cloud classification by altitude. Examples of low cloud types are cumulus, stratocumulus, and stratus. Altocumulus, altostratus, and nimbostratus are midlevel clouds. Upper-level clouds include cirrus, cirrocumulus, and cirrostratus. Cumulonimbus, which frequently span the entire depth of the troposphere, are typically included in the low-cloud category.

cirrostratus



altostratus



stratus



cirrocumulus



altocumulus



cumulus



cirrus



nimbostratus



stratocumulus



cumulonimbus



Examples of the 10 WMO cloud genera

Source: Nimbostratus cloud photo taken by Dr. M. A. LeMone, www.windows.ucar.edu/tour/link=/earth/Atmosphere/images/nimbostratus1_big_jpg_image.html. All other cloud photos, copyright © John Day, 2006, www.cloudman.com.



Although nearly all national meteorological services employ the WMO cloud classification, other useful cloud taxonomies exist. A cloud classification based on hydrometeor composition (liquid, ice, or mixed phase) reflects the importance of cloud formation or growth mechanisms and is important when retrieving cloud properties (e.g., liquid water content or mean drop size) from remote sensing platforms such as satellites or radar. The International Satellite Cloud Climatology Project (ISCCP), begun in 1982, developed a nine-category cloud classification based on cloud top pressure and cloud optical depth obtained from satellite observations. These nine ISCCP categories have much in common with the 10 WMO cloud genera.

Cloud Formation and Development

Clouds originate from the condensation or deposition of water vapor. Cloud formation requires the presence of water vapor and some mechanism to achieve supersaturation conditions, defined as a relative humidity over 100%. Most commonly, a supersaturated water vapor field comes about via cooling of air as it flows over topography, ascends in the vicinity of frontal surfaces, or rises in buoyant convective updrafts. As the rising air expands and cools, relative humidity increases above 100%, and embryonic cloud droplets form on soluble atmospheric aerosol called *cloud condensation nuclei* (CCN). Without the presence of these naturally occurring CCN, a relative humidity of approximately 400% would be required to nucleate cloud droplets, a consequence of the free energy barrier associated with the creation of the curved droplet surface. The role of soluble CCN is to reduce the equilibrium vapor pressure over the droplet surface, a mechanism commonly referred to as the *solute effect* (Raoult's law). The interplay between the effects of curvature and dissolved solute is described using Köhler theory.

Once a critical size or relative humidity is reached, the droplet is said to be *activated* and subsequently grows by condensation. Condensation growth of small droplets is rapid and can explain the existence of typical cloud drops of radius $\sim 10\ \mu\text{m}$ (micrometers). Condensation is not, however, sufficient to explain the growth of precipitation-sized droplets. Once a small

number of $20\text{-}\mu\text{m}$ droplets are present, rapid droplet growth of precipitation-sized droplets can occur through the process of collision-coalescence, where larger droplets fall and collect smaller cloud droplets, with the large drops growing in the process. The large drops ultimately fall below the cloud base as precipitation.

The requirements for the nucleation of ice-phase hydrometeors are somewhat different. Ice particles can form either directly from the vapor phase or via the freezing of supercooled liquid drops. Homogeneous nucleation—the freezing of liquid drops without the need for any nuclei—occurs near $-40\ ^\circ\text{C}$. Nucleation at warmer temperatures requires the presence of ice nuclei, broadly categorized as either deposition nuclei or freezing nuclei. Suitable ice nuclei are typically insoluble, with a crystalline structure similar to that of ice. Kaolinite, a clay mineral, is one of the naturally occurring ice nuclei, while insoluble inorganics such as silver iodide have been employed to nucleate ice particles in cloud-seeding experiments. Ice-phase nucleation is highly temperature dependent, with appreciable ice nucleation only beginning at $-10\ ^\circ\text{C}$. Often, clouds $-10\ ^\circ\text{C}$ or warmer contain very little ice.

When cloud physicists began flying instrumented aircraft through cold clouds, it was noted that the concentration of ice-phase particles was much higher (often by orders of magnitude) than the concentration of ice nuclei. This discrepancy necessitated a secondary ice production mechanism or ice multiplication process. The most commonly accepted explanation of ice multiplication is the Hallet-Mossop process (rime splintering), which occurs over a narrow temperature range when graupel interacts with supercooled liquid droplets, ultimately resulting in the production of a large number of small ice splinters.

Small, just-nucleated ice-phase particles can grow very efficiently by vapor deposition, which is the ice-phase analog to condensational growth for liquid droplets. The presence of pristine ice crystals evinces depositional growth, with the actual temperature and humidity characteristics determining the particular crystal structure, or *habit*, that forms. Possible crystal habits are dendrites, columns, plates, and needles.

Depositional growth in mixed-phase clouds, composed of both ice crystals and supercooled



liquid water, is governed by the Bergeron-Findeisen mechanism. Because the equilibrium vapor pressure over liquid water is much greater than that over ice, the interior of a cloud that is saturated with respect to liquid water (i.e., a relative humidity of 100%) is greatly supersaturated with respect to a surface of ice. This difference promotes the depositional growth of the ice-phase hydrometeors and evaporation of the liquid water to maintain 100% relative humidity. Rapid depositional growth of the ice particles will continue as long as sufficient supercooled liquid water is present.

Ice-phase particles can also grow by accretion of supercooled liquid water in a process called *riming*, the mechanism responsible for hail growth, and by aggregation with other ice particles.

Developing Global Cloud Climatologies

Surface meteorological observations often contain information about clouds, usually in the form of sky condition (a measure of the fractional sky coverage by clouds) and cloud base height. Cloud observations may, where applicable, contain descriptions of multiple cloud layers, though of course not all layers may be visible to an observer at the surface. Stephen Warren and Carole Hahn developed and digitized a global climatology of clouds from surface-based observations over the land and ocean. The land-based observations are taken from regular surface observations at fixed locations, while the ocean-based observations are based on cloud observations made by ships at sea.

The advent of polar orbiting and geostationary satellites over the past few decades has made possible a comprehensive cloud climatology spanning the entire globe. Satellites have the advantage of consistent spatial and temporal coverage, but they are nevertheless limited by the fact that conventional passive techniques cannot fully sample multiple cloud layers. This limitation also applies to surface-based remote sensing of clouds. The most significant consequence of this limitation is that climatologies of single-layer clouds are better represented relative to regimes where multiple cloud layers dominate. It is expected that this problem will be ameliorated somewhat in the coming years with the advent of profiling cloud

radars, both land and satellite based, optimized to collect cloud information relevant for climate.

Influence of Clouds on Global Climate

Because of their brightness relative to the underlying Earth surface, clouds exert a profound impact on the global radiation balance. Whether specific clouds constitute a cooling or a warming effect (in the *global mean* sense) depends on cloud albedo and cloud top temperature. In the short-wave, cloud feedbacks are always negative; that is, clouds always exert a radiative cooling effect. In the long-wave, however, cloud top temperature ultimately determines the magnitude of warming. A low cloud whose top is perhaps only a few degrees cooler than the surface results in nearly the same outgoing long-wave flux as if the cloud were not there. A cloud high in the atmosphere, on the other hand, because of its cold temperature, yields a much smaller upward flux and a significant warming effect relative to the warm surface below. Whether the shortwave *albedo effect* (always cooling) or the long-wave *greenhouse effect* (either warming or near neutral) dominates depends on the cloud thickness and cloud top height. In general, low clouds such as marine stratocumulus cool the climate system. Upper-level clouds, particularly high, thin cirrus, warm the system.

Cloud radiative properties are strongly modulated by the character of the aerosol on which the cloud droplets form, a dependence that can lead to a series of complicated aerosol-cloud-precipitation interactions. These cloud-mediated radiative feedbacks are termed *aerosol indirect effects*. For example, clouds forming in an environment with higher CCN concentrations will be brighter, reflecting more solar radiation back to space (known as the *first indirect* or *Twomey effect*). Additionally, a higher concentration of CCN tends to suppress the formation of precipitation in warm clouds, in principle leading to longer cloud lifetimes, since liquid water remains in the cloud rather than raining out (the *second indirect*, *cloud lifetime*, or *Albrecht effect*). However, the second aerosol indirect effect is poorly constrained in this simple relationship between a reduction of precipitation and greater cloud lifetime, since it neglects important cloud dynamical feedbacks.



These aerosol-cloud-precipitation feedbacks must be understood so that they may be adequately represented in global climate models.

The Intergovernmental Panel on Climate Change (IPCC) in the Fourth Assessment report stated that cloud feedbacks remain the largest uncertainty in assessments of global climate change. Understanding cloud feedback mechanisms is crucial, since any change (natural or anthropogenic) in Earth's climate would most likely result in a change of cloud properties, with important consequent feedbacks.

David B. Mechem

See also **Albedo; Atmospheric Moisture; Precipitation Formation; Weather and Climate Controls**

Further Readings

- Houze, R. A., Jr. (1993). *Cloud dynamics*. San Diego, CA: Academic Press.
- Lohman, U., & Feichter, J. (2005). Global indirect aerosol effects: A review. *Atmospheric Chemistry and Physics*, 5, 717–737.
- Rogers, R. R., & Yau, M. K. (1989). *A short course in cloud physics*. Boston: Butterworth Heinemann.
- Stephens, G. L. (2005). Cloud feedbacks in the climate system: A critical review. *Journal of Climate*, 18, 237–273.
- Warren, S. G., & Hahn, C. J. (2006, February). *Climatic atlas of clouds over land and ocean*. Retrieved December 31, 2008, from www.atmos.washington.edu/CloudMap
- World Meteorological Organization. (1956). *International cloud atlas* (Vol. 1). Geneva: Author.
- World Meteorological Organization. (1956). *International cloud atlas* (Vol. 2). Geneva: Author.

is particularly poignant in human and, more specifically, economic geography, it is an important concept across the social sciences. In simplest terms, a cluster can be understood as a group of similar or linked firms within a defined geographical area, although in addition to its importance as an empirical project, the concept provides a basis for considering the relationship between actors and space.

The term *cluster* was first coined and subsequently popularized by the regional scientists Stan Czamanski and Luiz Augusto de Q. Ablas in 1979; however, it was the seminal work of Alfred Marshall in the late 19th century that provided the foundation for these debates. Without explicit reference to clusters, Marshall's study of the British textile industries in Lancashire and Yorkshire, potteries in Stoke on Trent, and metallurgical industries in Sheffield identified the existence of "industrial districts." Marshall observed that the high capital costs associated with such Fordist industries meant that they tended to remain in a place for a long time once located, a characteristic fundamental to the establishment and sustenance of the business and the sociocultural relationships of industrial districts.

Through cooperation and competition among firms, Marshall found, industrial districts offered advantages not available to those outside the locale. Indeed, so great were the advantages of the industrial district that it became a significant factor in the location decisions of firms. More specifically, Marshall identified four aspects of external economies whereby industries sought to extend and refine social and economic relationships as well as physical infrastructure through the scale of production: (1) the reduction of transportation costs, (2) the creation of a common specialized labor force, (3) the specialization of input products, and (4) an intangible dimension that Marshall (1890) referred to as how "the mysteries of trade become no mysteries, but are as it were in the air" (p. 271).

Marshall's work on industrial districts, agglomeration economies, and external economies provided an important focus for much of the cluster literature and the basis for more contemporary theorizations of the cluster. While the neologisms for the term *cluster* have become ever more numerous with the changing nature of the



CLUSTERS

Clusters have long been a subject of much debate within human geography. While historically informed by location theory and regional science, the cluster has evolved as a highly interdisciplinary concept. While the concept of the cluster

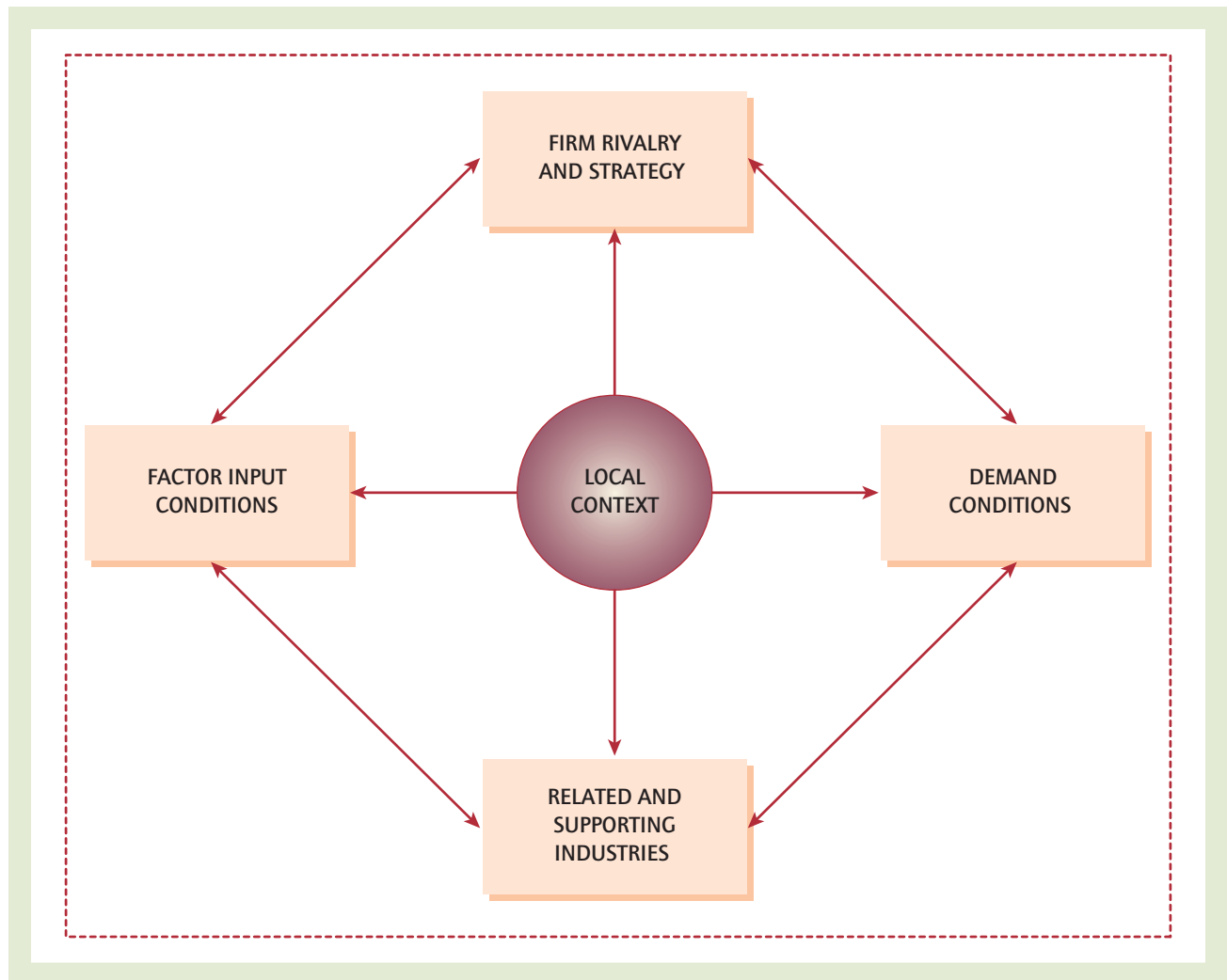


Figure 1 Porter's competitive diamond. Geographical clustering intensifies interactions within the competitive diamond.

Source: Vorley, T. (2008). The geographic cluster: A historical review. *Geography Compass*, 2(3), 803.

political-economic landscape, the essence of cluster theory continues to be based on the principles of economic localization and increasing returns. The theoretical evolution of cluster debates has not been orderly but rather comprises a diverse range of interrelated perspectives, and economic geography has embraced this intellectual sophistication in the study of clusters.

One of the most prominent recent contributions to the literature has been the "rebranding" of the cluster concept by the economist Michael Porter. Despite reiterating the characteristics of the Marshallian industrial district, Porter's refashioned concept draws on Joseph Schumpeter's

notion of creative destruction. Thus, it represents more than a rediscovery or reinvention of the cluster concept. The Porterian model identified competition as the catalyst to clustering, which, based on Porter's *competitive diamond*, helps understand the interaction of factors that affect competitiveness and productivity. The model shown in Figure 1 finds the intensity of relations among the four spheres of the competitive diamond enhanced through clustering and reinforces what Porter termed the *importance of local context*.

Porter has had a profound impact on the contemporary clusters debate in both academic and



policy-making communities. However, his work has also sustained some vehement critiques, from his use of aggregated data rather than empirical studies to his overly flexible interpretations of geographical scale and the use of competitiveness as the theoretical basis for his conceptualization of the cluster. Despite the impact Porter has had on the contemporary cluster debate, the literature has continued to diversify, both as a heuristic and as a technical concept, as clusters have been positioned as part of the institutional matrix at regional, national, and supranational scales.

The transition from industrial to knowledge-based economy has added a new dimension to the cluster literature, whereby the emergence of knowledge as a core factor of production has resulted in organizational changes with significant geographical implications. This newfound focus on colocation and proximity incorporates numerous topics, ranging from regional innovation systems to technopoles that embody the innovative, high-technology, knowledge-intensive nature of what may be classified as *new industrial districts*. Further to local, place-based conceptualizations of the cluster, the focus on knowledge raises the issue of relational proximity. This is considered in the work on *buzz* and *pipelines*, which seeks to explain both the local and extralocal dimensions of clusters as collectively integral to the innovative development of clusters themselves. Another dimension of the cluster debate is the temporality of clusters. While Marshall recognized traditional industrial districts to be long-standing agglomerations, and although this continues to be the case with contemporary conceptualizations of clusters, there has been a focus on exhibitions and conferences as examples of temporary clusters.

In addition to the work on clusters as an empirical project, more conceptual debates have sought to address what appears as a highly confused literature with multiple and conflicting claims about the nature, meaning, and form of clusters. In acknowledging the complexities of the clusters literature, Paul Benneworth and Nick Henry contend that debates of colocation and proximity have become too big to be encompassed by any single theorization; instead, they advance the multiperspectival approach as a more nuanced way for understanding clusters. Recognizing the scope

of the cluster concept, the multiperspectival approach permits the coexistence of multiple theoretical perspectives, thereby emphasizing the dynamism of the cluster concept.

The concept of the cluster has generated significant interest within and beyond economic geography since Marshall's seminal work on industrial districts. While theoretical and empirical accounts continue to present alternative directions for cluster theory, the cluster remains an important yet elusive concept and as such can be seen to represent a work in progress.

Tim Vorley

See also **Agglomeration Economies; Industrial Districts; Innovation, Geography of; Knowledge Spillovers; Learning Regions**

Further Readings

- Asheim, B., Cooke, P., & Martin, R. (Eds.). (2006). *Clusters and regional development: Critical reflections and explorations*. London: Routledge.
- Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, 28, 31–56.
- Benneworth, P., & Henry, N. (2004). Where is the value added in the cluster approach? Hermeneutic theorising, economic geography, and clusters as a multiperspectival approach. *Urban Studies*, 41(5/6), 1011–1023.
- Czamanski, S., & Ablas, L. (1979). Identification of industrial clusters and complexes: A comparison of methods and findings. *Urban Studies*, 16, 61–80.
- Karlsson, C., Johansson, B., & Stough, R. (Eds.). (2004). *Industrial clusters and inter-firm networks*. Cheltenham, UK: Edward Elgar.
- Marshall, A. (1890). *Principles of economics*. London: Macmillan.
- Porter, M. (1990). *The competitive advantage of nations*. New York: Free Press.
- Porter, M. (1998). *On competition*. New York: Free Press.
- Vorley, T. (2008). The geographic cluster: A historical review. *Geography Compass*, 2(3), 790–813.



COAL

Coal is the most abundant fossil fuel, though its global distribution is highly uneven, and it powered the Industrial Revolution. Readily combustible and solid, it is formed in ecosystems where plant matter has been preserved by water and mud from oxidation and biodegradation. The fuel is black, brownish-black, or brown. Coal reserves are classified into categories or ranks based on the degree of *coalification*, or progressive alteration, that has occurred over time—this refers to changes in its energy and carbon content and environmental constituents. Ranks include anthracite (most desirable), bituminous (most abundant), subbituminous, and lignite (least desirable). Coal use often has been limited because of high emissions of sulfur dioxides, nitrogen oxides, particulates, and, most recently, carbon dioxide (it has the highest carbon emission rate among the fossil fuels). Other properties affect the desirability of coal—for example, heating value/volatile matter, moisture content, ash content and ash characteristics, and hardness. This entry reviews the geography of coal in countries with the largest proved reserves, primarily the United States and China, and briefly discusses its future in a carbon-constrained world.

United States

U.S. proved coal reserves account for 28.6% of the world total, more than 50% higher than the next largest country (Russia). Coal has provided the largest single source of domestically produced energy in the United States since 1984, and it has been one of the three most commonly consumed energy resources since the mid 19th century. The vast majority of coal is used for electricity generation, with the remainder dedicated for coking coal in the steel industry and other industrial applications, with a small quantity used in heating homes or offices or exported.

Two main U.S. coal regions exist: one each east and west of the Mississippi River. The eastern market developed first, with its coal older and of higher rank. The main mining areas are in the Appalachian states of West Virginia, Kentucky, Ohio, and Virginia, as well as Pennsylvania

(Figure 1). In general, eastern coal has higher heating value and more sulfur and is mined by both underground and surface (strip) mining methods. There are also significant coal reserves and mining in the Illinois Basin, which includes Illinois, Western Indiana, and Western Kentucky. Eastern mines are known for high production costs, being more labor intensive, and having higher unionization rates. However, United Mine Workers of America membership has steadily fallen for decades.

The Western state of Wyoming is by far the dominant coal producer in the nation, and it has been so since 1988. Almost all its output comes from 20 large surface mines, with thick seams, high capital requirements, and low labor and production costs. All subbituminous and lignite coal in the United States is in the west. Several other Western states provide much smaller coal output, including Texas, whose ample lignite supply is usually consumed close to the mines because of low energy content and high production costs.

China

China's coal sector is more dominant than any other country's. While it is only third in reserves (after the United States and Russia), China is the world's largest coal producer and user, and the fuel accounts for 69% of its total primary energy consumption. In contrast to the United States, coal use in China is much more concentrated in industrial applications and residential heating, though electricity generation is still the main application.

Northern China, Shanxi Province in particular, has most of the country's readily accessible coal and almost all the large state-owned mines (Figure 2). In contrast, coal areas of Southern China are generally higher in sulfur and ash, and more restrictions have been placed on their development. Following a decline in China's coal use from 1997 to 2000, due to restructuring of the industry and the closure of many small mines, output has been rapidly increasing ever since.

The process of restructuring China's coal sector has continued as production expands. Traditionally, the industry was spread out among large and local state-owned mines and thousands of village and town mines. There were 28,000

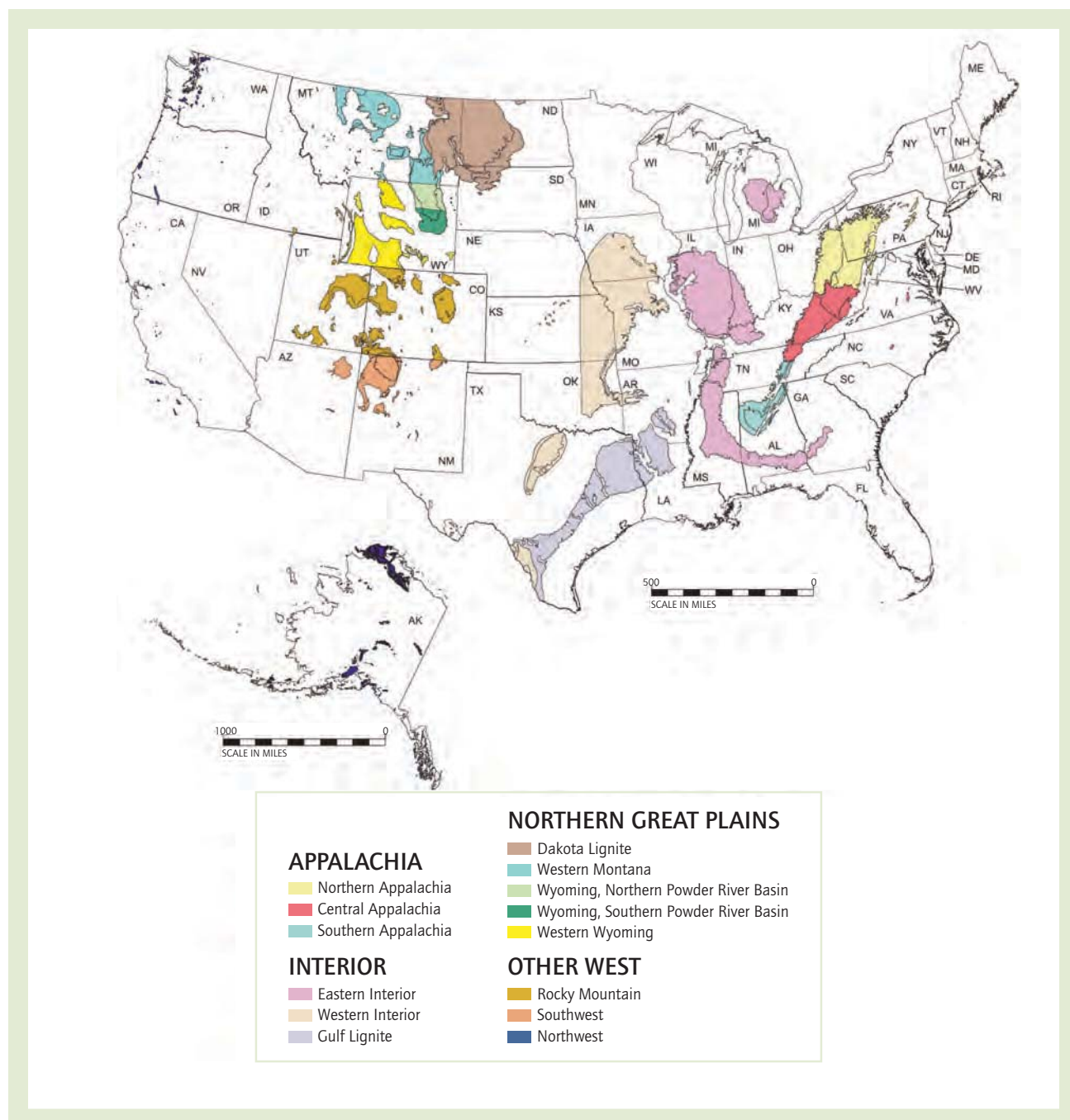
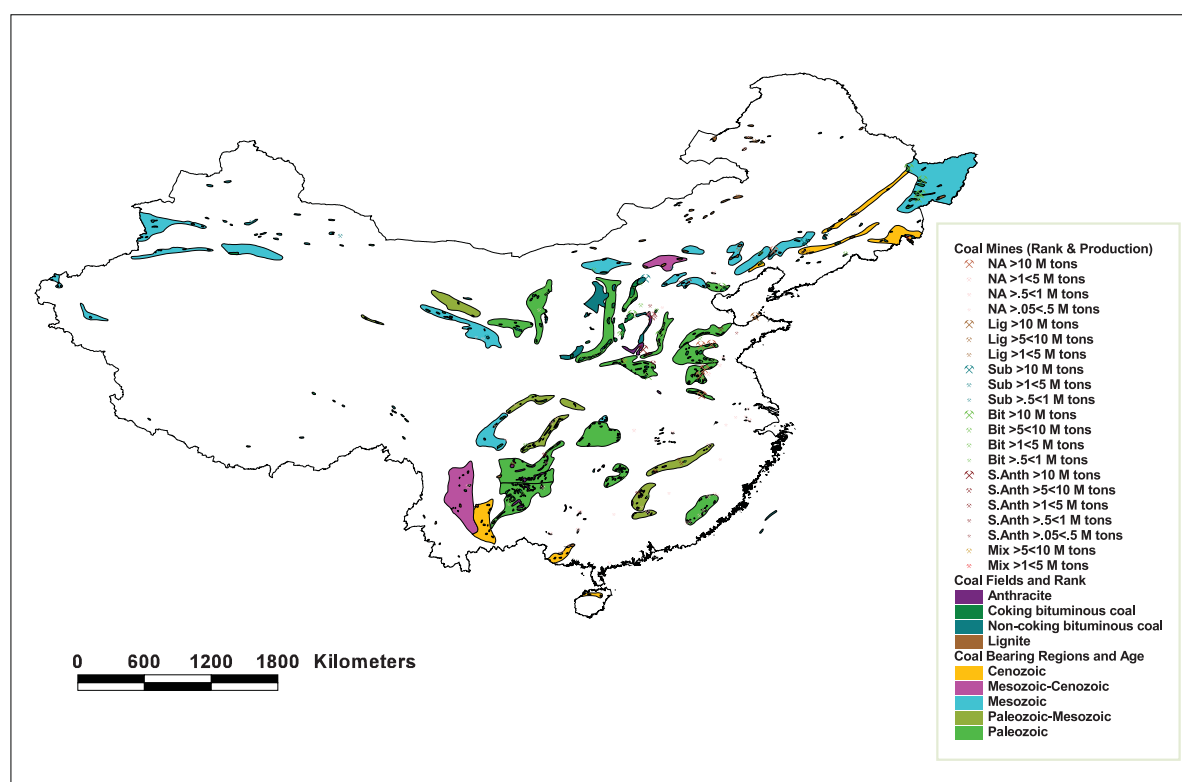


Figure 1 Coal supply regions of the United States

Source: Energy Information Administration, U.S. Department of Energy, Washington, DC.

coal mines in China at the start of 2006, compared with just 1,400 in the United States. The National Development and Reform Commission released a plan in 2006 to consolidate the industry into five or six giant conglomerates in the

main coal-producing provinces, attract more foreign investment, and close down all small mines by 2015. The smaller mines are considered inefficiently managed, with inadequate capital and poor safety records.



Layout 1. Three coverages (Coal Mines, Coal Fields and Rank, Coal Bearing Regions and Age) are shown. The Coal Mines layer shows the locations of major coal mines, type of coal (NA=not available, Lig=Lignite, Sub=Sub-bituminous, Bit=Bituminous, S. Anth=Sub-Anthracite, Mix=mix of coal ranks), and approximate annual yields of coal in millions of metric tons (M). The Coal Fields and Rank coverage displays locations of individual coal fields and associated coal rankings. The Coal Bearing Regions and Age layer shows potential coal-bearing areas of common geologic age.

Note: some coalfields are too small to be shown on map.

Data sources: U.S. Environmental Protection Agency Report ERP 430-R-96-005, USGS Open-File Report 00-047.

Figure 2 Coal mines, fields, and regions of China

Source: Courtesy of the U.S. Geological Survey from Open File Report OF 01-318, 2004, Reston, Virginia.

Other Countries

While Russia has the second largest coal reserves in the world, it is much less reliant on coal than is China. It has, however, seen a revival of its coal industry in the past decade. Among other former Soviet Republics, Kazakhstan and Ukraine are also significant producers. Besides China, the next most important coal regions in Asia are India and Indonesia, both of which have rapidly expanded output in the past decade. Other significant players in the global coal industry and trade include Australia

(with the fourth largest reserves) and South Africa (by far the dominant market in Africa).

The Future

Given the world's large coal reserve base, the fuel cannot be ignored, especially as oil and gas scarcity becomes more apparent in the 21st century. However, the need to control carbon dioxide emissions has given pause to further coal development in many countries. Consequently, only a few countries seem intent on rapidly expanding coal



production (e.g., China, Indonesia, Australia, and India), and even here, technologies to remove or sequester the carbon from coal combustion or conversion have become increasingly attractive.

Barry D. Solomon

See also **Anthropogenic Climate Change; Climate Policy; Energy Policy; Petroleum**

Further Readings

Elmes, G. A., & Harris, T. M. (1996). Industrial restructuring and the United States coal-energy system, 1972–1990: Regulatory change, technological fixes, and corporate control. *Annals of the Association of American Geographers*, 86, 507–529.

Hudson, R. (2002). The changing geography of the British coal industry. *Transactions of the Institution of Mining and Metallurgy (Section A)*, 111, 180–186.

Thomson, E. (2002). *The Chinese coal industry: An economic history*. Oxford, UK: Routledge.



COASTAL DEAD ZONES

As river drainage basins collect the runoff from the continents, they carry the flush of agricultural runoff, fertilizers, manure, sewage, and other waste. This discharge load acts as nutrient enrichment that forces *eutrophication* (from the Greek *eutrophos*, meaning “well nourished”). Huge spring blooms result as phytoplankton in the upper *photic zone* of coastal waters flourish. Anthropogenic (human-forced) pollution is damaging some 400 estuarine and coastal marine systems worldwide. These damaged ecosystems are Earth’s *coastal dead zones*.

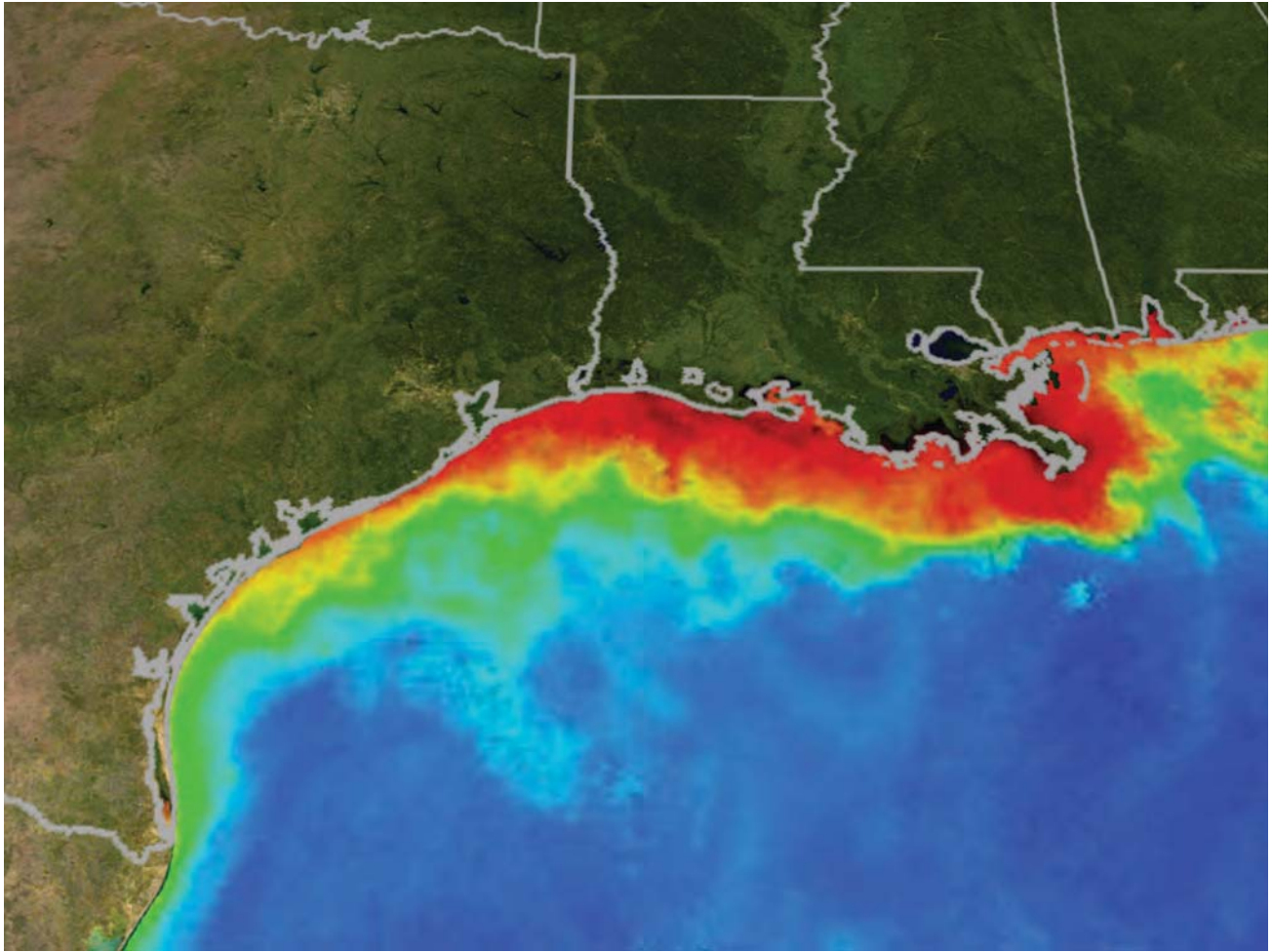
As algae die, they drift to the seabed and accumulate in the bottom sediments, feeding bacterial action in the *benthic zone*. The bacteria consume oxygen as they process the organic debris. As a function of this bacterial respiration, dissolved oxygen (DO) levels decline. The biological oxygen demand (BOD) of bacteria feeding on the

decay exceeds the dissolved oxygen, and *hypoxia* develops, killing any fish that venture into the area. Benthic-dwelling animals (flounder, crab, lobsters) and immobile animals (worms, clams, oysters) are killed. These low-oxygen conditions act as a *limiting factor* on marine life.

Conditions are worsened by physical factors and can vary seasonally. Stratification of waters by temperature produces a warmer surface layer and cold deep layers following spring blooms and the approach of summer warmth. Some recovery is possible from seasonal depletions, but hypoxic conditions can spread spatially with the increasing influx of nutrients over time. Thus, the dead zone, a region of oxygen-depleted (hypoxic) water off the coast of Louisiana in the Gulf of Mexico has expanded to more than 22,000 km² (square kilometers), or 8,500 mi.² (square miles), each summer (first photo). The Mississippi drainage system handles the runoff for 41% of the continental United States, delivering the nutrient load to this region of the Gulf. In fact, all along the Texas coast, an extensive dead zone prevails, stretching in a discontinuous concentration some 32 km (20 mi.) from the coastline, fortified by nutrient-laden runoff and coastal septic systems.

Various events can worsen conditions, such as heavy precipitation from storms or hurricanes tracking inland, and produce periodic episodes of eutrophication. Dead zones occur in episodes such as the one in North Carolina in 1999. In short succession during September and October, Hurricanes Dennis, Floyd, and Irene delivered several feet of precipitation to the state, each storm falling on already saturated ground. In North Carolina, more than 10 million hogs, each producing 2 tons of waste per year, were located in about 3,000 agricultural factories. These operations collected almost 20 million tons of manure into hundreds of open lagoons, many set on river floodplains. The three-hurricane downpour flushed out waste lagoons into wetlands and streams and on to Pamlico Sound and the ocean, producing a spreading dead zone and an environmental catastrophe.

When the 1993 Midwest floods hit, the Mississippi river’s nutrient discharge was such that the size of the dead zone in the Gulf of Mexico doubled. Following Hurricane Katrina in 2005, the dead-zone region was overwhelmed by the



The large region of low-oxygen water often referred to as the *Dead Zone* spreads across the Gulf of Mexico in what appears to be an annual event. NASA satellites monitor the health of the oceans and spot the conditions that lead to a dead zone. This image shows how ocean color changes from winter to summer in the Gulf of Mexico. Aqua shows highly turbid waters that may include large blooms of phytoplankton extending from the mouth of the Mississippi River all the way to the Texas coast. When these blooms die and sink to the bottom, bacterial decomposition strips oxygen from the surrounding water, creating an environment in which marine life find it difficult to survive. Red and orange represent high concentrations of phytoplankton and river sediment.

Source: NASA/Goddard Space Flight Center Scientific Visualization Studio.

discharge carrying all the sewage, chemical toxins, oil spills, household pesticides, animal wastes and carcasses, and nutrients. The agricultural, feedlot, and fertilizer industries dispute the connection between their nutrient input and the dead zone.

In other parts of the world, the connection between nutrient inflow and eutrophication leading to depleted dissolved oxygen and hypoxia is well established. In Sweden and Denmark, a concerted effort to reduce nutrient flows into their

ivers reversed hypoxic conditions in the Kattegat Strait (between the Baltic Sea and the North Sea). The Black Sea is chronically plagued by dead-zone conditions. However, after regional political changes and the decline in state farms, fertilizer use is down more than 50% since 1990, and for the first time in recent decades, the Black Sea is getting several months' break from its year-round hypoxia. As oxygen levels improved, so did ecosystem recovery, although still not to original



biological conditions. In water bodies such as the Thames and Mersey river estuaries in England and the Hudson and East rivers in New York, reducing nutrient inflows has healed dead zones.

As with most environmental situations, the cost of mitigation is cheaper than the cost of continued damage to marine ecosystems. For the Mississippi river drainage, a 30% cut in nutrient inflow upstream is estimated to increase dissolved oxygen levels by more than 50% in the dead-zone region of the Gulf.

One mitigating strategy might be to mandate application of only the levels of fertilizer needed. In addition to reducing nutrient outflows from farmland, this action would lead to a savings in overhead costs for agricultural interests. Also, action is needed to begin dealing with animal wastes in many of the world's drainage basins, including the Mississippi.

The strategy is simply to keep fertilizers and manure and other nutrients on the land and not in the water. Inorganic fertilizers are chemically produced through artificial nitrogen fixation at factories using the Haber-Bosch process, developed in 1913. The annual production of synthetic fertilizers now is doubling every 8 years; worldwide, some 1.82 million tons (i.e., almost 2 million tons) are produced per week. Humans fix more nitrogen per year than all terrestrial sources combined, overwhelming natural denitrification systems. Anthropogenic sources of fixed nitrogen first exceeded the normal range of naturally fixed nitrogen in 1970.

Robert J. Diaz, an important scientist researching dead zones, considers hypoxia and anoxia as evidence of the widespread deleterious anthropogenic influence on coastal systems. He ranks this as a major global environmental problem. The ongoing decline in dissolved oxygen and the rate of that decline are unprecedented over such a short time span. Understanding and mitigating this problem requires the spatial analysis tools of geographic science.

Robert W. Christopherson

See also *Agricultural Land Use; Agriculture, Industrialized; Biogeochemical Cycles; Coastal Zone and Marine Pollution; Environmental Impacts of Agriculture; Nutrient Cycles*

Further Readings

- Diaz, J. D., & Rosenberg, R. (2008). Spreading dead zones and consequences for marine ecosystems. *Science*, 321, 926–929.
- Goddard Earth Sciences Data and Information Services Center, NASA. (2008, May). *Science focus: Dead zones*. Retrieved January 11, 2010, from http://disc.gsfc.nasa.gov/oceancolor/scifocus/oceanColor/dead_zones.shtml
- Rabalais, N. N., & Turner, R. E. (Eds.). (2007). *Coastal hypoxia: Consequences for living resources and ecosystems*. Washington, DC: American Geophysical Union.



COASTAL EROSION AND DEPOSITION

Coastal erosion is the term used for the removal of land or sediment from a coastline, whereas *coastal deposition* is the addition of sediment to a coastline. Factors influencing erosion and deposition include the rate of sediment supply to the coast, the shape of the underlying geology, the rate at which coastal processes transport sediment, and the rate and direction of sea-level change. These can ultimately be attributed to tectonics, climate, geology, and eustasy, all of which vary spatially and temporally. It is important to understand these processes, given the significance of the coast for habitat, recreation, and resources.

Coastal morphodynamics, a systematic approach to integrating the processes and boundary conditions that influence coastal erosion and deposition, was introduced by Don Wright and Bruce Thom in 1977. This integrates the effects of instantaneous processes (e.g., wave and swash processes including incident waves, rip currents, bed return flows, and infragravity waves), long-term processes such as sea-level change, and geological processes (e.g., tectonic changes). Using this approach, the coasts can be divided into three categories: prograding, eroding, and stationary (where net sediment movement is zero) coasts.



The Twelve Apostles, on the southern coast of Australia, formed by bedrock eroding at a variable rate

Source: Natalie Townsend.

Coastal Erosion

Eroding coasts, often termed *retrograding*, *encroaching*, or *receding coasts*, result from a net negative sediment budget. This can occur due to factors including wave energy increase, wave direction change, currents, relative sea-level rise, and losses to the coastline by tidal and aeolian transport. The less aggregated and finer grained the beach, the easier it is to transport and remove the sediment from the coast.

On rocky coasts, constant wave pounding, chemical and mechanical weathering, abrasion, and hydraulic action play a major role in degrading the parent rock into finer particles for deposition elsewhere. The ease with which the bedrock is eroded depends on the characteristics of the

parent material. This may result in the formation of rock stacks such as the Twelve Apostles on the southern coast of Australia (see photo).

Other coastal features formed by coastal erosion include beach and dune scarps on sandy coasts. This often leads to infrastructure being compromised or stranded on the beach or, ultimately, the loss of human life. An example of eroded dunes due to a net loss of sediment is on the northern French coast (see photo), where stationary World War II concrete bunkers are gradually being exposed.

Coastal Deposition

Coastal deposition, often referred to as *progradation* or *transgression*, occurs when there is a net



The erosion along the northern French coast has left relict World War II bunkers exposed along the coast.

Source: Denis Marin.

sediment input. Deposition frequently results in the development of large alluvial deltas (e.g., Mississippi and Rhone deltas), beach ridge plains (e.g., Normandy coast, France), Chenier plains (e.g., Princess Charlotte Bay, Northern Australia; see photo), or mud flats. The nature of each shoreline depends on the origin of the sediment supply (i.e., whether it is dominated by river sediments or reworked beach sediment) and on wave conditions.

Factors Affecting Coastal Erosion and Deposition

In the following sections the most common factors influencing coastal erosion and deposition are reviewed.

Wave Climate

Waves and their induced sediment disturbance, infragravity waves, bed return flows, and rip currents are mechanisms for sediment transport. The amount of sediment that is transported depends on the incident wave climate, which ultimately depends on geographically variable wind climate. An increase in wind speed leads to an increase in wave energy. Greater wave energy and wave

length also enable larger grain sizes to be transported and larger volumes of sediment to be disturbed and displaced due to the increased depth of the wave base (D):

$$D = 1/2L,$$

where L is the wave length.

Storm surge and increased rip intensity on wave-dominated coasts often accompany elevated wave conditions. Storm surge accelerates erosion by exposing higher land elevations than normal to these more energetic wave conditions and by raising the water table and saturation of the soil. Increased rip current intensity also transports greater volumes of sediment and larger grain sizes offshore, often beyond a depth from which they may be returned onshore by normal wave action or above the swash zone as a berm deposit that may also include debris. This may lead to permanent or transient alterations to the shoreface during storms and hurricanes.

On a sandy coast, the movement of sediment offshore is a consequence of the beach adjusting to a flatter offshore profile that tends to dissipate more of the wave energy prior to reaching the shoreface. With a lowering of wave energy, beach water tables are lowered, and sediment is deposited on the upper shoreface. This is because the



An example of a chenier ridge in Princess Charlotte Bay, Northern Australia. Both chenier plains and beach ridge plains can be observed as parallel rows of sediment ridges and vegetation on the shore.

Source: Dylan Horne.

sediment-laden swash drains downward as it runs up the beach, leaving the entrained sediment behind. This results in a steeper beach profile. Thus, small waves tend to form steep profiles, and larger waves tend to form flatter profiles. This is because steep beaches tend to reflect incoming waves, and flatter beaches tend to dissipate wave energy in the nearshore zone. The beach may change continuously from steeper to flatter according to changes in wave energy.

Longshore currents are generated when waves approach the beach at an angle. For example, a general northward trend in sediment transport occurred in Eastern Australia at lower sea levels (before approximately 6,000 years BP), when the coast consisted of long straight beaches aligned at an angle to the dominant southeast swell generated in the Tasman Sea. This led to the development of several sand islands located at the end of

the transport path, off the coast of Southern Queensland—for example, Fraser Island. Locally, a change in wave direction can lead to beach rotation, where the beach appears to rotate within an embayment due to erosion and deposition at its opposite ends. Beach rotation occurs as a consequence of beach profile readjustment, so that the beach angle remains perpendicular to waves. These shifts in wave direction may be seasonal or aseasonal in nature, for example, El Niño/La Niña or winter/summer cut/fill cycles.

Longshore transport may initiate exchange of sediment between adjacent sandy beaches through headland bypassing, where sediment accumulation occurs on the downdrift side of a headland due to the currents. This sediment then moves subaqueously around the headland as a downdrift spit and migrates shoreward. Some of the sediment will result in net accretion as a sand wave;



Mangroves aid accretion by increasing wave attenuation and entraining sediment in the pneumatophores. Also seen in this picture is the effect of erosion by the running stream as the tides ebb and flow or as rain water is added to the estuary.

Source: John Rae, Oyster Bay, Australia.

however, most remains subaqueous. The sand wave then migrates and merges with the down-drift beach, with a topographically controlled rip moving in advance, causing localized erosion.

Dunes

Wind and washover transfer sand into and out of the nearshore zone and dunes. Wind transports fine-grain sand into aeolian dunes, which is then trapped by pioneering sand plants, such as *Spinifex* spp., and accumulates into ridges. These ridges may be eroded or transported landward into mobile transgressive dunes during storms or if the vegetation is disturbed.

Tidal Currents

Tidal currents are important in areas with tidal ranges greater than 2 m (meters; macro- and mesotidal beaches) or in channels where flow velocities are fast. These currents move sediment with the direction of flow or incise and erode into adjacent deposits. Tides also alter the water table level, causing small-scale erosion and deposition cycles.

Reefs, Tombolos, and Biota

Reefs and islands are natural offshore features resulting in reduced wave energy in their lee. This can result in the formation of salient features or the development of a tombolo. If a tombolo



The undermining and collapse of a sea wall structure on the Northern French coast due to high erosion rates and inappropriately engineered structures

Source: Author, Wissant, France.

feature is formed, adjacent beaches are protected from incident wave energy, leading to changes in beach morphodynamics and patterns in deposition and erosion. Sea grass, kelp beds, and mangroves (see Oyster Bay photo) also aid shoreline accretion by reducing incident wave energy through wave attenuation.

Fragments of coral may be eroded from the reefs and deposited onshore, creating coral beaches. Reef islands themselves tend to vary in behavior. High wave energy, coral shingle, and boulder motu islands prograde during storms and redistribute the sediment during fair-weather conditions, whereas less exposed sandy cays erode

during storms and recover during fair-weather conditions.

Chemical Effects

Apart from chemical weathering of parent rock due to the slight acidity of sea water, in temperate to tropical regions, beaches may become cemented into beach rock by an excess of calcite crystals. During erosive conditions, the presence of beach rock leads to accelerated erosion due to a decrease in beach permeability. Eventually, it may be completely eroded, leaving behind a newly formed reef.



Human Interference

Sea walls are shore-parallel features built on the subareal beach between the shoreline and foredune with the aim of protecting adjacent property and stopping shoreline retreat. If the sea wall is built impermeable and within the swash zone, the water table rises, and increased wave reflection and turbulence are initiated against the wall. This ultimately exacerbates erosion. Ultimately, this can result in erosion of the adjacent beach or undermining and failure of the structure (see Wissant photo).

Breakwaters are also shore-parallel structures, built away from the shoreline with the aim of decreasing wave energy in their lee and protecting the coast from erosion. The presence of these features may have no impact on the system if the erosion is due to longshore transport. Alternatively, they can cause deposition in their lee, building up a salient feature or, possibly, tombolo.

Groynes, training walls, and jetties are shore-perpendicular structures extending into the surf zone and put in place to minimize erosion. However, they often exacerbate erosion, particularly on coastlines dominated by drift transport. The presence of these structures causes beach realignment due to up-drift accumulation of sediment and down-drift erosion. Wave refraction around the groyne and induced rip currents increase the potential for offshore transport of sediment and beach erosion.

Changes to beach sediment may occur due to beach nourishment, sand mining for soil aggregates or heavy minerals, dredging and spoil dumping, and increased runoff and soil erosion due to land development, clearing, and degradation. This not only has a direct impact on the removal and deposition of sediment but also alters the beach slope and wave dissipation conditions, altering its response to wave climate changes.

Sea-Level Change

The sea level may be altered through processes including an increase in water temperature and changes to the volume of land ice (*eustasy*), tectonic movement and land subsidence (*isostasy*; e.g., the North American Pacific Coast), and deglacial uplift (*glacio-isostasy*; e.g., Sweden).

Erosion or deposition may occur with a change in sea level, depending on the rate and direction of the sea-level change and the rate of sediment supply. If the rate of sediment supply exceeds the rate of sea-level rise or sediment accumulation occurs during sea-level fall, then deposition occurs. If the rate of sea-level rise exceeds the rate of sediment supply, then erosion occurs. If the rate of sediment supply is equal to the rate of sea-level change, then the shoreline remains stationary. If sea-level rise is a consequence of climatic changes, there may be exacerbated consequences of erosion through increased wave energy.

The most widely accepted model for sea-level change was initially developed by Per Bruun, termed the *Bruun rule*. In his papers, Bruun formulated how shorelines retreat to rising sea levels and undergo deposition under falling sea levels to maintain an equilibrium profile. The equilibrium profile is based on the assumption that the shoreface maintains a constant profile slope for any given depth, which balances offshore movement by gravity and water currents and onshore movement by wave motion. This shape is maintained through sea-level changes, so that the amount of sediment eroded from the upper shoreface is equal to the amount deposited on the lower shoreface. The resultant landward recession distance due to sea-level rise according to the Bruun rule is

$$R = S(L/B + h) = (S)/\tan\phi$$

where R is the recession distance, S is the amount of sea-level rise, L is the length of the profile, B is the berm height, h is the wave base closure depth, and ϕ is the profile slope angle.

However, the validity and applicability of the Bruun rule in real-life situations has been the subject of debate. It has been pointed out that the assumptions made in the model are unrealistic, that the nearshore system is not closed and sediment is frequently exchanged with dunes or seaward of the shoreface, and that the equilibrium shoreface is unlikely to exist or be present at every coast. Thus, various modifications were made to the Bruun rule, which resulted in the development of three main coastal responses: erosion, barrier rollover, and overstepping (Figure 1). The erosional response is a typical example of the Bruun

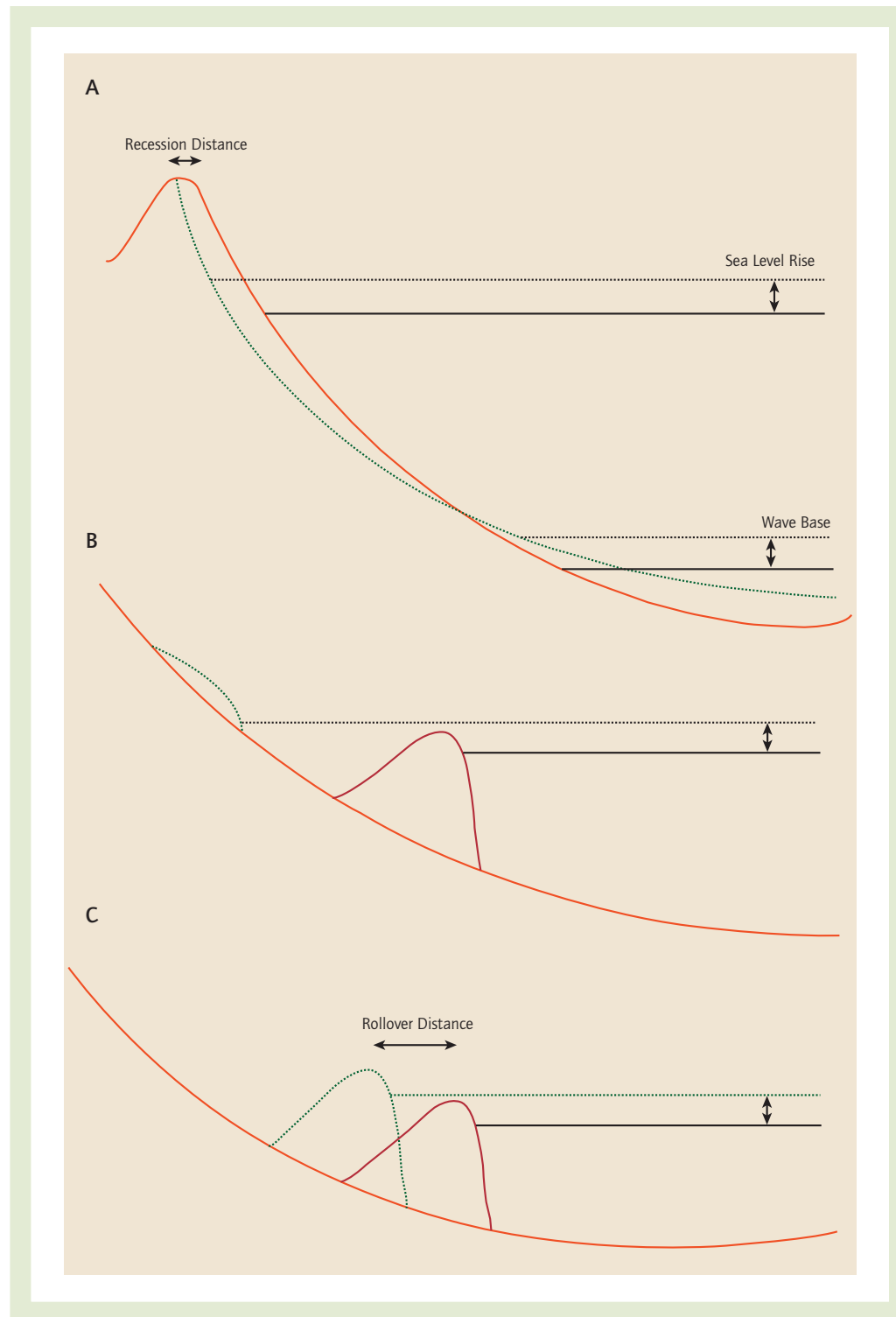


Figure 1 A diagrammatic representation of the various shoreface responses to sea-level rise: (A) the general Bruun rule of erosion, where offshore dispersal of sediment occurs and seabed rise equals sea-level rise; (B) overstepping, where the barrier is drowned and the sea level rises above it; and (C) barrier rollover, where the barrier moves landward, recycling the sediment

Source: Adapted from Carter, R. W. G. (1989). *Coastal environments: An introduction to the physical, ecological, and cultural systems of coastlines*. London: Academic Press.



Rule, whereby erosion of the upper shoreface occurs and the sediment is then transported offshore. *Rollover* is where the barrier recycles the sediment and moves progressively upward on the shoreface; and *overstepping* identifies the barrier being drowned and remaining on the shoreface. More recent adjustments to the Bruun rule and new models (e.g., the shoreface translation model [STM] introduced by Peter Cowell) have further minimized the potential flaws of the original Bruun model.

Shoreline Monitoring and Predictions

Shoreline retreat modeling is important given the globally dense coastal populations and the significance of coastal resources. New technology and models are now used to further understand shoreface behavior and aid in such predictions. For example, light detection and ranging allows precise beach topographies to be made and monitored for erosion and deposition (e.g., Cat Island, Mississippi); global positioning systems can track changes in shoreline features on a daily basis in 3D (three dimensions); and ground penetrating radar and other seismic tools can see subsurface profiles to show sediment deposition layers or erosion surfaces up to tens of meters below the land surface.

Elsbeth Rae

See also **Anthropogenic Climate Change; Climate Change; Coastal Hazards; Dunes; Tsunami**

Further Readings

- Anthony, E. J. (2000). Marine sand supply and Holocene coastal sedimentation in Northern France between the Somme estuary and Belgium. *Geological Society (London), Special Publications*, 175, 87–97.
- Bruun, P. (1988). The Bruun Rule of erosion by sea level rise: A discussion of large scale two- and three-dimensional usages. *Journal of Coastal Research*, 4, 627–648.
- Carter, R. W. G. (1989). *Coastal environments: An introduction to the physical, ecological, and*

cultural systems of coastlines. London: Academic Press.

- Cooper, J. A. G., & Pilkey, O. H. (2004). Sea-level rise and shoreline retreat: Time to abandon the Bruun Rule. *Global and Planetary Change*, 43, 157–171.
- Cowell, P. J., Roy, P. S., & Jones, R. A. (1995). Simulation of large-scale coastal change using a morphological behaviour model. *Marine Geology*, 126, 45–61.
- Curry, J. R. (1964). Transgressions and regressions. In R. C. Miller (Ed.), *Papers in marine geology* (pp. 175–203). New York: Macmillan.
- Houghton, J. T., Ding, Y., Griggs, D. J., Noguer, M., van der Linden, P. J., & Xiaosu, D. (Eds.). (2001). *Climate change 2001: The scientific basis* (Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change [IPCC]). Cambridge, UK: Cambridge University Press.
- Ranasinghe, R., McLoughlin, R., Short, A., & Symonds, G. (2004). The Southern Oscillation Index, wave climate, and beach rotation. *Marine geology*, 204, 273–287.
- Thom, B. G. (Ed.). (1984). *Coastal geomorphology in Australia*. Sydney, New South Wales, Australia: Academic Press.
- Woodroffe, C. D. (Ed.). (1994). *Coastal evolution: Late Quaternary shoreline morphodynamics*. Cambridge, UK: Cambridge University Press.
- Wright, L. D., & Short, A. D. (1984). Morphodynamic variability of surf zones and beaches: A synthesis. *Marine Geology*, 56, 93–118.
- Wright, L. D., & Thom, B. G. (1977). Coastal depositional landforms: A morphodynamic approach. *Progress in Physical Geography*, 1, 412–459.



COASTAL HAZARDS

A *coastal hazard* is a process occurring at the coastline that can cause damage to people living, working, or visiting the coastline. The damage can be physical, in terms of injury, loss of lives, and ruined properties, or economic, social, or cultural, in terms of interrupting the use of the



coastline (e.g., navigation, fisheries, and recreational use). It is commonly studied under the broad topic of geography because there are spatial variations to both the processes that cause the hazard and the behavior of the people who are affected by the hazard. Coastal hazards are mainly grouped into flooding (or inundation) hazards and erosion hazards but can also include swimming and navigation hazards.

People living near the coast depend on the sea for food, trade, and transport. In modern Western societies, where the wealthier economies allow the average person more time for recreation and relaxation, coastal properties have become an increasingly valuable asset. This has fueled a greater interest in using science to protect these properties from coastal hazards. However, not all interest in coastal hazards has been inspired by wealth protection. Advances in our understanding of coastal processes and our ability to provide increasingly accurate predictive computer models have been driven both from the top, by international efforts to avoid repeats of devastating coastal disasters (e.g., the Indian Ocean tsunami on December 26, 2004), and from the bottom up by local issues (e.g., such as surf life-saving organizational activities to decrease incidents of drowning).

Flooding Hazards

Coastal flooding is a hazard not only because of the damage that saltwater can inflict on property but also because the associated deep water, strong currents, and turbulence can cause drowning. Moreover, floating objects torn free by turbulent waters can injure and exacerbate inundation damage.

The water level at the coastlines at a single instant in time is made up of (1) the mean sea level, (2) storm surge, (3) the tide, and (4) run-up. The first influence on mean sea level to consider is that the ocean is intimately connected to the atmosphere. Currents and water levels respond to changing wind, pressure, and air temperature patterns. These properties change dramatically from season to season, from year to year because of climatic effects such as El Niño/La Niña, and over much longer timescales because of influences such as the arrival and passing of ice ages. The sea

level can also experience relative changes, as the landmasses can sink or rise slowly due to effects such as isostatic rebound (the lift in land masses that follows retreat of continental glaciers). It is therefore difficult to measure mean sea level at a site, let alone determine if it is changing in any permanent sense. Thus, the definition of mean sea level depends on the time interval over which the mean is calculated. For the most part, this is a yearly average and so varies from year to year and depending on location.

Storm surge is the rise in water level caused by the atmospheric changes that accompany storm events. The reduced air pressure lifts the surface of the water up in an effect called the *inverse barometer effect*. Strong winds that circulate around low-pressure events can cause seawater to pile up against the coastline. The relative importance of the pressure and wind effects depends on the location and intensity of the storm, with the latter more important in tropical cyclones and hurricanes. The lifting of the water surface (by wind or pressure) can initiate a large-scale wave or a long wave, which propagates away from the storm at a speed that is controlled by the depth of the coastal waters. If the storm travels at the same speed and direction as the wave, there is ample time for energy transfer, and the wave can get large. Some semi-enclosed areas such as bays and basins can resonate with the same period as the long wave, resulting in an extra large storm surge. This is the case of storm surges in the North Sea and the reason why the Netherlands has needed to invest so much money in storm surge defense structures.

The tide is the wave that is excited by the gravitational attraction of the sun and the moon. High tide corresponds to the crest of the wave and can occur either twice daily or once daily, depending on the location. The axial tilt of the Earth relative to the sun and moon cause, in part, this spatial variation. This large-scale wave propagates around the world at a speed that depends on the depth of the water. It reflects at the boundaries created by landmasses to create standing waves, which rotate around basins and in some cases cause resonance in these basins and bays. Thus, the size of the tide depends on the characteristics of basins and so varies with location, in addition to the variations caused by the Earth's axial tilt. Temporal changes depend on the proximity and



orientation of the sun and the moon, which vary with latitude, season, and the phases of the moon. The largest and most hazardous high tides occur when the gravitational effect of the sun and the moon combine (spring tide) and the sun and the moon are closest to Earth in their orbits (perigee and perihelion).

Run-up is the added elevation of the water level caused by waves. In deep water, the currents inside waves form circles or orbits, which are almost closed. The consequence is that the water does not move significantly inside waves. When these waves break, these orbits change dramatically and the water rushes on average forward near the surface. The result is water piling up at the shoreline in an effect that is called *set-up*. The magnitude of set-up depends on how quickly the waves lose energy across the surf zone, which depends on the seabed topography. On top of the set-up is *swash*, or the movement of the water line up and down with each incoming wave. These two effects combine to make run-up. In the event of a tsunami, the hazard consists of the associated run-up (only on a much larger scale).

Calculating the flooding hazard for a site is simply accomplished by adding together estimates of the size of these four effects. Of these, the run-up is probably the least well predicted by existing models. Obviously, the flooding hazard depends on the probability of these four flooding hazards occurring at the same time.

Coastal Erosion Hazards

The waves, currents, and elevated water levels that occur during storms can cause erosion of the coastline. This is a hazard because it can cause properties and roads to fall into the sea (see photo). When waves break and the currents rush forward on average near the surface of the water, continuity dictates that there must be a return flow or an undertow near the bottom. This return flow will quite often converge along the shore to make offshore streams of water called *rip currents*. Elevated water levels, waves, and turbulence near the coastline caused by breaking mean that it is easy for sand grains to get suspended or entrained from the seabed. This sand is then transported seaward by the undertow and rip currents, where it is deposited outside the zone of

breaking waves where the currents die out. The net result is a movement of sand from the beach face seaward into sandbars during storm events.

Shorelines that have steep slopes cause waves to reflect, and reflected waves have strong currents just seaward of the shoreline. This is why harbor walls are often designed with sloping seaward sides. It is also why building seawalls can actually exacerbate erosion by stirring and eroding the sand in front of the seawall. Predicting the extent of erosion during a storm is very difficult because not only is a water-level prediction needed, it is also necessary to predict the behavior of waves and currents very close to the shoreline as well as the mechanisms for entraining sand (which depend on the composition and shape of sand grains).

Coastal Hazard Zone

A coastal hazard zone is a tool for managing coastal development. It can be defined as a distance from the shoreline that is likely to experience significant erosion and flooding in a time frame that covers the lifetime of the building (e.g., 50 or 100 years). Coastal hazard zones are being continually updated as scientific advances and better records of storm events allow more realistic predictions to be incorporated. The increasing value of coastal land has put pressure on governments to minimize hazard zones. In some places, it is difficult to get insurance coverage for homes located in a coastal hazard zone, or there are stronger building restrictions, such as requiring houses to be relocatable or on stilts.

Defenses Against Coastal Hazards

Defense against coastal hazards most commonly involves a “hard” solution such as a protective barrier. For example, in the case of flooding hazard, defenses consist of floodgates that can be shut or walls or dykes to stem the flow of water. Temporary barriers are often constructed out of sandbags. Defending against coastal erosion can be accomplished by protecting the shoreline using a seawall, piles or bags of rocks, tires, concrete structures, or giant sandbags. The piles of rocks/structures are also aimed at removing energy from the waves by increasing the action of friction.



Erosion caused by a northeaster on the Outer Banks in North Carolina, 1987

Source: National Oceanic and Atmospheric Administration.

Coastal erosion can also be minimized by stopping the wave energy from reaching the shoreline. This can be accomplished by building an offshore structure that causes waves to break seaward of rather than at the shoreline. If currents tend to cause sand to move alongshore, walls projecting from the shoreline (*groins*) are built to trap the sand. The negative side of hard solutions is that they are costly, look out of place, and often cause a hazard in themselves. For example, rocks can come loose during storms, and injury can occur on decaying, poorly maintained seawalls where rusting steel reinforcements have become exposed.

More recently, there has been a focus on finding ways to protect the shoreline that also enhance or maintain its natural character and amenity value. The dunes that commonly back natural beaches are great reservoirs of sand that are tapped into during storm events. Keeping these reservoirs stocked for emergencies is a vital part

of a natural beach's ability to cope with storm events. Therefore, "soft" solutions are increasingly used, which are to enhance the dune by planting, removing nonnatural species, installing fences to trap sand, and limiting or channeling pedestrian access. An added benefit is that the natural beauty of the coastline is enhanced, increasing the potential for tourism and restoring increasingly rare natural habitats.

Many problems that have been associated with coastal protection works can be avoided by education about the inherent variability of natural systems. In many cases, the most economical approach is retreat, recognizing that the coastal hazard zone was never optimal for human habitation.

Coastal Hazards and Climate Change

Predictions of climate change have required reevaluation of coastal hazard zones. Not only is the sea



level predicted to change, but so too is the frequency and severity of storm events. The vast complexity of the ocean-atmosphere system makes it nearly impossible to make predictions of potential changes, let alone provide an indication of the risk associated with the scenarios. The Intergovernmental Panel on Climate Change reports are our best guess, and most governments base their precautionary approach on these predictions.

Karin Bryan

See also **Anthropogenic Climate Change; Coastal Erosion and Deposition; Coastal Zone and Marine Pollution; El Niño; Global Sea-Level Rise; Hurricanes, Risk and Hazard; La Niña; Natural Hazards and Risk Analysis; Oceans; Tsunami; Tsunami of 2004, Indian Ocean**

Further Readings

- Beatley, T., Brower, D. J., & Schwab, A. K. (2002). *An introduction to coastal zone management* (2nd ed.). Washington, DC: Island Press.
- Garrison, T. S. (2007). *Oceanography* (6th ed.). Florence, KY: Brooks/Cole.
- The H. John Heinz III Center for Science, Economics and the Environment. (1999). *The hidden costs of coastal hazards*. Washington, DC: Island Press.
- Komar, P. D. (1997). *Beach processes and sedimentation* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Schwartz, M. L. (Ed.). (2005). *Encyclopedia of coastal science*. New York: Springer.



COASTAL ZONE AND MARINE POLLUTION

The coastal zone is defined as the interface between the land and sea where the land and sea influence each other. Its landward and seaward boundaries are not fixed. If the water depth is extended to 200 meters (m), the waters cover an area of about 7% (26×10^6 square kilometers [km^2]) of the surface of the global ocean. This area accounts for at least 15% of oceanic primary

production, 80% of organic matter burial, 90% of sedimentary mineralization, 75% to 90% of the oceanic sink of suspended river load, and about 50% of the deposition of calcium carbonate. In addition, 90% of the world fish catch and its overall economic value and at least 40% of the value of the world's ecosystem services and natural capital are in this area. Fisheries provide livelihoods to about 40 million people worldwide, and 80% of them are in Asia; the three top fisheries producers are China, Peru, and the United States.

About 40% of the world's people live within 100 km of the coastline, or 7.6% of Earth's total land area. Each year, roughly 50 million more people move into this narrow fringe of coastal land worldwide. By 2050, with the world's population projected to be around 9 billion, some 60% will be living within 60 km of the sea. From another perspective, the contiguous coastal area less than 10 m above sea level covers 2% of the world's land area but contains 10% of the world's population and 13% of the world's urban population. This low-lying zone has 21% of the world's cities, with populations over 5 million; in Asia, 32% of the population lives in such coastal cities.

Population growth has a direct bearing on the extent and magnitude of physical alterations of coastal areas and their consequent destruction. The most damaging actions are changes in land use, including draining wetlands and mangroves for agriculture or settlements; building structures such as ports, seawalls, dams, aquaculture installations, and tourist facilities; and overuse of resources, including overfishing, water use, and sand and gravel extraction.

Several examples of the types of physical alterations currently occurring in coastal environments give an idea of the magnitude of the problem. Of the world's wetlands, 50% have been lost over the past century, and the percentage is higher for mangroves. Already 34% of the world's coral reefs are lost or seriously damaged, and another 20% are threatened in the next 20 to 40 years. The destruction of habitats varies from region to region, but all show deterioration of some kind.

Climate-induced changes in sea level are likely to increase the risk of inundation in many low-lying parts of the coastal zone. Hotspots of coastal



vulnerability are the populated deltas, especially the megadeltas of Asia; low-lying urban areas; and atolls, where the stresses on natural systems coincide with low human adaptive capacity and high exposure. Regionally, South Asia, southeast and East Asia, Africa, and small islands are the most vulnerable. Of growing concern is the impact of increasing atmospheric carbon dioxide concentrations and the resultant acidification of the sea. Acidification is expected to disrupt calcium carbonate formation, affect the oxygen metabolism of animals, and influence the availability of nutrients.

Despite its relatively small area, the coastal zone plays a significant role in the global biogeochemical cycles because virtually all land-derived materials (water, sediments, dissolved and particulate nutrients, etc.) enter this region in surface runoff or groundwater flow. The recent increases in coastal urban population and changes in land use practices have led to rapid and big changes in sediment supplies and increases in nutrient, pollutant, and pathogen loadings to coastal waters.

Marine Pollution

Marine pollution occurs due to the harmful effects of the entry into the ocean of various pollutants (chemicals, particles, and industrial, agricultural, and residential wastes) and the spread of invasive species. The pollutants come from three main sources: (1) land-based sources (44%), (2) atmospheric inputs (33%), and (3) maritime transport (12%).

Sewage

The discharge of untreated sewage is a major source of pollution of coastal waters. Sewage generally contains organic carbon, nutrients and human pathogens, as well as industrial chemicals, oils, and greases. The problem occurs mainly in the developing countries, where only a small portion of the domestic wastewater is collected and treated by sewage treatment plants, the majority of which do not work efficiently or reliably.

With the rising coastal populations, nearly 90% of the sewage entering the coastal zones in many developing countries is estimated to be raw and untreated. Untreated wastes entering the seas

vary from 10% to 20% in Western Europe to more than 50% in the Mediterranean Sea and more than 80% in the Caribbean and Latin America, East Asia, South Asia, West Africa, and the southeast Pacific. While the effects of discharging raw sewage into water bodies are generally local, some transboundary effects occur in certain areas. Overall, the control of pollution from sewage continues to be a major problem, particularly in the developing countries, where the constraints are financial and not technical.

Persistent Organic Pollutants

Persistent organic pollutants (POPs) are highly toxic and stable organic chemical substances that accumulate in organisms and persist for years and even decades in the marine environment. They consist of pesticides, industrial chemicals, and associated by-products. POPs pose risks to human health, principally through the ingestion of marine food. The Stockholm Convention on Persistent Organic Pollutants of 2001 is an international agreement to address the problem of POPs. It identified an initial set of 12 chemicals because they have the common hazardous characteristics of toxicity, persistence, and bioaccumulation and are capable of traveling vast distances via water and air. Of these 12, 9 are pesticides.

Since international controls were instituted, the situation has improved considerably, although the problem still persists in developing regions dependent on agriculture. It tends to be worse at high latitudes. For example, the Arctic has a relatively uniform distribution of POP levels in various sites, and the indigenous people are particularly exposed because of their diet.

Heavy Metals

Mercury, lead, and cadmium are metals of concern because of their high toxicity in certain forms and their ability to be transported over large distances in the atmosphere. Their effects are most pronounced near factories and in industrialized estuaries. A well-known example is Minamata disease, caused by severe mercury poisoning arising from the discharge of methyl mercury from a Chisso Corporation chemical factory in the late 1950s, which bioaccumulated in shellfish and fish



eaten by the local population around Minamata Bay, Japan.

Other metals of concern are arsenic, copper, nickel, selenium, tin, and zinc. Tributyltin, used in antifouling paints for ships and boats, and its derivatives disrupt the body's normal hormonal functions and have proven to be much more persistent in the environment than expected.

While most developed countries have taken the necessary steps to address the problem of heavy metals, this global progress is offset by new sources of pollution in emerging economies. An increasingly serious problem globally is "electronic waste," particularly the disposal of computers and mobile phones in China and southeast Asia, which contain thousands of different materials, many of them toxic.

Excessive Nutrients

Land-based activities such as agricultural runoff (fertilizer), atmospheric releases from fossil fuel combustion, and sewage and industrial discharges are the main contributors to nutrient overenrichment of the oceans. The global average for nitrogen loading in the coastal areas has doubled in the past century, making the coastal areas the most highly chemically altered in the world. Excessive nutrient content encourages the rapid growth of phytoplankton and results in algal blooms. Red tides or harmful algal blooms are caused by some algae species, producing toxins that cause shellfish poisoning and present serious health hazards to human consumers.

Worldwide, "coastal dead zones," or hypoxic areas of oxygen deprivation and devoid of life, numbered nearly 150, having doubled every decade since 1960. While many coastal dead zones are small coastal bays and estuaries, areas in marginal seas of up to 70,000 km² are also affected. The primary cause of these dead zones varies. For example, the very large dead zone in the Gulf of Mexico is caused primarily by nitrogen from agricultural runoff. In the Baltic Sea, northern Adriatic Sea, Gulf of Thailand, Yellow Sea, and Chesapeake Bay, the dead zones result from a combination of agricultural runoff, nitrogen compounds from fossil fuel burning being deposited from the air, and discharges of human wastes. Control varies from region to region as

the amount of nutrients entering the oceans tends to vary significantly over time and from region to region.

Marine Litter

Marine litter consists mainly of slowly degradable or nondegradable substances found in coastal areas and oceans across the world. Dispersed easily by marine currents and wind, it is found even in remote places far from human population centers. Of the litter entering the oceans, 70% lands on the seabed, 15% is deposited on the beaches, and 15% remains floating on the surface. Marine litter has a wide range of ecological, environmental, and socioeconomic impacts, including ingestion by and entanglement with the marine life, fouling of coastlines, and interference with navigation. For example, it is estimated that plastic litter kills more than 1 million birds and 100,000 marine mammals and sea turtles each year.

Marine litter originates from sea and land. The major sea-based sources include shipping and fishing activities; offshore mining and extraction; legal and illegal dumping at sea; abandoned, lost, or otherwise discarded fishing gear; and natural disasters. The major land-based sources include wastes from dump sites, rivers, and floodwaters; industrial outfalls; storm water discharge; untreated municipal sewerage; littering of beaches and coastal recreation areas; coastal tourism and recreation; fishing industry activities; ship-breaking yards; and natural storm-related events.

The problem of marine litter has steadily grown worse, despite national and international efforts to control it. The conventions or treaties that are most relevant to marine litter control are the MARPOL 73/78 (International Convention for the Prevention of Marine Pollution From Ships) and its Annex V (which prohibits the at-sea disposal of plastics and garbage from ships), the London Convention (Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter) and the Basel Convention (Convention on the Transboundary Movements of Hazardous Wastes and Their Disposal). While information, education and public awareness programs are proving useful, there is still room for improvement.



A pair of goats and a pig forage for food among the rubbish and debris on this “beach” in Mumbai, India.

Source: Gordon Dixon/iStockphoto.

Oil Pollution

A lot of the petroleum that pollutes the ocean comes from natural sources, such as natural seeps in the seabed, and cannot be stopped. By comparison, the largest portion of the annual input of oil into the coastal and marine environment worldwide comes from land-based sources as a result of ordinary, everyday activities on land—for example, atmospheric dispersion of volatile fractions, storm sewers, and sewage treatment plants. Oil spills, which epitomize the problem of oil pollution, account for 10% to 15% of all the oil that enters the ocean every year. Oil spills damage natural habitats, smother aquatic communities and are generally toxic to aquatic life, taint seafood, contaminate water supplies and generally affect human health, and foul coastlines and beaches. Although oil pollution from marine transportation has reduced significantly, land-based runoff is expected to increase.

Radioactive Substances

Radioactive substances enter the coastal and marine environment due to a variety of activities, including nuclear power generation and the use of radioactive materials in medicine, industry, research, and space exploration as well as military operations. All contemporary uses of large amounts of radionuclides should conform to the International Safety Standards for Protection Against Ionizing Radiation and the Safety of Radiation Sources. Although accidents can occur, the impacts on human health and the environment are generally minor. The situation in the marine environment in this respect is stable, and controls on routine discharges are generally stringent.

Future Issues and Challenges

Four global issues have emerged as requiring priority in the marine environment: (1) sewage and



the management of municipal wastewater, (2) nutrient overenrichment, (3) marine litter and physical alteration, and (4) habitat destruction. Other emerging challenges include the coastal dead zones; new chemicals, numbered by the thousands, released into the environment; and sea-level rise, which is expected to cause salinization as well as physical alteration, posing a major challenge for coastal management.

Poh Poh Wong

See also **Agrochemical Pollution; Chemical Spills, Environment, and Society; Coastal Dead Zones; Global Sea-Level Rise; Heavy Metals as Pollutants; Nonpoint Sources of Pollution; Oceans; Oil Spills; Point Sources of Pollution; United Nations Environment Programme (UNEP); Water Pollution**

Further Readings

United Nations Environment Programme. (2006).

The state of the marine environment: Trends and processes. The Hague, Netherlands: Coordination Office of the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities of the United Nations Environment Programme.

United Nations Environment Programme, Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities: www.gpa.unep.org



COLD WAR, GEOGRAPHY OF

The Cold War was a geopolitical division between the Western allies and the Soviet Union that emerged in the late 1940s, shortly after the end of World War II, and continued through the collapse of the Soviet Union in 1991. During World War II, the United States was allied with the United Kingdom and the Soviet Union against Germany, Italy, and Japan. However, within several years of the war's conclusion, this global division of power changed dramati-

cally to one where the United States and its allies in Western Europe and Japan were aligned against the Soviet Union and its satellite states in Eastern Europe.

From the U.S. perspective, the Cold War geopolitical model of the world saw the United States and its allies (the "First World") competing with the Soviet Union and its allies (the "Second World") for control of those places not directly aligned with either (the "Third World"). After the 1949 communist takeover of Eastern Europe, the Soviet Union also sought to extend its influence over parts of the Third World. For U.S. foreign policymakers in the late 1940s and early 1950s, the Soviet Union was an inherently evil and expansionist state bent on world domination that must be stopped, in the parlance of the day, "wherever it reared its ugly head." On the other hand, Soviet foreign policymakers in the late 1940s saw the United States as an aggressive, expansionist state determined to destroy the Soviet Union.

Thus, the Cold War saw skirmishes between the two superpowers and their surrogates in Latin America and the Caribbean, Africa, the Middle East, and South and southeast Asia. In this Cold War, local events, movements, and revolutions in the Third World were not understood in local terms (e.g., as the overthrow of a local despotic ruler or as part of a local uprising trying to overthrow the government to bring greater social welfare to the poor) but rather were interpreted as possible gains or losses for the First World or Second World based on how they fit into the grand global "battle" between "democracy" and "communism." Hence, in the name of stopping potential communist threats, the United States helped overthrow governments or intervened directly in Iran and Guatemala in the 1950s, Vietnam in the 1960s, Chile, Laos, and Cambodia in the 1970s, and Nicaragua, El Salvador, and Grenada in the 1980s.

The Soviets were certainly not immune to such meddling, as seen in their interventions in Hungary in 1956 and Czechoslovakia in 1968 and in their 10-year battle to control Afghanistan throughout the 1980s.

Guiding U.S. actions under this Cold War global geopolitical model were two crude "geographical" principles, containment and the



domino theory, which engage with geography as being primarily about location.

Under the concept of containment, the United States established a policy that the forces of the Soviet Union and China should be bottled up and not allowed to expand beyond their spheres of influence, whether beyond China itself or in terms of the Soviet Union beyond that which they had established in the immediate aftermath of World War II in Eastern Europe. Hence, the United States set up a series of military alliances with countries surrounding the perimeter of China and the Soviets' sphere, arguing that if any of these countries were attacked, the United States would step in and protect them. These alliances ranged from the North Atlantic Treaty Organization (NATO), set up in 1949 between the United States and the non-Soviet-dominated countries of Western Europe, to ANZUS, an alliance between the United States, Australia, and New Zealand. Any attack on these allied countries would be treated by the United States as if it were an attack on itself.

However, it might be tough to sell the American public on the necessity of fighting the forces of communism anywhere in the world, especially if that was half a world away (e.g., in Vietnam). So in the 1950s, the concept of the "domino theory" was introduced, which suggested that the forces of communism were cunning and that one victory in some far-flung part of the world would lead to a series of victories in the neighboring countries, which would fall to the communists like a row of falling dominoes. Through this metaphor, distant events were able to be linked back home. Thus, intervention in southeast Asia was sold to the American public as necessary because once the countries in southeast Asia "fell," then, like a row of falling dominoes, communist forces would ultimately continue until they reached American soil.

The domino theory continued to be used well into the 1980s to sell the American public on the importance of containing communism. For example, Ronald Reagan sold his administration's support of the *contra* rebels fighting the socialist Sandinista government in Nicaragua to the American public in part by arguing that the United States had to defeat the Sandinistas because it was only a 2-day drive from Nicaragua to South

Texas. Despite the fact that the domino theory has fallen into disfavor, it is still occasionally invoked today.

One of the appeals and dangers of conceptualizing global geopolitical divisions of power in broad terms such as the Cold War's tripartite division is its ability to take a large variety of complex unique places with different histories, cultures, and languages and homogenize them under broad, sweeping generalizations and categorizations. Such conceptualizations represent grand oversimplifications of the world, as when we refer to the Cold War as being a battle between the First and Second Worlds for control of the Third World. Recognize that lumped together in a Third World that the First or Second World felt compelled to respond to potential threats for fear of their going "communist" or "Western" were places as different as Angola, Chile, Cuba, Grenada, Iran, Nicaragua, and Vietnam. Rather than recognizing the vast differences and complexities among these places, they were seen in simple uniform terms as part of an undifferentiated Third World.

Jonathan Leib

See also **Domino Theory; Geopolitics; Political Geography**

Further Readings

- Agnew, J. (2003). *Geopolitics: Re-visioning world politics* (2nd ed.). London: Routledge.
- Nijman, J. (1992). The limits of superpower: The United States and the Soviet Union since World War II. *Annals of the Association of American Geographers*, 82, 681–695.
- O'Sullivan, P. (1982). Antidomino. *Political Geography Quarterly*, 1, 57–64.
- Ó Tuathail, G., & Agnew, J. (1992). Geopolitics and discourse: Practical geopolitical reasoning in American foreign policy. *Political Geography*, 11, 190–204.
- Ó Tuathail, G., Dalby, S., & Routledge, P. (Eds.). (1998). *The geopolitical reader*. London: Routledge.

COLLABORATIVE GIS

Local and global problems such as land use and land cover change, poverty and deprivation, health and diseases, and global warming are all directly linked to the intricate biophysical and sociopolitical networks operating within geographic space. Resolving the complex issues embedded in these problems requires the involvement of multiple interest groups, reliable baseline geographic data, and relevant decision support technologies. A collaborative geographic information system (GIS) provides the integrated structure in which to embed the interest groups, geographic data, and relevant technologies for planning and decision outcomes.

Collaborative GIS is defined as a combination of interrelated theories, tools, and technologies focusing on, but not limited to, the structuring of human interactions in group spatial planning and decision processes. For planning tasks, the collaborative GIS facilitates the collective development of the stages needed to achieve a desired outcome. For decision tasks, the collaborative GIS facilitates the generation of decision options and selection

among alternatives. To implement the overall integrated structure, the collaborative GIS design uses GIS technology as a platform on which to combine the geographic data, interest group interactions, and structured processes that would lead to agreeable planning, problem-solving, and decision-making outcomes. GIS technology has been in constant development since the 1960s. Today, a GIS is considered to be an organized arrangement of computer hardware, software, and trained personnel to manage, transform, and analyze spatially referenced data in order to find solutions for unstructured real-world problems.

Components of a Collaborative GIS

The main components of a collaborative GIS are shown in Figure 1. A meaningful problem initiates the establishment of a collaborative GIS. Choices about whether to implement the collaborative process in a same-place or same-time configuration as compared with a different-place or different-time configuration is influenced by the extent of the problem being addressed and the wishes of any organization that is directly

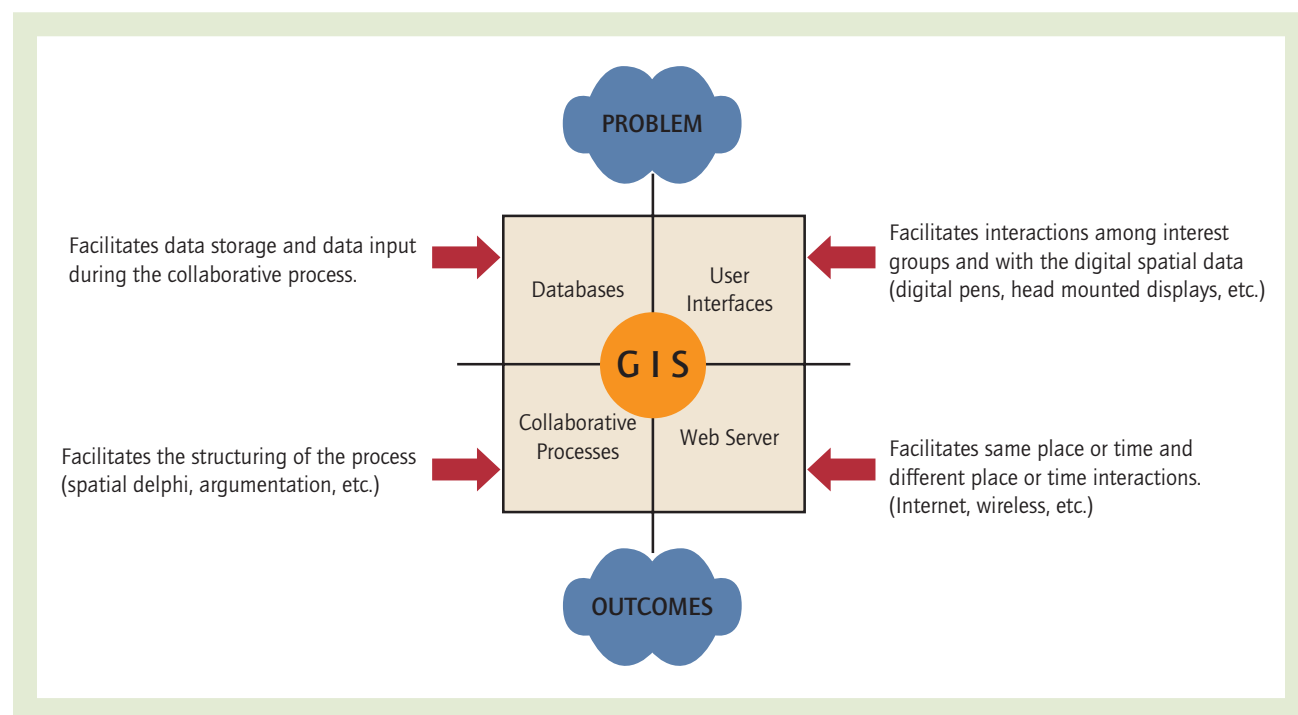


Figure 1 Components of a collaborative GIS

Source: Authors.



<i>Application Areas</i>	<i>Summary Description</i>
Natural resources management	Collaborative GIS is used primarily to develop scenarios and to forecast eventual outcomes. It has also been used to generate agreement on conflicting issues among multiple interest groups. In addition, collaborative GIS processes have been used to generate model-based tools for natural resources management tools.
Disaster management	Collaborative GIS is used primarily to integrate multiple personnel and data resources in a command and control setting. It has also been used to collect field data from mobile devices to monitor evolving disaster situations.
Health and disease management	Collaborative GIS is used primarily to integrate field data from the public for use in identifying disease hotspots in remote areas.

Table 1 Application areas of collaborative GIS

Source: Authors.

sponsoring the decision process. The core of the collaborative GIS design contains a GIS that combines the geospatial databases, user interfaces, Web servers, and collaborative process components. There are two key roles for the geospatial databases. First, they will contain the baseline data that the multiple interest groups will use to develop a well-defined problem to be addressed within a specified time frame. Second, they will store the new information generated from the collaborative GIS process as the interest groups work toward an agreeable solution. The user interfaces allow the multiple interest groups to interact with each other and with the existing geospatial data. Standard user interfaces such as the computer mouse and keyboard are usually not sufficient for dealing with digital map data on the computer screen. User interfaces for collaborative GIS provide the end user with a richer experience and include digital pens for sketch mapping, head-mounted displays for simulated real-world experiences, and multitouch screen displays for rapid database browsing and query. The Web server allows the collaborative GIS group members to make use of the Internet to interact with an extended public audience, such as citizens, experts, or government representatives. This is useful as it removes the barriers of location and time for those interested in contributing to the decision process. The collaborative process component is a set of well-established methods that can be used by facilitators to structure the process toward agreeable solutions to

the problem. Structuring approaches such as shared workspace, argumentation mapping, spatial Delphi, real-time conferencing, and sketch maps are widely used. The collaborative GIS process generates solutions in the form of digital maps, visualization products, and data attributes in response to the problem. Implementing the solutions is done within an organizational and technical framework to ensure continued development of the collaborative GIS process.

Linking Collaborative GIS With GIScience

Geographic information science (GIScience) is the assumptions, theories, and methods that inform the practical design and application of GIS. As a discipline, GIScience is now well established, with a research agenda containing 12 well-defined themes and multiple research challenges. Collaborative GIS is positioned as a subarea of the “GIS and Society” research theme, together with other implementations of spatial decision support systems such as planning support systems, spatial understanding support systems, and geocollaboration systems.

Applications of Collaborative GIS

Collaborative GIS designs have been applied widely in multiple contexts. Table 1 summarizes some of the more popular areas of application.

Suzana Dragicevic and Shivanand Balram



See also **GIScience; Neogeography; Public Participation GIS**

Further Readings

- Balram, S., & Dragicevic, S. (2006). Collaborative geographic information systems: Origins, boundaries, and structures. In S. Balram & S. Dragicevic (Eds.), *Collaborative geographic information systems* (pp. 1–22). Hershey, PA: Idea Group.
- Jankowski, P., & Nyerges, T. (2001). *Geographic information systems for group decision making: Towards a participatory geographic information science*. New York: Taylor & Francis.
- MacEachren, A. M., & Brewer, I. (2004). Developing a conceptual framework for visually-enabled geocollaboration. *International Journal of Geographical Information Science*, 18(1), 1–34.
- Wright, D. J., Goodchild, M. F., & Proctor, J. D. (1997). Demystifying the persistent ambiguity of GIS as “tool” versus “science.” *Annals of the Association of American Geographers*, 87(2), 346–362.



COLONIALISM

Intimately associated with the development of capitalism was Europe's conquest of the rest of the globe. This process, often euphemistically called the “Age of Exploration,” can be viewed as the expansion of capitalism on a global scale. If the geographies of capitalism are typified by uneven spatial development, then colonialism involved the construction of uneven development on a global scale, with Europe at the center and its colonies on the world periphery. This theme is found in many theories of world development, such as world-systems theory.

Colonialism was simultaneously an economic, political, and cultural project. It was also an act of conquest, by which a small group of European powers came to dominate a very large group of non-European countries. Culturally, as Edward Said points out, this process involved

the emergence of the distinction between the “West” and the “Rest.” In conquering the “Orient,” Europeans came to discover themselves as Westerners, often in contrast to other people, whom they represented in highly erroneous terms.

Everywhere, colonized people fought back against colonial rule. Examples include the Inca rebellions against the Spanish, the Zulu attacks on the Dutch Boers, the great Indian Sepoy uprising of 1857, and the Boxer Rebellion in China in 1899–1901. Yet Western powers, armed with guns, ships, and cannons, effectively dominated the entire planet. While a few countries were nominally independent, such as Thailand, the only one to escape colonialism substantively was Japan, which, under the Tokugawa Shogunate, closed itself off from the world until 1868.

Colonialism had profound implications for both the colonizers and the colonized, which is why a sophisticated understanding of economic geography must include some understanding of this process. Globally, colonialism produced the division between the world's developed and less developed countries. Colonialism changed Europe too, increasing the formation of capitalist social relations and markets as well as nation-states in Western Europe. Prior to colonialism, Europe was a relatively poor and powerless part of the world, compared with the Muslim world, India, or China; afterward, Europe became the most powerful collection of societies on the planet.

The Temporal and Spatial Unevenness of Colonialism

It is important to note that colonialism did not occur in the same way in different historical moments and different geographic places. Temporally, there were two major waves of colonialism, one associated with the preindustrial mercantile era and the other with the Industrial Revolution. From the 16th century, when colonialism began, until the early 19th century, Western economic thought was characterized by mercantilism, in which state protection of private interests was justified as necessary for the national well-being. During this period, the primary colonial powers were Spain and Portugal, and their primary colonies were in the New World and parts of Africa.

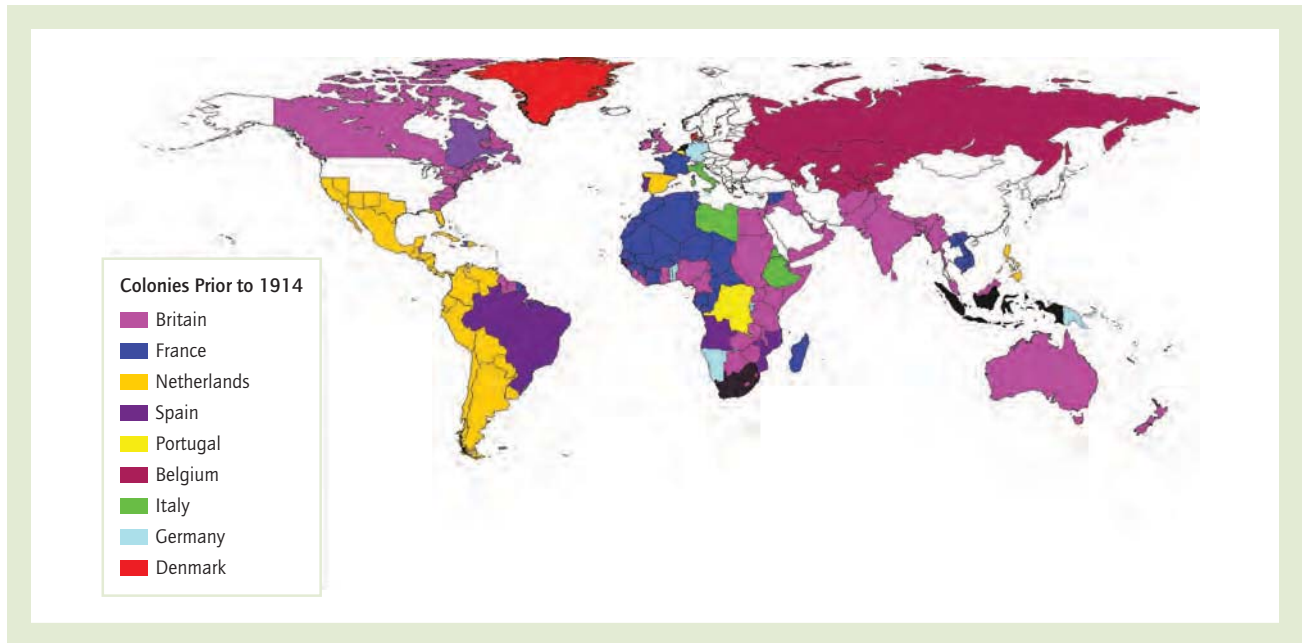


Figure 1 Colonial empires prior to 1914. Different European powers conquered various regions of Earth at different moments in time.

Source: Author.

Following the Napoleonic wars, which ended in the Treaty of Vienna in 1815, the European powers were relatively weak. This opening provided an opportunity for nationalists in Latin America, led by Simon Bolivar, to break away and become independent countries. Thus, the number of colonies declined sharply in the early 19th century. However, during the subsequent phase of industrialization, characterized economically by the ideology of free trade, the number of colonies grew again. This time, Britain emerged as the world's premier power and, along with France, colonized large parts of Africa and Asia. Finally, the number of colonies declined rapidly after World War II, in the era of decolonization.

Spatially, colonialism was also uneven. Different colonial empires had widely varying geographies, as illustrated by the distribution of empires at their peak in 1914, the eve of World War I (Figure 1). The British Empire, which encompassed one quarter of the world's land surface, stretched across every continent of the globe, including Canada, much of the Middle East, large parts of Eastern and Southern Africa, the Indian subcontinent, and parts of southeast Asia. The French ruled in parts of Western Africa and in Indochina.

The Portuguese had Brazil; Goa in India; Angola, Mozambique, and Guinea Bissau in Africa; Timor; and Macau. The Belgians possessed Congo, the private domain of Leopold II. Italy was in Ethiopia and Libya. Even Germany, late to unify and to industrialize, controlled parts of Africa (Togo, Namibia, Tanganyika) and New Guinea.

How Did the West Do It?

What allowed Europe to conquer the rest of the planet? The answers to this question are not simple. Obviously, they do not lie in any innate superiority of the Europeans. Indeed, for much of history, Europe was relatively weaker and poorer than the countries it conquered. By the 16th century, however, Europe did come to possess several technological and military advantages over its rivals.

Jared Diamond, in his famous book *Guns, Germs, and Steel*, maintains that Western societies enjoyed a long series of advantages by virtue of geographical accident. Agriculture in the West, centered on wheat, was productive and could sustain large, dense populations. Old World societies were often stretched across vast East-West axes, or regions with common growing seasons. There



was a long Western history of metalworking, which not only increased economic productivity but also allowed for the manufacture of weapons such as guns and cannons. By the Renaissance, Europeans had become highly skilled at building ships and navigating the oceans. And by the late 18th century, the West had discovered inanimate energy, which offered numerous economic and military advantages. In addition, the Europeans unleashed diseases (if unintentionally), particularly smallpox and measles, on the New World, which not only provided them with an unintended advantage but also led to labor shortages.

Central to this process were the oceans. The new European relationship to the seas was forged through the navigational revolution of the 15th century, which allowed open-ocean sailing rather than coastal voyages. The ensuing voyages of exploration and conquest brought the world's maritime regions within the expanding circuits of European capital circulation and accumulation. Colonialism transformed the oceans from barriers into a means of accessing the lands beyond, even if those were unknown or only dimly perceived. Often this process was born out of dire necessity: Portuguese and Spanish entries into the Atlantic Ocean were in many respects an attempt to circumvent the Turkish domination of the Middle East (including the seizure of Constantinople in 1453), a force that motivated Europeans to find new ways to the lucrative Asian trade. The eventual result was a series of colonial empires that bound together vast regions separated by enormous maritime spaces. Because sea voyages did not allow penetration of continental interiors, ship-based empires were confined to coasts, littorals, archipelagos, and islands. Oceanic discoveries and conquests also propelled a gradual restructuring of European spatiality, with a decline in the Italian city-states and the Hanseatic League and a rise of the Atlantic sea powers, shifting the primary locus of trade and balance of power from the Mediterranean and Baltic to the Atlantic, in which not one but several empires operated simultaneously. Under Henry the Navigator, Lisbon became the new global center of navigational and cartographic expertise. Henry's headquarters at Sagres pioneered the European exploration of the Atlantic and West Africa and Portugal's entry into Asia, and it revolutionized

cartography. Sailing ships such as the Portuguese caravel, the only ship capable of sailing anywhere on the planet, and its successor, the galleon, were able to sail into the wind and in shallow waters in all weathers, cut weeks from time at sea, and allowed sailors ("men of the sail") to return home more quickly and reliably, initiating a feedback loop in which geographic knowledge became cumulative and its growth self-reinforcing and continuous. Bartholomeu Dias returned from rounding Southern Africa in 1488, which rendered Christopher Columbus's original intentions superfluous and encouraged him to think about a westward voyage. Portuguese expansion replaced the older land-and-sea trade networks with an all-ocean one, greatly lowering the costs of bringing goods from Asia to Europe. Around 1600, the Dutch began using a new vessel, the *fluytschip*, for trade across the Baltic, which reduced labor costs by half in waters that had been cleared of pirates. The *fluytschip*, produced in large numbers, had as much an impact on European trade as did the steamship centuries later. Using this technology to dominate European ocean shipping transformed Amsterdam from a backwater of the Hapsburg Empire into one of the first great commercial and banking centers of mercantile capitalism. Similarly, the rise of Britain was enabled by the "race-built" ships, which were the first to consciously emulate the streamlined design of a fish. Unlike the Venetians, Portuguese, or Spanish, who compelled all traders to travel in government-organized convoys, the Dutch and English used privately owned but state-chartered monopoly corporations such as the Hudson Bay Company, the British East India Company, and the Dutch Vereenigde Oost-Indische Compagnie (VOC) or Dutch East India Company.

Others scholars maintain that the West's advantages were not just technological but also political. The Western "rational" legal and economic system stressed secular laws and the importance of property rights. Yet others point out that unlike the Arabs, Mughal India, or China, Europe was never united politically. Indeed, every time one European power attempted to conquer the others, it was defeated, as exemplified by France in the early 19th century and Germany twice in the 20th century. Europe's very political separation into competing powers—in contrast to the



Muslim world, India, or China—fostered intense rivalries and arms races that generated a self-reinforcing series of changes. In the view of world-systems theory, colonialism witnessed numerous hegemony dominate the global economy at successive historical moments, including Portugal, Spain, the Netherlands, Britain, and, later, the United States, a pattern that may be indicative of long-wave cycles of capital accumulation in the capitalist economy. The lack of centralized political authority created a climate in which dissent and critical scholarship were tolerated. For example, the French Huguenots, Protestants in a predominantly Catholic country, could flee persecution by moving to Switzerland, where they started the Jura district watch industry. Similarly, when Columbus failed to obtain financing for his voyages from the Italians and Portuguese, he could switch to Spain, whose king ultimately consented.

A Historiography of Conquest

To appreciate colonialism, it is necessary to briefly delve into its specifics in different times and places. This short review is intended to demonstrate that colonialism meant quite different things under different contexts (i.e., it was historically and geographically specific).

Latin America

Home to wealthy and sophisticated civilizations such as the Inca, Mayan, and Aztec cultures, Latin America was one of the first regions to be taken over by the Europeans. Two years after Columbus arrived, Spain and Portugal struggled over who owned the New World—a contest settled by the Pope through the Treaty of Tordesillas in 1494. The conquistadors who spread out over Mexico and Peru annihilated the Aztec and Inca states, respectively. In large part, this was accomplished through the introduction of smallpox, which killed 50 million to 80 million people within a century of Columbus's arrival, the largest act of genocide (whether intentional or not) in human history.

Subsequent to the extermination of tens of millions of Native Americans, the New World was methodically transformed into a global periphery

that aided greatly in the development of Europe, allowing that continent to escape domestic ecological constraints by tapping into new supplies of fish, lumber, minerals, and other resources. Of course, chronic labor shortages in the Western Hemisphere were alleviated largely through the forced importation of 10 million to 20 million African slaves, a phenomenon that reflects the repeated misery visited on that highly marginalized continent by successive waves of capitalism. In keeping with early modernity's maritime emphasis, Spanish colonialism generated a series of coastal entrepôts, such as Havana, Veracruz, and Cartagena. Sugar plantations, which became prototype factories of a sort, were among the first to subject their labor force to the discipline of commodity production.

Under the philosophy of mercantilism, which stressed bullion, or precious metals, as the key to national wealth, the Spanish took home large quantities of silver from the New World. The silver mines in Central Mexico were among the largest in the world, and in the enormous Potosi mines in Bolivia, two million Aymara Indians perished digging silver. Argentina takes its name from *argentum*, the Latin word for silver, and is home to the Rio Plata. Most of this metal was taken back to Spain in galleons and provided an enormous base of capital that financed economic activities throughout Europe. By far the most important contribution of the New World to the Old was silver; 10 times more of it than gold was shipped back to Spain in galleons (financing luxuries such as the palace at El Escorial). Silver became the primary medium for integrating the world's spaces in the 16th and 17th centuries and the force that produced a series of distinctively novel geographies (Figure 2). New World silver became the primary specie integrating the mercantile world economy, and it essentially allowed Europe to "buy itself a ticket on the Asian train" (Frank, 1998, p. xxv). American silver was so ubiquitous that merchants from Boston to Havana, Seville to Antwerp, Murmansk to Alexandria, Constantinople to Coromandel, Macao to Canton, and Nagasaki to Manila all used the Spanish peso or piece of eight (*real*) as the standard medium of exchange. Given Europe's large trade deficits with Asia, two thirds of European payments for Asian imports consisted of precious



metals. From Spain, silver flowed to England, France, and the Netherlands to purchase manufactured goods, from where much of it went to Russia to finance imports of furs. Russian silver, in turn, flowed along the Volga River to Persia. Spanish silver also found its way directly to the Ottomans and thence to the Indian Ocean. Much of the Mughal Empire in India was financed by silver, a considerable portion of which went to purchase horses from Central Asia. Indian silver also flowed through Malacca to China, or at times overland via the Silk Road routes. At the easternmost end of this network, China, in which the Ming dynasty was remonetizing the economy from paper to silver, was the “sink” for half to three fourths of the world’s silver flows between 1500 and 1800. Indeed, the 17th century witnessed a broad financial crisis across eastern and Southern Asia associated with this restructuring. When Spain established its Manila colony in the Philippines in 1571, it became possible, for the first time, for New World silver to travel back to Europe in two directions, that is, in galleons across both the Atlantic and the Pacific Oceans.

Spain also introduced the *encomienda* land grant system into the New World, giving large tracts of lands to potential rivals to the Spanish throne. This set of practices was an extension of the ancient latifundia system practiced in Roman Iberia. As a small landed aristocracy consolidated its hold, the distribution of farmland became highly uneven, with a few wealthy landowners and large numbers of landless *campesinos*. This pattern continues in the present, indicating how colonialism has shaped the geographies of the contemporary world.

The Spanish Empire in the New World was largely ended by the independence movements of the 1820s that followed the Napoleonic Wars (although it took the Spanish-American War of 1898 to finish it off). After gaining independence, the erstwhile Spanish Empire broke up into a series of independent countries stretching from Mexico to Argentina. The Portuguese Empire in Brazil did not fragment in the same way, leaving that nation as the giant of Latin America.

Finally, the Caribbean exhibited a complex mosaic of colonial powers. The Spanish dominated Cuba, Eastern Hispaniola, and Puerto Rico, exterminating the native Taino Indians. The

British colonized Jamaica, the Bahamas, and many smaller islands in the Windward and Leeward Islands chain. The French took Haiti and small islands such as Martinique and Guadeloupe, trading others periodically with the British. The Dutch also settled in Curacao and Aruba.

North America

The colonialization of North America proceeded along somewhat different lines. Here, the Spanish were active in Florida and in the Southwest. A century before the Pilgrims arrived at Plymouth Rock in 1620, the Spanish had control of what is now Texas and California. The French took over Quebec and the St. Lawrence River valley, only to lose it to Britain in the 18th century, and the Mississippi River valley, with the key port of New Orleans, only to sell it to the United States in the Louisiana Purchase of 1803. The Russians crossed the Bering Straits and seized Alaska but sold it to the United States in 1867. The Dutch established colonies in New Amsterdam, including Haarlem and Brooklyn, but the British captured the area in 1664 and renamed it New York. Britain emerged as the dominant power in North America, controlling New England and the Piedmont states along the eastern seaboard. Canada was colonized largely through the famous Hudson Bay Company, then the world’s largest, which controlled much of the region’s fur and fish trade.

British colonialism in North America began with a series of port cities on the east, typically at the mouths of rivers (e.g., Boston, New York, Philadelphia). After the independence of these colonies in the Revolutionary War, the settlers moved west, across the Appalachians in the early 19th century and across the Great Plains and Rocky Mountains somewhat later. Railroads opened up this region to the east. As in Latin America, this process involved the wholesale eradication of Native American peoples, theft of their land, and commodification of territory.

Africa

Colonialism in Africa was unique, as it was everywhere. This process included slavery, the kidnapping of roughly 20 million people and exporting them to the New World, where they

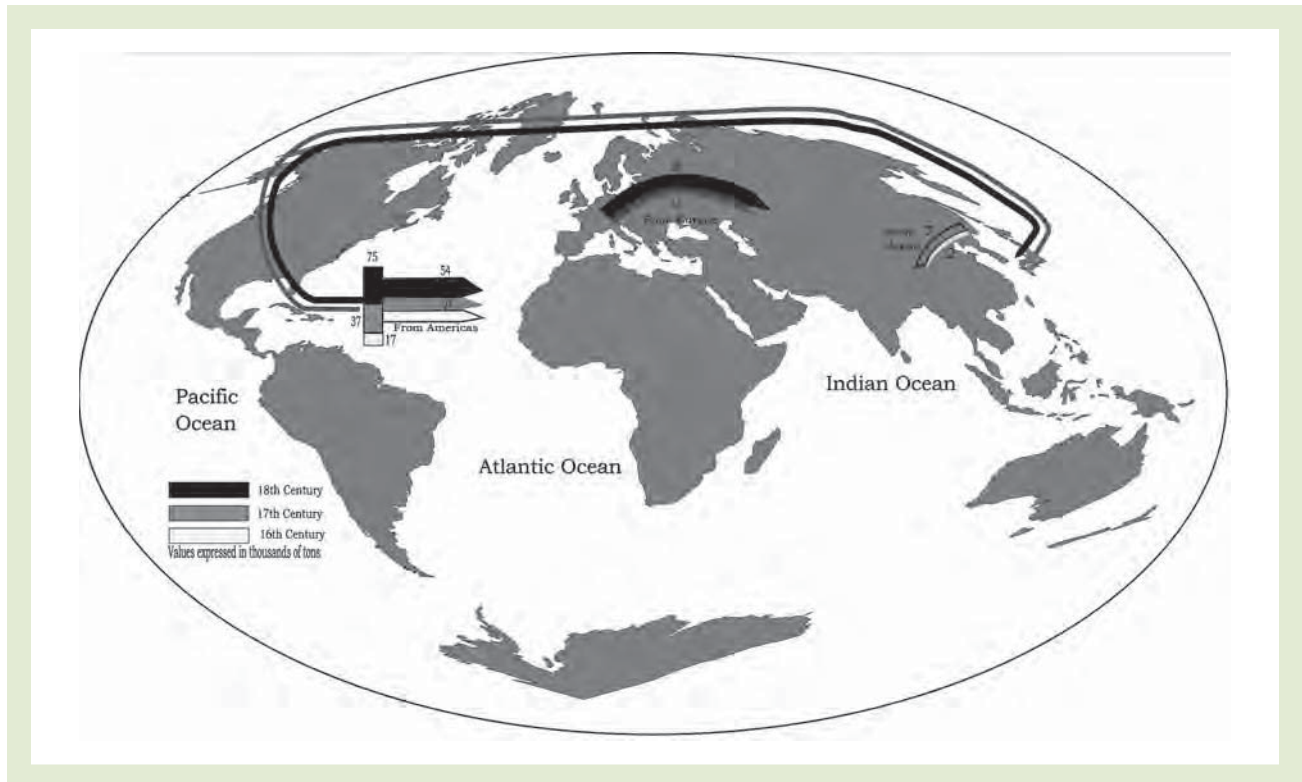


Figure 2 Global silver flows, 16th to 18th centuries. Silver from the New World largely financed Europe's entry into the global economy.

Source: Adapted from Frank, A. (1998). *ReOrient: Global economy in the Asian age*. Berkeley: University of California Press.

were used to compensate for the labor shortages brought on by the decimation of the Native Americans. The capture of slaves robbed these societies of young adults in their prime working years and sometimes occurred with the assistance of local kings who sought to profit from the trade, using the revenues to buy British textiles and whiskey. Slaves were generally taken from Western Africa, and the largest numbers were brought to work in the sugar plantations in Brazil and the Caribbean. Others were brought to work in the cotton and tobacco plantations of the American South. In Eastern Africa, there long existed a smaller system of slavery operated by the Arabs.

Africa is rich in minerals, and the colonialists were quick to seize on that fact. In the 19th century, when the European powers penetrated from the coastal areas into the interiors, mines for copper, gold, and diamonds were opened, often using slave labor. These remain the basis of many African economies today.

Perhaps the most important colonial impact on Africa was the political geography that Europe constructed. Following the famous Berlin Conference of 1884, when the European powers drew maps demarcating their respective areas of influence, the colonies of Africa bore no resemblance whatsoever to the distribution of indigenous peoples. Roughly 1,000 tribes were collapsed into about 50 states. Some groups were separated by colonial boundaries; many others, with widely different cultures and economic bases, were lumped together. Not surprisingly, on attaining independence in the 1950s and 1960s, many African states, including Angola, Congo, Rwanda, Liberia, and Sudan, have been wracked by numerous civil wars and tribal conflicts, in which millions have perished.

The Arab World

The Arab world, which was one of the most powerful and sophisticated centers of world



culture from the 7th through the 15th centuries, had been colonized long before the Europeans arrived. The expansion of the Ottoman Empire over several centuries saw one group of Muslims, the Turks, dominate another group of Muslims, the Arab peoples of the Middle East and North Africa. Gradually, starting in the late 18th century, European powers encroached on this vast domain. In 1798, the French seized Egypt from the Ottomans, only to lose it to Britain 4 yrs. (years) later. The British used Egypt as a source of cotton, growing large plantations along the Nile River and building the Suez Canal in 1869.

After World War I, the Ottoman Empire collapsed, and the French and British seized its Arab colonies. The French took over Morocco, Algeria, and Tunisia, as well as Syria and Lebanon. The British assumed control over Palestine, Jordan, much of which became Israel in 1948, as well as Iraq and the sheikdoms of the Persian Gulf. Many Arabs, who initially welcomed the Europeans as liberators, quickly learned that the new boss was very similar to the old one in its suppression of indigenous liberties.

South Asia

As the first of the European powers to infiltrate Asia and set up foreign colonies, Portugal, the world-system's first hegemon, played a uniquely important role in the construction of the colonial world system. Portugal's invasion of the Indian Ocean in the early 16th century pulled the plug on the centuries-old Arab-Asian trade and set the stage for the Ottoman conquest of the Arab world. Portugal's seizure of Malacca in 1511 was followed in short order by Timor, Macau, and Formosa. Given how far such places were from Europe—a round-trip voyage to Asia could take 3 yrs.—direct control over colonial entrepôts was often loose at best.

The Indian subcontinent later became the jewel in the crown of the British Empire. Starting in the 17th century, the British East India Company established footholds in this domain, founding the city of Calcutta (now Kolkata) in 1603. India, which is predominantly Hindu, had long been controlled by Muslim rulers, chiefly the Mughals, whose power was gradually usurped by the foreigners. A vast land that stretched from Muslim

Afghanistan in the east through Hindu India to Buddhist Burma, the Indian colony was the largest colonial possession on Earth.

Britain had enormous economic impacts on this land. In the 19th century, British textile imports flooded India, destroying the Mughal textile industry, a classic example of colonial deindustrialization. This event later became symbolically important in the independence movement after World War II. Indian laborers were exported throughout the British Empire, including the Caribbean, Eastern Africa, and parts of the Pacific, such as Fiji. Tea plantations were established in Bengal and Ceylon (now Sri Lanka). Britain also built railroads to facilitate the extraction of Indian wealth.

In 1857, a mass uprising against the British took place known as the Sepoy Rebellion. Encouraged by the local raj, or the Mughal ruler of Calcutta, the revolt claimed the lives of tens of thousands of Indians when it was crushed. Although it failed, the action forced the British crown to assume direct control over this land rather than administer it through the East India Company.

East Asia

East Asia, comprising China, Korea, and Japan, also had a unique colonial trajectory. Japan, as noted earlier, was never colonized. When it emerged from a long period of isolation that began in the early 17th century and lasted until 1868, Japan rapidly Westernized and industrialized and became the only non-Western power to challenge the West on its own terms, gradually expanding its power through Northeast Asia. Korea, which opened up under the threat of force in the 1870s, was taken over by Japan in 1895 and annexed in 1905, and Japan held it until the end of World War II. A similar situation held in Taiwan. Later, Japan extended its colonial hold over Manchuria, parts of China, and, briefly, most of southeast Asia.

China, however, was a different story. Under the rule of the Manchus, foreigners from the north (Manchuria) who ruled the Chi'n dynasty from 1644 until the revolution of 1911, the Chinese government was weak and corrupt. Except for a few cities along the coast, China was never



formally colonized; rather, European control operated through a pliant and cooperative government. Chinese coolie labor was exported to British colonies in southeast Asia and to the United States, where Chinese labor built railroads in the American West. British, French, German, and American trade interests purchased vast amounts of Chinese tea, silks, spices, and porcelains. In fact, Britain ran a negative balance of trade with China in the 18th and early 19th centuries, which it rectified by introducing large amounts of opium. By the 1830s, opium addiction was widespread in China, creating severe social disruptions in Chinese society. Nonetheless, profits were more important, and the British trade balance was restored.

In a rare moment of defiance, the Manchu government resisted the opium imports, and Britain and China fought two short, nasty conflicts, the Opium Wars of the 1840s. The British won easily. As compensation, the British seized “treaty ports,” coastal cities such as Hong Kong and Shanghai, where Western, not Chinese, law applied. Britain held Hong Kong until 1997.

Chinese resentment against the Manchus culminated in the Taiping Rebellion, a huge uprising in the southern part of the country led by the Chinese Christians. Lasting from 1851 to 1864, this rebellion led to the deaths of more than 20 million people but was ultimately crushed by the Chinese government with Western backing. The shorter Boxer Rebellion of 1899–1901 was more explicitly anti-Western. These revolts set the stage for the successful nationalist revolution of 1911, which ended Manchu rule and initiated the Republic of China.

Southeast Asia

The peninsula of Indochina and the islands of southeast Asia, long home to a rich and diverse series of peoples and civilizations, were conquered by different European powers. The Philippines was Spain’s only Asian colony and served as the western terminus of the trans-Pacific galleon trade. Administered as part of Mexico, the Philippines was heavily shaped by Spanish rule, which affected land use patterns (including sugar plantations) and the language and made it the only predominantly Catholic country in Asia. Spanish rule

ended in 1898, when the United States took over, and it became independent after World War II.

The French controlled much of Indochina, including Vietnam, Laos, and Cambodia. French rule shaped the design and architecture of cities such as Saigon, and large numbers of Vietnamese converted to Catholicism. French domination did not end until 1954, with the defeat at Dienbienphu, an event that laid the foundations for American military involvement there.

Britain was also a major power in southeast Asia, controlling Burma and, only informally, the economy of Thailand. These were made into rice exporters for other parts of the British Empire. The British controlled the colony of Malaya (later Malaysia), including the strategically critical Malacca Straits. Sir Edmund Raffles founded the city of Singapore as a naval station and commercial center to exercise British control over this region. Malaya, like other colonies in the area, became a major producer of rubber products, as well as timber and tin.

Indonesia, now the fourth most populous country in the world, was dominated by the Dutch for several hundred years. Dutch rule, starting with the founding of the Batavia colony on Java (now Jakarta) in the 18th century, gradually expanded to include the other islands. The primary institution involved was the Dutch East Indies Company, a chartered crown monopoly similar to the British East Indies and British West Indies Companies. Indonesia became a significant source of spices, tropical hardwoods, rubber, cotton, and palm oils. In all of southeast Asia, Chinese immigrants came to play major roles in the economy as bankers and shopkeepers.

Oceania

Australia, New Zealand, and the Pacific Ocean islands, which are commonly grouped as the region of Oceania, formed yet another domain of colonialism. Australia was inhabited for thousands of years by indigenous aborigines, most of whom were eradicated by the British as they exerted control. The native Tasmanian population was completely exterminated. The continent served originally as a penal colony for criminals. In the 19th century, it became a significant exporter of wheat and beef.



New Zealand, also a British colony, had a much larger native population, the Maori, who continue to form a significant presence there. The introduction of refrigerated shipping in the late 19th century turned this island nation into a major producer of lamb and dairy products.

Finally, the countless islands of the Pacific Ocean, home to varying groups of Polynesians, Micronesians, and Melanesians, were conquered by the British and the French. Captain Cook sailed through in the 17th century, paving the way for followers. Fishing and whaling interests used these islands to refuel in the 19th century. Following World War II, when the United States drove Japan out of the Pacific, America became the leading political force in the area.

The Effects of Colonialism

By now, it is abundantly evident that colonialism had enormous consequences on colonized places, the effects of which are often still felt today. Above and beyond simple, brutal annihilation of entire societies, colonialism entailed a series of massive economic, political, cultural, and spatial transformations.

Often, colonialism involved traumatic consequences for the people who were conquered. At times, this involved open genocide, such as in Australia, in which more than 90% of the aboriginal population was exterminated. In the New World, disease led to the deaths of tens of millions. The African slave trade devastated tribal societies on that continent. While this is the bluntest expression of colonial control, it serves as a reminder that the European conquest of the world was often violent.

The incorporation of colonies into a worldwide division of labor led above all to the development of a primary economic sector in each of them. Primary economic activities are those concerned with the extraction of raw materials from the Earth, including logging, fishing, mining, and agriculture. In Latin America, Africa, and southeast Asia, cash crops such as sugar, cotton, fruits, rubber, and tobacco were grown in the plantation system for sale abroad. Silver, tin, gold, and other metallic ores were mined using slave labor or peasants working in slavlike conditions. Mercantilist trade policies worked to suppress

industrial growth in the colonies. This process is largely responsible for the fact that many developing countries today export low-valued goods and must import high-valued ones.

Colonialism brought with it great inequality in the colonized societies. Often, colonial powers used a small, native elite to assist them in governing the colonies, typically drawn from an ethnic minority. For example, the French used the Alawites in Syria, a sect of Islam neither Sunni nor Shiite; the Germans and the Belgians favored the lighter-skinned Tutsi over the darker-skinned Hutu in Rwanda and Burundi; and the British relied on the Muslim Mughal rulers to govern Hindu India.

For the bulk of the population, colonialism entailed declining economic opportunities, a theme central to dependency theory. Traditional patterns of agriculture were disrupted, often with disastrous effects. Land use patterns favored the colonialists, while indigenous peasants had to pay for the costs of their own exploitation with taxes. People living in dry climates in Western Africa, for example, coped well with drought until the British forced them into a system of cash cropping. Huge famines shook India, Egypt, and China in the 19th century.

As the colonial societies became polarized, so too did the spaces they occupied. Ports, which were central to European maritime trade and control, became important centers of commerce, often to the detriment of traditional capitals further inland. For example, in Peru, Lima displaced the Incan city of Cuzco; in Western Africa, the famous trade city of Timbuktu declined as new maritime routes flourished; in India, coastal cities such as Calcutta (now Kolkata), Bombay (now Mumbai), and Madras (now Chennai) displaced the Mughal capital of Delhi; in Burma (now Myanmar), Mandalay fell far behind coastal Rangoon; in Vietnam, the imperial capital Hue declined in the face of Saigon; and in Indonesia, the traditional center of Jogjakarta was marginalized by the Dutch port city of Batavia (later Jakarta). As cities grew and offered more opportunities, millions of people left the poorer rural areas in waves of rural-to-urban migration. From the coasts, railroads extended colonial control into the interior, often reaching into mineral-rich regions or plantations. A long-term consequence of this design is that the road and rail networks of developing countries often



bear little resemblance to the distribution of the population that lives there and their needs; rather, they were constructed to facilitate the export of raw materials to the colonizing country and, today, to the global economy.

The nation-state, as we observed earlier, was fundamentally a European creation. Nonetheless, it was widely dispersed around the world as colonies were made into states. In Africa, where this process was the most notorious, it led to the formation of unstable states with highly artificial borders. Similarly, Burma and Afghanistan were creations of the British. Even India, which is more culturally diverse than all of Europe, was stitched into one country; surprisingly, it was partitioned only into two upon independence, including Pakistan. (Later, in 1971, Bangladesh split from Pakistan.) Unlike Europe, where states were centered on some degree of ethnic similarity, the states of much of the developing world were too diverse to be understood in the same terms as in Europe. In such societies, where local religious, ethnic, and tribal loyalties supersede nationalism, political conflicts can impair economic growth and development. Of course, the United States is also very diverse ethnically and culturally, but it emerged under very different historical circumstances from the former European colonies in the developing world. Above all, the United States was primarily a colonizer rather than a colony, able to exert military and economic power over other countries and ultimately rising to become the world's premier superpower, and that makes all the difference.

Colonialism is not simply an economic or political process but also a cultural and ideological one. Western economic and political control was accompanied by the imposition of Western culture. Missionaries, for example, sought to spread Christianity throughout the colonial world, sometimes successfully (e.g., Latin America, the Philippines) and sometimes not (e.g., China); in Africa, Christianity jostled for converts alongside Islam. Missionaries both legitimized colonial rule as God's work and at times established schools and hospitals. School systems in colonies, generally set up to benefit the ruling elite, offered extensive instruction in the history and culture of the colonial country but little about the society in which the students lived. More

broadly, colonialism may be seen as one chapter in the broader process by which global capitalism homogenizes lifestyles, values, and role models around the world, turning disparate sorts of peoples into ready consumers.

The End of Colonialism

The European empires were long-lived, lasting almost half a millennium. Yet ultimately, they collapsed. In Latin America, this process began relatively early, following the Napoleonic wars, which weakened the core sufficiently to allow the periphery to break away. In Africa and Asia, the end of colonialism came much later, following World Wars I and II, which, similar to the global geopolitical situation of the early 19th century, saw the European powers self-destruct.

The international environment following World War II provided an ideal opening for various nationalist and independence movements in the Arab world, Africa, India, and southeast Asia. Sometimes the communists were involved. The Japanese occupation of Indochina, the Philippines, and Indonesia destroyed the myth of European invincibility. Often, independence movements were led by intellectuals educated in the West, such as Ghana's Kwame Nkrumah, Vietnam's Ho Chi Minh, and India's Mohandas Gandhi. Moreover, the Cold War rivalry between the United States and the Soviet Union allowed political leaders in the developing world to play the superpowers off each other.

Independence movements succeeded, sometimes peacefully, as in India, and often violently, as exemplified by the Vietnamese and the Algerian defeat of the French in their respective countries. As a result of this process of decolonization, the number of independent states multiplied rapidly in the 1950s, 1960s, and 1970s. Today, there are very few official colonies remaining, although as the theory of neocolonialism suggests, colonialism survives in practice if not in name.

Barney Warf

See also Columbus, Christopher; Decolonization; Dependency Theory; Diamond, Jared; Exploration; Gama, Vasco da; Imperialism; Magellan, Ferdinand; Orientalism; World-Systems Theory



Further Readings

- Blaut, J. (1993). *The colonizer's model of the world: Geographical diffusionism and Eurocentric history*. New York: Guilford Press.
- Boorstin, D. (1983). *The discoverers*. New York: Random House.
- Chiot, D. (1985). The rise of the West. *American Sociological Review*, 50, 181–195.
- Diamond, J. (1999). *Guns, germs, and steel*. New York: W. W. Norton.
- Frank, A. (1998). *ReOrient: Global economy in the Asian age*. Berkeley: University of California Press.
- Hugill, P. (1993). *World trade since 1431: Geography, technology and capitalism*. Baltimore: Johns Hopkins University Press.
- Marks, R. (2007). *The origins of the modern world: A global and ecological narrative from the fifteenth to the twenty-first century* (2nd ed.). Lanham, MD: Rowman & Littlefield.
- Mignolo, W. (1995). *The darker side of the Renaissance: Literacy, territoriality, and colonization*. Ann Arbor: University of Michigan Press.
- Modelski, G., & Thompson, W. (1988). *Seapower in global politics, 1494–1993*. Seattle: University of Washington Press.
- Pomeranz, K., & Topik, S. (1999). *The world that trade created: Society, culture, and the world economy, 1400–the present*. Armonk, NY: M. E. Sharpe.
- Said, E. (1978). *Orientalism*. New York: Vintage Books.
- Wallerstein, I. (1979). *The capitalist world-economy*. Cambridge, UK: Cambridge University Press.

distinct wavelength of visible light. The purest hues include blue, green, and red. Saturation refers to the amount of color, or hue, displayed on a surface area, and the intensity of color is associated with the brightness of hues. When applied properly, the use of color in maps enables more effective communication of spatial information. Used improperly, color will not only decrease the effectiveness of communication but can also lead to false interpretations of the information. An awareness of the intricacies of color use in map design and the incorporation of common cartographic conventions developed to address some of those intricacies will promote more effective communication of spatial information in maps.

Color can be used in both raster and vector data to represent a range of values within cells or to give more meaning to point, line, and area features. There are many considerations when using color in map design that collectively make the process of choosing appropriate colors intricate. For example, color provides an additional amount of contrast to map symbols that can add weight to the meaning and/or values of features on a map. In addition, certain colors have connotative and associative meanings. Moreover, interpretation of the meaning may vary for different map users. Thus, a brief discussion of these and other considerations is in order. Some considerations include color connotation and psychological reactions, color association, color interactions, and light source.

Different colors and variations in color intensity may have a variety of connotations. For example, when viewing a map of voting results by county within California for a proposition, counties could be symbolized with color to represent those that voted in favor of the proposition versus those that voted against. If we chose red to symbolize those in favor and blue to symbolize those that voted against, both colors are the same level of purity and the same intensity and saturation. Consequently, one color does not stand out over another. Thus, these colors provide equal weight and importance to each result. In addition, the colors are clearly distinct. A connotation that might result from the use of red and blue is in the relation of these colors to the Republican and Democratic parties, respectively. The use of blue for those counties that voted in favor might imply that the decision is also supported by the Democratic Party. If,



COLOR IN MAP DESIGN

One of the principal methods of communicating geographic information is visually on a map. For both two-dimensional paper maps and digital maps displayed on a computer screen, color is often an essential component. The use of color in map design is a method of symbolization where hues, sometimes with varying amounts of saturation and intensity, are employed to symbolize features and differentiate between values for quantitative and qualitative spatial data. A hue is a

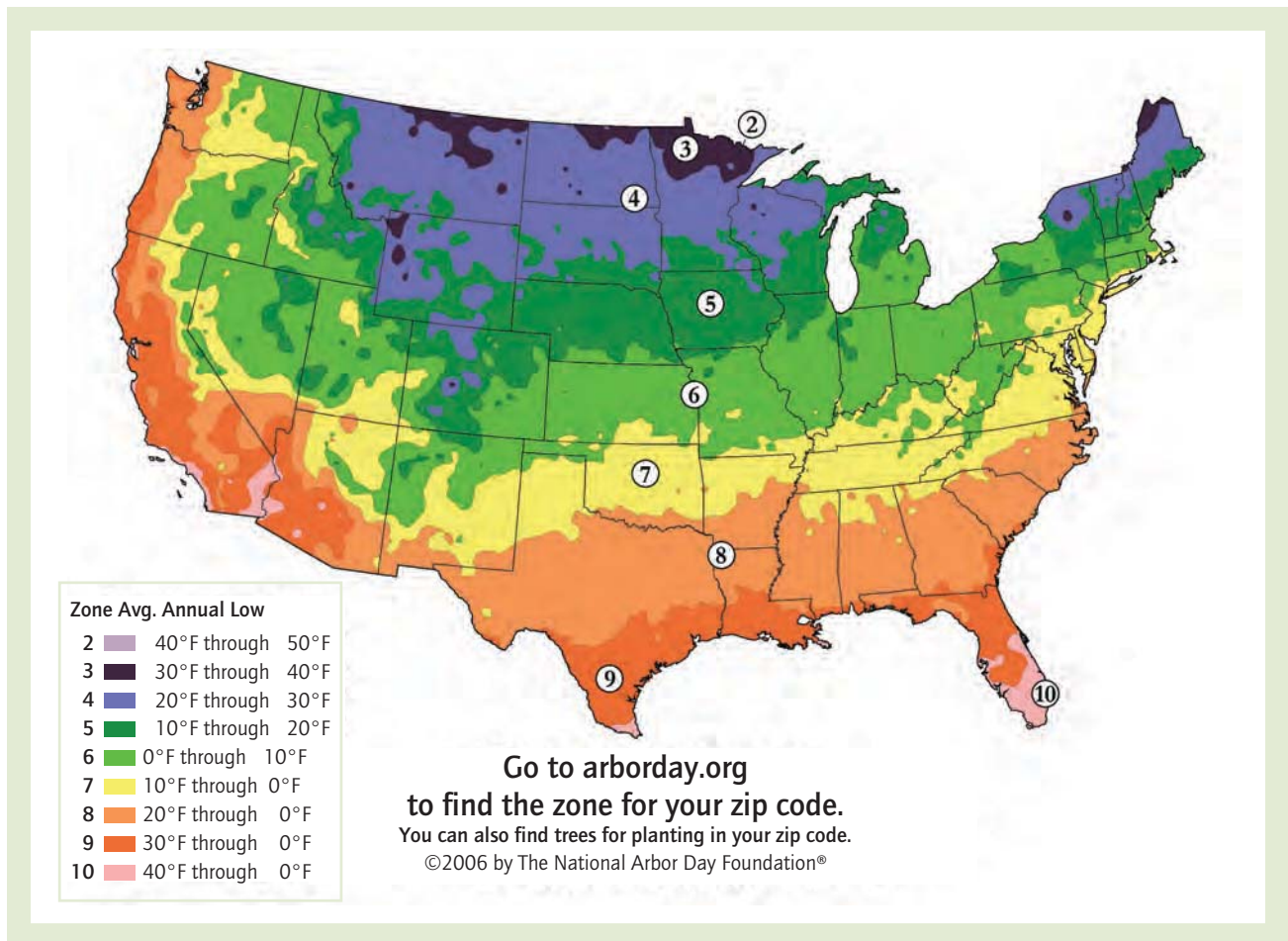


Figure 1 Map of hardiness zones in the United States

Source: © 2006 The National Arbor Day Foundation.

however, we chose red for those in favor and yellow, a less pure color resulting from the combination of red and green, for those against, the red counties would stand out more on the map and potentially harbor a connotation that the decision to vote in favor of the proposition is more important than the decision to vote against. When a hue is used with different saturation levels and or intensities to create a range of color for symbolizing features on a map, lower saturation and intensity levels might be interpreted as having less value than those categories that are represented with higher saturation and intensity levels. This might provide clarity when representing quantitative data in a map of precipitation. However, when used with qualitative data, such as a map of dominant ethnicity, the use of those same colors might imply that there is an order to the data that does not exist.

The use of color can evoke psychological reactions by map users. Blue and green are often described as being cool or mellow colors, while red and yellow are warm colors. Feelings are linked with color as well. For example, red can be associated with aggression. Consequently, when choosing color in map design, consideration should be given to potential psychological reactions to color.

Through the observation of color in the real world, humans develop expectations about colors in everyday life and how those same colors are used to represent certain features on a map. For example, the color blue is associated with water and green is associated with vegetation. Using magenta to symbolize an ocean can create confusion for the map reader. Consideration should be given to associations when choosing colors. In Figure 1, blue shades are used for colder climates and



reds for warmer ones. A temperature map that symbolizes warmer areas with blues and cooler areas with reds would be confusing to the map user and require more scrutiny of the map legend.

The interactions between colors are important considerations as well. For example, the appearance of one color may change when displayed on different backgrounds. As a result, a single color defined in a map legend may actually appear as two different colors within the map when displayed with different background colors. In addition, the ability of a map user to differentiate between similar colors improves when the colors are displayed side by side but decreases when the colors are spread out throughout a map and are no longer adjacent.

The intended use of the map and the subsequent light source for the map user should also be considered when choosing colors. The appearance of colors will vary significantly when viewed on different computer monitors, in direct sunlight, in incandescent light, and in fluorescent light.

Common cartographic conventions have been established regarding the use of color in map design. In general, hue is used to symbolize different categories of data, while saturation and intensity are employed to represent numerical values in data. In addition, the use of certain colors to represent common map features has been established. For example, contour lines are depicted in brown, water features are cyan, roads are red, human-made features such as buildings and borders are black, and vegetation is represented with green. Maintaining a balance of color on a map is also important. When symbols vary significantly in areal size on a map, larger areas are typically symbolized with lighter colors, while smaller areas are symbolized with darker colors to achieve more visual balance.

Judd Michael Curran

See also **Cartography; Map Design; Map Visualization**

Further Readings

Brewer, C. A. (2005). *Designing better maps: A guide for GIS users*. Redlands, CA: ESRI Press.

Garo, L. A. B. (1998). *Color theory*. Retrieved March 14, 2009, from <http://personal.uncc.edu/lagaro/cwg/color/index.html>

Krygier, J., & Wood, D. (2005). *Making maps: A visual guide to map design for GIS*. New York: Guilford Press.

Robinson, A. H., Morrison, J. L., Muehrcke, P. C., Kimerling, A. J., & Guptill, S. C. (1995). *Elements of cartography* (6th ed.). Hoboken, NJ: Wiley.



COLUMBUS, CHRISTOPHER (CA. 1451–1506)

Christopher Columbus (or Colón in Spanish) is widely held to be the first European to “discover” the New World of the Americas, which was a major turning point in world history. In 1484, while still in Portugal, Columbus’s challenge was not about the shape of the Earth but about the distance needed to travel to the Indies and the Spice Islands. Columbus’s miscalculations came from his reading of Ptolemy, who declared each degree of the Earth to be 50 mi. (miles) and the total circumference to be 18,000 mi. In addition to classical sources, Columbus read and annotated *The Travels of Marco Polo* (1298), *The Travels of Sir John Mandeville* (1371), Pius II’s *Historia Rerum Ubique Gestarum* (1477), Pierre d’Ailly’s *Imago Mundi* (1480–1483), and the Bible, among many other books preserved in the Biblioteca Colombina by Ferdinand Columbus. These texts confirmed the existence of the Antipodes, suggested the possibility of arriving in the East by traveling west, and provided him with myths and fables as he explored unknown geographies.

Genoa, with its flourishing maritime environment, is considered Columbus’s birthplace and the port city where he spent his first 21 years. In this context, it is easy to understand his profound interest in cartography and navigation. Genoa was at the time a maritime commercial center where some of the best mapmakers of portolano charts of the Mediterranean resided. Columbus arrived at the Portuguese coast in 1576 and joined his younger brother Bartholomew in Lisbon. There they made and sold navigation charts and met and



interviewed mariners who had new information to update old maps and charts. These were the circumstances that supported the story of the *piloto desconocido*, the unknown pilot who arrived from an unknown hemisphere and returned sick to Lisbon, dying at Columbus's home. This story was later used as evidence in the important legal battles between Columbus's heirs and the Spanish Crown and undermined Columbus's own claims of conquest and promises contracted under the *Capitulaciones de Santa Fe* (April 17, 1492).

As with many of Columbus's actions, his intellectual contributions to physical and human geography are the subject of many ethical, legal, and historical debates that were initiated after Europe recognized the significance of his journeys and explorations. The same questions still permeate the historiography on Columbus: Was he erudite enough? Were his actions the product of his own genius, or did he simply use the knowledge and resources provided by others? And for those who opposed the Spanish treatment of the Amerindian populations, what role did he play in the expansion of slavery and colonialism? A whole series of early colonial chroniclers writing about Columbus came to the rescue of his historical legacy; among them were his own son, Ferdinand Columbus; the Dominican advocate of Amerindian rights, Bartolomé de las Casas; and other well-known historians such as Pietro Martire d'Anghiera, Gonzalo Fernández de Oviedo, and Hernán Pérez de Oliva. Their accounts reveal their own ideological positions on Spanish geopolitical aims of domination and provided evidence of Columbus's life and writings that still help readers understand the political, religious, and cultural milieu of the Columbian experience and the first years of European colonization.

Both Bartolomé de las Casas and Ferdinand Columbus protested the 1507 map by Martin Waldseemüller, the first portrait of the lands explored by Columbus that depicted a continent separated from Asia; the new land was named "America" after Amerigo Vespucci. These biographers and many others who favored Columbus's heirs in the legal claims they had against the Spanish court emphasized the extensive reconnaissance undertaken by Columbus at the service of Spain. The Caribbean, South America, and parts of Central America (e.g., Honduras, Costa

Rica, Panama) were all recognized in his journeys without knowing that these regions belonged to a separate continent.

A sketch of the northwest coast of Hispaniola is the first illustration of that island attributed to Columbus that registered the Americas in European consciousness. It was drawn in 1492 as he surveyed the region believed to be Cipango (Japan); Columbus, experienced in cartography, used his drawings as instruments to account for his experience and name regions he encountered on behalf of the Spanish Crown. In his texts, the need to map the regions explored is crucial; not only did he reassure the Crown that his letters would be accompanied by his own maps and charts, but he also included textual geographical descriptions.

With Christian cosmology and medieval *map-pamundis* in mind, the speculation that Columbus believed that he had found Paradise is crucial to understanding how his sense of geography was informed by religion. After encountering volumes of freshwater gushing into the ocean and the different currents of the Orinoco River, in his account of the third journey, Columbus placed himself in the middle of the four rivers of Paradise: the Nile, Euphrates, Tigris, and Ganges. The shape of the world is depicted using the metaphor of a woman's breast, like a pear, with Paradise located on the nipple. The search for Paradise, the conquest of Jerusalem, and the conversion of indigenous populations to Christianity became some of Columbus's last pleas to the imperial court. The lands, free labor, gold, and wealth of the New World had become secondary to an enterprise that more importantly represented the triumph and supremacy of Catholic Spain over the rest of Europe.

Santa Arias

See also **Cartography, History of; Exploration; Human Geography, History of; Magellan, Ferdinand**

Further Readings

Columbus, F. (1992). *The life of the Admiral Christopher Columbus by his son Ferdinand* (B. Keen, Ed.). New Brunswick, NJ: Rutgers University Press.



Gómez, N. (2008). *The tropics of empire: Why Columbus sailed south to the Indies*. Cambridge: MIT Press.

Harley, J. (1990). *Maps and the Columbian encounter*. Milwaukee: University of Wisconsin Golda Meir Library.

Morison, S. (1942). *Admiral of the ocean sea: On the life of Christopher Columbus* (2 vols.). Boston: Little, Brown.

Zamora, M. (1993). *Reading Columbus*. Berkeley: University of California Press.



COMMODITY CHAINS

A commodity chain encompasses a set of inter-related activities associated with the production of one good or service such as manufacturing, consumption, design, retailing, marketing, and advertising. In commodity chain analyses, the economy is conceptualized as an assemblage of individual chains, each possessing a unique logic, organization, and spatiality. Using the lens of the commodity chain, geographers have explored the dynamics of production and consumption in a range of commodities, including fashion, furniture, footwear, gold, diamonds, fruits, vegetables, coffee, chocolate, and cut flowers. The focus is on the vertical relationships between buyers and suppliers of a particular product, tracing the flow of material resources, value, finance, and knowledge—as well as signs and symbols—between sites along a chain. Processes of coordination and competition among actors operating at the same node or function are given less weight. This tradition thus marks a break with horizontal approaches to the economy, which focus on general activities such as retailing or on one stage in the life of a commodity such as manufacturing.

The notion of a commodity chain is related to a number of similar concepts that also involve tracing connections between interrelated sites, such as filieres, global value chains, systems of provision, circuits, and actor-networks. The growing attractiveness of this methodology relates to a broader “cultural turn” in human geography,

which aims to bring together economy and culture, production and consumption, and the material and the symbolic. The interest in commodity chains can also be traced to a growing political concern among consumers with the origins, quality, and ethics of products and with the vast distances and inequalities that often separate producers and consumers. A key problem is that the images and meanings of consumer goods often contain few traces of the production processes and environments that created them. The aim of a commodity chain analysis is to uncover these connections.

The Global Commodity Chain

The work of Gary Gereffi is a key reference point in the commodity chain literature. Gereffi uses the term *global commodity chain* (GCC) to describe the complexity of interfirm relationships within globally dispersed production networks. According to Gereffi, commodity chains have three main dimensions. The first is an input-output structure, encompassing a group of products and services linked together in a sequence of value-adding activities. Second, individual chains possess a distinct territoriality, a pattern of geographical diffusion or concentration of raw materials, production, export, and marketing activities. Finally, commodity chains are characterized by a particular governance structure.

Governance Structures

Of these attributes, governance structures have received the greatest attention in the literature. Governance structures refer to relationships of power and authority that determine how financial, material, and human resources, as well as economic surpluses, are allocated within the commodity chain. Governance defines the functional division of labor along a chain, as well as delineating the terms of chain membership and exclusion.

As one example of governance, the state is a key actor in mediating the dynamics of commodity chains. Through labor legislation, training, education, and foreign investment programs,



governments play a critical role in regulating chain relationships. In addition to the state, a range of other institutions govern chains such as trade organizations and unions.

While external actors are important, the literature on commodity chains has tended to foreground internal governance mechanisms and, in particular, the nature of interfirm linkages along a chain. Two types of governance are commonly associated with commodity chains. The first includes producer-driven chains that are typical of capital-intensive industries such as aerospace, computers, and automobiles. In these chains, transnational producers, typically in core countries, play a central role in coordinating production networks, including backward and forward linkages.

The second type of governance structure is represented by buyer-driven commodity chains, where large retailers and brand-name marketers play the dominant role in establishing decentralized production networks in a variety of exporting countries. These dynamics are common in labor-intensive consumer goods industries such as garments, footwear, toys, and electronics. Production is generally executed by tiered networks of contractors that make finished goods according to the design specifications of retailers or marketers. In buyer-driven chains, profits derive from innovations in design, sales, and branding rather than from advantages in scale, volume, or technology.

Many commentators chart a shift in recent years from producer-driven to buyer-driven chains in key sectors of the economy. One example is found in the case of fresh fruit and vegetable chains, where supermarkets exercise heightened control in determining what products will be offered to consumers and when, as well as dictating the quality, appearance, and packaging of produce. To achieve this control, large grocery chains have been shifting from sourcing products through wholesale markets to establishing their own tightly managed supply chains.

While these ideal types constitute a useful heuristic device, it is also important to recognize that different types of governance may coexist within a sector and that governance structures change over time and across space. Chains may not be exclusively producer or buyer driven, and different forms and degrees of power may accrue at

different sites in the chain, not just those assigned “key agency.”

Revised Typology of Governance

Empirical research has revealed tremendous variation and complexity in models of governance. Moving beyond this binary formulation, Gereffi and his colleagues have recently elaborated a more nuanced portrait of commodity chain governance based on three factors: (1) the complexity of information involved in a transaction, (2) the extent to which knowledge can be codified (communicated or traded), and (3) the capabilities of suppliers with regard to the requirements of the transaction. Based on these criteria, they offer a revised typology identifying five types of governance.

The first form of governance is markets. This situation applies to transactions where the complexity of information exchanged is low and knowledge is easily codified. Product specifications are typically simple, requiring little input from buyers. Under these conditions, transactions can be governed with little coordination. The second variation in governance is represented by modular value chains. Here, technical standards simplify the process of interaction by creating uniform component, product, and process specifications. Suppliers often have the ability to supply full modules, which internalizes knowledge and lowers the need for direct monitoring of suppliers. As with simple market exchange, codification enhances the ability to exchange information with little coordination, and the cost of switching partners is low. The third model of commodity chain governance is found in relational value chains. In these chains, transactions are more complex, and product specifications and knowledge cannot be codified. Buyers and suppliers exchange tacit knowledge (knowledge based on shared norms and conventions, which cannot be easily communicated). Because suppliers have high competencies, relations of mutual dependence develop, which are regulated through reputation, as well as social and spatial proximity. The cost of shifting to new partners is high. A fourth form of governance is associated with captive value chains where the complexity of product specification is high, as is the ability to codify information. However, supplier capabilities are low, leading to



a high degree of intervention and control by the lead firm. Suppliers are often engaged in a narrow range of tasks, such as basic assembly. Under these conditions, suppliers face considerable switching costs and are therefore “captive.” A final type of governance is hierarchy. This form occurs when products are complex and specifications cannot be codified. If capable suppliers cannot be found, then lead firms will tend to manufacture products in-house.

Each type of governance involves weighing the costs and benefits of outsourcing, and entails different levels of coordination and power asymmetry between buyers and suppliers, ranging from low in the case of markets to high in the case of hierarchy.

A prominent area of enquiry is how chain governance affects the possibilities for industrial upgrading among firms in developing countries. Upgrading can take place in a number of capacities, including possibilities for upgrading processes through reorganizing production systems or implementing new technology, upgrading products by shifting into the production of more sophisticated lines, or upgrading functions by expanding into new areas such as research, design, or marketing. A central issue surrounds the role of buyers in transferring knowledge to their suppliers. Researchers have found that chains organized according to more hierarchical relations may facilitate product and process upgrading but are unlikely to enable firms to expand into design or marketing. These patterns elucidate how chain governance influences whether and how firms in developing countries can realize gains from their participation in global commodity chains.

Alternatives to the GCC Approach

While the GCC approach has proven useful in understanding the unique power dynamics and inequalities associated with individual commodity chains, authors such as Ian Cooke, Philip Crang, and Peter Jackson call for a conception of commodities using a less linear logic of “circuits” and “networks.” Rather than searching for a singular or determining logic of a chain and tracing relationships of causality, these accounts unsettle the prioritization of any one moment in the commodity’s circulation. The aim is to furnish a more

contextual analysis of the multiple meanings attached to commodities at different times, places, and phases. These accounts consider how goods are displaced from one site to another and the way knowledges animate and are animated by the process of displacement. The notion of circuits allows for dense webs of interdependence between sites.

Extending these ideas, recent accounts also draw on actor-network theory to explore the multistranded relationships between firms, states, and organizations in individual commodity networks. In actor-network theory, power is theorized as a composite of the actions; agency is an effect generated by a network of heterogeneous, interacting materials, including not only actors located at various sites in the chain but also technologies, natures, and the commodity itself. Agency is granted to human and nonhuman actors in the network. Nodes do not exist as concrete objects per se but are constituted in the networks of which they are a part.

Approaches informed by the literature on circuits of culture and actor-network theory extend commodity chain analysis in fruitful directions, furnishing a dynamic and fluid understanding of power along a commodity chain. These approaches also incorporate processes of circulation and feedback between a wide variety of actors.

Applications of Commodity Chain Analysis

Regardless of the metaphors and concepts used to understand the linkages between sites, a commodity chain analysis provides a helpful framework for understanding some of the central characteristics and geographies of contemporary capitalism. Labor organizations are increasingly using the tool of commodity chain analysis to map the connections between workers around the world as well as between workers and consumers at a variety of sites and scales. Unions have begun organizing across commodity chains and developing transnationally networked forms of mobilization (such as alliances with other unions and ethical trade initiatives). The commodity chain approach not only holds analytical appeal, but it also affords the political potential to challenge relations of exploitation, inequality, and injustice across space. This is not to deny that there are problems associated with ethical consumption initiatives



and other strategies designed to mobilize actors along the chain. Acting politically through commodities is often associated with contradictions and ambivalences. However, commodity chain analysis provides us with an interesting approach to understanding not only the dystopias of modern commodity systems but also the twists and turns of ethical consumption practices that may further processes of marginalization and uneven development. In following commodity narratives and engaging with these political productivities, there is hope though for questioning and ultimately transforming the nature of commodity production and consumption.

Deborah Leslie

See also **Actor-Network Theory; Consumption, Geographies of; Cultural Turn; Economic Geography; Fair Trade and Environmental Certification; Food, Geography of**

Further Readings

- Cook, I., & Crang, P. (1996). The world on a plate: Culinary culture, displacement and geographical knowledges. *Journal of Material Culture*, 1, 131–153.
- Fine, B. (2002). *The world of consumption: The material and cultural revisited*. London: Routledge.
- Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of International Political Economy*, 12, 78–104.
- Gereffi, G., Korzeniewicz, M., & Korzeniewicz, R. (Eds.). (1994). *Commodity chains and global capitalism*. Westport, CT: Greenwood Press.
- Hartwick, E. (1998). Geographies of consumption: A commodity-chain approach. *Environment and Planning D: Society and Space*, 16, 423–437.
- Hughes, A., & Reimer, S. (Eds.). (2004). *Geographies of commodity chains*. London: Routledge.
- Jackson, P. (2002). Commercial cultures: Transcending the cultural and the economic. *Progress in Human Geography*, 26, 3–18.
- Leslie, D., & Reimer, S. (1999). Spatializing commodity chains. *Progress in Human Geography*, 23, 410–420.



COMMON POOL RESOURCES

Common pool resources (CPRs) are resources for which the exclusion of prospective users is difficult and whose utilization by one person affects the availability or quality of the resource for others (a property known in the literature as subtractability). Examples of CPRs include pastures, fishing grounds, irrigation systems, groundwater basins, forests, atmosphere, wildlife, and, more recently, biodiversity and the “digital commons.” CPRs contrast with private goods, where exclusion is feasible, and public goods, which do not exhibit subtractability. The management challenge of CPRs derives from the resultant user incentives. The benefits of exploitation tend to accrue to individual users, but the costs of use, in terms of a reduced resource base or higher extraction costs, are spread among all users. At the same time, the cost of investment in the resource (e.g., groundwater recharge structures) is with the individual investors, but the benefits can often be garnered by all users, creating a “free rider” problem. The dual result is often assumed to be an overexploited and degraded system.

This assumption led to the formulation of Garrett Hardin’s famous but now somewhat discredited “Tragedy of the Commons” thesis. Hardin put forward the view that rational users of the commons would continue making demands on the resource as long as the expected benefits of their action equaled or exceeded the expected costs. Moreover, since the self-interested individual user ignores the costs imposed on others, rational individual decisions would, in the long run, lead to destruction of the commons. However, later work, in particular by Elinor Ostrom and her associates, showed that such pessimistic outcomes were not universal. The large consensus that emerged over the past two decades is that the tragedy of the commons that Hardin referred to was indeed the tragedy of open-access resources (*res nullius*, or no property) and not that of common property resources (*res communes*). The confusion, it became apparent, was that CPRs could be either ungoverned under an open-access regime—this is what Hardin referred to as tragedy of the commons—or managed as a private or government property, or as common property.



Geography and Common Pool Resources

At a basic level, the use of CPRs revolves around humans, their environment, and the spatial interaction between the two—the core subject matter of human geography. Geographers' work in the field has tended to focus on applied issues of nature-society relations within common property or open-access resource regimes rather than on theoretical aspects of the commons *per se*. For example, Gordon Matzke and Nontokozo Nabane examined the outcomes of communally owned forests and wildlife in Zimbabwe. Toward the other scalar extreme, Itay Fischhendler and Eran Feitelson studied the spatial dimensions of transboundary rivers in explaining water management regimes between the United States and Mexico. A notable exception is Paul Robbins, who used empirical studies of cattle grazing in Western India to challenge assumptions about commons "ownership" (e.g., private, state, and open access) and resource outcomes. Another exception is Mark Giordano, who attempted to develop a spatially explicit framework for considering differential commons outcomes and management responses. More recently, Lisa Campbell used this framework to understand sea turtle conservation policies in Costa Rica.

Almost all scholars working on the commons have acknowledged the role of scale and space in managing CPRs. For example, nested institutional arrangements that operate at different sociopolitical scales have been often cited as one of the preconditions of successful governance of the commons. The issue of scale is especially useful because in recent times many governance issues of the commons are at a global scale (e.g., climate change, loss of biodiversity), while much of the accrued knowledge on governance of the commons stems from small-scale systems and institutions (e.g., traditional irrigation systems, local fishing grounds). Hence, an appreciation of scale is important for transposing lessons from local cases to global ones. From a geographical perspective, equally, if not more, important is the understanding of spatial issues as they relate to the use of CPRs.

Yet, curiously, geography as a discipline has not deployed geographical concepts of scale and space in developing a theoretical understanding

of CPRs, despite the considerable empirical work referred to above.

A Geographical Typology of Common Pool Resources

Some geographers have characterized the commons as a spatial relationship between the resource and the resource users. Based on spatial interaction, Giordano has developed an explicitly geographical typology of CPRs by classifying them into one of three categories—open access, fugitive, and migratory. Figure 1 illustrates the spatial aspects of private, open-access, fugitive, and migratory resources.

An open-access resource, defined from a geographic perspective, is one in which resource boundaries and the right of several users to use the resource intersect. In such a case, while the parties involved in resource extraction enjoy the full benefits of resource use, they share only a part of the cost. In the absence of any property rights regime (be it private, public, or common), such spatial interlinkage between the resource and the user leads to overexploitation of the resource. Overgrazing in a pasture that is totally unowned is an example of an open-access resource problem.

A fugitive resource is one where although the rights domain of two users, say A and B, are clearly demarcated (e.g., say Countries A and B) but the resource itself travels in a unidirectional way (say a river that flows from Country A to Country B). Here too, the threat of overexploitation exists, since at least one of the users can gain the full benefit of resource use, without paying the full cost of resource exploitation. An example of a fugitive resource problem is that of pollution in a transboundary river. An upstream country can pollute the river and get benefits from it, but it does not have to share the cost of pollution that the downstream country faces in consequence.

A migratory resource is similar to fugitive resource in that user right domains are separate, but it is different from fugitive resource in that the movement of the resource is bidirectional. An example is that of wildlife, birds, and fish that migrate from one domain to the other and back. Here again, like open-access resources, but unlike

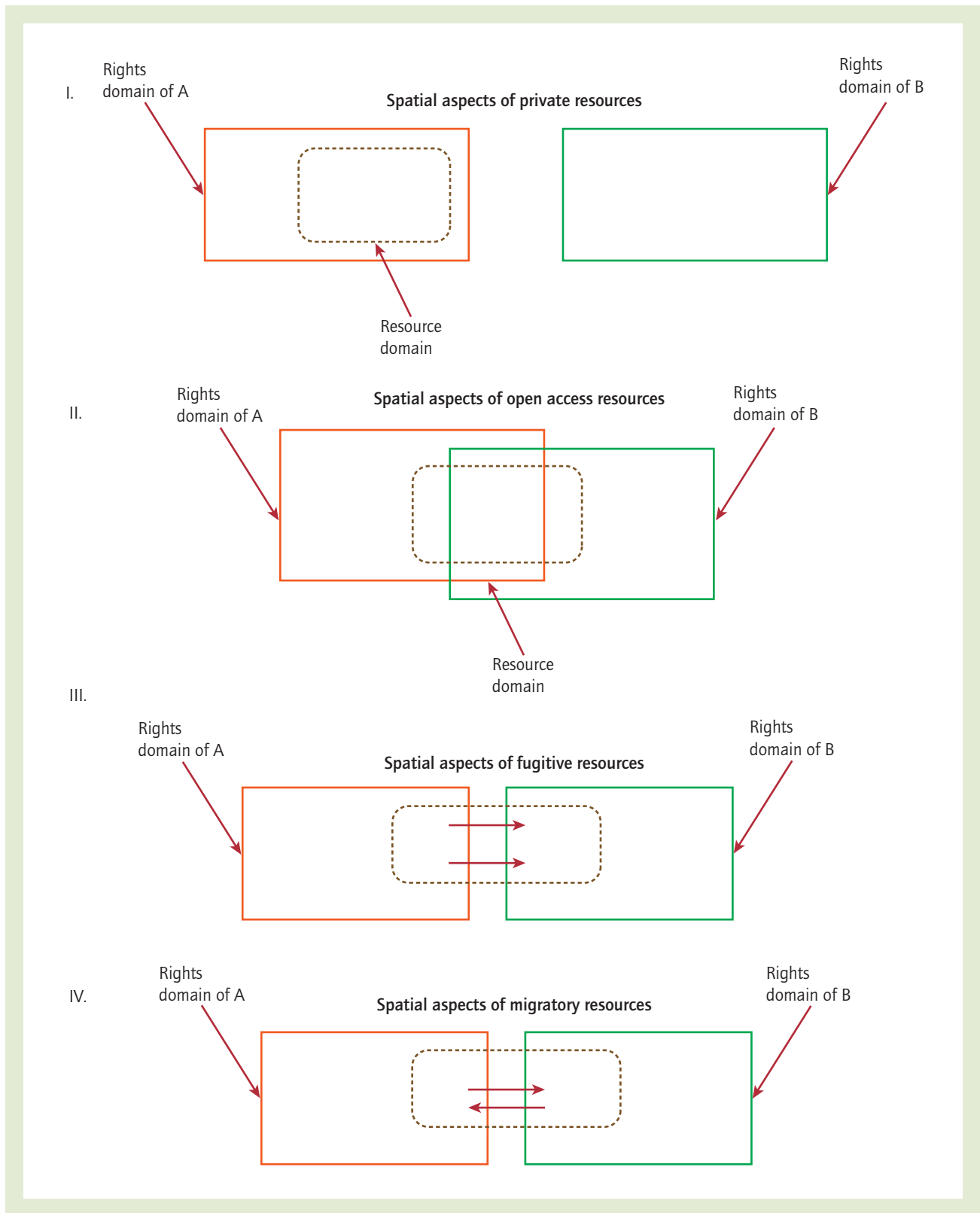


Figure 1 Spatial adjustment as a mechanism for resolving river basin conflicts: the U.S. versus Mexico case

Source: Giordano, M. (2003). The geography of the commons: The role of scale and space. *Annals of Association of American Geographers*, 93(2), 320.



fugitive resources, the full benefit of exploitation may accrue to the party using the resource, but the costs of resource exploitation have to be shared by both the parties. However, resource users' perception regarding optimal rates of resource use might vary significantly between open-access and migratory resources, leading to very distinct outcomes.

This threefold classification of CPRs from a geographical perspective of space emphasizes the point that resource governance regimes ought to be different depending on the spatial interlinkages between the resource users and the resource endowments. Therefore, the spatial interaction of the resource and the resource users has to be explicitly understood within a geographical framework of space and scale in order to effectively govern the commons.

Aditi Mukherji and Mark Giordano

See also **Common Property Resource Management; Commons, Tragedy of the; Community-Based Conservation; Externalities**

Further Readings

- Campbell, L. M. (2007). Local conservation practice and global discourse: A political ecology of sea turtle conservation. *Annals of the Association of American Geographers*, 97, 313–334.
- Dietz, T., Ostrom, E., & Stern, P. (2003). The struggle to govern the commons. *Science*, 302, 1907–1912.
- Fischhendler, I., & Feitelson, E. (2003). Spatial adjustment as a mechanism for resolving river basin conflicts: The US-Mexico case. *Political Geography*, 22, 557–583.
- Giordano, M. (2003). The geography of the commons: The role of space and scale. *Annals of Association of American Geographers*, 93, 365–375.
- Hardin, G. J. (1968). The tragedy of the commons. *Science*, 162, 124–142.
- Matzke, G. E., & Nabane, N. (1996). Outcomes of a community controlled wildlife utilization program in a Zambezi Valley community. *Human Ecology*, 24, 65–85.

- Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge, UK: Cambridge University Press.
- Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the commons: Local lessons and global challenges. *Science*, 284, 278–282.
- Ostrom, E., Gardner, R., & Walker, J. (1994). *Rules, games and common pool resources*. Ann Arbor: Michigan University Press.
- Robbins, P. (1998). Authority and environment: Institutional landscapes in Rajasthan, India. *Annals of the Association of American Geographers*, 88, 410–435.



COMMON PROPERTY RESOURCE MANAGEMENT

Common property resource management regimes are defined as a set of institutional arrangements that regulate the use of common pool resources (CPRs, also called the commons). The institutional arrangement or property rights governing CPRs could be no property (open access), private property, government property, and common or communal property. Owing to the historical development in the field of knowledge on the commons, there is much confusion between the nature or characteristics of a CPR and the management mechanisms forged to address the problems of the commons. CPRs are those natural and human-constructed resources where it is difficult to exclude potential users and the benefits derived from the resource are subtractable. These are called the principles of difficulty of exclusion and subtractability. Examples of CPRs are irrigation systems, groundwater basins, fishing grounds, pastures, forests, the atmosphere, wildlife, biodiversity, digital commons, and so on. The problem of subtractability makes CPRs particularly vulnerable to congestion, overuse, and degradation, while the difficulty of exclusion creates a “free rider”



problem (where some users consume more than their fair share of a resource), which in turn threatens the long-term sustainable use of the resources.

In his hugely influential, but now controversial, 1968 thesis of “The Tragedy of the Commons,” Garrett Hardin argued that because of the unique characteristic of the commons, the users of the commons were trapped in a behavioral situation that ultimately led to the destruction of the very resources they depended on. To avoid the tragedy from playing out, Hardin suggested that the commons should be either privatized or managed by the government in which right to entry and use could be controlled. Hardin’s thesis proved to be one of the most influential works in the environmental field and has had a huge sway over policy making in the field of natural resources management. However, later scholars such as Elinor Ostrom (among others) found that Hardin’s simple policy prescription that the tragedy of the commons could only be avoided by privatizing the resource or putting it under government control was erroneous. This was because it disregarded a range of cases where CPRs were governed effectively under common or communal property regimes and where the predicted tragedy did not occur. The large consensus that emerged over the past two decades is that the tragedy of the commons that Hardin referred to was indeed the tragedy of open access (*res nullius*, or no property) and not that of common property (*res communes*). The confusion, it became apparent, was that CPRs could either remain ungoverned under an open-access regime—this is what Hardin referred to as “Tragedy of the Commons,” or be managed as private property, government property, or common property and that the absence of a property regime was often confused with a common property regime.

Types of Property Rights Systems for Governing CPRs

Commons or CPRs may be held under four categories of property rights: open-access, private, government, and common/communal property. It should be noted that these are idealized analytical

categories. In reality, CPRs may be governed under overlapping combinations of these four kinds of property rights regimes.

Open access is defined as the absence of property rights, where there is no restriction on the use of natural resources by anyone. Under such a case, access to the resource is open to and free for all, and it is the classic case where Hardin’s tragedy of the commons plays out most often. Examples of open-access resources are the global atmosphere and climate, noncoastal ocean fisheries, and a common pasture.

Under private property, the rights to use the commons are exclusively transferred to a private entity (usually an individual or a corporation), which means that the commons are no longer subject to difficulty of exclusion. Such private property rights are usually held up in the state in the form of legal rights. Examples include privately held forests or inland fishing grounds leased to private entrepreneurs.

Under state or government ownership, the rights to the commons are exclusively vested in the state, which in turn can create the rules of the games vis-à-vis use, allocation, and management of the resource. Examples include pastures and forestlands that are vested in or controlled by the state. Unlike the other two property regimes (private and common property), which depend on the state to enforce their property rights, in case of state ownership, the state also has the coercive powers of enforcement.

Under common or communal property rights regime, the resource is held jointly by a well-defined group or community of people, so that from an outsider’s perspective the common property regime has the appearance of a private good (since outsiders are excluded), while for the insider it resembles a CPR (since the problems of difficulty of exclusion and subtractability are faced by the members of the group who own the resource). Examples include indigenous irrigation systems managed by communities all over the world. Recent scholarship has found that many of our natural resources are indeed managed under a common property regime, and hence, the tragedy of the commons has not played out as frequently as one might have expected if these resources were left ungoverned. It should be noted that the most successful cases of common property regimes



relate to the local commons (e.g., irrigation systems, pastures, inland fisheries) rather than the global commons (the atmosphere, air pollution, ocean fisheries, etc.).

These four property rights regimes have different implications for the two aspects of the CPRs—that is, ease of excluding potential users (exclusion) and possibility of regulating use and users (subtractability). In the case of open-access or no property rights, both exclusion of potential users and regulation of use are difficult, if not virtually impossible. In the case of private property, excluding potential users is easier; however, there are cases, such as the right to exploration of oil or groundwater, where exclusion becomes difficult even when private property rights are invoked. Under private property regimes, the possibility of controlling use and users is also much easier, while it is not so under state or government ownership due to the bureaucratic nature of such control. A wealth of literature in the past three decades has shown that under common property resource management regimes, outsiders can be effectively excluded and the behavior of insiders can be influenced by rules and regulations, so that the resources held under such regimes can be effectively governed with long-term positive feedbacks. The conditions under which common property regimes succeed have become a major area of research in recent times.

Conditions for the Success of Common Property Regimes

Since the early 1980s, a large number of social scientists, including anthropologists, economists, political scientists, human geographers, and sociologists, have contributed to the burgeoning study of common property resource management. They have found that defying the doomsday prediction of the tragedy of the commons, CPR users around the world often forge institutional arrangements and management regimes that help them use CPRs equitably for a long duration of time with no negligible equity losses. This observation has led to the next analytical question, that is, under what conditions have such successful institutional arrangements for

managing the commons been forged? Much of what is known about the conditions under which common property regimes can succeed stems from local commons managed by small user groups and communities; knowledge about global commons is much more limited.

Arun Agrawal has come up with and added to a comprehensive list of critical factors that ensure sustainable use of CPRs or the commons. These enabling or critical conditions can be divided into four main categories:

1. Resource system characteristics
2. Group characteristics
3. Institutional arrangements
4. External environment

Furthermore, interaction between (1) and (2), that is, the relationship between resource and resource users' characteristics, and interaction between (1) and (3), that is, the relationship between resource characteristics and institutional arrangements, make for the fifth and sixth critical conditions for the success of common property regimes (Table 1). Within each of these broad conditions, there are several factors, and the presence or absence of each factor influences the governance of the commons, and often these interactions are poorly understood.

Conclusion

An important conclusion that can be drawn from the list of factors shown in Table 1 is that there are numerous factors that encourage or impede the successful management and sustainability of common property resources. Almost all these factors emerge from case studies of local commons managed by small communities. This set of factors, as can be seen, turns out to be quite large and, thus, is a potential barrier to the formulation of an overarching theory of common property resources and their management. Also, the lack of a general theory of common property resource management makes the governance of global commons (the atmosphere, oceans, biodiversity, etc.) much more difficult than that of local



- | | |
|--|---|
| <p>A. Resource system characteristics</p> <ol style="list-style-type: none"> 1. Small size 2. Well-defined boundaries 3. Low levels of mobility 4. Possibilities of storage of the benefits of the resource 5. Predictability <p>B. Group characteristics</p> <ol style="list-style-type: none"> 1. Small size 2. Clearly defined boundaries 3. Shared norms 4. Past successful experiences and social capital 5. Appropriate leadership 6. Interdependence among members 7. Heterogeneity of endowments, homogeneity of identities and interests 8. Low levels of poverty <p>C. Institutional arrangements</p> <ol style="list-style-type: none"> 1. Rules are simple and easy to understand 2. Locally devised access and management rules 3. Ease in rule enforcement 4. Graduated sanctions 5. Availability of low-cost adjudication 6. Accountability of managers to the users | <p>D. External environment</p> <ol style="list-style-type: none"> 1. Technology: low-cost exclusion technology and ease of adoption 2. Low levels of interaction with outside markets and gradual change in interaction with outside markets 3. State: governments not to undermine local authority, supportive external sanction mechanisms, appropriate external aid if needed and nested governance at different sociopolitical levels <p>E. Relationship between resource and group characteristics</p> <ol style="list-style-type: none"> 1. Overlap between resource domain and rights domain 2. High dependence on the resource 3. Perceived fairness in allocation of benefits 4. Low levels of users demand 5. Gradual change in levels of demand <p>F. Relationship between resource system and institutional arrangements</p> <ol style="list-style-type: none"> 1. Match extractable quantity with its regeneration capacity |
|--|---|

Table 1 Critical factors determining success of common property management regimes

Sources: Adapted from Agrawal, A. (2001). Common property institutions and sustainable governance of resources. *World Development*, 29, 1649–1672; Wade, R. (1988). *Village republics: Economic conditions for collective action: Lessons from cooperative action in South India*. Oakland, CA: ICS Press; Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge, MA: Cambridge University Press; Baland, J. M., & Platteau, J. P. (1996). *Halting degradation of natural resources: Is there a role for rural communities?* Oxford, UK: Clarendon Press.

commons, because knowledge of global commons is more limited.

Aditi Mukherji

See also Biodiversity; Common Pool Resources; Commons, Tragedy of the; Oceans; Sustainable Fisheries

Further Readings

Agrawal, A. (2001). Common property institutions and sustainable governance of resources. *World Development*, 29, 1649–1672.

Baland, J. M., & Platteau, J. P. (2000). *Halting degradation of natural resources: Is there a role for rural communities?* New York: Oxford University Press.

Feeney, D., Berkes, F., McKay, B. J., & Acheson, J. M. (1990). The tragedy of the commons: Twenty-two years later. *Human Ecology*, 18, 1–19.

Hardin, G. (1968). The tragedy of the commons. *Science*, 162, 1243–1248.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge, UK: Cambridge University Press.

Ostrom, E. (1999). Coping with tragedies of the commons. *Annual Review of Political Science*, 2, 493–535.



Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the commons: Local lessons, global challenges. *Science*, 284, 278–282.

Wade, R. (1994). *Village republics: Economic conditions for collective action in South India*. Oakland, CA: ICS Press.



COMMONS, TRAGEDY OF THE

The tragedy of the commons is the idea that in an open natural system, the depletion of commonly held resources is inevitable. Competing individual and group interests place resource users in a trap that results in overexploitation and eventually decimation of common resources. While the idea of a “commons” was noted by many scholars, dating as far back as Aristotle, it is largely attributed to Garrett Hardin and his seminal 1968 article of the same name. His article focuses on the issue of overpopulation; however, its central impact has been its theories related to natural resource management. Given its influence on understandings of common resources and the architecture of natural resource policies, the tragedy of the commons is an important concept for geographers, particularly those working in the subfield of political ecology who explore issues surrounding natural resource use.

The Commons

The commons refers to a set of resources that are used by many people but privately owned by no one. Examples include fisheries, forests, water resources, the atmosphere, and pastures. Usage of the term *commons* dates to Medieval Europe, where it referred to the meadows that peasants were allowed to live on under the manorial system. The commons or common pool resources possess two important characteristics: (1) excludability—the resource is such that excluding users from access is either extremely costly or physically impossible—and (2) subtractability—exploitation of the resource by one user has negative consequences for the rest of the users by reducing the quantity or quality of the resource.

The Tragedy

In his article, Hardin used the analogy of herdsman to explain how conditions of the commons will lead to the tragedy of resource decimation. A herdsman grazing livestock in open pasture will seek to maximize his gain, so he will add an additional animal to graze on the field. The animal in turn will deplete the quality and quantity of the pasture resource. The herdsman will receive all the profit from the sale of that piece of livestock. However, the cost of the depletion of the pasture will be shared by all the users, so it will only cost him a small fraction of the profits. There are no incentives for individual users to be protective of the common resource, and “rational” actors will continue to deplete resources for their own gain, ultimately leading to ruin for all.

Hardin emphasized the futility of an appeal to conscience in the management of common resources. He suggested that telling resource users to voluntarily limit their use of resources would place them in a double bind. First, they will be condemned for taking more than their share of resources. However, if they don’t take their share, users will still feel condemned for standing by while other users openly exploit the commons. Resource users cannot be expected to limit use on their own because they will always be worried that “free riders” will continue to exploit resources while they refrain from taking their share.

Examples

There are many examples of the tragedy of the commons—situations in which the open access to a common resource has led to its decline. This concept can be presented as the root of many of the major environmental problems that humanity faces. Some of the most prominent examples are in the arena of natural resources.

Fisheries are a kind of commons problem, and the decline of fisheries worldwide as well as the collapse of stocks, such as the Canadian cod stock in 1992, are largely attributed to this tragedy of the commons. Forests and pastures or grazing lands are also considered common pool resources, and large-scale deforestation and overgrazing, particularly in developing countries, are other examples of the tragedy of the



Fire in the Amazon rain forest. A significant percentage of deforestation in the Amazon results from cattle ranches and soybean cultivation, while the rest mostly results from small-scale subsistence agriculture. Although each individual farmer benefits from cutting the forest, collectively their behavior destroys a commonly held resource.

Source: iStockphoto.

commons (see photo). The decline of harvested animals, including the world's species of whales or all the large land birds of New Zealand, is a historical example of this phenomenon.

Hardin also suggested that both overpopulation and pollution are examples of the tragedy of the commons. Individuals contribute to population while minimally feeling the effects of the added resource user on the system. In the case of pollution, individuals and corporations have little financial incentive to limit pollution, as they only minimally, if at all, feel the economic consequences of their pollution. This behavior leads to continued pollution of the commons. Global warming is considered one of the most recent examples of the tragedy of the commons, representing degradation of the global atmospheric commons.

The concept of the commons is not limited to the environment or natural resources. Some unconventional examples of the commons, which might be subject to Hardin's theories, include highway systems or traffic levels, government funds or subsidies such as welfare, and issues affecting public health, such as the proper use of antibiotics.

Solutions

Given the grim prospects for common resources, Hardin envisioned only two possible solutions to reverse the trend toward degradation: socialism or privatization. By socialism, he meant government ownership and control of resource use through the development of legal restrictions and



incentives. With privatization, users are given ownership over a restricted part of the resource, converting it from common property to private property. To Hardin, this will lead to increased stewardship of natural resources as any cost of depletion or degradation will only be subsumed by the private users.

Influence

The metaphor of the tragedy of the commons has captured the imagination of the modern world. The concept has underlain the development of many contemporary natural resource regulatory structures. Its conceptions of common property are frequently taught in the university education system in economic, political, and environmental contexts. Hardin's article spawned a surge of research into real-world cases of common pool resources to examine some of his theories from a more empirical basis. This work by scholars from several different disciplines, including geography, ecology, political science, economics, conservation biology, and natural resource management, has led to findings that complicate some of the ideas outlined in his arguments.

Critiques

Researchers have critiqued Hardin's pessimistic understanding of human nature and the commons predicament. The tragedy of the commons suggests that the destruction of commonly held resources is inevitable; however, empirical research has identified a multitude of historical and present-day cases in which this has not happened. Hardin stated that "rational" human actors would always choose their own benefit over that of the group, leading to the inexorable decline of common resources. Commons scholars, of whom the political scientist Elinor Ostrom is the most prominent, have found many cases in which groups of users have worked together to limit exploitation. Instead of watching the decimation of important resources before their eyes, she finds that "rational" actors will work to develop systems that protect their decline. Throughout the world, there is evidence of groups developing varied and innovative solutions to successfully sustain common resources such as fisheries, forests, grazing lands, and water

resources, even without the external force of a governmental institution.

Another common critique of the tragedy of the commons is the overly narrow set of solutions that Hardin offered to counteract the tragedy. Hardin suggested that the only possible means of evading resource demise is through privatization or centralized government control. Some researchers argue that Hardin overlooked an entire category of successful commons governance—communal property. Communal property is a type of commons systems in which a community of users has excluded outsiders from access to a particular resource and developed its own extragovernmental set of norms or policies regarding use of the resource. These systems are often local and culturally based. Successful examples of communal property systems include management of hunting and fishing lands by the James Bay Amerindian community in Subarctic Canada, water-sharing plans in the irrigation regimes of Northern New Mexico, management of lobster fisheries by local fishermen in Maine, and modern fishing cooperatives in Japan. Some scholars believe that Hardin's limited understanding of commons solutions may have prevented lawmakers from considering other possibilities, including communal property, in natural resource policy.

Additionally, critics argue that Hardin's proposed solutions are not always effective at preventing resource decline. In some cases, privatization has not only prevented the conservation of resources, but it has also increased the rate of their decline. Some scholars argue that, unchecked, private users have no incentive to maintain resources if they can make a large profit from the decimation of the resources in the present. Private users can always be tempted to exploit the resource to turn it into capital, which, once invested, may grow at a faster rate than money gained by the sustainable extraction of resources ever could.

These scholars argue that socialism or large-scale governmental control of resources has not proven immune to failure either. Top-down governance of resources can degrade the authority of local, community-based forms of communal property management, which have worked to protect resources throughout history. When these local forms of resource governance lose authority, chaos and degradation of previously protected



resources can result. In addition, state-controlled resources are subject to corruption, which can ultimately lead to resource decline. Corruption amid government-controlled resources has been a widespread problem, particularly in less developed countries. For example, poor state control has been attributed to the decimation of India's forests and the dire state of Russia's fisheries.

Critics have also attacked Hardin's ideas from a social justice perspective. To Hardin, the inevitable future decline of resources has created an emergency situation that supersedes questions of social justice or acceptability. Critics suggest that his ideas have justified large-scale government seizure and control of resources as well as a broadscale movement of natural resource policy toward privatization, both of which have contributed to social problems. Top-down government control of natural resources has in many cases lacked input from the very users who are most influenced by changes in resource policy. Some scholars argue that while sustaining natural resources, this type of governance may ignore factors important for the economic and cultural sustainability of communities who use the resources.

Resource privatization schemes include the distribution of public lands (e.g., grazing and forested lands) to private users and quota systems in fisheries that award a certain percentage of fish stocks to particular users—once awarded, these quotas can be bought and sold on the market. These privatization efforts have led to questions of equity because a chosen few users are awarded access to resources, gaining a windfall of economic benefit, while others remain unfairly excluded. In addition, privatization schemes create generational inequity where the first generation of users is freely granted access to a resource while subsequent generations must pay prohibitively high amounts to access the resource. Critics argue that privatization schemes have often favored large industries, which have significant capital, leading to the consolidation of resources with large corporations, to the exclusion of local, community-based users.

Current Research

Since Hardin's article appeared in 1968, thinking about the commons has been significantly expanded and refined. Recent scholars argue that

instead of Hardin's prescriptive solutions of privatization or socialism, the keys to successful commons governance are more contingent and context dependent. However, most commons scholars agree that without some kind of system or intervention, common pool resources are subject to large-scale degradation.

Geographers have contributed to commons research in many ways, examining the biological, social, political, and economic aspects of various common pool resource management scenarios. Current commons research focuses on examining both successful and failed cases of common pool resource management to learn what types of institutions promote the sustainability of common resources. Scholars continue to develop theories regarding the qualities that are necessary for sustaining common pool resources in a variety of contexts.

Laurie S. Richmond

See also **Common Pool Resources; Common Property Resource Management; Environmental Management; Political Ecology**

Further Readings

- Agrawal, A. (2003). Sustainable governance of common-pool resources: Context, methods, and politics. *Annual Review of Anthropology*, 32, 243–262.
- Baden, J. A., & Noonan, D. S. (Eds.). (1998). *Managing the common* (2nd ed.). Bloomington: Indiana University Press.
- Feeny, D., Berkes, F., McCay, B. J., & Acheson, J. M. (1990). The tragedy of the commons twenty-two years later. *Human Ecology*, 18, 1–19.
- Giordano, M. (2003). The geography of the commons: The role of scale and space. *Annals of the Association of American Geographers*, 93, 365–375.
- Hardin, G. (1968). Tragedy of the commons. *Science*, 62, 1243–1248.
- Ostrom, E. (1990). *Governing the commons*. Cambridge, UK: Cambridge University Press.
- Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the commons: Local lessons, global challenges. *Science*, 284, 278–282.

ENCYCLOPEDIA OF
Geography

EDITORIAL BOARD

Editor

Barney Warf
University of Kansas

Associate Editors

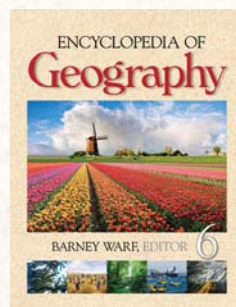
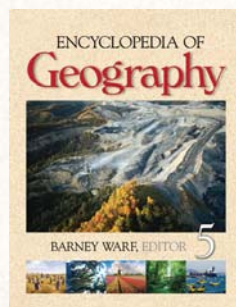
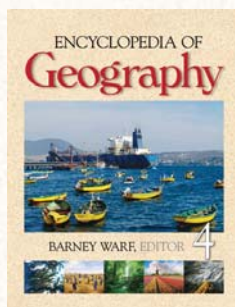
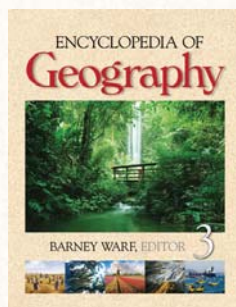
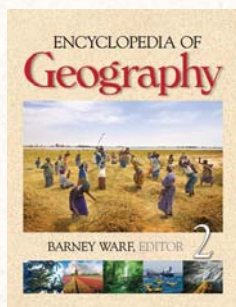
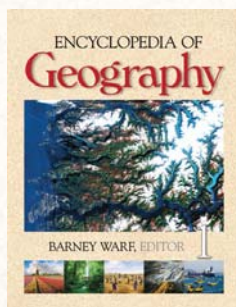
Piotr Jankowski
San Diego State University

Barry D. Solomon
Michigan Technological University

Mark Welford
Georgia Southern University

Managing Editor

Jonathan Leib
Old Dominion University



ENCYCLOPEDIA OF Geography

BARNEY WARF, EDITOR

University of Kansas

2



Los Angeles | London | New Delhi
Singapore | Washington DC

Copyright © 2010 by SAGE Publications, Inc.

All rights reserved. No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

For information:



SAGE Publications, Inc.
2455 Teller Road
Thousand Oaks, California 91320
E-mail: order@sagepub.com

SAGE Publications Ltd.
1 Oliver's Yard
55 City Road
London, EC1Y 1SP
United Kingdom

SAGE Publications India Pvt. Ltd.
B 1/I 1 Mohan Cooperative Industrial Area
Mathura Road, New Delhi 110 044
India

SAGE Publications Asia-Pacific Pte. Ltd.
33 Pekin Street #02-01
Far East Square
Singapore 048763

Printed in Singapore.

Library of Congress Cataloging-in-Publication Data

Encyclopedia of geography, volume I - VI / edited by Barney Warf.

6 v., p. cm.

Includes bibliographical references and index.

ISBN 978-1-4129-5697-0 (cloth)

1. Geography—Encyclopedias. I. Warf, Barney, 1956-

G63.E554 2010

910.3—dc22

2010009453

This book is printed on acid-free paper.

10 11 12 13 14 10 9 8 7 6 5 4 3 2 1

<i>Publisher:</i>	Rolf A. Janke
<i>Assistant to the Publisher:</i>	Michele Thompson
<i>Acquisitions Editor:</i>	Robert Rojek
<i>Developmental Editor:</i>	Diana E. Axelsen
<i>Reference Systems Manager:</i>	Leticia Gutierrez
<i>Reference Systems Coordinator:</i>	Laura Notton
<i>Production Editor:</i>	Tracy Buyan
<i>Copy Editors:</i>	QuADS Prepress (P) Ltd.
<i>Typesetter:</i>	C&M Digitals (P) Ltd.
<i>Proofreaders:</i>	Penelope Sippel, Rae-Ann Goodwin, Annette Van Deusen
<i>Indexer:</i>	Julie Sherman Grayson
<i>Cover Designer:</i>	Ravi Balasuriya
<i>Marketing Manager:</i>	Amberlyn McKay

Volume 2 cover photo: Rice harvest near Timbuktu. © Atlantide Phototravel/Corbis.

CONTENTS

2

List of Entries

vii

Entries

C 536

D 663

E 809

LIST OF ENTRIES

- | | | |
|---|---|--|
| <p> Abler, Ronald
 Absolute Space
 Accessibility
 Acid Rain
 Actor-Network Theory
 Adaptation to Climate Change
 Adaptive Harvest Management
 Adaptive Radiation
 Adiabatic Temperature
 Changes
 Aerial Imagery: Data
 Aerial Imagery: Interpretation
 African Union
 Agamben, Giorgio
 Agent-Based Models
 Agglomeration Economies
 Aging and the Aged,
 Geography of. <i>See</i> Elderly,
 Geography and the
 Agnew, John
 Agricultural Biotechnology
 Agricultural Intensification
 Agricultural Land Use
 Agriculture, Industrialized
 Agriculture, Preindustrial
 Agrobiodiversity
 Agrochemical Pollution
 Agroecology
 Agrofoods
 Agroforestry
 AIDS, Geography of. <i>See</i>
 Disease, Geography of;
 HIV/AIDS, Geography of
 Air Masses </p> | <p> Air Pollution. <i>See</i> Atmospheric
 Pollution
 Albedo
 al-Idrisi
 Altitude
 Ambient Air Quality
 American Geographical Society
 Analytical Operations in GIS
 Anarchism and Geography
 Anaximander
 Animal Geographies
 Annales School
 Anselin, Luc
 Antevs, Ernst
 Anthropogenic Atmospheric
 Change. <i>See</i> Anthropogenic
 Climate Change;
 Stratospheric Ozone
 Depletion
 Anthropogenic Climate Change
 Anthropogeography
 Antiglobalization
 Antipodes
 Antisystemic Movements
 Applied Geography
 Appropriate Technology. <i>See</i>
 Sustainable Development;
 Sustainable Development
 Alternatives; Sustainable
 Production
 Aquaculture
 Archipelago
 Architecture and Geography
 Argumentation Maps </p> | <p> Arid Topography
 Aristotle
 Armstrong, Marc
 Art and Geography
 Asia-Pacific Economic
 Cooperation
 Association of American
 Geographers
 Association of Geographic
 Information Laboratories
 for Europe
 Association of Southeast Asian
 Nations
 Atmospheric Circulation
 Atmospheric Composition and
 Structure
 Atmospheric Energy Transfer
 Atmospheric Moisture
 Atmospheric Particulates
 Across Scales
 Atmospheric Pollution
 Atmospheric Pressure
 Atmospheric Remote Sensing
 Atmospheric Variations
 in Energy
 Atoll
 Automobile Industry
 Automobility
 Avalanches
 Aviation and Geography

 Barrier Islands
 Barrows, Harlan
 Basin and Range Topography </p> |
|---|---|--|

- | | | |
|---|--|---|
| Batty, Michael | Business Models for Geographic Information Systems | Class, Geography and Class, Nature and Client-Server Architecture |
| Bayesian Statistics in Spatial Analysis | Buttimer, Anne | Climate: Dry |
| Behavioral Geography | | Climate: Midlatitude, Mild |
| Berkeley School | | Climate: Midlatitude, Severe |
| Berry, Brian | Cadastral Systems | Climate: Mountain |
| Bhopal, India, Chemical Disaster | CAD Systems | Climate: Polar |
| Biblical Mapping | Câmara, Gilberto | Climate: Tropical Humid |
| Biodiversity | Canadian Association of Geographers | Climate Change |
| Biofuels | Cancer, Geography of | Climate Policy |
| Biogeochemical Cycles | Carbonation | Climate Types |
| Biogeography | Carbon Cycle | Climatic Relict |
| Biome: Boreal Forest | Carbon Trading and Carbon Offsets | Climatology |
| Biome: Desert | Carcinogens | Clouds |
| Biome: Midlatitude Deciduous Forest | Carrying Capacity | Clusters |
| Biome: Midlatitude Grassland | Cartograms | Coal |
| Biome: Tropical Deciduous Forest | Cartography | Coastal Dead Zones |
| Biome: Tropical Rain Forest | Cartography, History of | Coastal Erosion and Deposition |
| Biome: Tropical Savanna | Castells, Manuel | Coastal Hazards |
| Biome: Tropical Scrub | Caverns | Coastal Zone and Marine Pollution |
| Biome: Tundra | Cellular Automata | Cold War, Geography of |
| Biophysical Remote Sensing | Census | Collaborative GIS |
| Bioregionalism | Census Tracts | Colonialism |
| Biosphere Reserves | Centers of Domestication | Color in Map Design |
| Biota and Climate | Central Business District | Columbus, Christopher |
| Biota and Soils | Central Place Theory | Commodity Chains |
| Biota and Topography | Chemical Spills, Environment, and Society | Common Pool Resources |
| Biota Migration and Dispersal | Chernobyl Nuclear Accident | Common Property Resource Management |
| Biotechnology and Ecological Risk | Chicago School | Commons, Tragedy of the Commonwealth of Independent States |
| Biotechnology Industry | Childhood Spatial and Environmental Learning | Communications Geography |
| Biruni | Children, Geography of | Communism and Geography |
| Blaikie, Piers | Chinooks/Foehns | Community-Based Conservation |
| Blaut, James | Chipko Movement | Community-Based Environmental Planning |
| Blindness and Geography | Chlorinated Hydrocarbons | Community-Based Natural Resource Management |
| Body, Geography of | Chlorofluorocarbons | Community Forestry |
| Borderlands | Cholera, Geography of | Commuting |
| Borders and Boundaries | Chorley, Richard | Comparative Advantage |
| Bourghassi, Carmina | Chorology | Competitive Advantage |
| Bowman, Isaiah | Choropleth Maps | Complexity Theory |
| Brownfields | Chrisman, Nicholas | Complex Systems Models |
| Built Environment | Christaller, Walter | Conference of Latin Americanist Geographers |
| Bunge, William | Circuits of Capital | |
| Bush Fallow Farming | Citizenship | |
| Business Cycles and Geography | Civil Society | |
| Business Geography | Clark, Andrew | |
| | Clark, William | |

- Conflation
 Conservation
 Conservation Zoning
 Consumption, Geographies of
 Continental Drift. *See* Plate Tectonics
 Cook, Captain James
 Coordinate Geometry
 Coordinate Systems
 Coordinate Transformations
 Coral Reef
 Coral Reef Geomorphology
 Coriolis Force
 Corporate Voluntary Environmental Initiatives and Self-Regulation
 Cosgrove, Denis
 Cosmopolitanism
 Cost-Benefit Analysis
 Council for Mutual Economic Assistance (COMECON)
 Countermapping
 Counterurbanization
 Coupled Human and Animal Systems
 Coupled Human and Natural Systems
 Creep
 Crime, Geography of
 Crisis
 Critical Geopolitics
 Critical GIS
 Critical Human Geography
 Critical Studies of Nature
 Crop Genetic Diversity
 Crop Rotation
 Cross-Border Cooperation
 Cultural Ecology
 Cultural Geography
 Cultural Landscape
 Cultural Turn
 Cyberspace
 Cyborg Ecologies
 Cyclones: Extratropical
 Cyclones: Occluded

 Dangermond, Jack
 Darby, Henry Clifford
 Darwinism and Geography
 Dasymetric Maps

 Database Management Systems
 Database Versioning
 Data Classification Schemes
 Data Compression Methods
 Data Editing
 Data Format Conversion
 Data Indexing
 Data Querying in GIS
 Datums
 Davis, William Morris
 Dear, Michael
 Debt and Debt Crisis
 Decolonization
 Deep Ecology Movements
 Deforestation
 Deindustrialization
 Delta
 Democracy
 Demographic Transition
 Dendrochronology
 Dependency Theory
 Derechos
 Desertification
 Desert Varnish
 Deterritorialization and Reterritorialization
 Developing World
 Development Theory
 Diamond, Jared
 Diaspora
 Diastrophism
 Difference, Geographies of
 Differential Heating
 Differential Vulnerabilities to Hazards
 Diffusion
 Digital Divide
 Digital Terrain Model
 Digitizing
 Disability, Geography of
 Disaster Prediction and Warning
 Disaster Preparedness
 Discourse and Geography
 Disease, Geography of
 Distance Decay
 Distributed Computing
 Distribution of Resource Access
 Division of Labor

 Domestication Centers. *See* Centers of Domestication
 Domestication of Animals
 Domestication of Plants
 Domino Theory
 Dot Density Maps
 Drought Risk and Hazard
 Drugs, Geography of
 Dunes
 Dynamic and Interactive Displays

 Earle, Carville
 Earthquakes
 Earth's Coordinate Grid
 Eastman, Ronald
 Ecofeminism
 Ecological Economics
 Ecological Fallacy
 Ecological Footprint
 Ecological Imaginaries
 Ecological Justice
 Ecological Mapping
 Ecological Modernization
 Ecological Regimes
 Ecological Risk Analysis
 Ecological Services. *See* Environmental Services
 Ecological Zones
 E-Commerce and Geography
 Economic Base Analysis
 Economic Geography
 Economies of Scale
 Economies of Scope
 Ecoregions
 Ecoshed
 Ecosystem Decay
 Ecosystems
 Ecotone
 Ecotourism
 Education, Geographies of
 Egenhofer, Max
 Elderly, Geography and the
 Electoral Geography
 Electronic Atlases
 Electronics Industry, Geography of
 El Niño
 Emerging Markets

- | | | |
|------------------------------------|-------------------------------------|---------------------------------|
| Emotions, Geography and Empiricism | Environmental Protection | Feminist Environmentalism |
| Endogenous Growth Theory. | Environmental Racism | Feminist Geographies |
| <i>See</i> Knowledge Spillovers; | Environmental Refugees | Feminist Methodologies |
| Learning Regions | Environmental Restoration | Feminist Political Ecology |
| Energy and Human Ecology | Environmental Rights | Fertility Rate |
| Energy Models | Environmental Security | Fieldwork in Human |
| Energy Policy | Environmental Services | Geography |
| Energy Resources | Environmental Social | Fieldwork in Physical |
| Enlightenment | Movements. <i>See</i> International | Geography |
| Enterprise GIS | Environmental Movements | Film and Geography |
| Environmental Certification | Environment and Development | Filtering |
| Environmental Determinism | Epistemology | Filtration |
| Environmental Discourse | Equator | Finance, Geography of |
| Environmental Entitlements | Equinox | Fisher, Peter |
| Environmental Ethics | Eratosthenes | Fish Farming |
| Environmental Footprint. | Error Propagation | Fjords |
| <i>See</i> Ecological Footprint | Ethics, Geography and | Flash Floods |
| Environmental History | Ethnicity | Flexible Production |
| Environmental Imaginaries | Ethnicity and Nature | Flocculation |
| Environmental Impact | Ethnic Segregation | Floodplain |
| Assessment | Ethnocentrism | Floods |
| Environmental Impacts of | Eurocentrism | Flow |
| Agriculture | Euromarket | Flow Maps |
| Environmental Impacts of | European Green Movements | Folding |
| Cities | European Union | Folk Culture and |
| Environmental Impacts of | Everglades Restoration | Geography |
| Manufacturing | Everyday Life, Geography and | Food, Geography of |
| Environmental Impacts of | Existentialism and Geography | Food and Agriculture |
| Mining. <i>See</i> Open-Pit | Exotic Species | Organization (FAO) |
| Mining | Exploration | Footprint Analysis. |
| Environmental Impacts of | Exploratory Spatial Data | <i>See</i> Ecological Footprint |
| Oil Fields | Analysis | Fordism |
| Environmental Impacts of | Export-Led Development | Fordism |
| Pipelines | Export Processing Zones | Foreign Aid |
| Environmental Impacts of | Externalities | Foreign Direct Investment |
| Roads | Extinctions | Forest Degradation |
| Environmental Impacts of | Extractive Reserves | Forest Fragmentation |
| Tourism | Extreme Geography | Forest Land Use |
| Environmental Impacts of War | Exurbs | Forest Restoration |
| Environmental Impact | Factors Affecting Location | Fotheringham, A. Stewart |
| Statement | of Firms | Frank, Andrew |
| Environmental Justice | Fair Trade and Environmental | Frontiers |
| Environmental Law | Certification | Fronts |
| Environmental Management | Famine, Geography of | Gaia Theory |
| Environmental Management: | Faulting | Gama, Vasco da |
| Drylands | Fear, Geographies of | Game Ranching |
| Environmental Mapping | Febvre, Lucien | Gated Community |
| Environmental Perception | Feminist Environmental | Gays and Lesbians, |
| Environmental Planning | Geographies | Geography and/of |
| | | Gazetteers |

- Gender and Environmental Hazards
 Gender and Geography
 Gender and Nature
 General Circulation Model (GCM). *See* Anthropogenic Climate Change; Atmospheric Energy Transfer; Climate Change
 Genetically Modified Organisms (GMOs)
 Genocide, Geographies of
 Gentrification
 Geocoding
 Geocollaboration
 Geocomputation
 Geodemographics
 Geodesy
 Geographical Ignorance
 Geographical Imagination
 Geographically Weighted Regression
 Geographic Information Systems
 Geography Education
 Geolibraries
 Geologic Timescale
 Geomancy
 Geometric Correction
 Geometric Measures
 Geomorphic Cycle
 Geomorphology
 Geophagy
 Geopolitics
 Geosensor Networks
 Geoslavery
 Geospatial Industry
 Geospatial Semantic Web
 Geostatistics
 Geothermal Energy
 Geothermal Features
 Geovisualization. *See* Cartography; Dynamic and Interactive Displays; Three-Dimensional Models
 Getis, Arthur
 Ghetto
 Giddens, Anthony
 Gilbert, Grove Karl
 GIS, Environmental Model Integration and
 GIS, History of
 GIScience
 GIS Design
 GIS Implementation
 GIS in Archaeology
 GIS in Disaster Response
 GIS in Environmental Management
 GIS in Health Research and Health Care
 GIS in Land Use Management
 GIS in Local Government
 GIS in Public Policy
 GIS in Transportation
 GIS in Urban Planning
 GIS in Utilities
 GIS in Water Management
 GIS Software
 GIS Web Services
 Glaciers: Continental
 Glaciers: Mountain
 Global Climate Change. *See* Anthropogenic Climate Change
 Global Environmental Change
 Globalization
 Global Positioning System
 Global Sea-Level Rise
 Global Warming. *See* Anthropogenic Climate Change
 Globes. *See* Cartography; Map Projections
 Glocalization
 Golledge, Reginald
 Goodchild, Michael
 Goode, J. Paul
 Google Earth
 Gottmann, Jean
 Gould, Peter
 Governance
 Governmentality and Conservation
 Gravity Model
 Great American Exchange
 Greenbelts
 Green Building
 Green Design and Development
 Greenhouse Gases
 Green Revolution. *See* Environmental Impacts of Agriculture
 Gregory, Derek
 Gross Domestic Product/Gross National Product
 Ground Reference Data
 Groundwater
 Growth Machine
 Growth Poles
 Gully Erosion
 Guyot, Arnold
 Hadley Cell
 Hägerstrand, Torsten
 Haggett, Peter
 Hanson, Susan
 Harley, Brian
 Hartshorne, Richard
 Harvey, David
 Hate, Geographies of
 Haushofer, Karl
 Hayden, Ferdinand
 Health and Health Care, Geography of
 Heavy Metals as Pollutants
 Hegemony
 Herbicides
 Herodotus
 Hettner, Alfred
 Heuristic Methods in Spatial Analysis
 High-Performance Computing
 High Technology
 Hipparchus
 Historical Geography
 Historicism
 Historic Preservation
 History of Geography. *See* Cartography, History of; GIS, History of; Human Geography, History of; Physical Geography, History of
 HIV/AIDS, Geography of
 Home
 Homelessness
 Hou Renzhi

- Housing and Housing Markets
Housing Policy
Hoyt, Homer
Human Dimensions of Global
Environmental Change
Human Ecology
Human Geography, History of
Human-Induced Invasion of
Species
Humanistic Geography
Humanistic GIScience
Human Rights, Geography and
Humboldt, Alexander von
Humidity
Hunger
Hunting and Gathering
Huntington, Ellsworth
Hurricane Katrina
Hurricanes, Physical
Geography of
Hurricanes, Risk and Hazard
Hybrid Geographies
Hybridization of Plant and
Animal Species
Hydroelectric Power
Hydrological Connectivity
Hydrology
Hydrothermal Energy. *See*
Geothermal Energy
- Ibn Battuta
Ibn Khaldūn
Ice
Identity, Geography and
Idiographic
Image Enhancement
Image Fusion
Image Interpretation
Image Processing
Image Registration
Image Texture
Imaging Spectroscopy
Immigration
Imperialism
Impermeable Surfaces
Import Substitution
Industrialization
Incubator Zones
Indigeneity
Indigenous Agriculture
- Indigenous and Community
Conserved Areas
Indigenous Cartographies
Indigenous Environmental
Knowledge
Indigenous Environmental
Practices
Indigenous Forestry
Indigenous Reserves
Indigenous Water Management
Industrial Districts
Industrial Ecology
Industrialization
Industrial Revolution
Inequality and Geography
Informal Economy
Information Society
Infrastructure
Innovation, Geography of
Input-Output Models
Institute of British Geographers
Interactive Mapping. *See* Map
Animation
Intergovernmental
Environmental
Organizations and Initiatives
International Criminal Court
International Environmental
Movements
International Environmental
NGOs
International Geographical
Union
International Monetary Fund
International Watershed
Management
Internet. *See* Communications,
Geography of; Cyberspace;
Digital Divide;
Telecommunications and
Geography
Internet GIS
Interoperability and Spatial
Data Standards
Interviewing
Invasion and Succession
Isard, Walter
Island Biogeography
Islands, Small
Isopleth Maps
- Jackson, John Brinckerhoff
Jefferson, Thomas
Johnston, R. J.
Journey-to-Work. *See*
Commuting
Justice, Geography of
- Kant, Immanuel
Karst Topography
Kates, Robert
Keystone Species
Knowledge, Geography of
Knowledge Spillovers
Köppen, Wladimir
Köppen-Geiger Climate
Classification
Kropotkin, Peter
Krummholtz
Kuhn, Werner
Kwan, Mei-Po
Kyoto Protocol. *See* Climate
Policy
- Labor, Geography of
Lahar. *See* Volcanoes
Land Degradation
Landfills
Landforms
Land Reform
Landscape and Wildlife
Conservation
Landscape Architecture
Landscape Biodiversity
Landscape Design
Landscape Ecology
Landscape Interpretation
Landscape Quality
Assessment
Landscape Restoration
Landslide
Land Tenure
Land Tenure Reform
Land Use
Land Use Analysis
Land Use and Cover Change
(LUCC)
Land Use and Land Cover
Mapping
Land Use History
Land Use Planning

- Land-Water Breeze
 Languages, Geography of
 La Niña
 Lapse Rate
 Latent Heat
 Latitude
 Law, Geography of
 Learning Regions
 Lefebvre, Henri
 Legal Aspects of Geospatial Information
 Lewis, Peirce
 Lewis and Clark Expedition
 Ley, David
 LiDAR and Airborne Laser Scanning
 Lightning
 Lillesand, Thomas
 Linear Referencing and Dynamic Segmentation
 Literature, Geography and
 Livingstone, David
 Locality
 Locally Unwanted Land Uses (LULUs)
 Location-Allocation Modeling
 Location-Based Services
 Location Quotients
 Location Theory
 Logical Positivism
 Longitude
 Los Angeles School
 Lösch, August
 Love Canal
 Lynch, William
- MacEachren, Alan
 Mackinder, Sir Halford
 Magellan, Ferdinand
 Mahan, Alfred Thayer
 Malaria, Geography of
 Malthusianism
 Manufacturing Belt
 Map Algebra
 Map Animation
 Map Design
 Map Evaluation and Testing
 Map Generalization
 Map Projections
 Map Visualization
- Marcus, Melvin G.
 Marginal Regions
 Marine Aquaculture
 Maritime Spaces. *See* Oceans
 Mark, David M.
 Market-Based Environmental Regulation
 Marsh, George Perkins
 Marxism, Geography and
 Masculinities and Geography
 Massey, Doreen
 Mass Wasting
 Mather, John Russell
 Maury, Matthew Fontaine
 McKnight, Tom L.
 Media and Geography
 Medical Geography
 Meinig, Donald
 Mental Maps
 Mercator, Gerardus
 Metadata
 Metropolitan Area
 Microwave/RADAR Data
 Migration
 Military Geography
 Military Spending
 Miller, Harvey J.
 Minerals
 Mining and Geography
 Mitchell, Don
 Mixed Farming
 Mobile GIS
 Mobility
 Models and Modeling
 Modernity
 Modernization Theory
 Modifiable Areal Unit Problem
 Money, Geographies of
 Monmonier, Mark
 Monsoons
 Morrill, Richard
 Morse, Jedediah
 Mortality Rate
 Most Favored Nation Status
 Movimento Sem Terra
 Multimedia Mapping
 Multispectral Imagery
 Multistakeholder Participation
 Multitemporal Imaging
 Multivariate Analysis Methods
- Multivariate Mapping
 Music and Sound, Geography and
 Nation
 National Aeronautics and Space Administration (NASA)
 National Center for Geographic Information and Analysis
 National Council for Geographic Education
 National Geographic Society
 Nationalism
 Natural Growth Rate
 Natural Hazards and Risk Analysis
 Nature
 Nature-Society Theory
 Neighborhood
 Neocolonialism
 Neogeography
 Neoliberal Environmental Policy
 Neoliberalism
 Neo-Malthusianism
 Network Analysis
 Network Data Model
 New International Division of Labor
 Newly Industrializing Countries
 New Urbanism
 Nitrogen Cycle
 Nomadic Herding
 Nomadism
 Nomothetic
 Nongovernmental Organizations (NGOs)
 Nonpoint Sources of Pollution
 Nonrenewable Resources
 Nonrepresentational Theory
 Nonvisual Geographies
 North American Free Trade Agreement (NAFTA)
 North Atlantic Treaty Organization (NATO)
 Not in My Backyard (NIMBY)
 Nuclear Energy

- | | | |
|---|---|--|
| Nutrient Cycles | Patches and Corridors in Wildlife Conservation | Positionality |
| Nyerges, Timothy | Path Dependence | Positivism. <i>See</i> Logical Positivism |
| Object-Based Image Analysis | Patriarchy, Geography and Peasants and Peasantry | Postcolonialism |
| Oceanic Circulation | Peat | Post-Fordism. <i>See</i> Flexible Production |
| Oceans | Pedology. <i>See</i> Soils | Postindustrial Society |
| Offshore Finance | Peet, Richard | Postmodernism |
| Oil Spills | Penck, Walther | Poststructuralism |
| Okabe, Atsuyuki | Periglacial Environments | Poverty |
| Olsson, Gunnar | Permaculture | Powell, John Wesley |
| Ontological Foundations of Geographical Data | Permafrost | Prairie Restoration |
| Ontology | Pesticides | Prairies |
| Open Geodata Standards | Pest Management | Precipitation, Global |
| Open Geospatial Consortium (OGC) | Petroleum | Precipitation Formation |
| Open-Pit Mining | Peuquet, Donna | Pred, Allan |
| Open Source Geospatial Foundation | Phenomenology | Primate Cities |
| Open Source GIS | Phosphorus Cycle | Prime Meridian. <i>See</i> Longitude |
| Open Space | Photochemical Smog | Privacy and Security of Geospatial Information |
| Organic Agriculture | Photogrammetric Methods | Producer Services |
| Organisation for Economic Co-operation and Development (OECD) | Photography, Geography and Physical Geography, History of | Product Cycle |
| Organization of the Petroleum Exporting Countries (OPEC) | Pickles, John | Production of Space |
| Organophosphates | Pilgrimage | Psychoanalysis, Geography and |
| Orientalism | Place | Ptolemy |
| Ortelius | Place Names | Public Housing |
| Other/Otherness | Place Promotion | Public Participation GIS |
| Outsourcing | Plantations | Public Policy, Geography of |
| Overpopulation. <i>See</i> Malthusianism; Neo-Malthusianism | Plate Tectonics | Public-Private Partnerships |
| | Playas | Public Space |
| | Point Pattern Analysis | Public Water Services |
| | Point Sources of Pollution | Pyrogeography |
| | Poles, North and South | |
| | Political Ecology | Qualitative Methods |
| | Political Economy | Quantitative Methods |
| | Political Economy of Resources | Quantitative Revolution |
| | Political Geography | Queer Theory |
| | Polychlorinated Biphenyls (PCBs) | |
| | Popular Culture, Geography and | Race and Empire |
| | Population and Land Degradation | Race and Nature |
| | Population and Land Use | Race and Racism |
| | Population Density | Racial Segregation |
| | Population, Environment, and Development | Radiation: Solar and Terrestrial |
| | Population Geography | Radical Geography |
| | Population Pyramid | Radiometric Correction |
| | Portolan Charts | Radiometric Normalization |
| | Ports and Maritime Trade | Radiometric Resolution |
| | | Railroads and Geography |
| | | Raisz, Erwin |
| Palimpsest | | |
| Panchromatic Imagery | | |
| Panopticon | | |
| Parks and Reserves | | |
| Parsons, James | | |
| Participant Observation | | |
| Participatory Learning and Action | | |
| Participatory Mapping | | |
| Participatory Planning | | |
| Participatory Rural Appraisal | | |
| Pastoral Herding. <i>See</i> Nomadic Herding | | |

- Rank-Size Rule
 Ratzel, Friedrich
 Real Estate, Geography and
 Realism
 Reclus, Élisée
 Recycling of Municipal Solid
 Waste
 Redistricting
 Refugees
 Regional Economic
 Development
 Regional Environmental
 Planning
 Regional Geography
 Regional Governance
 Regional Science
 Regional Science Association
 International (RSAI)
 Regions and Regionalism
 Regulation Theory
 Relational Space. *See* Relative/
 Relational Space
 Relative/Relational Space
 Religion, Geography and
 Relph, Edward
 Remittances
 Remote Sensing
 Remote Sensing: Platforms and
 Sensors
 Remote Sensing in Disaster
 Response
 Renewable Resources
 Rent-Gap
 Representations of Space
 Research and Development,
 Geographies of
 Resilience
 Resistance, Geographies of
 Resource Economics
 Resource Geography
 Resource Management. *See*
 Environmental Management
 Resource Management,
 Decision Models in
 Resource Mapping
 Resource Tenure
 Restoration Ecology. *See*
 Environmental Restoration
 Restructuring
 Retail Trade, Geography of
 Rill Erosion
 Risk Analysis and Assessment
 Ritter, Carl
 Rivers
 Rock Weathering
 Rose, Gillian
 Royal Geographical Society
 Rural Development
 Rural Geography
 Rural-Urban Migration
 Russian Geographical Society
 Satellites and Geography
 Sauer, Carl
 Scale, Social Production of
 Scale in GIS
 Schaefer, Fred
 Science, Technology, and
 Environment
 Science and Technology Studies
 Scott, Allen
 Sedimentary Rock
 Sedimentation
 Segregation and Geography
 Self-Organizing Maps
 Semantic Interoperability
 Semantic Reference Systems
 Semple, Ellen Churchill
 Sense of Place
 Sequent Occupance
 Services. *See* Producer Services
 Settlement Geography
 Sexuality, Geography and/of
 Shifting Cultivation
 Shortest-Path Problem
 Single Large or Several Small
 (SLOSS) Debate
 Situated Knowledge
 Smart Growth
 Smith, Neil
 Smog. *See* Photochemical Smog
 Social and Economic Impacts
 of Climate Change
 Social Construction of Nature
 Social Darwinism
 Social Forestry
 Social Geography
 Socialism and Geography
 Social Justice
 Social Movements
 Soil Conservation
 Soil Degradation
 Soil Depletion
 Soil Erosion
 Soils
 Soja, Edward
 Solar Energy
 Solstices
 Sovereignty
 Space, Production of. *See*
 Production of Space
 Space of Flows
 Spaces of Representation/
 Representational Spaces
 Spatial Analysis
 Spatial Autocorrelation
 Spatial Cognition
 Spatial Cognitive Engineering
 Spatial Data Infrastructures
 Spatial Data Integration
 Spatial Data Mining
 Spatial Data Models
 Spatial Data Structures
 Spatial Decision Support
 Systems
 Spatial Econometrics
 Spatial Fix
 Spatial Inequality
 Spatial Interaction Models
 Spatial Interpolation
 Spatialization
 Spatially Integrated Social
 Science
 Spatial Multicriteria Evaluation
 Spatial Optimization Methods
 Spatial Resolution
 Spatial Statistics
 Spatial Strategies of
 Conservation
 Spatial Turn
 Species-Area Relationship
 Spectral Characteristics of
 Terrestrial Surfaces
 Spectral Resolution
 Spectral Transformations
 Spit. *See* Coastal Erosion and
 Deposition
 Sports, Geography of
 Squatter Settlements
 State

- | | | |
|--|---|---|
| Steel Industry, Geography of | Textile Industry | United Nations Conference on Environment and Development |
| Stereoscopy and Orthoimagery | Thales | United Nations Environmental Summits |
| Storper, Michael | Thermal Imagery | United Nations Environment Programme (UNEP) |
| Strabo | Thornthwaite, C. Warren | United States Census Bureau |
| Strahler, Arthur | Three-Dimensional Data Models | United States Geological Survey (USGS) |
| Stratospheric Ozone Depletion | Three Mile Island Nuclear Accident | University Consortium for Geographic Information Science |
| Strip Mining | Thrift, Nigel | Unsupervised Classification |
| Structural Adjustment | Thunderstorms | Unwin, David |
| Structuralism | Thünen Model | Urban and Regional Development |
| Structuration Theory | Timber Plantations | Urban and Regional Planning |
| Subaltern Studies | Time, Geographies of | Urban Ecology |
| Suburban Land Use | Time-Geography | Urban Environmental Studies |
| Suburbs and Suburbanization | Time-Space Compression | Urban Gardens |
| Sui, Daniel | T-in-O Maps | Urban Geography |
| Suitability Analysis | Tobler, Waldo | Urban Green Space |
| Sunbelt | Tomlinson, Roger | Urban Heat Island |
| Supervised Classification | Topological Relationships | Urban Hierarchy |
| Supranational Integration | Toponymy | Urbanization |
| Surface Water | Topophilia | Urban Land Use |
| Surveillance | Tornadoes | Urban Metabolism |
| Surveying | Tourism | Urban Planning and Geography |
| Sustainability Science | Township and Range System | Urban Policy |
| Sustainable Agriculture | Trade | Urban Solid Waste Management |
| Sustainable Cities | Transhumance. <i>See</i> Nomadism | Urban Spatial Structure |
| Sustainable Development | Transnational Corporation | Urban Sprawl |
| Sustainable Development Alternatives | Transnationalism | Urban Storm Water Management |
| Sustainable Fisheries | Transportation Geography | Urban Sustainability |
| Sustainable Forestry | Trap Streets | Urban Underclass |
| Sustainable Production | Travel Writing, Geography and | Urban Water Supply |
| Symbolism and Place | Tree Farming | Usability of Geospatial Information |
| Symptoms and Effects of Climate Change | Trewartha, Glenn | |
| | Triangulated Irregular Network (TIN) Data Model | Vagueness in Spatial Data |
| Taphonomy | Troll, Carl | Vance, James |
| Taylor, Griffith | Tropical Rain Forests. <i>See</i> Biome: Tropical Rain Forest | Varenius |
| Taylor, Peter | Tsunami | Vectorization |
| Technological Change, Geography of | Tsunami of 2004, Indian Ocean | Vernacular Landscapes as Expressions of Environmental Ideas |
| Telecommunications and Geography | Tuan, Yi-Fu | |
| Teleconnections | Turner, Billie Lee, II | |
| Television and Geography | Typhoons. <i>See</i> Hurricanes, Physical Geography of | |
| Temperature Patterns | Typography in Map Design | |
| Temporal GIS | | |
| Temporal Resolution | Underdevelopment | |
| Terrain Analysis | Uneven Development | |
| Territory | United Nations | |
| Terrorism, Geography of | | |
| Text/Textuality | | |

-
- | | | |
|---|------------------------------------|---|
| Via Campesina (International Farmers' Movement) | Water Needs | Wine Terroir |
| Vidal de la Blache, Paul | Water Pollution | Wise Use Movement |
| Video Games, Geography and | Watershed Management | Wittfogel, Karl |
| Viewshed Analysis | Watershed Yield | Wood, Denis |
| Virilio, Paul | Water Supply Siting and Management | Woodfuel |
| Virtual and Immersive Environments | Watts, Michael | Woodlots. <i>See</i> Forest Fragmentation |
| Virtual Geographies | Wayfinding | World Bank |
| Virtual Globes | Weather and Climate Controls | World Cities |
| Vision and Geography | Weber, Alfred | World Court |
| Volcanic Eruptions as Risk and Hazard | Web Geoprocessing Workflows | World Health Organization (WHO) |
| Volcanoes | Web Service Architectures for GIS | World Summit on Sustainable Development |
| Voronoi Diagrams | Wetlands | World-Systems Theory |
| Vulnerability, Risks, and Hazards | White, Gilbert | World Trade Organization (WTO) |
| | Whiteness | Wright, Dawn |
| Waldseemüller, Martin | Whittlesey, Derwent | Wright, John Kirtland |
| Walker, Richard | Wilderness | Writing |
| War, Geography of | Wildfires: Risk and Hazard | |
| Waste Incineration | Wilson, John | Xeriscaping |
| Wastewater Management | Wind | |
| Water Degradation | Wind Energy | Zelinsky, Wilbur |
| Water Management and Treatment | Wind Erosion | Zoning |
| | Wine, Geography of | |



 COMMONWEALTH OF INDEPENDENT STATES

The Commonwealth of Independent States (CIS) is an organization founded to address economic and security situations facing the 15 former republics of the Soviet Union after the collapse of that country in 1991. The organization is a loose coalition addressing economic, trade, and security issues and has several constituent bodies. Headquartered in Minsk, Belarus, it is an organization that throughout its short history has been a weak organization despite initial fears that it was a vehicle for the recentralization of power to the Russian Federation.

Context and Genesis

The demise of the Union of Soviet Socialist Republics (USSR) in 1991 led the republics to confront the economic and political realities facing them collectively. After years of domination by the Soviet Union, the constituent republics had a high level of interdependence and varying levels of experience in governing their own affairs. The various republics had developed economic specializations predicated on the Soviet Union’s series of Five Year Plans addressing economic development and production quotas.

This led to intrarepublic dependence on goods from newly independent countries that were formerly produced under the auspices of a single state. Formerly domestic trade had become international, necessitating the development of new agreements and bodies to govern disputes.

The organization was formed on December 8, 1991, by Belarus, Russia, and Ukraine through the Minsk Agreement. The group expanded to encompass another nine former Soviet republics with the Alma-Ata (now Almaty) Protocol on December 21, 1991. (Turkmenistan gave up full membership, opting for associate member status in 2005; see Table 1.)

The Charter of the CIS called for developing close ties and resolving disputes in several arenas, including the political, military, economic, social, and cultural. Article 2 of the Charter focuses on the settling of conflicts between Commonwealth states, while Article 17 requires members to

<i>Current Full Members (Year of Membership)</i>	<i>Associate Members (Year of Membership)</i>
Armenia (1991)	Turkmenistan (1991,
Azerbaijan (1993)	changed to associate
Belarus (1991)	member in 2005)
Georgia (1993)	
Kazakhstan (1991)	
Kyrgyzstan(1991)	
Moldova (1994)	
Russian Federation (1991)	
Tajikistan (1991)	
Ukraine (1991)	
Uzbekistan (2000)	

Table 1 Membership in the Commonwealth of Independent States

Source: Author.

resolve disagreements through negotiations and discussion or alternative procedures. The Charter allows for appeal to the Council of Heads of State if attempts to resolve the dispute fail.

Military Cooperation

Originally, military cooperation was to run through the CIS Joint Armed Forces High Command (formed in 1992). The structure was reformed in 1993 as the Coordinating Staff. The divergent geopolitical goals of the member states have led to problems. Key issues include the drive by the governments of Ukraine and Georgia to align their countries with security organizations such as the North Atlantic Treaty Organization (NATO) over the the question of objections by the Russian Federation and Russian actions in the breakaway Georgian provinces of Abkhazia and South Ossetia.

The Collective Security Treaty Organization (CSTO) was formed out of the CIS effort. The treaty was signed in 1992 by Armenia, Kazakhstan, Kyrgyzstan, the Russian Federation, Tajikistan, and Uzbekistan. Azerbaijan, Georgia, and Belarus joined in 1993, and the treaty came into force in 1994. The treaty was to last for 5 years initially. Three countries—Azerbaijan, Georgia, and Uzbekistan—declined to extend the treaty. The three states were joined by Ukraine and



Moldova in withdrawing from the Commonwealth's collective Security and Economic Cooperation Pact. Georgia, Moldova, and Ukraine withdrew to reduce dependency on Russian supplied energy, while the others sought to find alternative routes for oil and natural gas pipelines. The departure of these five countries leaves the Russian Federation in a dominant position vis-à-vis the other CIS members.

Economic Affairs

The intent of the CIS was to foster the continuation and enhancement of previously established trade linkages between member states. Under the centrally planned economy of the Soviet Union, the republics developed distinct specializations, leading to high levels of interdependence. The dissolution of the Soviet Union forced a reworking of economic relationships. Additionally, the republics were eager to develop trade linkages with other countries, but all remained cognizant of the markets they had and needed to maintain connection with.

Economic cooperation in the CIS is governed by the Economic Council and the Economic Court of the CIS. The latter is focused on ensuring that economic obligations taken on by member countries are fulfilled as specified by the CIS charter. The Economic Court comprises 24 judges. Sixteen are permanent judges, and the other eight are chief justices. Judgments by the court are only recommendations and, therefore, are not legally binding, thus weakening the effectiveness of the body as seen by several states' refusal to submit to the court's findings.

Current Status and Prospects

Observers note the relative weakness of the CIS and the continued dominance of the Russian Federation. Leaders of the CIS member states have noted the weak status of the organization, but it continues to serve a purpose for the members. Other groups have formed that are seen as challengers to Russian Federation dominance of the CIS. The GUAM Organization for Democracy and Economic Development was founded in 2001 by Georgia, Ukraine, Uzbekistan, Azerbaijan, and Moldova (Uzbekistan withdrew in 2005). The

group, despite official denials, is seen as a move to counter Russian goals of continued regional dominance.

The CIS has been hampered by concerns by member states over the role of the organization in furthering Russian Federation interests. New alignments are being constructed as countries such as China, India, Japan, and the United States, along with European Union members, attempt to forge new relationships with CIS states. Concerns over the erosion of independence are also an important factor. The role of the CIS may change as leaders use it as a consultative organization where states can engage common issues in a political forum, but the possibility of the CIS becoming an organization with the strength of the European Union and NATO is seen to be unlikely by many experts.

Darren Purcell

See also Cold War, Geography of; Communism and Geography; Council for Mutual Economic Assistance (COMECON)

Further Readings

Sakwa, R., & Webber, M. (1999). The Commonwealth of Independent States, 1991–1998: Stagnation and survival. *Europe-Asia Studies*, 51, 379–415.



COMMUNICATIONS GEOGRAPHY

Communications geography is a nascent subdiscipline of human geography exploring the relationships between information and communication technologies (ICTs) and human conceptions of space and place. Historically, the unifying theme through much of the research was the movement of information and the physical geography of the networks making such a movement possible. More recent scholarship has focused on the socially constructed nature of technology, which engages the role of social processes in the creation and use of new technologies. This shift has resulted in research focused on issues such as the



global digital divide (gaps in access to ICTs that are along class and ethnic lines), the use of ICTs to achieve political and economic development goals, and the facilitation of community formation at multiple scales. Additionally, the subdiscipline has become an umbrella for cultural geographers researching the impacts of cultural products, such as the various media (television, film, advertisements, music, literary works, and performance arts such as dance). As a subdiscipline, the field is inherently interdisciplinary. Various literatures in political communication, communication, cultural studies, media studies, and Internet studies, as well as sociological work on ICTs, are incorporated into the understanding of the relationship between ICTs and space.

Background

Interest in communications and geography can be traced to the 1960s. Observers have noted that even then the rapid change in ICTs made it difficult to study the phenomena facilitated by new technologies. The earliest prominent texts were produced in the 1970s, with calls for geographers to engage communication practices and technologies more strongly. Much of this work was situated in the tradition of transportation geography and spatial analysis, with an emphasis on understanding the movement of data and the physical form of networks, both of which could be studied empirically. Such work was seen as supporting the progress-oriented, utopian visions of a technologically enhanced world in the 1970s. This strand of thought dovetailed with a view common among techno-optimists, such as Alvin Toffler, that space and distance were enemies to fulfilling human potential and that technology would usher in a new postindustrial era of peace and prosperity by conquering the tyranny of space. Despite this emphasis, some geographers were engaging social issues in terms of societal changes being facilitated by ICTs, asking about the resulting uneven social impacts. This cluster of work in the 1970s failed to take a strong foothold in geography, and engagement with ICTs dwindled by the end of decade.

The decline in engagement was shaped by a shift in the theoretical orientation of the discipline, namely, toward more humanist, Marxist,

and behavioral approaches to geography, which criticized the spatial modeling approach to geography, which had dominated early work on ICTs and geography. What resulted was a shift in the discipline as a whole toward great engagement with concepts of representations of space (how places are portrayed), culture, and political economy. Unfortunately, research examining communication processes declined.

During the 1980s and early 1990s, the landscape of ICTs changed dramatically. The early Internet was being used by academics, and the foundations for the transfer of the network to the private sector were under way. Greater levels of digitization of analog data facilitated greater levels of transferability and economies of scale that transformed telecommunications. The breakup of the AT&T monopoly also ushered in an era of greater competition, resulting in new technologies being developed and offered to businesses and, later, individuals. Additionally, the decline in the cost of computing power and the exponential increases in processor speed and storage capacity facilitated the conversion of many forms of communication to digital form. The greater computerization and digitization of many social processes, such as converting voice communication to digital data and money to digital forms, and efforts to attain a “paperless society” have all necessitated adaptation to ICTs, providing social scientists much to study. Today, the processes are further enhanced as new ICTs are adopted by more firms, agencies, and individuals and formerly face-to-face communication is substituted for by social networking sites and text messages. Additionally, the overall diffusion of these computing networks, while uneven and not totally global in scope, reflects the fastest adoption of a communications technology the world has seen.

Research on the actual geography of ICT networks, the absolute and relative accessibility of the networks, and the impacts these have on the interactions between people in different places is still important, and these are more easily explored with advances in geographic information systems designed to facilitate network analysis. Another theme from the 1970s, the perception of ICTs and their use to facilitate strategic goals such as political or economic development, is still important across a range of subdisciplines. Communications



geography encompasses research concerns within the entire range of communication processes and technologies used to communicate ideas and data. These processes include older, dominant media such as radio, television, and film, along with existing print media that still have an influence on perceptions across the globe, despite the merging of their forms of content onto electronic platforms. The diffusion of fiber optic networks and 24/7 communication technologies, along with the exponential increase in computing power and speed, has created new opportunities for geographic analysis of ICTs and their impacts on societies.

Dominant Themes in Communications Geography

Spatial Science and Modeling

Communications geography has its roots in the thinking of the spatial science tradition and owes much to formulations related to transportation geography. Early efforts to engage the role of communications technology and human geography emphasized the manner in which such technologies were used to decrease the friction of distance, as all transportation advances have done. Instead of moving goods, the emphasis was on the movement of ideas and culture. The concept of time-space convergence was central to understanding the spatial impact of ICTs, the effect new forms of transportation or communication technologies had on the ability to move goods, people, or ideas in terms of communication. Other authors invoked the term *time-space compression* but linked it more closely with the changing geography of capitalism as it developed over time. Research following this tradition can be seen today, examining issues of accessibility to networks, the role of accessibility in facilitating economic growth, and personal usage, among other themes.

Geography Is Dead, or Is It?

A cover of *The Economist* magazine in 1995 proclaimed the “Death of Distance” thanks to the telecommunications revolution, with greater diffusion access to ICTs. Others went so far as to provocatively reference the end of geography in article titles, as ICTs were said to eliminate spatial

barriers. Many geographers and other social scientists have expended (and continue to do so) great intellectual effort to rebut this position, arguing that if anything, geography is more important thanks to the ability to connect places with greater speed and data capacity. ICTs connect people in disparate places, thus there must be a reason to connect. The characteristics of the peoples and places being connected are vital to understanding the spatial patterns of usage. One example can be found in the literature exploring globalization and the use of ICTs to offshore production processes and information processing to places with lower labor costs. Other work focuses on the mapping of cyberspace and other communication and media flows, demonstrating that despite claims of universality and the ability to facilitate footloose movement, flows of power, money, and information follow earlier established patterns, with only incremental changes occurring.

The City

Early scholars working in the early utopian-influenced era considered the impact ICTs had on global urban structures, going so far as to question why cities such as New York would continue to exist in the decentralized world envisioned by various futurists, where telecommuting would be the norm and the centralizing impacts of the city would be waning. The present sees urban areas swelling across the globe but being reworked through the impacts of ICTs. Contrary to the futurists, the city and the multitude of daily interactions at the local and global scales have been intensified as people seek greater speed and mediation of their interactions. Cities that are well connected through infrastructure and information flows have prospered and continue to dominate the world system. The use of ICTs to aid in the governing of cities, the reworking of the urban form, and the economic prospects of cities in the future are topics often engaged by scholars. Much of this work has examined the local conditions for the increased production of knowledge, a resource vital in the competitive environment today.

Cyberspace and Virtual Space

The popularization of the Internet and the use of the term *cyberspace* led to the use of many



geographical metaphors to describe the “space” of interactions that were occurring online. Early Internet browsers invoked the terms *explorer* and *navigator*, implying the conceptualization of the technology as a place to be discovered by the individual, and books such as *Virtual Community: Homesteading on the Electronic Frontier* certainly evoked the idea of a place facilitating interaction. Chat rooms became spaces of meeting and exchange, and Web portals became focused on generating traffic. The technological hype about the possibilities of the Internet mirrored that of the early 1970s futurists (see, in particular, *Wired* magazine), and in similar fashion, geographers responded to the changes the new ICTs were facilitating, but in greater numbers and with a larger variety of methods. Studies focused on networks engaged the material connections that needed to exist to support the virtual worlds used by Internet browsers. This point was of particular interest as the Internet’s origin as a communications network for the military meant that the data traffic flows mirrored already existing geographic, namely, urban, hierarchies.

The idea of mapping cyberspace reflects a Cartesian view of geography, where to understand the phenomenon of the Internet, it must be mapped. The challenges of mapping a network that was growing exponentially were undertaken by several, but most notably in the book *Atlas of Cyberspace*. Further work in geovisualization of data has aided such efforts.

Theoretical engagement about what is a virtual space engages our understanding of the term *virtual* and notes that many things taken as real can be classified as virtual, and vice versa. The virtuality of the phenomena does not matter, as individuals still choose to act as if they were real, bringing into question the notion of the virtual world as constructed separately from the material or real world. As the Internet has attracted large numbers of people, it has come to form a virtual public space of debate, dialogue, and many other forms of interaction.

Interaction and Social Consequences

The social impacts of the use of ICTs has been very important to consider. A burgeoning body of work has engaged the idea of generational

differences in the use of the Internet and its construction as a threat to children in various news media and policy outlets. Others have explored the role of ICTs in areas of conflict and rapid cultural change, such as the Middle East, and the various restrictions placed on the use of the Internet and other ICTs. In general, one research trend has been the study of groups in various societies and their adoption of ICTs, how they differ and how they are deployed in ways that transform societies through their use.

Economic Changes

Much of geography’s engagement with ICTs has concerned economic geography, in particular the issue of globalization of services. Service industries lend themselves to taking particular advantage of ICTs and the new geographies they fostered. Early studies noted the impact of ICTs on legal services, offshore finance, and the vertical disintegration of many firms as they concentrated management and strategic operations in large cities, where telecommunications infrastructure was available, while back office functions such as forms and data processing were offshored to sites with infrastructure but cheaper labor than in the core regions. Additional contributions have explored the level to which various societies have become “information societies.” The term is debated, as observers point out that while services (industries usually seen as information processing) are expanding across the globe, the increased use of ICTs across all industrial pursuits, including primary and secondary economic activities (such as farming, fishing, and the processing of their products), in addition to manufacturing, has changed the nature of such work. Observers argue that all work has been information rich in terms of tacit knowledge, but with ICTs, the ability to track and replicate such information is enhanced, making the information age not a new era but one of greater emphasis on the informational nature of all work.

Additionally, the role of place in fostering the Internet industry has been examined within the larger theme of economic innovation and development, critically engaging the idea of fostering future Silicon Valleys and Silicon Glens across the globe.



ICTs, Media, and Geopolitics/ Political Geography

The 1990s and early 2000s witnessed an expansion of work engaging the power of various media to frame places for consumption and as a political power resource. Early work was critical in that it engaged the idea of using the power of the media to craft place images that served as a resource or a dominant frame by which to understand places. Later work, a subset of critical geopolitics, engaged the production of what is termed *popular geopolitics*, the representations of the place that reflect popularly held geopolitical views. These representations of places are considered geopolitical acts themselves, as they structure what the populace may know about areas of strategic concern to policymakers and elites. A variety of media have been explored in conjunction with the role of elite-produced texts that inform mass publics about the priorities and concerns of various states, such as news magazines, movies, and comic books. Much of the research has concluded that the subtle power of the media to shape geopolitical worldviews is quite real and not questioned by those who consume such media products. Newer work has engaged the issue of communication platforms as a space of engagement for political struggle.

The political possibilities of ICTs have been discussed since the 1970s by utopian thinkers, but the realities of who controlled the media and ICTs became more apparent in the 1980s. Observers in the 1990s noted that the introduction of ICTs only seemed to concentrate power in the core regions of the world and worked against the empowerment of the masses to facilitate greater levels of democracy and political participation. Concerns over the increasing surveillance and self-surveillant nature of ICTs were expressed, in particular after the September 11, 2001, terrorist attacks in the United States. Much of this work can be found in writings focused on the development of closed-circuit television systems in cities. Other authors have conceived of the Internet and its spaces for discussion as a new form of Habermas's public sphere, though critics argued that the Internet's capabilities to facilitate communication across groups is limited as the categories of the material world such as class, race, gender,

and ideology are present in the virtual world, thus guiding users to likeminded sites and, thus, only reinforcing preconceived notions.

The Current and Future States of Communications and Geography

The subdiscipline of communications geography continues to grow in terms of status, the types of research conducted, and the numbers claiming an interest in related research. Methodologically, the subdiscipline is very heterogeneous, with researchers employing network analysis, quantitative measures via geographic information systems, and qualitative methods such as textual analysis and interview techniques. This mirrors the broad variety of methodologies seen in other disciplines that engage communications and media questions. The Association of American Geographers hosts the Communications Geography Specialty Group, which was officially recognized as a specialty group in 2003. Other geography associations are interested in communications, such as the International Geographical Union (IGU), which also has a commission on the Geography of the Information Society. Other academic associations' conferences also see an increasing presence of geographers as members and in the number of sessions devoted to spaces, place, globalization, and ICTs.

Darren Purcell

See also **Cyberspace; Media and Geography; Telecommunications and Geography; Television and Geography**

Further Readings

- Adams, P. (2005). *The boundless self: Communication in physical and virtual spaces*. Syracuse, NY: Syracuse University Press.
- Dodge, M., & Kitchin, R. (2001). *Atlas of cyberspace*. Edinburgh, UK: Pearson Education.
- Dodge, M., & Kitchin, R. (2001). *Mapping cyberspace*. London: Routledge.
- Graham, S. (Ed.). (2004). *The cybercities reader*. London: Routledge.



- Hillis, K. (1998). On the margins: The invisibility of communications in geography. *Progress in Human Geography*, 22, 543–566.
- Kellerman, A. (2002). *The Internet on Earth: A geography of information*. Chichester, UK: Wiley.
- Rheingold, H. (1993). *The virtual community: Homesteading on the electronic frontier*. New York: HarperPerennial.
- Shields, R. (2004). *The virtual*. London: Routledge.
- Torrens, P. (2008). Wi-Fi geographies. *Annals of the Association of American Geographers*, 98(1), 59–84.
- Wheeler, J., Aoyama, Y., & Warf, B. (Eds.). (2000). *Cities in the telecommunications age: The fracturing of geographies*. New York: Routledge.
- Zook, M. (2005). *The geography of the Internet industry*. Malden, MA: Blackwell.



COMMUNISM AND GEOGRAPHY

Communism, the political and economic regime characterized by a command economy and single-party rule dominated by the members of the Communist Party, wrought significant effects on the cultural, urban, economic, and physical geography of communist-ruled states in both Europe and Asia. While there are differences between the way communist goals were pursued in the Soviet Union after World War I and in Eastern Europe and Asia in the second half of the 20th century, there are a number of commonalities. Because of the control exercised by the Party, communist countries were able to be single-minded in their pursuit of goals, as exemplified by the proliferation of Five Year Plans, especially in the areas of industrialization, agricultural restructuring, and urban morphology.

Industrialization

One of the most striking aspects of communist rule, especially in the Soviet Union and Eastern Europe, was the implementation of quick and massive industrialization. While there had been some industrial development in Russia and

Eastern Europe prior to World War II, notably in Poland and Czechoslovakia, Stalin implemented an aggressive program of rapid industrialization to raise the USSR to the level of the advanced capitalist countries within 10 years with specific focus on heavy industry and defense. Estimates of the annual growth in industrial production during the first two Five Year Plans (1928–1937) range from 10.5% to 18%, with dramatic increases in power production, blast furnace capacity, steel production, capital stocks, and factories. After World War II, industry remained a priority, with the development of industrial complexes, especially east of the Ural Mountains and in Central Asia. These sites, such as the one in Ust Ilimsk, featured natural resource extraction, huge factories, and large cities built often ex nihilo. Rapid industrialization was also undertaken in the satellite states so that former agricultural countries such as Hungary and Poland witnessed the development of industrial centers where once there were only small towns.

In China, the government also undertook nationalization and rapid industrialization once communist control was established in 1949. During the 1950s, China increased production in the industrial sector with annual growth rates of 8% to 10%, though small-scale rural industrialization also received special attention. During the Great Leap Forward (1958–1961), for example, “backyard furnaces” were developed to smelt scrap iron, though this proved to be untenable. This period of experimentation resulted in reverses in industrial growth and negative effects on agricultural production as a result of the diversion of labor. However, the groundwork for more successful small-scale and rural development was laid, and the 1960s and 1970s witnessed the creation of rural factories and widespread electrification through hydroelectric power production. The controversial building of the Three Gorges Dam is the latest chapter in providing power for the country.

Collectivization

Communist states also pursued collectivization, effectively nationalizing agriculture into large



cooperatives. In the USSR, Stalin implemented an ambitious program with two aims: to destroy the power of the kulaks (wealthy landowning peasants) and to increase yields to provide food for the growing urban workforce. The number of agricultural workers declined from 72 million in the mid 1920s to between 48 million and 53 million in 1939. Both state farms and collective farms existed, and strict production quotas were imposed. Peasants were allowed individual garden plots, which, because of their high productivity, were an important piece of the Soviet agricultural picture. The results of collectivization, especially during the first Five Year Plan and again in the period after World War II, were less than successful. While production of cotton and potatoes increased, livestock numbers dropped precipitously, and large-scale famines occurred in grain-producing areas such as the Ukraine in the early 1930s and again in the 1950s. Despite this, agricultural growth was on par with that in the rest of the world throughout the 1960s and 1970s. In the Soviet satellite states, collectivization was also imposed with varying degrees of intensity.

China in the early 1950s undertook gradual collectivization, introducing cooperative use of tools and then the grouping of land purchased from peasants, with initially positive impacts on grain production. During the Great Leap Forward, collectivization was pushed forward with the aim of organizing social life in the countryside. Large-scale communes consisting of up to 5,000 families were created, and private plots were abolished. In some places, family life was severely controlled with the establishment of single-sex dormitories and children's nurseries. Dissatisfaction, combined with weather-induced poor harvests and subsequent mass famines with estimates of 17 million to 30 million dead, led to a return to the more successful cooperative model by the 1960s. North Korean collectivization also followed the commune model, organizing production as well as nonfarm services such as education and health care. In the 1990s, North Korea was plagued by widespread famine, resulting in death, chronic malnutrition, and political defection. In Vietnam, collectivization was undertaken in the North with allocations for a small percentage of collective land to be held privately. After

1975, attempts were made to collectivize South Vietnam, with little progress, and the effort was eventually abandoned.

Communist Cities

Communist rule brought changes to urban morphology—namely, in the areas of housing, architectural style, and public space. While urbanization was actively pursued in Europe, in China urbanization was more controlled, resulting in special emphasis on the development of rural areas and distinct periods of counterurbanization (e.g., the Cultural Revolution in 1966–1969). Cambodia under the Khmer Rouge (1975–1979) presents an extreme example of counterurbanization.

Architecture, Ideology, and Public Space

In the period immediately following the Russian Revolution, architecture was viewed as an ally in achieving utopian goals; modernism and the Russian avant-garde were embraced throughout the 1920s. However, formalism came under suspicion in the 1930s and was abandoned in favor of the neoclassical forms of socialist realism. Characterized by buildings on a monumental scale and the use of classical columns and sculptural elements and reliefs featuring the proletariat, socialist realism predominated in the USSR and the Eastern Bloc from the 1930s through the mid 1950s. Eastern Bloc architecture has since been characterized by modernist industrial building techniques represented by the bloc flat.

Public space in communist countries was uniquely marked. Streets, squares, and cities were viewed as potent canvases on which to project socialist ideology, resulting in the wholesale renaming of places after the heroes (e.g., Lenin, Ho Chi Minh), the martyrs (e.g., the Rosenbergs), and the ideals (e.g., people's republics) of the movement. Cities and towns were inscribed with posters and monuments conveying didactic messages about the regime, depicting the heroic proletariat and women as mothers and workers and propagating the "cult of personality." Notable was the scale of public monuments, such as the Ernst Thälmann monument in Berlin (which was



May 1, 1987: In Moscow, a banner showing Friedrich Engels (*center*), Vladimir Lenin (*right*), and Karl Marx (*left*) hangs over Red Square crowd during May Day celebrations.

Source: Time & Life Pictures/Getty Images.

13 m [meters] high), the 25-m-high Stalin statue in Budapest, and the 170-m-high Juche Tower in Pyongyang. Boulevards and squares were crafted or coopted as sites of state-sponsored events, for example, the May Day parades featuring military hardware, workers, and youth (see photo). Building types specific to communist cities also marked the landscape, including trade union headquarters, so-called people's palaces, pioneer camps, and culture houses, which were found in cities and small villages and offered programs such as folk dancing and youth activities in support of the ideological goals of the regime.

Housing

In Europe, the concomitant urbanization that resulted from rapid industrialization, coupled with the wartime destruction of cities, meant

that housing presented an ongoing challenge to communist states. In the aftermath of the Russian revolution and later after World War II, private property was confiscated, and large villas and apartments were split into smaller units. Industrial techniques including the production of ferroconcrete slabs were enlisted in the 1950s to alleviate the ongoing housing shortages, resulting in the construction of multistory housing estates, which are a characteristic feature of socialist cities. Known in Russian as *microraion*, these estates were organized to house hundreds of thousands of people. As they were often built on the urban fringes, they were linked to efficient mass transportation and provided on-site services such as nurseries, shops, cultural centers, and parks.

Michelle Marie Metro-Roland



See also **Chernobyl Nuclear Accident; Cold War, Geography of; Commonwealth of Independent States; Geopolitics; Marxism, Geography and; Political Geography; Russian Geographical Society; Socialism and Geography**

Further Readings

- Bailey, P. (2001). *China in the twentieth century* (2nd ed.). Malden, MA: Blackwell.
- Crowley, D., & Reid, S. (Eds.). (2002). *Socialist spaces: Sites of everyday life in the Eastern Bloc*. Oxford, UK: Berg.
- Fuchs, R., & Demko, G. (1979). Geographic inequality under socialism. *Annals of the Association of American Geographers*, 69, 304–318.
- Hosking, G. (1992). *A history of the Soviet Union, 1917–1991*. London: Fontana Press.
- Shvidkovsky, D. (2007). The Soviet and Post-Soviet eras. In D. Shvidkovsky (Ed.) & A. Wood (Trans.), *Russian architecture and the West* (pp. 357–385). New Haven, CT: Yale University Press.



COMMUNITY-BASED CONSERVATION

Community-based conservation is one term of many describing the direct involvement of local people and organizations in decisions and activities associated with locally based environmental management. Its introduction marks a shift that includes humans in ecosystems and a shift from management by experts toward management that includes local perspectives and interests. Other related concepts include comanagement, ecosystem management, civic science, grassroots environmental management, and public ecology. Its rationale is rooted in the subsidiary principle that decisions should be taken at the level closest to where effects are most likely to be felt. This implies that the people most affected should have a direct influence on the decisions that are taken. Proponents of community-based conservation typically also promote ecosystem management, a

management approach that attempts to consider the environment holistically and explicitly works to restore and sustain healthy ecosystems, including their multiple functions and values.

Many benefits have been attributed to community-based conservation. Governments and private proponents may find that they can be more efficient in the long term if their plans are locally discussed prior to implementation and they involve local people directly in management efforts. Others have suggested that community-based conservation may also democratize scientific knowledge by linking experts and stakeholders in planning social, economic, and environmental improvements.

Furthermore, it has been suggested that by working together, people can accomplish more than as individuals or as organizations working in isolation. Additionally, involving those affected will provide for a broader range of values and inputs into the decision-making process. Local people may have specific knowledge about their local environment that can help tailor conservation to local conditions. Involving local people may increase the likelihood that decisions and practices are accepted locally, while encouraging compliance through peer pressure and by setting good examples locally. Involvement of local people in community-based conservation activities may also help build and enhance local skills, interests, and capacities that will continue to serve these communities in other areas. Finally, community-based organizations may be more nimble than larger institutions and so may be able to harness opportunities within smaller areas efficiently and effectively.

Activities associated with community-based conservation are wide-ranging. They may include undertaking environmental cleanups, bird counts, or habitat restorations that may or may not involve ongoing commitments. They may involve activities that supplement government functions related to environmental conservation, including public education, monitoring, and construction of facilities. They may model environmentally friendly behaviors such as conducting creative experiments or establishing land protection programs. Increasingly, the term also refers to activities that involve partnerships among government, private sector, and citizen organizations where



Cheryl Whalen, Natural Resources Conservation Service, discusses the landscaping plan for a community garden in the Echo Park area of Los Angeles, California.

Source: Bob Nichols, USDA Natural Resources Conservation Service.

groups share information, labor, money, and even decision-making authority, including advisory or comanagement committees.

Evaluating the success of community-based conservation is challenging. Many assessors focus on procedures whereby criteria such as holding a broadly shared vision or establishing an open, accessible, and transparent decision-making process are important. Others suggest that both socioeconomic and procedural outcomes must be addressed. Criteria focused on outcomes might assess changes in employment, reductions in expenditures, or improvements in habitat conditions or water quality. The challenge, however, lies not only in determining appropriate criteria and acquiring supporting data but also in being able to attribute

ecological or social changes to specific conservation activities.

Notwithstanding possible benefits, several concerns have also been raised about the efficacy and appropriateness of community-based conservation. First, there is concern that promoting active citizenship at the community level encourages governments to abrogate their responsibilities, so that tasks once delivered by the welfare state are taken up by the local community. Paradoxically, communities may find themselves disempowered if resources once provided by central levels of government are reduced while expectations of what communities can achieve locally mount. Second, community-based conservation requires legitimacy both locally and extralocally so that participants will have an incentive to contribute.



However, concerns expressed by scientists and industry and government representatives frequently revolve around whether local residents have the capacity or the expertise to engage in conservation efforts, thus reducing the incentive for local residents to take part. Third, questions are also raised about how local people are selected and to what degree local individuals may be representative of the diversity of interests at the community level. Local elites may use the rhetoric of fairness and equity to mask the pursuit of self-interest and entrenchment of power at the local level. Local communities are not necessarily more democratic than centralized authorities as power relations within communities may exclude some social groups, stifle debate, and/or generate a form of paternalism that is locally generated.

These concerns also raise issues about the uneven capacity of communities to maintain or restore healthy ecosystems, local livelihoods, and associated sociocultural values. Due to differences in circumstances, such as the economic base, natural resource endowments, proximity to urban locations, and demographic characteristics, some communities may have a relative advantage over others in providing environmental services. Furthermore, local groups may vary in the strength of their internal structure, the ability to obtain funding, their willingness to take risks, and their effectiveness in networking with other organizations and agencies. Thus, by emphasizing local programs, geared to local ecological and social conditions, community-based conservation may contribute to highly differentiated application of conservation practices.

These concerns have now given way to understanding that no level of governance—community or nation-state—can manage ecosystems for conservation in isolation from other levels. Instead, community-based conservation now also focuses on ways to ensure that decision-making processes are legitimate, accountable, and inclusive of multiple stakeholders and interests. To meet these conditions, all the actors in conservation should establish strong linkages across spatial and temporal scales, and authority should be spread across multiple institutions to sustain and improve conservation practices.

Maureen G. Reed

See also **Community-Based Environmental Planning; Community-Based Natural Resource Management; Indigenous Environmental Knowledge**

Further Readings

- Berkes, F. (2004). Rethinking community-based conservation. *Conservation Biology*, 18, 621–630.
- Cortner, H., & Moote, M. (1999). *The politics of ecosystem management*. Washington, DC: Island Press.



COMMUNITY-BASED ENVIRONMENTAL PLANNING

Community-based environmental planning (CBEP) emerged in the 1990s as a result of concerns over the state-directed or top-down character of environmental planning. CBEP can be defined as decentralized environmental planning conducted by place-based communities at the local scale. It has a number of perceived advantages of interest to geographical inquiry, including promoting deliberation about environmental concerns and potentially higher local acceptance of the legitimacy of a given planning process, leading to effective implementation of planning outcomes. However, these prospective advantages are not always realized, suggesting that the application of CBEP is limited to particular settings.

Conceptual Ancestry and Rationale

Underpinning CBEP is a strong focus on place-based environmental management. It therefore directs attention to the unique constellation of characteristics that constitute a given environment that provides the problem context for planning. In some cases, this has also been interpreted as prioritizing local residents and local knowledge in a given situation. However, in other cases, particularly in remote locations, nonresidents with



particular knowledge or social connections to places have also been given strong recognition in planning processes.

Another important aspect of the ancestry of CBEP is the well-chronicled failings of the so-called top-down, or rational-comprehensive approach to planning, which, it has been argued, is insensitive to the particularities of locality and, thus, poorly adapted to human and ecological diversity across landscapes. In addition, top-down planning has been deemed authoritarian, implementing its prescriptions with insufficient sensitivity to and regard for local values and interests. These problems, as J. C. Scott has powerfully argued in *Seeing Like a State*, result in the failure of top-down planning to understand and use local, *indigenous* knowledge, which is crucial to designing and implementing effective interventions.

Advantages

Both the scholarly literature and practice in diverse circumstances across the world provide evidence that CBEP has a number of advantages. First, CBEP is more sensitive to the local characteristics of a given environmental problem. Essentially, place-based communities are thought to be more intimately familiar with environmental problems and solutions and can incorporate local knowledge to better inform the planning process, which in turn increases awareness of environmental issues.

Second, the planning outcomes that result from CBEP enjoy higher levels of legitimacy because they involve local residents and interested parties and promote “ownership” of problems. A common limitation of state-directed environmental planning has been a lack of legitimacy, which has hindered acceptance of planning outcomes. This is, indeed, part of the *raison d’être* of CBEP: By facilitating the participation of local, place-based actors, CBEP has the potential to avoid community resistance to plan implementation. As a result, CBEP has been seen as a more effective and more efficient mode of planning.

A further advantage of CBEP concerns the fundamental role of community participation in plan development. Relating to Jürgen Habermas’s

concept of communicative action, citizen involvement in planning processes is perceived to have a democratic benefit in its own right. This benefit stems from the importance of deliberation in the form of questioning, rationalizing, and comparing different perspectives in the planning process. On this basis, even if the planning outcome was identical to a state-dominated process, the social learning that occurs in developing an environmental plan has intrinsic value and is central to a healthy democratic process.

Problematic Aspects

There are, perhaps inevitably, some problematic aspects to CBEP. The first of these relates to the character, role, and functionality of “community.” Common conceptions of community imply a homogeneous, spatially fixed social group that shares a consciousness of being a “community” and that is characterized by social consensus and solidarity. Such a view has been subject to critique, particularly by those concerned with understanding how “difference”—gender, ethnicity, class, age, and other forms of social identity—divide so-called communities. Second, empirical reports of the practice of CBEP suggest that this mode of planning has tended to empower powerful and articulate actors and marginalize others. These reports directly undermine one of the perceived advantages of CBEP—its democratic effects.

A third problem with CBEP relates to the *capacity* of communities to plan and implement strategies for the management of environmental assets and problems—given the technical complexity, time frames, and scales at which some environmental problems are manifest. Fourth, one of the promises of CBEP is to enable the integration of local, experiential (indigenous) knowledge with scientific knowledge. Questions have been raised as to whether community-based approaches can harness indigenous knowledge while retaining technical fidelity in their response to environmental problems. Others have questioned whether different and competing knowledges can be reconciled in a single planning process.

Finally, CBEP has been criticized for being maladapted to the scale of contemporary environmental issues. There are multiple issues here,



including the following: the potential for parochial thinking to dominate, the possibility that strategies that seem appropriate at local scales can have harmful effects at wider scales, and the possibility that environmental planning is focused on the symptoms rather than the drivers of environmental problems.

Potential Applications

These complications suggest that CBEP cannot be universally applied; its utility is limited to particular circumstances. The first is when the “community” involved has established a degree of cohesion, a shared history, and mechanisms for resolving differences. The second is when CBEP receives institutional support from the wider governance system, including adequate resources to facilitate deliberation. Finally, CBEP is more likely to work at smaller spatial scales and when there are finite and discrete planning concerns to be addressed.

Thomas G. Measham and Marcus B. Lane

See also **Community-Based Conservation; Community-Based Natural Resource Management; Community Forestry; Environmental Planning; Participatory Planning**

Further Readings

- Agrawal, A., & Gibson, C. C. (1999). Enchantment and disenchantment: The role of community in natural resource conservation. *World Development*, 27(4), 629–649.
- Kapoor, I. (2001). Towards participatory environmental management? *Journal of Environmental Management*, 63(3), 269–279.
- Lane, M. B., & McDonald, G. T. (2005). Community-based environmental planning: Operational dilemmas, planning principles and possible remedies. *Journal of Environmental Planning and Management*, 48(5), 709–731.
- Scott, J. C. (1998). *Seeing like a state: How certain schemes to improve the human condition have failed*. New Haven, CT: Yale University Press.



COMMUNITY-BASED NATURAL RESOURCE MANAGEMENT

Community-based natural resource management (CBNRM) has been characterized as both a practice, the management of local resources by a geographically limited community, and a process, the shifting or devolution of power and authority from bureaucrats working within national or state governments to more local and often indigenous institutions and peoples. Though theoretically feasible for any number of natural resources, in practice, community-based management has been almost exclusively limited to flow resources such as forests, fish, and game, which, as common property, have tended to suffer from overexploitation. CBNRM has received increasing attention of late in geography and related disciplines, which likely stems from the fact that it stands in marked contrast to the still dominant distant-centered model of resource management used throughout the world and is perceived as superior to it, especially with respect to ensuring long-term resource sustainability.

CBNRM as a Practice

In practice, CBNRM is probably best recognized in innumerable community forests that exist throughout the world, some of which, as with Italy's Magnifica Comunita di Fiemme, have existed for many centuries. Fish and game have also commonly been subject to community scale management, as exemplified by Zimbabwe's Communal Areas Management Programme for Indigenous Resources (CAMPFIRE), through which small-scale rural district councils manage lucrative sport hunting of elephant and other wildlife and the harvest of lesser local resources such as crocodile eggs, timber, and river sand. The defining feature of these and other cases of CBNRM is that local landholders own, or at least gain access and use rights to, valued local resources, which they manage in their interests. This feature makes CBNRM distinct from comanagement (whereby communities share authority with governments), citizen-based environmental



management (whereby governments manage resources based on citizen input or, as in the case of California's "Ballot Box Planning" approach, voter dictates), and even civic environmentalism (whereby community groups assume responsibility for the cleanup of local environmental problems).

Beyond this core criterion of ownership or access rights, reviewers have regularly identified, or at least promoted, several other defining characteristics of CBNRM, such as the use of participatory models of decision making within the community; the promotion of social equity and justice, especially for traditionally disadvantaged community members; the inclusion of traditional knowledge and values in the management of community resources; and the reconciling of the typically antithetical objectives of economic development and resource conservation.

Unfortunately, real-world cases of CBNRM have often been challenged to achieve these laudable goals, and indeed, many have never sought to. Research on community forestry as practiced around the world offers insight. While not capturing all instances, reviewers have come to identify three distinct forms:

1. Community forestry as ecological forestry, whereby managers seek to halt deforestation and improve ecological conditions
2. Community forestry as social forestry, whereby timber and nontimber resources are promoted as a basis for improved subsistence or modest commercial enterprise among poorer strata
3. Community forestry as essentially small-scale industrial forestry, whereby the unapologetic avowed goal is economic gain

In other words, CBNRM is commonly characterized in geographic and other disciplinary scholarship in idealized terms that may not match its real-world practice.

CBNRM as a Process

For many reviewers, the significant aspect of CBNRM is not the practice of resource management by communities but rather the process by which these communities come to secure management authority over local resources. This

focus of interest reflects not only the phenomenon's still nascent status but also the considerable challenge to devolve power fully from distant-centered bureaucrats to community institutions in many parts of the world. Indeed, even well-known cases of CBNRM often reflect incomplete forms of devolution. In the case of CAMPFIRE, for example, the Central Zimbabwean government must approve the proposed harvesting rates. The same is true for British Columbia's (Canada) many community forests, which must negotiate with provincial officials to establish their annual allowable cut.

Though incomplete in too many instances, devolution continues to be promoted around the world for a variety of related reasons. For example, in countries and subregions where colonialism resulted in the expropriation of traditional landowners' resource use rights, CBNRM has been advanced as a necessary step to redress past injustices. These cases challenge the view of CBNRM as a novel phenomenon, so asserted Stephen Kellert and colleagues in a 2000 study; rather than being new, the authors argued, CBNRM can be viewed as a modern attempt to revive traditional, cultural, and institutional mechanisms for managing and *conserving* natural resources. This latter aspect, the expectation that resources will be better conserved, constitutes another key driver of devolution. In these same colonial contexts, observations of overexploitation of formerly closed- but now open-access resources eventually led governments to impose Western-style regulatory systems (based on external rules and enforcement) in an attempt to stop this tragic outcome. Given the limited success of these systems, not just in former colonial contexts but also in places such as Canada's east coast, where cod stocks were harvested to exhaustion in the 1980s, CBNRM has been promoted as a practical means of addressing the problem of common resource overexploitation.

CBNRM as Sustainable Management?

It is not enough for advocates of CBNRM to simply discredit the capacity of central governments to sustainably manage flow resources that are harvested by multiple resource users, typically at great distances from the place of management;



they must also identify the basis for expecting that CBNRM can do better. Fortunately for them, there is ample logic and considerable evidence that supports this expectation. Drawing on the widely embraced principles of adaptive harvest management, which calls on managers of flow resources, such as a fishery, to be prepared to alter a management decision if it is later found to be ill conceived, CBNRM advocates contend that this is only achievable, or at least best achieved, if the manager is there, on site, to see how a system responds to a management action. While it may be reasonable to accept that community-scale managers can respond faster with site-specific solutions than can distant managers, what ensures that they will want to do so, especially if the solution entails reducing the community's harvest? To address this concern, CBNRM advocates commonly invoke two arguments. The first, which Bonnie McCay and Svein Jentoff labeled *the feed-back effect* in a 1996 study, posits that local management, unlike distance-centered management, directly subjects decision makers to the repercussions of their decisions and thereby promotes more conservative decisions. The second, which Robert Paehlke labeled the *bioregionalist promise* in a 2001 study, posits that communities of people who have lived in a particular place for generations and thereby gained a "sense of place and belonging" are expected to not only have superior local ecological knowledge but, more important, a vested interest in ensuring the survival of that place.

Innumerable historic and present-day cases of CBNRM support this logic; however, there are other cases that challenge it. Based on emergent research in geography and related disciplines, the determinants of "successful" CBNRM, whether it be defined in economic, social, or environmental terms, are gradually being revealed. In the case of environmentally oriented CBNRM, it is increasingly becoming clear that if communities can secure sufficient ownership and authority over a local resource such that resource users benefit from its sound management, especially in financial terms, stewardship of the resource will likely follow. This likelihood has afforded CBNRM increasing attention and promotion.

Ben Bradshaw

See also Adaptive Harvest Management; Common Property Resource Management; Community-Based Conservation; Community Forestry; Environmental Management; Indigenous Environmental Practices; Indigenous Forestry; Sustainable Forestry

Further Readings

- Bradshaw, B. (2003). Questioning the credibility and capacity of community-based resource management. *The Canadian Geographer*, 47, 137–150.
- Egan, B., Ambus, L., Evans, B., Boyd, D., Spak, S., Tyler, S., et al. (2001). *Models of community-based natural resource management*. Victoria, British Columbia, Canada: EcoResearch Chair of Environmental Law and Policy, University of Victoria.
- Kellert, S. R., Mehta, J. N., Ebbin, S. A., & Lichtenfeld, L. L. (2000). Community natural resource management: Promise, rhetoric, and reality. *Society & Natural Resources*, 13, 705–715.
- McCay, B. J., & Jentoff, S. (1996). From the bottom up: Participatory issues in fisheries management. *Society & Natural Resources*, 9, 237–250.
- Paehlke, R. C. (2001). Spatial proportionality: Right-sizing environmental decision-making. In E. A. Parson (Ed.), *Governing the environment: Persistent challenges, uncertain innovations* (pp. 73–123). Toronto, Ontario, Canada: University of Toronto Press.
- Pagdee, A., Kim, Y. S., & Daugherty, P. J. (2006). What makes community forest management successful: A meta-study from community forest throughout the world. *Society & Natural Resources*, 19, 33–52.



COMMUNITY FORESTRY

Community forestry is collective management of forests by local residents, often in collaboration with diverse interests that have competing claims on forest resources, to enhance community well-being and improve forest health. It entails reconfiguring relationships between communities, the



state, and other groups that claim rights to ownership and the benefits of forest management. The goal is to rectify the negative environmental and social impacts of industrial-scale forestry, which has often had significant backing from the state. Although community forestry is intended to build the capacity of communities to steward natural resources and have a voice in their own affairs, it faces challenges in enabling broad and meaningful participation, defining community, and sustainable forest management.

Participation and Building Community Capacities

Colonial administration of forestlands in developing countries led to the breakdown of traditional local natural resource management institutions, degradation of forest ecosystems, and impoverishment of local peoples. While conservation and poverty alleviation programs were implemented after independence from colonial rule in the 1950s and 1960s, by the 1970s, it was clear that they were failing. Professional foresters, conservationists, and development practitioners began questioning state control of forestlands. They advocated reorienting forestry to management for multiple forest values, and to ensure that this new management benefited local peoples, they called for participation by community members in defining how forests should be understood and managed. A decade later, similar reasoning was applied in the United States, where communities experience limited access to forest resources, restricted opportunities for participation in forest decision making, and, at that time, heightened conflict over logging and endangered species protection. In hundreds of communities across the United States, local residents, scholars, and land management professionals have come together seeking innovative ways to collaborate on forest management.

Community members often need new skills to navigate the current global political economy, and capacity building is a central component of community forestry. Nicholas Menzies observes that community members need capacities in five areas: (1) building local institutions for setting priorities and mediating conflicts, (2) representing their interests in wider social and political

arenas, (3) managing resources sustainably, (4) participating as informed actors in markets, and (5) building community assets with benefits derived from managing the resource.

Building local capacities requires working with community members as equal partners and reshaping relationships of power so that local people are positioned to make decisions about policy formulation and implementation. Participatory research developed hand in hand with community forestry as a means of increasing community capacities. When done well, it facilitates mutual learning among professionals and community members in ways that can, under the right conditions, enhance community members' ability to apply research results to improve their situation. Yet people in positions of authority—whether local, regional, or national—are often reluctant to relinquish power. Communities, state agencies, and other interested parties worldwide struggle to negotiate the equitable distribution of rights, powers, and responsibilities.

Because of unique combinations of historical, economic, political, social, cultural, and environmental factors, these negotiations lead to unique tenure and sociopolitical arrangements in every place. Some examples of the multiple forms of community forestry include joint forest management in India, in which state forest agencies and local communities share rights and responsibilities for forest management; communal ownership of land in Guatemala; and collaboration among government agencies, community groups, environmental organizations, and lumber companies on the management of U.S. public lands. Whatever the case, the central concerns common to all community forestry efforts are clearly defining rights of access to forest resources, specifying protocols for participation in decision making, and enforcing rules to ensure that forest use is sustainable so that it is economically efficient, socially equitable, and environmentally sound. To community members, this often means working to maintain a particular way of life.

Central Issues in Community Forestry

Many difficult issues arise in establishing rights and protocols. A major issue is the enabling of participation itself. The institutionalization of



participatory development and research as embodied by requirements for local participation in development projects sponsored by international development organizations, for example, the World Bank, has led some scholars to describe participation as a “new tyranny.” They are concerned about participation being done only to fulfill a requirement of the sponsoring agency or because it is fashionable. Under such circumstances, community members are not given real power to influence forest management or economic development, and participation becomes nothing more than an empty promise.

But an empty promise for whom? Just who is “the community” in the first place? “Community” defies definition because people associate with one another in many different ways and for many reasons. There are diverse interests within communities that may conflict, just as national and local interests often do. How a community is conceived accords strategic political advantages to some groups while effectively excluding others. Racial and ethnic minorities, women, workers, and other marginalized groups find that their interests are often not well represented or addressed by community forestry.

Even when a broadly inclusive participatory process is achieved, a question remains as to what extent communities can manage their resources sustainably. While local communities may be good land managers when ecological, economic, and social factors are favorably aligned, community forestry is no guarantee of high-quality environmental stewardship.

Evidence suggests that secure rights to access forest resources and participate in decision making as well as strong local-level resource management institutions are necessary but insufficient to help communities halt environmental degradation and improve the well-being of their members. The challenge lies in delineating rights and responsibilities among the many different interests involved in each case and creating conditions conducive to making choices about the use and management of forests that are equitable, environmentally sound, and adaptable to changing economic, social, political, and environmental conditions.

Carl Wilmsen

See also **Common Property Resource Management; Community-Based Natural Resource Management; Participatory Rural Appraisal; Political Ecology; Social Forestry**

Further Readings

- Baker, M., & Kusel, J. (2003). *Community forestry in the United States*. Washington, DC: Island Press.
- Menzies, N. K. (2007). *Our forest, your ecosystem, their timber*. New York: Columbia University Press.
- Tyler, S. R. (Ed.). (2006). *Communities, livelihoods and natural resources*. Ottawa, Ontario, Canada: International Development Research Centre.
- Wilmsen, C., Elmendorf, W., Fisher, L., Ross, J., Sarathy, B., & Wells, G. (Eds.). (2008). *Partnerships for empowerment*. London: Earthscan.



COMMUTING

The term *commute* has become shorthand for traveling some distance between one's home and place of work on a regular basis. The term *commuting* is derived from *commutation ticket*, the U.S. term for a season ticket because the daily fare is commuted to a single payment. Commuting clearly implies the routine and repeated nature of a work-related journey. Hence, commuters are defined as those who travel to work (sometimes also to school) by mainly motorized transportation (private car or public transport), and non-commuters are those who work at home or walk or cycle to work.

Policymakers and researchers are very interested in collecting statistics on commuting behavior and studying commuting patterns and trends in and around metropolitan areas. The primary objective is to better understand the variations in commuting distances and times, modal usage and choices, and trip planning and chaining behavior among different groups. Usually, a multidimensional approach is followed, whereby economic, social, health-related, and spatial aspects come to the fore.



The main factor behind the increased demand for mobility in general and commuting in particular has been the geographical dispersion of economic activities, which in turn resulted from the effect of motorization and the related substantial increase in the use of the private car. It is true that most people have become more mobile and foot-loose and experience greater locational freedom, which in turn has led, in many modern, industrialized societies, to a clear trend of moving away from traditional older urban centers in favor of suburban and rural locations. The result is urban sprawl and suburban development. This separation of the place of work and the place of residence has led to a substantial increase in commuting distance and time. Other noticeable trends that also have an impact on commuting are the increasing number of households in which at least two family members work at distinct locations other than the place of residence, the increase in the number of solo drivers (the so-called single-occupant vehicles, or SOVs), and a higher average disposable income, resulting in a higher number of car owners.

Studies in both the United Kingdom and the United States have shown that the average one-way travel time for a commuter in 2000 was about 25 min. (minutes), which represented a 3-min. increase in travel time over the average in 1990. This increase in commuting distances and times, leading to longer peak hours, also brought into the open the issue of long-distance commuting and excess commuting. In general, long-distance or extreme commuting occurs when a daily journey to work takes more than 90 min. each way, and this phenomenon has contributed to what economists term the *commuting paradox*. The commuting paradox refers to the fact that people usually overestimate the value of the things they will obtain by commuting (e.g., an intrinsically or financially more rewarding job, additional welfare gained from a pleasant living environment, more material goods, lower rents for housing, and more prestige) and underestimate the benefit of what they are losing: social connections, hobbies, and/or health. One extreme was noted in 2006, when America's Longest Commute award was given to a person who drove 372 miles (or about 4½ hours) roundtrip to and from work each day. Excess commuting,

on the other hand, is defined as the additional journey-to-work travel represented by the difference between the average actual commute and the optimum (or minimum) possible average commute, given the spatial configuration of workplace and residential sites. This concept is interesting because it relates to the issue of defining and modeling what could be termed an ideal commute time and a relative desired commute amount. Obviously, a single answer is not possible here because of the huge heterogeneity in commuting behavior.

It is universally assumed that commuting (and by extension all travel) is considered a source of disutility—a burden or a hassle—given the conventional derived-demand justification for travel. In other words, commuting always has “its price,” and people seek to minimize its cost, subject to a number of constraints. This cost is the monetary cost of congestion and journey delay, calculated on the basis that time spent traveling is assumed to be nonproductive and wasteful to the economy. In economic terms, this translates time into a monetary value (i.e., the principle of value of time, or VOT) using the average wage of the commuter. There are also additional, unpredictable costs due to the unreliability of travel time, and of course, there is the (generalized and out-of-pocket) cost of travel itself. Studies in the United States have indicated that a typical household spends nearly 20% of its income on driving costs, which is more than it spends on food. Besides these private costs, there are the social costs of commuting, due to congestion, noise, and pollution of the environment.

Commuting not only takes time and generates costs but also has important physiological and psychological impacts. For one, there is the physical and mental burden of stress, health risks, fatigue, and combining work with family life linked with the nature of the trip to work. Delays caused by traffic volume (congestion), accidents, or bad weather conditions; the driving behavior of other road users (for car users); the unreliability and the lack of frequency of public transport services; the negative effects of crowding or unforeseen strikes (for public transport users); and the imbalance between work and family (especially when children are involved, who need to be dropped off, picked up, and cared for), all



contribute to increased travel stress levels. Moreover, when there is less control over these factors, commuting becomes more stressful. The results are well-known: high blood pressure, stiff neck, tiredness, self-reported tension, aggression, negative moods, increased sense of frustration, more frequent illness, reduced task performance, work absences, less job stability, and overall lower life satisfaction. Note that all aspects typical of less commuter-dependent jobs (such as jobs with flexible working schedules, part-time work, teleworking, and jobs closer to the home location) have a strong stress-reducing impact.

Having considered the negative impacts of commuting, it can also be a source of a positive utility. Commuting time is thus conceived as a gift rather than a burden. Depending on the transport mode used, scholars argue that there are opportunities for social and professional interaction and opportunities to experience the pleasures of the surrounding landscape or the social environment through gazing out of the window or watching other people, respectively. Longer commuting times also allow one to listen to music or the radio, to read, to relax, or to use the time more productively (e.g., work or study while traveling). With respect to the latter, the increased use of information and communication techniques (e.g., mobile phones, laptops, iPods, and Bluetooth technology) adds to the concept of new forms of copresence—that is, people are no longer restricted to connecting place to place but can now connect person to person. Sometimes commuting time is also experienced as “time out”—that is, time for being alone, time for doing nothing, or time to reinvest in maintaining social networks.

Apart from the economic, social, and health issues, there are also the spatial effects of the interaction of land use or urban form (characterized by density, diversity, design, and accessibility) on commuting behavior. For instance, a change in the location of the activities in which a person wants to participate and a change in the design characteristics of these locations will alter travel patterns. Therefore, integrating land use and transportation policy could alleviate transportation problems. Illustrative of this approach are the New Urbanism movement in the United States and the Compact City or Polycentricity Policy in Europe. These policies aim at modifying

travel behavior (i.e., reducing average journey distances, trip frequencies, traffic volumes, energy consumption, and/or transport emissions) through land use planning. The basic idea is that high-density and mixed-use neighborhoods are believed to be associated with shorter trips and more non-motorized trips, hence less commuting.

Frank Witlox

See also [Automobility](#); [Exurbs](#); [Mobility](#); [Suburbs and Suburbanization](#); [Transportation Geography](#); [Urban Land Use](#); [Urban Sprawl](#)

Further Readings

- Jain, J., & Lyons, G. (2008). The gift of travel time. *Journal of Transport Geography*, 16(2), 81–89.
- Lyons, G., & Chatterjee, K. (2008). A human perspective on the daily commute: Costs, benefits and trade-offs. *Transport Reviews*, 28(2), 181–198.
- Ma, K.-R., & Banister, D. (2006). Excess commuting: A critical review. *Transport Reviews*, 26(6), 749–767.
- Mokhtarian, P., & Salomon, I. (2001). How derived is the demand for travel? Some conceptual and measurement considerations. *Transportation Research A*, 35(8), 695–719.
- Pisarski, A. (2006). *Commuting in America III: The third national report on commuting patterns and trends*. Washington, DC: Transportation Research Board.
- Redmond, L., & Mokhtarian, P. (2001). The positive utility of the commute: Modeling ideal commute time and relative desired commute amount. *Transportation*, 28(2), 179–205.
- Schwanen, T. (2002). Urban form and commuting behaviour: A cross-European perspective. *Tijdschrift voor Economische en Sociale Geografie*, 93(3), 336–343.
- Sheller, M., & Urry, J. (2006). The new mobilities paradigm. *Environment and Planning A*, 38(2), 207–226.
- Wener, R., Evans, G., Phillips, D., & Nadler, N. (2003). Running for the 7:45: The effects of public transit improvements on commuter stress. *Transportation*, 30(2), 203–220.



COMPARATIVE ADVANTAGE

As the capitalist world economy unfolded, different regions increasingly came to specialize in the production of different types of goods and services. In Europe during (and often before) the Industrial Revolution, for example, Britain became a major producer of textiles, ships, and iron; France produced silks and wine; Spain, Portugal, and Greece generated citrus, wine, and olive oil; Germany, by the end of the 19th century, was a major exporter of steel, ships, and chemicals; Czechs were selling glass and linens; Scandinavia sold furs and timber; and Iceland exported cod to the growing middle classes. Within the United States, similarly, different places acquired advantages in some goods and not in others: The northeast was dominated by light industry, particularly textiles; the Manufacturing Belt became the center of heavy industry; Appalachia developed a large coal industry to feed the furnaces of the industrial core; the South grew crops such as cotton and tobacco; the Midwest became the agricultural products behemoth of the world; and the Pacific Northwest was incorporated into the national division of labor based on the expanding timber and lumber industry.

When regions, cities, or countries specialize in the production and export of some goods or services, they enjoy a comparative advantage. Although Adam Smith also used the idea to examine how firms specialized within a broader division of labor, this notion was spatialized by the famous 19th-century economist David Ricardo. Like all classical political economists, he assumed the labor theory of value (the value of goods reflects the amount of socially necessary labor time that goes into their production) and thus ignored demand. Ricardo concluded that nations will specialize in the production of a commodity that they can produce using the least labor compared with other nations.

Ricardo's classic example of this process is demonstrated in Table 1, which illustrates the allocation of labor time in England and Portugal, two long-standing trading partners, before and after they specialized. In the first part, which depicts the labor hours per unit of wine or cloth

that England and Portugal must each dedicate to the production of one unit of each good, it is evident that Portugal has an *absolute advantage* in both goods—that is, it can produce both of them with fewer labor hours than England can. If Portugal is more efficient, does it make sense for Portugal to trade? The answer is yes, implying that even the most efficient producer benefits from trade. Ricardo's analysis examined what happens when each country allocates its resources to the good it can produce most efficiently compared with its trading partners—that is, when it acquires a comparative advantage. Thus, in the second part, England only produces cloth (two units at 100 hrs. [hours] each), and Portugal only produces wine (two units at 80 hrs. each). In the process of specializing—that is, of producing for a market that consists of both economies together rather than either of them alone, each country frees up some resources that would otherwise have been dedicated to the inefficient production of a good in which it did not have a comparative advantage. England saves 20 labor hours, Portugal saves 10, and the combined trading system thus saves 30, which can be reallocated toward investment (although the original model is static and says nothing about change over time).

The Ricardian model—the simplest of many, more complex notions of comparative advantage—has important implications for economic geography. First, it shows how powerfully trade and exchange shape local production systems. It demonstrates that trade allocates resources to the most efficient (i.e., profitable) ends. The only costs of free trade are those borne by inefficient producers—in this case, English wine makers and Portuguese textile producers. Second, Ricardian notions of comparative advantage reveal that specialization reduces the total costs of production; thus, trade improves efficiency even without reallocating resources. Indeed, a good part of the long-term productivity growth of capitalism may be attributed to an increasingly specialized division of labor. Thus, specialization can be as important as technological change in stimulating productivity growth. For this reason, the vast majority of economists favor free trade as beneficial to all parties concerned. Third, this approach points out that large markets allow more specialization than do small ones. Adam Smith noted



	<i>Before Specialization</i> (labor hours/unit)			
	<i>Wine</i>	<i>Cloth</i>	<i>Total</i>	
England	120	100	220	
Portugal	80	90	<u>170</u>	
Units produced	2	2	390	
	<i>After Specialization</i> (labor hours/unit)			
	<i>Wine</i>	<i>Cloth</i>	<i>Total</i>	<i>Savings</i>
England	0	200	200	20
Portugal	160	0	<u>160</u>	<u>10</u>
Units produced	2	2	360	30

Table 1 Ricardo's model of comparative advantage. By revealing the gains created when England and Portugal traded, Ricardo's model illustrates how specialization leads to more efficient resource use.

Source: Ricardo, D. (1817). *Principles of political economy and taxation*. London: John Murray. (Reprinted in 1996 by Prometheus Books)

the same thing when he famously stated that the division of labor is governed by the size of the market. In this case, when the market expanded from one country to two, it allowed firms to specialize and become more efficient in the process. More generally, large countries with substantial internal markets facilitate more specialized firms and lower prices than do smaller countries.

Just as there is no specialization without trade, likewise there can be no trade without transportation. Goods must be moved across space from producer to consumer, and these transport costs must ultimately be borne by those who consume them. To the degree that transport costs affect the delivered price of commodities, they also influence consumers' willingness to buy them and, thus, the competitiveness of the regions that export them. If transport costs are low, their impacts on the division of labor will be low. However, sometimes, particularly for heavy and bulky goods, transportation costs may increase the market prices of exports and imports prohibitively—that is, make the goods too expensive to ship profitably across regions. Throughout the

history of capitalism, declines in transport costs have made it progressively easier for regions to realize their comparative advantage; thus, lower transport costs have contributed to lower production costs. For example, New Zealand became a major producer of lamb and mutton following the introduction of refrigerated shipping in the late 19th century. Similarly, the Pacific Northwest began to export vast quantities of wood and paper to the cities of the Midwest and the east coast following the completion of the transcontinental rail lines in the 1890s. In the post-World War II era, containerization likewise has facilitated the rise of various comparative advantages worldwide.

Ricardo's two-country, two-product theory of comparative advantage can be expanded by allowing several production factors. The multi-factor approach to trade theory derives from the work of two Swedish economists, Eli Heckscher and Bertil Ohlin. The Heckscher-Ohlin theory holds that a country should specialize in producing those goods that demand the least from its scarce production factors. Unlike the original Ricardian model, it includes demand and allows for the production of more than one good. In this formulation, specialization of production will be incomplete—that is, countries may continue to produce some part of a good even if they do not enjoy total economic superiority in the costs of production. The Heckscher-Ohlin theory argues not only that trade results in gains but also that wage rates will tend to equalize. The reasoning behind this factor-price equalization, as it came to be called, is as follows: If a country specializes in a labor-intensive good, its abundance of labor diminishes, the marginal productivity of labor rises, and wages increase. Conversely, if another country specializes in capital-intensive goods, labor becomes less scarce, the marginal productivity of labor falls, and wages also fall.

The traditional theory of comparative advantage is simplistic and unrealistic. Ricardo never gave an adequate account of why regions specialize in some goods and not in others, instead offering a picture that is static with respect to time, overemphasizes labor and climate, ignores consumption as well as the role of economies of scale and agglomeration, says nothing about the nature of competition, and is silent concerning the



impacts of public policy. These shortcomings were addressed in the theory of competitive advantage.

Barney Warf

See also **Competitive Advantage; Division of Labor; Economic Geography; Trade**

Further Readings

Maneschi, A. (1998). *Comparative advantage in international trade: A historical perspective*. Cheltenham, UK: Edward Elgar.



COMPETITIVE ADVANTAGE

An improvement on the traditional theory of comparative advantage is the theory of competitive advantage. Unlike the Ricardian model, which was useful for understanding the simpler economies of the early period of the Industrial Revolution, this approach focuses on the social creation of innovation in a rapidly changing, knowledge-based economy. The key to competitiveness in this view is productivity growth: Over the long run, rising productivity creates wealth for everyone, if not equally. Productivity growth in turn reflects many factors, including the education and skills of the labor force, the available capital and technology, government policies and infrastructure, and the presence of scale economies.

Competitive advantage is dynamic and changes over time. The goal of national development strategies is to move into high value-added, high-profit, high-wage industries as rapidly as possible. To accomplish this goal, firms and countries should seek to sell high-quality goods at premium prices in differentiated markets. Quality is a key variable here; countries often acquire reputations for producing high- or low-quality goods, earning (or not earning) brand loyalty as a result. By moving into high value-added goods, nations seek to automate the low-wage, low-skill functions and retain the knowledge-intensive ones.

Although the global economy is increasingly seamless, competitive advantage is created in

highly localized contexts—that is, within individual metropolitan areas. Globalization therefore does not eliminate the importance of a home base. Thus, countries that succeed internationally do so because a few regions within them move into “cutting-edge” products and processes. Within the United States, propulsive regions include Silicon Valley, Boston’s Route 128, and New York, with its premier position in finance and producer services; in Europe, they are Italy’s Emilia-Romagna, the continent’s largest high-technology region, as well as Germany’s Baden-Wurtemberg, Denmark’s Jutland peninsula, and the Cambridge region of the United Kingdom; in Japan, the government has actively constructed a series of technopolises toward this end (e.g., Toyota City).

The overall determinants of competitive advantage include the following: skilled labor, good educational systems, and technical training; agglomeration economies, including pools of expertise, webs of formal and informal interactions, trust, linkages, strategic alliances, trade associations, and integrated networks of suppliers and ancillary services; and a culture that rewards innovation—adaptation, experimentation, risk tolerance, and entrepreneurship—which includes heavy levels of corporate and public research and development and the continual upgrading of capital and skills. Corporations must engage in ongoing and organizational learning, anticipating changes in markets and demand; rigid corporate bureaucracies, like public ones, lead to complacency and short planning horizons. Competitive firms operate within competitive domestic markets; uncompetitive markets (i.e., private or public monopolies) exhibit little innovation. In the world economy today, increasingly sophisticated buyers spur a constant upgrading in the quality of output; adequate financing and venture capital; public policies that encourage productivity growth, including subsidized research, export promotion, and educational systems; and an up-to-date infrastructure (i.e., airports, telecommunications).

The theory of competitive advantage, largely attributable to Michael Porter, concludes that four attributes of a nation combine to increase or decrease its global competitive advantage and world trade:



1. Factor conditions
2. Demand conditions
3. Supporting industries
4. Firm strategy, structure, and competition

Factor conditions, or production factors, include human resources (the quantity of labor, skills, educational level, human capital, productivity, and cost of labor), physical resources (raw materials and their costs, location, access, and transport costs), capital resources (funds to finance the industry and trade, including the amount of capital available; the savings rate; the health of money markets and banking in the host country; government policies that affect interest rates, savings rates, and the money supply; levels of indebtedness; trade deficits; and public and international debt), knowledge-based resources (research, development, the scientific and technical community in the country, its achievements and levels of understanding, and the likelihood for future technological support and innovation), and infrastructure (all public goods and services necessary to facilitate the production of goods and services that provide a country with a competitive advantage). Also included are transportation systems; communications and information systems; housing, cultural, and social institutions; and education, welfare, retirement, pensions, and national policies on health care and child care. These five factors are identified in current international and economic circles as the keys to the competitive advantage of a nation in the foreseeable future.

Demand conditions are the market conditions in a country that aid the production processes in achieving better products, cheaper products, scale economies, and higher standards in terms of quality, service, and durability. Demand conditions cause firms to become innovative and, therefore, produce products that will sell not only in the domestic market but also in the world market.

To be competitive internationally, firms require easy and continuous access to networks of other firms specialized in different tasks. For example, large financial institutions require law firms, marketers, computer services, accountants, advertisers, and management consultants, subcontracting tasks that require heavy investments in human capital. Access to these industries, which generally

provide specialized expertise, is often obtained through face-to-face contact.

Firm strategy, structure, and competition relate to the conditions under which firms originate, grow, and mature. For example, because stockholders demand U.S. companies to show short-term profits, U.S. corporate performance may be less successful in the long run than it would be if it were judged over a longer period of time, as Japanese and German corporate performance is.

State support of corporate strategy and performance is important. For example, a country can regulate taxes and incentives so that investment by a firm is high or low. In addition, competition within a country can impose demands on company performance; new business formations often pressure existing firms to improve products and lower prices and thus increase competitiveness.

Barney Warf

See also **Clusters; Comparative Advantage; Economic Geography; Innovation, Geography of; Trade**

Further Readings

Porter, M. (1998). *The competitive advantage of nations*. New York: Free Press.



COMPLEXITY THEORY

The umbrella term *complexity theory* is used to explain complex adaptive systems, which are systems composed of a large number of interacting components, or agents, whose aggregate activity is nonlinear (and thus not predictable) and out of which order emerges. The study of “complexity” recognizes that the way the individual parts of a system interact may give us more insight into the entire system than the study of its individual agents, thus the focus turns to the relationships between agents, as opposed to the agents themselves; in this way, the study of complexity may be closer to an approach than it is to a theory.

The study of complex systems and the tools developed to analyze such systems has roots in



distributed artificial intelligence, in which entire societies of intelligent agents interact with one another to simulate the interaction of individuals in large populations. The geographer Michael Batty explains that a complex system is based on simple rules or interactions that give rise to unanticipated spatial outcomes. John Holland, a pioneer of complexity and nonlinear science, notes that a complex adaptive system (CAS) is a dynamic network of many agents (which may represent cells, species, individuals, firms, or nations) acting in parallel, constantly acting and reacting to what the other agents are doing. The control of a CAS tends to be highly dispersed and decentralized. If there is to be any coherent behavior in the system, it arises from competition and cooperation among the agents themselves, as opposed to being orchestrated by a higher-level authority or structure. The overall behavior of the system is the result of a large number of decisions made every moment by many individual agents. Thus, order in a complex system is understood as an emergent property of individual interactions at lower levels of interaction.

These fairly general definitions of complexity science bear an uncanny resemblance to those offered by general systems theory (GST), introduced to geography in the 1960s as part of the quantitative revolution to provide a framework in which to understand and theorize various disparate strands of work. GST was based on the work of Ludwig von Bertalanffy, who claimed that GST allowed for the transfer of principles discovered in one context to other situations. Although dismissed by Nicholas Chisholm in 1967 as an “irrelevant distraction,” the themes of GST continue to haunt geography, coming to the forefront once again in the dialogue between Jonathon Raper, David Livingston, and Doreen Massey in the late 1990s, as they discussed what Massey (1999) called the “commonalities between physical geography and human geography in emerging ways of conceptualizing space, time, and space-time” (p. 261). David O’Sullivan joined this conversation in 2004, when he brought it into the complexity arena, noting that “research in the complexity *modus operandi* can be useful, which brings us back to the potential for intra-disciplinary discussion provided by the complexity venture” (p. 283). The distinguishing

element between general systems theory and complexity theory is the reconceptualized understanding of equilibria in complexity theory. Chaos theory, and later complexity theory, allows for small shifts in system parameters to produce positive feedback loops, pushing the system to new levels of equilibria as opposed to dampening it through negative feedback.

The first application of complexity theory to geography may have been the segregation experiments done by the Nobel Laureate Thomas Schelling in 1971, who found that he could show how even the most racially and ethnically tolerant urban residents produce a highly segregated landscape in their individual search for a home. Batty may now lead the field in his application of complexity theory to urban systems, ultimately noting that “the city [is] the example *par excellence* of organized complexity” (p. 4). Steven Manson seeks to define complexity and its role in geography, detailing three categories of research where the term is used most frequently: algorithmic complexity, deterministic complexity, and aggregate complexity. While the first and second remain the purview of computer science, the third, aggregate complexity, has potential ramifications in geography. Defined as “the study of phenomena characterized by interactions among distinct components” (p. 409), this understanding or interpretation of complexity is of particular interest to geographers as it implies that the local spatial configuration of interactions affects outcomes at the whole-system level. Labeled *emergence* in the computer science and more popular literature, this phenomenon, also called self-organization, is a central feature of complex systems.

While complexity science remains fairly poorly defined, the tools that it has spawned are potentially powerful in geographic research. Most notably, multiagent systems, the newest and most complicated of a cadre of tools available, are composed of a set of agents and sets of cells or layers that define different landscapes or environments. Agents do not necessarily have fixed locations, and they interact with one another as well as with the environment in which they reside. These agent-based models allow social scientists to engage in thought experiments related to real-world phenomena. Multiagent systems are inherently geographic, due to their fundamental



understanding and modeling of the interaction between agents and the environment.

Unlike research in general systems theory, research taking place under the rubric of complexity theory may produce substantive achievements. Batty has published several articles modeling the temporally dynamic features of spatial behavior—work that falls within the purview of complexity as defined here. While a significant portion of that work discusses the tools developed to simulate social-spatial behavior, Batty also has contributed to the theorization of cities as fractals—once again searching for universals in the most particular. Dawn Parker, an agricultural economist now making tremendous contributions to the geography literature, has written extensively of multi-agent systems in geographic research, especially in understanding land use and land cover change. Although Parker does not identify herself as a “complexity theorist,” the methods she has worked to develop and introduce to geography fall under the umbrella of complexity, most notably the multiagent systems. Parker’s models integrate decision-making agents (e.g., households and land parcel managers) working within social networks, markets, and political institutions, to influence the environment in the form of soil fertility, erosion, and the spread of invasive species. As opposed to previous techniques used to model land use and land cover change, Parker’s models are simulation, rather than equilibrium, based, once again putting her work clearly in the rubric of complexity, recognizing the nonlinear nature of these intensely interactive systems prone to positive feedback rather than equilibrium.

Christine Drennon

See also **Agent-Based Models; Cellular Automata; Complex Systems Models**

Further Readings

- Batty, M. (2005). *Cities and complexity: Understanding cities with cellular automata, agent-based modeling, and fractals*. Cambridge: MIT Press.
- Holland, J. (1998). *Emergence: From chaos to order*. Reading, MA: Helix Books.

- Manson, S. (2001). Simplifying complexity: A review of complexity theory. *Geoforum*, 32(3), 405–414.
- Manson, S., & O’Sullivan, D. (2006). Complexity theory in the study of space and place. *Environment and Planning A*, 38(4), 677–692.
- Massey, D. (1999). Space-time, science and the relationship between physical geography and human geography. *Transactions of the Institute of British Geographers*, 24, 261–276.
- O’Sullivan, D. (2004). Complexity science and human geography. *Transactions of the Institute of British Geographers*, 29, 282–295.
- Parker, D., Deadman, P., & Manson, S. (2003). Multi-agent systems for the simulation of land use and land cover change: A review. *Annals of the Association of American Geographers*, 93(2), 314–337.
- Raper, J., & Livingstone, D. (1995). Development of a geomorphological spatial model using object-oriented design. *International Journal of Geographical Information Systems*, 9, 359–383.
- Thrift, N. (1999). The place of complexity. *Theory, Culture and Society*, 16, 31–69.



COMPLEX SYSTEMS MODELS

Complex systems models are idealized and structured representations of a complex, holistic system in which many simple components are interacting in a nonlinear way according to simple, fundamental rules, with a potential to generate unexpected order. Because higher-level patterns of environmental systems and human society across time and space emerge from localized interactive processes occurring at lower levels, these systems have been regarded as typical examples of so-called complex adaptive systems (CAS). As such, attempts to model the principle and behavior of CAS have received increasing attention among geographers.

Rise of the Concept of Complex Systems: From Analysis to Synthesis

The triumphant progress of physics aided by mathematics since Galileo Galilei is associated with a major focus on linearity. Relying on the



assumption of linearity that a whole is the sum of its parts, our combined mathematical tools and physical knowledge have made a tremendous scientific contribution. Such an approach, for hundreds of years, produced a deep-rooted reductionist tradition characterized by an analysis of repetitively fractioned units (e.g., cell > molecular > atom > nucleus) rather than a synthesis of those components in the framework of holism.

The science of complexity originated from the recognition of complex systems whose behavior cannot be understood based only on the reductionist approach. For example, the study of individual cancer cells in detail provides a limited insight into how they interact and spread. Intensive knowledge on local atmospheric conditions across the planet, without integrating the discrete localities into a whole, would not lead to an understanding of the mechanism of global warming. Urbanization results from combination of a demographic process by which the size of a population and its concentration increase and economic processes in which its economic base grows. **In addition to these examples of complexity**, the origin of life, biogeochemical cycles, forest fragmentation, stock market gyrations, traffic jams, and rising riots from a silent crowd remain mysteries.

One of the underlying processes in the behavior of these complex systems is nonlinearity, which makes a whole larger or smaller than the sum of its parts. A system is considered complex not because it consists of multiple variables but because their interactions and associated processes are nonlinear. In CAS, a considerable number of components interact, continuously changing their state from moment to moment, which is a system evolving through self-organization. The system cannot be investigated by isolating any one part because the dynamic interactions lead to positive or negative feedback loops. In other words, a certain microlevel property can extend its control to a characteristic phase of the synoptic level at which the system is perceived as a whole, and the synoptic level pattern in turn controls the microlevel behaviors. At the microlevel, nonlinear dynamics in some cases leads to chaotic behavior by which variations in the initial conditions are magnified over time, which thereby hampers any precise predictability. Through the feedback

process, however, the synoptic level of self-organization can balance this microlevel chaotic behavior, producing a fractal pattern that is self-similar across levels.

A CAS is also characterized by emergent properties. They generate spontaneously without any defined rule during the process of self-organization in CAS and cannot be inferred if one simply aggregates the individual components. They maintain themselves as an unexpected, integrated whole for some time period. Emergent properties are therefore perceived as novel, coherent structures. In his model of spatially divergent self-organization on the Earth's surface as nonlinear dynamical systems, Jonathan Phillips suggests that self-organization involves the progressive differentiation of landscapes (i.e., emergence) from more homogeneous to more heterogeneous patterns. Here, a landscape is composed of sets of interacting components, and such mutual interactions can explain its self-organization without taking into account the direct effects of external forcing. He postulates that entropy serves as an appropriate measure of the organization in the following model:

$$\vec{\delta}(t) = \vec{C} e^{\lambda t},$$

where $\delta(t)$ is a perturbation at time t , C is a constant or initial variation at $t = 0$, and the arrows indicate vector quantities. λ is a Lyapunov exponent. The number of Lyapunov exponents is the same as the number of components in a system. In a mathematical sense, deterministic chaos is defined when there is at least one positive Lyapunov exponent, thus $\lambda > 0$ implies an exponential increase of variation and the unstable, divergent behavior of a landscape. The sum of positive Lyapunov exponents is known to represent the Kolmogorov (K-) entropy, or Kolmogorov complexity. It is therefore summarized that there is a local connection among nonlinear chaotic dynamics, the Lyapunov exponent, and K-entropy. For example, if the initial spatial variation of nutrients in a landscape is magnified over time (i.e., there is nonlinear chaoticity), vegetation cover would differentiate into diverse spatial units (i.e., result in landscape divergence). Such divergence involves positive Lyapunov exponents, thus positive K-entropy.



Complex Systems Models in Geography

Because the key to the science of complexity lies in the synthesis of the knowledge and techniques of various research fields, the study of CAS necessitates interdisciplinary cooperation. Geography in itself is multidisciplinary, so many geographical models have the potential to contribute to the progress of **complexity theory**. This multidisciplinary nature also implies that the complex systems models used by geographers are in most cases developed and improved in cooperation with adjacent fields.

Conceptual Models

Conceptual models are concise and simplified visualizations that illustrate how complex interactions among system components generate patterns (e.g., Figure 1). Compared with mathematical models, conceptual models tend to be less appreciated explicitly in the discussion of complex systems models.

Conceptual models are useful because they do the following:

1. They enhance an understanding of the mechanisms underlying systems operation, thus often becoming a basis for predicting complex interactions across space and time, under unprecedented scenarios.
2. They generate hypotheses that can be tested by experimental studies or mathematical modeling. These two approaches in turn help improve the conceptual models themselves.
3. They facilitate interactions among academics, policymakers, and the public because conceptual models express technical, complex details in a nontechnical, visually stimulating way.
4. They encourage interdisciplinary cooperation. Conceptual models involve a truly intensive process of synthesizing a variety of knowledge, which is hardly achieved without integrating perspectives from various disciplines.

Mathematical Models

Most mathematical models of complex systems are based on a common premise that simple underlying interactions are able to generate complex spatial and temporal patterns. This premise also implies that any complexity observed in natural and human systems does not necessarily involve complex causes. Focusing on complexity in time and space, three major categories of complex systems models are discussed below.

Discrete Temporal Models

Until the 1980s, when space was not often explicitly involved in mathematical and conceptual models of complex systems, discrete, non-overlapping temporal dynamics with the deterministic chaotic behavior of a system had been modeled predominantly using difference equations:

$$N_{t+1} = F(N_t) = \mu N_t(1 - N_t).$$

The logistic equation above represents population density N and the dynamics between generations t and $t + 1$, with μ being the population growth rate. As the growth rate μ increases, the population density shows a variety of dynamical long-term bifurcations (Figure 2). Chaos theory is typically associated with the “butterfly effect,” in which even slight changes in the initial system conditions stimulate nonlinear interactions among multiple elements to produce dramatically different final states.

Based on these random-like, aperiodic bifurcations, some considered chaotic behaviors as maladaptive or catastrophic since the violent unstable fluctuations may lead some population values to approach an extinction threshold as shown in Figure 2. However, such an argument does not take into account the spatial component in complex systems.

When space is incorporated into temporal chaotic models, for example, by introducing the concept of dispersal, the argument against chaos can be resolved. The stabilizing role of space explains that dispersal between local populations facilitates the persistence of metapopulations at the global spatial scale, while there may be extinctions at a local spatial scale. This global

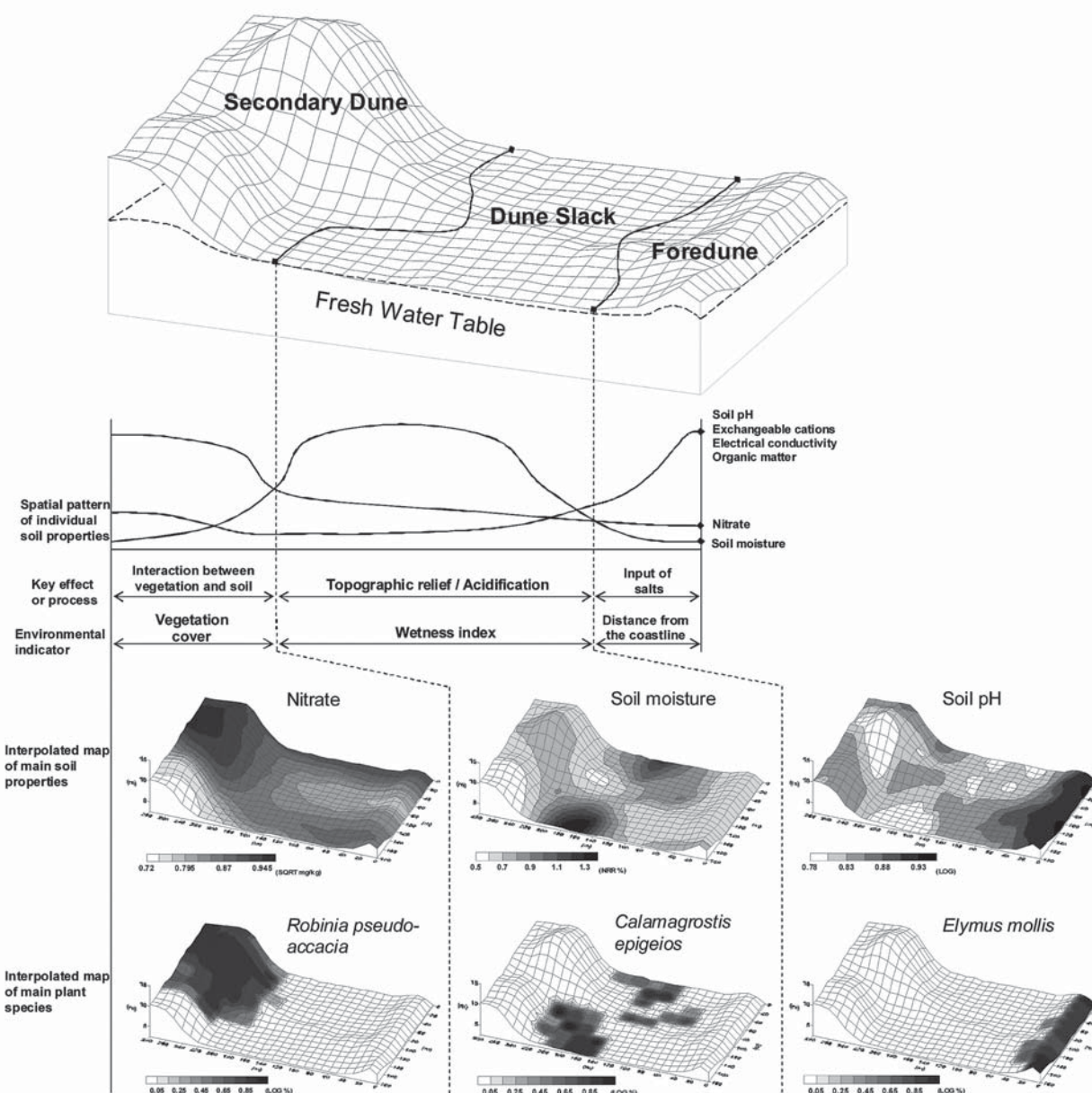


Figure 1 A conceptual model of coastal dune ecology synthesizing spatial gradients of vegetation, soil, and geomorphology. The model illustrates how spatial patterns of vegetation are related with soil conditions controlled by landform and geomorphic processes. Such a conceptualization can be of particular relevance in coastal ecosystems, where the dynamic interactions among atmospheric, marine, and terrestrial systems hamper empirical modeling.

Source: Kim, D., & Yu, K. B. (2009). A conceptual model of coastal dune ecology synthesizing spatial gradients of vegetation, soil, and geomorphology. *Plant Ecology*, 202, 135–148. Reprinted with kind permission of Springer Science + Business Media, via RightsLink.

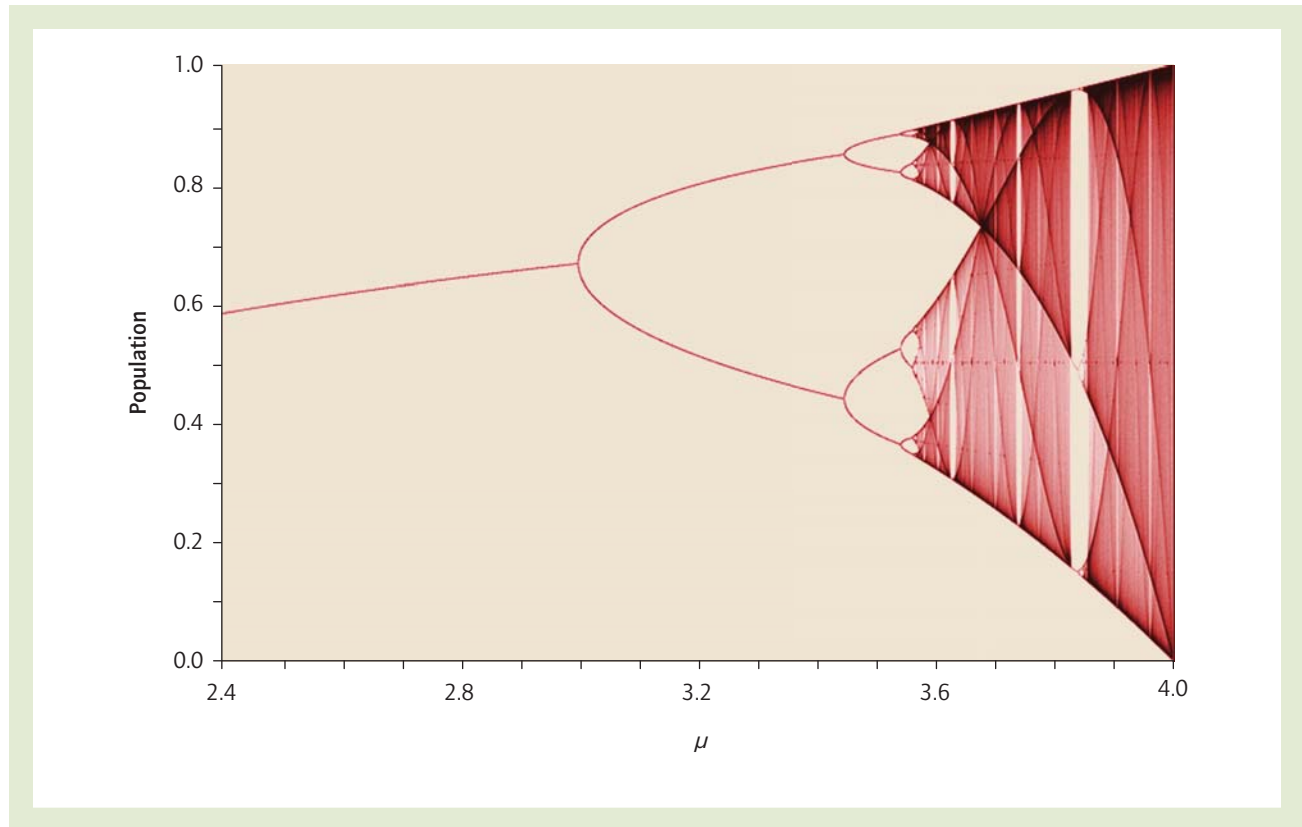


Figure 2 Chaos in population dynamics

Source: Redrawn from http://en.wikipedia.org/wiki/Bifurcation_diagram.

stability is termed *chaotic stability*. The next two sections discuss in greater depth complex systems models that couple space and time.

Continuous Space-and-Time Models

Continuous spatiotemporal models are equivalent to the so-called reaction-diffusion models in physics, simulating a system in which local quantities interact according to basic physical laws. One classic example is found in chemical reactions, in which a number of molecules (i.e., local quantities) diffuse across space and, in case of close contact, react with one another. In the field of geography, various spatially distributed processes, such as urban growth, land use change, and population dynamics that are influenced by the spatial structure of the environment, transport infrastructures, and movement patterns, can be investigated using the reaction-diffusion models.

In metapopulation epidemic models, for instance, diffusion is explained by the migration of people between cities, each of whom is classified into different states such as infected, susceptible, or immune. Here, reaction represents the probability of individuals in the same city being physically close enough to one another to change their state of disease.

In its simplest form, the model of diffusion-reaction is expressed by the following equation of population dynamics:

$$\text{Change in population} = \text{Growth of population} - \text{Diffusion of population.}$$

This elementary equation explains that a city grows through the growth of its population and spreads by the diffusion of the population in the suburbs. Here, some suggest that the equation should be generalized by taking into account the



advection processes by which a demographic excess is induced through the immigration of people from the rural areas or other cities. Such a suggestion holds that a city's growth and expansion are the result not only of the auto-growth of its population but also of the external input, as illustrated by the following revised equation.

$$\begin{aligned} \text{Change in population} &= \text{Growth of population} \\ &- \text{Diffusion of population} + \text{Advection of population.} \end{aligned}$$

One further generalization can be attempted for this model by coupling two or more equations or adding interaction terms. The population of the model, for instance, may consist of various ethnic groups or economic classes dynamically interacting with one another, as can be observed in real society. If one is interested in any two group types, the equation can be extended as follows:

$$\begin{aligned} \text{Change in Population A} &= \text{Growth of} \\ \text{Population A} &- \text{Diffusion of Population A} \\ &+ \text{Interaction of Populations A and B.} \end{aligned}$$

$$\begin{aligned} \text{Change in Population B} &= \text{Growth of} \\ \text{Population B} &- \text{Diffusion of Population B} \\ &+ \text{Interaction of Populations B and A.} \end{aligned}$$

In a biogeographical sense, Populations A and B can be two different plant species competing or facilitating each other.

To model geographical phenomena adopting the theory of diffusion-reaction, the theory should be enriched by the consideration of two aspects: spatial heterogeneity and human agents. Recently, a body of literature began to emphasize network heterogeneities across space, doubting the previous assumptions of spatial homogeneity, isotropy, and randomness that the classic diffusion-reaction models are implicitly based on. Geographers are concerned with human and natural processes occurring on the Earth's surface, which is always structured and heterogeneous. On a beach, sand grains are transported by onshore wind (i.e., diffusion), interacting with one another during their saltation (i.e., reaction). Here, the underlying **topography is the fundamental control** of the path of such transport (i.e., spatial heterogeneity). In a city, population changes by the emigration or immigration of

individuals predominantly along road networks (i.e., diffusion and advection). Underlying preliminary structures such as topography and land use constrain the spatial pattern of the networks, thereby making them spatially anisotropic and heterogeneous.

Second, the classic diffusion-reaction model itself cannot be fully compatible with geographic explorations because humans are not like physical and chemical entities such as molecules and atoms. Humans' behavior reflects their personal and societal needs, which involve emotional, cultural, and economic aspects. A challenge is then how to incorporate such original human actions into the physical diffusion-reaction models. The most important point for the human agent is that humans, as social species, interact with each other, thereby comparing their cultural and economic status with their neighbors' situation. Modeling studies have shown that the segregation of homogeneous quarters emerges from a random initial distribution of people who tend to continuously diffuse toward a place where they can share similar cultural values.

Discrete Space-and-Time Models

Discrete spatiotemporal models are classified into coupled map lattices (CMLs) and cellular automata (CA) models. The main purpose of a CML is to model the spatiotemporal chaos created by local nonlinear dynamics and spatial diffusion in a system with discrete space, time, and continuous state variables. In a CML, space is represented by a two-dimensional lattice in which the state dynamics of each point are defined as real numbers or real vectors. The definition here is achieved by coupling each site to its nearest neighbors, assuming that local interactions exist between the neighbors and the point in the middle. The simplest coupling is called the Von Neumann neighborhood, in which the state of a point at time $t + 1$ is an interactive function of the states of its four cardinal neighbors (i.e., north, south, east, and west) at time t . In square-lattice neighborhoods, this simple coupling can be extended to the Moore neighborhood, which considers all eight surrounding points. In many ecological systems and population dynamics models, where clustering of points or patches is important, a global



coupling is often used when interactions occur beyond the spatial extent of direct neighbors (i.e., the Moore neighborhood). In a formal way, a CML is expressed by the following equation:

$$x_{n+1}(i) = (1 - \varepsilon)f(x_n(i)) + (\varepsilon/2) \\ [f(x_n(i + 1)) + f(x_n(i - 1))],$$

where i is the spatial location of a point with a periodic boundary condition. In this basic model, the dynamics of a CML is determined by two competing components, such as individual non-linear reaction (i.e., f) and spatial interactions (i.e., coupling) with intensity ε .

Since their introduction to the field of physics and biology by Kaneko, Kapral, and Kuznetsov in the early 1980s, CMLs have been used by some geographers and others from related fields. One of the models' benefits is that CMLs are ideal for computer simulations. Traditionally, studies on the dynamics of spatially extended systems had been conducted under various discretization schemes required by partial differential equations. However, a direct numerical simulation without such schemes became possible using CMLs because CMLs are discrete in space. This advantage has been crucial for facilitating a variety of numerical simulations, thereby generating great insights into the spatiotemporal patterns of different regimes of dynamics.

Another group of discrete spatiotemporal models are the CA. Different from CMLs, where states are continuously defined as real numbers, CA are discrete in state. In a biogeographic vegetation dynamics model, for instance, the state of a cell can be defined as bare ground (0), pioneer stage (1), midsuccessional (2), or late successional (3).

Daehyun Kim

See also **Agent-Based Models; Cellular Automata; Complexity Theory; Models and Modeling**

Further Readings

Bascompte, J., & Solé, R. V. (1995). Rethinking complexity: Modeling spatiotemporal dynamics in ecology. *Trends in Ecology and Evolution*, 10, 361–366.

Czárán, T. (1998). *Spatiotemporal models of population and community dynamics*. London: Chapman & Hall.

Phillips, J. D. (1999). Divergence, convergence, and self-organization in landscapes. *Annals of the Association of American Geographers*, 89, 466–488.



CONFERENCE OF LATIN AMERICANIST GEOGRAPHERS

In 1963, the Association of American Geographers (AAG) inaugurated a Committee on Latin American Geography to encourage interaction among these regional specialists. To further this effort, a group of geographers attending the Ninth General Assembly of the Pan American Institute of Geography and History met on June 5, 1969, at the Cosmos Club in Washington, D.C., at the invitation of Preston E. James. After considerable discussion, it concluded that the time was ripe for a national conference to share information and stimulate geographical research, teaching, and planning activities.

The group sought and received the support of three influential Latin Americanist geographers, Preston E. James (a member of the U.S. National Academy of Sciences Committee on Geography), Arch C. Gerlach (president of the U.S. National Section of the Pan American Institute of Geography and History), and John P. Augelli (president of the newly established Latin American Studies Association), in their plans to organize a new professional association. The group established working committees for public relations/publications, local arrangements, program, and finances in the first meeting.

By 1970, the Committee on Latin American Geography became the Conference of Latin Americanist Geographers (CLAG), the first organization of specialists in the AAG to establish its own independent structure and membership. This move prompted the formation of a succession of AAG specialty groups, including the Latin American Specialty Group (LASG), with which CLAG cooperates to the full.



The CLAG is a nonprofit organization governed by a board of directors elected by the general membership, which has varied in number between 200 and 400. There are 13 members on the board, each serving for 3 yrs. (years). A rotation policy brings new members to the board each year and retires members who have completed their terms. Officers of the board are the chair, vice chair, and executive director, who may be assisted in their duties by appointed staff. Committees of the board are appointed by the chair to undertake organizational business; they include an executive committee as well as honors, membership, program, publications, teaching, and research committees. The executive committee is responsible for the integration and facilitation of the activities and plans of the organization.

CLAG meetings are scheduled at 1- to 2-yr. intervals. These meetings, which have been held in Latin America, Canada, and Spain, as well as the United States, consist of volunteered papers on a general conference theme, with a keynote address by a noted Latin Americanist. The first such meeting in 1970 was funded by the National Science Foundation, the Social Science Research Council, and the American Council of Learned Societies.

The CLAG annual business meeting, open to all members, is held in April each year. One meeting at the beginning of each decade is devoted to an inventory of geographical research in Latin America in the preceding 10 yrs. and a discussion of prospects for the future.

During the 1980s, CLAG made great progress in becoming a truly international organization; indeed, only two of CLAG's eight meetings since 1981 have been located in the United States; Latin American sites have included the Dominican Republic, Mexico, Colombia, Honduras, Peru, Costa Rica, Spain, and Guatemala.

Printed and electronic publications include the annual, peer-reviewed *Yearbooks* (1970–2001), now replaced by the two-issue-a-year *Journal of Latin American Geography*, special publications, occasional publications, instructional media, and the *CLAG Newsletter*. CLAG also maintains its own listserv.

David J. Robinson

See also **Association of American Geographers**

Further Readings

Conference of Latin Americanist Geographers: <http://sites.maxwell.syr.edu/clag/clag.htm>



CONFLATION

The word *conflation* refers to the process (compilation, reconciliation) or the resulting product of combining two or more versions of a complex information entity, such as a manuscript, map, or database, to produce a new improved version of the same entity. A map conflation is the process or the output map resulting from merging information from two or more maps of the same region. Spatial data conflation is the process of, or the output data set or database resulting from, merging two or more spatial data sets or databases for the same area or region. Although the terms *conflation* and *data fusion* are sometimes used interchangeably, data fusion is technically the more general concept of merging any two data sets, whereas conflation merges data sets that are presumed to each contain large subsets of common features. Map conflation is considered successful only after many or most features on one map have been matched to counterpart features on the other.

The first prototype semiautomated, computerized map conflation system was built in 1985 for a study of the feasibility of merging urban map data (Digital Line Graph [DLG] files) from the U.S. Geological Survey (USGS) with urban map data (Geographic Base File/Dual Independent Map Encoding [GBF/DIME] files) from the U.S. Bureau of the Census. At that time, long before the current widespread proliferation of spatial data sets, only government agencies had access to multiple map data sets of large coverages; hence, only government agencies had the opportunity, the resources, and the incentive to try to develop computer programs to conflate such data sets.

The USGS/Census semiautomated map conflation system employed a *match-and-merge conflation strategy*: Find duplicate features in the two



map versions, then display all the unique features (duplicated or otherwise) exactly once to create a conflated map of the two versions. More specifically, the steps are as follows:

1. Using a variety of map-feature similarity measures, find candidate matching pairs of features (every pair will have one element from each of the two map versions).
2. Apply a topology-preserving geometric transformation (commonly referred to as *rubber sheeting*) to all the points of one of the map versions to bring candidate-matched features into exact alignment with each other.
3. Simultaneously display the two realigned and newly registered map versions for visual assessment of the effect of collocating the candidate-match pairs and displaying each pair as a single feature.

Since 1985, many private companies, academic institutions, and government agencies have continued developing spatial data conflation software. Although the matching criteria and alignment transformations vary slightly from system to system, all systems use the two-part feature-matching/feature-alignment model to generate graphic displays of the results of the conflation processing.

Map-to-map conflation has been expanded to include map-to-image conflation and image-to-image conflation. Working with images requires an extra step of image feature recognition, but once image features have been identified, those features can be matched and merged (i.e., rubber sheeted) to align with map features or other image features using previously developed matching and rubber-sheeting tools.

Alan Saalfeld

See also Database Management Systems; Database Versioning; Data Editing; Data Format Conversion; Data Querying in GIS; Ground Reference Data; Interoperability and Spatial Data Standards; Metadata; Ontological Foundations of Geographical Data; Open Geodata Standards; Spatial Data Integration; Spatial Data Mining; Spatial Data Models; Spatial Data Structures

Further Readings

Hastings, J. (2008). Automated conflation of digital gazetteer data. *International Journal of Geographical Information Science*, 22(10), 1109–1127.



CONSERVATION

The term *conservation* usually refers to environmental conservation or preservation of natural resources. In the United States, the term came into use in the late 19th century, when valuable natural resources such as timber, farmland, and pasture were threatened by rapid economic development. Concerns extended to include the Great Plains as frontier settlement moved westward at an increasingly rapid rate with the construction of continental railroads, which laid land open for further development. The term suggests preservation and protection of natural resources to prevent exploitation and destruction. Conservation also includes the recognition of limits to growth. Presently, the term *conservation* embraces the ecosystems and resource base of the Earth by protecting its capacity for self-renewal and sustainability.

The Conservation Movement in the United States

The conservation movement has a long history in the United States. In the 1850s, Henry David Thoreau—the author of *Walden*—expressed his concern about the loss of nature and saw in the “wild” the hope for the preservation of the world. He called attention to the sacred laws of nature, which take precedence over human actions that disturb the ecological balance. In 1864, George Perkins Marsh formulated the physical geography of the Western states as modified by human action and drew attention to the fragility of the natural ecosystem. These early efforts of consciousness-raising led to a concerted effort to protect nature and establish national parks in the Western United States. It was President Theodore



Roosevelt, with the aid of his chief forester, Gifford Pinchot, who established the federal role in these efforts. Roosevelt began withdrawing large areas of western public land from further development, and in 1916, the National Park Service was created to preserve valuable nature for eternity. The drought conditions, known as the Dust Bowl of the 1930s, led to the foundation of the Civilian Conservation Corps in 1933 and the Soil Conservation Service in 1935 during the presidency of Franklin D. Roosevelt. Conservation efforts in the United States also include concerns about water resources, energy use, and water and energy conservation.

In the 1960s and 1970s, the conservation movement became more actively involved in the political debate about pollution and the destruction of nature in favor of economic profit. Social justice issues transformed the conservation movement into the environmental movement and engaged the political establishment in protecting resources and the environment. The environmental movement produced profound changes in the political climate concerning the environment, culminating in the establishment of the U.S. Environmental Protection Agency in 1970.

The Whole Earth Ecosystem

In the late 1960s and early 1970s, concerns about the health of the global ecosystem and resource base found resonance with Rachel Carson's message about the detrimental widespread use of pesticides in agriculture. In the same period, Paul Ehrlich and Barry Commoner raised issues about population, economic growth, and technology as causal factors in the limits-to-growth debate. Ehrlich presented a neo-Malthusian scenario of imminent population explosion and ensuing disaster and argued that society must find ways to limit population growth. Commoner presented an eco-socialist perspective to the limits-to-growth debate, arguing that capitalism and technology were chiefly responsible for the environmental degradation of Earth's ecosystem.

Conservation and sustainable development are closely related, and the integral relationship between the health of Earth's ecosystem and human well-being is widely recognized. Global wildlife conservation and biodiversity are high on

the agenda of the global conservation movement and find supporters in many countries, but equally important are concerns about fossil fuel use and greenhouse gas emissions. Protection of the global environment and conservation of Earth's resources represent an enormously complex challenge at a time of rapid globalization. The advancement in science and technology, communication, and transportation that has united the world physically has also greatly accelerated the threat of reduced biological diversity and climate change. Materialism, driven by the dogmas of consumerism, capitalism, and individualism, has in many instances been carried to excess and is now affecting livelihoods in many parts of the world. Extending social and economic justice to the entire global community and ensuring quality of life for subsequent generations are important principles underlying the global environmental conservation movement.

Ecological and Carbon Footprints

Concern about sustainable development and the threat of climate change has focused attention on humanity's ecological and carbon footprints. The political challenge of responding to the ecological crisis and climate change is daunting. The ecological footprint measures how much land and water area a human population requires to produce the resources it consumes and to absorb its waste products. Today, the ecological footprint is almost 25% larger than what the Earth can regenerate in 1 year. By measuring the ecological footprint of a population (i.e., of an individual, a city, a nation, or all humanity) one can assess overshoot, which should help in managing the ecological assets more carefully.

The carbon footprint is a subset of the ecological footprint and expresses the impact human activities have on the environment in terms of the amount of greenhouse gases produced, measured in units of carbon dioxide. It is meant to be useful for individuals, nations, and organizations to conceptualize their personal (or organizational) contribution to global warming. It is estimated that developed countries' average per capita carbon footprint is 10 times that of the average developing countries and that to attain "safe" levels of carbon dioxide concentrations



in the atmosphere, carbon emissions need to be reduced by 60% worldwide. To reduce the carbon footprint, alternative energy sources such as solar and wind energy need to be rapidly developed, and energy conservation has to be widely practiced.

Yda Schreuder

See also Biodiversity; Biosphere Reserves; Commons, Tragedy of the; Community-Based Conservation; Conservation Zoning; Ecological Footprint; Ecosystems; Environmental Management; Governmentality and Conservation; Landscape and Wildlife Conservation; Neo-Malthusianism; Patches and Corridors in Wildlife Conservation; Population and Land Degradation; Renewable Resources; Resource Economics; Resource Geography; Resource Management, Decision Models in; Soil Conservation; Spatial Strategies of Conservation; Sustainable Development

Further Readings

- Carson, R. (1962). *Silent spring*. Boston: Houghton Mifflin.
- Commoner, B. (1971). *The closing circle*. New York: Knopf.
- Cutter, S., & Renwick, W. (2003). *Exploitation conservation preservation: A geographic perspective on natural resource use*. New York: Wiley.
- Ehrlich, P. R. (1968). *The population bomb*. New York: Ballantine Books.
- Marsh, G. P. (1864). *Man and nature*. New York: Scribner.
- Thoreau, H. D. (1906). *Walden*. Boston: Houghton Mifflin.
- Van Dyck, F. (2008). *Conservation biology: Foundations, concepts, applications*. Berlin, Germany: Springer.
- Wackernagel, M., Onisto, L., Bello, P., Linares, A. C., Falfan, I. S. L., Garcia, J. M., et al. (1999). National natural capital accounting with the ecological footprint concept. *Ecological Economics*, 29, 375–390.
- Zimmerer, K. (Ed.). (2006). *Globalization and new geographies of conservation*. Chicago: University of Chicago Press.



CONSERVATION ZONING

Conservation zoning is a spatial planning strategy used to manage urban and rural landscapes and sometimes marine areas. The term can refer to any land use or marine planning process whose primary goal is purported to be the conservation of social and/or natural resources. It is a territorial mechanism that delineates bounded zones for which particular rules apply—in this case, rules meant to conserve particular environmental values. At its most basic, conservation zoning sets out acceptable density levels and residential footprints to ensure the persistence of green space. In urban landscapes, both social and environmental characteristics are targets of conservation zoning, whereas in rural areas, conservation zoning is used primarily to protect natural resources and ecosystem services. Geography and geographers have played a role in determining the types of conservation zones appropriate to a planning exercise and, through the use of spatial technologies and multicriteria decision support, have been integral to the establishment and mapping of conservation zones.

While residential, industrial, and commercial zoning are common practices in urban land use planning, conservation zoning is a relatively new addition to the urban-planning toolbox meant to promote the building of more sustainable communities. Urban conservation zones range from protected heritage architecture to riparian buffer zones that border fish-bearing streams and their floodplains, as well as urban green spaces. Commonly, conservation zoning limits particular kinds of development, such as land clearing and construction, that may threaten the targeted social or environmental characteristics.

In rural and peri-urban areas, conservation zoning is a way of promoting land-based conservation values on private property. Conservation easements and land trusts are ways in which property owners can receive municipal tax incentives in exchange for preserving their land to ensure the provision of habitat and/or ecosystem services. Greenbelts or greenways are examples of conservation zones found most often bordering urban areas. Both restrict development to preserve forest, agriculture, or otherwise environmentally sensitive land. Parks and protected areas can also be thought



of as exercises in conservation zoning where core zones are delimited from multiple-use, recreational, or buffer zones.

In the vast oceans, especially the Pacific, conservation zoning is a key means of ensuring and promoting networks of marine-protected areas (e.g., Papahānaumokuākea, Marianas Trench, Rose Atoll, and Pacific Remote Islands Marine National Monuments of the United States).

The process of conservation zoning is political and requires the spatially explicit analysis of numerous data sets—everything from soil, land cover, slope, and connectivity to property values, public perception, recreational use and potential, and demographic characteristics. Geographic tools, for example, remote sensing and geographic information systems, are ideal for such analysis. Their use informs decision-making processes and helps identify lands suitable for conservation zoning.

Robin J. Roth

See also Biosphere Reserves; Conservation; Environmental Certification; Governmentality and Conservation; Greenbelts; Indigenous and Community Conserved Areas; Land Use Planning; Resource Management, Decision Models in; Spatial Strategies of Conservation; Zoning

Further Readings

Arendt, R. C. (1999). *Growing greener: Putting conservation into local plans and ordinances*. Washington, DC: Island Press.

Norse, E. A., & Crowder, L. B. (Eds.). (2005). *Marine conservation biology: The science of maintaining the sea's biodiversity*. Washington, DC: Island Press.



CONSUMPTION, GEOGRAPHIES OF

Consumption has meant different things at different moments in time and has taken widely varying forms. The term comes from the Latin *consumere*, “to use up” (as in tuberculosis),

implying that consumption means to make full use of and to destroy simultaneously. In societies lacking a social surplus, consumption equals production. Economically, consumption is how consumers satisfy their needs. In social terms, consumption lies at the intersections of production, culture, everyday life, and psychology. In contrast to production, which has been studied in exhaustive detail in geography, consumption has long been ignored or regarded as unproblematic. The reasons for this silence are not clear but may reflect, among other things, Marxism’s emphasis on production and labor as the central acts of social life and, conversely, neoclassical economics’ sterile and asocial view of consumption. Consumption and production cannot be neatly separated and are closely intertwined: Most people work in order to consume, and everyone consumes in order to live.

Historically, the growth of mass production in the 19th century was accompanied by rising disposable incomes, mass consumption advertising, the ideology of consumerism, and, in the 1930s, Keynesian demand management. Consumption fuelled by debt was decried by moralists, often on religious grounds, as a violation of Protestant ethics, which focused on delayed gratification. In the late 20th century, changes in the world economy, including deindustrialization and the explosive growth of producer services, induced concomitant changes in consumption, including increasingly specialized niche markets and sophisticated consumers. By any measure, consumption is enormously important, as an economic act (constituting the bulk of the gross national product [GNP] of most countries), environmentally (e.g., energy use or the act of turning products into trash), and in terms of the lifestyles and self-image of much of the population. The geography of consumption is critical to understanding related issues such as travel and transportation, tourism, standards of living, and uneven development.

Theoretical Perspectives on Consumption

The historically dominant view of consumption came from neoclassical economics, which analytically privileges demand. In this perspective, individual consumers, personified by the



desolate, self-centered, asocial character *Homo economicus*, maximize their utility or happiness by allocating incomes among different goods. This subject has been examined extensively, including topics such as the impacts of changing incomes and prices, consumer surplus, elasticities of supply and demand, and the impacts of imperfect information. Consumption forms the vast majority of gross domestic product, often 80% or more. Inevitably, the conclusion of such views is that markets are optimally efficient (and hence morally optimal as well). While the neo-classical view is internally consistent within its own terms of reference, it is ultimately sterile and ahistorical, failing to do justice to the rich semiotics and social dimensions of consumption. In part, this failure arises because neoclassical economics does not represent consumption as a social act—that is, embedded within broader relations of class, gender, ethnicity, and power. For example, it offers no account of the origins of utility curves or why they assume their particular form. Social categories, if they arise at all, are defined largely by their relations to consumption: class in conventional Weberian social analysis, for example, refers to income and socioeconomic status.

A second interpretation of consumption comes from Marxism, which argues that social science must penetrate the veneer of outer appearances to reveal the social relations that lie beneath them. In this vein, Marx argued that commodities are not simply *things* but embodiments of social relations. To view commodities separately from their social origins is to commit the error of commodity fetishism. The means by which market relations render relations among producers opaque is functional for capitalism, hiding the source of wealth, that is, labor. Rather, Marxism drew on classical economics to differentiate the use value of commodities—the qualitative, subjective dimensions—from their exchange value, the quantitative price they command on the market (e.g., the use value of an apple is its taste and the relief from hunger it offers; its exchange value is how much it sells for on the market). Critically, for Marxists, labor too is a commodity whose use value to employers is less than its exchange value in wages. Class is thus defined by relations to production, not consumption. Marxism suggests

that the extraction of surplus value by employers inevitably leads to underconsumption by the working class and the tendency toward crisis. A third perspective on consumption focuses on the semiotic dimensions. Rather than a simple act of utility maximization, as represented by neoclassical economics, this body of work points to shopping and consumption as social and spatial practices that emanate from and in turn reinforce existing structures of power, culture, and ideology. Early sociologists, such as Thorsten Veblen, focused on the lifestyles of the robber barons and their propensity toward “conspicuous consumption” as a sign of wealth and status. In highly individualized societies such as the United States, personal status is typically achieved through the consumption of commodities. Indeed, self-identity and even self-esteem are frequently linked to owning the “right” brands of goods. What one may call the sensuous nature of consumption, thus, includes the complex social and psychological motivations that underpin the urge to buy, including consumers’ ego, sense of self, status definition, and alleged individuality that comes from the purchase of mass-produced commodities.

The highly influential early-20th-century cultural theorist, Walter Benjamin, extended historical materialism to include the bourgeois infatuation with the commodity. He sought to uncover the ways in which the commodity penetrated into the consciousness of buyers, charting the growth of bourgeois consciousness in the emerging malls and stores of early-20th-century Europe. Working in Paris and Berlin in the 1920s, Benjamin’s Arcades Project examined the linkages between the urban environment, experience, history, and memory, portraying cities as labyrinths in which individual subjectivity was swept aside by modernity and its impersonal relations, bureaucracies, and markets. Perception, Benjamin maintained, was itself historically specific. Commodities, in this reading, were far more than embodiments of labor power; they represented visual aesthetics with a significance above and beyond the narrow realm of the economic. In this light, Benjamin revealed that commodities are as much distillations of signs as they are embodiments of use and exchange values. Benjamin’s Arcades Project thus captured the commodified nature of modernity, the deep linkages between seeing and knowing, on the one



The Mall of America in Bloomington, Minnesota, is the largest shopping mall in the United States, with 35 million to 42 million visitors each year. Geographers have examined the shopping mall not simply as an economic phenomenon but as a cultural site.

Source: Mark Erickson/Getty Images.

hand, and money and the commodity, on the other. This step effectively opened up the analysis of consumption as a social process, noting its mounting autonomy from production and the pervasive role of symbols in the construction and manipulation of consumer consciousness.

This line of thought reemerged in postmodern analyses of consumption, particularly the astute critique of contemporary capitalism offered by the political economy of signs. For Baudrillard, the mass media have made the sign more important than its referents, creating a world of the simulacra, in which we can no longer distinguish between simulations and reality, between the true and the false. In the context of post-Fordism, postmodern consumption centers as much on the symbolic value of commodities as their use value. Thus, pseudo-Irish bars are more Irish than Ireland. Baudrillard's dissection of Disney World

reveals it to be just such a simulacrum, a giant shopping mall, and for Baudrillard, the United States is essentially Disney World writ large. Television carries this process of abstraction to new heights, reflecting and shaping the material world in complex and highly stylized ways.

Geographies of Consumption

Drawing on the work of sociologists, historians, philosophers, and anthropologists, geographers have engaged in numerous lines of thought that suture commodities to their social and spatial origins. This body of work has tended to fall into three major categories.

First, drawing on the tradition of humanistic geography, some geographers have examined the relations between consumption, the body, and individual experience. A considerable literature,



for example, has looked at food, its origins and cultural meanings in different geographic contexts, and its role in the unfolding of daily life. Similarly, geographers have examined the shopping mall not simply as an economic phenomenon but as a cultural site pregnant with meanings. Jon Goss, for example, studied the Mall of America in Bloomington, Minnesota, which has 520 stores, chapels, a roller coaster, an aquarium, and a rain forest (see photo). In this environment, fantasy, fun, and the commodity are seamlessly merged into a seductive whole.

Second, many geographers have turned to consumption in the context of economic landscapes, including the pivotal role played by retail trade and consumer services. Traditionally, economic geography focused on production and the role of the so-called export base in economic development. When geographers turned to consumption, it was through the static and ahistorical lens of central place theory. More recent work has called attention to so-called nonbasic functions, including retail trade and personal services, and has shed light on their potential for job generation and economic change. Some geographers have studied enormous chains and franchises such as McDonald's or Wal-Mart. Studies of the geography of tourism, which is essentially the consumption of place, are a burgeoning part of the discipline.

Third, geographers have focused on consumption in the context of the global economy, particularly the manner in which commodities are produced, distributed, and consumed via commodity chains. By embedding this sector within wider circles of finance, investment, trade, and consumption, this literature notes the ways in which globalization has unleashed a tidal wave of cheap imports that has propelled the high rates of consumer spending in societies such as the United States. This body of work traces the commodity through complex, contingent lines of causality linking sellers and buyers across multiple spatial scales. Variations of this theme point to the highly gendered nature of consumption as well as the moral and environmental dimensions that surround the way commodities are consumed, including, for example, the sacrifices made by low-wage labor trapped in sweatshops in the developing world to provide American consumers with cheap

goods. Such a perspective reveals consumption as being an economic, cultural, psychological, and environmental act that simultaneously reproduces both the world's most abstract space, the global economy, and the most intimate, the individual subject and body.

Barney Warf

See also **Applied Geography; Body, Geography of; Business Geography; Commodity Chains; Cultural Landscape; Economic Geography; Food, Geography of; Geodemographics; Humanistic Geography; Identity, Geography and; New Urbanism; Retail Trade, Geography of; Sense of Place; Spaces of Representation/ Representational Spaces; Sports, Geography of; Symbolism and Place; Tourism; Uneven Development; Urban Geography**

Further Readings

- Baudrillard, J. (1998). *The consumer society: Myths and structures*. Thousand Oaks, CA: Sage.
- Bell, D., & Valentine, G. (1997). *Consuming geographies: We are where we eat*. London: Routledge.
- Crewe, L., & Lowe, M. (1995). Gap on the map? Towards a geography of consumption and identity. *Environment and Planning A*, 27, 1877–1885.
- De Graaf, J., Wann, D., & Naylor, T. (2001). *Affluenza: The all-consuming epidemic*. San Francisco: Berrett-Koehler.
- Gereffi, G., & Korzeniewicz, M. (Eds.). (1994). *Commodity chains and global capitalism*. Westport, CT: Greenwood Press.
- Glennie, P., & Thrift, N. (1992). Modernity, urbanism, and modern consumption. *Environment and Planning D: Society and Space*, 10, 423–443.
- Goss, J. (1993). "The magic of the mall": An analysis of form, function, and meaning in the contemporary retail built environment. *Annals of the Association of American Geographers*, 83, 18–47.
- Goss, J. (1999). Once upon a time in the commodity world: An unofficial guide to the mall of America. *Annals of the Association of American Geographers*, 98, 45–75.



- Gregson, N., Crewe, L., & Brooks, K. (2002). Shopping, space, and practice. *Environment and Planning D: Society and Space*, 20, 597–617.
- Hartwick, E. (1998). Geographies of consumption: A commodity-chain approach. *Environment and Planning D: Society and Space*, 16, 423–437.
- Hartwick, E. (2000). Towards a geographical politics of consumption. *Environment and Planning A*, 32, 1177–1192.
- Lee, M. (Ed.). (2000). *The consumer society reader*. Oxford, UK: Blackwell.
- Marsden, T., & Wrigley, N. (1999). Regulation, retailing, and consumption. *Environment and Planning A*, 27, 1899–1912.
- Miller, D. (Ed.). (1995). *Acknowledging consumption*. New York: Routledge.
- Stearns, P. (2001). *Consumerism in world history: The global transformation of desire*. London: Routledge.
- Valentine, G. (1999). A corporeal geography of consumption. *Environment and Planning D: Society and Space*, 17, 329–341.
- Wilk, R. (2002). Consumption, human needs, and global environmental change. *Global Environmental Change*, 12, 5–13.
- Williams, C. (1997). *Consumer services and economic development*. London: Routledge.

to the development of geographical knowledge and gave birth, in the following century, to interest in the new anthropological area of study.

After spending his childhood working in a grocery and yearning for the sea, in 1756, when the Seven Years' War began, Cook enlisted in the Royal Navy. His map of the Saint Lawrence River played a role in the British victory in Quebec. Due to his abilities, Cook was charged with the topographic survey of the coastline and bottoms of New Scotland and Newfoundland. In 1768, Cook was sent by the Royal Society to Tahiti with the aim of having him record a rare passage of Venus across the face of the sun, but due to the lack of precise instruments, his observation could not be made in a satisfactory manner.

He then focused his attention on the exploration of the Southern Pacific Ocean to solve doubts about the supposed existence of the Terra Australis Incognita, a hypothetical continent that was imagined to be located at the southernmost part of the Earth to counterbalance the lands of the Northern Hemisphere. He reached New Zealand, mapped its coastline, and indicated the strait that separates its northern and southern islands, which have been named after him. In April 1770, Cook reached the eastern coast of Australia, where Sydney was founded.

In 1771, Cook started a new voyage. Two years later, he was the first to cross the polar Antarctic Circle. He then headed toward new islands in the Southern Pacific Ocean and reached what are now known as the Cook Islands. Despite the difficult climatic conditions, he did not hesitate to challenge the dangerous polar ice and succeeded in getting as far south as 71°11' S and circumnavigated Antarctica without sighting it. The aim of Cook's last voyage was to get information about the existence of the Northwest Passage, a sea route through the Arctic Ocean that for centuries was supposed to be icefree, and thus to connect the Atlantic Ocean and the Pacific Ocean. During this expedition, he mapped the coastline of Alaska and was the first European to visit the Hawaiian islands.

Susanna Servello



CONTINENTAL DRIFT

See Plate Tectonics



COOK, CAPTAIN JAMES (1728–1779)

Captain James Cook was a navigator, explorer, and cartographer whose fame is essentially due to his travels to the Pacific Ocean. His origins were humble, and he achieved his success thanks to his passion and insatiable thirst for adventure. The explorations led by him contributed enormously

See also **Exploration; Human Geography, History of; Royal Geographical Society**



Further Readings

- Cook, J., & Edwards, P. (2000). *The journals of Captain Cook* (Abridged ed.). London: Penguin Classics.
- Sahlins, M. (1995). *How "natives" think: About Captain Cook, for example*. Chicago: University of Chicago Press.
- Thomas, N. (2003). *The extraordinary voyages of Captain James Cook*. New York: Walker.



COORDINATE GEOMETRY

Creating a three-dimensional (3D) model of an object in a computer involves a coordinate system and algebraic calculations necessary to manipulate (change shape, scale, orientation, and location) the modeled object. Every spatial object, such as a 3D model of a house, is based on coordinates referenced to a specific coordinate system. The most popular system of coordinates used in

almost every 3D modeling software is the Cartesian coordinate system, described by three coordinates, x , y , and z , corresponding to the three dimensions of space. In the Cartesian coordinate system, all three axes are perpendicular to each other, and the system is defined by its origin (0, 0, 0) and the orientation of the x , y , and z axes. The simplest way of referencing one object to another object is when the axes of the first object are parallel to the axes of the second object. Two other conditions still must be met. First, one needs to know the exact position between the origins of two objects. Second, one also needs to know the scale or rather the distance unit that was used in both the coordinate systems. If, for example, one house is modeled using feet and the other house is modeled using meters, then the houses will be positioned wrongly in relation to each other, and one house will be approximately three times smaller than the other house since 1 meter equals approximately 3.28 feet (Figure 1).

Projecting geographic objects such as land masses or water bodies from a 3D model of the

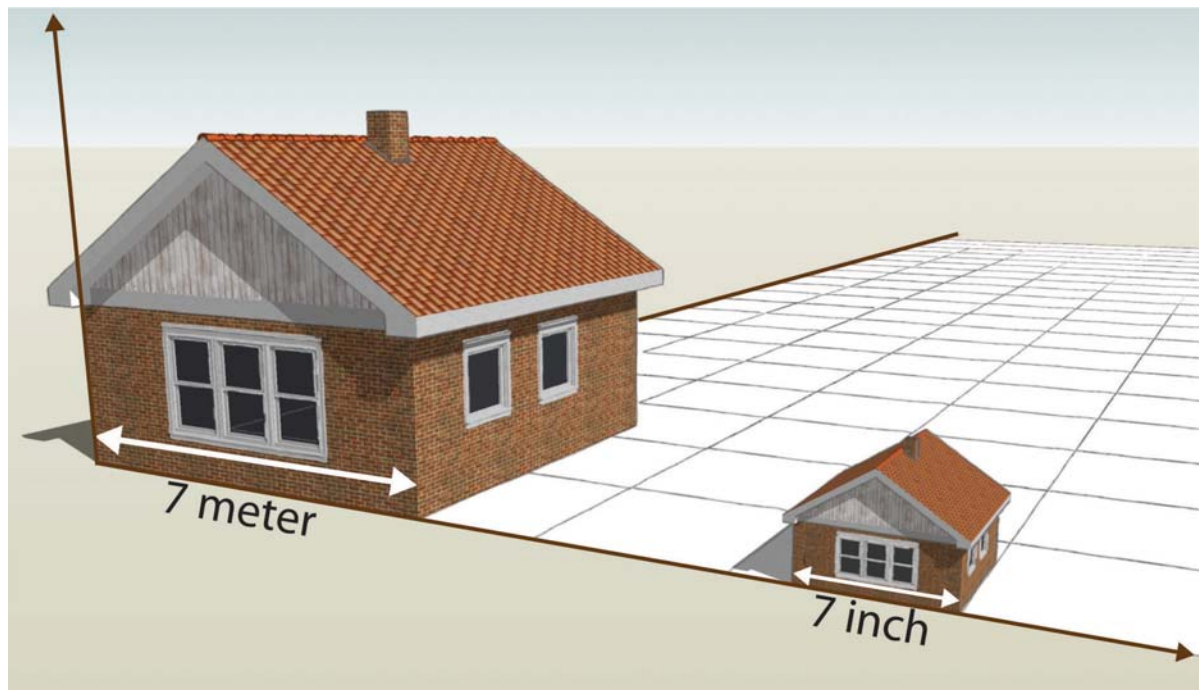


Figure 1 Scale and distance unit implications of a coordinate system for 3D models

Source: Author.

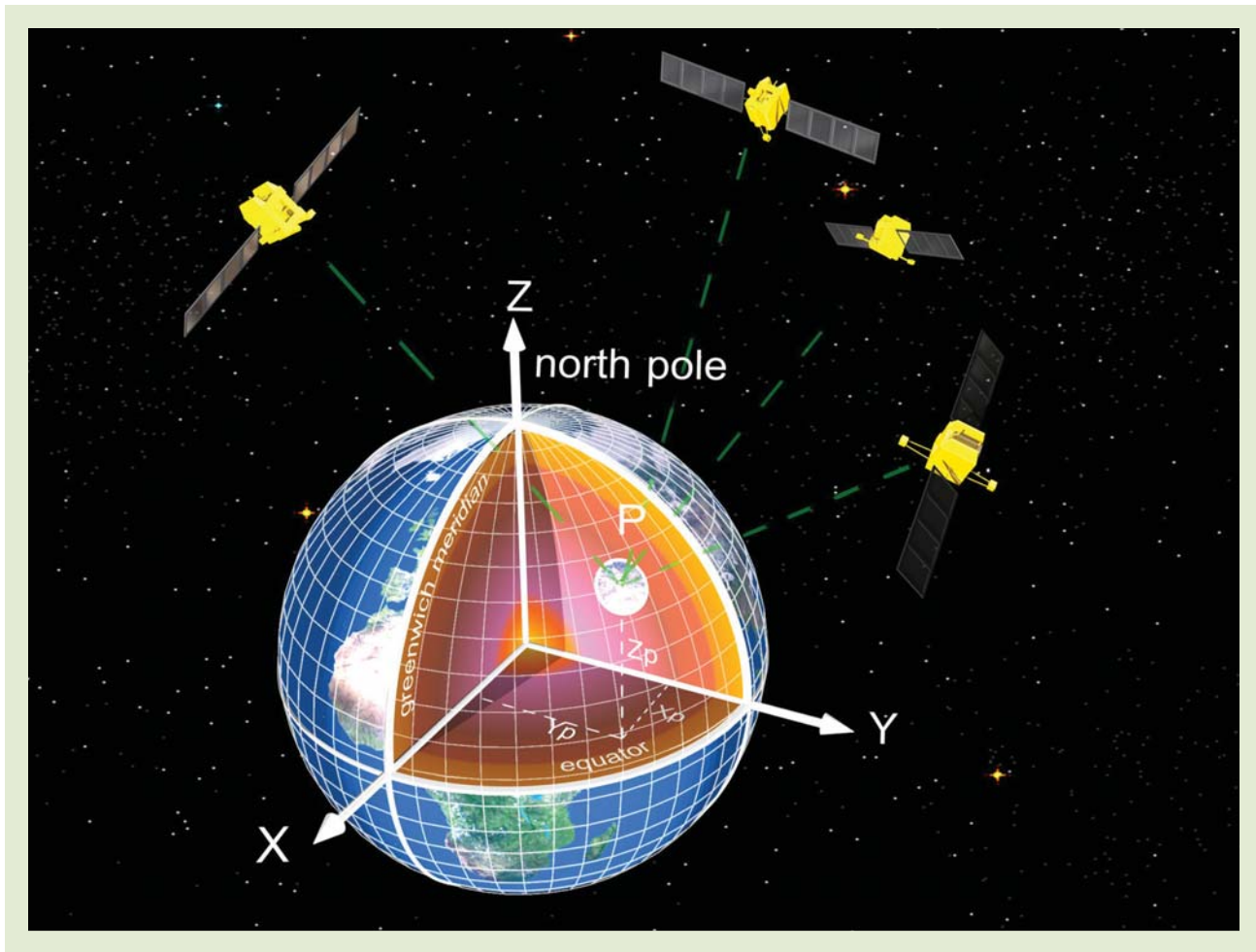


Figure 2 Geocentric coordinate system

Source: Figure created by Peter Skotte, Centre for 3D GeoInformation, Aalborg University.

Earth to a 2D map is more complex than translating a 3D object from one coordinate system to another because the shape of the Earth is rather irregular compared with well-defined shapes such as a sphere or a cube. But as in the process of referencing two 3D objects, projecting geographic objects from a 3D model to a 2D map involves a coordinate system that acts as a referencing system, allowing one to translate the shape, size, and location of objects, albeit with some compromises, called distortions. Maps describe the surface of the Earth on a flat, 2D plane, which cannot be done without distortions. The distortions in shape, size, location, and, in consequence, in the angle and direction of lines, increase dramatically when the size of the mapped area exceeds a certain limit. As soon as the model grows and covers

entire countries or a continent, the distortions rise to a significant problem, since the referencing between the real world and the modeled world gets rather imprecise.

There is a fairly simple and obvious solution for this problem as long as one wants to reference the real world to a virtual model, also called a model map. In a computer, there is a possibility of describing the world in all three geometric dimensions without distortions caused by moving objects from 3D to 2D representation. Global positioning systems are doing it already, and virtual globe applications are getting there. The coordinate systems that enable modeling geographic entities in 3D are called geocentric coordinate systems, because they have their origin in the center of the globe (Figure 2). Contemporary modeling software does not use



a geocentric coordinate system, but there are algorithms that can convert from one coordinate system to another.

Erik Kjems

See also **Absolute Space; Coordinate Systems; Earth's Coordinate Grid; Latitude; Longitude; Map Projections**

Further Readings

Loney, S. (2005). *The elements of coordinate geometry*. New York: Merchant Books.

COORDINATE SYSTEMS

Coordinate systems describe positions in space with one or more numbers. Coordinates can specify position as distance along a route, distance and direction from an origin, the intersection of two axes on a plane, the intersection of three axes in space, the intersection of spherical or ellipsoidal angles on the surface of the Earth, range circle or sphere intersections, a combination of vertical height and horizontal angles, or location with respect to celestial objects at a specified date and time.

Coordinate systems are sometimes called absolute methods of specifying location, as opposed to relative methods such as street addresses or proximity to landmarks. For the most part, coordinate systems can be converted, with some degree of uncertainty, from one coordinate system to another.

One of the most common coordinate systems used in geography is that of longitude, latitude, and altitude with respect to a specified horizontal and vertical datum. The spherical or ellipsoidal system of longitude and latitude angles is difficult to use for distance, direction, shape, or area estimation because longitude and latitude are not orthogonal to each other, are not equally scaled, and do not maintain a fixed relationship between their angular and distance dimensions on Earth. The Earth Centered, Earth Fixed X, Y, Z system (ECEF) defines a three-dimensional (3D)

orthogonal coordinate system with the center of mass of Earth as the origin. ECEF makes vector distances and directions easy to compute in space but does not define any Earth surface and so cannot be used to compute distances and directions over an Earth surface.

To facilitate wayfinding, navigation, mapping, surveying, pointing to place, and the easy and accurate computation of distance, directions, and area, coordinate systems map portions of the Earth on a flat surface. Some coordinate systems implicitly describe point positions, while others describe areas on a surface or volumes in space. Coordinate systems are defined for local surveys, engineering drawings, regional surveying, country mapping, designation of international borders, continental and global mapping and modeling of climate change, plate tectonics, seismic activity, and exploration and mapping in space.

Surveyors and engineers often consider regions spanning less than 20 km (kilometers) to be reasonably approximated by a flat plane on which distances and directions are not appreciably influenced by the curvature of the Earth. Within 20 km, the distance difference between a line on a flat plane and the surface of an ellipsoid is less than 1 cm (centimeter). Local plane coordinate systems are defined by a point of beginning (POB), with arbitrary X and Y values, and a base line (BL) defining the rotation of the local system. Coordinates are given for other points in the system through X and Y coordinates or distances and directions with respect to the POB and BL. If the POB and BL in the local system are known with respect to another coordinate system, it is often possible to convert from a local plane coordinate system to other regional or global systems.

Small countries, provinces, states, departments, or groups of counties are often mapped and surveyed with respect to coordinate systems that are based on map projections and projection parameters. These systems allow approximate distance and direction estimates to be made with the X and Y, or easting and northing coordinates for points. More exact values of distance and direction can be computed using correction values based on the position of points and lines within the projection system. The State Plane Coordinate Systems of the United States, the British National Grid, the Costa Rican National



Grids, and the Qatar National Grid are examples. The British and Qatar national grids are based on Transverse Mercator projections, the Costa Rican grids are Lambert Conformal Conics, and the U.S. State Plane System is based on almost an equal number of Lambert Conformal Conic and Transverse Mercator grids and a single Oblique Mercator projection used for southeastern Alaska.

Larger countries, provinces, or states are mapped with projections that allow position designation but are more difficult to use for precise surveys or engineering because they are more difficult to correct over longer distances. Most of the U.S. states have statewide systems for planning and transportation management that are based on a variety of projections, including Albers Equal Area, Lambert Conformal Conics, and Transverse Mercator systems.

When printed on maps, coordinate systems can identify feature positions on or above Earth. When used in geographic information system analysis, for finding a place or navigating with global positioning system receivers, coordinates must be associated with specific units, projections, projection parameters, and both horizontal and vertical geodetic datums to be unambiguous.

An example of a coordinate system in wide use is the Universal Transverse Mercator (UTM) system. UTM was defined in the 1940s by the U.S. Army as part of the Military Grid Reference System (MGRS). UTM maps the Earth from 80° S to 84° N with a series of six-degree longitudinal strips that divide the globe into 120 mapping planes, 60 above and 60 below the equator. These zones are numbered west to east with 60 easting zone numbers and designated south to north by 20 eight-degree latitudinal northing zones. With the exception of the Central Meridian, the line of longitude at the center of each easting zone, the projection parameters for each zone are the same. Above 84° N and below 80° S, MGRS uses the Universal Polar Stereographic (UPS) system.

Within MGRS, UTM designators are given as easting zone number, northing zone character, 100 km easting character, 100 km northing character, followed by easting digits and then northing digits. The number of digits indicates the precision with which the position is given. The UTM part of MGRS is now used as the U.S.

National Grid, defined with reference to the North American Datum of 1983 (NAD83).

UTM is also now used all over the world, with more than 100 UTM versions based on dozens of different geodetic datums. The UTM coordinates of a single point, often given as easting zone and northing zone, followed by the easting digits and northing digits, can differ by hundreds of meters when referenced to the wrong reference ellipsoid or geodetic datum. The same can be true for any coordinate system. Careful definition of coordinate system parameters is required for unambiguous use in positioning and analysis.

Peter H. Dana

See also **Coordinate Geometry; Coordinate Transformations; Datums; Earth's Coordinate Grid; Global Positioning System; Latitude; Longitude**

Further Readings

- Iliffe, J., & Lott, R. (2008). *Datums and map projections: For remote sensing, GIS, and surveying* (2nd ed.). New York: Taylor & Francis.
- Maling, D. (1992). *Coordinate systems and map projections* (2nd ed.). New York: Pergamon Press.



COORDINATE TRANSFORMATIONS

Coordinate transformations are methods that either convert the coordinates of locations between coordinate systems or alter locations' coordinates within the same coordinate system. Coordinate transformations are used commonly in geographic information science to assign or convert a geographic reference for data locations, to correct inaccuracies in remote sensing data pixel locations, and to change the display of geographic data on a computer screen. A coordinate transformation is specified by a mathematical model, or function, that relates locations in a source coordinate system to their corresponding locations in a destination coordinate system. When an appropriate transformation model is not known, the



coordinates in each reference system are used to either globally or locally calibrate a model from a set of point locations; then, the calibrated model is used to transform the data set.

Map projections are a commonly used coordinate transformation that apply a mathematical model to, for example, go from spherical coordinates of latitude and longitude, specified in degrees, minutes, and seconds, to planar map coordinates of Easting and Northing, specified in meters. This may involve a transformation between datums as well. Often, mathematical functions for converting between coordinate systems are not known. This is particularly the case for georeferencing remote sensor data or coregistering two geographic data sources to each other. In such cases, the model must be calibrated by establishing relationships between several locations in each coordinate system. These locations are referred to as control points (CP).

Affine Transformation

An affine transform is the most basic linear transformation model and is defined by the following equations:

$$u = \beta_0 + \beta_1x + \beta_2y$$

$$v = \beta_3 + \beta_4x + \beta_5y,$$

where (u, v) are coordinates in the target system, (x, y) are the coordinates in the source system, and β_0 through β_5 are the parameters to be estimated. These equations are solved simultaneously using a least squares technique so that the root mean-squared error,

$$\text{RMSE} = \sqrt{(u - x)^2 + (v - y)^2},$$

is minimized. The affine transformation requires at least three CPs. Once the parameters have been estimated by solving the affine equations using CP coordinates, the transformation can be applied to the entire data set.

Polynomial Models

Polynomial models are often used to transform coordinates that have greater distortion or geometric error between the input and output coordinate

systems that are not accounted for by the affine. The general form of polynomial models is

$$u = \sum_{i=0}^k \sum_{j=0}^{k-i} \beta_{ij} x^i y^j$$

$$v = \sum_{i=0}^k \sum_{j=0}^{k-i} \alpha_{ij} x^i y^j,$$

where β_{ij} and α_{ij} are the parameters to be estimated.

Local Models

In the affine and polynomial models, parameters are calibrated, then these same values are applied to all source coordinates to compute the destination coordinates. Thin-plate splines apply parameters locally across a set of data by calibrating parameters for an affine transform plus a radial basis function around CPs. Another method uses a Delaunay triangulation of the CPs and then applies a separate affine for coordinates within each triangle, where the affine is calibrated using the corner points of the triangles.

Grant Fraley

See also **Coordinate Geometry; Coordinate Systems; Earth's Coordinate Grid; Map Projections; Voronoi Diagrams**

Further Readings

Minkler, G., & Minkler, J. (1990). *Aerospace coordinate systems and transformations*. Baltimore: Magellan.



CORAL REEF

Coral reefs are a submarine geomorphologic feature found worldwide in tropical waters that provide habitat for thousands of species and invaluable resources for humanity. They are commonly distributed between latitudes 30 °N and 30° S. Coral reefs build in water temperatures



A swimmer in the Mariana Islands, Guam. Standing on or handling live corals can damage or even kill the coral polyps.

Source: David Burdick, National Oceanic and Atmospheric Administration/Department of Commerce.

that range from ~20 to ~30 °C and exist in clear waters with little to no suspended sediment or dissolved organic materials. Coral reefs also tend to be located at the western edge of ocean basins. The coral organisms that build reef structures are individual invertebrates that live in symbiosis with algae organisms known as *zooxanthellae*. As these individual corals grow, they produce a calcium carbonate (CaCO_3) shell. Empty coral shells are the primary building material from which coral reefs are formed.

Coral Reefs: A Resource at Risk

Although coral reefs exist in nutrient-poor waters, they are one of Earth's most diverse ecosystems in terms of species richness. Because of their high biodiversity and their efficiency in nutrient

recycling, coral reefs have been likened to rain forests. Not only is the living substrate diverse, but the habitat it provides allows for thousands of vertebrate and invertebrate species to exist there. Due to the high level of biodiversity that is present within coral reef ecosystems, they provide an important resource for use by humanity. Coral reefs provide a food resource rich in protein for human consumption around the globe that includes exotic dishes for export, such as Napoleon Wrasse Lips, and local staples, such as Queen Conch. Both of these species have been fished to dangerously low levels in some parts of the world. The reefs also bring in large sums of tourism income on an annual basis for the countries where they occur. Tourists spend money in these countries on food, lodging, diving supplies, and fees to experience the coral reefs. It should be noted that



even though visitors often have good intentions, they can often accidentally disturb or destroy the corals if they physically come in contact with them (first photo). Another resource that reefs provide is fauna for aquarists. The harvesting practices of aquarium fauna from coral reefs is largely unregulated and one of the most damaging. Cyanide is used by divers to stun reef fishes so that they can be captured; often the fish are evading the diver in protective crevices in the reef, and these parts of the reef are killed when they come in contact with the cyanide. The most destructive practice used to harvest stunned fish is the use of dynamite. With the use of dynamite, whole sections of coral reef structure that took hundreds of years to build are destroyed in seconds. The same reefs that provide so many resources are at risk of decline from many factors. These factors include increasing human population worldwide with increased food demands, ocean acidification, sea surface temperature increase, and harmful harvesting of fauna from the coral reef environment.

Coral Reef Formation

The geomorphology of coral reef features is formed primarily by living organisms and to a lesser extent by the cementing of available sediments. These organisms (cnidarian) provide habitat for many marine species, both vertebrates and invertebrates. There are primarily two types of corals worldwide: hard corals (scleractinians) and soft corals. The corals most responsible for reef development are hard corals, as it is these corals that build their skeletal system from CaCO_3 . It is important to note that calcareous algae existing in coral reef environments also add to the structure of a coral reef.

Young coral polyps grow on top of the previous generation of deceased corals. They add to the reef structure as they build skeletal tissue. This cycle is repeated over many generations, and after a long period of time, a reef structure begins to grow. Globally, there are three main types of reef structures that are derived from this process (first proposed by Charles Darwin): fringing reefs, barrier reefs, and atolls.

A fringing reef's development can easily be explained by using a young volcanic island as an

example. In this instance, a young volcanic island is formed, creating shallow waters that ring it. If the volcanic island is in tropical clear waters, coral polyps will attach themselves to the submerged and bare volcanic rock. The cycle of growth and deposition of calcareous skeletal material begins and aggregates to form the fringing reef. If the volcanic island remains stable, the fringing reef will remain. However, if the volcanic island begins to subside, a new reef feature will result.

When a young volcanic island with a fringing reef begins to subside, a new reef structure will form called a *barrier reef*. After the volcano begins to subside, it will pull the coral base down with it, while at the same time, younger coral grows upward. Ocean water will break through the fringing reef and separate the fringing reef from the subsiding volcanic island with a body of water called a lagoon. Given the older age of a barrier reef, corals will be just below, and may even project above, the water surface. A good example of a barrier reef is the one that surrounds Bora Bora, French Polynesia.

If the volcanic island continues to subside, a barrier reef will become an atoll. Atolls are characterized by a coral reef encircling a lagoon, with no landmass present within the reef. The landmass has subsided below the water surface and leaves the coral reef to continue to build after it has left. An example of an atoll is the Midway Atoll, a territory of the United States.

Coral Reefs and Climate

Because of coral reefs' persistence through time and their slow rates of accretion, they can be used to study past climates. Coral cores can provide a proxy for water temperatures, as each layer in a core represents winter and summer growth. Variations of these bands through time can give paleoclimatologists insights when deciphering past climates on Earth. Lately, environmental conditions (ocean temperature increase, acidification, and sea-level rise) on Earth have been changing rapidly. Because the rate of change is so rapid, reef-building organisms may not be able to adapt, leaving the future of coral reefs uncertain.

Jeffrey Dunn



See also **Atoll; Barrier Islands; Coastal Dead Zones; Coastal Erosion and Deposition; Coral Reef Geomorphology; Islands, Small; Oceans**

Further Readings

Bryant, D., Burke, L., McManus, J., & Spalding, M. (Eds.). (1998). *Reefs at risk: A map based indicator of threats to the world's coral reefs*. Washington, DC: World Resources Institute.

Waddell, J. E., & Clarke, A. M. (Eds.). (2008). *The state of coral reef ecosystems of the United States and Pacific Freely Associated States: 2008* (NOAA Technical Memorandum NOS NCCOS 73). Silver Spring, MD: NOAA/NCCOS Center for Coastal Monitoring and Assessment.



CORAL REEF GEOMORPHOLOGY

Coral reef geomorphology is the study of the distribution, morphology, and processes that control the formation and morphological change of coral reefs and reef-associated landforms. Coral reef landforms are unique, as they result from the interaction between ecological processes responsible for the growth of coral and other carbonate producers and physical processes such as waves and currents that modulate ecological processes and redistribute carbonate material within reef systems. Coral reef geomorphology aims to understand how these process interactions vary across a range of timescales and control the morphological development of whole reef structures and reef-associated features. The range of temporal and spatial scales of interest to coral geomorphology bridges both short-term ecological and long-term geological timescales. Consequently, the discipline of coral reef geomorphology makes a major contribution to global debate regarding the future geomorphic condition of coral reefs.

Coral Reef Landforms

Coral reef systems possess a range of geomorphic features (Figure 1). These features reflect

geomorphic development at a range of space and timescales and show varying levels of persistence in the geological record. A primary division is between *coral reefs* and *reef sedimentary landforms*. *Coral reefs* are three-dimensional structures consisting of veneers of living coral and reef-associated organisms that overlie sequences of previously deposited calcium carbonate separated by solutional unconformities (Figure 1). These structures evolve over geological (millennial) timescales. As geomorphic units, coral reefs range from less than 1 km² (square kilometers) in the case of smaller patch reefs to more than 100 km² in extent. Networks of reefs can form barrier complexes up to 2,400 km in length, such as the Great Barrier Reef, which is the largest biological construction on Earth.

Reef sedimentary landforms are surficial accumulations of unconsolidated sediment deposited by wave and current processes on, or adjacent to, a coral reef structure that includes reef islands and beaches (Figure 1). On geological timescales, they represent ephemeral stores of detrital material in the carbonate sediment budget. These deposits are important on the human timescale, as they form the foundation of a number of mid-ocean atoll nations, such as Tuvalu, Kiribati, and the Maldives. Both coral reefs and reef sedimentary landforms can be further divided into a suite of distinct geomorphic units that range from macro- to microscale (Figure 1).

Beginnings of Coral Reef Geomorphology

Coral reef geomorphology had its inception in the earliest modern voyages of scientific discovery to the tropical seas. Naturalists such as Joseph Banks and Alfred von Chamisso, together with navigators such as James Cook, provided the first accounts of the shape, extent, and distribution of coral reefs. These observations spawned the great *coral reef problem*, which focused on explaining the global distribution and form of coral reefs. Extensive geomorphological data sets on the apparent simplicity and recurring pattern of Pacific Ocean atolls were initially synthesized by Charles Lyell in *Principles of Geology*. These observations were later extended by Charles Darwin, whose subsidence model of coral reef development provided a

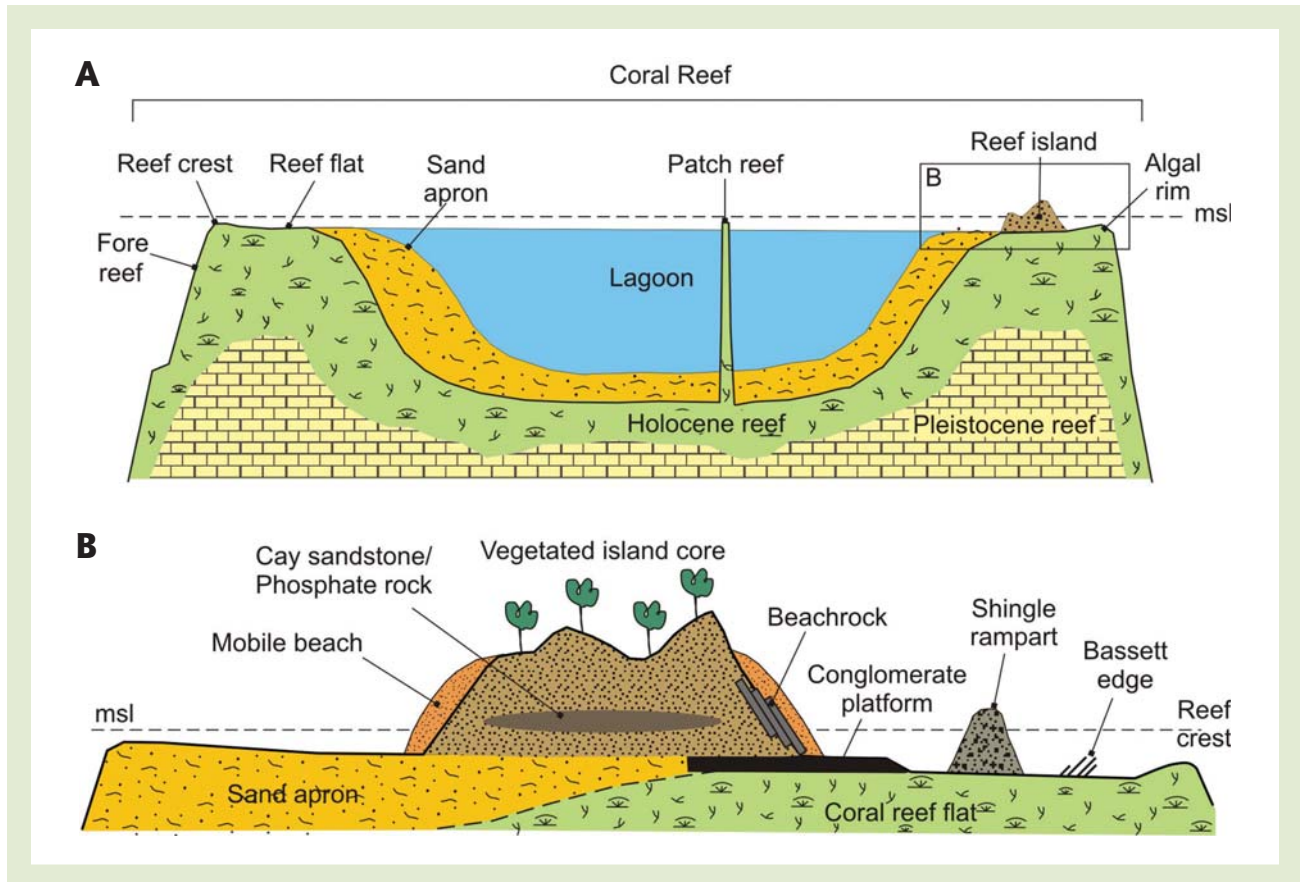


Figure 1 Schematic depiction of the range of coral reef geomorphic units: (A) cross-section of an atoll showing reef structure and major subunits of the reef platform typical of many reef settings and (B) sedimentary landform units typically found on or adjacent to coral

Source: Author.

genetic sequence explaining the formation of fringing reefs, barrier reefs, and atolls.

The coral reef problem was a geomorphological problem and dominated coral reef research for more than a century. Protagonists hotly debated competing theories on the geomorphic evolution of reef structures, which included the subsidence of volcanic cones, antecedent platforms cut by waves, rising depositional banks, and sea-level change. This debate was only resolved following deep drilling expeditions, first to Funafuti, Tuvalu, and, later, to Bikini, Eniwetok, and Mururoa atolls in the Central Pacific, where more than 1,000 m (meters) of shallow-water, reef limestone was recovered overlying volcanic foundations, thus confirming Darwin's subsidence model.

Space and Timescales of Relevance to Coral Reef Landform Development

While coral reef geomorphology had its inception in the 19th century, largely due to the coral reef problem, it was only during the early stages of the 20th century that it emerged as a clearly defined discipline. This discipline has continued to evolve and develop a deeper understanding of the process controls on reef landform development and change. The magnitude, style, and time frames of morphological adjustment of coral reef landforms are now known to vary considerably between different geomorphic units, which in turn are dependent on the timescale and space scale of interest.

The breakthrough in explaining the broad patterning of coral reefs in the ocean basins and on



basin margins relied on plate tectonics and the global arrangement of plate boundaries. These broadscale boundary controls on reef system evolution operate at geological timescales (10^6 yrs. [years]). Geomorphologists subsequently recognized that on this largely geophysical template, fluctuations in sea level at timescales of 10^3 to 10^4 yrs. control the morphological expression of contemporary reefs. Oscillations in sea level, which produced alternating periods of subareal exposure during low sea-level stands and reef growth during periods of high sea level, are responsible for the contemporary morphology of individual reef platforms.

At the intrareef-platform scale, geomorphologists have resolved the influence of sea level, waves, and tidal processes in controlling the zonality of reef organisms across reefs and the formation of reef sedimentary features such as reef islands at millennial timescales (10^2 to 10^3 yrs.). At shorter timescales, coral reef geomorphologists have also examined decadal-scale changes in reef island morphology in response to climatic, wave, and sea-level variations. At the event timescale, the impact of extreme events such as tropical cyclones and tsunamis on reef structure and function have been resolved. These latter studies have contributed greatly to understanding reef island stability and change, one of the most pressing concerns of midocean nations, with the specter of future sea-level rise.

Contributing to the Global Debate on the Future of Coral Reefs

Due to the focus on understanding reef landform-development spanning event to millennial timescales, coral reef geomorphology makes a critical contribution to global scientific debate regarding the future trajectory of coral reef landforms. In past decades, there have been contrasting views on the future of reef systems, with geologists promoting a robust view of reefs that have survived millions of years of climatic and sea-level variation, while ecologists, based on shorter-term observations of reef ecological condition, assert that reefs are fragile ecosystems that are under threat from future global environmental change. The geomorphic timescale (10^1 to 10^4 yrs.) provides a critical link between these two temporal

end members. It is able to place short-term interpretations of reef ecological condition in the context of reef dynamics over centuries and show how variations in ecology propagate through the coral reef system to influence landform change. Consequently, the discipline of coral reef geomorphology is able to address questions of landform change at timescales relevant to their management.

Paul S. Kench

See also **Atoll; Coral Reef; Geomorphology**

Further Readings

Guilcher, A. (1988). *Coral reef geomorphology*.

Chichester, UK: Wiley.

Hopley, D., Smithers, S. G., & Parnell, K. E. (2007).

The geomorphology of the Great Barrier Reef: Development, diversity and change. Cambridge, UK: Cambridge University Press.



CORIOLIS FORCE

The rotation of Earth, a spinning spherical planet, has been observed to cause a change in the trajectory of any moving body or mass (e.g., a current of air or water). This change in direction is caused by the Coriolis force, a force that is in turn created by the rotating frame of reference. The Earth's rotating frame is anticlockwise when viewing the Northern Hemisphere from space but the opposite for the Southern Hemisphere; thus, any mass given velocity across the Earth's surface will experience an apparent force that will veer it to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. Understanding the Coriolis force, named after the French engineer Gustave Gaspard de Coriolis, is fundamental to explaining major features of global atmosphere and ocean circulation, including cyclonic flow. However, the topic is often confusing, since it requires an appreciation of relative frames of reference and of scale of motion. Some essential properties of the Coriolis force are explained below.



The Coriolis force does not provide an actual push or pull on an object, nor does it originate from identifiable physical sources such as matter (as for electromagnetic or nuclear forces). Hence, it is referred to as a *fictional force*. Nevertheless, within a rotating frame of reference (i.e., noninertial), the Coriolis force has real effects on motion, causing acceleration.

The Coriolis force is proportional to the mass and velocity of the moving object and acts only to change its direction, not to reduce its speed. Therefore, the apparent deflection experienced by moving objects is often referred to as the Coriolis effect.

The magnitude of this effect, or deflection, is a function of the angular velocity of rotation and the relative location or proximity to the axis of rotation. For objects in the Earth system, this means that the Coriolis force scales according to both the rotation rate (or angular velocity, Ω) of Earth and latitude (ϕ). If the surface of the Earth is considered as a disc centered at any point location of interest, then it would have a spin about the local vertical equal to $\Omega \sin \phi$. Thus, the extra-apparent Coriolis acceleration given to all object (i.e., air mass) motion around the Earth is equal to

$$(2\Omega \sin \phi)u,$$

where u is the object's speed. This means that the slower-moving winds will be less deflected than the faster ones. Similarly, a quantity called the Coriolis parameter (f) is defined as

$$f = 2\Omega \sin \phi.$$

The Coriolis parameter remains constant for a given latitude. Moreover, the Coriolis parameter varies between zero at the equator and maximum at poles. This means that there is no need to account for the Coriolis effect acting at the equator, whereas the deflection of motion is greatest at the highest latitudes.

The Coriolis force must be accounted for in describing the dynamics of the atmosphere and oceans that have planetary scales of motion. The effect is named after the French physicist Gaspard de Coriolis, who first analyzed the phenomenon mathematically.

Bryan G. Mark

See also **Air Masses; Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Variations in Energy; Climatology; Wind**

Further Readings

Stommel, H., & Moore, D. (1989). *An introduction to the Coriolis force*. New York: Columbia University Press.



CORPORATE VOLUNTARY ENVIRONMENTAL INITIATIVES AND SELF-REGULATION

Corporate voluntary environmental initiatives are measures that aim to improve corporate environmental performance without directly involving government legislation. Though not mutually exclusive, voluntary initiatives are considered alternatives to market-based environmental incentives, such as taxes and charges and to compliance-based ones, such as government regulations. There are several different types of voluntary initiatives, and the motivations for pursuing self-regulation vary from firm to firm.

The movement toward voluntary environmental initiatives and self-regulation came to the forefront in the 1990s. Prior to this, the 1970s and 1980s were largely dedicated to command-and-control measures by governments. Some governments now believe that firms will do the right thing on their own and therefore government interference through regulation is unnecessary (i.e., market systems and influence will prevail). The increasing deregulation of the responsibilities for environmental management has led to the development of an array of voluntary corporate environmental initiatives. In many cases, eco-efficiencies (i.e., environmental and financial savings) play a large role in determining the extent of a company's environmental goodwill.

Some industries have developed set standards that businesses must voluntarily adhere to as a condition of membership, such as the chemical industry's Responsible Care program. In this



way, the industry becomes, in essence, a self-regulator, relying on peer pressure and public image as motivating factors. Other forms of voluntary initiatives include eco-labeling and accreditation programs, such as ISO 14000 of the International Organization for Standardization. Environmental reporting, such as the Global Reporting Initiative (GRI), is another way in which firms can participate in voluntary initiatives (though it should be noted that reporting may not necessarily indicate an improvement in environmental performance but rather a movement toward increased transparency of a firm's environmental performance).

Mechanisms for voluntary environmental initiatives and self-regulation can be applied separately or in combination. These range from government-to-industry pollution reduction challenges to more formal negotiated performance agreements between industry and government. In the former, government encourages the private sector to go beyond regulatory requirements, while the latter often consists of exemption from legal obligations in return for environmental improvement that goes beyond the current standards. Product stewardship programs are also gaining popularity as a type of voluntary environmental management. Liability issues are forcing businesses to rethink their environmental commitment, as banks and insurance companies are becoming increasingly stringent in their requirements of the businesses with which they work. Ideally, stewardship programs will include an examination of the entire life of a product, from the cradle to the grave. Companies with environmental management systems are also demanding that their suppliers meet similar standards. Likewise, suppliers can also influence a firm's performance. This forces businesses to improve in order to have a competitive edge. More specifically, corporate voluntary environmental initiatives can be divided into six categories:

1. Voluntary pollution control measures by individual firms (e.g., eco-efficiencies; collective industrial ecology initiatives)
2. Government-to-industry pollution reduction challenges (e.g., nonbinding challenges initiated by government)
3. Voluntary adherence to industry sector codes of practice or other certification programs (e.g., Responsible Care, ISO 14000, eco-labeling programs)
4. Performance agreements between industry and governments (e.g., formal arrangements between industry and government in the form of regulatory exemption programs)
5. Business-to-business challenges, incentives, and agreements (e.g., product stewardship programs that involve cooperation between various supply-chain stakeholders)
6. Agreements between industry and non-government third parties (e.g., involvement of community and public interest representatives)

While a few corporate environmental initiatives are undertaken simply because they are the right things to do, most voluntary initiatives are driven by one or more perceived obligations. Motivations are based on one or more of the following:

- Financial benefits (either through long-term strategies such as investing in low-emission technologies or as short-term eco-efficiencies)
- The desire to avoid or delay regulatory action
- Fear of damage to the firm's public image and associated customer and investor confidence
- Requirements imposed by banks/insurance companies (e.g., to avoid possible liability issues)
- Demands of suppliers or customers
- Pressure from fellow industry members
- Competitive advantage (or first-mover advantage over competitors)
- Image enhancement and/or branding
- The desire to be a good corporate citizen

The degree to which each of these incentives is important differs from sector to sector. For example, industries thought to pose a significant risk of environmental degradation can have a strong desire to regain public trust, which can be a powerful motivation for action. The financial benefits of environmental commitment range from short- and medium-term savings through improved resource management to long-term competitive advantages. While eco-efficiencies (e.g., energy



savings) may produce immediate and clearly measurable improvements, there is also a range of indirect benefits on which it is more difficult to put a precise monetary value (such as the outcomes of a firm's improved image or increased productivity as a result of employee "pride"). Financial incentives can be further defined to incorporate money saved and money earned as the result of a firm's level of corporate greening.

In addition to the motivations listed above, the level to which a firm participates in self-regulation or voluntary initiatives is highly dependent on other factors such as the firm's financial position, the culture in which the firm operates, and internal leadership within the firm (e.g., champions of environmentalism). These factors are known as *catalysts* and can help shape a corporation's actions by acting as a medium for encouraging or discouraging voluntary initiatives.

Voluntary initiatives are both promoted and condemned for being a replacement for regulation. Advocates of voluntary initiatives see them as being less costly and more flexible replacements for legislation. Critics see voluntary initiatives as a cover for deregulation and a mechanism for government and private sector interests to cut short-term costs by avoiding environmental responsibilities. Pure volunteerism is rare, in the sense that few firms do things to improve their environmental performance solely for altruistic reasons. Many motivations rest on the law or on possible financial gains from being green. Some would argue that corporations who put environmental and social goals over profits are in fact going against the number one goal of a firm: to make as much money as possible for its shareholders. Questions can be raised, therefore, to the extent that investors, such as shareholders, are willing to condone altruistic behavior that does not always have an immediate and positive impact on the company's bottom line. What makes voluntary initiatives challenging is also what makes them valuable.

Jennifer K. Lynes

See also **Competitive Advantage; Environmental Certification; Environmental Management; Fair Trade and Environmental Certification; Industrial Ecology; Market-Based Environmental Regulation**

Further Readings

- Annandale, D., Morrison-Saunders, A., & Bouma, G. (2004). The impact of voluntary environmental protection instruments on company environmental performance. *Business Strategy and the Environment*, 13, 1–12.
- Bakan, J. (2005). *The corporation: The pathological pursuit of profit and power*. New York: Free Press.
- Bansal, P., & Roth, K. (2000). Why companies go green: A model of ecological responsiveness. *Academy of Management Journal*, 43, 717–747.
- Gibson, R. B. (Ed.). (1999). *Voluntary initiatives: The new politics of corporate greening*. Toronto, Ontario, Canada: Broadview.
- Lynes, J. K. (2008). *Motivations for environmental commitment in the airline industry: A case study of Scandinavian Airlines (SAS)*. Saarbrücken, Germany: VDM.



COSGROVE, DENIS (1948–2008)

Denis Cosgrove was a prolific cultural geographer who is best known for his profound impacts in the field of landscape studies. In broad terms, his work dealt with issues of subjectivity, representation, and the imbrication of power and knowledge. Cosgrove connected geographic research with the arts and humanities, providing significant insights regarding the geographic imagination and representation of knowledge, especially within the practices of landscape depiction and mapping. In 1993, Cosgrove cofounded the journal *Ecumene: A Geographical Journal of Environment, Culture, and Meaning* (now *Cultural Geographies*), a significant forum within the field. He became the inaugural Alexander von Humboldt Chair of Geography at the University of California, Los Angeles (UCLA), in 1999. Cosgrove's contributions are associated with the "new" cultural geography, or cultural turn, and the "crisis of representation."



Working from historical and empirical details grounded in Renaissance and Enlightenment Europe, Cosgrove's work in cultural landscape studies focused on landscape as a "way of seeing" that represents and orders the world and humanity's relation to it. Cosgrove placed emphasis on the ways symbolic landscapes worked to order class relations and maintain social hierarchy. Since landscape may be understood as a culturally and historically specific construction, embedded with processes of social formation and naturalizing a particular social order, Cosgrove and Stephen Daniels advocated a methodology based on iconography. Iconography seeks to uncover and interpret symbolic meanings and make visible the ideology inherent in representations. These methods have been influential, especially to geographers working in various visual forms, including feminist geographers, who have explored and modified methods based on the principles of iconography.

During the 1990s, Cosgrove shifted emphasis to explore issues of representation in mapping and cartography and to deal with broader issues of cosmology and cosmography. This period is perhaps exemplified by his analysis of images from the *Apollo* mission, examining the impact of visualizing the whole of Earth from space.

Cosgrove's influence is widely acknowledged. He was an important contributor to the body of work that became known as the *new cultural geography*, drawing on social and cultural theory. Cosgrove and Mona Domosh helped develop the critique that became known as the *crisis of geographical representation* while expanding scholarly engagements with issues of authorship and authority. Through his long line of inquiry in the geographic imagination, Cosgrove's work was informed by and helped connect diverse scholarly fields, among them art history, cartographic history, and landscape architecture.

Melinda Alexander

See also **Art and Geography; Cultural Geography; Cultural Landscape; Cultural Turn; Geographical Imagination; Spaces of Representation/Representational Spaces; Symbolism and Place**

Further Readings

- Cosgrove, D. (1998). *Social formation and symbolic landscape* (2nd ed. with additional introductory chapter). Madison: University of Wisconsin Press.
- Cosgrove, D. (2001). *Apollo's eye: A cartographic genealogy of the Earth in the Western imagination*. Baltimore: Johns Hopkins University Press.
- Cosgrove, D., & Daniels, S. (Eds.). (1988). *The iconography of landscape: Essays on the symbolic representation, design and use of past environments*. Cambridge, UK: Cambridge University Press.
- Cosgrove, D., & Domosh, M. (1993). Author and authority: Writing the new cultural geography. In J. Duncan & D. Ley (Eds.), *Place/culture/representation* (pp. 25–38). London: Routledge.



COSMOPOLITANISM

Cosmopolitanism is an ethical, moral, and political philosophy that is simultaneously very old and relatively recent. The term has multiple meanings and is often used to connote someone who is sophisticated and urbane; for this reason, cosmopolitan culture is often associated with large, internationally oriented cities. There are many varieties of cosmopolitanism, including religious and secular, and conservative and liberal.

The most common form of cosmopolitanism seeks to uncouple ethics from distance, arguing that each person is bound up with, and obligated to, humanity as a whole. Cosmopolitans are moral universalists who insist on the inherent worthiness and dignity of all individuals, irrespective of their place of birth. Morally, therefore, national and cultural boundaries are irrelevant and meaningless or, worse, distractions from the important task of caring for others in light of their shared humanity. In this view, compassion and empathy know no borders. Nationalists sometimes denounce cosmopolitans for not "being one of us."

The origins of cosmopolitanism are often tracked to classical Greece, particularly to Diogenes, who when asked where he was from, famously replied



"I am a citizen of the world" (*kosmopolite*, or citizen of the cosmos), thus defying the then prevalent source of identity construction, the city-state. This notion, explicitly advanced by the Cynics and the Stoics in the 5th century BC, found its most celebrated form in Hierocles's circle model, in which each individual is located in progressively larger webs of obligation and compassion, extending from the self and family to community to region to the world as a whole. Others find elements of this notion in the Bahá'í faith, whose founder, Mirza Husayn Ali, proclaimed, "The Earth is but one country, and mankind its citizens."

During the Renaissance and Enlightenment, cosmopolitanism found new voices among the Western intelligentsia. Global circumvention initiated an incipient planetary consciousness among the elites of Europe, an understanding of the world as a unified entity. The 16th-century Spanish religious activist Bartolome de las Casas advocated on behalf of Native Americans and against the genocide then underway. In 1788, the German philosopher Christoph Martin Wieland wrote that all the peoples of the Earth are members of a single family. Immanuel Kant's 1795 essay "Perpetual Peace" offers the principle that the optimal means for avoiding war was to treat all human beings as equals; he also proposed a league of nations, but his vision collapsed in the face of the advancing nation-state. After World War II, Albert Einstein, advocate of world government, dismissed nationalism as an "infantile disease."

In this sense, cosmopolitanism is antinationalist and antipatriotic, viewing nation-states as artificial (but nonetheless very real) constructions, that is, as historical constructions, as made and not given, and therefore as mutable, plastic, and lacking inherent validity or meaning. Nationalism—with its emphasis on citizenship and on the moral geographies of inclusion and exclusion, its parochial narrowing of community to ethnic communities, its frequent xenophobia, its exaggerated importance of borders, and often its sanctification of violence against others—inherently tends to privilege some groups over others. Without this sanctification of difference, nationalism deprives itself of the legitimacy of violence against others—in other words, war, which is its central purpose. Cosmopolitans conscientiously reject the Westphalian system of national borders as

artificial and destructive constructs. As Martha Nussbaum (2002) puts it, "What is it about the national boundary that magically converts people toward whom our education is both incurious and indifferent into people to whom we have duties of mutual respect?" (p. 16). In this view, there is no such thing as an "illegal immigrant," for no human being can be "illegal."

In contrast, cosmopolitanism celebrates the commonalities that underlie human life everywhere, offering an "imagined community" that extends worldwide. In this respect, cosmopolitanism is not simply antiracist, antisexist, and antinationalist but is also at odds with much of the postmodern celebration of difference. Difference and diversity, to be sure, must be respected, but their assertion can also undermine the possibilities for collective action. Ironically, one of the central political projects of various postpositivist philosophies has been to uncouple difference from power. Thus, feminists attempt not to deny gender differences but to eradicate the power differentials between them, which typically foster male advantages and female disadvantages. Similarly, cosmopolitans seek to deny the power differences that accompany the accident of place of birth and national origin. Some cosmopolitanists maintain that they are "cosmopolitan patriots," who synthesize progressive nationalism and pride of place with sympathy and empathy for others.

The growth of cosmopolitanism may be seen in light of globalization and how it has steadily problematized issues of national origin and citizenship. For some, cosmopolitanism is a neoliberal ideology, a smokescreen for those seeking to unify various nationalities under the notion of a seamlessly integrated market. However, cosmopolitanism can also serve emancipatory purposes. Just as industrial capitalism induced a "scalar shift" in identity formation from the local city-state to the nation-state, cosmopolitanism fosters a similar scalar shift from the national to the global. The moral community to which each person owes an obligation is, by definition, worldwide, generating an obligation to "care at a distance," in which the concerns of distant strangers are held to be as important as those of people nearby. Such views are found, for example, in humanitarian interventions (by the United Nations, nongovernmental organizations, and others) and the internationalist



human rights movement in the case of genocide, famine, or other catastrophes. The ultimate expression of this line of thought is that of global citizenship, an avowed stance of many, but not all, cosmopolitans today.

Barney Warf

See also **Citizenship; Identity, Geography and; Justice, Geography of; Nationalism; Social Justice; Transnationalism**

Further Readings

- Appiah, K. (2006). *Cosmopolitanism: Ethics in a world of strangers*. London: Penguin.
- Archibugi, D. (2008). *The global commonwealth of citizens: Toward cosmopolitan democracy*. Princeton, NJ: Princeton University Press.
- Beck, U. (2004). *Cosmopolitan vision*. Cambridge, UK: Polity Press.
- Benhabib, S. (2008). *Another cosmopolitanism*. Oxford, UK: Oxford University Press.
- Brock, G., & Brighouse, H. (Eds.). (2005). *The political philosophy of cosmopolitanism*. Cambridge, UK: Cambridge University Press.
- Cheah, P., & Robbins, B. (Eds.). (1998). *Cosmopolitics: Thinking and feeling beyond the nation*. Minneapolis: University of Minnesota Press.
- Corbridge, S. (1998). Development ethics: Distance, difference, plausibility. *Ethics, Place and Environment*, 1, 35–53.
- Harvey, D. (2009). *Cosmopolitanism and the geographies of freedom*. New York: Columbia University Press.
- Nussbaum, M. (2002). Patriotism and cosmopolitanism. In Nussbaum, M. & J. Cohen (Eds.), *For love of country* (pp. 3–20). Boston: Beacon Press.
- Silk, J. (1998). Caring at a distance. *Ethics, Place and Environment*, 1, 167–182.
- Singer, P. (2002). *One world*. New Haven, CT: Yale University Press.
- Smith, D. (2000). Moral progress in human geography: Transcending the place of good fortune. *Progress in Human Geography*, 24, 1–18.
- Vertovec, S., & Cohen, R. (Eds.). (2003). *Conceiving cosmopolitanism: Theory, context, and practice*. New York: Oxford University Press.



COST-BENEFIT ANALYSIS

Cost-benefit analysis (CBA) is a decision-making support tool widely used to evaluate public sector interventions from a social perspective and in monetary terms. CBA is used to assess projects (e.g., roadway construction) as well as policies (e.g., environmental regulation). On the premise that decision making should include a comprehensive account of costs and benefits, CBA aims to provide a balance sheet of these costs and benefits.

To take the long-term impacts of a given intervention (e.g., a project) into consideration, CBA contrasts the costs and benefits of the project over its anticipated lifespan by discounting the future value of money. Essentially, the aim of CBA is to provide a *net present value* of the benefit-cost ratio. If this value is positive for any given project under consideration, the project is deemed to be feasible. Conversely, a negative value suggests that the project should be rejected, as society would be worse off with the project. This idea can be expressed mathematically as

$$NPV_p = \sum_{t=0}^t \frac{(B_t - C_t)}{(1+r)^t},$$

where NPV_p is the net present value of the project, B_t are the benefits generated at time t , C_t are the costs of the project at time t , and r is the discount rate.

While most often used *ex ante* to determine the feasibility of an intervention, CBA is also used *ex post* to evaluate the impacts of past decisions or *in medias res* to evaluate a project (or policy) during its lifespan. Additionally, CBA can be employed in a comparative manner to identify one intervention of any number of alternatives that is most beneficial to society. To arrive at a recommendation, CBA generally includes the following steps:

1. Define intervention and identify alternatives
2. Identify stakeholders and objectives
3. Catalog costs and benefits
4. Predict and quantify changes
5. Monetize the costs and benefits
6. Discount costs over the anticipated lifespan



7. Compute the net present value
8. Perform a sensitivity analysis

There are three criticisms regarding CBA. The first focuses on the fact that CBA considers the impacts on society as a whole rather than the impacts on individuals. While a given intervention may generate a positive net present value for all of society, the impact for individuals or a portion of society could well be negative (CBA does not take redistribution of benefits into consideration). The second criticism relates to difficulties of assigning a monetary value to certain impacts (e.g., environmental degradation) or even determining if a specific impact is considered a cost or a benefit. The third criticism is that CBA has been lacking a spatial perspective. Recently however, there have been advancements in linking CBA analysis and geographic information systems to increase the spatial sensitivity of the method.

C. Patrick Heidkamp

See also *Applied Geography; Business Geography; Business Models for Geographic Information Systems; Geographic Information Systems; Spatial Decision Support Systems*

Further Readings

- Bateman, I. J., Lovett, A. A., & Brainard, J. S. (2003). *Applied environmental economics*. Cambridge, UK: Cambridge University Press.
- Boardman, A., Greenberg, D., Vining, A., & Weimer, D. (2006). *Cost-benefit analysis: Concepts and practice* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.



COUNCIL FOR MUTUAL ECONOMIC ASSISTANCE (COMECON)

The end of World War II saw the United States and the Soviet Union in a struggle for dominance in Europe. The United States offered European states the Marshall Plan as a program to rebuild

<i>Full Members (Year Joined)</i>	<i>Observer Status</i>
Soviet Union (1949)	Afghanistan
Poland (1949)	Angola
Czechoslovakia (1949)	China
Bulgaria (1949)	Ethiopia
Romania (1949)	Laos
Hungary (1949)	Mozambique
Albania (1949)	Nicaragua
German Democratic Republic (1950)	North Korea
Mongolia (1972)	South Yemen
Vietnam (1978)	
<i>Associate Members (Year Joined)</i>	<i>Cooperation Agreements</i>
Yugoslavia (1964)	Finland
	Iraq
	Mexico

Table 1 COMECON membership

Source: Author.

the war-ravaged economies and their infrastructure. Invitations to participate were offered to Czechoslovakia, Hungary, and Poland, but under pressure from the Soviet Union, they declined. As a response, the Soviet Union formed the Council for Mutual Economic Assistance (COMECON). The majority of members were European, but as Soviet efforts to influence other countries gained ground, others in southeast Asia, southwest Asia, and Latin America established relationships, if not full-fledged membership (see Table 1 for membership).

Council Session: This was the main body of COMECON, whose decisions were not necessarily binding.

Executive Committee: Composed of deputy prime ministers, the group met quarterly. The body worked as the chief executive organ of the Council Session. Primarily, the Committee served to elaborate on policies and oversee their implementation between meetings of the Council Session.

Council Committees: These dealt with a range of issues, such as planning, metrical-technical supply,



and cooperation in scientific and technological development.

Permanent Secretariat: This body has been likened to a form of civil service, creating agendas for meetings and preparing statistical papers for use.

Standing Commissions: Several were created, focusing on issues such as the chemical industry, agricultural policy, and construction. Later in COMECON's history, a commission on environmental protection was established.

From COMECON's inception, multilateral trade was deliberately restricted by Joseph Stalin. After his death, the 1950s saw a trend toward increasing coordination of plans and economic integration. This resulted in attempts to foster specialization by the various members based on perceived comparative advantages. These efforts were hampered by the concept of the interested-party principle, where a member state could opt out of projects. Romania, for example, rejected the idea that it should focus on agriculture and instead sought to diversify and industrialize the domestic economy.

Bilateral trade (trade between two countries) dominated trade among COMECON members, affecting a state's ability to seek better prices within the COMECON sphere. This was partly a function of the inconvertibility of currencies to the so-called hard currencies of Western Europe. Emphasis on domestic 5-yr. (year) plans at the expense of COMECON goals was the norm. It was claimed that trade would occur when 5-yr. plans were evaluated and countries would see what other members were producing that could meet domestic shortages.

In the absence of normal price-setting markets, barter became an important process in COMECON trade. This clearly benefited countries lacking technology as they parlayed agricultural commodities and raw materials into finished goods produced by other members. This would extend to oil and natural gas exported from the Soviet Union in the 1970s and sold at submarket prices to support other member states.

Due to problems in coordinating trade prices between states, most COMECON members practiced autarchy (efforts at self-sufficiency) at many levels, seeking to insulate their citizens from

shortages stemming from missed production targets. Another issue was the tendency for the best-quality goods to be reserved for domestic consumption, resulting in shoddy, substandard goods and materials being traded with other member states.

Problems, namely, a lack of economic efficiency, plagued the organization throughout the 1970s and 1980s. Growth rates were declining throughout the period, and member states found themselves importing high-technology goods through hard-currency debt that could not be paid off easily.

Crises that affected efforts to reform COMECON included the rise of the Solidarity movement in Poland and the subsequent imposition of martial law, along with the deaths of former Soviet leaders Leonid Brezhnev and Yuri Andropov. These led to delays in talks that would address the economic issues the members were experiencing. Efforts by Mikhail Gorbachev to reform the organization and foster deeper connections were blocked by the more conservative members.

With the 1989 breach of the Austrian-Hungarian border by East Germans wishing to migrate to Western Europe, the rationale for COMECON ceased to exist. The Soviet Union did not intervene to stop the border crossings, signaling an acceptance that the COMECON members were on their way to independence from Soviet control. Eventually, the barter system gave way to trade in hard currencies, which caused a general decline in intrabloc trade. COMECON continued to hold meetings into the early 1990s. The final meeting, held in Budapest, Hungary, in 1991, saw an agreement between all members to disband the organization later that year.

Several countries expressed interest in the creation of a successor association, particularly addressing the economic concerns of Central and Eastern Europe. The demise of the organization meant that members with previously established economic specializations serving the markets in the Soviet Union lost customers as the Soviet Union reoriented its economy. Observers note that essentially, the Central and East European COMECON members traded dependence on the Soviet Union's market for the European Union market.

Darren Purcell



See also **Cold War, Geography of; Commonwealth of Independent States; Communism and Geography**

Further Readings

- Bideleux, R., & Jeffries, I. (2007). *A history of Eastern Europe: Crisis and change* (2nd ed.). London: Routledge.
- Jeffries, I. (1993). *Socialist economies and the transition to the market: A guide*. London: Routledge.
- Metcalf, L. K. (1997). *The Council of Mutual Economic Assistance: The failure of reform* (East European Monographs). New York: Columbia University Press.



COUNTERMAPPING

Countermapping refers to the use of cartographic tools and maps to correct or denounce injustice. It is usually carried out in opposition to maps or spatialities produced by powerful interests, be they from the state, the private sector, or elsewhere. Countermapping's uniqueness comes from its focus on explicit politics, advocacy, and activism. In geography, countermapping has most often been associated with questions and struggles over land use and conservation. Use of the term in the discipline began to pick up rapidly after the mid 1990s, with Nancy Peluso's work on countermapping in Indonesian forests. Despite the recent emergence of the term in Anglophonic geography, one could trace a countermapping tradition at least as far back as the Geographical Expeditions of William Bunge in the 1970s.

Rather than a subfield in its own right, it is better to conceive of countermapping as a social practice or tactic used by many different groups dealing with a variety of issues. Several mapping tendencies are emerging under the rubric of countermapping. These include the following:

PPGIS (public participation geographic information systems): As the name implies, this usually consists of methods of carrying out GIS-based projects that emphasize community input and participation.

Indigenous cartography: This is the remapping of territories according to indigenous concepts and uses. These maps have been useful in land claims struggles vis-à-vis government authorities.

Activist or radical cartography: This includes the creation of maps by and for social movements to analyze problematics, form alliances, or design strategies toward a campaign. Many projects of Activist Cartography are carried out by critical artists experimenting with the tool of mapping.

These three variations of countermapping should not be understood as subfields with their own canons. Rather, they are more like areas of focus for countermapping practitioners, and each has its own trajectory and referential projects. Additionally, these three ways of engaging the practice of countermapping are not exhaustive. They are mentioned to stress the fact that countermapping is not a set of unrelated sporadic experiments at using maps to "fight the powers that be." Countermapping in and of itself is becoming a community and network of practices, helping spread the use of maps and cartographic tools with aims of social justice.

Countermapping can include all kinds of cartographic forms, even standard ones. PPGIS, for example, often uses regular GIS representations to carry out its goals. Usually, though, countermapping also implies a critique of much of cartographic logic as such. Cartography in this sense is understood as a state-supported technology that often helps produce the situations of injustice against which countermapping is being deployed. This notion becomes clear in examples of indigenous and activist cartography. Both of these areas are developing innovative ways of presenting cartographic information, helping challenge traditional notions of the "map" or even what constitutes a map. Additionally, the tools used by countermapping projects run the full gamut of the imaginable, from the latest GIS software and locative media to sketch maps drawn by amateurs, imagination being the key limit.

Frequently, countermapping is practiced at the margins of geography departments and universities. This is especially the case with activist cartography, where small mapping groups carry out a project, often without formal cartographic



training. Countermapping is a growing phenomenon, increasingly brought up within the field of geography and increasingly used to support community struggles. With the spread of accessible geographic and mapping tools, especially through the Internet, it seems that countermapping will only spread further in the near future.

Sebastian Cobarrubias

See also Bunge, William; Cartography; Indigenous Cartographies; Justice, Geography of; Participatory Mapping; Public Participation GIS; Resistance, Geographies of; Social Justice; Social Movements

Further Readings

- Crampton, J., & Krygier, J. (2006). An introduction to critical cartography. *ACME*, 4(1), 11–33.
- Harris, L., & Hazen, H. (2006). Power of maps: (Counter) mapping for conservation. *ACME*, 4(1), 99–130.
- Hodgson, D., & Schroeder, R. (2002). Dilemmas of counter-mapping community resources in Tanzania. *Development and Change*, 33, 79–100.
- Holmes, B. (2004). *Imaginary maps, global solidarities*. Retrieved December 10, 2008, from Piet Zwart Institute Web site: <http://pzwart.wdka.hro.nl/mdr/pubsfolder/bhimaginary>
- Mogel, L., & Bhagat, L. (Eds.). (2007). *An atlas of radical cartography*. Los Angeles: Journal of Aesthetics and Protest Press.
- Peluso, N. (1995). Whose woods are these? Counter mapping forest territories in Kalimantan, Indonesia. *Antipode*, 27(4), 383–406.
- Pickles, J., & Cobarrubias, S. (2008). Spacing movements. In B. Warf & S. Arias (Eds.), *The spatial turn* (pp. 36–58). New York: Routledge.

19th-century English settlements. *Counterurbanization* can be defined as the deconcentration of people and economic activity from urban to rural areas. It first appeared in the 1960s in the United States, giving a name to the opposite of the classic urbanization process, which involves centralizing population and economic flows in the main cities and large metropolitan areas. A process in the opposite direction began, with movement outward from large cities to smaller urban and rural settlements. This marked a step forward from traditional theories based on a hierarchical organization of settlements and the demographic and economic prominence of cities over towns and villages.

Counterurbanization represents a reversal of demographic and economic flows from larger to smaller settlements. The flows of urban population to rural areas have a varied social mix, such as retired people looking for quiet places with a healthy environment, emigrants returning to their origins after working in the city, social groups looking for different forms of life related to green philosophies (“alternative counterurbanization”), and even liberal medical, administrative, or education professionals practicing as much in public service as in private. Counterurbanization can be planned or spontaneous; regional policies may contribute to the economic development and population of rural areas, and individual people or families may change their place of residence of their own will.

France now distinguishes between different forms of demographic deconcentration processes depending on the urban or rural viewpoint; from the urban viewpoint, counterurbanization is also called *exurbanization* and from the rural viewpoint, *rurbanization* or *peri-urbanization*. These terms mean essentially the same thing, as they are nothing more than expansion processes away from cities caused by the spread of rapid transportation, the rejection of collective housing, anti-urban tastes in the ownership of individual properties based on green philosophies, and so on. The concept of counterurbanization is part of the transition from an industrial to a postindustrial society, bringing with it new processes for which social scientists need to define new concepts. The decline of large industrial cities and the rural resurgence bring with them a demographic



COUNTERURBANIZATION

The concept of *counterurbanization*, as opposed to suburbanization, is relatively recent in international academic literature; nevertheless, the process to which it refers is not so recent, since counterurbanization was already noticeable in



deconcentration and a change in direction from the classic country-to-city migratory flows to city-to-country flows.

Carlos Ferrás Sexto

See also **Exurbs; Postindustrial Society; Suburbs and Suburbanization; Urban Hierarchy; Urban Sprawl**

Further Readings

- Berry, B. (1976). *Urbanization and counterurbanization*. New York: Arnold.
- Cloke, P. (1985). Counterurbanization: A rural perspective. *Geography*, 70(1), 13–29.
- Ferrás, C. (1998). *La Contraurbanización. Fundamentos teóricos y estudio de casos en Irlanda, España y México* [Counterurbanization: Theoretical fundamentals and case studies in Ireland, Spain, and Mexico]. Guadalajara, Mexico: Universidad de Guadalajara.
- Loeffler, R., & Steinicke, E. (2007). Amenity migration in the U.S. Sierra Nevada. *Geographical Review*, 93(1), 67–88.
- Mitchell, C. (2004). Making sense of counterurbanization. *Journal of Rural Studies*, 20, 15–34.



COUPLED HUMAN AND ANIMAL SYSTEMS

Coupled human and animal systems (CHAS) are those in which two elements—humans and animals (domesticated or semidomesticated)—are linked and depend directly on one another. Such systems represent one of many possible types of subsystem that exist within coupled human and natural systems. A CHAS is characterized by human and animal interactions, which create an interdependent relationship through reciprocal effects and complex feedback loops. Consequently, the system tends to react as a single entity to changes in the natural environment and to social, economic, and political human activities (Figure 1).

CHAS include various forms of nomadic pastoralism (e.g., transhumance and ranching), which,

unlike farming, is an extensive form of land use typically practiced in geographical areas with little to no arable land and where farming activities would be socially and economically unviable. These locations include areas with extreme and highly variable climatic conditions, such as the arid regions of Africa and inner Asia, the Arctic and sub-Arctic regions of Eurasia, and various mountainous regions (e.g., the Caucasus, Pamirs, and Pyrenees).

Although there is much debate over what constitutes a nomadic and a pastoralist existence, one must remember that the concept of CHAS serves research-analytical purposes only. When questioning what should or should not be considered as a CHAS, rather than focusing on terminology, it would perhaps be more useful to ask oneself the following question: Can the human and animal relationship under review be considered as an integral interdependent system? If mostly it can, then CHAS would probably be a useful concept when studying how changes in the natural environment (e.g., global climate change, disease and species extinction) and social, economic, and political human activities (e.g., technology, commodity prices and trade, land encroachment and legislation) influence human populations. However, not every group practicing nomadic pastoralism should necessarily be viewed as being a CHAS. The coupled system approach would be of low analytical value for groups for which pastoralism is merely one branch of their economic mix, which, even if it has considerable symbolic or cultural value, exists alongside other branches with similar or potentially higher economic importance. In such groups, changes in the total environment (i.e., the natural environment and social, economic, and political human activities) that affect animals are unlikely to have a comparable level of influence on humans, since the latter can compensate by relying on other economic activities. The relations between humans and animals inside CHAS can be best viewed as the complex interplay that exists between animal behavior and the actions of humans. Humans' actions are aimed at satisfying the biological needs of their animals while ensuring their own social, economic, and political needs. From humans' viewpoint, this interplay results in achieving control over their animals to maintain their cohesion, manageability, and safety without compromising their own

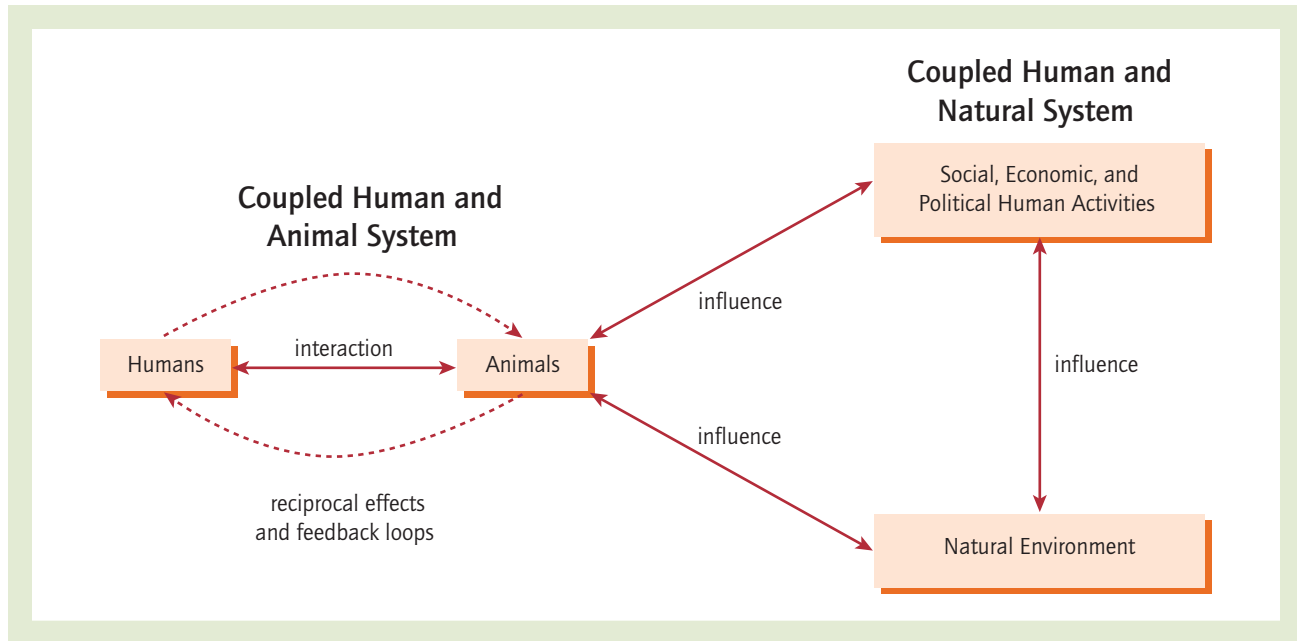


Figure 1 Coupled human and animal systems

Source: Author.

requirements. For animals, the interplay with humans offers pastures and protection, which, for many species, are vital for their survival. One of the most discernible outcomes of the existing interplay within CHAS is spatial and temporal movement. Movement is achieved by humans' skillful perception of animal behavior and their adeptness in reacting to it, which is also influenced by numerous social, economic, and political human activities. Therefore, the interplay is influenced, on the one hand, by the impact that ecological factors have on animals' behavior and, on the other, by nonecological factors that have an impact on the actions of humans.

The utility of CHAS as an analytical concept is particularly relevant in our present-day global world. There is tremendous uncertainty and alarm concerning the impacts that anthropogenic activities have on all manner of environmental processes, ranging from the loss of large mammals due to habitat loss, to the reduction of biodiversity due to farming practices, to landscape shifts due to climate change. In addition, much uncertainty exists with regard to how economic and political change affects human groups, particularly those that are numerically small, living in

discrete and relatively remote areas and having a domestic mode of economic production. Consequently, research concerned with understanding the complex systems of interaction between humans and their total environment is becoming increasingly popular. It no longer suffices to merely assess the impacts of a particular stress (e.g., a pollutant) on the environment; increasing attention is being paid to understanding the relative vulnerability of a system to a particular stress. Therefore, studying the interactions that exist between humans and animals is fundamental to assessing how external stresses are likely to influence that system.

The study of CHAS has become a multidisciplinary endeavor, largely undertaken within the field of human ecology, that includes the integration of quantitative and qualitative data. The understanding of a CHAS requires long-term participant observation of human and animal interaction, as well as biological and ecological studies aimed at understanding animal ethology. One of the greatest challenges in this endeavor is designing a common methodology.

Mark J. Dwyer



See also **Animal Geographies; Coupled Human and Natural Systems; Human Ecology; Nomadic Herding; Nomadism**

Further Readings

- Behnke, R. H., Scoones, I., & Kerven, C. (Eds.). (1993). *Range ecology at disequilibrium*. Boulder, CO: Westview Press.
- Dwyer, M. J., & Istomin, K. V. (2008). Theories of nomadic movement: A new theoretical approach for understanding the movement decisions of Nenets and Komi reindeer herders. *Human Ecology*, 36, 521–533.
- Khazanov, A. M. (1994). *Nomads and the outside world* (2nd ed.). Madison: University of Wisconsin Press.
- Little, M. A., & Leslie, P. W. (Eds.). (1999). *Turkana herders of the dry savanna*. New York: Oxford University Press.
- Tyler, N. J. C., Turi, J. M., Sundset, M. A., Strom Bull, K., Sara, M. N., Reinert, E., et al. (2007). Saami reindeer pastoralism under climate change: Applying a generalized framework for vulnerability studies to a subarctic social-ecological system. *Global Environmental Change*, 17, 191–206.



COUPLED HUMAN AND NATURAL SYSTEMS

Coupled human and natural systems (CHANS) are integrated systems in which human activities interact reciprocally with natural systems. As a species, humans' most successful adaptation has been the ability to manipulate our environment to suit our needs. Though people have always interacted with their environment, the scope of interactions has expanded significantly since the Industrial Revolution, as population, technology, and resource use have increased. Though the term *CHANS* is new in the 21st century, elements of this approach have been part of geography since its inception. In particular, a focus on human-environment relations has been a major theme in

geography since at least the 19th century. However, physical geographers have tended to focus on biophysical systems, and human geographers have tended to focus on social systems. CHANS adds several foci to the discussion of human-environment relations, including a systems approach, a focus on complexity, and a focus on the reciprocal nature of the relationship between humans and their environment. The interdisciplinary nature of geography has kept itself well poised to address questions regarding the interaction between humans and their environment. Unfortunately, the backlash following the rise and fall of environmental determinism caused geographers to focus on the effects of humans on the environment (environmental geography), at the expense of complex, two-way interactions that may reach from local to global scales. As a result, the varied responses of human societies to environmental change have received less attention, with the exception of hazards research. Recent projects supported by the National Science Foundation, the National Oceanic and Atmospheric Administration, and the National Institutes of Health have focused funding and attention on CHANS, not just in geography but across the sciences, making it an extremely relevant and timely topic.

Since the development of CHANS as an area of study, human-environment relations have been studied in a more holistic and reciprocal fashion to address pressing environmental challenges such as global climate change, land use and cover change, rapid urbanization, exotic species invasions, and population studies. These environmental and associated societal changes have necessitated a sophisticated and complex approach to understanding humans and their environment. Research approaches must be capable of measuring biophysical variables (land cover change, acid rain, greenhouse gases, biodiversity, and forest fragmentation), human variables (socioeconomic processes, qualitative and quantitative aspects of culture and societies, agents, policies, and governments), linkages across human and environmental spheres (resource use, natural hazards, and pollution), and complexity (nonlinearities, thresholds, feedbacks, nested scales, discontinuities, unintended consequences, emergent properties, ecological surprises). In addition, many interactions



between humans and their environment transcend single scales, so approaches must be capable of viewing problems from the scale of a single human actor up to the global scale.

The remainder of this entry is devoted to defining the major characteristics of CHANS, an exploration of climate change as a CHANS, and a review of methods and approaches used to study CHANS. The entry concludes with a discussion of recent gains in knowledge from studies of CHANS as well as limitations of CHANS for understanding environmental problems.

Characteristics of CHANS

CHANS are complex systems that pose unique challenges to science because of their linkages across spheres, varying spatial and temporal scales, and nonlinear behavior. CHANS, by their very nature, are defined by linkages across biophysical and socioeconomic spheres. For example, the production and transport of atmospheric pollutants, the importation and distribution of exotic species, and natural hazards all occur at the intersection of human and natural systems. Patterns that arise from these intersections and linkages cannot be understood without engaging multiple disciplines spanning the social and Earth sciences. Linkages are also characterized by reciprocal effects; human societies both act on the environment (generate pollutants) and are subject to environmental change (human health is affected by those pollutants once transported by the atmosphere). Human activities may generate feedbacks that further exacerbate (positive feedbacks) or dampen (negative feedbacks) the effects of their original activities. For instance, fire suppression in the Western United States during the mid 20th century may have led to an increase (positive feedback) in wildfire activity in later decades due to a buildup in fuel for fire. Linkages and feedbacks across spheres demand multidisciplinary science, sometimes across fields with starkly different philosophies, data, and models, so research in CHANS is interdisciplinary.

Scale is another major challenge to understanding CHANS. Interactions between humans and their environment transcend scales, including spatial scales (local to global), temporal scales (time lags from seasons to centuries), and organizational

scales (individuals to international organizations). Global patterns and processes can be generated by the synergistic and cumulative effects of local processes, which repeat throughout the globe (the cumulative effect of carbon dioxide [CO_2] emissions by cars and power plants on the atmosphere). Relationships can develop across great distances, for example, through teleconnections in the atmosphere, through outsourcing of jobs from developed countries to India, or in the interaction between social systems and natural systems (loss of native plants due to high deer populations and export of wild harvest products). Linkages also occur across political (importation of exotic species from other countries), economic (fossil fuel burning in developed countries affecting climate and livelihoods in underdeveloped countries), and ecological (passage of migratory animals through many ecosystems) boundaries or across urban to rural gradients (solid waste transport and storage). Even the response of socioeconomic systems to environmental problems may not match the scale at which biophysical phenomena occur. For example, lands that were set aside to protect threatened or endangered species are typically too small to maintain viable populations of those species, particularly in the face of environmental change. Cross-scale phenomena make CHANS difficult to measure and manage, since methods tend to be focused at a particular spatial scale and those scales tend to be more appropriate for socioeconomic and political systems than for biophysical ones.

CHANS are also characterized by their unique properties over time. While members of *Homo sapiens* have always manipulated their environment to their advantage, the speed at which we have altered our environment has exponentially expanded as populations, technology, and resource use have increased. Impacts themselves have become increasingly rapid in tandem with human development. For example, globalization and rapid international transportation has led to multiple introductions of the same exotic species, yielding faster rates of spread. Since industrialization, the impacts of natural phenomena on people have become more severe as population densities in areas subject to natural hazards have increased. This has combined with the increased frequency of natural hazards in some cases. For example,



the rising frequency and intensity of hurricanes with global climate change have been coupled with increasing population densities near coastal areas, resulting in more destructive and costly disasters.

Another pattern typical of CHANS is that the effects of linkages between humans and their environment may not be detectable for years, decades, or even centuries. These long-term impacts, or legacy effects, are particularly challenging for society. Deforestation and mining in Appalachia during the early 20th century, for instance, led to long-term, lagged costs for drinking water and recreation in the late 20th century. Like legacy effects, scale mismatches over time pose challenges to policy. When the rate of change in natural systems does not match that of human institutions, societies have difficulties addressing environmental problems. One of the great challenges to global warming policy is the slow rate of temperature increase (measured in decades) relative to the term limits of elected officials (measured in years).

The unique characteristics of CHANS across spatial and temporal scales, combined with the complexity of multiple spheres (socioeconomic, political, ecological, geological, atmospheric, etc.), tend to lead to nonlinear behavior—a small change in one variable might lead to a large change in another variable. Nonlinear systems may have thresholds (transition points between alternate states or regimes) that make them difficult to predict and model. In some cases, slow processes or fine scale patterns may accumulate to produce emergent properties or surprises not immediately observable or predictable based on the individual contributions. CHANS also tend to be characterized by not one but many linkages between spheres, resulting in multivariate, interacting relationships between humans and their environment. By recognizing these nonlinear properties, it might be possible to define patterns and processes typical of CHANS regardless of geographic and cultural differences.

Climate Change as a CHANS

One of the clearest examples of a CHANS is global climate change. The way societies choose to address climate change may also serve as a

model for addressing other CHANS. Since the Industrial Revolution, fossil fuel emissions, forest clearing, and biomass burning have added CO₂ to the atmosphere. This rise in CO₂ has led to increasingly serious concerns about global climate change and has generated many potential responses to mitigate and adapt to these changes. Humans interact reciprocally with the carbon cycle in a variety of ways and at a variety of spatial and temporal scales, generating a challenging system to study, model, and predict—a system that is an excellent case study of a CHANS.

While individual decisions about energy use and transportation drive individual contributions to the atmospheric carbon pool, human institutions such as private utility companies, regional and national transportation networks, and international oil and gas corporations influence CO₂ emissions regionally and globally. Direct human impacts on atmospheric carbon via fossil fuel burning are generated across several scales from individual actors (agents) up to regional, national, and international institutions. Forest clearing and biomass burning also contribute to atmospheric carbon, and these processes are similarly a function of individual decision making, local- to regional-scale economic conditions, and global economic forces. As a result, individual contributions, be they fossil fuel burning or forest harvest, have slowly accumulated to produce the emergent property of global climate change.

Human activities also have the potential to offset the rising levels of atmospheric CO₂. For example, rapidly growing forests take up large volumes of atmospheric CO₂ in their woody tissues. Local agents, such as private forest landowners, may make individual decisions about timber harvest, though these may be a function of local, regional, and global economic forces. If forces are regional or global (e.g., an international CO₂ market), then individual actions may have the potential to accumulate and influence the global carbon budget, in this case by sequestering large amounts of carbon in forests. Large industrial landowners may also influence timber harvest locally, regionally, and internationally and may respond to both local and distant economic forces. These types of local responses to distant events (teleconnections) are important characteristics of both the Earth system and CHANS.



Other important characteristics of CHANS are linkages across spheres and nonlinear changes over time. Forests in Eastern North America are currently reaching economic maturity following major cutting events at the turn of the 20th century. From a systems perspective, carbon has gradually been accumulating in these forests since about 1900, offsetting early emissions of CO₂. As these forests have matured, their rates of sequestration have slowed. Large amounts of carbon could be rapidly released when trees become large enough to mill and when markets materialize. Thus, a threshold in carbon sequestration could be reached when biophysical and economic processes align, resulting in a rapid release of accumulated carbon.

As the atmospheric concentration of CO₂ rises, local, regional, and global consequences emerge. In some cases, these consequences have the potential to feed back to human agents and institutions and ultimately to the carbon cycle itself. For example, as summers become longer and hotter, a larger proportion of homes are adding energy-intensive cooling systems—further driving energy use and additional carbon emissions. In Western North America, summers have grown longer, the duration of snow cover has been reduced, and fire activity has increased, resulting in larger CO₂ emissions from fires. Again, a positive feedback develops, resulting in major consequences for homeowners living at the urban-wildland interface, forest managers, and insurance agencies, as well as the atmosphere.

Methods and Tools

The methods and tools applied to CHANS are both quantitative and qualitative, including modeling, studies of land use and cover change (LUCC), and studies of historical land use change. Several modeling approaches have been applied to CHANS, including mathematical or statistical equations that predict human activity or environmental impacts, models that include spatial information (remotely sensed data or data collected on the ground that include spatial information) in a geographic information system, and agent-based models that focus on the behavior and interactions of individual agents. In some cases, several modeling approaches are combined, for example,

agent-based models of land use. Regardless of the framework, models must be able to integrate several data sources appropriate for studying human and biophysical systems, including interviews, local and national census data, biological processes, and spatial patterns.

Studies of LUCC may test hypotheses about how CHANS influence the spatial pattern of land use or how land use and land cover may affect human decisions. Landscape patterns are measured as important emergent properties of complex systems—properties that focus attention on the interactions between humans and their environment. Studies of LUCC might ask, “Do the locations of timber mills affect the spatial pattern of forest fragmentation?” or “How does the spatial pattern of coastal settlement affect inundation following a tsunami?”

Rather than focusing on spatial pattern, another approach uses change over long periods of time to test hypotheses about CHANS. This approach integrates historical data, archaeological data, and records of past environmental change (e.g., pollen, tree rings, or sediments) to understand how different societies have interacted with their environment over time. These studies have tended to focus on the role of climatic variability in affecting the trajectory of a culture, but some have also explored how depleted natural resources can lead to the collapse or expansion of cultures. These studies provide a long-term perspective on human-environment interactions and can provide compelling stories for understanding CHANS. However, it can be argued that because of the rapid pace of current changes, modern CHANS have no analog in the past.

Theoretical Frameworks

In response to the many challenges posed by CHANS, some have adopted a systems approach, which examines the linkages and interactions between the major elements of both the Earth system and human societies. This approach is useful because it is scalable from local to global scales, applicable to many social and environmental settings, and capable of addressing some of the complex thresholds, feedbacks, and unpredictable events inherent in human-environment interactions. Using the systems approach requires



that all flows or linkages in the system are identified and quantified. This poses considerable difficulties in human systems where certain aspects of human behavior cannot be quantified or even qualitatively described effectively. The systems approach is also less a theory (capable of prediction) than a framework for examining and describing CHANS.

One metaphor capable of generating hypotheses and potentially predicting trajectories of human-environmental systems, particularly in Western management systems, is the theory of adaptive change. This metaphor is characterized by phases and cycles dependent on speeds and connections between variables. As systems move through various phases, their resilience (the capacity to retain a similar structure following disturbance) can vary, and periodic shifts from one stable state to another may be mediated by slow variables that can suddenly trigger a fast-variable response (surprise). For example, slow changes in nutrient dynamics over time, such as nitrogen fertilization from acid rain, can lead to a rapid change in ecosystem dynamics when nitrogen saturation occurs and water flowing out of a watershed is laden with excess nitrogen. The theory of adaptive change has been applied to many ecological systems that are actively managed, but it has not been applied as often in the developing world, where management of natural resources is less regulated by government agencies and is instead conducted by interacting groups of private citizens.

Gains From CHANS

Regardless of the significant methodological challenges to understanding, modeling, and predicting the behavior of CHANS, significant gains have been made in recent decades. First, it is clear that human institutions need to plan for uncertainty, consider cross-boundary effects, anticipate indirect and long-term impacts, and account for cumulative impacts in natural and human systems. By accounting for cumulative impacts, human institutions can mitigate against the loss of resilience that follows cumulative insults to a natural or human system. When systems are disturbed (e.g., by a forest fire or rapid change in a market), those systems will either return to their

previous state or shift to a new stable state. The ability of a system to resist change to a new state following disturbance is a measure of its resilience. If the loss of resilience can be identified and monitored, human societies can potentially mitigate against surprises caused by rapid changes in a state that may be difficult, expensive, or impossible to reverse.

Future Directions and Challenges

Despite gains in recent decades, many challenges to understanding CHANS remain. Researchers must move beyond case studies and descriptions of behaviors or interactions and instead move toward theories. To do this, they must develop hypotheses that can be tested across geographic regions and environmental phenomena. Next, generalizable models will be needed; whether such models are conceptual, mathematical, or digital, they must work across scales, regions, and economic and social systems, with the ultimate goal of being able to forecast changes in resilience, ecological surprises, and responses to new perturbations. In all projects, however, researchers must recognize the uniqueness of human versus natural systems in data sources, methods, and models, taking into account the ability of humans to recognize their context, act in response to that context, and behave in sometimes unpredictable ways.

Amy E. Hessel

See also **Agent-Based Models; Anthropogenic Climate Change; Carbon Cycle; Complexity Theory; Coupled Human and Animal Systems; Land Use and Cover Change (LUCC); Nature-Society Theory**

Further Readings

- Gunderson, L., & Holling, C. S. (2002). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.
- Liu, J., Dietz, T., Carpenter, S., Alberti, M., Folke, C., Moran, E., et al. (2007). Complexity of coupled human and natural systems. *Science*, 317, 1513–1516.



- Liu, J., Dietz, T., Carpenter, S., Folke, C., Alberti, M., Redman, C., et al. (2007). Coupled human and natural systems. *Ambio*, 36, 639–649.
- Parker, D., Hessel, A. E., & Briden, S. (2008). Complexity, spatial modeling, and the human dimension: Fundamental challenges for mapping unknown outcomes spaces. *Geoforum*, 39, 789–804.
- Walsh, S. J., & McGinnis, D. (2008). Biocomplexity in coupled human-natural systems. *Geoforum*, 39, 773–775.



CREEP

In geomorphology, *creep* is a noun in terms of process as well as a verb in terms of velocities. Apart from the creep of glacier ice, two kinds of creep processes are of interest to geographers: (1) the mass-movement downhill creep of rock, sediment, soil, and snow and (2) the aseismic creep, or slow movement along part of a normally earthquake-producing fault or on a volcano. In spite of their differences, both processes involve long-term and almost imperceptible slow movement of rock and earth materials. In terms of velocities of mass movement, creeping motions are described as very slow or extremely slow. Very slow rates of motion are less than 5×10^{-5} mm/s (millimeters per second), with a typical velocity of 1.6 m/yr. (meters per year), whereas extremely slow creep rates are less than 5×10^{-7} mm/s, or a typical velocity of 16 m/yr.

Downhill Creep

Creep of many different kinds of natural materials occurs as a result of constant gravitational attraction downhill. Consequentially, any slight displacements of small portions of material from many diverse causes tend to be always moved in a generally downhill direction. The net result is that in aggregate the whole mass has moved downhill with gravity.

Rock-mass creep, or *deep creep*, in bedrock occurs inside some mountains where many small

fractures occur along foliation planes and between certain mineral grains so that spatially continuous deformation occurs. The volumes of rock masses involved are on the order of several thousands of cubic meters with thicknesses of many tens of meters. This process involves extremely slow and generally nonaccelerating differential movements among relatively intact rock masses. The deforming masses are not necessarily bounded by continuous yielding surfaces, but rather, such movements can be distributed along many internal shear surfaces that apparently are unconnected, so that the distributed shear results in bending, bulging, and folding. The total displacement is small relative to the large magnitude of the involved rock mass. The process roughly simulates viscous fluids in the distribution of velocities, with the result that some scientists refer to it as a kind of rock flow, albeit of a brittle-failure variety rather than the ductile kind characteristic of bedrock at a depth where it is under tremendous confining pressures and higher temperatures. In addition, this deep-seated gravitational creep of whole mountains can produce a sagging (*Sackung*) or settlement of the mountain so that ridge-top *grabens*, or trenches, can result, as well as *antislope scarps*, or escarpments that face uphill.

Creep of surficial sediment and soils on slopes is another of the processes characteristic of slopes worldwide, where material moves slowly downward on hillsides of low to moderate inclinations. Most of this creep is accomplished by expansion and contraction of the relatively unconsolidated materials when they freeze and thaw, or are just warmed and cooled in daily cycles with the sun, or through wetting during storms or snowmelt and later drying. In each expansion cycle, the granular soil materials move outward perpendicular to the slope, but in the return contraction part of the cycle, there is a tendency for them to move back in a slightly downhill direction because of gravity. This results in a ratcheting back and forth with a net downhill creep motion. In addition to the expansion and contraction cycles, there are also several miscellaneous additions to the creeping process. For instance, animals burrowing on slopes tend to move dirt preferentially downward with gravity, plant roots push soil preferentially downslope more than upslope as they grow, and abandoned burrows and dead



and rotted root cavities collapse downslope. Finally, deep snows on slopes push strongly downward on trees, with the result that this force is transmitted into the ground through the tree roots, with creep resulting if the ground is not frozen solid beyond the depth of the roots.

The effects of soil creep are detectable on slopes everywhere, including in tilted fences, grave-stones, and telephone poles; on displaced highways and railroads; and especially in tilted retaining walls and some old house foundations. Downhill-curved tree trunks, commonly cited as evidence of soil creep, are actually almost never the result of such processes but rather occur as the result of snow creep.

The creep of snow on slopes is well-known to residents in cold climates, who commonly have to shovel out the uphill sides of chimneys, ski-lift towers, and other such structures on roofs or slopes that are in danger of being knocked over by the slow movement of the snow downhill. Snow on slopes is always creeping because metamorphism is always occurring and the porosity between grains is high. Furthermore, creep is facilitated because temperatures are normally within 95% of the melting point on the Kelvin scale. The rate of snow creep increases exponentially as the temperature goes up, especially if meltwater increases in the snow.

Aseismic Creep

Aseismic creep is a different kind of creeping motion from the types described above. It occurs as a result of the tremendous forces or pressures in the Earth resulting from plate tectonics or from volcanic activity. In these cases, the rocks move past each other slowly along surfaces of rupture or fracture without significant earthquake seismicity. Where such fracture surfaces underground are locked together with many *asperities*, or irregular interlocking projections, the pressure builds up until final release results in an earthquake.

In the case of strike-slip faults, such as the San Andreas in California, two enormous crustal plates slide past each other, usually resulting in abrupt and damaging earthquakes. But in some places where the fault is not locked and is waiting for a big and damaging event, it creeps slowly

without any seismicity. For example, the town of Hollister, which sits astride the San Andreas Fault, is such a place and has numerous instances of slowly displaced curbstones, streets, and houses that are undergoing deformation of several millimeters (quarter to half an inch) a year, or about as fast as fingernails grow. Similarly, on some volcanoes, presumably in response to the movement of huge bodies of magma underground, fractures can result, and slow movements can occur that are also considered a kind of aseismic creep. Mount Etna, the large volcano on the island of Sicily off the coast of Italy, has fractures on it that move with aseismic creep.

John F. Shroder

See also Earthquakes; Landslide; Plate Tectonics; Rock Weathering; Soil Erosion; Volcanoes

Further Readings

- Burbank, D., & Anderson, R. (2000). *Tectonic geomorphology*. New York: Wiley-Blackwell.
- Govers, G., Quine, T. A., Desmet, P. J. J., & Walling, D. E. (1996). The relative contribution of soil tillage and overland flow erosion to soil redistribution on agricultural land. *Earth Surface Processes and Landforms*, 21, 929–946.
- Oehm, B., & Hallet, B. (2005). Rates of soil creep, worldwide: Weak climatic controls and potential feedback. *Zeitschrift für Geomorphologie*, 49, 353–372.
- Schulson, E. M., & Duval, P. (2009). *Creep and fracture of ice*. Cambridge, UK: Cambridge University Press.



CRIME, GEOGRAPHY OF

The geography of crime includes analyses of how criminal law defines crime, various approaches to the study of crime, the different types of crime, and crime mapping. This entry reviews the emergence and evolution of geographical research on crime, from the 19th century to the present day.



Criminal Law and the Causes of Crime

Often, during the first lecture of an introductory criminology course, the professor will pose the question “What causes crime?” After a few students respond, the professor will provide the answer: “Criminal laws cause crime!” To avoid the appearance of being facetious, the professor may bring up the 19th-century European maxim of *Nullum crimen sine lege, nulla poena sine lege*, that is, there is no crime or penalty without law. Specific behaviors, processes, or arrangements that are viewed as detrimental to the common good are codified into criminal laws with sanctions, forming part of a system of formal social control known as the criminal justice system. Many criminal laws are the outcomes of political debates in which different social interests struggle to get their views enacted into policy.

Jurisprudence has vast bodies of literatures focusing on the evolution of criminal laws and their political, social, and cultural biases. There are two major schools of thought regarding the function of criminal law. The conflict school believes that criminal law and the criminal justice system are established to protect the few from the masses and that the cause of crime is external to the individual, while the consensus school believes that criminal law and the criminal justice system serve the common good and that the cause of crime is within the individual.

Approaches and Issues in Studying Crime

Crime encompasses so many behaviors emanating from different motivations and circumstances that ascertaining the geography of crime has been more suggestive than definitive. Therefore, it has been imperative to break down crime into different distinct categories and ascertain the geographic and spatial properties of the different categories. A common distinction has been to compare violent crimes (crimes against a person, e.g., homicide or rape) with crimes against property (e.g., residential burglary or automobile theft). Other approaches focus on the specific settings and places in which crimes occur, such as gang territories or drug markets.

The majority of the crime data used in contemporary research come from reports to the police,

known as *official reports*. The geographic scale of these data range from the large scale (e.g., a burglarized home) to smaller scales representing larger areal units (e.g., census blocks, counties, or states). Another source of crime data is the U.S. National Crime Victimization Surveys (NCVS), which is intended to measure crimes not reported to the police. Currently, the geographic scales of these data are too general to yield meaningful geographic analyses. Self-reports are another source of crime information, whereby individuals are asked to give the researcher an accounting of their unreported or undetected crimes. Ethnographic studies acquire this type of data, but only a few have used any type of spatial analyses.

The metric of crime as the dependent variable is a frequency count expressed as crimes per population base. Other studies have developed different rates focused on the appropriate targets of the crime. For example, rates have been developed for sexual assaults per 1,000 females, residential burglaries per 1,000 dwelling units, and hotel/motel crimes per 100 rooms. Recently, location quotients are appearing more in the literature, providing a clearer picture of the spatial variation of crime.

The independent variables used to assess association and causation have usually relied on measures of socioeconomic status as well as housing and demographic measures. Other studies have employed variables pertaining to economic activity, city function, climate, and weather.

Back to the Future

During the 19th century, the works of the Belgian mathematician Adolphe Quételet and the French lawyer André-Michel Guerry collectively became known as the Cartographic School of Criminology. Employing statistical methods that were novel at the time, their works examined the covariation of crime with climate, season, geographic location, gender, age, and other social and physical environment variables. Moreover, visualization of these relationships was presented in graphs and choropleth maps. Among their findings were that violent crimes are more likely to occur in warmer climates and seasons and that more property crimes occur in colder climates and seasons; the departments in Northern France have higher



rates of property crime while those in Southern France have higher violent crime rates; males have a greater frequency and rate of involvement in crime than females; and individuals around the age of 25 have the greatest propensity for involvement in crime. Poverty and illiteracy were hypothesized as the major causes of crime; and Henry Mayhew's study of crime in London during 1860 also found that poverty is a major cause of crime.

The Chicago School of Social Ecology

During the early 20th century, the Chicago School of social ecology and urban geography played a dominant role in studies of urban structure. Clifford Shaw and Henry McKay, observing the spatial distribution of delinquency and crime rates across Chicago neighborhoods, found that those with higher incidences of both were characterized by high population turnover, due to immigration, and by poverty. The landscapes of these neighborhoods contained run-down housing, factories, and abandoned buildings, with recent immigrants being the main residents. Moreover, these neighborhoods were adjacent to the central business district (CBD). Shaw and McKay observed that regardless of which immigrant group resided in these neighborhoods, the delinquency rates were always high and stable. Furthermore, they found that as distance from the CBD increased, the crime and delinquency rates decreased (distance decay). These observations led the authors to conclude that crime and delinquency are produced by the characteristics of particular neighborhoods and that the primary causal process or mechanism is social disorganization. These neighborhoods lacked the resources and the capacity to counter the conditions creating crime and delinquency.

The Chicago School produced important benchmarks for others to follow. Their analyses of socially disorganized neighborhoods influenced subsequent researchers to examine poverty, transition, and racial-ethnic status in relation to crime. Nevertheless, the social disorganization approach became dormant because sociology-criminology changed its emphasis. There was a paucity of works replicating the social disorganization model in other cities. Moreover, some criminologists began to examine a more dynamic aspect of

crime, namely, the mobility of offenders, or the *journey to crime*.

It is important to note that geographers did not contribute to the antecedent literature regarding the geographic properties of crime. Geographers did not start examining crime until the late 1960s.

Geographers and Crime: The 1960s Through the 1980s

Crime was a major concern along with the other problems present during the 1960s and 1970s. Geographers began studying crime by publishing reviews of criminologists' work and engaging in their own studies of the spatial variation of crime across urban areas. The advent of computers and the greater use of statistical methods meant that many of these studies were in the form of factor-ecological models, whereby a collection of variables are grouped into orthogonal factors and used as independent variables regressed against crime-dependent variables. The findings were not too dissimilar from those of Shaw and McKay and others. Social rank is negatively related to crime; measures of family status are mixed; and measures of segregation and poverty are positively related to crime. During this period, a few geographers examined the spatial behavior of robbers and juvenile offenders with respect to the distance traveled by the offenders from their residences to the crime sites. Among robbers, distances varied according to the values of their targets (i.e., the expected benefit of robbing a particular location), while the distances of juvenile trips varied with race-ethnicity, gender, and age.

During the 1980s, crime studies by geographers changed in three ways. There were fewer geographers engaged in crime research; geographers' works began to be published in criminology and criminal justice venues; and much of the work focused on spatial behavior and interaction. For example, an ethnographic study of convicted burglars found that the locations of their crimes sites were influenced by their daily travel routines from home to work. This work integrated time budgets and routine activities to assess an offender's spatial-temporal opportunity for crime. Another study found that rapists travel different distances to encounter victims depending on the method they use to approach their victims (e.g., a break-in



at their residence, a kidnap attack on the street). Other works incorporated the notion of mental maps and perceptions of risk and target vulnerability. The works coming from this period were less about urban structure and more about spatial behavior and interaction. They integrated time and spatial perception and presented sophisticated analyses of travel distances.

1990s Crime Mapping

During the 1990s, as the proliferation and diffusion of computer hardware and software continued unabated from the 1980s, geographic information systems (GIS) and other information systems were employed by many police agencies. Suddenly, there was a large demand for the geographer's most faithful tool—the map. However, many of these new users of maps had very little knowledge about making or using maps. Initially, maps were used as props in operational criminal justice settings.

More widespread access to GIS, data systems, and spatial statistical software led more people to become interested in the geographic aspects of crime. Moreover, social disorganization theory was revived by the criminologists. Another group, known as *environmental criminologists*, grew as a result of the increased interest in crime and spatial questions.

Geographers' contributions from the 1990s to the present have been considerable. They have been responsible for bringing some order and sophistication to the crime-mapping scene. Geographic concepts and techniques have been used to delineate and classify urban drug markets. The approach and passage of warm and cold fronts of different duration alter the expected change of the levels of calls for police services from one day to the next. Studies of spatial behavior and interaction continue. One study measuring the tendency of serial rapists to return to a crime site close to a previous one has served as one of the foundation blocks for the investigative methodology known as *geographical profiling*. Another study examining hot spots in different neighborhoods revealed that neighborhoods produce different crime problems with different and distinctive temporal rhythms, leading the study's author to suggest different police responses based on the space, time, and problems.

Conclusion

What is the geography of crime? As previously stated, the answer is more suggestive than definitive. Research suggests that crime is greater in urban areas, in poorer neighborhoods, and in places occupied by disadvantaged populations. Such findings suggest that criminal laws and the criminal justice system are more focused on “street crimes,” or those in which minorities are overrepresented as victims and offenders, rather than “white-collar crimes,” which are often alleged to be comparatively underenforced, underdetected, and lightly sanctioned. The geography of crime can help illuminate such issues.

James L. LeBeau

See also **Chicago School**; **Drugs, Geography of**; **Justice, Geography of**; **Law, Geography of**

Further Readings

- Brantingham, P., & Brantingham, P. (1993). Nodes, paths and edges: Considerations on the complexity of crime and the physical environment. *Journal of Environmental Psychology*, 13, 3–28.
- Chainey, S., & Ratcliffe, J. (2005). *GIS and crime mapping*. London: Wiley.
- Harries, K. (1974). *The geography of crime and justice*. New York: McGraw-Hill.
- Harries, K. (1997). *Serious violence: Patterns of homicide and assault in America* (2nd ed.). Springfield, IL: Charles C Thomas.
- Herbert, S. (1997). *Policing space: Territoriality and the Los Angeles Police Department*. Minneapolis: University of Minnesota Press.
- LeBeau, J. (1987). The journey to rape: Geographic distance and the rapist's method of approaching the victim. *Journal of Police Science and Administration*, 15, 129–136.
- Lowman, J. (1986). Conceptual issues in the geography of crime: Toward a geography of social control. *Annals of the Association of American Geographers*, 76, 81–94.
- Ratcliffe, J. (2004). The hotspot matrix: A framework for the spatio-temporal targeting of crime reduction. *Police Practice and Research*, 5, 5–23.



- Rengert, G., Ratcliffe, J., & Chakravorty, S. (2005). *Policing illegal drug markets: Geographic approaches to crime reduction*. Monsey, NY: Criminal Justice Press.
- Sampson, R., & Groves, W. (1989). Community structure and crime: Testing social disorganization. *American Journal of Sociology*, 94, 774–802.
- Shaw, C., & McKay, H. (1969). *Delinquency and urban areas*. Chicago: University of Chicago Press.
- Smith, S. (1986). *Crime, space, and society*. Cambridge, UK: Cambridge University Press.
- Warf, B., & Waddell, C. (2002). Heinous spaces, perfidious places: The sinister landscapes of serial killers. *Social and Cultural Geography*, 3, 323–345.

CRISIS

Crisis is an elusive term, as the controversy surrounding its causes and cures have always been unsettled among the constituents of a society. Despite its elusive nature, acknowledgment of a crisis is based on a shared view among the constituents of a system that the existing economic system cannot be reproduced without substantial reforms or displacement of the existing system. Crises thus provide society with critical junctures for progressive development as they loosen up existing negative lock-ins within the system. Recurring economic crises since the 1990s and unsettled debates over their causes and cures have presented us with opportunities to reflect on the future trajectories of capitalism as well as the substantial challenges to face with regressive aspects of the global society.

Understanding the discursive nature of the crisis diagnosis is critical as it determines the ways in which constituents respond to the crisis and address necessary steps to fix the problem. Mainstream neoclassical/institutional economics and Marxist economics differ substantially in terms of both their understanding of the crisis and their spatial and temporal implications. Mainstream economists attribute crisis to temporal failures in the *localized* system (e.g., moral hazards in

financial markets resulting from Asian crony capitalism in the 1997 crisis) or to partial malfunction of the financial system (e.g., the credit crunch and failures of financial institutions due to defaulting of subprime loans in the U.S. housing sector). Resolution of the crisis, thus, would involve either reform of the localized system or reinforcement of supervision in the failing segments of the economic system so that natural market mechanisms could be restored. Ironically, mainstream resolution of crises has been more dependent on the workings of the state, including nationalization of failing financial firms or injection of public funds into failing financial firms, than on self-restoring market mechanisms.

In contrast, Marxist crisis theories suggest that capitalism is prone to long-term crises because of the fundamental contradictions in capital-labor relations. There have been variants of Marxist crisis theory, each of which attributes ruptures in capitalist accumulation to different causes. Among contemporaries, the overaccumulation theory of crisis (the first *cut theory* below) is the most widely accepted.

In *The Limits to Capital*, David Harvey pioneered a geographical explanation of the capitalist crisis dynamics. Harvey's view of crises consists of three theories, which are not sequential but are rather connected via complicated dynamics. The first theory examines the ways in which the falling rate of profit à la Marx drives capitalists' quest for surplus value-producing technologies, following the capitalist credo of "accumulation for accumulation's sake," and thus breaks the balance between accumulated capital and opportunities for employing capital. To fix this imbalance requires the devaluation of a portion of surplus capital and displacement of the laborer and his powers. The capitalist inner contradiction between the development of production capacity and the necessary devaluation of capital and labor, thus, supports recurring crises.

The second theory examines the ways in which the capitalist crisis tendency in production is relieved by the power of the credit system that allows investment booms in fixed capital and consumption fund formation in sales of various equities to absorb overaccumulated capital. At the same time, the power of the credit needs to be disciplined by state fiscal and monetary policies



to ensure an expanded reproduction of capital. While the disequilibrium in production is, thus, *temporarily* contained by finance capital, guided through the state apparatus, new forms of instability and internal dynamics emerge as part of a new capitalist evolution.

Harvey's geographical insight is eloquently laid out in the third theory, which integrates the geography of uneven development into the theory of crisis. The overaccumulation of the system cannot be resolved but can be relieved through localized devaluation, or *spatial fix*. Spatial fixes are possible because different places have different timings of upturns and downturns in accumulation cycles depending on the ways in which they are integrated into the global capitalist system. Capitals employing less competitive technologies or located in poor conditions are likely to be devalued, but the specific site of localized devaluation is hard to predict, as capitalist space economy is continuously reconfigured through territorial alliance and competition for accumulation's sake. The crisis tendency is, thus, transformed into a pattern of compensating oscillations of local economies rather than a totalizing phenomenon.

The crisis tendency within a capitalist economy is spatially expansive as economies in crisis find temporary relief by exporting production capacity to external regions and, thus, incorporating them into the newly expanded territorial division of labor. The newly incorporated regions, however, soon reach a state where they have to seek their own spatial fixes to avoid local devaluation. This chain reaction of overaccumulation crises and spatial fixes accrues to the global crisis unless there emerges a new mode of production other than the capitalist one. In sum, space has become an integral part of the capitalist crisis dynamics through Harvey's contribution to crisis theory.

There have been at least two additional major research efforts by geographers addressing capitalist crisis tendency and its spatial implications. First, in the 1980s and the early 1990s, geographers researched the ways in which the crisis of Fordism reconfigured uneven geographical development and was resolved through the installing of a new regime of flexible accumulation. Second, in recent research on neoliberal turns, geographers have focused on the ways in which the state

apparatus has deployed neoliberal policies to resolve the long-term crisis tendency.

Crisis occupies an important role in describing uneven geographical development on Earth. In turn, the geography of uneven development facilitates the spatiotemporal resolution of overaccumulation crises through switching crises in the form of localized devaluation. This dialectical relationship between crisis and space presents geographers with ample opportunities for intervention in contemporary crisis-ridden capitalism.

Bongman Seo

See also **Business Cycles and Geography; Circuits of Capital; Harvey, David; Marxism, Geography and; Restructuring; Uneven Development**

Further Readings

- Clarke, S. (1994). *Marx's theory of crisis*. London: Macmillan.
- Harvey, D. (2006). *The limits to capital* (New ed.). New York: Verso.
- O'Connor, J. (1987). *The meaning of crisis: A theoretical introduction*. Oxford, UK: Blackwell.



CRITICAL GEOPOLITICS

Critical geopolitics refers to an intellectual movement begun in the late 1980s and early 1990s that has as its goal the interrogation of "geopolitics" as a discourse produced through cultural and political practice. This view can be contrasted with prior academic engagements with geopolitics that sought to describe the global political landscape in realist terms, focusing on the power relations among states and neglecting issues of culture and ideology. Since then, critical geopolitics has become one of the most dynamic sectors in political geography and has become central to the subdiscipline. This entry begins by discussing the origins of critical geopolitics and the intellectual currents that stimulated it. The entry then discusses the three types of discourse that critical geopolitics has traditionally focused on: formal,



practical, and popular. Finally, the entry indicates some of the directions in which critical geopolitics seems to be moving at present.

Origins and Divisions

Following the end of World War II, the term *geopolitics* fell out of use in the Anglo-American world, as it was seen as irretrievably connected to the academic justification of Nazi aggression. Although some political geographers continued to engage in the study of power politics at the global scale, the discourse of geopolitics lay dormant. This lasted until the 1970s, when Henry Kissinger resurrected the term as a reference to the global balance of power between the superpower blocs, thus renewing an interest in territory, space, and power that only grew with the end of détente and the beginning of the second Cold War in the 1970s.

Heavily influenced by the work of Michel Foucault, attempts to study the resurrection of geopolitics during this time period critically viewed the enterprise of geography itself as a discursive actor rather than a passive descriptor of the world it inhabits. Geopolitics, then, was an enterprise engaged in by elites (both academic and political), who attempted to remap the world in ways that were advantageous. Using Foucault's notion of power/knowledge, it was argued that the ability to define the map on which politics would be contested was itself a key element of power. Thus, geographers (and, more specifically, practitioners of geopolitics) are key links in the construction of the taken-for-granted mappings of the world.

Less reflexively connected to the discipline of geography is the similar notion that some elites are hegemonic over the discourses of the rest of the world and, thus, have the ability to write (and rewrite) the rules by which geopolitics is conducted. Historical examples of this view include British attempts to eliminate the slave trade in the 20th century and the promulgation of a liberal individualist discourse of human rights by the United States and other actors through the late 20th and early 21st centuries. Thus, what had previously been deemed as normal and acceptable became discursively repositioned as abhorrent when the then superpower, Britain, rewrote the moral rules of slavery. However, critical geopolitics

has typically been more interested in the ways in which even more elemental facets of geopolitics are naturalized. For instance, drawing from similar intellectual currents in critical (or dissident) international relations, the very primacy of the nation-state itself was questioned. A move such as this opens up vast spaces for intellectual exploration, and indeed, critical geopolitics has ranged far and wide in the years since the project was initiated. Within critical geopolitics, there has been a traditional divide of subject matter into three main categories of formal, practical, and popular geopolitics. This tripartite division is important as a reminder that geopolitics is not the study of a single set of practices and discourses but an incredibly diverse set of ideas that are quite often in conflict with one other. Thus, there is no center from which geopolitical "truth" emerges; rather, it is distilled from multiple (and numerous) centers of production (the model for this is Henri Lefebvre's production of space).

Formal Geopolitics

Formal geopolitics refers to the practices and discourses associated with public intellectuals or academics in universities or think tanks such as the Heritage Foundation and Brookings Institution. This was an initial focus of much work on critical geopolitics, which cannibalized and deconstructed earlier geopolitical studies to show the workings of power/knowledge. In doing so, critical geopolitics explored the ways in which the geopolitical world, and its divisions, were produced and codified. Examples of this include Halford Mackinder's division of the world into a "heartland" surrounded by several crescents, Nicholas Spykman's similar heartland/rimland model, and long-standing divisions of the world into ontologically distinct oriental and occidental realms. Historically, these discursive creations use a veneer of objectivity to rhetorically advance their cause, imagining a panoptical perspective through which the world can be dispassionately observed and described. However, given the close-knit historical relationship between academic theorists and governmental apparatuses, these theories have been abundantly critiqued as being situated within nationalist perspectives that are rarely problematized. The discourses of formal



geopolitics filter through into governmental institutions through well-developed channels of journal publishing, research sponsorship, and personal relationship.

Practical Geopolitics

Practical geopolitics refers to the discourse and practice of politicians and governmental bureaucrats. In some ways, this is the most material of the three categories within critical geopolitics, because it occurs when the traditional apparatuses of statecraft and warfare synergize with the discourses formulated in the formal sphere. By adopting these discourses, adapting them for their own political purposes, or constructing their own geopolitical discourse in opposition to those writings, political figures promote their desired vision of the world and enforce it using the immense bureaucracy at their fingertips as well as the “bully pulpit” that comes with their positions.

Examples of this include President George W. Bush’s announcement, in 2002, of an “axis of evil” that included (and connected) Iraq, Iran, and North Korea. Regardless of any material contacts between those countries (or the lack thereof), the three were discursively connected and stigmatized as “evil” (thus implicitly leaving the United States as discursively “good”). Furthermore, the reference to the World War II Axis powers also scripted a normative response to the challenge implied in the idea of the axis of evil—that ignoring the threat amounted to appeasement. Constructions such as this are much more widely known than those of formal geopolitics because they have more immediate potential consequences, given the use of diplomatic language and practice as a way of signaling to friends and enemies alike.

Popular Geopolitics

Popular geopolitics is the third category of geopolitical practice and discourse. It refers to the discourse of the media and other avenues through which geopolitical knowledge circulates. While earlier practical geopolitics was described as the most material form of geopolitics because of its connection to the institutions of government, understood differently, popular geopolitics could be understood as the most material, because it

serves as a sea of geopolitical narratives, scripts, and symbols in which citizens are immersed every day. This includes the direct transmission of practical geopolitical discourse (and occasionally that of formal geopolitics as well) through the traditional media, such as newspapers, magazines, and cable news networks, and also through popular culture, such as cinema, comic books, novels, television, advertising, and so on.

Popular geopolitics should not be seen as the end of the chain of discursive dissemination (i.e., from theorists to government to the public) but instead as an originator of geopolitical knowledge in its own right that in turn feeds into the other two arenas of production. For instance, many cultural elites (e.g., authors, movie directors) intentionally produce works that represent their favored geopolitical visions (or at least critique the status quo). Theorists and politicians are not immune to the influence of these cultural elites, either harnessing popular discourse for their own purposes or being legitimately influenced by it. These three categories of geopolitical knowledge (practical, formal, and popular) together constitute a continually evolving field in which the nature of the natural and taken-for-granted is contested by varying agents. Chronicling the ways in which these contests are waged, and in which certain representations emerge hegemonic over others, has been the major occupation of scholars since critical geopolitics began.

Geopolitics in the Future

However, while discourse remains a key part of contemporary geography both inside and outside critical geopolitics, some scholars have begun to try to push the project forward in ways that often stretch the definition of critical geopolitics. Recently, there have been two dimensions to this.

The first challenge to conventional definitions of *critical geopolitics* has come from nonrepresentational theory, which argues that geopolitics (along with the rest of geography) has been overly mesmerized by texts and representation. Indeed, as described above, critical geopolitics has been largely driven by the deconstruction of texts, whether they be old theories of geopolitics, politicians’ speeches and policy documents, or comic books and movies. These critics argue that critical



geopolitics should focus less on the cognitive elements—how people think about geopolitics—and more on the affective elements—how people feel about geopolitics. One way to do this has been to conceptualize visibility as observant practice that is itself geopolitical rather than to analyze visibility by treating images as texts to be deconstructed. Similarly, some scholars of popular geopolitics have argued for cinema to be studied not as a geopolitical narrative but rather as a vehicle for geopolitical feeling, as emphasized in the way we talk about movies—as horror, thriller, suspense, and so on.

The second challenge to critical geopolitics as traditionally constituted comes from feminist critics who claim that the focus on macroscaled global discourses neglects women, who are often relegated to “private” spaces outside the public realm of discourse of the sort studied in critical geopolitics. They argue that a more embodied, microscaled study reveals the ways in which women’s agency is brought to bear in the geopolitical realm. Furthermore, they argue that women disproportionately bear the consequences of geopolitical action, for example, when they are bombed in air raids and when they are left destitute in the aftermath of war, often without men’s assistance.

Critical geopolitics is a thriving part of the discipline but one that is evolving, with different practitioners advocating new realms of inquiry that pull it in different directions. Nevertheless, a common denominator still exists in the expectation that critical geopolitics, of whatever variety (formal, practical, popular, feminist, nonrepresentational), is intended to question the taken-for-granted definitions that dominate public debate. It has an overtly political stance that seeks to promote equitable engagement in global affairs for all.

Jason Dittmer

See also Agnew, John; Cold War, Geography of; Colonialism; Critical Human Geography; Cultural Turn; Discourse and Geography; Domino Theory; Geographical Imagination; Geopolitics; Globalization; Gregory, Derek; Hegemony; Human Rights, Geography and; Identity, Geography and; Imperialism; Justice, Geography of; Nation; Nationalism; Neocolonialism;

Orientalism; Panopticon; Political Geography; Popular Culture, Geography and; Postcolonialism; Postmodernism; Poststructuralism; Production of Space; Radical Geography; Resistance, Geographies of; Spaces of Representation/Representational Spaces; Terrorism, Geography of; War, Geography of

Further Readings

- Agnew, J. (1994). The territorial trap: The geographical assumptions of international relations theory. *Review of International Political Economy*, 1(1), 53–80.
- Campbell, D. (1992). *Writing security: United States foreign policy and the politics of identity*. Minneapolis: University of Minnesota Press.
- Dalby, S. (1991). Critical geopolitics: Discourse, difference, and dissent. *Environment and Planning D: Society and Space*, 9(3), 261–283.
- Dalby, S., & Ó Tuathail, G. (1996). The critical geopolitics constellation: Problematizing fusions of geographical knowledge and power. *Political Geography Quarterly*, 15(6/7), 451–456.
- Hyndman, J. (2004). Mind the gap: Bridging feminist and political geography through geopolitics. *Political Geography*, 23(3), 307–322.
- MacDonald, F. (2006). Geopolitics and “the vision thing”: Regarding Britain and America’s first nuclear missile. *Transactions of the Institute of British Geographers*, 31(1), 53–71.
- Ó Tuathail, G. (1996). *Critical geopolitics: The politics of writing global space*. Minneapolis: University of Minnesota Press.
- Sharp, J. (2000). *Condensing the Cold War: Reader’s Digest and American identity*. Minneapolis: University of Minnesota Press.



CRITICAL GIS

Critical GIS incorporates both social theory and geographic information science (GIS) with the goal of increasing the relevance of GIS to multiple communities. The critical GIS agenda is concerned with science and technology studies, feminism, ontologies, and qualitative and participatory GIS.



While critical GIS emerged from critiques by human geographers, it has morphed in the 2000s into a creative blend of human and technical geography that has the potential to uniquely shape GIS and obliquely influence other information sciences. There are a number of issues that contribute to an understanding of critical GIS. They include its history, its relationship to science and technology studies (STS), feminism and GIS, ontology research, and public participation GIS (PPGIS).

Critical GIS did not materialize as a cohesive entity in the 2000s but rather descended from the struggles between human geographers and GIScientists in the 1990s. The 1990s witnessed a series of critiques of GIS by human geographers. That antagonism—which was influenced by the “Science Wars”—was based on concerns that GIS obeyed the dictates of the quantitative revolution. Human geography critics were keen to stress that GIS was based on Cartesian perspectivalism and, as such, could not contribute to an “emancipatory” politics. Critics were suspicious that GIS served large corporations, public agencies, and governments while eschewing the socially disenfranchised. By the end of the 1990s, however, human geography critics and GIS practitioners had reached a *détente*. This truce can be linked to two separate phenomena. First, GIS was pervasive by this time, and there was a general recognition that it formed a foundation of the discipline, regardless of its antecedents. Second, many GIScientists had listened closely to critics and had begun to incorporate social theory, feminism, and ontology research into their approaches to spatial research. This marked the inception of critical GIS.

This trend toward a constructive, creative critical GIS is partly due to a number of collaborative efforts between GIS researchers and social critics. At the same time, GIS researchers began to see that critical GIS is a way of democratizing the technology and extending its purview. One of the chief characteristics of critical GIS is that it is housed within the discipline rather than based on critique from outside.

Whereas external critique has little invested in the outcome, internal critique is necessarily cautious and careful, as it has a stake in the future of the technology. To be constructive, critique must

actually have something invested in the subject. While critical GIS began as an external critique with an attendant harshness, it has decidedly coalesced as an influence within GIS that is wedded to the goal of a better technology. Critical GIS shoulders the burden of responsibility to a discipline while simultaneously attempting to improve on it from a theoretical and applied basis. The following section describes the fundamental research areas within critical GIS, including epistemology and ontology, feminism, qualitative methods, and public participation GIS.

Epistemology and Ontology

In the 1990s, critics of GIS were keen to demonstrate that GIS suffered from an impoverished epistemology that focused on quantitative data while ignoring the complexity of social systems. This is, however, not the case in the 2000s. David Demeritt, a human geographer, provides a framework for understanding the role of critical GIS in framing the epistemological impulses of GIScience more positively. He posits *heterogeneous constructivism* as a way of acknowledging that natural systems, including geographical phenomena, are influenced by a broad range of social practices but are nevertheless linked to a fundamental reality. While not explicitly recognized as a tenet of critical GIS, heterogeneous constructivism is nevertheless the epistemological rubric for much current critical GIS research. It allows researchers to demonstrate social influences in the development of technology while accepting that we can never ascertain the degree to which the science reflects phenomena *as they truly are*. At the same time, heterogeneous constructivism allows us to emphasize that a hybrid set of material and social processes gives rise to any technology. For instance, the development of generalization techniques in GIS was strongly influenced by a cartographic tradition that stressed map simplification rather than database generalization. Heterogeneous constructivism is a tool for studying the algorithmic basis for GIS. It implies a more GIS-savvy researcher who is interested in questions that extend beyond social construction to the better construction of GIS technologies.

While epistemology is an important factor for social theorists, GIScience researchers adopted the goals of critical GIScience in the 2000s by



focusing on ontology construction. *Ontology* in the philosophical sense refers to the “essence of being.” In a computing or information science context, however, it refers to the universe of discourse defined within the information system, as well as all the possible relationships between data elements. It is this latter interpretation of ontology that has given rise to the most technically oriented dimension of critical GIS.

In the information sciences, there are no foundational ontologies. Instead, each classification system, map legend, data dictionary, and semantic database constitutes a different ontology. The challenge to GIScientists is to build systems in which multiple, perhaps conflictual, ontologies describing the same set of spatial entities from different perspectives can coexist.

Feminism and Critical GIS

Critical GIS researchers have developed unique means of incorporating feminism and GIS. In the 1990s, for instance, Sarah Elwood developed a neighborhood mapping project that used GIS to study spatial problems that involve women and other disenfranchised communities. She was able to use the research to illustrate that adoption of a critical, encompassing GIS was a means of positively affecting policy at various levels of government. Sara McLafferty developed a health and GIS project that investigated environmental links with breast cancer on Long Island, in New York State. This research departed from a focus on individual behavior and cancer to one that searched for common contextual elements between women who had the disease. Each of these is a practical example of the potential to incorporate feminism into GIS.

Mei-Po Kwan has advanced the integration of GIS and feminism further by arguing that feelings and emotions can and should be incorporated into GIS analysis. Likewise, Kwan has demonstrated that it is possible to develop feminist discourses in GIS using visualization. The conclusion from this seminal work is that the technology can, in fact, be used to enrich feminist geography and practices. Furthermore, GIS needs to be reconceptualized from a strictly quantitative practice to one that embraces elements of qualitative description as well.

Incorporating Qualitative Methods Into GIScience

Critical GIS played a key role in drawing attention to the potential of incorporating qualitative data and research into spatial analysis. One of the first papers in this area was by Scott Bell and M. Reed in 2004, who argued that qualitative data could be incorporated into GIS. Since then, many papers have grappled with this issue—indicating the extent to which this dimension of research has been integrated. In 2009, Sarah Elwood and Meghan Cope published a book on qualitative GIS. This is perhaps one of the best indicators of the extent to which qualitative GIS has been accepted—and forms part of the basis for critical GIScience.

Critical GIS researchers argue that spatial events are frequently products of dynamic social processes rather than static entities. This view allows the integration of survey data with GIS to model events. Likewise, it encourages the development of analytical methods that use both qualitative and quantitative data by incorporating ethnographies. The potential of qualitative GIS is emphasized by recent trends toward social networking and information sharing via Web 2.0. Social networking applications (e.g., bird counts and other reporting of spatial/social information via the Web) have the potential to catapult qualitative spatial data into greater prominence. This outcome is closely linked to greater participation in GIS from different communities with widely varying levels of training and expertise.

Public Participation GIS

PPGIS is a key component of critical GIS. PPGIS encompasses efforts to involve diverse members of multiple communities in the use of GIS in order to inform planning and decision making. PPGIS is a flexible system of human and computer networks that integrate many methods and technologies. In addition, PPGIS incorporates multiple perspectives and a diversity of alternative information forms and facilitates collaborative planning efforts, supporting inclusive public participation in decision-making processes. Clearly, the goals of PPGIS are closely related to the emphases of an emerging critical GIS. Yet in many ways, the two niches of GIS have remained quite separate—especially as many



PPGIS experts historically published primarily in urban studies venues. Increasingly, however, the interests of the two areas have begun to converge.

This is evident in the work of several key PPGIS researchers. LaDonna Knigge, for instance, used ethnographic techniques to elicit information from community members that can be integrated into a GIS framework. Rina Ghose has explored the influence of scale on access to GIS and information networks. Piotr Jankowski has demonstrated the importance of designing decision-making frameworks around the needs of local communities. Timothy Nyerges has explored the use of PPGIS by collaborative groups for community decision making. Jankowski recently extended the concepts of PPGIS to scientific decision making and demonstrated how the integration of spatial data and Web-based technologies can aid in scientific decision making. Each of these diverse examples illustrates how the concepts fundamental to critical GIS can change the everyday use of GIS when incorporated into PPGIS.

Critical GIS aims to extend the functionality of GIS while incorporating influences from science and technology studies, critical geography, feminism, ontology research, and PPGIS. As GIS researchers begin to integrate theory and technology, we can expect that critical GIS will continue to thrive.

Nadine Schuurman

See also Collaborative GIS; Critical Human Geography; Feminist Geographies; Feminist Methodologies; GIS, History of; GIScience; Humanistic GIScience; Ontological Foundations of Geographical Data; Public Participation GIS; Qualitative Methods; Scale in GIS

Further Readings

- Bell, S., & Reed, M. (2004). Adapting to the machine: Integrating GIS into qualitative research [Special issue]. *Cartographica*, 39(1), 55–66.
- Cope, M., & Elwood, S. (2009). *Qualitative GIS: A mixed methods approach*. Thousand Oaks, CA: Sage.
- O'Sullivan, D. (2006). Geographical information science: Critical GIS. *Progress in Human Geography*, 30, 783–791.



CRITICAL HUMAN GEOGRAPHY

The term *critical human geography* arose in the mid 1990s in Anglophonic geography as a way of representing a broad coalition of progressive approaches to the discipline. Critical human geography can be seen as a diverse set of ideas and practices linked by a shared commitment to a broadly conceived emancipatory politics, progressive social change, and the use of a range of critical sociogeographic theories. Critical human geographers draw on theoretical approaches such as anarchism, anticolonialism, critical race theory, environmentalism, feminism, Marxism, non-representational theory, post-Marxism, postcolonialism, poststructuralism, psychoanalysis, queer theory, situationism, and socialism. This entry describes the growth and development of critical human geography in primarily Anglophonic settings, and also in a number of other non-Anglophonic academic spaces (but ones that operate in, or articulate with, the wider hegemony of Anglophonic American geography). Much of the focus is on some of the key publications marking different eras in critical geography. From this perspective, the practice of critical human geography can be seen as a tentative move toward development of a historical geography of knowledge production in critical geographies.

The discussions that follow are necessarily schematic rather than a full outline of the nuanced character of these approaches. Suffice it to say that there is a good deal of overlap and a much more complex (and contradictory) character to these historical geographies of knowledge production than it is possible to present here. In outlining these various forms of geography, it is clear that critical human geography cannot be defined in a singular way but instead must be understood as multiple, dynamic, and contested and that the term *critical human geographies* should be used in recognition of this fact; that is, we should call them critical human geographies. Critical human geographers are committed to transforming their worlds, and they are thus—almost by definition—engaged in significant contestation over how we should interpret existing spatial relations and how we might improve



on them. At the same time, they recognize that coalitional politics may be one of the best ways to achieve their ends.

Early Roots of Critical Geographies

The radical roots of critical geographies lie in the 19th century, among writers such as Karl Marx, Friedrich Engels, Élisée Reclus, and Peter Kropotkin. Marx and Engels are not considered geographers in the formal sense, but both contributed immensely to the critical understandings of capitalism that form the foundation for much subsequent radical geographic analyses of class relations. Moreover, some would argue that Engels's first book, *The Condition of the Working Class in England in 1844* (published originally in German in 1845 as *Die Lage der arbeitenden Klasse in England*, then translated and published in English in 1887), considered to be a classic account of the material conditions endured by the industrial working class, can also be read as an early critical geography of urban conditions and class relations. Engels focused his analysis in part on a comparison between material conditions in cities and the countryside, and he pointed out that members of the urban proletariat in Manchester were worse off than most peasants living in the countryside.

Both Reclus and Kropotkin were anarchists who were also formally trained geographers and are understood by many to be the first radical geographers. Both are famous for writings on a wide spectrum of issues. Reclus is best known for his influential 32-volume work, *La nouvelle géographie universelle: La terre et les hommes*, for which he was awarded the prestigious Gold Medal of the Paris Historical Society in 1892 (at which time he was exiled from France for his anarchist political activism). Reclus is believed to have coined the term *social geography* because of his interest in the "social facts" of class struggle. Kropotkin was also a prolific writer, producing works on various aspects of the geographies of Asia and on scientific expeditions in Siberia, numerous articles in *The Geographical Journal*, and upward of 90 articles on Russian geography for the *Encyclopaedia Britannica*. He also published revolutionary pamphlets and numerous books, including two landmark treatises on

anarchist praxis (*Fields, Factories and Workshops* and *The Conquest of Bread*). For critical geographers, however, Kropotkin is perhaps best remembered for his essay "What Geography Ought to Be" (first published in 1885).

A broadly Marxist tradition was continued in early-20th-century Germany by Karl Wittfogel, the first explicitly critical German geographer, with the publication in 1929 of "Geopolitik, geographischer Materialismus und Marxismus" (reprinted in *Antipode* in 1985 as "Geopolitics, Geographical Materialism and Marxism"). Wittfogel was a member of the Institute for Social Research (better known as the Frankfurt School), and like many of his colleagues, he was highly critical of the growing conservatism in Germany (and for Wittfogel specifically, in German geography). Wittfogel was an isolated critical voice in German geography; it was not until much later—in the mid 1990s—that critical geography began to rise again as an institutional force. However, as Ulrich Best points out—and in spite of the institutional resistance to critical geography—a number of student groups kept ideas for a critical German geography circulating with the production of three different, albeit short-lived, critical geography journals: *Geografiker* (1968–1972), *Roter Globus* (*Red Globe*, 1971–1973), and *Geographie in Ausbildung und Planung* (*Geography in Teaching and Planning*, 1973–1976).

Marxist traditions were perhaps more marked in France than in Germany during the 20th century. Immediately after World War II, geographers and French Communist Party members such as Pierre George and Jean Tricart wrote a number of geographical articles for the Marxist journal *La Pensée*. They had much more influence on French geography than Wittfogel did in Germany, and they began a movement that challenged the traditionalist Vidalian school. Marxist spatial analysis and geography were furthered with the development of journals such as *Espaces et Sociétés* (founded by Anatole Kopp and Henri Lefebvre in 1970) and *Hérodote* (founded by Yves Lacoste in 1976). Illustrating the ongoing relevance of anarchist and Marxist approaches in French geography, *Hérodote* has published two special issues on Élysée Reclus, in 1981 and in 2005.

Anarchism, Marxism, and socialist theory formed the foundation for the rise of what in the



late 1960s and early 1970s came to be known as *radical geography* in American geographic circles. Two publications of that period are indelibly linked to Anglophonic radical geography: (1) *Antipode: A Radical Journal of Geography* began publication from the geography department at Clark University in 1969 (first edited by Ben Wisner and then by Richard Peet from 1970 to 1985) and (2) David Harvey's acclaimed book, *Social Justice and the City*, was published in 1973. *Antipode* continues publication to date and is celebrating its 40th anniversary. *Social Justice and the City* remains an important text on the reading list of almost every graduate course on the history and philosophy of Anglophonic human geography. Much of the 1970s and 1980s saw a significant output of publications and practical "interventions" in everyday life by radical geographers, most of which were dominated by anarchist, Marxist, and socialist theoretical approaches. Radical geographers were interested in using such theoretical views to expose and contest sociospatial power relations of inequity and oppression. They were also interested in better understanding the relationship between theory and practice, and they were therefore especially interested in theorizing the relationship between structure and agency. Unlike quantitative geographers, radical geographers saw human agency as important, but unlike humanistic geographers, they understood social, spatial, and economic structures to play a key role in constraining human agency. Marx's famous dictum that "people make history, but not under the conditions of their own making" became axiomatic among radical geographers of this period.

There are other critical geographies that developed in other spaces in the 1970s and 1980s, sometimes in concert with, sometimes parallel to, and sometimes isolated from Anglo-American radical geography. Geographers in the Nordic countries began to meet in 1980 for the Nordic Symposium on Critical Geography (a tradition that continues today as a special theme in the Nordic Geographers Meetings). Mediterranean architects, geographers, and sociologists have been meeting in the Seminars of the Aegean for more than a quarter of a century to critically analyze sociospatial relations in the region. Latin

American geographers, with Milton Santos (1926–2001) perhaps the most well-known among them, have also contributed significantly to international critical geographies. Finally, there is a long history of critical and radical geographies in white settler states in the Southern Hemisphere: Australia, Aotearoa/New Zealand, and South Africa. Critical geographers from all these locales have strong links with Anglo-American radical geography and wider sets of critical geographies.

The Challenge to Marxist Radical Geographies

The civil rights movements of the late 1960s led to a host of "new social movements" in the 1970s, including movements advocating for greater recognition of rights (in practice, not just in law) for people of color, women, gay and lesbian people, Aboriginal people, people with disabilities, as well as those impoverished in their role as workers (or unemployed) in the capitalist mode of production. As a result of these new social movements, radical geography branched out from its Marxist and socialist roots relatively early, with feminist, antiracist, and anticolonial works appearing in the 1970s and 1980s. Feminist geography, for example, first appeared in *Antipode* in 1974, with an article by Alison Hayford titled "The Geography of Women: An Historical Introduction." Feminist articles began to appear in other journals some years later, with Janice Monk and Susan Hanson's "On Not Excluding Half the Human in Human Geography," for example, appearing in *The Professional Geographer* in 1982.

Eventually, Marxist geographies could no longer provide a single epistemological space capable of accommodating all these different forms of identity politics. To give one example, while there were many important interventions in radical geography by feminist geographers, many feminists came to believe that they were not allowed full membership in "the project" of radical geography. Accordingly, Linda McDowell wrote of being both "inside and outside 'the project.'" The same can be said for members of other disaffected groups and their allies, including people of color, queer people, and disabled people.



Writing as disability activists (and disabled women), for example, Ali Grant and Vera Chouinard wrote of being “not even anywhere near the project.” Many of these people found intellectual inspiration in postmodern critiques of overarching theoretical metanarratives (e.g., anarchism, Marxism, and socialism) that rarely spoke to their experiences. Moreover, they engaged with postmodernism to criticize their exclusion from the project. In an important paper published in 1988, Michael Dear referred to this trend as part of a wider “postmodern challenge” to human geography. Postmodernism was always highly contested in human geography, albeit more so in the United Kingdom and the United States, where the stakes for those maintaining the status quo were much higher. Postmodernism as a set of ideas was much more welcomed in ostensibly “peripheral” spaces such as Australia and New Zealand, since geographers in these places were always both inside and outside the hegemonic project of radical geography. Notwithstanding its relatively short and contested life in geography—its currency as a theoretical approach lasted from the mid 1980s to the mid 1990s, although a closely related set of theoretical approaches known as *poststructuralism* continues to be a powerful force in critical geography today—postmodernism played an important role in a number of transformations of the discipline. One significant impact that postmodernism had on human geography was to precipitate a crisis of representation that in many respects continues to affect critical geographies to this day. Partly as a result of this crisis of representation and partly as a result of not personally identifying as Marxist (although all would identify as Left-progressives), very few geographers now use the label *radical geography* to define their work. Instead, most use the broader term *critical geography*.

The Critical Geography Forum and the International Critical Geography Group

The term *critical geography* had begun to be used by geographers in the 1980s and 1990s. The Nordic Symposium on Critical Geography, for example, was initiated in 1980. The Cincinnati Mini-Conference in Critical Geography started in 1994. Macmillan Publishers even

began to market a book series under the name “Critical Human Geography” in 1982. However, *critical geography* became institutionalized in geography as a term generally accepted by a broad constituency of Anglophonic geographers only following a series of events arising from the merger of the Institute of British Geographers (the scholarly society for academic geographers) with the much larger Royal Geographical Society. The story is worth recounting here, as many of the concerns raised are emblematic of the way critical geographers tend to operate as intellectuals, as knowledge workers, and as citizens of the world. The merger formed what became the Royal Geographical Society (with the Institute of British Geographers) (RGS-IBG), and it confronted Left-oriented geographers with a series of political and ethical dilemmas arising from the sponsorship of the RGS-IBG by the multinational company Royal Dutch Shell. First, many geographers had concerns about the RGS-IBG being sponsored by multinational capital, with its attendant exploitation of workers (through the appropriation of the surplus value of labor); they were also concerned with issues of indigenous rights, environmental justice, and environmental racism, and they were concerned with the neocolonial relationship that the RGS-IBG was implicated in because of its acceptance of money from Shell.

Shell had for some years prior to the merger of the RGS-IBG been engaged in oil extraction activities in the Niger River Delta in Nigeria. The Ogoni people, who lived in the delta, had long criticized Shell’s activities in the region—complaining in particular about its devastation of the environment and its lack of concern for local peoples and also about Shell’s indirect support of the military junta that ruled Nigeria through oil revenues accruing to the state from Shell. On November 10, 1995, nine Ogoni people, including the famous writer and political activist Ken Saro-Wiwa, were executed by the military regime. According to a press release dated April 6, 2009, Shell was to stand trial in a federal court in New York State on charges that it was complicit in human rights abuses in Nigeria, including the execution of the nine Ogoni people, as well as in crimes against humanity, torture, arbitrary arrest, and detention.



As a number of contributors to a special issue of *Ethics, Place and Environment* noted, Shell's activities in the Niger Delta and its links to the Nigerian military regime posed significant problems for the RGS-IBG, given that Shell was a major sponsor of the organization. After the execution of Saro-Wiwa and his colleagues, a campaign was launched to convince the RGS-IBG to end its relationship with Shell. Just prior to the execution, a number of critical geographers in the United Kingdom had already begun to explore options for developing an alternative geographical organization (of some sort) to the RGS-IBG, and some of these geographers created the Critical Geography Forum online (Joe Painter is the person credited with actually creating the list on the U.K.-based system in 1995). The Critical Geography Forum list came into its own as the space for discussions in support of the campaign to end Shell's sponsorship of the organization. Academic geographers voted overwhelmingly in support of a motion to end the sponsorship, but this was ignored by the RGS-IBG Council. Eventually, the critical geographers were successful in getting a motion to end the sponsorship put to a membership vote at a special general meeting of the RGS-IBG in November 1995. That vote was dominated by former RGS members (nonacademics, as opposed to the academics who made up the former IBG), and the motion to end the sponsorship was overwhelmingly defeated.

While the motion to end Shell's sponsorship of the IBG was defeated, the Critical Geography Forum became a venue for discussions that led to creation of an alternative geographic organization and for organizing alternative conferences. The inaugural International Conference of Critical Geographers (ICCG), which took place in 1997 in Vancouver, Canada, was organized by members of the Critical Geography Forum and gave rise to the International Critical Geography Group (<http://econgeog.misc.hit-u.ac.jp/icgg>). Subsequently, the International Critical Geography Group organized four more International Conferences of Critical Geography (in Taegu, Korea, 2000; Békéscaba, Hungary, 2002; México City, Mexico, 2005; and Mumbai, India, 2007).

Conclusion: Critical Geography as Human Geography

Critical geography is now institutionalized in much of Western academe. It is arguably hegemonic in places such as the United Kingdom, and it is certainly ascendant in places such as Australia, Canada, Denmark, Finland, New Zealand, Sweden, and the United States. Critical geographers often now hold senior positions in both their universities and the wider academy in many of these places. This positioning of critical geography as almost normative has transformed human geography, but it has also had transformative effects on critical geography itself. As part of a now "mature" approach in human geography, critical geographers are much less likely to be making programmatic statements about what geography ought to be. Instead, critical geographers are using a wide range of critical social theories to undertake substantive studies of people's geographies. At the same time, critical geographers are subjecting various forms of critical geography itself to interrogation for their contribution to classism, colonialism, inequality, injustice, racism, and sexism. Finally, many critical geographers (often under the rubric of nonrepresentational theory and/or theories of practice) are engaging in work that radically questions how we know our world and how we represent it, which might possibly bring us back again to an all-new kind of radical geography.

Lawrence D. Berg

See also Anarchism and Geography; Antiglobalization; Antisystemic Movements; Bunge, William; Critical Geopolitics; Cultural Turn; Disability, Geography of; Environmental Justice; Environmental Racism; Feminist Geographies; Gays and Lesbians, Geography and/of; Gender and Geography; Harvey, David; Human Geography, History of; Identity, Geography and; Imperialism; Justice, Geography of; Marxism, Geography and; Masculinities and Geography; Massey, Doreen; Mitchell, Don; Orientalism; Other/Otherness; Peet, Richard; Political Ecology; Political Economy; Postcolonialism; Postmodernism; Poststructuralism; Queer Theory; Race and Racism; Radical Geography; Smith, Neil; Social Geography; Social Justice; Walker, Richard; Whiteness



Further Readings

- ACME: *An International E-Journal for Critical Geographies*: www.acme-journal.org
- Bauder, H., & Engel-Di Mauro, S. (Eds.). (2008). *Critical geographies: A collection of readings*. Kelowna, British Columbia, Canada: Praxis (e) Press. Retrieved January 19, 2010, from www.praxis-epress.org/availablebooks/introcriticalgeog.html
- Berg, L. (2004). Scaling knowledge: Towards a critical geography of critical geographies. *Geoforum*, 35(5), 553–558.
- Gilbert, D. (1999). Sponsorship, academic independence and critical engagement: A forum on Shell, the Ogoni dispute and the Royal Geographical Society (with the Institute of British Geographers). *Ethics, Place and Environment*, 2(2), 219–228.
- Harvey, D. (1984). On the history and present condition of geography: An historical materialist manifesto. *Professional Geographer*, 36, 1–11.
- Jacobs, J. (1996). *Edge of empire: Postcolonialism and the city*. London: Routledge.
- Rose, G. (1993). *Feminism and geography: The limits to geographical knowledge*. Minneapolis: University of Minnesota Press.



CRITICAL STUDIES OF NATURE

The different ways in which people understand nature have been at the heart of struggles over what kind of discipline geography ought to be. Recent years have seen the emergence of a range of critical approaches to the study of nature that seek to critique and change it. Nevertheless, conceptually, *nature* remains notoriously difficult to define, and as will become clear, definitions often reveal much more about an overall political position—and a view about what geography ought to be—than they do about plants, animals, landscapes, and the many things we think of as nature.

In its earliest manifestations, geography was defined by an emphasis on the manner in which natural environments shaped and determined

human societies. Here, nature assumed a determining role over the social: Differing levels of civilization were interpreted through this deterministic lens. This position was brought into question by those who sought to place a greater influence on the role of culture as a mediating factor between the social and the natural. Nature, in the process, came to be understood as something imbued with a variety of social and cultural characteristics. Rather than being seen as a pristine realm, devoid of human influence, nature was viewed as a product or construct. These constructions of nature have varied historically and geographically. Subsequent debates have followed similar lines to these first confrontations, with contemporary critical work increasingly assuming an antiessentialist or denaturalizing track. To put things crudely, the aim has been to show that nature is anything but natural.

As several authors have noted, the dominant view of nature has served to deepen the gulf between human and physical geography. However, more recent critiques have sought to establish the myriad ways in which apparently discrete social and natural entities are actually co-constitutive. Although in according nature a greater agency this might seem to be a move back toward the ground of environmental determinism, the thrust of this work is entirely different. Instead, the aim has been to dismantle the false dichotomies through which nature and society have been read and interpreted. Perhaps here, there may be more grounds for a conversation, and it is perhaps no surprise that environmental geographies seem to be undergoing a minor renaissance. In what follows, this shifting focus from the social construction of nature toward a growing recognition of the mutually constitutive relationships between nature and society is charted. At the same time, the important synergies with other approaches, from feminism to Marxism, are captured.

Constructing Nature

If the overarching thrust of critical work has been to undermine the authenticity of the natural, this has tended to be through a focus on historically and geographically varying constructions or representations of nature. Different meanings are shaped by dominant representations of nature in



a particular place at a particular time, as well as an individual's place within a particular social structure. In spite of these particularities, it is possible to isolate three common understandings. Thus, nature is (1) the nonhuman world (and occasionally the human and nonhuman worlds together), (2) an inherent force directing the human or nonhuman world, and (3) the essence of something (as in a thing's "natural properties"). These definitions are potentially contradictory, again merely reemphasizing the real difficulty in isolating what exactly nature is. Critical studies of nature have picked up on these ambiguities while demonstrating the way in which meaning is constructed through particular relations of power. Here, the apparent neutrality of representations of nature has been exposed to be ideologically driven. Landscape painting, as one dominant mode of representing the beauty of a particular environment, has been presented as a representational practice that enables everything from property rights to gender relations to appear as natural or authentic expressions of the way the world ought to be. Both property rights and gender are social constructions, but associating them with the natural world appears to give them a much stronger legitimacy. They come to be dominated by a force outside human control. Because of this, work on the social construction of nature has had a broadly liberatory agenda. It seeks to demonstrate how many of those characteristics considered to be natural are social constructions. Rather than contenting ourselves with the world as a natural given, the possibilities for a better, more egalitarian, and more ecologically sustainable future begin to emerge.

Politicizing Nature and Denaturalizing Hazards

Political ecologists have worked with similar tools to demonstrate the ways in which environmental problems cannot be understood outside the power relations, institutions, and economic processes of which they are a part. Some have referred to the focus of political ecological research as "the politicized environment," and one of the key contributions has indeed been to politicize understandings of nature. To take a classic example from the literature, soil erosion

in Nepal was for many years linked to both geomorphological processes and the specific agricultural practices of farmers. Combating soil erosion required a change in cultural practices and a welter of development praxis focused on reeducating local farmers to care for their lands better. For political ecologists, it is vital to situate the decisions being made by farmers within broader systems of accumulation. Soil erosion, in short, should be seen to emerge from the limited options available to small-scale farmers within a capitalist society. Geomorphological processes and indeed the soil itself are crisscrossed with broader relations of power.

Turning their attention to famine, political ecologists have also played a key role in undermining a resurgent neo-Malthusianism in the late 20th century. Through in-depth ethnographic research, they have exposed the social causes of what some interpreted as natural disasters. Michael Watts, for example, has demonstrated that West African farmers coped successfully with drought until colonialism undermined indigenous food-producing systems. Here, there are connections with hazards research, which has similarly been an important terrain for pioneering critical approaches to understandings of nature. As with work in political ecology, critical hazards research has moved away from explanations of disasters based on natural processes and individual decision making. Instead, decisions have been rooted within broader political economy questions and linked more fully to the systems of accumulation in which hazards emerge.

Denaturalizing Gender and Socializing Nature

Feminist geographical research has similarly had a central role in shaping critical studies of nature. From the 1970s onward, feminist geographers have exposed the many ways in which apparently natural differences between the sexes have been produced and reproduced through a variety of social codes, representations, and practices. As with the question of nature, dominant epistemological frameworks have posited a series of dualisms around which differences are reinforced. Above all, femininity has been associated with nature, whereas masculinity has come to represent



the domain of culture. Again, these dualisms have been reinforced within literary and artistic forms of representation, as women have been visually and metaphorically connected to “Mother Earth.” These tropes are mutually reinforcing. Thus, a feminized view of nature emerges at the same time as a naturalized view of femininity. Exposing these dualisms and demonstrating their subversive operation in varying historical and geographical contexts has been the central aim of much feminist research. Paradoxically, certain approaches to researching gender and nature appear ultimately antithetical to this denaturalizing impulse. Biological ecofeminism has celebrated women’s proximity to nature as opening up possibilities for a new ecological consciousness. Although such a biologically determinist position is rejected by the vast majority of both feminist environmentalists and also ecofeminists, it nevertheless reopens aspects of the debate over nature. For more socially minded ecofeminists, divisions between men and women are the result of a gendered division of labor (and thereby a product of society and not nature). Thus, an interpretive response to a structurally determined (and socially produced) position is required if a radical ecological consciousness, a transformed conception of nature, and a challenge to patriarchy are to emerge from women’s role within broader ecosystems.

More recent work in feminist geography has sought to dismantle the assumption that gender is a social construct while sex and the body are natural givens. Again, the tendency is to naturalize what is actually a more complex social product. Bodies, in short, should be seen to be actively coded and produced. Neither fully natural nor fully social, they are a product of mutually constitutive socionatural relationships. Perhaps some women do indeed “throw like a girl,” but this cannot be seen outside the particular functions, movements, and performances that bodies are socially expected to undertake. Once again, this blurring of social and natural categories has both mirrored and informed critical studies of nature.

After Humanism

Integrating some of these insights more directly into critical studies of nature, researchers have sought to show the manner in which nature is

enacted or performed. This has emerged most clearly within work that is often referred to as *post-humanist*. Criticizing humanist thought for a hubristic overestimation of the agency of humans, post-humanists have sought to develop an agenda for researching interspecies connections. Whereas the rigid compartmentalization of natural and social processes might be seen to emerge from humanist perspectives, the notion that nature is a social construction is also criticized. The epistemological critique of the latter has been replaced by an ontological critique. In short, dividing the world into boxes labeled nature and society is seen to make little sense in reality, not to mention our ways of thinking about reality. Seeking to capture this reality within a more appropriate language, theorists have described a variety of socionatures, cyborgs, hybrids, and imbroglios.

Although now common within geographical work, most post-humanist writing has emerged from social studies of science and has been influenced in large part by French social theory. Perhaps the most common approach within such work has been actor-network theory. More clearly defined as an approach to social scientific research than as a coherent theoretical framework, *actor-network theory* has sought to demonstrate the manner in which reality is made up of networks of human and nonhuman actants (*actants* are essentially actors but can include nonhuman objects, which in actor-network theory enable and constrain the actions of others and thus have consequences). The term *actants* refers to the fact that neither the human nor the nonhuman is genuinely an actor. Instead they both depend on the other actants that constitute these broader networks. From studies of scallop fishing, in which the scallops themselves were viewed as actants in a chain of processes surrounding their harvest, to research on the practice of scientific research, this work has done much to trace the numerous connections that make up reality. Clearly, it becomes difficult to sustain any rigid boundaries between nature and society or between humans and nonhumans, as networks appear to defy any socially imposed framework of understanding. The division of geography into its social and natural scientific branches becomes increasingly problematic: Any discussion of a “human geography” is to automatically short-circuit a much broader network of



connections. More recently, geographers have been drawn to hybrid geographies and explorations of the myriad mixings between humans and nonhumans as ways to avoid a strict dichotomy between the social and natural worlds and emphasize that they are inescapably entwined.

Clearly, the post-human actor-network theory approach has appealed to those broadly interested in an ecosystemic approach to nature, and for some people, there are important connections to deep-green or deep-ecology philosophies. As with some deep-ecology work, the post-humanist emphasis on nonhuman agency has been criticized for its inability to address socially produced power differences, its inattentiveness to broader political economy questions, and its problematic approach to history. It can also exhibit a naive celebration of all life forms regardless of their impacts on human beings. For example, there is little to celebrate about the virus that causes AIDS or plague-carrying rats. Linguistically, there are also problems—the very term *hybrid* suggests a meeting of two things (whether species, inanimate objects, or whatever) that were formerly distinct. The point of post-humanist approaches such as actor-network theory is to overcome deeply embedded dichotomies such as between humans and nature and to stress their interconnections in such a way as to emphasize their inseparability. This approach has led to a blurring with more populist theses on the so-called end of nature, the notion that the natural world has been so utterly transformed by human beings that it is impossible to discuss it without reference to how people have constructed, modified, represented, and reproduced natural systems of energy, matter, and life. Here, a new era of techno-natural hybrids has been either celebrated or condemned. Even if the thrust of post-humanist work is to argue that we have never been fully human, it has been difficult to find a language that does not reproduce the sense in which humans and nature are only now beginning to intermingle. Nevertheless, from the turn of the millennium, research in hybrid geographies seems to have captured the imagination of many in the field of Anglophonic geography, inspiring a wealth of studies across the discipline and also bringing about some fascinating collaborations between human and physical geographers.

Producing Natures

Many of the criticisms of hybrid geographies have come from Marxist scholars, who claim that the inability to consider capitalist relations makes such research academically defunct and politically impotent. The result has been a muted standoff between two of the most important contributions to critical studies of nature within geography. The potential overlaps and grounds for dialogue have thus been neglected. Outside political ecological work, the key contribution of Marxist approaches to critical studies of nature has been to understand the latter as produced. Although this has echoes of the social constructionist position, it differs in several significant ways. First, as with post-humanist critiques, it develops an ontological argument against the separation of nature and society. Second, and relatedly, it focuses on everyday practices and, above all, on the labor process rather than on representations and ways of thinking about nature. For Karl Marx, work or practical activity is a metabolic process. By this, he means that through the creative act, nature is transformed at the same time as humans are transformed. Indeed, they are indissociable. If a carpenter produces a chair, this not only transforms the wood being worked on, it also provides something of use for society that changes the way it is organized. Although this applies directly in societies in which production is for the immediate satisfaction of one's own needs or the needs of one's direct friends or family, it becomes more complicated when commodities are produced for exchange. For exchange to operate effectively, a universal measure of value is needed—something that transforms the myriad qualities of a commodity (e.g., a chair's ability to provide rest, comfort, or relaxation) into a single, universally recognized measure of value. Money performs this role, and with the entry of money into exchange societies, nature is increasingly recognized for both exchange value and use value. The work process thereby serves to mediate the transformation of nature into both a use and an exchange value. Capitalist societies imbue a further set of relations in this production of nature, and nature comes to embody the relationship between worker and capitalist. Important within this framework is a sense that nature has always



been produced. It is clearly possible for humans to relate to one another in ways that are more or less beneficial for other life forms; however, the interdependence of ecosystems remains transhistorical. These insights have spawned work on cities as particular created ecosystems or, as some have referred to it, on the *urbanization of nature*.

If this historical materialist approach to the study of nature shares several of the insights of hybrid or actor-network approaches, it is in the sense that, ontologically, nature and society are one. For Marxists, the language adopted has tended to emphasize the manner in which nature is and has always been a differentiated unity comprising the social and the natural. For some, this is best referred to as a dialectical relationship. With the focus on historically and geographically specific relations, research on the production of nature has foregrounded the importance of capitalist forms of organization for questions about nature. Indeed, for historical materialists, none of the key questions around nature can be adequately understood unless some weight is given to these social relations. Malthusian approaches to nature and resources, for example, are turned on their heads if the necessity for capitalism to produce a surplus population is recognized. Resources come to be relationally defined. If those relations change, so do the resources and the key questions being asked around them. Here, there are connections back to research in political ecology, which has also been open to using the methodological tools provided by Marx as a form of nature critique. Finally, critical work on nature from a Marxist perspective has developed interesting connections with work on environmental justice. If nature is actively produced through the work process, it is the environment lived and experienced by people on an everyday basis. Rather than defending wilderness areas, environmental justice is about challenging the injustices that result from some people being forced to experience a dirty, polluted nature that harms the health of themselves and their families on a daily basis.

Conclusion

If the concept of nature employed in critical human geography appears to be some distance from that in the popular imagination, this is partly an

intentional move. Geographers have sought to expose the ways in which certain concepts of nature can have a paralyzing influence on a politics of liberation. At the same time, the example of environmental justice shows the way in which it might be possible to reconstruct a politics of nature that is critically relevant to everyday life. Overall, critical studies of nature appear to have moved from a strong social critique of the very concept of nature to a more qualified recognition that nature matters. An epistemological critique of the separation of nature and society has given way to an ontological argument about internally related socionatures. While these debates have inevitably been shaped by academic fashions, they have real import for both the type of discipline geography might be and the makeup of the world we wish to live in.

Alex Loftus

See also Actor-Network Theory; Class, Nature and; Critical Human Geography; Cultural Ecology; Ecofeminism; Ethnicity and Nature; Gender and Nature; Marxism, Geography and; Nature; Nature-Society Theory; Political Ecology; Race and Nature; Social Construction of Nature

Further Readings

- Castree, N. (2005). *Nature*. London: Routledge.
- Castree, N., & Braun, B. (Eds.). (2001). *Social nature: Theory, practice, and politics*. Oxford, UK: Blackwell.
- Fitzsimmons, M. (1989). The matter of nature. *Antipode*, 21, 106–120.
- Proctor, J. 1998. The social construction of nature. *Annals of the Association of American Geographers*, 88, 352–376.
- Smith, N. (1984). *Uneven development*. London: Blackwell.



CROP GENETIC DIVERSITY

Crop genetic diversity describes the genetic diversity within or between plant species that are either directly useful to humans in the context of food and agriculture or are relatives of such species.



To increase the genetic diversity of U.S. corn, the Germplasm Enhancement for Maize project seeks to combine exotic germplasm, such as this unusually colored and shaped maize from Latin America, with domestic corn lines.

Source: Keith Weller/ARS/USDA.

This genetic diversity can be assessed at different taxonomic levels, such as families, genera, species, subspecies, varieties, or landraces. Genetic diversity can be measured by different methods, ranging from the more traditional phenotypic approaches—in which the plant's physical appearance is assessed through field or greenhouse observations—to modern methods that assess genetic diversity at the molecular level.

Crops are thought to harbor less genetic diversity than their wild relatives, since selection by humans during domestication causes a loss in genetic diversity—a process also known as a *domestication bottleneck*. Modern breeding

efforts often lead to a further decrease in genetic diversity because of very strong selection pressures and the development of phenotypically uniform lines or varieties for commercial production. However, crop-breeding programs rely heavily on genetic diversity among different cultivars and crop wild relatives as a “genetic resource” for improvement. Also, the cultivation of a diverse array of varieties can be a promising preemptive strategy for disease management. Enhancing crop genetic diversity in agricultural production systems through the cultivation of a wide range of crops and varieties is increasingly recognized as a sustainable way to achieve food security, especially in areas with frequently fluctuating environmental conditions (see photo). However, as agriculture in most countries is being increasingly intensified using relatively few high-yielding and uniform varieties, crop genetic diversity is in decline, and much has already been lost. Increase of this decline in genetic diversity has been termed *genetic erosion* and is also caused by several other factors, including environmental and socioeconomic changes.

Genetic resource conservation programs exist that aim to counteract the loss of crop genetic diversity through in situ or ex situ approaches. In situ efforts attempt to protect habitats of crop wild relatives or encourage farmers to grow and evaluate a great diversity of crops and varieties. Ex situ conservation efforts consist of national gene banks or botanical gardens, as well as international collections such as the gene banks of the Consultative Group on International Agricultural Research (CGIAR) or international backup collections such as the Svalbard Global Seed Vault.

Since crop genetic diversity is geographically unequally distributed around the globe, there is a considerable interdependence among nations and across generations for these genetic resources. As a result, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) has been set up to govern international exchange of genetic diversity of many major crops, as well as ensure fair and equitable benefit sharing. Since humans exert much of the selection pressures that determine the amount of genetic diversity present within a crop's gene pool and genome, traditional knowledge of crop diversity and production systems is an important source of information and



as such needs to be considered in efforts that aim to conserve crop genetic diversity.

Hannes Dempewolf

See also **Agricultural Intensification; Agrobiodiversity; Agrofoods; Biodiversity; Biotechnology and Ecological Risk; Centers of Domestication; Conservation; Cultural Ecology; Domestication of Plants; Sustainable Agriculture**

Further Readings

- Food and Agriculture Organization of the United Nations. (1998). *The state of the world's plant genetic resources for food and agriculture*. Rome, Italy: Author.
- Tanksley, S. D., & McCouch, S. R. (1997). Seed banks and molecular maps: Unlocking genetic potential from the wild. *Science*, 277, 1063–1066.

CROP ROTATION

Crop rotation involves the planting of different kinds of crops, in a time and space sequence, given the differential attributes of the crops, whereby a number of agronomic benefits are obtained. Although crop rotation is an age-old practice, it generally went out of practice in the late 20th century with the widespread introduction of agrochemicals and advanced technologies in agriculture, although some observers advocate a return to crop rotation on ecological grounds. In most countries, including those of the developing world, crop rotation had been a response to the growing population pressure on land resources, allowing lesser and lesser room for leaving the land fallow for a set number of years. Fallowing (leaving cultivated land unseeded and unplowed for one or more growing seasons), practiced since the earliest years of crop cultivation, allowed the soil to recuperate and also break the life cycle of crop pests and diseases. Allowing vegetation to grow on the fallow land allows for

the accumulation of organic matter and other kinds of nutrients for the next cropping.

Crop rotation is a complex operation. It has a cultural context and is specific to agricultural systems. It should also be tailored to the social, economic, and environmental attributes of a place. Sorting of the crops grown in a particular area for the purpose of rotation also poses a challenge. Crops should be grouped, for instance, as grass crops or leguminous crops; those with shallow or deep roots; those with dense or light foliage; those with fibrous or large roots; those with allelopathic or nonallelopathic properties; those that need lesser or greater amounts of light, water, nutrients, and space; and those with susceptibility to the same pest or disease.

As chemical fertilizers, herbicides (weed killers), insecticides (pest exterminators), and treatments for plant diseases became more readily available, it became more attractive to use such convenient technologies in place of going through the drudgeries of rotating crops. The honeymoon with high-input farming did not last long. The skyrocketing prices of agricultural inputs (e.g., chemical fertilizers, herbicides, and insecticides) for the past 20-plus years have put crop farmers in a difficult situation. The resistance of some weeds, diseases, and pests to chemicals has posed a serious challenge to their effectiveness. Moreover, the environmental effects of the use of agrochemicals have also been reaching disastrous proportions. Although many farmers have continued to use agrochemicals, unimpressed by the looming environmental threats, there is an urgent need to revert to old and environmentally friendly farming practices, such as organic farming (which relies on crop rotation) and integrated pest management. A complete or partial shift to crop rotation could ensure agricultural sustainability as well as environmental sustainability.

The technological challenges that discourage the return to crop rotation are not limited to the relative ease in the use of artificial inputs. Most farming technologies are fit for monocropping and the application of chemical inputs. A return to crop rotation may involve redesigning of farm machines and implements. Even more intractable in this regard are the government policies and institutional arrangements, which are geared to high-input agriculture.

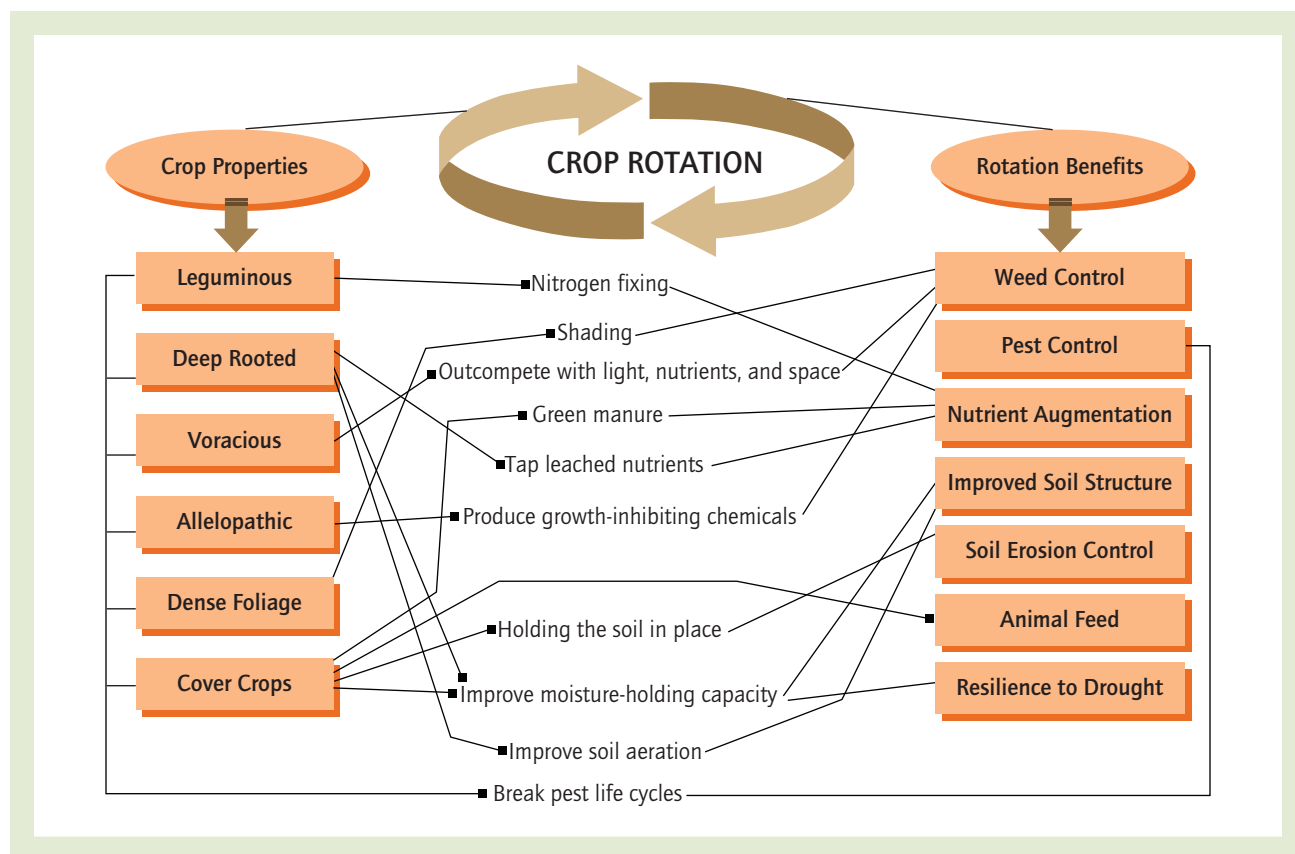


Figure 1 Crop rotation schema

Source: Author.

Crop rotation has several benefits that are provided by the varying botanical characteristics of the crops. It can improve the physical conditions, organic matter, and plant nutrient content of the soil; maintain the balance in the distribution of nutrients in the soil; enable nonchemical control of weeds, diseases, and insect pests, thus reducing reliance on pesticides; facilitate soil moisture management; make low-cost animal feed available; and enhance crop diversification (Figure 1).

For the best results, grass crops should not be followed by grass crops. When legumes are included in the rotation, their nitrogen-fixing and other characteristics will replenish the soil nutrient content depleted by the continued growing of grass crops. Since different legumes have different nitrogen-fixing capacities, crop selection should be an important consideration. Soil nutrient augmentation benefit also comes from other rotation crop properties. Deep-rooted plants could tap

leached nutrients from the lower soil layers and return them to the topsoil after they die. The green manure from cover crops plays a similar role. Deep-rooted crops also improve the structure of the soil, increasing the soil's aeration and water-holding capacity. Besides the advantage cover crops have in providing lower-cost feed for animals, they help improve the moisture-holding capacity and enhance resilience to drought. Moreover, by protecting the soil from being splashed by rain droplets and from being taken away by runoff, cover crops alleviate the problem of soil degradation.

Pests typically have specific host crops. When rotation is planned for the purpose of pest control, it is those crops that are not susceptible to the particular pest that should be planted. The crops can be of any type as long as they help break the life cycle of the pest, starve and kill it, or drive it away. The benefit of crop rotation for



Like farmers in the Northern Great Plains, those in the Central Great Plains have traditionally grown wheat one season and left the ground fallow the next. However, leaving the field fallow hurts the soil by decreasing its organic matter while increasing the likelihood of erosion. The rotation also wastes a lot of water through evaporation when the soil is bare. In 1990, a research team at the Agricultural Research Service Central Great Plains Resources Management Research Unit in Akron, Colorado, began a long-term alternative crop rotation study to find useful, profitable, and sustainable rotations. In this experiment, 23 alternative no-till dryland-crop rotations were compared with the old wheat-fallow system. This photo shows sunflowers and proso millet plots in the alternative crop rotation plots. Implementation of farming practices that were successful in the experiment can increase farm productivity while also helping the environment.

Source: David Nielsen/ARS/USDA.

weed control comes at least from three crop properties: (1) crops with dense foliage deny the weed sunlight and kill it; (2) some crops with allelopathic properties produce chemical substances that may inhibit the growth of weeds; (3) and those crops that could take more light, nutrients, and space could beat the weeds and eradicate them.

Crop rotation entails a significant change in the cropping pattern. The timetable and the types of crops grown may not be well-adjusted with the existing systems of production, marketing, and

consumption. An agribusiness specializing in a particular crop and supplying a preplanned quantity of its produce to the market could face problems of irregularities in prices or supply of inputs. When this involves global markets, the problem becomes more complex. As crop rotation implies some degree of diversification, agribusiness should look for new markets for the alternative crops grown. A return to crop rotation does not cause as much inconvenience for subsistence farming livelihoods as it does for commercial agriculture. For either system, larger plots could



be divided into two or four segments and different types of crops grown in each plot (see photo). This can be rotated seasonally or annually depending, among other things, on the extent of nutrient depletion and the length of time needed to break the life cycles of pests.

Yohannes Aberra

See also **Agriculture, Preindustrial; Crop Genetic Diversity; Organic Agriculture; Pest Management; Shifting Cultivation; Sustainable Agriculture**

Further Readings

- Kansas Rural Center. (1998). *Crop rotation* (Sustainable Agriculture Management Guides MG2A.1). Whiting, KS: Author.
- Poole, T. E. (2001). *Crop rotation* (Fact Sheet 784). College Park: University of Maryland Cooperative Extension.



CROSS-BORDER COOPERATION

Cross-border cooperation (CBC) is a response to the challenges that international borders pose to the surrounding areas. It is the process in which neighboring local and regional actors engage in multifaceted cooperation across state borders to find mutually beneficial solutions to common problems that cannot be adequately addressed in a national framework alone. The primary goal is to transcend the barrier function of state borders.

CBC practices first appeared in Europe in the 1960s, and by the 1990s, they had become an integral part of the European Union integration process. Globalization flows have engendered the emergence of such practices in other parts of the world as well, most notably in North America and East Asia. Economically, CBC has the potential to enhance the development of the borderlands by allowing economic actors to take advantage of opportunities situated on both sides of the border. Culturally, CBC can break down

negative stereotypes by promoting good neighborly relations. Politically, CBC could enhance the democratic process by bringing decision making closer to the borderland inhabitants. In achieving such objectives, CBC faces the considerable task of developing integrative mindsets among a variety of local actors to allow them to identify shared interests necessary to create common spaces of living.

CBC departs from traditional intergovernmental cooperation, allowing subnational authorities and civil society actors to engage in direct interaction across state borders. Nonetheless, these practices do not entirely bypass the national governments. They tend to be project specific rather than forming a comprehensive territorial strategy for the management of social life in the borderlands. CBC is generally oriented toward building cross-border institutions that can provide enabling frameworks for cooperative actions. The institutionalization of CBC typically assumes the form of multilevel governance networks that can involve local, regional, and national governments, supranational institutions, development agencies, universities, chambers of commerce, and nongovernmental organizations, all interacting in a loosely coupled relationship based on coordination and negotiation rather than top-down subordination.

Cross-border regions, commonly known in Europe as Euroregions, are currently the most common and complex spatial frameworks for CBC. They are territorially delineated regions that straddle state borders, where cooperation can be organized irrespective of state borders, to the benefit of the civil society (Figure 1). They can have governing institutions, such as councils and secretariats, and symbols, such as logos and flags. In practice, the persistence of national particularism among many actors involved in CBC has prevented cross-border regions from becoming meaningfully integrated spaces of living.

CBC processes aimed at cross-border spatial integration are often in a state of tension with the nation-state's sovereignty demands involving a border-containment territorial logic. These conflicting territorial logics often prevent CBC from reaching its full potential. Nonetheless, the overall impact of CBC has been to unsettle the long-established meaning of state borders as ultimate

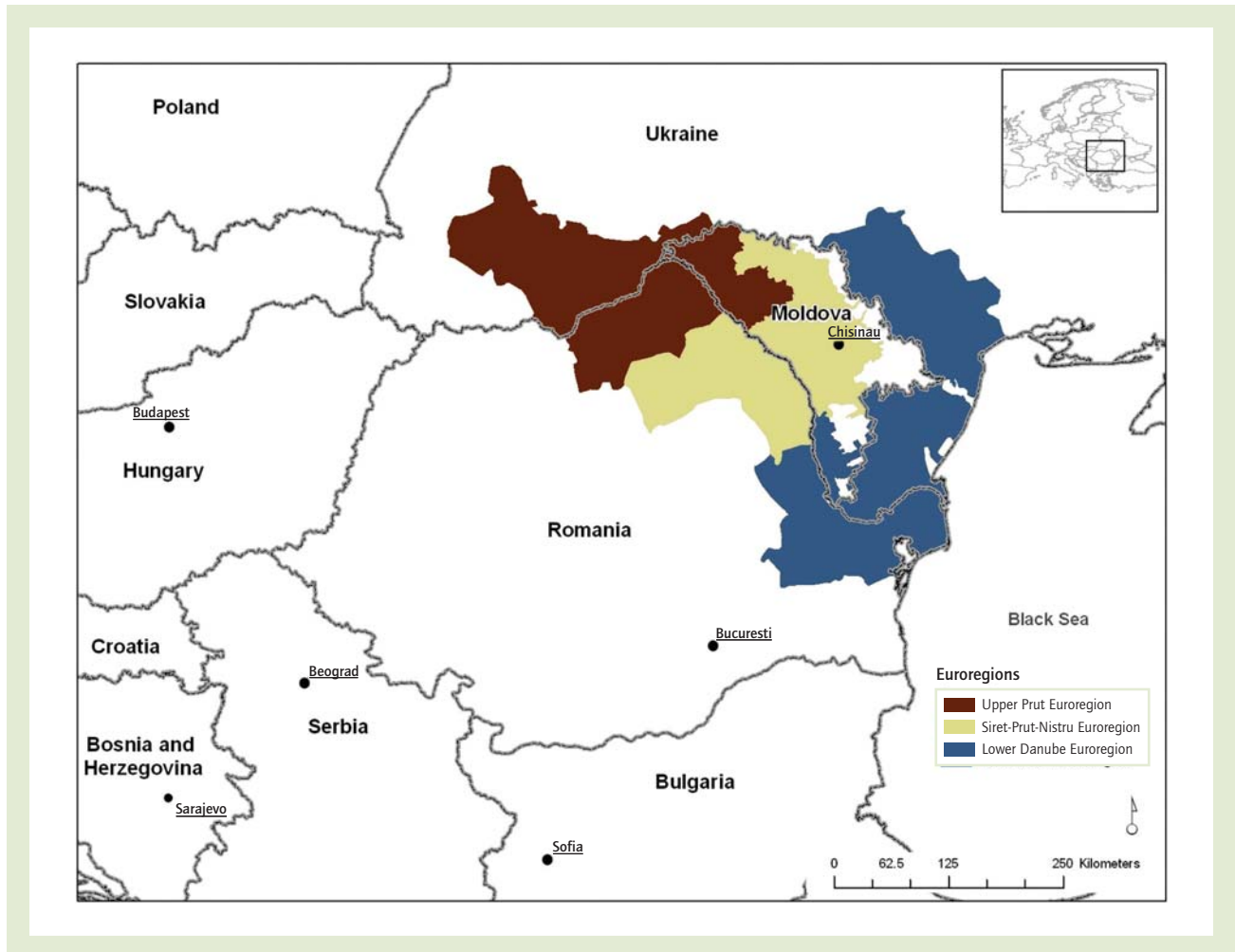


Figure 1 Euroregions situated between Romania, Ukraine, and Moldova

Source: Map created by Cristina Scarlat, Center for Advanced Spatial Technologies at the University of Arkansas.

lines of defense and to accommodate increased contact and gateway functions.

Gabriel Popescu

See also **Borderlands; Borders and Boundaries; Governance; Regional Governance; Sovereignty; Transnationalism**

Further Readings

Perkmann, M. (1999). Building governance institutions across European borders. *Regional Studies*, 33, 657–667.



CULTURAL ECOLOGY

Cultural ecology is a subfield of geography that is shared with anthropology and other allied fields. It positions itself in the center of the human-environment or “nature and society” tradition in geography (which itself is considered to be the core and uniqueness of geography) and concerns itself with the way in which humans are integral components of the environment and “ecology” of a particular place. It has long focused on the historical context of human-environmental relations, both the human *and* the natural history of place and how humans have adapted to nature, as well as how humans have modified nature for their



needs. Cultural ecology focuses on process rather than material culture. Key elements of the subfield are a focus on marginalized and/or vulnerable peoples (both in the developing periphery and more recently in the developed core), a concern with the impacts of economic development on local livelihoods, a focus on threatened landscapes as well as (agro)biodiversity conservation, an interest in local knowledge, and a focus on rural and agrarian systems, although recently, urban space has received significant attention.

Cultural ecology's research approach has always focused on intensive empirical fieldwork, often long-term and place based. Research questions are field based and use theory to inform, but they are not theory driven. Though originally focused on deep ethnographic fieldwork, often combined with historical analysis, cultural ecology has consistently used mixed methods, ranging from an incorporation of quantitative analysis (e.g., survey research, including approaches from microeconomics) to participatory methods (e.g., mapping, transect walks, seasonal calendars) and research methods from the physical sciences (e.g., soil surveys, plant measurements and surveys). More recently, cultural ecology has increasingly used discourse analysis and other tools from critical theory, as well as geospatial technologies (e.g., the analysis of remotely sensed images, use of global positioning systems [GPS] as a tracking tool, and use of geographic information systems to incorporate information from different sources and scales), in its methods suite. The use of the latter technologies has generally reduced field time for practitioners, but it has opened up the ability to scale up from what had been a focus on local-level studies.

Historical Development

Cultural ecology emerged as a subfield of geography in the 1960s and reached its peak in the 1970s and 1980s. An Association of American Geographers (AAG) specialty group, the Cultural Ecology Specialty Group, was formed in 1980 to represent and build cohesion in the subfield, which at that time focused on topics ranging from prehistory to Third World development and from environmental to economic issues. The

establishment of the new specialty group recognized the field's interdisciplinarity and eclectic nature.

Cultural ecology, having originated on the basis of the ideas of the cultural anthropologist Julian Steward, as presented in 1955, has long been interested in adaptation—not just how humans adapt to their environments but how they have modified their environments to suit their needs. It has been quite concerned with human agency and with the human capacity to manipulate the environment, and it interprets adaptation as choice and not as environmentally determined. William Denevan's work is seminal in this regard. Practitioners have worked hard to counter the ideas of environmental determinism, which were so destructive to the discipline of geography.

The rise of the quantitative revolution in geography was a great challenge to all subfields that did not embrace it, but especially cultural ecology, which was focused on localized case studies and was not interested in generalizing social science theory. The subfield was seen as marginal to the discipline during this era, although it remained active and provided a continual body of knowledge on changing livelihoods throughout the then Third World. It embraced systems ecology in the 1960s and 1970s, and some of its key research (e.g., Bernard Nietschmann's work) used energy flows to explain human livelihoods.

Although in its early days, cultural ecology was not explicitly political, it was never apolitical, although there was a persistent myth that it was. As Paul Robbins has noted, where cultural ecology did fall short was perhaps in its tool chest to explain the larger processes in which marginalized peoples of the Third World found themselves. Globalization and neoliberal structural reforms were accelerating change around the world, and the use of various approaches from critical theory permitted the unpacking of these structural layers.

The Rise of Political Ecology

Cultural ecology as an identifiable subfield fell out of vogue during the 1990s, in part because of the critique regarding the lack of political contextualization and in part because of the rise of



postmodern and poststructuralist tools to explain the larger processes of change. Political ecology, a cognate of cultural ecology that wholeheartedly embraces social theory, rose to prominence in the 1990s as the dominant approach in people-environment geography. Cultural ecology has long been driven by questions in the field and not by theory, whereas political ecology in general is driven more by theory, hence political ecology came to dominate at a time when theory was seen as the way to explain process.

During the 1990s, although cultural ecologists remained active, political ecology dominated, and many long-time cultural ecologists felt marginalized and turned their research in other directions. Some turned back to their earlier roots in physical geography; others embraced what began as historical ecology. Although some observers believe that cultural ecology has been subsumed under political ecology, there is a vibrant and growing community of young, neocultural or contextualized cultural ecologists practicing in geography today, many of whom eschew labeling their work as either cultural ecology or political ecology. These researchers have often trained with noted scholars from either classic cultural ecology or newer political ecology and are now setting forth on their own pathways and, in the process, are redefining the field. In reality, cultural ecology and political ecology are a continuum that as a whole is so rich because it is inclusive and can accommodate a range of approaches.

In recognition of the rise of political ecology, the AAG specialty group was renamed the Cultural and Political Ecology Specialty Group in 2002. While the name change debate left some traditionalists marginalized, it engaged many younger scholars, and the specialty group remains one of the largest and most active in the AAG, with more than 600 members in 2008.

Cultural Ecology Today

The subfield of cultural ecology continues today as the core of and a vibrant field within human-environment geography, although practitioners may not call their work *cultural ecology* (indeed, many have long resisted the label), even in the heyday of cultural ecology. Much of 21st-century cultural

ecology is labeled as livelihood, development, or landscape studies, all of which are integrative and cross-disciplinary fields, as are geo-archaeology, environmental history, or historical ecology, three other identities cultural ecologists have embraced. What continues to set apart this neocultural ecology from political ecology is a continued focus on local food and subsistence systems, and especially the environmental knowledge systems that support these. Still others include a much greater focus on the ecological and work in the field they call human ecology.

The newest turn for cultural ecologists is that they are working closely in or with the “land change” or “sustainability science” (including the LUCC, or Land Use and Cover Change) community, where the bigger questions of global environmental change are analyzed using a suite of methods, including those that cultural ecologists have long been using. Local, field-based cultural ecology often informs larger-scale models. Cultural ecologists, given their long-term interest in adaptation, have also become involved with climate change investigations and are positioned to contribute significantly to the field. Along with these, cultural ecologists have embraced looking at scale, recognizing the limitations of the local and the need to find ways to scale up from the local to the global.

Cultural ecologists, given their wide range of interests and contributions, publish their findings in a wide range of journals, including the key geographical ones (especially *The Geographical Review*) and some anthropological ones (e.g., *Human Organization*), but perhaps the greatest concentration of this type of research is found in the interdisciplinary journal *Human Ecology*. For a detailed review, the reader can consult the two surveys of the subfield written for the two benchmarks of the discipline of geography: Karl Butzer’s chapter in *Geography in America* and Tom Bassett and Karl Zimmerer’s chapter in *Geography in America at the Dawn of the 21st Century*. These two in-depth publications list most of the cultural ecological work completed during the past several decades. More recently, Zimmerer has written a series of articles published in *Progress in Human Geography*, in which he places current cultural ecological research within the dominant and dynamic strands of research to

which the subfield is contributing substantially thus far in the 21st century.

Antoinette M. G. A. WinklerPrins

See also **Class, Nature and; Critical Human Geography; Critical Studies of Nature; Environmental History; Ethnicity and Nature; Gender and Nature; Human Ecology; Land Use and Cover Change (LUCC); Nature; Nature-Society Theory; Political Ecology; Social Construction of Nature**

Further Readings

- Bassett, T. J., & Zimmerer, K. S. (2006). Cultural ecology. In G. L. Gaile & C. J. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 97–112). Oxford, UK: Oxford University Press.
- Butzer, K. W. (1989). Cultural ecology. In G. L. Gaile & C. J. Willmott (Eds.), *Geography in America* (pp. 192–208). Columbus, OH: Merrill.
- Denevan, W. M. (1983). Adaptation, variation, and cultural geography. *The Professional Geographer*, 35, 399–407.
- Nietschmann, B. Q. (1970). *Between land and water: The subsistence ecology of the Miskito Indians, Eastern Nicaragua*. New York: Seminar Press.
- Robbins, P. (2004). *Political ecology: A critical introduction*. Malden, MA: Blackwell.
- Steward, J. H. (1990). *Theory of culture change: The methodology of multilineal evolution*. Urbana: University of Illinois Press.
- Zimmerer, K. S. (2004). Cultural ecology: Placing households in human-environment studies: The cases of tropical forest transitions and agrodiversity change. *Progress in Human Geography*, 28, 795–806.
- Zimmerer, K. S. (2006). Cultural ecology: At the interface with political ecology—the new geographies of environmental conservation and globalization. *Progress in Human Geography*, 30, 63–78.
- Zimmerer, K. S. (2007). Cultural ecology (and political ecology) in the “environmental borderlands”: Exploring the expanded connectivities within geography. *Progress in Human Geography*, 31, 227–244.



CULTURAL GEOGRAPHY

Cultural geography is a major subfield of human geography focusing on the spatial expression, representation, and negotiation of the experience of being in the world. Because the definition of *culture* itself is controversial and because the historical trajectory of cultural geography varies both by place and by approach, cultural geography contains within it a variety of perspectives. Contemporary cultural geography experiences a continuity of enduring themes and the addition of new topics.

What Is Culture?

One of the most vexing aspects of cultural geography is the difficulty of defining its object of study: culture. In this, cultural geographers and cultural anthropologists share a similar dilemma, with the result that various attempts to define *culture* have long crossed disciplinary boundaries between geography and anthropology. In fact, it was the anthropologist Clifford Geertz (1973), drawing on earlier work by the sociologist Max Weber, who famously asserted, “believing . . . that man is an animal suspended in webs of significance he himself has spun, I take culture to be those webs” (p. 5). Culture has been defined as a whole way of life, a manner of thinking and doing things that encompasses an entire group of people. A more restricted definition of culture is synonymous with the tangible things that particular groups of people produce: material culture. Culture can be used in a way that indicates high culture, a society’s artistic and intellectual output. Finally, culture can have a temporal meaning, as opposed to being a static phenomenon, when the term is used to indicate the progressive advancement of a group.

In several of these definitions, culture is a thing. According to some understandings, culture is an attribute or a set of distinct qualities possessed by a group of people; in others, culture is literally things, the distinct material, artistic, spiritual, and intellectual output of a particular society. Definitions of culture as a thing have at least three problematic aspects associated with them. First is their tendency to accrete just about



anything. Even the design, technology, and location of the proverbial kitchen sink can be thought of as cultural. There is a loss in analytical precision when the definition of a term can potentially include everything. Second, if culture is a distinctive attribute of specific human societies, it is tempting to view the world as a patterning of diverse cultures that are juxtaposed side by side, as with a jigsaw puzzle. Such definitions cannot account for the persistent mobility, intermixing, and fluidity of culture. The third problem with approaches to culture as a thing is that culture is relegated to an intermediary role. Cultural output merely provides clues to deeper patterns: social, economic, political, and so on. Culture is thus epiphenomenal, rather than a powerful force in its own right.

In other definitions, culture is approached as a process. Culture is understood to involve ways of communicating, expressing, making meaning, and representing external reality to ourselves and others. Some scholars view cultures as language-like in their interactive and symbolic structure. Others have a less structured view of culture as a process, emphasizing instead culture's unstable fluidity. These approaches have been critiqued for at least two reasons. First is their tendency toward "realm-ness," for lack of a better term. In these approaches, culture is viewed as an arena in which activity occurs, distinct and separate from other arenas, such as the political, economic, environmental, and so on. Thus, culture is artificially cordoned off and reified as a separate realm, when, in fact, there are cultural aspects to many activities not typically seen as having a cultural dimension. Indeed, it is in the apparently obvious, but misguided, notion that some activities are acultural that culture can work in extremely powerful ways. To assume that politics or economics exist apart from culture, even in the abstract, is naive. Second, approaches to culture as a process often provide too vague answers to the straightforward question "What is culture?" Not only does this make research difficult, it can render practices deemed cultural difficult to hold accountable.

Frustration with the difficulties associated with culture has led some contemporary cultural geographers to assert that we inhabit a postcultural era, that there is no such thing as culture, or that

culture is such a plastic idea as to be dangerous. Others counter that while many definitions of culture are possible, it is vital to operationally define culture so that the important work of cultural analysis may continue.

Major Divisions Within Cultural Geography, by Place

Though we speak of cultural geography as if it were a coherent, unified subfield, it is not. This arises partly from the different conceptualizations of culture discussed above. Another major division in cultural geography concerns the site in which the distinct cultural geography traditions arose. The principal place-based division within cultural geography is between American and European approaches. It is important to state early on, however, that these two traditions in Anglophone cultural geography themselves are the product of much trans-Atlantic intermixing. As with all things cultural, it is important not to underestimate the importance of intellectual cross-place fertilization. Cultural geography is no exception.

U.S. Versus British Traditions

In the United States, cultural geography is known both for its carefully descriptive nature and its long history of discomfort with this aspect of its approach. The work of the best-known American cultural geographer, Carl Ortwin Sauer, distills this tension. Sauer's approach to cultural geography centralized the landscape as the product of the action of human society on nature, viewed over time. Human culture literally sculpts the natural world into its visible contours. The task of the cultural geographer, then, is to meticulously observe and record the features of the landscape and from these to deduce the features of the societies that shaped it. This is, however, no subjective interpretive task, though Sauer retained a respect for the aesthetic dimensions of landscape interpretation. Troubled by what he understood as a lack of scientific rigor on the part of earlier cultural geographers, Sauer insisted that a systematic methodology be employed to record, classify, and link the impress of human culture on



the natural environment. He called this methodology *morphology*. Sauer's many students, and his approach more generally, have influenced generations of American cultural geographers, whose work is characterized by its rich description of material culture, the central role of field-based research, and a deep concern with scientific rigor in data collection and analysis.

Institutionalized European cultural geography predates American cultural geography; indeed, early American cultural geographers were trained by European scholars and drew on their work. Sauer, for instance, incorporated the regional descriptive tradition of the French geographer Paul Vidal de la Blache as well as the German political geographer Friedrich Ratzel's emphasis on the separate yet interrelated natural and human worlds. It is British cultural geography, however, that has developed the highest profile among the European cultural geography traditions. British cultural geography emerged from a concern with the shaping effect of broad transformations in society. Thus, the work of important early British cultural geographers, such as W. G. Hoskins, was referred to as *landscape analysis* rather than cultural geography. Hoskins sought to understand the English landscape as a text of sorts, from which could be read the transformation from a rural peasant society to a modern, urban, industrial society. The driving force in Hoskins's understanding was the march of social history, including changes in transportation, industry, and agricultural technology, which used as well as shaped the landscape. Compared with its American counterpart, British cultural geography has less encyclopedic description and emphasis on scientific methodology and relatively more emphasis on social theory. Today, as well as in the past, however, these distinctions are oversimplified, and a vibrant trans-Atlantic exchange of ideas is ongoing.

Non-Anglophone Traditions

The oldest cultural geographic traditions are found in ancient Greek and Roman, as well as Muslim and Chinese, scholarship. Because the inhabitants of the ancient world were far more place bound than most people are today, speculation about distant lands and their inhabitants

was common, while empirical accounts were rare. Explorers constituted the earliest de facto cultural geographers, and they disseminated their findings to a wider audience. It is hypothesized that cultural geography as well as cultural anthropology are important dimensions of imperial societies. Thus, it is no accident that Chinese, Muslim, Greek, and Roman civilizations—all of them expansionist empires of the ancient world—counted what would now be classified as cultural geographers among their most visible intellectual ranks.

Today, for better or for worse (and as with much social science), Anglophone scholarship dominates the global marketplace in cultural geography. To complicate matters, disciplinary divisions can be very different from place to place. Scholars who might be classified as cultural geographers in the Anglophone tradition can be found in departments of anthropology, urban sociology, and planning, and even in government offices such as census bureaus, in non-Anglophone contexts. Finally, some academic traditions place a strong emphasis on activism, something that is fairly uncommon in Anglophone academia.

Major Divisions Within Cultural Geography, by Approach

Looking at different place-based approaches to cultural geography is one way to understand the differences within the subdivision and how they came about. Another way to frame these differences is by intellectual emphasis. Using this lens, at least three different approaches can be isolated: empiricist, humanistic, and critical. Three caveats are in order before proceeding. The first is that these labels are merely a convenient shorthand to convey more or less significant intellectual differences. Second, in reality, there is much overlap and mutual conversation among these three approaches. Third, the divisions discussed earlier concerning diverse definitions of culture and place-based distinctions in cultural geography traditions thread into these intellectual distinctions here, such that a tightly braided skein results. In practice, it is difficult (and rather boring) to attempt to isolate the multiple ways in



which cultural geographic traditions are different from one another; rather, the more interesting task lies in identifying constellations of productive focus within the larger subfield and working from those.

Empiricist Approaches

The foundational cultural geographers in Anglophone cultural geography were largely concerned with material culture. Empiricist cultural geographers particularly emphasize the visual features of the landscape, those aspects that are apparent to the human eye. Empiricist cultural geographers address questions such as “What traces have societies past and present left on the landscape?” and “What do these traces tell us about those societies: their political, economic, and social structures, the transformations in these structures, and the ways these societies have adapted to and modified the natural world?”

The type of housing built by a society, for instance, provides clues about that culture that one can decipher if one is attentive enough to the details. What building materials are used? How is the roof pitched? How large is the typical dwelling? What shape is it: round, square, triangular, or rectangular? Is human space shared with animals, or are living spaces for human and animals carefully separated? Are there common spaces among family dwellings, or are spaces entirely privatized and spatially marked as such? Are dwellings clustered together, isolated, or arranged along roadways? By definition, empirically oriented cultural geographers centralize the importance of long-term immersion in the field as vital to recording and understanding the level of detail required for accurate analysis.

The distinction between folk and popular culture has long been a mainstay of this approach. The empiricist strand of cultural geography was solidified during an era marked by the fascination with understanding the spatial dimensions of the transformation from rural peasant society to urban industrial society. Folk culture denotes the traditional practices, beliefs, and material cultural elements of rural people. Popular culture, in contrast, speaks to modern, urban, and nonlocal practices, beliefs, and material cultural elements.

Though it is hardly possible today to find purely local folk cultures untouched by modern influences, cultural geographers in this genre tend to retain some form of distinction between folk and popular cultures, though it is usually not delimited as starkly as it once was.

The work of empiricist cultural geographers has been likened to that of a detective decoding pieces of a larger puzzle. Thus, though all three of these approaches can be said to view the landscape as a sort of text, in the empiricist cultural geography tradition, the landscape is a book that, if read carefully, will yield up a straightforward story about the culture that wrote it.

Humanistic Approaches

Humanism can be simply defined as a strong belief in the redeeming quality of the human spirit. Humanistic scholars focus on the needs, abilities, and freedoms of human beings. Though most commonly found in the arts, art history, literature, and philosophy, some cultural geographers also draw from a humanistic tradition. Their work primarily examines human connections to place. The notion of dwelling, or establishing a deeply rooted connection to place over time through repeated activity, is important to humanistic cultural geographers. The affective dimensions of this connection to place can be summed up in the cultural geographer Yi-Fu Tuan's notion of *topophilia*: literally, love of place. Poetic, artistic, literary, and spiritual ways of establishing and representing landscape, belonging, home, sacredness, place, lifeworld, and states of being such as childhood are found in humanistic cultural geography.

Critical Approaches

Cultural geography is not immune to broader developments in social theory; indeed, cultural geographers have contributed to these developments, particularly through an increasing prominence of space and place in social theory more generally. In part as a reaction against the lack of attention to social theory by empiricist cultural geographers, as well as what was seen as the overly quantitative tone of mid-20th-century geography in general, critical cultural geographers



Jerusalem's Wailing Wall is a sacred site where Jews from all over the world come to pray. Cultural geographers find such sites to be incredibly rich. The Wailing Wall constitutes an axis mundi, or anchoring point, around which the entire city is referenced for Jerusalem's Jewish residents. A mixture of popular and folk cultures is evident in the styles of dress. Women and men pray at separate sections of the wall; the women's section is much smaller and more crowded than the men's section. Even the spatiality of the body is affected by the site's sacredness. The faithful refuse to turn their backs to the wall, as doing so would be disrespectful, and so they leave the site by walking backward.

Source: Author.

used insights from Marxism and feminism in their work. Later, postmodern and postcolonial approaches were also incorporated.

Critical cultural geographers are noted for their attention to the spatial expression, representation, and negotiation of broader power relations in society. The hidden aspects, silences, and omissions are every bit as important as those aspects of the cultural world that are manifest. In addition, a close attention to social justice—through exposure of inequality and the activism directed at rectifying it—is a hallmark of this approach.

Take, for instance, the representation of an idyllic landscape constituted of rolling hills, a rustic cottage, and peaceful cows. A critical cultural geographer would focus on how and why the landscape was produced in this fashion. Where are the laborers who planted, pruned, and mowed the vegetation? What of the woman who swept the path and tended the garden? Why are such landscapes, devoid of people and containing certain “natural” visual elements arranged just so, considered so appealing? Addressing such questions, and proposing solutions to the spatial injustices that produce the visible and invisible



worlds around us, is at the heart of critical cultural geography.

Cultural Geography Today

Cultural geography is today one of the most dynamic subfields of human geography. Many students find cultural geography's breadth of topics exciting. In addition, the sorts of questions that can be addressed using a cultural geography approach are among the most crucial facing us today: Globalization, identity, mobility, and human-environment relations have all been examined by contemporary cultural geographers.

Cultural geography's traditional themes are still present but share the stage with new approaches. Among these are nonrepresentational ways of apprehending cultural phenomena, which attempt to circumvent the contemplation, interpretation, and representation of reality. Rather, nonrepresentational theory emphasizes performative, embodied practices as valid forms of knowledge. Nonrepresentational cultural geography has focused on movement, such as dance, play, and exercise, as creating an experiential landscape that constructs and deconstructs as the subject moves through space. Rather than the stability provided by representative strategies, nonrepresentational cultural geography emphasizes the inherent instability of lived spatiality.

Another area of development in contemporary cultural geography involves emotions. Cultural geographers in this tradition examine the role of fear, hate, love, and other emotions in how we experience, represent, and contest spatiality. Related to this field are those cultural geographers who explore sensual geographies beyond the visual. Their incorporation of smell, taste, touch, and hearing broadens cultural geography's long emphasis on solely the visual aspects of spatiality.

Contemporary cultural geographers also include different subjects of study. Cultural geographies of the elderly, of children and youth, racialized minorities, and disabled people have become increasingly important. Geographies of pregnancy, prostitution, and queerness all focus on sexualized aspects of spatiality. Nature and animals, and the blurry boundaries between traditional human subjects of cultural geography,

constitute another emerging area of focus for contemporary cultural geographers.

Patricia L. Price

See also Architecture and Geography; Art and Geography; Berkeley School; Body, Geography of; Children, Geography of; Class, Geography and; Consumption, Geographies of; Cosgrove, Denis; Critical Human Geography; Cultural Landscape; Cultural Turn; Difference, Geographies of; Discourse and Geography; Emotions, Geography and; Ethics, Geography and; Ethnicity; Ethnocentrism; Eurocentrism; Everyday Life, Geography and; Existentialism and Geography; Feminist Geographies; Fieldwork in Human Geography; Folk Culture and Geography; Gays and Lesbians, Geography and/of; Gender and Geography; Geographical Imagination; Humanistic Geography; Hybrid Geographies; Identity, Geography and; Indigeneity; Jackson, John Brinckerhoff; Landscape Architecture; Landscape Interpretation; Languages, Geography of; Masculinities and Geography; Media and Geography; Music and Sound, Geography and; Nationalism; Nonrepresentational Theory; Nonvisual Geographies; Orientalism; Phenomenology; Place Names; Popular Culture, Geography and; Population Geography; Postcolonialism; Poststructuralism; Queer Theory; Race and Racism; Religion, Geography and; Representations of Space; Sauer, Carl; Sense of Place; Social Geography; Sports, Geography of; Subaltern Studies; Symbolism and Place; Text/Textuality; Topophilia; Tourism; Tuan, Yi-Fu; Urban Geography; Vidal de la Blache, Paul; Vision and Geography; Whittlesey, Derwent; Writing; Zelinsky, Wilbur

Further Readings

- Anderson, K., Domosh, M., Pile, S., & Thrift, N. (Eds.). (2003). *Handbook of cultural geography*. London: Sage.
- Blunt, A., Gruffud, P., May, J., Ogborn, M., & Pinder, D. (Eds.). (2003). *Cultural geography in practice*. London: Edward Arnold.
- Domosh, M., Neumann, R., Price, P., & Jordan-Bychkov, T. (2009). *The human mosaic: A thematic introduction to cultural geography* (11th ed.). New York: W. H. Freeman.



- Duncan, J., Johnson, N., & Schein, R. (Eds.). (2004). *A companion to cultural geography*. Oxford, UK: Blackwell.
- Geertz, C. (1973). *The interpretation of cultures*. New York: Basic Books.
- Mitchell, D. (2000). *Cultural geography: A critical introduction*. Oxford, UK: Blackwell.
- Oakes, T., & Price, P. (Eds.). (2008). *The cultural geography reader*. London: Routledge.
- Sibley, D., Jackson, P., Atkinson, D., & Washbourne, N. (Eds.). (2005). *Cultural geography: A critical dictionary of key concepts*. London: I. B. Tauris.
- Tuan, Y. (2004). Cultural geography: Glances backward and forward. *Annals of the Association of American Geographers*, 94(4), 729–733.



CULTURAL LANDSCAPE

The cultural landscape is a concept associated with human modification of Earth's surface. Cultural landscape studies have been a prominent component of cultural geography over the past century. Despite a long-standing interest in the topic, geographers over time have debated the concept and associated theories and methodologies used to understand cultural landscapes. The term *cultural landscape* is associated with the depiction of the Earth's surface in visual art, material artifacts such as buildings, and the area of territory itself. Furthermore, it is a term that is not exclusive to geography, as sociologists, anthropologists, and historians have used *cultural landscape* as well.

Early Development of Cultural Landscapes

The term *landscape* developed primarily from two words that display similarities and differences with one another. The Old English word *landscaef* referred to a clearing of forested land by humans or, to be more precise, the occupation or control of the "wilderness." This term provides geographers with the basis for studying the human-modified environment, as well as the interaction of humans with the land. The second term, *landschap*, comes from the Dutch and is

associated with the appearance of the land. This latter term was primarily linked to visual art, especially paintings. This allows for a certain "reading" of the landscape.

In geography, the concept of the cultural landscape has antecedents in the research and philosophies of French and German geographers of the late 19th and early 20th centuries. The German geographer Otto Schlüter, who is often credited with coining the term *cultural landscape*, held the landscape itself as the centerpiece for all geographers. The various forms and spatial arrangements create a bridge between physical geography and human geography, as the landscape itself is an object that both sides of the geographic dichotomy focus much attention on.

However, Schlüter's approach to the study of landscape geography, or more precisely landscape morphology, focused only on the visible landscape and therefore did not dwell entirely on the meanings and symbolism behind the landscape. In other words, Earth should be studied from a bird's eye view, where the roads, buildings, gardens, oceans, and forests create a visible image that is the focal point for geographical study. Others, however, felt that this limited focus on the *visible* landscape detracted from the pursuit of deeper meanings that could be discovered in the cultural landscape.

It is also worth noting that the German school of geography is credited with developing yet a third meaning for landscape associated with the German word *landschaft*. This term deals primarily with forms of landscape in a particular area. To the Germans, landscape studies were synonymous with regional studies.

Another aspect of the cultural landscape was the marriage of social and physical characteristics. The French geographer Paul Vidal de la Blache held that the natural landscape and the human landscape should be viewed as inseparable. To Vidal, every cultural group adapts to its natural environment in its own way and creates a unique region. A result of this adaptation is the formation of the cultural landscape, which is a reaction to the natural landscape. This process amalgamates two seemingly opposite ideas—society and nature—into one observable phenomenon, one that Vidal believed should be the focal point of geographic study.



Park Güell in Barcelona, Spain, was designed by the famous architect Antoni Gaudí. The cultural landscape is associated with the depiction of Earth's surface in visual art, material artifacts such as buildings, and the area of territory itself.

Source: Marek Slusarczyk/iStockphoto.

Early research involving the cultural landscape in the United States goes back to the work of Carl Sauer and the Berkeley School of cultural geography. Sauer saw in the cultural landscape an expression of the material features of cultural groups. His famous paper titled “The Morphology of Landscape,” published in 1925, attempted to solidify the landscape as the fundamental concept of geography (Figure 1). Through this idea, cultures shape the natural environment to create the cultural landscape. Sauer’s idea brings together Schlüter’s and Vidal’s concepts—the former’s attempt to bring together the physical and the human and the latter’s focus on regional uniqueness. As Sauer

(1925) stated, “The cultural landscape [is] fashioned from the natural landscape by a culture group. Culture is the agent, the natural area is the medium, the cultural landscape is the result” (p. 46). This view lent itself to the German term *landschaft*, as it stressed the importance of regional uniqueness.

Sauerian notions of landscape were seen as a reaction to environmental determinism, a theory that dominated early-20th-century U.S. human geography and that highlighted the ways in which the environment influenced humans. Sauer’s approaches to landscape focused on the interactions between humans and the environment,



providing emphasis on the role of human agency. Sauer did not ignore the impacts of the environment in the creation of the cultural landscape, which he emphasized was humanly produced. Despite Sauer's attempts to integrate cultural traits, this view still held the cultural landscape as simply a material manifestation of the cultural group, without understanding the deeper meanings behind the human creations.

Deeper Meanings in the Cultural Landscape

Many cultural geographers in the post-World War II era were heavily influenced by the work associated with the Berkeley School. For example, Wilbur Zelinsky and Fred Kniffen were among the many geographers who examined not only the occurrence of similar town designs but also their diffusion from a cultural hearth to other parts of a region.

J. B. Jackson is also prominently associated with studies involving the cultural landscape. He defined landscape as the portion of the Earth that can be comprehended at a glance. However, although he was trained in the visual and literary arts, Jackson became interested in the landscape as something that is lived in rather than a simply visual phenomenon. Jackson focused on the vernacular landscape, which consisted of everyday material items such as strip malls, fast-food restaurants, motels, and groceries. In this case, landscape was a reflection of human society and displayed a deeper understanding of that society. For Jackson, landscape, like art, needed to be “read” in order to gauge its deeper meanings. He likened the landscape to a book, one that is “always open before us.” However, while that book was open, we must “learn to read it.” And because different people—both within and outside a particular society—will read the landscape differently, this reading is often in the eyes of the beholder. As Donald Meinig notes, 10 different people looking at the same landscape could interpret it in 10 different ways. For example, a Wal-Mart in a small rural town could perceivably be read in a number of ways by both those living in the town and those who are just driving through the town. This notion speaks to the fluid nature of the cultural landscape.

While some early researchers did examine the cultural landscape with a deeper focus, many of the late-19th-century and early-20th-century geographers did not dig deeper than the surfaces of the landscape. The cultural landscape was viewed as static and represented a politically neutral vantage point. Today, however, cultural geographers do not hold landscape as a politically neutral manifestation of society. Since the end of World War II, geographers have recognized that while humans create and manipulate the landscape, the landscape also influences humans. Aspects of the cultural landscape can give rise to a certain meaning to a particular cultural group, or more simply a “sense of place.” This sense of place in terms of landscape can create an experience that is shared by those whose daily lives are somewhat connected to the cultural landscape. By creating this shared experience, a centripetal force is exerted that can be used to unite a cultural group together and potentially stir up nationalist sentiment.

Early geographers took the cultural landscape at face value, examining the diffusion and location of items such as housing types. This type of research did not observe why there was diffusion but tended to simply categorize the cultural landscape; it has since been replaced by various tactics that seek to bring about a deeper understanding of the landscape.

Research Approaches to Cultural Landscapes

Contemporary geographers have used various approaches to the study of the cultural landscape. Some geographers took a behaviorist approach to the cultural landscape, including the use of mental maps based on daily experiences. Mental mapping worked well at the local scale, where individuals' daily interactions with the cultural landscape produce a sense of place familiar to the particular individual. These mental representations create an understanding of spatial distribution that relies more on relative location than on absolute location. Another approach was analysis of the symbolism of a place in light of past historical experiences. For example, European colonizers were attracted to certain parts of the “New World” partly because those areas resembled

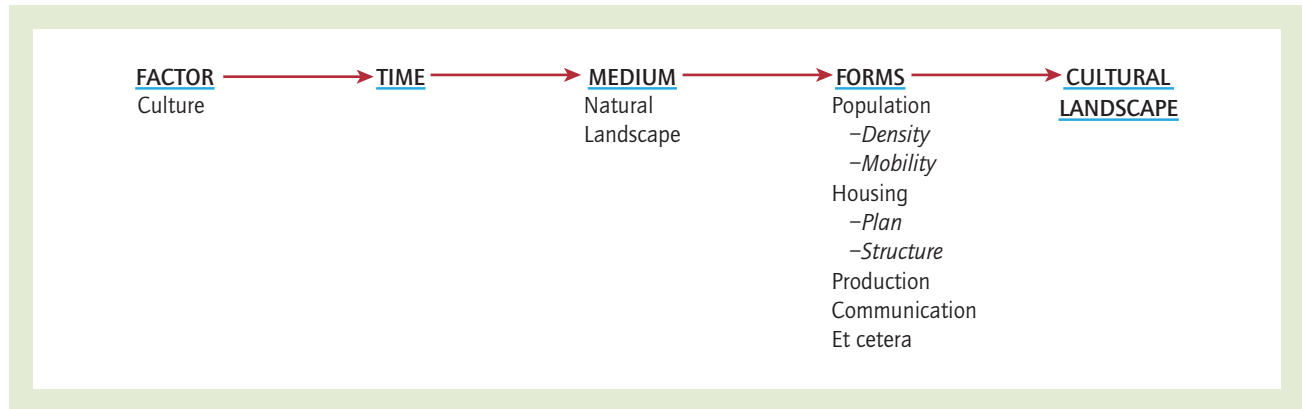


Figure 1 Carl Sauer's morphology of landscape

Source: Created by author, based on Sauer, C. (1925). The morphology of landscape. *University of California Publications in Geography*, 2(2), 19–53.

their homelands—an area and landscape with which they were familiar.

Another aspect that follows a humanist tradition is the concept of “reading” the landscape. In this view, the landscape is more than something to just look at; it is also a representation of the human interaction with nature. In other words, the landscape is a social construction of the world according to a particular cultural group. With this in mind, the cultural landscape not only is based on the individual's perception but is a representation of society as a whole.

Geographers also added the element of time, placing emphasis on the evolution of a natural landscape into a cultural landscape. This notion includes the temporal changes of various cultures and the effects that each culture has on the landscape to form a palimpsest. For example, the introduction of British and Dutch culture, as well as South Asian culture, to the indigenous African culture had a profound impact on the cultural landscape of South Africa. Another example is the changing demographics of the central cities of the United States, as many cities have experienced a shift from being predominantly white to predominantly black. In addition, immigration has also greatly affected the landscapes of urban areas, as with the Cubans in Miami, Irish in Boston, or Japanese and Chinese in San Francisco.

Another perspective focuses on the symbolism behind the creation of the cultural landscape. Religion, language, race and ethnicity, gender,

sexuality, and class all shape the cultural landscape. For example, Islamic mosques in Singapore, French place names in Louisiana, Chinatown in Vancouver, the Castro District of San Francisco, and the *favelas* of São Paulo have all been shaped by the ideologies and practices of specific cultural groups. Furthermore, these landscapes often mask conditions that promote stereotypes or obscure harsh conditions. In the view of Don Mitchell, the landscape can and often does “lie” to us, conveying one set of meanings as natural or inevitable (i.e., those of the dominant class) and hiding other, equally valid meanings generated by politically marginalized groups.

Geographers have attempted to understand the multiple, often contradictory, meanings embedded in the cultural landscape. This task involves exposing the power relations behind the construction of particular landscapes, including race or ethnicity, gender, sexuality, and class. For example, in the case of cultural landscapes that memorialize historical events, many geographers investigate the question of “whose” history is being depicted. These cultural landscapes typically display a history that promotes the dominant culture's version of events. However, there are also examples of minority cultural groups that have developed landscapes that depict their own history and challenge the dominant cultural landscape, such as the dedication of street names in cities in the United States in honor of the civil rights activist Martin Luther King Jr.



In short, geographers have embedded landscapes within the complex political and social dynamics of societies, seeing them as both reflective and constitutive of the organization of society. In this sense, the study of cultural landscapes has become highly attuned to politics, justice, and inequality. For example, cultural landscapes that depict a historical event typically do so from a particular point of view—most often the view of the elites. Even the language of the term has been challenged, with *space* or *social space* being preferred over *landscape*. Furthermore, the use of the word *culture* is also seen as problematic. Marxist geographers see culture as heavily manipulated by elites as a way of maintaining their power. Therefore, cultural landscapes represent a particular elite culture. Landscapes often naturalize social relations, hiding the system that produces them. To study landscapes, therefore, it is necessary to unveil the specific power relations that go into their making, including not only the material distribution of tangible phenomena but also the ideology of landscape. In this light, there can be no “objective” reading of landscape, only different power-laden views that serve different social interests.

Daniel McGowin

See also **Chorology**; **Cosgrove, Denis**; **Cultural Geography**; **Ethnicity**; **Hettner, Alfred**; **Jackson, John Brinckerhoff**; **Landscape Architecture**; **Landscape Design**; **Landscape Ecology**; **Landscape Interpretation**; **Landscape Quality Assessment**; **Landscape Restoration**; **Land Use Analysis**; **Meinig, Donald**; **Mitchell, Don**; **Palimpsest**; **Place Names**; **Sauer, Carl**; **Spaces of Representation/Representational Space**; **Symbolism and Place**; **Urban Land Use**; **Vidal de la Blache, Paul**; **Whittlesey, Derwent**; **Zelinsky, Wilbur**

Further Readings

- Cosgrove, D. (1998). *Social formation and symbolic landscape* (2nd ed.). Madison: University of Wisconsin Press.
- Domosh, M. (1996). *Invented cities: The creation of landscape in nineteenth-century New York and Boston*. New Haven, CT: Yale University Press.

- Duncan, J., & Duncan, N. (2003). *Landscapes of privilege: The politics of the aesthetic in an American suburb*. London: Routledge.
- Jackson, J. (1997). *Landscape in sight: Looking at America* (H. Horowitz, Ed.). New Haven, CT: Yale University Press.
- Meinig, D. (Ed.). (1979). *The interpretation of ordinary landscape: Geographical essays*. New York: Oxford University Press.
- Mitchell, D. (1996). *The lie of the land: Migrant workers and the California landscape*. Minneapolis: University of Minnesota Press.
- Sauer, C. (1925). The morphology of landscape. *University of California Publications in Geography*, 2(2), 19–53.



CULTURAL TURN

The term *cultural turn* refers to an intellectual recognition, within human geography and the wider human sciences, that all claims about the world and knowledge are mediated by culture. The logic of the cultural turn centers on the argument that no representation merely reproduces what it claims to represent. Representations construct, as much as they claim to explain, the person, place, or thing to which they refer.

The implications of the argument that knowledge produces the world, rather than simply mirrors it, are profound. The argument entails that to make, and/or accept, any claim, we need to attend to two interrelated terrains. First, we need to attend to how knowledge claims are complex products of particular contexts and specific perspectives and are shaped by forces such as history, gender, class, race, and location. Second, claims about objects and the world affect both the possibility of identifying objects as such and the ways objects and the world are made meaningful. Never simply passive, knowledge emerges from, and brings into being, dynamics of difference, power, effect, meaning, and influence. Questions of language, politics, history, identity, and interpretation (i.e., culture) are thus central to the knowledge and constitution of “reality.”



It follows that careful scholarship must reflexively attend to the interpretive and complex constitutions of knowledge. Denying the influence of culture on what and how claims are made excludes how knowledge and meaning making are enmeshed within practices of power. Arguments made from the cultural turn entail the impossibility of objective knowledge, for claims to objectivity elide their contingency and partiality. Naturally, claims about the world can be made in the realms of science, ethics, and politics, but they must self-consciously recognize their embeddedness within multiple and situated positions. Imperatives of heightened reflexivity render knowledge making not only more complex and humble but also more attentive to its construction and effects. Debates surrounding the cultural turn have shaken, fundamentally, the academic humanities and social sciences for the past three decades. While the turn to culture and its epistemic implications has been enormously influential in shaping the possibilities of humanities and social science research, the repercussions of acknowledging the close relationships of language, power, and knowledge continue to be ardently felt and debated.

The turn to culture emerges out of a history of thought whose lineages can be traced through the influence of both the social writings of Karl Marx and the perspectivism of Friedrich Nietzsche. Significantly for the cultural turn, the work of Marx and Nietzsche was central, in the 1960s, to post-structuralism, which argued that language is necessary for thought. If language and text are the constitutive apparatuses by which the world can be known, there is nothing that can be said of the world that is outside of, or beyond, language and texts and, hence, culture. This view, and its effect on philosophy and social theory, became known as the *linguistic turn*. The cultural turn extends the insights of the linguistic turn to thinking about how cultural practices shape both our being in the world and the possibilities of responding within discourses of power, subjectivity, governance, and accumulation. From these possibilities, understood as opportunities, the interdisciplinarity of cultural studies emerged. For human geographers, the influence of cultural studies is most keenly felt in cultural geography, although the cultural turn has also transformed how subdisciplines such as

economic, social, political, and environmental geographies are framed and engaged.

Often prefixed with the term *new* to denote the discourses emergent in the early 1990s, new cultural geographies, new economic geographies, new urban geographies, and so on work in a vast range of ways to reimagine traditional areas of research under the influence of new theoretical approaches, including postcolonialism; consumption; mobilities and their receptions; social constructions of identity with an attention to race, gender, and sexuality; the cultural bases to economic processes; and the hybrid assemblages of nature and the environment. What unites these new approaches is less the content of their interest than an embrace of the necessity to challenge dominant narratives with a heightened reflexivity to relationships of representation and power.

Yet however much the cultural turn has reshaped the methodological and theoretical possibilities for how research is done in human geography, many worry that the turn to culture elides or dodges key social and political concerns regarding injustice, inequality, growth, exclusion, and development. It is argued that the cultural turn relies on an excessively theoretical and not substantive—a soft—approach, which marginalizes the efficacy of investigative methods to construct a solid empirical corpus from which to make secure descriptive claims and normative or programmatic interventions. The turn has thus resulted in an overly decorative attention whose radical promises ring hollow in the face of exacerbating inequalities and injustices. Culture, it is argued, has become—ironically—simplified and is wielded as a disciplinary device, rather than being seen as the complex dynamic that matters most in our explanations and explorations.

Debates on the progress or fancy of the cultural turn expose differing visions of what humanities and social science research is meant to do. Does it change the world? Does it describe the world? Or does it do both and thereby reinvent how the world is made meaningful and pertinent to human and spatial diversity? Such debates are good for geography, which sits at the foot of unparalleled opportunity due to its inherent interdisciplinarity, unique diversities of insight and methodological approaches, and special focus on space in human and environmental relationships. Care, however,



must be exercised not to depend too heavily on *cultural turn* as a descriptive, disciplinary term. Overreliance risks reinforcing a narrow, historicist picture of geography. Geographical thought has always been multifaceted, contestatory, and plural. Suggesting that, as a discipline, geography made a turn to culture—or, conversely, should now limit its culturalist tenor—risks imposing, if implicitly, a common trajectory by which a less than reflexive disciplinarity might solidify its position and ignore its diverse pasts. Those on both sides of the debate would agree, however, that it is in how we explain culture, and what we do with those explanations, that the power and resonance to engage space, people, environments, and their dynamic, constituting relationships lie.

Mark Jackson

See also **Critical Human Geography; Cultural Geography; Poststructuralism; Spaces of Representation/Representational Space; Spatial Turn; Symbolism and Place**

Further Readings

- Barnett, C. (1998). The cultural turn: Fashion or progress in human geography. *Antipode*, 30(4), 379–394.
- Mitchell, D. (2004). Cultural geography at the millennium: A call to (intellectual) arms. *Journal of Cultural Geography*, 22(1), 155–157.
- Naylor, S., & Ryan, J. (2000). *Cultural turns/geographical turns: Perspectives on cultural geography*. Harlow, UK: Prentice Hall.
- Valentine, G. (2001). Whatever happened to the social? Reflections on the “cultural turn” in British human geography. *Norsk Geografisk Tidsskrift-Norwegian Journal of Geography*, 55, 166–172.



CYBERSPACE

The term *cyberspace* describes the worldwide network of interconnected computers and the amount of digital data to which it gives access. The word was coined in 1984 by William Gibson in a famous science fiction novel, *Neuromancer*.

The prefix *cyber* derives from the ancient Greek *kubernan*, which means “to navigate.” The metaphor of navigating, or exploring a new, virtual world, is justified by the incommensurable size and complexity of the Internet and the World Wide Web (the Web). Accessible information and applications are often structured in a way that replicates the real world. We connect on, and travel across, Web “sites.” An increasing part of everyday life—at least in wealthy countries—is spent connected to Internet-based applications, for purposes of business, shopping, gaming, travel, social meetings, and so on. Cyberspace has been the subject of thousands of books. The most comprehensive attempt to capture the complex geography of cyberspace was the *Atlas of Cyberspace* by Martin Dodge and Rob Kitchin.

History and Dimensions

Cyberspace should preferably not be confused with the Internet, although often the terms are used interchangeably. Electronic networks predate the Internet. Large firms, such as airline companies, started to establish electronic data interchange systems as early as the 1960s. In 1982, France pioneered the Minitel system. Although rudimentary by today standards, it was the first electronic network open to a large public.

Research on the Internet (for “inter-networks”) started in the Advanced Research Projects Agency (ARPA) of the U.S. Department of Defense. ARPANET, created in 1969, was the first packet-switching network. In the 1970s, Vinton Cerf and Robert Kahn created a new protocol for computer interconnection, TCP-IP (transfer control protocol, Internet protocol), officially adopted on January 1, 1983. Another important step, in 1991, was the creation of the World Wide Web by Tim Berners-Lee, a researcher in the European Organization for Nuclear Research in Geneva. The Web, which makes it possible to navigate between documents present on computers through hyperlinks, is the fundamental framework of cyberspace.

The growth and pervasiveness of cyberspace since the late 1990s was fuelled by the digital convergence of different media. Electronic devices, such as computers, television sets, cameras, and

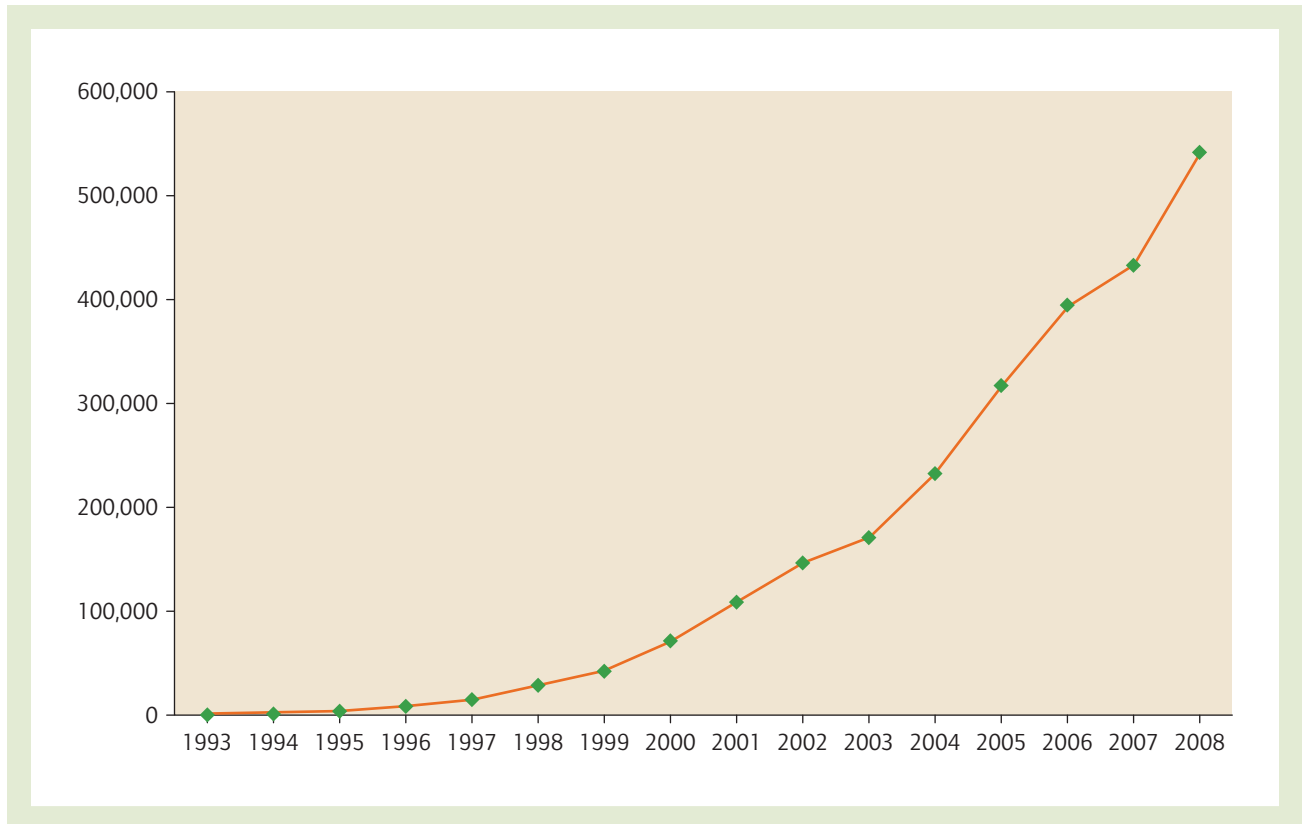


Figure 1 Growth of Internet domain names (in thousands)

Source: Created by author, based on data from Internet Systems Consortium. (2008). *The ISC domain survey*. Retrieved May 10, 2008, from www.isc.org/solutions/survey.

mobile telephones, can share data through portable supports or networks. Moreover, a single device, such as a telephone handset, has now “multimedia” capabilities: The user may take photos, watch TV, navigate the Web, and connect to sites and applications where he or she can read newspapers, send e-mail, do shopping, play online games, and so on.

Cyberspace features a hybrid nature. On the one hand, it is dependent on material infrastructures (servers, fiber-optic cables) rooted in real geographic space. Location has therefore an actual effect on cyberspace accessibility. For example, the distance between a given house and the nearest telephone exchange has a full impact on the available DSL bandwidth. A country such as India is subject to a permanent telecommunications bottleneck due to its poor infrastructure. Cyberspace is therefore characterized by a digital divide. Urbanized regions in developed countries

have high densities of networks, servers, computers, and cyberspace navigators. Peripheral regions, especially in the poorest countries, are less visible in cyberspace.

On the other hand, cyberspace can be conceptualized as a “virtual world,” where time and space seem to have collapsed. All other things being equal, given that Internet connections last milliseconds, navigation through cyberspace is almost insensitive to geography.

Since the invention of the Internet, the size of cyberspace in terms of complexity and amount of data has risen tremendously. In 2009, the Internet had more than 1.7 billion users. In 2007, the number of domain names crossed 500 million (Figure 1). Public institutions, firms, and individuals are frantically creating and posting digital content on the Web (e.g., libraries are digitizing their catalogs). Therefore, the exact size of the Web, measured in terabytes of data, cannot be measured



with a reasonable margin of error. Pundits often make the distinction between the “surface Web”—the part of cyberspace open to the public—and the “invisible” or “deep Web,” which is not indexed and stays out of the reach of search engines. It includes, notably, companies’ intranets and the enormous amount of digital material they warehouse in data centers. In May 2008, the Web contained more than 47 billion Web pages. The “deep Web” is several times larger.

A Mirror of Society

The spectrum of human activities that use cyberspace navigation has become as large as life itself. For many applications, cyberspace is merely an electronic marketplace, a “one-stop shop” where people have access to real items and services (e.g., visiting tourist sites, booking hotels). Business-to-business electronic commerce has become a normal standard in interfirm relations. Business-to-customer e-commerce lags behind: In 2007, e-commerce accounted for 3.3% of total U.S. retail sales. Individuals still prefer shopping experiences in real space rather than in cyberspace.

In many other cases, cyberspace may be conceptualized as a world in itself, although virtual, where people may spend a notable part of their life chatting, downloading movies, playing games such as “multiuser dungeons,” gambling, looking for pornography, and so on. Some social interfaces have reached a worldwide dimension. MySpace (www.myspace.com) and Facebook (www.facebook.com) are the best known. Second Life, a 3D (three-dimensional) virtual world created by Linden Research, boasts 13.6 million residents, who may participate in social events, play games, buy land and build structures, create businesses, and pay with money (the Linden dollar) withdrawn from virtual ATMs (<http://secondlife.com>). Addictive habits in cyberspace are common, especially among youth, sometimes ending in a social withdrawal syndrome. As a mirror of society, cyberspace has become a field for a large spectrum of illegal activities, or cybercrime: hacking, phishing, child pornography, identity theft, spying, securities fraud, and money laundering. In 2000, a study by PricewaterhouseCoopers estimated the cost to the world’s economy of computer hacking and virus writing and dissemination at \$1.6 trillion.

Finally, the pervasiveness of Internet applications must not divert us from the fact that the key issues of our time (e.g., environment, energy, food, health, sustainable development) are located in real geographic space, not in cyberspace. Up to now, navigating cyberspace remains a poor experience compared with navigating the physical world.

Bruno Moriset

See also Communications Geography; Digital Divide; Information Society; Spaces of Representation/Representational Spaces; Telecommunications and Geography; Video Games, Geography and; Virtual and Immersive Environments; Virtual Geographies

Further Readings

- Castells, M. (2001). *The Internet galaxy*. Oxford, UK: Oxford University Press.
- Crampton, J. (2003). *The political mapping of cyberspace*. Edinburgh, UK: Edinburgh University Press.
- Crang, M., Crang, P., & May, J. (Eds.). (1999). *Virtual geographies: Bodies, space, and relations*. London: Routledge.
- Dodge, M., & Kitchin, R. (2000). *Mapping cyberspace*. London: Routledge.
- Goldsmith, J., & Wu, T. (2006). *Who controls the Internet? Illusion of a borderless world*. New York: Oxford University Press.
- Janelle, D., & Hodge, D. (Eds.). (2000). *Information, place, and cyberspace: Issues in accessibility*. New York: Springer.
- Kalathil, S., & Boas, T. (2003). *Open networks, closed regimes: The impact of the internet on authoritarian rule*. Washington, DC: Carnegie Endowment for International Peace.
- Kellerman, A. (2002). *The Internet on Earth: A geography of information*. London: Wiley.
- Malecki, E. J., & Moriset, B. (2007). *The digital economy: Business organization, production processes, and regional developments*. London: Routledge.
- Zook, M. (2005). *The geography of the Internet industry*. Oxford, UK: Wiley-Blackwell.



CYBORG ECOLOGIES

The term *cyborg ecologies*, along with the allied notions of hybrids and nature-cultures, describes the view that the world is made up of both human and nonhuman networks. More specifically, it suggests that we must pay both empirical and theoretical attention to the connections among the biophysical, social, discursive, and technical elements of any given event, object, subject, idea, or thing.

This idea emerged in response to two different theoretical stances. First, cyborg ecologies sought to challenge the long-standing separation of nature from culture, or the notion that nature is a biophysical reality, while culture is a human construction. The concept is intended to disassemble the presumed unities of nature, culture, and technology, asserting that the world has always been made up of assemblages of animals, humans, and machines. Through this assertion, the boundaries between nature and culture, animal and human, and object and subject are unsettled. Moreover, the notion of cyborg ecologies is also on the forefront of a return to the material in the face of the so-called cultural turn in geography and its cognate disciplines, which emphasized the role of discourse in constituting the world. Thus, discourse became a primary analytical tool to explain “Nature” as a cultural container for ideas about wilderness, race, class, gender, sexuality, empire, and the like rather than a biophysical reality. While the “cultural turn” provided important insights into the way power works by making some things appear natural, it also evacuated the nonhuman from a discussion of nature, as animals and plants become yet another power effect produced through discourse. This perspective left out a whole range of nondiscursive practices, such as those of animals, plants, viruses, or technologies, for example, which, although they do not speak, can exercise their own particular forms of agency and are able to attach themselves to networks in unpredictable ways.

Using examples such as the ozone hole, nanotechnology, and mad cow disease as heuristics, ideas about cyborg ecologies insist on the recognition that the boundaries between nature and culture have always been porous and the effort to

draw distinctions between these two realms is suspect. The concept of cyborg ecologies emphasizes the endless but always contingent networks among various agents such as animals, plants, discourses, technologies, and humans.

The scholarship that uses the idea of cyborg ecologies draws on the work of science studies scholars such as Donna Haraway and Bruno Latour. Although the cyborg, or cybernetic organism, has long been a feature of both science fiction and social theory, it is with Haraway’s seminal 1985 text “A Cyborg Manifesto” (expanded and reprinted in 1991 in *Simians, Cyborgs, and Women: The Reinvention of Nature*) that the term gained substantial currency in geography. In response to both the binaries found in much scholarship of the time and their manifestations in feminist thinking, Haraway borrowed the notion of the cyborg as a means to think through the interconnections between the synthetic and the organic—a playful and ironic figure that disrupts neat categories. She uses the cyborg as a political metaphor that insists on partiality, contingency and also the relationality between animals and machines. This also finds common cause with the actor network scholarship of Latour. In his book *We Have Never Been Modern* (1993), Latour asserts that modernity is made up of two interrelated processes: purification and mediation. He contends that purification is the practice of bracketing the human (or culture) from the nonhuman (or nature), but this practice can only be supported by the work of mediation, that is, the proliferation of hybrids—in other words, Haraway’s cyborgs.

In geography, one scholar closely associated with the notion of cyborg ecologies (although she never uses the term) is Sarah Whatmore. Drawing on the works of Haraway and Latour as well as Gilles Deleuze and Felix Guattari, Whatmore contends that the stale debates between nature as either pure construction or absolute reality need to be left aside in favor of an understanding of the relational character of the world, involving all manner of human and nonhuman combinations, where agency can be found in more than human intention. An example might help flesh this out. In her book *Hybrid Geographies*, she draws on the case of the leopard in Roman games (among many others) to



make the notion of cyborg ecologies more concrete. She suggests that we must view the leopard in this context as not simply a biological organism but an assemblage of the technologies, devices, instruments, programs of training, colonial discourses, practices of commerce, performances, bodies, and places that brought it from Africa to the arena, making it a recognizable life-form infused with significance and ready for its eventual slaughter. By tracing the network of the Roman leopard, from its hunting to its death, Whatmore demonstrates that while we cannot imagine the leopard as a preexisting entity, we cannot suggest that it comes into being only as a product of discourse. It is both subject and object in this cyborg ecology.

Thus, the notion of cyborg ecologies explores how we might conceive the world as it is rather than as what the boundaries between inside and outside, human and nonhuman, nature and culture, or the various other dualisms that have structured humanist thought have tried to make it. It suggests, perhaps, a way out of dualistic thinking to a more nuanced understanding of the complex human and nonhuman entanglements that have always been with us.

Stephanie Rutherford

See also **Actor-Network Theory; Cultural Turn; Hybrid Geographies; Nature-Society Theory; Poststructuralism**

Further Readings

- Featherstone, M., & Burrows, R. (Eds.). (1996). *Cyberspace, cyberbodies, cyberpunk: Cultures of technological embodiment*. London: Sage.
- Haraway, D. (1991). *Simians, cyborgs, and women: The reinvention of nature*. New York: Routledge.
- Latour, B. (1993). *We have never been modern*. Cambridge, MA: Harvard University Press.
- Luke, T. (1997). At the end of nature: Cyborgs, "humachines," and environments in postmodernity. *Environment and Planning A*, 29, 1367–1380.
- Whatmore, S. (2002). *Hybrid geographies: Natures, cultures, spaces*. Thousand Oaks, CA: Sage.



CYCLONES: EXTRATROPICAL

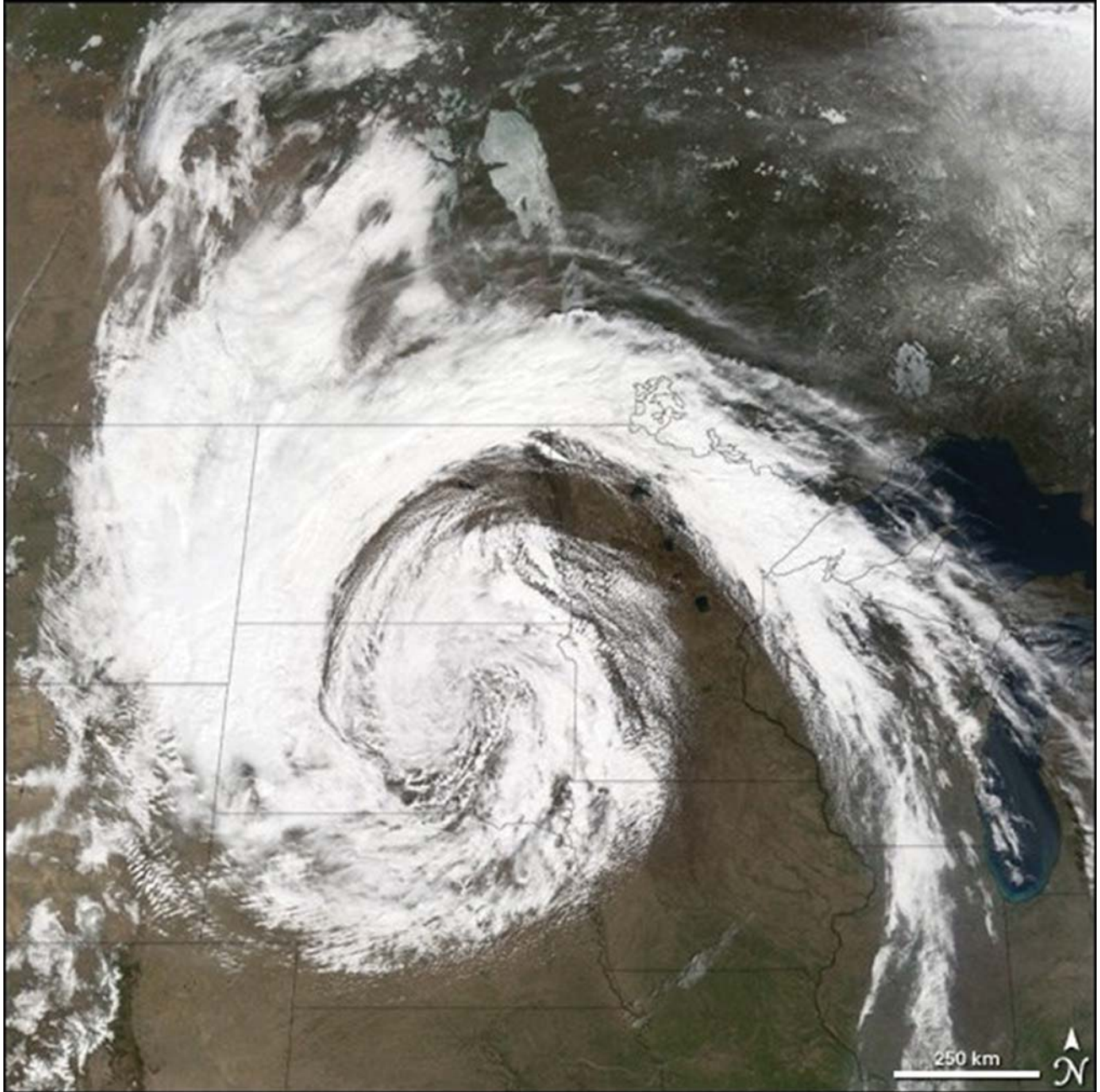
Extratropical cyclones (ECs) are organized synoptic-scale low-pressure (cyclonic) weather systems that govern a considerable proportion of midlatitude ($\sim 30^\circ$ – 60°) weather patterns (also commonly referred to as *midlatitude cyclones*). ECs ultimately form in response to the global circulation and energy balance. Given that the equator-to-pole temperature gradient is greatest during the transition and cool seasons, the magnitude and frequency of ECs is also greatest during these times. Part of the Earth's attempt to balance the surplus and deficit of net energy at the equator and the poles, respectively, involves large-scale equatorward and poleward air mass advections of relatively homogeneous thermal and moisture characteristics. The interaction along the fronts of these air masses is a key trait in the development and maintenance of ECs.

Satellites have enabled us to observe the typical comma-cloud shape of ECs, which typically have horizontal extents $\geq 1,000$ kilometers, with a life cycle of several days (see photo).

The resulting mesoscale weather from a passing EC comprises a vast spectrum of events, including light rain or snow, torrential downpours, blizzards, damaging winds, destructive hail, tornadoes, as well as just overcast or clear skies. Given the areal extent, duration, frequency, and resultant sensible weather from ECs, these midlatitude weather systems often have a profound effect on many lives. Thus, our understanding of the characteristics and behavior of ECs and the role they play in weather and climate is of critical importance.

Polar Front Theory

The polar front theory (PFT) serves as the modern conceptual framework for the characteristic life cycle of ECs. The PFT, otherwise known as the Norwegian Cyclone Model, was established during World War I by the Norwegian physicists and meteorologists Jacob "Jack" and Vilhelm Bjerknes (son and father, respectively) and Halvor Solberg and the Swedish meteorologist Tor Bergeron. Together, these scientists pioneered the meteorological school of thought known as the Bergen school of meteorology, of which the PFT was the



Visible satellite image showing the comma-cloud shape of an extratropical cyclone over the North-Central United States and South-Central Canada

Source: National Aeronautics and Space Administration (NASA).

foundation. In short, the PFT states that wave cyclones develop along frontal boundaries of contrasting air masses (e.g., continental polar and maritime tropical) and are driven by thermal advections (baroclinic instabilities) along the polar front. However, it is important to note that tropical

cyclones (TCs), that is, hurricanes, may evolve into ECs. This transition commonly occurs when a TC makes landfall in the middle latitudes, losing the forcing from the latent heat source of the warm tropical ocean waters but using the baroclinic energy to help sustain the cyclonic weather system.



Extratropical Cyclogenesis

Extratropical cyclogenesis refers to the development or strengthening of a cyclone in the middle latitudes. Cyclogenesis can commence from relatively strong disturbances located in the upper troposphere or in orographic regions (i.e., leeside lows) or from amplifying frontal waves (i.e., frontogenesis). With sufficient atmospheric lift along horizontal thermal and moisture gradients, an EC commonly follows predictable stages throughout its life cycle, according to the Norwegian Cyclone Model.

Stationary Front

The presence of a stationary front sets the initial stage by providing the potential energy required for a developing EC. The stationary front separates cool, dry air to the north and warm, moist air to the south (Figure 1).

However, a middle- to upper-level disturbance (e.g., short-wave trough) superimposed along the stationary boundary is necessary for the onset of interaction between the two contrasting air masses. The key here is that while frontal instability provides the foundation for cyclogenesis, the development and maintenance of an EC depend on supportive upper-tropospheric dynamical features (e.g., the meridional extent and orientation of the upper-level long-wave trough and ridge pattern of the polar jet stream—*Rossby-wave* configuration, named after Carl-Gustaf Rossby).

Incipient Frontal Wave

The first indication of cyclogenesis is signified by cyclonic shear along the stationary front, which promotes a developing wave form or kink within the stationary boundary (Figure 2).

This incipient frontal wave signifies the initial call and response between the lower and upper tropospheres (i.e., a system of continuity). That is, the development of a surface low-pressure center and its resultant convergence is positioned beneath an area of upper-level divergence and just downstream of the upper-level low (i.e., the low-pressure profile is tilted upstream). If the divergent airflow in the upper troposphere exceeds the low-level convergence, the low-pressure center will likely strengthen and the EC will mature into an open wave (Figure 3).

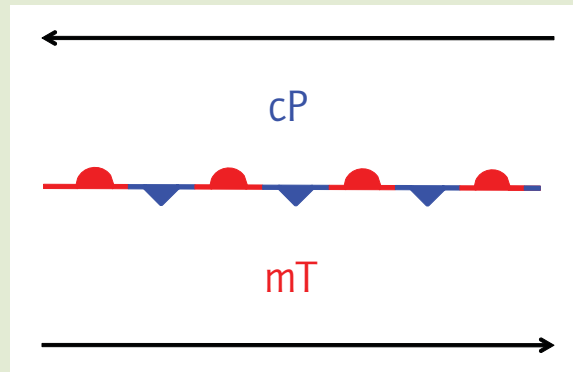


Figure 1 Conceptual model of the life cycle evolution of an extratropical cyclone during the stationary front

Source: Author.

Note: cP = continental-polar air mass; mT = maritime-tropical air mass.

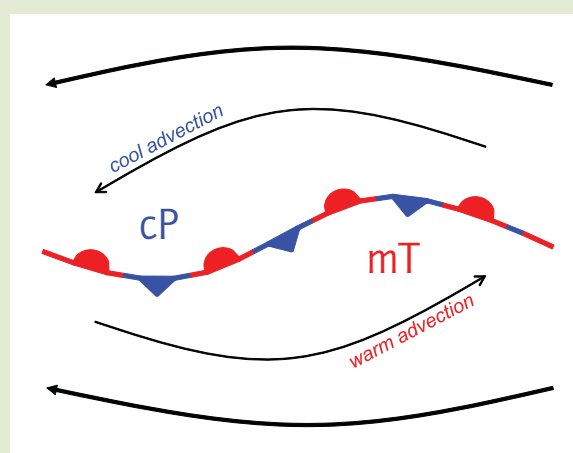


Figure 2 Conceptual model of the life cycle evolution of an extratropical cyclone during the birth of the incipient frontal wave

Source: Author.

Mature Open Wave

During this stage, the EC is marked by distinct warm- and cold-front boundaries that are anchored by a broad counterclockwise wind circulation around a low-pressure center (Figure 4).

Typically, easterly winds, amorphous cloud cover, and relatively lighter precipitation and cooler temperatures are located ahead of the warm

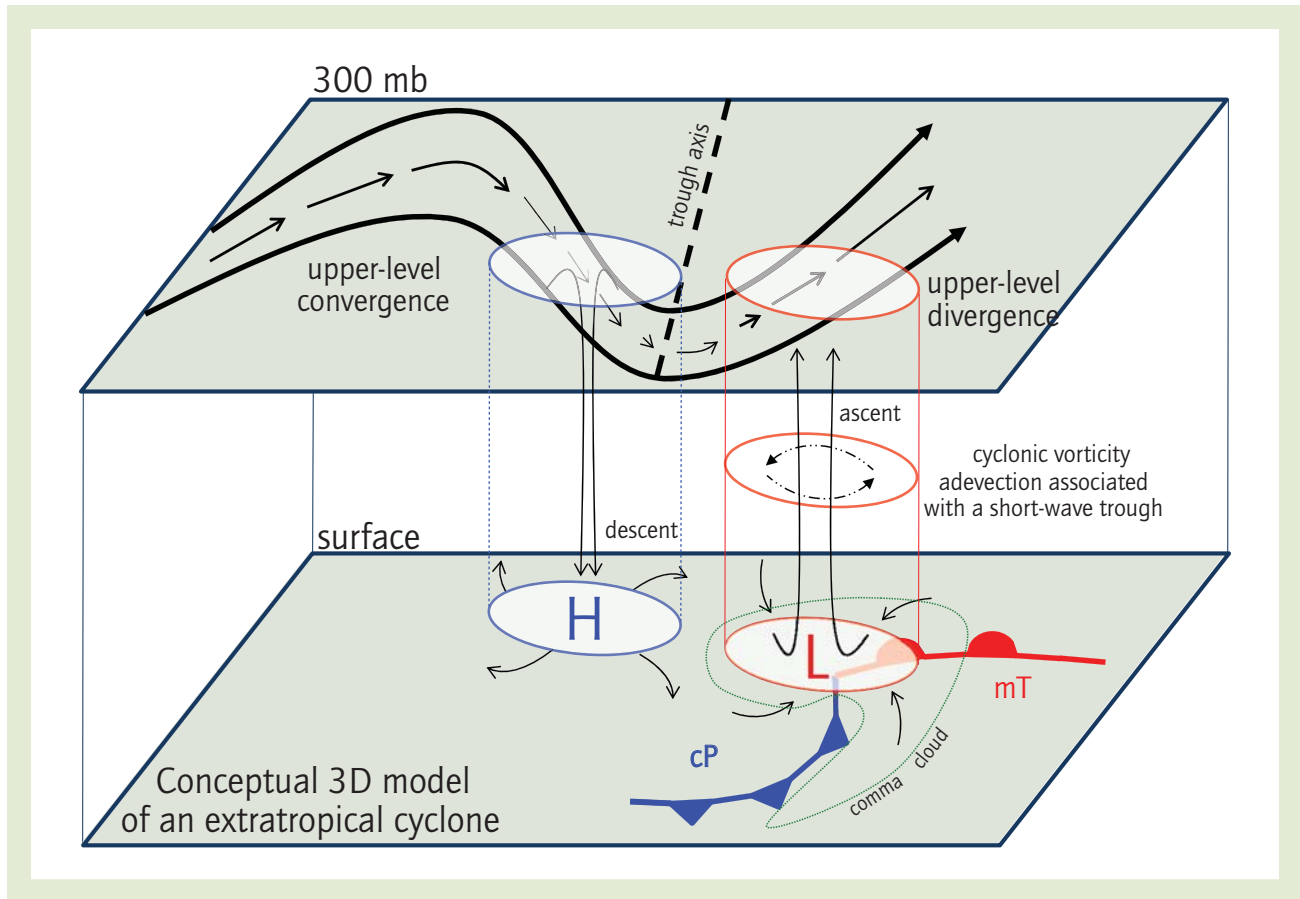


Figure 3 Three-dimensional conceptual model of the synoptic atmospheric environment conducive to the development and maintenance of an extratropical cyclone

Source: Author.

front. The advancing cold front often provides sufficient lifting of relatively warmer, moister air ahead of the cold front, often resulting in heavier precipitation events and other hazardous weather (e.g., tornadoes, hail, damaging winds). As the cold front sweeps through an area, abrupt decreases in temperature, moisture, and cloud cover are common as the troposphere stabilizes.

Mature Occlusion

The mature occlusion often marks the initial decay of the EC. The occluded stage is often explained with respect to a faster-moving cold front that overtakes the slower-moving warm front, forming the occluded front (Figure 5).

A more accurate description of this stage involves the orientation of the low-pressure profile. The

occlusion takes place when the surface low becomes positioned beneath the upper-level low and cooler air. This rearrangement of the low-pressure profile is what is referred to as a *stacked low*. When a low becomes stacked, the upper-level support becomes less conducive for maintaining the EC life cycle (i.e., a considerable decrease in baroclinic instability). However, with a supportive upstream Rossby-wave configuration, the cyclogenetic cycle can remain active and spawn what is called a “family of cyclones.”

Conclusion

The PFT is a simplistic conceptual model for explaining the development and evolution of an extratropical cyclone and remains widely accepted in our current understanding of ECs.

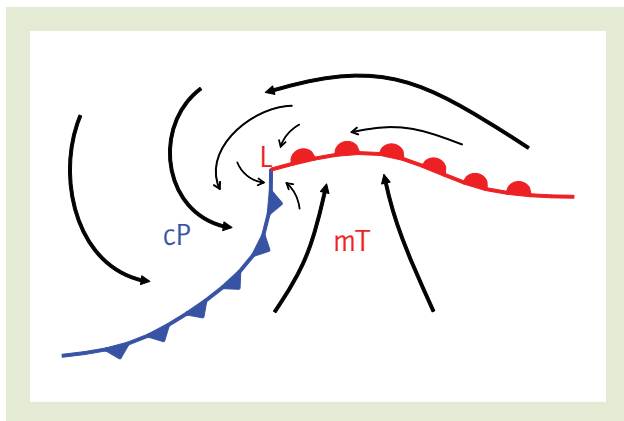


Figure 4 Conceptual model of the life cycle evolution of an extratropical cyclone during the mature open wave

Source: Author.

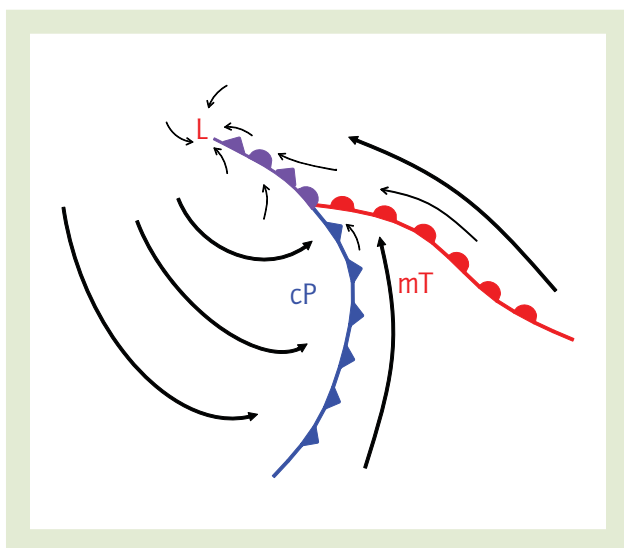


Figure 5 Conceptual model of the life cycle evolution of an extratropical cyclone during the mature occlusion

Source: Author.

It is important to realize, however, that as with most conceptual explanations, there are situations when reality fails the model. For example, continental versus oceanic ECs, upper-air fronts, and drylines are a few cases that complicate the conceptual framework of the PFT.

Joshua D. Durkee

See also **Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Pressure; Atmospheric Variations in Energy; Climate: Midlatitude, Mild; Climate: Midlatitude, Severe; Cyclones: Occluded; Hurricanes, Physical Geography of**

Further Readings

Shapiro, M. A., & Grønås, S. (Eds.). (1999). *The life cycles of extratropical cyclones*. Boston: American Meteorological Society.



CYCLONES: OCCLUDED

Occluded cyclones represent the late-mature stage of short-lived, rapidly moving extratropical cyclones that, with much slower-moving anticyclones, are responsible for the day-to-day weather changes in the middle latitudes. In redistributing energy and moisture, occluded cyclones are an integral component of the general circulation of the atmosphere. Juxtaposition of contrasting air masses with different temperatures and densities that resist mixing promotes the establishment of a front. A wave development on this front initiates cyclonic circulation and the genesis of a low-pressure region. The front develops discrete warm and cold portions separated by a warm sector. Through time, the cold front moves more rapidly than the warm front and eventually overtakes the warm one. Then, occlusion takes place. Precipitation associated with occluded cyclones may be of moderate to heavy intensity, resulting in significant amounts of rain-fall, especially during the partially occluded phase.

Jet Streams and Surface Weather

In the midlatitudes, the general airflow pattern is from west to east, termed the *Westerlies*, and this dominates throughout the depth of the troposphere. At upper-troposphere levels, the airflow commonly resembles a series of horizontal wave-like oscillations, referred to as *Rossby waves*, that encompass most of the midlatitude region. The nature of airflow through an upper-level Rossby wave has important ramifications for the development of weather systems at the surface.

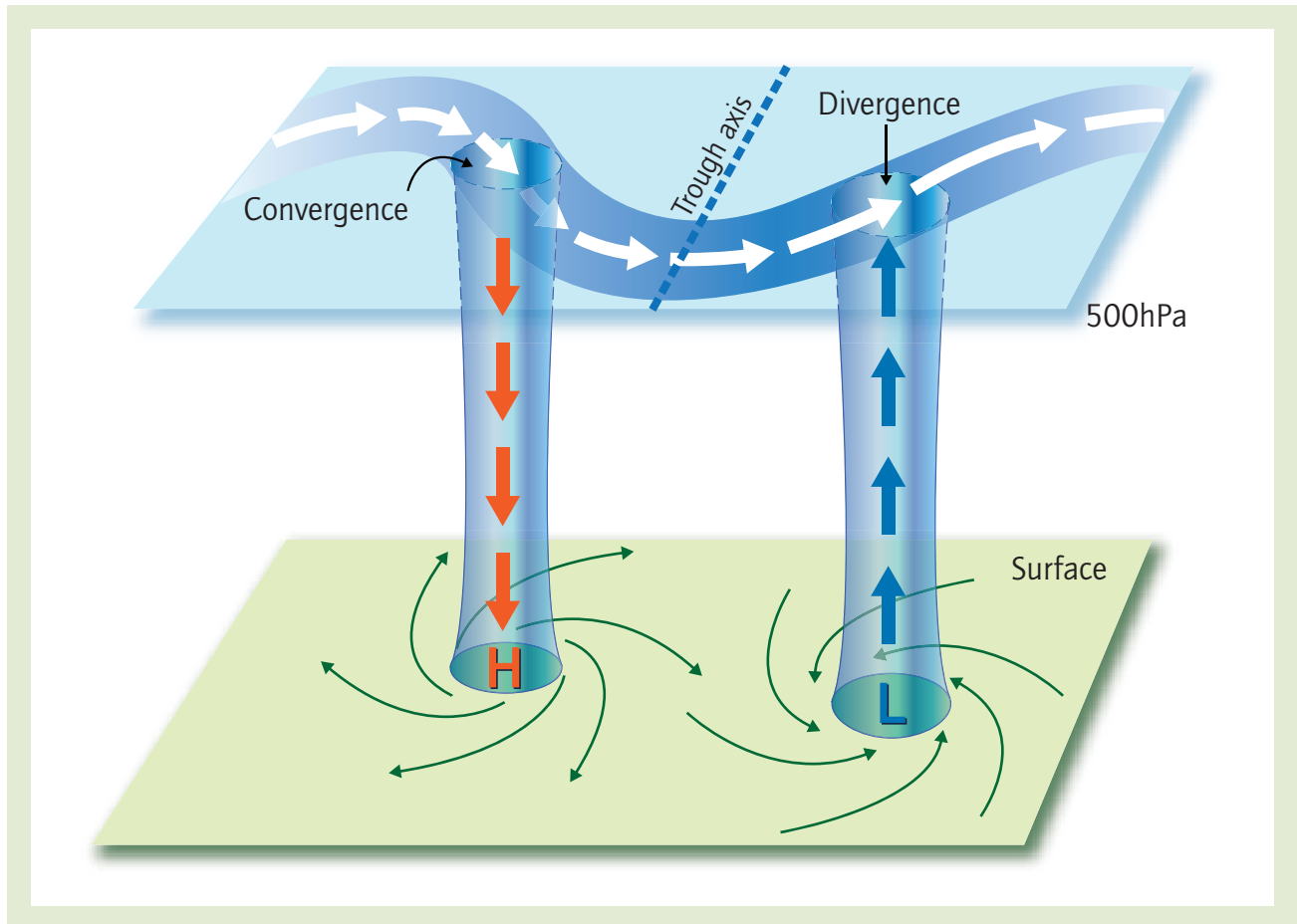


Figure 1 Upper airflow and surface extratropical cyclone formation

Source: Author.

The fastest-flowing airflow usually occurs in the trough of a Rossby wave, but as the air exits the trough, changes in the flow along the upper wave lead to divergence and convergence. When the air in the upper troposphere diverges (spreads out), this draws air upward from below and encourages the surface genesis of a low-pressure center accompanied by cloud development and precipitation. A zone of divergence exists just downwind of an upper-level trough (Figure 1). In contrast, immediately downwind of an upper-level ridge, convergence promotes subsidence, which inhibits cloud development and induces pressure to rise at the surface and anticyclone formation to occur.

Low-pressure development at the surface originates with wave development on the front that separates two air masses of markedly different temperature and humidity. Cyclogenesis continues

through stages to produce a mature extratropical cyclone—a synoptic-scale feature some 1,500 to 3,000 kilometers in diameter.

Frontal Development From Maturity to Occlusion

The mature extratropical cyclone comprises a distinct low-pressure region at the crest of the wave. A warm front occupies the leading edge of the wave that normally progresses east or northeastward. The warm front is followed by a warm sector comprising the warm air enclosed by the wave on its southern side. Finally, the cold front leads the cold air mass at the rear of the wave.

Figure 2 illustrates how, as the extratropical cyclone continues to deepen, the cold front moves faster relative to the warm front and the area of

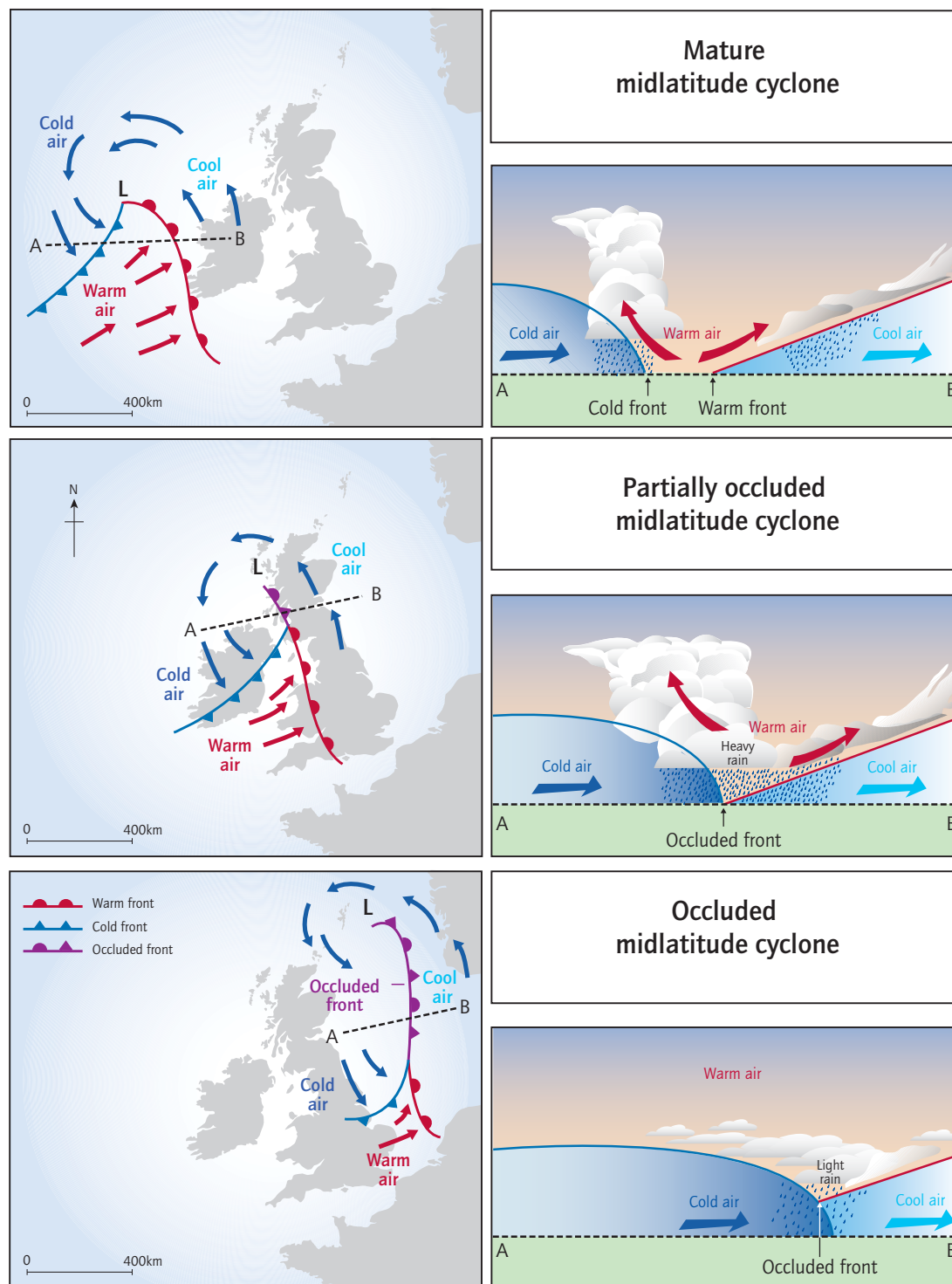


Figure 2 The process of occlusion

Source: Author.



the warm sector contracts. At the warm front, the warm lighter air is moving forward and upward away from the surface over the heavier colder air with which it comes into contact. It can also be seen that the cold air at the rear of the cyclone is undercutting the warm air and pushing it forward and upward at the cold front. At both the warm and the cold fronts, cooling and condensation occur within the rising air associated with the warm conveyor belt, inducing cloud development and zones of precipitation in advance of the fronts. Eventually, an occluded front forms where the cold front overtakes the warm front, with the warm air being completely lifted off the ground. This ascent and cooling of air in the vicinity of the occluded front generates precipitation.

Occluded fronts, unlike warm and cold fronts, do not separate tropical from polar air masses. Instead, at the surface they appear as the boundary between two polar air masses. A warm air mass exists aloft but is detached from the surface. Occlusions are classified as either warm or cold, depending on the relative states of the air masses lying in front and to the rear of the warm sector. A cold occlusion occurs when the air behind the original cold front is colder than that ahead of the warm front. In the reverse situation, it is termed a warm occlusion, and indeed, most occlusions are warm. Air in advance of the cyclone is likely to be coldest when cyclones occlude over Europe in winter and very cold continental polar air is affecting the continent. Similar circumstances are observed in warm occlusions over British Columbia and the Pacific Northwest of the United States when the relatively mild maritime polar air behind a Pacific cold front moves onshore and encounters the colder polar continental air.

The extent of an occluded front progressively increases away from the center of the cyclone and, in so doing, eliminates the waveform at the surface. Eventually, the cyclone dissipates, but often with the polar front becoming reestablished further south than previously. Extratropical cyclones usually occur sequentially in families, with each new system forming progressively south on the trailing cold front of its predecessor. Eventually, the front trails far to the south, and frontolysis (frontal decay) occurs when there cease to be differences in the temperature and humidity properties of adjacent air masses.

By no means do all frontal cyclones follow the sequential development outlined above, and not all extratropical low-pressure systems originate as frontal waves. This is more generally characteristic of oceanic cyclogenesis, and over Central North America, cyclones forming in winter and spring depart considerably from the standard pattern.

Case Study of an Occluded Cyclone

While the process of occlusion is a later stage of the life cycle of an extratropical cyclone, significant and intense precipitation may be associated with the occluded front. This is exemplified by the extratropical cyclone of October 21 to 22, 1987, which produced significant rainfall totals categorized as “remarkable” and associated record floods in Northern Ireland.

Synoptic Situation, October 20 to 22, 1987

At the 500-hPa (hectopascal) level, a marked cold trough located west of Ireland at 12:00 UTC (Universal Coordinated Time) on October 20 moved east over the next 24 hrs. (hours), with a closed low developing over Ireland, apparent on the 500-hPa chart for midday on October 21 (Figure 3a). At 00:00 UTC on October 21, a shallow cyclone (LD) with surface pressure of 1,001 hPa was moving north-northwest. An associated warm front, aligned north-south along the west coast of Scotland, and through the Welsh Borderland, was moving slowly westward (Figure 3b). By 06:00 UTC on October 21, the deepening cyclone had moved up the Irish Sea; a distinct westward moving warm front and a northward progressing cold front then affected Northern Britain (Figure 3c). Further deepening occurred with continued northward movement, and at noon, the cyclone was centered over the North Channel (Figure 3d). The cold front moved rapidly, turned cyclonically, and by early afternoon of October 21, an occlusion had formed over Northern Ireland, which affected the province during the remainder of the day. By 00:00 UTC on October 22, the cyclone lay off Western Scotland, and the associated chart (Figure 3e) indicated the rotational aspect of the system, with the occluded front in the southern sector of the cyclone returning eastward and skirting the north coast of Ireland.

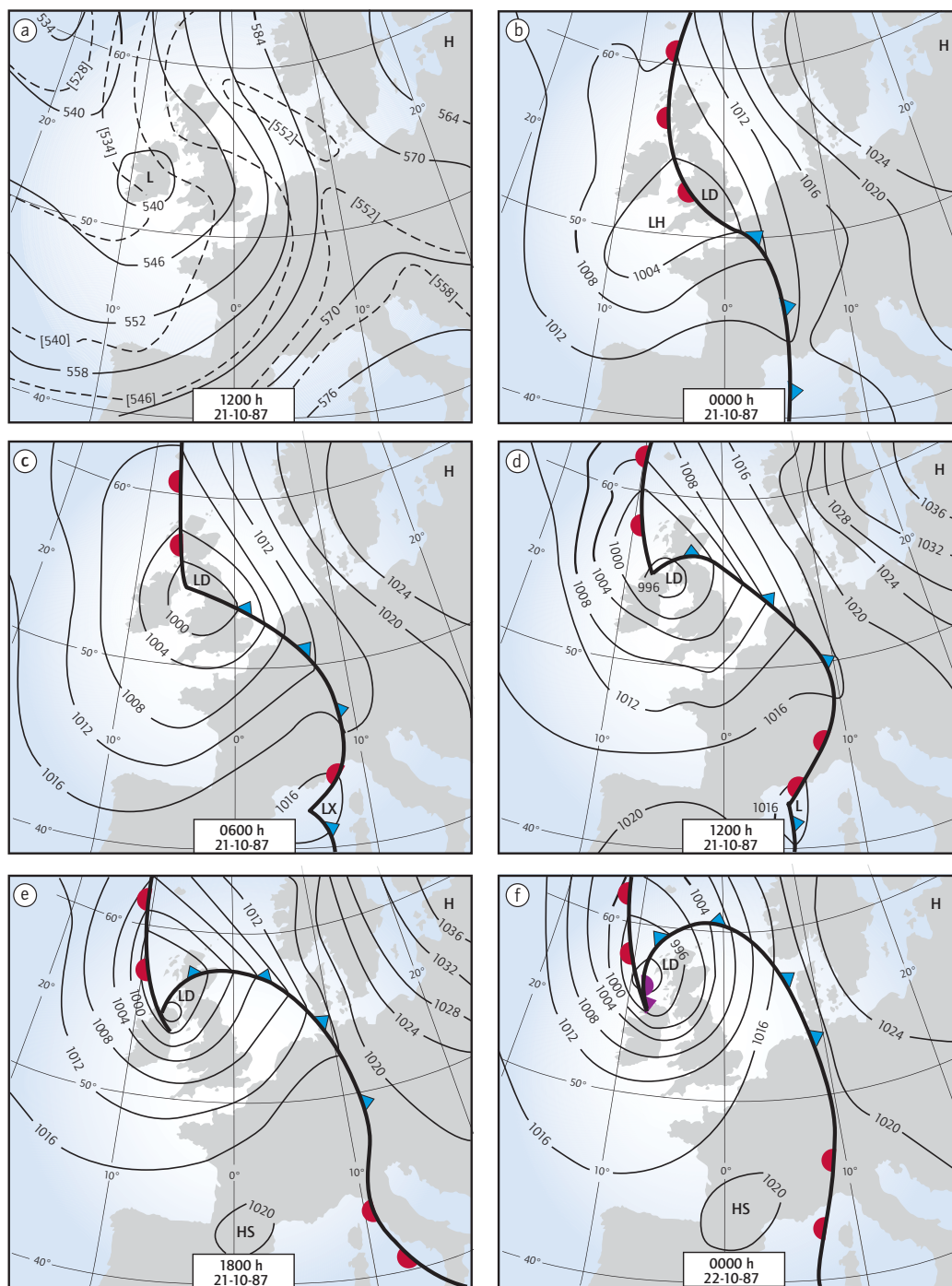


Figure 3 Synoptic situation, October 20 to 22, 1987: (a) 500-hPa height (dam, solid lines) and 1,000- or 500-hPa thickness (dam, dashed lines) for 12:00 UTC on October 21; (b) to (f) surface charts for 00:00 UTC, October 21, and 00:00 UTC, October 22, with isobars at 4-hPa intervals

Source: Adapted from Daily Weather Summary, London Weather Centre, Meteorological Office.



Figure 4 Total precipitation (in millimeters) between 00:00 UTC, October 21, and 09:00 UTC, October 22, 1987

Source: Adapted from data provided by the Meteorological Office, Belfast, Northern Ireland.

Total Precipitation Distribution

Precipitation began in the south of the province before 01:50 UTC on October 21 and by 03:00 UTC in the west; and by 04:45 UTC, precipitation was experienced throughout Northern Ireland. This lasted 20 to 25 hrs.

Upland sites generally recorded twice the precipitation amount as adjacent lowlands. This orographic enhancement resulted from differential intensities rather than durations. Most upland sites recorded over 75 mm (millimeters), the highest areas more than 100 mm (Figure 4). The greatest total (137 mm) occurred at Glenanne, County

Armagh, while at many sites, amounts were categorized as “very rare,” with return periods of 160 years or more. Precipitation totals of less than 50 mm were confined to the east coast, the north coast fringe, and an area extending across part of the mid Antrim Plateau.

Distribution of Shorter-Period Precipitation Amounts

Prior to occlusion, as the synoptic system encroached northward between 00:00 and 06:00 UTC on October 21, a major precipitation area developed, producing more than 15 mm over the

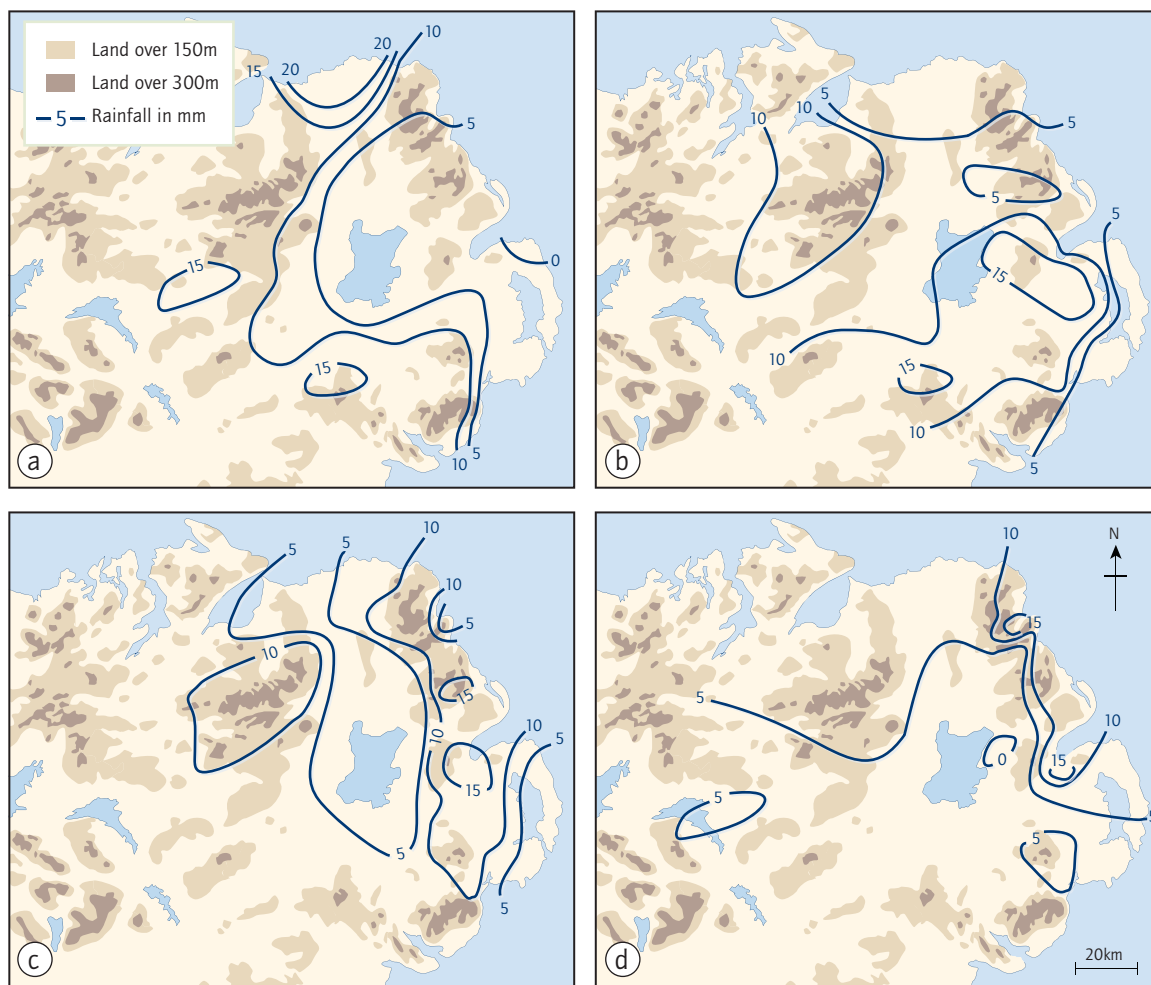


Figure 5 Surface precipitation (in millimeters) that fell in the period (a) October 21, 12:00 to 15:00 UTC; (b) October 21, 15:00 to 18:00 UTC; (c) October 21, 18:00 to 21:00 UTC; and (d) October 21, 21:00 to 00:00 UTC, in 1987

Source: Betts, N. L. (1990). Meso-scale precipitation distributions within a frontal depression. *Transactions of the Institute of British Geographers*, N.S., 15, 277–293.

Mournes. Between 06:00 and 12:00 UTC, as the cyclone and its associated fronts crossed eastern areas of the province, 6-hr. totals were recorded of 40 mm in the Mournes, 35 mm over upland South Armagh, 25 mm over areas of the Antrim Plateau, and 20 mm throughout the Sperrins.

As the cyclone began to occlude after midday, between 12:00 and 15:00 UTC, a distinctive feature of precipitation receipt was a relatively dry zone in the east of the province (Figure 5a). The

west and south remained wet, but the greatest totals now occurred along the north coast, and Coleraine received 13 mm between 12:00 and 13:00 UTC. This marked contrast of wetness across the region coincided with the occluded front having crossed eastern areas and having become aligned from Londonderry to the Mournes.

A return to precipitation of moderate to heavy intensity in eastern areas between 15:00 and 18:00 UTC occurred, with cyclonic rotation of



the occluded front and the edging back eastward of associated rain bands (Figure 5b). The Belfast area consequently experienced intensities of up to 8 mm/hr., and a drier zone replaced the rain band that had affected the northernmost areas in the previous 3 hrs.

The precipitation patterns for the period October 21 18:00 to 21:00 UTC (Figure 5c), and the subsequent period of 3 hrs. to 00:00 UTC on October 22 (Figure 5d), indicate that the linear rain band extending over the eastern part of the province was aligned parallel to the occluded front. Furthermore, as the depression and the associated rotating occlusion progressed north-northwest, the precipitation signatures associated with this precipitation area depicted the position of the front.

After 00:00 UTC on October 22, the southern areas became virtually dry. The only significant precipitation occurred around Londonderry, along the north coast and over the northernmost areas of the Antrim Plateau as the occluded front skirted the north coast.

The heavy precipitation of October 21, 1987, was a significant event in the climatological history of the province. Widespread—and in places, severe—flooding occurred throughout Northern Ireland. The physical, social, and economic

repercussions had impacts on both urban and rural communities, with Strabane, Omagh, Lissnaskea, and the Coleraine area among the most affected localities. Furthermore, the event demonstrates how occluded cyclones can impart significant weather before progressing to the dissipating stage of the life cycle of extratropical cyclones.

Nicholas L. Betts

See also **Air Masses; Atmospheric Circulation; Atmospheric Moisture; Climate: Midlatitude, Mild; Climate: Midlatitude, Severe; Cyclones: Extratropical; Floods; Hurricanes, Physical Geography of; Precipitation Formation; Weather and Climate Controls**

Further Readings

- Aguado, E., & Burt, J. E. (2009). *Understanding weather and climate* (5th ed.). Upper Saddle River, NJ: Prentice Hall.
- Barry, R. G., & Chorley, R. J. (2003). *Atmosphere, weather and climate* (8th ed.). London: Routledge.
- Semple, A. T. (2003). A review and unification of conceptual models of cyclogenesis. *Meteorological Applications*, 10, 39–59.



DANGERMOND, JACK

Jack Dangermond and his wife Laura are the founders of the Environmental Systems Research Institute (ESRI), the world's fourth largest privately held software company. Founded in 1969 and headquartered in Redlands, California, ESRI is arguably the technical and market leader in geographic information system (GIS) software. ESRI is the largest commercial GIS software provider in the world, with more than 1 million users in more than 100,000 organizations representing government and nongovernmental organizations, academia, and industries such as utilities, health care, transportation, telecommunications, homeland security, military, retail, and agriculture industries.

Dangermond initially founded ESRI as a small consulting firm/research group to perform land use analysis. However, its focus evolved into GIS software development, highlighted by the release of ARC/INFO in the early 1980s. The development and marketing of ARC/INFO positioned ESRI with the dominant market share among GIS software developers. Today, ESRI is the largest GIS software developer in the world, and its core product, ArcGIS, has direct linkages to Dangermond's initial efforts in developing ARC/INFO during the early years of the company's inception. Workstation ARC/INFO evolved into ESRI's flagship product, developed for spatial analysis,

now aptly called ArcGIS, which is a desktop graphical user interface (GUI)-driven product that possesses myriad spatial analysis functionalities.

Dangermond graduated with a bachelor of science degree in environmental science from California State Polytechnic University in Pomona, California. He holds a master of science degree in urban planning from the Institute of Technology at the University of Minnesota and a master of science degree in landscape architecture from the Graduate School of Design, Harvard University, where he worked in the Laboratory for Computer Graphics and Spatial Design. The experience there led to the eventual creation of ESRI and its subsequent software products. Dangermond also holds several honorary doctorates from various higher-education institutions around the globe.

Dangermond fostered the growth of ESRI from a small research group to an organization of more than 2,700 employees, known internationally for GIS software development, training, and services. In 2007, ESRI had 16 subsidiaries and 72 distributors worldwide. ESRI also has 11 regional offices throughout the United States. Dangermond is recognized not only as a pioneer in spatial analysis methods but also as one of the most influential people in the realm of GIS. Dangermond explains why the development of GIS techniques and technologies has become such an integral part of his vision pertaining to geographic research and its role in society: "We are visual creatures. Seeing promotes understanding. If GIS



helps us see what is happening in a larger, graphical context; and helps us to model and estimate change; perhaps more collaboration and compromise will result.”

If the discipline of geography is the framework for understanding, conceptualizing, modeling, and visualizing the world, then GIS is a tool that facilitates and enhances the process of integrating what we know. Dangermond has arguably built a career and a company that endeavor to accomplish this task.

Shawn Lewers

See also **Database Management Systems; Geospatial Industry; GIScience; GIS Software**

Further Readings

Dangermond, J. (2005, March). GIS is just getting started. In *Proceedings of the GITA Annual Conference 28*. Denver, CO: GITA. Retrieved August 25, 2009, from <http://tinyurl.com/ntsshe>



DARBY, HENRY CLIFFORD (1909–1992)

Henry Clifford Darby, arguably Britain’s best-known historical geographer, sought to break down the barriers between history and geography as separate disciplines. He produced a prodigious body of scholarship, especially concerning medieval England.

Born in Wales, he began attending Cambridge University at age 16 and then received a teaching post there on graduation with the PhD, soon becoming a college Fellow. During World War II, he worked for the Naval Intelligence Division of the British Admiralty and then left Cambridge to assume the John Ranking Chair at the University of Liverpool from 1945 to 1949. He then relocated to University College London before returning to Cambridge to hold a chair of the geography department in 1966. He retired in 1976 and was knighted in 1988. Intellectually, he was greatly influenced by the works of Paul Vidal de la Blache and Lucien Febvre.

Darby wrote extensively on the medieval history and geography of England, including topics such as the draining of the English fens, about which he published two books in 1940. (While most of his work focused on England, he also coauthored books on the history of France and Greece—in 1942, he produced a 1,630-page handbook on France.) He emphasized the cross-sectional or horizontal approach to historical geography, that is, the reconstruction of past geographies at a given moment in time, as opposed to the vertical approach, which centers on historical change. His focus remained relentlessly on landscapes: In his words, he was not much interested in shifting from “places changed by men to men as changers of places.” In this approach, Darby stood in contrast to contemporaries such as Carl Sauer (whose work he knew), who advocated a more temporally dynamic perspective of landscape change.

By far his most well-known work, one that consumed much of the latter part of his life, consisted of a gargantuan seven-volume tome on the Domesday geography of England written between 1952 and 1977, based on the famous *Domesday Book* of 1086 (also known as the *Book of Winchester*) following the Norman conquest of 1066. (The title *Domesday* comes from the Old English *dom*, an account or reckoning, which is also the source of the word *doom*.) William the Conqueror, eager to understand the new lands he had acquired, commissioned something like a medieval census, largely for purposes of taxation. The *Domesday Book* consists of detail inventories of people, farmland, crops, animals, forest cover, and other phenomena, providing an enormous trove of information about medieval geography. The entire project appears to have been carried out by one person. Darby’s work carefully translated, summarized, and mapped this information and noted its historical context. Subsequently, much of this information has been digitized.

Darby’s work and scholarly views were largely traditional and empirical, as was common with the subdiscipline of historical geography before the rise of social theory in the late 20th century. Darby himself recognized that the discipline had changed irrevocably in his time. Nonetheless, he had considerable influence on subsequent historical geographers, and his work continues to draw



admiration for its careful attention to detail and painstaking reconstruction of past landscapes.

Barney Warf

See also **Historical Geography**

Further Readings

- Darby, H. (1986). *Domesday England*. Cambridge, UK: Cambridge University Press.
- Darby, H. (2001). *The relations of history and geography*. Exeter, UK: Exeter University Press.
- Darby, H., & Maxwell, I. (Eds.). (1977). *The Domesday book of Northern England*. London: Cambridge University Press.
- Prince, H. (1992). H. C. Darby 1909–1992. *Journal of Historical Geography*, 18, 456–460.



DARWINISM AND GEOGRAPHY

Although Charles Darwin was actively engaged in geographical exploration and his work would have been hardly possible if not for geographical differences in the distributions of species and characteristics, Darwin has received little direct attention in geography. Despite Darwin's lack of recognition as an influential figure for geography, much geographical research since the publication in 1859 of *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* has been either explicitly or implicitly inspired by Darwin. David Stoddard suggested that the Darwinian theme of evolution as change through time, with emphasis on the relationship between organic life and the environment, and his analysis of selection and struggle, exerted a strong influence on research in geomorphology, pedology, and ecology; led to the organicist interpretation of regions and states; and resulted in a deterministic application of the concepts of selection and struggle in human and political geography. Another major theme of Darwin's work, the random nature of original variations, was ignored by geographers until the late 20th century, which was largely the result of Darwin's inability to provide a good explanation for it.

The impact of Darwin's work constituted nothing short of a revolution in science, confronting the old mode of doing natural history head-on. Rather than attributing the diversity of natural forms to the will of a divine creator, Darwin's book provided a theoretical framework that explained the diversity of species in a purely naturalistic, causal fashion. Darwinism itself is best understood as an evolving entity as opposed to a homogeneous body of knowledge. If the interpretations and meanings of Darwinism change and evolve, can we still identify a set of conceptual pillars that make up Darwinian evolutionary theory? At a general level, we can identify a set of concepts and principles that characterize a Darwinian view of evolution:

- At any moment in time there is sustained variation of species produced through random mutation.
- The environment winnows on this variation through natural selection. Individuals and species that are relatively better adapted to their environment are more likely to leave more offspring and so expand at the expense of relatively poorly adapted individuals and species. The competition for scarce resources does not require "survival of the fittest."
- There must be a mechanism that keeps variation stable long enough for selection to operate. If species were to adapt instantaneously to demands of their environments there would be no variety left to select from. Although Darwin realized that there must be a mechanism to pass on information between generations, he was never able to prove that, because genetics was developed only after the publication of *The Origin of Species*.
- There is no progression or development toward some ideal, perfect, or higher stage of development. Although humans are more complex than single-cell organisms, they are not necessarily better in terms of some preconceived ideal and optimal state of adaptation. They simply fill different niches in an environment.

Some writers have argued that Darwin's evolutionary principles can be generalized, although the mechanisms by which variation is produced, maintained, and destroyed are domain specific. While



random mutation is the only source of variation in biological systems, a deliberate search for improvement and problem solving generates variety in social systems. While genes pass on information from one generation to the next in the biological domain, learning and knowledge acquisition are the primary means of passing on information in social systems. Collective knowledge is often embedded in institutions and organizations, constraining and enabling the creation, transmission, and destruction of new knowledge. Although natural selection produces gradual evolution through the elimination of relatively ill-adapted forms and differential growth of relatively well-adapted forms, there is no reason to assume that competition is always beneficial for the survival of species. In various biological and social contexts, altruistic and cooperative behavior may benefit some groups over others in the evolutionary process.

Evolution and Time

In his work on the development of landforms, William Morris Davis explicitly referred to a cycle of life and used terms such as *birth*, *youth*, *adolescence*, *maturity*, *old age*, *second childhood*, *infantile features*, and *struggle* to emphasize the analogy of an organism undergoing a sequence of changes in form through time. Landscapes rose through tectonic uplift and were then shaped by erosive agents until they reached the end of their life cycle, a low plain. The idea of evolution as change through time also found its way into plant geography, social anthropology, the historical interpretation of technological development, or the understanding of cities as organisms changing through time. In geography, evolution soon implied little more than the idea of change, development, and progress, the simple linear and irreversible development of something over time, rather than the outcome of a process characterized by the interplay of variety, selection, and inheritance.

The geological metaphor of layering and evolution as change was picked up late in the 20th century again by economic geographers to conceptualize economic landscapes as layers of accumulation where value sunk in fixed capital gradually builds up over time. The basic idea of value accumulation driven by the logic of capital and class

struggle comes from Marxist economic geography. However, the fact that economic landscapes change slowly and that sunk capital, industrial structure, capital-labor relations, and institutional environments constitute relatively stable entities that transfer information over time and form barriers to instantaneous adaptation to new economic requirements fits squarely with gradual evolutionary change. While existing regional value configurations represent adaptations to the past or current requirements of the economic environment, they are often difficult to adapt to future requirements. Therefore, further change often requires the violent destruction of previously well-adapted regional value configurations through plant closures and relocations, job loss, and decay of economic and social infrastructure.

Organization and Ecology

Darwin was impressed by the complex interrelationships and connections between living things and their environment, giving rise to organicist interpretations of entities above the level of the individual. In geography the organism analogy operated at the level of the Earth, its regions, and the state, and predates Darwinian evolutionary theory, although much of this work was teleological. For Alexander Von Humboldt and Carl Ritter, unity, harmony, and independence of the parts in nature were the organic analogy that they interpreted as evidence of the work of a divine creator. In regarding regions as organic wholes, French and German regional geographers of the 1920 and 1930s reached conclusions similar to those of Humboldt and Ritter, writing half a century earlier.

The organism analogy was picked up by Friedrich Ratzel in his *Anthropogeographie* and "The Territorial Growth of States," where he interprets states as expanding organisms with an increasing need for resources and living space (*lebensraum*) such that geographic expansion is inevitable. Ratzel not only adopted the organism analogy but was also influenced by Ernst Haeckel's ecology, economist Herbert Spencer's view on survival of the fittest, and Jean-Baptiste Lamarck's views of evolution allowing for the direct and immediate influence of the environment on human behavior. For Ratzel, there existed a



strong, indivisible, and almost mystical relationship between people and land. The organic quality of states depended on the organization and interdependence of the parts. But by adding the properties of growth and competition, Ratzel goes beyond the organic analogies of the Earth and geographical regions, as proposed by Paul Vidal de la Blache and Alfred Hettner.

In the early 1900s, science still struggled with the relationship between individuals and wholes, and the organic analogy was little more than a metaphor hinging on formal and functional comparisons between living matter and complexly interrelated facts in areas rather than causal explanations. Because the organic analogy was unable to guide empirical investigation, it was largely dismissed during geography's quantitative revolution of the 1950s and 1960s, in which it was transformed from an idiographic to a nomothetic science promoting methodological reductionism in the form of either methodological individualism or spatial fetishism. Recent developments in complexity science may finally put the part-whole dilemma to rest and may provide new theoretical foundations for an organicist geography.

Selection and Struggle

A critical argument in Darwin's theory is natural selection and the struggle for existence. Environments shape species through their influence on reproductive success. Relatively better-adapted species are more likely to survive and reproduce, such that they expand their size in the overall population relative to poorly adapted ones. Darwin's theory explaining adaptation in nature by variation and natural selection was based on empirical evidence, but he could not, before the discovery of Gregor Mendel's work on genetics, offer any explanation of the origin and persistence of variation. And although Darwin's evolutionary theory is based on probabilistic principles where random variation is probabilistically translated into differential growth of different variants, Darwin himself never used the word *probability*, even though Pierre-Simon Laplace's work on probability was already available at the beginning of the 19th century. This limitation of Darwin's work made room for Lamarckian evolutionary theory, where species adapt to environmental

conditions and where those changes are then passed on to the next generation. In this view, the environment is deterministically related to the behavior of individuals and so opens up the door to environmental determinism in geography.

While the organism analogy simply indicated that regions or states could be considered as wholes that are more than the sum of the individual parts, the struggle for existence was now applied to the struggle of states for living space. States, like other organisms, have a natural tendency to grow and expand. With increasing population size, the demands to feed the population increase, and so the struggle for territory increases. The size of the territory of a state is then the spatial expression of the level of civilization. Ratzel's theory was in line with German imperial thinking at its time as it provided a "scientific" underpinning for its expansionist policy. The same lines of thinking also provided the underpinnings for British and American empire building. For Halford Mackinder, the key to British survival was control of the "Heartland," the vast area of land in Eurasia immune to sea attacks, where civilizations could create a natural power base. The key for British policy was then to make sure that no single power would control this mass of land, from where it could develop a power base to control the world.

While Ratzel's struggle for *lebensraum* is a crude interpretation of Darwin's struggle for existence, the question of who wins the struggle is a different one. It was politically expedient to find a natural explanation and justification for European and U.S. dominance at the beginning of the 19th century, and a crude Lamarckian interpretation of the relationship between the environment and people would deliver just that. Environmental determinists argued that climate or frontier conditions were selected directly for specific human traits and influenced ideas, racial characteristics, and cultures. In the crudest interpretations, differences in climates would so account for differences in intelligence and political and economic power. The writings of Ellen Churchill Semple, Ellsworth Huntington, and Frederick Jackson Turner are examples of these lines of thinking.

Russian geographer Pyotr Kropotkin advanced the notion that the struggle for existence does not necessarily entail competition between individuals,



regions, and states. In his travels to Siberia, he was impressed by the cooperation among species to survive in harsh environments. Altruistic and cooperative behavior could thus favor groups of individuals better than mere competition. While the empire and frontier politics of Europe and the United States highlighted competition as the main force in the struggle for survival, socialist governments emphasized cooperation and altruism.

Recent Developments

The racial politics of the German National Socialist Party brought the application of all biological theories, concepts, analogies, and metaphors in the social sciences into disrepute. The demise of biological concepts in the social sciences was further accelerated through the propagation of methodological individualism in sociology, economics, and political science (particularly in the United Kingdom and the United States), leaving little room for organicist ontologies.

It was only in the 1970s that a few economists started to challenge the neoclassical pillars of the perfectly rational individual and competitive equilibrium. In their attempt to overhaul mainstream economics, they looked for inspiration in biology rather than mechanical physics and so reintroduced the Darwinian notions of variety, heredity, selection, disequilibrium, and human-environment interdependencies into economics. Similarly, network metaphors and notions of embeddedness started to resurface in sociology.

Evolutionary economics was picked up by economic geographers in the 1990s to account for regional differences in technology evolution and institutional environment and to offer a dynamic explanation of the uneven evolution of the space economy. Although some of this work draws its inspiration from Darwin, others prefer complexity theory or the principle of path dependence as theoretical anchors for the development of an evolutionary economic geography. The organicist ontology is increasingly invoked to challenge methodological individualism and highlight the irreducibility of wholes to parts. This opens up the possibility of emergent properties at various spatial scales, with spatially varying features such as culture or institutions exerting a downward causal pressure on individual behavior.

With Darwinism and complexity science evolving at a rapid pace, these newer applications are more careful in their transposition of causal processes and concepts from the biological to the social domain. While a general theory of evolution based on the principles of variety, inheritance, and selection may hold in different domains, domain-specific auxiliary concepts and hypotheses are required to establish how variety is produced, maintained, and destroyed differently in different domains and what varieties of characteristics matter for the evolution of environments, species, humans, institutions, or regions.

Jürgen Essletzbichler

See also **Biodiversity; Ecosystems; Environmental Determinism; Geopolitics; Nature; Ratzel, Friedrich; Semple, Ellen Churchill; Social Darwinism**

Further Readings

- Boschma, R., & Lambooy, J. (1999). Evolutionary economics and economic geography. *Journal of Evolutionary Economics*, 9, 411–429.
- Darwin, C. (1958). *The origin of species*. New York: Penguin. (Original work published 1859)
- Hodgson, G. M. (2001). *How economics forgot history*. London: Routledge.
- Hodgson, G. M., & Knudsen, T. (2006). Why we need a generalized Darwinism, and why generalized Darwinism is not enough. *Journal of Economic Behavior & Organization*, 61, 1–19.
- Livingstone, D. (1992). *The geographical tradition*. Oxford, UK: Blackwell.
- Livingstone, D. (2006). The geography of Darwinism. *Interdisciplinary Science Reviews*, 31, 32–41.
- Nelson, R., & Winter, S. (1974). Neoclassical and evolutionary theories of growth: Critique and prospectus. *Economic Journal*, 84, 886–905.
- Rigby, D., & Essletzbichler, J. (1997). Evolution, process variety, and regional trajectories of technological change in U.S. manufacturing. *Economic Geography*, 73, 269–284.
- Special issue on evolutionary economic geography. (2007). *Journal of Economic Geography*, 7(4).
- Stoddard, D. (1966). Darwin's impact on geography. *Annals of the Association of American Geographers*, 56, 683–698.



DASYMETRIC MAPS

Dasymetric mapping is a cartographic technique with roots in choropleth mapping. Both techniques originated in the 1800s when cartographers and others began to design maps of population distributions. Like the choropleth map, the dasymetric map uses area symbols to show variations in topics collected by standard political units (e.g., census tracts, county boundaries). The advantage of this particular representation lies in its treatment of the boundaries of the political units. A choropleth map of county population density, for example, would suggest uniform densities within each county, with possible abrupt changes occurring between adjacent counties due to the geography's artificial nature.

The mapping of the topic with this technique is heavily influenced, then, by the geography of the political units used; displaying population densities by census tracts may result in quite different density patterns when compared with a similar map using counties as the geographic foundation (Figure 1).

The dasymetric version of the same data uses ancillary data sets, such as land use, as the boundaries for representing changes in population density (Figure 2).

The density data from each county are reassigned to land use areas within the county using formulas to determine how many people should be assigned to each inner-county area. The result is a more accurate mapping of the topic; areas of abrupt change follow more closely the real-world distribution because they are tied not to political

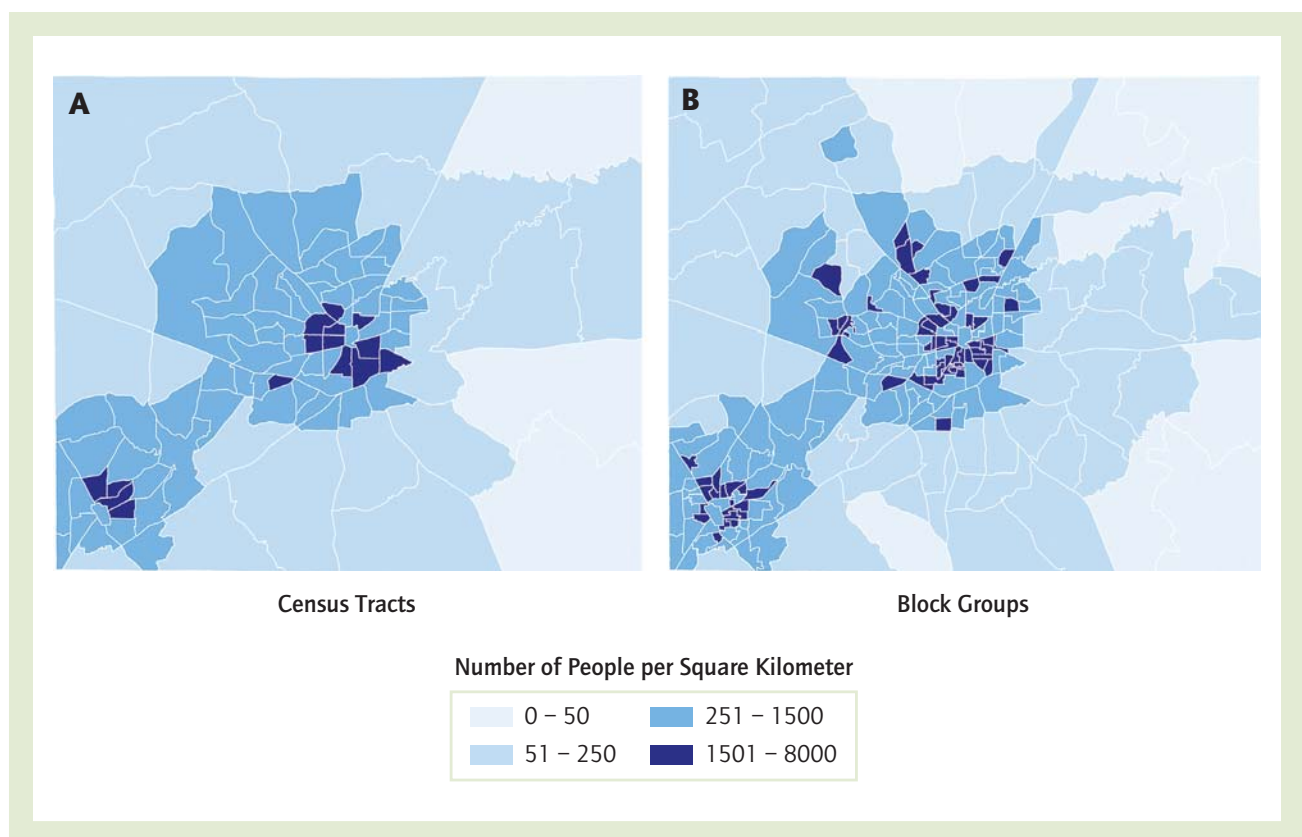
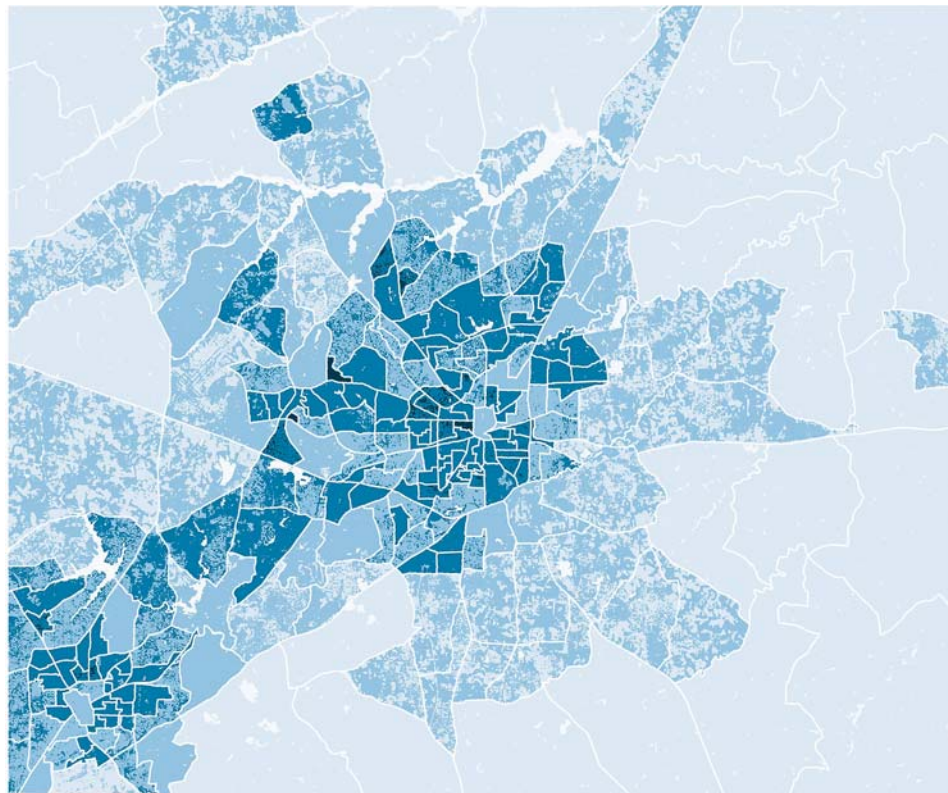


Figure 1 Population density of Guilford County, North Carolina, by census tract and block group

Source: Map created by author based on data from ESRI Data and Maps, 2000; Census 2000 Summary File 1 (SF 1) 100-Percent Data, U.S. Bureau of the Census, 2000; and National Land Cover Database, Multi-Resolution Land Characteristics Consortium, 2001.



Number of People per Square Kilometer

0 – 50	251 – 1500
51 – 250	1501 – 8000

Figure 2 Population density of Guilford County, North Carolina, using dasymetric mapping

Source: Map created by author based on data from ESRI Data and Maps, 2000; Census 2000 Summary File 1 (SF 1) 100-Percent Data, U.S. Bureau of the Census, 2000; and National Land Cover Database, Multi-Resolution Land Characteristics Consortium, 2002.

boundaries but to natural boundaries. The initial interest in dasymetric mapping seems to have originally peaked during the 1920s and 1930s, around the time that J. K. Wright published his seminal work on the subject. It is back at the forefront of cartographic research today, largely because of its more precise representation potential and its ease of implementation with current state-of-the-art software.

Elisabeth S. Nelson

See also **Choropleth Maps**

Further Readings

- Chrismon, N. (2002). *Exploring geographic information systems* (2nd ed.). New York: Wiley.
- Dent, B. (1999). *Cartography: Thematic map design* (5th ed.). Dubuque, IA: WCB McGraw-Hill.
- Eicher, C., & Brewer, C. (2001). Dasymetric mapping and areal interpolation: Implementation and evaluation. *Cartography and Geographic Information Science*, 28(2), 125–138.



- Mennis, J. (2003). Generating surface models of population using dasymetric mapping. *The Professional Geographer*, 55(1), 31–42.
- Robinson, A., Morrison, J., Muehrcke, P., Kimerling, A., & Guptill, S. (1995). *Elements of cartography* (6th ed.). New York: Wiley.
- Wright, J. K. (1936). A method of mapping densities of population: With Cape Cod as an example. *Geographical Review*, 26, 103–110.

DATABASE MANAGEMENT SYSTEMS

Developed in the 1960s by computer scientists who required an efficient storage and access mechanism for large data sets, database management systems (DBMS) have become a core component of present-day information systems. Database technology drives billions of transactions each day, from grocery store purchases to Web searches. The technology is also critical to research applications. DBMS facilitate efficient, scalable, secure storage of data and include query and manipulation tools that can be controlled via the standard structured query language (SQL). Properly applied database design techniques produce databases that eliminate data redundancy and provide for efficient queries across multiple tables. In geography, DBMS are used in multiple ways but are best known as a key component of geographic information systems (GIS), where they enable the storage and manipulation of attribute data associated with spatial features. Certain GIS data formats contain file-based attribute data, while others store attributes in a database table. Spatial databases are specially constructed to hold spatial features and their attributes and to provide functions for performing spatial analysis operations within a database.

Definition and History of Database Models

A database is simply a structured collection of related data. While the term *database* could refer to any collection of data, such as a set of alphabetically sorted recipes on index cards, it most commonly refers to a set of data stored

electronically. A DBMS consists of a database and the associated software constructs that not only maintain interrelationships among the stored data but also provide methods for data insertion, manipulation, and extraction.

A database model describes the structure of a database. Several DBMS implementations emerged in the 1960s that employed either the *network model* or the *hierarchical model*, which together represented the first generation of database models. Although these early models differed in implementation, they both represented data as records with links (from one record to another) that described relationships among the records. This approach provided limited search capabilities and was inefficient when dealing with databases containing empty records. In 1970 Edgar Codd described the *relational model*, which represented a groundbreaking approach to database modeling that solved many limitations of the linked-list approach of the first-generation models. Codd's work eventually guided the development of the relational DBMS, which remains the most widely implemented DBMS standard today. In later years, the *object-relational model* emerged, which supported the object-oriented programming concepts of objects, classes, and inheritance within the database. Many major DBMS support both relational and object-relational models.

Relational Database Management Systems

Relational databases offer many advantages over file-based information systems. Although text files are simple, are easy to read and edit, and can be processed in many ways, they do not scale well when dealing with large data sets, have limited structuring, and may contain redundant data. A relational DBMS can handle enormous data sets and maintain data integrity, eliminate data redundancy, enable user-based security, and provide structured methods for querying and manipulating the data.

Relational Database Structure and Design

A relational database contains a set of tables of related data. A table is a mathematical relation that contains a set of *tuples* (rows) and *attributes* (columns). Each table cell must contain a single value corresponding to the data type assigned to



Primary key attribute →

Column (attribute) names →

Rows (tuples) →

Table (relation) name: States

<i>state_id</i>	<i>name</i>	<i>abbr</i>	<i>fips_state</i>	<i>est_order</i>	<i>est_date</i>
36	Oklahoma	OK	40	46	1907-11-16
37	Oregon	OR	41	33	1859-02-14
38	Pennsylvania	PA	42	2	1787-12-12
39	Rhode Island	RI	44	13	1790-05-29
40	South Carolina	SC	45	8	1788-05-23

Figure 1 A relational database table with a subset of its content

Source: Author.

the attribute (i.e., the value “541” would be allowed for an attribute of an integer data type, but the value “541, 503” would not). Rows can be arranged in any order within the table. Each row must be unique; data may be duplicated across rows for some attributes but not for all. To ensure uniqueness, an identifier called a *primary key* that holds a value unique to each row is often defined in each table. A single column (e.g., the *state_id* column in Figure 1) or multiple columns together can form a primary key.

A column or set of columns that match the primary key of another table may be designated as a *foreign key*. Tables can be linked on common attributes by defining relationships between primary and foreign keys, and the use of foreign keys enables referential integrity, an important aspect of relational databases. Referential integrity is enforced by the relational model such that any foreign key value must have a matching primary key value in the related table (as in Figure 2). This ensures that the relationships between tables remain valid by guarding against accidental deletion of important data or the creation of “orphan” records that contain old data. Primary and foreign keys are also used to establish relationships (one-to-one, one-to-many, many-to-many) between tables, which helps prevent the insertion of redundant data. A classroom of students is an example of a one-to-many relationship (one classroom has many students). Figure 2 illustrates the modeling of a one-to-many relationship.

The structure of a relational database determines its usefulness in transforming data into meaningful output. Proper database design requires the consideration of many factors, including data types, normalization, relationships, referential integrity, and common queries that will be performed. The needs of the project represented by the database must be determined prior to the development of the database, and careful planning must take place to identify how the database design will meet those needs. An important aspect of the design process is database *normalization*, which involves breaking down tables until they represent single entities and their columns describe only those entities. A fully normalized database has no redundant data across tables. Graphical database modeling software tools can aid in database design, including the modeling of table relationships. Many such tools can automatically generate SQL statements for creating the tables and relationships depicted in the design.

Query Language and Methods

Modern relational DBMS provide for query and manipulation of data via SQL. Although SQL is designated as both an ANSI and ISO standard, variations in its implementation exist across different relational DBMS, so that the syntax of a query in Oracle might vary slightly from the same query in PostgreSQL. The SELECT command forms the basis of all SQL queries and can be

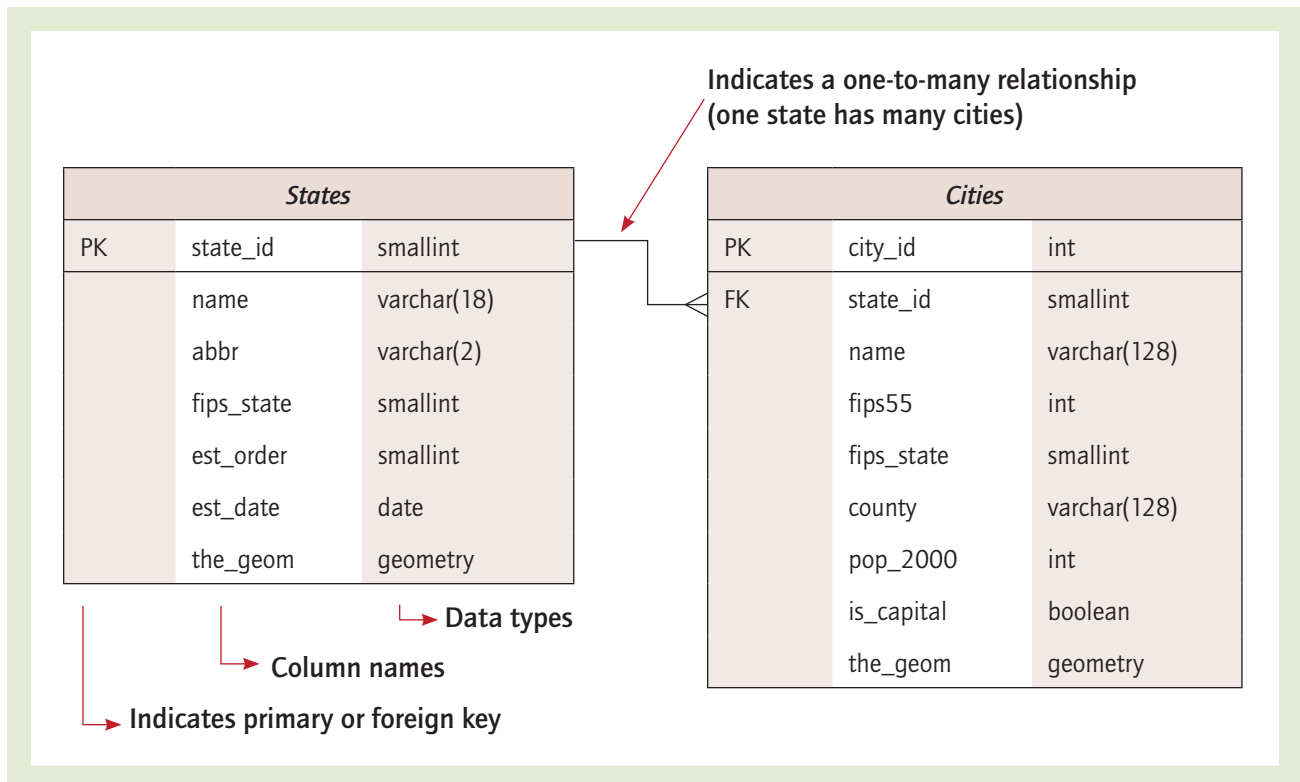


Figure 2 A representation of two relational database tables from a logical data model. The tables possess a one-to-many relationship through the common state_id column, designated as a foreign key in the Cities table.

Source: Author.

modified by several clauses, including FROM, WHERE, and ORDER BY to extract the desired information from a table (or set of tables). Common functions that handle tasks such as date conversions can be placed inside the query as well. For example, in a PostgreSQL table (such as Figure 1), the following SQL command would return a list of all states established after the year 1850, in ascending order by date:

```
SELECT name, est_date FROM States
WHERE to_char(est_date, 'YYYY') > 1850
ORDER BY est_date ASC; Common SQL
data manipulation commands include INSERT,
UPDATE, and DELETE
```

These commands enable virtually all data input and modification operations within the relational DBMS. As an example, assume that “Oklahoma” was misspelled as “Oklohoma” in the name column of the States table (Figure 1). The following

SQL command would fix all instances of the error (in this case, a single instance):

```
UPDATE States SET name =
‘Oklahoma’ WHERE name = ‘Oklohoma’
```

Relational DBMS provide a command-line interface for directly submitting SQL commands to the database. Many vendors also create graphical user interfaces for connecting to the database that can make certain query and management tasks more efficient. Programmatic access is yet another method for data access and manipulation—many programming languages such as Perl, PHP, Python, Java, and C++ provide built-in functions for connecting to a remote database and performing queries or data manipulation tasks. This powerful access method enables much of the behind-the-scenes database transactions that take place every day. A great deal of Web sites are “database driven,” with active processes performing database



operations on the back end, and Web server code pulling data from the database to the front end, dynamically populating the browser with content.

Database Management Systems in Geography

In geography, as in other disciplines, DBMS have been used for many years as general tools for storing and accessing diverse data sets; however, the most prominent use of DBMSs in geography today is within the context of geographic information systems (GIS). A GIS is an information and analysis system that links data attributes with spatial features by geographic coordinates. As such, a GIS contains not only tools for working with spatial features but also a DBMS for handling attribute data.

GIS Data Formats

Early efforts at encoding geographic data in large databases were pursued by the Canadian Geographic Information System (CAGIS) and by the U.S. Census Bureau, which developed the Dual Independent Map Encoding (DIME) scheme in the late 1960s to prepare for automated geocoding of the 1970 census. By 1990, the Bureau had integrated all their spatial data into a database called TIGER (Topologically Integrated Geographic Encoding and Referencing), an important data product that contains spatial feature and attribute data for the entire United States.

Early GIS data formats consisted of an attribute data file associated with a spatial features file by a common identifier. Some of these formats remain popular today. For example, the ESRI *shapefile* format uses the standard dBase .dbf file format to store attributes—a .dbf file is linked in a one-to-one relationship with a matching .shp file (which stores the spatial features) by a .shx index file. Together the three files constitute a single shapefile. Many GIS software programs can read shapefiles and have DBMS tools for manipulating attribute data stored in the .dbf format. The proprietary ESRI ARC/INFO *coverage* format, which predated the shapefile format, also uses a file-based approach.

More recently, ESRI introduced the *geodatabase* format, in which spatial features and attribute data are stored together as a hierarchical group of data objects. ESRI's "personal

geodatabase" stores data objects within a Microsoft Access database, while the "file geodatabase" stores data in a flat file structure. Enterprise versions of the ESRI geodatabase allow the use of more advanced relational DBMS technologies such as Oracle, SQL Server, or PostgreSQL with the geodatabase framework.

Spatial Databases

Relational DBMS products such as Oracle Spatial or PostgreSQL with the PostGIS extension add geometry data types that enable the storage of spatial data features (points, lines, and polygons) and also add spatial indexing schemes to facilitate fast searching across spatial features. These additions essentially "spatially enable" tables, allowing the database to not only store and manipulate spatial data and their attributes but also perform advanced spatial analysis operations traditionally done using a desktop-based GIS. For example, using a PostgreSQL/PostGIS table representing city limit polygons, with the spatial features stored in the column "the_geom," the following SQL statement returns the area of the city of Seattle in hectares:

```
SELECT ST_Area(the_geom)/10000 AS hectares
FROM Cities WHERE name = 'SEATTLE'
```

Using a spatially enabled table containing river features, a slightly more complicated query returns the length of river segments in each state they pass through:

```
SELECT r.name AS river, s.name AS state,
ST_Length(ST_Intersection(r.the_geom, s.the_geom))
AS length FROM Rivers r, States s WHERE
ST_Crosses(r.the_geom, s.the_geom) = 'T'
```

Spatial databases can perform many additional operations, such as coordinate transformations, buffering, and overlays. The results of these operations can be output as plain text or written into a new table to be used in further spatial analyses.

Dylan Keon

See also [Data Querying in GIS](#); [Enterprise GIS](#); [GIS Design](#); [GIS Software](#); [Spatial Data Models](#); [Spatial Data Structures](#)



Further Readings

- Beaulieu, A. (2005). *Learning SQL*. Sebastopol, CA: O'Reilly.
- Codd, E. (1970). A relational model of data for large shared data banks. *Communications of the ACM*, 13(6), 377–387.
- Date, C. (2003). *An introduction to database systems* (8th ed.). Reading, MA: Addison-Wesley.
- Foresman, T. (Ed.). (1998). *The history of geographic information systems*. Upper Saddle River, NJ: Prentice Hall.
- Rigaux, P., Scholl, M., & Voisard, A. (2002). *Spatial databases: With application to GIS*. San Francisco: Morgan Kaufmann.
- Zeiler, M. (1999). *Modeling our world: The ESRI guide to geodatabase design*. Redlands, CA: ESRI Press.



DATABASE VERSIONING

A spatial information system provides storage and management for data such that it has integrity in the representation of information. Integrity refers to the fact that the information stored in the system represents accurately the physical world. After all, a computer's data are an abstraction of reality. To develop integrity, an information system must have a data model describing the relationships among data and the types of data being stored. This approach has come to define, in conjunction with the actual data being stored, what an information system is. The information system also needs to support several practical considerations from a user's point of view and an administrator's point of view. One of these is the need for versioning and annotation of groups of related information, such as multiple spatial data sets about the same subject. For example, multiple data sets about town X can exist covering a period of time.

The design of versioning and lineage into a spatial information system can be accomplished in its underlying data model via a recursive relationship on an entity. This entity describes groups or collections of related, but disparate, spatial information. Such information might include vector and raster data, aerial photographs, and ground observations. For discussion purposes, let us call this entity *Set*.

Typically, versioning of groups of spatial information occurs as descendant versions of a set are created. As versions of a set are created, the relationship of the sets to each other can be described by a lineage tree. The versioning lineage tree is composed of ancestors and children derived from a single ancestral spatial data set entity instance. All children in the lineage tree and thus the sets described by the tree represent collections of information about a spatial extent of data at a given point in time.

The physical implementation of the set concept and lineage trees could be created by putting all data for a spatial set into a given directory on the computer system. A collection of these directories represents a lineage tree and versions of the same spatial data set. These directories could have a flat structure or a hierarchical structure.

Hierarchical structure is the most natural method and closest in structure to the concept of lineages where children folders are descendants of the root spatial set. However, as children are versioned, this physical implementation will rapidly lead to a directory tree that can be very deep and unwieldy. The concept of the set entity in the data model and its physical implementation is to contain descriptive information about all the types of data stored in a given directory. The types of information that could be described and stored should at a minimum include the data files, schema files, SQL procedural code, annotational information about use, version number for the data, security policy, backups, and the types of users with access of use to the set data.

At some point in the life cycle of a set, a user may create a new branch of the lineage tree that may represent a different version of the original data. With multiple branches for a given collection of spatial information, versioning management systems should allow a branch to be merged back into a parallel branch that it was originally derived from. Merging branches can be done easily if there is no spatial extent overlap in the data sets. If there is overlap, it still can easily be done if the objects in the versioned sets have not been edited in such a way that an object in set A did not exist in set B when the spatial set was originally versioned. Of course, merging of sets with no common ancestor should be relatively straightforward.

In the set management approach a set should be considered and treated as a single spatial



information entity, but it is in reality a collection of individual data files, each of which may be changed to make the entire set a candidate for a new version. Each set can thus be thought of as uniquely containing information denoted by a spatial extent. In a simple spatial set lineage tree with no branching allowed, it is a relatively easy problem to create new versions of a set. A user would simply create a new version and make the lineage ancestry association using the recursive link provided in the *Set* entity in the data model describing sets of spatial information.

Branching and versioning in the set approach is also equally straightforward. Versioning, the creation of a new branch, could occur for a variety of reasons but would most likely occur to express a change in the user's ownership of a given set. In this case, new versions can only be created from the tip of a lineage tree's chain (i.e., the most recent set of data files). If a new user wanted to work on a set further back in the lineage set tree, a new branch could be created at that point, which then becomes a parallel lineage chain as shown in Figure 1.

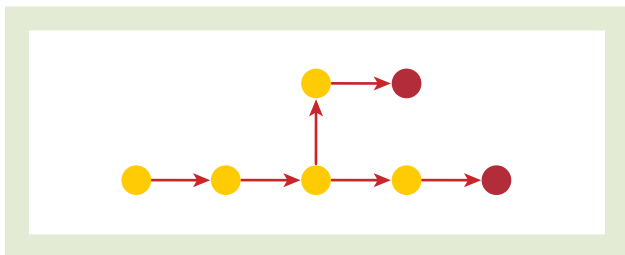


Figure 1 Parallel lineage tree with active versions at tips (red node)

Source: Author.

In Figure 1, the centerline is the primary lineage for a set; each circle represents a new version of the original set. Versioning can only occur at the tip of each branch; however, parallel lineages can be created of the set's information. Each node in Figure 1 represents a set of related spatial information that can be implemented in the physical directory structure mentioned previously. Note that because the versions of set data are derived from the same original set, merging of the lineage trees needs to be done carefully to prevent corruption of the integrity of information as mentioned in the previous discussion. For example, spatial object A

in the main lineage and its copy in A' could be potentials for information corruption if both of them are modified with different information and then the lineages are merged. If the information in A and A' are in conflict, the question of which contains the correct information arises. This could be resolved by setting a rule that when there are conflicts in spatial object information, the object on the main lineage is accepted as being the accurate information. Of course, other priorities could be established for management of merge conflicts.

The main goals for the application of the set concept in versioning and version management are to

- allow for the existence of different ownerships of information,
- maintain integrity in information, and
- manage and point directions to how merging of different lineage version might be accomplished for various types of spatial set relations.

In summary, the application of the set concept, versioning, and the lineage tree can be a powerful paradigm for the management of multiple collections of spatial information. It allows aggregation of disparate types of spatial information into a set model that can be managed, suggests an implementation structure, and allows different versions of sets containing spatial information to coexist peacefully without the loss of data integrity.

Gregory L. Vert

See also *Business Models for Geographic Information Systems; Client-Server Architecture; Critical GIS; Database Management Systems; Geographic Information Systems; GIScience*

Further Readings

- Vert, G., Alkhaldi, R., & Nasser, S. (2005). An architectural model for low overhead spatial data authentication and distribution in a peer to peer based spatial database model. *Proceedings of the 20th International Conference on Computers and Their Applications* (pp. 423–428). New Orleans, LA, March 16–18.
- Vert, G., Morris, A., & Stock, M. (2003). Converting a fuzzy data model to an object-oriented design for



managing GIS data files. *IEEE Transactions on Knowledge and Data Engineering*, 15, 510–511.

Vert, G., Stock, M., Jankowski, P., & Gessler, P. (2002). An architecture for the management of GIS datasets. *Transactions in GIS*, 6(3), 259–275.

Vert, G., Stock, M., & Morris, A. (2002). Extending ERD modeling notation to fuzzy management of GIS datasets. *Data and Knowledge Engineering*, 40, 163–169.

DATA CLASSIFICATION SCHEMES

In the graphic display of quantitative information, various classification schemes are used to organize data for meaningful interpretation. The

human mind makes sense of the world by grouping and ordering what the senses perceive. The mind *groups* elements such as plants, animals, clothing, and so on in processes of qualitative judgment. It *orders* elements such as big trees, small trees, and so on in processes of quantitative judgment. Grouping and ordering are fundamental to classification schemes used to prepare data for mapping.

A set of data is a selected group of elements—a “population.” This population is first ordered (arranged along the number line from smallest value to largest) and then divided into classes of closely related numeric value. Each class is then represented on the map by a distinctive symbol. The process of assigning data elements to a class can be accomplished with simple arithmetic processes or with statistical processes.

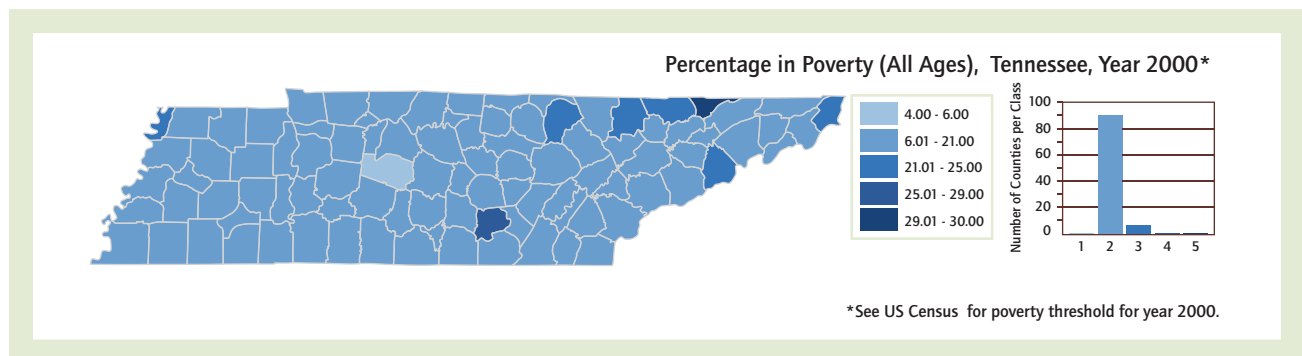


Figure 1 Classification by natural breaks

Source: Cartography by Alex Feldman; data by U.S. Census American FactFinder.

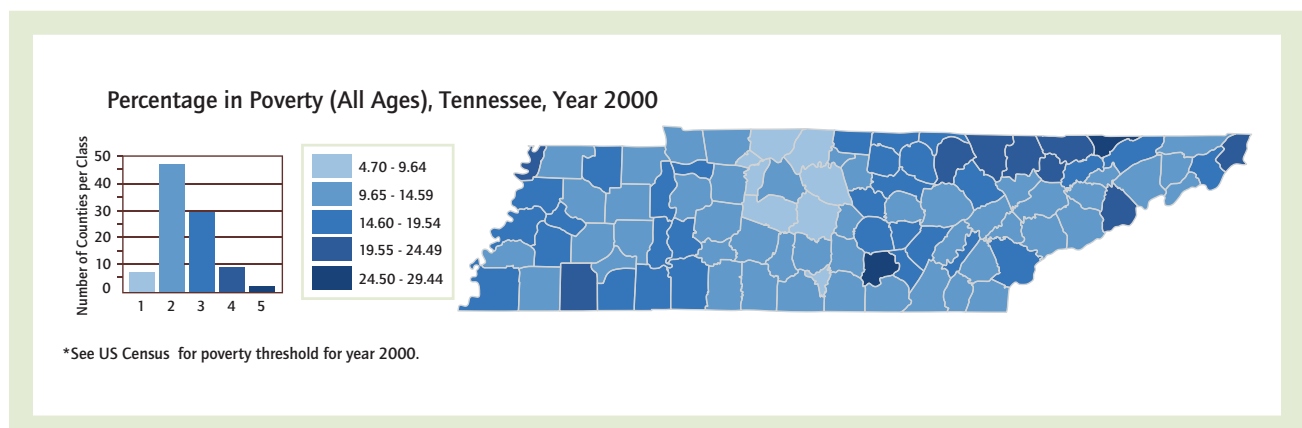


Figure 2 Classification by equal interval

Source: Cartography by Alex Feldman; data by U.S. Census American FactFinder.

A simple, yet effective, arithmetic process is the division of the data by *natural breaks*. Once arranged along the number line, similar-value data elements are assigned a class. Each class is then assigned a specific color symbol and mapped. Using this classification scheme, a simple choropleth (value by place) map results (Figure 1).

The data can also be classed by *equal interval* (Figure 2). In this method, the data are divided into an arbitrary number of classes (percentiles, deciles, quintiles, etc.), and the same number data elements are grouped into each class. The arbitrary assignment into equal-interval classes, however, frequently obscures significant differences in data values. Compare Figures 1 and 2.

Another simple, yet effective, classification method is the *interquartile range*. In this method,

the data are grouped into four equal intervals (quartiles). The middle intervals are collapsed into one class—the interquartile range. This interquartile range is assigned one symbol, while the first and last quartiles are assigned other symbols. The resulting map is a three-class map that emphasizes the lowest and highest values of the data set. The effectiveness of this method is seen in Figure 3, where the richest and poorest areas of Tennessee are easily identified.

For a more nuanced classification, the *standard deviation* is determined for each data element, and then groups of similar standard deviation are clustered into classes. While this is a preferred method for many mapping tasks, a thorough interpretation of the map is not possible for the reader with little knowledge of descriptive statistics. A map classed by standard deviation can still

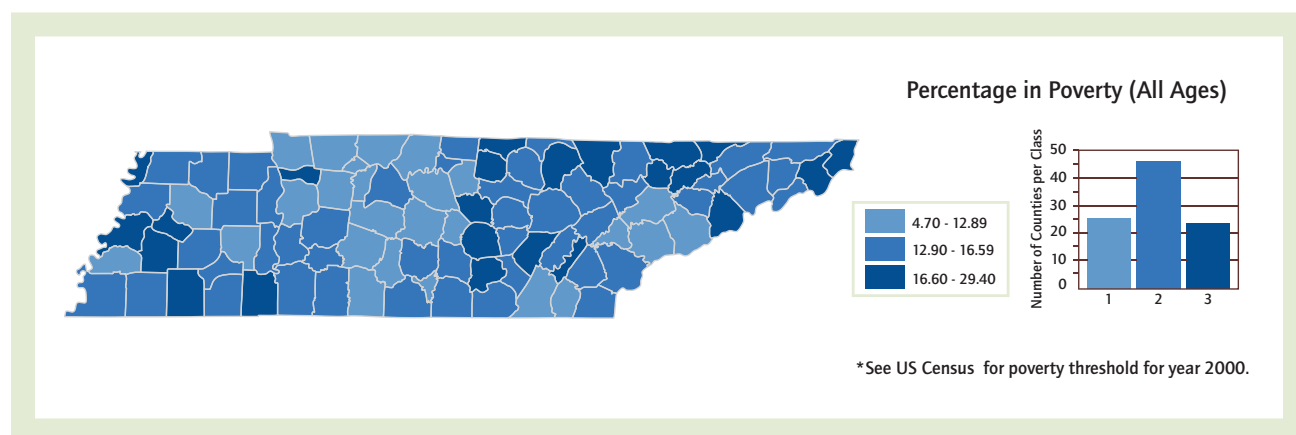


Figure 3 Classification by interquartile range

Source: Cartography by Alex Feldman; data by U.S. Census American FactFinder.

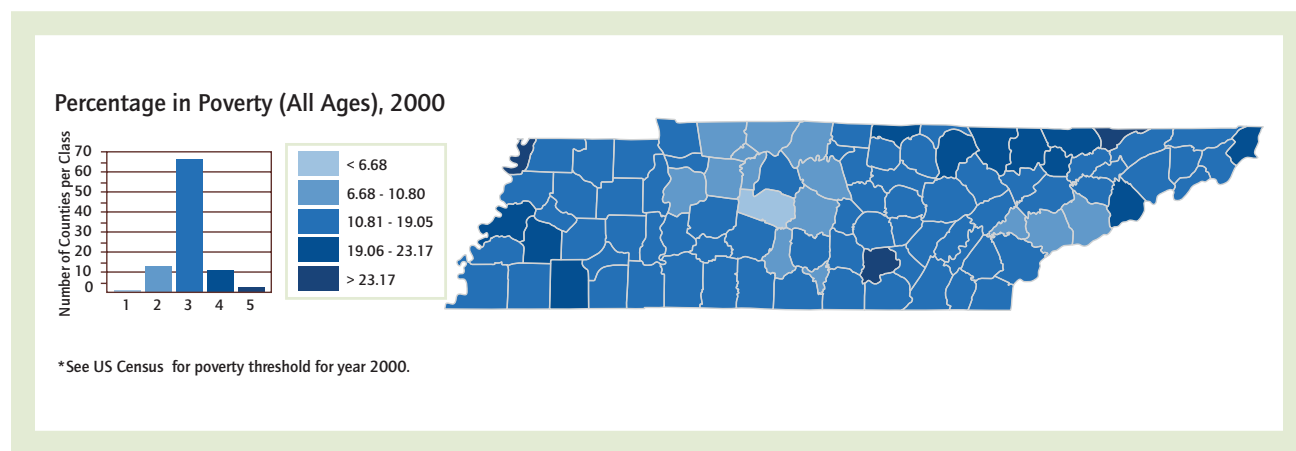


Figure 4 Classification by standard deviation

Source: Cartography by Alex Feldman; data by U.S. Census American FactFinder.



be a powerful communication tool if it is properly symbolized. As Figure 4 demonstrates, the areas of greatest and least poverty are still discernable to the reader aware that color differences represent value differences.

Other and more complex classification schemes can be found at various sources.

Elizabeth Vaughan

See also **Choropleth Maps; Map Design; Map Visualization**

Further Readings

- Chapman, M. J., Jr., & Monroe, C. (2000). *An introduction to statistical problem solving in geography* (2nd ed.). Boston: McGraw-Hill.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2008). *Thematic cartography and geovisualization* (3rd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.



DATA COMPRESSION METHODS

Data compression is a common solution to two problems: (1) the need to decrease the storage space required for spatial data and (2) the need to minimize the resulting transmission times. Extensive exploratory research has been carried out and many algorithms have been implemented for the compression of image data and video data. Several industrial standards, such as JPEG2000 and MPEG4, have been approved as well. Three factors have to be carefully considered when the user selects or implements one data compression method, namely, the degree of compression, the amount of “lossy” information, and the time required to compress and decompress the data.

Data compression can be considered to be “lossy” or “lossless.” Lossless compression methods (e.g., Huffman coding, arithmetic coding) first detect the probability of each symbol and then encode them according to some coding algorithms and require a decoding algorithm to reconstruct the original data from the compressed data. The reconstructed data are identical to the original.

Several solutions can be directly applied for lossless compression, such as running length encoding, dictionary coders (e.g., LZW), the Burrows-Wheeler transform, context mixing, and Slepian-Wolf coding. For example, Huffman coding-based algorithms create a Huffman tree according to the frequency or probability of a symbol’s appearance and encode high-probability symbols with low bits. Arithmetic coding-based algorithms represent each possible sequence of n symbols by a separate interval on the number line between 0 and 1. Compared with lossless compression, lossy compression is another kind of compression method that is possible if some loss of fidelity is acceptable. Lossy compression methods include the discrete cosine transform, fractal compression, wavelet compression, vector quantization, linear predictive coding, Modulo-N code for correlated data, A-law Compander, Mu-law Compander, and Wyner-Ziv coding.

Generally, a lossy data compression will be guided by research on how people perceive the data in question. Compression methods are commonly used in conjunction with two representations of spatial data: raster data and vector data. Various sophisticated algorithms have been implemented for the compression of raster data (e.g., remote sensing imagery, digital elevation models), such as wavelet-based compression algorithms, and for the compression of triangulated irregular network (TIN)-based models (e.g., terrains). Nevertheless, algorithms for compressing raster data and TIN-based models cannot directly compress vector data because of the intrinsic complexity of topology within vector data. As a consistent topology has to be maintained, viable solutions for the compression of vector data should be carefully considered. Alternatively, the time performance of decompression is also an important factor.

Vector quantization (VQ) is a lossy data compression method based on the principle of block coding. It is a fixed-to-fixed length algorithm. The main principle of VQ is as follows: Given a vector source with its known statistical properties, a distortion measurement and the number of vectors find a dictionary (codebook) that results in the smallest average distortion. Therefore, the procedure of VQ is to create a dictionary with S' symbols from the message with S symbols ($S' < S$) and to build a mapping between S' and S . VQ-based algorithms are more suitable for the compression of points in geographic data layers.



Besides the degree of compression, the amount of lossy information, and the time performance of compressing and decompressing data, the consistency of topology and the data quality of decompressed data must be considered for selecting or implementing a viable compression solution. The decompressed data should maintain the maximum similarity of geometric shapes and maintain a consistent topology; otherwise, the compression method will have difficulties in meeting user requirements even if it enables a high compression ratio.

A key factor for vector data compression is to find a subset of the original vertices to represent a polygonal curve, and maintain an optimal approximation of the polygonal curve and topological consistency of a set of polygonal curves (e.g., vector map data). Bisheng Yang, Ross Purves, and Robert Weibel recently proposed a variable resolution compression method for vector maps. The main idea of the proposed method is to first transform the compression of the lines constituting polygons to vertices. Then, a VQ method is adopted to compress the vertices. The proposed method

- preserves consistent topology within the compressed results for a correctly selected distance threshold,
- compresses vector data at different compression ratios according to varied requirements, and
- achieves a reasonable balance between the compression ratio and the distortions of geometric shapes.

Data compression methods, particularly for the compression of vector data, are receiving more attention because of increasing requirements in Web-based GIS applications and geospatial information services. The compression of vector data is central to mobile visualization, Internet transmission, and interactive visualization due to increasing data volumes, narrow network bandwidths, and limited screen sizes. One of the key challenges for current and future research efforts is fast compression and decompression of vector data online to facilitate real-time mapping and visualization of geospatial data.

Bisheng Yang

See also **Data Editing; Digital Terrain Model; Geospatial Industry; Internet GIS; Triangulated Irregular Network**

(TIN) Data Model; Vectorization; Web Service Architectures for GIS

Further Readings

- Gersho, A., & Gray, R. (1991). *Vector quantization and signal compression*. Norwell, MA: Kluwer Academic.
- Huffman, D. (1952). A method for the construction of minimum redundancy codes. *Proceedings of the IRE*, 40, 1098–1101.
- Nelson, M., & Gailly, J. L. (1995). *The data compression book* (2nd ed.). New York: M&T Books.
- Yang, B., Purves, R., & Weibel, R. (2008). Variable-resolution compression of vector data. *GeoInformatica*, 12, 357–376.



DATA EDITING

Simply stated, *data editing* refers to the activity of detecting and rectifying errors in data. This could also involve updating a data set to make it more contemporary. From a geographical perspective, data collected could be *spatial* (locational) in nature, or they could be *aspatial* (descriptive) data. For example, the coordinates (e.g., latitude/longitude) of groundwater monitoring wells are spatial data, while descriptive data about groundwater depth, yield, and so on would be aspatial data.

There are several ways in which geographical data collected can be in error or in need of updating. Errors may arise from a systematic shift in measurements due to calibration procedures, they may be random in nature, or they may be due to errors in data entry (coding) or updating methods. Usually, systematic errors manifest as a set of values either above or below an expected value, while random errors can be seen as outliers. However, there are times when an outlier could be real and indicate a dip or a spike in the measured value, for example, a soil sample taken over a sweet spot indicating a high mineral ore concentration.

Correcting errors in data involves evaluating the magnitude of error by comparing the measured value with a reference value. This task is known as accuracy assessment. In general, reference data constitute values collected at a higher degree of accuracy and precision. For example, locational



data collected using a GPS unit with a higher precision (decimal degrees) and accuracy (submeter) could be used for accuracy assessment. Additionally, high-resolution aerial images (georeferenced) could be used in assessing the accuracy of location data. On the other hand, aspatial data could also be collected at higher levels of precision and thus serve as references, for example, soil samples analyzed for plant nutrients using high-precision instruments. Additionally, the error might be due to data duplication (recorded more than once), inconsistency (conflicting values), deviation from historical trends, and so on. Thus, error detection is basically applying “rules” to data, and these rules are usually formulated by expert knowledge.

Rectifying systematic errors in spatial data involves adding or subtracting the *delta value* (error between the reference and measured values) from the location data. This is similar to systematically shifting the longitude (x), and latitude (y) data coordinates. Editing *aspatial data* ranges from manual editing of the data values to writing simple programs (macros) that seek and fix the errors present in attribute data. Also, this process could involve a statistical edit wherein the attribute value in one record is compared against a frequency distribution for that attribute for all other records. So how exactly do we fix the erroneous value? Well, we could delete the erroneous value and thus eliminate it from our subsequent data analysis. Alternatively, *imputation* procedures could be used to fill in gaps or missing values. We could interpolate a simple mean for the erroneous or missing value based on its immediate neighboring values or class. Advanced interpolation techniques take into account the magnitude and direction of the neighboring values in the interpolation process. Also, specialized programs (expert systems) can automatically impute data based on a knowledge base or a statistical method.

Thus, data editing is a valuable data management operation that ensures data quality by providing data that are accurate, consistent, and complete. This greatly enhances the validity and credibility of subsequent analyses implemented using the data.

Mahesh Rao

See also **Analytical Operations in GIS; Database Management Systems**

Further Readings

- Bolstad, P. (2008). *GIS fundamentals: A first text on geographic information systems* (2nd ed.). White Bear Lake, MN: Eider Press.
- Bossler, J., Jensen, J., McMaster, R., & Rizos, C. (Eds.). (2002). *Manual of geospatial science and technology*. London: Taylor & Francis.
- Burrough, P., & McDonnell, R. (1998). *Principles of geographical information systems*. Oxford, UK: Oxford University Press.
- Longley, P., Goodchild, M., Maguire, D., & Rhind, D. (2005). *Geographic information systems and science* (2nd ed.). Chichester, UK: Wiley.



DATA FORMAT CONVERSION

Data format conversion refers to the conversion of digital data from one encoding scheme to another. Common examples include the conversion of a Microsoft Word document to Adobe PDF format, a TIFF image to JPEG format, and a WAV audio file to MP3 format. Many popular software packages provide Save As, Import, and Export functions, all of which perform data format conversions. While certain data conversion operations retain all data (*lossless* conversion), others result in an irrecoverable loss of data (*lossy* conversion). For example, when an uncompressed image (e.g., TIFF format) is converted to JPEG (a lossy format), certain bits are eliminated during the conversion, resulting in a permanent loss of data and a concomitant reduction in file size. Some lossless conversions (e.g., of a WAV audio file to FLAC format) use data compression techniques, achieving smaller file sizes while retaining information that allows full reconstruction of the original file.

Data format conversions are common operations in geographic information systems (GIS). The conversion of a delimited text file containing point data (coordinates and attributes) to the shapefile format is an example of a lossless conversion—no data are lost during the conversion. Likewise, data collected by a GPS unit can be converted to a shapefile or other vector format with no loss of information. A common GIS operation is the conversion of vector data to a raster format



for use in map algebra and other raster analysis techniques. The conversion of vector data to a raster representation is often a lossy operation; for example, data would be lost if a line layer of roads data collected using a commercial-grade, submeter-accuracy GPS was converted to a raster data set of 10-meter resolution. Vector data can also be converted to other vector formats. For example, the conversion of an ESRI coverage to a shapefile preserves feature and attribute data, but results in a loss of topological information. Information can also be lost when a geographic data set is converted to another representation of lower resolution and less information content, which often results from a change in scale.

Most GIS software programs can perform common GIS data format conversions. The open source Geospatial Data Abstraction Library is capable of converting nearly 100 raster data formats to other supported raster formats, and its analog, the open-source OGR Simple Features Library, can convert many vector data formats to other supported vector formats. Other specialized GIS data conversion tools exist, such as shapelib, a library for manipulating shapefile data sets. Transformational languages such as variants of the Extensible Markup Language (XML) can also be used for data conversion. One example, the Geographic Markup Language (GML), is a common format for transformation and exchange of spatial data sets. Tools such as OGR enable the conversion of shapefiles and other vector data formats to GML, which can then be manipulated or directly converted to another vector file format or spatial database. Data format conversions can also be accomplished within databases, using standard functions such as *to_number()*, which converts a text string to a numerical representation.

Dylan Keon

See also **Data Compression Methods**; **Data Editing**; **Spatial Data Structures**

Further Readings

FreeGIS Database. (n.d.). *Features: Data conversion*. Retrieved November 13, 2009, from <http://freegis.org/database/?cat=11>

Hohl, P. (Ed.). (1998). *GIS data conversion: Strategies, techniques, and management*. Albany, NY: OnWord Press.



DATA INDEXING

Stripped of its numerous complexities, data indexing is the high-tech version of the tedious indexing process familiar to any 20th-century textbook author and results in the same benefits for the reader. The major difference is that computers are doing both the indexing and the accessing of the indexes. Just as with a textbook index, the basic goal behind data indexing is to prevent the reader (in this case, the computer) from having to search and sift through an *entire* data set—a prohibitively slow process—to find only the *specific* information it needs. More formally, this allows the reader random access to indexed elements, which is much more efficient than sequential access. Data indexes, crucially important data structures in computer science, make possible a vast number of technologies, particularly those dealing with the enormous information repositories so prevalent in the modern age. Without them, everything from a Google search to the dynamic display of geographic information would be exponentially slower, easily to the point of total impracticality. Two types of data indexing are prevalent in geography. The first is “nonspatial indexing,” and the second is “spatial indexing.” Nonspatial indexing is applied throughout computer science and related fields, while spatial indexing is designed specifically to work with *n*-dimensional data, where $n \geq 2$ (in geography, we usually find that $n = 2$ or 3).

Nonspatial Data Indexing

As noted above, nonspatial indexing appears in the implementation of a very large percentage of computer applications. While there are many types of nonspatial indexes, they all allow a program to query a data set or database for specific information much faster than would be possible if the computer had to look through the entire data set or database for that information. The type of index included in a particular application is usually carefully chosen

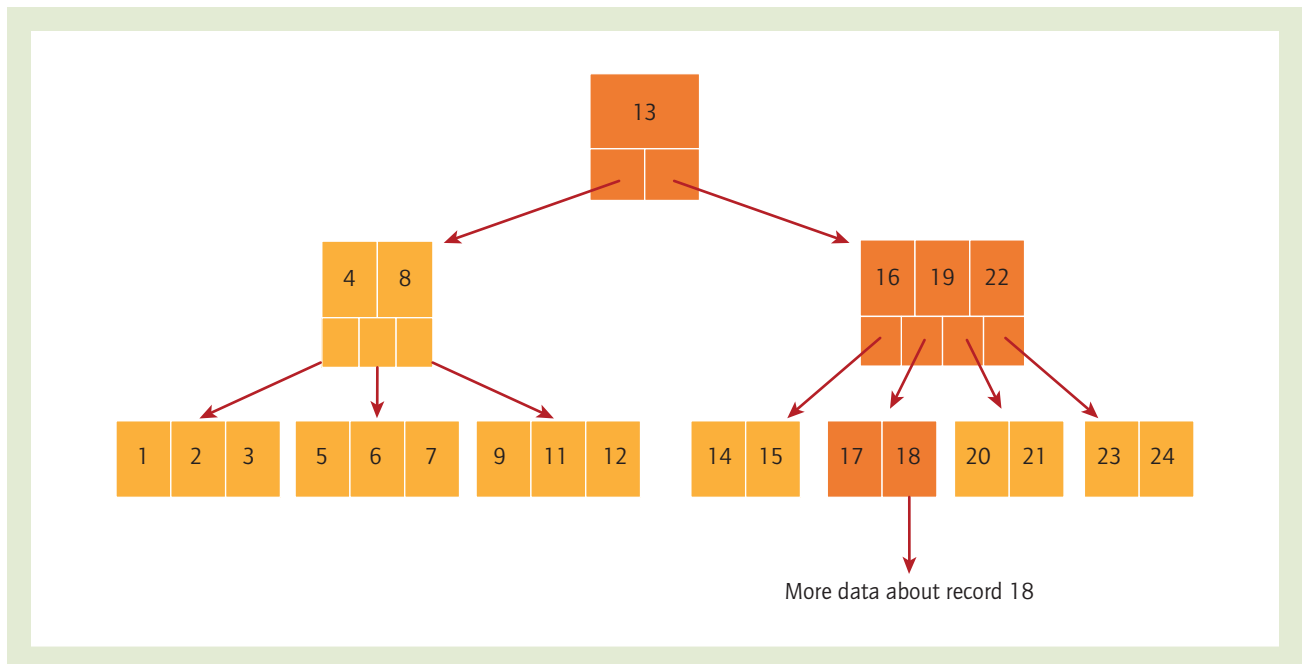


Figure 1 A diagram of a simplified B-tree index

Source: Author.

based on certain key properties, such as the additional data storage costs (just like a book's index, data indexes take up additional space), the type of data that will be indexed, and, of course, the speed of lookups. Sometimes the indexing process and the data index type can be very simple. For example, the file with the ".shx" extension that is part of the shapefile specification is purely a rudimentary index file that makes it easier for any program reading the shapefile to find the data related to a specific point, line, or polygon. It is essentially made up of a set of pointers to the beginning of data records in the .shp file.

Many times, however, more complex data index approaches are needed. One important type of nontrivial data index is the B-tree index. Invented in 1972, B-trees and their variants are still vital in modern systems. For example, B-trees are the default nonspatial indexing method in the very popular MySQL database management system. While the details of B-tree implementations are outside the scope of this text, the basic idea of their structure is illustrated in Figure 1.

The shaded entries indicate which "nodes" need to be examined to find the record number "18" (and data about record 18). A "sequential scan" of the "data set" would have had to look at 18 different

entries (assuming the data had been presorted), while the B-tree reduces that number to 3.

Spatial Data Indexing

Spatial data indexing was also in use long before the computer became a primary method of storing and analyzing spatial information. In fact, the indexes at the back of atlases, with page numbers and grid cell identifiers given for each entry, are an (inverted) elementary form of a spatial data indexing methodology called "grid indexing."

Currently, spatial data indexing is frequently implemented through an R-tree data structure or a derivative. MySQL, for example, uses an R-tree implementation for indexing spatial data, and Oracle Spatial, IBM Informix, and PostGIS implement them as well. R-trees, originally presented in 1984 by Antonin Guttman, effectively allow the efficient answer of queries along the lines of "Retrieve all school objects within 2 miles of my current location." Instead of searching through all entries in a database of school objects, which may number in the millions, the implementing application can access the R-tree index and can usually receive the answer in exponentially fewer steps along the same lines as seen in the B-tree example.



A popular variant of the R-tree is the R*-tree. Themselves a variation on the theme of the B-tree, R-trees essentially split a given space into nested or overlapping minimum bounding rectangles (MBRs), known to geographers as bounding boxes, and store data entries hierarchically based on these MBRs.

While R-trees (and derivatives) are likely the most common spatial data indexing methodologies in the computer science world, other methodologies are optimal under certain conditions that appear frequently in geography contexts. The grid index, an elaboration on the aforementioned “low-tech” atlas index methodology, is easy to understand and create, is relatively fast, and can support many types and densities of data. As such, grid indexes are quite often found in parts of commercial GIS, including many areas of ArcGIS (as of Version 9.3). Quadrees, specialized forms of the grid index and well-known index types in and of themselves, are used by GIS developers when they need to consider many types of geographic data—particularly both vector and raster data—and need do so in a relatively easy-to-implement and efficient fashion.

Brent Hecht

See also **Database Management Systems; GIScience; High-Performance Computing; Spatial Data Infrastructures**

Further Readings

- Cormen, T., Leiserson, C., Rivest, R., & Stein, C. (2001). B-trees. In T. Cormen (Ed.), *Introduction to algorithms* (2nd ed., pp. 434–454). Cambridge: MIT Press.
- Guttman, A. (1984). *R-trees: A dynamic index structure for spatial indexing*. Paper presented at the ACM SIGMOD international conference on management of data, Boston.
- Hellerstein, J., Naughton, J., & Pfeffer, A. (1995). *Generalized search trees for database systems*. Paper presented at the 21st international conference on very large databases (VLDB 95), Zurich, Switzerland.
- Longley, P., Goodchild, M., Maguire, D., & Rhind, D. (2005). Creating and maintaining geographic databases. In *Geographic information systems and science* (2nd ed., pp. 217–239). Chichester, UK: Wiley.

Manolopoulos, Y., Nanopoulos, A., Papadopoulos, A., & Theodoridis, Y. (2006). *R-trees: Theory and applications*. London: Springer.

DATA QUERYING IN GIS

A database system is an essential component of a geographic information system (GIS). GIS are driven off databases. Almost all entities in the world are tied to some geographical location, expressed by x (longitude) and y (latitude) coordinates. These entities are stored in GIS as a series of points, lines, and polygons.

The power of a GIS is its ability to store the coordinate information; however, most GIS have the ability to connect to other information stored in a database management system (DBMS). For example, usually one land parcel within a city is more than likely owned by one person; however, if that land parcel is located in Manhattan, with the dollar value of it being 20 million, more often than not that land parcel is likely owned by more than just one person. We can store information about this land parcel, such as acreage, asset value, and ownership information, in a single database table, but some of the information would be duplicated. To help prevent this duplication, a good database management practice is to create a unique key that distinguishes each land parcel from other parcels. To build a database dealing with land parcels, a good practice is to assign a parcel identification number to each land parcel. This step ensures that the land parcel can be distinguished from all other land parcels.

Instead of storing all the information in one table, where duplication can be a problem, relational database techniques can be applied and tables broken up into two or more tables. Certain unique fields within the tables are assigned a key that uniquely identifies them. Once unique key fields are established in the database tables, most DBMS have functions called joins and links that allow many tables to act as one table, thus preventing duplication of data. Most GIS have join and link functions built within the software. For example, in most GIS one can select a single land parcel and link it to the ownership table and return all the current owners for that land parcel.

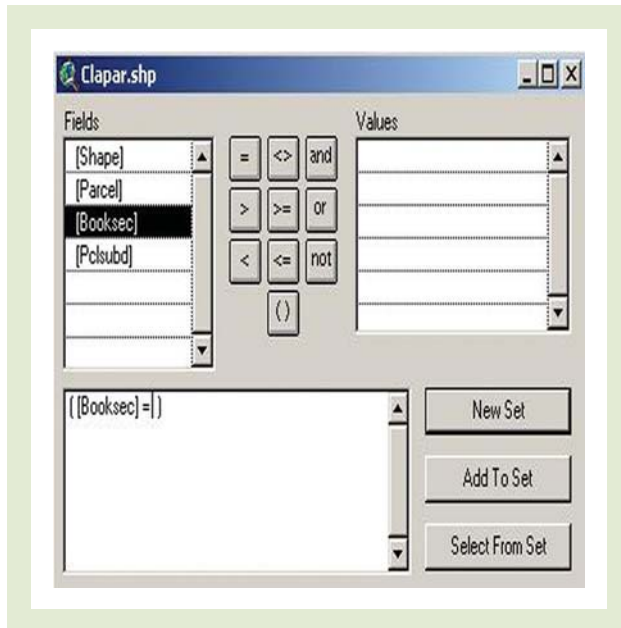


Figure 1 Database query interface in ArcGIS software

Source: The Select by Attributes dialogue box is the intellectual property of ESRI and is provided herein by permission. Copyright © 2009 ESRI. All rights reserved.

Relational database standards have facilitated querying and retrieving data from database tables. In particular, one such standard called the SQL language has been one of the major reasons for the success of relational databases. So what is SQL? The acronym SQL stands for structured query language. Originally SQL was called SEQUEL (for structured English query language). Over the years several versions of the SQL standards have evolved, and several database vendors have created their own version of SQL or optioned a current standard.

The power of SQL is its ability to extract information from the database based on some user-defined criteria. For example, if you wanted to get all land parcels with acre size greater than 5, you would create an SQL query such as “Acres” > 5. In the early days, before today’s easy-to-use Application Programming Interfaces were created to construct SQL queries, querying databases was time-consuming and challenging. Today, several advanced SQL tools are in use that have a user friendly interface. Figure 1 is an illustration of a database query interface created

by the Environmental Systems Research Institute, the leader in GIS technology.

What makes GIS technology stand out from other database systems is its ability to perform a spatial query. A spatial query is a special type of database query supported by geodatabases. Spatial queries differ from SQL queries in several important ways. Two of the most important are that they allow the use of geometry data types such as points, lines, and polygons and that these queries consider spatial relationship between the objects of query.

For example, you work for a highway district as a planner and a new proposed highway plan passes through a number of land parcels. You want to get in touch with the owners of these land parcels to coordinate preparations for the proposed highway plan. To do this using a GIS, you could perform a query, in which a spatial relationship between the new highway map and the land parcels would be represented by a line-in-polygon intersection. The result of the query would include the contact information for those land owners whose parcels are to be intersected by the proposed highway.

Tyson Taylor

See also **Analytical Operations in GIS**



DATUMS

A geodetic datum is a fixed reference point according to which the size and shape of Earth are measured. They are also used in measuring gravitational pull and rotation. There are at least three kinds of geodetic datums used in geography. Vertical datums form the zero surface for vertical measurements of altitude and elevation. Horizontal datums define the size and shape of Earth and the origin and orientation of a horizontal coordinate system. Complete datums can provide both vertical and horizontal zero origins and coordinate system definitions. Some complete geodetic datums define Earth’s shape, horizontal and vertical coordinate system origins, gravity fields, and physical constants such as rotational velocity and Earth’s gravitational constant.



Without a vertical datum, the altitude of a point is ambiguous, and without a horizontal datum the longitude and latitude of a point are not sufficiently well-known to locate it on the Earth. With the specification of a vertical zero, such as the ground level, the mean sea level, or the surface of a particular reference ellipsoid, the elevation of a point can be known. If the equator is defined as the origin for lines of latitude, and Greenwich, England, is defined as the origin for lines of longitude, then any point can be found to at least within a few kilometers on the globe. To specify a position to within a few meters, coordinates must be associated with specific geodetic horizontal and vertical datums.

Since the French geodetic expeditions of the mid 1700s to Peru and Lapland, Earth has been considered to be a slightly flattened sphere, a spheroid, an ellipse of rotation, or an ellipsoid. There have been dozens of different Earth shapes on which mapping systems and coordinate systems have been based. While there have been other Earth shapes proposed and used in geodesy, most are specified as ellipsoids with an equatorial radius and either a polar radius or a parameter that represents the relationship between the equatorial radius and the polar radius.

The equator forms the zero point for lines of latitude. There is no equivalent physical feature on Earth that naturally lends itself to the origin for lines of longitude. The zero point, or zero line of longitude, the *prime meridian*, has been defined at different times by different interests to pass through 1 of more than 20 cities, including Moscow, Paris, Madrid, Rio de Janeiro, Lisbon, the Canary Islands, Washington, Tokyo, and Greenwich, England. A geodetic datum defines at least a single monument with a specific longitude and latitude as well as the distance and direction to another monument.

Most modern datums use a network of monuments to define a system of longitude and latitude or vertical heights over regions covering small islands, countries, continents, or the entire Earth. The Cape Canaveral Datum is a local datum defined for use in Florida and the Bahamas. The North American Datum of 1983 (NAD83) is a regional horizontal datum. The U.S. National Geodetic Vertical Datum (NAVD 88) is a regional vertical datum. Geodetic Reference System 1980

(GRG80) is a global horizontal geodetic datum. World Geodetic System 1984 (WGS-84) is a complete global geodetic datum with both horizontal and vertical components, as well as Earth's gravitational and rotation parameters.

Peter H. Dana

See also **Altitude; Earth's Coordinate Grid; Geodesy; Latitude; Longitude**

Further Readings

- Burkard, R. (1983). *Geodesy for the layman*. Washington, DC: National Oceanic and Atmospheric Administration.
- National Imagery and Mapping Agency. (1997). *Department of Defense world geodetic system 1984: Its definition and relationships with local geodetic systems* (3rd ed., NIMA TR8350.2). Bethesda, MD: National Imagery and Mapping Agency.
- Torge, W. (1991). *Geodesy* (2nd ed.). New York: de Gruyter.



DAVIS, WILLIAM MORRIS (1850–1934)

William Morris Davis is the single most influential geomorphologist to have written in the English language, and perhaps in any language. Given the enormous growth and diversity in the discipline, it is unlikely that anyone will ever again dominate it to the degree that he did. The primary component of his reputation is the creation and indefatigable proselytism of the geomorphic cycle, also known as the geographical cycle. The model attempts to provide a comprehensive theoretical explanation of the development of landforms and many of their individual elements during the perceived lengthy periods between regional uplifts. The model gained enormous, but not unchallenged, currency and represented the prevailing orthodoxy in the English world from about 1900 until around World War II. It was challenged in research circles starting just before the war and more vigorously



thereafter; in some places it lingered longer, and in the realm of teaching, considerably longer.

The model itself was supported by Davis's prolific publication record and introduction of innumerable technical terms. Many such terms are morphogenetic; that is, they not only describe how something looks but also purport to explain its origins, *penneplain* being an exemplar.

Davis was reared in an influential East Coast Quaker family, attended Harvard University, and was on the faculty from the late 1870s until 1912. He conducted fieldwork on every continent save Antarctica. His numerous professional honors included being president of both the Association of American Geographers and the Geological Society of America. His role as a bridge builder between the two disciplines is an important part of his personal story.

Davis was a prodigious worker, writing hundreds of articles, introducing well over 100 technical terms, accepting numerous speaking engagements on both the national and international levels, and conducting what today would probably be called *outreach* (i.e., talking to the nonscientific community). An additional personal attribute was his real flair for sketching. His beautifully conceived and executed diagrams essentially present his geomorphological ideas in a separate language. His influence in retirement was considerable because he moved to the Western United States, where he inspired many students of geology in his post-Harvard years and exhibited much greater intellectual flexibility than is often recognized.

Whatever limitations are now assigned to Davis and his geomorphic cycle, it is appropriate to view the latter as a monumental intellectual achievement: influential when it dominated and also a powerful intellectual challenge to be satisfactorily met for those who followed and sought to modify the framework of geomorphology. Furthermore, Davis provided a powerful personal aura of scientific professionalism in an embryonic discipline.

Colin Edward Thorn

See also **Association of American Geographers; Geomorphic Cycle; Geomorphology; Gilbert, Grove Karl; Penck, Walter**

Further Readings

- Chorley, R., Beckinsale, R., & Dunn, A. (1973). *The history of the study of landforms: Vol. 2. The life and work of William Morris Davis*. London: Methuen.
- Davis, W. M. (1909). An inductive study of the content of geography. In D. Johnson (Ed.), *Geographical essays* (pp. 3–22). Boston: Ginn.
- King, P., & Schumm, S. (1980). *The physical geography (geomorphology) of William Morris Davis*. Norwich, UK: Geo Books.



DEAR, MICHAEL (1944–)

Michael Dear has been a significant force in human geography and urban analysis for close to four decades. A provocative and prolific writer, Dear has authored or edited 19 books and more than 100 scholarly articles, covering topics, including the mentally ill, homelessness, the state, social theory, postmodernism, and, most recently, comparative urbanism.

Born in Treorchy, in the Rhondda Valley of South Wales, Dear obtained a BA in geography from the University of Birmingham (1966), an MPhil in town planning from the University of London (1966), and MA (1972) and PhD (1974) degrees in regional science from the University of Pennsylvania. He taught at McMaster University in Hamilton, Ontario, Canada. He was a professor of geography and urban planning at University of Southern California for many years before moving to the department of urban and regional planning at the University of California, Berkeley in 2009. He has held fellowships at the Center for Advanced Study in the Behavioral Sciences at Stanford University and the Rockefeller Center in Bellagio, Italy, and was a recipient of a Guggenheim Fellowship.

Dear has remained steadfast in his attempt to refashion geography to align more closely with social theory. Throughout his career, he has been a strong advocate and outspoken proponent in the development and promotion of key theories and methods, including Marxism, structuration, and postmodernism. With respect to postmodernism,



Dear argued that its emphasis on difference places an intense spotlight on the subject, the body, and personal identity. Consequently, postmodernism is a powerful means to examine questions of social justice. A concern with policy issues remains a strong focus in his entire oeuvre.

Dear is the founding editor of the journal *Environment and Planning D: Society and Space* (with Edward Soja, Allen Scott, Michael Storper, and Mike Davis) and is a leading exponent of the “Los Angeles School” of urbanism. Interdisciplinary in his work, Dear draws insights from and has contributed to geography, planning, social work, psychiatry, public health, history, and political science.

Not averse to controversy, Dear has been a highly visible and vocal participant in the ongoing debates and discussions shaping human geography throughout the late 20th and early 21st centuries. In 1988, Dear issued a “postmodern challenge” to human geography. In his “reconstructed” human geography, the objective should be to “understand the simultaneity of time and space in structuring social processes” (p. 270). More recently, Dear has called attention to the “politics of hate” that he argues may be found in the discipline.

James Tyner

See also **Los Angeles School; Postmodernism**

Further Readings

- Clark, G., & Dear, M. (1984). *State apparatus: The structures and language of legitimacy*. London: Allen & Unwin.
- Dear, M. (1988). The postmodern challenge: Re-constructing human geography. *Transactions of the Institute of British Geographers*, 13, 262–274.
- Dear, M. (2000). *The postmodern urban condition*. Oxford, UK: Blackwell.
- Dear, M. (Ed.). (2002). *From Chicago to LA: Making sense of urban theory*. Thousand Oaks, CA: Sage.
- Wolch, J., & Dear, M. (Eds.). (1989). *The power of geography: How territory shapes social life*. London: Unwin Hyman.
- Wolch, J., & Dear, M. (1993). *Malign neglect: Homelessness in an American city*. San Francisco: Jossey-Bass.



DEBT AND DEBT CRISIS

The accumulation of Third World debt and the 1980s debt crisis are key historical events that have had long-lasting and dramatic economic, political, and social consequences for a number of countries in Africa, Asia, and Latin America. This entry discusses the history of the debt crisis, structural adjustment, responses and solutions to the crisis, and resistance to Third World debt.

History

In the 1970s, oil-producing countries increased the price of oil significantly, generating massive profits. These profits, referred to as petrodollars, were deposited in a number of Western banks, especially in the United Kingdom and the United States, and they were recycled by bankers in the form of loans to developing countries. Many of the loans were channeled to Latin American countries as well as to several countries in Asia and sub-Saharan Africa. In some cases, money was lent to military dictatorships that had never been democratically elected. They used the loans in wasteful and unproductive ways, including the creation of large steel plants that never produced steel, and environmentally damaging dams, and to purchase weapons. At the time, however, interest rates were low and commodity prices were rising. External debts, while large, could be serviced with export revenues.

This situation changed in the 1980s, when conservative world leaders such as Ronald Reagan and Margaret Thatcher began to put restrictive monetarist policies in place, which led to increases in interest rates. Commodity prices began to fall, while the prices of manufactured goods began to rise, which resulted in deteriorating terms of trade for commodity-producing developing countries. As a result, many borrowing countries found it increasingly difficult to meet their debt service obligations.

The worsening situation came to a head in August, 1982, when the Mexican government announced that it had run out of foreign exchange reserves and would be unable to service its debt. The bankers reacted promptly to the Mexican default, fearing its repeat across the continent.



The 1982 debt crisis created a new role for the International Monetary Fund (IMF), which was charged with managing the crisis. The banks were forced by the IMF to contribute to the Mexican bailout and that of other countries that were running into difficulties. Lengthy negotiations were held with countries on a bilateral basis to prevent the formation of a debtors' cartel and to save the banks that had lent the money.

The response to the question of default was to provide fresh loans so that debtor countries could continue to service old loans and to keep the dollars flowing from the developing countries to the northern banks. Effectively, the debt crisis was "resolved" by further increasing the already unpayable debts of Third World countries. These actions converted the poorer countries of the South into net exporters of capital to the wealthier countries of the North. By 2000, many countries of the South had much higher total debt burdens compared with two decades earlier.

Although the debt crisis sent the banking world into turmoil, for some economists it was seen as a blessing in disguise. At this historical moment, neoliberal thought, a belief in the economic efficiency of the market and the need to reduce the role of the state in economic affairs, was once again in ascendancy and was being promoted by influential economists such as those of the Chicago School of Economics. The debt crisis was seized on as a means to reorient Third World economies toward more promarket economic policies and dismantle protectionisms and state subsidies. Bailout packages were thus accompanied by strict conditionalities in the form of structural adjustment policies, and Third World countries were discursively constructed as sites of economic inefficiency and malaise that required harsh economic medicine.

Structural Adjustment

After the debt crisis of the 1980s, structural adjustment became the dominant development model, promoted and enforced by the institutions of global governance. In return for new loans, countries are required to adopt a series of economic measures that involve trade liberalization, an emphasis on export production, and the withdrawal of state intervention. Import tariffs are

lowered and economies are opened up to transnational capital. The local currency is devalued to stimulate exports. State-owned enterprises are privatized. State subsidies on food or fuel are removed, and cutbacks in public spending are made. Essentially, countries are required to earn more and spend less to keep debt service payments flowing.

The social costs of the debt crisis are well documented. There is no doubt that the burden of debt has been borne by the poorest and most vulnerable sectors of the population. In the 1980s and 1990s, several countries were spending more of their export revenue on debt service than on health care and education. In many countries, rapid trade liberalization resulted in job losses and an increase in poverty and malnutrition. Working people saw their real wages and purchasing power plummet. The emphasis on exports devastated small farmers who produce food for domestic consumption. These farmers found themselves deprived of access to credit, and many have been displaced from their land by large export-oriented agribusinesses. The export-oriented economy has also hastened environmental degradation in many parts of the world, given its dependence on resource extraction and monocultures that require an intensified use of chemical fertilizers and pesticides. Women, too, have been particularly negatively affected as the cutbacks in health care and education and the removal of subsidies on basic foodstuffs complicate the task of feeding families and caring for children and the elderly. The human cost of the debt crisis was so severe in Latin America that the 1980s are often referred to as the "lost decade."

Responses and Solutions to the Crisis

A number of official solutions to the debt crisis have been proposed by First World governments and the international financial institutions. The 1985 Baker Plan was focused on further lending with strict conditions attached, and so it further institutionalized the implementation of structural adjustment. The 1989 Brady Plan, also conditional on economic reforms, achieved limited debt relief through a range of mechanisms that converted debt into tradable bonds. While these two plans restructured and diversified the debt to



some extent, they failed to achieve sustainable debt relief.

In 1996, the IMF and the World Bank introduced the Heavily Indebted Poor Countries (HIPC) initiative as a means to provide debt relief for some of the world's poorest and most debt-laden countries. The vast majority of HIPC countries are in sub-Saharan Africa. In Latin America, Honduras, Nicaragua, and Bolivia also qualified for the HIPC.

To qualify for debt relief, countries are required to produce a Poverty Reduction Strategy Paper (PRSP) in consultation with civil society. The savings in debt servicing are then to be channeled into poverty reduction. While theoretically providing much needed debt cancellation of up to 80% of a country's debt, the HIPC initiative has attracted significant criticism from NGOs, lobby groups, and intellectuals. Despite the shift in language, the HIPC continues to place emphasis on macroeconomic stability and growth. To access the HIPC, countries must continue to adhere to strict adjustment and austerity measures, and countries that do not meet these conditions and fail to satisfy the IMF can be and sometimes are refused debt relief. Criticisms have also been leveled at the length of time it takes for a country to meet the completion point (at which debt is cancelled), the fact that only a part of a country's external debt is cancelled, and the limitations and weaknesses in the model of consultation. Critics have also called into question the IMF and World Bank definition of debt sustainability, which means that many countries with considerable debt burdens are unable to enter the HIPC.

Nevertheless, the HIPC does at the very least recognize that debt cancellation is the only viable and long-term solution to the problem. Over the past decade, some lender countries have also canceled their bilateral debts with some of the most indebted states. Full cancellation of external debt continues, however, to be resisted by the multilateral institutions as it would remove the leverage that these institutions exert over domestic economic policy in the Third World.

The latest official approach to debt relief is the 2006 Multilateral Debt Reduction Initiative (MDRI), developed by the G8. The MDRI

strengthens the focus on the cancellation of multilateral debt but has a number of limitations. It continues to insist on the completion of HIPC conditions, it only includes a small number of countries, and it only includes debts to the IMF, World Bank, and the African Development Fund. It does not include bilateral debts that have not been cancelled, commercial debts to private banks, IMF debts incurred after 2003, World Bank debts incurred after 2004, and debts to other multilateral lenders such as the Inter-American Development Bank. Debt relief has also been accompanied by a reduction in aid allocations.

Despite the flaws of the existing mechanisms, some countries have begun to invest in health care, education, and infrastructure as a result of the partial reduction of their unpayable debt burdens.

Resistance to Third World Debt

There has been widespread political activism across the world as a result of Third World debt since the 1980s. In the Third World, there were many forms of resistance to neoliberal structural adjustment, including riots against the IMF and the creation of coping mechanisms such as communal kitchens where women pooled labor and resources to feed their families. In the 1980s, campaigns and boycotts against the high street banks implicated in the debt crisis were commonplace.

The economic model ushered in by the debt crisis has led to a proliferation of globalized political activism. High-profile protests in Seattle in 1999, in Cochabamba, Bolivia, in 2000, and in many other cities across the world constitute historically significant popular victories against neoliberalism and the actions of transnational capital.

The most high-profile global campaign against Third World debt has been the Jubilee Coalition, which began its campaigning in the 1990s and called for complete debt cancellation by the year 2000. Since 2000, it has continued to campaign for debt cancellation and has closely monitored the HIPC process. Similarly, the Make Poverty History campaign, organized to lobby the G8 summit in Scotland in 2005, was successful in putting Third World debt back on the political agenda.



While the PRSP process has attracted criticism, it has provided a space for political engagement in some places. In both Nicaragua and Uganda, civil society organizations have mobilized around the PRSP process to ensure savings from debt relief are channeled in a transparent and equitable way into poverty reduction programs. As a result, in some places local people have been demanding greater accountability from their national governments.

Conclusion

While some debt relief has been granted, campaigners continue to call for full debt cancellation as existing debt burdens continue to deprive millions of people in the Third World of social and economic opportunities. The Jubilee Campaign estimates that the world's 50 poorest countries are still sending around US\$100 million a day to rich countries in debt service and that they have a combined debt of around US\$300 billion.

Neoliberal structural adjustment and financial deregulation have not prevented ongoing turmoil in financial markets. In the past decade, there have been severe financial crises in Eastern Asia, Russia, Brazil, Argentina, and Mexico. In 2008, a new financial crisis swept the world, once again brought on in part by overzealous and irresponsible lending policies of Northern banks. The 2008 financial crisis was global in its scope and had particularly harsh impacts on First World countries, including the United States and the United Kingdom. As in 1982, the official response focused on saving the banks through a financial rescue package, while ordinary people faced credit restrictions, job losses, and home foreclosures. The 2008 credit crunch, as it came to be known, is likely to undermine the ability and willingness of First World actors to find a solution to the ongoing problem of Third World debt.

Julie Cupples

See also **Antiglobalization; Dependency Theory; Development Theory; Export-Led Development; International Monetary Fund; Neoliberalism; Structural Adjustment; Uneven Development; World Bank; World-Systems Theory**

Further Readings

- Corbridge, S. (1993). *Debt and development*. Oxford, UK: Blackwell.
- George, S. (1988). *A fate worse than debt*. London: Penguin.
- Potter, G. (2000). *Deeper than debt: Economic globalisation and the poor*. London: Latin America Bureau.
- Roodman, D. M. (2001). *Still waiting for the jubilee: Pragmatic solutions for the Third World debt crisis*. Washington, DC: Worldwatch Institute.
- Shah, A. (2007). *Third World debt undermines development*. Retrieved December 31, 2008, from www.globalissues.org/issue/28/third-world-debt-undermines-development



DECOLONIZATION

Decolonization refers to the disintegration of large empires, usually meaning the European ones that took shape starting in the 16th century, and the formal independence of former colonies. Just as colonialism began unevenly over the surface of the Earth, so too did its end. World-systems theorists argue that the opportunities for states on the global periphery to exert themselves against colonial powers are best when the core is in crisis. Thus, the Napoleonic wars of the early 19th century afforded Latin America the opportunity to break away relatively early. Similarly, World Wars I and II proved to be the pivotal moments when Western control over much of Africa and Asia was finally broken.

The shift toward decolonization during the post-World War II era was complex. Often independence movements comprised broad coalitions of nationalists, students, the intelligentsia, and peasants, frequently led by Western-educated intellectuals (e.g., Ho Chi Minh in Vietnam, Mohandas Gandhi in India). Such movements frequently had roots that extended to the 19th century and gradually grew in power over time. The Cold War rivalry between the United States and the Soviet Union afforded nationalist movements a political space that allowed them to play the superpowers off against each other as both



the United States and the USSR were eager to appear different from older European colonial conquerors and friendly to the masses of the emerging states. Often the struggle for independence was violent, involving protracted guerrilla conflicts and wars (e.g., Malaysia, Vietnam, Algeria). The relatively peaceful independence movement in India was the exception, although the country's division into India and Pakistan involved extensive civil strife and the deaths of millions.

Independence movements succeeded in Asia and Africa throughout the late 1950s, 1960s, and 1970s, leading to a proliferation of newly independent countries (from roughly 50 in 1945 to about 196 today in the United Nations). Major milestones in this process include India and Pakistan in 1947, Indonesia in 1949, Algeria in 1964, and Angola and Mozambique in 1975. Virtually all parts of the globe today have been decolonized, with a few small exceptions (e.g., French Guiana, Martinique, Gibraltar, Tahiti, Puerto Rico).

Decolonization involved political, economic, and ideological changes. Politically, this shift brought with it a new administrative and legal apparatus in the former colony, typically modeled after the colonial one. Indeed, often the very same people who served the foreign colonial power became leaders in the newly independent one. Ideologically, decolonization opened the door to challenges to long-standing racist notions of white superiority (e.g., Ghana's Kwame Nkrumah), allowing a variety of experimental social projects (e.g., Tanzania's *ujamaa*, or "African socialism").

While formal political independence inevitably brought with it the trappings of a new society—a new flag, currency, and national airline, for example—many observers pointed out that decolonization did not simply end colonial relations overnight. Indeed, to dependency and world-systems theorists, it is no accident that the former European colonies are inevitably part of the "Third World," the enormous, diverse set of societies that encompass the vast bulk of the world's people but relatively little of its wealth. Despite ostensible political independence, such societies were often woefully unprepared for independence economically and remained heavily dependent on their former colonial power for capital, trade assistance, and foreign aid, leading to widespread

fears of neocolonialism, generally via multinational corporations. The dominant role of the United States as the world's leading neocolonial power, in both economic and military terms, made the contrast between nominal political and substantive economic independence all the more apparent. Most former colonies have inadequate infrastructure and human capital, with economies centered on raw materials (foodstuffs, mineral ores). Regardless of the measure used—GDP per capita, energy consumption, access to health or education services—former colonies almost always lag behind the industrialized world (although some, such as Singapore, rival it, and the newly industrializing countries have made rapid progress).

Barney Warf

See also **Colonialism; Dependency Theory; Neocolonialism; World-Systems Theory**

Further Readings

- Betts, R. (1998). *Decolonization* (The Making of the Contemporary World series). London: Routledge.
- Duara, P. (Ed.). (2004). *Decolonization: Perspectives from now and then* (Rewriting Histories series). London: Routledge.
- Le Sueur, J. (Ed.). (2003). *The decolonization reader*. London: Routledge.



DEEP ECOLOGY MOVEMENTS

Deep ecology emerges from the intuition that nature and self are one. It is important because it provides the motivation for much of the environmental activism that is conducted in the name of geography and education for sustainable development, and it is the source of most eco-centric (ecosystem-centered) thinking within geography. Deep ecology emerged in the early 1970s from the work of the philosopher Arne Naess. Naess sought to distinguish between environmental thinking that gave the highest priority to human welfare, which he called "shallow ecology" and that which gave priority to the welfare of the



whole ecological system, which he called “deep ecology.”

Deep ecology suggests that, even if it were desirable or ethically apt, the human species is incapable of existing in isolation. So it is in humanity’s best interest to prioritize to the welfare of the life support system that it shares with all other forms of life, the living planet, ahead of any human want or desire. To aid this, John Seed and colleagues’ advice to “think like a mountain” aims to encourage the search for the viable consciousness that will help humans secure a sustainable future. Seed also promotes the connective educational exercise known as the “Council of All Beings,” where humans try to give voice to the concerns of other species.

Ecological Self

Deep ecology’s purpose is to make human minds fit for the biosphere. Deep ecology sees the environmental crisis as a symptom of an anthropocentric delusion that imagines the world to be merely a resource for human use. Its aim is transformational, the creation of a new worldview, through ecological self-realization, a notion that owes much to Naess’s work on the philosophies of Baruch Spinoza and especially Mahatma Gandhi’s Hindu Vedanta.

Ecological self-realization is a three-step process by which one gains self-identity with nature; it is the pedagogical framework of deep ecology. Each step involves a transformation of self-consciousness, which may be linked, metaphorically, to human maturation. Step 1 is located in childhood, when the individual self recognizes its personal autonomy and individuality, including the will to contradict. Step 2 is adolescence, when this self redefines itself in terms of a place in a social group such as family, peer group, nation, and eventually, it is hoped, the whole of humanity. In this process, the “I-self” becomes subsumed within a larger “we-self.” This is the intuition that underpins anthropocentric ecosocialism and the doctrines of shallow ecology. Step 3, maturity, is recognition of the ecological self, where the self is redefined in terms of a role and a place within the community of all life. As Gandhi advises, all living beings are members one of another. Elsewhere, researchers discuss “egoistic”

values that predispose people to protect environmental attributes that affect them personally, “altruistic” values that express concern in terms of the welfare of human society, and “biospheric” values that concern the welfare of the whole biosphere and all life, a position often criticized as antihuman or occult. Thus, ecological self-realization strives to shift the focus of the self from “ego” to “eco” and toward treating nature with the same consideration that is traditionally limited to one’s own body or immediate family. Each step diminishes the amount of the universe that is external to the s/Self. Each step also contains the realization that a human is not alone or self-sufficient and that, ultimately, humans are merely a recent addition to a much larger, respectably ancient, organic wholeness, often called “Gaia.” Here, “Earth systems science” also demonstrates that human survival depends on a myriad other creatures, both macroscopic and microscopic, some of which have long played a more important role in the global environment.

Political Platform

Under the influence of George Sessions, such thinking crystallized in the much criticized eight-point political platform of the deep ecology movement (Table 1). However, Naess distinguishes four levels of deep ecology discourse constructed on and below areas of agreement within Level 2 of these platform principles (Table 2). Above, Level 1 admits the role of a developed worldview or religion. Today, deep ecology positions are developed within many traditions, including New Age Panentheism, Dharmic religions such as Buddhism and Hinduism, and Abrahamic traditions such as Christianity and Islam. Moving downward from Level 2 principles, the scheme leads through a Level 3 of policy development to Level 4, the level of practical actions, which are executed through grassroots movements as in Gandhi’s Sarvodaya model of development.

Deep ecology is a broad school of thought, but at its heart, it is always about personal transformation—a personal spiritual quest, a search for a Holy Grail of enlightenment and self-realization. Equally, deep ecology writings commonly demonstrate typically eclectic New Age influences and meta-narratives that have roots in theosophy and

1. The well-being and flourishing of human and nonhuman life on Earth have value in themselves (synonyms: intrinsic value, inherent value). These values are independent of the usefulness of the nonhuman world for human purposes.
2. The richness and diversity of life forms contribute to the realizations of these values and are also values in themselves.
3. Humans have no right to reduce this richness and diversity except to satisfy vital human needs.
4. The flourishing of human life and cultures is compatible with a substantial decrease in the human population. The flourishing of nonhuman life requires such a decrease.
5. The present human interference with the nonhuman world is excessive, and the situation is rapidly worsening.
6. Environmental policies must therefore be changed. These policies affect basic economic, technological, and ideological structures. The resulting state of affairs will be deeply different from the present.
7. The ideological change is mainly that of appreciating life quality (dwelling in situations of inherent value) rather than adhering to an increasingly higher standard of living. There will be a profound awareness of the difference between big and great.
8. Those who subscribe to the foregoing points have an obligation to directly or indirectly try to implement the necessary changes.

Table 1 The platform principles of the deep ecology movement

Source: Based on the work of Arne Naess. Adapted from Drengson, A. (1999). *Ecophilosophy, ecosophy and the deep ecology movement: An overview*. Retrieved November 13, 2009, from www.ecospherics.net/pages/DrengEcophil.html.

Level I	Ultimate premises	Ecosophies T (T"), Buddhism, Christianity, Hinduism, Taoism, etc.
Level II	Platform principles movements	Deep Ecology Movement, Education for Sustainable Development Movement, Peace Movement, Planetary Citizenship Movement, etc.
Level III	Policies	A, B, C, etc.
Level IV	Practical actions	W, X, Y, etc.

Table 2 Deep ecology: Levels of questioning and articulation

Source: Based on the work of Arne Naess and George Sessions. Adapted from Drengson, A. (1999). *Ecophilosophy, ecosophy and the deep ecology movement: An overview*. Retrieved November 13, 2009, from www.ecospherics.net/pages/DrengEcophil.html.

1960s counterculture. However, despite an approach to meta-narrative that is far from post-modern, the deep ecologist’s emphasis on personal experience and emotional intelligence draws it close to the realms of cultural geography, notably situationism and its schools of landscape aesthetics. These affinities and differences are most clearly highlighted by the deep ecology doctrine of the wilderness epiphany, an individually unique threshold of self-realization that is traditionally crossed

while in communion with nature in a remote place, which for Naess was the crossed stones of the Tvergastein mountain in Norway. It remains a cliché of physical geography fieldwork that it should involve long periods of living “on the edge” in a remote region, but in fact, what is going on, consciously or unconsciously, is a retreat from the world of the human and into a communion with the world of nature and identification as kinship in a Gaian sense. On a more practical Gandhian level,



deep ecology has been proposed as a means of validation for applied physical geography.

Fellow Travelers

Deep ecology has many fellow travelers. Related concepts include ecopsychology, which concerns the fostering of ecological consciousness, healing the division that has grown between humans and nature and links outward into environmental psychology and social work; transpersonal ecology, which again describes a sense of self that extends beyond one's ego and seeks an ecophilosophy based on identification rather than values; and interbeing, an idea that arises from engaged Buddhism and the mindfulness teachings of Thich Nhat Hanh, which flows into deep ecology through the connective practice work of Joanna Macy. Other affiliated notions include the sacred Earth ideas of many nature religions and the Hindu doctrine of reincarnation, which places a past or future human soul within every living creature. Groups such as the University of the Trees carry forward Joseph Beuys's expanded conceptions of art into the development of connective practices designed to awaken human ecological consciousness.

Gaia is an independent scientific theory of the living Earth. However, the Gaia concept is fundamental to deep ecology. James Lovelock and Stephan Harding have shown how the science can help us link with the Gaia Superorganism. Gaian Earth systems science is, in turn, a relative of organicist general system thinking, while systems ideas are a characteristic aspect of deep ecological thought and education.

In sum, deep ecology is the realization that the ideas of "I" and "Nature" are one. The connective practices of deep ecology concern the creation of a deep personal bond with the living world. Deep ecology regards anthropocentrism as the cause of the planet's problems and, hence, considers "ecological self-realization" to be the most important goal for both an individual and all society.

Martin J. Haigh

See also **Ecofeminism; Ecological Justice; Environmental Ethics; Gaia Theory; Nature; Nature-Society Theory; Situated Knowledge**

Further Readings

- Drengson, A. (1999). *Ecophilosophy, ecosophy and the deep ecology movement: An overview*. Retrieved October 12, 2008, from www.ecospherics.net/pages/DrengEcophil.html
- Drengson, A., & Inoue, Y. (Eds.). (1995). *The deep ecology movement: An introductory anthology*. Berkeley, CA: North Atlantic Books.
- Haigh, M. (2002). Land reclamation and deep ecology: Towards a more meaningful physical geography. *Area*, 34, 242–252.
- Harding, S. (2006). *Animate earth: Science, intuition, and Gaia*. White River Junction, VT: Chelsea Green.
- Katz, E., Light, A., & Rothenberg, D. (Eds.). (2000). *Beneath the surface: Critical essays in the philosophy of deep ecology*. Cambridge: MIT Press.
- Lovelock, J. (2005). *Gaia and the theory of the living planet*. London: Gaia Books.
- Macy, J. (1991). *World as lover, world as self*. Berkeley, CA: Parallax Press.
- Macy, J., & Brown, M. Y. (1998). *Coming back to life: Practices to reconnect our lives, our world*. Gabriola Island, British Columbia, Canada: New Society.
- Naess, A. (1973). The shallow and the deep, long range ecology movement: A summary. *Inquiry*, 16, 95–100.
- Naess, A. (1987). Self-realization: An ecological approach to being in the world. *The Trumpeter*, 4, 128–131.
- Seed, J., Macy, J., Fleming, P., & Naess, A. (1988). *Thinking like a mountain: Towards a council of all beings*. Gabriola Island, British Columbia, Canada: New Society.



DEFORESTATION

One of the most notable processes by which humankind has affected the Earth's surface is via the conversion of forested land for agriculture, logging, and urbanization, that is, deforestation. Up through the latter decades of the 20th century, deforestation had accelerated and come to be almost totally concentrated in the tropics, almost



wholly within developing countries. In the 1990s, the extent of old-growth forests was approximately one fifth of their original cover.

Estimates of land use change over the 20th century (the lion's share of which was concentrated in its last four decades) are crude, but research suggests that though Asia and Africa had a slightly greater percentage of their forests cleared (34% to 38%) compared with Latin America (approximately 28%), a far greater absolute amount was cleared in Latin America due to the vastness of the Amazon basin. A continuation of those rates would mean the end of tropical forests within 50 years and therefore the elimination of an area prized as a repository of biodiversity.

More recent estimates of global deforestation rates reveal that while the conversion of forest to agricultural land continues at the alarming rate of roughly 13 million ha/yr. (hectares per year), countervailing forces of afforestation (the conversion of open land into forest) via planting and natural expansion have significantly reduced the net loss of forested area. From 2000 to 2005, there was an estimated net decrease of 7.3 million ha/yr., a rate substantially lower than the average 8.9 million ha decrease per year between 1990 and 2000. During the 2000 to 2005 period, while the largest net forest losses occurred in Africa and South America, net forest loss also took place in Oceania and North and Central America. During the same period, Asia reported a net gain, primarily because of reported afforestation in China, despite the fact that Indonesia had one of the world's highest forest-clearing rates, though exact rates are contentious. Of all forested areas, primary forest constitutes 36%. Each year 6 million ha of primary forest are lost or modified, continuing trends reported in the 1990s. Although the trend in primary forest was toward a net loss, a few European countries and Japan reported gains in primary forest.

Forest-clearing "hotspots" in the humid tropical forest biome are revealed by the fact that 55% of the clearing occurs in 6% of the tropical biome's total area and is largely confined to the current agro-industrial clearing centers of South America and insular southeast Asia. The next level of intensity of clearing, constituting 40% of the clearing within the biome, is dispersed over 44% of the land area. The remaining 5% of

clearing takes place within the predominately intact forest, which makes up 35% of the biome area, and within the 15% of the biome area that had already been substantially deforested prior to 2000. In this period, Brazil and Indonesia stand out as centers of humid tropical forest loss, with Brazil constituting 47.8% of all clearing and Indonesia another 12.8%. Other Latin America hotspots include Northern Guatemala, Eastern Bolivia, and Eastern Paraguay, with the Asian countries of Malaysia and Cambodia, particularly along the Thai border, having exceptional clearing rates. Africa's humid tropical forest loss is primarily through low-intensity selective logging, without the agro-industrial-scale clearing seen elsewhere. The loss of humid tropical forest in Africa, therefore, constitutes a much less substantial portion of the loss of this biome, at 5.4% of the worldwide loss within this biome between 2000 and 2005.

Explanatory Frameworks

Attempts to explicate deforestation outcomes have moved beyond simple Malthusian assumptions in an attempt to capture the dynamic and complex multiscaled causal mechanisms, often framing causation in a host of proximate and underlying causes to land use and land cover change. The tropical deforestation literature seeking to categorize proximate causes has highlighted three essential types: agricultural expansion, timber extraction, and infrastructure development. The underlying causes have more often identified demographic, socioeconomic, technological, political-economic, and environmental factors.

Within geography, deforestation has been examined from a variety of perspectives, from a more purely land cover standpoint seeking improved methods of measuring its extent and rates of change across different locations to human-environment research seeking to characterize the drivers of deforestation. One of the challenges of addressing deforestation is having accurate measures of the extent, intensity, and pattern of the deforestation. Thus, many of the tools that fall within the domain of geography, such as remote sensing and geographic information science, seek improved methods for characterizing the changes in this land cover in space and time.



Logging and slash-and-burn agriculture have led to extensive deforestation in Eastern Chiapas, Mexico, which is home to the Lacandon Maya.

Source: Jami Dwyer.

A recent academic framework attempting to incorporate both agency and structure for explicating land change, often via the case study, is land change science (LCS), which serves as a foundational element in the study of global environmental change and sustainability science. The focus on the individual or the “agent” of change arises from the cultural ecology and risk hazards traditions, which have focused on the behavior of local agents. Structural explanations arise from the political ecology and vulnerability traditions. While in the past each perspective has often been employed at the exclusion of the others, more recent approaches have sought to incorporate both perspectives.

Causes

The most common proximate cause of forest clearing on the planet is the expansion of small farms along forest frontiers, followed in importance by in situ agriculture and livestock expansion, timber harvesting for fuel and construction, and the expansion of infrastructure. Road building for the last two activities often precedes expansion into the external frontier, while the in situ agriculture and pasture expansion often follows it. These proximate, immediate causes most often have at their root demographic, political, economic, and environmental processes.



While population and demographic dynamics are invoked in the great majority of deforestation case studies, they are never the only causes but instead correspond to other proximate and underlying drivers, such as socioeconomic, technological, and ecological conditions. In the early stages of development, for example, impacts on the forest are low and then accelerate during development, followed again by lower forest impacts. From a political perspective, wealthier and more democratic countries are more likely to have stable or expanding forests when compared with poor and despotic countries, which tend to experience rapid forest loss.

Much research on tropical deforestation has focused on Latin America, which is home to the greatest area of closed tropical forests in the world. In this context, small-farmer agricultural expansion along forest frontiers is the primary proximate cause of forest clearing, and examples of rapid forest conversion following colonization are abundant in the literature. Satellite imagery has illustrated particularly high rates of clearing adjacent to new roads. Road building, therefore, is a prerequisite to frontier deforestation, pointing toward corporate and state policies, which promote access to certain regions for economic or geopolitical motives. These rural frontier environments are characterized by their remoteness, abundant but often insecure resource access, and scarcity of labor. This farming technique often leads to the depletion of soil nutrients from the thin, oxidized tropical soils in 2 to 4 years' time, leading to farm abandonment on completion of a swidden farming cycle, followed by the consolidation of lands in the hand of rural elites, who often convert the land to cattle pasture. The poor then often leave to go to the next forest frontier, beginning this deforestation cycle anew. An often overlooked point in the literature is that demographic, ecological, and political-economic drivers elsewhere spur migration to the frontier and thus serve as a necessary underlying cause of frontier agricultural expansion.

While much frontier deforestation has, at least as the proximate cause, been at the hands of small subsistence farmers, a recent trend in the expansion of large-scale mechanized agriculture into frontier-forested areas has introduced an alternate pathway to deforestation. Frontier areas of the

Amazon, for example, have seen a rapid rise in the establishment of industrial-scale plantings of crops such as soybeans, though these plantings are still dwarfed in areal extent by more traditional frontier uses of small-scale agriculture and pasture. The Brazilian state of Mato Grosso, for example, saw a trend in the rise of large-scale deforestation events for the establishment of industrialized soybean farms from 2001 to 2004, often in direct relation to the price of soy in global markets. Given the current trends of soy farmers in the developed world converting to cropping maize to meet the production demands for biofuels, the forest frontiers of the developing world are increasingly vulnerable to this industrial cropping.

Unlike in Latin America, a greater proportion of deforestation in Africa derives not from colonization along the agricultural frontier but from the expansion of sedentary intensive agriculture and fuelwood harvesting. Wood fuel demands have a great impact on deforestation in Africa, perhaps more than farm expansion, though this is not always the case in countries with significant remaining tracts of forest. In the humid forests of Central Africa, logging concessions have become the most extensive form of land use in the area, making up 30% of the area, and, even though selective, alter the ecosystem and increase depredation in affected areas.

In Asia, the principle factors in deforestation have been commercial logging and the continued migration of peasants into formerly remote areas on roads established by loggers. As in all world regions, scale-dependent relationships representing social, biophysical, and geographical factors interact dynamically. Results from a case study in Thailand indicate the importance of population factors at finer scales and biophysical factors at coarser scales for explaining the variation in plant biomass levels.

Impacts

Even though deforestation is largely limited to within the tropics, its impacts are global, affecting global biogeochemical cycles and hydrological flows and threatening to aggravate climate change at both the local and global levels. The geographic literature has placed an emphasis on highlighting the spatial variation of the environmental impacts



of each of these processes, such as the disproportionate warming of the tropical and subtropical climates from forest clearing. Similarly, geographic research has shown not just the total forest area lost but also that the patterning of deforestation has profound implications for the physical landscape, with forest fragmentation leading to the inhibition of forest regrowth and biodiversity loss and compromising the integrity of ecosystems.

Geographers also play a lead role in the understanding of how deforestation affects the biological integrity of tropical ecosystems. Despite the fact that this biome covers only 7% of Earth's terrestrial surface, virtually all the recent species extinctions occurring in recent years have taken place in it, causing damage to Earth's biological gene pool, a potential treasure trove for science, medicine, and food advancements.

A disproportionate number of global species extinctions are concentrated in those places set up to protect them, such as national parks and ecological reserves. The amount of land under legal protection has increased at an exponential rate, and by 2005, 17.1 million square kilometers of total land across more than 100,000 protected areas had been established, constituting 11.5% of the planet's terrestrial surface. As governments expand the area of wild lands under protection and as little unclaimed forest remains outside these areas, protected areas represent an increasingly large proportion of unoccupied land available to migrant farm households.

Conclusion

The study of deforestation is quintessential geography. Given the enormity of the process to humans and the environment, geographers stand to make an ever-greater contribution, being strategically positioned to pioneer future research endeavors by pressing the discipline's comparative advantage of linking human-environment interactions at diverse spatial scales. Future efforts within geography include increasing the efficiency and accuracy of monitoring via remote sensing. And given the emphasis on the case study within land change science, developing further methods of comparability between case examples will likely increase in importance.

David L. Carr and Laurel Suter

See also Biodiversity; Biome: Tropical Rain Forest; Forest Fragmentation; Global Environmental Change; Human Dimensions of Global Environmental Change; Land Use and Cover Change (LUCC)

Further Readings

- Carr, D. (2009). Population and deforestation: Why rural migration matters. *Progress in Human Geography*, 33, 355–378.
- Chowdhury, R., & Turner, B. (2006). Reconciling agency and structure in empirical analysis: Smallholder land use in the southern Yucatan, Mexico. *Annals of the Association of American Geographers*, 96, 302–322.
- Geist, H., & Lambin, E. (2001). *What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on sub-national case study evidence* (Land Use and Land Cover Change [LUCC] Report Series No. 4). Louvain-la-Neuve, Belgium: LUCC International Project Office.
- Hecht, S. (2005). Soybeans, development and conservation on the Amazon Frontier. *Development and Change*, 36, 375–404.
- Morton, D., DeFries, R., Shimabukuro, Y., Anderson, L., Arai, E., Espirito-Santo, F., et al. (2006). Cropland expansion changes deforestation dynamics in the southern Brazilian Amazon. *Proceedings of the National Academy of Sciences of the United States of America*, 103, 14637–14641.
- Turner, B., Lambin, E., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Sciences of the United States of America*, 104, 20666–20671.
- Walker, R., Moran, E., & Anselin, L. (2000). Deforestation and cattle ranching in the Brazilian Amazon: External capital and household processes. *World Development*, 28, 683–699.
- Walsh, S., Messina, J., Crews-Meyer, C., Bilsborrow, R., & Pan, W. K. (2002). Characterizing and modeling patterns of deforestation and agricultural extensification in the Ecuadorian Amazon. In S. Walsh & K. Crews-Meyer (Eds.), *Linking people, place, and policy: A GIScience approach* (pp. 187–214). Norwell, MA: Kluwer Academic.



DEINDUSTRIALIZATION

Deindustrialization refers to the large-scale loss of manufacturing jobs, a process of capital abandonment that generally leaves devastated communities in its wake. The process reflects the mobility of capital, its constant and restless search to minimize costs and maximize profits, and its mounting ability to pit places against one another and force workers to make concessions in wage rates and benefits. The traditional view is that deindustrialization in some places and industrialization in others are mirror images of each other. Industrial growth and decline are offsetting tendencies, representing a zero-sum, or even a positive, global game. The shift of production processes from the industrial heartland to the periphery releases a skilled labor force for more sophisticated forms of production in developed countries and allows labor in the developing countries to move from relatively unproductive employment to more highly productive employment in industry. The shift may lead to some transitional unemployment, but job losses in the industrial heartland are of little significance compared with the enormous rewards attached to a global reallocation of production. Typically it witnesses steep declines in manufacturing as a proportion of the GDP and the labor force (see Figure 1).

The process of deindustrialization, often held to be synonymous with the collapse of Fordist systems of production in the late 20th century, began in earnest in the 1970s, especially in Britain and the United States and then in numerous other industrialized countries as well. In Britain, the decline of textiles, iron, and steel production, coal mining, and automobile firms devastated many once-prosperous cities of Northern England and Scotland.

Several factors contributed to the deindustrialization of the United States. Between 1945 and 1960, most United States-based companies were content to produce in the old industrial districts. But by 1960, Western European countries and Japan had become competitors. Mounting international competition and falling profit rates at home coerced American companies to decentralize not only within the United States but also

abroad. Thus domestic restructuring and internationalization can be seen as two sides of the same coin. By 1980, the 500 largest U.S.-based corporations employed an international labor force almost equivalent to the size of their labor force within the United States. The rise of foreign competitors, many with lower labor costs, state-of-the-art technologies, and public subsidies, led to burgeoning trade deficits in many critical sectors, especially steel, automobiles, textiles, industrial parts, tool and die, agricultural and medical equipment, and merchant ships. U.S. corporate reinvestment, including research and development, tended to lag behind its competitors, as did productivity growth. Others note that technological change and capital intensification would have generated manufacturing job loss even without mounting international competition.

The United States experienced massive industrial devolution in the 1970s and 1980s, a period during which its share of world manufacturing output decreased significantly. This trend was accompanied by the growth of manufacturing employment and output in other countries, especially the newly industrializing countries in Eastern Asia. Inside the United States, a major corporate crisis led to declining rates of profit, inducing ever-more mobile firms to switch capital in space, going global in an effort to restore profitability: 500,000 manufacturing jobs per year were lost between 1978 and 2002. Toy production, for example, has largely moved into East Asia, particularly China. The textile industry fled much of the South for cheaper sites in Taiwan, Hong Kong, Singapore, and, now, China. The automobile industry, caught by the petrocrisis and cheap, fuel-efficient imports, gradually gave way to competitors from Japan and Europe. Steel offers another compelling example of the decline in industrial capacity. Between 1970 and 2005, the North American and Western European proportion of total global steel production declined from 67% to 42%, whereas developing countries' production levels increased from 10% to more than 30%. Many steel-manufacturing firms have gone out of business as the global steel production capacity exceeds global demand. Because of government subsidies, steel mills in some countries, especially in Europe, have remained open in the face of dwindling quotas. The U.S. government,

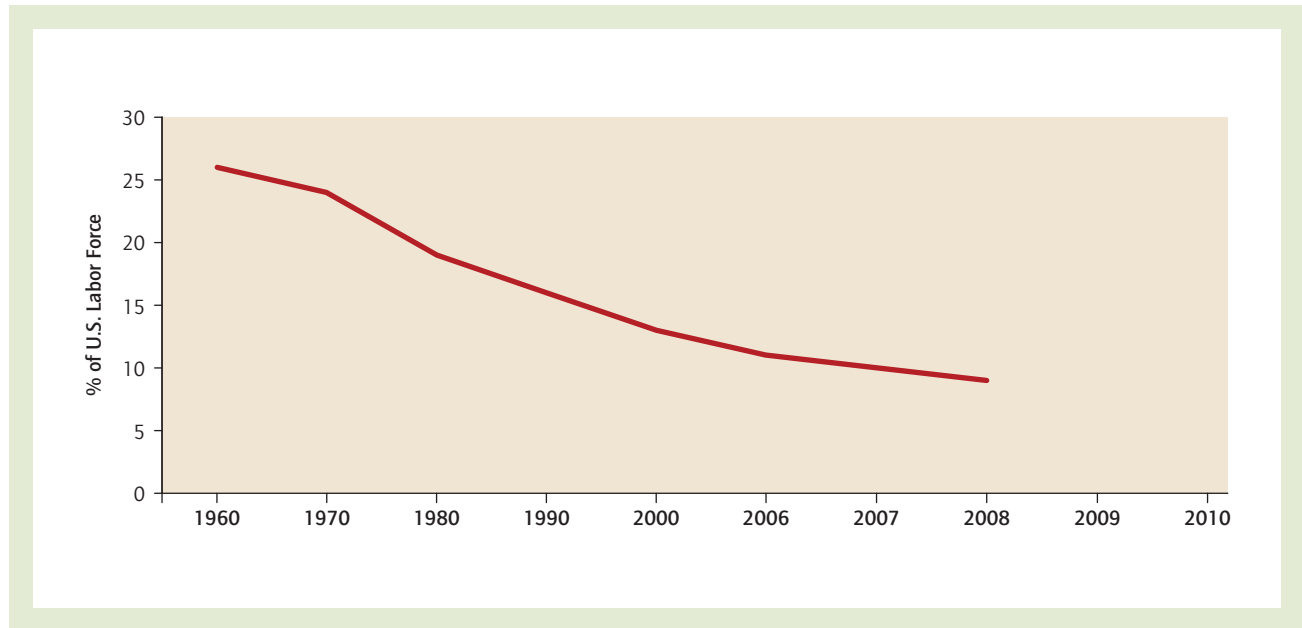


Figure 1 Decline in manufacturing as share of U.S. labor force. Deindustrialization led to significant declines in manufacturing jobs and output.

Source: Author.

however, has been less willing to pay unemployment compensation to displaced workers and has allowed the U.S. steel industry to decline. Since the 1970s, U.S. production has decreased by 33%, whereas employment in the steel industry has declined by 66%.

The dispersal of manufacturing investment to foreign lands resulted in enormous savings for American firms and enormous losses for American workers, largely due to the differences in wage rates. In terms of average wages, workers in Europe, particularly Scandinavia and Germany, fare the best, with wages often one third higher than those of American workers (as well as longer paid-vacation periods and universal health coverage). U.S. wages are comparable with those of Australia, slightly higher than those of Ireland or Japan, and well above those of the developing world.

The effect of the globalization of manufacturing change has been most severe in the Manufacturing Belt, which lost millions of relatively well-paying jobs as factories closed, with devastating economic and social impacts on their communities. Indeed the Manufacturing Belt was effectively transformed into a “Rust Belt” through

a painful process of industrial restructuring, which led to numerous corporate bankruptcies, plant closures, layoffs, and rising unemployment. The region contends with problems of obsolescence and reduced productivity, especially in leading industries such as steel, tool and die production, agricultural implements, rubber, automobile and auto parts manufacturing, and shipbuilding. Many of its inner-city areas are littered with closed factories, bankrupt businesses, depressed real estate, and struggling blue-collar neighborhoods. Faced with massive job losses and eroding memberships, many unions succumbed to corporate demands for wage and benefit rollbacks. Indeed, the loss of high-paying manufacturing jobs is one of the major reasons for the stagnant incomes of American households since the 1970s. As the multiplier effects spread throughout local areas, retail sales, personal services, and real estate markets suffered accordingly. Communities increasingly desperate to prevent plant closings readily negotiated tax breaks and other incentives to keep companies from leaving town. The effects of disinvestment on workers and their communities have been devastating. Victims of plant closings sometimes lose



not only their current incomes but often their accumulated assets as well. When savings run out, people lose their ability to respond to life crises and often suffer bankruptcy, depression, marital problems, homelessness, and suicide. Although job losses occurred in many occupations, some groups were more vulnerable than others. Unskilled workers are particularly likely to bear the costs of globalization, including job displacement. African American workers, many of them unskilled or semiskilled, were particularly hard hit, and by driving up unemployment, the deindustrialization of the inner city was in no small part responsible for the creation of the impoverished ghetto communities there.

Although the widespread manufacturing decline has produced a lasting effect on people and communities in the Manufacturing Belt, all is not lost in the region. There have been numerous attempts to respond to the economic crisis. Some old industrial cities such as Pittsburgh successfully built new bases for employment in services, and others, such as Cleveland, indicate the potential for doing so. Southern New England, which suffered high unemployment rates throughout much of the post–World War II period, underwent a new round of industrial expansion based on electronics and producer services, one that took advantage of its pool of highly skilled workers. Selective reindustrialization and the migration of manufacturing from the American Manufacturing Belt to the South and the West helped disguise, but not alleviate, the trauma of the Midwest and Northeast.

Barney Warf

See also **Flexible Production; Fordism; Industrialization**

Further Readings

- Bluestone, B., & Harrison, B. (1982). *The deindustrialization of America: Plant closings, community abandonment, and the dismantling of basic industry*. New York: Basic Books.
- Linkon, S., & Russo, J. (2002). *Steel-town U.S.A.: Work and memory in Youngstown*. Lawrence: University Press of Kansas.



DELTA

A delta is the landform that results where a sub-aerial channelized flow (e.g., a river) enters a basin of standing water (e.g., the sea, a lake). In deltaic areas, flow velocities drop and sediment transport stalls, which results in bifurcation of rivers, a downstream widening of floodplains, and the buildup of deltaic plains that make the coastline protrude. Many deltas have become densely populated today. Industrial and urban uses of deltaic areas must deal with issues of flood hazard mitigation.

The word *delta* resembles the character “Δ” in the Greek alphabet. Its shape mimics that of the largest delta known in ancient Greece (that of the Nile River in Egypt as viewed from the north). Deltas come in many forms, and the term is used in various contexts. Fluvial landforms such as river channels, levees, and floodplains; lagoonal landforms, including swamps, wetlands, and lakes; and coastal features such as beach ridges, spits, salt marshes, mangrove, tidal creeks, and tidal rivers (estuary channels) can all be part of a larger area typified as a “delta,” which can further contain isolated “islands” of inherited, partly eroded, and/or buried older landforms.

Deltas grade upstream into feeder valleys, with no strict definition of their inland limits. At their downstream end, deltas terminate in open water and grade laterally into nondeltaic segments of coast—again without strictly defined limits. The word is applied to describe features at a range of spatial scales, from the small size of a flume experiment or a mouth bar at the end of a natural channel (typical in engineering textbooks) to the much larger area occupied by a full network of divergent river channels between the most-upstream bifurcation (“delta apex”) and the most-downstream subaqueous deposition as can be traced offshore (typical in geomorphological textbooks) to even larger areas based on the presence of deltaic deposits that a river has delivered over geological time over thousands (Holocene) if not hundreds of thousands (Quaternary) or millions of years (Cenozoic) (typical in sedimentary geological textbooks).

For example, the Netherlands as a whole is geologically considered a Quaternary delta of the



Time, weather, and human intervention have all shaped the Mississippi Delta in Louisiana, a giant bird's foot shape protruding into the Gulf of Mexico. The Mississippi River deposits sediment into the ocean, and over 25 years, NASA Landsat satellites observed changes in the delta's shape.

Source: NASA.

Rhine and Meuse within the shallow southern North Sea basin in northwest Europe. But the central part of the Netherlands is also geomorphologically considered the Holocene Rhine-Meuse Delta. Furthermore, areas where the deltaic Rhine branches terminate in the Netherlands' central lagoon host small deltas, which are considered elements of the larger Rhine-Meuse delta. The urbanized westernmost part of the delta, Randstad Holland, a conurbation along the mouth of the rivers Rhine and Meuse (Rotterdam), the coastal barrier (The Hague) and the central lagoon (Amsterdam), is commonly referred to as a "delta metropole." The Randstad conurbation covers the downstream part of the Rhine delta and adjacent coastal and lagoonal

landforms. In the Rhine delta, the raising of dikes has restricted deltaic sedimentation in the past 800 years to narrow embanked floodplains. Consequently, the modern floodplain has a width that is only a fraction of the preembanked situation—with impacts on style of sedimentation (allowing the floodplains to be mined extensively for bricks) and river management. In contrast, the dike-protected flood basins were starved from sediment and became subject to land subsidence owing to artificial water table lowering—a common phenomenon and management problem in urbanized deltas.

Deltas are progradational landforms that build out in size and shape up to a dynamic equilibrium state where coastal erosion balances river sediment supply—provided that circumstances such as water level (*base level*) and climate are semistable for a sufficiently long time. For modern coastal deltas, this has been more or less the case for the past 6,000 years, and the history of human occupation of modern deltas goes back to that time. The various types of deltas that result today are typically classified based on the physical conditions in the receiving basin (deep/shallow, tides, wave regime), character of the feeding river (sediment capacity and type of sediment, discharge regime, multichannel braiding or single-channel meandering feeder), and inherited geographical setting (nature and geometry of the basin, climate, degree of urbanization). Deltas produce fan-shaped bodies with sedimentation *up to* a water level, and for that property "deltaic fans" are distinct from "alluvial fans" (fan-shaped bodies *above* a water level as found along the foot of mountain chains) or submarine "abyssal fans" (fan-shaped bodies as found *at depth* on the ocean floor along the rims of continents).

"Estuaries," like deltas, are landforms that result where rivers enter a water basin. The



difference is that *estuary* principally refers to the water body, that is, the river's mouth, and an estuary experiences an inland marine influence (drowned valley, tides, salinity gradient), whereas *delta* principally refers to the body of accumulated sediment that protrudes into a water body (see photo). This conceptual difference ensures that the two terms are not mutually exclusive. In practice, whether an area surrounding the mouth of a river is named a delta (with or without channels termed estuaries penetrating it) or estuary (with or without substantial deltas filling it) reflects the topography surrounding the river mouth, the size of the river mouth water body versus total delta/estuary width, and whether or not the coastline protrudes into the basin in the direct vicinity of the river mouth. Estuaries of larger rivers often fill up from their upstream end by a deltaic deposit, for example, the Tagus (Tejo) River in Portugal and the River Paraná building out into the Rio de la Plata in Argentina.

Deltas often host great amounts of sedentary and migratory birds, fish, aquatic mammals, and so on, owing to a rich diversity of spatially connected ecotopes. These delta ecotopes differ in frequency, duration, and nature of flooding. Deltaic ecotopes have a relative high level of nutrient availability due to (a) a constant fresh nutrient supply by floodwaters (dissolved and as a fine sediment) and (b) waterlogged soil conditions that promote biological recycling. Marine deltas furthermore have a salinity gradient with distance to the river mouth, adding another ecological gradient and further diversity.

In the modern urbanized world, many deltaic areas have become economic hotspots, hosting a vast majority of the global population (60% to 80%, depending on one's definition). This is the outcome of a complex history of occupation (settling, transport, urbanization) and economic development (trade, imperialism, globalization). The fringes of deltas were originally attractive settling sites because of access to water, wood, and food and opportunities for transportation. Flooding occurs frequently in natural deltas, both from rivers and from the sea, but paradoxically the flood risk is low; the sheer width of the flooded area makes extreme floods away from the coast and river cause only marginally higher water levels compared with normal floods. Consequently,

living on modestly raised structures provides fair protection against floods of smaller and larger magnitudes. This changes with increased urbanization and introduction of embankments in historical (e.g., the Po Delta, Italy; the Rhine Delta, the Netherlands) to modern times.

Where delta populations and their spatial needs continue to grow after the most suitable areas in the delta have been occupied (e.g., natural levees and beaches where sedimentation occurs up to the highest flood levels and that thus flood last and least), less suitable areas such as wetlands are occupied. At that stage, embankment becomes necessary, compartmenting the floodplain and reducing the flooding frequency outside restricted dedicated flooding areas (retention basins). Embankment prevents regular flooding but increases potential damage; as a result, when flooding does occur, it has severe impacts (e.g., Hurricane Katrina). When the delta is almost completely urbanized, in addition to reusing already occupied space in new ways, there are three other strategies to further urbanize an area: (1) using the vertical dimension (building skyscrapers, tunnels), (2) reclaiming coastal water to land (building into the sea), and (3) expanding inland into the feeding valley or surrounding uplands (at growing distances to existing centers of economic activity).

Given the projected sea-level rise due to global warming in the next century, in combination with an increasing population and urbanization, many deltas in the world face severe planning issues in mitigating the flood hazard while maintaining economic vigilance and the quality of nature and living.

Kim M. Cohen

See also **Coastal Erosion and Deposition; Coastal Hazards; Floodplain; Floods; Nature-Society Theory; Rivers; Urban and Regional Development**

Further Readings

Berendsen, H. (1998). Bird's-eye view of the Rhine-Meuse delta. *Journal of Coastal Research*, 14, 740–752.



- Blum, M., & Robberts, H. (2009). Drowning of the Mississippi Delta due to insufficient sediment supply and global sea-level rise. *Nature Geosciences*, 2, 488–491.
- Hudson, P., Middelkoop, H., & Stouthamer, E. (2008). Flood management along the lower Mississippi and Rhine rivers (the Netherlands) and the continuum of geomorphic adjustment. *Geomorphology*, 101(1/2), 209–236.
- Stanley, D., & Warne, A. (1994). Worldwide initiation of Holocene marine deltas by deceleration of sea-level rise. *Science*, 265(5169), 228–231.
- Syvitski, J., Kettner, A., Overeem, I., Hutton, E., Hannon, M., Brakenridge, G., et al. (2009). Sinking deltas due to human activities. *Nature Geoscience*, 2, 681–686.
- Syvitski, J., & Saito, Y. (2007). Morphodynamics of deltas under the influence of humans. *Global and Planetary Change*, 57(3/4), 261–282.



DEMOCRACY

Democracy means “rule by the people.” The meaning of *the people* and of *rule* is far from straightforward. Delimiting the scope of rule and of the identity of the people are intrinsically geographical processes. Since the 18th century, the normative assumption of much democratic theory has been that *the people*, or *demos*, is coterminous with the identity of the *nation* and that the territorially bounded nation-state is the primary agent of democratic rule and subject of democratic legitimacy. Research on democracy in geography falls into two broad areas: research in electoral geography, which investigates the mechanisms of liberal-representative democracy, and research in critical human geography, which focuses on alternative sites and spaces of democracy.

Electoral Geographies of Liberal-Representative Democracy

Liberal democracy refers to forms of institutionalized popular representation, involving periodic

mass election of representatives to authoritative legislatures, under conditions of free speech and association. This model of democracy is unevenly developed in the West and is often presented as the ideal to be emulated throughout the world. Electoral geography focuses on how the mechanisms of representative politics are spatially organized in liberal democracies. This field maps the spatial distribution of votes, explains the context-specific factors affecting voting behavior, and explains how the spatial organization of electoral systems affects how votes are translated into representative majorities in liberal democracies. Research on electoral processes has also broadened out to include the geographies of campaigning, party formation, and political communication. It has also focused on the processes of democratization. The so-called diffusion of democracy as a global form of governance since the late 1980s has followed in the wake of the collapse of communism in Eastern Europe, political transitions away from authoritarianism in Latin America, Africa, and Asia, and the application of norms of democratic governance in the geopolitics of Western international financial policy, trade negotiations, and military engagements. Geographers have investigated whether the adoption of democratic forms of governance can be accounted for by specifically geographical factors. They have also critically assessed the theoretical assumptions and the practical devices through which liberal forms of electoral democracy have been circulated as the global norm.

Critical Geographies of Democracy

Democracy has only recently become an explicit object of concern in critical human geography. Recent work in this tradition searches for the signs of alternative understandings of radical democracy in the fractures and margins of liberal-representative politics. This work defines democracy as more than a set of procedures for legitimizing the decisions of centralized bureaucracies and holding elected representatives accountable. Radical democracy is understood to be a process of ongoing contestation, in which the objects and subjects of politics are constantly redefined. Radical democracy holds



to an alternative sense of “democratization,” understood not as the geographical diffusion of established norms of democracy but as the deepening of democratic impulses and their extension of new arenas of everyday life. Radical democracy also opens up to scrutiny the role of all sorts of social and cultural practices in sustaining or undermining a broader democratic culture through their contribution to the quality of the public sphere.

Geographers working on radical democracy tend to be suspicious of the normative value ascribed to the nation-state in liberal democratic theory and practice. There is a burgeoning literature that focuses on the city as the privileged scene for realizing the possibilities of radical democracy. However, this work easily falls into the trap of assuming that subnational scales of governance are somehow more democratic by virtue of being closer to people’s everyday concerns. There is also increasing attention given to emergent forms of transnational democracy. This work focuses on whether systems of globalized economic and political governance can be subordinated to democratic oversight. Settled assumptions about the objects of democratic decision making are challenged by the proliferation of nonterritorial concerns, such as global climate change, pandemic disease, and integrated transnational financial markets. These sorts of issues throw into relief the limitations of territorialized models of democratic representation.

Theorizing Democracy Geographically

To date, geographers have largely relied on normative theories of democracy drawn from other fields, political science, political theory, and political philosophy. They have applied and assessed these theories empirically, and they have often argued that they suffer from inadequately complex understandings of space, place, and scale. Meeting the challenge presented by David Slater, of developing a geographically informed conceptualization of democratic politics that can talk back to these disciplines, has proven more difficult. There are three aspects to an agenda for theorizing democracy geographically that would respond to this challenge:

1. A charitable *interpretation of the imaginary geographies of democratic theory*: Rather than castigate other disciplines for not holding to the spatial concepts that geographers have perfected, this agenda is sensitive to the analytical and normative problems that democratic theorists are articulating when they have recourse to what, from the geographers’ perspective, appear to be rather stylized understandings of, for example, globalization, borders, or the transnational. For example, discussion of geographical boundaries serve the function of framing the problem of how to translate broadly diffused processes of opinion formation into legitimate and effective forms of will formation; or appeals to the value of the nation-state form serve as the frame through which to reflect on the qualities of social solidarity associated with democracy. If geographers aim to contribute to debates in democratic theory, then they must do more than simply point out the limitations of these spatial “metaphors” while not addressing the analytical and normative problems at stake.

2. A diagnostic *investigation of the types of influence to which particular fields of power are susceptible*: A key issue in any democracy is whether the forms of “influence” that can be generated in the civil society and the public sphere can or should be articulated with the institutionalized “exercise” of power. Analysis of the “steering media” through which different fields of practice are coordinated can provide resources for an analysis of the forms of influence that different practices might be susceptible to, the forms of contention and grievance they generate, and the type of democratic politics that might be expected to emerge around them. It is here that geographers’ sensitivity to the differential spatiotemporal constitution of fields of power, added to an appreciation of the differential validity claims enacted by these formations, might contribute to broader projects of theorizing democratic futures.

3. A parasitical *analysis of the ordinary deployment of normative concepts of democracy in political processes*: This sort of parasitical analysis focuses on how democratic norms are invoked in new contexts in the course of ongoing political contestation; it tracks the routes through which



democratic practices circulate, and the conjunctures that account for their articulation in particular contexts. By focusing on the contestation of democratic norms in historical-geographical contexts of *application*, such an analysis helps disclose what values are invoked, and what harms or concerns are motivating different actors, when recourse is made to the discourses and devices of democracy. This style of analysis is context-sensitive but attuned to the processes of translation through which democratic practices travel; it is attuned to different understandings of what democracy is good for; it is sensitive to the articulation of democratic practices with non-democratic practices of bureaucracy, violence, patriarchy, and so on; and it is sensitive to the ways in which new meanings accrete to “democracy” in this process of translation and contested application.

This program for geographical research on democracy does not abandon the normative dimension of democratic theory. The mobility of democratic practices suggests that the devices through which different imperatives of democratic rule are enacted can be combined, adapted and reordered in different geographical contexts. As a consequence, the values enacted through these devices—the ways in which interests are represented, conflicts resolved, participation practiced, and accountability enforced—might be highly variable between different geographical contexts. Acknowledging that democracy collects together a series of values—including liberty and equality; participation and publicity; accountability and accommodation; contingency; contestation; and consensus, responsibility, and representation—suggests that critical attention should focus on the ways in which particular claims to instantiate democracy advance certain values over others. Judgment over the validity of any such combination will, no doubt, remain open to further contestation.

Clive Barnett

See also **Citizenship; Civil Society; Electoral Geography; Justice, Geography of; Political Geography; Redistricting; Social Justice; Social Movements**

Further Readings

- Barnett, C., & Low, M. (Eds.). (2004). *Spaces of democracy: Geographical perspectives on citizenship, participation and representation*. London: Sage.
- Dahl, R. (2000). *On democracy*. New Haven, CT: Yale University Press.
- Dunn, J. (2005). *Setting the people free: The story of democracy*. London: Atlantic Books.
- Held, D. (2006). *Models of democracy* (3rd ed.). Cambridge, UK: Polity Press.
- Saward, M. (2003). Enacting democracy. *Political Studies*, 51, 161–179.
- Slater, D. (2002). Other domains of democratic theory: Space, power, and the politics of democratization. *Environment and Planning D: Society and Space*, 20, 255–276.



DEMOGRAPHIC TRANSITION

Developed by several demographers in the 1950s, the demographic transition stands as an important alternative to neo-Malthusian notions of population growth. Essentially, it is a model of a society's fertility (birth rate, BR), mortality (death rate, DR), and natural population growth rates (NGR) over time, using the simple relationship $NGR = BR - DR$. Because this approach is explicitly based on the historical experience of Western Europe and North America as they went through the Industrial Revolution, “time” in this conception is a proxy for industrialization. This approach can be demonstrated with a graph of birth, death, and natural growth rates over time that divides societies into four major stages (Figure 1).

Stage I: Preindustrial Society

In the first stage, a traditional, rural, preindustrial society and economy, fertility rates are high and families are large and extended. In agrarian economies, children are a vital source of farm labor, helping plant, weed, and sow crops, tending to farm animals, performing chores, carrying water and messages, and helping with younger siblings.

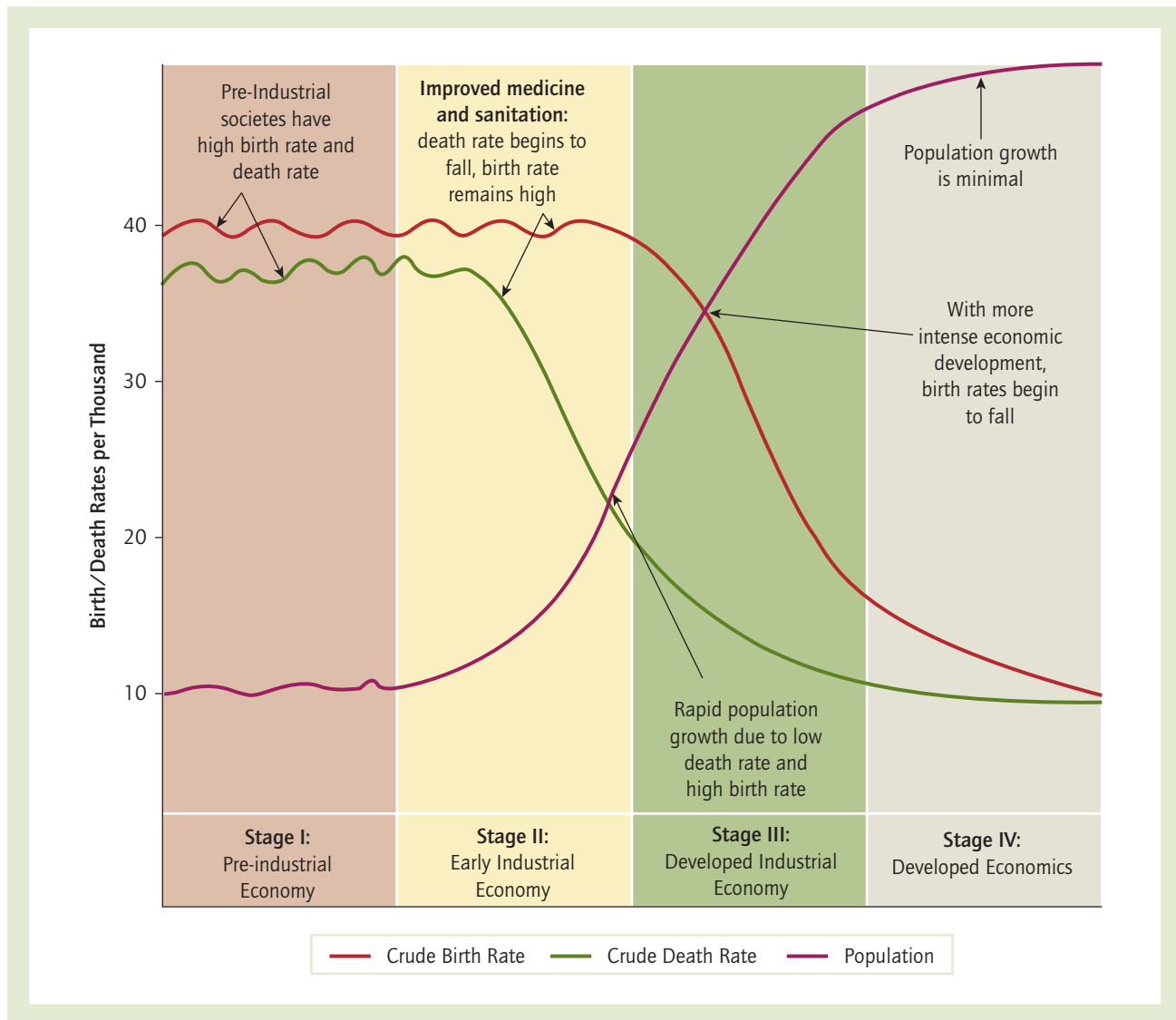


Figure 1 Stages in the demographic transition. This model illustrates stereotypical changes in birth, death, and growth rates as societies industrialize.

Source: Stutz, F., & Warf, B. (2005). *The world economy: Resources, location, trade and development* (4th ed., p. 82). Copyright © 2005. Reprinted by permission of Pearson Education Inc., Upper Saddle River, NJ.

Children also take care of their elderly parents when they are infirm. In societies with high infant mortality rates, having many children is a form of insurance that a significant number will survive until adulthood. Thus, the distribution of birth rates around the world reveals that the poorest societies have the highest rates in the world, particularly in sub-Saharan Africa and most of the Middle East. In contrast, birth rates in North America, Europe and Russia, Japan, Australia, and New Zealand are relatively low.

However, in preindustrial societies, mortality rates are also typically quite high, which means that the average life expectancy is relatively low. The primary causes of death in poor, rural contexts are the result of inadequate diets, as well as unsanitary drinking water and bacterial diseases. The world geography of death rates thus closely reflects the wealth or poverty of societies. Because both fertility and mortality rates are high, the *difference* between them—natural population growth—is relatively low, fluctuating around



zero. While relatively few societies in the world live in these circumstances today, Stage I may describe certain tribes in parts of Central Africa, Brazil, or Papua New Guinea, that is, the places most remote from the world system.

Stage II: Early Industrial Society

The second stage of the demographic transition pertains to societies in the earliest phases of industrialization, such as 19th-century Britain or the United States, or selected countries in the developing world today, such as Peru. Early industrial societies retain some facets of the preindustrial world, particularly high fertility rates. Because most people still live in rural areas, children remain an important source of farm labor. The major difference is the decline in mortality rates, which leads to longer life expectancies. Mortality rates decline as societies industrialize, not primarily because of better medical care but because of improved food supplies due to the industrialization of agriculture, which plays a major role in improving immune systems, including lowering infant mortality rates. Because the death rate has dropped but the birth rate has not, the natural growth rate grows explosively, a situation evident in a wide number of countries in the developing world today.

Stage III: Late Industrial Society

Societies in the throes of rapid industrialization, in which a substantial share, if not the majority, lives in cities, exhibit a markedly different pattern of birth, death, and growth rates compared with those earlier in the transition. Death rates remain relatively low, but in this stage fertility rates also exhibit a steady decline. Birth rates typically fall and families get smaller as societies become wealthier because urbanization and industrialization change the benefit/cost ratio of children. In societies in which large numbers of women enter the paid labor force—become commodified labor outside the home, rather than unpaid workers inside it—mothers must typically drop out of the labor market, if only temporarily, to take care of their children. Economically, this process generates an opportunity cost to having children: The more children a couple has, or the longer a mother

refrains from working outside the home, the greater the opportunity cost she faces, or she and her husband face as a family. As women's incomes rise, either over time or comparatively within a society, the opportunity cost of children increases accordingly, leading to lower fertility rates. As fertility rates decline, so too does the natural growth rate. In short, relatively prosperous societies tend to have smaller families, and there is frequently a corresponding shift from extended to nuclear families in the process.

Historically, fertility levels fell first in Western Europe, followed quickly by North America, and more recently by Japan and then Eastern Europe and Russia. In these areas, reproductive levels are near, or even in some countries below, the level of generational replacement. Elsewhere, however, birth rates remain at much higher levels, although in China and southeast Asia the birth rates are dropping quickly. There has been a modest decline in South Asia, the Middle East, much of Latin America, and parts of sub-Saharan Africa.

Stage IV: Postindustrial Society

The fourth and final stage of the demographic transition, postindustrial society, depicts wealthy, highly urbanized worlds, a context indicative of Europe, Japan, and North America. Such societies typically witness low death rates, the causes of which change from infectious diseases to lifestyle-related ones, particularly those associated with smoking and obesity, as well as, to a lesser extent, car accidents, suicides, and homicides. Birth rates too, continue to fall in such contexts, as many couples elect to go childless or have only one. When birth rates drop to the levels of death rates, a society reaches zero population growth (ZPG). When birth rates drop below death rates, as they have in most of Europe, Russia, and Japan, the society experiences a negative natural population growth. Such countries are characterized by large numbers of the elderly, a high median age, and a relatively small number of children, all of which have dramatic implications for public services.

Globally, uneven economic development generates uneven patterns of natural population growth. The most rapid rates of increase are found throughout the poorer parts of the developing world, that is, sub-Saharan Africa, the Arab



and Muslim worlds, India, and Indonesia. The economically developed nations, in contrast, have low rates of growth, including in North America, Japan, Europe, Australia, and New Zealand.

Criticisms of Demographic Transition Theory

Although the concept of demographic transition has wide appeal because it links fertility and mortality to changing socioeconomic circumstances, it has also been criticized on several grounds. Some critics point out that it is a model derived from the experience of the West and then applied to non-Western societies as if they are bound to repeat the exact sequence of fertility and mortality stages that occurred in Europe, Japan, and North America. It is not inevitable that the developing world will follow in the footsteps of the West. Some have pointed out that the developing world is in many ways qualitatively different from the West, in no small part because of the long history of colonialism. Furthermore, demographic changes in the developing world have been much more rapid than in the West. Whereas it took decades, or even centuries, for mortality rates in Europe to decline to their modern levels, in some developing countries the mortality rate has plunged in only one or two generations. Because mortality rates do not vary geographically as much as fertility rates do, most of the spatial differences in natural growth around the world are due to differences in fertility.

Barney Warf

See also **Development Theory; Fertility Rate; Malthusianism; Mortality Rate; Natural Growth Rate; Neo-Malthusianism; Population Geography**

Further Readings

- Jones, G., Caldwell, J., D'Souza, R., & Douglas, R. (Eds.). (1998). *The continuing demographic transition*. New York: Clarendon Press.
- Kirk, D. (1996). Demographic transition theory. *Population Studies*, 50, 361–388.
- Peters, G., & Larkin, R. (2002). *Population geography: Problems, concepts and prospects*. New York: Kendall/Hunt.



DENDROCHRONOLOGY

Dendrochronology, a name derived from the Greek words for “tree” and “knowing the time,” is a set of techniques by which the annual growth layers of trees, called tree annual rings, can be assigned to the specific year of their formation. The history of changes in the tree’s environment can be reconstructed using various properties of annual tree rings, for example, their width, cell size, wood density, trace element composition, and radioactive and stable isotope ratios. Andrew Douglass established the scientific basis of dendrochronology in the early years of the 20th century in North America. Douglass, the founder of the Laboratory of Tree-Ring Research at the University of Arizona in Tucson, invented the technique of cross-dating by means of skeleton plots, that is, the process of assigning year dates to annual tree rings by cross-comparison of rings from several trees growing in the same area. Cross-dating is a technique that aids the dendrochronologist in relating groups of specimens to each other by matching ring patterns and determining the exact date for each ring (Figure 1).

Cross-dating is a simple technique to undertake, although it requires an experienced person with a microscope, pencil, and graph paper for the task to be successful. The set of fundamental principles that have been established for cross-dating include the following:

1. Trees that will be used for cross-dating produce one annual ring for each year.
2. One environmental factor, such as precipitation or temperature, dominates in limiting the annual growth of the tree.
3. The intensity of the growth-limiting environmental factor varies from year to year, and the resulting annual rings reflect such variations in their growth.
4. The growth-limiting factor is effective over a large geographical area.

Tree-ring series have been used to reconstruct patterns in the variations in precipitation, temperature, soil moisture, frequency of extreme droughts, forest fires, pest outbreaks, and a diversity of other growth-limiting factors over past centuries and, occasionally, millennia. What can be reconstructed specifically depends mainly on the

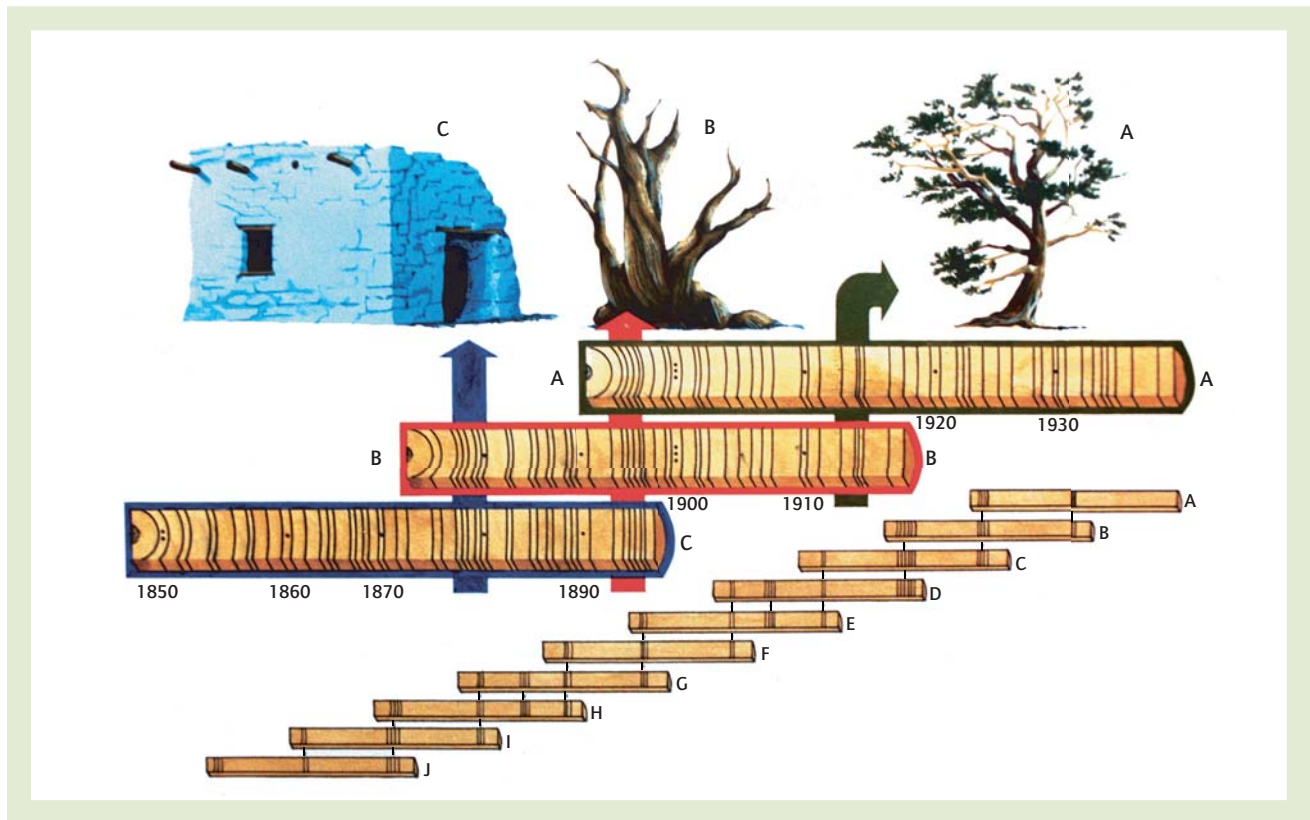


Figure 1 Concept of cross-dating: extending chronologies by cross-dating living and dead wood samples

Source: Laboratory of Tree-Ring Research, University of Arizona.

factor(s) that limits tree growth. Dendrochronology has made significant contributions to the science of geography, most specifically to physical geography. Physical geography centers on the spatial analysis of all the physical elements and processes that make up the environment, such as energy, water, climate and weather, landforms, soils, animals, plants, Earth itself, and the impacts of human activities on the environment.

Some of the earliest geographical writing on dendrochronology included investigations of tree rings as a means to understand arctic and alpine ecosystems and glacial environments. However, the first dendrochronological writings by a noted geographer, Ellsworth Huntington, were reports on investigations of giant sequoia tree rings, used by the author to understand climatic variations. Climatology is a time-honored theme in geographical studies because of the interest in the spatial variability of climates and the spatial and temporal variability of atmospheric circulations and related climate phenomena such as droughts, floods, and

large storms. Seminal works in paleoclimatology such as Hays and Imbrie's investigations of the origins of Ice Ages and Hubert Lamb's compendia of global climate variations accelerated interest in past climate variations and their relationships to cultural and economic history and geography.

As people have become increasingly interested in Earth's climate, dendrochronology has often been adopted by geographers and other scientists as one of the methods available for the reconstruction of past climates and the effects of past climates on the historical evolution of vegetation, water resources, and other landscape features of a region. Furthermore, by knowing the nature of past climates, probabilities of future climates are obtained by linking the knowledge of past climates obtained through the analysis of the tree-ring series to stochastic (statistical) models that generate the future likelihoods of selected precipitation regimes or temperature patterns.

The reconstruction of past climates through cross-dating analysis extends the climatic record



for a regime much further into the past compared with on-site instrumental measurements, which are often limited to less than 100 years. Consequently, a more reliable depiction of the nature of climates is available for projection into the future. The impacts of future long-term climatic changes on landscape features and the people living on these landscapes can be assessed and, when necessary and feasible, appropriate actions taken in the planning process to mitigate undesirable consequences and attain desirable outcomes.

With the availability of high-speed computing systems and improved spatial analysis through geographic information systems and other innovations, dendrochronology has often become an increasingly important tool in investigations of landscape geography. One measure of the contributions of dendrochronology to geography is supplied by the International Tree-Ring Data Bank's online database of dendrochronologists (<http://web.utk.edu/~grissino>). This Web site lists dendrochronologists at 64 academic and research institutions in 20 countries worldwide with "geography" in their name. Dendrochronology sessions are also common at the annual meetings of the Association of American Geographers.

Ramzi Touchan and Peter F. Ffolliott

Further Readings

- Hays, J. D., Imbrie, J., & Shackleton, N. J. (1976). Variations in the Earth's orbit: Pacemaker of the ice ages. *Science*, 194(4270), 1121–1132.
- Huntington, E. (1912). The secret of the big trees. *Harper's*, 125, 292–302.
- Lamb, H. (1972). *Climate: Present, past and future*. Vol. 1. *Fundamentals and climate now*. London: Methuen.
- Stokes, M., & Smiley, T. (1968). *An introduction to tree-ring dating*. Chicago: University of Chicago Press.

global system. Dependency theory is a response to the earlier modernization theory and its failure to generate economic growth in Latin America in the 1950s and 1960s. Whereas modernization theory was the brainchild of thinkers in core countries, that is, the economically developed world, dependency theory was the product of intellectuals in the world periphery or less developed countries disillusioned by the idea of modernization. Instead of arguing that poor countries are simply further behind richer countries in terms of development, dependency theorists argued that poorer countries are exploited by richer, developed countries, or, more pointedly, that the development of European and other Western countries depended on the underdevelopment of non-Western countries. In this framework, poorer regions such as Latin America are peripheral to the capitalist industrial core, or the rich, developed countries of Europe and North America. Dependency theory was important in opening the door within geography and in other social sciences to discussions around the social construction of poverty.

The roots of dependency theory lie in the work of the United Nations Economic Commission for Latin America (ECLA) in the 1960s, under the direction of Argentinean Raúl Prebisch. Prebisch, in his "ECLA Manifesto," criticized the international division of labor, in which Latin America provided food crops and raw materials for the industrial core and received finished goods in return. In his opinion, the continuation of this relationship would inhibit Latin America's process of capital accumulation because of the unbalanced terms of trade. Prebisch proposed instead that Latin America industrialize, which would require protectionism and a heavy role on the part of governments. The ECLA's proposal was not received well by Latin American governments and indeed was overly optimistic in assuming that industrialization would solve all the problems of development in the region.

The ideas planted in the ECLA then emerged in more radical forms in the late 1960s and 1970s from two main sources. In the United States, socialist writers such as Paul Baran of the leftist journal *Monthly Review* argued that developing economies were kept in stagnant positions by monopolistic corporations that controlled competition and profits and that the only way to achieve true development was to exit the global



DEPENDENCY THEORY

Dependency theory falls within a group of neo-Marxist theories that attempt to explain development, underdevelopment, and inequalities in the



capitalist system of monopolies and build society and economies on a socialist base. In Latin America, a group of radically critical intellectuals, including Fernando Cardoso, Enzo Falleto, and Celso Furtado, known as *dependistas*, developed a more radically critical set of theories of dependence that held that the rich countries' development was the result of the destruction of poor countries' social and economic systems through forced integration into the global capitalist economy and thus a changing of their previously viable institutions. This was a parting from the original idea of underdevelopment, which was conceived by core modernist thinkers as the state of being in the periphery before core intervention, that is, the problem to be solved by development. In the *dependistas'* thinking, underdevelopment is not an original condition but an active process.

André Gunder Frank was instrumental in bringing the ideas of dependency theory to young North American intellectuals, who were in the midst of an era of protest and social rebellion at the time, as well as presenting dependency theory as a critique of modernization, which offers an internal explanation for underdevelopment, that is, that there is something inherently wrong with the culture, for example, of underdeveloped countries that keeps them from developing. Frank coined the term *the development of underdevelopment* to describe the process of underdevelopment. He argued that Latin American countries had been involved in a chain of dependence since colonial times, a phenomenon that core countries had never experienced; thus underdevelopment cannot be explained by modernization theory. Frank and other *dependistas* instead argued that colonialism was a forced changing of institutions, society, culture, and economy.

According to dependency theory, exploitation extended from the global to the individual scale. Thus, landless workers and peasant tenants were exploited by landowners who bought their goods cheaply, who then sold the goods to merchants for a profit, the chain continuing until the goods were exported to the core. Thus, the development of dependence and the development of underdevelopment are interdependent. The point is that the continuous chain of exploitation from core to periphery created a situation of developed and underdeveloped, one necessitated by the other,

and was seen by *dependistas* as key to understanding the social construction of poverty. Dependency also restricted the social and political development of places marginalized by their relationship to the core, a situation that was further aggravated by the forces of the unfettered market, which tend to exacerbate socioeconomic inequalities.

Theotonio Dos Santos further developed dependency theory by distinguishing between three forms of historical dependence. Colonial dependence was the original form of dependence, in which the colonial or core power dominated and benefited from the extraction of raw materials and human resources from the colonized country. This form of dependence transitioned in the latter part of the 19th century to financial-industrial dependence, which was based on a system of specialized export of food products, as well as other sectors that depended on the export sector. The third historical form of dependence is technological-industrial dependence, which emerged after World War II. Dos Santos argued that the development of the industrial sector in the periphery was grossly restricted by its dependence on the export sector and an unequal balance of payments due to industry's dependence on imported necessary synthetic materials.

Solutions to the problem of dependency are restricted by the ideas of dependency themselves. Harold Brookfield has argued that the core itself depends on the periphery for labor, markets, and natural resources for its own continued state of development and that therefore it becomes increasingly difficult to distinguish who depends on whom. Within the school of dependency theory, opinions differed as to the solutions to the problem of dependence. Some argued that reform of the global capitalist system with state intervention would be sufficient. Frank and other *dependistas* took a more determinist position and argued that development of exploited regions such as Latin America was more likely to take place during periods of less integration in the global capitalist economy, such as during World War II. This tendency argued that only the overthrow of the capitalist system would truly solve the problem of capitalist exploitation of underdeveloped regions.

Dependency theory was especially important because it came from the experiences of the non-Western world and broke the dominance of



Western voices in development theory; however, its relevancy as well as its applicability to policy has been heavily challenged. First, its assertion that peripheral countries cannot develop in the context of the global capitalist system was weakened by the spectacular growth of East Asian countries. Another critique of the dependency school is that it does not sufficiently include social or political contexts in its analysis, instead laying all the weight of causality on economic factors. A lack of attention to the social or cultural contexts of dependence signifies that dependence is only a material relationship when it is in fact social. This marks dependency theory's limitations as an applicable theory of underdevelopment and poverty as well as a source of policy solutions to poverty.

Heather R. Putnam

See also **Developing World; Development Theory; Globalization; Industrialization; Modernization Theory; World-Systems Theory**

Further Readings

- Cardoso, F., & Faletto, E. (1979). *Dependency and development in Latin America*. Berkeley: University of California Press.
- Celso, F. (1976). *Economic development in Latin America*. Cambridge, UK: Cambridge University Press.
- Chew, S., & Denmark, R. (Eds.). (1996). *The underdevelopment of development: Essays in honor of Andre Gunder Frank*. Thousand Oaks, CA: Sage.
- Frank, A. (1969). *Capitalism and underdevelopment in Latin America*. New York: Monthly Review Press.



DERECHOS

Straight-line winds associated with convective weather activity cause property and crop damage and loss of life each year, comparable with tornado losses. A derecho is such a strong linear wind that is not tornadic, with wind speeds in

excess of 26 m/s (meters per second) (58 mph [miles per hour]). The term *plow wind* applies in the Canadian vernacular. The name, coined by University of Iowa physicist G. Hinrichs in 1888, derives from a Spanish word meaning "direct" or "straight ahead."

Derecho winds generated convectively from a downburst cluster forms a *progressive* derecho (major axis of effects less than 400 km [kilometers]; 250 miles), whereas, on a larger scale a group of downburst clusters produces a *serial* derecho (damage axis more than 400 km). Derechos tend to blast in linear paths fanning out along singular or multiple curved-wind fronts, known as *bow echos*, over a wide swath of land. Their duration and spatial dimensions provide data for identification.

The danger stems from the potentially large areas affected by the highly variable derecho winds. And derechos are associated with unstable bow echo systems that migrate rapidly, sometimes exceeding 50 mph or more in speed, making prediction difficult and forecasts uncertain. People can be overtaken by such a system with little warning.

Regarding their climatology, derechos can occur in any month but peak in May through July and form principally east of the 100th meridian in North America. Derechos pose distinct hazards to summer outdoor activities by swamping boats, throwing flying objects, and breaking trees and limbs. Typically, there are warm-season and cool-season patterns. May to August finds them in the region stretching from Southern Wisconsin across Illinois, Indiana, and Western Ohio in the upper Midwest and in a region of Oklahoma, adjoining Kansas and Missouri. This accounts for nearly 70% of occurrences.

From September through April, areas of activity migrate southward to Eastern Texas through Alabama, extending along the lower Mississippi Valley to the Ohio River and Southern Indiana. The causative association for this cool season is with migratory low-pressure systems. Derechos have been reported elsewhere in the world; however, data are lacking for specific assessment.

As an example, the speed of a derecho in 1998 in Eastern Wisconsin exceeded 57 m/s (128 mph): Overall, some 139 counties in nine states were affected in related storms. In August 2007, a



series of derechos across Northern Illinois reached this same intensity. Researchers, such as Walter Ashley, identified 377 events in the United States between 1986 and 2003, with 153 deaths and more than 2,600 injuries—an average of about 21 derechos per year.

Robert W. Christopherson

See also **Temperature Patterns; Tornadoes; Weather and Climate Controls; Wind**

Further Readings

- Ashley, W., & Mote, T. (2005). Derecho hazards in the United States. *Bulletin of the American Meteorological Society*, 86, 1577–1592.
- Bentley, M., & Mote, T. (1998). A climatology of derecho-producing mesoscale convective systems in the Central and Eastern United States, 1986–95. *Bulletin of the American Meteorological Society*, 79, 2527–2540.
- Johns, R., & Hirt, W. (1987, March). Derechos: Widespread convectively induced windstorms. *Weather and Forecasting*, 2, 32–49.



DESERTIFICATION

Desertification is a contentious term, most commonly referring to human- and climate-induced changes to dryland regions of the world resulting in a loss of their biological and economic potential. Much debate surrounds the degree to which this change is human or climate induced and whether or not the process is irreversible. Despite this contention, desertification is a significant environmental problem that has been the subject of two United Nations (UN) conventions (treaties) and scholarly attention of both physical and human geographers.

Desertification occurs when human action, frequently accompanied by less than favorable climatic trends, conspires to reduce the productive potential of land in arid, semi-arid, and dry subhumid areas of the world. Desertification occurs neither in true deserts (as it is sometimes mistakenly believed) nor in more humid environments.

Desertification encompasses a wide array of anthropomorphic forms of soil degradation in dryland areas, which are often aided and abetted by lower-than-average rainfall in certain climatic cycles. These forms of degradation include soil acidification, compacting, crusting, erosion, nutrient depletion, and salinization, as well as the impoverization of surface biomass and diversity. Such degradation is often brought on by deleterious modern and traditional crop farming practices (such as the indiscriminate use of mineral fertilizers, overly aggressive tillage, poor ground cover in the off season, and insufficient organic amendments); poor pasture management for livestock; and unsustainable forestry practices, mining, and maladapted irrigation practices (such as excessive diversion or flood irrigation without proper drainage) leading to destruction of natural floodplains or salinization.

Geographic Occurrence

Arid, semi-arid, and dry subhumid regions receiving less than 800 millimeters of rainfall annually are susceptible to desertification. With their variable rainfall, skeletal soils and scant vegetation, these drylands are more susceptible than are other areas to wind and water erosion. More than one-third of Earth's surface is considered dryland, including the Sahel, stretching across Africa south of the Sahara; parts of Southern and Northern Africa; much of Australia; Central Asia and parts of China; much of the Middle East and the Mediterranean; Southern South America, including the Patagonia region; and the North American West. Many of these areas are on the edges of deserts, such as the Sahara, the Gobi, and the Negev. It is important to keep in mind that desertification does not mean that the desert is expanding and eating up arable land, as the name implies, but that land has been (permanently) degraded and can no longer support productive vegetation. This degradation occurs in patches at the local level.

Although international bodies such as the United Nations wholly accept the reality of desertification and are committed to mitigating its effects, many researchers are not convinced that there is evidence of this widespread degradation. Desertification is difficult to measure, and it is hard to determine whether degradation is due to climate change,



Ma Wangzhen walks through her onion farm on the edge of the ancient Chinese city of Dunhuang in Gansu province (October 25, 2007). As a result of desertification in Gansu province along the historic Silk Road, Dunhuang is in danger of being swallowed by the sands of the adjacent Kumtag desert, which are creeping closer at a rate of up to 4 meters (13 feet) a year.

Source: Peter Parks/AFP/Getty Images; used by permission.

human action, or a combination of the two. Furthermore, many scientists caution that geographical and temporal scale must be taken into account. Degradation thus may occur in some locations, but in other locations land that is considered degraded actually is recovering. These differing assumptions about the extent and severity of desertification worldwide inherently lead to very different ideas about how to combat it.

Causes of Desertification: Human Versus Biophysical

The causes of desertification are complex and interrelated, making it difficult to cite one single factor as its ultimate cause. Researchers generally fit into one of two groups: those who see human impacts as the drivers of land degradation follow

the equilibrium approach, while those who see random biophysical processes as the main factors use the nonequilibrium approach. Human activities said to degrade marginal land include overgrazing, deforestation, salinization of soils due to inappropriate irrigation, and farming techniques such as field burning. Farmers with small landholdings stereotypically are seen as investing too little in soil fertility, while overgrazing is viewed to be the result of a “tragedy of the commons” effect. Industrial agriculture also puts stress on the land, particularly through the use of tractors and reliance on chemical fertilizers as opposed to biological soil fertility.

Biophysical factors influencing land degradation include rainfall, vegetation, wind and water erosion, albedo (the proportion of sunlight that is reflected back into the atmosphere rather than absorbed by the soil), slope, evapotranspiration,



and soil moisture. These biophysical factors influence each other through complex feedback loops. For example, lightly vegetated land is more susceptible to degradation through wind and rain erosion, which decreases soil moisture and in turn decreases vegetation. The fact that desertification occurs across cultures and on every continent on Earth, with the exception of Antarctica, lends credence to the importance of biophysical factors as underlying causes of desertification. As global climate change progresses, these factors will potentially gain even more importance as temperatures rise and rainfall patterns change.

Desertification Around the World

More than 40% of Earth's surface is covered by drylands susceptible to desertification. Combined, these regions have a population of more than 250 million people. Each region faces unique challenges stemming from the complex interactions between people and their environments. Farmers practicing slash-and-burn agriculture in mountainous countries such as Honduras and Nicaragua, for example, face different challenges from those faced by peasants in remote oasis regions of China experiencing sand dune encroachment. On the other hand, many dryland dwellers worldwide are similar in that they tend to live in relatively sparsely populated, remote parts of the country, often distant from government. Affected populations differ greatly in their vulnerability to desertification, depending on the country's level of development and dependence on subsistence agriculture.

While susceptibility to desertification is widespread throughout the world, Africa receives the most attention from both the scientific and the aid communities as its peoples are thought to be the most vulnerable and its lands the most degraded. The North American West may be at risk of widespread land degradation, but its inhabitants are not particularly vulnerable because the region's economy is not based primarily on subsistence agriculture. Poor populations dependent on the land for farming and grazing, however, risk decreasing incomes and famine if their land becomes degraded. According to the conventional view, these populations are

driven to farm or graze more intensively as soil fertility decreases to maintain yields, further degrading the land and leading to a vicious cycle where poverty and environmental degradation reinforce each other. If the land becomes so degraded as to no longer support vegetation, these populations have no recourse but to leave in search of less degraded land. Often, displaced populations end up on marginal lands on the outer fringes of urbanizing areas, where their subsistence activities once again degrade the land. Desertification thus increases pressure on the land, leaving poor populations increasingly susceptible to drought-induced famine and conflicts over land. This limited and conventional view of the impacts and causes of desertification has been widely critiqued by human geographers. Moreover, the conventional wisdom may shift as global climate change threatens prosperous industries in the developed world, such as the Australian wine industry, or leads to increased tensions in areas such as the Middle East as water sources dry up. Furthermore, changing climates may affect yields of staple grains produced in traditional bread baskets such as the North American Great Plains, while increasing demand for meat and ethanol worldwide decreases the amount of arable land used for grain production, driving up food prices and increasing global hunger.

Evolving Understandings of Desertification

While scientists and commentators have been writing about desertification for centuries, the concept first grabbed significant global attention during the Dust Bowl phenomenon of the 1930s and 1940s in the United States. Here, human mismanagement coupled with a prolonged drought led to widespread aeolian erosion, and devastation of many farming communities, on the Great Plains. While the proximate causes of this crisis were, in part, related to maladapted farming practices, subsequent scholarship has implicated agrarian capitalism in the United States.

Desertification again attracted worldwide attention in the 1970s and 1980s following major droughts in the Sahelian grasslands south of the Sahara Desert. During this period of below-normal



rainfall there was considerable concern that the Sahara Desert was expanding southward as the Sahel was desertified. While it was acknowledged that below-average rainfall was contributing to desertification of grasslands in this region, much of the blame was attributed to human causes such as overgrazing, population growth, and destructive crop farming practices. Subsequent scholarship revisited conventional understandings of desertification in the Sahel, leading to a series of reinterpretations of this process. First, there was a general acknowledgment that the role of local natural resources management as a contributor to Sahelian desertification during the 1970s and 1980s had probably been overestimated. Second, along with a greater recognition of fluctuating climatic variables (mainly rainfall) as the major drivers behind desertification, there was a greater appreciation of how resilient some forms of dryland vegetation could be when the rains eventually did return. Third, the recognition that the desertification process had been misunderstood in the Sahel, especially the role of local people, led several human geographers, and those in allied fields such as anthropology and environmental history, to examine the term's past, from the colonial era to the present. This line of inquiry dovetailed with a broader postmodern movement that took great interest in the social construction of nature.

With regard to the specific history of the term *desertification* in the Sahel, both British and French scientists were concerned about desertification during the colonial era (and were influenced by the literature on the U.S. Dust Bowl). While some colonial era scientists attempted to apply scientific methods rigorously to understanding African environments (by, e.g., carrying out a range of applied and basic research projects to developing a savanna ecology model for the region), this science suffered from several problems. In many cases, European understandings of desertification in Africa were based on ecological models derived from temperate climates; an underlying belief that Africans employed backward or primitive natural resource management practices; the use of findings from very localized and short-term studies to explain broadscale environmental changes; and an unwillingness to incorporate local understanding of environmental

processes into research and policy agendas. Explaining why these misunderstandings of desertification persisted over time has also been the subject of much scholarship. In the case of African governmental agencies and nongovernmental organizations, these entities had an incentive to perpetuate crisis understandings of desertification as they often resulted in more funding. Certain scientists and consultants also had a motivation to reinforce such beliefs if it meant future contractual assignments.

Combating Desertification

Following the Sahelian drought and famine in the late 1960s and early 1970s, the world awareness of desertification reached a peak. In 1977, the UN convened in Nairobi for a conference on desertification. The conference cited human factors such as overgrazing and destructive farming techniques, based on the assumption that underdevelopment and environmental degradation reinforce each other, the conference developed a plan of action to be implemented by national governments in affected countries. Recommended actions to combat desertification included the development of land use plans, awareness campaigns, and revegetation initiatives. Local people were called on to use their land and water resources more efficiently by improving rangeland and farmland management. Recommendations also included measures to improve rural development with the aim of increasing education and access to health care and decreasing rural-to-urban migration. The belief was that if desertification was not reversed, up to one third of agricultural land would be lost and food production would not be able to meet the demands of a rapidly growing world population.

By the time of the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, the scientific community believed that desertification and degradation had only intensified over the past 15 years (although the Conference on Desertification's dire predictions had not become reality). The UN thus initiated the Convention to Combat Desertification in 1994 with the aim of reinvigorating antidesertification efforts and paving the way for sustainable



development. The convention currently meets biennially and is implemented through national action plans administered by each signatory country. As of 2008, this convention had been ratified by 193 countries. Actions taken under these plans, such as those following the 1977 conference, include measures to combat soil erosion, reforestation campaigns, and efforts to reduce the incidence of bush fires. These measures are to be taken in conjunction with efforts to increase human development. Tools proposed by geographers include practicing local environmental knowledge to meet the unique demands of each community facing land degradation.

William G. Moseley and Erika S. Jermé

See also Biome: Desert; Environmental Discourse; Nomadic Herding; Population and Land Degradation; Soil Degradation; Soil Erosion; United Nations Environment Programme (UNEP); Vulnerability, Risks, and Hazards; Xeriscaping

Further Readings

- Hermann, S., Anyamba, A., & Tucker, C. (2005). Recent trends in vegetation dynamics in the African Sahel and their relationship to climate. *Global Environmental Change*, 15, 394–404.
- Mortimore, M., & Turner, B. L. (2005). Does the Sahelian smallholder's management of woodland, farm trees, rangeland support the hypothesis of human-induced desertification? *Journal of Arid Environments*, 63, 567–595.
- Thomas, D. (1993). Sandstorm in a teacup: Understanding desertification. *Geographical Journal*, 159, 318–331.
- United Nations Convention to Combat Desertification. (1994). *Elaboration of an international convention to combat desertification in countries experiencing serious drought and/or desertification, particularly in Africa* (U.N. Doc. A/AC.241/27, 33 I.L.M.1328, United Nations). Geneva: Author.
- Wang, X. M., Chen, F. H., & Dong, Z. B. (2006). The relative role of climatic and human factors in desertification in semiarid China. *Global Environmental Change*, 16, 48–57.



DESERT VARNISH

Desert varnish is but one of more than a dozen rock coatings (Table 1) that drastically alter the appearance of rock surfaces. The better term is *rock varnish* because this coating occurs in virtually all environments, including alpine, antarctic, arctic, desert, periglacial, stream, temperate, and tropical settings. This paper-thin accretion is characterized by extremely high concentrations, typically more than 10%, of manganese oxides that give it a characteristic black to dark brown appearance. Clay minerals, however, make up the bulk of rock varnish along with iron oxides.

There are four general explanations for how rock varnish accretes on top of rock surfaces, but all these models reject the old idea that the constituents of varnish derive from the underlying rock. The model that has not yet been falsified is the polygenetic model of rock varnish formation (see first series of photos). This explanation combines bacterial enhancement of manganese and iron with abiotic fixation of the manganese by clay minerals. The process starts with bacteria fixing manganese on cell walls. Wetting events dissolve manganese. The desert dust supplies interstratified clay minerals, and the dissolved manganese reprecipitates as nanometer-sized fragments of manganese oxides. These tiny minerals fit into the weathered edges of clays, tightly cementing clays to the rock surface. The effect is a highly layered texture at the micrometer and nanometer scales imposed both by the clay minerals and the cementing manganese-oxides.

The most exciting development in varnish research in the past several decades is the development of varnish microlaminations (VMLs). This tool is based on 12 years of detailed analyses of more than 10,000 microsedimentary basins by Tanzhuo Liu (www.vmldatinglab.com). Working in the deserts of Western North America, Liu found that black varnish layers correspond with wet events and developed calibrations for the late Quaternary and a separate calibration for the Holocene. The second photo illustrates just one rock varnish VML sequence from Death Valley, California, formed over the past 20,000 years.



<i>Coating</i>	<i>Description</i>	<i>Related Terms</i>
Carbonate skin	Composed primarily of carbonate, usually calcium carbonate (CaCO_3) but sometimes magnesium carbonate (MgCO_3)	Calcrete, travertine
Case hardening	Addition of cementing agent to rock matrix material; the agent may be manganese, sulfate, carbonate, silica, iron, oxalate, organisms, or anthropogenic	Sometimes called a particular type of rock coating
Dust film	Light powder of clay- and silt-sized particles attached to rough surfaces and in rock fractures	Clay skins, clay films, soiling
Heavy-metal skins	Coatings of iron, manganese, copper, zinc, nickel, mercury, lead, and other heavy metals on rocks in natural and human-altered settings	Sometimes described by chemical composition
Iron film	Composed primarily of iron oxides or oxyhydroxides; unlike orange rock varnish because it does not have clay as a major constituent	Ferric oxide red staining, iron staining
Lithobiontic coatings	Organisms forming rock coatings, for example, lichens, moss, fungi, cyanobacteria, algae	Organic mat, biofilms, biotic crust
Nitrate crust	Potassium and calcium nitrate coatings on rocks, often in caves and rock shelters in limestone areas	Saltpeter, niter, icing
Oxalate crust	Mostly calcium oxalate and silica with variable concentrations of magnesium, aluminum, potassium, phosphorus, sulfur, barium, and manganese; often found forming near or with lichens	Oxalate patina, lichen-produced crusts, patina, scialbatura
Phosphate skin	Various phosphate minerals (e.g., iron phosphates or apatite) sometimes mixed with clays and sometimes manganese	Organophosphate film, epilithic biofilm
Pigment	Human-manufactured material placed on rock surfaces by people	Pictograph, paint
Rock varnish	Clay minerals, manganese (Mn) and iron (Fe) oxides, and minor and trace elements; color ranges from orange to black, produced by variable concentrations of different manganese and iron oxides	Desert varnish, patina, Wüstenlack
Salt crust	Chloride precipitates formed on rock surfaces	Halite crust, efflorescence
Silica glaze	Usually clear white to orange shiny luster but can be darker in appearance; composed primarily of amorphous silica and aluminum but often with iron	Desert glaze, turtle-skin patina, siliceous crusts, silica-alumina coating, silica skins
Sulfate crust	Sulfates (e.g., barite, gypsum) on rocks; not gypsum crusts that are sedimentary deposits	Sulfate skin

Table 1 Major categories of rock coatings

Source: Author.

Liu and other researchers in different settings are in the process of developing calibrations for other regions of the world. Although there are other dating methods that have been proposed for varnish, VML is the only method that has gone beyond the experimental stage.

Subject to successful blind testing, the great power of this method is that it is now possible to determine the minimum age of exposure of the underlying rock surface. Liu and other researchers have applied VML to dating features such as alluvial fans, meteorite impact



**Mn and Fe
concentrated
on bacteria**

↓

**Mn encrusts
bacteria in form
of nm-scale
granules**

↓

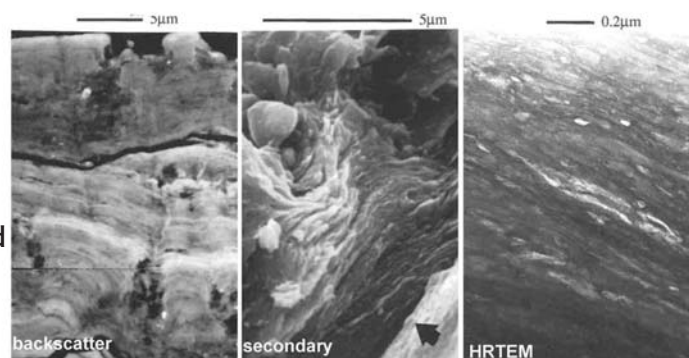
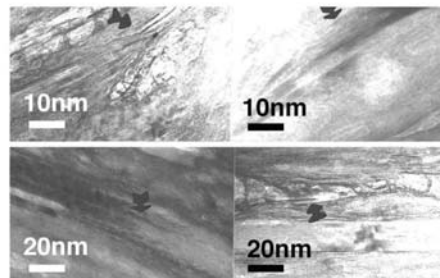
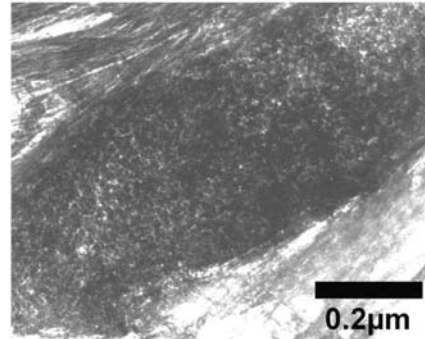
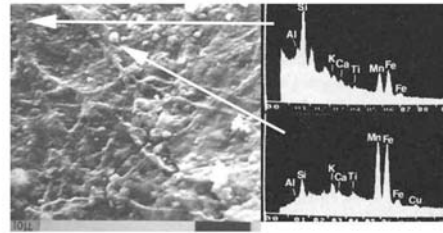
**Mn mobilized
from cell walls**

↓

**Mn moves a
few nm to
cement clays**

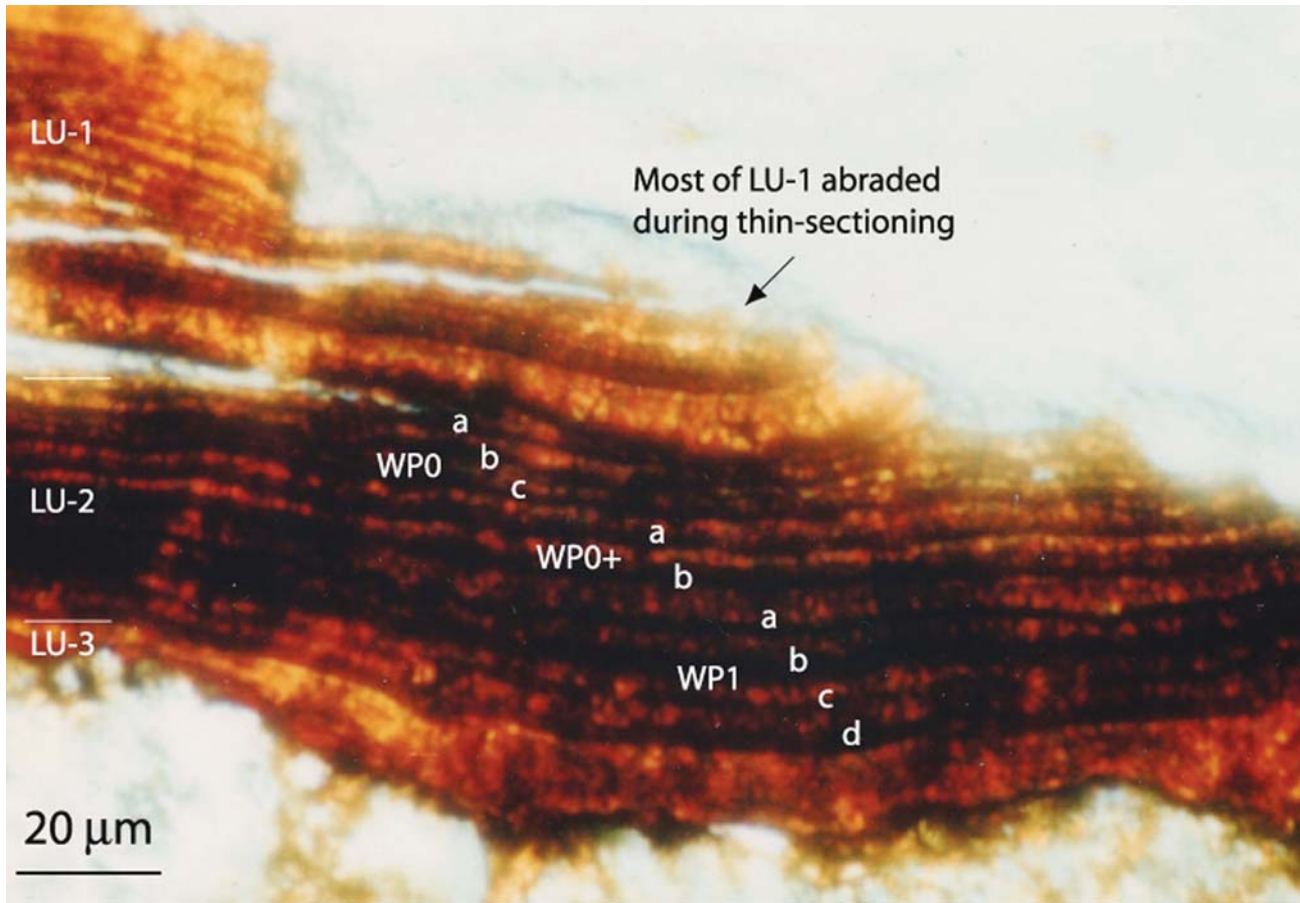
↓

**Mn-Fe
& clay
minerals
in layered
structure**



Varnish formation starts with bacteria that concentrate manganese (Mn) and iron (Fe), as revealed by electron microscope observations. Then, using a high resolution transmission electron microscope, it is possible to see how the manganese moves from the bacteria and into weaknesses in the clay minerals that fall onto desert rock surfaces. The manganese and iron then fit into the clay structure in a way that cements everything together onto rock surfaces. Thus, rock varnish is analogous to a brick wall, where the bricklike clays are cemented by the mortarlike oxides.

Source: Author.



This ultrathin section of rock varnish from Death Valley, California, records wet periods in the form of black layers. The black layers in LU-1 formed during the past 12,000 years during the Holocene. The black layers in WP0, WP0 +, and WP1 accreted during the very end of the Pleistocene from about 18,000 to 12,000 calendar years ago. The oldest layer, LU-3, formed about 20,000 years ago.

Source: Reprinted by permission of Tanzhuo Liu from www.vmldatinglab.com.

craters, faulting events, landslides, stone artifacts, and ancient petroglyphs.

Ronald I. Dorn

See also **Biome: Desert**

Further Readings

- Dorn, R. (1998). *Rock coatings*. Amsterdam: Elsevier.
 Liu, T., & Broecker, W. (2008). Rock varnish microlamination dating of late Quaternary geomorphic features in the drylands of Western USA. *Geomorphology*, 93, 501–523.



DETERRITORIALIZATION AND RETERRITORIALIZATION

Deterritorialization and reterritorialization processes are spatial manifestations of contemporary changes under way in the relationship between social life and its territorial moorings. The two terms were originally employed in the 1970s in the work of French theorists Gilles Deleuze and Felix Guattari, who are often associated with poststructuralism and postmodernism. Using insights from philosophy and psychoanalysis, Deleuze and Guattari developed a sophisticated understanding of capitalism, power, and identity,



which are locked in a fluid process of territorialization, deterritorialization, and reterritorialization of social structures and processes. These terms have subsequently been adopted by the social sciences and humanities, that is, geography, anthropology, international relations, linguistics, and others.

Deterritorialization has often been associated with globalization. The bonds that tied economics, politics, and culture to fixed spatial configurations such as national territories are loosened under globalization pressures. Globalization flows, suggesting mobility, are perceived as replacing the space of places, suggesting territorial fixity. In a broader interpretation, deterritorialization processes indicate a decrease in the significance of territory for social life, which is thus an unraveling of territoriality as it has been constructed during the modern era. It appears that a primarily networked organization of spatial power is replacing a primarily territorial organization of spatial power. Specifically, deterritorialization processes take aim at the global system of sovereign nation-states and their boundaries that has dominated the territorial organization of power during the modern era. Nation-states are devolving powers on two main geographical scales: upward to the supranational bodies such as the European Union, NAFTA, and the International Monetary Fund; and downward to subnational institutions such as regional governments, local councils, and development agencies. These developments are unseating the traditional role of the nation-state as the territorial container of social relations and opening up novel possibilities for the spatial organization of social relations.

From a political economy perspective, deterritorialization processes are understood in terms of the spatial dimensions of successive rounds of capital accumulation. If the previous strategies of capital accumulation largely took place at the scale of the national markets, the current ones favor global markets. Financial markets, in particular, are among the most dynamic global markets. Financial flows circle the globe at unprecedented speeds via digital telecommunications networks, unsettling national control over the economy and making national boundaries appear archaic. Manufacturing is outsourcing

jobs from the developed to the developing economies as part of a strategy to compete in global scale markets. At the same time, numerous firms have adopted truly global production models that involve an integrated network of places.

Geopolitically, with the end of the Cold War the world political map has registered dramatic developments that have dismantled the geography of power that once appeared unshakable. Sovereign states have fragmented, while new ones have appeared on the map. The lines between the domestic and the foreign spheres of politics have blurred as national governments face increasing difficulties in managing crisis situations that often acquire transnational dimensions.

Cultural and social issues are increasingly playing out in the global arena rather than simply within nation-state borders. Globalization-induced migration flows and information technologies have created transnational networks of diasporic communities and have reinvigorated local and regional identities that are now enacted globally. Numerous governmental social policies and executive functions have been privatized, indicating a spatial shift from hierarchical government to networked governance.

Deterritorialization processes have raised critical questions regarding the spatiality of social relations under globalization. Some authors have interpreted deterritorialization as the “end of geography” and the emergence of a border-less world, in the sense that territory and territoriality will be of little consequence to social life in the future. In this view, deterritorialization appears as a transcendental phenomenon leading an unstoppable march to “a-territorial” social relations. Such a unidirectional understanding of globalization has poor explanatory power for the complex territorial changes contemporary society faces.

Evidence suggests that there is a reterritorialization of economic and political activity that transcends the spatial framework of the nation-state system. Reterritorialization processes are generally understood as the restructuring of territorial forms of organization of social relations, such as the nation-state. This implies the uncoupling of the exclusive links between state sovereignty and territory and the emergence of new territorial configurations beyond the scope and the scale of the



nation-state. Globalization has not led to ceaseless deterritorialization but has created conditions for the spatial reconfiguration and rebordering of social relations. Geography has not ended, and the world has not become border-less. Rather, geography is being reorganized, and borders are acquiring new significance.

The global reach that the sovereign state system has achieved means that globalization flows have to necessarily engage with territorial actors such as nation-states. Moreover, networked globalization flows do touch down in various geographical places, such as global cities and resource rich regions that serve as network anchors, resulting in an archipelago-like geography. National borders may do little to control financial flows, but nation-states do play a role in regulating global financial markets. Digital information technologies may have the power to undermine a government's monopoly over information, but the Chinese government has managed to regulate domestic Internet content. Since the end of the Cold War, the world political map has seen the emergence of new geopolitical actors such as the European Union, China, and other smaller regional powers, indicating the persistence of territorial power politics. Transfer of state powers to sub- and supranational levels does not necessarily mean the end of state sovereignty. Instead, it can signal the emergence of a new architecture of political territoriality with multiscalar and overlapping sovereignties. Some identities may be enacted at a global scale, but the emergence of new ethnic and territorial identities points to the salience of the nation-state as a territorial framework for social life.

The emerging picture of the current moment of globalization suggests that territoriality as a principle of organization of social relations is far from disappearing. The territorial nation-state, in its quest to remain relevant in the 21st century, plays an active role in the twin processes of deterritorialization and reterritorialization. States lose some powers but also gain new ones. They are not fading away, but they reinvent themselves and share some of their power with nonstate structures of territorial power such as global cities, supranational organizations, and subnational regions.

Deterritorialization and reterritorialization are best understood as processes that unfold

simultaneously. Geographically, some spaces can experience deterritorialization, while others may experience reterritorialization. Social relations do not completely lose their territorial grounding and their boundaries before they reterritorialize. Rather, social relations acquire other territorial configurations and boundaries even as they lose the previous ones. This means that the new territoriality of social relations, while being qualitatively different, will include vestiges of the old one.

Gabriel Popescu

See also **Borders and Boundaries; Globalization; Nation; Sovereignty; State; Territory; Transnationalism**

Further Readings

- Brenner, N. (1999). Globalisation as reterritorialisation: The re-scaling of urban governance in the European Union. *Urban Studies*, 36, 431–451.
- Ó Tuathail, G. (1999). Borderless worlds? Problematising discourses of deterritorialization. *Geopolitics*, 4, 139–154.
- Ó Tuathail, G., & Luke, T. (1994). Present at the (dis)integration: Deterritorialization and reterritorialization in the new wor(l)d order. *Annals of the Association of American Geographers*, 84, 381–398.



DEVELOPING WORLD

The developing world comprises a vast set of heterogeneous societies that includes the bulk of the world's population. The distinction between “developed” and “underdeveloped” is usually made in economic terms. The gross domestic product (GDP) per capita and level of industrialization are the key indicators used to define a country's level of development. Many factors influence this variable, including a country's colonial legacy, government policies toward trade and investment, resource endowments, and levels of human capital, including literacy. One dimension

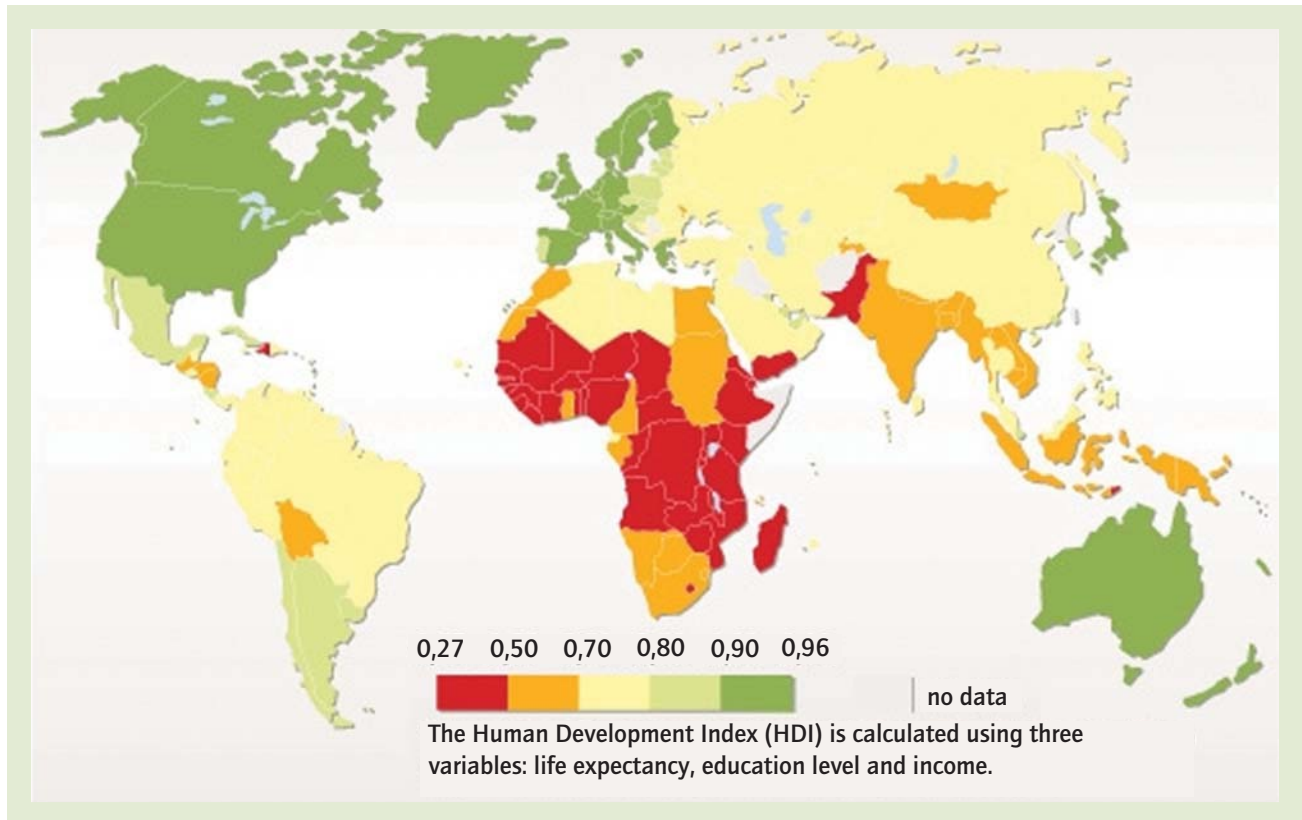


Figure 1 The developing world: United Nations Human Development Index in 2002

Source: Rekacewicz, P. (2004). *Human Development Index (HDI) in 2002* (UNEP/GRID-Arendal Maps and Graphics Library). Retrieved October 28, 2009, from <http://maps.grida.no/go/graphic/human-development-index-hdi-in-2002>. Copyright © 2008 UNEP/GRID-Arendal.

often overlooked is the role of geography. Factors regarding the physical, political, and human geography of a region are normally not considered among economists when looking at the potential development of certain regions of the world. This entry seeks to connect the physical geography of a given country and its challenges for economic development.

It is unrealistic and naïve to think that all countries in the world will develop in the same linear fashion as those in North America, Western Europe, and the Pacific Rim. The geography of many countries is too diverse and in many cases a limiting factor for them to take the same trajectory of development. Financial power centers fail to consider some of those limiting factors. However, countries are not forever relegated to living in poverty. Rather, they need to take different roads toward “developing” that take into consideration their unique geographical conditions.

Consideration will be given to the “3 Ds” that challenge developing countries: disease, drought, and distance to world markets. These are key geographical factors to consider when determining the developmental track of a “developing” country (see Figure 1).

If one were to look at a world map and label all the countries that could be considered “developed” as opposed to “developing,” the vast majority of the developed countries lie north of the Tropic of Cancer ($23\frac{1}{2}^{\circ}$ N). This area includes North America, Western Europe, Eastern Europe, South Asia, and East Asia. The developing world also includes the continents or regions of South America, Africa, and southeast Asia. Although there are obvious exceptions to this generalization, the trend is a significant one.

There are two significant reasons for the relevance of the Tropic of Cancer. First, the tropics lie between this latitude and the Tropic of



Capricorn, at $23\frac{1}{2}^{\circ}$ S. In this area, there are unique geographic factors generally not found outside the tropical zone that challenge the developmental trajectory that individual countries are able to take. Second, there are very few landmasses south of the Tropic of Capricorn in the temperate zone of the Southern Hemisphere. Much more land lies in the temperate Northern Hemisphere: There is simply more temperate land in the north.

A number of features of the physical geography of a given country present obstacles to economic development. Natural hazards, including flooding, droughts, earthquakes, volcanoes, storms, hurricanes, diseases, illnesses, and pests can all undermine economic development. Large natural disasters can set countries back greatly in their economic development, as in the periodic flooding of Bangladesh. Volcanoes and floods can often have both positive and negative effects as they bring in fertile sediment. Areas around volcanoes and flooding deltas are often heavily populated, as in Egypt, Bangladesh, and Indonesia. Diseases such as malaria that thrive in tropical climates and AIDS, which is endemic in Africa, prevent people from working and create an economic burden on society. Pests such as locusts reduce agricultural output and make it more difficult for a country to earn sufficient money to escape from subsistence agriculture. Reliable sources of water are necessary for productive agriculture and to a lesser extent for industry.

Most people in the economically “developed world” cite population growth in poor countries as the reason for poverty and for other global issues such as illegal immigration, climate change, and economic stresses in their own countries. There is a direct relationship between an exponential population growth and the incidence of poverty. Actually growth rates and poverty have a symbiotic relationship: A rising population growth leads to more poverty, and more poverty leads to population growth. The poor compensate for their lack of resources by having more children to help with farming needs and bring in another income and to compensate for high infant mortality rates. However, the rising population means more mouths to feed in the family and fewer resources to pass on to the next generation. It is no coincidence that in the developing world it is the countries that have the highest annual

population growth rate that are also those with the highest percentage of people living in extreme poverty. However, one must also consider the certain geographical factors that come into play in contributing to this cycle. Geographers see issues of the developing world not merely as economic or demographic problems that need solutions from the “developed” world. They see the issues in the totality of their context, one which includes some of the following observations.

Landlocked Status

Often the borders of developing countries were created on the basis of which colonial power had control over them and the policies of that power and when it relinquished control. One of many determinants to a country’s level of development is whether it has access to the sea through navigable harbors and rivers, which is essential to be connected to the rest of the world, which in turn promotes commerce, investment, trade, and intellectual interaction. A landlocked country often has a difficult time in facilitating any kind of extensive exports and imports, at least without a friendly relationship with its neighbors. Africa alone has 15 landlocked countries, by far and away the most of any continent. Many of the world’s poorest countries are severely hindered by high transport costs because they are landlocked; are situated in high mountain ranges; or lack navigable rivers, long coastlines, or good natural harbors.

Diseases

Most of the tropics have ecological conditions that favor deadly diseases such as malaria, schistosomiasis, cholera, dengue fever, yellow fever, bilharzia, and dozens of others. Sub-Saharan Africa, in particular, has an ideal rainfall, temperature, and mosquito type that make it the global epicenter of malaria, one important factor in slowing Africa’s economic development. Almost every country that lies between the Tropic of Cancer and the Tropic of Capricorn is subject to the risk of one of these vector-borne diseases in the zones below 2,000 meters in elevation.



Malaria is a major international public health problem, causing 350 million to 500 million infections worldwide and approximately 1 million deaths annually. No vaccine is currently available to prevent malaria or dengue fever. Malaria is largely a tropical disease as it needs high temperatures, plenty of breeding sites, and mosquitoes that are attracted to humans. When children die in large numbers, parents compensate by having numerous babies. Too poor to invest in the education of all the children, the family might educate just one child, usually the elder son. Some development experts point out that a world map of low-income countries overlain with a map of malaria risk will reveal much commonality between the two.

Additionally, research from Kenya indicates that a malarial infection may lead to a higher incidence of HIV/AIDS cases; there may also be a reciprocal effect of HIV infection cases on incidences of malaria. HIV/AIDS is an endemic disease in sub-Saharan Africa, where in some countries up to 40% of the population is infected. This fact has devastated the social-cultural dynamics of many communities that now lack a whole middle-aged sector of society. In 2007 alone, the AIDS epidemic in Africa claimed the lives of an estimated 1.6 million people; more than 11 million children have been orphaned by AIDS. The extent of the AIDS crisis is only now becoming clear in many African countries, as increasing numbers of people with HIV are becoming ill. In the absence of massive prevention, treatment, and care efforts, the AIDS death toll in sub-Saharan Africa will continue to rise. This means that the impacts of the AIDS epidemic on these societies will be felt most strongly in the course of the next 10 years and beyond. Its social and economic consequences are already widely felt, not only in the health sector but also in education, industry, agriculture, transport, human resources, and the economy in general.

Plant diseases and pests are another type of obstacle that developing countries in the tropics are forced to confront. A case in point is the countries in Northern Africa such as Kenya, Somalia, Ethiopia, Sudan, and Eritrea, which are subject to annual infestations of locusts. A single swarm can cover 1,200 square kilometers and can contain

between 40 and 80 million locusts per square kilometer. With each insect capable of eating its own body weight in vegetation each day, a swarm that size could consume 192,000 metric tons of vegetation each day.

Drought

The distinction between the developed and developing worlds is often based on agricultural production. The production of food is contingent on the amount and availability of water for rain-fed and potentially irrigated agricultural land. The use of this potential is frequently not great in the developing world: Out of the 1,620,104,000 ha (hectares) in the developing world, only 207,432,000, or 3.9%, are considered as potentially irrigable. The reasons for this are variable. The terrain may be too steep, the soils may be inadequate, or the land may be arid or hyperarid. These conditions are not subject to change in spite of any number of external inputs.

Many of the least developed countries in the world are trapped in arid conditions with low agricultural productivity or are vulnerable to prolonged droughts. When there is no predictable pattern of annual rainfall amounts, it is very difficult for farmers to make long-term agricultural plans or to invest in capital improvements. Climatic studies in Africa indicate that long-term changes in rainfall have occurred in the semiarid and subhumid zones of West Africa. Rainfall during the 1968 to 1997 period was, on average, 15% to 40% lower than during the period 1931 to 1960. A similar but smaller change has occurred in semiarid and subhumid regions of Southern Africa. When there is such variability in the year-to-year mean amounts of rainfall, it is difficult to maintain a consistent level of food productivity.

The arable land per capita is also a major concern in many developing countries. The rapid population growth has meant that the arable land per capita has declined sharply in recent years. In 1961, for example, developing countries as a whole had an average of about one half of a hectare of arable land per person; by 1992, the amount had fallen to less than one fifth of a hectare. If current trends in population growth



and land use continue, in 2050 the amount of arable land will be just more than one-tenth of a hectare per person.

Economist Jeffrey Sachs argues that the biggest determinant to why some countries have escaped the ravages of poverty and others have not is food productivity. Soil fertility is the principal constraint for sustaining agricultural production in many developing countries. With rapid population growth, soil nutrient stocks are being mined due to a reduction in fallow lengths, cultivation of fragile lands, and limited use of inorganic or organic sources of fertility, lowering agricultural productivity and increasing poverty. For example, 19 of the 25 poorest countries in the world are located in Africa. Sachs says that unless the downward spiral of increasing poverty, declining agricultural productivity, and resource degradation is reversed, sub-Saharan Africa will continue to be the locus of poverty with the world highest proportion of poor people.

None of the basic resources required to expand food production—land, water, energy, and fertilizer—can now be considered abundant or inexpensive. In many developing countries, there has been a serious degradation of arable land. Population pressures have caused grave overexploitation of soils. Irrigation, overgrazing, and denudation of huge forest areas to obtain wood for fuel and to clear land for farming have further reduced the soil's capacity to produce. Some of this land is marginal for farming, with soil and climatic conditions poorly suited for annual cropping. This is especially true where the more fertile lands are already crowded and the population spills over on to marginal land. Such land can only produce low yields and is more or less susceptible to degradation, depending on the quality of management.

International development experts who monitor progress toward a sustainable world say that soil erosion is slowly undermining the productivity of one third of the world's cropland. Each year, the world's farmers lose an estimated 24 billion metric tons of topsoil in excess of new soil formation. Deforestation is leading to increased rainfall runoff and crop-destroying floods. Between 1970 and 1990, the world lost nearly 200 million ha of tree cover and deserts expanded by some 120 million ha.

Conclusion

The factors that determine whether a country falls within the category of “developed” or “developing” are numerous. They include per capita income, population growth rates, education levels, trade policies, climate, governance, proximity to markets, outside investments, and effects of colonial history. However, the physical environment also plays into this mix and is one of the factors not often considered by economists and international development experts. It is, however, a salient issue that needs to be considered. The process can usually start with examining a map carefully and analyzing the spatial distribution of the physical features in relation to a given country.

An adverse geography poses problems that can be solved, typically through physical investments and good conservation management. But an adverse geography raises the costs of solving the problems of farming, transport, and health and thereby makes it much more likely that a country will be caught in a poverty trap. The diverse geography of the world also challenges development experts to think in a new paradigm. That is, what works in one country may not work in another. Solutions to the problems found in the “developing world” may not come out of what works in the North. Most likely, they will come out of each region with assistance (not direction) from the North.

William M. Van Lopik

See also Agriculture, Preindustrial; Colonialism; Decolonization; Dependency Theory; Development Theory; Disease, Geography of; Drought Risk and Hazard; Environment and Development; Fair Trade and Environmental Certification; Gross Domestic Product/Gross National Product; HIV/AIDS, Geography of; Informal Economy; International Monetary Fund; Malaria, Geography of; Malthusianism; Modernization Theory; Neocolonialism; Neoliberalism; Neo-Malthusianism; New International Division of Labor; Newly Industrializing Countries; Peasants, Peasantry; Plantations; Political Economy of Resources; Population and Land Degradation; Shifting Cultivation; Soil Degradation; Sustainable Development; Underdevelopment; World Bank; World Summit on Sustainable Development; World-Systems Theory



Further Readings

- Burnell, P., & Randall, V. (2008). *Politics in the developing world* (2nd ed.). Oxford, UK: Oxford University Press.
- Laith, J., Padmaja Patnaik, J., & Kublin, G. (2006). Dual infection with HIV and malaria fuels the spread of both diseases in sub-Saharan Africa. *Science*, 314(5805), 1603–1606.
- Payne, R., & Nassar, J. (2007). *Politics and culture in the developing world*. New York: Longman.
- Sachs, J. (2005). *The end of poverty: Economic possibilities for our time*. New York: Penguin.
- Weatherby, J., Evans, E., Long, D., Reed, I., Carter, O., Arceneaux, C., et al. (2008). *The other world: Issues and politics of the developing world* (8th ed.). New York: Longman.

DEVELOPMENT THEORY

Development theories generally fall into one of two approaches. First, there are theories that provide explanations of the meanings, trajectories, and characteristics of socioeconomic progress and put forth policy frameworks to aid in the design of social and economic interventions to aid poor communities, regions, and less industrialized (i.e., developing) economies. Second, there are theories that critique mainstream ideas about development with the goal of demonstrating how economic and political powers/elites exploit the poor, working classes, and/or once-colonized peoples through ideologies and practices of development that ignore the real needs, voices, and knowledge of these individuals and their communities. In both cases, the primary focus is on communities and economies that were once colonized by European, American, or Asian powers (i.e., the developing world or Global South).

Origins

Development theory's contemporary manifestations were inspired by three schools of thought about society and progress: classical political economy, historical idealism (Georg Wilhelm Friedrich Hegel) and historical materialism

(Karl Marx), and sociological conceptualizations of societal evolution. Classical political economists (Thomas Robert Malthus, Adam Smith, David Ricardo, and John Stuart Mill) characterized societal progress (development) as being made possible through wealth creation, a divinely inspired process guided by the invisible hand of the market and improved or facilitated through international trade based on the comparative advantages of nations. For the classical scholars, development (i.e., progress) would occur if there was an adequate division of labor and effective economic circulation mechanisms (i.e., money, trade, and capital flows) to sustain wealth creation.

A second early inspiration came from Hegel and Marx's theories of social evolution. For Hegel, humanity (but principally Europeans) evolved through a dialectical progression of ideas that would lead to the absolute idea, a point in history when humanity would be spiritually unified through the discovery of reason in its highest form. For Marx, a universal history, was possible but he rejected Hegel's spiritual notions and argued instead that it was the historical-material conditions of life that would lead societies toward higher levels of consciousness, an ideal endpoint being the resolution of class struggles and capitalist exploitation through the emergence of a classless society.

The third important foundation emerged from sociological explanations for the evolution of modern capitalism. Max Weber, Thorstein Veblen, Michael Polanyi, and others sought to explain how the institutions of capitalism (e.g., property, money, firms, classes, or markets) emerged in Europe, the United States, and Japan and what their rise meant for social well-being. Modern development occurs when social rules, norms, and institutions evolve to guide individuals toward the rational decisions needed to sustain and support the capitalist system. Particularly significant is the notion that modern development involves an increasing separation or disembedding of economic institutions (i.e., markets, firms, property rights) from political ones. However, as Polanyi observed, this separation is at best only partial as the crises and inequalities inherent in capitalism inevitably force the state to interfere with the "natural" market system.



Growth and Modernization Theories

The mid 20th century was a revolutionary period for development as growth and modernization theories came of age. John Maynard Keynes's theories on economic multipliers, full employment, and the role of the state in guiding the creation and distribution of prosperity inspired the birth of growth theory. His protégés Roy Harrod and Evsey Domar posited that it is through appropriate levels of growth that full employment (i.e., optimal prosperity or development) is sustained, and their models sparked an intense debate within economics that led to the Solow-Swan growth theory. Robert Solow and Robert Swan argued that growth is driven by the productivity increases that accompany modern industrialization (e.g., increasing capital intensivity, technological change, knowledge accumulation, and labor efficiency improvements). Productivity growth remains a central theme in development economics, and it is viewed by many as the critical mechanism for generating and sustaining economic progress.

Early growth theories were important influences on the new generation of modernization theorists such as Arthur Lewis, Simon Kuznets, Albert Hirschman, Gunnar Myrdal, and Walter Rostow. For Lewis, modernization—a transition from a traditional (i.e., subsistence and/or agrarian-based) to an industrialized economy—would occur as the unlimited supply of low-wage labor existing in “backward” countries shifted into commercial activities sustained by favorable terms of trade. If the state intervened appropriately, the resulting profits could be reinvested in projects to reduce poverty and improve the commercial sector continuously. Kuznets, like Lewis, viewed underdeveloped countries as being structurally different from modern societies. His most lasting contribution is the Kuznets curve, a model showing that increases in inequality are inevitable at the beginning of modernization but that inequality eventually decreases in the transition to an industrial economy. For Hirschman, geographic inequality or the polarization of modernity within countries was a necessary first stage toward widespread development. Myrdal too recognized the inevitability of such regional inequalities and argued that states must intervene aggressively to

mitigate their negative consequences. In his infamous attack on Marxism, Rostow posited that while inequalities were inevitable during the modernization process, these would dissipate as a large middle (consumer) class emerged through economic growth, industrial diversification, and an effective liberal democracy. For Rostow, every underdeveloped, noncommunist society could modernize independently through five stages of growth that would effectively transform the economy from a traditional system to one driven by mass consumption and modern industries.

During the 1960s and 1970s, geographers such as Brian Berry, Lawrence Brown, Peter Gould, and Akin Mabogunje played an important role in development theory by analyzing, mapping, and theorizing about the spread of modernization within developing countries. These studies were inspired in large part by François Perroux's regional growth pole theory, Walter Christaller's ideas about central places, Hirschmann and Myrdal's work on polarization and cumulative causation, and Torsten Hagerstrand and Everett Rogers's studies of innovation diffusion. Common research themes included analyzing and mapping the spatial distribution of modernization in cities and regions, studying the demand and supply-side mechanisms that facilitated the diffusion of innovations, and developing spatial models to maximize the efficiency of transportation, communication, and other distribution systems.

Neoliberalism and the New Institutionalism

In the 1980s, neoliberalism became the dominant ideology worldwide shaping mainstream policies of institutions for development. Early neoliberal theorists believed that state-led import substitution industrialization programs had failed to deliver the promised levels of modernity and that freer markets and trade could more efficiently drive development. Inspired in part by the works of the economist Friedrich Hayek, neoliberal thinkers argued that market forces would be the most effective way to advance social progress and that states needed to allow the private sector to guide development. International trade—in as “free” a form as possible—is central to these theories, and developing countries were encouraged to



liberalize import markets and industrialize through export-led strategies. Citing the “miraculous” success of the export-oriented East Asian “tigers”—South Korea, Taiwan, Singapore, and Hong Kong—the Washington Consensus (the International Monetary Fund, the World Bank, and the U.S. Treasury) promoted an aggressive free trade agenda instituted in part through the establishment of the World Trade Organization (WTO).

Neoliberalism’s promoters quickly realized that achieving a transition from a state-led to a market-driven development process required a dramatic transformation of the institutions structuring and regulating economies. Inspired in large part by the work of scholars such as Ronald Coase, Oliver Williamson, Douglass North, and Robert Bates, the “new” institutional economics became an important theoretical influence on neoliberal (and other) development theories. Institutionalists believe that individuals and firms make rational choices in response to the cost and price signals transmitted to them through the markets, rules, norms, laws, and conventions (i.e., the institutions) structuring socioeconomic activity. Successful neoliberal institutions clarify and protect property rights and reduce the transaction costs individuals encounter when making consumption or production decisions (i.e., choices that create profits or an economic surplus). These theories, when coupled with neoliberal ideology, translated into development policies (e.g., structural adjustment programs) aimed at dramatically restructuring market, state, and civil society institutions to increase economic efficiency, raise productivity, and spur rapid integration into global markets.

Recent Trends

Since the 1990s, development theory has advanced along a number of fronts: economic sociological approaches, sustainable development, and postcolonial and cultural theories. The first group of recent theories, inspired by economic sociology and political science, argues that economic actions are embedded in social structures and that the ability of individuals, communities, or nations to “develop” is determined in large part by their ability to progressively mobilize these institutions and networks and the social capital derived from them.

Social capital is constituted by trust, social networks, norms of reciprocity, and levels of civic engagement, and it can facilitate progressive development if it is widely distributed throughout society and maintained, reproduced, and increased through appropriate state and nongovernmental interventions. Development projects can increase social capital by providing institutional mechanisms to connect a diversity of individuals, firms, markets, states, and communities in networks characterized by high levels of trust and reciprocity. In contrast to modernization and neoliberal approaches, these theories deemphasize material worlds and market forces and focus on how historically, socially, and geographically embedded networks, civic institutions, and cultures shape development processes and the ability of a society to create external ties to other places and regions.

Sustainable development theory is a second significant area of contemporary research. This field grew out of increasing concerns in the 1970s and 1980s about global environmental problems and the long-term prospects for development through modernization. With the publication of the Bruntland Report in 1987, the concept of sustainable development entered the mainstream, and the field has grown dramatically in scope and scale since that time. Sustainable development’s advocates believe that long-term human progress can only be achieved if economic desires and social needs are in balance with environmental limitations such that present-day development is not achieved at the expense of future generations’ abilities to do so. Central to these debates is the question of whether development through economic growth, driven by the production and consumption of natural resources, is possible indefinitely. Weak proponents of sustainable development believe that growth and sustainability are compatible, provided technological changes enable humans to find substitutes for declining or nonrenewable resource stocks. Strong proponents of sustainability believe that there are profound limits to growth and that long-run development will only be possible if humans create and sustain an ecologically and thermodynamically balanced economic system (i.e., a steady-state economy).

A third strand of contemporary thinking emerged in the context of postcolonial and



postdevelopment critiques of modernization and neoliberal theory. While there are differences between the postcolonial and postdevelopment approaches, there is general agreement in both communities that modern development theory has been essentialized, universalized, and violently exercised by colonial and Northern economic powers who view it as a necessary transition from one binary state to another (e.g., from traditional to modern; backward to progressive). These theorists argue that development, if there is such a thing, should be an emancipatory process through which the knowledge, voices, and livelihoods of the subaltern (people in the Global South who have been subjugated to colonialism and exploitation by the global economy) are understood, appreciated, and empowered through direct political action. To do so, development policy and theory must be decentered away from Western experts, neoclassical and neoliberal economics, and hegemonic multilateral institutions such as the World Bank and the International Monetary Fund. Once these powerful institutions are destabilized, it may be possible to transform development thinking and practice progressively through an understanding of the subjectivities, social movements, cultures, power relations, and knowledge situated in the postcolonial world (i.e., developing regions).

Critiques

Critiques of development theory have been significant and continuous since the 1950s. Central to these criticisms has been the concern that development theory and practice are not meant to help the poor or disempowered but are instead pursued by powerful states as a means of perpetuating exploitative modes of capitalist production, geopolitical relations, and meanings of “progress.” In broad terms, these criticisms have come from two primary perspectives—radical political economy and postcolonial and postdevelopment studies.

The radical political economy of the 1960s and 1970s drew heavily on classical Marxian theory and responded directly to modernization and growth theorists. Dependency theorists such as André Gunder Frank and Raúl Prebisch viewed modernization schemes as neocolonial mechanisms for sustaining unequal exchange

relationships between poor and rich countries. Specifically, modernization and international trade were tools to encourage developing countries to export cheap raw materials while keeping them dependent on wealthy economies for more expensive manufactured goods and services. Because of this unequal exchange, the capitalist trading system linking metropole states (industrialized economies) and satellite economies (the developing world) would inevitably and perpetually siphon surplus value away from poor countries even if they established more advanced industrial sectors. Thus convergence between rich and poor, what Rostow argued in his stages-of-growth framework, was never really possible, and developing economies were better off focusing on strategies to promote autarky or self-reliance.

Dependency theory was extended by Immanuel Wallerstein through the development of world-systems theory in the early 1970s. World-systems theory posits that the world economy is organized into a tripartite system of power relations (core economies (most powerful), semiperipheral economies, and peripheral economies (weakest) that historically evolved through geopolitical and geo-economic conflicts between countries seeking to maintain or increase their global power. As such, and in contrast to Rostovian notions that internal factors alone determine a country’s ability to develop, development is determined in large part by a country’s ability to overcome the external structural constraints (e.g., unequal exchange relations) imposed on it by more powerful countries and global capitalism.

More recent radical critiques have drawn on Michel Foucault, Antonio Gramsci, and political ecology literatures to attack the strategies of neoliberal institutions and expose the social, environmental, and economic outcomes of their policies. These scholars have placed particular emphasis on the role of multilateral development institutions, neoliberal states, multinational corporations, and empowered development “experts” in perpetuating unequal power relations between haves and have-nots in the global economy. Such critiques, while they are not without flaws, have exposed significant weaknesses in neoliberal development theory and demonstrated why it has not led to a dramatic redistribution of power, wealth, and opportunity in the world economy.



Radical scholars have also drawn on political ecology theories to show how neoliberal development strategies are adversely transforming ecosystems and human-environment relations throughout the global South.

Beyond radical political economy, development theory has been critiqued through the lenses of postcolonial and postdevelopment studies. Postcolonial and postdevelopmental theorists have examined the historical and cultural production of the power relations driving development processes and detailed how modernist visions of progress objectify once-colonized peoples in the Global South (the subaltern), effectively silencing their voices in debates and discussions about what development is and how it might be achieved. As Paul Farmer argues, development interventions are often forms of structural violence against the institutions shaping the everyday realities, understandings, and rationalities of poor people, not liberating projects to empower and improve the lives of the subaltern. Moreover, because development experts lack sufficient reflexivity and humility about how projects are designed, funded, and implemented, their understandings of the “targets” of development programs (poor people, public health, etc.) are at best partial, and it is this partiality, hubris, and rigidity that doom many development interventions from the outset. Postcolonial and postdevelopment critiques have raised important concerns about how development is practiced and forced a critical rethinking of what development is, how it might best be achieved, and how the poor might take real control over the process.

James T. Murphy

See also **Dependency Theory; Developing World; Diffusion; Economic Geography; Export-Led Development; Foreign Aid; Globalization; Growth Poles; Import Substitution Industrialization; Industrialization; International Monetary Fund; Modernization Theory; Neocolonialism; Neoliberalism; New International Division of Labor; Newly Industrializing Countries; Orientalism; Political Ecology; Political Economy; Population, Environment and Development; Postcolonialism; Poverty; Regional Economic Development; Rural Development; Spatial Inequality; Structural Adjustment; Subaltern Studies; Sustainable Development; Technological Change,**

Geography of; Underdevelopment; Uneven Development; World Bank; World-Systems Theory; World Trade Organization (WTO)

Further Readings

- Bebbington, A., & Bebbington, D. (2001). Development alternatives: Practice, dilemmas and theory. *Area*, 33, 7–17.
- Blaut, J. (1987). Diffusionism: A uniformitarian critique. *Annals of the Association of American Geographers*, 77, 30–47.
- Blunt, A., & McEwan, C. (Eds.). (2002). *Postcolonial geographies*. New York: Continuum Books.
- Escobar, A. (1995). *Encountering development: The making and unmaking of the Third World*. Princeton, NJ: Princeton University Press.
- Frank, A. G. (1971). *Capitalism and underdevelopment in Latin America*. Harmondsworth, UK: Penguin.
- Leys, C. (1996). *The rise and fall of development theory*. Bloomington: Indiana University Press.
- North, D. (1990). *Institutional change and economic performance*. Cambridge, UK: Cambridge University Press.
- Peet, J. (2007). *Geography of power: The making of global economic policy*. London: Zed Press.
- Potter, R., Binns, T., Elliott, J., & Smith, D. (2004). *Geographies of development*. Harlow, UK: Pearson.
- Power, M. (2003). *Rethinking development geographies*. New York: Routledge.
- Scott, J. (1998). *Seeing like a state: How certain schemes to improve the human condition have failed*. New Haven, CT: Yale University Press.
- Simon, D. (2006). Separated by common ground? Bringing (post)development and (post)colonialism together. *Geographical Journal*, 172, 10–21.
- Sneddon, C., Howarth, R., & Norgaard, R. (2006). Sustainable development in a post-Brundtland world. *Ecological Economics*, 57, 253–268.
- Williamson, J. (2004). *The Washington Consensus as policy prescription for development*. Washington, DC: Institute for International Economics.
- Woolcock, M. (1998). Social capital and economic development: Toward a theoretical synthesis and policy framework. *Theory and Society*, 27, 151–208.



DIAMOND, JARED (1937–)

Jared Diamond is a well-known physiologist and evolutionary biologist. In addition to his research in these fields and in conservation ecology and anthropology, Diamond has published a variety of works on biogeography and human geography. He has been a professor of physiology in the medical school at the University of California at Los Angeles (UCLA) since 1986 and professor of geography in the department of geography at UCLA since 2001. Diamond also serves on the boards of directors of World Wildlife Fund and Conservation International.

Diamond has conducted more than two dozen expeditions since the 1960s to research biological diversity in New Guinea. Recently, he led National Geographic Society and World Wildlife Fund projects to survey the distribution and spatial characteristics of bird species in Papua New Guinea. Notable among his resulting publications is *The Birds of Northern Melanesia: Speciation, Ecology, and Biogeography*, coauthored with Ernst Mayr. This tome compiles and updates more than a century of taxonomic data and uses these data to address questions about oceanic avian speciation and, more generally, island biogeography. Diamond's ongoing surveys in this region are part of a broader conservation effort to curb loss of biodiversity; he has also contributed to the design and implementation of conservation parks in the Southwest Pacific.

Diamond is best known for his studies of human geography, particularly his global-scale studies of historical, cultural, and environmental geography. These include attempts to answer major disciplinary questions in the fields of archaeology and anthropology, history, and sociology through geographical surveys of the human present and past. His 1997 tour-de-force work is *Guns, Germs, and Steel*, which examines the historical contingencies of human biological variability at a worldwide scale. Diamond uses biogeographical and environmental patterns to account for the cultural-historical trajectories of the New World versus Old World. The book won a Pulitzer Prize in 1998 and is hailed as an unparalleled, global reexamination of human geography spanning the past 14,000 years. In a similar

vein, his 2005 book *Collapse: How Societies Choose to Fail or Succeed* examines the historical geography of societal disintegration through a wide survey of ancient and modern case studies. Here, he links social collapse to human decision making in the context of ecological and geographical patterns. Parallel to his work in New Guinea, *Collapse* ultimately addresses modern conditions and future prospects, outlining ecological management, environmental stewardship, and other social solutions to future global crises.

Diamond regularly contributes popular articles on topics ranging from evolutionary biology and the origins and spread of human disease to commentaries on current discoveries and research in *Nature* and other scientific journals. He has received numerous prestigious awards, most notably a MacArthur Foundation Fellowship (1985), the President's National Medal of Science (1999), the Cosmos Prize (1998), and the Alfred Russel Wallace Award by the International Biogeography Society in 2007.

Scott Van Keuren

See also **Biogeography; Environmental Determinism; Environmental Management; Environment and Development; Island Biogeography**

Further Readings

- Diamond, J. (1997). *Guns, germs, and steel: The fates of human societies*. New York: W. W. Norton.
- Diamond, J. (2005). *Collapse: How societies choose to fail or succeed*. New York: Penguin.



DIASPORA

Originally used to describe the scattering or dispersion of Jews from Palestine in the 6th century BC, the term *diaspora* has evolved into a widely used reference point for understanding human migration, settlement, and transnationalism. Since the late 20th century, the term *diaspora* has become a common label for any ethnic population living in places other than that considered their historic homeland and also refers to



collective practices that challenge the boundaries of the nation-state. The broad and growing interest in diasporas has helped forge diaspora studies as a distinct academic discipline; however, other disciplines, including geography, have also made important contributions to the subject.

Academic studies on diaspora center on several themes, including migration, loss, memory, settlement, and transnational experiences. Migration and settlement themes focus on the historical origins and experiences of diasporas as they develop as unique cultural and political communities outside “native soil.” These experiences of displacement and resettlement furthermore provide context for studies that examine the loss and remembering of cultural practices and meanings. Recently, the notion that diasporas are communities that characteristically suffer cultural loss has given way to the view that they form hybrid identities, mixtures of the cultures of their origin and the host countries. Furthermore, many current studies concentrate on how members of diasporas construct their own personal identities both in relation to their diaspora communities and as participants in the construction of the broader significance of their diaspora.

The theme of transnationalism has become especially important in contemporary dialogues about diasporas. The idea that diasporas involve complex interrelationships between people and places, and often across political and socio-cultural boundaries, predates the concept of transnationalism. Yet, with the recent interest in transnationalism as an aspect of globalization and contemporary migration, the transnational nature of diasporas has attracted wider interest. One reason for this renewed interest is that studies on the transnational practices undertaken by members of diasporas acknowledge the symbolic as well as material interchanges among places. In particular, the treatment of transnational ties in studies concerning diasporas often include emotional and psychological dimensions that are elsewhere often neglected.

One of the remarkable details about the diaspora concept is how quickly the usage of the term has expanded to represent many different migrant and ethnic groups. The extension of the term has been associated with increasing migration and cosmopolitanism, but some have also

suggested that it reflects the broadening alienation of people from meaningful political representation within existing nation-states.

In addition to the recent expansion of usage of the term in academic circles, there has been a remarkable rise in the attention of policy makers. Since 2005, several global institutions, as well as a number of countries, have published reports and policies acknowledging diasporas as significant agents of change in their countries of origin. Geographers have been among the small number of social scientists who have examined the rise of these policies, which are sometimes referred to as “diaspora strategies.” The growing and far-reaching interest in diasporas, as social phenomenon, political constituency, and analytical concept, underscores the deeply political nature of this subject.

Alexander Malcolm Lovell

See also **Ethnicity; Hybrid Geographies; Immigration; Migration; Transnationalism**

Further Readings

- Appadurai, A. (1990). Disjuncture and difference in the global cultural economy. In M. Featherstone (Ed.), *Global culture: Nationalism, globalization and modernity* (pp. 295–310). London: Sage.
- Cohen, R. (1997). *Global diasporas: An introduction*. London: UCL Press.
- Hall, S. (1990). Cultural identity and diaspora. In J. Rutherford (Ed.), *Identity, community, culture and difference* (pp. 222–237). London: Lawrence & Wishart.
- Larner, W. (2007). Expatriate experts and globalizing governmentalities: The New Zealand diaspora strategy. *Transactions of the Institute of British Geographers*, 32, 331–345.
- Mitchell, K. (1997). Different diasporas and the hype of hybridity. *Environment and Planning D: Society and Space*, 15(5), 533–553.
- Safran, W. (1991). Diasporas in modern societies: Myths of homeland and return. *Diaspora*, 1(1), 83–99.
- Tololyan, K. (1991). The nation-state and its others: In lieu of a preface. *Diaspora*, 1(1), 3–7.



DIASTROPHISM

Diastrophism or tectonism is the group of mechanisms by which large-scale portions of the Earth's crust are deformed by natural processes. Such diastrophic processes lead to the formation of continents and ocean basins, mountain systems and rift valleys, and other related features by the chief mechanisms associated with the plate tectonic movements of the lithospheric plates of the planet. The study of diastrophism, or of tectonic processes, is the central unifying principle in much of modern-day geology and geophysics.

Five main kinds of diastrophic processes occur:

1. Orogeny, in which narrow mountain belts are formed
2. Epeirogeny, which is broad regional uplift or down warping of the crust
3. Isostasy, which is broad down warping or uplift related to loading and unloading of the crust
4. Eustasy, which is worldwide sea-level changes from addition or removal of water or through tectonic change in ocean basin volume
5. Igneous processes, which include intrusive ones, or plutonism, which are emplacements of molten magma at depth in the Earth, and extrusive or volcanic emanations of lava and pyroclastics on the surface.

The main driver of all diastrophic processes is the movement of the great tectonic plates, whereby new rock is created at the spreading centers and old rock subsides down subduction zones to be melted and partially recycled.

Mountain building orogenesis is the group of processes whereby plate tectonics drives up the great ranges as the moving lithospheric plates rift apart in some places and collide in other places. Thus there are five main kinds of orogenies:

1. Uplift and rifting of a continent above a spreading center, which produces moderate-sized mountain uplifts and volcanoes, much like those in East Africa
2. Island arc growth into a cordillera above a subduction zone at a continental margin, as happened with the ancient Appalachian mountains

3. Collision of a volcanic island arc with a continent, as happened in the Andes and elsewhere
4. Collision of two continents, as happened with India as it moved into Asia and pushed up the Himalayas
5. The tectonic aneurysm, as happened at both ends of the Himalaya, where great river systems such as the Indus and the Tsangpo-Brahmaputra were captured and diverted so that their ferocious denudation unloaded the crust so quickly that its pressure release at depth resulted in igneous and metamorphic effects and a mountain pop-up on the surface

Epeirogeny in which the crust is broadly and slowly up-warped or down-warped without significant faulting, folding, metamorphism, or igneous activity and other tectonism is not well understood. It may reflect dynamic effects of motions in the mantle below the crust, phase transitions in the mantle that the crust accommodates, or be the result of variations in the white-hot and plastic asthenosphere below the lithosphere as the surficial plates move laterally over it. In any case, areas such as the Colorado Plateau and much of Central North America that were once below sea level are now well above it, which reflects their epeirogenesis.

Isostasy, the balance in Earth's crust, which is likened to icebergs floating in water, is the situation wherein any great load such as water or ice added or removed from the crust will result in up-warping or down-warping as a result. The great glacier masses on North America and the Scandinavian countries during the Pleistocene, for example, greatly depressed the crust, with the result that Hudson Bay and the Baltic Sea still represent remnants of that down-warping once the ice melted away. Compensatory isostatic uplift is slowly under way in both places to restore the crust to the higher level it was at once prior to the advent of the glaciation. Similarly, in the state of Utah, Great Salt Lake is the small remnant of the once-huge, Lake Superior-sized, Lake Bonneville of the Pleistocene. Prominent wave-cut beach lines that are now high and dry were established at the high stand of this lake. Those old beach lines around islands in the deeper center of Lake Bonneville are now much higher in elevation than



those on the lake's periphery, which is a reflection of the greater isostatic rebound where the water was once much deeper.

Eustasy, or worldwide sea-level change, has occurred throughout geologic time as water from the sea has been locked up in glacier masses up on the continents or has melted and returned to the sea to raise the sea level. Similarly, as the continents have alternately rifted apart or drifted together and ocean basins have come and gone, the volume of ocean basins has also changed as subsurface volcanoes grew in them and displaced the water onto the land. Thus, at times in the past the seas have alternately covered the continents and withdrawn from them to expose their marine sediments in many places worldwide.

Igneous processes are a major part of diastrophism in that a significant part of the rocks on the Earth's surface have once been molten magma intruded at depth or extruded as lavas and pyroclastic fragments at the surface. The plutonic igneous intrusions are classified in part on the basis of their size and their relations to the layers of the surrounding country rock into which they intrude. Thus the discordant intrusions that cut across the layers of the country rock are the tabular dikes and cone sheets, as well as the irregular small stocks and large batholiths, whereas the concordant plutons are tabular sills, mushroom-shaped laccoliths, and the bowl- or funnel-shaped lopoliths. The volcanic igneous extrusions are the surface manifestations of intrusive processes at depth and are classified on the basis of their size, the steepness of their sides, and the types of eruptive activity. Thus ash and cinder cones are composed of explosively ejected pyroclastic (fire broken) fragments that pile up steeply as relatively small accumulations. Shield volcanoes are large, broad areas where fairly fluid lava effusions have accumulated on gentle slopes. Lava domes are small, steep-sided volcanoes where viscous lavas have piled up quietly, although if pressure builds up beneath such lavas, they can explode violently. Composite volcanoes or stratovolcanoes are those that combine elements of the other three types so that mixtures of explosive and effusive eruptions combine to build large, steep-sided volcanoes.

John F. Shroder

See also **Geothermal Features; Global Sea-Level Rise; Oceans; Plate Tectonics; Volcanoes**

Further Readings

- Bucher, W. (1964). *The deformation of the Earth's crust: An inductive approach to the problems of diastrophism*. New York: Hafner.
- McKnight, T., & Hess, D. (2000). *The internal processes: Diastrophism. Physical Geography: A Landscape Appreciation* (pp. 173–188). Upper Saddle River, NJ: Prentice Hall.



DIFFERENCE, GEOGRAPHIES OF

Difference is a measure by which individuals, societies, and even nations seek to distinguish themselves. It is a measure of separation (as being unlike someone) and distinctiveness. In its assertion it creates an “other”—those we are not. Forms of difference have been grouped into broad social categories such as class, gender, race or ethnicity, and sexuality. However, difference can be asserted using any criterion, such as language, nationality, birthplace, religion, ancestry, and profession. It can also be tied to particular places and operates across many scales. This entry examines the concept of difference and the many types of difference that geographers have studied. It then discusses the various theoretical approaches that have been used in this field and considers its significance for future research.

For geographers, difference is an important analytical concept. Its examination is used to assert that individuals' distinctiveness matters: to their experience, and the constitution, of particular places; to their life opportunities; and to the functioning of communities and societies. Individuals, and particular groups, will experience particular social processes differently (such as the closure of a factory that might affect men and women in different ways), and these differences will occur unevenly over space. The geographies of difference can be understood by exploring what differences have been studied and how these



have been measured and analyzed. There are also a number of approaches to exploring difference and an ongoing debate within geography as to whether we need to move beyond difference as a field of enquiry.

Geographers use the study of difference to expose the generalizing assumptions of earlier geographical work—some of which failed to acknowledge the diverse experiences of certain groups, such as women or the disabled. Thus difference as a concept is used to highlight, and fill, the silences and gaps in geographical scholarship. It is also used to understand how particular groups suffer because of their difference—through oppression or exclusion—in other words, “geographies of exclusion.” This understanding of what divides us also enables us to explore how we might build connections across differences and how we might overcome tensions between us (such as racial or religious divides) and thus live together more harmoniously. In this sense geographies of difference can take on a particular political project by being part of the debate as to how to build better societies. However, there remains a problem between valorizing difference and the need to understand the commonalities of human existence. For example, if we give too much credence to difference we can undermine the need for universal principles of justice and the power of working together (e.g., through collective action).

Geographers have explored a multitude of differences. The most frequently studied categories of difference have been class, gender, race, and sexuality. However, recent work has explored previously absent categories, for example, “old age,” and there is a nascent field of children’s geographies focusing on childhood and youth. Geographies of disability have also been investigated, including for example, reconceptualizing what it is to be deaf. In addition, what is studied within these categories and conceived of as different changes over time. These changes are in response to new contexts that give rise to new tensions. For example, since the terrorist attacks in the United States in September 2001 and in London in July 2005, the concept of race has been complicated by the emerging importance of religion as a defining marker of difference. Moreover, geographers have sought to interpret difference more broadly to

incorporate majority groups, investigating masculinity and “whiteness.” Thus, how we conceive of difference continues to evolve.

Theoretical and Methodological Approaches

The ways in which these categories have been explored and analyzed have changed markedly over the past few decades. There remains much debate as to the most appropriate theoretical and methodological ways of perceiving and measuring difference. While there may be a spatiality to the differences that can be mapped and charted quantitatively (such as migration or housing patterns by category), more often geographers have taken a qualitative approach to exploring difference. This approach has involved understanding the processes, relations, and experiences that divide people and that shape and affect places and spaces. Such work has sought to bring the specificity of difference into view, to identify processes of exclusion, prejudice, or, conversely, solidarities and the assertion of rights and to understand how such differences are created and maintained and their consequences. In other words, differences have been explored through the examination of categories, spatial patterns, relations, and processes.

This variety of approaches can be illustrated through the example of one category—gender. In the late 1970s, gender emerged in geographical scholarship as a category of social difference. At first gender was explored through the absence of female academics in geography and the absence of women as a valid topic of geographical research. Feminist geography emerged as a field that asserted the need to explore gender relations and inequality in work, housing, and everyday life. Next, gender as a construct began to be problematized. Geographers sought to examine how the understanding of gender was socially constructed and contested, and thus studies of femininity and masculinity emerged. Moreover, the intersections between gender and other social differences, such as sexuality, class, and race complicated gender as a discrete identity. Recently, overlap with research on the geographies of sexuality has encouraged more work to explore the embodiment of gender, gender as a negotiation of our bodily beings, and how gender is performed



(expressed, practiced, and displayed) by different groups. From this very brief trajectory, it is clear that there are a number of alternative approaches to the exploration of gender as a form of difference and that these approaches can challenge each other.

It is possible to identify a number of approaches to understanding difference and, in particular, the geographies of difference. Difference is most easily defined as being in opposition to others around us. In this way it is relational as it only makes sense if we define how different we are in *relation* to others. This can be taken further to understand that the context (or place) in which we exist shapes how we understand those differences. Thus, people will identify commonalities and differences in part due to the place they are in (and those differences in turn shape how place is constructed). This notion becomes most obvious when we are displaced—we move to another place, and that movement makes us realize something about ourselves that we might not have particularly noticed previously. For example, we might not have considered our race if we grew up surrounded by those of similar race, but moving elsewhere to a place where our race is markedly different enables us to understand our race as a difference. Thus, place and, hence geography, is a key aspect of how we should understand difference, and difference is significantly informed by the place in which people exist.

If difference is relational, then it is also dynamic and fluid, rather than static and fixed. This is because if our understandings of difference can change according to the place we are in, they will also change over time or through encountering others in everyday life. So what it means to be a particular gender will change as we age, change location, change jobs, have children, and so on.

Difference can be understood as an assertion of a particular identity. This can happen in several different ways. People might unite around a common identity (such as being gay) despite differences (such as race, gender, and class). They might do this to assert political rights or in response to a personal need for expression and a sense of belonging. Identity may also be an outcome of several layers of difference on a broader scale, for example as a national identity. Geographers also increasingly understand that identity is not fixed;

rather, we have multiple identities (such as being a woman, a mother, and an academic). Taking an identity approach enables us to understand how difference is a dynamic mix of choice, history, and place and is a result of power relations.

The notion of multiple identities illustrates the permeability of many categories of difference and how they intersect and overlap. Some scholars have argued that this degree of intersection is key to understanding how people experience difference. Thus, the negative implications of being different—oppression and exclusion—will be compounded by the interconnection of multiple forms of difference (such as being gay *and* black). Consequently, to fully comprehend difference we need a broad and complex examination of these intersections and power relations within society. Such an approach raises important questions about what broader processes might be occurring behind these categories of difference to which we should pay attention. The examination of power is a way to explore the relations of difference, but more than that it is potentially an approach that moves beyond difference and seeks instead to understand the unevenness of societies as a result of uneven power relations. An examination of power enables a nuanced exploration of why difference will manifest itself unevenly across social and spatial relations, and, thus perhaps most important, how the negative aspects of difference can be challenged.

Approaches to the geographies of difference continue to evolve. Just as difference came to be perceived as a social construction, there are those who challenge such assumptions or argue that we accept too easily what counts as sameness: We need to look beneath apparent similarity to understand more complex geographies. New theorizations of difference are emerging, such as the examination of fleeting encounters or temporary transient events as moments through which we can explore the possibilities of moving beyond difference or articulating new forms of difference that challenge existing conceptualizations. Perhaps examining the geographies of *indifference* is just as important an endeavor. For example, certain acts such as racism can be allowed to continue precisely because of a broader indifference to others. Scholars are also exploring the notion of hybridity, which rejects the traditional categories of difference such as gender and race and



instead focuses on the performative subjectivity of individuals and integration of seemingly irreconcilable elements.

Regardless of the new directions scholarship might take, the geographies of difference are important precisely because the categories of difference are so enduring. The categories represent the real divisions and inequalities that continue to shape people's lives and the places they inhabit. Geographers continue to explore how differences emerge, why certain markers of difference "stick" more than others and matter more in some places than others. Some differences, such as class and gender, have longer historical stories that appear to constrain the possibility of their radical reinvention or change. Other forms of difference are embraced, reclaimed, and subverted as powerful identifiers and useful intersections of commonality. Whatever their histories, boundaries, or expression, the task remains for geographers to acknowledge difference and yet understand and assert what it is that we have in common.

Jenny Pickerill

See also **Cosmopolitanism; Disability, Geography of; Ethnicity; Ethnic Segregation; Feminist Geographies; Gays and Lesbians, Geography and/of; Gender and Geography; Hybrid Geographies; Identity, Geography and; Nationalism; Orientalism; Race and Racism; Racial Segregation; Subaltern Studies**

Further Readings

- Harvey, D. (1996). *Justice, nature and the geography of difference*. Oxford, UK: Blackwell.
- Pain, R., Mowl, G., & Talbot, C. (2000). Difference and the negotiation of "old age." *Environment and Planning D: Society and Space*, 18, 377–393.
- Panelli, R. (2004). *Social geographies: From difference to action*. London: Sage.
- Pratt, G., & Hanson, S. (1994). Geography and the construction of difference. *Gender, Place and Culture*, 1(1), 5–29.
- Sibley, D. (1995). *Geographies of exclusion*. London: Routledge.
- Valentine, G. (2008). Living with difference: Reflections on geographies of encounter. *Progress in Human Geography*, 32(3), 323–337.



DIFFERENTIAL HEATING

Land surfaces warm and cool much quicker than water bodies, leading to differential heating of the Earth's surface. Water has a higher specific heat (capacity to hold energy) and circulates energy to greater depth than does land, and so water bodies such as oceans, seas, and large lakes can absorb more energy yet heat more slowly than land surfaces. Since energy is more evenly distributed throughout the water column, water bodies also release energy and cool more slowly than do land surfaces. Nearly three quarters of Earth's surface is covered with water, and so oceans and other large water bodies represent immense reservoirs for energy storage and release, strongly influencing climates worldwide. For example, differential heating results in the development of a series of regional thermal high and low pressure systems that reverse positions during daily and seasonal cycles. Wind and precipitation patterns reflect these alternating pressure patterns, and areas where these patterns persist for several months may experience a monsoon climate.

Water bodies and land surfaces transfer energy to depth by distinct processes. The land surface is relatively immobile, and so energy is transferred by conduction from one particle to the next. Conduction is a relatively slow process, resulting in most energy on land being stored near the surface. Energy is rapidly transferred and stored to great depths by convection in water via turbulence. Water is also relatively transparent, while land surfaces are opaque, and incoming solar radiation ("insolation") penetrates deep into the water column but is absorbed at the surface on land. With more energy stored near the surface, land has much greater daily and seasonal temperature fluctuations.

The specific heat of water is also much higher than those of typical land surfaces, meaning it requires more energy to heat water than to heat land by equivalent amounts. Because of the high specific heat of water relative to the land surface, the temperature change is less even though waterbodies typically absorb and release more energy than does the land surface. During the daytime and summer, when insolation is greatest, water bodies absorb and store vast amounts of energy



with only moderate increases in temperature. At night and during winter, a portion of this stored energy is released with only minor cooling of the water body.

During periods of maximum insolation, more energy is transferred to the atmosphere by evaporation over water bodies than over land surfaces. As water molecules change from a liquid to a gaseous phase, energy is used to break the molecular bonds attracting individual water particles, causing the water temperature to decrease as energy is transported to the atmosphere as latent heat. Therefore, during periods of high insolation, increased evaporation diminishes temperature increases of water bodies and further intensifies land-water temperature contrasts.

Differential heating results in temperature and precipitation patterns for coastal areas distinct from locations in continental interiors, particularly in the midlatitudes. Water heats and cools much slower than does land, and, consequently, coastal areas experience only moderate annual temperature variations. In addition, rainfall is typically more evenly distributed throughout the year in coastal areas because of the proximity to extensive moisture sources. In the continental interior, temperatures fluctuate considerably in response to seasonal variations in insolation rates, and most precipitation is delivered as convective summer storms. For example, San Francisco, California, along the west coast of the United States, and Kansas City, Missouri, in the Central United States, are at similar latitudes and have similar mean annual temperatures. However, Kansas City has a humid continental climate, with cold, dry winters and hot summers with increased precipitation, while San Francisco experiences a relatively Mediterranean climate, with similar temperatures year-round, moist winters, and dry summers.

The pattern and degree of differential heating is directly related to daily and seasonal insolation variations. Wind and precipitation patterns along coastlines are particularly responsive to these variations. During the daytime the land surface is heated by insolation, which warms the overlying air, causing it to expand and rise to form a thermal low-pressure system. As a result, a sea breeze develops because the warm air rising over the land surface is replaced by cooler, moister air originating

over the ocean. A sea breeze usually begins in the morning as soon as temperature and pressure differences are great enough to cause a horizontal airflow, and winds reach their maximum strength in the late afternoon, when the differences are greatest. Sea breezes cease shortly after sundown, when the land surface cools to a temperature close to that of the ocean. In the night the land surface cools quicker and the wind pattern reverses as a thermal low develops over the now warmer ocean, and a land breeze forms, with winds blowing from the land to the sea. However, land breezes are not as strong as sea breezes since overnight temperature contrasts between land and water are typically less. In the summer, due to the insolation being the maximum, the temperature differences between land and water are greatest and land and sea breezes are strongest; during winter, the temperature differences are not as great and the winds are not as strong. The precipitation patterns are similar to the wind patterns, with the most precipitation delivered in late afternoons, slightly lagging the time of the most intense sea breezes. Also, more precipitation is delivered during the summer, when sea breezes are strongest. Skies typically clear overnight, when a land breeze develops, and less precipitation is delivered in winter, when sea breezes are weakest.

If differential heating persists for several months, such as throughout winter and summer, prevailing wind and precipitation patterns can develop that result in a monsoon climate. Monsoon winds and rains occur over large land masses and vary seasonally rather than daily. A semipermanent thermal low-pressure system developed over land during the summer draws in cool, moist air from the ocean and causes prolonged intense precipitation. As the land cools in winter, cool, dry airflows to the ocean, resulting in persistent clear, dry weather. The Indian subcontinent and southeast Asia, with clear skies in winter and intense summer precipitation from moisture-rich air originating over the Indian Ocean, provide some of the most dramatic examples of monsoon climates driven by differential heating. Monsoon weather patterns affect almost all tropical and subtropical regions, including parts of North and South America, sub-Saharan Africa, and Australia.

Mark W. Bowen



See also **Atmospheric Pressure; Atmospheric Variations in Energy; Climatology; Land-Water Breeze; Latent Heat; Monsoons; Wind**

Further Readings

- Aguado, E., & Burt, J. (2007). *Understanding weather and climate*. Upper Saddle River, NJ: Prentice Hall.
- Ahrens, C. (2000). *Meteorology today: An introduction to weather, climate, and the environment*. New York: Brooks/Cole.
- Krishnamurti, T., & Ramanathan, Y. (1982). Sensitivity of the monsoon onset to differential heating. *Journal of the Atmospheric Sciences*, 39, 1290–1306.



DIFFERENTIAL VULNERABILITIES TO HAZARDS

The term *differential vulnerabilities to hazards* refers to the differences in impacts of various types of hazards on different segments of society, which are often related to class, gender, ability and disability, race, age, and geographic location. For example, the greatest users of electricity are the wealthy, but the places of extraction and power plants are not normally near them. The same is true of consumption of goods as the wealthy use the most, but landfills and dumps are rarely near them, whether one considers the Cherry Island landfill in Wilmington, Delaware, in the United States or the pile of smoldering trash at Smokey Mountain in Manila, Philippines, that has collapsed and killed the poor people living off its meager resources. Such differential vulnerabilities are important to geographers in part because of the way that they illuminate factors affecting society's exposures and consideration of ways to mitigate hazards and in part because such issues relate back to human rights and questions of good governance.

Hazards fall broadly into the categories of immediate and creeping hazards. Creeping hazards, such

as desertification, occur so slowly that their onset is not recognized, whereas an immediate hazard is very apparent and often elicits a significant response. Vulnerability to hazards is determined by a combination of human and biophysical systems. There are many ways to dissect this confluence of factors. One way to examine vulnerability is to contrast wealthy-industrialized and less wealthy geographic and technological contexts.

Less Wealthy Versus Wealthy Societies

In the less wealthy parts of the globe people tend to be relatively directly dependent on the natural environment. Their resilience is mostly locally determined, and buffers against hazards are thin in terms of time, as well as economic and material resources. For example, when powerful storms such as Typhoon Chataan strike a less wealthy and nonindustrial place such as the Federated States of Micronesia (FSM), there is typically less warning, less locally based technology for emergency response, and less wealth to support nutrition and recovery. Consequently, people are caught relatively unprepared, and often their capacity to feed themselves and recover quickly is weak. It should be noted, however, that such people do at times develop their own low-technology systems to aid in coping with hazards such as drought (see photo).

In wealthier and industrialized parts of the world, people generally have more capacity to prepare for, and respond to, what are commonly termed major natural hazards, such as earthquakes and strong storms. They have greater infrastructure, and their wealth allows both recovery and massive importation of food from outside the local area. However, such places also create their own hazards through industrial processes and technologies.

An example of a creeping hazard is California's preparations to manage the water supply during drought (climate change) through reservoir infrastructure. However, the state quietly and accidentally polluted significant portions of its groundwater supplies in the 1990s and early 2000s though the introduction of chemicals such as MTBE (methyl tertiary butyl ether) into the water supply, which was added to gasoline to reduce air pollution!



Circular breadfruit pit layered with stones on the island of Fefan, FSM, which can hold breadfruit for around a decade to avoid starvation

Source: Dr. William James Smith Jr.

A different example can be pointed to in New Orleans, Louisiana, in the United States, where Hurricane Katrina became the costliest hurricane in U.S. history during the last week of August 2005. The faulty levee systems of New Orleans created a sense of security, but this technology and the policies connected to it led to populations living in areas that flooded terribly, and many, especially African Americans, the disabled, and the sick, were trapped with inadequate paths for escape. Hurricane Katrina killed more than 1,500 people in Louisiana alone. The estimated population of New Orleans in 2000 was 484,674. According to the Rand Corporation, as of September 2008 its estimated population was only 272,000.

Contrast this with the tsunami of December 26, 2004, which struck from southeast Asia to Africa,

hitting many poor communities. In this case it was the lack of technology and no or poor warning systems that led to a terrible toll on life. Some small atolls in places such as off the coast of India were endangered by their location and island height of perhaps 2.3 meters and were physically reshaped by columns of waves that passed over them. Overall, this tsunami killed 230,000 people, according to the United Nations.

Several risks associated with fossil fuels create differences in vulnerability to hazards between wealthy and less wealthy countries. The vulnerabilities of the environment, fuel prices, and fuel supply risks are relatively severe and difficult to overcome in less wealthy countries due to their capital and technology constraints. Air emissions from fossil fuel consumption pose serious, and



sometimes extreme and immediate, threats to both public health and natural ecosystems. Countries are increasingly exposed to fuel price volatility because most new electricity generation in recent years has been gas fired, and oil demand has kept increasing due to greater vehicle miles traveled and increasing car ownership (fuel price risk). Many less wealthy countries are heavily reliant on imports to meet current oil and natural gas demands. As a result, they are vulnerable to disruptions in international trade, as was dramatically illustrated by the oil crisis of the 1970s (fuel supply risk).

Natural Versus Technological Hazards

It is highly debatable whether a stark line can be drawn between natural and technological hazards and human adaptation. When traditionally defined, natural hazards are easily categorized by the layperson, and technological hazards can be seen as hazards such as automobile crashes and nuclear plant accidents. However, in an era of global climate change due to fossil fuel consumption, the lines between natural and technological hazards are blurred. Researching and adapting to such hazards requires attention to human and biophysical systems, including technology studies. If indeed systems for economic growth and high technologies are often developed to serve the interests of the relatively rich, then differences in vulnerability are likely to be systematic.

Environmental Justice

Differences in vulnerability to hazards represent the root causes of environmental injustice. If all persons have environmental rights, then not addressing the varying impacts of hazards while taking into account class, age, ability and disability, gender, or geography represents an unjust response in terms of hazard mitigation. Differences in vulnerability to hazards by subgroup can occur for many reasons, including systems for managing natural resources and food and water systems in particular. For example, women serve as the primary water and food collectors in much of the world. If contamination occurs in the fields where they work, then they will be affected to a greater degree than men.

Other important vulnerability distinctions include the relatively high susceptibility to infectious disease of children and the elderly due to weak immune systems. Also worth noting is the enhanced vulnerability of the disabled when it comes to water and sanitation and, as previously noted, in times when evacuation is required. Yet another example is the relatively greater exposure of non-English-speaking groups to contaminated fish due to the lack of signs that they can understand to warn them not to consume fish at particular locations. A stark global inequity in vulnerability to hazards occurs to the small island countries of the world living just above sea level, which are remarkably vulnerable to sea-level rise, while emitting a negligible amount of greenhouse gases. A similar argument can be made in favor of the less wealthy countries that emit significant levels of greenhouse gases but have forest or land “sinks” that offset their emissions to an extent that many industrialized countries do not. Clearly, the examination of hazards requires geotechnical capacity. However, without blending human and geotechnical knowledge, it is not possible to effectively evaluate differences in vulnerability.

*William James Smith Jr. and
Young-Doo Wang*

See also Coastal Hazards; Drought Risk and Hazard; Environmental Justice; Environmental Rights; Floods; Global Sea-Level Rise; Hurricane Katrina; Natural Hazards and Risk Analysis; Tsunami of 2004, Indian Ocean; Vulnerability, Risks, and Hazards

Further Readings

- Carvajal-Escobar, Y., Quintero-Angel, M., & Garcia-Vargas, M. (2008). Women's role in adapting to climate change and variability. *Advances in Geosciences*, 14, 277–280.
- Comfort, L., Wisner, B., Cutter, S., Pulwarty, R., Hewitt, K., Oliver-Smith, A., et al. (1999). Reframing disaster policy: The global evolution of vulnerable communities. *Global Environmental Change, Part B*, 1, 39–44.
- Cutter, S. (2003). The vulnerability of science and the science of vulnerability. *Annals of the Association of American Geographers*, 93, 1–12.



- Denton, F. (1996). Vulnerability to environmental hazards. *Progress in Human Geography*, 20, 529–539.
- Denton, F. (2002). Climate change vulnerability, impacts, and adaptation: Why does gender matter? *Gender and Development*, 10, 10–20.
- Nyong, A., Adesina, F., & Osman Elasha, B. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitigation and Adaptation Strategies for Global Change*, 12, 787–797.
- Smith, W., Jr. (2008). A geographic analysis of the impact of scale and isolation on coping with hazards on small islands. *IEEE Technology and Society*, 27, 39–47.
- Yeo, R., & Moore, K. (2003). Including disabled in poverty reduction work: “Nothing about us, without us.” *World Development*, 31, 571–590.

DIFFUSION

Although diffusion research is a central part of modern social science, it has a long and sometimes contentious history, with intellectual roots in anthropology and archaeology as well as in cultural geography. Diffusion research studies both diffusion—how innovations move—and innovation itself, which is the creation of new technologies that allow humans to control their environment better, whether such technologies are artifacts (hardware) or simply ways to program how work is done (software). Its third concern is adoption—how different societies receive, reject, and modify innovations. Such studies are common not only in geography but also in agriculture, education, rural sociology, history, and business studies. Understanding the processes by which technologies are transferred—innovation, diffusion, and adoption—is highly desirable in policy development and management studies. Within geography, there have been two main “schools” of diffusion studies. The Berkeley School of cultural geography, which emerged at the University of California in the 1920s, focused mainly on early human technologies such as agriculture. The Lund School, more theoretical and mathematical, emerged at Sweden’s Lund

University in the 1960s. In 2003, a new journal, *Comparative Technology Transfer and Society*, appeared, covering diffusion studies across a variety of disciplines but with a heavy interest in case studies of technology transfer.

The Nature of Culture

The origins of diffusion research lie in 19th-century attempts to understand the nature of culture. Did human culture traits evolve in a manner analogous to biological evolution or did they appear rarely and diffuse out from a very limited number of innovation centers? Two extreme schools of thought developed. An evolutionary position that postulated the psychic unity of humanity concluded that all human beings were innately and equally innovative and that innovation was either continuous or triggered by relatively exogenous variables, such as population pressure. Driven also by notions that contact between human groups in preindustrial societies was minimal, this position led to the notion that most invention was independent and diffusion was either nonexistent or minimal. This has been described as the “utopian” theory of culture change.

At the other extreme, the second position held that there were a limited number of innovation centers or culture hearths from which key innovations such as agriculture diffused. Some argued for only one. This is usually referred to as the idea of *Kulturkreis*—“culture circles” of diffusion outward from the innovation center. Much early mapping of culture traits was an attempt to trace them back to a definable innovation center. For example, the remarkable data collected by the Soviet botanist Nikolai Vavilov in the 1920s and 1930s indicated that there were only eight centers of agricultural innovation. The implications drawn from the fact of the limited number of centers of innovation were that humans were essentially uninventive, that innovation was rare, that contagious diffusion—literally catching an innovation in a manner akin to catching a contagious disease—occurred easily even among preindustrial societies, and that people readily accepted new ideas. These conclusions form the basis of the theory of cultural change based on epidemic or extreme diffusion.



Eurocentric and Other-Centric Diffusionism

Epidemic or extreme diffusionism has been accused of Eurocentrism. Such diffusionism contributed to a powerfully held and generally unquestioned belief that European societies were inherently more, perhaps even uniquely, innovative and that the way to understand world history for the past 1,000 years or so was as the result of the diffusion of superior ideas and technologies out of Europe. One of the clearest rejections of this idea, although it drifts toward Sinocentrism in consequence, came from the British scholar Joseph Needham, whose seven-volume work covers the massive number of Chinese scientific and technological innovations over time. This work clearly demonstrates that China was the source of many innovations we consider European. Additional examples of other-centric forms of diffusionism can be found.

The Eurocentrism argument implies that non-European folk were too unschooled or naive to adopt European ideas and technologies. Diffusionism appeared at the high point of European imperialism, with Europe convinced that its machine technology was vastly superior to any other way of doing things. However, most of the colonial administrators of the great age of European imperialism were derived from the gentries and petite bourgeoisies that had seen their position in European society seriously eroded by industrialization. They were not about to re-create in their imperial possessions the same destructive forces that had damaged their social standing at home. Equally, indigenous elites in colonized societies had no vested interest in adopting the technologies that had already so damaged their societies.

Diffusion as a Theme in Geography

The Berkeley School of cultural geography came to a set of conclusions regarding culture change different from those of either the utopians or the epidemic diffusionists, although some Berkeley-trained geographers veered toward the latter position. The Berkeley School, led intellectually by Carl Sauer, separated origins from dispersals, provenance from process. Process was central since the Berkeley School embraced a cultural

historical geography. Berkeley geographers did not follow the idealist explanations of the *Kulturkreis* School, nor did they easily fall into the trap of Eurocentrism. The Berkeley School blended idealist, environmental, and social-structural explanations to come up with relatively sophisticated depictions of provenance. But innovation was seen as rare, and the result was that the process of diffusion was much more easily explained and modeled. Heavily influenced by the Berkeley School, British geographer Peter Hall has returned to provenance issues, focusing on the concentration of particular innovations in particular cities at particular historical moments driven by particular historical processes.

The Soviet economist Nikolai Kondratiev observed that there appeared to be half-century-long wave rhythms in the global economy, accelerations and decelerations of the underlying growth rates of prices. The Austrian economist Joseph Schumpeter suggested that the root cause of long cycles lay in innovations in technology that drove gales of creative destruction followed by the flight of investment capital from less productive arenas into more productive ones. Geographers have contributed to the study of such long cycles in the global economy and have argued that innovation and diffusion can be seen as the very motor of capitalist development.

The main focus of diffusion research tends to be pragmatic, in part concerned with how societies innovate and in part concerned with how such innovations move around and are rejected, adopted, and modified. The unique contributions of geography to studies of diffusion have been to resist extreme diffusionism, concentrate on innovation as a process, and, in the case of the Lund School, develop highly theoretical and mathematical techniques to model and predict the spatial diffusion of innovations over time. This has also led to studies of the spatial structure of communication, in particular how it has been mediated by the life courses of individuals and families over time.

Diffusion as a Theme in History

Historians studying major themes such as the rise of Western civilization have emphasized not only the interchange of technologies and ideas among



the major global cultures but also the tendency of cultures to “forget” their borrowings from other cultures. Business historians and historians of technology have made clear over the past 40 years or so that diffusion is commonplace in the development of the industrial world. But it has always been easier and cheaper to copy than to innovate, and it seems to the uninformed that such a process would be simple. The existence of informal communications networks, such as networks of letter writers, has been shown by literary historians to be responsible for much “under-the-radar” diffusion. The supposed simultaneous development of ideas and technologies in different parts of the world has often resulted from the exchange of ideas through informal networks.

Technology Transfer and Development

No less a person than Karl Marx believed that the transfer of British railroad technology to India would result in the rapid and easy transfer of vital other mid-Victorian technologies such as machine textile production, the consequence of which would likely be British industrial decline. Similar arguments have been advanced by modern observers with regard to the likely shift of the information economy, again to India because of its common use of English, the main global business language, as a second language. Other countries, first Japan and now China, but also others, have been suggested as the likely heirs to Western production of goods.

Such claims usually ignore the problems of technology transfer. American attempts to acquire British textile machine technology in the aftermath of the American Revolution show how difficult such transfers are. The problems lay not in transferring (smuggling) machines out of Britain but in establishing in America the complex infrastructure of knowledge, machine tool making, and skilled labor. Case studies show that transfers of complex technologies are never easy because of the likely disparities between the receiving and sending cultures. This is even true of almost equally sophisticated societies: The transfer of organic chemistry from Wilhelmine Germany to America during World War I was long, arduous, and often flawed, despite the huge pressure of the war to increase explosives production.

Technology Transfer in the Automobile Industry

The increased importance given to patent infringement and copying in today’s world means there is a vested interest in both concealing and revealing such copying. No company readily admits that its product is legally copied from a competitor, let alone that it copies illegally. Some of the best examples appear in the automobile industry and come from Japan but have to be extracted from a complex literature in business history, enthusiast magazines, and books. An example of such technology transfer is the development of the Japanese Datsun automobile. The Japanese company DAT Motorcar, needing to market a small car in the early 1930s, simply copied the Rosengart, a version of the British Austin Seven. The Japanese intended to market the car, initially named Datsun and later renamed Datsun, in Australia as well as Asia. Charged by Austin with patent infringement, DAT bought a license in 1934. After World War II, DAT Motorcar renewed the license, and their Datsun products displayed a strong Austin heritage. This status changed with the development of the Datsun 240Z, which had German origins both in its engine, modeled after the Mercedes, and in its body design. DAT Motors was never very willing to admit any of this. Only after much legal prompting did the company recognize that Albrecht Goertz, the designer of the BMW 507 and Porsche 911 sports cars, was largely responsible for the body design for the 240Z.

Conclusion

The clear prevalence of diffusion in industrial societies makes it hard to sustain utopian theories of cultural change without running foul of the reasonable assumption that some sort of equivalent to the law of uniformitarianism has to operate in the cultural realm; it makes little sense to argue that the processes observably at work today are somehow radically different from those at work in the past.

It makes sense to distinguish innovation from diffusion. It is equally clear that theories of contagious diffusion are idealistic and almost never operate in the real world. Barriers to diffusion are often high, in particular in the cultural realm, and



so it makes sense to consider adoption environments. Knowing what makes a group able and willing to accept an idea or technology is as critical as knowing what makes them reject it: At a popular level, the latter is summed up as the NIH (“not invented here”) syndrome. Not all messages sent will be received: An important component of the adoption environment is thus the prestige of the sender, what geographer Philip Wagner refers to as *geltung*. Understanding how technology transfer sometimes fails is important. Finally, innovations simply must fit into preexisting structures of time and space, which implies the displacement of previous innovations, which can be described as de-novation.

Peter J. Hugill

See also **Berkeley School; Business Cycles and Geography; Communications and Geography; Hägerstrand, Torsten; Haggett, Peter; Innovation, Geography of; Modernization Theory; Product Cycle; Sauer, Carl; Space of Flows; Technological Change, Geography of**

Further Readings

- Blaut, J. (1991). *The colonizer's model of the world: Geographical diffusionism and Eurocentric history*. New York: Guilford Press.
- Hägerstrand, T. (1967). *Innovation diffusion as a spatial process*. Chicago: University of Chicago Press.
- Hall, P. (1998). *Cities in civilization*. New York: Pantheon Books.
- Hugill, P. (2003). Technology, its innovation and diffusion as the motor of capitalism. *Comparative Technology Transfer and Society*, 1, 89–113.
- Hugill, P., & Dickson, D. (Eds.). (1988). *The transfer and transformation of ideas and material culture*. College Station: Texas A&M University Press.
- Jeremy, D. (1981). *Transatlantic industrial revolution: The diffusion of textile technologies between Britain and America, 1790–1830s*. Cambridge: MIT Press.
- Rogers, E. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.
- Sauer, C. (1952). *Agricultural origins and dispersals*. New York: American Geographical Society.
- Tushman, M., & Moore, W. (Eds.). (1988). *Readings in the management of innovation* (2nd ed.). New York: Ballinger.



DIGITAL DIVIDE

By now, digital reality and everyday life for many people have become so thoroughly fused that it is difficult, if not impossible, to disentangle them. In this context, simple dichotomies such as “offline” and “online” fail to do justice to the diverse ways in which the “real” and virtual worlds are interpenetrated for hundreds of millions. Yet for many others—the familiar litany of the poor, the undereducated, ethnic minorities, and the socially marginalized—the Internet remains a distant, ambiguous world. Denied regular access to cyberspace by the inability to purchase a personal computer, the lack of technical skills necessary to log on, or public policies that assume their needs will be magically addressed by the market, the information have-nots living in the economically advanced world are deprived of many of the essential skills necessary for a successful or convenient life. While those with regular and reliable access to the Internet drown in a surplus of information—much of it superfluous, irrelevant, or unnecessary—those with limited access have difficulty comprehending the opportunities it offers, the savings in time and money it allows, the sheer convenience and entertainment value it provides, and the ability to acquire data from it, from bus schedules to recipes to global news.

As the uses and applications of the Internet have multiplied, the costs sustained by those denied access rise accordingly. At precisely the historical moment that contemporary capitalism has come to rely on digital technologies to an unprecedented extent, large pools of the economically disenfranchised are shut off from cyberspace. As the Internet erodes the monopolistic roles once played by the telephone and television, and as the upgrading of required skill levels steadily renders information technology skills necessary even for lower-wage service jobs, lack of access to cyberspace becomes increasingly detrimental to social mobility. Indeed, those excluded from the Internet may be more vulnerable than ever before to social forces they do not and often cannot perceive.

The Global Digital Divide

In 2009, roughly 1.7 billion people, or 26% of the planet, used the Internet on a regular basis. The United States continues its long-standing

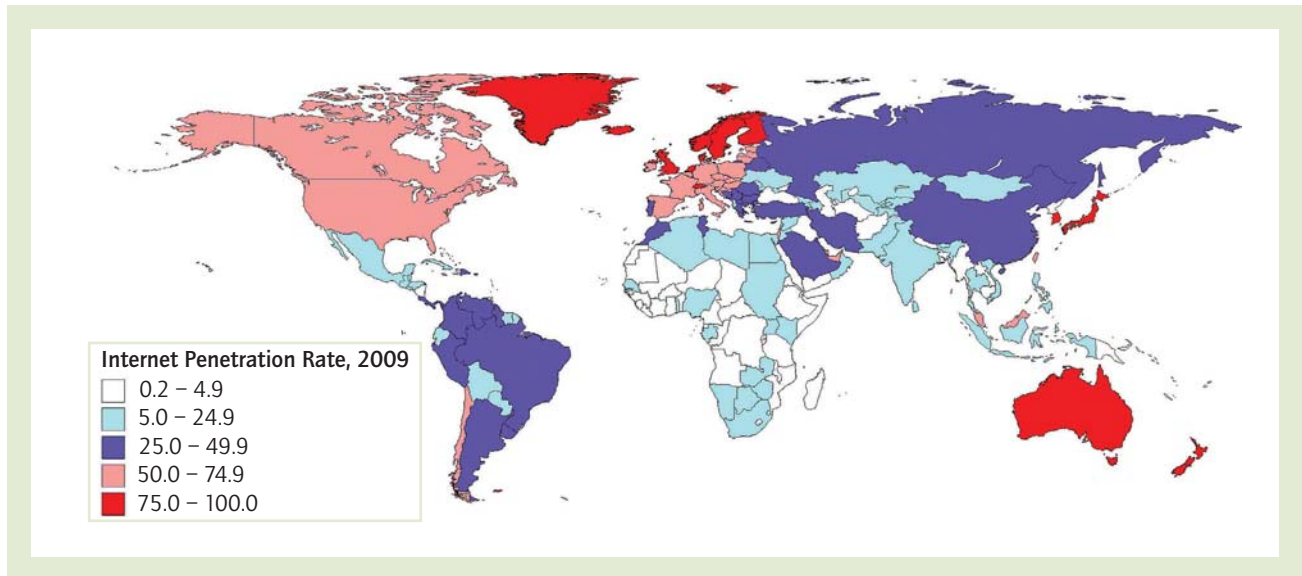


Figure 1 Internet penetration rates internationally, 2009. International patterns of the digital divide mirror broader economic differentials among countries.

Source: Author.

position as one of the world's societies with abundant access to the Internet. Inequalities in access to the Internet internationally reflect the long-standing bifurcation between the First and Third Worlds. While virtually no country is utterly without Internet access (although portions of Africa come close), the variations among nations in relative accessibility are huge. Outside the global core, the vast bulk of the world's people, particularly those in the Third World, have little to no access, a reflection of centuries of colonial occupation and their modern institutional legacies. To speak of the Internet as liberatory in impoverished social contexts such as Mozambique or Bolivia, with high illiteracy rates and few telephones, is absurd. What is more, within such countries networks are invariably concentrated within cities, whereas the plurality, and often the majority, of the population lives in rural areas. With slow connections and out-of-date telephone systems, graphical information—which uses much more bandwidth than text—is virtually out of the question (see Figure 1).

Global access to the Internet is deeply conditioned by the density, reliability, and affordability of national telephone systems, which form the heart of the architecture of cyberspace. For this

reason, the distribution of Internet hosts also mirrors the enduring legacy of the superpower bifurcation during the Cold War: Soviet-backed regimes distrusted the telephone, which allows two-way communication, and preferred television, which allows only one-way flows of information. Most Internet communications occurs along fiber optic lines leased from telecommunications companies (which carry 80% of international communications), many of which are state regulated, in contrast with the largely unregulated state of the Internet itself. Prices for access vary by the duration of the phone call, the distance, and the degree of monopoly: In nations with telecommunications monopolies, prices are much higher than in those with deregulated systems. The global move toward deregulation in telecommunications, which started with the breakup of AT&T and privatization of British Telecommunications and has spread rapidly in many countries, will likely lead to more use-based pricing and fewer cross-subsidies (e.g., between commercial and residential users), a trend that will likely make access to cyberspace less affordable to low-income users worldwide.

The constraints on Internet access are not only economic but also political, given that the



electronic dissemination of knowledge can challenge established relations of power. Many governments have come to fear the Internet for its emancipatory capabilities. The Chinese government, for example, stung by students' use of fax and e-mail during the 1989 Tiananmen Square massacre, limits access to Internet nodes. Private satellite dishes are still illegal in China and Malaysia. Singapore, no model of democracy, censors electronic information with a national standards review board. In 1996, the Guatemalan government, relying on the state-owned telecommunications company, Guatel, made private satellite or telecommunications links to the Internet illegal.

Digital Divide in the United States

Although Internet penetration rates in the United States (74.9% in 2009) are not as high as in Scandinavian nations, they remain higher than those in many other urbanized, industrialized countries, and Americans as a whole still constitute the largest and most influential national bloc of Internet users in the planet. Several factors have conspired to accelerate Internet usage in the United States among and within different social groups. Of these, the continued decline in the price of personal computers (PCs) looms large. Following Moore's Law, which speculates that the cost of computers falls by half every 1½ years, PCs have become ubiquitous across the United States. Indeed, relatively fast, low-end machines are readily available for less than \$600 in numerous retail outlets. With 574 PCs per 1,000 people in 2005, the United States stands second only to San Marino in terms of availability of this device. Almost 80% of Americans use a PC (although not necessarily the Internet) once or more per week either at work or at home, the vast bulk of the PCs being networked. Because the value of a network rises in proportion to the square of the number of users, the Internet and the PC made each other increasingly powerful and attractive. Simultaneously, the rise in user-friendly graphics interfaces such as Netscape greatly facilitated Internet access for the parts of the population lacking in sophisticated computer skills. Moreover, as the number of applications of the Internet has grown, the hours of usage have increased steadily to more than 9 per week. The rise in PC

ownership has been central to those who argue that the digital divide will disappear on its own accord.

Throughout the 1995 to 2009 period, the growth in Internet use among various sociodemographic groups was rapid, often spectacular. Average Internet penetration rates—including access at home, work, or school—more than quadrupled, from 14% to 74.9%; by 2009, 253 million Americans were using the Internet regularly. Thus, the innovation, the most rapidly diffused technology in world history, went from a tool or toy of a minority to an essential implement used by the vast majority. Every social group, as differentiated by age, gender, race/ethnicity, educational level, or household income, experienced marked gains. Thus, to the extent that the digital divide persists in the United States (and other economically advanced countries), it must be understood within the context of this sustained and rapid increase in the number of users and proportion of the population (see Table 1).

This growth, however, did not occur at identical rates among all social categories. Take, for instance, age. The young (i.e., below 30 years of age) steadily exhibited the highest Internet penetration rates, reaching 83% in 2006. For many children who grow up surrounded by digital technologies, the Internet is hardly mysterious. In contrast, in both benchmark years, the elderly experienced the lowest rates of Internet usage (a mere 2% in 1995 vs. 33% in 2006), as well as the slowest rate of increase in users. Many elderly people find new technologies to be difficult or intimidating, do not appreciate the potential benefits, and are easily frustrated by their lack of technical skills. The digital divide, therefore, is closely wrapped up with generational differences.

Notably, gender differences in Internet usage, which included an eight-percentage-point lead among men in 1995, declined steadily throughout this period, so that by 2006 it declined to a relatively minor two percentage points. Despite its popular reputation as an exclusive haven of masculinity, the Internet has in fact been harnessed by increasing numbers of women. Gender differentials in access reflect both the lower socioeconomic status of women relative to men as well as sexist cultural attitudes toward science and technology. The declining gender gap speaks of the increasing



	<i>Percent Online in</i>		<i>Percentage of Growth</i>
	2006	1995	
Age			
18–29	83	21	62
30–49	82	18	64
50–64	70	9	61
65+	33	2	31
Total	70	14	56
Sex			
Men	71	18	53
Women	69	10	59
Race/ethnicity			
White	72	14	58
Black	58	11	47
Latino/Hispanic	69	21	48
Education			
Less than high school	36	2	34
High school graduate	59	8	51
Some college	84	20	64
College graduate	91	29	62
Household income			
Less than \$30,000	45	8	37
\$30,000–\$49,000	75	15	60
\$50,000–\$75,000	90	23	67
More than \$75,000	93	32	61

Table 1 Growth in adult U.S. Internet users, 1995–2006. Falling personal computer prices have contributed to rapid, if uneven, growth in Internet access in all major socioeconomic groups in the United States.

Source: Created by author, based on data from www.census.gov/compendia/statab/tables/08s1128.xls.

familiarity with digital technologies among many women, particularly the young and well educated, who are often employed in producer services in which minimal computer skills are an essential prerequisite. Moreover, enrollment rates in American universities for women have consistently surpassed those for men, indicating that the future gendered digital divide will become smaller yet, if not disappear altogether.

The dimension of the U.S. digital divide that has drawn the most serious scrutiny concerns racial or ethnic differences. Given the profound inequalities in U.S. society in terms of income,

educational opportunities, and employment that exist between whites and ethnic minorities, it is not surprising that this gap is manifested in terms of access to cyberspace, that is, much of the racial ravine in digital access is due to income discrepancies. In 1997, for example, white Internet usage rates were more than double that of Latinos/Hispanics (37.7% vs. 16.6%) and roughly double that of blacks or African Americans (19.0%). In 2006, Internet access rates for whites remained well above those for minorities or the national average. There are signs, however, that this dimension of the digital divide is slowly, if hesitantly, diminishing. Today, the majority of ethnic minorities uses the Internet, and the relative difference between them and the white population has declined. There are important differences within minority populations, however. Among African Americans, Internet usage tends to be concentrated among the young and the college educated, particularly women. Likewise, the Latino population is far from heterogeneous, and significant discrepancies in Internet access and usage remain among various subgroups; usage rates tend to be much higher among bilingual Latinos than among those who speak only Spanish. Indeed, among English-dominant Latinos, Internet usage rates are identical to that of whites. Generally, Mexican Americans and those with origins in Central or South America had lower rates of access than did Cuban Americans or Puerto Ricans. In short, while racial or ethnic discrepancies in Internet access and usage remain, all groups have experienced significant growth in use, and the relative differences between them have declined.

Persistently underlying the digital divide in the United States are vast socioeconomic differences, particularly education and household income, which effectively serve as markers of class. Although populations at all four broad educational levels (less than high school, high school graduate, some college, college graduate) exhibited gains in Internet access, profound differences remain. Among college-educated Americans, Internet usage is almost universal (91%); those with a high school education or less witnessed a growth in usership from 2% in 1995 to 35% in 2006. Educational level, therefore, is a prime predictor of who is online and who is not. Similarly, income remains a useful measure of who



has access and who does not, particularly at home. In 1995 roughly one third of upper-income households (more than \$75,000 annually) used the Internet; by 2006, this share had risen to 93%. Rapid growth rates also occurred among those of more modest means, although less than a majority (45%) of poor households (less than \$30,000 annually) were users in 2006. Thus, as with race/ethnicity and educational level, absolute discrepancies persisted, but relative differences declined as Internet usage rates advanced most rapidly among those with hitherto the least access.

Schools remain perhaps the most important arena in which the digital divide is manifested and reproduced. In an age in which the acquisition of skills to participate in advanced producer services is key to upward social mobility, this issue assumes special importance. Inequalities in school funding are mirrored in the prevalence of the Internet in public classrooms: While 99% of schools offer children access to networked PCs in one way or another, these rates vary significantly in terms of quality of access. After home and school, public libraries are the third most common point of Internet access for children, especially for lower-income minorities; however, libraries have limited hours and often lack high-speed connections. Not surprisingly, the digital divide in schools has strongly racialized overtones: White students are much more likely than are minorities to use the Internet in the classroom or school library.

The latest frontier in the digital divide is unquestionably the arena of broadband delivery services. Broadband applications include digital television, business-to-business linkages, Internet gaming, telemedicine, videoconferencing, and Internet telephony. With large, graphics-intensive files at the heart of most Internet uses today (e.g., downloading forms, reading online newspapers), broadband has become increasingly imperative for Web browsing. In 2006, roughly 44% of the U.S. population used broadband technologies of one sort or another. This proportion is relatively low compared with most of the economically developed world; indeed, under the Bush administration, the U.S. slipped from 3rd to 13th internationally in terms of relative access to broadband services, and Americans pay 10 to 20 times as much per megabit for broadband as do their

counterparts in Korea and Japan. Broadband accessibility in 2006 closely mirrored that of the Internet as a whole: It tends to be most prevalent among the young, males, whites, and the well educated and rises monotonically with household income. Such social differentials are accompanied by spatial ones. Broadband technologies have been slow to reach rural America: Whereas 86% of residents in cities with more than 100,000 residents have access to DSL, very few in towns with fewer than 10,000 people do so. Thus, there are strong reasons to believe that far from eliminating the digital divide, broadband reproduces it, gives it new form, and, in some cases, accentuates it.

Conclusion

Contrary to the hyperbole that continues to swarm around the Internet, multiplying even faster than do viruses and Web pages, cyberspace reflects all the inequalities and social divisions that permeate the nonvirtual world. Far from constituting some mythologized world of unfettered individualism, as some advocates portrayed it, cyberspace is in fact thoroughly shot through with relations of class, gender, ethnicity, and other social categories. Theorizations of the digital divide must of necessity take these dimensions into account to avoid the overly optimistic, technologically determinist, and often conservative perspectives that deny their ongoing existence and significance to understanding the Internet. When viewed in social terms, the interpenetration of the virtual and real worlds is mutually constitutive: Discrepancies in access to the Internet both mirror and constitute inequalities in the world outside cyberspace.

Barney Warf

See also **Cyberspace; Telecommunications and Geography; Virtual Geographies**

Further Readings

Bolt, D., & Crawford, R. (2000). *Digital divide: Computers and our children's future*. New York: TV Books.



- Compaine, B. (Ed.). (2001). *The digital divide: Facing a crisis or creating a myth?* Cambridge, UK: Cambridge University Press.
- DiMaggio, P., Hargittai, E., Newman, W., & Robinson, J. (2001). Social implications of the Internet. *Annual Review of Sociology*, 27, 307–336.
- Graham, S. (2002). Bridging urban digital divides? Urban polarisation and information and communication technologies (ICT). *Urban Studies*, 39, 33–56.
- Korupp, S., & Szydlík, M. (2005). Causes and trends of the digital divide. *European Sociological Review*, 21, 409–422.
- Kuttan, A., & Peters, L. (2003). *From digital divide to digital opportunity*. Lanham, MD: Scarecrow Press.
- National Telecommunications and Information Administration. (2004). *A nation online: Entering the broadband age*. Washington, DC: U.S. Department of Commerce. Retrieved from www.ntia.doc.gov/ntiahome/dn/index.html
- Stevens, D. (2006). *Inequality.com: Money, power and the digital divide*. Oxford, UK: Oneworld.
- Warf, B. (2001). Segueways into cyberspace: Multiple geographies of the digital divide. *Environment and Planning B: Planning and Design*, 28, 3–19.
- Warf, B. (2010). The digital divide in the U.S. in the 21st century. In E. Ferro, Y. Dwivedi, J. Ramon Gil-Garcia, & M. Williams (Eds.), *Overcoming digital divides: Constructing an equitable and competitive information society* (pp. 112–130). New York: IGI Global Press.

are introduced; next, the methodology for generating digital terrain models is described; and finally, the analysis and application of such a model are outlined.

Basic Concepts

A DTM is a digital representation of the terrain topography. The term was coined by Miller and Laflame of the Massachusetts Institute of Technology (MIT) in 1958. Their original definition was simply a statistical representation of the continuous surface of the ground by a large number of selected points with known X, Y, Z coordinates in an arbitrary coordinate field.

A number of terms related to DTM have been in use. These include *digital elevation model* (DEM), *digital height model* (DHM), *digital ground model* (DGM), and *digital terrain elevation model* (DTEM). These terms originated from different countries. DEM was widely used in the United States; DHM came from Germany; DGM was used in the United Kingdom; and DTEM was introduced and used by the U.S. Geological Survey (USGS). They have slightly different meanings. A DGM more or less has the meaning of “a digital model of a solid surface.” In contrast to the use of *ground*, the terms *height* and *elevation* emphasize the “measurement from a datum to the top” of an object. They do not necessarily refer to the altitude of the terrain surface, but in practice, this is the aspect that is emphasized in the use of these terms. Among these terms, DEM is nowadays the most widely accepted one for the digital representation of terrain topography, with terrain heights organized in a matrix form. The meaning of *terrain* is more complex and embracing. It may contain the concept of height (or elevation) but also attempts to include other geographical elements and natural features. Therefore the term *DTM* tends to have a wider meaning than does DEM and attempts to incorporate specific terrain features, such as rivers, ridge lines, and break lines, into the model.

Beyond DTM is a model called the *digital surface model* (DSM). It is a digital representation of the actual terrain surface. In other words, in a DSM, not only the terrain topography but also the spatial features (such as buildings, trees, and roads) on the terrain topography are represented.



DIGITAL TERRAIN MODEL

Terrain models have always appealed to military personnel, planners, landscape architects, and civil engineers, as well as other experts in various Earth sciences. Originally, terrain models were physical models, made of rubber, plastic, clay, sand, and so on. Today, terrain models are represented in digital form, leading to the terminology *digital terrain model* (DTM). In this entry, first the basic concepts



If one removes all these spatial features from a DSM, one obtains a DTM. Indeed, the relationship between a DTM and a DSM may be compared with that between a contour line map and a topographic map.

Related to DTM, there are four basic issues: (1) how to acquire a set of data for the generation of DTM, (2) how to generate a DTM, (3) how to control the quality of the DTM, and (4) what can be done with DTM.

The process of construction of a DTM surface is called *digital terrain modeling*.

Data Acquisition for DTM Generation

Data acquisition is the collection of data to answer three basic questions:

1. From what sources (data sources) are data to be acquired?
2. What kinds of points are to be measured?
3. What techniques should be used for measurement?

Data sources are the materials from which data can be acquired. For the generation of a DTM, the actual terrain surface is of course the direct source. Indirect sources include aerial and/or satellite (or space) images and existing contour maps. The images could have been taken using scanners, radar, or frame cameras. For the height information of terrain points to be obtained, there is a need of an overlap between two images (taken at slightly different positions). For aerial photographs taken by a camera, the standard overlap is 60%. Such images are called *stereo images*, and a three-dimensional (3D) model can be reconstructed only in the overlapping area. For radar images, both the amplitude image and the phase angle are recorded.

To model a piece of terrain surface, first a set of data points needs to be acquired from the surface. In data acquisition, two stages are distinguished: sampling and measurement. Sampling refers to the selection of locations, while measurement determines the coordinates of the locations.

A number of sampling strategies have been in use. The most popular strategy is grid-based sampling. In this strategy, only those points that are

located at the nodes of a designed grid are selected. Resultant height data can be easily organized into a matrix form. However, this doesn't consider the importance of individual points, and, indeed, very important points (VIPs) may have been omitted. In contrast to grid-based sampling is a strategy called selective sampling. In this strategy, VIPs are selected, such as peaks, pits and passes, points along ridges, courses, and break lines, and those points at which the change in slope is significant. A combination of grid-based sampling and selective sampling leads to a new strategy called composite sampling. Some other sampling strategies are also in use, although they are not very popular, such as progressive sampling (a type of grid-based sampling, with the grid made progressively finer) and contour-based sampling (i.e., selection of points along contour lines). After sampling, three attributes may be used to measure the quality of the data, that is, accuracy, distribution, and density.

Field surveying instruments such as total station and GPS (global positioning systems) receivers may be employed for measurement of the 3D coordinates of any points directly from the terrain surface. Field surveying is feasible only for a small area, although high-quality (or high-accuracy) data can be obtained. Photogrammetry is a technique used for measurement/computation of 3D coordinates from stereo images (or photographs). Traditionally, a pair of stereo images are used to reconstruct an analog model, and the measurement is carried out on the reconstructed analog model. The reconstruction is a process to restore the six orientation elements (three for position and three for angular rotations) of each image. In the digital era, the measurement has been replaced by computation. If the positions (x , y coordinates) of a point on both images (of the stereo pair) and the orientation elements of each image are known, then the 3D coordinates of the point on the ground can be computed using a mathematical model. Nowadays, for a given point on one image, the search for a correspondence point (conjugate point) on the other image has also been automated by a technique called *image matching*. With matching techniques, the acquisition of data from digital images for DTM generation has been fully automated. In radar (more precisely synthetic aperture radar—SAR)



images, when only the amplitude images are used, the principle is similar to that of photogrammetry, although different mathematical models are used for the computation due to the different imaging geometry. The technique is called radargrammetry. If, on the other hand, the phase angle information of the SAR images is used, then interferograms can be generated, and the heights are computed from the information contained in the interferograms. This technique is called SAR interferometry or interferometric SAR (InSAR). Cartographic digitization from existing contour line maps using digitizers or scanners is employed. If scanning is used, then a raster-to-vector conversion is required to convert the scanned contours into vector-based contour lines.

Modeling Approaches for DTM Surface Reconstruction

The process of reconstruction of a DTM surface is called digital terrain modeling. It is also a process of mathematical modeling, that is, fitting a mathematical surface onto the set of acquired data. Triangle-based and grid-based modeling are the two approaches commonly used. In the former, the set of data points is first triangulated into a triangular irregular network (TIN), and then a surface is fitted onto the TIN. If the surface determined by each triangle is used to represent only the area covered by the triangle, then the whole DTM surface can be formed by a linked series of contiguous triangles. It is also possible to fit a polynomial of order 2 or higher into the TIN to reconstruct a smooth surface. In grid-based modeling, if a surface is reconstructed from four grid nodes only, then the result is a bilinear surface; however, it is normal practice to fit a polynomial of order 2 or higher onto a large set of nodes to form a smooth surface over a large area.

In the case of triangle-based modeling, the DTM surface can be reconstructed directly from acquired data. However, in the case of grid-based modeling, if the acquired data are not in a grid form, then an interpolation is applied to the acquired data to form a regular grid and then the surface is reconstructed from the grid data. Such an interpolation process is often referred to as *random-to-grid interpolation*.

Interpretation of DTM

To interpret a DTM means to understand the terrain characteristics through the extraction/computation of the parameters. DTM interpretation is also called DTM-based *terrain analysis*.

The term *terrain analysis* means different things to people with different backgrounds because they emphasize different aspects. In some literatures, the emphasis in digital terrain analysis is on interpolation methods for terrain surface modeling; and in some other literatures, the emphasis is on visualization of DTMs. However, to most people, it means the derivation of attributes from terrain surfaces.

Some parameters related to the geometry, morphometry, hydrology, and visibility of a terrain surface can be computed from a DTM. The geometric parameters include the surface area, projection area, volume, and so on. Morphometric parameters are those that can be derived directly from the DTM using some local operations, such as slope and aspect, rate of change in slope and aspect, plan and profile curvatures, roughness, and so on. Flow lines, catchments, and hydrological networks can be extracted from a DTM. Two fundamental parameters in *visibility analysis* can also be computed from a DTM, that is, point-to-point visibility (intervisibility of line of sight) and point-to-area visibility (viewshed).

These parameters are also called *primary topographic attributes*. A number of other secondary topographic attributes can be computed from them, such as wetness indices, stream-power indices, radiation indices, and temperature indices.

Quality and Accuracy of DTM

Quality, efficiency, and economy are three critical parameters in digital terrain modeling. The question of how to measure the quality of a DTM is not easy to answer. In general, two types of quality measures are suggested, that is, the producer's measures and the user's measures. DTM users may demand that the quality of terrain parameters computed from a DTM should be used as a measure of the DTM quality. This insistence is reasonable. However, this approach requires a larger number of measurements to be used, and this is not feasible in practice. The producers of



DTMs are national mapping agencies, and they make use of the root mean square (RMS) errors at check points as a quality measure, following the tradition of topographic maps. Such a quality measure is referred to as *DTM accuracy*. If there are no height errors in a DTM, then all terrain parameters computed from the DTM are also free of error.

It has been found that the RMS error of a DTM increases with greater intervals between acquired data points. The trend is quite linear if a composite sampling strategy is employed for data acquisition. However, the trend will be of the second order if only grid-based sampling is employed for data acquisition.

Another issue related to the quality of DTMs is quality control. This refers to the precautions or actions taken to ensure the quality of the final DTM. Quality control could be applied online and/or offline. Online quality control means making quality inspections during data acquisition and/or surface modeling to avoid gross and/or systematic errors. Offline quality control means detecting gross errors and rectifying systematic errors after data acquisition and surface modeling. Various gross error detection techniques are available.

Applications of DTMs

DTMs have recently become an important part of national geospatial data infrastructure. DTMs has found widespread uses in all geosciences and engineering, such as

- planning and design of civil, road, and mine engineering;
- 3D animation for military purposes, landscape designing, and urban planning;
- analysis of catchments and hydraulic simulations;
- analysis of the visibility between objects on the terrain surface;
- terrain analysis and volume computation;
- geomorphological and soil erosion analysis;
- remote sensing image interpretation and processing; and
- various types of geographical analysis.

Zhilin Li

See also [Aerial Imagery: Interpretation](#); [Cadastral Systems](#); [GIS in Land Use Management](#); [Landscape Architecture](#); [Landscape Quality Assessment](#); [Land Use Analysis](#); [Map Animation](#); [Map Visualization](#); [Scale in GIS](#); [Suitability Analysis](#); [Terrain Analysis](#); [Three-Dimensional Data Models](#)

Further Readings

- Li, Z., Zhu, Q., & Gold, C. (2005). *Digital terrain modelling: Principles and methodology*. Boca Raton, FL: CRC Press.
- Miller, C., & Laflamme, R. (1958). The digital terrain model: Theory and applications. *Photogrammetric Engineering*, 24, 433–442.
- Petrie, G., & Kennie, T. (1991). *Terrain modelling in surveying and civil engineering*. New York: McGraw-Hill.
- Wilson, J., & Gallant, J. (Eds.). (2000). *Terrain analysis: Principle and applications*. Singapore: Wiley.
- Zhou, Q., Lees, B., & Tang, G. A. (Eds.). (2008). *Advances in digital terrain analysis*. Berlin, Germany: Springer.



DIGITIZING

Digitizing or digitization is a process that represents an object, image, or document by a discrete set of points, lines, polygons, or raster images. The result is called a *digital representation* or a *digital image* of the object represented. In geographic information systems (GIS), digitizing is often the process of converting features on paper or an analog map into digital format. To digitize a map, a GIS practitioner will often use a digitizing tablet (also known as a digitizer) connected to a computer to trace over the features of interest or a scanning device that creates a digital image that is later manipulated in the GIS software.

When using a digitizing tablet, the x , y coordinates of the features are automatically recorded and stored as spatial data after the paper map is registered in a coordinate system that the user designates. Digitizing with a digitizing tablet



offers another way, besides screen digitizing “freehand” (also called “heads-up” digitizing), to create and edit spatial data. Users can convert features from almost any paper map into digital features. Typical devices used for digitizing are a digitizing board or a tablet and a cursor. The digitizing board consists of tiny wires that run horizontally and vertically, forming a grid. The digitizing cursor has an optical viewer with crosshairs, often called a puck, which allows the user to visually locate a point on the map. The most common cursor has at least 16 buttons and contains a user-definable keyboard. Digitizing converts spatial features on a map into a digital format. Before actually starting to digitize, a map is mounted on a digitizing board and then registered on a coordinate system, and a digitizer cursor is used to trace each map feature. When a point is identified on the map, the user presses a button on the cursor and the computer records the current x, y coordinates of that position in the designated digitizer units. These become the x, y coordinates of the point feature or one of the points comprising a line or polygon. The location of the digitizer cursor’s crosshairs on the board and the map is simultaneously displayed on the graphic display screen. In addition to using a digitizing tablet, large-format scanning devices are also used to create digital representations of maps, which are then “vectorized” and edited within a GIS application.

Users often use a digitizer in conjunction with editing tools in GIS applications such as ArcMap or MapInfo to create new features or edit existing features on a digital map. The user can digitize features into a new GIS data set and then add additional data to an existing map once it is in a digital format. Cadastral mapping is a common task involving a digitizing tablet that traces property parcels drawn on photography printed on Mylar or paper. This process allows the user to create a digital representation of property parcels that can be updated and/or edited more easily. Furthermore, the digital representations can be used to perform spatial analyses that would be more cumbersome using paper or Mylar maps.

Shawn Lewers

See also **GIScience**; **Vectorization**

Further Readings

Hughes, L. (2004). *Digitizing collections: Strategic issues for the information manager*. New York: Neal-Schuman.



DISABILITY, GEOGRAPHY OF

The geography of disability is an important and emerging area of human geography scholarship. Research in this area of the discipline has increased over the past two decades, to the point that it is now a distinctive subdiscipline referred to often as the geographies of disability. The nature of research in this subdiscipline has greatly evolved over time due to changes in research interests, the infusion of ideas from other disciplines such as disability studies, the use of a greater range of research methods, and the development of stronger connections with other geographic subdisciplines such as health geography. Much research in the geographies of disability is united by a shared interest in understanding sociospatial experiences of disability and processes of disablement. This entry gives an overview of models of disability and examines research on the geography of disability, including emerging work on mind and body differences as well as issues of research design and dissemination of concern to the subdiscipline.

Central to all disability research, including that undertaken by geographers, is understanding what disability is; there is, however, no single, definitive way of doing this. Rather, there are multiple models to assist with characterizing disability. The key difference between these models centers on where the “cause” of disability or disablement is located. Biomedical models of disability identify mind and body differences (often expressed as physical and mental impairments) as the source of disability. In such a model, disability is based on individual deficiency (i.e., an inability of one’s body and/or mind to work in expected and “normal” ways). Social models locate the causes of disability as external to the body and mind, often attributing disabling experiences to social structures, systems, and institutions that constrain people’s abilities to live in



desired ways. Numerous other models of disability exist, including the biopsychosocial and social justice models. There are debates within human geography and beyond as to which model is most appropriate to use in research. From this brief overview, it can be understood that what constitutes disability varies quite significantly, based on the model that is employed. The particular model adopted by a geographer to guide his or her work in the geographies of disability subdiscipline will very much inform the research question(s) ultimately posed. The adoption of different models of disability by geographers within the subdiscipline has, in part, contributed to the breadth of topics investigated.

Human geographers in this subdiscipline have explored a range of research topics that have changed in focus over time. An early area of inquiry, for example, was related to physical access to the built environment for those with a range of bodily impairments. More recently, theoretical developments in human geography and beyond, the evolution of models of disability, and the emergence of the discipline of disability studies have all contributed to a broadening of areas of inquiry. Recent years have seen the emergence of research in the subdiscipline regarding the enabling and disabling nature of technologies, sociospatial barriers to desired participation in society and space, the embodiment of disability and impairment, disability activism and engagement, and work and leisure spaces occupied by disabled people.

The increasing breadth of inquiry in the geographies of disability has also resulted in a greater range of mind and body differences being explored in research, particularly in the past decade. Chronic illnesses, for example, are diseases, disorders, and syndromes that are not curable and have symptoms, and resulting impairments, that typically fluctuate and may be invisible. People living with such illnesses can be constructed as disabled and/or experiencing disablement, depending on the model of disability employed. Chronic illness is an area gaining increasing attention in this subdiscipline, and such research is often situated at the intersection of geographic research on both disability and health. Other mind and body differences rising in interest in the subdiscipline include mental



A wheelchair-bound athlete on the tennis court. Wheelchair tennis was initiated in 1976. It follows the same rules as able-bodied tennis, except that two bounces of the ball are allowed. Today wheelchair tennis is included in the Paralympics, there is an international wheelchair tennis tour, and all four Grand Slam tournaments include the sport.

Source: Nicholas Rjabow/iStockphoto.

illness and learning disabilities. Emerging areas of study in human geography more broadly are also developing foci on mind and body differences that have implications for how we understand disability, including within the geographies of disability subdiscipline, such as research related to environmental illness, obesity and fatness, and cancers in that these can all have disabling outcomes for individuals.



The power dynamics inherent in conducting research with marginalized populations, and a desire to conduct research with and for disabled people and not on them, have brought forth attentiveness to issues of research design and dissemination within this subdiscipline. The ethics and politics of knowledge production, accessibility and usefulness of research findings to disabled people and their struggles for inclusion, and the achievement of desired social and political outcomes resulting from the research process and uptake of findings, for example, are issues that have gained considerable attention within recent years. Not surprisingly, debates regarding such facets of the research process are not isolated in the subdiscipline but rather borrow from and contribute to those of disability scholars across disciplines. Another issue increasingly gaining the attention of human geographers involved in disability research is that of the potential for developing participatory processes in research. Doing so serves as a response to the desire of some community members and advocates to serve as partners in research and a response to academics' increasing interests in developing useful working partnerships with participants/coresearchers as a way of partially undoing power hierarchies.

Valorie A. Crooks

See also **Accessibility; Blindness and Geography; Body, Geography of; Difference, Geographies of; Health and Health Care, Geography of**

Further Readings

- Butler, R., & Parr, H. (Eds.). (1999). *Mind and body spaces: New geographies of illness, impairment and disability*. London: Routledge.
- Crooks, V., Dorn, M., & Wilton, R. (2008). Emerging scholarship in the geographies of disability. *Health & Place*, 14(4), 883–888.
- Gleeson, B. (1999). *Geographies of disability*. London: Routledge.
- Imrie, R., & Edwards, C. (2007). The geographies of disability: Reflections on the development of a sub-discipline. *Geography Compass*, 1, 623–640.

DISASTER PREDICTION AND WARNING

In addition to building safer communities through mitigation and preparedness, emergency managers face the critical challenge of predicting disasters and warning the public. Prediction involves determining the location and time at which a disaster might strike; disaster warnings apply predictive information to communicate potential threats to the public. An awareness of disaster types coupled with effective prediction technologies helps society alert its members to common and not-so-common threats. The social, cultural, and political features of human communities play a fundamental role in the success of disaster prediction and warning systems. Within communities, individual groups face the challenge of communicating and interpreting warning information. This entry discusses types of disaster and prediction methods and the warning communication process.

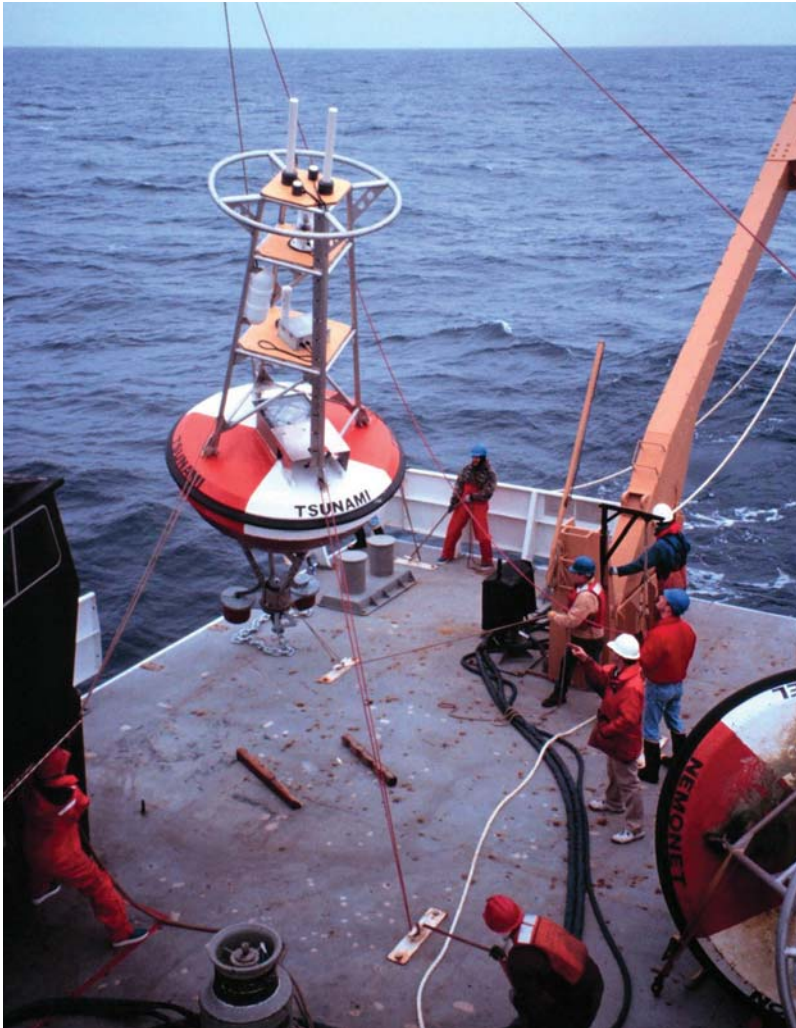
Types of Disaster and Prediction Methods

Disaster Types

Disasters are classified as natural or technological. Natural hazards include floods, earthquakes, hurricanes, storm surges, tornadoes, wildfires, landslides, tsunamis, volcanic eruptions, severe winter storms, droughts, extreme heat, coastal erosion, thunderstorms, hailstorms, snow avalanches, land subsidence, expansive soils, and dam failures. Technological hazards include fires, hazardous material accidents, nuclear plant accidents, terrorism, and biological or chemical weapons. Not all disasters are equally predictable. Hurricanes can be predicted several days in advance, whereas tornadoes and earthquakes often take communities by surprise. Warnings therefore tend to be much more successful for hurricanes in comparison with tornadoes. Earthquakes are virtually unpredictable, and therefore, society cannot be warned with much success.

Prediction Technologies

Disaster warning systems and the communications technologies through which warnings reach



A tsunami buoy on the National Oceanic and Atmospheric Administration ship *Ronald H. Brown* in the Pacific Ocean. It is part of an image that will provide an early warning in the event of a tsunami.

Source: NOAA.

communities remain limited without improvements in prediction technology. One goal of improving prediction technologies is to increase the lead time. Lead time is the amount of time between when a warning or alert is issued and when the hazard for which the alert was issued strikes the community. If, for instance, a warning was issued for a tornado at 10:00 a.m. and the tornado struck at 10:10 a.m., the warning generated only 10 minutes of lead time. Short lead times (the result of poor predictive technology) give communities little time to prepare, which, in turn, leads to increases in the number of fatalities

and injuries. Tornadoes are one disaster for which prediction technologies are rapidly evolving.

The Warning Decision Support System (WDSS) is an example of a new technology that is also communication friendly. WDSS applies automated algorithms through the WSR88-D Doppler weather radar system to automatically detect and predict severe weather, revealing weather conditions using the color display system that is now widely known to the public and used by weather forecasters in the communication process. The Automated Weather Interactive Processing System (AWIPS) serves to integrate the data that come from Doppler, ASOS (Automated Surface Observing Systems), GOES-8 and GOES-10 (Geostationary Operational Environmental Satellites), wind profilers, and other observing systems.

Recently three-dimensional (3D) numerical modeling studies of tornadoes have been carried out. These models show a tornado's structure and wind field. Beyond providing information on the formation of a tornado, the Doppler system has increased the lead time for tornado warnings. These systems can be set so that an automatic alert goes off in the forecast office whenever a

storm, within that station's radar umbrella, exceeds a given value of reflectivity. The challenge lies in adjusting the 120 geographically dispersed Doppler systems to local climatologies and developing new algorithms for tornado detection and warnings. In addition, prediction can be improved with 3D numerical prediction improvements.

The Warning Communication Process

Successful disaster predictions, however, do not always lead to effective warnings. To be truly



effective, hazard alerts must meet the needs of those participating in the communication process. Warnings should take into account goals, participants, processes, and technologies available to local communities.

Notification Types and Goals

The goal of disaster communication is to inform the public of the danger and the means by which threats can be avoided. The details of warning communication goals vary depending on the types and degrees of hazard in a disaster. For instance, with tornadoes, two levels of notification are employed: a “watch”—meaning that conditions for a tornado are present—and a “warning”—meaning that a tornado is about to occur, is presently occurring, or has occurred. Depending on the type of notification, different goals and processes will be used in communication.

Participants in the Communication Process

For a disaster warning communication to be efficient and effective, all participants in the process must be considered. The general public, federal agencies (such as the National Weather Service, NWS), meteorologists, forecasters, news media, public officials, local emergency personnel, and volunteers are all involved in the process of disseminating and receiving pertinent disaster notifications. Coordination strategies must take into account the different structures and cultures of these organizations.

Steps of the Process and Technologies Employed

Due to the complexity of disaster situations, the steps of the communication process are not always linear and systematic. Forecasting and prediction agencies, both public and private, work in partnership to share prediction information and assessments. Federal, state, and local agencies will often converge and communicate among themselves prior to issuing warnings to decrease the likelihood of providing contradictory information to the public. In the case of the NWS, all levels of government must coordinate their efforts in warning the public. Local, county, and

state emergency managers cooperate with the NWS in the prediction process. The media then disseminate the information using television, radio, and Web sites. The NWS may activate tone-activated NOAA (National Oceanic and Atmospheric Administration) radios in the United States, whereas local emergency managers might sound sirens or activate “Reverse 911” to warn the public. Reverse 911 is a telephone communications alert system that uses a patented combination of database and geographic information systems mapping technologies to deliver outbound notifications.

Interpretations of Warnings

Even if a disaster warning is issued timely and effectively, the public still faces the problems of interpreting the information that the warning intends to convey. Interpretation takes place on many levels; however, there are two important trends in how the public interprets warnings. The first of these is the influence that social stratification has on a warning’s interpretation. Second, local and popular myths about the dangers of disasters may lead some people to disbelieve warnings. Both these factors influence how and why people respond to disasters.

Social Stratification and the Receipt and Interpretation of Warnings

Forecasts inform responders and the public as to where, when, and with what level of severity a disaster is likely to occur. Eliciting a response requires forecasters to know how communities perceive and react to weather forecasting and warnings. Warnings only save lives and prevent injuries if they are understood, meet individual needs, and are accurate, reliable, and timely. In reality, these ideal conditions are difficult to meet: rates of poverty, education, gender roles, race, ethnicity, culture, and previous experience with weather among communities limit the effectiveness of public forecast information. People who have the most access to forecasts, for example, are usually the educated and affluent and tend to be members of majority groups. Assuming that the forecast



has been heard, the forecast still needs to be understood, believed, confirmed, and responded to, all of which depend on public demographics, social, cultural, economic, and psychological patterns. Minorities, for example, are less likely to adopt an emergency plan because they receive the warnings less frequently.

Weather Web sites are the primary form of weather information. However, not all groups have equal access to computers—the elderly, for instance. Another emerging form of disaster communication is Reverse 911, as noted earlier. This, too, is a stratified warning system as many young adults do not have landlines and rely on cell phones.

Jamie Mitchem studied the effects that a tornado can have on an urbanized area. The tornado hit Marion County, Indiana (which includes the state capital, Indianapolis), which had a population of 860,454 in 2000. Eleven percent of the population was above the age of 65. Of all the characteristics of the people within the county, the most striking was that 157,908 had disabilities. People with disabilities are most susceptible to disasters. When the tornado hit Marion County, 47% of respondents never received a warning. Of the respondents who were aware of the tornado, 81% received warnings. Of that 81%, only 31% felt that they were in real danger. Of the people who received warnings, 27% ignored the warnings, and 49% did not seek shelter. Of all the respondents, only 70% knew what a tornado watch meant; 21% were unaware of the definition of a tornado warning; and 22% had never performed a tornado drill and lacked a family emergency plan. The most effective forms of warning were tornado sirens and local television networks.

Influence of Myths and Exaggerations on Interpretation

Myths and exaggerations concerning disasters and how people typically respond to them are perpetuated by the media and by Hollywood films. The media, for its part, tends to overstate the number of incidents of looting, postabandonment by officials, price gouging, and public panic. In actuality, some researchers suggest that

crime may actually decrease after a disaster has struck. Price gouging is rare in disaster situations, and most behavior during disasters is altruistic in nature. The perpetuation of these myths and exaggerations can be detrimental to the communication and response process. It is important that they be debunked for officials, volunteers, and the media to improve public response rates.

Hollywood, rather than exaggerating actual events through reporting, perpetuates myths by repeating stereotypical disaster responses. *Dante's Peak*, *Volcano*, and *Asteroid* serve as key examples within Hollywood's disaster genre. In these films, lawlessness and violence are presented as how humans normally respond to disasters. These films also promote erratic and self-centered behavior as typical and expected. Research in sociology and other social sciences regard this typification as false.

Myths and exaggerations also distort the types of behaviors that people in actual disaster situations should expect from one another and could decrease the likelihood that the public will follow response tactics and take appropriate action at appropriate times. For example, some people may refuse to evacuate for fear of looters. It is vital that emergency managers and volunteers understand how people behave in disaster situations.

*William Donner, David Cohen,
and Marci Cottingham*

See also Coastal Hazards; Differential Vulnerabilities to Hazards; Disaster Preparedness; Earthquakes; Floods; GIS in Disaster Response; Hurricane Katrina; Natural Hazards and Risk Analysis; Three-Dimensional Data Models; Tornadoes; Tsunami of 2004, Indian Ocean

Further Readings

Golden, J., & Adams, C. (2000). The tornado problem: Forecast, warning, and response. *Natural Hazards Review*, 1, 107–118.



- Haddow, G., Bullock, J., & Coppola, D. (2007). *Introduction to emergency management* (3rd ed.). Boston: Butterworth-Heinemann.
- McEntire, D. (2007). *Disaster response and recovery*. Hoboken, NJ: Wiley.



DISASTER PREPAREDNESS

Disaster preparedness consists of those actions taken by individuals, organizations, or communities to ready themselves to respond to and recover from emergency situations. As the word *preparedness* may indicate, these are actions taken prior to an impact, when disaster preparedness is in reality getting ready for a *hazard*, which is a potential threat to society. Disasters are events that cause a significant disruption to society or the environment. Risk, vulnerability, and resilience are related concepts in that they refer to a community's susceptibility to or capacity to withstand or bounce back from future hazardous events. Disaster preparedness is important because the better prepared an individual, organization, or community is for such an event, the smaller the disruption ought to be. Disaster preparedness is one phase of emergency management. It has also been a topic of research for geographers interested in studying the human response to hazards, a field pioneered by Gilbert White, the father of floodplain management and founder of the Natural Hazards Research and Applications Information Center. This entry briefly discusses disaster preparedness from both emergency management and hazards geography perspectives. The impact of research on human response to hazards has the ability to inform public policy, and the emergency management system provides the context for community-, state-, and national-level decision making and is an important subject for future research.

Emergency Management Perspective

In the United States, the Federal Emergency Management Agency (FEMA) is responsible for

government action in preventing, preparing for, responding to, and recovering from disasters. FEMA was formed in 1979 as a merger of several agencies with a diverse range of responsibilities, including the Federal Disaster Assistance Administration and the Defense Civil Preparedness Agency. Much of the history of emergency management was characterized by response to disasters, rather than preparedness activities. Early attempts to prevent damage and loss of life from natural disasters included the Flood Control Acts of the 1930s through 1950s, which established and defined the government's role in flood control and authorized flood preparedness and emergency operations. The National Flood Insurance Program, created in 1968, was also an effort to lessen the impact of flood hazards and prevent losses from floods. The Civil Defense program was one of the most important influences on the need to prepare for emergencies. Part of its efforts to prepare for a Cold War attack included education campaigns and the development of evacuation plans. Preparedness and mitigation activities for other hazards became more important in the 1990s as the Cold War ended. The Disaster Mitigation Act of 2000 required that states maintain mitigation plans as a condition for receiving disaster assistance. In 2003, 2 years after the terrorist attacks of September 11, FEMA became part of the Department of Homeland Security, and a renewed prominence of preventing, preparing for, and responding to willful disasters was added to dealing with natural and technological hazards.

Governmental organizations similar to FEMA exist in other countries, such as Public Safety Canada or National Disaster Management of India. Also, the United Nations' International Strategy for Disaster Reduction aims to reduce disaster-related losses through increasing awareness of the importance of disaster reduction as a component of sustainable development. The World Health Organization also maintains a disaster preparedness and response program to assist countries in preparing for disasters.

Disaster preparedness is one of the four phases of an emergency management model,



along with mitigation, response, and recovery (Figure 1). Mitigation involves long-term practices that prevent or lessen the impact of disasters and includes actions such as improvements in forecasting and warning technologies, land use regulations, and building codes. The National Flood Insurance Program is considered mitigation. Preparedness activities include actions taken to prepare for an expected event, including gathering supplies for a disaster kit, making an evacuation plan on the part of a household and conducting drills, and acquiring resources to aid in disaster recovery efforts on the part of communities. Response and recovery occur during and after the disaster and include search and rescue, evacuation or sheltering in place (response), and reconstruction and rebuilding of infrastructure (recovery). The four phases are interrelated, non-mutually exclusive, and cyclic. The post-impact desire to prevent future losses can encourage mitigation efforts that might otherwise have a difficult time gaining acceptance. Recent events can also encourage preparedness for as well as response to subsequent events.

Preparedness actions for individuals and households generally involve being ready either to evacuate or to shelter in place, depending on the location and the event. Items that are often recommended to have at hand in the event of a disaster include several days' supply of food and water, a battery-powered radio and flashlight, extra batteries, a first-aid kit, sanitation items, a can opener, and cash. Families with special needs or animals have other requirements, including medicine, diapers, and pet supplies such as pet food and a means to transport an animal. In addition to a preparedness kit, preparedness actions are also encouraged, such as identifying an out-of-town contact that family members can communicate with and planning ahead of time

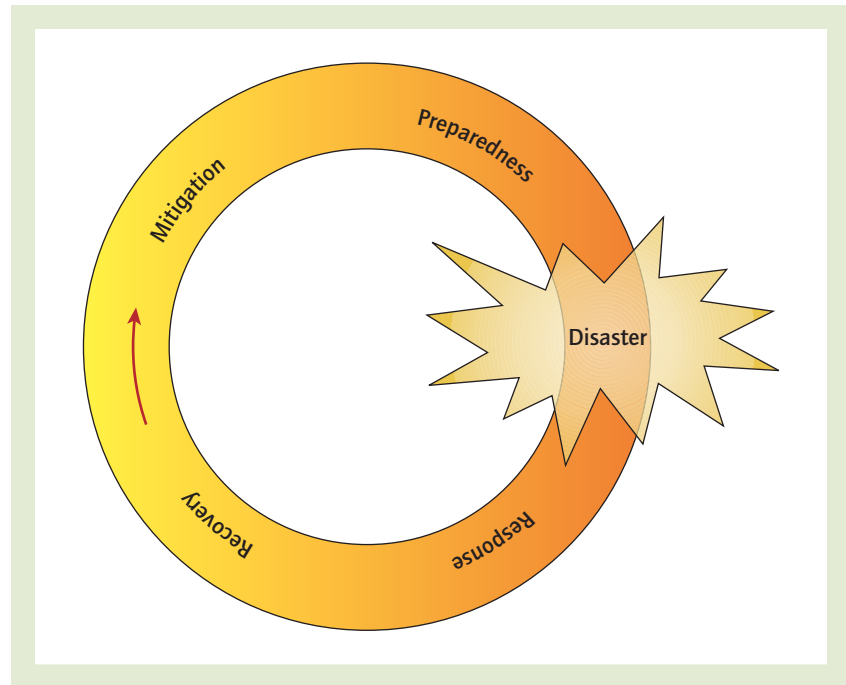


Figure 1 The four phases of emergency management

Source: Author.

where one would go in the event an evacuation was required.

Community-level preparedness is concerned with the immediate response to the event as well as the preparedness of the community for the recovery process. Research has identified four basic functions that emergency management must perform. Preparedness begins by assessing the demands a disaster will place on a community and its ability to respond in those four basic ways, which include (1) an assessment of the possible impacts of the event, (2) last-minute mitigation efforts to protect property such as sandbagging, (3) population protection through actions such as evacuation orders, and (4) management of incident personnel and resources. These four functions identified by research are similar to the initial response objectives specified by the Department of Homeland Security's National Incident Management System, which are saving lives, incident stabilization, and property preservation. Planning for the recovery process is important because more planning can mean a more efficient allocation of resources and better odds of full recovery.



Hazards and Disaster Research

Historically, much of hazards and disaster research has been on natural (e.g., hurricanes, earthquakes, floods) hazards and their impacts; later, there has been research on technological (e.g., toxic waste, nuclear power accident) hazards. Willful hazards (e.g., terrorist attacks) and disasters have recently gained greater attention from researchers. Much of the existing literature has been devoted to preparedness and mitigation for individual hazards, although there are several publications that attempt to address decision making across hazards. Preparedness includes those actions taken by individuals and households as well as those actions taken by organizations or communities. Most research tends to focus on a single level, especially individual or household-level decision making. Recent work has examined decision making in organizations or private businesses. Research generally agrees that hazards and disaster preparedness are not typically given high priority by individuals, organizations, businesses, and even communities until some event threatens or until action is mandated.

Research on individual or household-level disaster preparedness has focused on factors that make some individuals more likely to prepare for disasters, the types of adjustments they are likely to make, and the time or money they are likely to spend on preparations. Decisions are generally made by households but are situated within larger social groupings. Community norms can influence the range of preparedness activities seen as available options. Communities holding attitudes such as the belief that disasters are “acts of God” and cannot be controlled may make preparedness decisions different from those of communities that acknowledge the potential of risk and believe that the event can be predicted. Other factors associated with whether or not one takes any preparedness actions can be classified broadly as situational or cognitive factors. Cognitive factors can be either attitudinal or psychological and include individuals’ personality characteristics, perceptions about the hazard, perceptions about the preparedness action, or beliefs about personal vulnerability. Situational factors include the physical environment (characteristics of the hazard) and the socioeconomic environment (e.g., education and income).

An individual’s socioeconomic status can be a limiting factor to taking actions to prepare for a disaster. Poverty limits one’s ability to make some adjustments that can reduce future impacts from disasters. Income, education, and home ownership have also been related to making preparations for specific hazards, with higher levels of these being associated with higher levels of preparedness or a greater number of preparedness actions. Psychological and attitudinal factors commonly associated with preparedness include self-efficacy, which is the belief that one has the ability to carry out successfully the protective action, perceived personal responsibility, and perceived threat of the hazard, which can be influenced by many factors itself. Prior experience with the hazard has also been associated with preparedness and mitigation decisions.

Less research has been conducted on community- or business-level preparedness than on household-level preparedness. Communities with repeated and recent exposure to hazards tend to be more organized. Legal incentives and mandates have been responsible for some preparedness efforts. The Mitigation Act of 2000 noted earlier is one example of mandating preparedness plans as a precondition to receiving federal disaster assistance. Another is a Louisiana state law requiring businesses that care for companion animals to file emergency plans. Size, access to resources, and awareness of the hazard are factors that have been associated with preparedness by communities or businesses.

Several strategies to study preparedness activities have been used by different disciplines throughout decades of research. Utility models, in which individuals make decisions to maximize all the possible outcomes of those decisions, provided a basis for early hazards research. Individuals cannot process all the information available to make a rational decision, however, and they bring other goals to the decision-making process. Decisions are made with *bounded* rationality and thus are based on subjective assessment of utility and result in less than optimal final decisions. Heuristics explain individuals’ decision-making behavior as the result of several common subjective assessments. Heuristics help place the decision making in the context of more familiar events through mental shortcuts and are important



because people must make decisions based on new information under conditions of uncertainty. The availability heuristic, for instance, could lead individuals to believe that a particular event was rare if they could not recall any instances of such an event (and therefore they would not have to prepare for it). The general model of risk communication, which emerged through years of hazards research, stated that a message must be heard, confirmed, understood, believed, and personalized before action would be taken. Many of the ideas discussed above are complementary and acknowledge that individuals' preparedness or mitigation actions are the result of internal and external factors and that a combination of factors either encourage or constrain actions. Most also operate under the assumption that an individual (or business or community) is not likely to prepare for an event unless he or she becomes aware of the event and believes that the event has consequences for him or her.

Kathleen Sherman-Morris

See also **Differential Vulnerabilities to Hazards; Disaster Prediction and Warning; Floods; GIS in Disaster Response; Hurricane Katrina; Hurricanes, Risk and Hazard; Natural Hazards and Risk Analysis; Resilience; Tsunami of 2004, Indian Ocean; Vulnerability, Risks, and Hazards; White, Gilbert**

Further Readings

- Dynes, R., & Drabek, T. (1994). The structure of disaster research: Its policy and disciplinary implications. *International Journal of Mass Emergencies and Disasters*, 12, 5–23.
- Federal Emergency Management Agency. (2004). *Are you ready? An in-depth guide to citizen preparedness*. Retrieved October 28, 2008, from www.fema.gov/pdf/areyouready/areyouready_full.pdf
- Lindell, M., & Hwang, S. N. (2008). Households' perceived personal risk and responses in a multihazard environment. *Risk Analysis*, 28, 539–556.
- Mileti, D. (1999). *Disasters by design: A reassessment of natural hazards in the United States*. Washington, DC: Joseph Henry Press.

National Research Council, Committee on Disaster Research in the Social Sciences. (2006). *Facing hazards and disasters: Understanding human dimensions*. Washington, DC: National Academies Press.

Tierney, K., Lindell, M., & Perry, R. (2001). *Facing the unexpected: Disaster preparedness and response in the United States*. Washington, DC: Joseph Henry Press.

Tobin, G., & Montz, B. (1997). *Natural hazards: Explanation and integration*. New York: Guilford Press.



DISCOURSE AND GEOGRAPHY

Discourse is a particular claim about the relationship between words and the things they represent. Discourse theory began with Michel Foucault, the famous French philosopher, as a critique of the Enlightenment idea that science and scientific investigation—using observation, measurement, and hypothesis testing—act as a mirror to the world, thus providing us rational objective truth about the world. Discourse theory rejects the claim that science offers us objective knowledge of the world and claims instead that all objects—while certainly real in a material sense—are also discursive constructions. Discourse theory claims that an object cannot be understood as a mere object but can only be understood in context, that is, in relation to the conversations, or discourses, that surround it. Imagine a car: It is in one sense a vehicle to get from Point A to Point B. But it is at the same time an object embedded in myriad discourses—environmental, social, and political, among others that reach far beyond its mere meaning as a way to get to and from work.

Discourses must be understood as constellations of statements that are not free-floating or disembodied but that act in powerful ways to shape our conception of the world and the objects in it. Invariably, the play of discourse sanctions some forms of knowledge as normal or true while excluding others. Social institutions play an important role in the production and circulation of discourse—what we talk about, how we talk



about it, and what context we choose, or are allowed by the rules of what is normal, to discuss an object in. This is what is meant by the proposition that all objects are at once objects in a material sense and social constructions, and that is why Foucault equated discourse with power, knowledge, and truth. These claims have profound implications for scientific explanation, education, social policy, and politics of social change.

Discourse theory in the main rests on two principles common to all science and to geography: selection and aggregation. It is, of course, true that any object possesses an infinite number of attributes. Consider, for example, a human body, which presents itself to us as a single, tangible, bounded, objective unit of reality. But a human body has innumerable aspects such as physiology, personality, sexuality, medical history, and identity characteristics within each of which is another endless list of metric and nonmetric attributes. For a doctor, a body is a site of healing and surgery. For a biologist, a human body is a site of cellular processes. To a soldier, a human body is a target. To a census taker, it is a statistic; to a lover, a site of pleasure, and so on ad infinitum. So what exactly is a scientific definition of a human body? Every description of a body is by necessity a partial description of attributes that have been selected from an infinite list. In other words, the body is discursively constructed for a purpose, and there are as many such constructions as there are purposes. Consider the proposition "The man is black." A person's skin color does not describe something fundamental or essential about him or her. The statement represents a discursive construction of a particular human body relative to the powerful body discourses that are prevalent in society. The constructivist claims I have made about the body of a single person are true for all objects of scientific inquiry ranging from a grain of sand to the near-infinite realms of the known universe. From an infinite number of attributes, we select certain elements; this is a natural and essential process, without the ability to select certain attributes and ignore others, conversation of any sort would be rendered impossible. The claim of discourse theory is simply that what we select, and what we ignore, are shaped by social forces and certainly

cast doubt on the rational scientific claim to objective knowledge free from discourse.

The second constructivist principle is discursive aggregation. Every word is not only a partial description of the objects it represents but also a discursive aggregation of disparate things. Words group things together to enable conversations. Consider the word *capitalism*. That word has no objective, discrete, bounded, scientific entity that lies at the core of the word. The term *capitalism* groups a number of disparate things, including ownership over the means of production, flows of money, wages, advertising, pollution, personal consumption, health, nutrition, lifestyles, cultural values, and innumerable other elements. It represents a way of talking about the world at particular levels of discursive aggregation. The term does not represent a pregiven segment of reality but is simply a useful way of talking about some aspects of the social world. Discourse theory does not demand that we abandon such aggregate concepts but only that we be aware of aggregation and its implications for scientific study and conversation.

All objects, and the names we use to identify them, are by necessity aggregations of other objects. Consider the terms *molecule*, *soil*, *tree*, *forest*, *capitalism*, *deciduous forest*, *global warming*, and *terrorism*. We obtain the concept of a "deciduous forest" by *selecting* the characteristic of "annual leaf fall" out of the infinite number of attributes possessed by trees. The concept does not correspond to a bounded entity existing in the natural world; it is simply a way of representing a set of trees at a particular level of discursive aggregation.

The fundamental claim of discourse theory is that the relationship between words and the things they represent is always mediated by the two principles of selection and aggregation and that thus the "objective" world of science is in fact a discursive construction. There is no known methodology to escape discursive construction.

Application of Discourse Theory to Geography

How does the notion of discursive construction apply to geography—to its objects of study and



its concepts of space and scale? Unlike systematic sciences such as economics and geology, geography is not defined by a unique set of objects. The nearest formulation to the concept of a geographic object is “anything that has a specified location.” Such objects are shown on maps as points, lines, and areas, but the interest of geographers in them arises from their ability to represent substantive features such as cities, roads, and regions. Following the two principles invoked earlier, it is clear that all geographic objects are discursively constructed because the actual description of cities, roads, and regions cannot escape the rules of attribute selection and level of aggregation. Depending on the context, a city, for example, is more than just its population size; it is also defined by a number of other attributes such as air pollution, safety, lifestyle, and so on. It is also a discursive aggregation—of people, neighborhoods, streets, and traffic.

The rules of discursive construction apply with equal force to the concept of geographic space. Traditionally, geographers have viewed space as an *a priori* given (alongside time) that exists prior to geographic investigation, where the subject was in fact defined as the study of the organization of objects in space. The notion of space as a pregiven dimension is also evident in the literature on time-geography and space-time cubes. But why are geographers concerned with the concept of space? Independent of objects there is nothing intrinsically interesting about space itself. This provides us with a succinct definition of space: “Space is that in which objects are located.” Space is not an *a priori* dimension; it comes into being only through objects, their attributes, and their spatial relationships. But if objects are discursively constructed and space comes into being only through the location of objects, then elementary logic leads us to the proposition that space is also a discursive construction.

The geographic concept of scale provides a powerful insight into the role of discourse in geography. At its most elementary level, a scale is a ratio between a linear unit on the map and the number of ground units it represents. The appearance of detail of a city drawn at a scale of 1:5,000 is very different from what is depicted of the city at 1:500,000. The transition involves the selection of features and attributes to represent.

Therefore, every map, drawn at whatever scale, is a discursive construction of the world. Geographers also use the concept of scale to speak about places as they range over the levels of households, neighborhoods, communities, counties, regions, and continents. Those conversations take place at particular levels of discursive aggregation. In fact maps of landforms, climate, or vegetation classifications are nothing but fact groupings based on the principles of selection and aggregation at different levels of generalization.

The written records of geographic knowledge dating back to the Greeks and Arabs show that they routinely employed concepts of space, scale, and classification. So the role of discourse was always present in geography and is not something that simply surfaced in “postmodern times.” It is manifestly clear that no geographic knowledge can exist outside discourse, but the more important point is to explore the significance of that relation.

The importance of discourse to geography can be illustrated by considering the common practice of drawing “poverty maps.” A household is considered poor when its income falls below a specified income threshold. Areas with high concentrations of poverty households are deemed “poverty areas.” Such areas are then compared with other areas of high income, permitting geographers to extract a series of explanatory indices such as unemployment, race, gender, type of household, education level, and behavioral profile. The list of such indices determines how social policy will be formulated and, consequently, who will be authorized to address the poverty problem. The extraction of explanatory indices based on the spatial distribution of household income is not an objective act of scientific investigation that simply mirrors a given underlying social reality but is, rather, a profound discursive construction of the material conditions of people’s lives. Poverty is not an inherent characteristic of certain countries, states, or even neighborhoods. Furthermore, the common practice of “mapping poverty” may tell us where poor people live but offers us no location for where the causes of poverty reside. As reasonable as the geography of poverty may at first seem, as a discourse it is linked as a causative agent of the very problem it is designed to address. By comparing poor areas with those



that are not, poverty maps set up an unhelpful binary along the following lines: poor versus non-poor, problem versus nonproblem, undeveloped versus developed, inner city versus suburbs, areas without resources versus those that have, poor as the other versus nonpoor as self. Such binaries privilege nonpoor areas and their residents, houses, landscapes, and lifestyles while ignoring the role of wealthy areas in creating poverty. By presenting the income levels and consumption habits of nonpoor areas, not just as the location of the nonproblem but in fact as the standard to emulate and aspire to, the geography of poverty has become a prescription for the creation of permanent scarcity and inequality.

Presenting the geography of poverty as discourse rather than as objective science not only allows us to contest that particular representation but also allows us to create alternative discursive constructions that may prove more useful. Alternative constructions will select different features to highlight, present them at different levels of discursive aggregations, authorize different social policies, and thus empower different agents to act. If we move away from the concept of income—on which poverty maps are based—and ask instead a series of alternative questions, such as why poor people find it difficult to obtain good nutrition, live in healthy bodies, or find affordable transport to work, the new discourse we generate leads us to very different solutions, social policies, and social change agents empowered to act. This is what Foucault meant by employing the neologism “power/knowledge”—that power is exercised through knowledge; contesting established discourses is indeed a form of political practice because it enables the exercise of power by different agents.

Lakshman Yapa

See also Art and Geography; Cultural Geography; Cultural Turn; Epistemology; Ethnocentrism; Eurocentrism; Film and Geography; Geographical Imagination; Humanistic Geography; Orientalism; Phenomenology; Photography, Geography and; Positionality; Postmodernism; Poststructuralism; Representations of Space; Spaces of Representation/ Representational Spaces; Text/Textuality; Toponymy; Vision and Geography; Writing

Further Readings

- Elden, S., & Crampton, J. (Eds.). (2007). Introduction. *Knowledge, space and power: Foucault and geography*. London: Ashgate.
- Foucault, M. (1980). *Power/knowledge: Selected interviews and other writings, 1972-1977*. New York: Pantheon Books.
- Harley, J., & Woodward, D. (1987). *The history of cartography* (Vol. 1). Chicago: University of Chicago Press.
- Sheppard, E., & McMaster, R. (2004). *Scale and geographic inquiry: Nature, society, and method*. Oxford, UK: Blackwell.
- Yapa, L. (1996). What causes poverty? A postmodern view. *Annals of the Association of American Geographers*, 86, 707–728.



DISEASE, GEOGRAPHY OF

Waldo Tobler's first law of geography states that things closer in space are more similar than things farther apart in space. Thus, it is no surprise that disease burdens, often measured by disease rates, create spatial patterns in their distribution and spread. These patterns can be caused by an array of factors, including population demographics, rate and method of infectious disease transmission, environmental contamination, health behaviors, access to health care, and spatial distribution of social or economic conditions.

Identifying spatial patterns of disease distribution or spread is valuable to both public health practice and the expansion of scientific knowledge. Visualization and analysis of spatial patterns can inform public health and medical efforts by improving public health surveillance, identifying places that require additional resources, identifying the best location for a health care facility, generating hypotheses about disease etiology and spread, and forming the basis for additional study. It can also raise public awareness of risk, potentially affecting behavioral or other risk factors for disease. Analyses that relate suspected risk factors for disease to burdens of disease can provide a basis for public health intervention,

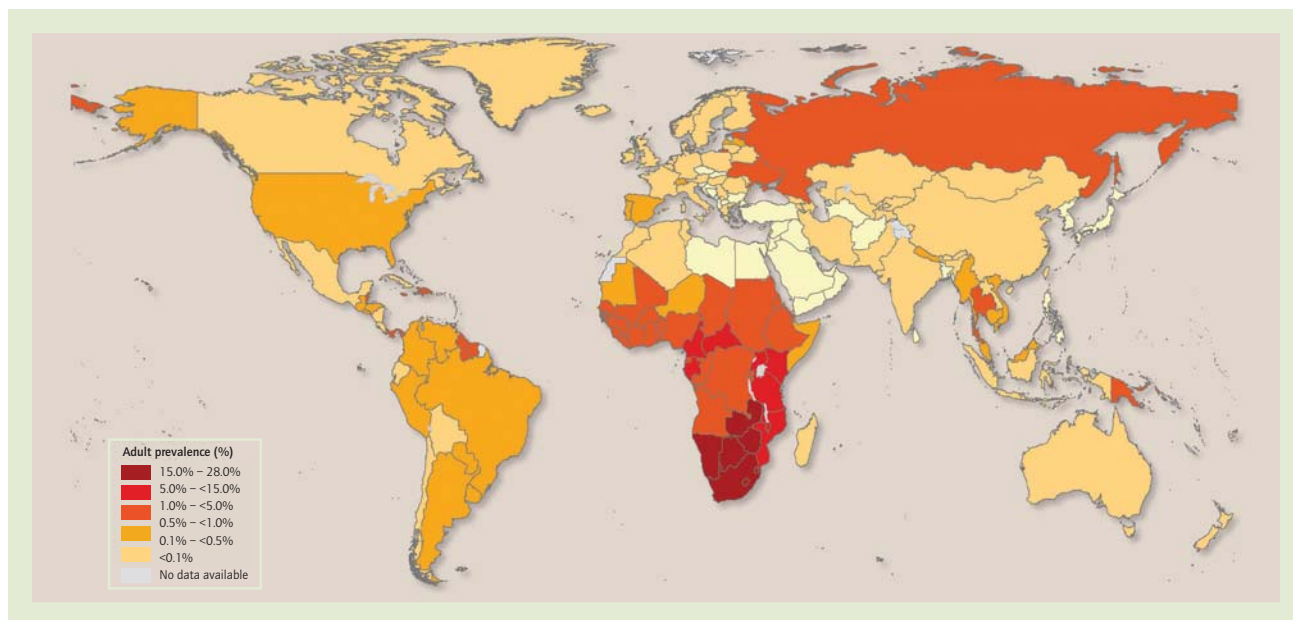


Figure 1 A global view of HIV infection. According to UN estimates, about 33 million people worldwide were living with HIV/AIDS in 2007.

Source: Figure 2.2 from p. 33 in *2008 Report on the Global AIDS Epidemic* by UNAIDS. Copyright © Joint United Nations Programme on HIV/AIDS (UNAIDS) 2008. Reprinted with permission from UNAIDS.

focusing time and effort on evidence-based approaches to disease prevention and health promotion. Figure 1 shows a global view of HIV infection.

Historical Foundations

Although the acknowledgment of the relationship between environment and health can be traced back to 400 BC, when Hippocrates wrote *On Airs, Waters, and Places*, the first high-profile, and best-known, study of disease geography is likely that undertaken by John Snow. There was an epidemic of cholera in London during the year 1854. Snow, who hypothesized that cholera was a water-borne disease, plotted cases of cholera in the London neighborhood of Soho on a dot map and identified a water pump on Broad Street as the likely source of the epidemic. The handle was removed from the pump, disabling it, and the epidemic abated. Snow's use of dot maps in identifying the source of the epidemic was novel and is the earliest case of the use of disease mapping in addressing a health problem.

Causes of Spatial Patterning

There are many reasons for the patterns of disease that we observe. In Snow's case, the reason for the spatial patterning of cholera cases in Soho was the location of a pump making contaminated water available to the local population. It is clear that the quality of the physical environment in which people live is of great importance in affecting rates of disease. The physical environment includes both the natural environment and the built environment. Commonly explored features of the physical environment, which can affect spatial patterns of disease, include air and water quality and sources of pollution that may be point sources (such as facilities releasing toxics into the air), nonpoint sources (such as agricultural runoff), and mobile sources (such as automobile exhaust). Climate is a factor of growing importance due to global climate change, which has the potential to affect the locations where disease vectors, such as mosquitoes that carry malaria, can survive. Built environment considerations range from the quality of indoor air affecting asthma rates to the walkability and safety of neighborhoods affecting rates of obesity.



In addition, spatial patterns of underlying social and economic conditions or population demographics can have a significant effect on disease burdens. For example, a poor neighborhood may be more likely to have higher rates of lead poisoning due to old or badly maintained housing stock containing lead paint, or higher rates of respiratory diseases due to a local, polluting facility. A working-class neighborhood may be more likely to suffer higher rates of musculoskeletal injury, due to the occupational duties of many residents. A neighborhood inhabited by people of a certain race, ethnicity, or origin could have higher rates of a particular disease associated with genetic or cultural factors. Finally, poverty can be associated with lack of financial access to health care and could increase rates of late-stage cancer diagnosis, for example, as people cannot afford the preventive care necessary to identify cancers in the earlier stages, waiting instead for symptoms to arise. Age is a factor likely to affect burdens of many diseases.

Population density can also affect spatial patterns of disease as individuals in rural areas may not have the same access to health care facilities as those in more populated places. Likewise, occupations associated with rural areas—such as farming—are known to have an increased risk of certain types of injuries. There is a growing interest in studying inequality and injustice aspects of differential burdens of disease associated with specific population groups.

In considering infectious diseases, the rates and methods of transmission must be considered. The length of time that a person can be infected but show no symptoms, the length of time an individual can be infected, and the characteristics of individuals that make them susceptible to infection all come in to play. Disease patterns may observably diffuse across space from a certain location of origin or may spread in a cascade, as individuals infected early on may travel to new locations, resulting in additional centers from which diffusion may occur.

Developments in the Field

Since the time of Snow, much has occurred in the way of developments in computer technology and statistics and the availability of geographically

referenced health data, making disease geography a growing focus of study. The most important development may well be the birth of the field of geographic information science (GIScience) and the accompanying software programs that fall under the heading of geographic information systems (GIS). GIS are computer-based systems for integrating and analyzing spatially referenced data. These developments both increased the sophistication of the underlying theory guiding the study of disease geography and made it possible for researchers to undertake complex analyses without requiring large amounts of computation time. GIS are organized to allow the integration of different types of geographical information (such as data associated with points, lines, polygons and field presentations, such as rasters) and to make readily available a number of cartographic and statistical operations that can be performed on these data. In tandem with developments in GISc and GIS were developments in statistics—specifically spatial statistics—that make possible statistical modeling of risk, detection of clusters, hypothesis testing, simulation, and association studies.

The application of GIS and spatial statistics to health questions would not be possible without sufficient georeferencing of health data. In recent years, it has become more commonplace for disease registries and public health authorities to attach geographic codes—or geocodes—to health data, thus enabling the consideration of space in epidemiological and other analyses. Geocodes can include latitude-longitude of residence, ZIP code, or census tract information, and the available geocode often has significant implications on the type of analyses that can be performed. Along with developments in geocoding, there has been increased concern with the confidentiality implications of the availability of finely geocoded health data. Because of the ability to reverse geocode health records (i.e., determine the address of a residence associated with a particular latitude-longitude coordinate attached to a disease record), data holders must be cautious in releasing geocoded data.

A major regulation affecting the use of geocoded health data is the Health Insurance Portability and Accountability Act (HIPAA) of 1996. This act, implemented by the HIPAA Privacy Rule, prohibits covered entities (such as disease



registries) from disclosing private health information about an individual without his or her written, informed consent. Identifiers that make health information individually identifiable do include geocodes, making the use of these data highly regulated. The rule is qualified by exceptions, including mandatory reporting of diseases to public health authorities and the conduct of research by approved parties.

Current Methods

Current methods of studying the geography of disease include mapping, statistical analysis, simulation, and qualitative investigation. The most basic of exploratory methods is likely the mapping of a selected health statistic (e.g., a mortality rate) by a selected geographic unit, such as the county or census tract. These choropleth maps make use of discrete, bounded units and have been criticized for several reasons. Disease burdens do not adhere to borders of administrative units, and thus, the presentation of disease maps based on these units is misleading. Some have described the maps that result from this method as smoothed maps of disease data with the bounded areas chosen acting as spatial filters of different shapes and sizes—making the approach hard to defend.

In addition, mapping data in this fashion creates a surface populated by areas for which statistics have been calculated based on differing amounts of spatial support, making some statistics more reliable than others. In this case, for example, counties containing significant urban areas will have more stable rates than very rural counties due to higher population densities. For some units, such as census tracts, the area covered by a unit will be much larger in rural areas than in urban areas, giving visual focus to rural areas, where fewer people live. Also, mapping using discrete, bounded units masks all the geographical variation that occurs at a level below that of the unit chosen, giving the impression that the rate is constant throughout the entire areal unit. A final concern is that of the modifiable areal unit problem (MAUP), as the size and shape of the geographical units chosen to map disease burdens affect the overall spatial pattern that can be observed.

Approaches developed to improve the mapping of disease burdens include methods of interpolation,

filtering, and smoothing. Some have smoothed data for discrete units by calculating a new rate for each unit—that of the average of the unit in question combined with all units that border it. A more recent approach, called *headbanging*, has used the median value instead of the mean to more carefully smooth rates. Still others have implemented methods of Bayesian adjustment, which shrink extreme values toward a central value to limit extremely high or low rates.

Other approaches have begun to disregard borders entirely, creating continuously varying surfaces. These approaches include geostatistical techniques such as Kriging, as well as density estimation and spatial filtering. In the most basic sense, Kriging smooths data based on the spatial dependence inherent in the data itself and was actually developed to enhance mineral exploration and mining. Density estimation and spatial filtering approaches make use of a grid and use filters of a selected shape to pull in data from neighboring areas to calculate a statistical rate for each grid point. These filters can be associated with functions whereby observations closer to the center of the filter are more heavily weighted than those at the edges of the filter. They can also vary in size. Whereas fixed filter spatial filtering would set the size of the filter to be constant (e.g., a filter with a diameter of 5 miles), adaptive spatial filtering would set a threshold for the denominator (e.g., pull in observations until a certain population threshold has been met), thus allowing the filter to expand variably across the surface to create a surface with more statistically stable rates throughout.

In addition to exploratory analyses such as mapping are analyses that seek to identify statistically significant rates of a disease. These analyses often make use of cluster detection statistics, which compare, for example, the rate observed at a particular location with what the expected rate would be, given, for example, a standard rate applied to a local population. A popular cluster detection statistic is SaTScan, which uses a circular or elliptical window to scan a data set through space and time to identify significant clusters. Similarly, statistics can be used to test hypotheses using spatial data. Because of the advent of Markov Chain Monte Carlo (MCMC) statistics, which allow the repeated simulation of



an expected spatial distribution, given an a priori statistical distribution or hypothesis, researchers can create what are known as *p*-value maps, which indicate the reliability of rates calculated across a study area using a disease mapping method.

Spatial autocorrelation, the likelihood of things closer in space being more similar, is a fundamental consideration in spatial analysis. Because of spatial autocorrelation, methods such as *p*-value map calculation must be used with caution as spatial dependence in the data violates the assumption of independent observations, which underlies many statistical tests. In the case of *p*-value maps, this means that there is a problem with multiple testing of the hypothesis. Statistics do exist to identify spatial autocorrelation in the data, including the global and local Moran's *I* statistics and the *K*-function statistic.

Understanding the degree to which data are spatially dependent can inform approaches to modeling the data. For instance, residuals from a regression model that makes use of spatial units can be mapped to determine whether patterns exist that should be incorporated into the model. Models can then incorporate this autocorrelation, or other approaches can be taken, such as geographically weighted regression, which allows regression parameters to vary over space.

Simulation, including MCMC approaches, has been increasingly used with health data. Models such as the susceptible-infected-recovered (SIR) model for disease transmission can be implemented using simulation models to estimate the way in which an epidemic could spread. More recently, agent-based models have been used to simulate disease transmission through a set of probabilities associated with each agent.

Finally, in addition to the quantitative approaches described above is an entire set of qualitative research methods, such as interviews, focus groups, participant observation, and more structured exercises such as concept mapping, diagramming, and photovoice, which can be used to explore the mechanisms and causal pathways by which geography influences disease burdens. Theoretical constructs such as neighborhood, community, place, and social space can be used to guide these activities.

Conclusion

Disease geography is a growing field of study that has benefited from recent developments, including the advent of GIS and the increasing availability of geocoded data. New approaches to mapping and analyzing geocoded health data are developed frequently, and the importance of the “where” in understanding diseases makes it certain that the field will continue to develop. The geography of disease is of interest at many different geographical scales, from the impacts of global climate change and modern transportation on the global spread of disease to the impact of the choice of location for a health care facility in a small town.

Future directions for the study of geography of disease include the increasing involvement of the public and affected communities in exploring geographical data. Web-based map servers and software packages are increasingly moving the field toward a more democratic use of technology and information. New questions regarding the importance of area level influences—such as the level of deprivation in a census tract—are leading the field toward consideration of multilevel models, which consider both individual and contextual risk factors for disease. Spatially aware approaches to multilevel modeling are also under development. There are many opportunities for new approaches to studying the geography of disease, and these approaches have the potential to yield much new information, as well as new approaches to combating diseases.

Kirsten M. M. Beyer

See also **Anthropogenic Climate Change; Cancer, Geography of; Carcinogens; Cholera, Geography of; Diffusion; Environmental Justice; Environmental Racism; GIS in Health Research and Health Care; Global Environmental Change; Global Warming; Health and Health Care, Geography of; HIV/AIDS, Geography of; Inequality and Geography; Malaria, Geography of; Medical Geography; Public Participation GIS**

Further Readings

Cromley, E. (2003). GIS and disease. *Annual Review of Public Health*, 24, 7–24.



- Cromley, E., & McLafferty, S. (2002). *GIS and public health*. New York: Guilford Press.
- Elliott, P. (2000). *Spatial epidemiology*. New York: Oxford University Press.
- Lawson, A., Biggeri, A., Bohning, D., Lesaffre, E., Viel, J., & Bertollini, R. (Eds.). (1999). *Disease mapping and risk assessment for public health*. New York: Wiley.
- Lawson, A., & Williams, F. (2001). *An introductory guide to disease mapping*. Chichester, UK: Wiley.
- Meade, M., & Earickson, R. (2005). *Medical geography*. New York: Guilford Press.
- Rushton, G. (2003). Public health, GIS, and spatial analytic tools. *Annual Review of Public Health*, 24, 43–56.
- Rushton, G., Armstrong, M., Gittler, J., Greene, B., Pavlik, C., West, M., et al. (Eds.). (2007). *Geocoding health data: The use of geographic codes in cancer prevention and control, research and practice*. Boca Raton, FL: CRC Press.



DISTANCE DECAY

Distance decay is a major cornerstone of spatial-temporal analysis and, hence, geography. Essentially, it states that the nearer two locales are, the greater is the expected attraction/interaction between the two and, conversely, the greater the distance is between two locales, the less the expected interaction. This seemingly common-sense notion has been restated as a formulation of spatial autocorrelation by the geographer Waldo Tobler. It has come to be known as Tobler's "first law of geography," which states that "everything is related to everything else, but near things are more related than distant things."

In its simplest form, the distance decay function can be portrayed graphically as a concave curve descending from the y axis, representing the intensity of a phenomenon, and extending along the x axis, representing the distance from some origin. Examples of this phenomenon can be found in virtually all subfields of geography and at all scales for a wide range of travel interactions. The universality of distance decay necessarily limits the discussion here to travel and

human geography. In human geography, the distance decay effect has been noted in the movement of international tourists; travel to local coffee shops in Japan; use of mental health clinics in New York City and Baltimore; behavior of a serial killer in Baton Rouge, Louisiana; and forest land use patterns in the northeastern Philippines. An example of the distance decay function for a series of everyday activities is presented in Figure 1.

Distance decay functions are quantitatively rooted in the family of gravity models based on Isaac Newton's fundamental law of attraction. The term *distance decay* characterizes how the attraction between two bodies decreases as the distance between them increases. The distance decay concept can be traced to the principle of least action, first espoused by Pierre Louis Moreau de Maupertuis (1698–1759), who first gave the notion verbal expression:

The laws of movement and of rest deduced from this principle being precisely the same as those observed in nature, we can admire the application of it to all phenomena. The movement of animals, the vegetative growth of plants . . . are only its consequences; and the spectacle of the universe becomes so much the grander, so much more beautiful, the worthier of its Author, when one knows that a small number of laws, most wisely established, suffice for all movements. (1744, p. 417)

It is difficult for any single discipline to "claim" Maupertuis for he wrote in physics, mathematics, metaphysics, and biology. He was the force behind expeditions to Lapland and Peru, traveling to the former to measure the difference in Earth's radius and demonstrate that Earth was an oblate spheroid rather than ovate (egg shaped).

The concept of distance decay formulated by Maupertuis, although somewhat deterministic today, does capture much of the essence of mechanics. In applying it to physics, Maupertuis suggested that the quantity to be minimized was the product of the duration (time) of movement within a system and the *vis viva* (living force), twice what we now call the kinetic energy of the system.

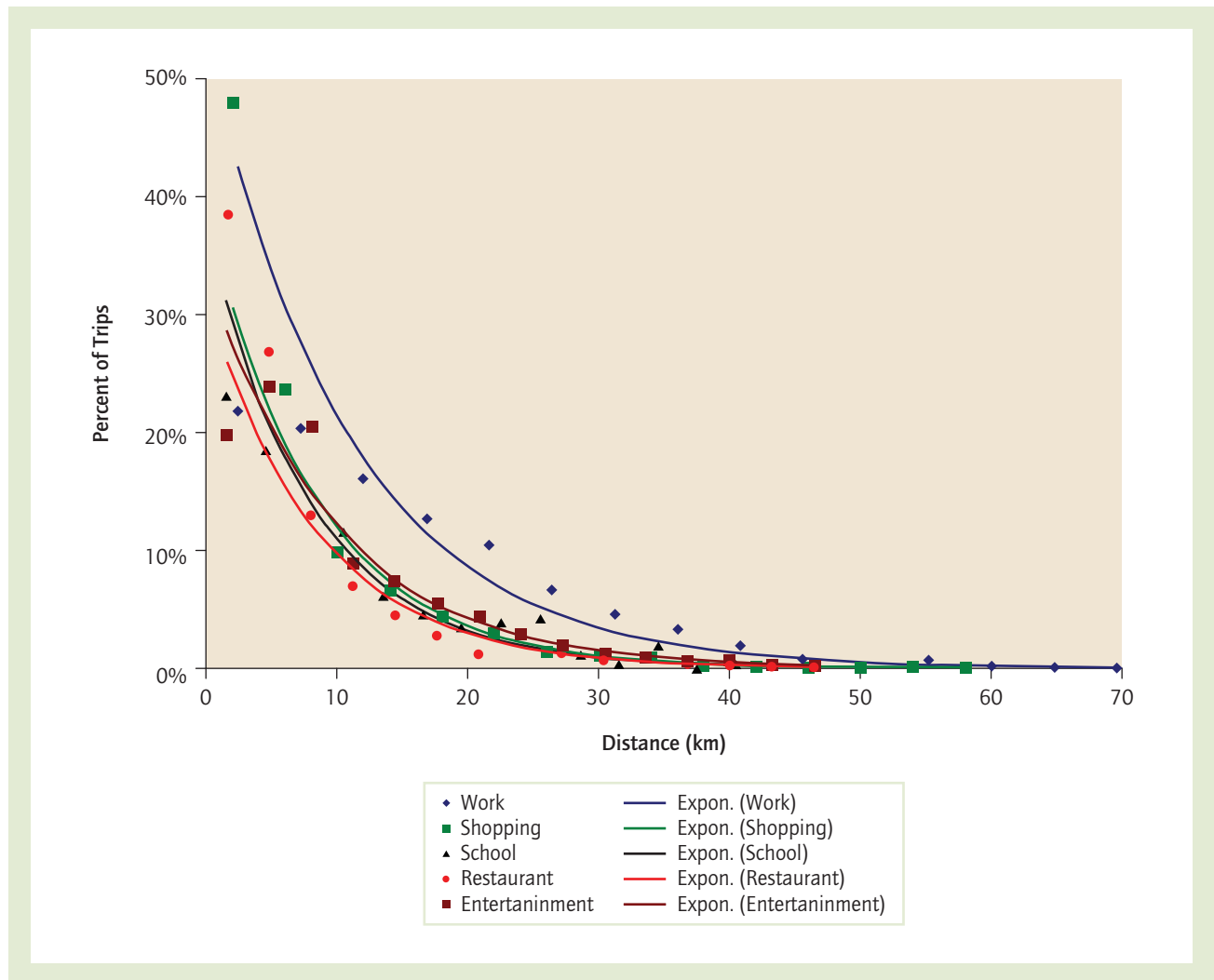


Figure 1 Distance decay curves for single-occupant auto trips. Automobile trips, like other forms of spatial interaction, exhibit distance decay as the friction of distance makes longer trips more costly.

Source: Figure 7, p. 19 from *Access to Destinations: How Close Is Close Enough? Estimating Accurate Distance Decay Functions for Multiple Modes and Different Purposes* by Michael Iacono, Kevin Krizek, and Ahmed El-Geneidy, May 2008. Published by Minnesota Department of Transportation.

Ravenstein (1885, 1889) is generally credited with the incorporation of distance decay theories into migration and spatial interaction studies. He noted in his “laws of migration,” for example, “The more distance from the fountainhead which feeds them (migrants), the less swiftly do these currents flow” (1885, p. 191). And “[We have] proved that the great body of our migrants only proceed a short distance” (p. 198). Furthermore, “Migrants enumerated in a . . . center of absorption will . . . grow less with the distance

proportionally” (p. 199). Finally, “The process of dispersion is the inverse of that of absorption, and exhibits similar features” (p. 199).

Ravenstein’s distance decay observations pertaining to migration are frequently cited as among the earliest observations pertaining to human behavior. However, Edward Jarvis observed, documented, described, and, in fact, explained the impact of distance on travel behavior in his assessment of the admission rates to “insane asylums” of the mid 19th century. He



was writing at a time when there was concern in the United States and Europe “that insanity (had) increased in prevalence of late years, to an alarming extent, and that the number of lunatics, when compared with the population, is continually on the increase” (Jarvis, 1852, quoted in Shannon & Bashshur, 1986). In these articles describing what today is known as “Jarvis’s Law,” he demonstrated that the number of patient admissions (amount of use) to mental hospitals of the period was inversely proportional to the distance at which the patients lived from that asylum (service) (Shannon & Bashshur, 1986). In 1852, he documented the phenomenon in an article with insane asylum admissions data from New York and Massachusetts to Kentucky and Ohio. Beyond merely documenting the distance decay phenomenon, however, Jarvis provided an explanation that must be considered cogent 170 years later. Among the factors he noted as possibly contributing to the distance decay effect were (a) cost of travel, (b) unwillingness of relatives to be separated from loved ones, and (c) lack of accurate information pertaining to the benefits of asylum care with increasing distance from the institution.

The distance decay principle is a cornerstone of spatial analysis. As such it is fundamental to classic models and theories of geography as well as current analyses in virtually every subject matter addressed by geographers.

Gary W. Shannon

See also **Gravity Model; Migration; Mobility; Spatial Autocorrelation; Spatial Interaction Models; Tobler, Waldo**

Further Readings

Fotheringham, A. (1981). Spatial structure and distance-decay parameters. *Annals of the Association of American Geographers*, 71(3), 425–437.

Jarvis, E. (1850). The influence of distance from and proximity to an insane hospital on its use by any people. *Boston Medical and Surgical Journal*, 32(11), 409–422.

Kent, J., Leitner, M., & Curtis, A. (2006). Evaluating the usefulness of functional distance measures when calibrating journey-to-crime distance decay functions. *Computers, Environment and Urban Systems*, 30, 181–200.

Maupertuis, P. L. M. de. (1744). *Accord de différentes lois de la nature qui avaient jusqu’ici paru incompatibles* [Accord Between Different Laws of Nature That Seemed Incompatible]. *Mém. As. Sc. Paris*, p. 417.

McKercher, B., Chan, A., & Lam, C. (2008). The impact of distance on international tourist movements. *Journal of Travel Research*, 47(2), 208–224.

Ravenstein, E. (1885). The laws of migration. *Journal of the Statistical Society of London*, 48(2), 167–235.

Sadahiro, Y. (2005). Spatiotemporal analysis of the distribution of urban facilities in terms of accessibility. *Papers in Regional Science*, 84(1), 61–84.

Shannon, G., & Bashshur, R. (1986). Distance and the use of mental health services: Review and prospect. *Milbank Memorial Quarterly*, 64(2), 302–330.

Tobler, W. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography*, 46(2), 234–240.

Verburg, P., Koen, P., & Witte, N. (2004). Accessibility and land-use patterns at the forest fringe in the northeastern part of the Philippines. *Geographical Journal*, 170(3), 238–255.

Zipf, G. (1941). *National unity and disunity*. Bloomington, IN: Principia Press.

Zipf, G. (1947). The hypothesis of the ‘minimum equation’ as a unifying social principle: With attempted synthesis. *American Sociological Review*, 12(6), 627–650.



DISTRIBUTED COMPUTING

Distributed computing is an important research domain in computer science and information technology. It plays a significant role in the development of next-generation geographic



information systems (GIS), including Web GIS and mobile GIS. The major goal of distributed computing is to provide an effective, open, and dynamic computing framework to facilitate via networks the integration of data, applications, and services physically located in different places. There are several distributed computing frameworks available today, such as Microsoft .NET, the JAVA platform, and Common Object Request Broker Architecture. For many GIS applications, these frameworks provide sharable and interoperable software environments for developing online, distributed geographic information services (GIServices). The deployment of high-level distributed GIServices is built on low-level distributed computing technologies. Distributed computing technologies can facilitate the interoperability and federation of GIS computing tasks.

The term *distributed* reflects the fact that the hardware and software components of distributed computing systems are physically distributed in different computers, which are connected via the Internet or other types of networks. Interoperability is the key issue for the establishment of distributed computing frameworks because distributed hardware machines, programming languages, operating systems and other online resources may vary drastically. To provide online information services effectively, most distributed computing applications use open and interoperable computing environments and protocols (such as TCP/IP, File Transfer Protocol, Remote Procedure Calls, and Z39.50 protocol) and distributed programming languages (Java, JavaScript, Python, or C-sharp) to connect multiple machines and servers together.

History of Distributed Computing

Along with the rapid progress of network technology, distributed computing technologies have been widely used in the computer industry since the 1980s. Suggested by Orfali, Harkey, and Edwards in 1996, the development of distributed computing systems can be categorized into four major stages: (1) stand-alone file servers, (2) generic database servers, (3) distributed database servers and file servers, and (4) distributed component object servers. The following paragraphs discuss

the four stages by their definitions, network features, and system structures.

Stand-Alone File Servers

A file server is a device that stores and distributes digital files to every user on a local area network (LAN). It allows everyone on the network to access files from a centralized storage space, on one server. A file server directs movement of digital files and data on a multiuser communication network. From a network management perspective, file servers usually handle a huge amount of transactions, which might become a significant bottleneck in a LAN. Different file servers such as Windows servers and Unix servers have their own protocols and file formats, which may not be compatible with others.

Generic Database Servers

A generic database server is a stand-alone computer that sends out database data to users on a LAN. With a database server, the server only sends out the requested results from a database rather than send the whole database to a user's workstation. Thus, a database server incurs less network traffic than a file server. Database servers are more flexible than file server systems, especially on the client side. Multiple users can easily establish new client-side applications to access the same database server from different operating systems. However, the server-side applications are fixed in most cases. It is very difficult to combine heterogeneous databases in one single server.

Distributed Database Servers and File Servers

The main functions and capabilities of distributed database servers mimic generic database servers, but the physical locations of databases are distributed across a network. As with the architecture of distributed databases, distributed file servers appear as a single logical file server but are physically distributed in different places. Distributed file servers are designed for file sharing instead of database access. Distributed file servers can provide users with a virtual integration of distributed file servers on a LAN. An



example of this is the active directory services in the architecture of Microsoft Windows 2000 and XP. Both generic and distributed database/file server systems basically follow the traditional client-server architecture. There are several potential problems with the traditional client-server architecture because it cannot provide rich transaction processing and rich data management or handle overly complex queries. For example, if a traditional database server receives requests from 500 client-side applications at the same time, the server's operating system may hang or crash. Without a transaction control function, traditional database architecture is not appropriate for complex GIS applications or Web GIS services.

Distributed Component Object Servers

Distributed component object servers are advanced client-server systems that can handle complex transactions and requests from heterogeneous systems. Distributed component technology, including Java applets and ActiveX controls, adopts the concepts of object-oriented modeling and distributed computing environment. Currently, both academic and industrial studies of distributed systems are focusing on distributed components in open environments that can provide new capabilities for the next generation client/server architecture. Comparing the distributed database/file servers, the main advantage of distributed component object servers is the interoperability, reusability, and flexibility for cross-platform applications.

In summary, traditional GIS are closed, platform-dependent, centralized systems, incorporating interfaces, programs, and data in a single computer. Distributed computing technologies provide a new direction for GIS to become more flexible, interoperable, and platform independent. Many wireless mobile GIS applications and Web GIS services are adopting the concepts and technologies of distributed computing.

Ming-Hsiang Tsou

See also **Business Models for Geographic Information Systems; Complex Systems Models; Error Propagation; Geocomputation**

Further Readings

- Armstrong, M. (1997). Emerging technologies and the changing nature of work in GIS. In *Proceedings of GIS/LIS'97* (pp. 800–805). Cincinnati, OH: American Society for Photogrammetry and Remote Sensing.
- Ganti, N., & Brayman, W. (1995). The transition of legacy systems to a distributed architecture. New York: Wiley.
- Gosling, J., & McGilton, H. (1996). *The Java language environment: A white paper*. Mountain View, CA: Sun Microsystems.
- Montgomery, J. (1997). Distributing components. *BYTE*, 22(4), 93–98.
- ORACLE. (1992). Distributed databases. In *ORACLE 7 server concepts manual* (pp. 21.1–21.6). Retrieved September 14, 2009, from http://download.oracle.com/docs/cd/B12037_01/server.101/b10739/ds_concepts.htm
- Orfali, R., Harkey, D., & Edwards, J. (1996). *The essential distributed objects survival guide*. New York: Wiley.
- Peng, Z. R., & Tsou, M.-H. (2003). *Internet GIS: Distributed geographic information services for the Internet and wireless network*. New York: Wiley.
- Schroeder, M. (1993). A state-of-the-art distributed system: Computing with BOB. In S. Mullender (Ed.), *Distributed systems* (pp. 1–16). Wokingham, UK: Addison-Wesley.
- Tanenbaum, A., & van Steen, M. (2002). *Distributed systems: Principles and paradigms*. Englewood Cliffs, NJ: Prentice Hall.



DISTRIBUTION OF RESOURCE ACCESS

Resource access describes a relationship between humans and their needs and wants as obtained from the surrounding environment. A geographic analysis of the relationship evaluates how humans differ in the ways they acquire resources at different localities and, more important, the local and extralocal factors that influence their ability to acquire these resources. Much research on



resource access is embedded in a broader study of human-resource relationships that also considers resource availability and the resource use practices of humans. For example, applied research and development planning regarding food security evaluates how the natural endowment of resources and production strategies influences food availability, how household incomes can be provided and improved to gain access to food resources, and how household practices and individual discrimination influence the distribution and quality of food for use. Access to resources and how it varies geographically relate to the need of regions and households to gain incomes to supplement local livelihoods and what sources of income can be made available to these populations. Regional studies of resource access are therefore linked to studies that examine the magnitude and problems associated with regional poverty at different geographic scales.

Garrett Hardin's classic work on the "tragedy of the commons" emphasized that when resources are free or open to communities, overuse or exploitation will affect future generations. Access to "common" resources should therefore be managed under environmental regulations that dictate who gains access and for what purpose. The ways in which environmental (resource) regulations differ geographically and are directed at certain populations add a political dimension to the distribution of resource access. These regulations are defined by local "traditional" practices and/or by extralocal agendas designed to promote resource conservation and sustainability. Communal access and community management as directed by the local populations and their traditions are compared with the controls that may be imposed by authoritative structures. Resource access is therefore dictated more by boundaries and controls on the use of common resources than by environmental conditions and processes that influence distribution patterns. Moreover, the distribution of resource access is redefined by political structures that allocate ownership of common resources and/or authority over their use. Embedded in these political debates on resource access are questions about whose knowledge matters and who is in the better position to ensure the long-term sustainability of common property resources.

Geographic studies in historical ecology also document interesting relationships between the distribution of resource access and land cover dynamics. Technological changes and regional patterns of development can promote access to resources and consequent human activities. For example, historical change in the agricultural land use of the Central United States relates significantly to technological developments that provided access to the Ogallala aquifer, just as deforestation in the Amazon basin can be related to the development of roads and consequent settlement patterns. Resource access, while it is related to endowment, can be altered by technological development that provides and limits distributions among regions. Access to water resources have been grossly modified through the development of dams, irrigation canals, wells, and other access strategies that promote its distribution to some locations while limiting access to other locations. The distribution of resource access and its modification by technology and human resource practices can intensify differences in regional endowments in ways that lead to conflict across regional and state boundaries.

The distribution of resource access, according to geographers working in political ecology, relates to power relations in societies and among locations. For these studies, a special focus is placed on the relationship between access to resources and control over their management. Authoritative powers at both global and local scales can impose restrictions that limit access to common resources through the establishment of protected areas or other types of tenure arrangements, or they can redirect decision-making opportunities and management to designated populations. Power relations can be modified by redefining who has control over the management decisions that determine resource access and its use. Feminist research in political ecology focuses on how access and control differ within communities and households. Women may have access to resources, but the traditional practices of societies may limit ownership or dictate other forms of control over how these resources are managed and sustained. Accordingly, marginalized groups of people often experience a very different distribution of resource access in a region, and they possess little authority over how resources are



used and how distributions may be modified by human activities. Classic studies in feminist political ecology have examined women's role in agricultural production, water collection, and fuelwood collection and critiqued how their roles are constrained by the distribution of resource access and control. Geographic studies on the distribution of resource access are necessarily integrative in their examination of resource endowments, human and resource relationships, and power relations within and among locations.

Kimberley E. Medley

See also **Common Property Resource Management; Commons, Tragedy of the; Feminist Political Ecology; Land Tenure; Land Use Analysis; Resource Tenure**

Further Readings

- Brechin, S., Wilshusen, P., Fortwangler, C., & West, P. (Eds.). (2003). *Contested nature: Promoting international biodiversity with social justice in the twenty-first century*. Albany: SUNY Press.
- Hardin, G. (1968). The tragedy of the commons. *Science*, 162, 1243–1248.
- McCay, B., & Acheson, J. (Eds.). (1987). *The question of the commons: The culture and ecology of communal resources*. Tucson: University of Arizona Press.
- Rocheleau, D., Thomas-Slayter, B., & Wangari, E. (Eds.). (1996). *Feminist political ecology: Global issues and local experiences*. New York: Routledge.



DIVISION OF LABOR

Perhaps Adam Smith's most famous dictum is that "the division of labour is limited by the extent of the market." By allowing individuals to specialize in the production of some goods and trade them for different goods (including arts and sciences) produced by other individuals, the division of labor was, in Smith's eyes, the ultimate source of wealth and economic development. The bigger the market, the more numerous and varied the number of tasks and opportunities become.

For Smith, the benefits of the division of labor derive from three sources: (1) increased dexterity of a worker, (2) time saved from switching between tasks, and (3) increased likelihood of new inventions. The first two effects are today referred to as increasing returns. Unlike David Ricardo, Smith considered the inherent advantages of specialization as inferior to those acquired by learning and experience. The last benefit of the division of labor stresses the idea that individuals are more likely to come up with new ways to facilitate their work when they concentrate on certain tasks. Furthermore, Smith observes that some improvements have been developed by producers of machinery, while others were created by individuals who specialize into combining ideas from distant fields. In short, the division of labor yields not only static benefits through better organization of production but also new innovations and improvements developed through time.

The division of labor has always had critics. In the early days of industrialization, it was feared that it would result in ever duller and more mechanistic work. Another recurring concern has been regional or social inequality. Yet the division of labor is also an argument on behalf of globalization since the expanding market allows for more division of labor and its attending benefits.

While the division of labor can be studied in various contexts such as households, three levels, following Allen Scott, are generally considered especially relevant for geographers. The first is the individual level, where individuals specialize in different tasks within a firm (*the technical division of labor*), in the process yielding a greater output for a firm, such as Smith's classic example of a pin factory. The second division operates at the firm level, where firms in a market specialize in producing different goods and services (*the social division of labor*). Last, due to natural or other advantages, it is sometimes beneficial for regions (or firms in some geographical areas) to specialize in producing some goods and trading them with other firms and individuals located elsewhere (*the spatial division of labor*).

The geographical division of labor has two main dimensions. The first deals with how the divisions are achieved through space and how they are affected by geographical factors. Second, the division of labor being "limited by the extent



of the market,” it is interesting to study the spatial borders of the market and their evolution over time, as well as trade and other linkages between locations.

As Richard Baldwin and Philippe Martin have noted, there have been two major phases in this respect in the past two centuries. During the so-called first unbundling (1820–1914), the development of transportation technologies allowed the spatial separation of the production and consumption of many goods. As a result, the division of labor became less dependent on the size of the local demand. The second unbundling (1960 to the present), however, was characterized by the separation of different stages of production. In addition to transportation technologies, advanced communication technologies were helpful in coordinating the production of goods when different inputs and some supporting services became increasingly geographically dispersed. These impacts of new technologies, themselves products of the division, underline the dynamic character of the division of labor.

A deepening division of labor increases the interdependence of individuals and societies, which often creates negative reactions against increased dependence on foreign goods and services. As Friedrich Hayek noted, however, the division of labor is analogous and strongly connected to the division of knowledge. People know little about the trade of others and will rarely be as good at doing these tasks themselves but can nonetheless benefit from others’ expertise through market exchange. The market mechanism—and especially the price system—is therefore crucial for coordinating interdependent activities when the complexity of the economic system increases due to specialization. Besides the extent of the market, the division of labor is thus also limited by coordination costs and the amount of general knowledge. While the division of labor provides opportunities for further developments, it also generates new challenges and links economies more closely together, now on a global scale.

Samuli Leppälä and Pierre Desrochers

See also Agglomeration Economies; Comparative Advantage; Economic Geography; Globalization; Massey, Doreen; Outsourcing

Further Readings

- Becker, G. (1985). Human capital, effort, and the sexual division of labor. *Journal of Labor Economics*, 3, S33–S58.
- Becker, G., & Murphy, K. (1992). The division of labor, coordination costs, and knowledge. *Quarterly Journal of Economics*, 107, 1137–1160.
- Hayek, F. (1937). Economics and knowledge. *Economica*, 4, 33–54.
- Massey, D. (1984/1995). *Spatial divisions of labour: Social structure and the geography of production* (2nd ed.). Houndmills, UK: Macmillan.
- Scott, A. J. (1986). Industrial organization and location: Division of labor, the firm, and spatial process. *Economic Geography*, 63, 215–231.
- Smith, A. (1776/1904). *An inquiry into the nature and causes of the wealth of nations* (5th ed., E. Cannan, Ed.). London: Methuen. Retrieved November 13, 2009, from www.econlib.org/library/Smith/smWN.html



DOMESTICATION CENTERS

See Centers of Domestication



DOMESTICATION OF ANIMALS

For most of human existence, people lived as seasonally mobile gatherers, hunters, and fishers. A profound change in the human relationship with nature occurred when people established control over the reproduction and evolution of owned populations of other species, which became domesticated plants and animals. The early integration of agriculture and animal husbandry has been called the “Neolithic Revolution” because of its epochal transformation of the nature-society relationship. The domestication of animals is a major part of this transformation, and geographers have investigated it from their discipline’s earliest formalization, in the 19th century. Early geographers who wrote



Tsaatan women at Hovsgal—a territory of about 65,000 km² in northwestern Mongolia—patrol a wild maze of evergreen forests and snow-capped mountains on the backs of their stocky reindeer. Unlike other reindeer-breeding cultures, the Tsaatan do not traditionally breed their reindeer for meat. They depend on a healthy domesticated reindeer population for milk and to ride into the forests to hunt for food and furs.

Source: Hamid Sardar/Corbis.

about the domestication of animals included Alexander von Humboldt, Friedrich Ratzel, and Eduard Hahn and, in the 20th century, Carl Sauer, Erich Isaac, Frederick and Elizabeth Simoons, and Carl Johannessen.

Archaeologists, ecologists, and zoologists share this interest, but the geographers' approach differs from those of others in three distinctive ways. First, the geographic tradition in animal domestication studies uniquely stresses the role of ritual and religion in motivating people to take on the work and risk of animal husbandry.

Second, many geographers assert a three-stage scheme of cultural ecological change, from migratory gathering-hunting-fishing societies, through settling down in villages securely supported by fishing and successful experiments with plant propagation, to the domestication of animals, all in stable environments not strongly

affected by postglacial changes. They argue that economic necessity could not have motivated such well-fed folk to domesticate animals, and so these sometimes dangerous endeavors were driven by the desire to get along with the supernatural.

A third focus of the work of many geographers is diffusion(ism). This attempts to pin down the original “hearth” of domestication and then trace out the paths along which the animals themselves or the idea of their active management might have diffused.

The evolution of animals under human control eventually led to significant genetic and phenotypic divergences from wild populations. Some phenotypic changes allow advanced animal domestication to be recognized in faunal remains. Earlier stages can be detected in changing age-sex structures. The archaeological and paleoenvironmental



record both contradicts and sometimes supports the distinctive geographic argument.

Almost certainly the animal that has been domesticated for the longest time is the dog—actually a wolf, *Canis lupus* (*C. lupus familiaris*). The oldest archaeological remains of domesticated dogs go back about 14,000 cal. (calibrated) BP (years before the “present” of 1950) in Germany and 12,000 cal. BP in Israel, while analysis of mitochondrial DNA (mtDNA) in modern dogs suggests descent from three females in east Asia some 15,000 years ago (roughly the end of the last Pleistocene glaciation). Changes in the age-sex structure of gazelles (*Gazella gazella*) in the Levant imply that the Late Natufian culture of 11,500 to 12,800 cal. BP initiated their domestication during the cooling and drying of the Younger Dryas.

A second wave of animal domestications followed quickly after the dog’s (and gazelle’s), in the 11,000 to 10,000 cal. BP time frame in the early Holocene Hypsithermal warming. These have long been understood to include sheep, *Ovis orientalis aries* (Northern Iraq), and goats, *Capra aegagrus hircus* (Western Iran), but recent analyses have pushed pig (*Sus scrofa domesticus*) domestication back to the same time in southeastern Turkey and Northern Syria. Recent DNA analyses suggest that cattle, *Bos primigenius taurus*, long considered a much later domesticate, were domesticated in that same 11,000- to 10,000-BP window in northeast Africa. Chickens, *Gallus gallus domesticus*, may also go back to this time frame or slightly later, according to mtDNA analyses, with origins in southeast and South Asia. Archaeological finds on Cyprus put the domestication of cats (*Felis sylvestris catus*) at 9,500 cal. BP.

This second wave shows animal domestication underway in several specific locations in two broad regions, the southwest Asia/northeast Africa region and the southeast/South Asia region, loosely supporting the notion of a hearth. For decades, however, geographers and archaeologists dismissed significant Pleistocene-Holocene environmental change in the Near East as relevant to early domestications. Physical geographers increasingly document the magnitude and, often, abruptness of environmental changes at that transition, both in the Near East and southeast/South

Asia, as well as globally. They are an important context to domestication processes in the 14,500- to 10,000-BP time frame.

Within these two broad regions, particular animal domestications evolved in specific locations that both overlapped and differed from those in which plant domestications were going on at the same time (not long before, as the geographers’ three-stage models had assumed). Animal and plant domestications were integrated into agricultural and/or horticultural complexes through rapid crisscross diffusion from one place to another within these regions. These domestications then exploded outward with rapidly expanding human populations and with the ensuing exchange of resources and ideas.

A third wave of animal domestications followed much later, from 7,000 to 4,500 cal. BP. This involved the New World and extensive portions of the Old World. Species domesticated then included the alpaca (*Vicugna pacos*), llama (*Lama glama*), and guinea pig (*Cavia porcellus*) in Peru; the pigeon (*Columba livia domestica*) in Mesopotamia and Assyria; the horse (*Equus ferus caballus*) in the Ukraine, Southern Russia, and Western Kazakhstan; the ass (*E. africanus asinus*) in northeast Africa and possibly Somalia; the Bactrian (*Camelus ferus bactrianus*) camel in northwest China, Turkmenia, and Eastern Iran; the dromedary (*Camelus dromedarius*) in the Arabian Peninsula; several bovines in India, Southern Iraq, southeast Asia, and Tibet; and the silkworm (*Bombyx mandarina mori*) in China.

Newer domestications have continued all over the world to the present. Some of these are utilitarian, for meat, fur, honey, working, or laboratory use (turkeys and rabbits, mink, bees, cormorants, and rats); some are experimental, with an eye toward utilitarian value (eland, fallow deer, ostrich, and foxes), while others are for pet keeping (parakeets, koi, “fancy rats”).

Christine M. Rodrigue

See also **Animal Geographies; Centers of Domestication; Climate Change; Diamond, Jared; Domestication of Plants; Humboldt, Alexander von; Hunting and Gathering; Nomadic Herding; Ratzel, Friedrich; Sauer, Carl**



Further Readings

Zeder, M., Bradley, D., Emshwiller, E., & Smith, B. (Eds.). (2006). *Documenting domestication: New genetic and archaeological paradigms*. Berkeley: University of California Press.



DOMESTICATION OF PLANTS

Domestication is the evolution and creation of a mutualistic, interdependent relationship between humans and wild plants (and animals). During the domestication process, wild plants become selected for and adapted to human cultivation, use, and consumption. Domesticated plants are an inherent part of agriculture, and their appearance, evolution, and dissemination throughout the world is closely intertwined with the origin, spread, and current dominance of agriculture. The study of the domestication process is therefore in large part also the study of the origin and evolution of agriculture. Major lines of inquiry are determining the actual locations of agricultural origins and their characteristics, the causes for the adoption of agriculture, the effects of selection on plants during domestication (leading to the so-called domestication syndrome), and the consequences of the adoption of agriculture on a worldwide scale.

Domestication as a Genetic and Evolutionary Process

During the process of domestication, three sets of factors are of paramount importance to determine the degree, speed, and ultimate success of domestication. These include biological characteristics such as the length of the plant's life cycle and its reproduction method, environmental conditions such as the climate, and human cultural traits such as knowledge of the surrounding environment and toolmaking techniques. During domestication, evolutionary processes come into play. For example, naturally occurring or de novo mutations are selected, consciously or unconsciously, by humans. Mutant traits selected by humans increase yield under cultivation, enhance the flavor of the harvest (or reduce its toxicity),

or improve the quality of the product. Demographic processes such as small sample size also influence the process of domestication.

The domestication selection process has led to profound changes in the morphology, biochemistry, and physiology of plants. These domestication traits are similar in widely different species and are collectively called the "domestication syndrome." For grain and seed crops, the two most important traits of the syndrome are the loss of seed dormancy and dispersal. Both traits are essential in natural environments but are undesirable under cultivation. In addition, domesticated plants tend to be smaller than their wild progenitors, with fewer and shorter branches. However, the harvested parts, such as leaves, seeds, and fruits, tend to be larger and show more diversity in shape and color than do their wild progenitors. This diversity is a direct consequence of selection by humans, who favor novelty. Selection during domestication has been so marked in several crops that domesticates have lost the ability to survive without human intervention. Humans and their crops have, therefore, established an obligate mutualism, both depending on each other for survival.

Geographic Centers of Domestication

Agriculture originated independently in several regions of the world in so-called centers of agricultural origins or domestication, which are generally located on either side of the equator, between latitudes 35° N and 35° S. Many of these centers are located in bioregions with an alternation of dry and wet seasons, such as the Mediterranean, savanna, and tropical deciduous forest biomes. This alternation may have stimulated the transition from gathering to agriculture. Domestication centers are generally located in areas of high biodiversity that are often characterized by a heterogeneous topography. Biodiverse regions provided opportunities for the first farmers to experiment with a wide range of plants and to identify species that were more amenable to domestication. Figure 1 shows the approximate location and boundaries of six major centers of domestication and agricultural origins.

In each of these centers of agricultural origin, a similar complement of crops has been domesticated that address basic human needs or activities.

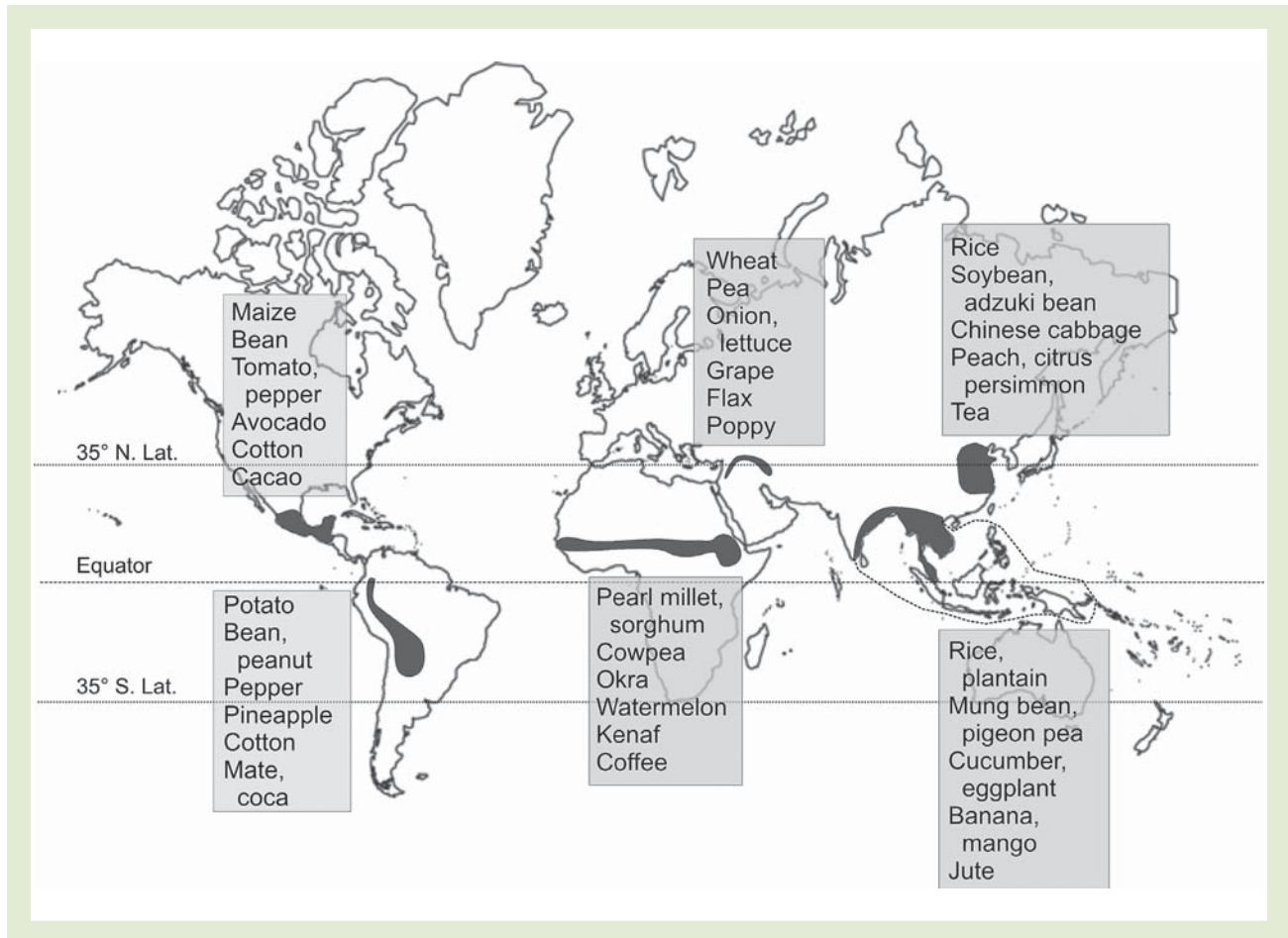


Figure 1 Approximate location and boundaries of the six major centers of domestication and agricultural origins. For each of these centers, a sample of crops domesticated in them is shown.

Source: Gepts, P. (2008). Tropical environments, biodiversity, and the origin of crops. In P. Moore & R. Ming (Eds.), *Genomics of tropical crop plants* (pp. 1–20). Berlin, Germany: Springer.

Crops can be categorized as sources of carbohydrates, protein, oil, fibers, and stimulants. Each center has developed a complex of crops with one representative from each of these categories. In addition, some of these crops offer complementarity from an agronomic and human nutrition standpoint. For example, legumes such as beans and peas complement cereals by providing nitrogen to cereal plants in the field and by adding protein to the human diet. Thus, domestication should be seen not only as a process affecting individual crops but also as a process leading to more complex agricultural systems consisting of multiple crops grown in association or rotation.

Timing of Domestication

A striking feature of these multiple origins of domestication is their near-simultaneity around the world. Archaeobotanical research has identified remains of domesticated plants that are as old as 10,000 years in several of these domestication centers. Around the same time—some 15,000 to 10,000 years ago—global climate change associated with the end of the last Ice Age raised the temperature and caused changes in rainfall patterns and distribution. This situation, and other factors, may have led to an imbalance between the supply and demand of food and other crop products. Humans responded by supplementing



their food intake obtained from gathering with food derived from cultivation. The conversion to agriculture may have been helped further by the more stable climate appearing at that time.

Dispersal of Agriculture and the Columbian Exchange

In its strictest definition, domestication pertains to the process that took place in the incipient stages of the invention and adoption of agriculture. However, subsequent events are also part of domestication in a broader sense. Because agriculture provides a higher production per unit area, it outcompeted gathering and spread to all but the most extreme environments of the globe. Through agriculture, crops began to spread beyond their centers of origin as they were selected to adapt to new environments. The most important dispersal event was the Great American (Columbian) Exchange, which took place after the first European contact with the American continent in 1492. In the following years, crops from the Old and New Worlds were exchanged, forever changing the face of agriculture and human subsistence on the planet. Through this exchange, the Italians discovered tomatoes; the Irish, the potato; and Thailand, the chili pepper—formerly exotic ingredients that now form the backbone of these cuisines.

Current Importance of Domestication Centers

Modern agriculture is characterized by many crops being cultivated far outside their initial domestication center. However, the diversity of a crop is often greatest in its respective center of domestication due to environmental and cultural factors. While efforts at preserving crop diversity in seed banks (ex situ conservation) have several advantages, maintaining crop diversity on-farm (in situ conservation) has many benefits in addition to the maintenance of biodiversity, such as improved human health and economic status. A mechanism to reward the farmers, the stewards of this diversity, must be developed to ensure that future generations can use this resource to develop improved crop varieties in the face of

looming challenges—large human population increases and the global climate change our world is witnessing.

*Paul Gepts, Matthew B. Hufford,
and Kraig H. Kraft*

See also **Agriculture, Preindustrial; Agrobiodiversity; Centers of Domestication; Crop Genetic Diversity; Diamond, Jared; Domestication of Animals; Food, Geography of; Great American Exchange; Hunting and Gathering**

Further Readings

- Doebley, J., Gaut, B., & Smith, B. (2006). The molecular genetics of crop domestication. *Cell*, 127, 1309–1321.
- Fuller, D. (2007). Contrasting patterns in crop domestication and domestication rates: Recent archaeobotanical insights from the Old World. *Annals of Botany*, 100, 903–924.
- Gepts, P. (2004). Domestication as a long-term selection experiment. *Plant Breeding Review*, 24(Pt. 2), 1–44.
- Gepts, P. (2008). Tropical environments, biodiversity, and the origin of crops. In P. Moore & R. Ming (Eds.), *Genomics of tropical crop plants* (pp. 1–20). Berlin, Germany: Springer.
- Sang, T. (2009). Genes and mutations underlying domestication transitions in grasses. *Plant Physiology*, 149, 63–70.
- Zeder, M., Emshwiller, E., Smith, B., & Bradley, D. (2006). Documenting domestication: The intersection of genetics and archaeology. *Trends in Genetics*, 22, 139–155.



DOMINO THEORY

The domino theory was an important component of the U.S. Cold War geopolitical model of the world, which divided the world into three parts: the First World (the West), the Second World (communist states), and the Third World (colonies and newly independent states). Proponents of the domino theory argued that the loss of one



country in the First or Third World to communist control would trigger the loss of its neighboring countries to communism.

While the origins of the concept have been traced to early in the 20th century, the domino theory emerged in full force in U.S. foreign policy circles in the aftermath of World War II. The concept was advanced in 1947 both by the former U.S. ambassador to the Soviet Union, William Bullitt, who warned of communism advancing out of the USSR and sweeping over the world, and President Truman's Secretary of State, Dean Acheson, who warned that a communist victory in Greece would lead to communism sweeping through Africa and Western Europe.

The domino analogy was first used in 1954 by U.S. Admiral Arthur Radford to justify his call for using nuclear weapons in support of French attempts to hold Indochina. President Eisenhower used the term *domino* that year to argue for U.S. intervention, arguing that "the loss of Indochina will cause the fall of southeast Asia like a set of dominoes" (quoted in O'Sullivan, 1982, p. 58). The domino theory reached its highpoint in U.S. foreign policy circles in the 1960s, when it helped guide the Kennedy and Johnson administrations' escalation of U.S. involvement in Vietnam. That escalation was based on a belief that if South Vietnam fell to the communists, then the rest of southeast Asia would fall in quick succession, with potential consequences beyond.

The domino theory continued to be used to convince the American public of the importance of containing communism into the 1980s. For example, the Reagan administration sold its support of the contra rebels fighting the socialist Sandinista government in Nicaragua to the American public in part by arguing that the United States had to defeat the Sandinistas because if left unchecked, communism would spread throughout Central America and Mexico, bringing it to the Texas-Mexico border.

Throughout the Cold War, the domino theory suggested that one communist victory in some far-flung part of the world would lead to a series of victories in neighboring countries. Through this metaphor, distant events could be linked back home. Thus, intervention in southeast Asia in the 1960s and in Central America in the 1980s was

portrayed as necessary because once countries in southeast Asia and Central America "fell," then, like a row of falling dominoes, communist forces would ultimately continue until they reached American soil.

However, over time, the domino theory has been discredited, both empirically and theoretically. Attempts to demonstrate the domino theory in action have fallen short, and critics have argued that the domino theory's mechanistic approach to the fall of countries ignores the vast differences and complexities among them. Despite the fact that the domino theory has been thoroughly discredited, it is still invoked by some today, for example, to predict the spread of terrorist activity.

Jonathan Leib

See also **Cold War**, **Geography of**; **Geopolitics**; **Political Geography**

Further Readings

- McNamara, R. (1995). *In retrospect: The tragedy and lessons of Vietnam*. New York: Times Books.
- Moise, E. (2002). The domino theory. In A. DeConde, R. Burns, & F. Logevall (Eds.), *Encyclopedia of American foreign policy* (2nd ed., Vol. 1, pp. 551–559). New York: Charles Scribner's.
- Ninkovich, F. (1994). *Modernity and power: A history of the domino theory in the twentieth century*. Chicago: University of Chicago Press.
- O'Sullivan, P. (1982). Antidomino. *Political Geography Quarterly*, 1, 57–64.
- Ó Tuathail, G., Dalby, S., & Routledge, P. (Eds.). (1998). *The geopolitics reader*. London: Routledge.



DOT DENSITY MAPS

Dot density maps, or dot maps, portray the geographic distribution of discrete phenomena using an arrangement of identical point symbols, most



commonly dots. The dot density technique dates to at least the 19th century and is today accepted as one of the primary techniques for representing geographic patterns. Dot density maps are particularly useful for understanding global distribution of the mapped phenomenon and comparing relative densities of different regions on the map. Dot density maps are also easy to understand, requiring little cognitive effort from the map reader when compared with isoline maps. However, retrieval of specific information from dot density maps is difficult as map users find manual counting of dots tedious and tend to underestimate dot totals as the density increases.

Types of Dot Density Maps

There are two kinds of dot density maps: one-to-one maps and one-to-many maps. In one-to-one dot density maps, each point on the map corresponds to a single incidence of the mapped phenomenon. One-to-one dot density maps are general-reference maps, symbolizing spatial location only. Because of this, care should be taken to ensure that a dot is accurately located on the map. Examples of data sets ideal for one-to-one dot density mapping include the major cities in Europe or locations of recent earthquakes along the Pacific Rim.

Although one-to-one dot density maps are more common in practice, the term *dot density map* typically refers to one-to-many dot density maps. In one-to-many dot density maps, each point on the map represents a predetermined number of incidences of the mapped phenomenon, called the dot value. One-to-many dot density maps are thematic maps, symbolizing an aggregated variable atop a reference base map. Use of a one-to-many dot density map, rather than the one-to-one counterpart, is necessary when the only available data are aggregated to areal enumeration units or there are too many point incidences within the map extent for legible representation, necessitating aggregation by the cartographer. Examples of data sets ideal for one-to-many dot density mapping include the population of the United States and the number

of dairy cows in Wisconsin, both aggregated by county.

Aggregated Data and One-to-Many Dot Density Maps

Not all aggregated data are appropriate for one-to-many dot density mapping. Alan MacEachren and David DiBiase developed a typology of aggregated data based on two characteristics of the mapped phenomenon depending on whether (1) the phenomenon occurs at discrete locations in space or exists continuously throughout the extent of the map or (2) the phenomenon changes abruptly at enumeration boundaries or varies smoothly throughout the extent of the map. Each data model is then paired with a recommended mapping technique. Figure 1 provides simple and effective guidance for determining the appropriate thematic map technique for representing aggregate data, given the characteristics of the mapped phenomenon. Only aggregated data of phenomena that exist discretely in space and vary smoothly across space should be mapped using the dot density technique. Only magnitude data should be displayed with dot density maps; derived values, such as averages, rates, and percentages, are theoretically continuous and should therefore be mapped with a choropleth.

One-to-Many Dot Density Map Design Considerations

There are four important design considerations for one-to-many dot density maps that affect the accuracy, clarity, and effectiveness of the image: (1) units of aggregation, (2) dot size, (3) dot value, and (4) dot placement. The size, shape, and distribution of enumeration units at which the data are aggregated can influence the mapped pattern greatly. Generally, the smaller the size and the more regular the shape and distribution of enumeration units, the more realistic the mapped pattern. When possible, enumeration units that are meaningful to the mapped phenomenon should be used over those that are arbitrary.

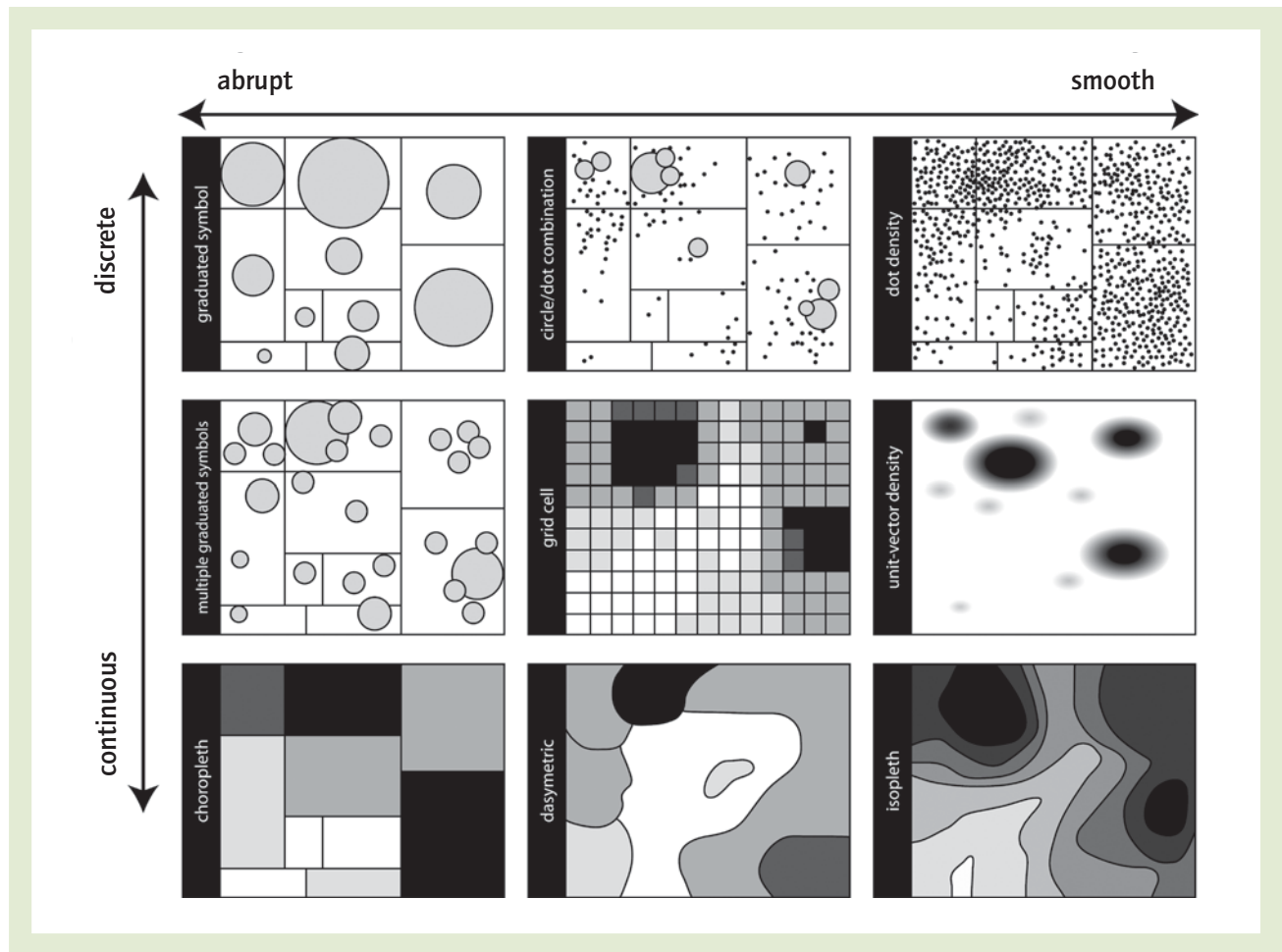


Figure 1 A reference for matching mapping technique to aggregated data set based on the characteristics of the mapped phenomenon

Source: Adapted from MacEachren, A. M. (1997). Visualizing uncertain information. *Cartographic Perspectives*, 13, 16. With permission from *Cartographic Perspectives* and The North American Cartographic Information Society.

The dot size and dot value should be considered in tandem and together determine the number of dots on the map. An intermediate dot size should be chosen in most cases; dots that are too small produce an overly sparse dot pattern and convey an inappropriate amount of map accuracy, while dots that are too large produce excessively dense dot patterns, overwhelming subtleties in the distribution of the mapped phenomenon. A rounded, easily understood number should be chosen for the dot value for

easy estimation. Selection of an appropriate dot size and dot value always requires some experimentation, but it can be made easier by using a visual tool called a nomograph. When an appropriate dot value and dot size are chosen, there should be two or three dots in the enumeration units with the smallest values, and the dots should just begin to coalesce in the enumeration units with the largest values.

The final important design consideration for one-to-many dot density maps is the method of



placing dots in the enumeration units. Most mapping software now allows automated, random placement of dots. However, random placement does not take into account the distribution of the mapped phenomenon and may lead to spurious clustering on the map. There are two recommended alternatives: (1) a geographically weighted approach that shifts dots toward neighboring enumeration units with higher values and away from those with lower values and (2) a geographically based approach that uses ancillary information about the mapped phenomena to weight dot placement negatively in prohibited areas and weight dot placement positively in suitable areas. Uniform placement of dots produces abrupt, unwanted boundary effects and should therefore be avoided.

Robert E. Roth

See also **Cartography; Choropleth Maps; Dasymetric Maps; Isoleth Maps; MacEachren, Alan; Map Design**

Further Readings

- Dent, B. (1999). *Cartography: Thematic map design*. Boston: McGraw-Hill.
- MacEachren, A., & DiBiase, D. (1991). Animated maps of aggregate data: Conceptual and practical problems. *Cartography and Geographic Information Systems*, 18(4), 221–229.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2005). *Thematic cartography and geographic visualization*. Upper Saddle River, NJ: Prentice Hall.



DROUGHT RISK AND HAZARD

Drought is a complex concept with both physical and socially constructed components. The idea of a drought conjures a popular image of cracked brown earth, fallow agricultural fields, and suffering human communities. This realistic image confuses the physical drought hazard with the

social impacts of drought in contexts with high drought risk. *Drought* does not lend itself to a single, universal definition because *drought* has different spatial and temporal characteristics in distinct climates and regions. *Drought hazard* refers to the physical phenomenon of a meteorological drought, generally defined as a departure from a long-term precipitation (e.g, rainfall or snowfall) average that results in an impact in a specific place. A drought is a temporary yet recurring phenomenon that occurs in all climates, but occurs with a greater frequency and more severe impacts under certain regional conditions than in others.

Unlike other hazards such as floods and tropical storms, a drought is gradual or “creeping.” Drought hazards are spatially vast and affect more people worldwide than do other “natural” disasters. Notable drought-prone regions of the world include Australia, Northern Mexico, northeast Brazil, Western Africa, and southwestern United States. With respect to drought, Africa experiences the greatest loss of life, Asia has the most people affected, and the West sustains the highest economic damages. Drought can lead to a massive loss of life, famine, desertification, deforestation, loss of livelihood, and migration.

Drought risk refers to the vulnerability associated with the exposure of an individual, a community, or a region to a drought hazard, as well as the capacity of that entity to adapt or respond in an effective way to the drought hazard. A drought hazard does not in itself cause a social disaster. Rather, socioeconomic attributes and policy choices determine whether a meteorological drought will create conditions of high drought risk. For example, in a poor country with a high proportion of subsistence farmers, a drought may imperil the country’s overall food security, while in a country with high levels of imported foods and widespread irrigation, a drought may have limited impacts. Drought hazard and risk are therefore separate yet related concepts.

Drought Types

Donald Wilhite, a geographer and former director of the U.S. National Drought Mitigation



Sun-parched sediment is all that is left by drought in this Arkansas lake.

Source: Tim McCabe, USDA Natural Resources Conservation Service.

Center, defines four distinct types of drought: meteorological drought, hydrological drought, agricultural drought, and socioeconomic drought. At their root, all droughts originate as *meteorological drought*, defined as a deficiency in precipitation over a preestablished time period relative to an accepted “normal” longer-term historical average (e.g., 75% of normal precipitation over a 6-month period). Meteorological droughts in turn give rise to other identifiable types of drought. *Agricultural drought* refers to an insufficiency in soil water to support crop and forage growth; regional variations in crops and soil types help condition whether decreased precipitation develops into an agricultural drought. *Hydrological drought* occurs when there are

insufficient surface and groundwater supplies to fulfill multiple and competing water demands, including irrigation, hydroelectric power, domestic use, and ecosystem management. *Socioeconomic drought* is at the nexus of the supply and demand for water or an economic good reliant on water (e.g., hydroelectric power). The supply is variable, based on precipitation and water availability, while the demand is conditioned by dynamic social factors such as demographic change and economic development trends. A precise definition of drought with regard to its type, timing, climate, and region can help in the development of targeted adaptive responses.

China, the Middle East, and India all experienced drought in prehistoric and historic times,



leading to dire consequences such as mass starvation, though these impacts were also conditioned by sociopolitical factors. In recent years, researchers have cited decade-scale variations in ocean-atmosphere interactions in the Pacific and Atlantic Ocean basins as the ultimate causes of severe sustained droughts. Paleoclimate studies confirm the influence of interannual-to-decadal ocean-atmosphere variability on extended drought episodes, more severe and extended than those in recorded memory, in North America, Asia, and the Mediterranean. North America tree ring drought reconstructions have provided evidence of multidecade “mega-droughts” from AD 900 to 1300, with devastating impacts, making it clear that drought contributed significantly to the dissolution of Pueblo Indian society in the American Southwest. Mega-droughts of similar magnitude may be a normal aspect of current and future climate regimes.

Drought Indices

Measuring drought hazard is constrained by the lack of a common definition of drought. The departure of precipitation and reservoir levels from a threshold or decision-making criterion are common hydroclimatic drought indicators. Drought indices range from a straightforward percentage of average precipitation to supply-side indices, such as the Standardized Precipitation Index, to complex water balance formulae, such as the Palmer Standard Drought Indices, which factor in temperature. Other indices integrate information such as snowpack, streamflow, and reservoir storage or measure vegetation stress based on remote sensing.

The U.S. Drought Monitor and North American Drought Monitor combine multiple quantitative drought indicators with expert scientific assessment and impact reports to create snapshots of drought conditions each week and month, respectively. These drought indices subjectively associate drought status with drought impacts on resource management and agriculture. The U.S. National Drought Mitigation Center’s Drought Impact Reporter monitors and measures drought impacts through news media reports, volunteer reports, and economic losses.

Drought Prediction, Monitoring, and Mitigation

Climate scientists seek to understand the relationships between climate and drought in multiple contexts. Drought occurs on many spatial and temporal scales, thus a variety of physical mechanisms have been associated with drought. On weekly-to-monthly timescales, diminished precipitation, late precipitation (e.g., delayed monsoon onset), sublimation of mountain snowpack, and heat waves may be the proximate causes of drought impacts on agriculture, streamflows, or wildlife habitat. On seasonal-to-decadal timescales, hemisphere-scale interactions between the ocean, atmosphere, and land are usually implicated. The El Niño-Southern Oscillation (ENSO) is strongly associated with interannual drought in the global tropics and subtropics and some midlatitude regions (e.g., Western North America). ENSO effects on seasonal precipitation can be particularly strong in monsoon climates, such as in Asia. Drought impacts can be exacerbated by feedbacks between human activities and atmospheric circulation, such as deforestation, which leads to lower soil moisture retention.

Monitoring is the first step toward mitigating drought impacts, and several coordinated monitoring networks have been established (e.g., North America, the Mediterranean, sub-Saharan Africa, and Asia). However, in many cases mitigation and response actions are not taken until impacts are apparent. In contrast to other climate and weather-related hazards, drought is spatially pervasive, encompassing large parts of the landmass for months to years. Consequently, a variety of factors must be monitored, including water supply indicators (e.g., precipitation) and impact indicators (e.g., vegetation health, wildlife abundance, water quality). Some monitoring systems lack sufficient observations of key indicators, such as soil moisture or evapotranspiration, or a sufficient density of observations to gauge the spatial extent and severity of a drought to meet the needs of local decision makers. Remote sensing, a key component of drought and famine early warning networks, holds the promise of filling in monitoring data gaps. A key



challenge for improving the effectiveness of drought monitoring networks as an early warning tool is adequate and transparent provision of data and value-added information such as those provided in innovative research involving citizen scientists trained to report regional drought impacts.

Apart from improved monitoring, enhanced and reliable prediction frequently tops the request list of decision makers. At present, scientists have limited ability to predict drought, and the seasonal-to-annual drought prediction skill is primarily linked to the ENSO prediction skill. Even when the onset of a drought has occurred, the severity and duration of the drought are difficult to predict. Short-term forecasts, useful to agriculture and ecosystem management, may be derived from remotely sensed data, which may include directly measured subsurface soil moisture, which is less dependent on precipitation, and thus can incorporate irrigation as a component of the surface water budget.

Seasonal-to-annual drought prediction is a function of initial hydrologic conditions and ocean-atmosphere forecast skill; thus, fruitful areas for research and model improvement include measurement or modeling of initial conditions, representation of air-sea interactions, translation of initial drought conditions into probabilities of impacts, and improved understanding of interactions between multiple ocean basins. On longer timescales, characteristics of Pacific and Atlantic tropical ocean-atmosphere circulation persist and may make possible the prediction of decade-length dry episodes and pluvials. Multiple ensembles of global circulation models are necessary for such predictions.

Social Construction of Drought

The conceptual understanding of drought has evolved in recent decades from a purely technical phenomenon based on hydrometeorological metrics to a largely social one. Political ecology research in geography approaches drought as a social construction, positing that drought risk is conditioned by a range of socioeconomic and political drivers. These include the gross domestic product, regional economy, patterns of water use and changing demand,

land tenure regimes, government stability, and policy choices. Drought disasters are therefore subject to mitigation and societal adaptation. Vulnerability is a function of both exposure to drought risk and the capacity to adapt or make effective adjustments to socioeconomic systems in response to the impacts of drought. Geographer Diana Liverman, for example, demonstrated that access to agricultural technology and large landholdings reduced drought vulnerability relative to small, communal landholdings for farmers in Northern and Central Mexico. Vulnerability assessment methods may include participatory mapping (involving citizens and communities) and institutional capacity assessments. The institutional capacity of government agencies and civil society to anticipate drought impacts and respond via planning and mitigation strategies can reduce vulnerability to drought. Emerging participatory research models highlight the agency of citizens and institutions in anticipating and adapting to drought and involving key stakeholders in adaptive planning to reduce vulnerability.

Drought Planning

Drought planning can be an effective strategy to help a community, state, or country anticipate the challenges of drought and reduce the vulnerability of high-risk populations by establishing early warning mechanisms and coordinating responses of governmental levels and agencies. Australia's 1992 national drought policy is considered emblematic for involving rural producers and balancing the competing demands of agriculture and the environment. In the United States, where there is a highly effective drought monitoring system at the national level, drought planning has been carried out largely at the state level. As of 2006, 37 U.S. states had developed state drought plans. Such plans generally frame drought severity levels and propose triggers of distinct actions to be taken at each level. Recent research has highlighted the contrast in drought and climate change preparedness in industrialized countries relative to developing countries; this gap needs to be addressed to reduce the high vulnerability of poor regions and protect human security.



Climate Change and Drought

What does climate change portend for the future of droughts worldwide? The Intergovernmental Panel on Climate Change suggests that the subtropics, low latitudes, and continental interiors are likely to experience more frequent and more severe drought through a combination of decreased annual precipitation and increased annual temperatures. Factors increasing the likelihood of drought vary regionally but include migration of storm tracks, increased evapotranspiration, and decreased soil moisture. Nonstationarity refers to an inherent dynamism or changing nature of climate associated with processes of human-induced climate change, meaning that the past climate does not serve as a reliable linear predictor of the future climate. Nonlinearities in the climate system (e.g., rapid continental ice sheet melt) can lead to abrupt climate changes or “climate surprises,” and nonlinear ecosystem responses can lead to dramatic changes in the landscape, evapotranspiration, and water quality. An example is rapid drought-induced forest mortality, with feedbacks that include substantial changes to insect pest life cycles.

The implications of climate change for future drought occurrence, prediction, and societal response are manifold. Traditional statistical methods of drought prediction may be confounded by nonstationarity, further challenging drought forecast efforts. Significant agricultural and ranching adaptations may be necessary to account for changing growing season lengths and temperatures. Water managers will need to seek additional sources of water, reuse treated effluent, or promote increased conservation as a way to cope with increased likelihood and severity of drought. Societies need to evolve globally a new adaptive sensibility that frames drought not as an inevitable disaster but as a hazard that can be managed to reduce vulnerability and build resilience.

Margaret Wilder and Gregg M. Garfin

See also [Adaptation to Climate Change](#); [Anthropogenic Climate Change](#); [Biome: Desert](#); [Desertification](#); [Differential Vulnerabilities to Hazards](#); [El Niño](#); [Natural Hazards and Risk Analysis](#)

Further Readings

- Adger, W. (2006). Vulnerability. *Global Environmental Change*, 16, 268–281.
- Kallis, G. (2008). Drought. *Annual Review of Environment and Resources*, 33, 85–118.
- Liverman, D. (1990). Drought impacts in Mexico: Climate, agriculture, technology, and land tenure in Sonora and Puebla. *Annals of the Association of American Geographers*, 80, 49–72.
- Liverman, D. (2009). *Suffering the science*. London: Oxfam.
- Stahle, D., Fye, F., & Cook, E. (2007). Tree-ring reconstructed megadroughts over North America since AD 1300. *Climatic Change*, 83, 133–149.
- Wilhite, D. A. (Ed.). (2005). *Drought and water crises: Science, technology, and management issues*. Boca Raton, FL: Taylor & Francis.



DRUGS, GEOGRAPHY OF

Drugs comprise an array of chemical compounds that affect the human mind and body, and they occur in natural and synthetic, and licit and illicit forms. They are produced, exchanged, and consumed for numerous reasons, including for use in recreational and religious settings as well as medicinal purposes. Drugs and drug use are central to human health, welfare, and custom, and hold high cultural and economic value. At the same time, they can cause profound public health issues that often relate to drug abuse and dependence and also issues of criminalization. The geographies of drugs are therefore complex and contradictory. They operate at multiple scales that overlap and entwine, both linking and distancing people and places with and from each other, reaching through time as well as space. This entry begins with historical geographies of drugs in their various traditional, popular, commercial, medicinal, and illicit forms. It then looks at narcotics production under UN regulation; illicit drugs in the developing world; the growth in production of synthetic drugs; issues of drug addiction, related health problems, and treatment; and the use of spatial approaches in the analysis and policing of drugs.



Historical Drug Geographies

Some drugs have very long traditions and uses associated with specific places. They include the ceremonial drinking of *kava* root by Pacific islanders, the ritualized ingestion of *yagé* or *ayahuasca* by shamans in South America, and the use of hallucinogenic *peyote* cactus by Midwestern American desert Indians and in the Native American Church. These traditional practices have tended to avoid strict legal control and criminalization but have instead suffered from disuse and marginalization. (Exceptions include the use of *kat* in Africa and the chewing of betel nut across Asia, both of which can be frowned on but are important in sociocultural and economic terms.) Even traditional drug practices are regaining importance in their respective landscapes, however, and are significant for ecotourism and revenue creation, and for the reinvigoration of indigenous identities and cultural practices. Although such drug use does affect altered human states, it is far less problematic than modern drug abuse and rather is respected for reasons such as those cited above as well as for fostering local native knowledge and links back to more spiritual relationships with natural environments. Arguments for protecting pristine “Nature” and tropical rain forests, in particular, similarly promote renewed reverence for different peoples, places, and practices by claiming that they might hold the key to finding miracle cures for modern ills such as AIDS and cancer. Ethnobotanists therefore work with traditional healers and medicinal foragers in diverse, sometimes very small or isolated, communities as well as with large bioprospecting companies in seeking to convert folklore remedies into modern medicines (and large profits).

From a historical perspective, during the European “Age of Expansion,” for example, maritime explorers voyaged to Asia, Africa, and the Americas in pursuit of wealth from the spice trade and also in the hope of discovering plants with possible medicinal and culinary uses. The territorializing histories of colonialism that then followed subsequently featured valuable new drugs including quinine, caffeine, and tobacco. They have remained important cash crops for some local economies but still depend on transnational

corporations, global markets, financial flows, and commodity chains. Such linkages also raise ethical questions as actors in affluent nations must decide whether or not to export products that might not be well distributed and are poorly regulated or costly in the less developed world, or whether to import cheap raw materials that sometimes rely on the exploitation of nonunionized and child labor or monopolistic markets. Alcohol is another drug with spatial manifestations shaped by political economy, history, and culture with attendant moral, legal, and health issues. Its geography connects (and disconnects) licensed venues, state legislation, dry Mormon states, Muslim nations, local temperance movements, and U.S. prohibition, for example, whereas wine regions, *terroir*, DOC appellation, and viticulture concern the more physical particulars of place, including soil, aspect, and climate.

Opiates used for the legal manufacture of analgesics likewise have their obverse in the drug heroin. India’s current position as the world’s primary producer of licit raw opium (exported mostly to the United States for processing) has a historical geography extending back at least to its Mughal rulers, the East India Trading Company, the growth of the British Empire, and Britain’s Opium Wars with China between 1839 and 1860. These narcotic drugs are also entwined in a complex geopolitics that has intensified in recent decades. The opium poppy is the oldest known medicinal plant and traces back millennia to around the Mediterranean and Asia Minor. With a Sanskrit name meaning “joy plant,” its main use has been to provide pain relief. Opium preparations were commonly taken until the 19th century, when alkaloids including codeine and morphine were first isolated. Then they and heroin, which was discovered in 1897 through a simple manufacturing process, became the main ingredient in remedies ranging from cough syrups to cure-alls. Addiction had previously been associated with, for example, Chinese opium smokers, British literary romanticism, or “morphinism” among American Civil War soldiers. It was seen as a more widespread problem in the 20th century as the moral panic over delinquency (embodying issues of youth and race), the criminalization of drugs, and black markets all boomed. As a result, several “wars on drugs” were announced



in the 1970s and onward. They have been fought on various domestic and international fronts but are yet to be won.

Narcotics Production Since UN Regulation

The cultivation of poppies as well as coca and marijuana for legal narcotics production is licensed worldwide by the United Nations. Such regulation was first attempted at the International Opium Commission in Shanghai in 1909. Today, almost all nations are party to the United Nations' key agreement of the 1961 Single Convention on Narcotic Drugs (as amended by the 1972 Protocol) as well as the 1971 Convention on Psychotropic Substances and the 1988 Convention against Illegal Traffic in Narcotic Drugs and Psychotropic Substances, which have been agreed on to control new problems such as the development of synthetic drugs, global drug cartels, and international money laundering. The main regulatory body is the International Narcotics Control Board, which works with the UN Office of Drugs and Crime. These conventions are mostly prohibitive. However, the United Nations does not have the power to enforce implementation or punish noncompliance, which remains under the domestic jurisdiction of individual parties. Most important are the multilateral agreements, which determine the areas to be cultivated and the quantities of licit narcotics to be produced annually for each nation by comparing the global stocks with estimated demand and by balancing imports and exports.

Traditional opium production involves scraping latex from the incised green poppy capsules by hand, and this labor-intensive agriculture has supported millions of peasant farming families from the Middle East to the Indian subcontinent. Its legitimacy has waned though, and the modern "poppy straw process" is now most common and encouraged under UN licensing. The process is highly mechanized and relies on industrial chemical extraction, and thus world production of licit narcotics is now led by nations including Australia, France, Hungary, and Spain. However, the UN ensures that two major traditional producers are still accommodated. India is therefore uniquely licensed to continue exporting opium, whereas Turkey, which was banned from production in

1972, underwent modernization with relicensing 2 years later and now leads global production with its output of "concentrate of poppy straw" (Table 1). Also, the United States is the world's biggest importer and consumer of licit narcotics. In 1980, it passed the "80/20 rule," requiring that at least 80% of its imported raw narcotic materials come from India and Turkey. This legislation concerns both opium and poppy straw but forms of the latter that are most usually rich in morphine. However, it overlooks a new form of poppy straw rich in the alkaloid thebaine (rather than morphine). The official reporting of thebaine production for the United Nations began in 1999. Reports reveal rapid increases, which they explain in terms of the growing international demand for particular pharmaceutical drugs such as oxycodone and buprenorphine (painkillers so popular that the former now has a name, "hill-billy heroin," in the United States). Australia has led global production, accounting in 2005 and 2006 for 70% and 80%, respectively, of the total 70 tons and 72 tons of thebaine equivalent produced those years.

In regulating narcotics, the United Nations tries to guarantee the world's licit supplies but also aims to address the problems of the illegal drugs trade. Licensing a modernized poppy industry has lessened the crop diversion, for example, which was once rife in India and Turkey. Government legislation, official inspections, and policing at various levels are also central to its security. The Australian industry, as a relative newcomer, even confines its poppy cultivation to the island state of Tasmania and until very recently was dominated by just two international companies following its establishment in the 1970s. Narcotics production is most profitable for licensed farmers across the world complying with regulations. However, the illicit cultivation, manufacture, and trafficking of illegal drugs that are part of the international organization of crime (and sometimes terrorism) can resist such control. Such farmers have links especially to fragile states struggling with political instability, armed conflict and dire poverty.

Lure of Drugs for the Developing World

In the 1950s, communist prohibition pushed poppy cultivation from China to southeast Asia



	2003	2004	2005	2006	2007	2008
Australia	151	96	130	70	68	53
France	68	101	96	56	25	49
Hungary	9	30	15	17	15	49
India	57	92	37	38	30	24
Spain	44	55	36	17	70	85
Turkey	145	60	64	106	30	70
Others	13	13	13	12	14	22
Total	487	447	391	316	252	352

Table 1 Global production of licit raw narcotics rich in morphine in the years 2003 to 2008. The world's major producers of morphine-rich narcotics include several European countries as well as India and Australia.

Source: Created by author, from data in International Narcotics Control Board. (2008). *Narcotic drugs: Estimated requirements for 2008: Statistics for 2006*. New York: Author.

to Central Asia, where the infamous “Golden Triangle” (Burma, Laos, Thailand) and “Golden Crescent” (Afghanistan, Iran, Pakistan) are found. With the Cold War and increased militarization in these regions, opium and heroin manufacture were not suppressed but simply shifted to become involved in the political conflicts and related financing of local war efforts. In Burma (now Myanmar), both the ruling junta and the autonomous ethnic groups backed by the United Wa State Army rely on and negotiate ceasefires around their illegal drug production and trade. The U.S. provision of foreign aid to such nations is most often tied to the eradication of illicit crops. However, the CIA's backing of resistance groups that include the Hmong in Laos, the Nationalist Chinese or *Guomindang* in Northern Burma, and the Islamic *mujahideen* in Afghanistan has implicated them in the continued and increasing production of opium and heroin in these two regions. While poppy cultivation had been forbidden under the Shah in Iran since the 1950s, it is now, like Pakistan, a place instead for processing and trafficking. Likewise, in Afghanistan, following the Soviet withdrawal, the Taliban reduced opium production there from 3,300 tons in 2000 to a miniscule 185 tons in 2001 (but was still trading from stockpiles).

Afghanistan's return and rapid rise to lead the world in opium production has reached record-breaking levels each year since 2006. This illicit economy involves more than half a million

households with a total farm gate value there of US\$1 billion, and its opiate exports to neighboring countries in 2007 have been put at US\$4 billion, constituting an estimated 33% of Afghanistan's GDP. International commentators have therefore investigated the prospect of Afghanistan becoming a licensed producer. However, the suggestion is hampered by problems of poverty, food scarcity, political conflict, and the inadequate progress made with crop substitution programs and infrastructure development, including the repair of irrigation systems completely destroyed by war. More than half the illicit production in this country now occurs in the one southern province of Helmand, where the Taliban has a strong presence. With the movement southward of production to there, trafficking has also shifted from the old Silk Route to the Balkan route. Therefore, while heroin seizures are increasing in Russia and other former Soviet states, so are institutionalized crime and corruption, heroin addiction, and HIV infection rates.

Patterns of drug production and trafficking (and, less so, consumption) change quickly. Coca cultivation, associated with South America, is appearing on islands in the Caribbean and Oceania, for example. Diversification of drug economies is occurring worldwide, and opiates are now being grown in addition to coca and marijuana in Colombia, for example. There the drug lords and traffickers (*cocaleros*) have had alliances with the revolutionary army, FARC, since the early 1980s,



Opium poppies after flowering, Northern Tasmania, Australia. Poppies are the source of both opium and heroin, some of the world's most widely used illegal drugs.

Source: Author.

wielding great power through political corruption and “narcoterrorism.” However, dismantling of the Medellín and Cali cartels through the 1990s revealed a capacity for dynamic reorganization. Coca paste continues to be produced, almost all for export as cocaine, but then it was also being marketed as “base” or crack, triggering a new epidemic in the United States that affected black urban neighborhoods already in decline. The method of its transport also changed from air to maritime routes. And as coca production increases in Colombia, Bolivia, and Peru, trafficking to Europe has incorporated more West African transit points, which once focused only on the local production of marijuana and hashish. Mexico has

similarly become a major processing and transit point for different drugs destined for the United States and elsewhere. Dynamic drug geographies are also evident, with the decriminalization of marijuana in Amsterdam spreading to some Australian and U.S. states too. Indeed, the focal point that California once played in the psychedelic era of the 1960s and 1970s has lessened, and the geography of LSD or acid has since been reconfigured along with many other, newer synthetic drugs.

Synthetic Drugs

The manufacture of synthetic drugs is also meeting new demands in the illicit economy.



Chemically manufactured drugs such as amphetamines or “speed” have had links to British and North American rebellious youth cultures of rock ‘n’ roll and motorcycles for decades. They once relied on the diversion of pharmaceuticals such as benzedrine, but nowadays a new industry that manufactures an array of illegal synthetic drugs is meeting the increasing demand here. Ecstasy pills (“E”) are easily produced for illicit markets in bulk, for example, and are then sold with international brand names known to consumers. They are often used en masse at dance parties and rave scenes and has been associated most with the British independent music coming out of Manchester in the 1990s as well as with select, international tourist locations for young people, ranging from Ibiza to Goa. Other designer drugs that are now appearing include “fantasy” and “GBH.” Likewise, the production of ATS or “amphetamine-type stimulants” such as methamphetamine in Burma is fuelling a new drug consumption culture in Thailand. The use of methamphetamine, known worldwide as “ice” or as *yaa baa* (meaning “madness”) in southeast Asia, is associated with students and workers as much as with party-goers and nightclubs but still threatens serious psychological, generational, and socioeconomic damage. Related factors in controlling the problem’s spread are the small size, mobility, and number of drug factories that can now easily and quickly change location so as to evade detection by the authorities, with minimal disruption of their illegal operation.

Addiction, Health Problems, and Treatment

Like the problems that they are designed to address, public health strategies around drug use exhibit distinct and dynamic spatial patterns. Harm reduction policies constitute an alternative to the usual efforts at control through criminalization and policing of drugs (their supply, in particular). Radical versions have included free prescription drugs, public injecting rooms, and acceptance of “heroin parks” variously in the Netherlands, Switzerland, and the United Kingdom. But more generally, they involve education on safe drug use practices, provision of needles and syringes, peer support, counselling, and rehabilitation and reduction or maintenance of drug

use through substitution programs (especially using the synthetics methadone in the United States and Australia and buprenorphine in France to treat addiction to opiates). They have been perhaps most successful in the United Kingdom, Canada, and Australia in significantly reducing the incidence of HIV/AIDS and hepatitis B and C infections as well as other drug-related morbidity and mortality rates. The uptake of such policy and practices varies greatly between national and subnational jurisdictions and even at the state and county levels. Therefore, in examining the epidemiology of addiction and the problems of drug epidemics, HIV/AIDS, and overdose fatalities, as well as possible solutions, geographers have looked at other factors. In addition to the role of local drug economies and subcultural practices, they include the location, type, and accessibility of service delivery; the influence of the built environment; housing and tenure type; and community factors such as race, ethnicity, income, and transience. Still predominant though is a belief in the broader approaches and their capacity to influence supply-side controls through legislation and policing in conjunction with anti-drug campaigns to lessen demand.

Spatial Approaches to Analysis and Policing

Early-20th-century geographies of social and spatial disadvantage, including social area analysis and urban ecology, sometimes included drug use or delinquency as a variable. The geography of drugs has also developed with the use of environmental approaches to crime. Using “routine activity” and “social disorganization” theories; mapping the spatial distribution of crimes; analyzing hotspots; constructing geographical offender profiles, distribution networks, and mobility patterns; and applying traditional tools such as “distance decay,” “spatial diffusion,” and “journey-to-work” models have all helped describe where and how different drug markets operate. But the geographical understandings of crime and policing that are most pronounced in policy and practice are situational crime prevention and crime prevention through environmental design. They are now being similarly applied to the problems of drugs. Initiatives in the United States, for example, involving increasing the



presence of police on street corners renown for drug activity have led to local reductions in violent and drug crimes and a significant spatial diffusion of these preventive benefits as well as some probable displacement of the original problems. It is possible though that the creation and enforcement of zero-tolerance and exclusionary antidrug zones within cities are too simply further extending the failed war on drugs.

GIS tools have been significant in recent approaches to understanding and managing the geography of drugs. They are capable of handling massive amounts of complex statistical and spatial data; they can operate at and make links between multiple scales; and they present information in a powerful visual medium. Much of the analytic and cartographic work noted above relies on GIS. It is also being used with other new technologies such as satellite imagery, for example, to map Colombia's excessive loss of natural vegetation due to both defoliant spraying under U.S. eradication programs and deforestation by farmers who have abandoned coca and are seeking new sources of household income. While the geography of drugs continues to present such immense and complex problems (as well as opportunities and benefits), the development of spatial thought and its technological and other applications will help deal with them in an increasingly sophisticated and, it is hoped, successful manner.

Stewart Williams

See also **Carcinogens; Disease, Geography of; Health and Health Care, Geography of; HIV/AIDS, Geography of; Indigenous Environmental Knowledge; Law, Geography of; Medical Geography**

Further Readings

- Chouvy, P.-A., & Meissonnier, J. (2004). *Yaa Baa: Production, traffic and consumption of methamphetamine in mainland southeast Asia*. Singapore: Singapore University Press.
- McCoy, A. (1991). *The politics of heroin: CIA complicity in the global drugs trade*. New York: Lawrence Hill Books.
- Rengert, G. (1996). *The geography of illegal drugs*. Boulder, CO: Westview Press.

- Rengert, G., Ratcliffe, J., & Chakravorty, S. (2005). *Policing illegal drug markets: Geographic approaches to crime reduction*. Monsey, NY: Criminal Justice Press.
- Steinberg, M., Hobbs, J., & Matthewson, K. (Eds.). (2004). *Dangerous harvest: Drug plants and the transformation of indigenous landscapes*. New York: Oxford University Press.
- Thomas, Y., Richardson, D., & Cheung, I. (Eds.). (2008). *Geography and drug addiction*. New York: Springer.
- United Nations Office of Drugs and Crime. (2008). *World drug report 2008*. Vienna, Austria: Author.
- Williams, S. (2010). On islands, insularity and opium poppies: Australia's secret pharmacy. *Environment and Planning D: Society and Space*, 28, 290–310.



DUNES

Dunes are depositional landforms, comprising accumulations of sediment (sand, silt, or clay), typically deposited by wind (eolian) action. They may be defined according to the type of sediment they comprise (sand dunes, clay dunes), their morphology (linear dunes, barchan dunes, star dunes, parabolic dunes, transverse dunes), their position relative to other geomorphic features in the landscape (barrier dunes, lunette dunes, headland bypass dunes, climbing-falling dunes), the time of their formation (contemporary dunes, paleo- or relict dunes), or even according to their genesis (natural dunes, artificial dunes).

Dunes vary in extent and, typically, reach heights of between 5 m (meters) and 30 m. Megadunes reach 100 m or, in extreme cases, 400 m or more in height. Dunes occur typically, but not exclusively, in hot deserts and coastal environments. The sediment comprising a dune is usually quartz sand, with a carbonate component in coastal environments and a gypsum component in certain arid environments. The formation of sand dunes requires a plentiful supply of sand and a consistent wind direction. An obstacle, commonly vegetation, may retard the flow of air near the surface, initiating deposition. Once a

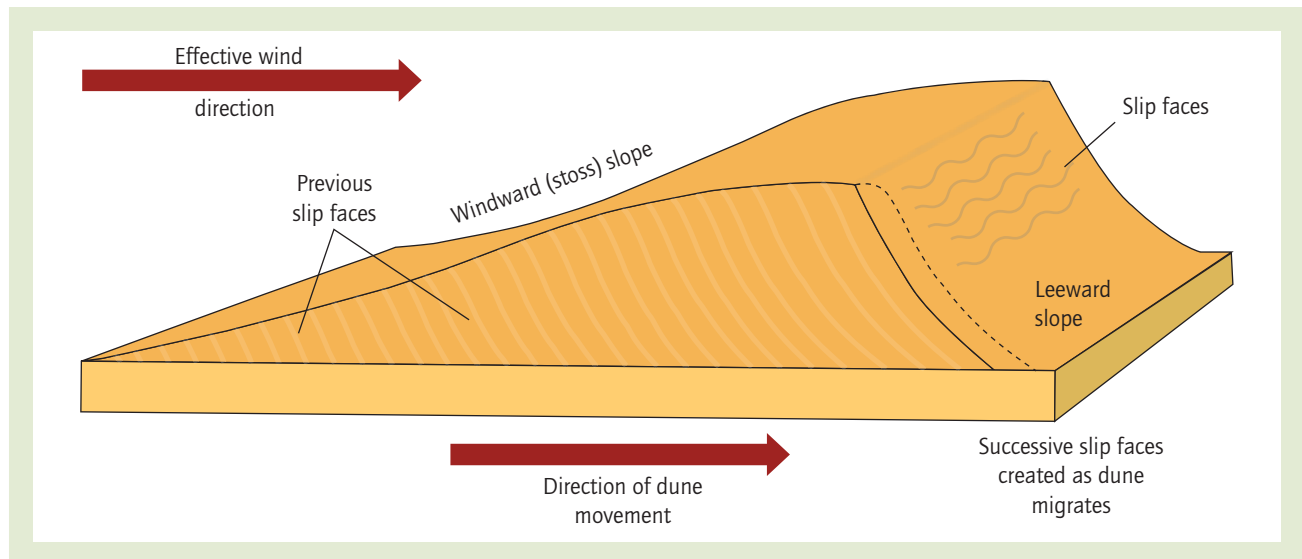


Figure 1 Dune cross-section. Note successive slip faces, the product of sand migration up and over the windward slope.

Source: Redrawn from Christopherson, R. W. (2009). *Geosystems: An introduction to physical geography* (7th ed.). Upper Saddle River, NJ: Pearson Education. Copyright © 2009 Pearson Education. Reprinted with permission of Pearson Education, Inc., Upper Saddle River, NJ.

dune is established, it will continue to grow, provided that the upwind sand supply is maintained. Its ultimate height and form are a product of factors described below.

Dunes may have a complex internal structure, particularly where the wind direction is highly variable. Dune morphology (shape or form), internal structure (bedding), and composition (the nature of the sediment comprising the dune, and its inherent physical and geochemical properties) reveal evidence regarding the formation and growth of the dune and regarding the source of its sediment. Ground-penetrating radar may reveal the internal structure of the dune. Radiometric dating techniques such as optically stimulated luminescence (OSL) facilitate the determination of the time when the dune sediment was last exposed to sunlight. Effectively, this is the last time the dune was active.

The morphology of dunes underpins the most common means of classification. The amount of sand available, variability of wind direction, wind strength, presence or absence of vegetation cover, and nature of the terrain interact to determine the type of dune that will form. Much of our understanding of dune formation and dune-building

processes is derived from the classic work of R. A. Bagnold in the 1940s. When wind blows over a surface, frictional resistance between moving air and the surface results in a complex pattern of turbulence, vortices, and eddies. Dune building is the result of an intricate and dynamic interplay between wind, sediment, and obstacles or irregularities on the surface.

Barchans are the most common dune type, and so their formation is described here as an example of dune processes. Barchans form where there is a limited sand supply and sparse vegetation cover. Barchans are asymmetrical, with a gently sloping ($\sim 5^\circ$ to $\sim 10^\circ$) windward (stoss) face and a steeper ($\sim 30^\circ$ to 35° , which is the angle of repose of dry sand), concave lee or slip face. The horns of these crescent-shaped dunes point downwind. Under unidirectional wind conditions, sand grains advance up the windward face of the dune through a process of short hops (saltation). As the top of the lee face oversteepens through the accumulation of more and more sand, it eventually fails and sand moves down the face till the angle of repose is reestablished. The process repeats itself as long as there is a supply of wind-blown sand off the windward face, onto the top

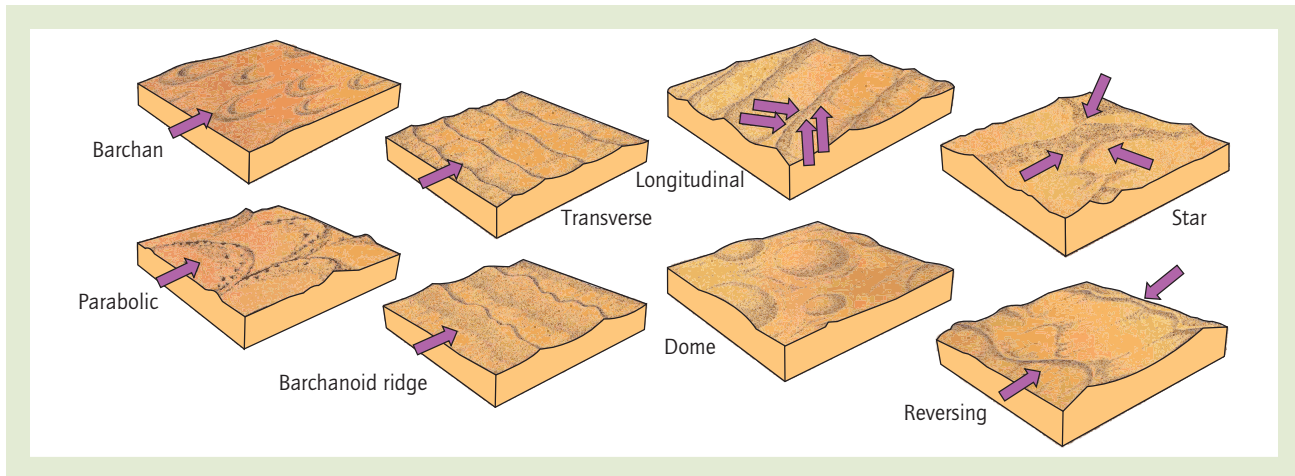


Figure 2 Major dune types

Source: Redrawn from Christopherson, R. W. (2009). *Geosystems: An introduction to physical geography* (7th ed.). Upper Saddle River, NJ: Pearson Education. Copyright © 2009 Pearson Education. Reprinted with permission of Pearson Education, Inc., Upper Saddle River, NJ.

Note: Arrows show predominant wind direction.

of the slip face. The result is twofold; clearly defined foreset beds occur on the slip face, and the dune advances downwind. Barchans may migrate downwind over long distances. Figure 1 shows a dune cross-section.

Transverse dunes are formed where the sand supply is more abundant, and individual barchans coalesce. Where the crests are sinuous, these dunes are referred to as *barchanoid ridges*. Crests are at right angles to the prevailing wind.

Linear or longitudinal dunes are, as their name implies, long and straight. They often form under a bidirectional wind regime. Dune crests run parallel to one another and to the wind. These knife-edge crests give rise to the alternative name *seif* (Arabic meaning “sword”) *dune*.

Star dunes form when multidirectional winds are prevalent. Their radiating arms are a characteristic feature.

Parabolic dunes are U-shaped, with the arms pointing upwind. They are common in coastal environments where the wind maintains a constant direction off the ocean. A complex array of parabolic dunes, with multiple crests and slip faces, results. Blowouts often occur on the upwind side of such dunes.

Lunette dunes have a half-moon (crescent) shape and occur on the downwind side of playas

(depressions periodically occupied by standing water to form a temporary lake). Sand or clay is deflated from the playa surface or shore and accumulates above the shoreline.

Dome, star, and reversing dunes are derivatives that occur when the wind direction is either multidirectional or highly variable.

Figure 2 shows the various dune types.

The world’s hot, dry deserts, in particular the Sahara, Arabian, Atacama, Namib, North American, Great Australian, and Gobi deserts, are the repository for a variety of dunes on a vast scale. However paleodunes, often stabilized by vegetation, are found in both tropical and temperate climatic regions. They are presumably an artifact of past climate change. The reverse holds true: Areas of sub-Saharan Africa that comprised scrub or grassland half a century ago are now covered by mobile sand dunes.

Sand seas or ergs are found in the Sahara, Namib, Arabian, and Gobi deserts. They comprise vast areas of mobile sand, often covering tens of thousands of square kilometers. A variety of dune types occur, though some sand seas are dominated by a particular type, for example the linear dunes of the Namib sand sea. The mobility of the dunes produces a constantly shifting, hostile landscape.



Part of star dunes, showing three curving arms with steep slip faces oriented in various directions, at Tsonab Vlei in the northeastern part of the Namib Desert, Namibia, southwest Africa. The formation of sand dunes requires a plentiful supply of sand, and a consistent wind direction. An obstacle such as vegetation may retard the flow of air near the surface, initiating deposition.

Source: E. T. Nichols, U.S. Geological Survey.

Coastal dunes are common along sandy coasts. They are intimately connected to beaches, which serve as a source and sink for sediment, and beach processes. Wave action deposits sand onshore, from where it may be reworked by the wind, thereby nourishing the coastal dunes.

The failure to recognize the dynamic nature of dunes can be disastrous. Settlements, infrastructure, and productive land may be smothered by migrating dunes. The stabilization of dunes can have unintended consequences. For example, alien Australian species introduced to South Africa to control shifting dunes now threaten the plant diversity of the unique Cape *fynbos* (fine bush) floristic kingdom. On the positive side, dunes may serve as a source of building or glass sand. Sedimentological evidence from paleodunes or fossilized dunes can be used to reconstruct past

environmental conditions, thus abetting an understanding of climate change.

Peter J. Holmes

See also Biome: Desert; Coastal Erosion and Deposition; Desertification; Environmental Management: Drylands; Geomorphology; Global Environmental Change; Landforms; Wind Erosion

Further Readings

Skinner, B., & Porter, S. (2000). *Dynamic Earth*.

New York: Wiley.

Strahler, A. (2004). *Physical geography*. New York: Wiley.

Summerfield, M. (1991). *Global geomorphology*. Burnt Mill, UK: Longman.



DYNAMIC AND INTERACTIVE DISPLAYS

The term *dynamic display* is applied to displays capable of *change*, in contrast to static displays, such as paper maps and graphics. Changes in a dynamic display may occur in an automatic manner or in response to actions of the user. The term *interactive display* is applied to dynamic displays that change in response to a user's actions. Dynamic displays capable of changing automatically are often called *animated displays*. An animated display may at the same time be interactive. At the very least, the user may interactively stop, resume, and restart the play, but more advanced interaction possibilities may also be provided.

Computer animation is often used in a straightforward way to display dynamic phenomena. In particular, dynamic phenomena related to geographic space are most often visualized by means of animated maps. Many examples of such maps may be found on the Web. Thus, animated maps depicting various topics of American history are available at AnimatedAtlas.com. The Web site of the National Atlas of the United States contains animated maps portraying the spread of invasive species during a range of years and the progression of vegetation growth during a year.

Another frequently encountered class of animated displays is fly-through displays, which present various objects or geographical areas as they appear from different viewpoints. Typically, fly-through displays allow very little or no interactivity. Animation may also be used to present large and/or complex content by portions. For example, different themes may alternate in an animated map of a geographic area: terrain, rivers and lakes, landmarks, vegetation, administrative boundaries, roads, and so on.

Interactive displays and, in particular, maps and virtual globes are nowadays frequently encountered on the Web. Well-known among these are Google Maps and Google Earth, online mapping and route planning services such as Map24, and maps displaying election results (e.g., those at NYTimes.com). Typically, interactive maps and globes (as well as other types of display representing large amounts of data and complex data) provide facilities for view navigation. The

most basic navigation tools are zooming and panning. Perspective views of three-dimensional objects or spaces provide tools for controlling the user's viewpoint in the scene. Visualization researchers suggest "intelligent" navigation techniques that adjust the view to the user's focus of interest so that the visual prominence (in particular, size of graphical elements) and level of shown detail vary depending on the relevance of the information in different parts of the display for the user.

Another typical feature of interactive displays is providing additional information about objects or places in response to clicking on graphical elements representing these objects or places. The information may be shown in a pop-up window that appears near the cursor position, in a dedicated area of the display or in an adjacent subwindow.

Thematic maps, such as tourist maps and maps of election results, often support more advanced interaction, allowing the user to alter the information content of the display or the representation of the information. Examples of such interaction include the following:

- Selecting information layers (e.g., accommodation, museums, restaurants, bar/nightlife) on a tourist map or toggling the visibility of the layers
- Selecting time moments or intervals in displays of time-related information
- Changing the spatial scale (e.g., states or counties)
- Changing the theme (e.g., president elections or governor elections, absolute values or differences in comparison with the previous time)
- Choosing the visualization method (e.g., choropleth map or proportional symbols)

Interactive displays used for specialized services may be supplied with specific interaction facilities, such as selection of source, destination, and intermediate places in route planning.

Interactive displays play a very important role in the exploration and analysis of data and information. Typically, the size, dimensionality, and/or other complexities of data that need to be analyzed preclude the possibility of simultaneous

(Continued on page 808)

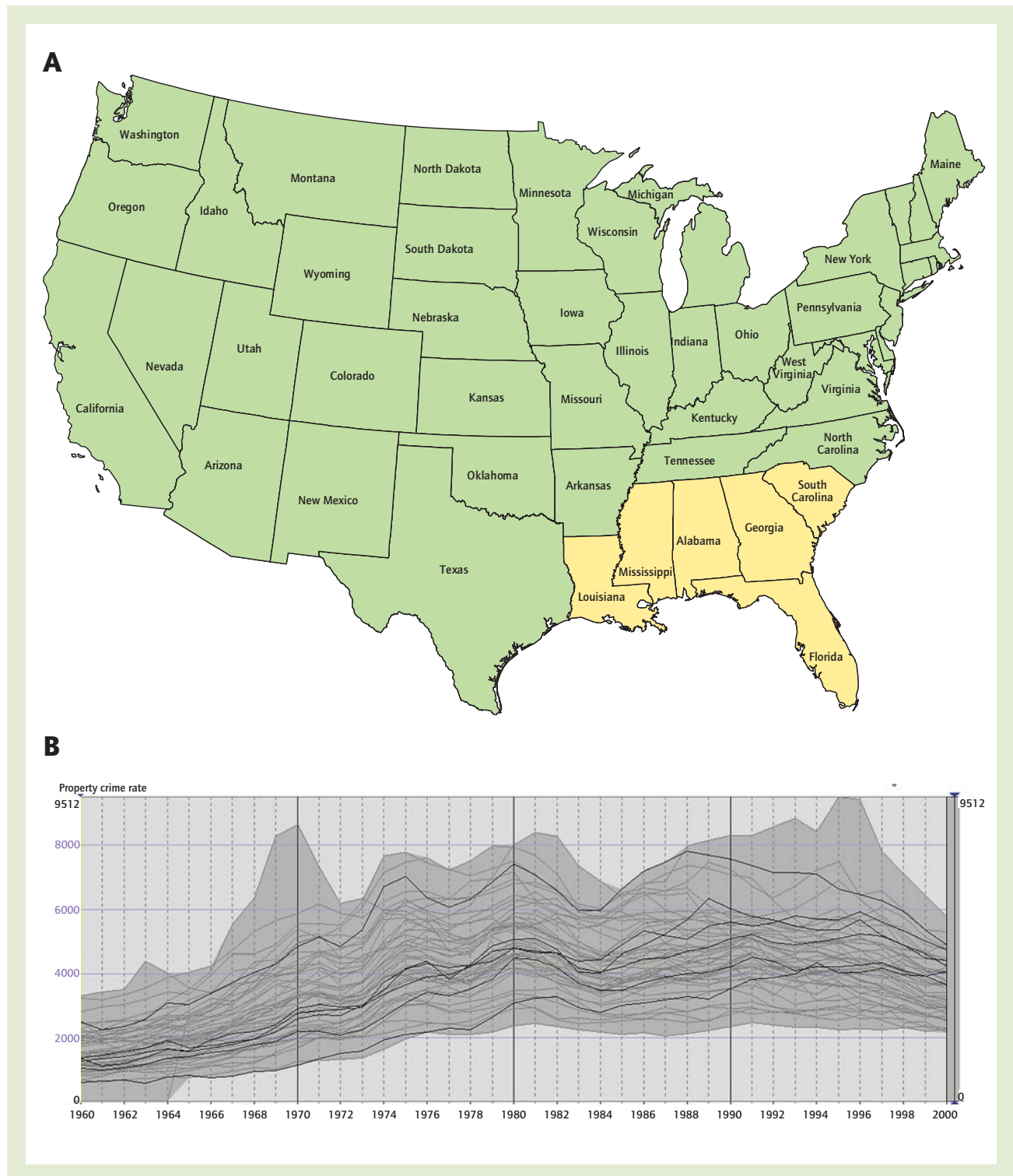


Figure 1 A map (A) is dynamically linked to a time graph display (B) by simultaneous highlighting of corresponding graphical elements.

Source: Gennady Andrienko.

Note: The user has selected several states on the map; the states are designated in yellow. Simultaneously, the lines on the time graph representing the temporal dynamics of the property crime rates in these states are shown in black.

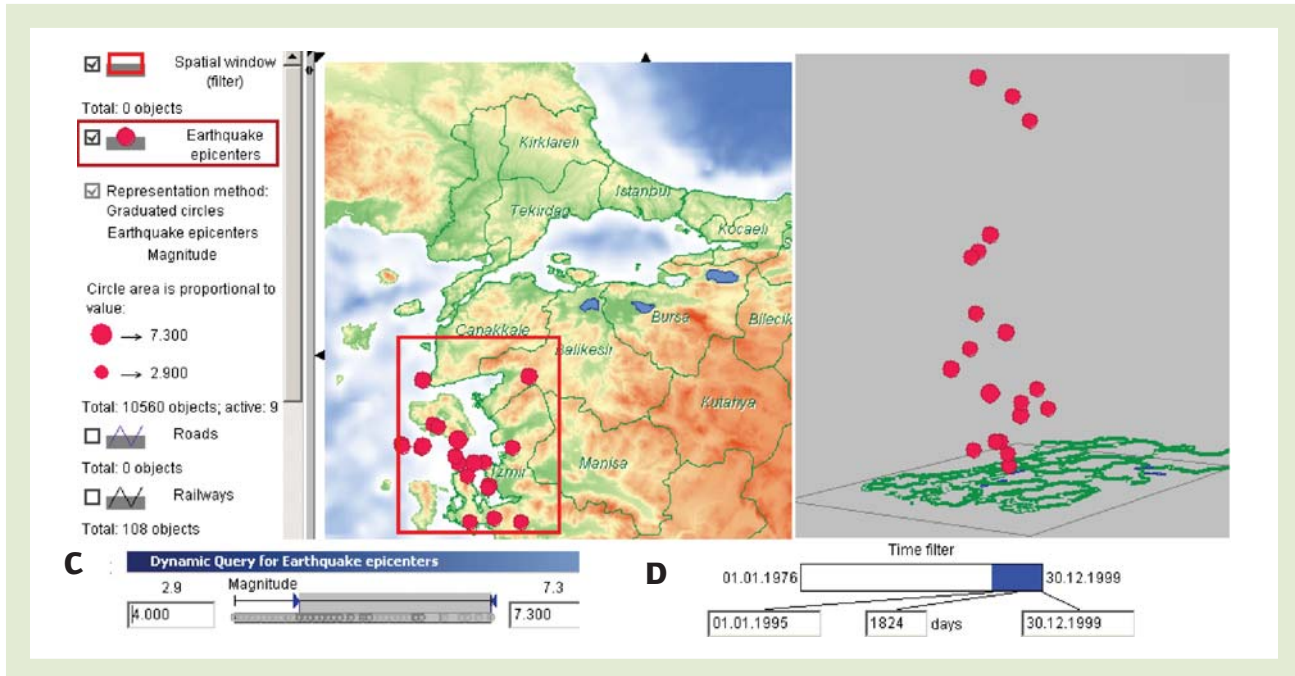


Figure 2 Dynamic filtering

Source: Gennady Andrienko.

Notes: The map (A) shows the spatial positions of earthquake epicenters; the perspective view (B), where the vertical dimension represents time, shows the positions of the earthquakes in space and time. Both displays show the same subset of the data selected by means of three different filters: (1) spatial window, which has been drawn by the user within the map display; (2) attribute filter (C), which selects the earthquakes with the magnitudes 4 or more; and (3) temporal filter (D), which selects the earthquakes that occurred in the period from the beginning of 1995 till the end of 1999. All three filters may be interactively changed by the user; in response, the displays will immediately change their content to satisfy the new filter conditions.

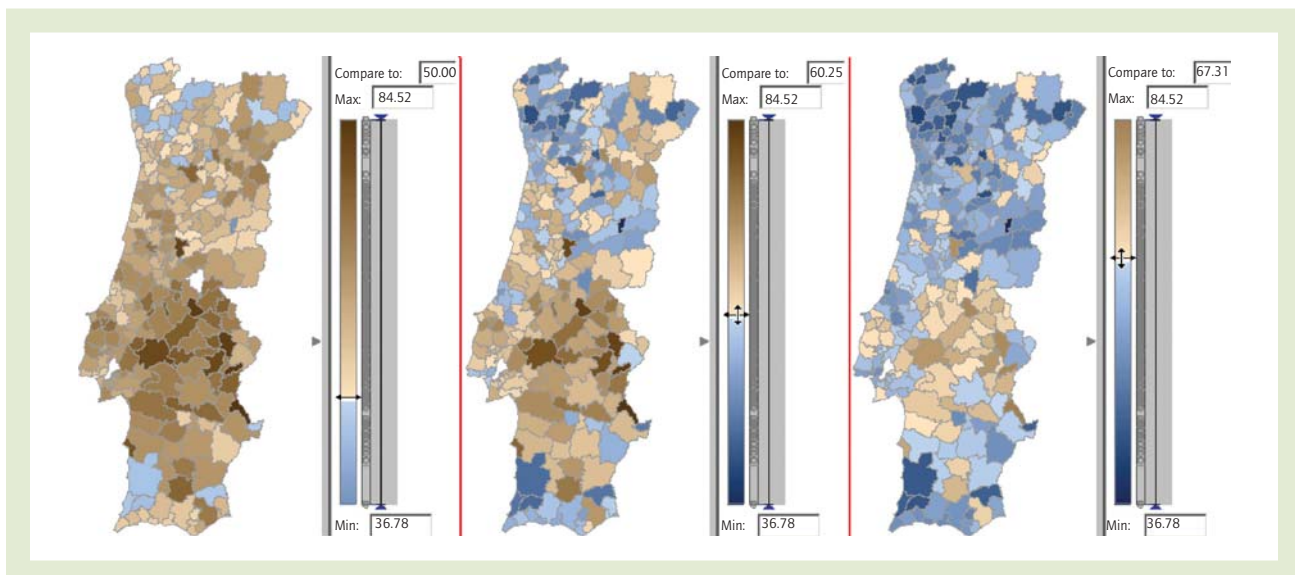


Figure 3 The process of interactive change of the color scale in a choropleth map

Source: Gennady Andrienko.

Notes: On the left, the percentages of female among unemployed people in the districts of Portugal are represented on a map by means of a diverging, or double-ended color scale: shades of blue represent values below 50% and shades of brown are used for values greater than 50%. Moving the slider along the color bar on the right of the map changes the reference value and, hence, modifies the color scale. The middle and right screenshots correspond to the reference values of 60.25% and 67.31%, respectively.

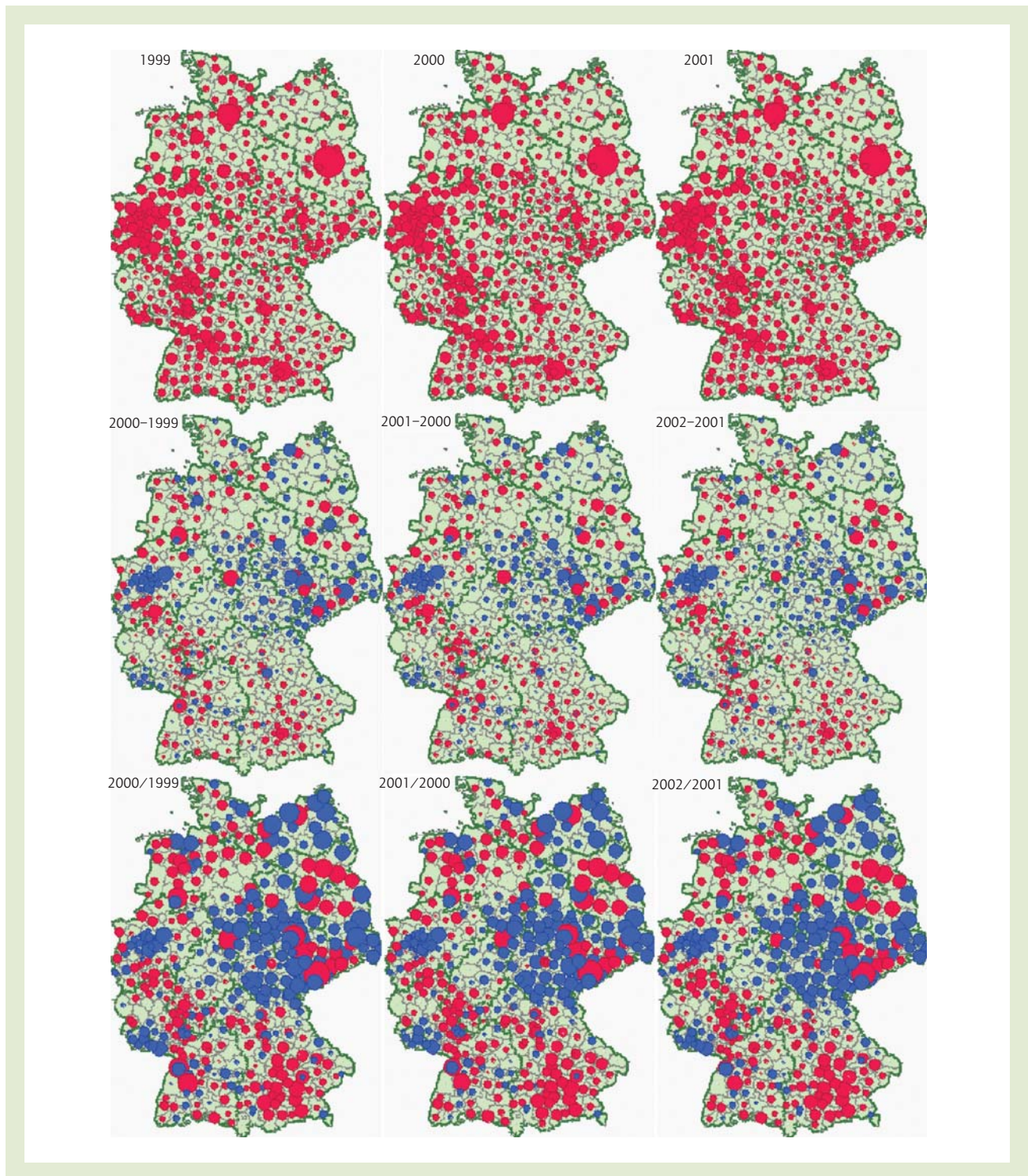


Figure 4 Interactive data transformation applied to an animated map of the population dynamics in Germany.

Source: Gennady Andrienko.

Notes: Each row contains screenshots of the states of the animated map corresponding to three consecutive years. *Upper row:* The map represents the absolute population numbers. *Middle row:* The data have been transformed from the absolute values to the differences between two consecutive years. The blue circles represent negative differences. *Lower row:* The same data have been transformed to ratios between consecutive years. The blue circles represent ratios below 1, the red circles are ratios greater than 1.



(Continued from page 804)

representation of all data items, dimensions, structural parts, relationships, and so on in a single display. Hence, the analyst has to understand the whole by looking at subsets, components, projections, and aspects of the data. Interactive displays enable a dialogue between the analyst and the data. A fundamental interactive operation required for exploration and analysis is focusing, that is, selection of subsets, projections, and so on for viewing. Since any view can only convey partial information, the analyst needs multiple views, which need to be linked so that the pieces of information contained in them could be fit together. Thus, multiple displays simultaneously present on the screen may be linked through identical marking of corresponding graphical elements, for example, with the same color. The best-known technique, often referred to as “brushing,” is simultaneous highlighting of graphical elements corresponding to objects selected by the user in one of the displays (Figure 1).

Another well-known technique that supports both focusing and linking is dynamic filtering (also known as conditioning): All displays show only the data satisfying user-specified conditions and dynamically update their content when the user interactively changes the conditions. Data may be filtered according to the values of one or more attributes as well as according to their spatial and/or temporal references (Figure 2).

Apart from focusing and linking, the role of interactive displays is to help the analyst discover unobvious patterns in data. Two major groups of interaction techniques intended for this purpose are display manipulation techniques and data manipulation techniques. Display manipulation is interactive modification of the method of encoding elements of the data by graphical elements and

their properties. For example, Figure 3 demonstrates the process of interactive change of color scale in a choropleth map. This operation allows the analyst to explore more comprehensively the spatial distribution of the attribute values.

Data manipulation is interactive transformation of the data elements represented in a display. For example, Figure 4 demonstrates interactive transformation of time-referenced data. Initially, the animated map represents the original data values corresponding to the geographic areas and consecutive time moments. These values can be interactively converted into differences or ratios with respect to the previous time moments. The resulting map exposes previously unnoticeable spatial patterns.

Gennady Andrienko and Natalia Andrienko

See also **CAD Systems**; **Cartography**; **Kwan, Mei-Po**; **Map Animation**; **Map Visualization**

Further Readings

- Andrienko, N., & Andrienko, G. (1999). Interactive maps for visual data exploration. *International Journal of Geographic Information Science*, 13(4), 355–374.
- Andrienko, N., & Andrienko, G. (2006). *Exploratory analysis of spatial and temporal data: A systematic approach* (Sections 4.4–4.6, pp. 207–396). Berlin, Germany: Springer.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2009). *Thematic cartography and geovisualization* (3rd ed., pp. 389–407). Upper Saddle River, NJ: Pearson Prentice Hall.

E

EARLE, CARVILLE (1942–2003)

Carville Earle was a historical geographer whose primary goal was to answer vexing historical questions of the American past using the tools and methods of geography. Earle's research spanned from colonial Jamestown to the 21st-century United States. He often referred to himself as a geographical historian practicing geographical history. He was a pioneer in using geographic information systems in the cause of answering problems of the past with the Historical United States County Boundary Files, which allowed scholars to map and analyze historical data at the county level. Earle also served as editor of the *Annals of the Association of American Geographers* from 1994 to 1996.

Earle's major contributions to historical geography emerged from his insistence that historical geographers were social scientists with a focus on using a geographic or environmental approach to studying problems of the American past. Historical geography could provide new insights and answers to historical questions. Earle and Donald Meinig sparked debate among historical geographers on what direction and guidance historical geography needed. Earle critiqued what he called Meinig's continuous imperialistic expansionist interpretation of the American past. He believed

that constant upheaval and change were caused by the ravenous appetite and cyclical nature of capitalism. He saw the American past as a process of economic stops and starts and of crisis and recovery that were manifested and interpreted on the settled landscape. His book *The American Way* highlighted the cyclical nature of the American past based on Kondratieff long waves and a 50-year cycle of government policies in response to the cyclical nature and expanding influence of the American state in response to crisis in capitalism. Methodologically, Earle's greatest influence will be his advocacy of spatial and empirical methods. Theoretically, he contributed to the understanding of alternating policy regimes of the American state and how they are manifested spatially on the landscape.

His major publications included *The Evolution of a Tidewater Settlement System: All Hallows' Parish Maryland 1650–1783* and *Geographical Inquiry and American Historical Problems*, which included previously published seminal journal articles and new research. *Geographical Inquiry and American Historical Problems* included the influential pieces "Environment, Disease, and Mortality in Early Virginia," "Staple Crops and Urban Development in the Eighteenth-Century South" with Ronald Hoffman, "A Staple Interpretation of Slavery and Free Labor" and "Socialism in America: A Geographical Interpretation of Its Failure" with Sari Bennett. His final work was



The American Way: A Geographical History of Crisis and Recovery.

John Heppen

See also **Historical Geography**

Further Readings

- Earle, C. (1992). *Geographical inquiry and American historical problems*. Stanford, CA: Stanford University Press.
- Earle, C. (2003). *The American way: A geographical history of crisis and recovery*. Lanham, MD: Rowman & Littlefield.



EARTHQUAKES

Earthquakes involve the travel of elastic, or seismic, waves of energy through the Earth's rigid crust. They result from the sudden liberation of accumulated stress and strain along faults, which are planar discontinuities in the crust. Around the world, more than 3,000 seismic events occur each year, but few of them are damaging or lethal. However, when major earthquakes occur in highly populated areas, they can cause major destruction and death tolls in the thousands.

Distribution of Seismicity

The global distribution of seismicity is conditioned by the pattern of tectonic plates, which is a function of patterns of convection in the Earth's mantle and variations in the planet's spin rate. Most earthquakes are concentrated at the plate margins and in particular around the subduction zones, where crustal material is subsumed by over-riding plates. Transcurrent plate margins also generate significant seismicity, as occurs along the west coast of North America, where the Pacific Plate is moving north against the continental plates to its east. Collisional plate margins generate seismicity through their impact on orogeny, or mountain building. In such regions, seismicity is usually associated with landslides. Finally, the

regional geometry of stress creates some "hot spots" of intraplate seismicity, which are not associated with the plate margins. Particular problems are experienced with "seismic gaps"—sections of plate margins, or other seismogenic areas, where strain has built up and not been released in a major earthquake for decades or centuries.

Owing to the world distribution of the human population, the pattern of human effects of earthquakes does not coincide exactly with the global pattern of seismicity. Major earthquakes occur in unpopulated areas (e.g., in Alaska and Siberia) with limited consequences for human settlement. Much less severe earthquakes can have terrible human consequences if they occur in areas of dense settlement.

Earthquake Mechanisms

It is a common misconception that earthquakes can be characterized adequately by a single measure. This is usually given as magnitude or intensity, but in reality more information is needed. Magnitude is a surrogate measure of the energy liberated in the shaking, known as strong motion. Modern scales owe much to the pioneering work of the Californian seismologist Charles F. Richter. However, although his name is widely used in the mass media, the Richter scale has been abandoned by seismologists as it tends to be inaccurate at high magnitudes. Instead, a combination of measures is used that characterizes the magnitude of different seismic waves, particularly body waves, which travel through crustal material, and surface waves, which travel along surfaces and discontinuities in rock formations. The six kinds of seismic waves (i.e., P waves, S waves, body waves, surface waves, Rayleigh waves, and Love waves) involve different forms of motion. For example, the first waves to arrive (P waves) at a point on the Earth's surface are compression-extension movements of a longitudinal kind, and these are followed by the undulatory motion of S waves.

In terms of surface effects and damage, two other measures are vitally important. The first is hypocentral depth, the distance below the surface at which earthquake shaking begins. In most geophysical models of earthquake generation, intensive microfissuring coalesces to create sudden variations in stress within a block of rigid crustal



material. As stress and strain are liberated, shaking spreads out dynamically from the small area in which the earthquake hypocenter, or focus, is born. Hypocenters that are deeper than 50 to 80 km (kilometers) seldom generate damaging earthquakes, and so the lethal seismic events tend to be those that have shallow foci, perhaps 5 to 20 km below the surface. In the Tonga Trench, in the South Pacific, major earthquakes occur as deep as 700 km, but by the time the seismic waves reach the surface they have dispersed their energy and are harmless. Conversely, the earthquake that occurred in Bam, Southern Iran, in December 2003 had a hypocenter only 10 km below the surface, and it killed 26,271 people.

A further measure of importance is bracketed duration, the length of time that strong motion lasts. Whatever its magnitude, an earthquake of 10 to 15 s (seconds) is likely to do less damage than one that lasts a full minute and is therefore fully able to propagate cracks in buildings. In Mexico City in 1985, shaking lasted intermittently for 5 min. (minutes), and the damage was considerable. However, many engineers regard the most useful descriptor of an earthquake's power to be seismic acceleration. This is measured or calculated as a proportion of the universal gravitational constant, $g = 9.81 \text{ cm/s}^2$ (centimeters per square second). In major earthquakes, acceleration can exceed $1.0g$, although most antiseismic construction is predicated on values of 40% or 60% of g . Acceleration depends on both the crustal adjustment forces liberated during the earthquake and the type of rocks through which the seismic waves travel. It can be particularly strong in soft sediments, such as sands and coastal infills.

In addition, the frequencies of seismic waves are an important means of characterizing an earthquake. Particular frequencies interact with buildings, bridges, and vehicles in especially destructive ways. Each building has a fundamental period (the inverse of frequency), as if it were a bell that resonates at a particular pitch when struck. Given the additive properties of waves, if the earthquake's mix of frequencies matches the fundamental period of a building, shaking effects will be amplified. Moreover, if the Japanese Shinkansen high-speed train is struck laterally by seismic waves with a dominant frequency of 56 Hertz it may be rolled off the tracks, as

happened in the 2004 Chuetsu earthquake in Niigata Prefecture.

Finally, seismic intensity is a measure of the felt effects and damage caused by earthquakes. As these depend on perception (at low intensities) and the resistance of buildings to damage (at high intensities), intensity values tend not to be correlated very strictly with magnitude or other physical measures. Hence, a relatively weak earthquake can cause very serious damage if building stock is not resistant to seismic shaking. In Bam in 2003, an earthquake of magnitude 6.6 caused extensive high-intensity damage in weak-walled masonry and adobe buildings, which were not sufficiently resistant. Modern intensity measures stem from the work of the Italian seismologist Giuseppe Mercalli (1850–1914). In the Americas, the Modified Mercalli (MM) scale is used, while in Europe the Mercalli-Cancani-Sieberg and Medvedev-Sponheur-Karnik scales are preferred. The difference is a function of the differing building techniques that are used in the two continents.

Measuring Earthquakes

The process of seismic measurement is less precise than it would seem to be. Despite advances in laserometry and digital measurement, seismometers (continuously recording devices) and accelerometers (which are triggered by strong motion) must still achieve a difficult balance between sensitivity and robustness, just as they had to when the first modern measuring apparatus was invented more than 100 years ago. An epicenter, the location on Earth's surface directly above the original source of shaking, the hypocenter or focus, is in reality an ellipse, not a point, as it can only be determined approximately. It is not necessarily the location of maximum damage, as this will also depend on the configuration of topography and rock formations, across which the waves are transmitted, and the patterns of human settlement and land use.

Physical Effects of Earthquakes

Earthquakes can be major sources of mass movement or landsliding. Large seismic events can generate as many as 15,000 landslides, largely confined to the area of intense shaking, perhaps



Loma Prieta, California, earthquake October 17, 1989. Damaged reinforcement base from a support column of the Cypress viaduct of Interstate 880.

Source: U.S. Geological Survey.

MM intensity VI and above. Some landslides can be extremely large; however, few types of mass movement are largely or exclusively set in motion by earthquakes. Liquefaction, block slides, and lateral spreads, involving plastic-fluid movements at very low angles, are characteristic of seismic effects. Most other movements, from mudflows to slumps, may be activated or reactivated by earthquakes but can equally occur in the absence of seismicity, albeit seldom in such copious quantities.

One common effect of major earthquakes in mountainous areas is to cause landslide dams on rivers. The sequence of six earthquakes that occurred in Calabria, Southern Italy, in 1783–1785 created 211 landslide-dammed lakes. However, when landslide debris invades a river channel and blocks it, the result is likely to be not a permanent lake but a sudden outburst flood. Permeable, unconsolidated debris, increasing pore

pressures, and the weight of water as it accumulates all conspire to cause breaching within 2 wks. (weeks) of the blockage. Such an event occurred on the flanks of Mount Huascarán in Peru after the May 1970 earthquake, and only prompt action by the Chinese authorities stopped it from happening after the Sichuan earthquake of May 2008. Finally, earthquakes can reroute rivers. This has frequently occurred in the deltaic sediments of Bangladesh, which has 254 rivers and occasional high seismicity derived from the nearby Himalayan orogeny.

Tsunamis, which are sometimes called seismic sea waves, may be generated when earthquakes occur at the coast or beneath the seafloor. Generally, a shallow-focus event of magnitude of at least 7 must be involved—that is, a powerful earthquake. Not all undersea events cause tsunamis as there must be an abrupt movement of the whole body of seawater, usually in a vertical

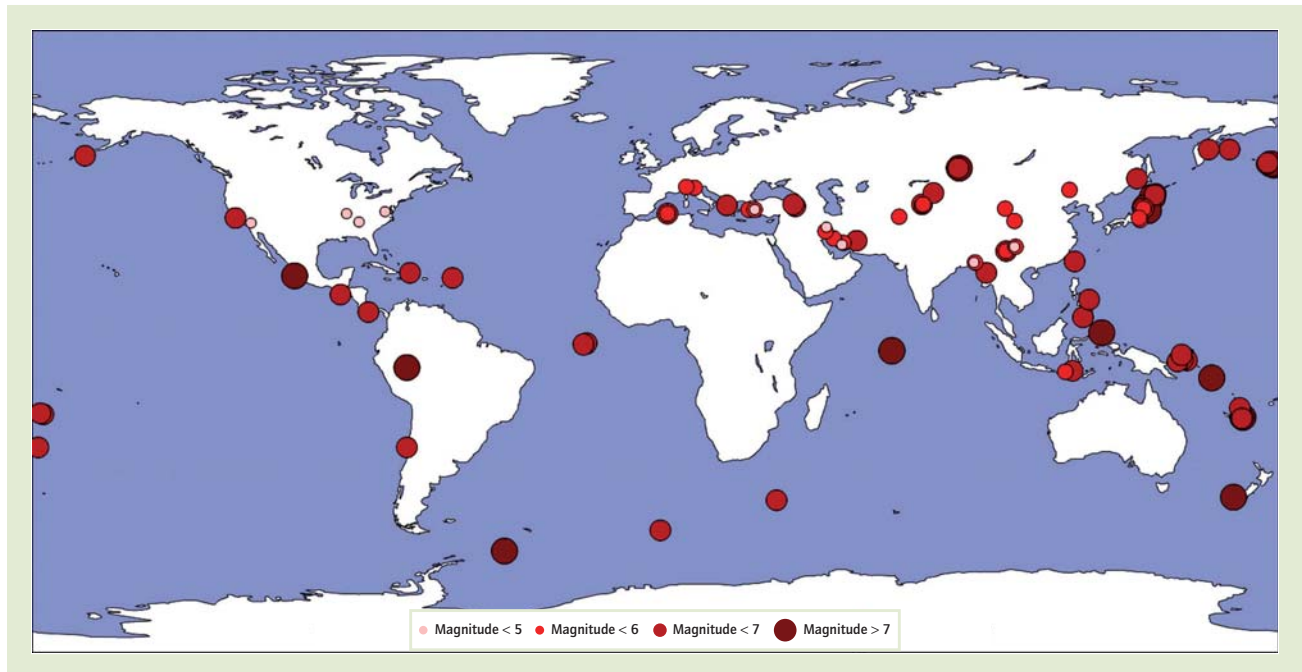


Figure 1 A deadly year for earthquakes. This map shows the location of the largest or most damaging earthquakes of 2003. In January 7, 2004, the United Nations Office for Coordination of Humanitarian Affairs had confirmed 32,819 earthquake-related deaths during 2003.

Source: Map by Alex McClung, NASA Earth Observatory, based on data provided by the U.S. Geological Survey.

direction, perhaps by sudden displacement of the seafloor and hence the column of water above it. Energy moves out from the source with an elliptical motion that propagates water waves of low amplitude and long wavelength. When these reach the shallow water of the coast, the principle of energy conservation dictates that friction on the seabed and the associated velocity reduction will cause the wave to rear up (in about one third of tsunamis the trough arrives at the coast before the first crest, causing the sea to retreat for several minutes). Waves can be refracted around islands and funneled by inlets such that a coastal amplitude of 3 or 4 m (meters) may be increased by an order of magnitude in specific places. A tsunami can have a devastating effect on low-lying and densely populated coasts. Given the huge distances and long travel times in open oceans, the opportunities for warning and evacuation are substantial, but the greatest risks occur with near-field tsunamis, those that are generated locally and in which the time between inception and arrival at the coast may be limited to a few tens of minutes, not several hours.

The earthquake of December 26, 2004, in the subduction trench off the coast of Indonesia caused a devastating tsunami that greatly affected 12 countries bordering on the Indian Ocean basin. Wave heights at run-up exceeded 9 m in some areas and over-wash obliterated large sections of coast, for example, in Banda Aceh, Indonesia and Sri Lanka. The death toll was 292,000, largely through drowning.

Human Effects of Earthquakes

Each year between 7 and 20 earthquakes cause deaths and injuries. Tens more cause damage to buildings and structures. The worst effects occur where high concentrations of population coincide with powerful seismicity, for example, in China, Indonesia, Iran, Afghanistan, and Japan. The January 2010 earthquake in Haiti killed more than 200,000 people.

Specialists in earthquake injury epidemiology have postulated a ratio of one death per three significant injuries, but whereas there are earthquakes that produce this sort of pattern, data



tend to be highly variable from one event to another. This reflects the complexity of various factors. The first of these is the seismic resistance of building stock, which depends on construction type and on state of maintenance. Generally, well-maintained frame structures built according to antiseismic criteria perform well, whereas dilapidated rubble masonry dwellings that incorporate no seismic protection tend to collapse easily. Despite this, the ratio of deaths to collapsed buildings appears to be low, perhaps in the range of 12 to 33 per 100 buildings that totally collapse. If this is so—and research is inconclusive—it may reflect both building occupancy rates and the impact of self-protective behavior.

Another factor whose impact on death rates is poorly understood is search and rescue. Although healthy people who have not been injured can survive trapped under rubble for up to 2 wks., the vast majority of people who are rescued from collapsed buildings are brought out within a matter of hours after the earthquake strikes. Injury can substantially reduce survival times, especially if it involves loss of blood, vital functions, or body heat. One common medical effect of entrapment is the crush syndrome, in which the rupture of cells liberates potassium and lipids into the bloodstream and causes kidney failure. People rescued alive with crush injuries may need dialysis.

Field experience suggests that serious injury in earthquakes can take many forms. Whereas paraplegia and the need for in situ amputation are rare, multiple fractures, cranial trauma, and compression of the thorax are common. In many cases, minor injuries are associated with flight and result from falling down stairs (broken or sprained limbs) or walking on shards of glass (lacerations).

Currently, the greatest risk of casualties from earthquakes exists in several of the world's "megacities," notably Tehran, Istanbul, and Tokyo. Tehran, a city of roughly 13 million inhabitants, last had a major earthquake in 1840. Three active geological fault structures run through the urban area, and all of them are deemed capable of generating shallow-focus earthquakes of magnitude around 7. As about half of the city's building stock is not antiseismic, the death toll in a future disaster has been estimated at between 400,000 and 3.4 million.

Seismic Performance of Structures

There are very serious questions about the performance of critical infrastructure during major earthquakes. Hospitals may suddenly be inundated with mass casualties, but in many parts of the world they tend to be the first buildings to suffer damage. This may be true even in California, where the San Fernando Valley earthquake of 1971 put two trauma centers out of action. Where hospitals remain functional and receive mass casualties, the number of available beds is not the operative criterion so much as the ability to diagnose and treat injuries (i.e., surgical capacity—beds can be improvised to meet demand). In El Salvador, four hospitals collapsed in both the 1986 and 2001 earthquakes, despite the efforts of the Pan American Health Organization (a branch of the World Health Organization) to improve seismic safety in such buildings. Field hospitals can seldom be set up in time to treat primary injuries caused by earthquakes and are usually relegated to providing backup care and general medicine. If hospitals have been put out of action, the only alternative may be to airlift casualties to distant locations, which tends to increase the mortality rate. This was the strategy adopted in Bam after the 2003 earthquake as the two local hospitals were irreparably damaged.

Postearthquake Relief Efforts

When a major earthquake occurs, especially in a low- or medium-income country, an international relief effort may be mounted. Generally between 1,200 and 2,200 foreign rescuers, organized into teams of 20 to 56 people, will be sent to the area from many countries. The United Nations Office for the Co-ordination of Humanitarian Affairs will send teams to coordinate the rescue efforts. However, these teams tend to arrive after the critical period in which people need to be rescued, especially if there are problems, as frequently happens, of obtaining visas and importation clearance for equipment and dogs. Even local rescue teams may arrive relatively late. For example, in the Kobe earthquake of 1995 in Japan, 70% to 90% of the 30,000 people who were pulled out of the rubble of collapsed buildings were rescued by local people, not by officials and experts. This



underlines the importance of neighborhood-level organization for rapid response in areas of high seismic risk. It also emphasizes the need for a high level of seismic resistance in building stock and infrastructure.

David E. Alexander

See also **Landslide; Plate Tectonics; Tsunami; Tsunami of 2004, Indian Ocean**

Further Readings

Bolt, B. A. (2006). *Earthquakes* (5th ed., centennial update: The 1906 Big One). New York: W. H. Freeman.

Coburn, A., & Spence, R. (2002). *Earthquake protection* (2nd ed.). New York: Wiley.

EARTH'S COORDINATE GRID

Gridding the globe with abstract lines has been put forward since the 2nd century BC, when Hipparchus suggested parallels of latitude and meridians of longitude constructed over a spherical model of Earth. Three hundred years later, Claudius Ptolemy refined these ideas and produced map projections with a graticule of longitude and latitude lines.

After the French-sponsored geodetic expeditions in Peru and Lapland in the 1730s, the ellipsoidal shape of the Earth became the basis for more accurate positioning of lines of latitude. After the International Meridian Conference of 1884 recognized the center of the transit instrument of the Royal Observatory at Greenwich, England, as the zero origin for longitude, the prime meridian, most nautical charts, and many maps agreed on the alignment of the longitude and latitude on small-scale charts and maps.

Spherical trigonometry is sufficient for distance and direction computations on the sphere, but the ellipsoidal shape of Earth makes these computations difficult. Additionally, the very meaning of distance is changed by different conceptions of appropriate paths from one point to another.

Gerardus Mercator designed a map projection in 1569 that allowed one to plot a single compass bearing as a straight line on a map. The course followed by steering this single azimuth is not the shortest path from one point to another, but often the efficiency of steering a single bearing and the ease of course design makes the longer path worthwhile. On a spherical Earth surface, the shortest path is a great circle. On the sphere, the meridians of longitude all describe great circles. The parallels of latitude describe small circles, not the shortest path between points of the same latitude, unless they are both on the equator. The shortest path over the surface of an ellipsoidal Earth is the ellipsoidal geodesic. Following any great circle or geodesic other than along a meridian or the equator requires continuously changing the heading with respect to true north. On the ellipsoidal Earth, spherical trigonometry is not sufficient for computations of distance, direction, area, path intersection, and other practical problems. Software to perform geodetic direction and distance algorithms can require several pages of source code. Software for projecting the ellipsoidal Earth onto a flat plane can be complex and slow to execute for large geodatabases.

There are other global coordinate systems based on longitude and latitude. In the *plate carrée* projection, the lines of longitude and latitude are mapped as though they were orthogonal and equally scaled everywhere. The World Geographic Reference System and Maidenhead Grid Squares divide the surface of Earth into nested rectangles in longitude, latitude space described by alphanumeric characters. These are useful for pointing to positions or small regions, but dividing the world up into equal areas using longitude and latitude is as impossible as flattening Earth with a single map projection without introducing distortions.

While longitude and latitude are useful, especially for storing of database vertices, for index maps, and for point descriptions, there are major problems for mapping, navigation, and spatial analysis. Hundreds of useful map projections have been devised, resulting in local and regional coordinate systems with which distances, directions, areas, and shapes can be portrayed and measured. These map projections, based on the notion of flattening all or a portion of Earth's surface onto



a flat plane, all fail to portray the Earth without distortion. Cylindrical, conic, and flat planes are geometric surfaces on which features on Earth's surface are projected. Cartographers can minimize one or more distortions of distance, directions, area, local shape, or global shape but never all of them. Small local regions can be portrayed on large-scale maps with reasonable fidelity, but tiling such maps to cover larger areas is not possible without overlaps or gaps. Global portrayals of Earth at smaller scales are often based on compromise projections that introduce minimal distortion of a few characteristics.

While Greenwich and the equator are meaningful concepts as the origin for longitude and latitude, they are not sufficient for mapping and positioning, especially at large scales. Geodetic datums are models of the size and shape of Earth and for the origin and orientation for longitude and latitude. The problem is that there have been many Earth shapes and many prime meridians, even those that pass through Greenwich. Distance and direction computations can differ significantly when different Earth radii are used. Maps and databases referenced to one geodetic datum can have point positions that differ by hundreds of meters when inappropriately tied to the wrong datum.

Geographic databases are often associated with a specific scale or resolution. They are appropriate for display and analysis within a limited range of scale. We live now in a time when large-scale mapping and spatial analysis is often done over long distances and wide areas. Research efforts are underway to develop multiscale data sets that can be used appropriately over a broad range of mapping and analysis scales. Scale-appropriate smoothing and thinning of large-scale databases could result in global databases based in longitude and latitude that could be projected on the fly for display and analysis. There are attempts to tile the globe and the ellipsoid with equal-area regions based on hierarchical global tessellations in triangular or hexagonal shapes. Global elevation data sets can be similarly processed for use at multiple scales.

Peter H. Dana

See also **Coordinate Systems; Datums; Equator; Latitude; Longitude**

Further Readings

- Brown, L. A. (1977). *The story of maps*. New York: Dover.
- Dutton, G. H. (1999). *A hierarchical coordinate system for geoprocessing and cartography*. New York: Springer.
- Robinson, A. H., Morrison, J. L., Muehrcke, P. C., Kimerling, A. J., & Guptill, S. C. (1995). *Elements of cartography* (6th ed.). New York: Wiley.
- Snyder, J. P. (1987). *Map projections: A working manual* (USGS Professional Paper No. 1395). Washington, DC: Government Printing Office.



EASTMAN, RONALD (1949–)

J. Ronald Eastman is a professor at Clark University's Graduate School of Geography and the director of Clark Labs. He is an expert in the fields of geographic information science (GIS), remote sensing, and cartography. He received his PhD in geography from Boston University in 1982 and joined the faculty at the Graduate School of Geography in 1981, where he served as director from 1998 to 2002.

As the director of Clark Labs, he oversees the development of the GIS and image-processing software Idrisi and the vector-editing software Cartalinx. He personally pioneered the development of both software titles during his early years at Clark, and Idrisi was first released publicly in 1987. With more than 35,000 users worldwide, it is now the most widely used raster GIS on the market. Clark Labs operates as a nonprofit institution within the George Perkins Marsh Institute at Clark University in Worcester, Massachusetts.

In addition to his software development activities, Eastman has conducted extensive research in the areas of land use planning and optimization, environmental and biodiversity modeling, and GIS tool development, with an emphasis on addressing international development issues. Through the United States Agency for International Development, United Nations Institute for Training and Research, United Nations Environment Programme, Conservation International, Google, and the Moore Foundation, he has conducted myriad research



projects in South America, Asia, and Africa. He is widely published in peer-reviewed professional journals and industry periodicals.

Eastman is one of the early pioneers of GIS. As an integrated GIS and image-processing system developed with the researcher in mind, Idrisi offers unique functionality not available in any other program.

Christopher D. Lippitt

See also Environmental Management; GIS in Land Use Management; GIS Software

Further Readings

- Eastman, J. (2001). Uncertainty management in GIS: Decision support tools for effective use of spatial data. In C. Hunsaker, M. Goodchild, M. Friedl, & E. Case (Eds.), *Spatial uncertainty in ecology: Implications for remote sensing and GIS applications* (pp. 379–390). New York: Springer-Verlag.
- Eastman, J., Van Fossen, M., & Solarzano, L. (2005). Transition potential modeling for land cover change. In D. Maguire, M. Batty, & M. Goodchild (Eds.), *GIS, spatial analysis and modeling* (pp. 357–386). Redlands, CA: ESRI Press.

ECOFEMINISM

Ecofeminism is the study of women's connections to nature and how they inspire particular forms of environmental activism, stewardship, and spiritual attachments to Earth. This entry explores the evolution and key debates within ecofeminist thought, identifying some influential thinkers and suggesting avenues for further exploration. The three main themes within ecofeminism addressed here are (1) patriarchy and the domination of Earth, (2) Earth-centered spirituality, and (3) historical materialism and women's knowledge.

The term *ecofeminism* often conjures up images of women chaining themselves to logging equipment, yet ecofeminism is far more than an activist and spiritual movement. Ecofeminism emerged as a field of study in the mid to late 1970s, heralded

by the publication of a seminal paper by Sherry Ortner and a book by Susan Griffin, *Woman and Nature: The Roaring Inside Her*, both of which examined the associations of women with nature. These texts marked the beginning of more than three decades of feminist and other scholarship challenging the Enlightenment binaries through which modern Western culture has developed. While ecofeminism diversified and evolved, and alternative ecological feminisms and feminist political ecology emerged, the argument that the oppression of women and environmental degradation are connected remained an important contribution to knowledge. Ecofeminists assert that the association of women with nature and men with culture is not an innocent by-product of modernity but rather is integrally linked to a host of other binaries, including rational/emotional, nurturing/competitive, and nature/society.

Key to understanding the themes of ecofeminism is understanding what is meant by *essentialism* and the critiques of it. Essentialism refers to the idea that a particular group of people contain essential characteristics that give them privileged knowledge or physical attributes. Common examples of essentialist thinking are the assumptions that all women are inherently nurturing and that a particular race of people are inherently good athletes. Many ecofeminists embraced the idea that women are closer to nature and used it to insist that women are inherently better environmental protectors. Griffin's work employed evocative and poetic literary devices to equate the violence done to the land with violence done to women. The phrase "roaring inside her" suggested that women, like nature, could fight back and were doing so, using their "nature"; here, it is assumed that patriarchy and women's inherent nature lead to their understanding of and "rage" over environmental exploitation. But other ecofeminists have rejected this kind of essentialism and insist that it is women's material existence or their experience that gives them an understanding of nature. They therefore postulate a *nonessential* association with nature. The tension between essentialist and nonessentialist renderings of the women-nature connection has in many respects been a defining feature of schisms within ecofeminist debates. This is elaborated as follows.

A core premise of ecofeminist thinking is that patriarchy and the domination of women



underlie other problematic social inequalities such as racism, heterosexism, and environmental exploitation. Ecofeminists have diverged over the implications of this association and the best way to overcome such binaries. Some have remained committed to the idea that women are closer to nature than are men and seek to celebrate that closeness and the privileged knowledge they believe it gives women. These so-called essentialist feminists have been widely criticized, although to suggest that their point of view has been rejected entirely is inaccurate. The second main focus of ecofeminist scholarship is that of spirituality. Spiritual ecofeminists seek to recover a metaphysical understanding of the world that worships Earth as a nurturing, living, female being to foster more sustainable environmental practices. Yet both an understanding of women as inherently closer to nature, and the notion of a female-centered spirituality, rely on essentialist notions of what it means to be a “woman.” Critiques of essentialist thinking from within ecofeminism have emphasized that any privileged knowledge women have of nature arises from the material conditions of their lives. As women work in forests or fields or fulfill other (usually household-related) duties, they gain a deeper knowledge of environmental change and a better sense of environmental stewardship. It is their experience that makes them “closer to nature,” not their biology or inherent characteristics. Ecological feminisms and feminist political ecology have emerged from these critiques, although within ecofeminist thinking itself, a strong anti-essentialist focus continues to counterbalance essentialist thinking.

Patriarchy and the Domination of Earth

In the late 20th century, the feminist movement was deeply concerned with questions of patriarchy and its impact on a wide range of issues in society and scholarship. Especially important was Carolyn Merchant’s work, which explored the ways in which science and the Enlightenment transformed the ontology of “nature” from a living, maternal being into an inanimate entity governed by mechanistic laws based on Newtonian physics. Her overall argument was that our present overexploitation of nature is grounded in an ontology of the world that no longer values Earth

as a living organism in its own right. Merchant asserted that the “living Earth” that was “killed” by science was female. The idea that Earth is female has not changed; the “death of nature” corresponded with the emergence of a patriarchal society that devalued and dominated women as well as nature.

Merchant’s work detailed examples of how society moved from worshipping and respecting “Mother Earth” in activities such as mining to an industrial, scientific understanding of geology that opened the door to far more damaging and exploitative forms of mining that are still seen today. She argued that the discourses and practices of domination were predicated on an equivalent devaluing and domination of women. Thus, the reversal of environmental destruction cannot occur without women’s emancipation.

Although Merchant’s work remains at its core anti-essentialist, it was an important inspiration for ecofeminists who failed to make distinctions *among* women. Merchant does not make fine distinctions between the kind of activities that might give women privileged knowledge of nature and those that might not. Rather, all “women” were assumed to have the same kind of sympathies and understandings of environmental change as a consequence of their close connection to nature, which has subjected Merchant to critiques of being essentialist. Ironically, some of the most important work in this vein has been by women from developing countries; yet it was women of color who later successfully challenged the dominant feminist thinking at the time, which failed to understand how race and class, along with gender, were equally important axes of oppression.

Vandana Shiva’s book *Staying Alive: Women, Ecology and Development* is perhaps the most famous exploration of the supposed innate connection women have with nature. Shiva drew from work on the grassroots Chipko environmental movement in the Indian Himalaya. Chipko activists fought commercial logging companies by chaining themselves to trees and sitting across roads to prevent logging from occurring. The movement gained global recognition in part because village women were on the front lines of such protests and in part because of their success at blocking logging companies on the ground. Shiva argued that the symbolic resources these



village women drew on to save their forests from commercial loggers were deeply rooted in their instinctive understanding of Earth as mothers and nurturers and spiritual ideas of women as protectors of Earth. From this position, she asserted that the inspiration for women risking their lives in front of logging machinery arose from these inherent connections to nature. In the context of modern Indian society, it is difficult to see women as powerful, but Shiva highlighted ancient stories and religious beliefs to show how women are in fact more powerful than men and certainly have a more profound understanding of environmental change. This work has been important in advocating for a global women's movement, linked together by threats to women's home environments. Shiva asserted that the inherent understanding women have of their environments would help bridge cultural gaps and provide a focus around which they could join together globally. Although Shiva's work has been heavily criticized within India and by other feminists for inaccuracies and problematic assumptions about different women's experiences, it has inspired women worldwide to defend environmental resources and was central in making "Chipko" a household name in many places. She also helped inspire others to explore situations where women were emerging as leaders in fighting environmental pollution or destruction.

Conceptualizing the relationship between women and nature as an essential one also challenged the hegemony of (male) scientific knowledge as the privileged source of information about nature. This helped open the door for alternative knowledges to inform debates about environmental change, and, indeed, traditional ecological knowledge (TEK) owes a large debt to ecofeminist work in this regard, even if it is rarely acknowledged. The TEK literature tends to suffer from its lack of attention to what feminist political ecologists call "gendered knowledges."

Spirituality and Restoring a Female-Centered Metaphysics

One strand of ecofeminist thinking that has maintained an essentialist perspective on the relationship between women and nature is found in the writings on goddess worship and Earth-based spirituality. Vandana Shiva's early work in many

respects was part of this strand, but many ecofeminists in North America are also important contributors. Building from Merchant's historical exploration, spiritual ecofeminists seek to recover the idea that Earth is alive and that human actions are threatening the health of this organism as much as they are threatening the individual species on Earth. James Lovelock's ideas of Gaia have been taken up, and ecofeminists have a synergy with deep ecology in seeking to realign the human relationship with nature. This realignment can only take place when people embrace the importance of a spiritual connection with Earth and accept that every action affects the whole. It is therefore an ontology of holism, using ecological and organism metaphors to understand how humans affect the planet.

This kind of ecofeminist thinking has both been an inspiration and come under attack as it again reinforces essentialist ideas of women as well as nature and spirituality. It is unclear how this new Earth-centered spirituality sits in relation to the world's dominant religions and, importantly, how it provides a better foundation for action than do the present ontologies.

Historical Materialism and Women's Knowledge

Although celebrating the clear link between women and nature had some positive outcomes, essentialist conceptualizations of women rely on the notion of a fundamental female nature and ignore the diversity that exists between women. Such conceptualizations do violence to the very real differences between women, particularly the way race and class subject women, making the experience of being "a woman" far from universal. Women of color in the United States were some of the first feminists to challenge the white, middle-class bias in feminism. Latino American and African American women argued that in many contexts race was more salient in shaping their experiences of inequality, and thus the intersections of race, class, and gender need to be theorized.

Bina Agarwal used similar arguments to challenge Shiva's essentialist rendering of the women and environment nexus. She argued that the relationship between women and their motivation to protect the environment was based on



material realities and not an inherent, close connection to nature. Drawing from her own work on women and fuelwood issues in the Himalayas, Agarwal demonstrated how many Indian women are responsible for the food and fuel needs of their families, requiring them to work closely with forests and agricultural fields every day. These activities give them an intimate knowledge of their ecosystems and a strong need to ensure that resources are used sustainably, as failure to do so results in increased work burdens for themselves. Agarwal named her feminist historical materialist account “ecological feminisms” to distance herself from the essentialist conceptions of women dominant in the literature of ecofeminism.

Agarwal’s appeal to historical materialism provided an empirical basis to the idea that women have unique environmental knowledge and, significantly, brought a political economic analysis into the debate around gender and environment. She argued that the material conditions of people’s lives are complicit in producing particular kinds of environmental problems and that these problems place extra burdens on women responsible for the subsistence needs of their families.

Although Agarwal sought to distance herself from ecofeminism, many ecofeminists have built on her ideas and rejected the early essentializing of Shiva and others. Rather than assuming that all women have the same experience, this work looked at how culturally specific ideas of gender define differences between men’s and women’s associations and knowledges in relation to the environment. The gender-environment nexus is therefore shaped by material practices, in particular men’s and women’s work practices, and culturally specific gender roles rather than innate understandings and spiritual connections. Many ecofeminists therefore argue that the emphasis needs to shift to how environmental issues affect men and women differently, without the assumption that women innately understand environmental issues better.

Andrea Joslyn Nightingale

See also **Chipko Movement; Deep Ecology Movements; Feminist Environmentalism; Feminist Political Ecology; Gaia Theory; Gender and Nature; Indigenous Environmental Knowledge; Nature-Society Theory; Social Construction of Nature**

Further Readings

- Agarwal, B. (1992). The gender and environment debate: Lessons from India. *Feminist Studies*, 18, 119–158.
- Agarwal, B. (1997). Environmental action: Gender equity and women’s participation. *Development and Change*, 28, 1–44.
- Cuomo, C. J. (1998). *Ecological feminism*. London: Routledge.
- Diamond, I., & Orenstein, G. F. (Eds.). (1990). *Reweaving the world: The emergence of ecofeminism*. San Francisco: Sierra Club Books.
- Griffin, S. (1978). *Woman and nature: The roaring inside her*. New York: Harper & Row.
- Kobayashi, A., & Peake, L. (1994). Unnatural discourse: “Race” and gender in geography. *Gender, Place and Culture*, 1, 225–243.
- Merchant, C. (1990). *The death of nature*. New York: HarperCollins.
- Mies, M., & Shiva, V. (1993). *Ecofeminism*. London: Zed Books.
- Moraga, C., & Anzaldúa, G. (Eds.). (1988). *This bridge called my back: Writings by radical women of color*. New York: Women of Color Press.
- Ortner, S. (1974). Is female to male as nature is to culture? In M. Rosaldo & L. Lamphere (Eds.), *Women, culture, and society* (pp. 67–88). Stanford, CA: Stanford University Press.
- Plumwood, V. (1991). Nature, self, and gender: Feminism, environmental philosophy, and the critique of rationalism. *Hypatia*, 6, 3–27.
- Shiva, V. (1989). *Staying alive: Women, ecology and development*. London: Zed Books.



ECOLOGICAL ECONOMICS

Goods and services from the natural world are vital components of the human economy. Eco-system processes provide energy and regulate wastes, and natural resources are used for a variety of goods and services, including food, medicine, and recreation. Ecological economics is a transdisciplinary field that studies the allocation of natural resources, with emphasis on the view of the human economy as a subset of the ecological world. Drawing on expertise from the natural



and social sciences, physics, and other fields, ecological economists seek to include natural resources in the traditional economic view of capital and promote limitations of growth in favor of sustainable development. The field further redefines traditional ideas of sustainability to include responsible use of resources that does not preclude future generations from enjoying standards of living comparable with those of citizens living today.

The field's conceptual basis was anticipated as early as the 1800s, when scholars began to express concern over limitless population growth and economic expansion. These ideas became joined with concepts from the physical sciences that highlighted energetic and material limits to growth to form discussions on resource use that include considerations from ecology, conservation biology, geography, and economics. To date, thousands of scientists and practitioners are organized in regional and international societies for ecological economics, and several degree programs have been established worldwide in ecological economics.

A Break From Neoclassical Economics

Although ecological economics shares many of the fundamental principles of neoclassical economics and environmental economics, its evolution represented a significant paradigm shift that drew natural resources into the concept of capital from which they had traditionally been excluded.

Economy as a Subset of the Environment

Ecological economics differentiates itself from neoclassical economics in its philosophical stance on the relationship between the environment and the economy. In the neoclassical purview, the economy exists as a system separate from its environment and with the potential for infinite expansion. It concentrates on the monetary exchanges among producers and consumers, whereby the optimal allocation of goods among alternative uses is determined primarily by market forces. Value can be generated irrespective of the natural resource base as

long as beneficial technological change occurs rapidly enough.

In contrast, ecological economics applies laws from the physical sciences to present the human economy as a part contained within a larger ecosystem filled with finite resources. Growth of the economy necessarily depletes the base of natural resources, many of which are nonrenewable, and technology itself—however rapidly changing—cannot function without a minimum of materials and energy flow. In this view, economic growth is inherently limited. Thus, growth over time results in a shift from an “empty world” (i.e., many natural resources available) to a “full world” (i.e., most natural resources have been depleted or nearly depleted). During this transition, there is a point of economic growth beyond which human welfare is in fact reduced rather than increased, becoming uneconomic growth.

Consideration of Natural Resources as Capital

Ecological economics emerged in part from criticisms of the view of natural resources in traditional economics as fully substitutable with other standard input factors to production, such as capital and labor. In contrast, ecological economics stresses the relationship between resource flows and human-made production funds as complementary and not substitutable.

Ecological economists in the field have criticized the neoclassical economic production function

$$Q = F(K, L),$$

where the quantity (Q) of a good that firms choose to manufacture is a function (F) of capital (K) and labor (L) inputs to production.

Ecological economics modifies the production function to include explicitly nonrenewable and renewable resources (N and R , respectively):

$$Q = F(K, L; N, R).$$

This modified equation accounts for natural resources as a limiting factor of production. Thermodynamic limits on material and energy use for specific technologies and for technical change



play a central role when specifying production functions and the underlying substitutability of factors of production for each other.

Growth Versus Development: Themes and Policies in Ecological Economics

Ecological economics views increasing welfare as dependent on the ability to make qualitative improvements versus the neoclassical emphasis on growth, which implies a quantitative increase in the flow of materials and energy from the ecosystem through the economy and back into the environment in the form of wastes. Development requires little or no additional throughput but emphasizes designs of existing commodities and institutions that improve the status of *scale*, *allocation*, and *distribution* of resources.

Optimal Scale of the Economy

In economic terms, *scale* refers to the volume of matter and energy used to provide goods and services in the economy. Many ecological economists posit that our current scale of natural resource use is unsustainable and that the human economy is approaching the full-world scenario, in which growth is uneconomic. Empirical assessments of many of the resources most critical to the economy suggest that continued expansion will come at very high costs. For example, 69% of the world's primary commercial fish species are in decline, mineral resources are becoming scarce and declining in quality, and future projections of freshwater availability indicate that nearly 50% of the world's population will experience water shortages in the next 50 years. This is in part due to negative externalities (e.g., pollution) resulting from economic growth and from failure of the market to capture scarcity of resources without monetary value.

Some ecological economists see the optimal scale of natural resource use as one that does not cause the resource in question to depreciate or erode over time but will provide a relatively constant stock for future generations. The challenge for natural and social scientists, as well as for

policymakers, is to identify appropriate scales of consumption for various natural resources and to design incentives for firms not to extract these resources at higher rates.

Command-and-control regulations have historically been the primary mechanisms for setting limits on resource consumption. These policies set strict limits on pollution, extraction, or harvest levels and fine firms for violation. However, a recent shift in the discourse about the effectiveness of such policies favors more flexible solutions that provide incentives to reduce scale beyond one set cap in a more cost-effective manner. For example, "Pigouvian" taxes, named after the British welfare economist Arthur Pigou, involve charging firms per unit of pollution to achieve a socially optimal outcome. Similarly, Pigouvian subsidies may be levied to encourage the generation of certain benefits from production, for which there may otherwise be no monetary incentive. Tradable permits and quotas are also thought to provide monetary incentives for firms to reduce their scale of production and negative impacts on the environment to perhaps a greater extent than can be achieved through direct regulation.

Efficient Resource Allocation

Like neoclassical microeconomics, ecological economics is concerned with the allocation of goods and services (i.e., resource flow) among alternative uses, placing particular emphasis on scarce resources. While accepting the basic laws of supply and demand as useful tools of market analysis, ecological economics draws attention to the inefficiency of the market to allocate many types of natural resources due to various types of market failures. Open-access regimes such as fisheries, for example, are nonexcludable (i.e., traditionally lack property rights), and individuals may overexploit these resources because any costs incurred are shared among many other individuals also using the resource. Public goods (e.g., fresh water, clean air, scenic beauty) are subject to similar effects because they can be used for free and thus scarcity will not be adequately reflected in the market price. The production of goods can also produce positive or negative externalities (e.g., pollution)



that are not captured in the market price. Whenever these market failures occur, goods will not be produced or priced efficiently, contributing to the inefficient use of natural resources.

Environmental economics typically suggests that some of these problems can be solved by assigning prices to natural resources and taxing polluters. Ecological economics, while generally not averse to this solution, sees clear limitations and emphasizes the intrinsic and moral value of ecosystems and their role in supporting the human endeavor that is fundamentally different from the contributions that come from ordinary goods and services. Ecological economists typically suggest implementation of policy mechanisms that reflect the fact that natural goods and services do have some value without always attempting to calculate a dollar value for each.

Equitable Resource Distribution

Ecological economics places importance on the fair distribution of resources, wealth, and income for sustainability and responsible use of resources, even the fair distribution of resource flows between humans and other species. Income distribution can undermine sustainability because poor communities may not be able to afford to address environmental impacts, while the very rich consume vast amounts of limited resources and may be better able to adapt to growing resource constraints or decreasing environmental quality. There is also an ethical consideration of temporal distribution; future generations are viewed as having ownership of natural capital as well, and thus, their needs should be included in the picture of what is considered sustainable today. Some proponents of an equitable distribution argue that reductions in inequality of wealth would not only improve the condition of the ecosystem and its valuable resources but would have other positive social benefits, including economic stability and reduced incidence of crime.

Policies designed to redistribute wealth include progressive income and wealth taxes, mandated minimum wages, unemployment insurance, and welfare programs. Ecological economists also typically advocate expanded ownership opportunities as mechanisms to redistribute wealth. Employee Stock Ownership

Programs and Consumer Stock Ownership Programs are designed to give stock and managerial influence to employees in firms so that profit-making decisions are spread over a larger number of individuals than those in the top tiers of management. This way, the external costs of profiteering may be to some extent internalized when a number of the invested workers live in an area influenced by negative impacts of production, for example. Trust funds can serve an analogous function for redistribution of natural capital, facilitating community ownerships of natural resources and associated profits.

Questions for the Future

With increasing populations and changing environmental conditions come lively debates about natural resource use and equitable distribution. In addition to broad concerns over environmental quality and demographic and temporal equity, specific recent concerns in ecological economics that will pose challenges to researchers in the future include the development of aquaculture versus open-sea fisheries; the ability of agricultural systems to meet food demand; the implications of genetically engineered seeds for food production; the availability and development of sinks for the vast amounts of waste generated by the human economy; the development of tools and institutions that help economies transition away from their current growth mentality; and the development of sustainable consumption habits.

Rebecca R. Gasper and Matthias Ruth

See also **Common Pool Resources; Distribution of Resource Access; Ecological Footprint; Ecological Justice; Ecological Modernization; Energy and Human Ecology; Energy Resources; Environmental Ethics; Externalities; Neoliberal Environmental Policy; Nonrenewable Resources; Political Economy of Resources; Population and Land Degradation; Population, Environment, and Development; Renewable Resources; Resource Economics; Sustainability Science; Sustainable Agriculture; Sustainable Cities; Sustainable Development; Sustainable Development Alternatives; Sustainable Fisheries; Sustainable Forestry; Sustainable Production**



Further Readings

- Daly, H., & Townsend, K. (Eds.). (1993). *Valuing the Earth: Economics, ecology, ethics*. Cambridge: MIT Press.
- Lawn, P. (2000). *Toward sustainable development: An ecological economics approach*. Boca Raton, FL: CRC Press.
- Martinez-Alier, J. (1990). *Ecological economics: Energy, environment and society*. Oxford, UK: Blackwell.
- Ruth, M. R. (2006). A quest for the economics of sustainability and the sustainability of economics. *Ecological Economics*, 56, 332–342.
- Stahl, C., Cimorelli, A. J., & Chow, A. H. (2002). A new approach to environmental decision analysis: Multi-criteria integrated resource assessment. *Bulletin of Science, Technology & Society*, 22, 443–459.
- Van der Bergh, J. C. (2000). *Ecological economics: Themes, approaches, and differences with environmental economics*. Amsterdam: Free University Press.



ECOLOGICAL FALLACY

The ecological fallacy arises when inferences are made about the characteristics of individuals in a population based on analyses using aggregate statistics of those same individuals. The general usage of the term applies to inferences made about individuals that are based solely on the group characteristics of that population. Such would be the case with stereotyping or geographical profiling, where individuals are characterized by the general traits of the area in which they live. In a more specific manner, the ecological fallacy occurs when an ecological correlation between variables based on statistical constants such as group rates or means is assumed to characterize individual members of that population. William Robinson first demonstrated that statistical correlations of variables aggregated by group or geographic area can differ markedly from correlations based on individual-level variables of that same population. The possibility of false or misleading associations

has significant implications for geographical studies since relational inferences about members of a population are often based on data aggregated by spatial units.

In addition to the ecological fallacy, Hayward Alker identified other forms of fallacy that prevent valid generalizations from being made across different levels of analysis. The individualistic fallacy occurs when coarse-level aggregate relationships are inferred from individual or fine-level relationships. Cross-level fallacy exists when inferences are drawn from one subpopulation to another subpopulation at the same level of analysis. The universal fallacy applies when inferring generalized relationships based on nonrandom subsamples of a population. The selective fallacy typically occurs when a few cases are chosen to prove a universal point. Cross-sectional and longitudinal fallacies infer generalized relationships across many time frames based only on one point in time. Applying to all the above are contextual fallacies, where context or social structure may alter the strength or form of the causal or statistical relationship.

At the root of these fallacies is the concern that inferring generalized causal relationships based on spatially aggregated data can generate erroneous conclusions. Part of the problem is that errors arising from ecological inference are unquantifiable because of the lack of access to individual-level data. The spatial aggregation of data into defined areal units is common in geography and especially so with the increasing availability of digital data sets, digital boundary geographies, and geographic information systems. The Modifiable Areal Unit Problem is a derivative of ecological fallacy. There are many possible combinations of modifiable spatial units, such as voting districts, that can be used to spatially aggregate nonmodifiable units, such as the individual voter. As Openshaw demonstrated, aggregating data into arbitrary spatial units, which often have no meaningful geography, can greatly influence the outcomes of a study. Solving the ecological problem as to how to make inferences about individual behavior based on aggregate data continues to be an active focus of research in the social sciences.

Trevor M. Harris

See also **Modifiable Areal Unit Problem**



Further Readings

- Alker, H. (1969). A typology of ecological fallacies. In M. Dogan & S. Rokkan (Eds.), *Quantitative ecological analysis in the social sciences* (pp. 69–86). Cambridge: MIT Press.
- King, G., Rosen, O., & Tanner, M. (Eds.). (2004). *Ecological inference: New methodological strategies*. Cambridge, UK: Cambridge University Press.
- Openshaw, S. (1983). *The modifiable areal unit problem: Concepts and techniques in modern geography*. Norwich, UK: Geo Books.
- Robinson, W. (1950). Ecological correlations and the behavior of individuals. *American Sociological Review*, 15(3), 351–357.

ECOLOGICAL FOOTPRINT

The ecological footprint is a measure of the biologically productive area that a human population requires to produce the resources it consumes, and absorb its wastes, using prevailing technology. A fundamental requirement for sustainability is that renewable resources must be used at a rate slower than the rate at which nature can replenish them and wastes be emitted at a rate slower than that at which the biosphere can absorb them. Societies that do not meet this minimum condition run ecological deficits.

To know whether humanity meets this requirement, and to properly manage ecological assets, measurement of the use of nature is required. Resource accounts are needed to track how much nature exists and how much is used by people. Ecological accounting operates like financial accounting: It tracks income (the ecological services that nature provides) and expenditures (human use of these ecological services). As with financial assets, it is possible to spend more than is being regenerated. But this is possible only for a short period of time. Such overspending depletes natural capital and cannot be sustained in the long term. Continued ecological deficit spending leads to environmental bankruptcy, eroded economies, decreased quality of life, and societal instability. In short, just as a successful business needs to keep track of revenues and expenditures,

human society must keep robust accounts of demands on, and the renewal rates of, ecological assets. This is what the ecological footprint accounts offer.

The Ecological Footprint Analysis Method

The ecological footprint accounts measure people's demand on nature. This demand includes both the resources that are consumed and the wastes produced. These resources are obtained from forests, cropland, fisheries, grazing land, and other ecosystems. The built environment compromises the land's ability to provide biological resources. Additionally, ecosystems absorb and assimilate the wastes produced as a result of human resource consumption. The ecological footprint adds up these ecosystem services in terms of the biologically productive areas needed to provide the services. In other words, ecological footprint analysis builds on "mass flow balance," and each flow is translated into the ecologically productive areas necessary to support these flows.

The ability of ecosystems to supply humans with natural resources is limited by climate, technology, environmental management practices, and the availability of water and solar energy. This supply of ecosystem services and natural resources is called biocapacity. When a population's ecological footprint exceeds its biocapacity, ecological overshoot occurs.

The ecological footprints of nations can be calculated on an annual basis. Yearly figures are published by the nongovernmental organization (NGO) Global Footprint Network, along with methodological improvements that are used as reference points for applications by its partner organizations. These national accounts are presently the most scientifically scrutinized and well-documented national footprint assessments available. Adding up all nations' footprints and biocapacities yields the global assessment. Overshoot measured on a global scale is an indicator of global unsustainability.

Global Footprint Network data show that humanity's resource demands and waste production began to exceed Planet Earth's ability to meet them around 1986 (Figure 1). By 2005, humanity exceeded the planet's ability to provide biological resources by 31%—thereby dipping into the

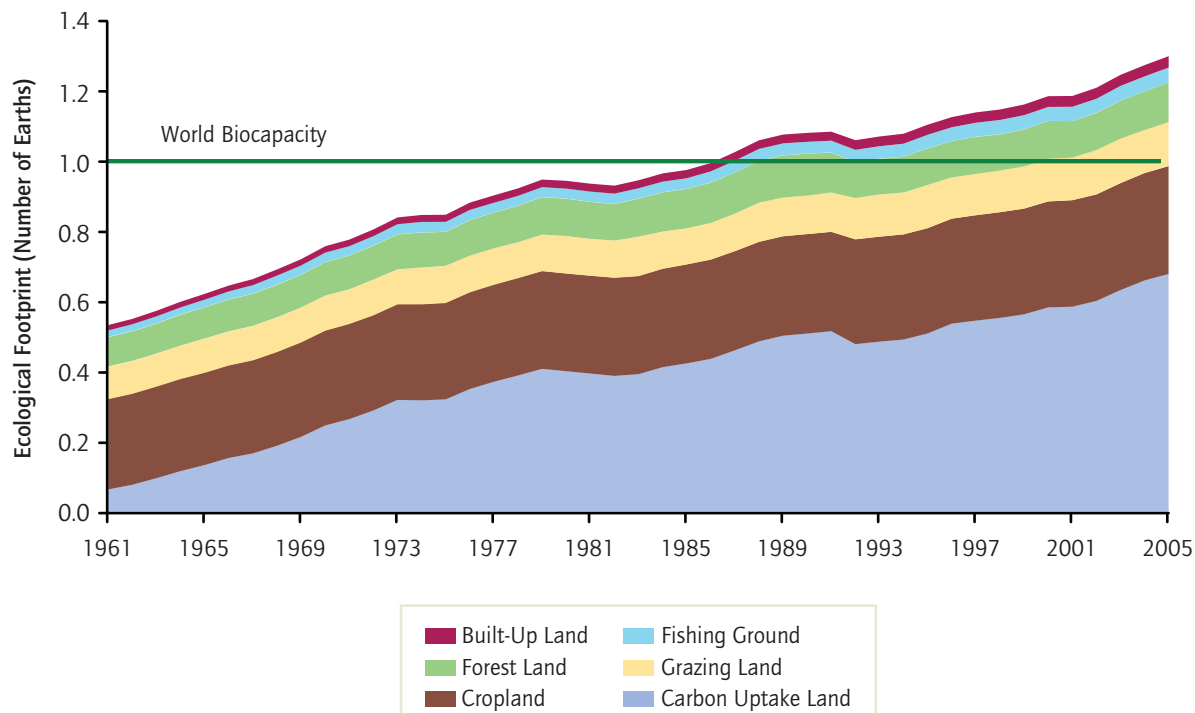


Figure 1 Humanity's ecological footprint, 1961–2005

Source: Reproduced from Global Footprint Network. (2008). *The ecological footprint atlas 2008*. Oakland, CA: Author. Retrieved November 26, 2008, from www.footprintnetwork.org/atlas.

natural capital stock. While the world average per capita biocapacity was 2.1 ha (hectares) per person, the world average per capita footprint was 2.7 ha per person. Ecological footprints vary significantly among nations. For example, the average footprint in Italy was 4.8 ha per person, against a domestic biocapacity of 1.2 ha per person, whereas the average footprint in Peru was 1.6 ha per person, against a domestic biocapacity of 4.0 ha per person (Table 1).

National Ecological Footprint accounts can also show local or regional ecological performance. For instance, ecological creditors (countries with a footprint smaller than their biocapacity) and ecological debtors (countries with a footprint exceeding their biocapacity) can be distinguished. In 2005, only 20% of the human population lived in ecological creditor countries. With increased resource scarcity, it may well be that geopolitical lines will shift from the division

between “developing” and “developed” countries to that dividing ecological debtors and ecological creditors.

The ecological footprint measures one aspect of sustainability: the availability of, and human demand on, Earth's regenerative capacity. A comprehensive assessment of sustainability requires other complementary measures as well: measures of social well-being, the depletion of nonrenewable resources, inherently unsustainable activities such as the release of persistent pollutants, and the degradation of ecosystems.

History of the Concept

The original ecological footprint methodology resulted from collaboration between Mathis Wackernagel and William Rees at the University of British Columbia in Vancouver. Their 1996 book made the concept more widely accessible.



	<i>Population (millions)</i>	<i>Total Ecological Footprint (gha/pers)^a</i>	<i>Total Biocapacity (gha/pers)</i>	<i>Ecological Deficit or Reserve (gha/pers)</i>
World	6,476	2.7	2.1	(0.6)
High-income countries	972	6.4	3.7	(2.7)
Middle-income countries	3,098	2.2	2.2	(0.0)
Low-income countries	2,371	1.0	0.9	(0.1)
Africa	902	1.4	1.8	0.4
Egypt	74	1.7	0.4	(1.3)
Ethiopia	77	1.4	1.0	(0.3)
Kenya	34	1.1	1.2	0.1
Madagascar	19	1.1	3.7	2.7
South Africa	47	2.1	2.2	0.1
Middle East and Central Asia	366	2.3	1.3	(1.0)
Afghanistan	30	0.5	0.7	0.3
Iraq	29	1.3	0.3	(1.1)
Israel	7	4.8	0.4	(4.4)
Jordan	6	1.7	0.3	(1.4)
Asia-Pacific	3,562	1.6	0.8	(0.8)
Australia	20	7.8	15.4	7.6
Bangladesh	142	0.6	0.3	(0.3)
China	1,323	2.1	0.9	(1.2)
India	1,103	0.9	0.4	(0.5)
Japan	128	4.9	0.6	(4.3)
Americas	884	5.0	5.4	0.5
Argentina	39	2.5	8.1	5.7
Brazil	186	2.4	7.3	4.9
Canada	32	7.1	20.0	13.0
Colombia	46	1.8	3.9	2.1
Costa Rica	4	2.3	1.8	(0.4)
Cuba	11	1.8	1.1	(0.7)
Mexico	107	3.4	1.7	(1.7)
Peru	28	1.6	4.0	2.5
United States of America	298	9.4	5.0	(4.4)
Europe (EU)	487	4.7	2.3	(2.4)
France	60	4.9	3.0	(1.9)
Germany	83	4.2	1.9	(2.3)
Italy	58	4.8	1.2	(3.5)
Poland	39	4.0	2.1	(1.9)
Spain	43	5.7	1.3	(4.4)
United Kingdom	60	5.3	1.6	(3.7)
Europe (Non-EU)	240	3.5	5.8	2.3
Russia	143	3.7	8.1	4.4
Ukraine	46	2.7	2.4	(0.3)

Table 1 Ecological footprint and biocapacity results for selected countries (2005 data)

Source: Based on Global Footprint Network. (2008). *National footprint accounts, 2008 edition*. Oakland, CA: Author.

a. gha/pers = global hectares per person.



Since then, many others, including academics, leaders of NGOs, and business analysts have employed the concept and contributed to its methodological development.

To bring this community together, the Global Footprint Network was founded in 2003, with the goal of advancing the scientific rigor and practical application of the ecological footprint, and making the ecological footprint as prominent a metric as gross domestic product. The Global Footprint Network comprises a 23-member advisory board of leading scientists and politicians and has offices in Oakland, California (United States); Zurich; and Brussels. More than 100 organizations, spanning six continents, have become formal Global Footprint Network partners. The ecological footprint is now widely used by governments, communities, and businesses to set targets, monitor ecological performance, and evaluate risks and opportunities in an increasingly resource-constrained world.

The adoption of the ecological footprint as a trusted sustainability metric depends on the scientific integrity of the methodology, consistent and rigorous application of the methodology across analyses, and the clear and objective presentation of results. To meet these goals, Global Footprint Network and its partners have created a consensus-based committee process for improving the method and for developing international ecological footprint standards. In addition, a partner-based science committee oversees the development of the national footprint accounts.

Mathis Wackernagel and Kristin Kane

See also **Carrying Capacity; Ecological Economics; Environmental Services; Sustainability Science; Sustainable Agriculture; Sustainable Cities; Sustainable Development; Sustainable Development Alternatives; Sustainable Fisheries; Sustainable Forestry; Sustainable Production**

Further Readings

Global Footprint Network. (2008). *The ecological footprint atlas 2008*. Oakland, CA: Author.

Global Footprint Network. (2008). *National footprint accounts*. Oakland, CA: Author.

Moran, D. D., Wackernagel, M., Kitzes, J. A., Goldfinger, S. H., & Boutaud, A. (2008). Measuring sustainable development: Nation by nation. *Ecological Economics*, 64, 470–474.

Rees, W. E., & Wackernagel, M. (1996). *Our ecological footprint: Reducing human impact on the Earth*. Gabriola Island, British Columbia, Canada: New Society.

Wackernagel, M., Schulz, N. B., Deumling, D., Linares, A. C., Jenkins, M., Kapos, V., et al. (2002). Tracking the ecological overshoot of the human economy. *Proceedings of the National Academy of Sciences of the United States of America*, 99, 9266–9271.

World Wide Fund for Nature, Zoological Society of London, & Global Footprint Network. (2008). *Living planet report 2008*. Gland, Switzerland: Author. Retrieved December 22, 2008, from www.panda.org/livingplanet



ECOLOGICAL IMAGINARIES

Ecological imaginaries are ways of conceiving nature with attendant but often unacknowledged social and cultural implications. These visions typically foreground purportedly neutral ideologies of nature while displacing often contentious political, social, and economic relations. Geographers seek to identify how seemingly durable conceptions of nature such as “rain forests” or relationships to nature such as “sustainability” attain their taken-for-granted status, that is, how they come to be accepted uncritically among large sections of the public. Articulated through material, social, and discursive practices, dominant ecological imaginaries reinforce ideologies of nature and society and naturalize particular conceptions of space, place, and landscape so that they appear inevitable, impartial, or cyclical. In short, they often function to make human relations with ecosystems appear to lie outside the capacity of people to change them. The term emerged from the common academic focus on meaning making and the consideration of nature in social theory and has been applied to purportedly apolitical concepts currently in vogue within urban planning, governance, redevelopment, and



environmental politics, as well as attempts to “green” capitalism in response to ecological crises. These linked ecological narratives frame policy discussions that are about more than just nature, throwing into question the neutrality of claims for ecological preservation and conservation. Instead of a singular nature, ecology, or public, investigators of environmental imaginaries argue for the recognition of multiple natures, ecologies, and publics but have been criticized for relying on explanations located primarily within discourse and not in material processes.

Origins

Firmly established within the “cultural turn” that has reshaped geography and the “green turn” in the social sciences, the term *environmental imaginaries* incorporates a recognition of the significance of ecological thinking to the constitution of place, space, and landscape as part of meaning making and identity. The attention paid to these ways of thinking or discourses was seen as a necessary corrective to the practice of geography as an abstract spatial science in which people and the way they make their worlds was of little importance to the discipline. Recognized as a constitutive element of social life, views of nature have become of increasing importance across the social sciences.

Uses

The consideration of ecological imaginaries has involved illuminating those representational strategies that naturalize particular conceptions of the landscape with social, economic, and political identities. It has also involved investigating environmental politics or the ecological imaginary of the “good city” in balance with nature and looking into taken-for-granted conceptions of environment, nature, conservation, and sustainability to see how social and economic visions are bound up with wish images expressed through representation of nature.

Ecological or organic metaphors underpin urban theories that explain political, economic, and social processes. For example, equating the city to the human body led to a concept of the role of transportation networks as circulatory

systems, to arguments that parks need to act as the “lungs” of the city, and to a view of blight as cancerous decay. These narratives naturalized the processes that constituted urban landscapes so that they appear inevitable as opposed to the result of historical relations.

In other contexts, unpacking ecological imaginaries involves uncovering a “false” ecological view asserted for political or economic ends. For example, unpacking the cultural narratives around the American lawn requires unraveling the complex social, economic, and political relationships that have made this highly manicured, exotic, monoculture crop a ubiquitous part of the landscape and a central component of suburban identity.

Investigating environmental imaginaries illuminates representational and material spatial strategies that intertwine seemingly divergent concepts of nature, community, identity, and citizenship. Visions of improving on nature by controlling and harnessing rivers through waterworks and dams have reflected a desire to better society by supplying clean water to create a hygienic city and serve as a nationalistic demonstration of having attained the trappings of a modern city.

Recently, ecological imaginaries have sought to confront ecological and social dislocations that have resulted from modern urbanization and capitalist industrialization by mythologizing the control of nature and practice of urban design to suggest that environmental damage and a decline in sociability can be reversed. Livability and sustainability, considered as ecological imaginaries, mark conscious attempts to restore and reconnect ecological and social systems in compromised locations. The result is a politics of conservation, redevelopment, or aesthetic values that purports to be neutral but in doing so silences histories, voices, and opinions that fall outside the frame. This strategy has been pursued in the consideration of the epistemological politics of spatial thinking in relation to postcolonial critiques of contemporary environmental and resource politics as well as waterfront redevelopment projects.

The investigation of ecological imaginaries often highlights how utopian or dystopian themes become naturalized in ways that ignore the social relations that have constituted particular places, spaces, and landscapes. Instead of preserving or restoring “pristine” ecologies, this position argues



for more honest and transparent dialogues about the social and natural futures represented by ecological imaginaries. This shifts the focus of discussion toward considering what work the nature-based wish images do, what politics they support, which positions they erase, and ultimately what would constitute more just visions of social and natural landscapes.

Criticisms

By declaring all visions of ecological futures as “imaginaries” bound up with culture, society, and economy, it can become more difficult to make the sort of strong or objective claims about the exercising of power in the construction of landscape that make alternative spatial politics possible. Ecological imaginaries highlight complexity and context, which can obscure the attempt to criticize and oppose how such visions are mobilized in a political arena.

Chris Hagerman

See also **Cultural Turn; Environmental Discourse; Environmental Imaginaries; Geographical Imagination; Nature-Society Theory; Political Ecology; Social Construction of Nature; Sustainability Science**

Further Readings

- Braun, B. (2002). *The intemperate rainforest: Nature, culture, and power on Canada's west coast*. Minneapolis: University of Minnesota Press.
- Gandy, M. (2006). Urban nature and the ecological imaginary. In N. Heynen, M. Kaika, & E. Swyngedouw (Eds.), *In the nature of cities: Urban political ecology and the politics of urban metabolism (questioning cities)* (pp. 63–74). London: Routledge.
- Hagerman, C. (2007). Shaping neighborhoods and nature: Urban political ecologies of urban waterfront transformations in Portland, Oregon. *Cities*, 24, 285–297.
- Kaika, M. (2006). Dams as symbols of modernization: The urbanization of nature between geographical imagination and materiality. *Annals of the Association of American Geographers*, 96, 276–301.



ECOLOGICAL JUSTICE

Conceptions of justice typically address notions of what is right and what is fair. Ecological justice addresses how humans relate with nonhuman species and the natural world. Sometimes called *justice to nature*, it seeks to delineate human's moral obligations to other species. This entry considers definitions, concepts, and issues central to ecological justice, which is different from *environmental justice*. The latter term refers to social justice environmentalism. Commentators attribute the term *ecological justice* to geographers Nicholas Low and Brendan Gleeson, but its scholarly antecedents date as far back as the mid 20th century, to Aldo Leopold's “land ethic” and Rachel Carson's *Silent Spring*, which sought to extend ethical behavior to biotic communities. As a research perspective, ecological justice recognizes that nature has intrinsic value and acknowledges the interconnections and mutual interdependence of all species. Proponents seek to expand the domain of “moral considerability” beyond humans to encompass animals, plants, and even inanimate objects such as rocks, rivers, and oceans.

There are several bases of ecological justice. Religious grounds often posit humans as custodians of the natural world and are founded on humans' moral responsibility to other species, stemming from supernatural entities (God, Buddha, Allah, Australian Aboriginal Dreamtime beings, etc.). Instrumental grounds see current and future generations of humans as reliant on the natural world for their needs (e.g., food, medicine, and clothing). Without these species, humans may suffer extinction. More recently, some commentators have argued that humans have a kinship with nonhuman species, as fellow animals and “ecological citizens,” and are thus morally obliged to care for other species. In short, ecological justice seeks to reposition humans' relationship with nature and to establish moral obligations to nonhuman entities.

Key Thinkers

There are too many key thinkers in this field to discuss in detail here. Some key contributions are outlined below, but others also merit attention



(including those of J. Baird Callicott, Tom Regan, Ted Benton, and James Lovelock).

Peter Singer: Animal Rights

Perhaps best known for his book *Animal Liberation*, Singer argues for extending the notion of rights to animals, with some limits. He argues that many animals can feel pain, manipulate the world around them, have cultural expression, and develop deep familial bonds, thus making them worthy of ethical consideration. But Singer dismisses the notion of sentience (intelligence) as a test for moral considerability, arguing that very young humans or mentally disabled individuals may have lower intelligence levels than do many mammals.

Christopher Stone: Do Trees Have Standing?

Stone sought to challenge long-standing notions of legal inclusivity, expanding the community of legal right to include trees and inanimate objects. He proposed a system of legal rights for nature. Tried in U.S. courts, his propositions failed the test of jurisprudence but paved the way for legal recognitions of nonhuman species.

Roderick Nash and Luc Ferry: Rights of Nature

Roderick Nash traced the foundations of “natural rights,” exploring the philosophical and religious foundations of Western humanism. Together with philosophers such as Luc Ferry, Nash has researched how the Cartesian divide between humans and animals developed (i.e., a worldview that separates nature from culture) and how various religious and philosophical traditions have allowed for the development of ecological ethics (e.g., the animal trails of the Middle Ages). Ferry and Nash have challenged some ideas within the deep-ecology movement as being potentially fascist (e.g., what is natural, and place-based ecological connections that determine who and what belong where).

Arne Næss: Deep Ecology

Moving beyond Singer, Arne Næss has proposed a doctrine of equal rights of nature,

espousing that all living entities are inherently valuable. Deep-ecology proponents hold nature to be sacrosanct and seek to protect “pristine nature” from human-induced harm by cultivating ethical, spiritual, and emotional identification with nature. But the ecocentric ethics of deep ecologists have been criticized for rendering the idea of rights meaningless, for not paying enough attention to social inequalities, for essentializing nature (ignoring the inherent differences between humans and nonhuman life forms), and for risking social Darwinism (i.e., naturalizing famine or legitimizing paternalism).

Val Plumwood: Ecofeminism

The late Val Plumwood strove to develop a feminist basis for ecological justice. She and other ecofeminists have sought to understand and undo structures of domination and oppression (e.g., class, patriarchy, racism, and speciesism) within the broader goal of theorizing how humans relate to nature and how in turn these relationships shape various power relations. They particularly challenge the association of women and nature—and women’s supposedly closer affinity to nature, defined by their “natural” reproductive capacities. This thinking they term *mutual inferiorization*. The ecofeminist project is framed around the liberation of the other (including both women and nature) from masculine, rationalist oppression.

Geographers’ Contributions

Within geography, ecological justice proponents include ecosocialists, ecofeminists, human ecologists, and animal geographers. Two areas merit closer attention—animal geography and political ecology.

Animal Geographies

Geographers such as Jennifer Wolch have over the past decade radically redefined the field of human geography to encompass the study of animals and nonhuman nature. Sarah Whatmore, Jennifer Wolch, and Bruce Braun—among others—have sought to create a “more than



human” geography, studying for instance how humans are already “hybridized” with nature (e.g., cities are socionatural entities), how human-animal relations have shaped spaces and places (e.g., how ideologically charged animal representations are used to construct ethnoracial identities), and how linkages between ideas about animals and racism, sexism, colonialism, and nationalism have configured cultural practices and power relations. Animal geography has often entailed reconceptualizing animals as what Sarah Whatmore has called *strange people*, showing how animals possess agency and subjectivity and are worthy of moral consideration and ethical treatment.

Political Ecology

Recognizing the interconnections between environmental degradation and socioeconomic exploitation, political ecologists have shown how the workings of capitalism (re)produce large-scale human and animal suffering and environmental harm. The political ecology perspective has cast light on how nature is distributed within cities; how cities function as metabolic entities and as habitats for myriad species; how capitalism “produces” nature—differentially shaping access to nature and determining who and what lives and dies; and how habitat destruction is linked with consumptive lifestyles (e.g., lawn chemicals and groundwater pollution). Understanding political and economic processes and institutions reveals impediments to the flourishing of humans and nonhuman nature.

Animal geographers and political ecologists have not only broadened our understanding of nature-society relations but also sketched out research agendas that place ecological justice as a subject of inquiry and goal of action-oriented research.

Jason Byrne

See also **Animal Geographies; Deep Ecology Movements; Ecofeminism; Environmental Ethics; Environmental Justice; Feminist Political Ecology; Justice, Geography of; Nature-Society Theory; Political Ecology; Political Economy of Resources; Social Justice; Sustainability Science**

Further Readings

- Baxter, B. (2004). *A theory of ecological justice*. London: Routledge.
- Benton, T. (2008). Environmental values and human purposes. *Environmental Ethics*, 17, 201–220.
- Braun, B. (2005). Environmental issues: Writing a more-than-human urban geography. *Progress in Human Geography*, 29, 635–650.
- Castree, N. (2003). Commodifying what nature? *Progress in Human Geography*, 27, 273–297.
- Foster, J. B. (2002). *Ecology against capitalism*. New York: Monthly Review Press.
- Low, N., & Gleeson, B. (1998). *Justice, society and nature*. London: Routledge.
- Nash, R. F. (1989). *The rights of nature*. Madison: University of Wisconsin Press.
- Plumwood, V. (1994). *Feminism and the mastery of nature*. London: Routledge.
- Robbins, P., Polderman, A., & Birkenholtz, T. (2001). Lawns and toxins: An ecology of the city. *Cities*, 18, 369–380.
- Wolch, J. (2002). Anima urbis. *Progress in Human Geography*, 26, 721–742.
- Wolch, J. (2007). Green urban worlds. *Annals of the Association of American Geographers*, 97, 373–384.



ECOLOGICAL MAPPING

Ecological maps are playing an increasing role in land management and planning. Their purpose is to display units of land of various sizes that reflect differences in response to management and resource production capability. An ecological map shows an area divided into ecosystems—that is, areas within which there are associations of interacting biotic and abiotic features. How these features are associated or integrated can be shown at two general levels. One level shows the integration within the local level, and another shows how the local area is integrated and linked with other areas across the landscape to form larger systems. All these areas are ecosystems, albeit at different scales or relative sizes.



Subdivision of land into systems of different sizes is needed for several reasons. Because of the linkages between systems, a modification of one system may affect the operation of surrounding systems. Furthermore, how a system will respond to management is partially determined by relationships with the surrounding systems linked in terms of runoff, groundwater movement, and microclimate influences. Because ecosystems are spatially nested in each other, each level subsumes the environment of the system at the level below it. Therefore, it conditions or controls the behavior of the system at the level below it. Understanding these relationships is important in analyzing cumulative effects of action at one scale and its effects at another.

Given this need, landscape ecologists and ecosystem geographers have been interested in hierarchical schemes of ecosystem units. The nomenclature and number of levels in these schemes vary. One scheme that has been adopted by the U.S. Forest Service and others for use in ecosystem management recognizes ecosystems at three scales of perception. The smallest, or microscale, ecosystems are the homogeneous *sites* commonly recognized by foresters and range scientists. At the mesoscale, linked sites create a *landscape mosaic* that looks like a patchwork. At the macroscale, mosaics are connected to form larger systems. These units of connected mosaics are called *ecoregions*.

The fundamental question facing all ecological land mappers is "How are the boundaries of different-sized systems to be determined?" Different methods have been used to identify units where ecosystem components are integrated in a similar way, thereby classifying land as ecosystems. One method is to overlay maps of ecosystem components at a similar resolution to look for associations of these components to identify ecological units with similar patterns. Some ecosystem mappers have employed a gestalt approach in which boundaries are drawn intuitively around areas that appear homogeneous. Others used multivariate clustering to classify grid cells. A map is produced by drawing lines around cells of similar class. These methods are termed *empirical* because they are descriptive and do not explain why units should be distinguished.

In an alternative to the empirical approach, a major emphasis is on mechanisms that produce the pattern of ecosystem distribution. Establishing a hierarchy of ecosystem boundaries is based on an understanding of the formative processes that operate to differentiate the landscape into ecosystems at various scales. The units derived from such an approach are termed *genetic* in that they are predicated on an understanding of the causal processes that control the pattern of ecosystems. Understanding spatial relationships between causal mechanisms and resultant patterns is key to understanding how ecosystems respond to management.

The notion that knowledge of processes should define landscapes has a long history in geography (cf. William Morris Davis). Building on this precedent, several workers have outlined principles to study and delineate ecosystems using the genetic approach. Delineating units involves analyzing factors controlling the geography of ecosystems at various scales and then *using significant changes in controls as boundaries*. A spatial hierarchy is constructed by successive subdivision of large ecosystems on the basis of controlling factors operating at different scales. Proponents of this approach argue that because subsystems can be understood only within the context of the whole, a classification of ecosystems begins with the largest units and successively subdivides them. This approach "from the top down" is advantageous as it provides a meaningful global context for local concepts and problems.

A primary value of the genetic or controlling factor approach to ecosystem mapping is that it screens out the effects of disturbance or plant succession because boundaries are not based on existing conditions. By this approach, permanent boundaries can be identified that allow ecosystems to be recognized regardless of current land cover or condition.

This approach is based on understanding the role of climate in ecosystem differentiation. To a considerable extent, climatic factors determine the boundaries of ecosystems at all scales. The most important of these is climatic regime, defined as the diurnal and seasonal fluxes of energy and moisture. As these fluxes change, the kinds and patterns of dominant life forms of



plants and animals change, as do the kinds of soils. As a result, ecosystems of different climates differ significantly. Controls over the climatic effect change with scale. Understanding these controlling factors on a scale-related basis is key to setting ecosystem boundaries.

At the macroscale, the ecosystem patterns are controlled by the macroclimate, which is the climate that lies just beyond the local modifying irregularities of landform and vegetation. Several factors are involved:

Latitude: If Earth had a homogeneous surface, circumferential zones of climate would result from variations in solar radiation and resulting atmospheric circulation. These zones would be divided along lines of latitude.

Continental position: Because Earth's surface is divided between land and sea, each with quite different thermal characteristics, the boundaries of climatic zones are "bent" as they cross the continents. These zones also fluctuate annually due to the inclination of Earth's rotational axis.

Elevation: Earth's landmasses are not, however, of a low, uniform elevation. The geology of the landmasses creates topographic variation. This topographic variation further affects the climate and therefore the regional distribution of ecosystems.

At the mesoscale, within the same macroclimate, broadscale landform patterns (topography and geology) break up the zonal pattern and provide a basis for further delineation of ecosystems. For example, geologic structure comes into play, creating mountains and valleys that create another climatic gradient: a combination of orographic precipitation and rain shadow.

At the microscale, the landforms created by crustal activity are shaped by processes and agents of denudation, creating a group of sequential landforms, such as dissected topography, where taller, denser vegetation demarcates the north-facing slopes. The local variations in topography will cause small-scale variations in the amount of solar radiation received, create topoclimate, and affect the amount and distribution of soil moisture. The variables will subsequently affect the

biota, creating ecosystem sites as subdivisions of the larger zone.

To summarize, all natural ecosystems are recognized by differences in climatic regime. Regional ecosystems (ecoregions) are areas of a homogeneous macroclimate. Landform is an important criterion for recognizing smaller divisions within macroecosystems since it exerts the major control over the climate (through aspect and steepness of slope) at the meso- and microlevels. As modified by landform, climate offers the logical basis for delineating ecosystems, both large and small.

Boundaries are recognized by perceived changes in the ecological relationships of climate, vegetation, and landform. But when vegetation has been drastically disturbed or even destroyed, boundaries between potential ecosystems can still be mapped to coincide with changes in those landform characteristics known to regulate the reception and retention of energy and moisture.

Robert G. Bailey

See also **Biogeography; Ecoregions; Ecosystems; Environmental Management**

Further Readings

- Allen, T. H. F., & Starr, T. B. (1982). *Hierarchy: Perspective for ecological complexity*. Chicago: University of Chicago Press.
- Bailey, R. G. (1996). *Ecosystem geography*. New York: Springer-Verlag.
- Cleland, D. T., Avers, P. E., McNab, W. H., Jensen, M. E., Bailey, R. G., King, T., et al. (1997). National hierarchical framework of ecological units. In M. S. Boyce & A. Haney (Eds.), *Ecosystem management: Applications for sustainable forest and wildlife resources* (pp. 181–200). New Haven, CT: Yale University Press.
- Godron, M. (1994). The natural hierarchy of ecological systems. In F. Klijn (Ed.), *Ecosystem classification for environmental management* (pp. 69–83). Dordrecht, Netherlands: Kluwer Academic.
- Rowe, J. S. (1996). Land classification and ecosystem classification. *Environmental Monitoring and Assessment*, 39, 11–20.



ECOLOGICAL MODERNIZATION

Ecological modernization is shorthand for two ideas: (1) that it is possible to maintain or increase the rate of economic growth *and* protect the environment and (2) that diseconomies and ecological harm may be diminished by policy correctives and technological fixes that design environmental criteria into economic systems. Its apparent appeal lies in its capacity to generate positive-sum solutions to problems conceived as zero sum, move beyond remedial and regulatory environmental strategies of the 1970s, avoid structural change seen as intractably difficult, and accommodate (however uncomfortably) both radical environmental critiques and neoliberal economic practices. In short, the term refers to the restructuring of the capitalist economy along environmentally sound lines. Nevertheless, it has been criticized for perpetuating social injustices, economic unfairness, and environmental harm because it remains inside the capitalist system, from which stem many of the problems of modernization.

Modernization and Globalization

Modernization is a term and idea describing various pathways for human and social development and various changes in social and spatial relations over time. These processes involve modifications to production and consumption, as well as adjustments to industrial practices, land use, migration, settlement, transportation and social, economic, and political organization. Modernization and globalization are interrelated, the latter enacted or operating at various spatial scales. It gives effect to increased and accelerated flows of financial and other transactions, capital, resources, goods and services, ideas, people, or communications. These flows are unevenly distributed, with varying consequences, both positive and negative.

Concerns about the harmful effects of modernization and globalization have given rise to diverse environmental values. Emphasis is sometimes placed on the intrinsic or essential worth of nature or the environment. Sometimes the instrumental or practical worth of such entities for human

needs and desires is stressed. On balance, however, whether environmental values arise from self-interest or selflessness, they prompt calls for nature or the environment to be better conserved and managed, given the growth and globalization of modernization's damaging effects. Among such effects are poverty, malnutrition and ill health, excessive consumption and the unfair distribution of goods and services, anthropogenic or human-induced climate change, and habitat and species loss. Such loss occurs across all habitat types at all latitudes and arises from inappropriate forms of urbanization, primary and secondary production, and other human activities and from the pollution of the environment by hazardous substances.

The Emergence of Sustainable Development and Neoliberalism

Sustainable development is one prominent response to such effects, gaining rapid authority in international governmental circles from the mid 1980s via work by the World Commission on Environment and Development (WCED). The WCED described sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs, stressing the crucial need to ease poverty and work within social and technological limits. The idea began to displace the established, if controversial, agenda that questioned unfettered economic growth (free market capitalism), and sought to promote local economic self-sufficiency and a steady-state approach. Among the chief advocates of such economic reform, the ecological economist Herman Daly suggested that the modern "evils of growthmania"—a prevailing attitude that there is no such thing as enough—cause social injustice, economic malfunction, and environmental harm.

Conversely, members of the WCED proposed that human development needs could be met *within* existing economic systems. This idea was entrenched via major United Nations conferences on environment and development, which gave rise to Agenda 21 in 1992 and Action 21 in 2002. Arthur Mol and David Sonnenfeld have suggested that these international events served to *codify* how changes to economic, social, and



environmental relations could be undertaken *inside* modernization and globalization processes.

The simultaneous rise of neoliberal forms of governance during the same period goes some way to explain the success of this codification and its use in government policy. Neoliberalism, like sustainable development, is informed by challenging questions about how to live that are linked to social, economic, and ecological values and systems. Neoliberalism includes a range of philosophical and practical developments of the traditional classical liberal agenda. Classical liberals argue that no other liberties are possible without a guarantee that benefits will flow from property and freedom of contract—hence their backing of laissez-faire capitalism and the unregulated exercise of choice in the marketplace. For social liberals, social equality is more important than economic freedom, and although the latter remains important to them, they argue that markets must meet the basic needs of all, including their social, political, and economic goals.

Neoliberalism has several variants, but these hold in common the following: fiscal restraint to create surplus budgets; free trade; privatization of publicly owned goods, services, and infrastructure; legal security for property rights; minimal government intervention; and deregulation of labor and financial markets and (by extension) of laws and rules for environmental management. Like sustainable development, neoliberalism has profoundly affected general understandings of the conception of society, the place of the citizen, and the role of government. Among these new understandings is the idea of responsible autonomy, that citizens are accountable, dependable, and conscientious, act in their own (enlightened) self-interest, and do not depend on government for their welfare.

Given its apparent accord with neoliberalism and its capacity to shore up “business as usual,” the rapidity with which sustainable development was mobilized in national and international systems of governance is not surprising; it has served, intentionally or otherwise, to protect vested interests and the status quo. While criticism of the concept has been trenchant, it remains remarkably resilient and continues to have widespread influence. Under the influence of neoliberalism, for some analysts sustainable development represents

the “greening” of modernization and has given rise to ecological modernization theory (EMT).

Ecological Modernization Theory

Much of the work on EMT originates from Germany, the Netherlands, and the United Kingdom, with empirical studies emanating from other parts of Europe and North America; Australians have also been instrumental in advancing significant work in the field. Chronological, national, and theoretical divergence is inherent to EMT, but there are several identifiable stages to it. Initially, EMT was championed by the two German sociologists, Joseph Huber and Martin Jänicke. Huber sought to justify a shift from sufficiency to efficiency and to explain how technological innovations could help environmental reform, particularly in industrial production, especially if the free market were enabled and bureaucratic strictures to its rationality removed. Jänicke’s early work, focused on environmental policy, also emphasized what Maarten Hajer later described as a *techno-corporatist* form of ecological modernization centered on industrial ecology and economic and technological efficiency.

Numerous critiques of such techno-corporatist works exist, many by those who had earlier promulgated ideas about sufficiency, by those otherwise deemed politically “red-green,” or by those seeking to refine EMT from the “inside.” Arthur Mol and Gert Spaargaren are among the last group, and they have argued that critiques of capitalism have been important in improving EMT, having generated at least three new insights. The first is that capitalism is responsive to environmental change. The second is that environmentally sound production and consumption are possible but require diverse and targeted environmental reforms. The last stems from an assertion that all chief alternatives to the existing economic order are infeasible and assumes the necessity of transforming free-market capitalism while protecting society’s sustenance base—sustainable development recast.

A second identifiable stage in EMT produced work focused more on the institutional and cultural dynamics of ecological modernization and on national and comparative studies of industrial production. Maarten Hajer has described this



stage as *reflexive* ecological modernization. His work, an early example of the empirical testing of ecological modernization through policy processes, maps a shift in EMT's focus *away from* understandings of nature as a free good and a sink for wastes and *toward* anticipatory techniques of environmental policy making, new roles for science in policy, and new legislative and regulatory frameworks emphasizing risk and uncertainty.

The Risk Society and Reflexive Modernization

Work theorizing the inherent risk of life, and of the uncertainty that typifies it, emerged at the same time as that on ecological modernization. Ulrich Beck was among the first to posit that ours is a risk society, involving a shift from modernization as the quest for wealth using industrialization to master external threats (often sourced in the environment) to modernization as a way to manage the inherent dangers of those very processes of industrialization. A consequence of this shift is that modern environmental risks are understood to be globally democratic insofar as the uncertain effects of threats such as climate change, pesticide residues, or epidemic diseases do not (fully) recognize class differences, and therefore, such differences are not able to explain the distribution of risk among the population.

Ulrich Beck later developed these ideas as reflexive modernization, in which some commentators now position ecological modernization. He argued that modernization actually and paradoxically dissolves the foundations of modern industrial society, a crucial point that highlights the inadequacy of the central institutions of that society to solve the ecological crisis using existing means; these institutions are, then, both flawed and incomplete. For scholars such as Maarten Hajer, who posits a new reflexive ecological modernization, the challenge now lies in finding new institutional arrangements and in correcting the bias that favors particular forms of economic and scientific knowledge and practice that have proven destructive and incapable of addressing such tendencies. This challenge is pressing.

Elaine Stratford

See also Ecological Footprint; Ecological Justice; Environmental Ethics; Externalities; Globalization; Modernity; Modernization Theory; Nature-Society Theory; Neoliberal Environmental Policy; Neoliberalism; Nonrenewable Resources; Political Economy of Resources; Population and Land Degradation; Population, Environment, and Development; Renewable Resources; Resource Economics; Sustainability Science; Sustainable Agriculture; Sustainable Cities; Sustainable Development; Sustainable Development Alternatives; Sustainable Fisheries; Sustainable Forestry; Sustainable Production

Further Readings

- Beck, U. (1992). *Risk society: Towards a new modernity* (M. Ritter, Trans.). London: Sage.
- Bridge, G. (2008). Environmental economic geography: A sympathetic critique. *Geoforum*, 39, 76–81.
- Buttel, F. H. (2000). Ecological modernization as social theory. *Geoforum*, 31, 57–65.
- Christoff, P. (1996). Ecological modernisation, ecological modernities. *Environmental Politics*, 5, 476–500.
- Daly, H. (1977). *The steady state economy: Toward a political economy of biophysical equilibrium and moral growth*. San Francisco: W. H. Freeman.
- Dryzek, J. (1997). *The politics of the Earth: Environmental discourses*. Oxford, UK: Oxford University Press.
- Hajer, M. (1995). *The politics of environmental discourse: Ecological modernisation and the policy process*. Oxford, UK: Clarendon Press.
- Harvey, D. (1989). *The condition of postmodernity*. Cambridge, MA: Blackwell.
- Huber, J. (2000). Towards industrial ecology: Sustainable development as a concept of ecological modernization. *Journal of Environmental Policy and Planning*, 2, 269–285.
- Jänicke, M., Mönch, H., Ranneberg, T., & Simonis, U. (1989). Economic structure and environmental impacts: East-west comparisons. *The Environmentalist*, 9, 171–183.
- Mol, A. P. J., & Sonnenfeld, D. A. (2000). Ecological modernisation around the world: An introduction. *Environmental Politics*, 9, 1–14.



- Mol, A. P. J., & Spaargaren, G. (2000). Ecological modernisation theory in debate: A review. *Environmental Politics*, 9, 17–49.
- Peck, J., & Tickell, A. (2002). Neoliberalizing space. *Antipode*, 34, 380–404.
- Redclift, M. (1984). *Development and the environmental crisis: Red or green alternatives?* London: Methuen.
- Sneddon, C., Howarth, R. B., & Norgaard, R. B. (2008). Sustainable development in a post-Brundtland world. *Ecological Economics*, 57, 253–268.
- Soyez, D., & Schulz, C. (2008). Facets of an emerging environmental economic geography (EEG). *Geoforum*, 39, 17–19.



ECOLOGICAL REGIMES

Ecological regimes can be defined as the way societies, institutions, or groups manage relations to their physical environment. This notion designates fields of activity, which are as such normatively regulated and which thereby determine relations between social and physical structures.

Regulating Society: Environment Relations

Since physical interventions in the world are often constitutive elements of actions, the coordination of actions or interactions incorporates physical aspects into social order at any scale. The regulation intends to establish or maintain specific environmental conditions. Ecological regimes thus constitute a realm of objects and related targets.

Typical examples of ecological regimes are the regulation of forestry, agriculture or other forms of land use; taking precautions against epidemics, floods, avalanches, and other natural hazards; energy policies; or the waste systems. Since literally everything may become involved in actions or interactions, there is no a priori limitation to the object realm of ecological regimes. However, the regulative targets determine what belongs to a regime or not. Insofar as ecological regimes are constituted by a normative coordination of actions, they resemble institutions. They may

encompass institutions as well as individual actions, though.

Toward an Integration of Social and Physical Structures

That people do not make their history under self-chosen conditions is obvious. What is controversial, however, is what ways and to what extent material nature and artifacts contribute to the constitution of society. In general, the social sciences, including human geography, obey the rule of explaining social facts by referring to other social facts and processes exclusively. The purpose of this methodological imperative is to ensure that research avoids any kind of physical determinism, such as environmental determinism, normative naturalism, or racism. However, approaches such as ecological economics, science and technology studies, environmental philosophy, actor-network theory, ecofeminism, or political ecology strive to integrate material elements into their conceptions of the social. In this context, the concept of ecological regimes offers an approach to study the interrelations between social and physical structures that avoids physical determinisms and does not make the social an absolute.

By producing and referring to physical facts, actions and interactions may link social conditions to physical conditions. Consequently, the latter may even steer social processes to some degree. If, for instance, an annual budget for road repairs depends on weather conditions, then physical conditions are allowed to determine that money is spent for certain purposes instead of others.

The concept of ecological regimes might play a key role in developing perspectives in social theory that stress the coevolution of “nature” and “culture.” In contrast to notions of hybridity, which tend to sweep the specific differences between human actors, animals, plants, and physical conditions generously away, analyses setting out from ecological regimes trace the integration of physical and social facts down to individual actions or interactions and their regulation.

There are related notions in use. Like Christoph Görg, several authors address the regulation of society-nature relations, and when referring to

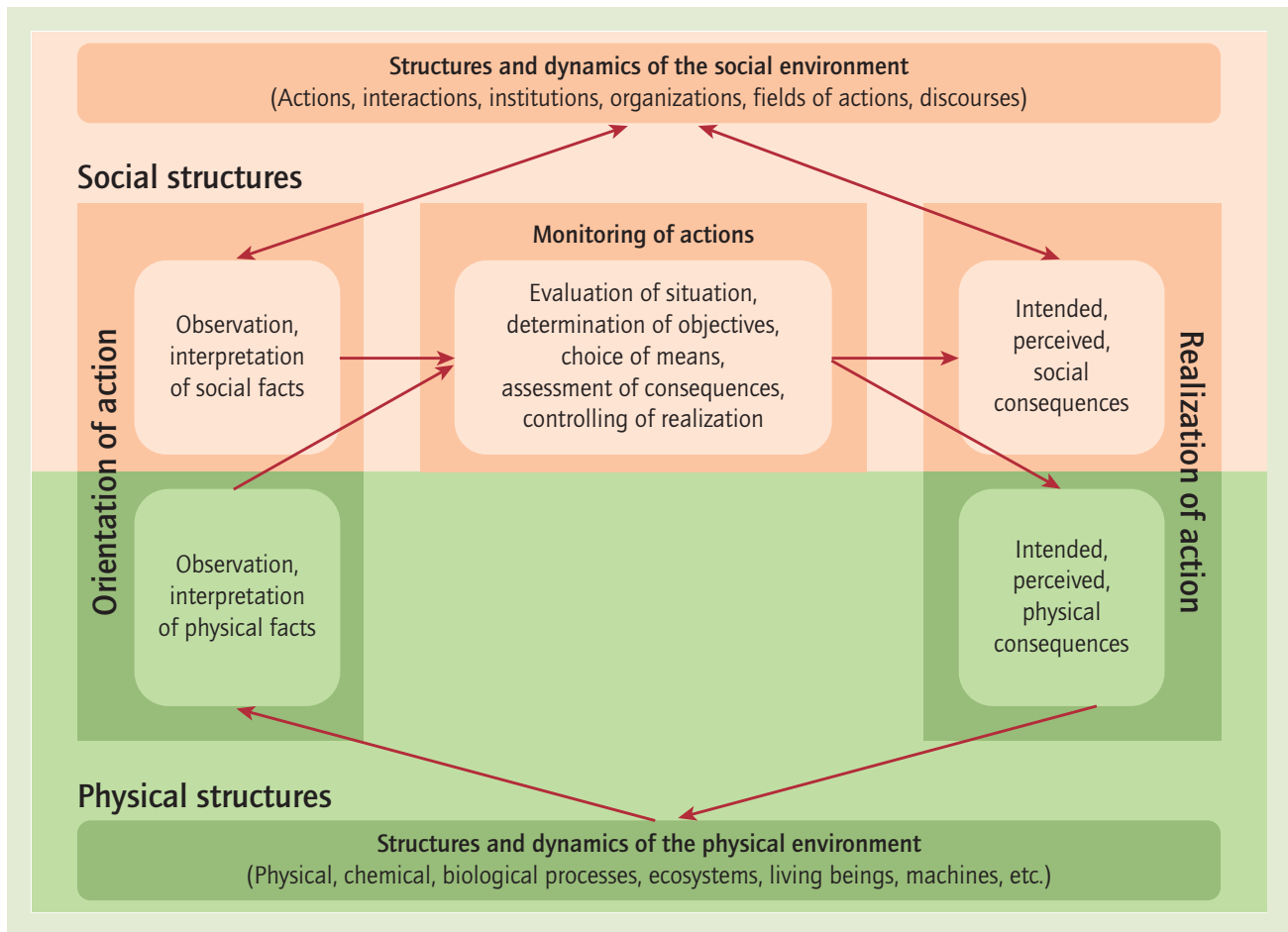


Figure 1 Actions establish relations to both the social and the physical sphere.

Source: Author.

the shift from wood to coal or oil as the primary energy resource, Marina Fischer-Kowalski and Rolf Peter Sieferle speak of different socio-ecological regimes. For geography, this concept offers not only possibilities to relate physical and human geography in novel ways but also an alternative to the often problematic use of “space” or “landscape” as concepts, which somehow should integrate material and social facts.

Empirical Analysis of Ecological Regimes

The empirical analysis of ecological regimes preferably sets out from the regulation of certain types of actions. Figure 1 illustrates how certain actions establish relations to the social and the physical spheres and thereby integrate material circumstances into social structures. The scheme may be

read as an abstraction of ecological regimes, and it may serve as a guideline for empirical analysis. In addition, Figure 2 illustrates how physical facts enter the coordination of actions. Unlike traditional social sciences, the concept of ecological regimes does not reduce the physical environment to a set of objects that play only a passive role within processes of social structuration. Rather, insofar as actions refer to and intervene into the physical sphere, physical facts become constitutive elements for actions and for the coordination of actions. Following Bruno Latour, one may conceive of interactions as an interplay of intersubjectivity and interobjectivity.

Like institutions, ecological regimes are reproduced or altered through discourses, which challenge or defend the legitimacy of the objectives and the means of regulation. As long as physical

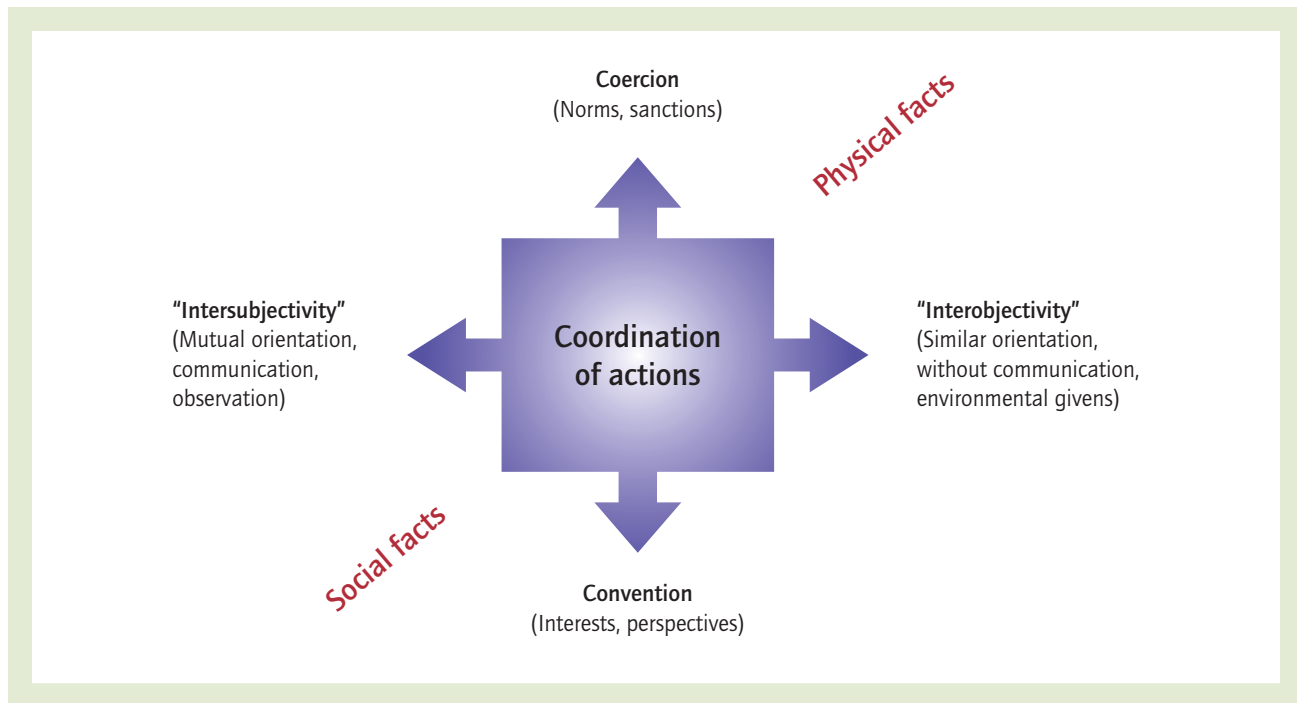


Figure 2 Physical facts play a constitutive role for actions and their coordination.

Source: Author.

conditions are not ignored, the empirical investigation of ecological regimes may also be carried out by discourse analyses.

Wolfgang Zierhofer

See also Actor-Network Theory; Coupled Human and Natural Systems; Ecological Footprint; Ecological Justice; Ecological Modernization; Environmental Ethics; Environmental Management; Human Ecology; Nature-Society Theory; Neoliberal Environmental Policy; Political Economy of Resources; Population and Land Degradation; Population, Environment, and Development; Sustainability Science; Sustainable Development; Sustainable Development Alternatives

Further Readings

Fischer-Kowalski, M., & Haberl, H. (2007). *Socioecological transitions and global change*. Cheltenham, UK: Edward Elgar.



ECOLOGICAL RISK ANALYSIS

Ecological risk analysis (ERA) is a method used to analyze and describe the environmental impacts of a project, program, or policy with the aim of parameterizing the cause-effects chain in a structured but overall simplistic way. In most applications, ERA is directly combined with environmental risk assessment (ERAS). In ERAS, the social dimension about the ecological value of the system parameters or indicators is added to the analysis in terms such as *good*, *bad*, *action needed*, *low*, *high*, and so on. The basis of the analysis is the best but incomplete and uncertain environmental information. The problem of missing knowledge and local information about the interactions in ecological systems and the different timescales of environmental systems must be solved by qualitative approximations and knowledge. ERA results only in assessments about the system behavior, and it is not suitable for the prognosis of landscape developments.

ERA is a method of impact analysis, for example, part of an ERAS procedure for usage in



environmental impact assessment (EIA) or strategic environmental assessment (SEA), and has been formalized by environmental impact directives issued by government agencies, especially in Europe and North America. Another type of ERA is applied to determine the impact analysis of different complex problems, for example, analysis of the risks of contaminated sites or wastes potentially affecting the environment and determination of remediation requirements. This entry includes discussion about the term *environmental risk*, describes the fields of application of ERA in environmental planning, introduces ERA tools and geographic information system (GIS) applications, and concludes with a discussion of further developments in ERA.

Environmental Risk

In ERA, the term *environmental risk* is defined as the degree of interferences of the natural resources caused by significant changes in a planned project. This risk definition differs from the usage of the term *risk* in decision theory, which focuses on probabilities of risks. An ERA application in planning normally results in assessment values of a risk index by aggregation of different aspects, parameters, or indicators (e.g., soil, water, climate, fauna, flora, human, culture, heritage, social and economical conditions and their interferences) of the environment. The main aspect is the differentiation between analysis or modeling and the valuation step. The analysis and modeling normally result in nominal, ordinal, or cardinal outcomes (e.g., a soil erosion risk does [not] exist, the soil erosion risk is in the class between 1 and 2 tons ha⁻¹ yr.⁻¹ [per hectare per year], or the soil erosion risk will be 11.5 tons ha⁻¹ yr.⁻¹). The assessment categorizes the results of the environmental analysis or modeling to a societal view of risk, for example, the result of an analysis of 11.5 tons soil erosion per hectare per year is compared with thresholds, norms, qualitative goals, or standards given by law or society by categorizing the cardinal measurements or modeling results into a class of high erosion risk. The categorization of the assessment into ordinal classes of risks is a standard application in environmental risk analysis.

Ecological Risk Analysis in Environmental Planning

ERA is used for different applications in practice. When focusing on sectoral approaches in agriculture, forestry, industry, tourism, or urban development, ERA applications use sectoral indicators sets (e.g., for the assessment of the sustainability of the land use of farms). When analyzing, for example, the impacts of a planned infrastructure project, a wide range of potential impacts on the environment is within the scope of the investigation.

The aim of ERA in planning is the evaluation or assessment of the suitability of a planned use change or use variants to locate a land use change in the best place. The operationalization of the technique can also be done if essential information is lacking by using proxies for the analysis of indicators or causal chains. The approach is based on three steps, by describing (1) the sensitivity of the landscape, (2) the intensity of the potential impacts of the planned land use, (3) and the impairment of landscape sensitivity as a result of the risks associated with the project.

ERA for a planned project to describe the sensitivity of the landscape is applied in several logical steps. The situation is analyzed first without the impacts of a project—that is, a baseline is estimated, which is a function of the sensitivity of the geographic area. The impacts on potential natural factors are then analyzed by using the knowledge of several disciplines about a single factor. The following descriptors are analyzed: the impacted natural factors; the services provided by the natural factors; the indication of their suitability for different land uses (ecological functions, goods, and services); and the ecological interdependencies in general, also by including the indication of their suitable usages and ecological interdependencies in a spatially explicit way for the area of the planned project. An additional step combines thresholds and the analysis with the resulting maps of sensitivity of the natural factors. The procedure is applied for each factor, and maps of classes of sensitivity are produced. A formal approach for the analysis might use a decision tree for each natural factor or a specialized and detailed modeling of the factors.



The intensity of the potential impact of the planned land use is analyzed as follows. The environmental impacts of the planned project are formalized by starting with a description of the planned land usages and an analysis of their impacts on the natural factors. Following this step, indicators are chosen to describe the impacts of a natural factor, which is generally followed by a spatially explicit description of the impacts by the indicators. Analysis of the intensity of the planned land use impairment results in a set of maps of the factors chosen in classes of impact intensity. Again, the formal approach for the analysis is the use of a decision tree for each natural factor or for specialized and detailed modeling of the factors.

The result of ERA is a determination of the impairment or sensitivity of the landscape based on impacts of the planned project in terms of risks of ecological impacts. For this purpose, steps of sensitivity analysis and impact analysis are merged with the help of a combination matrix when combining the maps that include the classes of sensitivity and the maps of impact intensity into classes of risk for each factor. In modern applications, ERA results in maps for each single factor. The resulting table of an ERA in EIA contains the project's impacts on the different factors included; a further aggregation, for example, into a figure representing the total impact of the project will not be done because of the difficulty in aggregating different factors into a commensurable sum or index. Decision makers in planning will understand the ERA results better if impacts of a project in the form of each single factor are demonstrated and, furthermore, a decision on the basis of an ERA is not predetermined by the ERA study. The decision will be made by competent authorities or by politics. Owing to the reasons mentioned above, ERA is the standard method for EIA applications and is often compared with "utility value analysis" methods. The latter method has been used recently only for analyses of very large and complex projects when different time steps are analyzed (e.g., to assess the impacts of an open-cast lignite mine, after which a lake is planned, and the impacts on groundwater that will result from changes during and after the project period).

Ecological Risk Analysis Tools and GIS Applications

The mapping, analysis, and modeling in ERA are done today using many different approaches, including geographic information systems (GIS). Only the main aspects of these applications are briefly described here because of the rapid progress in the availability of spatial data; the processing of new data, especially about climate change; and land use on the basis of remote sensing technologies. In early applications of ERA, GIS has been used only for the production of maps. Modern systems-oriented approaches of ERA use a multiplicity of digital data layers in the GIS, as an analysis tool, to model the sensitivities of the landscape and the project's impacts. Because of the diversity of landscapes, projects, and the projects' impacts, each ERA application will use a combination of suitable tools or models for each factor.

When digital data are publicly available, the scientific and pragmatic aspects of the methods should be applicable to analysis or modeling of the project's risk, which is the focus of interest of ERA. Several frameworks for ERA are available in practice (e.g., at the U.S. Environmental Protection Agency or the European Commission). In geography, several assessment models have been developed for single factors or combinations of factors. Examples include SWAT (Soil and Water Assessment Tool) and MULBO (Multicriteria Landscape Assessment and Optimisation) and tools for multicriteria landscape assessment and optimization. SWAT is a river basin-scale model developed to quantify the impact of land management practices in large, complex watersheds. The model is physically based and computationally efficient, uses readily available inputs, and enables users to study long-term impacts. MULBO offers an open and structured framework to analyze and assess the risk surfaces of landscape functions by GIS. The optimal distribution of land uses are modeled in MULBO on the basis of linear programming to find ideal compromises between multiple goals on the basis of landscape functions and project goals.

An increasing number of modules for applications are available for more detailed analysis. A new focus should be to calculate the data



uncertainties when using GIS-based approaches and when combining data from different sources. The intersections and unions of the data layers can sometimes result in misleading outcomes.

Further Developments

New developments in policy analysis and stakeholder participation open new fields of application for ERA. When widening the focus of EIA from the analysis of natural factors to a general analysis and assessment of sustainability, the spatially explicit assessment of social, cultural, or economic factors is focused on the needs of risk analysis. The recent development of sustainability impact assessment tools (SIAT) to forecast changes as a result of policy initiatives integrates social, economic, and ecological analysis. Examples have been developed for trade sustainability impact assessment by following the two main goals of integrating sustainability into trade negotiations and informing the public and other stakeholders as early as possible. A trade sustainability impact assessment is applied on the basis of a small number of indicators by using simple calculations of qualitative and quantitative statistics. Other examples of SIAT have been developed for sustainability impact assessments of land use changes on an indicators-based frame of land use functions when using a set of models for each indicator analysis. Another recent SIAT development is based on the combination and formal linkage of different models to develop and test a multiperspective set of economic, social, and environmental indicators of the sustainability and multifunctionality of systems, policies, and innovations in agriculture and agroforestry. When SIAT are used, ERA is developed further through a general sustainability analysis. New evaluation frameworks combine participatory tools, environmental appraisal tools, multicriteria analysis, monetary assessment tools, and scenario analysis on the basis of models and physical assessment tools.

Burghard C. Meyer

See also Environmental Impact Assessment; Environmental Planning; GIS in Environmental Management; Participatory Planning; Regional Environmental Planning; Risk Analysis and Assessment

Further Readings

- European Commission. (2009). *Strategic environmental assessment*. Retrieved July 1, 2009, from <http://ec.europa.eu/environment/eia/sea-legalcontext.htm>
- European Commission. (2009). *Trade issues: Sustainability impact assessment FAQ's*. Retrieved July 1, 2009, from <http://ec.europa.eu/trade/issues/global/sia/faqs.htm>
- Helming, K., Pérez-Soba, M., & Tabbush, P. (Eds.). (2008). *Sustainability impact assessment of land use changes*. Berlin, Germany: Springer.
- MULBO (Multikriterielles Landschaftsbewertungs- und Optimierungsverfahren; Multicriteria Landscape Assessment and Optimisation): www.mulbo.de
- National Center for Environmental Assessment, U.S. Environmental Protection Agency. (2009). *Guidelines for ecological risk assessment*. Retrieved July 1, 2009, from <http://cfpub.epa.gov/ncea/CFM/recorddisplay.cfm?deid=12460>
- SEAMLESS (System for Environmental and Agricultural Modelling: Linking European Science and Society): www.seamless-ip.org
- Soil & Water Assessment Tool: www.brc.tamus.edu/swat
- van Herwijnen, M., & de Ridder, W. (2007). The selection of suitable tools for sustainability impact assessment. In C. George & C. Kirkpatrick (Eds.), *Impact assessment and sustainable development: European practice and experience* (pp. 161–184). Cheltenham, UK: Edward Elgar.

ECOLOGICAL SERVICES

See Environmental Services

ECOLOGICAL ZONES

An ecological zone is a landscape unit that unites certain interrelated animal and plant communities (biocenosis) with a particular social formation and environmental conditions as part of an integrated system. The definition of an ecological



zone relies on flexible criteria. However, humidity and altitude are key factors in terrestrial systems, while salinity and depth are key factors for maritime and continental water environments. Temperature is one of the common elements that affect these environments. All these factors, together with territorial configuration, hydrologic regime, organic matter, mineral content, and isotopic composition of soil or water, define ecological zones and their buffer areas.

The notion of ecological zones can be associated with other landscape ecology concepts, such as ecotope, biome, and niche. An ecotope is a pure land unit of the lowest rank that is associated with a uniform or homogeneous landscape. On the other hand, niche is the species' or population's specialized role and function in an ecosystem and biome. Last, a biome is a land unit characterized by similar climatic and geographic conditions that correlates with specific plants and animal communities. Often biomes are defined by the characteristics of the most popular plants (e.g., trees define forests, grasses define grasslands). All these concepts follow the criteria of a hierarchical classification of landscape units.

An ecological zone has a broader geographic scope or scale than does an ecotope as it is not necessarily defined by a homogeneous landscape. On the other hand, unlike biomes, ecological zones take into account not only the living communities but also their geographical setting. Last, an ecological zone has a regional scale, making it a much broader concept than an ecological niche. Hence, an ecological zone is based on the concept of a whole functioning system from a historical perspective, giving less importance to biotic or abiotic factors alone. As the categories above note, an ecological zone becomes an important part of the landscape ecology terminology.

Andrés D. Izeta

See also **Biogeography**; **Ecoregions**; **Ecoshed**; **Ecosystems**; **Ecotone**; **Landscape Ecology**

Further Readings

Allaby, M. (2006). *Oxford dictionary of ecology* (3rd ed.). New York: Oxford University Press.

- Turner, M. G., Gardner, R. H., & O'Neill, R. V. (2003). *Landscape ecology in theory and practice: Pattern and process*. New York: Springer-Verlag.
- Wiens, J. A., Moss, M. R., Turner, M. G., & Mladenoff, D. J. (Eds.). (2006). *Foundation papers in landscape ecology*. New York: Columbia University Press.
- Zonneveld, I. S. (1989). The land unit: A fundamental concept in landscape ecology, and its applications. *Landscape Ecology*, 3, 67–86.



E-COMMERCE AND GEOGRAPHY

Electronic commerce (e-commerce) is generally defined to encompass any commercial activity that uses the transmission of electronic data to facilitate buying and selling. E-commerce therefore spans a wide variety of industries, not only those trading in tangible goods (as traditional brick-and-mortar storefronts do) but also those brokering the transfer of intangible ownership rights. It also uses a wide variety of technologies, ranging from the simple buying and selling of products using electronic mail to more complex inventory-tracking systems that automatically replenish stock based on sales. Over the past 10 years, e-commerce has become an integral part of business organization and economic strategy—accounting for more than \$3.3 trillion worth of transactions in the U.S. economy in 2007 (Census 2009). E-commerce is of particular relevance to the study of geography as it enables (though it does not guarantee) change in the spatial organization of the economy. This entry reviews how e-commerce can help overcome the frictions of geographical distance while operating as a centralizing force throughout the global economy.

E-Commerce and the “Death of Geographical Distance”

As e-commerce and other information technologies became more widely available, many observers predicted the “death of geographical distance,” a concept that gripped both the popular and the



policy imagination. The core supposition is that anyone anywhere can engage in the global market. This idea is based on the concept that electronic technologies remove the geographic barriers to entry that previously prohibited some people and some communities from full participation in economic activities. Indeed, some prognosticators have proposed that certain industries will cease to conduct sales at physical locations, removing the need for large sums of capital investment before starting business. These discourses are compelling because of their egalitarian promise, but they greatly oversimplify the complex relationship between distance, electronic technologies, and the economy.

Despite the rhetoric, bank branches and retail stores still operate, and would-be entrepreneurs still face many of the same barriers to entry. There are several reasons why online exchanges have not rendered physical locations completely obsolete. First, many economic activities rely on the knowledge embodied in skilled labor, capabilities that are most easily exchanged (and regulated by managers) over minimal physical distances (at least among today's workers). Second, Internet adoption rates vary widely throughout the world. In some countries, such as Sweden or Canada, more than 75% of the population has regular Internet access, while in other countries, such as India or Indonesia (not to mention sub-Saharan Africa), the rate is less than 10%.

Perhaps the most important reason why e-commerce and other information technologies are unlikely to eradicate geographical barriers is that moving physical products through e-commerce is not as easy as transferring data. For example, moving tangible products from one place to another imposes logistical costs that might favor centralized distribution to a large number of customers (e.g., through traditional storefronts) rather than decentralized distribution straight to each buyer. Similarly, consumers may feel more confidence when buying some products, such as clothing or appliances, if they can see and feel them before making a purchase. Although some products are available for instantaneous exchange and are sufficiently standardized for consumers to buy them remotely with confidence (e.g., music, video, or e-book downloads), these products are relatively few.

E-Commerce as a Centralizing Force

Although the death of distance has been overstated, e-commerce does help ameliorate the friction of distance—sometimes by directly replacing traditional sales channels but more importantly by operating in the background to make them proceed more efficiently. Many individuals engage in e-commerce, of course—either shopping directly through online retail stores or buying and selling items through intermediaries such as eBay or Amazon. These exchanges may be the most visible form of e-commerce, and they have experienced positive growth in many countries around the world, but they actually make up a rather minor portion of it. For example, retail transactions, also known as business-to-consumer (B2C) sales, account for only a quarter of e-commerce shipments in Canada and a negligible 3.2% of total retail sales in the United States.

The bulk of e-commerce activities are concentrated in the manufacturing and wholesale sectors—which is to say business-to-business (B2B) sales. E-commerce can make it easier for businesses to overcome the friction created by physical distance. It provides a cheaper means of communication with workers, suppliers, and customers located in various places around the world. For example, when a customer buys an item from Walmart, the product supplier (who may be located on the other side of the world) immediately receives notification of the point-of-sale purchase and can begin processing a new shipment for that particular store. Although this is a vast oversimplification of an extremely complex supply and distribution chain, by changing the organization and geography of their distribution network, companies such as Wal-Mart successfully blend e-commerce with the physical movement of goods.

The use of e-commerce is not limited to large multinational corporations. Small- and medium-sized enterprises around the world have also adopted e-commerce activities. In Thailand, for example, silk merchants used e-commerce to widen their distribution channels, attract new customers, and facilitate more seamless transactions with existing customers. However, the integration of e-commerce activities among smaller businesses does not tend to be as expansive as it is



among larger corporations, primarily due to the financial costs.

E-commerce is undoubtedly changing the spatial economy, but geography is still an important and relevant factor in economic exchanges.

Candice Wallace

See also **Business Geography; Cyberspace; Digital Divide; Telecommunications and Geography**

Further Readings

- Graham, M. (2008). Warped geographies of development: The Internet and theories of economic development. *Geography Compass*, 2(3), 771–789.
- Leinbach, T., & Brunn, S. (Eds.). (2001). *The worlds of e-commerce: Economic, geographical, and social dimensions*. Chichester, UK: Wiley.
- Malecki, E., & Moriset, B. (2008). *The digital economy*. London: Routledge.
- U.S. Census Bureau. (2009, May 28). *E-stats*. Washington, DC: U.S. Department of Commerce Economics and Statistics Administration. Retrieved January 25, 2010, from www.census.gov/econ/estats/2007/2007reportfinal.pdf
- Zook, M. (2005). *The geography of the Internet industry: Venture capital, dot-coms, and local knowledge*. Oxford, UK: Blackwell.

such that any change in the basic sector produces changes in the nonbasic sector sufficient to restore their proportional relationship. The relationship, or linkage, between the two sectors takes two forms. First, the nonbasic sector is assumed to supply the basic sector with many of the goods and services it needs to produce its exports. Second, workers in the basic sector demand a variety of residential goods and services (e.g., groceries, dry cleaning, utilities) that the nonbasic sector supplies. None of these residential goods and services would exist, according to the theory, in the absence of the basic sector.

The economic base model seeks to quantify the relationship between the basic (B) and nonbasic (NB) sectors that constitute the total economy (T). Typically expressed in terms of employment or earnings, the simplest economic base model is expressed as

$$T = B + NB. \quad (1)$$

Assuming a stable relationship in the basic-nonbasic ratio, nonbasic activity is proportionately related to total activity, or

$$NB = aT. \quad (2)$$

Substituting (2) into (1) and rearranging yields

$$T = [1/(1 - a)]B, \quad (3)$$

where a is the propensity to spend locally. The term $[1/(1 - a)]$, equal to T/B , is called the economic base impact multiplier. While the basic-nonbasic relationship is theorized to be stable over time, it is not assumed to be the same across all regions.

Typically, the economic base model is used for economic impact analysis. Suppose, for example, that a region successfully attracts a new manufacturing plant that will employ 300 people and sell to national markets. Furthermore, suppose the regional impact multiplier to be 1.75. With sufficient excess capacity, the total impact on the region would be $(300 \times 1.75) = 525$ jobs, that is, 300 jobs in the basic sector and 225 jobs in the supporting nonbasic sector.

A critical step in economic base analysis involves dividing the regional economy into basic

ECONOMIC BASE ANALYSIS

Economic base analysis is a mainstay in economic geography and regional development. It stems from a simple theory of regional economic growth: that the growth of cities and regions is tied to their success in exporting goods and services beyond their borders.

Economic base analysis is a demand-driven theory that divides the regional economy into two sectors: a “basic” sector that fulfills demand originating from outside the region and a “nonbasic” sector that satisfies demand from within the region. The theory posits a strong and stable relationship between the basic and nonbasic sectors



and nonbasic sectors, a process called bifurcation. The four most commonly discussed methods for identifying exports are assignment, surveys of local businesses, the location quotient method, and the minimum requirements approach. There are also several variations and hybrid approaches.

The assignment method simply relies on the analyst's judgment about which sectors, or portions thereof, serve external markets. It is common for federal government, agriculture, mining, and manufacturing to be assigned to the basic sector since activity in these sectors is usually exogenous to the region, especially in small or rural areas. Though there is no theoretical basis for the assignment method, a knowledgeable analyst might produce a reasonably accurate description of the region's economic base. At the other end of the spectrum is a complete survey of businesses in the area to determine what portion of their output is sold to customers residing outside the region. Because complete surveys are costly, partial surveys are sometimes used to inform the assignment method.

Location quotients are probably the most common technique used to identify export activity. A location quotient is a measure of relative concentration. It compares the proportion of activity in each regional industry to the proportions found in a reference region, usually the nation. If a region's proportion of employment in, say, construction is greater than the national average, the excess is assumed to be exported. Using employment as the numéraire, location quotients are calculated as

$$LQ_{ir} = \frac{E_{ir}/E_r}{E_{in}/E_n}, \quad (4)$$

where i , r , and n refer to the industry, region, and nation, respectively. For all LQ_{ir} greater than 1, export employment, X_{ir} , is determined by

$$X_{ir} = \left[1 - \left(\frac{1}{LQ_{ir}} \right) \right] E_{ir}, \quad \forall LQ_{ir} > 1. \quad (5)$$

Adding all the X_{ir} terms together produces an estimate of the basic sector, or

$$B = \sum X_{ir}. \quad (6)$$

Location quotients require several assumptions:

1. Labor productivity in the region and that in the nation are equal.
2. Regional and national consumption patterns are identical.
3. There is no cross-hauling (i.e., the region does not import and export the same commodities).
4. The nation is not a net exporter.

Of the four, the cross-hauling assumption is the most problematic. Cross-hauling is commonplace, and in its presence, the location quotient provides an estimate of net exports rather than gross exports, which is desired. In such cases, the size of the basic sector will be underestimated and the resulting impact multiplier inflated.

The minimum-requirements approach is a variation of the location quotient method but uses similar-sized regions as the basis for comparison. On an industry-by-industry basis, the analyst finds the smallest proportion of activity in each sector within the set of comparison areas. The smallest proportion is thought to represent the minimum level of production required to satisfy local demand. The remainder is assumed to be exported.

Empirically, the economic base model is sensitive to aggregation, both industrial and geographic. The most reliable results are obtained for relatively small regions using the most detailed industry data available. Furthermore, the basic-nonbasic relationship is not stable over time, and so the model should not be used for long-run projections. Perhaps the greatest shortcoming of economic base analysis is its focus on exports as the sole source of growth, ignoring the roles of consumption, investment, and government spending as sources of demand.

In spite of its shortcomings, economic base analysis remains heuristically useful for students and practitioners, offering a simple growth model that can be readily extended to incorporate additional relevant variables. Furthermore, advances in spatial data analysis and spatial econometrics may breathe new life into the simple model.

Harrison S. Campbell Jr.



See also **Comparative Advantage; Economic Geography; Export-Led Development; Growth Poles; Input-Output Models; Location Quotients; Location Theory; Regional Economic Development**

Further Readings

- Biles, J. (2003). Using spatial econometric techniques to estimate spatial multipliers. *Review of Regional Studies*, 33, 121–141.
- Isserman, A. (1980). Alternative economic base bifurcation techniques: Theory, implementation, and results. In S. Pleeter (Ed.), *Economic impact analysis: Methodology and applications* (pp. 32–53). Boston: Martinus Nijhoff.
- Krikelas, A. (1992, July/August). Why regions grow: A review of research on the economic base model. *Economic Review*, pp. 16–29.
- Lesage, J., & Reed, D. (1989). The dynamic relationship between export, local and total area employment. *Regional Science and Urban Economics*, 19, 615–636.
- North, D. (1955). Location theory and regional economic growth. *Journal of Political Economy*, 63, 243–258.
- Tiebout, C. (1956). Exports and regional economic growth. *Journal of Political Economy*, 64, 160–164.



ECONOMIC GEOGRAPHY

Economic geography is one of the most diverse, vibrant, and catalytic subdisciplines within human geography. It is concerned with describing and explaining the varied places and spaces in which economic activities are carried out and circulate. It was institutionalized as a subdiscipline during the late 19th century in both Western Europe and the United States. Initially connected to projects of empire (especially in its earliest form, commercial geography), economic geography has since been through a series of intellectual transformations, including a regional approach, spatial science, radical political economy, and, most recently, a “cultural turn.” Each new framework, however, has rarely eradicated the previous one. Rather, economic geography is more like a

palimpsest, with previous versions and approaches to the discipline continuing to remain at least partially visible in present incarnations. The contemporary version of the discipline is now highly variegated, with research conducted on a wide front and reflecting the changing and expansive character of what has increasingly become its object of study, global capitalism.

History

Existing in embryonic form as commercial geography, the discipline was formally defined in 1882 by the German geographer Götz. While commercial geography served immediate practical purposes, the goal of economic geography was loftier. It was to be a science, to explain how the character of different geographical areas influenced the production and movement of goods. By the 1890s, economic geography courses appeared in U.S. and British university calendars. In 1896, George Chisholm began lecturing at Birkbeck College, London, using his own economic geography text, *Handbook of Commercial Geography*, the first ever written in English. And in 1903, Lionel Lyde, at University College London, was appointed the first professor of economic geography. The discipline was up and running.

Chisholm’s book (published in 20 editions) and J. Russell Smith’s later American version, *Industrial and Commercial Geography*, set out an initial disciplinary agenda and intellectual style that continues to resonate. The original colonial context of the two books no longer applies, but remaining germane are their concerns with empirical detail and numbers, their predilection for geographical categorization made visible by the map, and their tracing of relations among places through economic flows, especially commodity flows.

Chisholm and Smith stressed the physical character of goods, particularly those of natural resources, with spatial relations or physical location coming second. The American geographer Ray Whitbeck argued it should be the other way around: The emphasis should be on the country, not the commodity. That increasingly became the case, at least in U.S. economic geography after World War I, when a regional approach took hold. Regions were portrayed as unique and obvious once the descriptive typologies used to pigeonhole



different regions' economic facts were compared. The only interesting question was which typology to deploy. Whitbeck and Finch's 1924 textbook used a typology with four categories, while Clarence Fielden Jones's 1935 economic geography primer daringly deployed eight.

Richard Hartshorne's *The Nature of Geography*, published in 1939, provided at least a splash of scholarly respectability to economic geography's idiographic regional approach by drawing on a set of earlier German philosophers and geographers. But it did nothing to prepare the discipline for what was about to occur after World War II, especially in the United States, as a number of social sciences, and even some humanities, began modeling themselves on the hard sciences, drawing on formal statistical methods and abstract reasoning. Economic geography initially resisted that impulse, but by the mid 1950s it too joined the others. The resulting "quantitative revolution" profoundly altered the discipline, bringing the systematic application of scientific forms of theorizing and rigorous statistical techniques of description and analysis.

The discipline over the period 1955–1975, sometimes labeled spatial science, was defined by the following:

1. Formal theory and models, many borrowed or stolen from neoclassical economics (rational choice theory, general and partial equilibrium, location theory) and physics (spatial interaction and, later, entropy maximization models)
2. Quantitative methods, which were initially imported from inferential statistics but later designed in-house to meet the peculiar features of economic geographical data (e.g., spatial autocorrelation models)
3. The use of computers, at first very crude and limited, but within a decade performing hitherto unimaginable calculations for instrumental purposes, for example, inverting large regional planning input-output matrices that would otherwise have taken a lifetime to calculate
4. A philosophical justification based on some form of positivist philosophy, the idea that only scientific knowledge is authentic knowledge
5. A focus on abstract spatialities and a geometrically defined location

Regions remained part of the economic geographical lexicon but were conceived utterly differently—as explanatory, theoretical, and instrumental, spatial units to achieve functional objectives, not to be “merely” described. Clarence Fielden Jones and his eightfold typological scheme for classifying regions were no longer recognizable as part of the discipline.

This often abstract, closed, and narrowly conceived discipline did not last. It was out of sync with economic geography's own history and, by the late 1960s, increasingly out of sync with its wider historical moment. Radical geography emerged during the early 1970s, propelling economic geography in a different direction. David Harvey's classical Marxist theorizing of capitalist accumulation and crisis was important, but even more so was Doreen Massey's work on industrial restructuring, underpinned philosophically by critical realism and culminating in the locality project that dominated British economic geography during the late 1980s. Across the Atlantic, a group of radical economic geographers in California carried out important empirical and theoretical work, not on cases of industrial capitalism's decline (much of the focus of the locality project was a deindustrializing Britain) but on its successes, such as high-tech industries in places such as Silicon Valley and Orange County outside Los Angeles. British and American interests merged in the late 1980s, producing discussions around the transformation of an old, disintegrating Fordism, defined by assembly-line techniques and the mass production of a standardized product, into a new, emerging post-Fordism, defined by flexible workers and machines engaged in batch production of differentiated products. Heavily influenced theoretically by French regulation theory, which was more open-ended, less abstract, and deterministic than classical Marxism, the economy remained central, but it was softened at the edges by recognition of the social institutions, and even culture, in which it was embedded.

Culture and *embeddedness* soon became keywords of the “cultural turn” entering economic geography from the mid 1990s. Often drawing on poststructural theory, there was an attempt to rethink both the larger nature of the discipline—its empiricist epistemology, its entrenched masculinism, its narrow methods, and its economicist



logic—as well as particular substantive topics such as labor and work, financial and business services, consumption and retailing, and the firm. Proponents argued that this turn was not simply intellectual fashion but a reflection of fundamental changes occurring within capitalism itself as it moved to a “soft,” “reflexive,” or “symbolic” form where the line between culture and economy was not just hard to see but was no longer there.

The cultural turn is far from dominant, however, and already criticisms have been mounted, often with alternatives or versions of old alternatives proposed. In truth, there is no received view, orthodoxy, or standard paradigm within economic geography. But while there is no single leading approach, or maybe *because* there is no leading approach, the discipline is marked by vibrancy, experimentation, and fecundity, as is evident in several areas of contemporary substantive research.

Globalization and Neoliberalism

Perhaps no research topics in contemporary economic geography are more energetically pursued than globalization and neoliberalism. The two are not necessarily connected, but over the past decade, they were often twinned. In many ways, globalization was made for economic geographical study and seen in the very first texts of the discipline, those by Chisholm and Smith. By the 1920s, however, this focus weakened. It was not until 60 years later, with the emergence of a new international division of labor, the increasing number, size, and dominance of multinational corporations, the growth of international financial capital, and new forms of communication and long-distance transportation, that economic geographers began again to deal systematically with the world as a whole. Peter Dicken, in his 1988 book *Global Shift* (2007 marked its fifth edition), was the first contemporary economic geographer to do so. One of his critical points, corroborated in subsequent economic geographical studies, is that globalization does not seamlessly eradicate geographical difference. Rather than “the end of geography,” as some economists maintain, processes of globalization show only geography’s continuing importance. Geographical differentiation is the very precondition for

globalization’s possibility and achievement. In tandem with discussions of globalization has also gone a critical examination of neoliberalism, the political ideological project of promoting free markets as the optimal means for undertaking economic activity. While originating as an idea in the 1920s, it began to be practiced politically during only the 1980s. Neoliberalism’s central injunction is that places where free markets either do not exist or are insufficiently free must be transformed to meet neoliberal strictures. This means enacting policies such as trade and financial market liberalization, deregulation, privatization, and the securing of private property rights. The global consequences of neoliberal (de)regulation have been critically examined by economic geographers in studies of international finance, the internationalization of education, the international migration of skilled labor, and international trade in primary resources including diamonds, lumber, and water.

The Firm and Finance

Understanding why firms locate where they do and how companies organize economic space has long been a key theme of the subdiscipline, mostly associated with location theory. The traditional approach was based on individual case studies listing specific factors influencing firm location. But with spatial science, some economic geographers turned to complex mathematical equations. The firm was represented as an unproblematic entity working according to the laws of the market or a mathematical node in geometric space. Even during this approach, however, another school of thought developed, the geography of enterprise, concerned with treating the firm as an institution embedded in its social and cultural context. Later expanded under the cultural turn, the aim was to open up the firm to understand what goes on inside. Important themes of study include analysis of the firm’s varied production and knowledge networks (and now increasingly internationalized), the connections between firms and regional development, gender relations within the workplace, and finally the cultures of company business strategy. Connected to scholarship about the firm is also the study of finance. Finance geographies investigate the relationships between



space, place, and money, focusing on topics such as the restructuring of the financial services industry and the continued dominance of international financial centers such as New York City, London, and Tokyo. Also analyzed are offshore financial centers, such as the Cayman Islands, and their role in economic development.

Nature and Environment

While the interests of economic geographers in nature start with Chisholm's and Smith's first textbooks, the contemporary interest in the topic likely dates from David Harvey and his work in the early 1970s. He was concerned to set nature within the larger context of capitalism (an approach further developed by his student Neil Smith). Current research includes studies of particular natural resources, such as water, forests, agricultural crops, and minerals, often stressing social justice and analyzing which groups of people control, access, exploit, or benefit from the transformation of nature for economic purposes. Furthermore, the recent move in the West to "go green" has spawned new trends of research around the environmental impacts of economic activity. Economic geographers are examining topics such as environmentally conscious consumers, green supply chains such as the fair-trade movement or organic farming, carbon finance or carbon taxes levied by governments, and environmental governance. Together, research agendas on both nature and the environment connect small-scale economic activity, such as the purchase of a commodity, to larger global issues such as climate change or land degradation (and link the pursuit also to political ecology).

Transportation and Communication

Transportation and communication is again a topic found in the earliest textbooks of the subdiscipline. Later, under spatial science, transportation and communication studies became effectively a branch of mathematics, topology. But even then broad questions were still asked about the relation of different forms of transportation and communication and geographical patterns of economic activity on the ground.

Revolutions in transportation and communication technologies since World War II have provoked the thesis of a shrinking world, or "time-space collapse." With respect to transportation, container traffic, new, larger, and faster cargo vessels, and air cargo have been critical innovations, dramatically changing the geography of global competitive advantage. Hand in hand have also gone changes in communication modes, facilitated by computerization: e-mails, fax machines, pagers, blackberries, cell phones, and more. They have fundamentally altered business and its geography, transfiguring financial operations and flows of information and capital and permitting head offices to be half a world away from production facilities. The result is myriad new commercial products and services.

High-Tech and Creative Economies

Economic geographers have noted that the economic growth of the 1980s and 1990s, particularly around creative industries (such as film and fashion) and high-tech industries, resulted in new spatial dynamics on the economic landscape, especially in North America. Rather than being dominated by large corporations, these industries thrived on decentralized business systems and flexible production networks that tended to cluster in certain places, for example, Silicon Valley, outside San Francisco, and Route 128, on the outskirts of Boston. Explaining such agglomerations of high-tech and creative industries has involved partly going back to an older conceptual framework of industrial districts. Industrial districts were specific areas within a city associated with a tight-knit assemblage of small firms involved in the manufacturing of the same product. Contemporary high-tech and creative industry agglomerations follow a similar pattern. Firms within them tend to be small or medium sized and closely linked (networked) with other firms in the cluster both formally and informally. Richard Florida expands this idea in his work on creative industries by relating such clusters to particular districts within the city that are defined by a specific workforce, the young and well educated. He argues that creative industry workers,



or the “creative class,” are drawn to edgy, diverse, gentrifying neighborhoods, which in North America primarily means the inner city. Hence, creative industries now predominately locate according to the residential patterns of the gentrifying creative class.

Labor and Work

Until recently, labor and work were given little attention in economic geography. While workers are a necessary input to production, they were viewed as passive and hence not very interesting. That has changed partly because one of the effects of globalization has been to mobilize labor in radically different ways. Economic geographers now study both ends of an internationally mobile labor market. On the one hand, they are concerned with (literally) high-flying professionals, such as accountants, bankers, and CEOs, who work in large multinational corporations and, on the other hand, with immigrants working in low-end jobs, as janitors, in back-of-the-house hotel positions, and in sweatshops. Both types of labor come together in world cities but in radically different spaces. A second spur to the study of labor in economic geography has come from feminism. In the late 1960s, spatial science showed that women in Western countries faced different geographical labor markets and consequences (especially in commuting). Doreen Massey’s political economy went further, demonstrating that the gendered character of labor markets was central to understanding the fundamental industrial restructuring occurring during the late 1970s and early 1980s. Furthermore, under the cultural turn, a new focus on the body as an important agent in production processes has produced a substantial literature. Its larger point is that labor and work are not neutral, merely a technical input into production, but instead are corporeally inscribed by the social, cultural, and geographical contexts in which work is practiced.

Conclusion

The immense range of economic geography is clearly marked by the diversity of these core areas. They capture many of the dynamic and vast shifts occurring in contemporary economic space,

particularly as they connect to global capitalism. Such an open-ended approach to scholarship makes the discipline inclusive toward a variety of researchers, methodologies, and topics of study and often an exciting place to be. However, others suggest that the very diversity that gives economic geography its vibrancy is producing a subdiscipline without a central core. In some cases, the works of some scholars are incomprehensible to others in the community. The future challenge for economic geographers will be to continue to keep pace and navigate the inevitable shifts in economic space while maintaining a common ground on which to speak to and learn from each other.

Trevor J. Barnes and Jayme Walenta

See also Agriculture, Industrialized; Business Cycles and Geography; Class, Geography and; Clusters; Colonialism; Commodity Chains; Comparative Advantage; Consumption, Geographies of; Debt and Debt Crisis; Deindustrialization; Dependency Theory; Development Theory; Division of Labor; Ecological Economics; E-Commerce and Geography; Economic Base Analysis; Export-Led Development; Finance, Geography of; Flexible Production; Fordism; Globalization; Growth Poles; High Technology; Import Substitution Industrialization; Industrial Districts; Industrialization; Industrial Revolution; Informal Economy; Information Society; Innovation, Geography of; International Monetary Fund; Knowledge, Geography of; Labor, Geography of; Location Theory; Marxism, Geography and; Modernization Theory; Money, Geographies of; Neocolonialism; Neoliberalism; New International Division of Labor; Newly Industrializing Countries; Offshore Finance; Political Economy; Population, Environment, and Development; Ports and Maritime Trade; Postindustrial Society; Poverty; Producer Services; Regional Economic Development; Regional Science; Research and Development, Geographies of; Resource Economics; Resource Geography; Restructuring; Retail Trade, Geography of; Rural Development; Structural Adjustment; Sustainable Development; Technological Change, Geography of; Telecommunications and Geography; Transnational Corporation; Transportation Geography; Underdevelopment; Uneven Development; Urban and Regional Development; Urban Geography; Urbanization; World Bank; World-Systems Theory



Further Readings

- Barnes, T. (2001). "In the beginning was economic geography"—A science studies approach to disciplinary history. *Progress in Human Geography*, 25, 521–544.
- Chisholm, G. G. (1889). *Handbook of commercial geography*. London: Longman.
- Cooke, P. (1989). *Localities: The changing face of urban Britain*. London: Unwin Hyman.
- Corbridge, S., Martin, R., & Thrift, N. (Eds.). (1994). *Money, power and space*. Oxford, UK: Blackwell.
- Dicken, P. (1988). *Global shift: Industrial change in a turbulent world*. London: Paul Chapman.
- Florida, R. (2002). *The rise of the creative class: And how it's transforming work, leisure, community and everyday life*. New York: Basic Books.
- Harvey, D. (1974). Population, resources and the ideology of science. *Economic Geography*, 50, 256–277.
- Harvey, D. (1982). *Limits to capital*. Chicago: University of Chicago Press.
- Leinbach, T., & Capineri, C. (Eds.). (2007). *Globalized freight transportation: Intermodality, e-commerce, logistics and sustainability*. Cheltenham, UK: Edward Elgar.
- Massey, D. (1984). *Spatial divisions of labour*. London: Macmillan.
- McDowell, L. (1997). *Capital culture: Gender at work in the city*. Oxford, UK: Blackwell.
- Peck, J., & Tickell, A. (2002). Neoliberalizing space. *Antipode*, 34, 380–404.
- Pratt, G. (2004). *Working feminism*. Edinburgh, UK: University of Edinburgh Press.
- Saxenian, A. (1994). *Regional advantage: Culture and competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
- Schoenberger, E. (1997). *The cultural crisis of the firm*. Oxford, UK: Blackwell.
- Scott, A. J. (1988). *Metropolis: From the division of labor to urban form*. Berkeley: University of California Press.
- Smith, J. R. (1913). *Industrial and commercial geography*. New York: Henry Holt.
- Smith, N. (1984). *Uneven development: Nature, capital and the production of space*. Oxford, UK: Blackwell.
- Storper, M. (1997). *The regional world: Territorial development in a global economy*. New York: Guilford Press.

- Stutz, F., & Warf, B. (2010). *The world economy: Resources, location, trade, and development* (6th ed.). Englewood Cliffs, NJ: Prentice Hall.
- Tickell, A., & Peck, J. (1992). Accumulation, regulation and the geographies of post-Fordism: Missing links in regulationist research. *Progress in Human Geography*, 16, 190–218.
- Walker, R., & Storper, M. (1989). *The capitalist imperative: Territory, technology, and industrial growth*. Oxford, UK: Blackwell.



ECONOMIES OF SCALE

Economies of scale refer to the reductions in cost that firms achieve by producing in larger rather than smaller volumes of output. "Economies" in the context refers to the benefits incurred by reducing costs, largely by spreading fixed costs over a greater quantity of output.

Mass production occurs through the standardization of parts and a detailed division of labor. Specialized divisions of labor, however, require a relatively large scale of output because a large pool of workers is generally necessary. Scale economies operate when increases in factor inputs generate disproportionately larger increases in output or, in more technical terms, the production function is not linear. For example, if a firm increases its inputs of labor and capital by 20% but sees its output rise by 30%, it enjoys economies of scale. Thus, they represent the opposite of diminishing returns in the production process.

Economists portray scale economies as a curve of long-run average costs (Figure 1), which graphs the unit costs as a function of scale of output. As unit costs decrease, they reach an optimum point and ultimately began to increase, reflecting the diseconomies of scale (diminishing marginal returns to scale) that occur when a firm becomes too large to manage and operate efficiently.

Economies of scale tend to favor the formation of larger firms and hence relatively oligopolistic market structures (those dominated by a few giant companies). Large firms generally pay much less for material inputs than do small firms because they buy in bulk and often enjoy economies of scale in transportation as well as in the production process. The presence of economies of scale varies

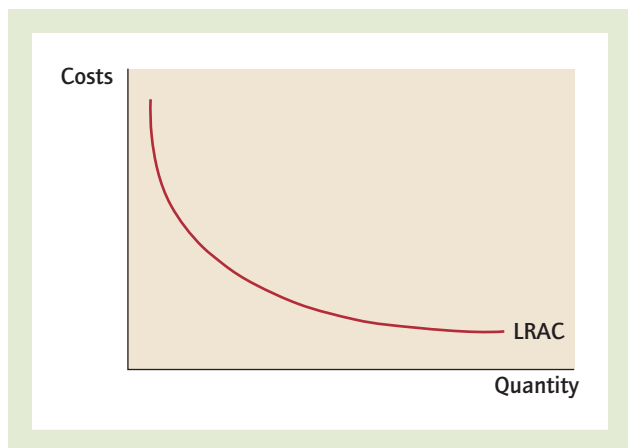


Figure 1 Economies of scale lower long-run average costs as output increases by spreading the fixed costs over a larger volume of goods.

Source: Author.

widely among firms and industries. It is indisputable in sectors such as industrial agriculture and capital-intensive forms of manufacturing, such as steel and automobiles. The degree to which services, with intangible outputs, enjoy economies of scale is less clear.

Economic scale is closely intertwined with geographic location. Indeed, the choice of location cannot be considered in isolation from scale and production technique. Different scales of operation may require different locations to give access to markets of different sizes. Conversely, location itself can influence the combination of inputs and, hence, the technique adopted. Economies of scale tend to favor a select group of geographic locations over dispersed production patterns.

Barney Warf

See also **Agglomeration Economies; Economic Geography; Economies of Scope; Location Theory**

Further Readings

- Krugman, P. (1992). *Geography and trade*. Cambridge: MIT Press.
- Stutz, F., & Warf, B. (2010). *The world economy: Resources, location, trade, and development* (6th ed.). Upper Saddle River, NJ: Prentice Hall.



ECONOMIES OF SCOPE

The term *economies of scope* refers to the economies, or benefits, that firms derive by producing particular combinations of output. These exist if one firm can produce two separate products more efficiently than two firms can independently produce them separately. Economies of scope resemble economies of scale but operate in a different manner. Whereas economies of scale refer to the lower costs involved in producing larger quantities of a single type of good, economies of scope refer to the benefits generated from producing a mix of goods and are thus common in multiproduct firms. These arise essentially because a firm can use a given stock of factor inputs to generate a variety of related or complementary outputs. Average costs decline due to the *mix* of output between two or more products. Thus, economies of scope refer to the potential costs savings that result from the joint production of products not directly related to one another. If a firm can produce multiple goods and services more efficiently than several firms could produce them independently, then it enjoys economies of scope. Otherwise, it suffers from diseconomies of scope (increases in price that accompany the production of different goods).

For example, a fast-food franchise may produce two types of foods more quickly than it could produce each in isolation, largely by using the same storage and preparation facilities. Or a firm's administration and management may carry out services necessary to the production of a variety of different goods, including research, marketing, and financing. Economies of scope are common in the learning process when the knowledge and experience gained in the production or sale of one good are useful in the production and sale of other goods. One warehouse may be used to store a range of products. The salaries and transportation costs of a sales force may be used effectively to sell a variety of different goods or services. Or a publishing firm may realize cost savings by using staff to write content for more than one magazine. These benefits are



frequently found in marketing and distribution, where they underscore strategies such as product bundling.

Economies of scope also occur when there are cost savings generated by the production of by-products, when the production of one good automatically triggers the production of another. For example, a beef producer may also generate leather, and a lumber company may also create sawdust.

Potential economies of scope underlie the mergers, acquisitions, and takeovers of firms seeking to diversify into new product lines and markets. In this case, the attraction is the ability to reduce costs by operating two or more businesses under the same corporate umbrella.

Economies of scope and scale are often inversely related, particularly as firms face a “make” or “buy” decision regarding their inputs. For example, firms may subcontract (“buy”) inputs rather than make them “in-house” when they face rising uncertainty or rapid change in products or technology, when the labor process resists easy automation, or when the optimal scales of operation of production processes are markedly different. Thus, from the transactions costs perspective, externalization allows external economies of scale to replace internal economies of scope. By externalizing, firms substitute variable costs for fixed ones and spread the risks of production over their subcontractors. Achieving this is a particularly vital role of economies of scope during peak periods of demand.

Barney Warf

See also **Agglomeration Economies; Economic Geography; Economies of Scale**

Further Readings

Stutz, F., & Warf, B. (2010). *The world economy: Resources, location, trade, and development* (6th ed.). Upper Saddle River, NJ: Prentice Hall.



ECOREGIONS

There is an increasing realization that natural resources do not exist in isolation but interact with each other. Understanding this has led to a focus on a more holistic approach of managing whole ecosystems that considers both biotic and abiotic components of the ecosystems. Ecosystems are of different sizes and can be identified at multiple scales in a hierarchy. The smaller systems are embedded, or nested, within larger macroscale ecosystems. The larger systems are the environments that control their behavior. By understanding the larger forces that create macroscale ecosystems, we can better predict how management practices will affect smaller local systems. At the macroscale, ecosystem patterns are controlled by macroclimate (i.e., the climate that lies just beyond the local modifying irregularities of landform and vegetation). Over large continental areas, macroclimatic units—also termed *ecoclimatic zones* or *ecological zones*—are reflective of those ecosystems at the macroscale that biogeographers have recognized as ecosystem regions, or ecoregions. Based on macroclimatic conditions, they have developed systems that classify the natural ecoregions of Earth (Figure 1). Ecoregion classification is hierarchical in that mapping is accomplished at different scales. These classification systems are similar but differ in the hierarchical arrangement used.

The fundamental question facing ecological land mappers is “How are the boundaries of different size systems determined?” Delineating units involves analyzing the controlling factors that cause ecosystem patterns at various scales and then using significant changes in controls as boundaries. Areas of uniform climate are used to identify ecosystem units because climate acts as the primary input of energy and moisture into the system. As the climate changes, the kinds and patterns of dominant life forms of plants and animals change, as do the kinds of soils. Ecosystems of different climates differ significantly. Controls over the climatic effect change with scale. Understanding these controlling factors and the scale at which they operate is key to setting ecosystem boundaries.

Ecoregion subzones or provinces such as savanna, steppe, or tundra correspond to major

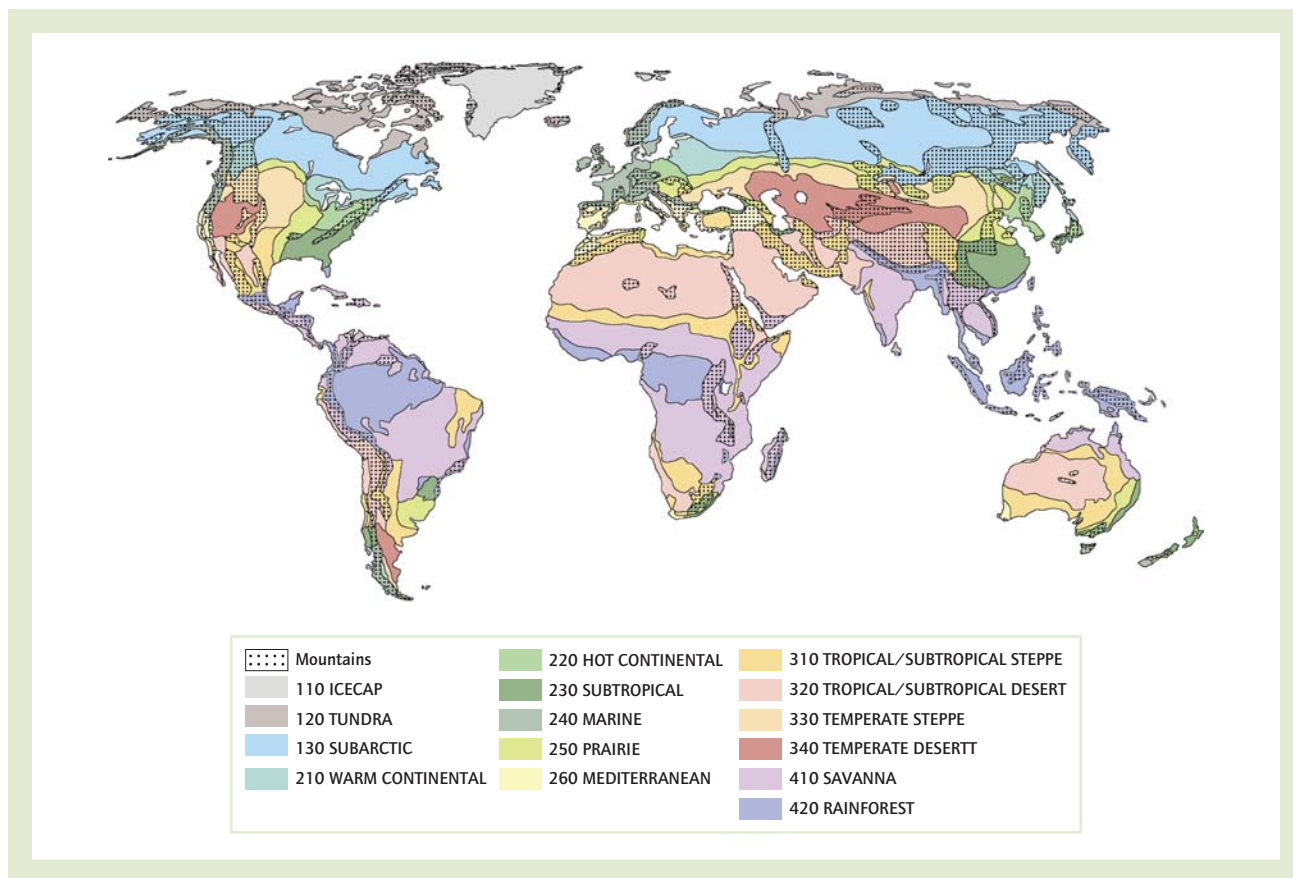


Figure 1 Ecoregion divisions map (Level 2 of the ecoregion hierarchy) of the world

Source: Bailey, R. G. (1996). *Ecosystem geography* (Plate 1). New York: Springer-Verlag.

plant formations, which are delimited on the basis of features of the vegetation. These subdivisions express more refined climatic differences than do the zones. Mountainous provinces are distinguished within a zone where, as a result of altitude, the climate differs sufficiently from the adjacent lowlands to cause a typical sequence of altitudinal belts.

Within an ecoregion, landforms, through varying height and degree of ground surface inclination, further modify the macroclimate to local climate to form repeated patterns of smaller ecosystems, called sites. By observing the behavior of the different kinds of systems in a region, it is possible to predict the behavior of an unvisited one. Hence, an ecoregion's map can be used to spatially extend data obtained from limited sample sites. The results of observations at representative sample sites from each ecoregion would be

potentially useful in detecting and monitoring global change effects.

Robert G. Bailey

See also **Biogeography; Climate Change; Climate Types; Ecological Mapping; Ecological Zones; Ecoshed; Ecosystems; Ecotone; Environmental Management**

Further Readings

- Bailey, R. G. (1996). *Ecosystem geography*. New York: Springer-Verlag.
- Schultz, J. (2005). *The ecozones of the world* (B. Ahnert, Trans.; 2nd ed.). Berlin, Germany: Springer-Verlag.
- Walter, H., & Box, E. (1976). Global classification of natural terrestrial ecosystems. *Plant Ecology*, 32, 75–81.



ECOSHED

An ecoshed is a geographical niche network of community food webs practicing adaptive watershed rehabilitation. The ecoshed concept is similar to a social ecosystem, except that the culturally defined geographic area is set by the watershed boundary. *Ecoshed* is a contraction of the terms *ecology* and *watershed*. Local community food webs are interconnected networks in which each ecoshed can exchange food, goods, and services. Healthy watershed rehabilitation management based on integrated river science foundations will form resilient ecosystems. Local cultural restoration results when community food webs empower its human members through shared goals. Ecoshed processes can reestablish local control and knowledge relationships in food supply systems that have become distorted by increasing distance (physical, social, and metaphorical) between producers and consumers.

An ecoshed uses bottom-up strategies to rehabilitate watersheds through community participation. Top-down government policies are often tied into capitalistic limitations and thus take many years to become established. The concept is analogous to how organic food certification was eventually established from small groups of empowered citizens growing their own organic food and communities without government subsidies.

An ecoshed establishes a boundary within the watershed of a community-based food consumption framework. Localization of food systems and chains implies that food should be consumed as close to the point of origin as possible. The term *foodshed* has been used to include all food within a certain distance. As defined by Gail Feenstra, a foodshed is an area that is defined by a structure of supply and the foods that can be grown within it, as well as the social and cultural elements of a community. An ecoshed reflects deep local watershed ecosystem knowledge and passively integrates communities with global ecological degradation. Instead of the global powers dictating the value of ecosystem services, the ecoshed concept works with local cultures and economies from the bottom up.

Ecosheds can meet the needs of its citizens through locally owned enterprises empowering

communities to have greater control over their basic need of foods and services. The profits are recycled back into the community, stabilizing the economy and providing incentives to protect the environment. The full cost pricing of energy, materials, and land use will expose the true inefficiencies of conventional agriculture, making ecosheds the better alternative.

The ecoshed concept may seem abstract and faces challenges to adoption; however, many foundations are working to create proper distribution and marketing systems. Millions of enterprises and public initiatives that value local food economies at the fringes of the global economy are gaining momentum. Local grassroots food movements such as Slow Food, community-supported agriculture, and farmers' markets are already established. A healthy watershed will evolve from a successful ecoshed objective. The basic healthy food and clean water benefits of the ecoshed are the first drops in the bucket to solving global environmental crises such as climate change and river rehabilitation. Through integrated adaptive watershed rehabilitation, local food webs, and social restoration, the synergisms to achieving ecosystem integrity will spin food webs of ecoshed districts.

Benjamin Newton

See also [Bioregionalism](#); [Ecoregions](#); [Ecosystems](#); [Food, Geography of](#); [Organic Agriculture](#); [Permaculture](#); [Watershed Management](#)

Further Readings

- Allen, P., & Guthman, J. (2006). From "old school" to "farm-to-school": Neoliberalization from the ground up. *Agriculture and Human Values*, 23, 401–415.
- Brierley, G. J., & Fryirs, K. A. (2008). Moves toward an era of river repair. In G. J. Brierley & K. A. Fryirs (Eds.), *River futures* (pp. 3–15). Washington, DC: Island Press.
- Feenstra, G. (1997). Local food systems and sustainable communities. *American Journal of Alternative Agriculture*, 12, 28–36.



ECOSYSTEM DECAY

Ecosystem decay is a term coined by the conservation biologist Thomas Lovejoy to describe the process by which species become locally extinct and ecosystem functions deteriorate following habitat fragmentation. The term has become synonymous with an ongoing, ambitious study of ecosystem decay in the Amazon rain forest, initiated by Lovejoy and colleagues in the 1980s. In this study, forest fragmentation has been found to have unexpected and cascading impacts on species remaining in forest fragments. This entry first describes the process of ecosystem decay and then examines impacts on the Amazon rain forest that have been identified by researchers with the Biological Dynamics of Forest Fragments Project.

It has been long recognized that habitat fragmentation is a leading cause of species loss worldwide. This widespread threat is also referred to as “islandization,” whereby a fragment of untouched habitat is isolated in a sea of altered habitat. Nature reserves have been ongoing testament to the negative effects of islandization; for example, populations of mammals with large home ranges visibly decrease within reserves, and this decrease is relative to the size of the reserve. Nonetheless, the mechanisms by which most species cease to exist in such habitat fragments have been difficult to isolate within the complexities of an ecosystem, a difficulty recognized by Lovejoy when he labeled this complex process as ecosystem decay.

To grasp the impacts of habitat fragmentation, biogeographers turned to island biogeographic theory soon after it emerged in the 1960s. By understanding the impacts of area, isolation, species immigration, and extinction within virtual islands, conservation biogeographers aimed to improve nature reserve selection. However, debates over optimal sizes of reserves ensued, a well-known one being the SLOSS (single large reserve or several small) debate. The questions driving such debates were based on the unknown complexities of ecosystem decay.

Today, the term *ecosystem decay* is often replaced by *habitat degradation* or *habitat loss*,

reflecting the tendency of biogeographers and conservation scientists to focus on habitats rather than ecosystems. Because we are still far from understanding the inner workings of ecosystems and because biodiversity loss is occurring at an unprecedented rate, it is generally more manageable to work toward the preservation of habitats when making conservation decisions. Habitats can be defined at many scales and do not necessarily require in-depth knowledge of entire systems.

Ecosystem Decay in the Amazon Forest

The ecosystem decay study in the Amazon rain forest is called the Biological Dynamics of Forest Fragments Project. Initially, the project targeted questions around optimal reserve size, through an in-depth, long-term study of ecosystem decay. The study began with the experimental clearing of large tracts of pristine rain forest in the early 1980s—an approach that sparked controversy at the time. The purpose of this clearing was to create a matrix of forest fragments representing different areas and different levels of isolation from intact forest. The areas of the fragments ranged from 1 to 100 ha (hectares), and the isolation ranged from 80 to 650 m (meters) from intact forest or other fragments.

Since creating the fragments, numerous scientists from around the world have monitored, and continue to monitor, the ecosystem decay occurring within these fragments. Some of the more consequential findings have to do with conditions on the edge of fragments (called the edge effect), total area and the species-area relationship, and fragment isolation.

Edge Effects

The conditions occurring on the edge of a forest differ considerably from those within the interior of a forest. For example, temperature alone will change dramatically as one moves from the edge of a tropical forest to its interior. If a forest is carved up into smaller pieces, then the ratio of edge to total area will be altered; the portion of



Aerial picture of forest fragments monitored by the Biological Dynamics of Forest Fragments Project

Source: Richard Bierregaard.

the forest experiencing edge conditions will increase as the portion experiencing interior conditions will decrease (Figure 1). The effects of such increased exposure to edge conditions (the edge effect) has been a key focus of the Biological Dynamics of Forest Fragments Project.

What Thomas Lovejoy and his team found is that many species occurring within the interior of the forest are ill adapted to the conditions found on the edge, such as increased temperature and light. While variables such as temperature and light are predictable drivers of plant species occurrence, the team found that trees responded to edge effects with an unexpected and dramatic increase in mortality rates. Additionally, understory plants, leaf litter, soil nutrients and moisture, humidity, and wind penetration were all subsequently and simultaneously altered. These effects were generally found up to 60 m into the interior.

Edge effects on animal species were equally surprising. Light exposure detracted some birds to the point where they would not emerge into the less dense edge vegetation, even if it was a means to accessing greater food resources. The many species relying on leaf litter disappeared from the edge transition zone, as did most species associated with the trees and understory vegetation that died along the edge. This means that the impacts on microfauna were more far-reaching than predicted, contradicting previous beliefs that habitat fragmentation affects large-bodied animals more than it does small-bodied animals.

In addition to the effects of edge conditions, fragments were exposed to intrusion by species from the peripheral habitat; in some cases, this included cattle grazing land, and in others, it included regenerating forest. Non-rain forest species rapidly filled the niches within the edge

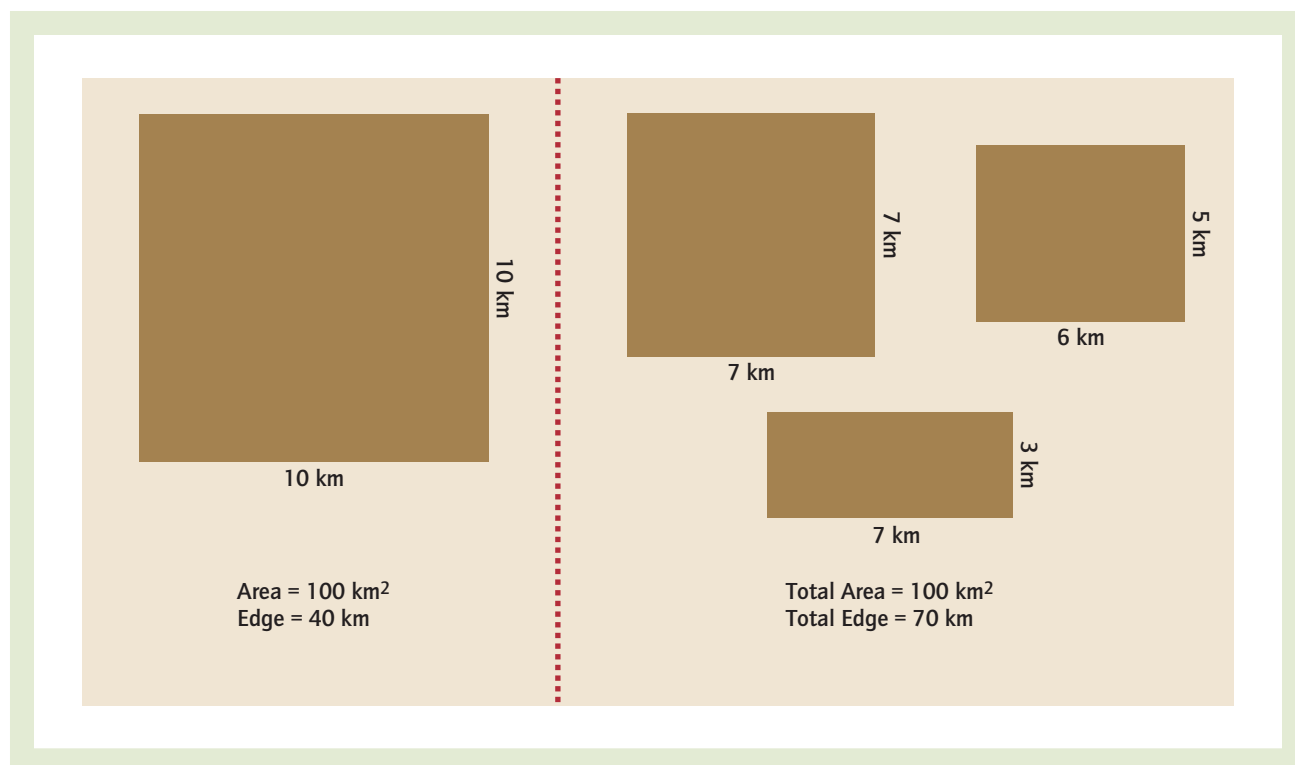


Figure 1 Edge-to-area ratios for contiguous versus fragmented areas

Source: Author.

transition zone, as was expected, but in some instances, they altered species compositions as far as 200 to 400 m into the interior of the forest, as was the case with butterflies. Competition for resources, altered microhabitats (canopy structures and ground cover), and altered predation were just some of the resulting impacts on highly specialized species within the forest interior.

The negative effects of invasive species on true islands are usually the result of passively dispersed species (i.e., rats on boats), since there is no bordering terrestrial habitat from which threatening active dispersers can migrate. Hence, the findings of the Biological Dynamics of Forest Fragments Project have demonstrated some of the unique threats to habitat fragments on land.

Edge effects in habitat fragments are now widely accepted as key drivers of ecosystem decay and have been recorded in numerous habitat

types. There is always a transitional zone on the periphery of a habitat fragment that is unsuitable to certain species of the interior. The extent to which ecosystem decay occurs depends on the individualistic responses of each species.

Due to the long-existing, self-regulated climatic conditions of rain forests, many species have evolved to fill highly specialized niches. Hence, the number of species affected by edge effects might be profound in a rain forest fragment surrounded by cattle grazing but less profound in a scrubland fragment surrounded by cattle grazing. So the concept of edge effect is transferable to other habitats only as a general guideline for identifying ecosystem decay processes.

Area

Before the concept of ecosystem decay emerged, it was generally believed that larger areas harbored



greater species diversity and that therefore the larger the nature reserve, the better it was. This belief reflected a key principle of island biogeographic theory, which is that there is a negative relationship between area and extinction rates—the larger the island, the lower the extinction rate, and vice versa. Some, however, believed that species diversity depended heavily on the diversity of habitat within the fragment and not necessarily on size. While several studies set out to prove and disprove these hypotheses, the ecosystem decay study in the Amazon played an important role in supporting island biogeographic theory and the species-area relationship.

The mechanisms by which extinction rates increased with decreased area were found to be grounded in resource limitation and reproduction. Species with large range requirements, often due to the distribution of food sources, decreased much more rapidly in the small forest fragments (1 ha) than in the larger fragments (10 and 100 ha). Studies in other environments have shown how wide-ranging large mammals are often the first to become extinct in habitat fragments. The Amazon study demonstrated that large mammals as well as many small animals, such as ant-following birds and dung beetles, suffered the same fate. This extent of area-related ecosystem decay was unexpected.

The reproductive success of a species is also a function of area, particularly in species with low densities. The smaller the fragment, the fewer individuals there will be and the greater chance of a genetic bottleneck. This effect is also controlled by an area's level of isolation. In the Amazon, many low-density species managed to move from forest fragments to intact forest—this movement was triggered first in the small fragments but eventually in all fragments. But in reserves that are more isolated (i.e., surrounded by human settlements), such movement of large mammals is often impossible, and the species become locally extinct.

Isolation

The extent to which a fragment is isolated from source populations of species will dictate the

number of species occurring in that fragment. The further a species must travel, the less likely it is to successfully immigrate to the fragment or to leave the fragment and find greater resources. With little incoming or outgoing movement, extinctions can often outnumber immigrations, and the resulting decrease in species number causes ecosystem decay.

The significance of the immigration-to-extinction ratio is highlighted in island biogeographic theory, and isolation plays a key role in defining this ratio. Levels of isolation are relatively easy to measure for islands because it can be assumed that ocean water is a constant barrier to most terrestrial species (birds excluded). Hence, if access to an island involves the crossing of 100 km (kilometers) of sea, one can assume that this obstacle of distance will be unchanged when estimating immigration rates. However, if one tries to measure the isolation of a habitat fragment, then the continuous changes of peripheral habitats must be accounted for (i.e., occurrence of seasonal corridors, fires, flooding).

Lovejoy and his colleagues designed their Amazon experiment so that each fragment would be surrounded by cattle farming and have different distances between fragments and intact forest. In some cases, cattle grazing persisted around the fragment perimeters, but in others, it was replaced with regenerating forest. Their studies have shown that fragments surrounded by regenerating forest had significantly greater movement to and from the fragment when compared with fragments with cattle on their perimeter. The results illustrate the significance of perimeter land uses in aggravating or abating ecosystem decay and the need to identify each fragment's ever-changing barriers instead of focusing only on distances to source populations.

The study also highlights the need to recognize species' individual responses to varying levels of isolation in order to understand ecosystem decay. Small animals, such as certain crawling insects, were unable to cross rain forest clearings of only 15 m. Large carnivores, such as jaguars, can easily cross the distances between fragments, but human activity, especially hunting, can restrict their movement. Seemingly mobile species, such



as birds, were surprisingly constrained even in fragments bordered by regenerating forest. While ant colonies were able to move to nearby fragments, some ant-eating birds were not. Each species' response affects another species, which affects another species and so on, a complex process of ecosystem decay that we are yet to understand fully.

Jennifer S. Lalley

See also **Deforestation; Ecosystems; Extinctions; Forest Degradation; Forest Fragmentation; Island Biogeography; Land Degradation; Single Large or Several Small (SLOSS) Debate; Species-Area Relationship**

Further Readings

- Laurance, W. F., Lovejoy, T. E., Vasconcelos, H. L., Bruna, E. M., Didham, R. K., Stouffer, P. C., et al. (2002). Ecosystem decay of Amazonian forest fragments: A 22-year investigation. *Conservation Biology*, 16, 605–618.
- Quammen, D. (1996). *The song of the dodo: Island biogeography in an age of extinctions*. New York: Scribner.



ECOSYSTEMS

The term *ecosystem* is defined by the Convention on Biological Diversity as a dynamic complex of plant, animal, and microorganism communities and their nonliving environment interacting as a functional unit. As further detailed by the convention, this definition does not specify any particular spatial unit or scale. Thus, the term *ecosystem* does not, necessarily, correspond to the terms *biome* or *ecological zone* but can refer to any functioning unit at any scale. The scale of analysis and action should be determined by the different functions, properties, spatial levels involved and by the issues highlighted in this entry.

Ecosystems: From Passive Support to Active Component

Many studies made in the fields of biology and ecology during the past few decades have progressively shown the inadequacy of a traditional representation of nature as a passive entity containing all the resources extracted by human activity and receiving all the emissions and waste produced by mankind. A description in terms of ecosystems that actively produce and allocate natural services is far more satisfactory because the role of natural systems is anything but passive. The network of ecosystems provides a great number of *natural services*, which are vital for the survival of the human and of the other living species. The Millennium Ecosystem Assessment (MA), following several other studies, describes the following four categories of ecosystem functions, further detailed in several ecosystem services:

1. Supporting services such as
 - the capture of solar energy and its embodiment as biomass,
 - the decomposition and recycling of organic waste,
 - the formation of soil, and
 - the fixation of nitrogen in soils
2. Provisioning services such as
 - the production of food (which makes the life of all heterotrophic organisms, including human beings, possible) and
 - the provision of biotic materials or fuel
3. Regulating services such as
 - regulation of the composition of the atmosphere,
 - climate regulation (including the redistribution of humidity),
 - regulation of the water cycle,
 - water purification,
 - pollination,
 - biological control of disease and pests, and
 - land stabilization and the control of soil erosion
4. Cultural services, including aesthetic, spiritual, educational, and recreational ones



All the services listed here contribute directly or indirectly to making our planet a suitable place to live in, for humankind and for all the other living species.

Each of these services derives from living organisms and in particular from some species that are critical in maintaining habitat stability and in supporting ecosystem services. Thus, a reduction of these species at a local level will have negative consequences on ecosystem services also at the global level.

Resilience, Resistance, Stability, and Persistence of Ecosystems

There are some properties that focus on the way that ecosystems respond to disturbance. Following C. S. Holling, we define *resilience* as the capacity of an ecosystem to return to the initial state after a perturbation, maintaining its essential characteristics. This emergent property of ecosystems refers to the ability of an ecosystem to cope with environmental disturbances (climate change, pollution, floods, fires, etc.), without changing its state into a qualitatively different level. For a high level of resilience, an ecosystem is characterized by a great capacity to survive shocks and, if damaged, to restore itself. This property is conferred at multiple scales by genes, species, functional groups of species, and processes interacting within the system. This process of restoration after disturbance helps ecosystem renewal and further development.

Resistance is defined as the capacity of the ecosystem to absorb disturbances and remain largely unchanged. If an ecosystem is resistant, it shows little alterations to withstand non-catastrophic perturbations. Ecosystems may be highly resilient but have low resistance to a given perturbation: For example, grasslands have a low level of resistance but a higher level of resilience to fire.

Resistance is related to the concept of *stability*, which reflects the capacity of an ecosystem to maintain a dynamic equilibrium over time while resisting change to a different state. A stable ecosystem *persistent* when it is able to absorb disturbances and remain largely unchanged over long periods of time.

Ecosystems and Spatial Scale

It is important to describe the properties of ecosystems with respect to spatial scale. Many recent geographical studies have highlighted, from different points of view, the complexity and the importance of scale in contemporary debates due to the role of scale in most of socioeconomics and environmental dynamics, as described in several geographical theories and topics.

An analysis of the spatial scale of ecosystems shows that they behave in ways that can be described on a local scale, but they also have characteristics that can be understood at other levels and cannot be described in terms of local ecosystems alone. According to a deeper analysis, at least three different levels characterizing ecosystems can be distinguished.

1. The local level: First, ecosystems are spatially localized systems, which, although local from the territorial point of view, have permeable and blurred borders. Hence, only some of the properties that characterize these systems can be explained correctly by a local description. The actions of human origin that lead to local environmental externalities (pollution of local soil or lakes, fires in local areas, etc.) fall within this level of representation.

2. The intermediate level (mesoscale): This scale is taken into consideration in analyses by geographers referring to the concept of “ecoregion,” introduced by Robert Bailey in 1976 and progressively deepened by him and his collaborators. These studies propose a description not limited to the consideration of local ecosystems because such a description is unable to capture the quality and processes (orography, hydrography, climate, flora, fauna, etc.) that emerge only at the regional level. At this scale, the network of interactions and feedbacks linking the ecosystems integrates them to form an ecoregion, a natural environment that, in spite of its local variations, is characteristic of that territory (i.e., the desert zone of the Colorado Plateau, the Appalachian mountains, the Amazon forest, etc.).

3. The global level: As they have permeable borders, the various ecosystems exchange energy



and material through a network of relations that takes in the whole planet. The case of emissions into the atmosphere is typical: Even if they are localized in a small area, winds and atmospheric currents disperse the pollutants, which generate fallout of acid rain, ozone depletion, and the greenhouse effect, at a global level. The only level at which the system becomes really closed is the planetary level. Most of the functions, relations, and feedbacks existing among ecosystems are closed only on the global scale. It is precisely at this level that there emerge effects that do not derive from the mere addition of local behaviors but represent the result of out-and-out synergies. There are many examples of this level, including the regulation of carbon dioxide (CO₂) in the atmosphere, where the CO₂ emitted (locally) is not reabsorbed by the local ecosystems (except for a very small portion) but becomes part of the atmosphere, whose CO₂ composition is controlled by the balance that exists only on the global scale, between the activities of photosynthesizers and respirators.

Strategies for Better Management of Ecosystems

From 2001 to 2005, the MA was conducted, which was called for by the United Nations to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contribution to human well-being. Their results offer a state-of-the-art scientific appraisal of the conditions and trends in the world's ecosystems and the services they provide and the options to restore, conserve, or enhance the sustainable use of ecosystems. According to MA conclusions, human actions are depleting Earth's natural capital, damaging the ability of the planet's ecosystems to sustain future generations. At the same time, the assessment shows that, with appropriate actions, it is possible to reverse the degradation of many ecosystem services over the next 50 years, but the changes in policy and practice required are substantial and not currently underway.

Many of the different ways of improving management of ecosystems and several methodologies can be integrated with each other. One of the most important strategies is the ecosystem approach, which provides a framework that can be implemented to reach the aims of the Convention on Biological Diversity, the international treaty that focuses on ecosystems and on their problems, and in particular its three main objectives: (1) conservation, (2) sustainable use, and (3) fair and equitable sharing of the benefits of biological diversity. Thus, the ecosystem approach is a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way. It is based on the application of appropriate scientific methodologies focused on the levels of biological organization, which encompass the essential structure, processes, functions, and interactions among organisms and their environment. This approach recognizes the relationships between healthy and resilient ecosystems, biodiversity conservation, and human well-being and sets out a series of principles for decision making and action regarding the different dimensions of sustainability, environmental and socioeconomic. It also recognizes that ecosystem processes are often nonlinear and that management must be adaptive to be able to respond to such uncertainties. It can be applied at any scale from the local, to the meso, to the global scale. To reach this aim it proposes new types of collaboration between civil society, the private sector, and governments.

Marco Bagliani and Antonella Pietta

See also **Adaptive Radiation; Agroecology; Agroforestry; Animal Geographies; Biodiversity; Biogeochemical Cycles; Biogeography; Bioregionalism; Biosphere Reserves; Biota and Climate; Biota and Soils; Biota and Topography; Biota Migration and Dispersal; Coupled Human and Animal Systems; Cultural Ecology; Cyborg Ecologies; Ecological Economics; Ecological Regimes; Ecological Zones; Ecoregions; Ecoshed; Ecosystem Decay; Ecotone; Environmental Management; Environmental Protection; Environmental Services; Gaia Theory; Landscape Ecology; Resilience**



Further Readings

- Bailey, R. G. (1988). *Ecoregions*. New York: Springer-Verlag.
- Brown, J. C., & Purcell, M. (2005). There's nothing inherent about scale: Political ecology, the local trap, and the politics of development in the Brazilian Amazon. *Geoforum*, 36, 607–624.
- de Groot, R., Wilson, M., & Boumans, R. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics*, 41, 393–408.
- Drever, C. R., Peterson, G., Messier, C., Bergeron, Y., & Flannigan, M. D. (2006). Can forests management based on natural disturbances maintain ecological resilience? *Canadian Journal of Forest Research*, 36, 2285–2299.
- Gunderson, L. (2000). Ecological resilience: In theory and application. *Annual Review of Ecology and Systematics*, 31, 425–439.
- Holling, C. S. (1973). Resilience and stability of ecosystems. *Annual Review of Ecology and Systematics*, 4, 1–23.
- Manson, S. M. (2008). Does scale exist? An epistemological scale continuum for complex human-environment systems. *Geoforum*, 39, 776–788.
- McCarthy, J. (2005). Scale, sovereignty, and strategy in environmental governance. *Antipode*, 37, 731–753.
- Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Biodiversity synthesis*. Washington, DC: World Resources Institute. Retrieved October 31, 2009, from www.millenniumassessment.org
- Secretariat of the Convention on Biological Diversity. (1992). *The convention on biological diversity*. Retrieved October 31, 2009, from www.cbd.int
- Thompson, I., Mackey, B., McNulty, S., & Mosseler, A. (2009). *Forest resilience, biodiversity, and climate change: A synthesis of the biodiversity/resilience/stability relationship in forest ecosystems* (Technical Series No. 43). Montreal, Quebec, Canada: Secretariat of the Convention on Biological Diversity.
- Volk, T. (1997). *Gaia's body: Toward a physiology of Earth*. New York: Springer-Verlag.

- Wilson, G. A. (2009). The spatiality of multifunctional agriculture: A human geography perspective. *Geoforum*, 40, 269–280.
- World Wide Fund for Nature. (2008). *Living planet report 2008*. Gland, Switzerland: Author.

ECOTONE

An ecotone is a boundary or transition zone between adjacent ecological communities or systems. Ecotones are produced where a combination of environmental conditions and biotic interactions exceed the physiological limits of the species on either side. They may result from steep environmental gradients such as abrupt changes in temperature or soil moisture or from nonlinear responses of species to more gradual changes in environmental factors. They are a focus of current research in physical geography due to their scale-dependent nature, their effect on species population dynamics and the movement of matter and energy, their relevance to the study of ecological



An alpine tree line (forest-tundra) ecotone in Glacier National Park, Montana

Source: Photo by D. Cairns. From Bekker, M. F. (2005). Positive feedback between tree establishment and patterns of subalpine forest advancement, Glacier National Park, Montana, U.S.A. *Arctic, Antarctic and Alpine Research*, 37(1), 97–107. University of Colorado, Boulder. Used with permission.



Endogenous feedback between trees, wind, and snowdrift produces this crenulated, advancing tree line (forest-tundra) ecotone in Glacier National Park, Montana.

Source: Photo by G. Malanson. From Bekker, M. F. (2005). Positive feedback between tree establishment and patterns of subalpine forest advancement, Glacier National Park, Montana, U.S.A. *Arctic, Antarctic and Alpine Research*, 37(1), 97–107. University of Colorado, Boulder. Used with permission.



A view of upper and lower tree line ecotones in Rocky Mountain National Park, Colorado

Source: G. Malanson.

complexity and self-organized ecosystems, and their potential sensitivity to climate change. Recent advances in spatial technologies and techniques have allowed biogeographers and ecologists to understand better the important role that ecotones play in the pattern and functioning of the biosphere.

The structural characteristics and dynamics of ecotones are scale dependent; they may appear sharp or gradual with varying spatial scales and static or ephemeral with varying temporal scales (see images). The ecotone concept, however, is scale independent; ecotones can be identified and have been studied at various scales, ranging from edge-effect investigations of wood lots in agricultural fields, to the boundary between trees and tundra on a mountain slope, to continental-scale biome transitions, such as those between deciduous forest and grassland in North America.

Frederic Clements coined the term *ecotone* in 1907 from the Greek words *oikos* (home) and *tone* (tension), accentuating the interaction between the adjacent communities. However, the work of Clements and other early ecologists emphasized the importance of and interaction among species within communities, which directed attention away from the boundaries between them. Additionally, analytical methods in ecology were designed to deal with homogeneous communities, which led ecologists to further ignore transitional areas. Research that did focus on boundaries emphasized an “edge effect,” which included both positive (e.g., increases in species diversity) and



negative (e.g., increases in bird nest predation) impacts on wildlife and plant communities. The emphasis of these studies was on the effects of edges as static elements.

Within the past 25 years, four factors have shifted interest back to ecotones, emphasizing their role as a dynamic component of pattern in the biosphere. First, the emergence of landscape ecology led to the explicit consideration of interactions between vegetation patterns and environmental processes and to a focus on the effects of scale on those interactions. Patterns arise from heterogeneity, itself a consequence of boundaries between relatively homogeneous patches of vegetation, land, and water, and researchers have studied how the patterns created by ecotones affect the ability of species, matter, and energy to flow across a landscape. New conceptualizations of scale produced greater interest in the scale-dependent properties of ecotones, including the recognition that different factors constrain ecotone patterns and dynamics at different spatial scales and that the constraints are more numerous and complex at fine scales than at broad scales.

Second, complexity theory, another concept with strong ties to landscape ecology, suggested that some ecosystems and landscape patterns are self-organizing, that is, the pattern is an emergent property of positive feedback between vegetation and environment within the system. Where these properties are present, abrupt ecotones can develop over gradual environmental gradients, complex ecotone patterns can develop over a homogeneous abiotic template, and vegetation change at ecotones can be amplified or diminished. Computer simulation models have been at the forefront of this area, emphasizing the creation of complex spatial structures through self-organization, and field observations have confirmed the important role of endogenous biotic interactions in ecotone pattern and dynamics.

Third, increasing concerns over global climate change, coupled with the recognition that ecotones represent the physiological limits of



A lower tree line (forest-grassland) ecotone in Yellowstone National Park, Wyoming

Source: Author.

species' distributions, led to interest in their potential as indicators of climate change. An ecotone that is controlled primarily by temperature, such as some alpine tree lines, would be expected to shift upslope with warmer temperatures. A low-elevation, forest-grassland ecotone that is controlled primarily by moisture would be expected to shift downslope with an increase in rainfall. However, the usefulness of ecotones in monitoring climate change has been questioned due to their typically slow movement and to complex interactions among climatic variables that might constrain ecotone dynamics.

A final factor in the recent interest in ecotones is the development of increased computing



A meadow-forest ecotone from the Cranberry Glades Botanical Area, West Virginia

Source: L. Resler.



A view of the Grand Canyon, Arizona, illustrating two ecotones: water-riparian and riparian-desert scrub

Source: D. Butler.



power, advances in spatial technologies such as geographic information systems (GIS) and remote sensing, and improved edge detection techniques. These advancements have enhanced our ability to identify ecotones, explore and map their properties over various scales, and monitor their dynamics. Once ecotones have been identified, remote sensing provides images of the vegetation and terrain with increasingly finer resolution, allowing the assessment of multiple variables influencing ecotones. Spatially explicit computer simulation models allow an exploration of the relative influence abiotic and biotic factors on ecotone pattern and dynamics. Finally, GIS provides a platform for the coupling of models and remote sensing data, the analysis of spatial pattern, and the creation of maps to display ecotone properties and dynamics.

Matthew F. Bekker

See also **Climate Change; Complexity Theory; Ecological Zones; Ecoregions; Ecoshed; Ecosystems; Landscape Ecology**

Further Readings

- Bekker, M. F. (2005). Positive feedback between tree establishment and patterns of subalpine forest advancement, Glacier National Park, Montana, USA. *Arctic, Antarctic, and Alpine Research*, 37, 97–107.
- Butler, D. R., Resler, L. M., Cerney, D. L., & Gielstra, D. A. (2003). Ecotones in mountain environments: Illustrating sensitive biogeographical boundaries with remotely sensed imagery in the geography classroom. *Geocarto International*, 18, 1–10.
- Clements, F. E. (1907). *Plant physiology and ecology*. New York: Holt.
- Fortin, M. J. (1994). Edge detection algorithms for 2-dimensional ecological data. *Ecology*, 75, 956–965.
- Gosz, J. R. (1993). Ecotone hierarchies. *Ecological Applications*, 3, 369–376.
- Hansen, A. J., & DiCasteri, F. (Eds.). (1992). *Landscape boundaries: Consequences for biotic diversity and ecological flows*. New York: Springer-Verlag.

- Holland, M. M., Risser, P. G., & Naiman, R. J. (Eds.). (1991). *Ecotones: The role of landscape boundaries in the management and restoration of changing environments*. New York: Chapman & Hall.
- Kent, M., Gill, W. J., Weaver, R. E., & Armitage, R. P. (1997). Landscape and plant community boundaries in biogeography. *Progress in Physical Geography*, 21, 315–353.
- Kupfer, J. A., & Cairns, D. M. (1996). The suitability of Montane ecotones as indicators of global climatic change. *Progress in Physical Geography*, 20, 253–272.
- Malanson, G. P., Zeng, Y., & Walsh, S. J. (2006). Complexity at advancing ecotones and frontiers. *Environment and Planning A*, 38, 619–632.
- Naiman, R. J., & Decamps, H. (Eds.). (1990). *The ecology and management of aquatic-terrestrial ecotones*. Paris: United Nations Educational, Scientific and Cultural Organization.
- Risser, P. G. (1995). The status of the science examining ecotones. *Bioscience*, 45, 318–325.



ECOTOURISM

Although it may seem conceptually simple, ecotourism has suffered from the lack of a precise, widely accepted definition. The International Ecotourism Society has attempted to minimize this confusion with a short and simple definition of ecotourism as “responsible travel to natural areas that conserves the environment and improves the well-being of local people.” Many ecotourism scholars have instead argued that it is more important to focus on essential criteria to be met rather than trying to craft a universal definition. Most scholars agree that to be considered ecotourism, nature-based travel must meet at least four criteria:

1. **Minimization of environmental impacts:** through sensitive “green design” using locally available materials; energy conservation and use of renewable energy; reduction, recycling, and proper disposal of wastes; and regulation of visitor numbers and activity



2. *Generation of funds for conservation:* through visitor fees and, if feasible, voluntary contributions
3. *Benefits to local communities:* through park revenue sharing as well as through employment and provision of local goods and services and community empowerment through ownership or management of operations
4. *Education of visitors:* through orientation programs and interpretation by trained guides on both conservation issues and cultural norms

Unlike other traditional forms of nature-based tourism, ecotourism has been explicitly conceived as an ethical form of travel and can therefore be regarded as a subset of nature tourism that meets certain criteria. Familiar forms of nature-based tourism such as wildlife tourism and adventure tourism may or may not be considered ecotourism depending on whether they meet these criteria. The relationship between different forms of nature-based tourism is depicted in Figure 1. While nature-based tourism, like other forms of tourism, has a long history, the concept of ecotourism is relatively new. The concept arose out of a convergence of trends in the 1970s and 1980s. Researchers and scholars noted with alarm the enormous environmental, social, and economic problems created by conventional mass tourism; the rapid destruction of pristine natural areas in the developing world; and the opposition by local communities to nature conservation efforts through Western-style national parks, leading to calls for an alternative form of tourism that is more ecologically and socially responsible. This view of ecotourism blended nicely with the concept of “sustainable development,” which has rapidly gained in popularity since its introduction by the World Commission on Environment and Development in 1987.

The Practice of Ecotourism

Ecotourism is by far the fastest growing segment of the global tourism industry, itself one of the largest enterprises of the world. From a handful in the 1980s, ecotour operators have proliferated rapidly, with virtually every major travel company offering some sort of ecotravel and millions

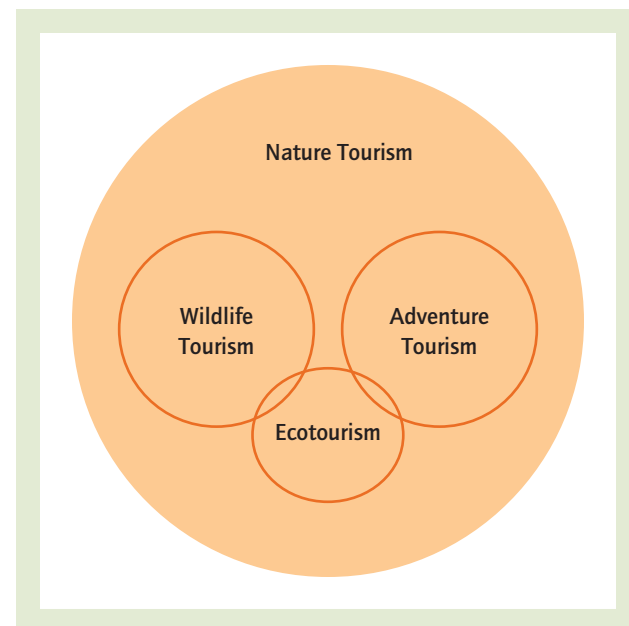


Figure 1 The relationship among different forms of nature tourism

Source: Banerjee, A. (2007). *An evaluation of the potential and limitations of ecotourism as a vehicle for biodiversity conservation and sustainable development in the protected areas of India*. Doctoral dissertation, University of Delaware.

of people taking part in eco-vacations each year. These statistics are somewhat inflated because they lump together most nature and adventure travel with ecotourism, but they do demonstrate a growing public interest in this sort of travel.

As the popularity of ecotourism has grown, so has its attractiveness to governments, particularly those in developing countries. Many governments have viewed ecotourism as less problematic than other avenues of economic growth, such as mining, logging, and ranching, and perhaps even more profitable. By the early 1990s, most developing countries were promoting ecotourism as part of their development strategy. In several countries, nature-based tourism mushroomed into the largest foreign exchange earner, regardless of whether the entire country, such as Costa Rica, or a part of it, such as the Galapagos Islands in Ecuador, was being promoted as an ecotourism destination. Even countries formerly suspicious of international contact, such as China and Cuba, have now enthusiastically joined the ecotourism bandwagon. Multilateral institutions and aid agencies such as

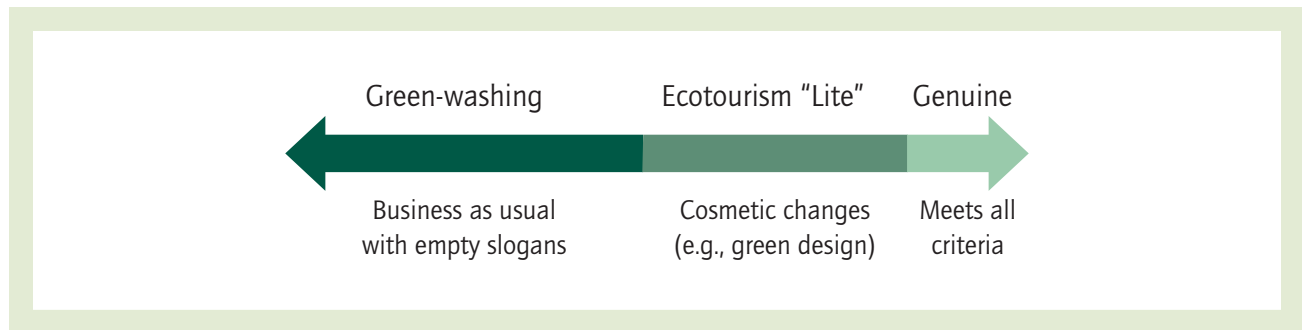


Figure 2 The ecotourism continuum

Source: Banerjee, A. (2007). *An evaluation of the potential and limitations of ecotourism as a vehicle for biodiversity conservation and sustainable development in the protected areas of India*. Doctoral dissertation, University of Delaware.

the World Bank, United Nations (UN), and U.S. Agency for International Development (USAID), which had always been supportive of conventional tourism as a development strategy, have now become important promoters of ecotourism as a vehicle for sustainable development. Indeed, the UN proclaimed 2002 as the International Year of Ecotourism, thereby promoting its status further. Even major conservation groups such as World Wide Fund for Nature (WWF), the Nature Conservancy, and Conservation International have played a significant role in promoting ecotourism as a win-win solution for conservation and economic development.

However, when poorly planned, unregulated, and overhyped, ecotourism, like mass tourism, can bring only marginal benefits and serious social and environmental consequences. Once, unique places such as Nepal, Kenya, and the Galapagos Islands were visited by a handful of adventurous travelers, but by the 1990s the explosion of tourists had caused large-scale deforestation in Nepal, led to detrimental changes in cheetah behavior in Kenya, and threatened the survival of exotic species in the Galapagos. As ecotourism has grown in popularity, the travel industry has seized the opportunity and in the process has largely succeeded in diluting its meaning, taking advantage of the confusion over its precise definition, through the use of heavy marketing, catchy slogans, and misleading logos and awards. With the mainstreaming of ecotourism, “softer” ecotourists have demanded more mechanized transport, easy accessibility, and high levels

of services and have become less interested and concerned about conservation. Many scholars agree that much of what goes on under the name of ecotourism today is “green-washing,” that is, conventional nature tourism with cosmetic changes in marketing. Another significant and growing segment is what is called “ecotourism lite,” which may incorporate solar panels, water conservation, and waste recycling but does little to benefit or empower local communities, aid conservation, or educate visitors. Genuine ecotourism that meets all of the minimum criteria is very rare. Ecotourism practice today can be represented as a continuum (Figure 2).

Where genuine ecotourism is to be found, it is most often the outcome of conservation or community groups and dedicated and passionate individuals, and such scattered successes hold out significant promise. These successful models are usually small-scale and community oriented, with visionary individuals, conservation groups, or government agencies playing important facilitating roles in organization development, guide training, and marketing. The CAMPFIRE program in Zimbabwe has instituted revenue sharing from game reserves with local communities, building schools, clinics, and water supplies, which has helped turn former poachers into conservationists. Similar programs have helped the Maasai in some of Kenya’s national parks, who have also started their own community-run ecotours. The Annapurna Conservation Area Project in Nepal has helped form a wide network of village-level committees that run lodges, maintain



trails, and guide tourists in a self-sufficient model. Advocacy and watchdog groups, such as Tourism Concern, Tourism Watch, the Ecumenical Coalition on Third World Tourism, and the Indigenous Tourism Network, have worked with local communities to advance the cause of sustainable and equitable tourism.

Criticisms

Ecotourism has many critics. The idea that individual tourists, by virtue of their choice of a “green” trip, will bring about social and environmental benefits, seems to fit perfectly with the dominant neoliberal paradigm, which advocates free markets and a diminished role of government regulation. As investment becomes more deregulated, local ecotourism enterprises in developing countries cannot compete with strong foreign companies, and their viability is undermined. The dominance of external players who repatriate profits leaves little benefit for local communities. Under increasing pressure, tourism facilities in many protected areas have been privatized, and private tour operators facing competitive pressure are more likely to sacrifice sustainability and equity goals. Privatization also decreases revenue for governments, making it even more difficult to maintain well-managed protected areas. The neoliberal paradigm increasingly reinforces the view that conservation must demonstrate its financial viability, forcing governments or protected area managers to allow more and more tourists, thereby undermining long-term sustainability. Overreliance on ecotourism forces destinations to engage in destructive competition with other regions and countries, where a win for one may be a loss for another. It also puts local economies at the mercy of global market forces, and events beyond their control, such as a recession in Japan or a terrorist attack in the United States, can suddenly dry up the flow of tourists.

Ecotourism usually depends on marketing of the destination as “exotic” and “unspoiled,” often referring to locals as “happy” and “friendly” people. Such characterizations can gloss over uncomfortable realities such as poverty, crime, corruption, human rights abuses, and environmental threats that may hinder tourism prospects.

This helps perpetuate fantastic perceptions of the host country or region, precluding opportunities for an improved understanding of problems and potential progress toward solutions. Insensitive ecotourists often leave behind profound sociological and cultural transformations in their wake, particularly in remote indigenous communities with little prior exposure to the “modern” world. The rush to enjoy the exotic leads to trivialization of the local culture, the sudden introduction of a cash economy, the craving for modern gadgets, and the consequent breakdown of cultural norms, particularly among the youth. Promotion of ecotourism by governments or corporations also frequently sets the stage for conflicts over traditional resource use, such as when water is diverted to the tourist resort, which further worsens with the subsequent intrusion of other exploitative forms of “development.” Indeed, concerns such as these have led an international coalition of indigenous groups to condemn the 2002 UN International Year of Ecotourism.

Ecotourism Certification

Ecotourism certification involves setting criteria for the social and environmental impacts of ecotourism, auditing, and awarding ecolabels to enterprises with outstanding performances. Proponents of ecotourism certification argue that good ecolabels will help the public distinguish between responsible ventures and green-washing claims and thus mobilize consumer purchasing power for more desirable forms of ecotourism. Although logical in theory, several factors hinder the effectiveness of ecocertification programs. Critics argue that since genuine or hard ecotourists are a very small niche, and the majority of the traveling public desires only soft ecotourism or ecotourism lite, the consumer demand for genuine ecotourism is too small to bring about any appreciable change in the tourism market in favor of sustainable and responsible practices. Moreover, with the proliferation of certification schemes, there is confusion about which one to use or trust. Some such as “Green Globe” (heavily promoted by the World Travel and Tourism Council, an industry group) are misleading since they merely require a declaration of intent for certification without any performance criteria.



Although there are some well-regarded certification schemes (e.g., the Certification of Sustainable Tourism program in Costa Rica and the Nature and Ecotourism Accreditation Program in Australia), standards vary widely, and a need has been felt for developing a global ecotourism accreditation mechanism. Respected conservation groups such as the Rainforest Alliance have been involved since the early 2000s in establishing the Sustainable Tourism Stewardship Council (modeled after the successful Forest Stewardship Council), but its future success remains to be seen. One important limitation of certification schemes is that they tend to focus on easily measurable “green design” criteria while doing little to address equity issues such as community empowerment. In fact, certification schemes can even work against small, community-operated enterprises since they are expensive to implement. Therefore, voluntary ecotourism certification can, at best, play a minor role in moving ecotourism toward sustainability unless reinforced by strong legislative and community empowerment initiatives.

The Future of Ecotourism

As the concept of ecotourism has seemingly become hopelessly diluted, some experts have pronounced it dead. Others claim that ecotourism is still in its infancy and can mature and grow beyond its small niche to transform many aspects of tourism practice. Whether the potential of ecotourism can be reached depends on many factors, such as if governments adopt standards for responsible ecotourism. A deep understanding of the concept indicates that ecotourism alone is not a panacea for myriad conservation and development challenges. Mass ecotourism is an oxymoron; not only does increasing visitor numbers put more pressure on the local ecosystem, but an ever-increasing number of people engaged in long-distance travel in the name of ecotourism is self-defeating. Ecotourism ventures have commonly tried to limit visitor numbers by promoting expensive luxury vacations. But catering to the high-end market does not guarantee responsible visitors, and it increases ecological impacts and discriminates against passionate conservationists of ordinary means. An alternative way to

limit visitor numbers and attract responsible ecotourists is through limiting luxury and amenities instead. Under the right circumstances, responsible ecotourism can at best provide limited economic and conservation benefits. Therefore, ecotourism planning would ideally be conducted as part of a broader strategy of sustainable livelihoods development in which local communities can make informed and empowered decisions.

Perhaps the most important step toward fulfilling ecotourism’s promise is to build a more conscious traveling public. On the positive side, there have been numerous instances where dedicated tourists have fallen in love with the destination and its people and devoted their lives to these causes, whether human rights in Tibet, rain forests in South America, poverty reduction in Africa, or infrastructure in Nepal. Tourism has thus promoted “people-to-people” contacts that have aided the cause of sustainability and justice. Among the overwhelming negative trends, there is also the positive trend of a steady increase in volunteer tourism, in which groups of volunteers work on a variety of sustainable development projects while on “vacation.” If such linkages can be strengthened, ecotourism can become a force of positive change.

Abhijit Banerjee

See also **Biosphere Reserves; Conservation; Environmental Impacts of Tourism; Neoliberal Environmental Policy; Parks and Reserves; Sustainable Development; Tourism**

Further Readings

- Ceballos-Lascurain, H. (1996). *Tourism, ecotourism and protected areas*. Gland, Switzerland: International Union for Conservation of Nature.
- Duffy, R. (2002). *A trip too far: Ecotourism, politics and exploitation*. London: Earthscan.
- Fennell, D. (1999). *Ecotourism*. London: Routledge.
- Honey, M. (Ed.). (2002). *Ecotourism and certification*. Washington, DC: Island Press.



- Honey, M. (2008). *Ecotourism and sustainable development* (2nd ed.). Washington, DC: Island Press.
- McLaren, D. (2003). *Rethinking tourism and ecotravel* (2nd ed.). Bloomfield, CT: Kumarian Press.
- Norberg-Hodge, H. (1991). *Ancient futures: Learning from Ladakh*. San Francisco: Sierra Club Books.
- Weaver, D. (1998). *Ecotourism in the less developed world*. London: CABI.



EDUCATION, GEOGRAPHIES OF

Studies of geographies of education explore the complex interactions between education, space, and civil society. The topic is distinct from geographic education, which deals primarily with the teaching and learning of geography as a subject. In recent years a vibrant resurgence in this field has resulted in a growing body of work, theoretically and empirically dispersed within the discipline itself. Critical studies within this broader realm are concerned primarily with social justice, power relations, and structural inequities relating to or emanating from the educational system and have drawn on Marxist, feminist, and poststructuralist approaches to explore wide-ranging topics.

Educational spaces are imbued with multiple purposes and meanings, with the ideologies of the state and its corresponding discursive and material realities becoming discernible. As a lifelong learning process, education is an ongoing activity tied to the production and consumption of knowledge. Including early childhood education, primary to secondary schooling, postsecondary institutions, formal to informal learning, and collective to individualized prospects, the geographies of education reflect various sites and scales of opportunities to investigate an array of geographical concerns. As democratic public spheres, public schools are sites for justice, equality, freedom, and social transformation. Ronald Manzer defines schools as human communities, public instruments, and political symbols and the means

by which people in a political democracy collectively strive for civic virtue, economic wealth, and cultural survival. Apart from its educational mandate, these are places where neighborhood integration, social capital formation, and the fostering of civil society are ideally endorsed. The city-school relationship is also intrinsically linked to the planning and sustainability of urban regions through the quality and vibrancy of its educational institutions. Cities provide the context for communities of difference and have brought educational institutions to the forefront of these debates as sites of empowerment and social cohesion. In the smaller towns, the threat of declining populations and out-migration due to the closure of manufacturing plants and resource-based industries has had detrimental effects on the educational prospects of these places. In rural areas, schools provide one of the few opportunities for community engagement and civic participation, and the threat of school closures has widespread and long-term implications on the well-being of its citizenry.

Critical scholars have long argued, however, that in capitalist societies, educational spaces are sites of cultural and social reproduction succumbing to dominant class value systems. Relegating the educational sphere to the logics of the market and the pursuit of profit—for instance, the call for privatization and choice and the streamlining of the production of knowledge into professional, vocational, and technically trained workers—signals the manipulation of workers into complacency and servitude to capitalist regimes. These forms of institutional discrimination practices are reflected in the spatial segregation and redlining of schools, particularly along racial, class, gender, and disability divides. Similarly, the system of education that was imposed on indigenous peoples by colonial and neocolonial powers led to the historical and spatial processes of their marginalization, dependency, and humiliation. These exclusionary practices in turn have led to spaces of stigmatization and subversion and to the demoralizing and silencing of many marginalized communities. Spaces of education, however, are also sites of contestation, resistance, and possibility. As Ronald Manzer notes, public schools are not only the objects of domination and the products of compromise,



they are also potentially agencies for creating political consensus. Thus, despite the numerous obstacles faced through the experience of marginality, scholars in this field demonstrate that the collective consciousness and political agency generated within the spaces of education can also provide a public venue for social struggle and transformation. In Paulo Freire's classic, *The Pedagogy of the Oppressed*, he notes that there is no such thing as a "neutral educational process," and studies in geographies of education highlight its inherent political nature and corresponding spaces of contrasts and contradictions.

During the past few decades, the realm of education has faced innumerable challenges. These include the globalization and commodification of knowledge production; shifts in demographic composition and household structures spread unevenly across and within cities and regions; the retrenchment of the Fordist-Keynesian welfare state, affecting the redistribution of educational provision; and the neoliberalization of public policy reform, expounding and universally imposing its dictates of marketization, privatization, and accountability practices on the educational terrain. With the increased international migration and cross-border mobility in Western democracies, debates over multiculturalism, citizenship, and cultural identity rights; the unique needs of immigrant and refugee children; the provision of continuing education and second-language acquisition; the evaluation and negotiation of foreign credentials for adults; and the fluid circuitry of transnational experiences and outcomes have not escaped state-bound educational concerns. On a cautionary note, studies in geographies of education alert readers to the parallel hegemonic discourses involving the construction of new kinds of subjectivities that are constituted and entrenched spatially. Such discourses fuel a politics of fear, difference, and "dangerousness" and the targeting of "at-risk" students, which lead to further alienation of minority youth in particular. Landscapes of disparities have subsequently evolved at various scales, creating new spaces, subjectivities, and power relations within communities and schools.

Henry Giroux notes in *Theory and Resistance in Education* that changing historical conditions posit new problems, define different projects,

and often demand fresh discourses. In recent years, empirical studies in geographies of education, particularly in critical geographic thought, have addressed the globalization of education reform and comparative educational policy; the planning, restructuring, and governance of educational institutions; the uneven distribution of educational provision, outcomes, and resources; and the politics of school closures and communities in decline. They have also included provocative debates over private versus public schooling, including religious, linguistic, and minority-focused schooling. Studies on neoliberal governmentality of education have examined the impacts of geosurveillance, new forms of regulation and accountability practices, volunteering and fund-raising expectations, and the proliferation of educational quangos (quasi-governmental organizations) within a wider culture of audit.

The complexities of educational systems have invariably led to broader theorizations and critical debates related to space, place, and society. For example, research related to citizenship, pedagogy, and technologies of government; the politics of race, identity, and integration; and spaces of exclusion, power, and negotiation are among the many converging themes emerging in recent scholarship on the geographies of education.

Ranu Basu

See also **Children, Geography of; Citizenship; Democracy; Geography Education; Inequality and Geography; Knowledge, Geography of; Neoliberalism; Public Space; Segregation and Geography; Social Justice; Social Movements; Spatial Inequality**

Further Readings

- Basu, R. (2004). A Flyvbjergian perspective on public elementary school closures in Toronto: A question of "rationality" or "power"? *Environment and Planning C: Government and Policy*, 22, 423–451.
- Basu, R. (2004). The rationalization of neoliberalism in Ontario's public education system, 1995–2000. *Geoforum*, 35(5), 621–634.



- Bondi, L. (1987). School closures and local politics: The negotiation of primary school rationalization in Manchester. *Political Geography Quarterly*, 6(3), 203–224.
- Bourdieu, P., & Passeron, J. (1990). *Reproduction in education, society and culture* (Rev. ed.). London: Sage.
- Freire, P. (1981). *Pedagogy of the oppressed*. New York: Continuum Books.
- Giroux, H. A. (1983). *Theory and resistance in education: A pedagogy for the opposition*. South Hadley, MA: Bergin & Garvey.
- Kozol, J. (2006). *The shame of the nation: The restoration of apartheid schooling in America*. New York: Crown.
- Manzer, R. (2003). *Educational regimes and Anglo-American democracy*. Toronto, Ontario, Canada: University of Toronto Press.
- Mitchell, K. (2003). Educating the national citizen in neoliberal times: From the multicultural self to the strategic cosmopolitan. *Transactions of the Institute of British Geographers*, 28, 387–403.
- Robertson, S., & Dale, R. (2002). Local states of emergency: The contradictions of neo-liberal governance in education in New Zealand. *British Journal of Sociology of Education*, 23, 463–482.



EGENHOFER, MAX (1958–)

Max J. Egenhofer is a geographer whose research has included work on spatial reasoning and knowledge representation; user interfaces for geographic information systems; the design of spatial database systems; and mobile spatial information appliances. He has been an influential figure in the development and analysis of geographical information systems (GIS) not only in academia but also in the private sector.

Egenhofer is a professor in spatial information science and engineering (since 1999), a cooperating professor in computer science (since 1991), and former director of the National Center for Geographic Information and Analysis at the University of Maine (1993–2006). He has held the Libra Professorship of the College of Engineering at the University of Maine and visiting professor

appointments at the Westfälische Wilhelms-Universität Münster, Germany (2004), and the Università de L'Aquila, Italy (1993). He earned an MS in surveying engineering from the University of Stuttgart, Germany, in 1985 and a PhD in surveying engineering from the University of Maine in 1989.

Egenhofer has proved to be an exceptional research leader. As director of the National Center for Geospatial Intelligence Standards for 12 years, he made this unit the premier place worldwide for research in the technical domain of geographic information science, and he moved the University of Maine into the top rank among universities that receive research funding from the National Geospatial-Intelligence Agency. His service to the scientific community includes the organization of more than 20 national and international conferences. He is the founder of a highly successful GIScience conference series, has been program chair of most academic conference series in GIS, is a past editor of *GeoInformatica*, sits on six editorial boards, and has served on more than 120 program committees.

Egenhofer's work has had a significant influence in industry. Several international standards have been formulated explicitly around his work, and a series of commercial GIS and spatial databases (by Oracle, IBM, Microsoft, Intergraph, Environmental Systems Research Institute [ESRI], Intelligent and Spatial Technologies) have implemented his formalizations. In ISO 19107, the model of topological relations he developed was the "Egenhofer Operators." Fittingly, the University of Maine recognized him with the 2002 Presidential Research and Creating Achievement Award, and the UCGIS has honored him with the 2003 Researcher of the Year Award.

As an educator, Egenhofer has had an enormous impact on generations of doctoral and master's students in SIE. His SIE graduates have successfully published in competitive outlets and have gone on to become leaders in academia around the world or head their own successful companies (e.g., IST, Planet One, Spatial Minds).

Egenhofer has published more than 100 articles in refereed outlets, among which are the most frequently cited papers in four journals and another three conference series, including the most cited paper in the GIS flagship publication,



the *International Journal of Geographical Information Science*. Egenhofer's research record includes more than 50 research grants from the National Science Foundation, the National Institutes of Health, the National Geospatial-Intelligence Agency, the Federal Geographic Data Committee, the U.S. Air Force Research Laboratory, the Advanced Research Projects Agency, the Central Intelligence Agency, ESRI, and many others.

Maria Vasardani

See also **Geographic Information Systems; GIScience**

Further Readings

- Egenhofer, M., & Franzosa, R. (1991). Point-set topological spatial relations. *International Journal of Geographical Information Systems*, 5(2), 161–174.
- Egenhofer, M., & Mark, D. (1995). Naive geography. In A. Frank & W. Kuhn (Eds.), *COSIT '95: Lecture notes in computer science* (Vol. 988, pp. 1–15). Berlin, Germany: Springer-Verlag.



ELDERLY, GEOGRAPHY AND THE

In the absence of migration, the population of any area will become older when fertility and mortality levels decline. Western industrialized nations have already moved into the phase of pronounced population aging in the face of both fertility declines since the mid 1900s and an increase of almost 30 years in life expectancy during the 20th century. Over the next three decades, the aging of a large post-World War II birth cohort will cause an acceleration of this aging trend. Despite the overwhelming focus on aging in Western societies, the vast majority of the world's older individuals reside in less developed countries outside North America, Europe, and Japan. Rapidly changing political, economic, and social conditions within these areas are likely to result in precipitous shifts toward lower mortality

and fertility. With the modernization of these societies and a trend away from reliance on family-based care, the pending demographic tsunami is anticipated to create major problems in providing adequate care for elderly populations as they become frail.

Changing Location and Migration Patterns

The aging of economically developed societies in association with population redistribution (involving the migration of elders and labor force populations) has resulted in a geographical concentration of older populations. Regionally, patterns of aging-in-place lead to concentrations of elders in rural areas abandoned by out-migration of the young in search of employment. Increasing concentrations of retiree migrants are to be found in coastal and amenity-rich communities. The international migration of elderly populations is also becoming an increasingly significant phenomenon. On the scale of individual cities and communities, urban core areas have historically experienced high concentrations of elders as a result of abandonment during the suburbanization of the young. Many rural communities, especially small towns providing attractive retirement destinations, also have high concentrations of elders. Such patterns are complemented by a trend toward the spatial separation of older populations, both within naturally occurring retirement communities and in planned age-segregated retirement communities ranging from small groups of elders housed in specially designed housing complexes to communities of more than 75,000 elders, such as Sun City, Arizona.

Elders' Experience of Space and Place

Burgeoning elderly populations have led to an increasing concern with understanding how aging people use space and experience place and the manner in which such experience evolves as a result of changing physical, social, and psychological capabilities associated with advancing years. Older people spend more time at home. Limited mobility leads to progressively more constricted activity spaces. This pattern may be associated with an increasing emphasis on vicarious environmental participation and a growing



emotional attachment to easily negotiated and familiar settings including the immediate residence. A desire to preserve independence and age-in-place may be manifested in a geographical centralization of activity within a limited area within the home. Elders may engage in the proactive creation of place by surrounding themselves with treasured artifacts, including photographs that sustain an ongoing sense of home and personal identity. This, in combination with the physical and psychological advantages of environmental familiarity, may result in a reluctance to relocate.

Geographical Aspects of Service Provision and Care

Creation of a continuum of care involving an ever-expanding array of services and environments represents one societal response in most Western countries to the growing numbers of elders. In the United States, the public sector of this continuum is coordinated through a geographic network, Area Agencies on Aging, created under the aegis of the Older Americans Act of 1965. A pervasive imperative to preserve elders' independence and ability to age in place has given rise to home-delivered services (e.g., home care), enhanced community-based resources (e.g., nutrition programs and senior centers), and an ever-widening array of supportive residential options including sheltered housing, assisted living, and continuing care retirement communities. At the end of the continuum are nursing facilities providing skilled medical care to the most frail and hospice alternatives for those in the final phase of life. Major challenges are presented by questions of geographical accessibility (location of facilities within communities and relative to family networks) and social access (cultural expectations and ability to pay) to the continuum. As elders move along the residential continuum, the issue of relocation and associated influences on morbidity and mortality becomes increasingly significant.

Emergent Environments of Aging and Enduring Policy Dilemmas

The graying of populations has had major impacts on the geographical landscape over the past century through the transformation of community

spaces and built environments as successive generations have reshaped the milieu in which people grow old in parallel with changing societal attitudes toward elders. It has also given rise to a set of enduring issues with significant geographical implications. What constitutes successful or optimal old age may change as priorities focus more on aging in place and maintaining independence. A growing trend toward geographical separation, in some cases the segregation of older populations, must be balanced with the benefits of social integration across the population age spectrum. There is a further need to identify the appropriate role of families versus societal institutions in maintaining the personal autonomy of older people. Reconciling age and need as criteria for the provision of services represents an ongoing challenge for the welfare state. Resolution of such issues is central to the creation of spaces and places that will ensure optimal aging.

Graham D. Rowles and John F. Watkins

See also *Demographic Transition; Gated Community; Health and Health Care, Geography of; Housing and Housing Markets; Migration; Population Geography; Population Pyramid*

Further Readings

- Laws, G. (1993). "The land of old age": Society's changing attitudes toward urban built environments for elderly people. *Annals of the Association of American Geographers*, 84(3), 672–693.
- Macey, S., Smith, G., & Watkins, J. (2003). Aging and the aged. In G. Gaile & C. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 516–525). New York: Oxford University Press.
- Rowe, J., & Kahn, R. (1998). *Successful aging*. New York: Dell.
- Rowles, G. (1978). *Prisoners of space? Exploring the geographical experience of older people*. Boulder, CO: Westview Press.
- Warnes, A. (1990). Geographical questions in gerontology: Needed directions for research. *Progress in Human Geography*, 14, 24–56.



ELECTORAL GEOGRAPHY

Electoral geography is the study and analysis of the geographic patterns of elections, referenda, and legislative votes. The field originated in the early 20th century, particularly with the work of the French scholar André Siegfried, who produced some of the first maps showing the percentage of votes for parties by local region. Traditional electoral geography has focused on such spatial patterns of votes. Since the early 1970s, however, the field has also included other concerns such as the “neighborhood effect” and the spatial dynamics of political life.

Traditional Electoral Geography

Producing a map of election results is the most basic technique in electoral geography. These

maps reveal the relative strength of support for candidates, parties, or referenda in different regions and are now often a prominent feature of election coverage in the popular media. The infamous red-blue map of the United States from the 2004 election, for example, showed Republican support stretching across a vast area of the country, while Democratic strength was concentrated in the northeast, the west coast, border regions, and scattered counties in the Midwest (Figure 1). On the basis of this map, Republican candidate George Bush appeared to enjoy broad support across the country.

Yet such simple maps can mislead in at least two ways. First, using only two colors disguises variations in strength among regions, with areas won by a landslide appearing the same as counties won by narrow margins. Better cartographic techniques—using gradations of color, for example—can overcome such problems.

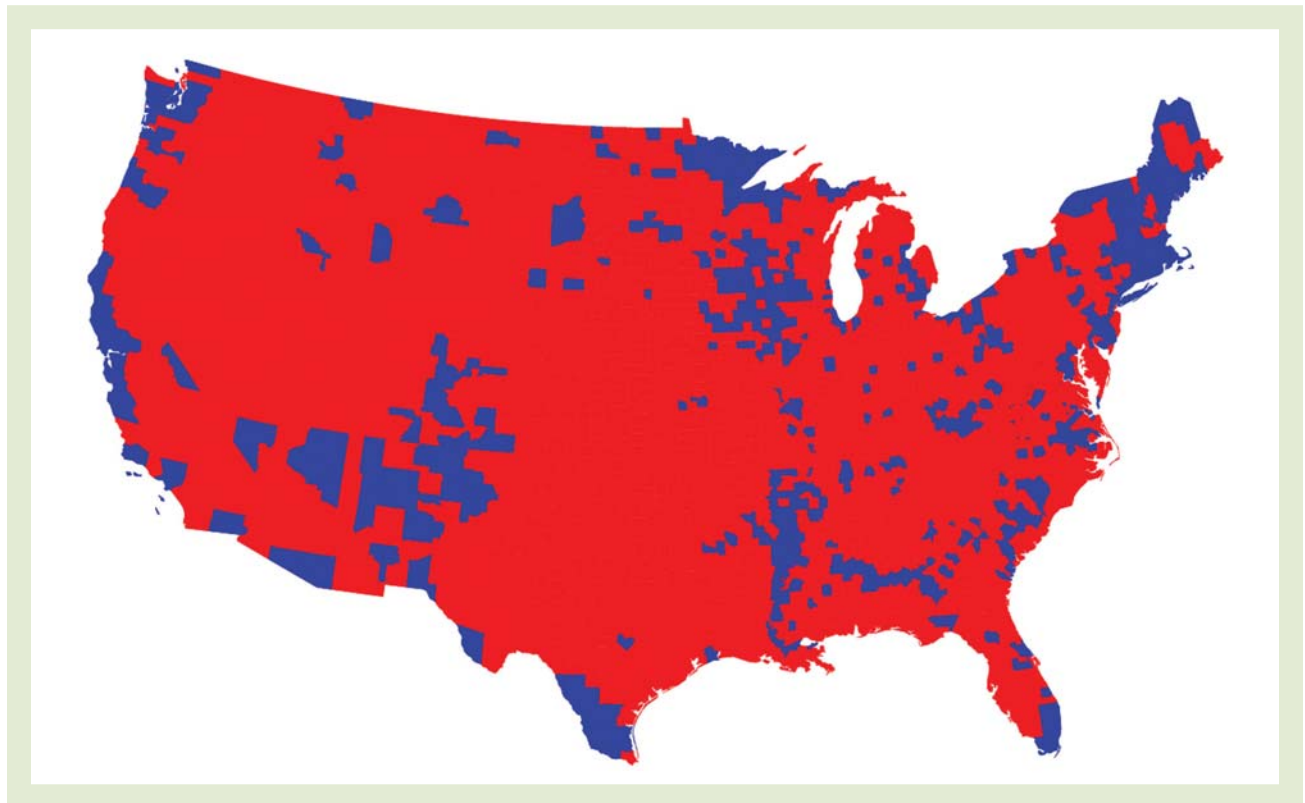


Figure 1 Choropleth map of counties won by President George Bush (Republican candidate) and Senator John Kerry (Democratic candidate) in the 2004 U.S. presidential election

Source: Michael Gastner, Cosma Shalizi, and Mark Newman, University of Michigan. Retrieved January 30, 2010, from www-personal.umich.edu/~mejn/election. Copyright © 2008 M. E. J. Newman. Used with permission.

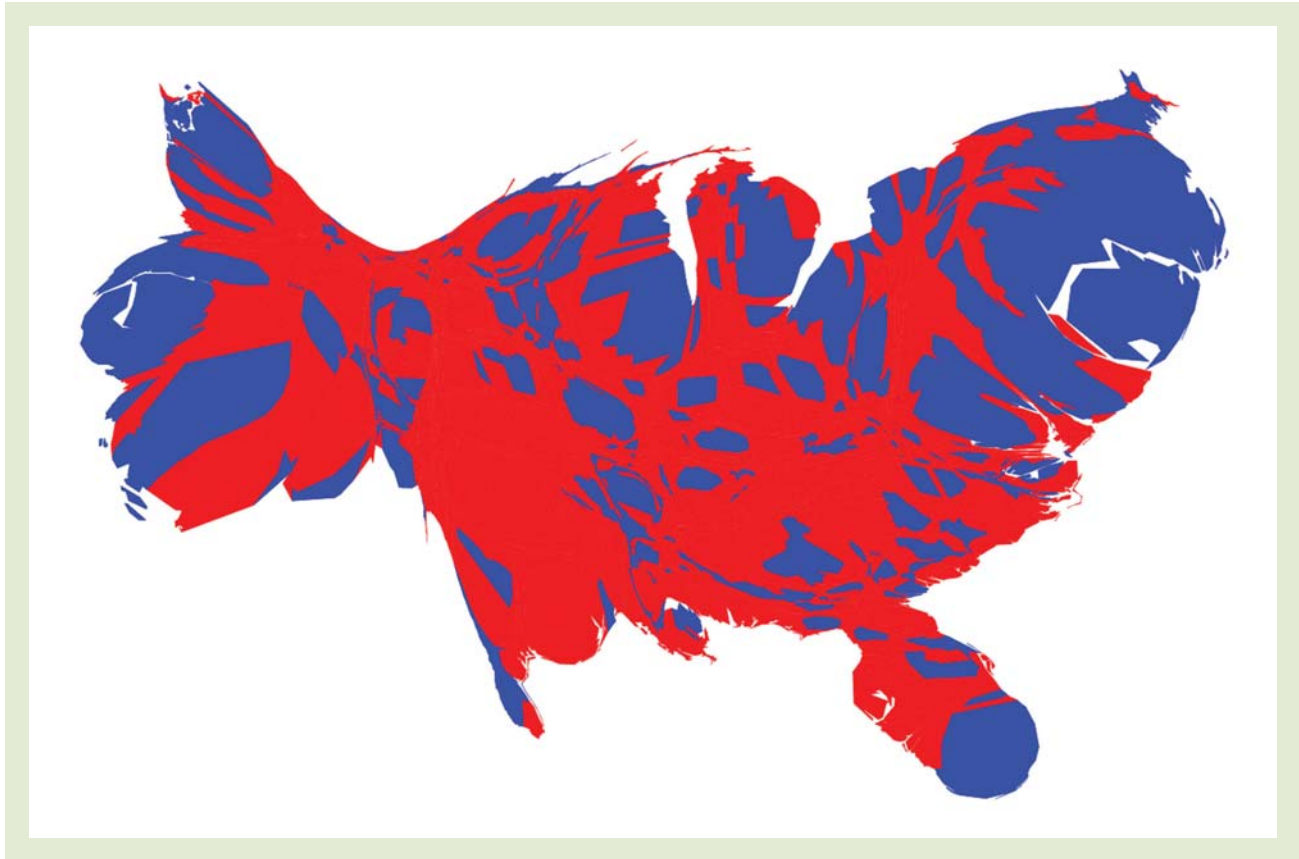


Figure 2 Cartogram by population of counties won by President George Bush (Republican candidate) and Senator John Kerry (Democratic candidate) in the 2004 U.S. presidential election

Source: Michael Gastner, Cosma Shalizi, and Mark Newman, University of Michigan. Retrieved January 30, 2010, from www-personal.umich.edu/~mejn/election. Copyright © 2008 M. E. J. Newman. Used with permission.

The second, and more fundamental, problem is that such maps represent area rather than votes or population size. In this case, the map appears to be almost overwhelmingly red, although President Bush won by less than 2.5% of the popular vote (3.3 million votes nationally) and by just over 6% (34) of electoral college votes. Using a cartogram where the sizes of counties correspond to their populations produces a map with areas of red and blue that are more nearly equal but at the cost of distorting the shape of county, state, and national boundaries (Figure 2).

Despite these limitations, such descriptive maps or cartograms can provide a vivid and easily understood snapshot of political patterns for particular elections. Comparing a series of maps based on several elections, or a single map based on data from a series of contests, can reveal

relatively stable political patterns, as well as areas of change. Particularly stable patterns can be used to identify and classify regional political cultures. Daniel Elazar, for example, divided the United States into three political cultural regions: Moral, Individual, and Traditional. These regions tend to consistently vote differently than each other over a series of elections, suggesting that each area has a different political culture.

Similarly, spatial patterns of voting are also used to trace the emergence and evolution of political parties. Parties tend to be more diverse and less stable in countries that use party-list systems (where voters cast a ballot for a party rather than for a particular candidate). When old parties decline and new ones appear, electoral geographers trace the way in which voters transfer membership and loyalty or, in some cases, discover



which voters display little party loyalty and are willing to switch between elections. Such transitions are typically tied to changes in regional economies, demographic and migration trends, and regionally based public investment. During the 1990s, there was special interest in the emergence of political parties in the democratizing states of the former Soviet bloc. In these cases, support for communist parties (or their direct heirs) or for extreme nationalist parties was often strongest in regions that had experienced more difficult transitions to a market economy.

Electoral Geography From a World-Systems Perspective

The basic analyses discussed above generally assume (explicitly or implicitly) that spatial voting patterns are relatively stable (the same or similar voters will vote in the same or similar ways over a series of elections), that voters consistently vote for political parties that best represent their interests, and that the resulting government policies will reflect the interest of the majority of voters. All these assumptions have been challenged by electoral geographies based in a world-systems perspective. Scholars using this framework—most prominently Peter Taylor—have argued that these assumptions only hold true (at best) in “core” states (wealthy, industrialized countries, primarily in North America and Western Europe). Electoral patterns outside the core tend to be highly unstable, as do elected governments in these regions.

There are two basic explanations for this difference. First, the modernization process that accompanied the development of representative democracies in Western Europe coincided with the emergence of two stable sets of party cleavages. Nationalization produced a split between subjugated and dominant cultures and between religious (church) and secular (state) authority. Simultaneously, industrialization produced a cleavage between agriculture and industry, and between capital and labor. These fissures remained stable in Western Europe through the late 19th and early 20th centuries, producing relatively stable spatial patterns and relatively stable party organization. Regional patterns of voting can be explained by alliances between different groups aligned along these two sets of differences. Other

regions of the world, particularly those previously colonized by Europe, experienced a different modernization process that did not produce such stable political divisions. Second, world-systems theory suggests that parties remain in power only to the extent that they can form governments that effectively redistribute resources (i.e., social welfare services) to the electorate. Noncore states, however, are not wealthy enough to consistently provide enough resources to effectively cultivate the loyalty of constituencies. Consequently, elections outside the core are characterized both by low party loyalty and by the consistent electoral failure of incumbent parties.

Redistricting and Roll-Call Analyses

The practice of redistricting is a special case of electoral geography. In political systems that use election by district—where candidates run for office in a specific geographic constituency—the location and behavioral pattern of voters are often of concern for the organization responsible for drawing new districts. Political parties attempt to use redistricting to distribute their likely voters so as to create as many districts as possible in which the party has a majority or plurality. This process thus involves a kind of “applied” electoral geography, where the spatial distribution of voters and the likelihood that they will vote in particular ways (for or against particular parties or candidates) are used to influence the outcomes of elections. Scholarly analyses of various districting plans employ similar techniques, albeit without explicit political agendas.

Another subset of traditional electoral geography examines votes by representatives in legislatures and parliaments (so-called roll-call votes). Such analyses may focus either on regional variations in voting patterns or (more typically) on the relationship between the composition of constituencies and the votes of the corresponding representative. Figure 3 shows the relationship between the vote on an amendment to the Voting Rights Act, the party of congressional representatives, and the racial composition of congressional districts in Pennsylvania in 2006. In this case, one might hypothesize that representatives from districts with a significant number of African Americans—the traditional

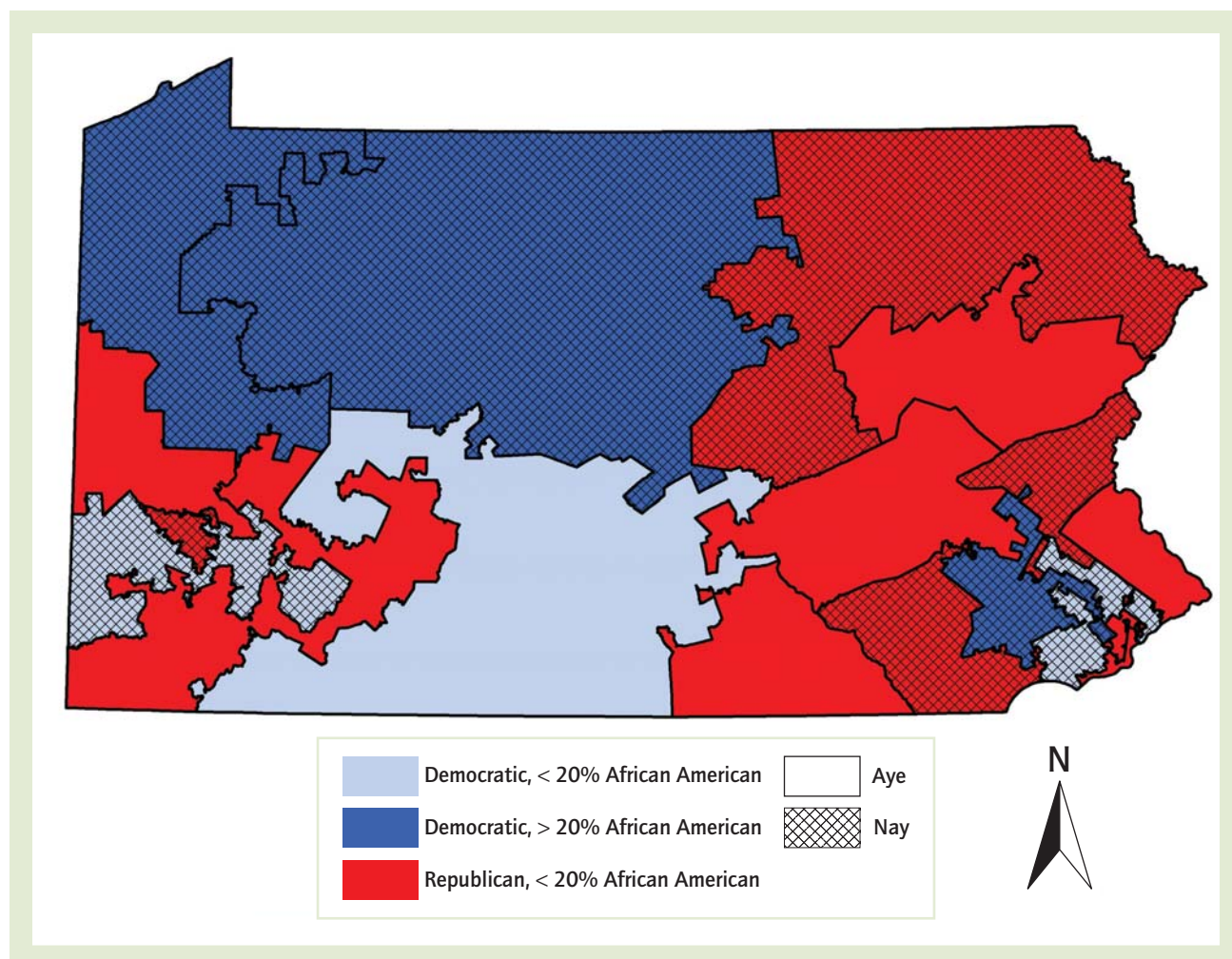


Figure 3 The geography of a 2006 congressional roll-call vote to amend the Voting Rights Act, by party, of the representatives and district percentage of African Americans in Pennsylvania

Source: Author.

beneficiaries of the Voting Rights Act—would have opposed this particular amendment (which would have weakened certain provisions of the legislation). Yet the map illustrates that at a minimum there are also important partisan effects at work: All Democratic and some Republican representatives (none of whom had a significant number of African Americans in their districts) also opposed the amendment.

The relationship between roll-call votes and independent variables such as party membership and constituency characteristics is often complex and typically needs to be modeled with multivariate regressions. Such studies are especially useful

in examining the role of political representation in mediating the relationships between political preferences and political action. Unlike election results, roll-call votes reveal how particular individuals (representatives) voted, rather than simply presenting the aggregate results of many individual, anonymous voters.

Scale and Electoral Geography

Starting in about the late 1960s and early 1970s, electoral geographers began to move beyond traditional descriptive maps to use election results to investigate the spatial dynamics of political



behavior. These efforts were distinguished from world-systems theory in the sense that they examined the effects of space and spatial organization on elections and politics. Two directions in this endeavor are especially notable: studies of the “neighborhood effect” and political party organization and dynamics, and “place-based” studies of politics.

Studies of the neighborhood effect attempt to explain local spatial variations in voting patterns that cannot be accounted for by individual economic, social, and demographic characteristics typical at the national level. They hypothesize that voters who are similar but who live in different locations will vote differently if their local political contexts are different. Differences in such contexts can arise from at least two sources: acquaintance circles (groups of people who typically socialize with each other) and the organizing efforts of political institutions, especially political parties. In the first instance, people’s political preferences will tend to converge as they spend more time talking with each other, particularly in face-to-face situations. If a majority of a voter’s neighbors and acquaintances are conservative, for example, she or he may tend to become more conservative over time even if she or he otherwise has the characteristics of a liberal. In the second case, political organizing on the local level affects both voters’ perception of their own political interests and their likelihood to vote.

Finally, certain political geographers, most notably John Agnew, have advocated a place-based approach to the study of politics that calls for a substantial reworking of traditional electoral geography. Like “neighborhood” studies, such place-based or contextual approaches also examine spatial variations but do not automatically set “neighborhood” patterns against national ones. This method sees the aggregate nature of electoral data as an advantage rather than a limitation because it focuses on the social nature of politics and political identities rather than on individual preferences. In particular, political life and political interactions are seen as being inherently place based, with a web of preferences, social divisions and constraints, associations (including political parties), and institutions being organized and experienced in particular spatial contexts. The choice of scale for electoral analysis

is fundamental, with national- or even regional-level electoral studies often disguising critical political relationships. From this perspective, microlevel electoral data (at the county, commune, or even precinct level rather than at the national level, for example) offer a better opportunity for analysis not because the data are more detailed (as traditional electoral geography might argue) but because the spatial units may correspond better to the scale of lived political experience. The approach does not assume a priori that there is a single best scale of analysis for electoral geography but rather that the appropriate scale depends on the specific situation and relationships in question.

Benjamin Forest

See also Agnew, John; *Citizenship; Democracy; Johnston, R. J.; Political Geography; Redistricting; Scale, Social Production of; Taylor, Peter; World-Systems Theory*

Further Readings

- Agnew, J. (1996). Mapping politics: How context counts in electoral geography. *Political Geography*, 15, 129–146.
- Agnew, J. (2002). *Place and politics in modern Italy*. Chicago: University of Chicago Press.
- Archer, J., & Shelley, F. (1988). The geography of U.S. presidential elections. *Scientific American*, 259, 44–53.
- Flint, C. (2001). A timespace for electoral geography: Economic restructuring, political agency and the rise of the Nazi party. *Political Geography*, 20, 301–329.
- Johnston, R. (2005). Anglo-American electoral geography: Same roots and same goals, but different means and ends? *Professional Geographer*, 57, 580–587.
- Johnston, R., & Pattie, C. (2006). *Putting voters in their place: Geography and elections in Great Britain*. Oxford, UK: Oxford University Press.
- Johnston, R., Rossiter, D., & Pattie, C. (2005). Disproportionality and bias in US presidential elections: How geography helped Bush defeat Gore but couldn’t help Kerry beat Bush. *Political Geography*, 24, 952–968.



- Pattie, C., & Johnston, R. (2000). "People who talk together vote together": An exploration of contextual effects in Great Britain. *Annals of the Association of American Geographers*, 90, 41–66.
- Shelley, F. (2002). The electoral college and the election of 2000. *Political Geography*, 21, 79–83.
- Taylor, P., & Flint, C. (2007). Rethinking electoral geography. In *Political geography: World-economy, nation-state, and locality* (5th ed., pp. 194–241). Harlow, UK: Pearson/Prentice Hall.
- Warf, B. (2009). The U.S. electoral college and spatial biases in voter power. *Annals of the Association of American Geographers*, 99, 184–204.



ELECTRONIC ATLASES

Electronic atlases are intentional combinations of maps or data sets structured in such a way that given objectives are reached. In the recent history of cartography, atlases deserve a prominent status among cartographic products due to the variety of their thematic content, the rather friendly appearance, and their utilization by a wide spectrum of users. Advances in information technology and more specifically in geographic information systems and digital mapping, have altered the traditional way of using maps and thus have a considerable impact on every aspect of electronic atlas design, content, and functionality. Considerable effort has been made in the production of electronic atlases, and successful systems are available with fascinating design and functional characteristics.

One way of understanding our neighbors better is to compare them with ourselves. The visualization of geostatistical data in electronic atlases with the support of basic analytical tools is the most effective way to represent quantitative and qualitative aspects of spatially distributed phenomena as well as their thematic and geographical relations.

Menno-Jan Kraak and Ferjan Ormelting consider atlases to be a higher form of cartography compared with maps and charts because their production involves both an extra planning and an extra structural dimension. Initially, electronic atlases

emulated the appearance of paper atlases and were sequential "slide shows." The more advanced electronic atlases have high interactive mapping capabilities that allow users to manipulate atlas data, to combine them with their own, and to examine spatial and thematic data dynamically, thus developing different representations. The distinction of electronic atlases into *view only*, *interactive*, and *analytical* is only an indication of the course followed until we reached the point where an electronic atlas is expected to virtually cover all realistic needs of the user community; from changing color schemes and the number of classes to combination, query, analysis, and dynamic presentation of geographic and statistical data sets. On the other hand, the increasing demand for sophisticated data presentation and manipulation is further stimulated by developments in scientific visualization, graphic user interface design, cognitive—usability, multimedia, and exploratory data analysis.

Another consequence of the technological change is the ability to access maps and related information via the Internet, which has changed people's daily lives. The Internet can serve as a source of spatial data, thematic data, finished maps, and software for exploring and analyzing data. Despite the increasing trend of accessing, processing, and displaying information via the Internet, a well-designed electronic atlas should not be restricted in this mode of operation. The system should enable the user to be capable of using the electronic atlas as a stand-alone—where the atlas will be stored on a removable medium such as a DVD—supported by an Internet alternative, which will provide the updating of the geographical and statistical data.

Lysandros Tsoulos

See also **Cartography**; **Internet GIS**; **Multimedia Mapping**

Further Readings

- Atlas of Switzerland: www.atlasderschweiz.ch/index_en.html
- Kraak, M.-J., & Ormelting, F. (2003). *Cartography: Visualization of geospatial data* (2nd ed.). Essex, UK: Pearson Education.



ELECTRONICS INDUSTRY, GEOGRAPHY OF

The electronics industry manufactures the suite of information and communications technologies that harness the processing capacity of semiconductors, or microchips. In practical terms, the core set of electronics industries includes chip design and fabrication, computers, consumer electronics, and communications equipment (e.g., cell phones). The boundaries of the sector could reasonably be drawn to include a range of associated industries such as advanced computer-numeric controlled machinery producers or robotics (though not software) industries that rely substantially on electronic engineering. Advances in electronics have had a pervasive impact on virtually all facets of economic activity over the past 50 years. Given this almost singular importance, the industry has proven especially crucial in driving regional development in the places where it locates. The following paragraphs discuss the industry's evolving spatial dynamics by emphasizing the roles of states, lead firms, and informal routes to skill formation.

Several key patterns define the geographical evolution of the electronics sector. The United States and in particular key regions such as Massachusetts' Route 128 and California's Silicon Valley are acknowledged as the crucibles of the electronics revolution, their emergence coinciding with the first commercial applications of the transistor in the 1950s. Silicon Valley persists as the world's leading electronics industrial district. It is home to key firms such as Intel, Hewlett-Packard, and Apple and derives additional advantage from its proximity to Stanford University, the sine qua non model for university technology transfer. The positive externalities of Silicon Valley act as a magnet for American and international talent, making it virtually imperative for the world's leading electronics firms to have a presence there too.

Apart from the United States, Japan has been perhaps the biggest foreign beneficiary of the early advances in American electronics technology. Indeed, the transfer of American technology and basic science to Japan, most famously exemplified in Sony's purchase of the Bell Labs/Western Electric transistor technology in 1954, provided the

foundations for the Japanese consumer electronics firms, whose brands continue to dominate the industry. More generally, the emergence of Japan signaled the ascendance of East Asia as the center of gravity for electronics manufacturing.

The diffusion of the electronics sector within East Asia reflects shifts in the industry's increasingly elaborate division of labor. Most basically, the electronics industry can be categorized into, on the one hand, high-value-added and specialized functions, such as chip design/production, that require significant economies of scale and state support—capital costs for new chip fabrication plants run upward of \$3 billion to \$4 billion. On the other hand, more routine functions such as component assembly for consumer electronics are attracted to low-labor-cost locations. An overwhelmingly female labor force persists as the constant characteristic of factories in these latter contexts.

The precise spatial articulation of this division of labor results from the twin motivations of firms and states. Electronics firms generally conduct higher-order functions such as R&D and pilot manufacturing in their home markets. This means that most R&D and patenting in electronics are concentrated in a relatively narrow set of advanced industrial nations with significant basic scientific capabilities (the United States, Japan, Germany, Finland, South Korea, etc.). In contrast, the routine production of electronics that occurs at later stages in the product cycle almost inevitably takes place in lower-cost locations. States that host multinational electronics firms therefore have a powerful incentive to enhance the skills of their workforce so that they can capture the investment of increasingly more sophisticated functions that are likely to spawn a domestic electronics sector.

To illustrate this crucial firm-state relationship in East Asia, Japanese electronics firms, for example, have exhibited a sequential pattern of investments through a succession of host nations, including Taiwan (1960s); South Korea and Singapore (1970s); Malaysia, Indonesia, the Philippines, and Thailand (1980s); and China and Vietnam (1990s). By using Japanese investments as a catalyst for learning, South Korea, Taiwan, and more recently China have been successful in cultivating domestic R&D-driven electronics industries capable of higher-order manufacturing/design functions. In contrast, Malaysia, Indonesia,



the Philippines, and Vietnam have served principally as magnets for investments in assembly-type functions. The lesson to be drawn from this example is that the economic development potential from electronics investments clearly hinges on the ability of states to both bargain for higher levels of technology transfer and encourage domestic skill formation for the management of more advanced functions. While formal state support and large firm investments are essential conditions for fostering an electronics sector, other less formalized factors are also important.

The success of the Japanese electronics industry in the postwar era owes much to the more informal skill base prevalent in Japan at the time. A case in point is the genesis of Akihabara, Tokyo's retail Mecca for electronics and pop culture content such as anime and video games. Following World War II, a network of amateur tinkerers descended on Akihabara's weekend bazaar, a former black market, for surplus military radio components. With guidance from electronics digests, this population learned to engineer their own radios and similar proto-electronics. As the Japanese electronics sector took off in the 1950s and 1960s, it leveraged the tacit skill base of this tinkerer cohort. Steve Wozniak, Apple's cofounder, tells a similar tale about his youth in Silicon Valley. Perhaps these historical anecdotes are a prologue, as poorer nations such as China and Bangladesh, which currently serve as the destinations for the world's cast-off electronic waste, may be able to translate the skills of today's component recyclers into a more formal electronic industry in the future.

Tim Reiffenstein

See also **Flexible Production; High Technology; Industrial Districts; Innovation, Geography of; Product Cycle; Research and Development, Geographies of; Technological Change, Geography of**

Further Readings

Dicken, P. (2007). "Chips with everything": The semiconductor industry. In *Global shift: Mapping the changing contours of the world economy* (5th ed., pp. 317–346). New York: Guilford Press.

Edgington, D., & Hayter, R. (2000). Foreign direct investment and the flying geese model: Japanese electronics firms in Asia Pacific. *Environment and Planning A*, 32, 281–304.

Saxenian, A.-L. (1994). *Regional advantage: Culture and competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.

Takahashi, Y. (2000). A network of tinkerers: The advent of the radio and television receiver industry in Japan. *Technology and Culture*, 41, 460–484.

Wozniak, S., & Smith, G. (2006). *iWoz: How I invented the personal computer, co-founded Apple, and had fun doing it*. New York: W. W. Norton.

Xin, T., & Wang, J. (2007). Transnational flows of e-waste and spatial patterns of recycling in China. *Eurasian Geography and Economics*, 45, 608–621.



EL NIÑO

The El Niño-Southern Oscillation (ENSO) is a joint oceanic (El Niño) and atmospheric (Southern Oscillation) phenomenon spanning the equatorial Pacific and is one of the more important causes of global climate variability. Its first-order impacts are on the distribution of sea surface temperatures (SSTs) and precipitation over the equatorial Pacific and environs. These changes in the locations of the vast quantities of energy stored in the ocean waters and their release to the atmosphere by means of latent heat during cloud formation are spread around the globe by a series of atmospheric linkages known as *teleconnections*. Differences in the speed of response of the atmospheric (rapid) and oceanic (slower) components of this coupled system ensure that it is intrinsically unstable, oscillating in a pseudoperiodic fashion with a frequency of approximately 3 to 7 yrs. (years) between three principal phases: "warm," closely linked to the popularly named "El Niño"; "cold," also variously called "La Niña," "El Viejo," or "Anti-El Niño"; and "neutral." The nomenclature refers to the dominant sea surface temperatures in the central and eastern equatorial Pacific rather than the resultant



local and regional climate conditions, which can be warmer or cooler, and wetter or drier, depending on the season and the geographic location.

History of Discovery

The term *El Niño*, or “Christ child” in Spanish, has been used for centuries by fishermen of the Northern Peru and Southern Ecuador littoral to describe a quasi-annual warming of coastal ocean waters shortly before Christmas, which persists for several months. Cold-water pelagic fish, such as anchovies and sardines, dominated and provided the basis of the regional maritime ecology, including guano birds, whose droppings constituted a large portion of the global fertilizer market, and the Peruvian economy before the advent of chemical fertilizers. The cold waters are the northernmost expression of the Chile, Peru, or Humboldt Current, flowing northward along the coast of Western South America from the sub-Antarctic Ocean and westward along the equator in a semipermanent feature called the “cold tongue.” Fishermen noted this seasonal change in the waters through the fluctuating size and composition of catches. Tremendous variability in the severity, onset, and duration of this phenomenon was also noted. On some occasions (“cold phase”) the losses were negligible, while other years (“warm phase”) brought a total collapse of the fishery and extensive deaths of guano birds and marine mammals. Colonial records from Peru indicate that the impacts of these changes were often exacerbated by contemporary devastating floods in the coastal Chira desert region and simultaneous droughts in the Altiplano.

Following a sequence of severe droughts, failed harvests, and millions of deaths resulting from the failure of the monsoon rains in India during the late 19th century, a leading British atmospheric scientist, Sir Gilbert Walker, was dispatched to determine their cause. Examining meteorological records from the subcontinent and surrounds, Walker noted a strong regional association in annual variations of atmospheric pressure over the area encompassing southeast Asia, particularly the Indonesian archipelago, and bordering the western equatorial Pacific and Australia, then another British dominion that was subject to severe and devastating climatic variability.

Encouraged by this hemispheric-scale association in atmospheric pressure variations, Walker extended his analysis to the global scale and noted a strong negative correlation between the atmospheric pressure over Indonesia and Australia (Djakarta and Darwin) and the Central Pacific (Tahiti). Interannually, pressures above these two nodes appeared to rise and fall in lockstep with each other but in opposing directions. Walker coined the term *Southern Oscillation* to describe this observation. Further analysis of fluctuations in pressures at other locations around the world offered hope that the phenomenon might provide an explanation for variations in what Walker termed *global weather*.

At the time, no connection was drawn between the oceanic El Niño phenomenon of the Eastern Pacific and the atmospheric Southern Oscillation in the west. Ironically, it is now clear that shortly after the publication of Walker’s work in the late 1920s and early 1930s, interest in the linkages in his “global weather” entered three of four decades of relative quiescence, till after his death in 1958. His obituary alludes to a prevailing contemporary feeling that Walker’s belief in the global significance of the Southern Oscillation was misplaced. However, within a decade of his death, a resurgence of interest in global fluctuations of climate and fish stocks and the reemergence of stronger “warm-phase” events (1965–1966, 1972–1973) led to a reevaluation of Walker’s contributions and the positing of causal linkages between oceanic and atmospheric phenomena as a means by which impacts are spread globally. In the past 50 yrs., scientific and public awareness of the significance of Walker’s discoveries and the impacts of ENSO have expanded greatly, aided by the devastating El Niño (warm-phase) events of 1982–1983 and 1997–1998 and a reevaluation of its role in global environmental, social, and political history.

Physics of ENSO

Warm air rising above the equatorial oceans causes surface winds to move in from both south and north of the equator to replace it. At the top of the troposphere (8–10 km [kilometers]), the air moves poleward, cooling, to descend at approximately 30° north and south. This continuous exchange of air north and south of the equator at



various altitudes is termed *Hadley Cell Circulation*. Air masses are deflected to the right (Northern Hemisphere) and left (Southern Hemisphere) of their intended path by the Coriolis force, resulting from Earth's rotation. The resultant surface winds, the northeast and southeast trades, are some of the most noticeable and permanent features of the global wind fields. The two winds converge in a broad discontinuous band of warm rising equatorial air known as the Inter-Tropical Convergence Zone (ITCZ). The ITCZ migrates seasonally, driven by the position of the overhead sun, differences in the thermal properties of oceans and continents, the global distribution of continental masses, and the underlying SSTs. The net result in the Pacific is to convey warmer surface waters away from western continental South America, along the equator toward Australia and southeast Asia, leaving a "warm pool" of warm water in the western ocean and a cold tongue in the east.

A similar geographic disparity is observed beneath the ocean waters. In the west, accumulated warm surface waters physically raise the ocean height and also drive the boundary between the warmer surface and cool subsurface waters, the 20° C thermocline, to 150 m (meters) beneath the surface. Along the Peruvian coast, cold subsurface waters appear at the surface, and the thermocline is located at a much shallower depth (40–50 m). The atmosphere above these two areas responds quickly to the differing SSTs, intensifying the low atmospheric pressures and lifting of air above Indonesia (SST 28° C), while the cool waters along the cold tongue (20–22° C) produce cooler, more dense, subsiding air. The air rising over Indonesia produces excessive rains and a transfer of latent heat to the atmosphere, while clear skies prevail in the eastern ocean. The rising air spreads east and west at the top of the troposphere, contributing, in part, to the descending air over the cold tongue. This cell of east-west circulating air and ones like it above the equatorial regions are termed *Walker Cell Circulation*, commemorating the seminal contributions of the climatologist.

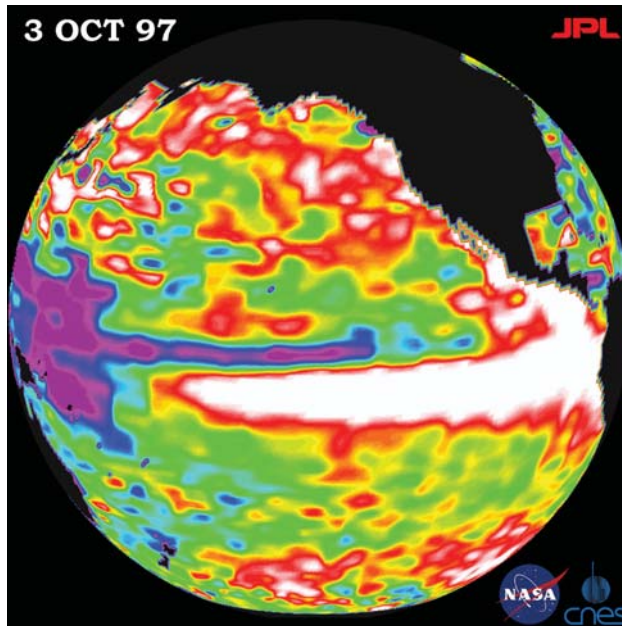
At some point, the strength of the trade winds and the north-south Hadley Cell weaken, allowing the warmer water to migrate westward. More important, a wave motion is set up in the

thermocline, which travels faster than any surface waters, spreading eastward across the Pacific with concomitant changes in SSTs. Such changes are generally detectable about the international date line in June or July, with their impacts reaching coastal South America in late November or December. As the wave moves eastward, it cannot dissipate north or south because the Coriolis force focuses the phenomenon along this equatorial belt. The precipitation associated with the warm pool moves eastward to the Central Pacific, producing a drought over Australia-Indonesia. This shift in associated release of energy in the form of latent heat strengthens the north-south Hadley Cell circulation over oceanic regions, enhances the trade winds, and begins to reverse the process. Generally, about 12 to 18 months elapse between the first appearance of warmer waters in the Central Pacific and the conclusion of a "warm-phase" event.

The cessation of a warm phase often portends intensification of both the warm pool and the cold tongue ("cold phase" of ENSO). The east-west Walker Cell now dominates, and the Hadley Cell begins to weaken, bringing the process back to its original condition with the noted periodicity. In this way, the conditions of both cold and warm phases ultimately contain the seeds of their own demise and tend toward the development of the opposing phase because of the different response times of the coupled atmospheric and oceanic systems. As such, the arrangement is inherently nonlinear and displays many of the properties of a chaotic system, with three nodes of attraction or the three phases of ENSO. No pair of similar phases is ever the same in its development, intensity, or duration, making the forecasting of the nature and extent of impacts difficult and sometimes leading to differences of categorization phases, which is actually all part of a continuum.

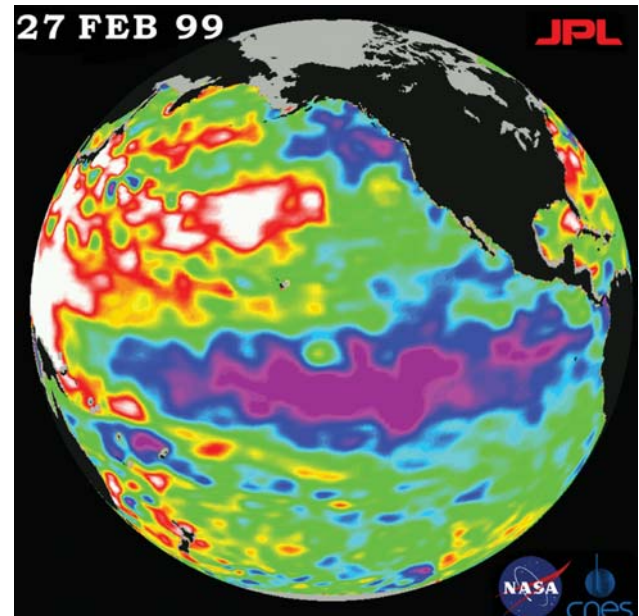
Global Impacts of ENSO

The direct impacts of ENSO are felt along the equatorial belt of the Pacific and marginal continents. In these regions, extra cloud cover is generally associated with cooler air temperatures and vice versa. Warm phases bring drought to the Western Pacific, as exemplified by the extensive forest fires of 1997–1998 in Indonesia. Excess rains fall over the Central Pacific islands as the



The image shows sea surface height relative to normal ocean conditions on October 3, 1997, as the warm water associated with El Niño (in white) spreads northward along the entire coast of North America from the equator all the way to Alaska. The warm water pool in the tropical Pacific resulting from El Niño seems to have stabilized. The white and red areas indicate unusual patterns of heat storage; in the white areas, the sea surface is between 14 and 32 cm (6 to 13 in.) above normal; in the red areas, it's about 10 cm (4 in.) above normal. The image was produced using sea surface height measurements taken by the U.S./French TOPEX/Poseidon satellite.

Source: NASA/Jet Propulsion Laboratory.



This image from the U.S.-French TOPEX/Poseidon satellite shows the cold pool of water in the Pacific known as "La Niña." Produced using sea-surface height measurements taken by the satellite, the image shows sea-surface height on February 27, 1999, relative to normal ocean conditions, reflecting the heat content of the ocean. The low sea level or cold pool of water along the equator (shown in purple and blue), commonly referred to as La Niña, still dominates the equatorial Pacific Ocean. This La Niña set off about 3 years of drought in the southeastern United States.

Source: NASA/Jet Propulsion Laboratory.

warm pool migrates and the weakening of the descending limb of the Walker Cell circulation over coastal Peru, combined with the diminished upwelling of cold water and a general warming of the near-shore waters, permits the progression of the ITCZ south of its general southernmost position of 3° N, bringing torrential rains to the coastal desert region. Figure 1 illustrates the diverse climatological impacts of ENSO around the world. Their exact timing depends on the interaction of the local annual cycle and that of ENSO. The strength and effectiveness of the teleconnections vary from event to event, with local conditions, notably the SSTs of the Indian, North Atlantic, and South Atlantic Oceans, either amplifying or dampening the transmission of the ENSO signal.

Long-Term Changes

Within the period of historic instrumental records, there is evidence for lower-frequency (decadal to multidecadal) changes in these teleconnections. A shift in global climate in the 1970s changed circulation patterns in the North Pacific; changes in the Indian Ocean are believed to change associations with the South Asian monsoon and the climate of East and southeast Africa; and changes in the temperatures in the tropical North and South Atlantic control signals to northeastern Brazil and West Africa. Spanish colonial records from Peru and Chile indicate that ENSO has been operating along this coast for more than four and a half centuries, while archaeological, ice core, and lake



sediment evidence indicate the persistence of extreme ENSO phases over at least 1,000 yrs.

Peter Waylen

See also **Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure; Atmospheric Variations in Energy; Coriolis Force; Hadley Cell; La Niña; Oceanic Circulation; Teleconnections**

Further Readings

Caviedes, C. N. (2001). *El Niño in history: Storming through the ages*. Gainesville: University of Florida Press.

Chavez, F. P., Ryan, J., Lluch-Cota, S. E., & Niquen, M. C. (2003). From anchovies to sardines and back again: Multidecadal change in the Pacific Ocean. *Science*, 299, 217–222.

Glantz, M. (2001). *Currents of change*. Cambridge, UK: Cambridge University Press.

Nials, F., Deeds, E., Moseley, M. E., Pozorski, S. G., Pozorski, T. G., & Feldman, R. A. (1979). El Niño and the catastrophic flooding of coastal Peru. *Field Museum of Natural History Bulletin*, 50, 4–14.

Quinn, W., Neal, V., & Antunes de Mayola, S. (1987). El Niño occurrences over the past four and a half centuries. *Journal of Geophysical Research*, 92, 14456–14478.

Thompson, L., Moseley-Thompson, E., & Amao, B. M. (1984). El Niño-Southern Oscillation events recorded in the stratigraphy of the tropical Quelccaya ice cap, Peru. *Science*, 226, 50–53.

International Finance Corporation (IFC), the private sector development arm of the World Bank Group, which created emerging markets as a financial asset class when it developed the first emerging market investment fund (the Korea Fund, in 1984) and provided the seed money for that fund. Between 1984 and 1994, the IFC underwrote and invested in more than 30 emerging market portfolio investment funds before spinning them off to private investment firms. There are now more than 600 equity emerging market investment funds, with most of the capital originating from international and domestic U.S. funds, offshore accounts, hedge funds, and insurance companies.

The countries designated emerging markets are not fixed as the criteria for defining them vary among investors and financial firms. However, the following IFC/World Bank criteria are typically used in identifying emerging market countries. They have experienced 3 yrs. (years) or more of rapid economic growth (based on gross domestic product [GDP] figures) yet remain low- or middle-income economies according to the World Bank. They have implemented liberal economic policies and practices such as adopting international financial standards and broad-based discriminatory controls for nondomiciled investors. They do not exhibit financial depth (i.e., the ratio of the country's market capitalization to its GDP is "low") and hold high levels of foreign debt and are subject to currency risks. They have a functioning stock market but often inadequate regulatory oversight, lack of transparency and liquidity, and broker, settlement, and custodian risks. Finally, emerging markets are typically considered risky investments because they are countries often considered economically, institutionally, and politically unstable.

Emerging markets represent more than 12% of world market capitalization. Overall private capital flows to emerging markets, as a percentage of their GDP, are now more than four times net official aid flows to those same nations. The issuance of international securities by emerging market sovereigns and corporations has increased from a level of \$325 million in 1995 to roughly \$700 million by 2003. By 2006, emerging market securities had increased in value by 243% compared with the United States, which had increased only 34%. Net equity flows (foreign direct investment and portfolio flows) to emerging markets have grown



EMERGING MARKETS

The term *emerging markets* typically refers to a distinctive financial asset class among international investors and financial firms and designates countries perceived as transitioning from developing to developed economies (often countries that were formerly part of the Third World or the communist bloc). The term *emerging markets* was coined in 1981 by Antoine van Agtmael, the then director of the Capital Markets Department of the



to roughly \$200 billion per yr. By 2006, emerging markets (led by China, Taiwan, and Korea) held more than 75% of all foreign exchange reserves, while the largest emerging markets (the so-called BRIC countries of Brazil, Russia, India, and China) now hold foreign reserves totaling more than double their foreign debts. The holding of foreign currencies is considered indicative of high levels of international trade and market integration. Economic integration has also produced a heightened tendency toward financial volatility and crises as the frequency of financial crises in emerging market economies since 1973 has become twice that of the Bretton Woods period.

There are currently more companies listed on emerging market exchanges than there are companies listed on developed country exchanges. The most common financial instruments used in emerging market funds include American Depositary Receipts (ADRs) and closed-end country funds (number of shares in the fund are fixed). ADRs are popular because they circumvent many of the geographic problems involved in international financial transactions (such as avoiding currency conversions, use of domestic brokers, and clearing and settlement institutions) affiliated with many emerging market exchanges, while closed-end funds allow emerging market states to regulate capital flows. However, the number of open-end country index funds (number of shares changes) is increasing.

It has been suggested that labeling former communist bloc and semi-industrialized Third World countries as emerging markets is symptomatic of the diminishing credibility of a passé Cold War geopolitical division of the world. Emerging markets have become more than simply a standard label for the semiperiphery in the unfolding world system of the new millennium. It has been argued that emerging markets have been produced by a geofinancial consortium of global news networks, international stock market analysts, mutual fund managers, institutional information agents, economists, debt security and bond-rating agencies, United Nations observers, and foreign affairs intelligentsia that actively rescript global economic space to imply an increasingly integrated (or globalized) world financial system. The discourse surrounding emerging markets speaks of them as “emerging” from underdevelopment and economic backwardness while taking the proper

steps up the ladder of development, and thus, emerging markets serve as models of development for the rest of the developing world to emulate. The media and financial sector literature is reminiscent of colonial discourse using metaphors of frontiers, pioneers, and exploration in places perceived of as wild and risky. Of course, the rhetoric also conceives of the world as a field for global capital flows and profit taking where emerging markets are treated instrumentally as yet another space for investing surplus capital, selling products, and extracting resources.

Jayson J. Funke

See also **Developing World; Finance, Geography of; Globalization; Money, Geographies of; New International Division of Labor; Offshore Finance; Political Economy; Underdevelopment; World Bank; World-Systems Theory**

Further Readings

- Das, D. (2004). *Financial globalization and the emerging market economies*. London: Routledge.
- Kolodko, G. W. (Ed.). (2003). *Emerging market economies: Globalization and development*. Hampshire, UK: Ashgate.
- Ó Tuathail, G. (1997). Emerging markets and other simulations: Mexico, the Chiapas revolt, and the geofinancial panopticon. *Ecumene*, 4, 300–317.
- Sidaway, J. D., & Pryke, M. (2000). The strange geographies of “emerging markets.” *Transactions of the Institute of British Geographers*, 25, 187–201.



EMOTIONS, GEOGRAPHY AND

Emotions have always had an important part to play in the theory and practice of geography. This observation holds despite what might be seen as a recent “emotional turn,” or persistent academic desires to keep such affects under scholarly wraps. Among other reasons for their apparent absence from mainstream geography is the frustrating intangibility of emotions; they are impossible to



locate, map, or measure in ways characteristic of the geographer's more typical field or object of study. Emotions are difficult to place but are nonetheless always everywhere. At times, they seem to come from "within" to affect the world around us, as when feeling "blue" all but blinds us to the beauty of a place that at other times (in other moods) can move us to experience joy. They can thus also seem "external" affairs; we may "find" happiness on the beach, find that graveyards "cause" despair, or find that we are bored by classrooms and rainy days that "make" us long to be elsewhere. Emotions are, then, relational, caught up with (in and around) people and places in profoundly important ways, and geographers are well placed to investigate such phenomena that shape and are shaped by the different—sociocultural, economic, political, and so on—worlds we live in.

One of the projects undertaken by recent works in "emotional geographies" has been to uncover emotion's hidden histories in the discipline and to reveal its suppression as well as expression in our various ways of "writing the world." Emotions have thus been shown to matter for geographies of all kinds, even those supposedly abstract or, say, economic. It is widely acknowledged that people's feelings about and "sense" of place will have an impact on the most significant purchase many make during their lives and can help transform those mortgaged houses into comfortable, comforting homes. Considering larger spatial scales, global financial markets are notoriously sensitive to consumer confidence or fears, and a population's aspirations and anxieties have long been seen as significant for political geographies too; the increasing presence and importance of "hope" in political discourse is becoming difficult to ignore, especially in the United States. Beyond such subdisciplinary concerns, emotions are clearly central for contemporary human geography—hardly surprising once we recognize how vital to human experience our emotions really are.

Recent geographical attempts to research and theorize emotions tend to coalesce around four main approaches or schools of thought. Feminist geographers such as Gillian Rose have been influential in questioning dualisms and insisting that all experience and knowledge is situated and relational, embodied and full of feeling yet never separate from or opposed to reason. Geographic

phenomenologists such as Yi Fu Tuan and Edward Casey provide insights into perceptions of and emotional responses to particular places. Psychoanalytic/psychotherapeutic geographers, such as Liz Bondi and David Sibley, highlight the importance of the formation and maintenance of psycho-social boundaries for understanding the emotional intersections between selves and spaces. Finally, nonrepresentational theorists such as Nigel Thrift attempt to negotiate the challenges associated with articulating emotional relations and affects by focusing on performance, on what people do rather than what they say they do. While such approaches differ in many ways, their shared interests are substantial and help advance geographical understandings of emotions that motivate how and with whom we spend our time, how and where we live and work, and indeed what we, as geographers, choose to study.

Joyce Davidson

See also Behavioral Geography; Body, Geography of; Everyday Life, Geography and; Fear, Geographies of; Feminist Geographies; Hate, Geographies of; Humanistic Geography; Identity, Geography and; Nonrepresentational Theory; Phenomenology; Psychoanalysis, Geography and; Sense of Place

Further Readings

- Anderson, K., & Smith, S. (2001). Emotional geographies. *Transactions of the Institute of British Geographers*, 26, 7–10.
- Bondi, L. (2005). Making connections and thinking through emotions: Between geography and psychotherapy. *Transactions of the Institute of British Geographers*, 30, 433–448.
- Davidson, J., Bondi, L., & Smith, M. (Eds.). (2005). *Emotional geographies*. Aldershot, UK: Ashgate.
- Davidson, J., & Milligan, G. (2004). Embodying emotion, sensing space: Introducing emotional geographies. *Social and Cultural Geography*, 5, 523–532.
- Ettlinger, N. (2004). Towards a critical theory of untidy geographies: The spatiality of emotions in consumption and production. *Feminist Economics*, 10, 21–54.



EMPIRICISM

Empiricism is a long-standing and highly influential philosophy, particularly within geography, which begins with the assertion that the only valid form of knowledge is experience and sense perception. That which is not observable is held to be nonexistent or meaningless.

Although its origins may be traced to scholars such as Francis Bacon, empiricism was largely a child of the British Enlightenment, in which intellectuals such as John Locke, David Hume, and George Berkeley emphasized the primacy of logic and empirical reality in the face of medieval metaphysics—that is, evidence rather than faith; in this sense, empiricism was a progressive ideology in its day. British empiricists also deployed the philosophy in their debates with continental rationalists such as Descartes, Spinoza, and Leibniz, who held that knowledge came from innate ideas alone. Without sensations and experience, empiricists maintained, the mind would have nothing to work with.

At the core of empiricism is the notion that statements about the world, that is, claims regarding sensations and data, are true or false without appeal to theory. The word *data* derives from the Latin *dar*, “to give,” indicating that data are given, not made. In this view, a fact is simply a statement about what is, an assertion of verified information that exists beyond reasonable doubt. (Ironically, the Latin *factus* refers to that which is made, not simply given.) There is thus an iron wall that separates facts and opinions, which empiricists dismiss as subjective. Facts—and the truths they lead to—exist independent of their interpretation and are thus true whether or not anyone knows or believes them, indicating that truth has an objective existence independent of the knower.

Empiricism shares some aspects with logical positivism, which also holds to a sharp dichotomy between fact and theory, the objective and the subjective, and a disregard for the role of the observing subject. However, unlike empiricism, positivism maintained a healthy regard for theory, particularly deduction, the view that if the premises of an argument are true, then so must be its conclusions. Deduction is thus the move from the abstract to the concrete; in this view, an observation is true because it consists of a special case of a broader

principle. Empiricism, however, generally subscribes to inductive, not deductive, logic, that is, the attempt to move from the observed to the unobserved, from the concrete to the abstract, from the specific to the general, from pattern to prediction. The explanatory basis of empiricism is the attempt to form generalizations without explanations. Unlike rationalism or logical positivism, empiricism holds that all conclusions are only probable or tentative and cannot be known with certainty, introducing a degree of skepticism and humility. Moreover, empiricism offered a healthy distrust of theoretical overdetermination and arm-chair speculation.

Empiricism has been a long-standing tradition in geography; for most of the discipline's existence, it consisted of little more than the encyclopedic collection of data. The philosophy reached its zenith during the heyday of chorology in the early to mid 20th century and particularly in the work of Richard Hartshorne. In this line of thought, geography was the integrative but static description of regions, and explanation was the province of other disciplines. Empiricist geography tended to celebrate the unique and idiographic at the expense of the abstract and theoretical, and the discipline acquired a popular reputation for being an analytical dead end.

Not surprisingly, abstraction and causation have always been the Achilles' heel of empiricism. The great danger of induction is in making sweeping and unwarranted generalizations or in confusing coincidence with causation. As the social sciences became increasingly self-conscious epistemologically, it became abundantly clear that the fact-opinion dichotomy was a false and misleading one: All data are theory laden, in the sense that it is theory, even if it is vague and unspecified, that tells one what data are relevant and important and what data are not. There are no “pure” facts as observations are always couched in terms of a theory: Observation requires interpretation, which in turn requires theory. Theory is necessary to move from description to explanation, to establish causality, test hypotheses, justify arguments, and make claims to truth. Theories are thus indispensable to knowing how the world works; understanding theory is not a choice because theory is inescapable. Thus, as geography and other disciplines moved into a welter of different theoretically



sophisticated schools in the late 20th century, including Marxism, phenomenology, and post-modern/poststructuralist frameworks, empiricism lost its credibility and today is virtually extinct.

Finally, it is important not to confuse empiricism with empirical work; many theoretical perspectives collect and analyze data in different ways. Almost all schools of thought place some value on empirical work to test or complement theoretical propositions, but the simple-minded upholding of data for their own sake, and the associated distrust of theory, is the unique province of empiricism.

Barney Warf

See also Chorology; Epistemology; Hartshorne, Richard; Human Geography, History of; Idiographic; Logical Positivism

Further Readings

- Bowen, M. (1981). *Empiricism and geographical thought: From Francis Bacon to Alexander von Humboldt*. Cambridge, UK: Cambridge University Press.
- Gould, P. (1981). Letting the data speak for themselves. *Annals of the Association of American Geographers*, 71, 166–176.
- Gupta, A. (2008). *Empiricism and experience*. Oxford, UK: Oxford University Press.
- Hart, J. (1982). The highest form of the geographer's art. *Annals of the Association of American Geographers*, 72, 1–29.
- Hartshorne, R. (1939). *The nature of geography*. Washington, DC: Association of American Geographers.
- Robinson, D., & Mayblin, B. (2004). *Introducing empiricism*. London: Totem/Icon Books.



ENDOGENOUS GROWTH THEORY

See Knowledge Spillovers; Learning Regions



ENERGY AND HUMAN ECOLOGY

Ecology is a holistic approach to studying how biological, hydrological, geochemical, and even social processes are shaped by interrelated relations between living beings and ecosystems. The term *human ecology* is probably most associated with the 1920s Chicago School of Urban Sociologists, who borrowed concepts from plant ecology (e.g., metabolism, competition, succession) to explain the growth and spatial patterns of American cities. In 1923, however, another University of Chicago scholar, Harlan Barrows, attempted to define the entire discipline of geography as “human ecology.” In contradistinction to the urban ecological school, Barrows did not want to simply use ecological metaphors to explain social patterns but sought to remake geography as a science of ecological relationships between human societies and the natural environment. For Barrows, geographers would examine all types of human livelihood patterns—from agriculture to industrial manufacturing—and trace the relationships with landscapes of natural resource production and evaluate the ecological impacts.

For reasons still debated, Barrows’s “human ecological” approach did not remake geography into a science of nature-society relationships. Barrows’s students—most notably Gilbert White—went on to undertake important policy-relevant research on the management of resources and natural hazards such as groundwater and floods. Yet none of this work explicitly invoked an *ecological* approach focused on mutually constitutive relations, flows, and networks between human and natural systems. Only 40 years or so after Barrows’s initial proclamation would geographers discover a concept that researchers could effectively operationalize into human ecological research—energy.

Energy as an Ecological Concept

In the 1960s, Howard Odum helped develop the “systems ecology” approach, which situated energy flows at the center of analysis. A self-proclaimed energetic determinist, Odum suggested that all natural and social systems could be



understood in terms of the energy available to accomplish work. Indeed, the very basis of life on Earth depends on plants making use of solar energy through the process of photosynthesis and respiration, which, in turn, provide energy for a variety of herbivores and omnivores, who, in turn, provide energy for carnivores. Moreover, since humans harnessed the concentrated sources of solar energy latent in fossil fuels (coal, oil, and natural gas), Odum suggested that energy is also at the basis of seemingly unnatural processes such as urbanization and industrialization. Through characteristic flow diagrams and circuit models, Odum and other systems ecologists mapped the ecological flows of energy and matter in a variety of systems from wetlands to households.

This systems ecological approach considers energy from the basis of the laws of thermodynamics. Although there are several debates on several laws, most agree that the first two are the most important. The first law states that from the perspective of an open system, energy can never be created or destroyed but only change forms. Ecologists can trace the different forms of energy from the sun through plants and animals, but the total amount of energy in the universe remains the same. The second law states that in an isolated system—such as Earth—entropy, or the incapacity of an energy system to do work, tends to increase over time. The second law is obviously most applicable to human and natural systems constrained by the availability of useable energy in a given environment. Moreover, modern society's dependence on the concentrated energy of finite fossil fuel reserves makes the second law even more worrisome. For example, when the concentrated energy of petroleum is burned within an internal combustion engine and dissipated into carbon dioxide gas, its capacity to do work is no longer present. As the combustion of fossil fuels yields greater and greater entropy dissipation, the second law of thermodynamics should predict that human societies will inevitably come up against profound and, perhaps, unsolvable energy constraints.

A Human Ecological Approach to Energy

A systems ecological approach coupled with the laws of thermodynamics held great promise for

resurrecting Barrows's original vision of geography as human ecology. With the concept of energy, researchers finally had a standardized way to *measure* ecological relationships between humans and the environment. In this section, we will discuss the two major areas through which geographers have applied energy to the study of human ecological systems—cultural ecology and ecological economics.

Cultural Ecology

During the 1960s—at the same time as the development of systems ecology—many geographers and anthropologists began to apply positivist methods of ecology to the study of human interactions with local environments. A cadre of field-based cultural ecologists began to study human behaviors in terms of functions within larger ecological systems regulating the flows of energy, nutrients, and biomass. Although the original method was to focus on rigorous comparative work to generate specific laws of nature-society interactions along a hierarchy of increasing social organizational complexity (from hunter-gatherers to industrial societies), eventually systems ecology proved to offer more testable quantitative tools of analysis. Energy emerged as a universal common metric with which different scholars could formally engage in cross-cultural comparisons of environmental interactions, a metric that had implications for evaluating the ecological efficiency of cultural practices from a seemingly objective standpoint.

For example, the anthropologist Roy Rappaport offered a systematic examination of the energy flows in the gardening practices among the Maring people of New Guinea. Through intensive field observations, Rappaport was able to estimate the calories expended through the performance of everyday garden maintenance—from clearing the land for tilling to weeding and harvesting. Through these measures, for instance, he was able to estimate how many calories per square feet were needed to clear a particular patch of forest in the New Guinean highlands. He could also estimate the calories made available from the production of potatoes and other vegetables meant for human and pig consumption. Measuring the flows of energy expended in



the production of food against the flows of energy afforded from the food itself allowed the calculation of specific numbers denoting the efficiency of energy expenditures.

Cultural ecologists are notorious for only examining small subsistence-based rural societies such as the Maring people of New Guinea. In the minds of the researchers, such settings seem to provide a model of a “closed” ecological system wherein the flows of energy in and out of the system can be clearly traced and measured. Indeed, such simplicity is a methodological necessity from a holistic systems perspective determined to measure and observe all the relationships constituting a particular system. In the following subsection, we discuss how energy concepts have been applied to the analysis of more complex industrial societies.

Ecological Economics

During the energy crisis of the 1970s, it became clear that standard economic production functions based on the contributions of labor, manufactured capital, and materials missed very important variables. Standard economic models ignored, on the one hand, the energy required for nearly every economic action of production and consumption and, on the other hand, the wastes produced through such actions, which themselves often had deleterious ecological effects.

Ecological economics emerged in the 1980s specifically to correct this blind spot in mainstream economic theory. Nicholas Georgescu-Roegen’s landmark work, *The Entropy Law and the Economic Process*, proposed a complete revision of economics to confront the biophysical foundations of the production and consumption of goods and services throughout the economy. Specifically, Georgescu-Roegen made much of the second “entropy law” of thermodynamics to call attention to the inevitable increase in entropy dissipation bound up in fossil fuel–based economies—and, by consequence, the need to move toward a very different energy system. After these pioneering insights, many ecological economists, such as Herman Daly, argued that ecological truisms compel us to move away from growth-based economies toward a “steady-state economy” that would balance overall material and energy throughput with the regenerative capacities of the biosphere.

While early ecological economics was high on theory, it was low in terms of the empirical applications and general testability of cultural ecology. In light of this gap, geographers such as Cutler Cleveland helped develop the groundbreaking concept of “Energy Return on Investment” (EROI) as a means to evaluate empirically the energy efficiency of economic systems. EROI calculates the energy expended in the production of particular energy resources in comparison with the energy obtained. A classic example of the utility of EROI is the case of corn-based ethanol. Although attractive from the perspective of corn growers and lessening the dependence on Middle Eastern oil, EROI reveals that it takes almost as much fossil fuel energy to produce corn-based ethanol as the energy one gets out of it. Cleveland and others have also used EROI to argue that although particular energy resources might be becoming cheaper moneywise—like oil in the late 1980s and 1990s—that doesn’t necessarily mean it takes *less energy* to produce such oil. EROI can both be used on a microscale in terms of comparing the energetic efficiency of different energy resources (coal, nuclear, solar, wind) for site-specific electricity generation and on the macroeconomic scale, focused on nations as a whole. By showing the economy-wide decline in EROI in the U.S. economy during the 20th century, Cleveland and colleagues were able to demonstrate Georgescu-Roegen’s “entropy law” on a grand scale. A thoroughly ecological EROI analysis could also link metrics on energy expenditures with the actual ecological impacts of energy provisioning. Such a perspective would not only trace the energy expended in certain economic actions (such as the production of energy) but also detail the ecological impacts of economic actions (e.g., water contamination in petroleum production or carbon dioxide produced through electricity generation at coal-fired power plants).

Critiquing Human Ecological Approaches to Energy

From a Barrowsian perspective, it is clear that human ecological approaches to energy have made important strides, but they may not be



ecological enough. Whether one is concerned with counting the calories expended in tilling the soil or the amount of energy invested in the production of coal for electricity generation, it is clear that merely tracing the flow of energy does not tell us the entire story of energy-society relationships. A holistic ecological approach must also take into account the political relations shaping access to and control over energy resources and flows. Political ecologists criticize cultural ecologists for approaching agrarian communities as if they were closed systems marked by a functional, homeostatic balance with nature. Indeed, demonstrating that the cultural practices of certain local communities are ecologically functional and energetically efficient does not necessarily mean that they are free of exploitation based on gender, ethnic, and class power relations. Nor is it really possible to treat any community on the planet as a closed ecological system. Nearly all human beings are to some extent embedded in a cash economy, which, by definition, intricately links them into global circuits of capital and commodity flows (and the energy relations therein).

As with cultural ecological examinations of subsistence economies, ecological economists often treat the economy as an isolated conceptual entity. EROI analysis tells us nothing of the dynamic geopolitical relations shaping access to and control over petroleum resources in the Middle East. In energy-intensive societies such as the United States, the consumption of energy resources is also shaped by profound political and cultural narratives situating cheap oil as necessary to a unique “American way of life.” Overall, a relational human approach to energy still has much work to do in terms of tracing the entirety of social, political, and economic relationships that shape energy systems.

Matthew T. Huber

See also **Barrows, Harlan; Chicago School; Cultural Ecology; Ecological Economics; Ecological Modernization; Energy Models; Energy Resources; Human Ecology; Landscape Ecology; Political Ecology; Political Economy of Resources; Renewable Resources; Resource Economics; Sustainability Science; Sustainable Development; Urban Ecology**

Further Readings

- Barrows, H. H. (1923). Geography as human ecology. *Annals of the Association of American Geographers*, 13, 1–14.
- Cleveland, C. J., Constanza, R., & Kaufmann, R. (1984). Energy and the US economy: A biophysical perspective. *Science*, 225, 890–897.
- Georgescu-Roegen, N. (1971). *The entropy law and the economic process*. Cambridge, MA: Harvard University Press.
- Odum, H. T. (1971). *Environment, power, and society*. New York: Wiley Interscience.
- Rappaport, R. A. (1975). The flow of energy and agricultural society. In S. H. Katz (Ed.), *Biological anthropology* (pp. 371–383). San Francisco: W. H. Freeman.



ENERGY MODELS

Energy models characterize the energy system, its evolution, and its interactions with the broader economy. The energy system consists of primary resources, including both fossil fuels and renewable sources; electric power plants, refineries, and other technologies to process and convert these resources into secondary energy carriers such as electricity and gasoline; technologies such as furnaces and light-duty vehicles that use these energy carriers to meet demands for energy services; and end-use demands for services such as indoor space heating and personal transportation.

Attention to energy has increased with growing concern over global imbalances between the demand and supply of petroleum resources, as well as the need to mitigate global climate change and other environmental impacts related to energy use. Understanding the role energy plays in these concerns requires an awareness of how energy is produced and consumed, the price dynamics that mediate this relationship, and the physical systems that transform primary energy into secondary energy carriers and ultimately the services energy provides. Modeling frameworks from both economics and operations research provide analytical tools for characterizing the energy system and its evolution and find wide use in design,



forecasting, scenario analysis, and similar applications. As the energy system is driven by region-specific patterns of resource availability, land use, technology deployment, and demand, energy modeling necessarily requires a geographic perspective. Likewise, spatially referenced energy models are useful for studying emissions related to climate change, infrastructure needs, land use, transportation, and other areas of interest in contemporary geography. This entry provides an introduction to energy models, first reviewing common analytical frameworks before discussing the importance of a spatial perspective.

Energy Modeling Frameworks

Unlike geologic models of petroleum reservoirs, assessments of single technologies, or statistical forecasts of demand, energy models characterize interdependencies between parts of a system or relationships between the energy system and the broader economy. The most commonly used energy models are dynamic, built around a mathematical optimization framework, and incorporate either classical economic theory or systems engineering principles. Outputs include technology choices, energy consumption, pollutant emissions, and marginal costs for energy resources, over time and by region.

Individual energy models differ in their representation of behavior (i.e., what is determined within the model endogenously rather than assumed exogenously), mathematical framework, economic focus, level of technological detail, and sectoral coverage, as well as in their geographic and temporal resolution and horizon. An important modeling distinction captures differences in the representation of economic feedbacks and technology detail. “Top-down” models adopt a macroeconomic perspective and balance the demand for and supply of resources, including energy, across sectors of the economy. The representation of technology in these models, however, tends to be very aggregate. The Second Generation Model provides an example of a top-down model with a substantial energy system focus. “Bottom-up” models, in contrast, downplay key economic feedbacks, such as the responsiveness of demand to changes in energy prices, in favor of a detailed representation of individual technologies.

Partial equilibrium models such as MARKAL, for instance, focus primarily on the physical energy system and determine the least-cost mix of technologies needed to meet specified demands across sectors of the economy. In practice, advances in computational power are blurring the top-down, bottom-up distinction.

Energy models also differ in the interpretation of their results. Models such as MARKAL are optimization based and are therefore prescriptive in orientation. Results reflect what a rational, cost-minimizing decision maker should do, subject to constraints that capture how the energy system functions, as well as policies such as emissions caps that influence the use of resources and technologies. More descriptive frameworks include regional econometric and input-output (IO) models, as well as simulation models. System dynamics models such as the U.S. Department of Energy’s FOSSIL2 and its successor IDEAS (Integrated Dynamic Energy Analysis Simulation), as well as LEAP (Long Range Energy Alternatives Planning System), provide examples of the latter.

Importance of a Spatial Perspective in Energy Modeling

Many energy models are capable of capturing regional differences in resources, transport costs, technology suitability, end-use demand patterns, policies, trading patterns, and other factors that drive energy production and use. Common geographic representations include administrative units such as national or state boundaries and census districts, or energy-system entities such as the North American Electric Reliability Corporation regions and Petroleum Administration for Defense Districts in the United States. Like the representation of time and technology, greater geographic resolution increases model run time, assumes that data are available at finer spatial scales, and compounds the assumptions needed for model calibration.

A spatial perspective, however, remains important for energy modeling. Input parameters, for instance, are often the product of detailed geographic information system (GIS) spatial analyses, even when aggregated up to a broader regional representation for model use. Likewise, GIS modeling provides a means to downscale



and visualize results. Surrogates such as human populations, to give an example, may be used to disaggregate air pollutant emissions from model regions to a finer raster grid. Such applications involve soft coupling of GIS and energy system models. While GIS modeling provides a valuable tool for energy-related analyses, few examples exist of tightly linked GIS energy system models. The AIDAIR modeling framework, which has been used for integrated energy-environmental analyses of Geneva, approaches this ideal.

Timothy Lawrence Johnson

See also **Anthropogenic Climate Change; Biofuels; Energy and Human Ecology; Energy Policy; Energy Resources; Geothermal Energy; Solar Energy; Three-Dimensional Data Models; Wind Energy**

Further Readings

- Craig, P. P., Gadgil, A., & Koomey, J. G. (2002). What can history teach us? A retrospective examination of long-term energy forecasts for the United States. *Annual Review of Energy and the Environment*, 27, 83–118.
- Huntington, H. G., & Weyant, J. P. (2004). Modeling energy markets and climate change policy. In C. J. Cleveland (Ed.), *Encyclopedia of energy* (pp. 41–53). Cambridge, MA: Elsevier Science.
- International Energy Agency. (2000, October). *Advanced local energy planning: A guidebook*. Retrieved September 22, 2008, from www.keabw.de/fileadmin/user_upload/pdf/ALEP_Guidebook.pdf
- Worrell, E., Ramesohl, S., & Boyd, G. (2004). Advances in energy forecasting models based on engineering economics. *Annual Review of Environment and Resources*, 29, 345–381.



ENERGY POLICY

The procurement and use of energy resources are defining characteristics of human society. Energy policy refers to the myriad collective public and private decisions taken to secure access to and

conserve energy resources necessary for sustaining a society, including provision for social reproduction and economic expansion. For the modern nation-state, energy policy extends far beyond the obvious rules and regulations governing public intervention in energy markets. Whether overtly or indirectly, energy policy also involves financial, military, trade, industrial, environmental, transportation, housing, and many other spheres of public policy. While this entry focuses on public, particularly U.S., policy since World War II, a broader recognition of energy policy is suggested.

In the past century, energy policy for the industrialized world has focused on three interrelated areas of continuing concern. These include access to secure resources (e.g., a major rationale for European incursion into the Middle East and Northern Africa), the cost and impact on the economy (especially after the oil “shocks” of the 1970s), and more recently environmental damage and global climate change.

U.S. Policy

Early federal energy policy involved major subsidies for oil, natural gas, and electric power production; delegation of retail service regulation to the states via the 1935 Public Utility Holding Company Act; and extension of electricity supply to all sectors of society through the Rural Electrification Act of 1936. It also supported new sources, as through the Federal Water Power Act of 1920, licensing nonfederal hydro projects, and the Price-Anderson Act of 1957, providing accident liability limits for nuclear power providers. Subsequent legislation addressed environmental concerns (e.g., the 1970 Clean Air Act and the 1982 Nuclear Waste Policy Act) and energy efficiency (e.g., the 1978 National Energy Conservation Policy Act).

Historically, U.S. energy policy has tended to be event and crisis driven, as with the 1950s “Atoms for Peace” program for nuclear power, the belated creation of the North American Electric Reliability Council to coordinate grid connection following the November 1965 northeast blackout, major changes in nuclear facility licensing following the March 1979 Three Mile Island accident, and President Richard Nixon’s Project Independence to bolster domestic supply and reduce foreign dependence following the 1973 oil



embargo by Arab members of the Organization of the Petroleum Exporting Countries (OPEC). While most of the 1970s policy initiatives failed, one notable success was approval of Corporate Average Fuel Economy (CAFE) standards for cars and light trucks under the Energy Policy and Conservation Act of 1975, though these were not raised beyond 1985 levels until 2007.

With just 4.5% of the world's population, the United States consumes a quarter of the world's nonrenewable fossil fuel energy and, by extension, contributes a similar amount to global greenhouse gas (GHG) emissions. Energy-generated carbon dioxide alone is responsible for 82% of total U.S. GHG emissions, principally through electric generation (41%) and transportation (33%). An abundant domestic supply allows coal to be used for over half of all electricity production. However, with combustion causing air pollution, coal policy since the 1970s has focused on a reduction in particulates and in nitrogen oxide and sulfur dioxide emissions (the latter causing acid rain). Belated acknowledgment of coal's major contribution to global warming led to federal support during the George W. Bush administration for carbon dioxide capture and geologic storage. Modeled after the successful sulfur dioxide trading program under the 1990 Clean Air Act Amendments, a market-based approach to carbon reduction through emission cap and trade undertaken by the European Union (EU) to meet its obligations under the Kyoto Protocol is slowly gaining political acceptance in the United States.

With training in nuclear engineering, President Jimmy Carter provided the boldest energy program of any recent administration. This culminated in the creation of the U.S. Department of Energy (DOE) in 1977—reorganized from more than 50 different federal agencies and with responsibility for a biennial National Energy Policy Plan—and the creation of the independent Federal Energy Regulatory Commission (FERC) from the preexisting Federal Power Commission. The FERC regulates the interstate transmission of natural gas, oil, and electricity, as well as natural gas and hydropower projects. From the late 1970s through the 1990s, federal policy shifted to remove regulations on oil and gas prices and encouraged states to restructure preexisting monopoly gas and electric utilities through provision of grid

access for independent generators, while allowing consumer choice with supply.

On taking office in 1981, President Ronald Reagan cut most federal spending for renewable energy research and allowed federal tax credits for production and residential installation to expire. Under his leadership, and generally continuing through the Bill Clinton and both Bush administrations, federal policy addressed increasing domestic fossil fuel supply through tax breaks, subsidies, price deregulation, and supply restrictions while avoiding demand management, such as through increased CAFE mileage standards or significant attention to renewable energy. The common belief was that liberalized markets would bring retail costs down and encourage new investment. During this period, new wind and solar supply tended to rise and fall according to the availability of a modest (compared with fossil fuel and nuclear power support) federal production tax credit. Vacillations in federal and state support notwithstanding, actual investment in wind and solar energy continued to grow due to a rapid increase in fossil fuel prices and utility concern with price stability. Proponents of renewable energy argue that it could compete on its own should the subsidized playing field be leveled.

During the Reagan administration and early in the George H. W. Bush administration, as global petroleum prices fell, U.S. energy policy continued to be reactive, with scant attention given to either conservation or the renewable energy supply. In place, neoliberal energy policy focused on deregulation of preexisting monopolies and privatization of public supply wherever possible. However, the affirmation that continued access to the vast Middle East petroleum reserves was of vital national strategic interest—a view first articulated by President Franklin Roosevelt and later embraced by Carter—continued to resonate with subsequent administrations, eventually reaching a crescendo under the George W. Bush administration. Thus, the United States provided guarantees of military support for accommodating regimes such as that of the Saudi royal family. It also employed covert or direct military intervention when faced with perceived threats to global trade in petroleum, as occurred in Iran during the 1950s and more recently with Iraq. In this manner, U.S. energy policy informs foreign relations and military policy.



Driven by environmental and energy security concerns, provision of renewable energy is now a major policy issue. Half the U.S. states have mandatory renewable portfolio standards (RPS), whereby a set percentage of utility output must come from certified sources. Adopted in the absence of federal standards and favored by free marketers, the state RPS is an alternative to the feed-in tariffs (FIT) deployed by Germany, Denmark, Spain, and most recently Australia and California. Here, utilities must purchase renewable energy at the geographic and technological cost of generation. This allows for a more secure investment climate for generators and leads to deployment over a wider geographic region with greater renewable energy penetration.

The most controversial national energy plan in the United States was prepared in 2001 by a panel chaired by Vice President Dick Cheney with representation from the major oil and energy trading firms (e.g., Enron) but with no public or environmental interest groups invited. With court challenges ongoing to release panel records, the National Energy Policy Report continued to serve as the basis for the Bush administration's energy policy. Described as a "strategy of maximum extraction" by the energy and defense correspondent Michael Klare, the Bush-Cheney plan blamed the rising prices on the lack of resolve to open up domestic supply, such as in the Arctic National Wildlife Refuge. With scant attention to demand management, the report proposed meeting the projected 1.8% annual growth in electric consumption with the installation of 1,300 to 1,900 new 300-MW (megawatt) (average) power plants through 2020.

As of late 2009, few of these proposals had been approved, with private investment and utility commitment still hampered by very high construction costs despite improved federal support in recent years. However, advocates anticipate that prospects for nuclear power will improve should the nation adopt a cap-and-trade program or carbon tax for GHG emissions. In the meantime, since 2008, major advances in hydrofracturing of deep shale formations contributed to a 35% increase in proven domestic natural gas reserves, with the "bridge" fuel to lower carbon emissions once again supporting new electric power construction.

Congress and the Bush administration supported development of hydrogen and ethanol as alternative transportation fuels through the Energy Policy Act of 2005 (with a goal of 100,000 hydrogen-fueled vehicles by 2010 and tax subsidies for biofuels and "advanced" nuclear reactors) and the Energy Independence and Security Act of 2007 (modestly raising CAFE standards to 35 miles per gallon by 2020 along with a continued subsidy and a major mandate for 36 billion gallons of biofuels by 2022). Critics were quick to point out, however, that these alternative fuels were only as "green" as the resources used to prepare them, with hydrogen stripped from fossil fuels or released via water hydrolysis, while corn-based ethanol is also linked to fertilizer runoff and rising world grain prices. By 2008, these concerns and international food riots led to a reassessment of hydrogen and biofuel needs in Europe, which had adopted similar goals, while the U.S. program has since been cut back under the Obama administration.

While neoliberal proponents of deregulation claimed that market competition would reduce retail prices and promote the independent renewable energy supply, the record with electricity is mixed, with no discernable trend toward either lower prices or increased renewable energy in the states undertaking market reforms compared with those remaining with regulated monopolies. The California electricity "crisis" of 1999–2001, culminating in widespread power outages, underscored what can happen when poorly devised market reform encourages independent traders, such as Enron, to "game" the system. In the interim, further restructuring is on hold in the United States. On the other hand, most EU nations have succumbed to the lure of market reform, with national monopolies broken up. Here, initial success with renewable energy provision may be attributed to national, and now unified EU, reform, rather than reliance on piecemeal state implementation as in the United States.

Energy Policy in Other Countries

Energy policy in most nations reflects the availability of domestic resources as well as foreign relations and international trade. Japan, for instance, has virtually no petroleum, so while its



policy has promoted nuclear power, solar energy, and energy efficiency, it has not been able to avoid a significant oil import dependence. Western Europe has similarly supported energy efficiency but has also used high taxes to control energy demand (as has Japan). European nations such as Germany, the United Kingdom, and Poland used to be major coal producers and consumers, though with diminished resource quality these nations have increasingly turned to other sources as they have phased out subsidies and reformed their economies. The United Kingdom capitalized on its North Sea oil reserves, which provided a temporary respite to foreign dependence in the 1970s through 1990s, though since then it has had to look elsewhere. Even Norway's vast North Sea petroleum reserves have been dwindling more recently. Energy policy in the EU since the late 1990s has focused on GHG reduction, with wind power development in Germany, Spain, and Denmark being notable success stories thanks to the FITs. Scandinavian countries, for their part, continue to promote the use of their substantial hydroelectric resources and geothermal energy (Iceland only). Another key regional player is Russia. Having revived its struggling fossil fuels industries following post-1990s economic restructuring, it is by far the largest fossil fuel producer in Europe.

In recent years, the rising electric and petroleum demand has been greatest in developing nations, such as India and China, the latter now responsible for a quarter of global greenhouse gas emissions. Even so, coal use is booming and supported by government policy, especially in China, the largest coal producer in the world. As is common in Russia and among OPEC nations, various subsidies contribute to increased domestic consumption, even as China and India are also growing leaders with wind and solar development. China is also the world's leading proponent of expanded use of nuclear power. In 2007 and 2008, China and India, respectively, published national climate change action plans emphasizing energy efficiency and renewable energy—although not at the cost of economic development. In the case of China, its automobile mileage efficiency standards now exceed those of the United States, which has been driven by the need to control foreign oil dependence, while China's domestic oil industry continues to develop.

The Future

Divergent discourse notwithstanding, the reality of global warming and the coming peak in global oil production, with much higher fossil fuel energy prices, will continue to push the United States, along with the rest of the industrialized and developing world, toward a common understanding of the need for a forceful reduction in demand and major expansion of sustainable supply. The required economic transformation and social accommodations will be revolutionary, but consensus has grown that such changes must be made. While national needs, however defined, are likely to continue to be the basis for most energy policy, an increasing number of international forums and organizations have been created to further common interests.

Michael K. Heiman and Barry D. Solomon

See also **Carbon Trading and Carbon Offsets; Climate Policy; Energy and Human Ecology; Energy Models; Energy Resources; Geothermal Energy; Hydroelectric Power; Market-Based Environmental Regulation; Neoliberal Environmental Policy; Nuclear Energy; Public Policy, Geography of; Solar Energy; Wind Energy**

Further Readings

- Cleveland, C. (Ed.). (2004). *Encyclopedia of energy* (6 vols.). Amsterdam: Elsevier.
- Goodwin, C. D. (Ed.). (1981). *Energy policy in perspective*. Washington, DC: Brookings Institution.
- Heiman, M., & Solomon, D. (2004). Power to the people: Electric utility restructuring and the commitment to renewable energy. *Annals of the Association of American Geographers*, 94, 94–116.
- Klare, M. (2005). *Blood and oil: The dangers and consequences of America's growing dependence on imported petroleum*. New York: Henry Holt.
- National Energy Policy Development Group. (2001). *National energy policy: Report to the President*. Washington, DC: Government Printing Office.



ENERGY RESOURCES

A distinction is made in the energy field between energy resources and energy reserves. Resources refer to the proportion of the total resource base that has been identified with at least a small degree of certainty and that might be recovered in the future. Energy reserves, in contrast, indicate the proportion of the total resource base that has been identified with certainty and that can be economically recovered and used with current technology. Both quantities are spatially specific and not fixed. However, estimated quantities of renewable sources of energy are highly variable and uncertain, given the highly uneven geographic distribution of resources and technology to capture sources such as solar, wind, and biomass energies.

It is useful to know the geographic distribution of energy reserves as well as production, consumption, and trade patterns of energy commodities such as petroleum and coal as these figures are used to calculate the energy import dependence and scarcity of fuels in a nation, region, or the world. Energy resource data, while they are

also potentially useful, are updated less frequently and are much more speculative than are reserves. Extensive nonrenewable energy resource data at a variety of geographic scales are available from organizations such as the U.S. Department of Energy, International Energy Agency, the United Nations, and private corporations or trade associations such as British Petroleum (BP), the European Wind Energy Association, or the Solar Energy Industries Association. Helpful statistics include the energy resource-to-production ratio for oil or gas in a country; national or state rankings of energy resources, reserves, and production for oil, gas, coal, and uranium (Figure 1); and wind energy resource by state or geothermal energy production by nation. It is widely recognized that petroleum and other fossil fuels are finite resources that contribute to local pollution problems and global climate change and instability, and for these and other reasons, renewable sources of energy will be more rapidly developed and deployed in the future. Despite this, geopolitical and global economic and military affairs are still intertwined with the use of fossil fuels, especially petroleum products.

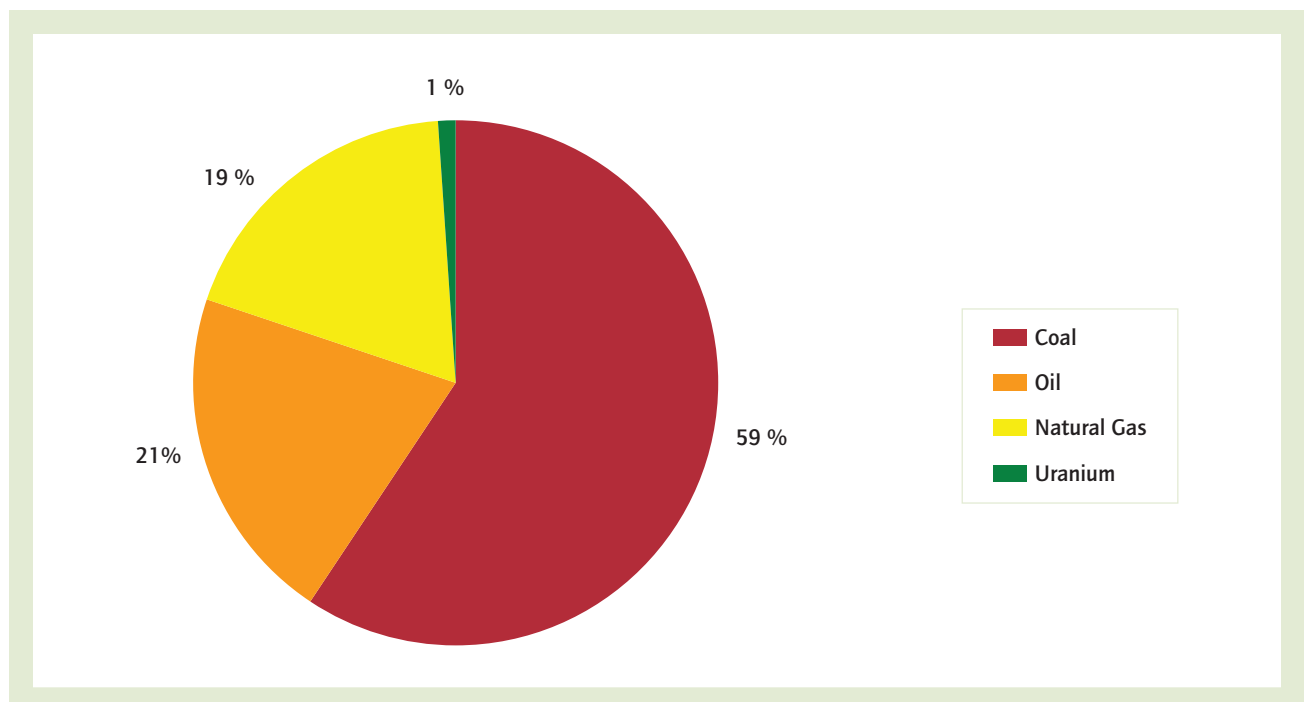


Figure 1 Global reserves of nonrenewable energy sources by type

Source: Adapted from British Petroleum. (2008). *BP statistical review of world energy June 2008*. London: Author.

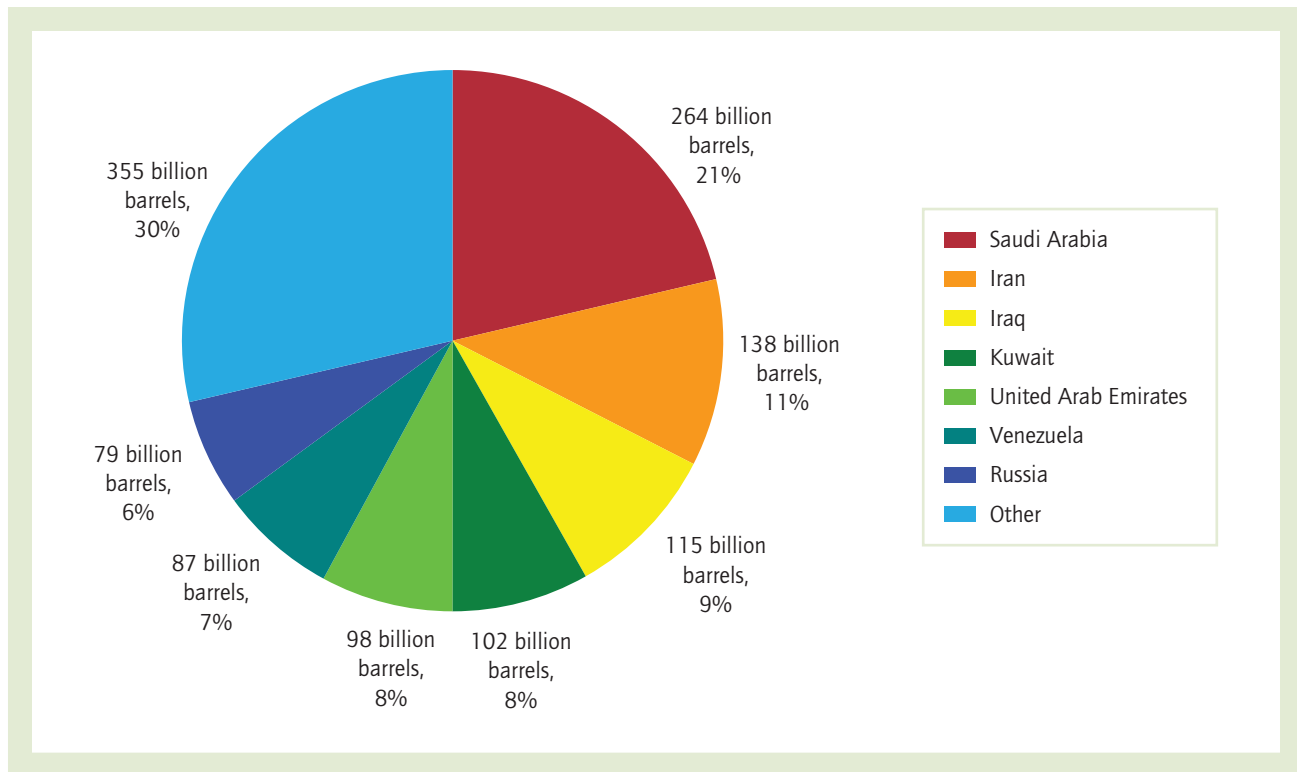


Figure 2 Global oil reserves by country

Source: Adapted from British Petroleum. (2008). *BP statistical review of world energy June 2008*. London: Author.

Fossil Fuels

Fossil fuels are divided into conventional sources such as crude oil, natural gas, and coal, and unconventional sources such as tar sands, shale oils, and methane hydrates (clathrates). Their commonality is that they are nonrenewable hydrocarbons found within the top layer of the Earth's crust or in the ocean floor and were formed over millions of years from the remains of dead animals and plants. The top five nations today in terms of oil reserves are in the Middle East, with the United States a distant 10th. Perhaps surprisingly, the Middle East's share of global proved oil reserves has changed little in the past half century, accounting for around 60% (Figure 2).

Much of global oil production is dominated by the 12 member nations of the Organization for the Petroleum Exporting Countries (OPEC). Half of its members are in the Middle East, including Saudi Arabia, the world's largest producer. Once accounting for over half of global production, OPEC's market share has varied through time and today

stands at around 45%. Other leaders in crude oil production include Russia (second, at 12.3%), the United States (third, at 8%), China (fifth, at 4.7%), and Mexico (sixth, at 4.7%). In recent years, there has been much debate about when global oil production will peak or plateau (U.S. oil production peaked in 1970), with some arguing that it has already occurred, while others claim that the growth can continue unabated for 20 to 30 years.

The consumption of refined petroleum products is concentrated in North America and Europe. Europe/Eurasia and the United States account for almost half of the global refining capacity, or about 20% and 29%, respectively. With the exception of Russia, many of the countries in these regions, along with Japan and China, are thus heavily dependent on oil imports (crude oil and refined products); for example, the United States is around 60% dependent on net petroleum imports. Most U.S. imports come from Canada, Saudi Arabia, and Mexico.

Synthetic forms of oil supplies could technically replace petroleum, and the most market-ready

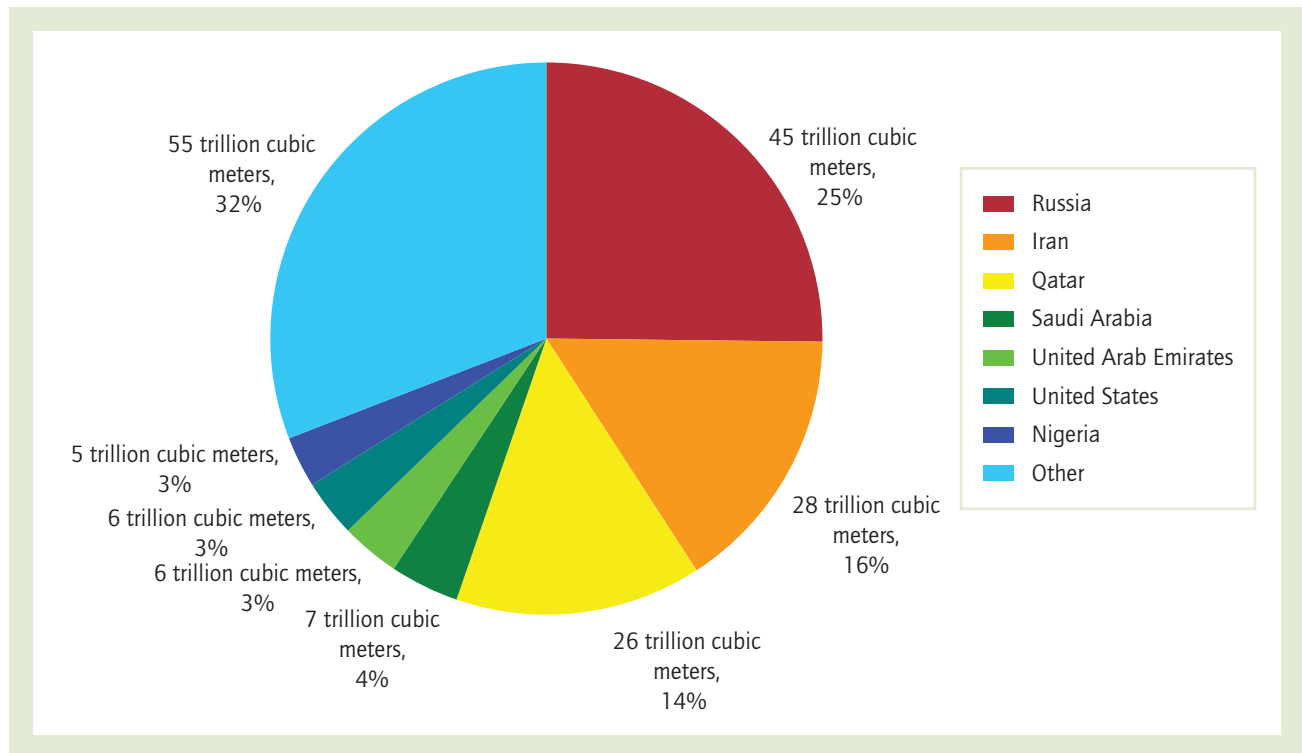


Figure 3 Global gas reserves by country

Source: Adapted from British Petroleum. (2008). *BP statistical review of world energy June 2008*. London: Author.

option is tar sands (also called bitumen or petroleum sources with high viscosity). The vast majority of these resources have been produced in Northern Alberta, Canada (in the Athabasca region), and Venezuela (in the Orinoco region in the eastern part of the country). Canada has been the leading producer as it has more reserves of tar sands than conventional oil. The United States has even larger reserves and more than 60% of the world's resources (found mostly in Western states such as Utah and Alaska), but it has yet to develop them. Another oil alternative is oil shale (also called kerogen), which is found in fine-grade sedimentary rocks in the Western United States and many other countries. The kerogen can be converted into synthetic crude oil via pyrolysis. Oil shale has been produced on a very limited scale in more than a half dozen countries. U.S. reserves are similar to those of its oil supply, but again commercial production has yet to commence. The Federal Bureau of Land Management has leased five research and development tracks to oil companies in Western Colorado. Production could occur after

2010 at the earliest, probably using in situ processing. Barriers to the development of these unconventional energy resources are mostly economic and environmental, with water pollution, waste generation, greenhouse gas emissions, and water requirements potentially huge. In addition, both oil shale and tar sands have much lower volumetric energy density than conventional crude oil.

Natural gas resources are found together with oil (so-called associated gas) as well as independently. While gas (which is 80–95% methane) is cleaner than oil, it was less intensely explored and developed until the 1950s, is inconvenient to store, and is much more costly to ship because of its low energy density. Overseas shipment of natural gas requires that it be first liquefied to 1/600 of its normal volume and at cryogenic temperatures. The procedure involved is costly. The gas reserve base is more geographically concentrated than is oil, with 55% of the world total found in Russia, Iran, and Qatar (Figure 3). Russia and the United States dominate global gas production, accounting for around 40% of the total, with

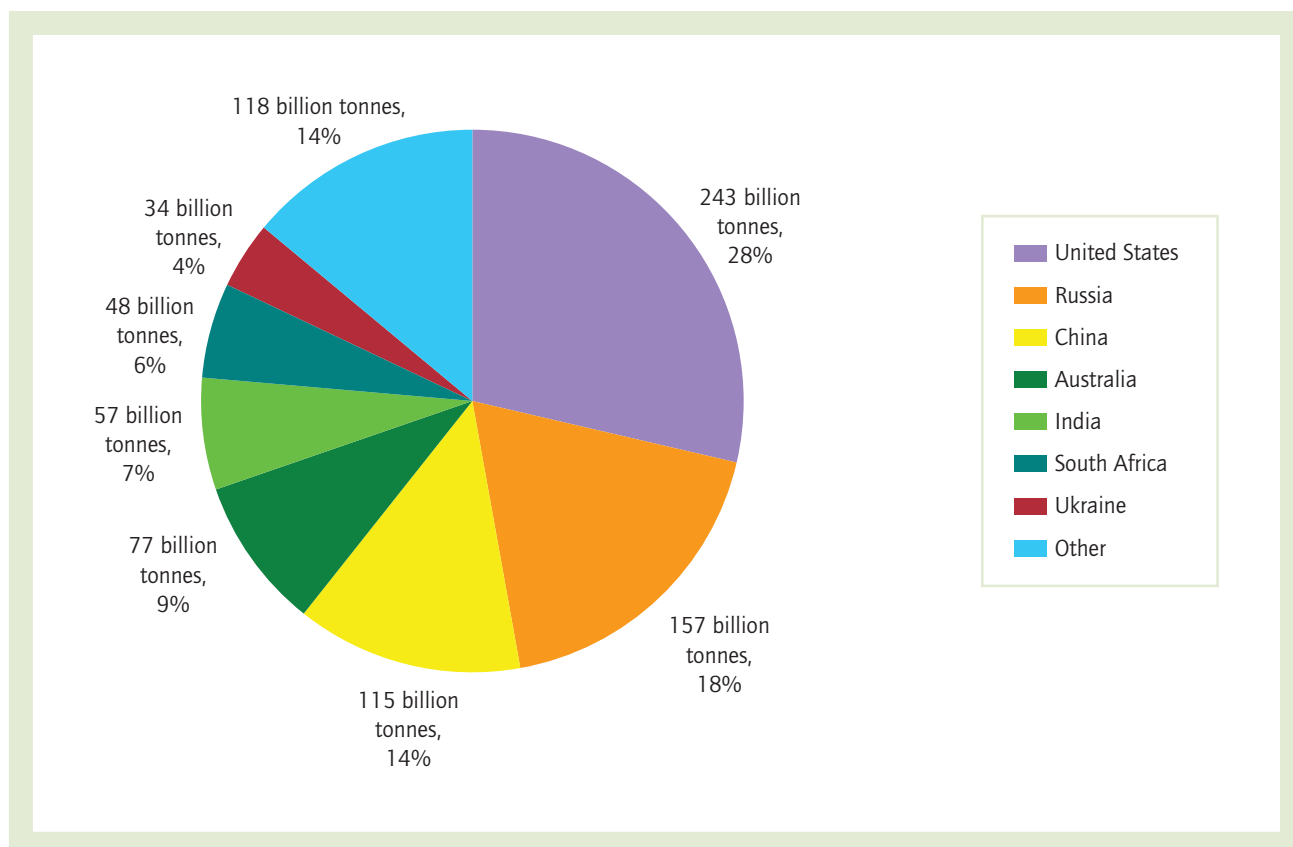


Figure 4 Global coal reserves by country

Source: Adapted from British Petroleum. (2008). *BP statistical review of world energy June 2008*. London: Author.

more than half of the gas consumption taking place in the United States and in countries of the Soviet Union and the European Union. The date of peak global gas production is even more uncertain than for peak oil, though U.S. production peaked in 1973.

Several unconventional gas sources could be exploited. The most important of these are coal-bed methane from underground coal mines and methane hydrates (clathrates). The latter are crystalline solids containing gas molecules surrounded by ice, which are found in outer continental shelf sediments and in polar regions. While methane hydrates resources are vast, they are yet to be developed. The United States has coal-bed methane reserves equal to about half those of conventional gas, which already account for 8% of total gas production.

The last of the three conventional fossil fuels, and the one by far in greatest abundance, is coal. It

is also the easiest one to find and develop, and consequently, it fueled the Industrial Revolution, first in Europe and later in the United States. Global coal reserves are even more geographically concentrated than those of natural gas, with the United States, Russia, and China accounting for 61% of the total; Australia, India, and South Africa account for an additional 21% (Figure 4). China is by far the largest producer, accounting for more than 41% of global production in 2007, more than double the production of the United States, at number two. Despite the growing global concern over controlling carbon dioxide emissions, only Europe (except for Russia) and North America, among the major producers, have experienced a leveling of production over the past decade. Coal consumption patterns are somewhat similar to those of production, with Asia dominating (60% in 2007), followed by North America and Europe. Major coal exporters include Australia, Indonesia,



Russia, South Africa, and Colombia, while major coal importers with little domestic production include Japan and South Korea.

Coal resources are primarily used as solid fuel for electric power generation as well as for some heating; it has a secondary market as coking coal for use as a fuel and reducing agent for smelting iron ore in blast furnaces for steelmaking. There is also increasing interest in the use of coal for technologies such as gasification (including methanation, or conversion into natural gas) and liquefaction, with increasing commercial development around the world.

Biomass Energy

Biomass provides the most important source of renewable energy in the world, but it is renewable only if it is used sustainably. Firewood and charcoal were among the initial energy sources of traditional societies, along with the sun, wind, water, human and animal muscle, crop residues, dried dung, and even gunpowder. Historical evidence shows that wood in any available form and other combustible resources were the first inanimate sources of energy for humanity. Other forms of biomass energy are readily available besides wood, such as dung, animal fats and tallow, agricultural crops and residues, and grasses. The use and benefits of biomass energy resources should be balanced against their other purposes, including agriculture and other nonenergy applications, as well as the many other sources of energy against which they compete. Consequently, statistics on the energy resource or reserve base for biomass and other renewable sources may not be very meaningful.

Much of the work of geographers on biomass energy has focused on the prominent role of fuelwood for home heating and cooking in developing countries, especially sub-Saharan Africa, India, Pakistan, and China. In many of these nations, biomass energy use accounts for 90% or more of total energy consumption, while the comparable figure for the whole world is 10% to 12%. These uses of biomass are often referred to as traditional or first generation, and most of this biomass energy is not traded in markets. Particular concerns of geographers include understanding the socioeconomic and cultural factors that

influence deforestation, sustainability, and health problems from inhalation of fine particles from cook stoves. While biomass energy accounts for just 3.6% today in the United States, it was the major energy source of the nation until 1885, when it was overtaken by coal.

Modern or second-generation sources of biomass include feedstock for alcohol fuels, such as sugarcane ethanol in Brazil, corn ethanol in the United States, and biodiesel from rapeseed in Germany or soybeans in the United States. Ethanol can also be made from wood, as can methanol (wood methanol was popular in the northeastern United States from the 1890s until the 1930s, when it was replaced by oil). Advanced ethanol based on cellulosic feedstock such as agricultural and forestry residues, switchgrass, and municipal solid wastes is in the process of being commercialized in several nations, but it will take a decade or more to establish significant market shares.

Hydropower

After biomass energy, the next largest source of renewable energy in the world is hydropower, which uses the force of moving water to generate electricity or do mechanical work. It is difficult to account for hydropower reserves because of the many competing uses for water. In addition, while fresh water is clearly a renewable source of energy, the lifetime of hydroelectric dams is quite variable because of eventual siltation of the reservoirs and variable rainfall and snowmelt. While most hydropower is used for electricity generation, it has also been used for irrigation and to operate machinery. In many parts of the world, hydropower is the cheapest source of renewable electricity.

The leading producers of hydroelectricity include China, Canada, Brazil, the United States, and Russia. The United States used to be the world's largest generator, but its output has been declining. Among the major producers of hydroelectric power, Canada and Brazil are the most reliant on it as water accounts for 65% to 85% of their respective electricity needs, depending on the year and weather conditions. Among some smaller countries, reliance on hydroelectric power is even larger, as it accounts for 95% to 99% of power needs in Scandinavian countries such as Norway and Iceland.



Since the best dam sites have long been tapped for hydroelectricity in the United States (and some of these sites have been decommissioned in recent years), most of the major new projects are being built in the developing countries. These include China, India, Malaysia, Vietnam, Brazil, and Azerbaijan. The most famous of these is the 22,500-MW Three Gorges Dam on China's Yangtze River, the world's largest hydroelectric plant.

Other Sources of Renewable Energy

There are several other sources of renewable energy. One of these, wind energy, has been the fastest-growing energy source in the world since the early 1990s. Available power is a function of the wind velocity cubed, so good steady winds of 15 miles per hour or more are especially desirable. However, intermittency is a problem with wind (as is the case with several renewable energy sources). Germany is by far the leading user of wind power in the world, followed by the United States and Spain, while India and China are the leading users among developing countries. Denmark has the highest rate of per capita reliance on wind for electricity, at around 15%. The United States, once the leading wind energy user, has had fluctuating demand growth in the past decade. The state of Texas is now the leading wind user in the nation, followed by California.

Solar energy, the demand for which is also growing rapidly, has a much smaller market. Western nations such as Germany, Spain, the United States, and Japan have been working to increase the conversion efficiency of photovoltaic cells but mostly sell space and water heaters. The cost of photovoltaics continues to fall, but they are competitive only in limited applications. Also, more than 10 solar power plants using parabolic troughs have been built in the Southwestern United States. Developing nations, in contrast, are much more interested in low-cost solar cookers, especially in rural areas.

Geothermal energy, although site specific and depletable on local scales, is generally still considered renewable. The United States and the Philippines are the largest users of geothermal electricity, though the United States has not experienced capacity growth in the past decade. Besides power

production, geothermal energy can also be used for space heating, aquaculture, and heating of swimming pools, spas, resorts, and greenhouses.

Finally, some remaining renewable energy sources that have not been seriously developed include tidal power, wave energy, and ocean thermal electric conversion.

Uranium and Nuclear Power

Uranium is used for fuel to generate electricity in nuclear power plants, which were first commercialized in the United Kingdom, Russia, and the United States in the 1950s. This naturally occurring and widely distributed element is found in minerals, soils, and seawater around the world. Australia, Kazakhstan, and Canada account for 50% of the world's uranium reserves, with Canada, the United States and South Africa accounting for another 23% (Figure 5). Naturally occurring uranium contains more than 99% uranium-238 (^{238}U) and about 0.7% uranium-235 (^{235}U). To provide fuel for most nuclear power plants, the ^{235}U concentration must be enriched to around 3%. Since fuel is only a small portion of the operating expense at nuclear plants (the majority is the capital investment), electric utilities in major countries such as the United States will import a majority or all of their uranium fuel for cost reasons even if there is a large domestic resource base.

In rank order, the leading generators of nuclear power in the world are the United States, France, Japan, Russia, and Germany. The most nuclear-dependent countries are France and Lithuania, which generate 77% and 64% of their electricity from nuclear power.

End Use Efficiency and Conservation as Energy Resources

While end-use efficiency and energy conservation are not a traditional energy "resource," they can provide low-cost energy services in all countries. Although the technical, economical, and social potential of such technologies varies by sector and country, these options are alternatives that can be considered to meet a large share of energy needs. There is no consensus as to how large this

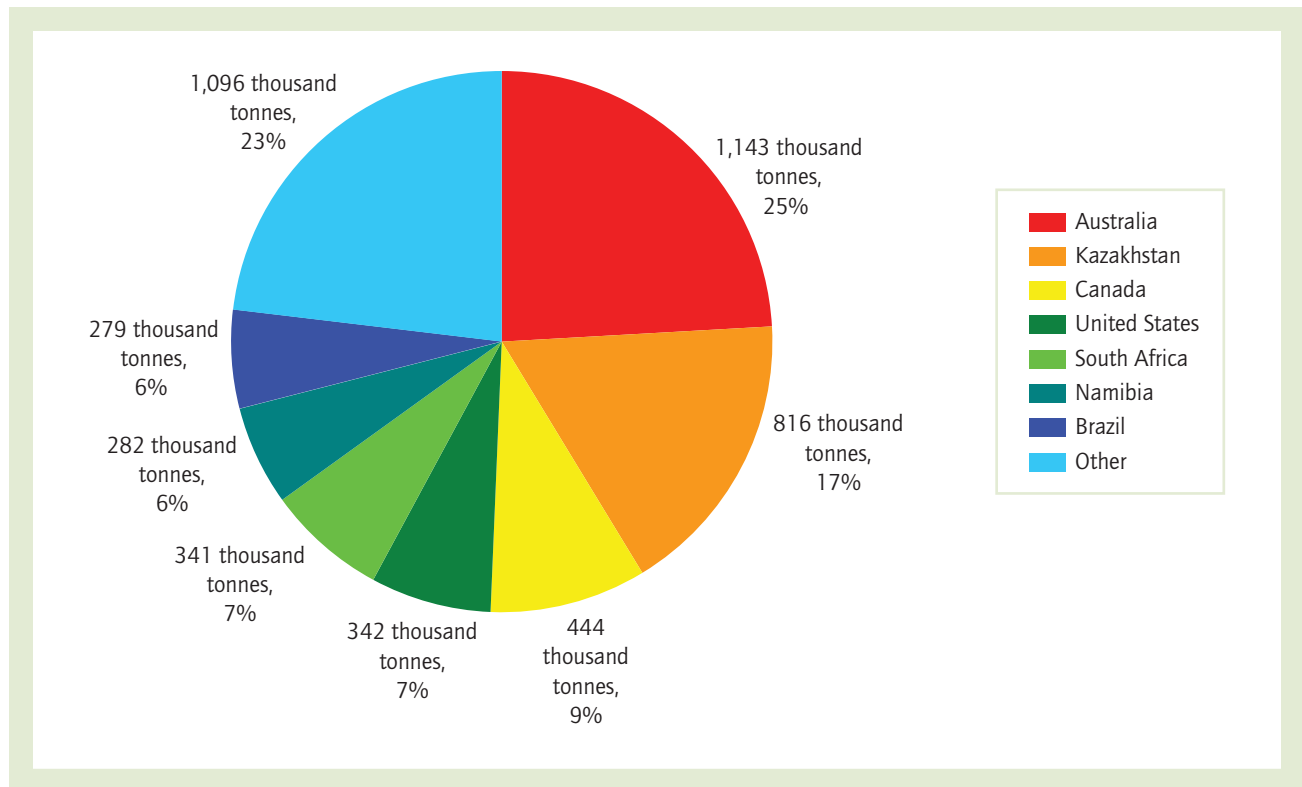


Figure 5 Global uranium reserves by country

Source: Organisation for Economic Co-operation and Development, Nuclear Energy Agency, & International Atomic Energy Agency. (2008). *Uranium 2007: Resources, production and demand*. Paris: Author.

potential is in most countries. Consequently, energy audits may be very useful to determine the potential for these technologies in buildings and in industrial sectors, for example, through the use of more efficient refrigerators and other appliances, lighting, ballasts, and motors and cogeneration of electricity and heat from currently discarded industrial process heat. Attractive transportation options include greater use of public transit, telecommuting, hybrid gasoline-electric vehicles, plug-in hybrids, and diesel-fueled vehicles. Most of these options are readily available. Many nations have government-sponsored energy-efficiency programs and centers, which often provide grants, loans, and technical assistance to meet the potential for energy-efficiency improvements. Industrial groups, such as the U.S. Electric Power Research Institute, provide similar services.

Barry D. Solomon

See also Coal; Energy and Human Ecology; Energy Models; Energy Policy; Geothermal Energy; Hydroelectric Power; Market-Based Environmental Regulation; Nonrenewable Resources; Nuclear Energy; Petroleum; Political Economy of Resources; Renewable Resources; Solar Energy; Wind Energy

Further Readings

- Energy Information Administration. (2007). *International energy annual 2005*. Washington, DC: U.S. Department of Energy. Retrieved January 25, 2009, from www.eia.doe.gov/iea
- Odell, P. R. (1983). *Oil and world power: A geographical interpretation* (7th ed.). Hammondsouth, UK: Penguin Books.
- Smil, V. (1983). *Biomass energies*. New York: Plenum Press.



- Solomon, B. D. (2004). Economic geography of energy. In C. Cleveland (Ed.), *Encyclopedia of energy* (Vol. 2, pp. 25–34). Oxford, UK: Elsevier.
- Solomon, B. D., Pasquetti, M. J., & Luchsinger, D. A. (2003). Energy geography. In G. L. Gaile & C. J. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 302–313). Oxford, UK: Oxford University Press.



ENLIGHTENMENT

The Enlightenment has typically been defined as a period of European thought, a broad intellectual movement, or the Age of Reason that took place in Europe approximately from the years 1685 to 1815 and that emphasized experience, reason, and mistrust of religion and traditional authority.

Definitions such as this one seem to confine the Enlightenment to a universal, static, and singular movement that existed within specific European countries. Such definitions also imply that it was understood and expressed similarly in all countries despite differences in languages, politics, economics, and religious beliefs. Nevertheless, the Enlightenment as a discourse and as a process was far more complex than what was originally envisioned, reaching more than one continent and being constructed in discrete and multiple forms around the globe. Scholars should not speak of the Enlightenment as a unitary phenomenon but rather as a process that was manifested in a variety of ways pending its locus of enunciation and reception. In this sense, the Enlightenment should be perceived, as Charles Withers notes, as a dynamic phenomenon characterized by a variety of local and temporal factors. Following Withers's suggestion, we should then think about the Enlightenment in the plural—the Enlightenments—understanding it as a dynamic transnational phenomenon. The Enlightenment ought to be considered as a series of processes, discourses, and lines of thought manifested in multiple ways in areas as diverse as religion, politics, science, literature, art, education, economy, and philosophy, to name a few.

The Enlightenment also implied a time in which the production of knowledge traveled at a global scale through printed books, maps, scientific expeditions, and economic trading. Political, economic, religious, and cultural transactions reflected many of the main premises of the Enlightenment with their emphasis on critical reason, progress, utility, and order. Within this context, space constituted an important element in the discourses produced during this time. Not only the locus of enunciation determined the nature of the Enlightenment as a process, but the space where it was read represented in itself another relevant factor when understanding the multiple layers of the Enlightenment. The famous ideological precepts of the Enlightenment, such as order, utility, progress, and reason, were articulated in different ways in countries such as France, Britain, Spain, Mexico, and Peru, to name a few. To this extent, as Livingstone and Withers suggest, the European Enlightenment was substantially molded through engagement with other parts of the world, notably with the Americas as a whole and with the Pacific. Furthermore, the Americas as well as the Pacific produced their own Enlightenments. To this extent, we can envision the Enlightenment as geographical in nature.

Livingstone and Withers have contributed greatly to our understanding of the Enlightenment as a geographical phenomenon. They both call attention to the centrality of space in the discourses belonging to this period. For them, geography encompasses the sites and practices in which the Enlightenment as a process took place. Also, according to them, the Enlightenment as a series of ideas was produced, debated, and consumed in multiple places and spaces. Exploring, traveling, mapping, and naming became key activities in such processes. Nature itself became a commodity, while traveling, mapping, and naming served as critical vehicles to inquire, survey, categorize, and give order to the world.

The obsession of Enlightenment intellectuals to study, categorize, and give meaning to the natural and physical world rendered geography, as it was practiced at the time, a perfect tool to understand and explain the world. Geography did not exist as a discipline in the 18th century. It was instead considered part of the empirical sciences, in which experience and the senses were



two crucial elements to understand the world. As Withers defines it, in the 18th century, geography constituted the descriptive study of the Earth as a whole, either in textual or in mathematical terms. However, the study of the Earth was a subject that guided the intellectual and political endeavors of philosophers, theologians, cosmographers, mathematicians, and even merchants. The local, or faraway, countries, kingdoms, and continents became the focus of their taxonomic studies as well as their political, religious, and economic interests. To understand the world and its spatial nature implied knowledge of it and consequently the ability to order it and master it. For Enlightenment thinkers, to achieve human progress, it was necessary to know the potential of the world they lived in. As Withers suggests, to think critically “in and about the world” became a significant trait of the age of the Enlightenment. For the intellectuals, that critical thinking involved the act of positioning themselves into or within a privilege location that would deem them wholly capable to describe and explain the world. That position constituted that ideal point of observation where the observer felt that he could explain the world in a transparent fashion or in its pure factual nature, free of any particular moral, political, or religious beliefs. The accumulation of geographical knowledge during the culture of the Enlightenment therefore became a crucial instrument to legitimate, reproduce, and perpetuate a specific social order.

The Enlightenment constituted a key element in understanding the origins and the nature of the world. Humans, plants, and animals were observed, studied, and explained in terms of where they were located. Place as well as space gave new meaning to the human and physical world. In this sense, the Enlightenment had its own geographies as it took place in and over space.

To understand the complexities and ambivalences that characterized the philosophies of the Enlightenment in its search for reason, order, and progress, one must recognize, on the one hand, its multiple places of enunciation and, on the other, the different manners in which it was received and read around the world. The Enlightenment required understanding beyond the limits of Europe as it implied a transoceanic movement that was transformed depending on its multiple

locations. The dynamic sites of production as well as reception constitute elements of the Enlightenment that call attention to the Enlightenment as a process, as a thought, and as a movement that challenges any scholar who approaches it as a singular cultural, scientific, and political form.

Mariselle Meléndez

See also **Cultural Geography; Human Geography, History of; Livingstone, David**

Further Readings

- Livingstone, D. (1992). *The geographical tradition*. Oxford, UK: Blackwell.
- Livingstone, D., & Withers, C. (1999). *Geography and Enlightenment*. Chicago: University of Chicago Press.
- Outram, D. (1995). *The Enlightenment*. Cambridge, UK: Cambridge University Press.
- Withers, C. (2006). Eighteenth-century geography: Texts, practices, sites. *Progress in Human Geography*, 30, 711–729.
- Withers, C. (2007). *Placing the Enlightenment: Thinking geographically about the Age of Reason*. Chicago: University of Chicago Press.



ENTERPRISE GIS

Enterprise GIS refers to geographical information systems (GIS) in private companies, governmental organizations, or any similar entity. The main requirement here is that the company or organization consists of a number of departments or other areas with professional activities that require at least some support of a GIS.

Requirements

In the early GIS years, GIS users were mainly working at separated and sometimes isolated workstations. Today, workstations are connected, linked to other applications, and therefore integrated in the whole information technology (IT) infrastructure of an organization.



The requirements for an enterprise GIS are as follows:

- Easy and flexible modeling of the business logics of the different processes
- Support of the different functional requirements in the departments from road construction to planning and facility management, just to mention a few
- Support of different user groups, experienced as well as occasional users
- Efficient organization of data commonly used internally by individuals or departments
- Ability to exchange data, integrate, or link data and software components of different GIS and other applications

- Client-server architecture (see Figure 1)
- (Distributed) database managements systems allowing multiuser access, definition of access rights, and so on—sometimes also data warehouses
- Sophisticated data management and integration tools
- IT standards such as SOAP or WSDL to implement service-oriented architectures (SOA)
- GI standards such as GML and OGC Web services such as WMS and WFS
- Work flow support

GIS vendors offer specific modules to build an enterprise GIS that in general support the techniques listed here.

Technical Issues

To establish an enterprise GIS, a number of IT-techniques/technologies have to be considered. The most important ones are as follows:

Organizational Issues

Establishing an enterprise GIS requires complex technologies, but the real challenge is often an organizational one. All the potential categories of

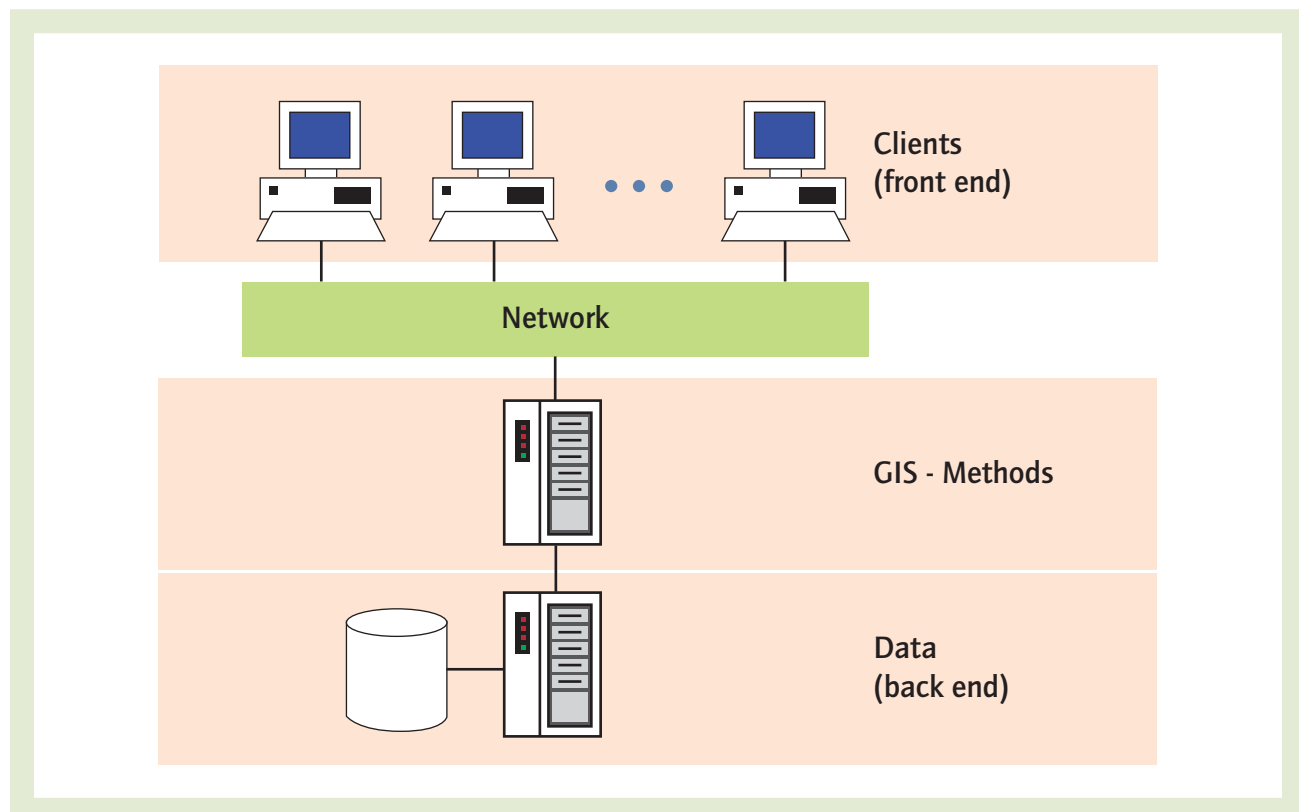


Figure 1 Three-tier client-server architecture

Source: Author.

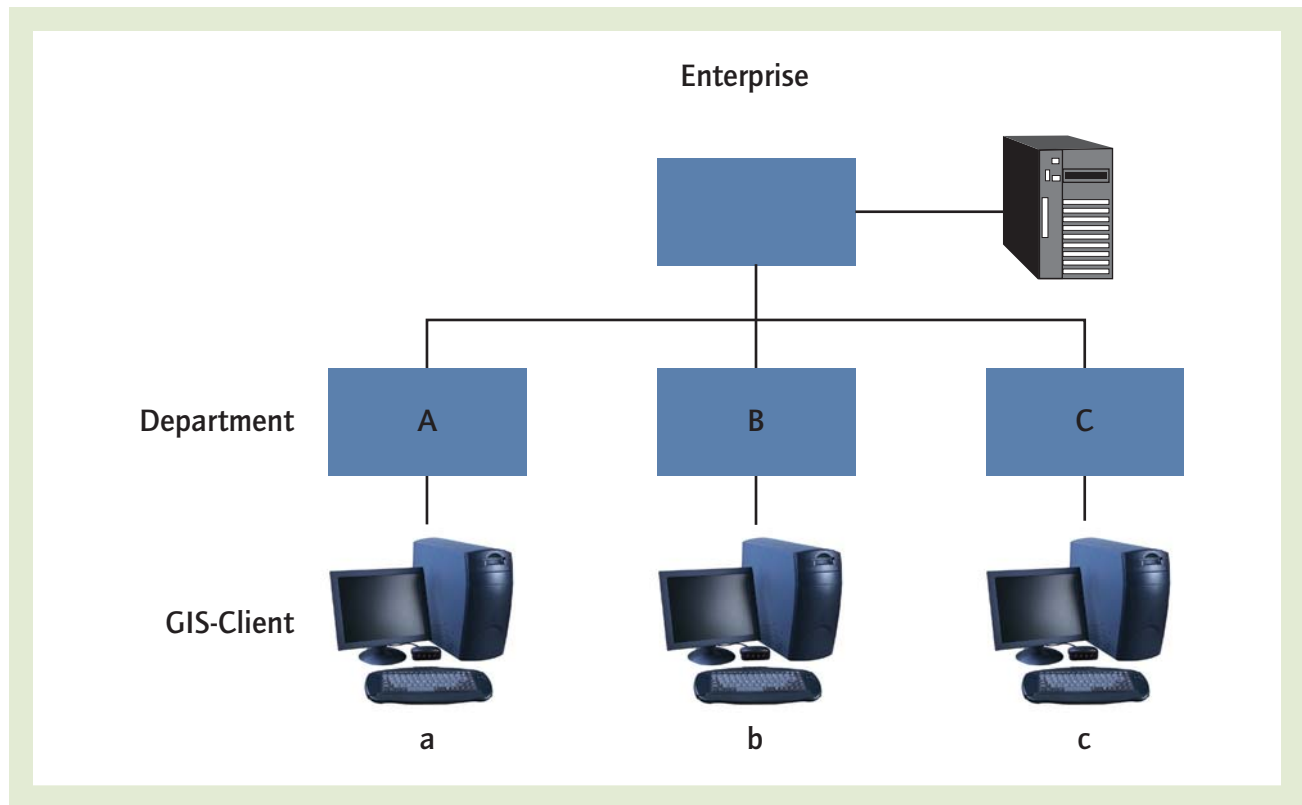


Figure 2 Overview of an example of the organization of an enterprise GIS

Source: Author.

users, their processes, the different kinds of data, functional requirements and software products, and the systems that must be linked have to be known, and a corresponding system architecture has to be defined. It is often a balance between having an IT landscape that is homogeneous and satisfying the different requirements of the various user groups.

Figure 2 gives an overview of one example of the organization of an enterprise GIS. Technically, it is client-server based and includes one central database and different GIS clients with external databases in the departments. Each of them can offer GIS-based services for the whole enterprise; however, many organizational decisions have to be made (who is doing what, where, in which way, and so on).

The organization of an enterprise GIS varies depending on the size of the enterprise, the complexity of the processes, the form and number of integrations of other systems, and other aspects

mentioned above. One common approach for an enterprise GIS does not exist.

Wolfgang Peter Reinhardt

See also **Business Models for Geographic Information Systems; Client-Server Architecture; Dangermond, Jack; GIS in Local Government; GIS in Public Policy; GIS in Urban Planning; GIS in Utilities; GIS Software**

Further Readings

- Harder, C. (1999). *Enterprise GIS for energy companies*. Redlands, CA: ESRI Press.
- Keating, G., Rich, P., & Witkowski, M. (2003). Challenges for enterprise GIS. *URISA Journal*, 15(2), 25–39.



ENVIRONMENTAL CERTIFICATION

Environmental certification is a procedure by which a third or second party gives written assurance that a product, process, or service is in conformity with certain environmental standards. It is used to give environmentally conscious consumers assurances on environmental aspects of the product or service itself or the production process.

Process

The producer (first party) or the buyer (second party) applies for certification to a third party that has created or adheres to a set of standards. *Product standards* are specifications and criteria characterizing products, while process standards characterize the way products are made or services are delivered. *Process standards* can be further subdivided into management system standards, which set criteria for management procedures such as monitoring and documenting, and performance standards, which define what actually happens, for example, whether certain pesticides and fertilizers are used. Because conditions vary worldwide, generic standards are often used, which provide a framework for a more local standard setting. Products or processes are checked against these standards in inspections, which are carried out either by the standard-setting certification bodies themselves or by an inspection body subcontracted by the certification body. The certification decision is then based on the inspection report and possibly other information provided by the producer. Successful certification is documented by a certificate, which can be shown to a buyer and is often signified by a label on products to show to final consumers. Standard-setting organizations for environmental standards can be governments, industry or non-governmental organizations (NGOs), or mixed stakeholder partnerships between these actors.

Origins

Environmental certification has existed for over 30 yrs. (years). In 1978, the German government

sponsored a standards-backed environmental label, “Blauer Engel” (blue angel). A multistakeholder jury awards the label to products that are more environmentally friendly than are competitor products, such as chlorofluorocarbon-free spray cans, recycled paper, and environmentally friendly heating systems. In 2008, around 10,000 products and services carried the label.

At an international level, the Agenda 21, a global plan of action for sustainable development adopted at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, called for the introduction of environmental certification and labeling schemes.

Example 1: Organic Agriculture

Today, one of the most well-known environmental standards focuses on “organic” production. From the 1920s onward, farmers were inspired by the ideas of Rudolf Steiner and others to develop production methods, which emphasized biological processes and minimized the use of nonrenewable inputs. They began to codify their methods and formed the International Federation of Organic Agriculture Movements (IFOAM), which formulated basic standards in 1980. These standards, which are reviewed every 2 yrs., serve as a guideline on which subsequent national regulation has been based. Organic standards, devised by governments and various IFOAM-accredited NGOs, now exist for all crops and some livestock. Organic standards include various process standards prohibiting, for example, the use of synthetic fertilizers and pesticides.

There are several other environmental certification schemes, including the ISO 14001 Standard for Environmental Management Systems and the Rainforest Alliance certification scheme, focusing originally on habitat conservation. Environmental certification schemes are often linked to public discourses around environmental concerns. They are linked, for example, to dolphin-friendly fishing methods, 100% recycled paper, non-genetically modified ingredients, non-air-freighted fruit, and vegetables and energy-efficient white goods.

Example 2: Forest Certification

The 1992 Rio Conference agreed on Forest Principles. Worldwide forest certification schemes,



such as the NGO Forest Stewardship Council (FSC), developed general international principles and criteria and accredited organizations, which in turn certify sustainably managed forest land. In 2008, 100 million hectares of forest in 79 countries was FSC certified. Other schemes include the Programme for Endorsement of Forest Certification, the UK Woodlands Assurance Scheme, the Sustainable Forestry Initiative, and Canada's National Standard on Sustainable Forest Management CAN/CSA-Z809. There have been several moves to harmonize these different schemes, but so far, these have not been successful.

Current Debates

Currently, several issues related to environmental certification are the subject of debates. These include integration of social and environmental certification, balancing global reach and local specificity, and accountability of those who set the standards.

Link between social and environmental certification. There is a need to further integrate social certification schemes such as Fair Trade, which mention environmental concerns, and environmental certification schemes such as organic certification, which include references to social issues.

Global reach and local specificity of standards. As producer circumstances, climates, soils, and land tenure systems vary, matching worldwide standards to the local reality is challenging. The aim is to keep standards focused on objectively verifiable performance goals (e.g., water quality) while not being overly prescriptive to producers.

Accountability of standard-setting NGOs. Certification and labeling are skewed toward consumers who have the economic means to choose more "ethical" products. Furthermore, NGOs acting as standard-setting or certification bodies are not systematically accountable to producers or consumers, although many invite these stakeholders onto their councils and advisory boards. Also, commercial auditing and certification have increased the risk that inspections can be superficial, affected by conflict of interest, or

too focused on details of the standard, without adequate recognition of the producers' situation. Producers generally pay the inspection and compliance costs, and in turn, they receive a better price or marketing advantage for products or services. Other actors in the chain may benefit without having paid the cost of compliance or certification.

Future Market Developments

As the demand for environmentally certified products increases, large retailers are offering such products. Their requirements for low administrative costs, uniformity, and traceability favor larger-scale producers, putting smaller producers at risk of being marginalized. Another important question is whether consumers can be persuaded to adopt a nuanced view of the different levels of environmental certification. Another key development for environmental certification is the developing global market for carbon emissions trading, where businesses or governments buy carbon certificates from certified carbon reduction and carbon capture projects to offset their own emissions.

Dorothea Kleine

See also Carbon Trading and Carbon Offsets; Fair Trade and Environmental Certification; Organic Agriculture; Sustainable Development; Sustainable Forestry; Sustainable Production; United Nations Conference on Environment and Development

Further Readings

- Dankers, C. (2003). *Environmental and social standards, certification and labelling for cash crops*. Rome, Italy: Food and Agriculture Organization of the United Nations.
- International Organization for Standardization. (1996). *ISO guide 2*. Geneva: Author.
- Klooster, D. (2006). Environmental certification of forests in Mexico: The political ecology of a nongovernmental market intervention. *Annals of the Association of American Geographers*, 96(3), 541–565.



- Rametsteiner, E., & Simula, M. (2003). Forest certification: An instrument to promote sustainable forest management? *Journal of Environmental Management*, 67, 87–98.
- Rundgren, G. (1998). *Building trust in organics: A guide to setting up organic certification programmes*. Tholey-Theley, Germany: International Federation for Organic Movements.



ENVIRONMENTAL DETERMINISM

Environmental determinism, also referred to as geographic determinism or even environmentalism, is the contention that the environment holds sway over humanity, controlling human actions and exercising a dominant influence on human development. While a range of perspectives exists on the degree of causal determinism that should be attributed to the environment, advocates of environmental determinism are unified in their recognition that the environment has an overriding influence on humanity. The implication is that the social and cultural behavior of humans is determined to a large extent by environmental factors that are asserted to exist beyond the influence of humanity. This conception of the relationship between humans and the environment has roots that stretch deep into classical history, possibly representing the earliest attempts to explain variations in sociocultural traits across geographic regions. Its compelling simplicity and promise of causal explanations for complex social phenomena have driven recurrent interest in environmentally deterministic theories up to the present.

An Ancient Belief

Belief in the power of the environment to shape society and mold human characteristics has been widely espoused since ancient times. Hippocrates, in his work *On Airs, Waters and Places*, asserts a connection between world climates and the perceived characteristics of different cultures. The proclivity of Northern Europeans to being

poverty-stricken could be attributed to their poor environment, while more climatically favorable regions led to easygoing and amiable societies. Plato and Aristotle believed that the influence of climate extended to the development of governments and was ultimately responsible for stimulating the progress of societies. An acceptance of this direction of influence, strictly from the environment to humans, persisted throughout many centuries and found renewed interest during the Enlightenment. Montesquieu contended that the climate was a potent influence on human behavior, asserting that cold climates led people to be stronger in spirit and body, more trustful and straightforward, and less cunning, while the heat of the lower latitudes resulted in passivity and indolence. As during ancient times, this profound influence on human behavior was believed to be the fundamental explanation for varying forms of government and social organization. For example, it was believed that monarchies tended to occur in more fertile environments, while republics prevailed where the climate was harsh and people were pressured to better their circumstances. Despite the claim that the environment had a vast influence on human life, the environment was rarely the subject of study by environmental determinists as it was commonly viewed as an inexplicable force and considered important only in accounting for sociocultural variations among different peoples.

Environmental Determinism and Evolutionary Theory

Environmental determinism returned to the fore of intellectual consideration of human-environment relations during the late 19th and early 20th centuries following the advancement of Charles Darwin and Alfred Wallace's theory of evolution. Even prior to evolution, scientists such as Herbert Spencer attempted to apply biological principles to the study of society. Although neither Darwin nor Wallace linked the principle of evolution with the concept of human social and economic development, many others did; they envisioned the potential for what, in their view, would allow for a more rational study of human society and culture. The theory of evolution was embraced as the



bridge linking all organisms (including humans) to the natural laws governing their environment. Friedrich Ratzel, a central figure in the refinement of environmental determinism during the modern period, is perhaps best known as a result of his often-quoted student Ellen Churchill Semple. Semple's forceful arguments in favor of a strong version of environmental determinism overshadowed the more moderated writings of Ratzel. Anthropogeography, Semple's brand of environmental determinism, envisioned nature as the supreme agent of influence, molding the physical features of humans and shaping nearly all aspects of humanity's social development. Environmental factors during this period came to be commonly viewed as the determinative cause of racial differences, cultural practices, moral values, ingenuity, and the ultimate capabilities of any given population.

Criticisms

Despite offering a convenient way to explain difference as a product of geography, environmental determinism quickly fell out of favor following the identification of several fundamental theoretical weaknesses. George Tatham, reflecting on the demise of this theoretical approach, identified three critical problems that ultimately led to its popular demise by the mid 20th century. First, the theory failed to prove that similar environments yielded the same response in human populations, demonstrating that other factors could override the effects of the physical environment on humanity. Second, an increasing awareness of the ability of humans to modify their environment greatly weakened the arguments of environmental determinism given the assumed unidirectional influence of the environment on humans. Last, a consideration of environmental factors alone failed to explain the most fundamental of social characteristics, such as the distribution of the human population.

These failures were further accentuated as early environmental determinists frequently relied on cause-and-effect relationships, established by overly simplistic correlations, to craft their analysis of the environment's influence on humanity. Additionally, their arguments were further weakened by a reliance on secondary data that limited

their conclusions to global scales of generalization. Finally, the deployment of environmental determinism to justify colonial exploits and the subjugation of other societies cast a pall over the entire body of work during this period.

Neo-Environmental Determinism

Renewed interest in the environment has led some to look past the failures of environmental determinism and advance new arguments that attribute greater causal determinacy to the natural environment. Widespread public and academic interest in the work of Jared Diamond, particularly in his Pulitzer Prize-winning book, *Guns, Germs, and Steel: The Fates of Human Societies*, indicates the persistence of environmentally deterministic logic and the failure of human-environment researchers to effectively communicate subsequent theoretical advances. Struggling to account for the distribution of wealth and power around the globe, Diamond forwards his deterministic theory that the conquest of non-Western societies by the West was largely the result of the uneven endowments of the natural environment. The title of the book acknowledges that more immediate factors (guns, germs, and steel) have played an important role; however, Diamond contends that their occurrence is causally determined by the influence of the environment, particularly the growing season of crops. Avoiding the racist conclusions attributed to earlier environmental determinism, neo-environmental determinists reject consideration of the influence of the environment on human characteristics, focusing instead on the effects of the environment on human society. With little substantive difference from earlier determinist perspectives, neo-environmental determinism continues to be plagued by the same theoretical weaknesses as its theoretical antecedent.

Gabriel Judkins

See also Anthropogeography; Blaut, James; Diamond, Jared; Human Geography, History of; Huntington, Elsworth; Race and Nature; Ratzel, Friedrich; Semple, Ellen Churchill; Social Darwinism; Taylor, Griffith



Further Readings

- Diamond, J. (2005). *Guns, germs, and steel: The fates of human societies*. New York: W. W. Norton.
- Ellen, R. (1982). Environmental determinism and causal correlation. In R. Ellen (Ed.), *Environment, subsistence and system: The ecology of small-scale social formations* (pp. 1–5). Cambridge, MA: Cambridge University Press.
- Gallup, J. L., Sachs, J. B., & Mellinger, A. D. (1999). Geography and economic development. *International Regional Science Review*, 22, 179–232.
- Glacken, C. J. (1967). *Traces on the Rhodian shore: Nature and culture in Western thought from ancient times to the end of the eighteenth century*. Berkeley: University of California Press.
- Judkins, G., Smith, M., & Keys, E. (2008). Determinism within human-environment research and the rediscovery of environmental causation. *Geographical Journal*, 174, 17–29.
- Peet, R. (1985). The social origins of environmental determinism. *Annals of the Association of American Geographers*, 75, 309–334.
- Schoenberger, E. (2001). Interdisciplinarity and social power. *Progress in Human Geography*, 25, 365–382.
- Sample, E. C. (1911). *Influences of the geographic environment: On the basis of Ratzel's system of anthropo-geography*. New York: Henry Holt.



ENVIRONMENTAL DISCOURSE

Discourse is a powerful concept that geographers and others have used to appreciate how nature and the environment—things that are typically thought to be self-evident, presocial, and taken for granted as being outside of, or beyond, politics—are invested with meaning, power, and politics. Thinking of environmental objects (such as a forest, landscape, and nature) as discursive products (i.e., as things made and remade through material and conceptual social labor and connected to deeply situated knowledges and experiences) has greatly opened up geographical understandings of both the “environment” and environmental practice.

The study of the environment *as* discourse and of *environmental discourses* (discourses about the

environment) has produced many critical insights into the social, political, and historical conditions and processes through which nature and the environment are made meaningful and visible to us as material entities, as well as about the manner in which environmental practices are made meaningful as viable possibilities. These include, for instance, insights into the manner in which concepts of “nature” and “wilderness” have been made and remade through colonial registers of meaning and used as powerful frameworks for dispossession in colonial contexts. The concept has also, in more general terms, enabled critical insights into how the manner in which the environment is made meaningful, incorporated into modes of production, and defined through environmental practice are intimately connected to (and constitutive of) practices of racialization, gendering, sexualization, and class distinction. In moral terms, the study of environmental discourse has helped geographers understand how and why it is—and through what strategies—that environments and the people living in them can come to be conceived in ways that authorize and legitimize their incorporation into regimes of extraction and other modes of production and consumption. For instance, these can include environments as sacrifice zones, places of recreation, or wilderness enclosures.

Conceptual Underpinnings

The intellectual claim that the environment is discursively constructed is grounded in distinct philosophical positions on (1) how the world *is* (ontology) and (2) how we come to know it (epistemology).

1. There is no external or innocent “reality” outside society or social experience, no natural “outside” to culture that can safely be called *nature*, no quality or state that can be thought *natural*. The truth about nature, the environment, and the world is therefore not self-evident or simply “out there,” waiting to be discovered; rather, it is an effect of social practice. In this sense, the environment and nature are “constructed”—encountered, brought into thought, and made meaningful through social practice.



2. Equally, there is no position outside society and culture (and its modes of production) from which to observe nature (or society for that matter) and make claims about its reality. Knowledges of the environment, about its reality and truths, are always discursive constructions since they cannot escape the socially mediated concepts, meanings, and practices through which we experience the environment and formulate claims about it. Nor can they escape the modes of cultural and economic production that bring knowledge into relation with the environment and already render it visible through technology and economy in particular ways. Furthermore, the idea of discourse incorporates the insight that observers of reality are always positioned in and constituted by social life, so that observations about and knowledge of the environment are contingent on the (gendered, racialized, sexualized, and classed) conditions and concepts according to which they were made. This means that we encounter the environment on particular, partial, and always political terms.

Environmental discourses are therefore the practices that bring into thought spaces of visibility in which environmental objects and our investment in them are constituted, the frameworks through which the environment (and whatever it is juxtaposed to) is rendered legible, and the ideas and concepts that materially alter and determine the state and form of the environment and those whose livelihoods depend on it. Crucially, these are all constructed within particular historical and material conditions and within specific sets of economic, cultural, and technological relations. Environmental discourses are the systems of meaning that bridge how we understand and come to know the world and how the world *is* as we experience and interact with it. Indeed, as an expression of the relationship between thought and materiality, epistemology and power, the symbolic and real, environmental discourse is a concept that collapses the distinction between the production of meaning and structures of the world.

Operation of Environmental Discourses

To clearly understand the concept of discourse, it is helpful to understand how it works—how

meaning is made and structured through discourse, how its truths are established, how knowledges are produced, and how social control is exerted. To this end, environmental discourses can be thought of as sets of related statements (including representational practices and performances) about an environmental object or objects that cohere to constitute and produce meanings about it and generate effects around it. To simplify, discourses have (1) objects (things that they constitute) such as the environmental effects of a proposed mine development; (2) effects (things that they accomplish and produce), for instance, to normalize a particular policy direction; and (3) strategies (techniques for establishing the meaning of objects and accomplishing effects).

1. The *objects* of environmental discourses are the environmental issues, subjects, ideas, and knowledges around which meanings (and more broadly discourses themselves) are made and cohere. For instance, a discourse connected to a proposed and controversial mine development might work to constitute and define objects such as the effects of the mining operations, whose knowledge is appropriate for predicting or determining these effects, and which knowledge-making techniques count as valid. To continue the example, if *risk* is used as the framework within which effects are constituted and appropriate knowledge determined, the result may be a *discourse of risk* that coheres around the definition of knowledge, who holds it and who does not, whose claims about the future are valid, how claims about the future should be made, and whether and if control of the future is possible. It is helpful to note here that environmental discourses are dialogical: They exist and change in relation to other, often competing discourses, sets of claims, experiences, and knowledges, as well as other sets of social and political designs. Insofar as they exist in relation to these alternatives, they also incorporate and represent their competing claims and experiences.

2. Environmental discourses also produce material outcomes and *effects*. They establish the truth about an environmental problem or development, normalize (make to seem natural and self-evident) policy outcomes and particular



knowledges or experiences of the environment, and establish truth about ideas such as “nature” or “the forest.” Environmental discourses, in other words, set the terms within which the environment and environmental problems can be thought; they determine the conditions of possibility for thinking them in the first place; they normalize and legitimize particular kinds of knowledges and experiences about the environment; they make environmental policy outcomes seem natural or legitimate; and they define the environment and nature according to the interests of (usually dominant) groups.

3. *Discursive strategies* are the material processes and practices through which objects are brought into discourse and through which objects and effects are constituted and defined. Discursive strategies are the devices through which knowledge about discourse objects is developed and through which meanings are conveyed. They are also the material processes and practices through which objects are defined and rendered meaningful. Discursive knowledges about the environment are developed and conveyed, in particular, through processes of *normalization* and *difference making* (see below).

Power

Environmental discourses work to realize and make material the interests and experiences (usually) of the powerful. While it is crucial to note that environmental discourses labor and are powerful in and of themselves, they always have authors attached to powerful sets of interests materially situated within uneven geographies of production, consumption, and accumulation. Discourse is itself a mode of production in which power is transformed through constant labor into material expressions on the ground—expressed as and through the subordination and privileging of peoples, the subjugation of environmental knowledges, and the advancement of environmental logics. As a result of the work that environmental discourses do (to define objects and establish outcomes) and of the ways in which they do this work (through practices of normalization and difference making), environmental discourses are powerful. They rely on particular

constellations of power, they produce power by laboring to maintain conditions of possibility and constitute their objects, and their effects consolidate and reflect existing power relations.

Normalizing Power and Difference Making

Environmental discourses are contingent. As the practices and frameworks that direct and make possible environmental practices, legitimize modes of production and regimes of extraction, and normalize ways of interacting with the environment, discourses reflect, normalize, and promote particular environmental knowledges, experiences, and epistemologies. Environmental discourses therefore universalize particular experiences and knowledges of the environment that are politically and socially situated. Discourses are powerful insofar as they connect *particular* (in the sense of partial, limited, local, and embodied) knowledges and experiences to the control of conditions possibility in terms of how the environment can be thought, encountered, mobilized, and used.

Power works through discourse as a result of its ability to hide and obscure the particularity of its constitutive epistemologies, experiences, and politically, historically, and socially situated constellations of meaning. Power also works through a discourse’s ability to make some knowledge claims and systems supersede others. This power to normalize—to present particular social experiences or epistemologies as though they were universal, to hide their particularity from view, and to define alternative experiences as abnormal—obscures the contingency of the discourse. In doing so, it substitutes particularity for universal applicability. Environmental discourses both hide and marginalize environmental knowledges and experiences. The objects and effects of environmental discourses must therefore always be seen to be the results of specific historical practices (including knowledge production) and specific and local environmental knowledges and experiences that arise within particular political, economic, and historical sets of relationships but that masquerade as universal.

Environmental discourses are also difference-making devices, in which the environment and difference are mutually structured. A discourse’s hidden knowledges work as instruments of



normalization around which difference is oppositionally defined. Discourses enact, and produce, registers of difference in relation to environmental objects and use concepts such as “nature” to normalize and naturalize the differential positioning of people in relation to each other in and through the environment. Groups are racialized, sexualized, and defined as deviant against the normal, in relation to how the environment is made meaningful through such registers. Discourses produce power as they produce difference (differentiate).

To conceptualize the environment (environmental knowledges, policies, environmental objects themselves, and ideas about the environment such as “nature”) as discursively constituted is to take a critical and political stance toward the operation of power in environmental practice. This stance highlights the importance of *deconstruction* as a political-environmental project and insists on the possibility of undoing the imperial work that discourses do. Deconstruction aspires to uncover and disable the contingency (and hence the power) of established discourses. As a critical, political project it recognizes that the power of discourse—enabled through the constant work required to maintain and rearticulate conditions of possibility—is susceptible. Despite the considerable authority that environmental discourses exert over our understandings of the world, and despite the manner in which discursive registers are often inextricably entrenched in the meanings through which we navigate the environment, their structures are fragile. If discourses are revealed to be particular, their partiality brought to light, and their disavowals uncovered, their dominance and hold diminish. The operations through which discourses establish their power thus also provide the political opportunities to overturn it. As a critical and political project, deconstruction enables us to see that the environment and our relationship to it *might* be oriented differently and in more socially just combinations.

Anna Stanley

See also Colonialism; Critical Studies of Nature; Difference, Geographies of; Discourse and Geography; Environmental Imaginaries; Environmental Justice; Nature-Society Theory; Situated Knowledge; Social Construction of Nature

Further Readings

- Braun, B. (2002). *The intemperate rainforest: Nature, culture, and power on Canada's west coast*. Minneapolis: University of Minnesota Press.
- Castree, N., & Braun, B. (Eds.). (2001). *Social nature: Theory, practice and politics*. Boston: Blackwell.
- Does discourse matter? Discourse, power and institutions in the sustainability transition [Special issue]. (2005). *Journal of Environment and Policy Planning*, 7(3), 161–276.



ENVIRONMENTAL ENTITLEMENTS

The Nobel Prize–winning economist Amartya Sen created an entitlement approach to the analysis of hunger and poverty, by which people are entitled to bundles of commodities by virtue of their inherent legal rights. The concept of environmental entitlements is a broadening of Sen’s approach. It is an extension not only in terms of linking economic entitlements to environmental resources, but the environmental entitlements perspective stretches much further, integrating actor-oriented approaches, theories of conflict, power and entitlement distribution, and discursive debates over the meaning of entitlements. In a seminal paper on environmental entitlements, Melissa Leach, Robin Mearns, and Ian Scoones started with a fundamental critique of the then prevailing narratives around community-based natural resource management (CBNRM), an approach that had emerged in the 1990s as a local-level, community-centered, and participatory concept to achieve sustainable development in rural areas of developing countries. The authors initiated their inquiry by asking why CBNRM initiatives had so often failed or fallen short of expectations.

The critique centered mainly on the flawed conceptualizations of both village communities and local environments, the categories that are central to the development efforts to support local-level sustainable development. The authors argued that CBNRM frames communities as well as local environments as basically distinct, undifferentiated,



and relatively stable entities. Moreover, a common image underlying people-environment relations in CBNRM is blamed as one of harmony, equilibrium, or balance between livelihoods and natural resources. Interrogating these basic assumptions on communities, the authors proposed an alternative framework that highlighted social difference and dynamics, people's agency, and the fundamentally contradictory and contested nature of local-level community-environment relations. They spoke to the ways in which gender, caste, wealth, age, origin, and other aspects of social identity divide and crosscut community boundaries. Also, they emphasized that communities are composed of people who actively monitor, interpret, and shape the environments around them. Social change, in this context, has to be framed as manifold processes of interactions between external and internal actors and events, in which path dependencies and contingencies play a significant part.

In a parallel strand of critique, the authors also challenged the conventional framing of local ecologies. On the basis of recent advances in the emerging field of "new ecology," they argued that a high degree of variability in space and time characterizes local environments and that historical dynamics and disturbance regimes have to be recognized in order to grasp the dynamics of environmental change at a variety of timescales and spatial levels.

Reconceptualizing CBNRM Approaches

Leach and colleagues concluded that local communities are best seen as the temporary and contingent outcomes of dynamic interactions between differentiated social actors, which are frequently manipulated by powerful and by no means shared interests. In parallel, local ecologies have to be framed as dynamic, transforming, nonequilibrium products of both social and ecological histories.

Rejecting the view of communities as static and undifferentiated, seeing the environment dynamically, and disaggregating it into its constituent parts has profound implications for analyzing the link between people and natural resources. In particular, these reconceptualizations raise a very different set of questions from those addressed by

conventional narratives around CBNRM: Which social actors see which components of variable and dynamic ecologies as resources at different time periods? How do different social actors gain access to and control over such resources? How does natural resource use by different social actors transform different components of the environment? To systematically address such questions, Leach, Mearns, and Scoones drew on three distinct strands of analysis: (1) an extended version of Sen's entitlement approach, (2) recent advances in institutional economics, and (3) structuration theory.

From Economic Entitlements to Environmental Entitlements

Sen's basic concern was to examine how different groups of people gain entitlements from their endowments and thus improve their well-being and their capabilities. Entitlement analysis, from Sen's perspective, focuses almost exclusively on entitlement mapping—how endowments such as land or labor power are transformed into entitlements—the rights and opportunities to effectively command resources through market channels and legal frameworks. While the shift from supply-driven to demand- and access-driven perspectives on well-being has made Sen's framework highly powerful for a disaggregated analysis of poverty and hunger, Leach and colleagues considered it to be too restrictive to grasp the real-world relations between differential communities and their resource use. They particularly criticized Sen's economic and legalistic ways of mapping entitlements. First, the entitlement approach gives limited attention to endowment mapping, thus ignoring the way which people gain or lose endowments in the long run. Second, the authors criticized the view that entitlements are exclusively distributed through market channels, highlighting the multiple alternative ways of gaining (or being denied) access and control over natural resources. Such alternatives, for example, consist of social networks, social capital, and other informal distribution mechanisms at the community level. Third, they challenged Sen's legalistic view, considering entitlements as stemming from formal legal property rights only. They pointed to the multiple ways in which entitlements are



distributed through customary laws, community rights, and culture-specific rules and norms.

Given these criticisms, Leach and colleagues defined endowments as the rights and resources that social actors have. More specifically, entitlements refer to legitimate effective command over alternative commodity bundles. Environmental entitlements, then, are defined as alternative sets of utilities derived from environmental goods and services over which social actors have legitimate effective command and that are instrumental in achieving well-being. This definition of environmental entitlements still lacks evidence on how legitimate and effective command over resources is constituted, contested, and struggled over in local communities; how it is gained and lost. From this perspective, environmental entitlements have to be conceptualized as the outcome of conflict and negotiations among social actors, involving power relations and discursive debates on meaning. Leach and colleagues thus argued that an institutional focus is needed for mapping environmental entitlements.

Institutional Perspectives on Environmental Entitlements

Following recent work on institutional economics that conceptualizes institutions as “the rules of the game” in society, Leach and colleagues argued that institutional arrangements and institutional change are central to the environmental entitlements framework. A multiplicity of formal and informal ways that regulate people-environment interactions have to be considered that mediate differential access to and control over environmental endowments and entitlements. As empirical analysis of environmental entitlements points to the fact that rules are constantly made and remade through people’s practices and that many of these practices are embedded in informal institutions, institutional change in local-level communities may be conceptualized as a slow, contingent, path-dependent process. From this perspective, Leach and colleagues defined community-based institutions not as the rules themselves but as regularized patterns of behavior that emerge from underlying structures or sets of rules in use.

This definition points to the problematic relationship between people’s agency, on the one

hand, and underlying structural settings, on the other. The authors concluded that actor-oriented approaches in general, and structuration theory in particular, may serve to elucidate how people-environment dialectics in the environmental entitlements framework are played out.

Structuration of People-Environment Interactions

While the environmental entitlements approach, in conjunction with institutional analysis, can serve to conceptualize how social actors access and use environmental goods and services and how this access is embedded in power relations and social conflict, the question remains, In what ways is the environment shaped and transformed through people’s interaction with it? When addressing the dynamic nature of both the social and the environmental constituents of the environmental entitlements framework, Leach and colleagues argued that environments are constantly emerging and transforming as the outcome of dynamic and variable interactions between ecological processes and human resource use. Institutional dynamics shape the ways in which differential social actors perceive, use, and manage components of the environment as resources. From the perspective of structuration theory, the environment provides a setting for social actions, but it is also a product of such action. Environmental entitlements are thus the outcome of dialectic processes between structure and agency in people-environment interactions.

Applications of the Environmental Entitlements Approach

When establishing the environmental entitlements approach, Leach and colleagues had three basic objectives in mind. First, they aimed at improving the conceptual and theoretical base of CBNRM through recent advances in social science and ecology theory. Second, they sought to enhance the social and environmental impacts of CBNRM through a new emphasis on entitlements and capabilities. Finally, they wanted to improve the practice of CBNRM through a particular focus on institutions as mediators of people-environment relations.



In the past decade, most of these objectives were implicitly achieved, in general terms, for community-based approaches to sustainable development, including use of the entitlement framework, institutional analysis, structuration theory, and new ecology approaches. Only rarely, however, was the environmental entitlement framework strictly applied as the basis for analysis. In most cases, the concept was extended or focused in specific ways. One such focus, for example, was on customary marine or inland fisheries systems, with particular emphasis on the empowering and institutional perspectives of managing fisheries. The environmental entitlements concept has also been extended beyond CBNRM and integrated into political ecology approaches, vulnerability analysis, conservation issues, and more recently conflict studies.

In practical terms, the environmental entitlements approach became part of the wider poverty-environment discussion, as, for example, pursued by the U.K. Department for International Development in the context of the Sustainable Livelihoods Framework. Stretching even further, the environmental entitlements approach was explicitly used in official water allocation frameworks. The Ministry for Environment of Victoria/Australia, for example, issued a new Water (Resource Management) Act in 2005 that created the legal foundation for water to be set aside to maintain environmental values of rivers and streams. This law is intended to embed environmental provisions into existing bulk entitlements that will be converted into individual or community-based environmental entitlements.

Criticisms and Prospects

The few preceding examples of how the environmental entitlements framework was applied point out that the concept, with its focus on CBNRM, was probably too narrow in its scope of analysis from the very beginning. In terms of scale, the framework did refer neither to individual nor to larger-scale environmental entitlements, for example, at the district, provincial, or country level. The timescale was also short-term, with little consideration of long-term social or environmental change. Regarding its theoretical and conceptual foundations, the environmental

entitlements framework did not really consider issues of social and environmental vulnerability, which were to become so prominent in the Sustainable Livelihoods Framework. Moreover, the epistemologically highly problematic relationship between society and nature, which has been critically examined by recent advances in the analysis of coupled social ecological systems or in social ecology approaches, was treated rather simplistically and superficially in the environmental entitlements approach. More specifically, the extension of the entitlement analysis as presented in the environmental entitlements framework probably did not go far enough too. As Michael Watts has noted, Sen's conceptualization of entitlements is not suited to grasp socially determined entitlements, nonlegal entitlements, and those dimensions of social well-being that are not based on entitlements at all.

Nevertheless, the environmental entitlement approach, if extended systematically, has a large, widely untapped potential in contexts that stretch far beyond its original objectives and applications. One such potential certainly lies in the vast field of global environmental change and, more specifically, climate change. Recent advances in vulnerability, adaptation, and resilience analysis as crosscutting themes on global environmental change could benefit greatly from environmental entitlement perspectives. The particular focus of the environmental entitlement approach on actors, action, and agency is widely missing in such new systems-oriented approaches to global environmental change. And so is an emphasis on power relations, conflict, negotiations, and institutions in globalized social-nature interactions and dynamics, which the environmental entitlements approach had so powerfully put forward. There is broad scope for an extended environmental entitlements approach to become an essential element in the broader discourse on global environmental change.

Hans-Georg Bohle

See also **Common Pool Resources; Community-Based Conservation; Community-Based Natural Resource Management; Environmental Justice; Environmental Rights; Environmental Security; Human Ecology; Hunger**



Further Readings

- Bohle, H.-G., Büttner, H., van Dillen, S., & Mayer, M. (2000). Water conflicts and environmental entitlements. *IGU Bulletin*, 50, 39–46.
- Janssen, M. A., & Ostrom, E. (Eds.). (2006). Resilience, vulnerability and adaptation. *Global Environmental Change*, 16, 235–316.
- Leach, M., Mearns, R., & Scoones, I. (1999). Environmental entitlements: Dynamics and institutions in community-based natural resource management. *World Development*, 27, 225–247.
- Sen, A. (1981). *Poverty and famines*. Oxford, UK: Oxford University Press.
- UK Department for International Development. (1999). *Sustainable livelihoods guidance sheets*. London: Author.
- Watts, M. J. (2002). Hour of darkness: Vulnerability, security and globalization. *Geographica Helvetica*, 57, 5–18.



ENVIRONMENTAL ETHICS

Environmental ethics represents an emerging area of philosophical inquiry concerning the morality governing human responsibility, valuation, and behavior toward the nonhuman biophysical environment. Traditionally, philosophical approaches to ethics have involved questions of personal, interpersonal, or societal behavior. The search for the moral life inspires questions such as “What is our moral responsibility toward each other?” and “How do we decide which behaviors are right and which are wrong?” This central concern of ethics is to establish an appropriate moral code for living and interacting with others around you. Social ethics are self-reflective; they help determine the guidelines by which we orient our behavior toward others. They inspire, limit, and regulate interpersonal or societal interactions. Environmental ethics is the extension of social ethics beyond the realm of interpersonal human interaction. As such, environmental ethics generate or reflect ideals that limit and inspire human behavior regarding the physical environment and ecological systems.

In the United States, the practice and systematic inquiry now termed *environmental ethics*

began to emerge during the growing environmental awareness of the 1960s and 1970s. Seminal writings by Rachel Carson, Garrett Hardin, and Lynn White resonated with the widespread public realization that large-scale, rapid, and perhaps irreversible changes to physical environments and ecological systems were causally linked to people. Human behavior, values, and attitudes became the problem—they were the causes of the environmental crisis. One outgrowth of this “Green Revolution” was a new form of environmental activism that led to the first Earth Day on April 22, 1970, and a body of federal legislation highlighted by the National Environmental Policy Act (1970), Clean Air Act (1970), Clean Water Act (1972), and Endangered Species Act (1973). Another outcome was a loss of faith in the dictum of modernistic progress and a desire to challenge the set of moral rules condoning patterns of human behavior contributing to environmental and ecological crises. To do so would require diagnosing why traditional ethics allow and even justify widespread degradation and despoliation and systematically eliminating these elements from a pro-environmental conception of ethics.

In response, writers and philosophers began turning their attention to reconstructing normative modes of morality and behavior that would not only counter but also reverse human-induced degradation of environmental and ecological systems. The goal for many of these ethicists was to establish a moral code that could impose limitations on human freedom of action with respect to the Earth. But far from viewing environmental ethics as a purely philosophical enterprise, practitioners always looked to apply these ideals to help solve environmental crises. J. Baird Callicott and others explicitly linked the products of their ethical theories to the goal of influencing human behavior at the structural scale as well as the personal scale. The immediacy of environmental problems led many activists to employ these ethical formulations in justifying emerging environmental laws and regulations, giving their ideas tacit institutional authority.

Modernism, scientific progress, and human exceptionalism came to be understood by environmental ethicists as separating humans from nature. This philosophical dualism, grounded in Western traditions dating back to Aristotle and



reasserted by René Descartes, lies at the root of environmentally destructive behavior because natural environmental systems are largely defined in opposition to people and society. As a counterweight to Cartesian dualism, much of the work within environmental ethics seeks to emphasize a more holistic, ecological approach.

Whereas social ethics tends to stress atomistic thinking by giving primacy to individual rights and claims against other individuals, environmental ethicists seek to reorient moral claims around collective rights and responsibilities toward the Earth. Monistic arguments take holism a step further by asserting that humans are an animal species that has developed and evolved within the ecological context of a historical Earth. Such fundamental questions arising over whether humans and the imprint of cultural practices and religious beliefs on the physical landscape are natural, supernatural, or otherwise distinct from nature led to a series of ongoing debates about how to categorize and assign value to landscapes and ecosystems that are, to some extent, artifacts of human action. Terms such as *nature*, *second nature*, *false nature*, and *wilderness* have become complex concepts embodying these debates over the separation of people from the nonhuman “other.”

At the core of many debates that have been generated within environmental ethics is the disharmony present in attempts to balance the interests of people, nonhuman life forms, and the underlying physical and chemical processes creating and supporting the habitats of both. Who or what has rights that need to be respected by humans and human behavior? Much of the fragmentation within the field of environmental ethics can be traced to the different ways of answering this question and justifying it philosophically.

Anthropocentric arguments align more generally with traditional philosophical positions claiming that either only humans have a moral standing or, if it is to exist outside of people, it is contingent on rights being granted by humans. Accordingly, it is not immoral to cut down a tree, kill a snake, or drain wetlands if it is deemed to be in the best interests of humans to do so. Anthropocentric ethics are not necessarily anti-environmental since protecting forests, species, and biotic communities may also be deemed to be moral if it is in our best

interests to do so. In both scenarios, people determine worth and are the source of moral value.

The concept of intrinsic value breaks down these traditional boundaries limiting rights to individual humans. It bridges the liberal extension of rights to oppressed or powerless people to other living things or even biotic communities. If an object, animal, or place has a moral standing beyond that granted by people, ideals of ethical behavior include an obligation of respect to these phenomena. Peter Singer argues that a refusal to extend moral rights to animals is a form of speciesism, similar to forms of racism or sexism that deny rights based on race or sex. An unrelated but similar vein of thought, ecofeminism, equates the subjugation of nature with the patterns and justifications made for the subjugation of women by men. Other writers such as Tom Regan contend that other species have some value in and of themselves that is independent of that which we are willing to grant. Such biocentrists have sought to reorient ethical mores on the conviction that all living things have intrinsic value and cannot be excluded from moral consideration.

One of the most influential authors on environmental ethics, Aldo Leopold, predated the formal development of the field itself. Leopold's conception of the “land ethic” has been seen as the blueprint by which intrinsic moral value can be extended to the synergisms of ecology. Ecocentrism extends moral consideration past either anthropocentrism or biocentrism. Not only living individuals contain intrinsic value; the integrity, stability, and beauty of the biotic community have value as well. The complex webs of organisms, chemical fluxes, and physical processes generating and sustaining ecosystems is the locus of intrinsic value, not an individual human. Therefore, behavior or public policies that degrade or despoil biotic communities for the benefit of individual people, social groups, or even the human species are morally unjust.

Michael A. Urban

See also Commons, Tragedy of the; Deep Ecology Movements; Ecofeminism; Ecological Justice; Environmental Discourse; Environmental Entitlements; Environmental Justice; Environmental Rights; Ethics, Geography and; Nature-Society Theory; Social Construction of Nature



Further Readings

- Callicott, J. B. (1994). *Earth's insights*. Berkeley: University of California Press.
- Carson, R. (1970). *Silent spring*. Greenwich, CT: Fawcett.
- Hardin, G. (1968). The tragedy of the commons. *Science*, 162, 1243–1248.
- Leopold, A. (2001). *A Sand County almanac*. New York: Oxford University Press.
- Marietta, D. E. (1995). *For people and the planet: Holism and humanism in environmental ethics*. Philadelphia: Temple University Press.
- Nash, R. (1989). *The rights of nature: A history of environmental ethics*. Madison: University of Wisconsin Press.
- Regan, T. (1983). *The case for animal rights*. Berkeley: University of California Press.
- Singer, P. (1975). *Animal liberation*. New York: Avon Books.
- White, L., Jr. (1967). The historical roots of our ecologic crisis. *Science*, 155, 1203–1207.



ENVIRONMENTAL FOOTPRINT

See Ecological Footprint



ENVIRONMENTAL HISTORY

There are two immutable facts that underlie human-environment interactions. First, humans are part of the biosphere, and we rely on it to meet our essential needs. Second, through human history, but increasingly over the past 300 yrs. (years), we have become the dominant agent of environmental change. Understanding the relationship between humans and their environment has become increasingly important in recent decades due to human-accelerated environmental change, most pronounced in global climate change, biological extinctions, and soil and water degradation.

Environmental history is the field of study concerned with the systematic understanding of

long-term transformations of landscapes, ecosystems, and natural resources through the interaction of humans with the environment, and the role of feedbacks of environmental change on human societies (Figure 1). Environmental history aims to provide the context for understanding our present environment, indicate what past environments were like, and identify lessons we can learn for building a sustainable future. The key elements of environmental history revolve around (a) analyzing human-modified landscapes through the linkage of socioeconomic and biophysical data, explaining how historical processes such as human settlement patterns and disturbance regimes help shape contemporary landscapes and ecosystems; (b) addressing the temporal and spatial dimensions of human-landscape transformation; and (c) understanding human-modified landscapes as cultural legacies.

Environmental history has discarded former dualistic approaches to human-environment relations, instead conceptualizing that social and natural systems are inextricably intertwined. Equally important, environmental history challenges the notion of pristine landscapes or “natural ecosystems” with the belief that it is difficult to find a landscape or ecosystem anywhere on the planet that has not somehow been changed by human activities. As human impacts on the global environment continue to accelerate, environmental sustainability has become an increasingly important part of the global social conscience and international policy agenda. In this context, environmental history is an essential component of environmental planning and management.

The following sections outline the emergence and development of environmental history as a discipline, the methods used by environmental historians, and some common issues in the study and application of environmental history. The final section considers the application of environmental history to contemporary human-environment interactions.

Development of Environmental History

Over the past 200 yrs., there has been a gradual recognition of the power of humans to transform whole landscapes and ecosystems through land use. Explorers, travelers, and natural historians

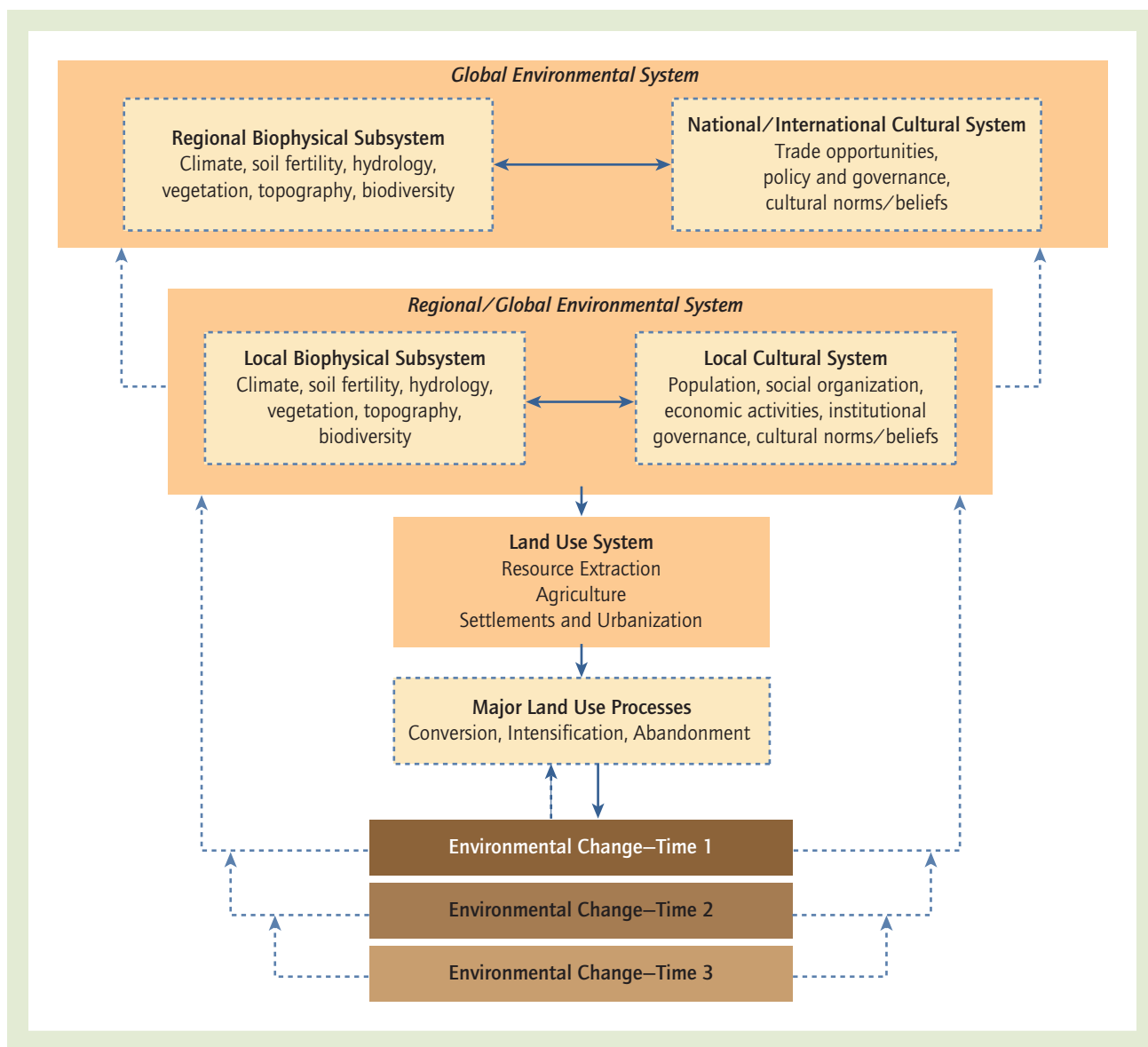


Figure 1 Framework of environmental change

Source: Authors.

Note: Solid lines indicate connectivity; dashed lines indicate feedback loops.

such as Pierre Poivre and Alexander von Humboldt at the turn of the 1800s saw the destructive impacts of colonialism and the consequences for tropical landscapes. In 1854, the American Henry David Thoreau published *Walden*, in which he reflects on the problem of land transformation during the Industrial Revolution, adopting a political and philosophical perspective. In 1864, George Perkins Marsh published *Man and Nature*, one of the first books to analyze the impacts of

human activities on the environment, comparing environmental changes in the Roman Empire with those in the United States at that time. In the 1920s, the cultural geographer Carl Sauer theorized also that different cultures developed distinctive cultural landscapes, rejecting the idea that the environment determined different cultural characteristics.

Two important origins of environmental history can be distinguished in the 19th and early



20th centuries: one from ecology, the other from geography. Ecology emerged from a historicized field of biology and geology in the 19th century, with the first ecology textbook written by Eugen Warming in 1895. The maturing of ecology in the early to mid 1900s became a source of inspiration and instruction to environmental historians by bringing an increasingly holistic framework to often scattered and narrative data and evidence. This was especially evident from the birth of Arthur Tansley's concept of an ecosystem in 1935 and the emergence of Frederic Clements's theory of succession to characterize long-term vegetation dynamics driven by the interaction of ecological and human management factors. The consolidation of plant ecology highlighted the importance of vegetation as an indicator of biophysical and management processes and its potential use in historical studies of the environment. In 1949, the American ecologist Aldo Leopold called for the development of an ecological interpretation of history.

Geography provided an increasing awareness of the spatial dimension of social and ecological processes and their interaction, with historical geographers documenting these relationships in many parts of the world. By the mid 20th century, however, geography became focused more on human activities, and the environment formed the backdrop to these activities rather than a central interest. In the 1950s, the German geographer Carl Troll pleaded for a more holistic conception and approach to the study of human-environment relationships. Troll understood the advantage of linking geography and the biological sciences and introduced the new discipline of landscape ecology, in which humans are considered an integral component of landscapes and ecosystems. The first half of the 20th century could be called the early period of the development of environmental history, with no formal disciplinary recognition.

Environmental history as a specific discipline emerged in the United States in the 1960s and 1970s, parallel to the rise of the environmental movement. People around the globe became aware of and concerned about the negative impacts of human-accelerated environmental change. Factors such as population growth, industrial and technological change, and the globalization of trade and

consumption were exhausting natural resources at an unsustainable rate. Societies recognized that not only was there a moral responsibility to minimize or mitigate the negative environmental consequences of our actions on the biosphere but humans were ultimately dependent on the natural world for their survival. By learning from history, the hope is that sustainable land management outcomes will arise.

The first course specifically concerned with environmental history was introduced at the University of California, Berkeley, in 1970. It centered on a long-standing interest in documenting the American experience with wilderness, with the environmental change as evidence of people's attitudes and actions. In 1976, the American Society for Environmental History was founded, while the first Institute for Environmental History in Europe was created in the 1980s, based at the University of St. Andrews in Scotland. In the mid 1980s, the environmental historian Donald Worster emphasized the need for an ecological perspective in historical study, refining this into an agroecological perspective. In fact, the term *ecological history* is often used interchangeably with *environmental history*. Worster stressed the need to understand the organization and functions of nature, how modes of agricultural production have altered human relationships with their environment, and the role played by human attitudes, values, and perceptions in transforming the Earth. The European Society for Environmental History was not organized until 1999, but it built on a strong tradition of historical geography research in Europe. The recently created International Consortium of Environmental History Organizations brings together American, European, and Australasian societies of environmental history. Interest in environmental history has followed different trajectories in different regions, with strong development in places such as the United States, Europe, Australia, and Africa but less so in Russia, the Middle East, and Japan.

Environmental history is increasingly becoming a meeting ground of historians, geographers, ecologists, biologists, anthropologists, and conservationists. Indeed, many scholarly contributions that are pertinent to environmental history are written by scholars who typically would not



identify themselves as historians. Topics range from human relations with wilderness through the development of agricultural lands, the use of different natural resources such as water or timber, and the impacts of colonial expansion and settlement of “new lands” to providing a basis for the holistic management of landscapes. There is a strong bias toward terrestrial environmental history, with little current work on marine areas.

In recent years, as a result of growing concerns about the accelerating rate of global environmental change, environmental history has transcended the academic arena and become a popular topic, with books such as Jared Diamond’s *Collapse* and *Guns, Germs and Steel*, Alfred Crosby’s *Ecological Imperialism*, and *1491*, Charles Mann’s synthesis of the reality of the extent and characteristics of human impacts on the landscapes of the Americas before European settlement.

Environmental History Methods

While environmental history can be constructed in myriad different ways, its distinguishing feature is the integration and synthesis of qualitative and quantitative data from a variety of sources to build a better understanding of the drivers and impacts of past human activities on their environments and the way in which those environments have in turn shaped societies. It is this transdisciplinary nature that sets environmental history apart from mainstream history, geography, or ecology.

Environmental history advocates the understanding of the human-environment relationship in both time and space to gain a holistic perspective of environmental change and its cumulative effects. Temporally, environmental history forms part of a continuum between paleontological studies and the present day and can span timescales from decades to millennia. As both human cultural traits and environmental systems are dynamic, neither is environmental change unidirectional, nor are the outcomes the same for different regions of the world. In addition, the effects of changes arising from human-environment interactions may take many years to become apparent. It is important, therefore, to identify key ecological stages and historical periods during the time period under consideration, together with their underlying processes and drivers.

Spatially, studies in environmental history can be conducted at scales ranging from local to national or regional to global and may focus on specific communities, localities, or occupations or specific resources such as water, fisheries, or agricultural land. However, even if a particular scale such as the region is the focus of the environmental history, consideration of external factors at broader scales is crucial as each factor is influenced by those around it as part of the hierarchy of influence and decision making. For example, individuals create new agricultural fields, but the decision to develop a region is often the responsibility of regional or national governments. Similarly, the type of agriculture may be influenced by international trade opportunities.

Environmental histories are in general narratives or stories about a locality or region, or even the whole Earth, through time. One of the strengths of environmental history lies in its narrative synthesis, which helps deepen our understanding of human-environment interactions, but it is important that the narrative be grounded in an ecologically sound base. Environmental history must work with and integrate heterogeneous data sources, ranging from qualitative accounts to quantitative scientific and statistical databases from different disciplines. It is common that the data that interest environmental historians are highly variable in quality and reliability as well as in their spatial and temporal coverage. This necessitates comparison of disparate sources of data to see if commonalities are present before relying on these data.

A variety of techniques are combined to establish ecological and environmental histories, depending on the focus of the particular study. Some techniques are spatially accurate and precise, documenting environmental change using data such as climate records, aerial photographs and maps, ecological studies, geology and sediment records, or economic development using statistical records of farm production or population growth. Others are more subjective interpretations or “stories” garnered from texts, memories, myths, and personal experience. These may include diaries, oral histories, government reports, or newspapers.

One major limitation for environmental history is the shortage and variable quality of long-term



quantitative data sets. However, especially from the 1990s, the study methods have become more quantitative due to the increasing availability of spatially explicit and quantitative data from remote sensing and geographic information systems, which has allowed the application of sophisticated modeling techniques, linked to those used for studying land use and land cover change. Maps and spatial representations of change are becoming increasingly important in environmental history. One of the latest advances in measuring and analyzing the impact of humans on the environment is the “ecological footprint” concept and its spatially explicit derivations such as the spatial footprint or the wilderness index.

There are several other issues to be aware of when developing or using environmental histories. Most important, the complexity and dynamic nature of both environmental and cultural systems over time mean that even a very detailed environmental history can tell only part of the tale. Second, which part is told depends on both available data and the expertise and background of the researchers, and often their political and ideological beliefs, since environmental historians are embedded in their own cultural and knowledge system. It is, therefore, possible that different and sometimes even contradictory conclusions are reached about the same event. In addition, the ability of a well-written story to sway opinion and become accepted as fact presents a danger that continuing research on an issue, or the development of alternative ideas, may be hindered. This does not mean that environmental histories are unreliable but that, as with any research, as new information becomes available the conclusions should be updated. These issues aside, environmental history has deepened our understanding of how past societies have interacted with and changed their environments. Increasingly, this knowledge is seen as underpinning environmental planning and management in a number of arenas.

Examples and Applications of Environmental History

As mentioned earlier, recognition of the unsustainable cumulative impacts of human activities on the biosphere led to the development of environmental movement and, from this, environmental history.

While environmental history, by its very nature, focuses on the past and allows us to know the ending of the particular story, the hope of most environmental historians is that it can also alert societies to a range of possible outcomes from present-day activities. “Big picture” environmental histories that document global or continental change have increased our understanding of the connectivity between human and environmental systems in both space and time. For example, the introduction of often highly invasive exotic plants and animal species associated with colonialism during the 18th and 19th centuries has left a permanent environmental legacy in many countries and continues to be a major contemporary threat with the increasing globalization of travel and trade. There are also common traits in human-environment interactions in the settlement of new lands, from the expansion of Europeans into the Americas, Africa, and Australia to the spread of Polynesians across the Pacific. Resources in new lands were often seen as limitless, and there was little understanding of the environmental impacts of settlement on native ecosystems. Landscapes were altered dramatically to conform with the different cultural and production systems of the colonizers, leading to rapid environmental change, but the colonizers in turn had to learn to adapt to different environmental conditions. Understanding the commonalities of settling new lands may guide more environmentally sensitive settlements in regions with current development frontiers, such as the Amazon basin.

An area of growing interest to environmental historians is the quantitative analysis of contemporary environmental change focusing at the landscape scale, where aerial photography and satellite imagery can be used, for example, to quantify landscape dynamics in response to both deforestation and reforestation. Studies of landscape changes are increasingly being used to inform regional conservation planning and global change policy.

Environmental history is increasingly being used as a landscape management and planning tool. This is based on the tenet that it is necessary to understand the legacies of past cultures on contemporary landscapes in order to manage and plan for a sustainable future. Even today’s wilderness areas are a legacy of human decisions and



planning whereby they were protected from development, intentionally because of their ecological and ascetic values or unintentionally because of biophysical constraints. Some wild areas are not “wilderness” at all, as in the case of the New England forests, which have regrown because of land abandonment in the mid 19th century, or even large areas of the Amazon rain forests that were cleared and densely settled at the time of European colonization. Because of the slow recovery of many vegetation communities, land use legacies can be extremely long lasting. Although often not explicitly stated, a common goal of environmental historians is to improve the relationship between people and the environment so that ecosystem functioning is maintained or restored as far as possible. To this end, environmental histories are a required stage for ecological restoration projects, identifying the components and processes required to rebuild ecosystem functions.

It is important not to overgeneralize about the relationship between humans and the environment. Just as culture varies among societies, the nature, extent, and intensity of environmental change also vary among societies over time. There was a tendency to see pre-European landscapes in North and South America and Australia as pristine wildernesses, but increasingly there is recognition of the modifications and transformations carried out by indigenous societies and how their cultural systems adapted to and interacted with their environment. Some traditional societies, such as the Australian Aborigines, have managed to live within the capacity of their environment for centuries, while others radically changed their environment within a short time span, such as the Maori in New Zealand. Yet others were unable to survive environmental change, with civilizations such as the Mayans in Central America disappearing at least in part due to drought and exhaustion of natural resources.

Conclusion

Environmental history has steadily evolved as a discipline over the past 200 yrs. Today, it is highly relevant for understanding legacies of past environmental change and guiding conservationists, scientists, policymakers, and land managers in understanding how the past shapes the present

and the present may shape the future. Environmental history is, therefore, an important ingredient for land use and environmental planning and policy in the era of climate change and human-accelerated environmental change.

*Leonie Seabrook, Andres Etter,
and Clive McAlpine*

See also Diamond, Jared; Ecological Footprint; Environmental Determinism; Environmental Discourse; Environmental Ethics; Environmental Imaginaries; Environment and Development; Global Environmental Change; Historical Geography; Human Dimensions of Global Environmental Change; Human Geography, History of; Landscape Ecology; Land Use and Cover Change (LUCC); Land Use History; Prairie Restoration

Further Readings

- Balée, W. (Ed.). (1998). *Advances in historical ecology*. New York: Columbia University Press.
- Crosby, A. W. (2004). *Ecological imperialism: The biological expansion of Europe, 900–1900*. Cambridge, UK: Cambridge University Press.
- Egan, D., & Howell, E. A. (2001). *The historical ecology handbook: A restorationist's guide to reference ecosystems*. Washington, DC: Island Press.
- McNeill, J. R. (2003). Observations on the nature and culture of environmental history. *History and Theory*, 42(4), 5–43.
- Worster, D. (Ed.). (1988). *The ends of the earth: Perspectives on modern environmental history*. Cambridge, UK: Cambridge University Press.



ENVIRONMENTAL IMAGINARIES

The term *environmental imaginaries* is used to explain how the natural environment shapes the attitudes, discourses, and practices of the people who dwell there. Derived from the broader concept of a spatial imaginary by Richard Peet and Michael Watts, an environmental imaginary describes how people draw on the familiar elements of their surroundings to understand natural and social processes and to inspire creative ways of shaping those



same processes. It has a strong regional component because of how the natural environment differs from region to region, and it is also closely tied to political ecology with its focus on economic and political institutions.

The environmental imaginary concept has a lineage that can be traced back to spatial and social imaginaries. Developed within sociology, a *social* imaginary describes how a particular society conceives of itself as well as how it explains both the world around it and its own characteristics. It can be thought of as a bridge between doctrines or discourses and embodied practices. The term *imaginary* can be interpreted in three ways. First, there is the fact that social imaginaries are implicit rather than explicit, so they exist within people's heads. Second, individuals use them as jumping-off points in their own ways of coping with the world and forming their own identities: Imaginaries spark creativity. Finally, imaginaries are used to apply processes that are already understood to the unknown future. An "imaginary" therefore does not only explain what has already happened but also provides a framework to conceive of the future.

In addition to factors such as political structures, existing institutions, and social makeup, all social imaginaries are shaped by the places in which they are developed and in turn shape those places. *Spatial* imaginaries describe how a society understands the spatial processes that it creates and encounters, as well as how spaces and places are constructed and made meaningful. Globalization is one of the best-known spatial imaginaries, with lively debate ensuing about whether it is an external force being imposed on helpless local places or constituted by millions of individual or local places and practices. At other scales, businesses use their spatial imaginaries to determine the best places to site a production facility or understand why their goods and services are or are not selling in a particular market; governments at all levels promote economic and social development with regard to their understandings of how processes occur across space; and individuals arrange their lives around spatial patterns of work, home, and recreation. These spatial imaginaries are all fluid and flexible as the actions taken lead to new or changed understandings of how spatial processes work.

The *environmental* imaginary, as developed by Peet and Watts, is even more explicit about the role of place, arguing that a society's concept of relationships between humans and the environment—and therefore how people act on their environment—varies based on the characteristics of that environment. Interactions between the human and nonhuman shape ever-changing environmental imaginaries. Because of the influence of political ecology, environmental imaginaries are often conceptualized as being about access to and the meaning of natural resources based on political structures as well as biophysical characteristics. Differentiations based on race, class, and gender also enter into the potential creation of multiple environmental imaginaries within the same space.

Peet and Watts use the concept of an environmental imaginary as a pivot point for change and transformation. They draw heavily on the creativity implied in the concept, arguing that liberation ecologies and social movements have to rely on people's conceptions of their own environment in order to be successful. In particular, because environmental imaginaries are constructed based on the physical environment of a particular place or region, they are not meant to be applied elsewhere, which often happens within the context of development programs. Disaster can result when, for example, actors with an environmental imaginary developed in the humid First World tell actors in an arid zone of the Third World that their farming practices are degrading the soil without taking into account existing local practices based on centuries of inhabiting that place.

Somewhat ironically, considering its origins in a book about the developing world, the environmental imaginary concept has been almost exclusively applied to the global North. This includes the transfer of acacia trees in and out of Australia, environmental conflicts in Central Appalachia in the United States, understandings of sustainable development in Australia, invasive species in Toronto, and the history of colonization in Canterbury, New Zealand. Much of this increased attention in recent years has been from the strand of geographic literature seeking to reconcile the human and nonhuman (or "nature") as well as urban political ecology, both of which are largely Western-centric. Still, significant potential exists to expand the concept within situations outside the developed world.



While there might be reluctance to engage with environmental imaginaries as a theoretical framework because of their narrow focus on the region as a key scale, the increasing interest in bioregionalism from a management and policy point of view (such as watershed management, regionally based green building criteria, and local food movements) makes them more pertinent than ever. Environmental imaginaries offer a way of thinking about the relationship between the human and nonhuman environments that includes both social and physical processes, as well as a means of explaining the past and laying out possible progressive futures.

Julie Cidell

See also Bioregionalism; Deep Ecology Movements; Ecofeminism; Ecological Imaginaries; Environmental Determinism; Environmental Discourse; Feminist Environmental Geographies; Feminist Environmentalism; Geographical Imagination; International Environmental Movements; Nature-Society Theory; Peet, Richard; Political Ecology; Political Economy of Resources; Social Construction of Nature; Watts, Michael

Further Readings

- Cowell, R., & Thomas, H. (2002). Managing nature and narratives of dispossession: Reclaiming territory in Cardiff Bay. *Urban Studies*, 29, 1241–1260.
- Foster, J., & Sandburg, L. A. (2004). Friends or foe? Invasive species and public green space in Toronto. *Geographical Review*, 94, 178–198.
- Kull, C. A., & Rangan, H. (2008). Acacia exchanges: Wattles, thorn trees, and the study of plant movements. *Geoforum*, 39, 1258–1272.
- McGregor, A. (2004). Sustainable development and “warm fuzzy feelings”: Discourse and nature within Australian environmental imaginaries. *Geoforum*, 35, 593–606.
- Nesbitt, J. T., & Weiner, D. (2001). Conflicting environmental imaginaries and the politics of nature in Central Appalachia. *Geoforum*, 32, 333–349.
- Peet, R., & Watts, M. (Eds.). (1996). *Liberation ecologies: Environment, development, social movements*. New York: Routledge.



ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment (EIA) is one of the most widely practiced environmental management tools in the world. The International Association for Impact Assessment, the world's leading authority on impact assessment, defines EIA as the process of identifying, predicting, evaluating, and mitigating the biophysical, social, and other relevant effects of development proposals on the environment prior to taking major decisions and making commitments. As a formal, systematic, and often regulation-based process, EIA is not to be confused with related environmental studies, such as environmental site assessments, whose purpose is to determine the nature and extent of environmental contaminants at a specific site and to identify remediation plans. These latter studies are much more common and shorter, though in some cases they lead to the preparation of an EIA.

The term *environmental impact assessment* is often used interchangeably with *environmental assessment* (EA) or *impact assessment* (IA). Regardless of the terminology used, EIA, EA, or IA refers to an organized and interdisciplinary process designed to gather information used to identify, understand, and manage the potential effects of proposed developments and actions, both public and private, on the biophysical environment (e.g., air, water, land, plants, and animals) as well as on the human environment (e.g., culture, health, community sustainability, employment, financial benefits).

Origins

EIA was first introduced in the United States in the late 1960s and is now practiced in more than 100 countries. The environmental movement of the 1960s played a key role in the birth of EIA. The post–World War II era in North America was marked by an unprecedented period of economic growth and also a period of rapid environmental change and increased public awareness of the widespread negative effects of development on forests, wetlands, and water and air pollution. Inspired by pioneering works such as Rachel Carson's *Silent Spring*, which described



the adverse effects of pesticide use on the environment, the environmental movement led to increasing pressures on central governments to take actions to address the negative environmental changes that were occurring. The response was the passage of several laws, each addressing a particular environmental concern, such as the Clean Air Act, designed to establish pollution limits and to regulate industrial emissions.

It was not until 1969, when the U.S. National Environmental Policy Act (NEPA) was introduced, that a framework was provided for the simultaneous consideration of the full range of environmental considerations associated with a proposed development activity. The term *environmental impact assessment* was coined to refer to this framework and the process that it generated. NEPA, which became law in 1970, was not designed to replace other laws and environmental programs but to complement them by providing the means to integrate environmental and public concerns about often controversial development proposals and to organize and present these concerns in a way that was meaningful to decision making. For the first time, those proposing to undertake certain development projects had to demonstrate that the projects would not adversely affect the environment and to document this in the form of an environmental impact statement (EIS)—an often lengthy and highly technical document that describes the proposed development or undertaking and reports on its potential environmental and socioeconomic effects and prescribed management measures. During the first decade of NEPA, approximately 1,000 EISs were prepared annually in the United States. This number has greatly increased since then.

Purpose and Objectives

The primary purpose of EIA is to facilitate the consideration of the environment in planning and development decision making and, ultimately, to make it possible to arrive at decisions and subsequent actions that are more environmentally sound. The specific objectives of EIA can be separated into output objectives and outcome objectives. The output objectives of EIA are the immediate, short-term objectives or returns of applying EIA and include

- improvements to the environmental design of the proposed developments;
- explicit integration of environmental factors in decisions about development actions;
- an opportunity to anticipate, avoid, minimize, or offset potentially adverse environmental impacts before a development becomes a reality; and
- provisions for public debate about a proposed development action.

The outcome objectives of EIA are longer term and the product of consistent and rigorous EIA application. They include

- protecting the productivity and capacity of human and natural systems and ecological functions,
- facilitating learning and environmental education, and
- promoting sustainable development.

EIA Process

EIA can be thought of as a framework or process to systematically examine the potential environmental implications of development actions prior to their approval. The specific components and application of EIA are dictated by the specific issues it attempts to address and by its regulatory or policy requirements. However, the EIA process stemming from NEPA and subsequently diffused throughout the world requires a series of systematic steps:

Project description. Prior to an EIA, the proponent prepares a detailed description of the proposed action and the project environment and a statement of the need for and purpose of the undertaking and its alternatives. This is often called the “application for development.”

Screening. The project information is screened against a list of projects that require assessment, regulatory or legal triggers for assessment, criteria and thresholds, or some combination of these to determine whether an EIA is necessary. The screening process ensures that unnecessary assessments are not carried out and that developments warranting an EIA are not overlooked.



Scoping. The proponent or government agency responsible for carrying out the EIA determines, in consultation with the affected public and various interest groups, the important issues and parameters to be considered in the assessment and establishes the spatial and temporal boundaries for the EIA. Attention is focused on identifying what studies need to be done and then establishing the current environmental baseline and socioeconomic conditions of the project region. Potential interactions between the project and a select few priority environmental components, often referred to as valued ecosystem components (VECs), are identified.

Impact prediction. The likely changes or effects caused by the project on the biophysical and human environment are predicted, and the potential impacts emerging from those effects are identified. Consideration is also given to the significance of effects and impacts and to the identification of those effects and impacts that require responsive management.

Impact management. The purpose of impact management is to find ways to reduce, eliminate, or avoid those potentially adverse effects and impacts that are likely to be caused by the development and to identify opportunities to create or enhance potentially positive ones. Impact management may include activities such as developing impact management plans, environmental protection plans, or compensation packages for those effects and impacts that cannot be avoided.

Draft EIS preparation. A draft EIS is prepared describing the project, the current baseline conditions, key issues and likely project impacts, and the proposed impact management strategies and programs for longer-term environmental monitoring.

Public and technical review. Under most environmental assessment systems there is an opportunity for a formal public and technical review of the EIS and related documentation prior to the preparation of the final EIS and a decision being made.

Final EIS preparation and decision. The results of the review are considered by the proponent and integrated into the final EIS. The EIS is then submitted to the responsible authority, which is

usually a government environmental agency or department, for a decision as to whether the proposed action should proceed and under what conditions. Under some environmental assessment systems, the responsible authority may conduct a second, independent public or technical review of the EIS prior to making a decision. If the EIS is rejected, it is sent back to the proponent for revision to address the identified deficiencies.

Implementation and follow-up. Once a decision is made for approval, the project is implemented along with any proposed impact management and mitigation measures. Monitoring programs are put in place and continue throughout the life cycle of the development project to provide feedback on the effectiveness of impact management and to identify any new or emerging environmental and public concerns.

EIA Beyond the Project

Although NEPA was never intended to be restricted to individual development projects, such as bridges, dams, and mine sites, EIA emerged throughout the 1970s and 1980s with a very strong project emphasis. It is only since the early 1990s that attention has turned to applying EIA above the project level, to address the potential environmental implications of policies, plans, and programs. This higher-order form of assessment, known as strategic environmental assessment (SEA), is gaining international attention as a means to address environmental impacts earlier in the decision-making process. The rationale for SEA is that development projects are often the result of policies, plans, and programs, or lack thereof, playing out on the ground. Thus, to capture the sources of environmental impacts, there is a need to apply environmental assessment before development projects are proposed. This, in turn, should lead to better project proposals and decisions about development.

Enduring Concerns

EIA has evolved considerably since NEPA. It is now applied on a global scale, occurs earlier in the decision-making process, and is focused more on broader sustainability concerns. However,



several significant issues concerning the practice of EIA exist. These include the ability of EIA to predict the future accurately, the role of the public in EIA, follow-up and monitoring of projects after they receive approval, and the cost-effectiveness of the EIA process.

Central to EIA is the prediction of environmental impacts. This requires some ability to foresee the future—an almost impossible task in a highly complex and changing environment. As a result, impact predictions are frequently inaccurate, resulting in public mistrust of the EIA process and of the science involved. A major challenge is that the impact predictions in an EIS rarely include any discussion of uncertainty or error about those predictions or indications of the quality of the data used. This is understandable for a development proponent in that the public and decision makers are often reluctant to accept uncertainty. At the same time, precise predictions about the future are often suspect, prone to criticism, and more likely to be wrong.

Public involvement has been a long-standing challenge to EIA. The standard approach has been to prepare an EIS and release it to the public for review and comment rather than to involve the public early in decision making, at a stage when the need for and the purpose of the project are being discussed. Early public involvement reduces potential conflict at later stages of the process and brings to EIA a host of public issues and concerns about development that may otherwise be missed.

EIA is often perceived as a means to an end, rather than a long-term commitment to environmental management. Once a development is approved, an EIS is often shelved, and little use is made of the results for postimplementation monitoring and follow-up. Without an ongoing commitment to monitoring, little is known about the actual impacts or effectiveness of the measures implemented to manage them. When monitoring occurs, it is often limited to those components of the environment for which ongoing data are required to renew project or operating permits and licenses.

Many development proponents argue that EIA is not worth the financial investment. Often, EIA and the preparation of an EIS are seen as hurdles that must be overcome to secure a development

permit. The result of this view is an EIA process that is separated from project management and ongoing improvements in environmental performance. This is not consistent with the intended purpose of EIA. An EIA presents a significant opportunity for a proponent to save money by minimizing public conflict and opposition to the project, thereby reducing costly project delays, and facilitates overall improved project environmental performance.

Bram F. Noble

See also **Environmental Impact Statement; Environmental Impacts of Agriculture; Environmental Impacts of Cities; Environmental Impacts of Manufacturing; Environmental Impacts of Oil Fields; Environmental Impacts of Pipelines; Environmental Impacts of Roads; Environmental Impacts of Tourism; Environmental Management; Open-Pit Mining; Public Policy, Geography of; Sustainable Development; Sustainable Development Alternatives**

Further Readings

- Canter, L. W. (1996). *Environmental impact assessment* (2nd ed.). Boston: McGraw-Hill.
- Carson, R. (1962). *Silent spring*. New York: Houghton Mifflin.
- Noble, B. F. (2006). *Introduction to environmental impact assessment: A guide to principles and practice*. Don Mills, Ontario, Canada: Oxford University Press.
- Petts, J. (1999). *Handbook on environmental impact assessment*. Oxford, UK: Blackwell Science.



ENVIRONMENTAL IMPACTS OF AGRICULTURE

Global environmental systems have been profoundly affected by agriculture throughout the Holocene epoch, but these impacts have been especially pronounced since the Green Revolution began around 1945. The environmental effects of food production include alterations of the Earth's hydrologic cycle, increasing levels of



atmospheric greenhouse gases, decreased biodiversity, accelerated rates of soil erosion, and the rapid spread of eutrophication in freshwater and marine ecosystems.

The Agricultural Revolution

Crop plants were first domesticated around 10,000 yrs. (years) ago, when centers of crop domestication emerged independently in the Eastern Mediterranean, Asia, Africa, and the Americas. The three staple grains that today account for more than 60% of all caloric intake—wheat, rice, and corn—were all domesticated by ca. 7,000 yrs. BP (before present). However, the domestication events themselves were inconsequential in terms of immediate environmental change. The pervasive and lasting imprints of the agricultural revolution on the global environmental commons did not begin to develop until ca. 4,000 to 5,000 yrs. BP, when agriculture was rapidly emerging across the globe as the primary means of food procurement.

Forest Clearance: Ecosystem and Atmospheric Impacts

Between 5,000 and 3,000 yrs. BP, large cities (10,000 to 100,000-plus inhabitants) were established on several continents, and this growing urban trend was fueled by the conversion of the wooded hinterlands into agricultural fields. Fire was used extensively as a means of clearing both dead and living biomass in preparation for the planting of agricultural plots; stone and metal tools (i.e., axes, metal plows) were also adopted for agricultural purposes, particularly in the Near East, Europe, and Asia. The oft-cited clearing of oak woodlands throughout the Mediterranean region during classical times led to increased soil erosion, which was made worse by the proliferation of domesticated grazing animals such as goats and sheep. The process of stocking domesticated animals on areas that were formerly forested has been repeated on every agricultural continent, often with the same end result: retardation of vegetative succession and the maintenance of the treeless landscape.

The decreases in natural vegetation cover lost to agricultural conversion have resulted in extensive

native habitat loss and forest fragmentation and have contributed significantly to modern extinction rates that are several orders of magnitude higher than those experienced during pre-agricultural times. Since agricultural landscape patchworks have been carved out of formerly contiguous tracts of native vegetation, large migratory and wide-ranging animal species have often been relegated to habitat patches too small to satisfy their dietary and breeding requirements. Farmers have also historically viewed native animal species, both herbivores and carnivores, as competitors or threats to successful food production. These “agricultural pests” have long been targets of local extermination efforts and include animals in the United States such as prairie dogs, gophers, wolves, and foxes. In summary, the net effect of agriculture on global ecosystems has been one of biological simplification or decreasing biodiversity.

The rise of agriculture has also precipitated a marked increase in anthropogenic greenhouse gas emissions. The conversion of native ecosystems—forests, shrublands, and grasslands—to agricultural fields has resulted in increased carbon dioxide (CO₂) fluxes from the biosphere to the atmosphere. Some scientists argue that this process of agricultural conversion led to climatically effective anthropogenic greenhouse gas emissions by the Middle Holocene (ca. 5,000 yrs. BP). Proponents of this theory contend that farming activities, increasing throughout the Holocene, led not only to elevated levels of atmospheric CO₂ but also to rapidly rising levels of atmospheric methane (CH₄) because of the pervasive adoption of rice paddy farming in Asia. Modern livestock production has further contributed to anthropogenic methane emissions via cattle and swine production, CO₂ emissions via fossil fuel consumption, and N₂O emissions via nitrogen-based fertilizer use. While the timing of agriculturally driven increases in greenhouse gas emissions is still a matter of some debate, agriculture today is clearly a major contributor to the anthropogenically enhanced greenhouse effect.

Agricultural Impacts on Water Supplies

The use of irrigation is a hallmark of modern agriculture although the practice goes back for many millennia. The settling of the arid American



West and the rise of the megalopolises of that region were contingent on the impoundment and redistribution of surface waters from the Colorado River. The impoundment and diversion of surface waters for agriculture is one of the reasons why as many as 50% of the world's freshwater fish are currently threatened with extinction. Agricultural practices in arid regions led to an increase in the salinity of surface waters, and the overpumping of groundwater for agriculture has resulted in subsidence, surface fissures, and salt-water intrusion.

One classic example of the impacts of agriculture on surface water supplies is the case of the Aral Sea in Central Asia, once the fourth largest freshwater lake in the world. Beginning in the 1950s, water was diverted for a large-scale cotton irrigation project. The diversion of the Amu Darya and the Syr Darya, the two largest tributary rivers to the Aral Sea, led to a dramatic reduction of the lake's surface area, a collapse of its large commercial fisheries, and a dangerous increase in dust storms carrying lake-bed salts and pesticide residues.

The Green Revolution and Modern Farming

Global food production took a dramatic turn during the two decades immediately following World War II. In what was widely perceived as a triumph over Malthusian doomsday food security scenarios, the Green Revolution (GR) ushered in a period of rapidly increasing global food production beginning around 1945 that gained momentum through the 1970s and 1980s. The GR came at a time when the world was struggling to feed its burgeoning populations, especially in the developing countries of Africa, Asia, and Latin America. The positive impacts of the GR are undeniable—famine reduction, food security for developing countries, and an incalculable number of lives saved. The environment also benefited from the GR in that more food was produced on the land under cultivation, potentially saving huge forested areas from imminent conversion to agriculture. In Asia, for example, cereal yields were doubled from 1970 to 1995, while the total land under cultivation rose by just 4%.

The GR, however, has not been such a boon for the overall health of global environmental

systems, and it gave rise to several new environmental challenges. As chronicled by Rachel Carson in her book *Silent Spring*, new chemical herbicides and pesticides such as DDT began to have detrimental impacts on nontarget organisms such as the iconic and quintessentially American bald eagle. Increased use of inorganic fertilizers and widespread adoption of new crop varieties have also had negative environmental consequences.

Pesticides and Nutrient Loading

The GR emphasized inputs of pesticides, herbicides, and inorganic fertilizers. These compounds, however, do not remain on the field surface where they are applied. Pesticides and herbicides can be ingested by nontarget organisms. In some cases, concentrations of these toxic substances increase as they move up the food chain via a process called biomagnification, resulting in increasing toxicity at higher trophic levels. Although many of the most immediately toxic herbicides and pesticides (such as DDT) have been banned or restricted, the longer-term impacts of common agriculture poisons are still not well understood.

The impacts of agriculture on the carbon and methane cycles have already been outlined here, but increased levels of greenhouse gas emissions are not the only changes that agriculture has wrought on global biogeochemical cycles. While the carbon cycle has been clearly altered by agricultural land use practices, perhaps even more striking are the impacts that agriculture has had on the nitrogen and phosphorus cycles. Nitrogen and phosphorus are essential nutrients for plant growth, but they are usually limiting in natural ecosystems. Agricultural applications of these nutrients to field surfaces result in nutrient-rich runoff from the fields. The leakage of nitrogen and phosphorus from field surfaces to rivers, streams, lakes, and oceans leads to the process of eutrophication and in some instances the eventual depletion of oxygen, necessary to support freshwater or marine organisms such as fish. The “dead zone” in the Gulf of Mexico just off the Mississippi River delta is directly attributable to farming in the Mississippi River basin and associated inputs of nitrogen and phosphorus to Gulf waters.

Robert A. Dull



See also **Agricultural Biotechnology; Agricultural Land Use; Agriculture, Industrialized; Agrobiodiversity; Agrochemical Pollution; Agroecology; Agrofoods; Agroforestry; Coastal Dead Zones; Coastal Zone and Marine Pollution; Crop Genetic Diversity; Cultural Ecology; Domestication of Animals; Domestication of Plants; Food, Geography of; Forest Fragmentation; Genetically Modified Organisms (GMOs); Greenhouse Gases; Herbicides; Nonpoint Sources of Pollution; Nutrient Cycles; Pesticides; Pest Management; Soil Erosion; Water Pollution**

Further Readings

- Carson, R. (1962). *Silent spring*. Boston: Houghton Mifflin.
- International Food Policy Research Institute. (2002). *Green revolution: Curse or blessing?* Retrieved November 6, 2008, from www.ifpri.org/pubs/ib/ib11.pdf
- Mannion, A. M. (1995). *Agriculture and environmental change: Temporal and spatial dimensions*. Chichester, UK: Wiley.
- Ruddiman, W. F. (2003). The anthropogenic greenhouse era began thousands of years ago. *Climatic Change*, 61, 261–293.
- Tilman, D., Fargione, J., Wolff, B., D'Antonio, C., Dobson, A., Howarth, R., et al. (2001). Forecasting agriculturally driven global environmental change. *Science*, 292, 281–284.



ENVIRONMENTAL IMPACTS OF CITIES

A city's urban environment—the area that it occupies—is directly affected by the city's use of materials, air, water, and land. A city's ecological footprint is the space needed to support the city, equivalent to the physical and biological regions disturbed to provide resources to the city and accept its wastes. A city's metabolism is the sum total of materials, fuels, water, and goods that flow into a city to sustain its populace and economy. Cities vary in size, from agglomerated urban settings of 5,000 people or more to megacities,

agglomerated urban settings with more than 10 million people. Global cities are a subset of megacities, cities that set global economic and cultural trends. All cities influence the environment. Large cities tend to have a disproportionately greater environmental impact than less populous ones.

At the turn of the 21st century, cities occupied only 3% of Earth's land surface; however, their impacts extended across the globe. Cities' voracious appetites for resources and their dispersal of pollutants into air, into water, and on land result in local, regional, national, and global environmental degradation. For example, in 2000, Los Angeles, California, had a population of about 4 million people and city limits covered an area of 1,290 square kilometers. The Los Angeles metropolitan area had more than 12 million people, including Los Angeles and Orange counties. The greater Los Angeles area, a megacity, covered much of five counties and included more than 17 million people. Direct effects of Los Angeles within the five counties of the megacity are smog, displacement of native habitats, contamination of surface and unconfined ground waters, and deposition of litter on city streets and beaches. The megacity's direct environmental impacts on the Western United States include air pollutants that diminish visibility at national parks of the Intermountain West, mountains of landfills for urban waste, and diminished flow and increased salinity of the Colorado River. However, the direct impacts to the region are only the beginning of the megacity's environmental impacts. Coal-fired plants in the west and Midwest provide electricity to Los Angeles, with associated environmental effects of surface and underground mining, coal combustion, and waste disposal. Power plant emissions send sulfur dioxide across national boundaries, affecting Canada's forests. The impacts of cars driven in Los Angeles are not limited to their emissions. Materials for cars come from mines, chemical plants, manufacturing centers, and cities that dispose of wastes on land, in the air, and into water. Beyond the impacts on local, regional, and global physical and biological environments are the effects on local, regional, and global populaces to sustain the city's appetite for goods and services. Los Angeles is one of 24,000 urban areas globally. It can be argued that the uneven distribution and unequal per capita



consumption of Earth's resources exemplified by Los Angeles exacerbate rifts among rich and poor nations and lead to war, famine, and pestilence.

Geographers study the webs of relationships among people, places, and environment. Almost every field of geography addresses an aspect of urban environmental geography, including physical geography, which explains (a) some of the reasons why cities are located where they are, such as regional resources and connectivity to transportation corridors, and (b) the probable consequences of urban development to Earth systems, and human geography, which explains (a) the growth of cities, by migration and natural increase, and (b) the probable consequences of urban development to social and behavioral systems.

History of Environmental Effects of Cities

In less than a few 100 years, the environmental effects of cities have changed from being largely absorbed by their locale to being globally pervasive and pernicious. Three hundred years ago, the world's population of approximately 600 million lived in what today would be considered a rural setting with scatterings of villages and towns and about two dozen cities with more than 100,000 inhabitants. Even at their worst, the environmental effects of most cities were largely confined within city limits: local sinkholes of misery, disease, stench, and smoke-filled interiors; outdoor scenes of rotting refuse and human feces; ecosystems supporting rats, vermin, and disease; and social structures vulnerable to recurrent famine.

Cities changed irrevocably in response to the widespread consumption of fossil fuels introduced during the Industrial Revolution and the increased crop yields of the Green Revolution. People migrated to cities in large numbers, leading to increased consumption of resources. Commerce and trade provided jobs, attracting more people to cities. In 1800, only 3% of the world's 800 million to 900 million people lived in towns of more than 5,000. Fewer than 45 cities had populations greater than 100,000. In 2008, over half of the world's 6.5 billion people are urban. Cities have evolved from local and regional centers of trade into drivers of national and global economies today.

The history of the environmental effects of cities is inseparable from the history of the environmental effects of the 20th century. The demand for goods and services in cities grew at a faster rate than did their increase in population due to (a) increased per capita consumption, (b) socioeconomic factors such as cultural migrations, and (c) political and economic policies, such as treating the costs to the environment as economic externalities. The metabolism of cities varies among developed versus developing nations and even within nations. The daily intake and output of water, energy, and food for a city of 1 million people in the United States in the 1980s is estimated as more than 500 million kg (kilograms) of water, almost 10 million kilojoules of energy, and almost 2 million kg of food. The daily output included somewhat less than 500 million gallons of sewage, almost 1 million kg of air pollutants, and 10 million kg of solid waste. Calculating and analyzing cities' metabolisms and their ecological footprint challenge geographers to agree on methodology as well as to model flows of materials into and from cities.

Environmental Effects on Earth Systems

Every city on every continent has an impact on the Earth. The cumulative environmental effects of cities are innumerable, with feedback loops that make a full assessment of the total environmental impact of a city almost impossible. Assessing even the local effects of cities on their urban environment requires assumptions about costs and benefits, the intangible values of quality of life, and issues of social justice. Although the litany of effects is long, it is possible to get a sense of the diversity of impacts and their scale by listing examples of impacts for each of the subsystems of Earth systems: the geosphere, hydrosphere, atmosphere, biosphere, and anthrosphere.

Geosphere

Impacts to the geosphere within the city's borders include land surface disturbance, such as changes in albedo and hydrologic capacities, and the consequences of waste disposal. It is estimated that globally, one third to two thirds of solid waste of cities is not collected, resulting in



contaminated land and water as well as a stench. Effects of cities on the land within their borders are minor compared with the environmental repercussions beyond their borders. At regional and global scales, the Earth's geosphere is affected by cities' needs for food, construction materials, and resources to sustain their economies. Cities' needs for food result in global losses of topsoil from wind erosion of cultivated fields and water erosion following deforestation. Addition of nutrients, such as phosphate, to increase crop production relies on the mining and processing of chemicals, with attendant environmental effects. Cities' needs for construction materials result in mining and resource extraction of sand, gravel, limestone, and road materials, including petroleum extracted for asphalt. Cities' needs for raw materials to sustain their economies require mining for metals, petroleum extraction for plastics, and agricultural disturbances to obtain animal products, in addition to land impacts associated with extraction of coal for electricity and petroleum products for transportation. Humans are geomorphic agents of erosion and deposition. Earth scientists use the term *Anthropocene Epoch* for the time frame of human impacts and to distinguish the sediment record on continental shelves and elsewhere of Earth moving attributable to humans.

Hydrosphere

Cities need water for their populace to drink. Most cities are located near water supplies. As cities grew, their impacts on local and regional water sources increased beyond the resources within their city limits. Cities in arid and semiarid regions disrupt natural water regimes by importing water for municipal and industrial uses and withdrawing groundwater from aquifers more rapidly than it is replenished. Agricultural demands of cities justify the construction of dams, diversions, and drainage systems. Cities also use water to dispose of wastes. Until the economic and social consequences of disease outweighed convenience and local economics, sewage and liquid industrial wastes were discharged into local surface waters. It is estimated that even in the first decade of the 21st century, 220 million urban dwellers did not have clean drinking water and

420 million did not have basic latrines. Shallow, unconfined groundwater of most urban areas is biochemically degraded with by-products of human waste, fertilizers, trace metals such as mercury, and emerging contaminants such as pharmaceuticals and antibiotic-resistant pathogens. Contamination of waterways associated with cities includes contamination of oceans and waterways used to transport materials to and from cities and impacts including petroleum spills, flushed bilge water with invasive species, and ubiquitous plastic flotsam.

Atmosphere

Cities depend on diverse fuels for heat, transportation, and industry. Combustion of fossil fuels emits gases that affect local, regional, and global air quality. Effects within city boundaries differ with topography, culture, and national regulations. It is estimated that in 1998, more than 1 billion city dwellers breathed unhealthy air. Breathing the air pollutants for a day in Kolkata (formerly Calcutta), India, equates to smoking a couple of packs of cigarettes. The impact of cities on the atmosphere is rarely constrained by city borders. Combustion of fossil fuels for transportation within and between cities discharges carbon dioxide and nitrous oxides into the atmosphere. Cities' needs for electricity and heat, largely met by burning coal and natural gas, release sulfur dioxide into the atmosphere, with downwind consequences of acid rain and increased greenhouse gases such as carbon dioxide and water vapor. Cities' needs for food result in emissions of methane and particulate pollution from agriculture. Cities' needs for raw materials for industry result in a potpourri of gaseous pollutants emitted locally and at their places of refining or manufacturing. The cumulative effects of local and global discharges of pollutants into the atmosphere, largely to sustain urban economies, are the inconvenient truths of global warming and climate change.

Biosphere

Cities affect the biota within their borders and, to an even greater extent, the biosphere of regions that supply their food and raw resources. Urban ecosystems favor generalists, omnivores such as



rats, animals that adapt to buildings such as pigeons, and biota appreciated by humans such as cats, dogs, and grass for lawns. Urban land uses displace natural biota. Urban corridors fragment habitats. Those impacts are minor compared with the effects of agriculture to sustain the growing urban need for food. In 1900, 20 million km² (square kilometers) of Earth was cultivated, and in 1990, 40 million km², the difference largely to feed city dwellers. The oceans, fished for millennia as an apparently inexhaustible source of nutrition, have been harvested of some species of mammals and fish to the brink of extinction. Aquaculture brings environmental challenges analogous to feedlots for cattle. Meanwhile, globalization and increased concentrations of urban populations have accelerated the spread of invasive species and enhanced dispersal of diseases to animals as well as to humans. Even more extensive than a city's effects on its urban biota or its effects on regional and global ecosystems will be the as yet unknown effects of atmospheric emissions on global climate and, consequently, the impacts on Earth's biosphere.

Anthrosphere

Not the least of the effects of cities on Earth systems are those on the anthrosphere, the sphere of Earth inhabited by humans. Cities are magnets for people, culture, and amenities. They are places of power, of jobs, of promise. However, the voracious appetite of cities for resources has social repercussions within cities and beyond their borders. Large cities are havens of poverty. It is estimated that between 25% and 50% of urban populations live in poverty. Environmental effects of urbanization and globalization have widened the divide between rich and poor within cities and among nations. One international environmental consequence of national materials policies is the exported pollution from rich countries, for example, those that regulated emissions from smelters to poor nations willing to accept the package deal of jobs and degraded air. Nations rich in fossil fuels have a natural advantage over those with minimal resources. Social justice competes with economic realities. Economic health competes with human health. Nations wage wars. People in cities feel the pain but also cause it.

Future Options

The environmental effects of cities are pervasive, persistent, and population driven. They are not inexorable. In fact, it can be argued that the environmental impacts of the populace concentrated in cities should be less than those of the populace spread more evenly across Earth's surface. Cities' environmental problems challenge modern society's mores because recent advances in the quality of human life have been tied to per capita consumption, gross national product, and fuel consumption, all of which have a negative impact on the environment. Cities can and have reversed the environmental degradation of their air, water, and land. The "environmental miracle" of Japan during 1965 to 1985 not only cleaned up the fouled air and water but also strengthened Japan's economy, establishing its reputation as the premier manufacturer of pollution control equipment. Collaborations of government, industry, and individuals, including scientific elites, has reduced acid rain from coal-fired plants in Europe, banned CFC (chlorofluorocarbons), and reversed the eutrophication of the Great Lakes.

Geography Matters

Environmental issues are issues of human geography as well as physical geography. The study of geography provides ways to appreciate the differences among cities and their impacts. Urban environmental geography examines how physical geography influences the viability and vulnerability of urban settings. Human geography helps explain why migrations into and among cities has had a greater impact on the environment than has an equivalent growth by natural increase.

The 20th century at first was ignorant of, and then denied, the environmental effects of cities, relegating debates to the concerned scientists and environmental activists. Disparities between the rich and poor nations driven by consumption now affect the world balance of power and undermine world stability. Issues of environmental and social justice include the dynamics of international aid, consequences of famines, and politics of population policies. In 2007, former U.S. Vice President Al Gore and the UN International Panel



on Climate Change received the Nobel Peace Prize for their work in identifying, quantifying, and publicizing the effects and probable consequences of human impacts on the environment. That the prize was given for peace is a signal that the 21st century may recognize that the environmental effects of cities extend beyond city boundaries and beyond their global ecological footprint to the social welfare of the human species.

Genevieve Atwood

See also **Ambient Air Quality; Anthropogenic Climate Change; Atmospheric Pollution; Climate Change; Coastal Zone and Marine Pollution; Environmental History; Environmental Impacts of Manufacturing; Environmental Impacts of Roads; Environmental Planning; Environmental Protection; Environment and Development; Greenbelts; Green Building; Green Design and Development; Human Dimensions of Global Environmental Change; Landscape Ecology; Love Canal; Nature-Society Theory; Photochemical Smog; Population and Land Use; Population, Environment, and Development; Public Water Services; Recycling of Municipal Solid Waste; Regional Environmental Planning; Resource Economics; Social Construction of Nature; United Nations Environmental Summits; Urban Ecology; Urban Environmental Studies; Urban Gardens; Urban Geography; Urban Green Space; Urban Heat Island; Urbanization; Urban Land Use; Urban Metabolism; Urban Solid Waste Management; Urban Sprawl; Urban Storm Water Management; Urban Sustainability; Urban Water Supply; Waste Incineration; Water Needs; Water Pollution; Zoning**

Further Readings

- The Earth Institute at Columbia University. (2005). The growing urbanization of the world. *Earth Institute News Archive*. Retrieved November 30, 2008, from www.earth.columbia.edu/news/2005/story03-07-05.html
- Goudie, A. (2005). *The human impact on the natural environment: Past, present, and future* (6th ed.). Malden, MA: Blackwell.
- McNeil, J. (2000). *Something new under the sun: An environmental history of the twentieth-century world*. New York: W. W. Norton.

United Nations Population Fund. (2007). *State of the world population 2007: Unleashing the potential for urban growth*. Retrieved November 30, 2008, from www.unfpa.org/swp/2007/english/chapter_1/index.html

World Resources Institute, United Nations Environment Programme, United Nations Development Programme, & World Bank. (1996). *World resources 1996–97: The urban environment*. Retrieved November 30, 2008, from www.wri.org/publication/world-resources-1996-97-urban-environment



ENVIRONMENTAL IMPACTS OF MANUFACTURING

Manufacturing is the application of labor and tools to raw materials to produce goods for use or sale. It ranges from handicrafts to large-scale industrial production. The hallmarks of industrial-scale production include the use of motorized machinery and a division of labor, both vastly increasing productivity and production compared with earlier manufacturing, with a commensurate increase in intensity and scale of environmental impacts. Environmental impacts can be divided into those associated with the procurement, use, and by-products of energy, water, and materials for manufacturing. The geography of impacts has changed dramatically: Regulations and technological innovations have helped reduce the impacts in industrialized countries, but globalization has shifted higher-impact manufacturing to lower-wage/regulation economies. There are several theorizations of approaches to control the environmental impacts of manufacturing.

Energy

The post-Industrial Revolution use of coal as a fuel seriously affected the environment at extraction and usage sites. Soot and sulfurous and hydrochloric acid fumes were an omnipresent bane of urban life in the 19th century. Using electricity rather than burning coal or coal gas directly and the switch to smokeless fuels improved air quality. However, advances in science and medicine



transferred environmental concern to microscale particles and acidic aerosols. Attention shifted from local to continental, and finally global, impacts, resulting in international negotiations over air quality protection (e.g., the 1979 United Nations Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution and the 1998 Kyoto Protocol to the United Nations Framework Convention on Climate Change). Energy-intensive industries, including electricity generation from fossil fuels, are the main contributors to air pollution and greenhouse gases such as carbon dioxide (CO_2). The major industrial air pollutants are acidic aerosols (e.g., sulfur, nitrogen oxides), volatile organic compounds (including contributors to ground-level ozone), particulates (especially those less than 10 micrometers in diameter, known as PM_{10}), and toxic metals (e.g., arsenic, chromium, lead). Although air pollution control technology can keep emissions below the prescribed levels, it generates potentially hazardous solid or liquid waste products.

Water

Water courses and coasts provide economical means to import raw materials and export goods, as well as sources of water for production and a sink for discharged effluent. Groundwater is also at risk of impact. Excessive water abstraction can change the properties of a river, altering biodiversity and the landscape. It can also increase pollutant impact by decreasing dilution. Water returned to rivers can cause damage if insufficiently cooled. Potential surface and groundwater pollutants from manufacturing effluents include volatile organic carbons (e.g., petroleum products and industrial solvents), detergents, heavy metals, and food production by-products. The environmental protection of water bodies and surrounding environments has radically improved in industrialized countries over the past 30 years with the advent of emissions and conservation regulations, though the out-migration or closure of many industrial plants has contributed to this.

Materials

Raw material extraction and processing have environmental consequences that occasionally

can be restorable to an extent. These consequences may be remote from the manufacturing location. Waste is not synonymous with pollution, but it may imply an inefficient use of raw materials and requires treatment and/or disposal. Some industrial waste or by-products can be fed back into production; others can become “raw materials” in complementary manufacturing sectors. Products may have an environmental impact during use. German, European Union, and other producer responsibility regulations extend manufacturers’ and importers’ liability to include products’ end-of-life phase, to both divert waste from landfills and encourage eco-design. Extraction and processing of raw materials and the disposal of by-products and products each requires a transportation infrastructure (water, rail, road, and/or air based) up to global in scale.

Geography of Impacts

The environmental impact of manufacturing has increased from local to global with the advances in industrial technology and increasing production scale. However, the impact is not uniform. Regulatory and voluntary initiatives in industrialized countries help reduce local-scale impacts; the air and rivers in industrialized nations are cleaner than they have been since the Industrial Revolution, although energy usage and waste production have increased. Even so, improvements in industrialized countries in significant part reflect the shift of manufacturing to Asia and Latin America. The decline of heavy industries in Europe and North America through deindustrialization revealed a legacy of contaminated land. Decades of industrial use with limited regulatory restraint resulted in contamination, for example, with phenols from industrial solvents and heavy metals such as lead and arsenic. Concern has also risen over “nuisance” pollution, for example, odor, noise, and traffic. Conversely, industrializing countries face the challenges of poverty and underdevelopment alongside the environmental impacts of industrial production and, increasingly, consumption. Environmental regulations may not be accompanied by the requisite funding, experience, or ability to enforce them.

While local- to continental-scale environmental impacts have shifted rather than disappeared,



environmental concern in industrialized countries focuses on the global-scale issue of CO₂ emissions to the atmosphere. In addition, the potential environmental impacts of emerging biotechnology- and nanotechnology-based industries are not yet well understood.

Theorizing Environmental Protection

There are several theoretical approaches to understanding the environmental impact of manufacturing, especially the extent to which it can be contained. The separation of economic growth from environmental impacts is a major goal of environmental policy, though improvements to efficiency (decrease in pollution emitted per unit of production) can be offset by production increases. As resource use and waste disposal represent costs for manufacturers, environmental efficiencies can bring economic benefits—the win-win of eco-efficiencies. Some argue that, conversely, the capitalist imperative for growth inevitably erodes environmental value.

Pauline Deutz

See also **Anthropogenic Climate Change; Atmospheric Pollution; Bhopal, India, Chemical Disaster; Brownfields; Chemical Spills, Environment, and Society; Chlorofluorocarbons; Climate Policy; Coal; Deindustrialization; Ecological Modernization; Energy and Human Ecology; Environmental Impacts of Cities; Environmental Protection; Industrial Ecology; Industrialization; Industrial Revolution; Open-Pit Mining; Petroleum; Polychlorinated Biphenyls (PCBs); Water Pollution**

Further Readings

- Clapp, B. W. (1994). *An environmental history of Britain since the Industrial Revolution*. London: Longman.
- O'Connor, M. (Ed.). (1994). *Is capitalism sustainable? Political economy and the politics of ecology*. London: Guilford Press.
- O'Riordan, T. (Ed.). (2000). *Environmental science for environmental management* (2nd ed.). Harlow, UK: Prentice Hall.



ENVIRONMENTAL IMPACTS OF MINING

See Open-Pit Mining



ENVIRONMENTAL IMPACTS OF OIL FIELDS

Development of oil fields—sites containing oil and gas reserves—may cause various changes to the natural and human environment of large geographic areas. The environmental impacts arise during the offshore or onshore oil field operation phases, which are exploration, development, production, and transportation. Environmental impacts may be direct if caused by the actual oil field operations, for example, water contamination by drilling wastes, or indirect if they result from other activities arising from oil field developments, for example, job-related migration. An overview of basic direct environmental impacts of oil field operations is essential to understand the nature, scope, and gravity of their influence on both biophysical and sociocultural environments.

Oil field development starts with broadscale geological and geophysical surveys to identify exploration targets. Offshore exploration usually consists of aerial geosurveys, ship traverses, bottom sampling, seismic surveys with explosives, and test drilling for geological data. These activities may result in disturbance of marine mammals, benthic communities, coral reefs, seafloor, and sediments as well as increase in water turbidity. Onshore seismic exploration may trigger environmental impacts such as noise, vibration, air emissions, and intensive surface and ground disturbance from explosive charges, transport traffic, access roads, and drilling of exploratory wells. Whether offshore or onshore, exploration may lead to the degradation of air, water, and soil quality by discharges of drilling fluids contaminated with mud, formation water, and oil. Despite being a nonintense land use with minor effects on existing activities, the exploration phase



may still cause land use conflicts, for example, interfering with fishing and boat use in coastal areas. It may also carry a risk of negatively affecting native communities or damaging cultural resources and sensitive ecosystems.

The onshore development phase consists of construction of roads, airfields, well sites, and production facilities that might modify topography through erosion, sedimentation, and compaction and cause vegetation loss/damage. These impacts may further reduce wildlife habitats, timber yield, and so on, and harm sensitive ecological areas (e.g., wetlands or endangered species). Air pollution might result from wind erosion and soil disturbance due to construction and traffic as well as from burning of fuel fossils that emit CO (carbon monoxide) and NO_x (nitrogen oxides), which in high concentrations are harmful to health. Offshore, the seafloor may be disturbed by anchor dragging, drill ship and platform siting, production facility installation, and pipeline trenching. This alongside the possible discharges of drill mud, cuttings, disturbed bottom sediments, and solid wastes may contribute to bottom contamination and increased mortality of benthic and coral communities. Offshore and onshore installations are commonly accompanied by noise and vibrations, potentially harmful for humans and buildings close to construction sites. Installed facilities may affect natural and cultural landscapes, thereby producing different-scale visual impacts and aesthetic damage. The development phase may accidentally damage cultural resources and historical or religious sites. Labor immigration may overtax community services and cause economic, social, or cultural conflicts.

An offshore production complex includes various types of platforms with production and injection wells, transport pipelines, storage, and primary processing facilities. Platforms are self-contained facilities with helipads, accommodation for work crews, power supplies, storage tanks, and so on.

Production requires an extensive shore-based support system for the permanent housing of workers, supplies, waste disposal, and refining. Platforms and drill ships are supplied by both ship and air transport. Extracted oil and gas is transported to shore-based refineries/gas processing

facilities by pipelines, tankers, or barges. Air emissions may result from fuel combustion, diesel-powered generators and pumps, barge or tanker product evaporation, operation of oil refineries, vessel up- and offloading, and accidents, for example, evaporation of oil spills or gas discharges from pipeline ruptures or ship collisions. Routine production may cause long-term, minor chemical contamination of the water around platforms.

Onshore production facilities are less complex than offshore ones. They include wells and pumps spaced over the field, gathering and transportation lines, storage tanks, and primary processing units. As in offshore oil field development, here air pollution may continuously result from equipment operations, flaring of unwanted gases, discharge of sour gas and treated formation waters, oil spills, and burning of oil waste.

Emissions of NO_x and SO₂ (sulfur dioxide) from oil and gas burning at offshore/onshore production facilities can contribute to large-scale negative environmental impacts (e.g., the greenhouse effect and acidification). NO_x and SO₂ can be converted into sulfuric and nitric acids in the atmosphere and deposited on the ground as dry particles after precipitation far away from the emission points, leading to acidification of soil, vegetation, and fresh water and consequently to adverse affects on human health and ecosystems. NO₂, CO, soot/dust, and heavy metals released from burning of fossil fuels for transportation and heating may cause serious health problems. Operational noise is generated periodically by gas flaring and regularly by turbines, burners, valves, pipes, and steam outlets.

During any oil field operation stage, catastrophic events may happen, including well blow-outs with fire or release of sour gas, platform collapses, tanker collisions and spills, refinery or gas processing plant fires, pipeline breaks, and breakdown of equipment due to corrosion, worn-out components or physical damage, poor maintenance, and leaky oil/water drainage systems. Accidents cause severe soil, air, and water contamination, calling for urgent cleanup activities and leading to additional environmental disturbances. Injuries and deaths from accidents in facility operation as well as increased maritime accidents in coastal areas may occur.



In many cases, environmental impacts from oil field developments can be mitigated or prevented by preproject environmental assessment and consequent environmental management/monitoring plans. The risk of severe air, water, and soil pollution, biodiversity loss, and accidents may be reduced through better technological solutions, energy efficiency measures, compliance with operation, maintenance, and safety guidelines, and development of skills and competences.

Maia Gachechiladze

See also **Chemical Spills, Environment, and Society; Coastal Zone and Marine Pollution; Environmental Impact Assessment; Environmental Impacts of Pipelines; Oil Spills; Petroleum**

Further Readings

Norwegian Agency for Development Cooperation. (1996). *Environmental impact assessment (EIA) of development aid projects: Initial environmental assessment: Oil and gas* (Series No. 14). Oslo, Norway: Author.

World Bank Environment Department. (1991/1999). *Guidelines for environmental assessment of energy and industry projects* (Environmental Assessment Sourcebook, Vol. 3). Washington, DC: World Bank.

toxic and hazardous nature of many of the transported substances, pipeline leaks result in both economic and environmental damage and may even cause human casualties.

Leaks are often difficult to detect when a pipeline is subterranean. When a leak is large or undiscovered for a longer period of time, substantial volumes of gases or liquids may leak into the soil and lead to the development of dangerous situations. Often, leaks also involve a costly remediation. The U.S. National Transportation Safety Board has reported that there have been millions of dollars in losses and several casualties due to gas pipeline leaks in recent years. Depending on whether the pipeline is above the surface or subterranean, the type of material transported through the pipeline, and the location where a pipeline might leak, the impact on the environment will be variable, detection methods might change, and remediation efforts will be different.

Different Pipelines

Different types of pipelines can be distinguished depending on the transported substance, the transport function, the material from which the pipeline is made, and whether it is above or below the surface. Each type of pipeline has its own specific potential environmental problems. Long-distance transportation between cities, countries, or even continents requires major high-pressure pipelines. For gathering and distribution functions, smaller and shorter pipelines are usually sufficient. Major transport lines are especially sensitive to damage since they run through communal areas that are not controlled by the owner of the pipeline and information on the exact location of the pipeline is not always readily available to people living or working in the area. Drilling activities and mechanical ground movement by third parties therefore occasionally result in leaks. In addition, product theft, which particularly happens in developing countries (e.g., Nigeria), leads to problems for pipeline owners, and occasionally casualties. Due to the size of pipelines and the hourly flux of substance through them, large quantities of environmentally damaging substances may be quickly spilled, causing a major environmental impact.



ENVIRONMENTAL IMPACTS OF PIPELINES

Pipelines are present worldwide, both below and on the Earth's surface. And as this is an economical and relatively safe transportation method, pipelines are extensively used to transport any type of chemically stable substance, in either gas or liquid form, over land and sea. Some pipelines transport liquids or gases that are related to our living environment, such as drinking water or sewage. Others are used for transport of hazardous substances such as hydrocarbons or chemical wastes from production processes. Because of the

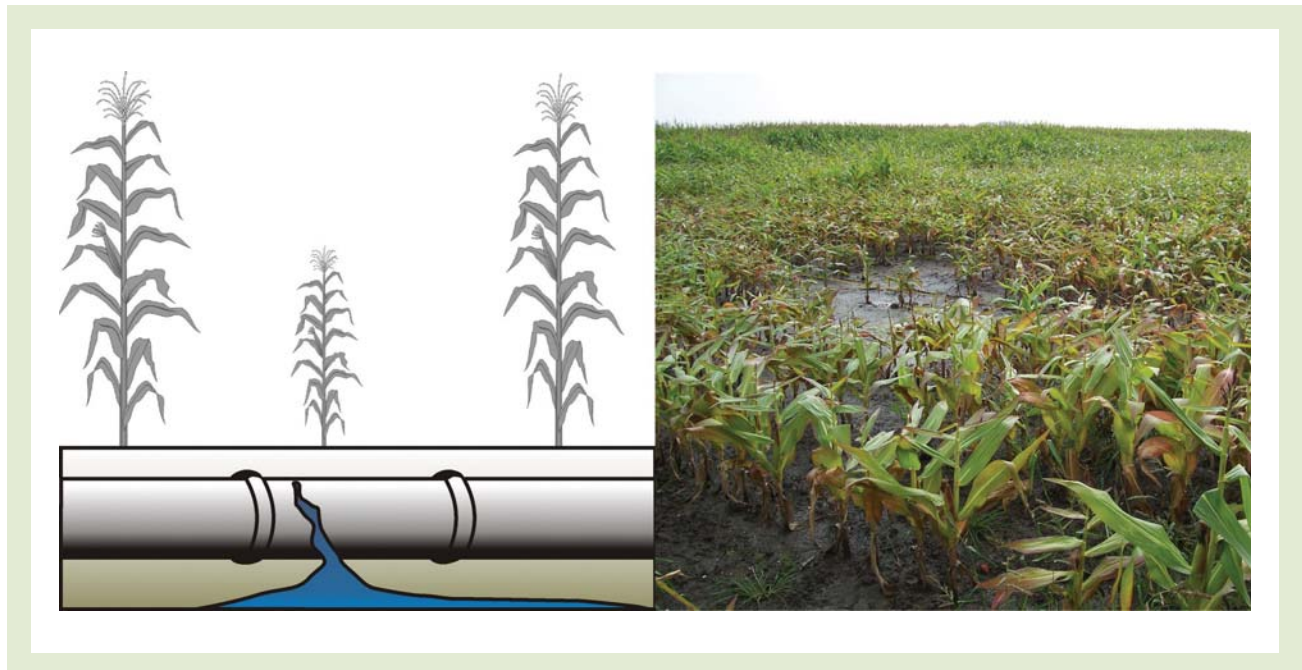


Figure 1 Substances leaking from pipelines affect the environment, both underneath and above the surface.

Source: Faculty of Geo-Information Science and Earth Observation, University of Twente.

Detection of Leaks

Since oil and gas pipelines are an important economic asset but may cause extensive environmental damage when they leak, regulations on either government or company policies have to ensure the safety of the environment, capital assets, and human welfare. Depending on the type of pipeline, different technologies and strategies have been developed. These range from visual inspection in the field to remote sensing techniques. Traditional inspection methods, such as visual inspection, drilling, and geochemical analysis, are both destructive to the soil and pipeline bedding and time-consuming and thus expensive. These techniques can only be used to investigate the extent of an already existing leak but are too expensive to be used for frequent monitoring. The most common technology for both surface and subsurface pipelines is pipeline integrity monitoring. A pipeline integrity system takes information from sensors in and outside the pipeline to detect anomalies in pressure, flow, stress, and temperature that may result from leakage.

Most types of pollution can also be detected by geophysical means. Ground penetrating radar (GPR) and resistivity/conductivity measurements have been applied widely in environmental studies. An advantage of these techniques is that they provide information on a larger scale at lower costs. A disadvantage of these methods is the nonuniqueness of the derived signal with respect to the pollution problem. Limited validation through geochemical analysis of drill cores is often needed.

A developing technique in pipeline investigation is remote sensing. Remote sensing offers a nondestructive investigation method, covers large areas in a relatively short time, and has significant added value to traditional methods. It is widely applicable since it offers a method for both direct and indirect detection of the presence of pollutants in the near-subsurface region (the latter through vegetation stress and mineralogical changes in soil composition). In addition, information is provided on the spatial extent of vegetation and soil composition anomalies on the Earth's surface, which may improve insights into

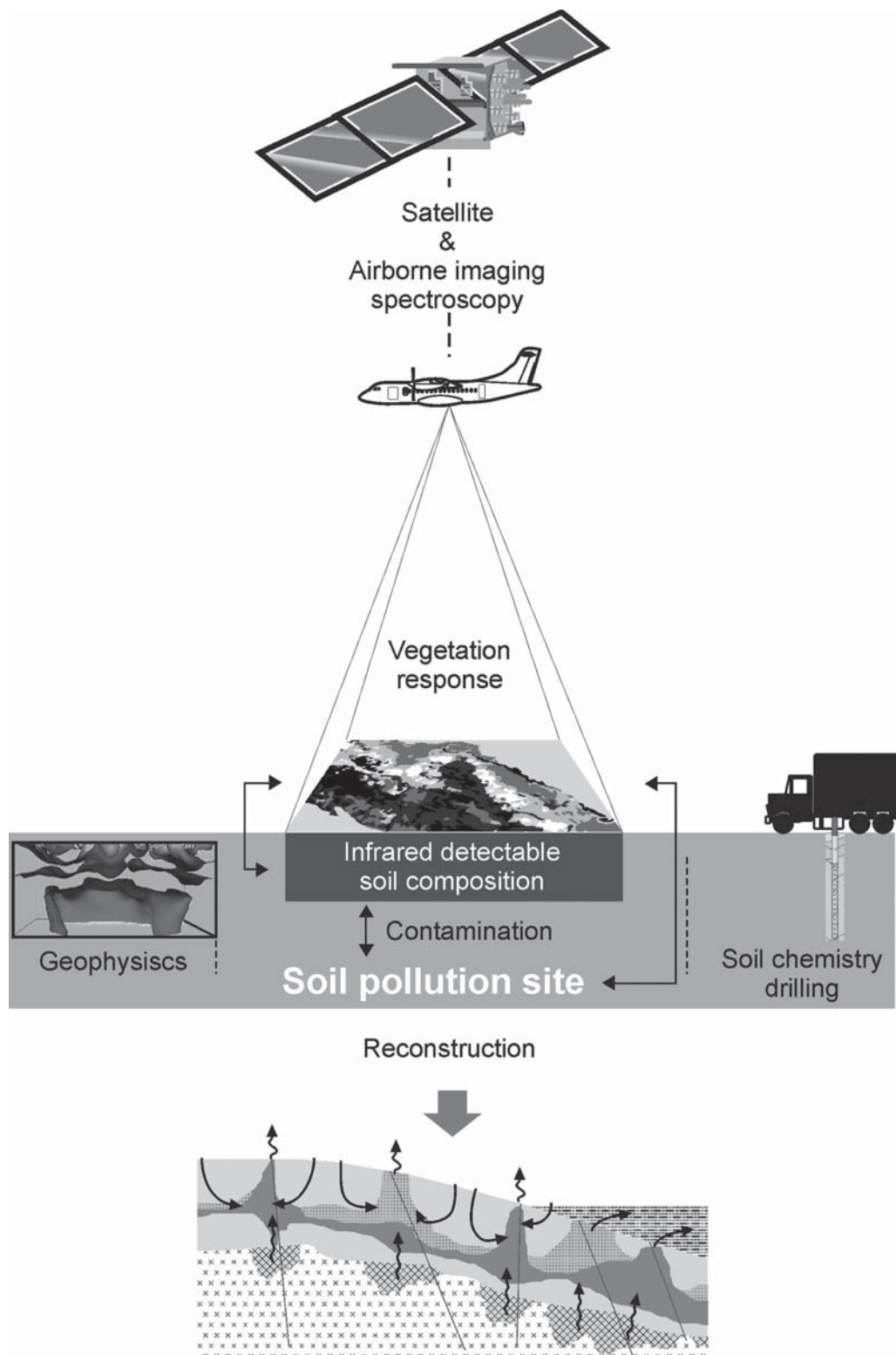


Figure 2 Schematic representation of the role of different techniques in pipeline inspection and monitoring

Source: Faculty of Geo-Information Science and Earth Observation, University of Twente.



pollution diffusion mechanisms (Figure 2). A drawback of optical remote sensing is that the observed anomalies are not unique indicators of pollution.

Monitoring and Remediation

Treatment of pollutants from pipeline leaks can be done *in situ* or *ex situ*. *In situ* treatment means that the pollutants are treated at the site, while *ex situ* involves the removal of contaminated material to be treated elsewhere. Remediation of contaminated soils can be done by chemical and biological treatments. Geochemical treatment methods are adsorption, absorption, filtration, distillation, and immobilization. Biological remediation is done through uptake of pollutants by vegetation (phytoremediation) and fungi (mycoremediation) or by stimulation of microorganisms that break down pollutants. These methods can usually be applied without the need to excavate the contaminant material and dispose of it elsewhere. Not all pollutants are absorbed or captured by plants or organisms, and the pollutants should be prevented from ending up in the human food chain.

Mark van der Meijde and
Harald van der Werff

See also **Chemical Spills, Environment, and Society; Coastal Zone and Marine Pollution; Ecological Risk Analysis; Environmental Impact Assessment; Environmental Impacts of Oil Fields; Environmental Management; Oil Spills; Petroleum**

Further Readings

- Master, G. M. (1991). *Introduction to environmental engineering and science*. Englewood Cliffs, NJ: Prentice Hall.
- O'Neil, P. (1993). *Environmental chemistry* (2nd ed.). London: Chapman & Hall.
- van der Meijde, M., van der Werff, H. M. A., Jansma, P. F., van der Meer, F. D., & Groothuis, G. J. (2009). A spectral-geophysical approach for detecting pipeline leakage. *International Journal of Applied Earth Observation and Geoinformation*, 11, 77–82.

ENVIRONMENTAL IMPACTS OF ROADS

Roads affect physical, chemical, and biological environmental systems in various ways. This entry describes the impacts of road construction, use, and maintenance on both living and nonliving systems. It then discusses the role of road ecology, an applied science oriented toward the mitigation of the environmental impacts of roads.

Roads are networked systems that include the roadway itself as well as the infrastructure required to maintain it, such as shoulders, retaining walls, bridge piers and abutments, and storm water management structures. Road networks provide for the transportation of goods and people, facilitating economic development through the exchange of resources and ideas. Traffic is an integral part of road system function. The environmental impacts of roads can be attributed to both their systemic structure and their function, and they are generally studied at local to regional scales (i.e., 10^0 – 10^9 square meters). Road construction creates significant environmental impacts, including habitat destruction and degradation, soil erosion, and the sedimentation of waterways. The persistent use and maintenance of expansive road systems produce extensive, unremitting environmental impacts. Road systems affect abiotic landscape processes, among them hydrospheric, atmospheric, and biogeochemical cycles. Climate and soil type are important factors that influence these effects. Roads and their traffic also affect living systems, including animal and plant populations. There are also indirect environmental effects of roads that occur as human activities respond to changes in road network structure or function, usually driven by economic factors.

Impacts of Roads on Nonliving Systems

Road systems affect hydrospheric processes by altering the flow of water on and below the surface of the land. Roads crossing low-lying areas can interrupt the movement of surface water, affecting the available water on both sides of the road. In rivers, bridge piers and abutments can cause changes to stream geomorphology, erosion



and sedimentation patterns, and local aquatic habitat conditions. Drainage swales associated with roads can increase stream density, hastening the removal of water from the landscape, reducing percolation, and increasing peak flows during storm events. Debris flows and landslides occur more frequently in sloping terrain with roads present, especially in tropical environments.

Roads affect atmospheric systems by creating microclimates near roads, changing the airflow and relative humidity, often making the air in the road environment more turbulent, hotter, and drier than in surrounding areas. Other atmospheric effects near roads include higher levels of dust, increased noise, and greater nighttime illumination from both vehicle headlights and roadway lighting.

Roads also affect other natural processes such as fire and biogeochemical cycles. While roadsides are often ignition points for vehicle-related fires, roads also limit the spread of fire and are used to manage prescriptive fires. Biogeochemical processes are affected by the chemical discharge related to road systems and traffic. These include emissions from vehicles, compounds used in maintenance activities, and leachates from infrastructure. The products consist of a wide array of nutrients, greenhouse gases, and contaminants, from heavy metals to hydrocarbons and carcinogenic compounds. Particulate and volatile elements and compounds enter the environment through storm water runoff and atmospheric deposition.

Impacts of Roads on Living Systems

Roads and their traffic affect living systems in various ways: They destroy and fragment landscapes, affect mortality rates and behavior in animals, and introduce exotic species. Roadside environments, with higher levels of light, nutrients, and storm water runoff, provide opportunities for some species to thrive, creating linear “edge” ecosystems that extend undisrupted across the landscape. Some of these are exotic invasive species, which compete with native species and disrupt ecological relationships. For some animals, roads provide opportunities for movement and are sources of forage or carrion. However, for many amphibians, reptiles, birds, and mammals,

roads act as barriers thwarting their movement. Roads sever contiguous land areas, causing fragmentation of habitats. Roads can isolate organisms from one another, undermining the ability of populations to recover from disturbances and local extinction events. Changing traffic patterns create ephemeral disturbances that enhance the barrier traits of a road. Mortality related to vehicle-animal collisions (i.e., “roadkills”) is significant, especially for large mammals. Traffic noise causes behavior modification in several species. For some, even the presence of small, remote roads is sufficient to affect their behavior and survival.

Road Ecology

The emergence of road ecology marks the coalescence of decades of research on the ecological effects of roads and the efforts of applied scientists and professional planners to grapple with the far-reaching and significant effects of road systems. During the latter half of the 20th century, the road network in the contiguous United States expanded considerably, and most places are now within about 1 kilometer of a road. Amid growing evidence of the environmental impacts of road systems, landscape ecologists and environmental planners proposed “road ecology.” Road ecology is an applied interdisciplinary science that addresses questions about various ecological effects of roads. Efforts to coalesce this incipient field culminated in 2003 with the publication of *Road Ecology: Science and Solutions*. Road ecology theory emerges from the collaborative experience and knowledge of physical scientists exploring broadscale ecological questions and social scientists involved in transportation research. Applications of road ecology thus far tend to focus on mitigating the environmental impacts of roads, including, for example, the design of roadside vegetation planting and maintenance regimes and the development of decision support models for transportation planning.

Alisa W. Coffin

See also [Environmental Impact Assessment](#); [Environmental Impacts of Pipelines](#); [Landscape and Wildlife Conservation](#); [Landscape Ecology](#); [Transportation Geography](#); [Urban Ecology](#)



Further Readings

- Coffin, A. W. (2007). From roadkill to road ecology: A review of the ecological effects of roads. *Journal of Transport Geography*, 15, 396–406.
- Forman, R. T. T., Sperling, D., Bissonette, J. A., Clevenger, A. P., Cutshall, C. D., Dale, V. H., et al. (2003). *Road ecology: Science and solutions*. Washington, DC: Island Press.
- Riitters, K. H., & Wickham, J. D. (2003). How far to the nearest road? *Frontiers in Ecology and the Environment*, 1, 125–129.
- Roedenbeck, I. A., Fahrig, L., Findlay, C. S., Houlahan, J. E., Jaeger, J. A. G., Klar, N., et al. (2007). The Rauischholzhausen agenda for road ecology. *Ecology and Society*, 12(1), 11. Retrieved February 26, 2009, from www.ecologyandsociety.org/vol12/iss1/art11

ENVIRONMENTAL IMPACTS OF TOURISM

Tourism is defined by the United Nations World Tourism Organization as the activities of persons traveling to and staying in places outside their usual environment for not more than one consecutive year for leisure, business, and other purposes. Tourism can also be viewed as a form of development that depends on natural resources and the built environment. The environment is at the core of tourism because tourism depends on maintaining the scenic attractiveness of a destination that people want to see and experience. However, as soon as tourism begins to occur, it changes the environment to facilitate its own development.

At one time, tourism was seen as a clean industry, causing few environmental impacts. Although it is the world's largest industry by employment and is acknowledged to produce significant environmental impacts, tourism is not as detrimental to the environment as other large industries such as mining and manufacturing. It was not until the late 1960s that the impacts of tourism on the environment began to be recognized. By 1970, the first studies of the environmental impacts of

tourism were made. Today, it is widely acknowledged that tourism produces environmental impacts across time and scale. As such, tourism's impacts are difficult to categorize, quantify, measure, and differentiate from those of other activities or natural processes. Tourism's environmental impacts are also often cumulative, coming from many small sources rather than a few large ones. These impacts can be manifest in the form of solid and liquid wastes; air, visual, and noise pollution; congestion; crowding; soil erosion; and deforestation. The intensity, location, and diffusion of these impacts change over time because of factors such as economics, technology, and social and political changes, making assessment difficult and constant monitoring important to maintain environmental integrity. Tourism also leads to further development of destinations due to land development or through infrastructure improvements such as road repair, increased water supply, and increased capacity to handle waste, attracting other economic activities that might otherwise not have come to the destination. Tourism's environmental impacts also originate in various economic sectors and in activities such as hiking, which are not recorded by the economy. Certain tourist activities are also activities of the destination population (entertainment, shopping), and impacts in a tourism-related sector can cause impacts in other unrelated sectors. All these factors make it difficult to determine the exact environmental impacts of tourism. In addition, the type and intensity of impacts depend on the type of development, the characteristics of tourists, and the characteristics of the destination.

To identify the environmental impacts of tourism, an assessment must be made of the physical impacts of tourism development independently of other activities, the baseline environmental conditions at the destination, the types of flora and fauna, and the ecosystem's ability to handle impacts caused by tourism. Often, the environmental impacts of tourism can be placed into one of three categories.

Direct effects are those that originate directly from tourism activities. These include

- sewage disposal,
- increased pollution from tourist transport (e.g., more solid wastes),



Litter left by tourists in the Namib-Naukluft Park, Namibia, Africa

Source: Nigel J. Dennis; Gallo Images/Corbis.

- use of fossil fuels to provide other services for tourists (accommodation and food),
- increased noise levels from entertainment and more traffic,
- hunting and fishing impacts on wildlife,
- damage to fragile beach areas by trampling and development, and
- destruction of vegetation by hikers.

Indirect effects on the environment from tourism development are those that occur in a manner not directly related to tourism activity. For example, an increase in tourism may lead to more hotels being built. Builders must purchase more building materials and transport these materials to the site. Thus, extracting and transporting the natural resources needed to build the hotel have indirect impacts on the environment.

Induced effects are results of the overall development brought about by tourism that occur in a manner unrelated to tourism, either directly or indirectly. For example, development of tourism in a region may lead to infrastructure improvements to accommodate more tourists; these improvements also attract other industries, and the environmental impacts of these new industries would be classified as induced effects. Similarly, when regional employment increases due to tourism, the additional spending by the workers leads to further impacts.

These environmental impacts are manifested at different scales. At the local level, there are impacts such as the destruction of vegetation from hiking, trekking, or mountain biking. Regionally, the development of services for tourists (e.g., restaurants and hotels) and the development of recreational attractions (e.g., golf

courses and theme parks) have environmental impacts. At the global scale, the burning of fossil fuels in different sectors of the tourism industry contributes to climate change through the release of greenhouse gases (GHGs). Many of these impacts can be attributed to the transportation and accommodation sectors of the tourism industry. In the transportation sector, travel by private



car or airplane contributes significantly to GHG emissions. In the accommodation sector, GHG emissions come primarily from energy used for heating, cooling, cooking, water heating, and lighting.

Because of the complexity of the tourism industry and its interconnections with other economic sectors and industries, it is difficult to quantify environmental impacts. Other factors that make it difficult to quantify environmental/ecological impacts and determine the carrying capacity of a destination are the lack of widely accepted environmental indicators, rapid changes in environmental problems stemming from technology and development, and direct versus indirect impacts, which are often difficult to decipher. Carrying capacity is the most widely used concept in quantifying environmental impacts for tourism planning. In a tourism context, carrying capacity is the ability of the environment to support tourism and associated activities without diminishing the quality of the environment and visitor satisfaction. Carrying capacity is an instrumental concept for guiding environmental management and policy making in tourism. However, in practice, applying this concept has proven difficult. First, it is difficult to identify the critical limiting resource to use as a basis for estimating carrying capacity. Second, the number of people a destination can handle depends on the type and intensity of tourist activity. Third, there are often many explanatory factors for environmental degradation, of which tourism might only be one.

Noting that tourism is a form of development that depends heavily on a healthy environment and that tourism changes the environment to facilitate its own development, the industry response has been to promote sustainable tourism and ecotourism. Unfortunately, there is very little environmental monitoring that occurs to accurately provide land managers with scientific data with which to determine the local carrying capacity and plan ecotourism development accordingly. Even so, both ecotourism and sustainable tourism not only seek to limit the negative impacts of tourism on the environment but also attempt to promote conservation through education, responsible behavior, and environmentally friendly development.

Keith Bosak

See also **Carrying Capacity; Ecological Footprint; Ecotourism; Sustainable Development; Tourism**

Further Readings

- Becken, S., & Hay, J. (2007). *Tourism and climate change*. North York, Ontario, Canada: Channel View.
- Briassoulis, H., & van der Straaten, J. (Eds.). (1999). *Tourism and the environment* (2nd ed.). New York: Springer.
- Goeldner, C. R., & Ritchie, J. R. B. (2008). *Tourism: Principles, practices, philosophies* (11th ed.). Hoboken, NJ: Wiley.

ENVIRONMENTAL IMPACTS OF WAR

War strategy has historically been configured by environmental factors in various ways. Armies have used forests for cover, mountains and valleys for strategic advantage, and rivers and waterways for transport of arms and materials. At times, deliberate destruction of natural resources has also been a military strategy through “scorched earth” campaigns that were practiced as early as the Scythian wars against the Persians around 500 BC to deprive the enemy of food crops. Most recently, Saddam Hussein deliberately set ablaze Kuwaiti oil wells in 1991 to diminish the economic potential of the adversary, leading to widespread air and water pollution in the Persian Gulf region in what was called an act of “ecocide.”

Often, strategic targets that are chosen for bombing have a particularly damaging impact on the environment. For example, the bombing in 1999 by the North Atlantic Treaty Organization of the Serbian city of Pancevo (in the former Yugoslavia) targeted fertilizer-manufacturing sites, chemical plants, and a refinery to reduce the productive capacity of the adversary. However, the most notable impact was the release of pollutants across a wide area of the surrounding countryside.

Apart from the direct and deliberate linkages between ecology and war, there are also specific



Several blown-out wells damaged by retreating Iraqi soldiers in Al-Ahmadi oil field burn June 5, 1991, in Southern Kuwait. In 1991, retreating Iraqi smashed and torched 727 wells, badly polluting the atmosphere and creating crude oil lakes. In addition, up to 8 billion barrels of oil were spilled into the sea by Iraqi forces, damaging marine life and coastal areas up to 400 km away. Kuwait sought more than \$16 billion compensation for the environment destruction caused by Iraq during the 1991 Gulf War.

Source: AFP/Getty Images.

indirect impacts of warfare on the environment since resources and physical space are needed to support the military-industrial complex. The ecological footprint of war has increased dramatically over the past century due to the need for massive material and energy sources to build and execute weaponry. Most weapons are still manufactured with metals despite the rise in composite materials for making some aircraft components. The energy consumption for military operations is staggering. For example, the U.S. military consumed 1,100 trillion British thermal units of energy in 2006 (1% of total U.S. energy consumption), which is equivalent to the entire energy consumption of Nigeria. Furthermore, the use of various chemicals, including radioactive

materials, is concentrated in military-industrial complexes. As reported to regulatory agencies, the U.S. military on average generates about 750,000 tons of toxic waste material annually, making it the largest polluter in the country (greater than the five largest chemical companies combined).

The physical space needed for research and testing of military weapons is also staggering. Entire island archipelagos have been displaced for military testing practices, such as Bikini Atoll in the South Pacific (site of nuclear weapons tests) and the Chagos Islands in the Indian Ocean (the site of the British military base of Diego Garcia).

A latent environmental impact of war is also evident in policy prioritization. During times of war, environmental factors are often considered



secondary to national security priorities, and accountability of armed forces in terms of environmental compliance is greatly diminished. For example, prior to the Iraq War, the U.S. military asked for a series of exemptions from environmental regulatory compliance and was granted several allowances pertaining to endangered species, hazardous waste disposal, and air emissions through the National Defense Authorization Act of 2003.

Occasionally, areas that have been reserved for military purposes to prevent any development can become ecologically more biodiverse in their “wild” state. The area near the Hanford nuclear test site in the Columbia River basin in Washington State is an example in this regard. The demilitarized zone between North and South Korea has been used as an example of how a state of hostility between armed neighbors can sometimes inadvertently benefit biodiversity. While this region is filled with land mines, the absence of development has allowed trees to grow to heights that support bird nests for endangered avian species such as cranes.

Guerrilla warfare affects ecosystems when fighters cut down trees for firewood and engage in poaching of forest animals for bush meat or for coveted commodity items such as ivory that can be smuggled to finance the battles. Such effects have been particularly prevalent in the numerous African civil wars and the conflicts in southeast Asia. Counterinsurgency tactics in such circumstances from conventional forces can also lead to extensive environmental damage, as exemplified by the use of defoliants such as Agent Orange during the Vietnam War.

Given the global concerns about the short-term and long-term impacts of warfare and the military-industrial complex, armed forces worldwide are beginning to consider the environmental footprint of war, often spurred by national regulations or threats of litigation from environmental activists. The U.S. army has now established an Environmental Command to “lead and execute environmental programs and provide environmental expertise that enables army training, operations, acquisition and sustainable military communities.”

There is no comprehensive treaty on environmental protection during times of war, though the Fourth Geneva Convention does stipulate that

widespread, long-term, and severe damage to the natural environment can be considered a violation of the agreement. The Environmental Modification Convention is a treaty that could be expanded to cover the larger environmental impacts of war; it has been ratified by most major military powers, including the United States. The United Nations Environment Programme also has a postconflict assessment branch that has been tasked with preparing environmental impact assessments of wars and to conduct some cleanup efforts. However, this unit still depends on mandates from member states on particular cleanup efforts that have to be financed by an ad hoc group of donor countries.

Considering the scale of military operations worldwide, the environmental impact of war is a continuing challenge for the international community.

Saleem H. Ali

See also Military Geography; Military Spending; War, Geography of

Further Readings

- Austin, J. E., & Bruch, C. E. (Eds.). (2007). *The environmental consequences of war: Economic and scientific perspectives*. Cambridge, UK: Cambridge University Press.
- Davis, J. S. (2007). Scales of Eden: Conservation and pristine devastation on Bikini Atoll. *Environment and Planning D: Society and Space*, 25, 213–235.
- Durant, R. F. (2007). *The greening of the U.S. military: Environmental policy, national security, and organizational change*. Washington, DC: Georgetown University Press.
- McCaffrey, K. T. (2002). *Military power and popular protest: The U.S. Navy in Vieques, Puerto Rico*. New Brunswick, NJ: Rutgers University Press.
- Neumann, R. P. (2002). *Imposing wilderness*. Berkeley: University of California Press.
- Williams, J. E., Dombeck, M. P., & Wood, C. A. (2003). *From conquest to conservation: Our public lands legacy*. Washington, DC: Island Press.
- Woodward, R. (2004). *Military geographies*. Oxford, UK: Blackwell.



ENVIRONMENTAL IMPACT STATEMENT

An environmental impact statement (EIS) is a public document presenting the results of an environmental impact assessment (EIA). An EIS is an often lengthy and technical document that describes a proposed public or private development or undertaking and reports on its potential environmental effects and prescribed impact management and monitoring programs. Numerous countries have laws requiring the preparation of an EIS whenever an EIA is completed, including Canada and the United States. The EIS is the primary means of communicating the potential environmental impacts of a project to the public and decision makers such that an informed decision on the proposal can be made.

Origins

The EIS originated from the U.S. National Environmental Policy Act (NEPA) of 1969, becoming law in 1970, which required that federal agencies conduct an EIA and prepare an EIS indicating, for any development or action with the potential to affect significantly the quality of the human environment, that the agencies have assessed and considered the environmental and socioeconomic consequences of the proposal. Since NEPA, the requirements for the preparation of an EIS have extended to include both public and private proposals and undertakings; however, the requirements for the assessment of private undertakings that do not involve a government agency vary from one EIA system to the next.

Many of the first EISs completed, under NEPA and elsewhere, were highly technical in nature, focused on detailed descriptions of project design, characterized by large inventories of biophysical data about the local environment, and completed after the development had already commenced. By the mid 1970s, many EISs were thousands of pages in length, contained multiple volumes of facts, and were often of limited value to the public and to decision makers. It was not until the mid 1980s, with the introduction of the scoping process in EIA, that EISs started to play a more meaningful role in development decision making—available to the public and decision makers prior to development

actions and containing less technical description and more analytical focus on a limited range of environmental effects and their implications. The scoping processes stressed the importance of focusing EIA on a select few priority environmental components, referred to as valued ecosystem components, for the purpose of more efficient and informative impact analysis.

EISs continued to evolve throughout the 1980s and early 1990s in response to several international developments, such as the 1987 report of the World Commission on Environment and Development and the 1992 United Nations Conference on Environment and Development (the Earth Summit), placing increased emphasis on the interrelationships between project actions, environmental change, and the resulting social and economic impacts. In recent years, with the growth of sustainability awareness, EISs have also begun to address the potential positive impacts of development proposals.

Contents of an EIS

The content of an EIS varies depending on the regulatory and policy requirements of the EIA system and on the complexity of the proposal. In the United States, for example, the requirements of an EIS are detailed under the 1978 U.S. Council of Environmental Quality Guidelines. In Canada, general guidance is provided under the Canadian Environmental Assessment Act and by the Canadian Environmental Assessment Agency. All EISs must include a description of the proposed action, including a statement of its purpose, and a description of the affected environment that is sufficient to allow an assessment of the potential impacts of the proposed action. An EIS typically consists of six major components:

1. A description of the project, including a statement of the purpose of and need for the proposed action
2. A description of the affected environment
3. Identification of alternatives to the proposed action and alternative means of carrying out the proposed action
4. Analysis of the impacts of the proposed action and its alternatives on the biophysical and human environment, including also direct and induced impacts



5. A statement of significant environmental effects and the strategies proposed for impact management
6. Identification of monitoring needs and programs

Enduring Concerns

An EIS is the primary means of communicating the results of an EIA to decision makers and to the public. EISs are now completed earlier in the development planning and decision-making process, are more integrative of biophysical and human systems, and are more responsive to emerging sustainability issues and concerns. However, many EISs are still largely inaccessible documents—lengthy and written in a language that is not easily understood by the nonengineer or nonscientist. If the technical and scientific language of an EIS is not translated to a lay language that is easily understood, then the objective of the EIS to communicate the potential environmental impacts of a proposal to the public and to decision makers such that an informed decision on the proposal can be made is not achieved.

Bram F. Noble

See also **Environmental Impact Assessment; Environmental Management; GIS in Environmental Management; Public Policy, Geography of; Sustainable Development; United Nations Conference on Environment and Development**

Further Readings

- Canter, L. W. (1996). *Environmental impact assessment* (2nd ed.). Boston: McGraw-Hill.
- Noble, B. F. (2006). *Introduction to environmental impact assessment: A guide to principles and practice*. Don Mills, Ontario, Canada: Oxford University Press.
- Page, J. (2006). Make it easy on your readers: Ideas on environmental impact document focus, organization, and style. *Impact Assessment and Project Appraisal*, 24, 235–245.
- Petts, J. (1999). *Handbook on environmental impact assessment*. Oxford, UK: Blackwell Science.



ENVIRONMENTAL JUSTICE

Environmental justice is both a social movement and a research frame. Rooted in the U.S. civil rights movement of the 1950s and 1960s, the idea of environmental justice gained traction in the United States during the early to mid 1980s. Proponents of environmental justice seek to ameliorate circumstances where people of color (e.g., African Americans, Asians, Latinos) and low-income earners (i.e., people below the poverty line and the working poor) are disproportionately exposed to environmental harms and/or lack access to environmental benefits. Advocates of environmental justice believe that all people—irrespective of race, ethnicity, gender, or class—have the right to live in a clean, healthy, and safe environment and to enjoy equal access to safe and healthy workplaces, schools, and recreation areas and to safe and nutritious food.

This entry considers the main concepts and issues that are central to environmental justice. It begins by reviewing the historical development of the environmental justice movement and then examines what we mean by “injustice” or “inequity.” Next, the various mechanisms behind environmental injustice (i.e., structures, processes, institutions, agencies) are considered. Academic responses to the social movement are discussed, with a focus on geographers’ contributions. Finally, the entry discusses recent developments in both the social movement and academic literature.

It is important to note that environmental justice is related to but different from environmental racism. Environmental justice is also different from ecological justice or justice to nature. Those concepts refer to efforts to protect animals, plants, and vulnerable habitats and recognize the “intrinsic” value of nature. Some commentators have distanced environmental justice from ecological justice, preferring instead to use the term *social justice environmentalism*. In reality, these three concepts have much in common and often overlap.

The Social Movement

When the environmental justice movement began is uncertain. Some commentators suggest that the movement began in the late 1960s. What is clear



is that by the early 1980s the movement had noticeably mobilized around two concerns: (1) getting law makers and decision makers to recognize that so-called minority groups and the poor were disproportionately exposed to environmental hazards and (2) developing effective remedies for these problems.

During the 1980s, groups of concerned citizens in the Southern United States, accompanied by religious leaders and politicians of color, mobilized to help vulnerable people combat toxic landfill facilities, hazardous industries, and other locally unwanted land uses within their communities. The movement has since expanded from a series of disparate grassroots initiatives to a recognizable collective with an international agenda.

Originally, environmental justice activists asserted that mainstream environmental groups such as Greenpeace, Sierra Club, and the Wilderness Society had ignored the plight of socioeconomically marginalized and vulnerable communities, focusing solely on nonhuman species. The movement's initial purpose was therefore to develop an alternative environmentalism, one based on direct action, social inclusiveness, and human concerns. More recently, many mainstream environmental groups have assisted in environmental justice struggles.

Early examples of successful campaigns include a predominantly African American community's fight against the siting of a PCB (polychlorinated biphenyls) landfill in Warren County, North Carolina; a battle by Latino mothers of East Los Angeles to prevent the construction of a waste incinerator in their community; and campaigns by Latino farmworkers against poisoning from toxic agricultural chemicals. The early 1980s to the early 1990s was a decade of progress for the movement. Activists garnered increasing publicity and leveraged local, state, and federal action against practices of intentional targeting of socioeconomically marginalized and vulnerable communities for toxic and unwanted land uses. They achieved this through multiple actions including lobbying, political incorporation, forced buy-outs and relocations, and lawsuits. By the early 1990s, the movement spanned the United States and encompassed issues as diverse as industrial "cancer alleys," uranium enrichment facilities, biotechnology labs, brownfield redevelopment,

"transit racism," lead paint in old houses, and radioactive waste sites. With the rapid expansion of the movement came formal organizations, such as the Citizens Clearinghouse for Hazardous Waste, that served to distribute information, enhance communication between groups, and promote collective action.

Major milestones included a U.S. General Accounting Office (GAO) investigation into the siting of hazardous waste landfills and low-income, nonwhite communities, and the subsequent report, which found a strong correlation between landfills and communities of color. This was followed by a report from the United Church of Christ, which corroborated the GAO findings and concluded that communities of color were intentionally targeted as recipients of hazardous waste and unwanted land uses. This period culminated with the passage of the Clean Air Act (1990), the first national summit of environmental justice advocates in Washington, D.C. (1991), and the formation of the U.S. Environmental Protection Agency's National Environmental Justice Advisory Council (1993). The movement arguably reached its zenith in 1994, when President Bill Clinton signed Executive Order 12989 to combat the unjust actions of government agencies in administering environmental law.

The movement has diversified since the mid 1990s and become more global in its reach. Participants from the United States attended international conferences and symposia on the environment—such as the United Nations Conference on Human Settlements, Habitat II in Istanbul—and formed alliances with people from developing countries. Internationally, people began to notice that while many environmental problems (e.g., ozone depletion, the Chernobyl disaster, climate change) had global impacts, these were disproportionately felt by impoverished and ethno-racially marginalized populations.

Geographers' Contributions

Environmental justice scholars have worked alongside activists to research environmental inequities and to substantiate claims of injustice. Although some scholars have criticized methods used for investigating environmental inequities, suggesting that inferior methods have led to



A protest march on October 21, 1982, in Warren County, North Carolina, where the state planned to locate a landfill for disposal of PCB-contaminated waste. Front center is Reverend Joseph Lowery, head of the Southern Christian Leadership Conference founded by the late Dr. Martin Luther King Jr. Many in the community contended that Warren County was targeted because the majority of its citizens was black and poor. Officials denied that race played a part in the selection of the hazardous waste site. Although the protest was unsuccessful, it drew national attention to the issue of environmental justice.

Source: © Bettmann/Corbis.

spurious findings, many scholars have corroborated claims of injustice made by ordinary citizens. Some scholars have themselves become environmental justice advocates and activists.

Geographers have strongly contributed to the now substantial volume of scholarly literature on environmental (in)justice in its various guises. These geographers have played a major role in identifying where, when, how, and why environmental injustice occurs (e.g., revealing vulnerable populations, identifying park-deprived communities, and showing how “minority” ethno-racial groups are disproportionately incarcerated). Geographers have also developed numerous methods to identify and ameliorate instances of

injustice. These range from mapping the connections between vulnerable populations and sources of environmental harm using geographic information systems (GIS), through mobilizing and empowering citizen resistance, to acting as expert witnesses and lending scholarly credibility to citizens’ struggles for justice. Perhaps most important, geographers have shown how many environmental injustices are place-based phenomena. Understanding that regional racial formations work across a range of scales and through a variety of mechanisms to instantiate and perpetuate environmental inequities is a key contribution from geographers. Similarly, geographers have recognized that different conceptions of justice



shape on-the-ground inequities and determine the efficacy of potential remedies.

Theories of Justice

Theorists generally recognize that there are four basic expressions of equity. These are (1) equitable distribution—all members of society have uniform access to environmental benefits and are identically exposed to environmental harms, regardless of who they are; (2) compensatory equity—environmental benefits are redistributed to the most disadvantaged and vulnerable populations, offsetting inequalities based on class, race, or gender differences; (3) demand distribution—the most vocal members of society are allocated the most resources; and (4) market-based distribution—people who can afford to pay for goods or services get the best access to those goods or services. Knowing how these different versions of justice are mobilized in environmental justice disputes can enable us to understand better how environmental inequities occur.

Mechanics of Injustice/Inequality

The processes that configure environmental injustices are rarely simple. Oftentimes, several imbricated mechanisms are responsible for why particular communities are exposed to environmental harms or why they have limited access to environmental benefits. These mechanisms include intentional targeting, differential law enforcement, market factors, biased decision making, and limited opportunities for public participation. Running through many of these explanations is what the geographer Laura Pulido has termed *white privilege*. White people typically have better access to resources such as income, education, and political connections by virtue of socioeconomic and ethnic or racial systems of privilege. These privileges enable most whites to secure the most salubrious environments and to escape the worst hazards.

Intentional Targeting

Many case studies have reported that ethno-racial minority groups and the poor have been systematically targeted by noxious industries and hazardous land uses as sites for their operations. Researchers assert that these social groups lack the

power to resist the siting of hazardous facilities in their neighborhoods because they are politically disenfranchised or unemployed or have low-paying jobs, may have higher numbers of dependents, may not speak the dominant group's language, may have low education levels, may lack health insurance, or may be undocumented workers who are at risk of being deported if they speak up.

Differential Enforcement of Environmental Laws

Research has demonstrated that often government agencies take longer to respond to complaints from low-income, nonwhite communities and are less likely to take punitive action against polluters within these communities and that when they take action, the remediation is less stringent than in white and wealthy communities. Furthermore, people of color are less likely to be employed within these agencies, potentially leading to biased decision making. Commentators label such practices as “institutional discrimination.”

Market Mechanisms

Some scholars—from both ends of the political spectrum—have argued that claims of injustice may be difficult to substantiate if we cannot tell who or what came first—the hazardous environments or the vulnerable community. What this suggests is that if the hazard came first, then the outcome is not an injustice. But vulnerability is associated with notions of choice. The less choice that people have, the more vulnerable they are to exploitation and/or harm. Market effects can compound this problem. When people have low-paying jobs or depend on welfare, they may only be able to afford the cheapest housing. This housing may be dilapidated, infested with vermin, contain lead paint or asbestos, or be located near a polluting factory, landfill, waste incinerator, or other potentially harmful sites or on flood-prone or radioactive land. Likewise, even when an environmental hazard preceded the community, that is, existed prior to the arrival of local inhabitants, urban encroachment means that housing may eventually be constructed near that hazard. And because land values will be lower around hazardous sites, vulnerable populations are likely to become disproportionately concentrated nearby—leading to injustice.



Sociodemographic Change

When a community changes from being predominantly white, or even a mixed community, to one constituted predominantly of people of color, there is a significantly greater likelihood that it will be the recipient of noxious or unwanted land uses. This is largely due to the combination of “white flight” (where wealthy, white residents flee inner-city locations in search of suburban refuges, leaving behind those people without means of escape) with institutional discrimination and intentional targeting.

Ineffective or Nonexistent Public Participation

Many environmental justice advocates assert that inequalities are produced through decision-making processes that are not inclusive. The literature is filled with cases of “back-room deals,” decisions being made “behind closed doors,” and polluting facilities that are approved with little or no community input. Without open, accountable, transparent, and inclusive decision-making processes, the interests of vulnerable communities will likely be subordinated to those of powerful corporations and landholders.

Regional Racial Formations

Finally, how ideas of race and ethnicity are mobilized for different ends in different places is a key concern for geographers studying environmental injustice. Geographers have recognized that race and ethnicity are produced as sets of social relations, which act to create and reinforce disadvantage and vulnerability. For example, if decision makers, lending institutions, and enforcement agencies are dominated by wealthier whites, power relations will likely favor their interests over others.

Questions Regarding Methods and Measurement

Geographers have helped refine how we identify and measure instances of environmental injustice, recognizing that environmental justice research requires more than just investigation of patterns of distribution of environmental hazards or historical processes that fostered unjust landscapes.

Research must also examine how communities respond to environmental hazards, how coalitions of resistance develop, how government agencies define and address environmental justice issues, how multiple forms of discrimination can lead to environmentally unjust outcomes, and which remedies are effective against various forms of inequality. Many recent advances in environmental justice research have come from alternative methodologies.

Changing Methodologies

Two decades ago the research emphasis was on proving that environmental injustice existed. Researchers favored quantitative methods such as GIS, which allowed them to examine spatial units (e.g., census collection districts, postcodes, neighborhoods) for ethno-racially differentiated patterns of exposure to environmental harm. Geographers and others found that depending on the measure used, injustices manifested in different places or at different scales. Susan Cutter, for example, illustrated how communities affected by hazardous materials transportation varied according to whether the density of the transport network was examined, the unit of measurement was changed (e.g., spills per mile), and population measurements were included (e.g., spills per capita). For a time, critics and proponents of environmental justice fought over issues such as incomplete data sets, inaccurate data, the variables that were included for analysis, and difficulties with spatially related variables that created problems in attributing causality. More recently, researchers have moved from simply identifying problems to examining how affected communities have responded to these problems. This transition reveals a philosophical shift from treating affected communities as passive victims to active agents.

Quantitative analyses have been joined and strengthened through the use of qualitative techniques, typically through case study approaches. They include archival research, oral histories, ethnographies, focus groups, discourse analysis, and performative methods. This shift has partly been driven by the growing recognition that incidents and experiences of injustice are historically and contextually contingent. For example, although Native Americans and Australian Aboriginals



likely experience similar impacts from the mining and dumping of radioactive materials in their communities, their experiences of colonization, the ways in which racial formations evolved in their respective homelands, and their capacities for, and types of, resistance are likely to be very different. Geographers have thus become more attuned to issues of essentializing environmental injustice.

Scale

Geographers have contextualized environmental inequalities and potential remedies for injustice by investigating how scale affects environmental (in)justice. Research has shifted from a singular focus on the community or neighborhood to cover the full range of geographic scales. Incidents of injustice affect individual bodies—expressed through harms such as cancer, asthma, birth defects, or miscarriage. Hazards occur in homes, workplaces, and education venues; sites of injustice include parks, factories, child care centers, farms, offices, and schools. Inequalities are increasingly manifest across scales from neighborhoods to cities and from states to nations. For example, the global electronic waste trade connects villages, cities, and nations in new webs of exchange and inequality. By studying environmental justice issues across various scales, geographers can illuminate the complex processes responsible for environmental inequalities.

Expanding the Research Agenda

Geographers have begun to expand the environmental justice research agenda. Issues studied recently include children's access to parks and playgrounds, the spatial distribution of recreation facilities, access to fresh water in the developing world, the impact of neoliberal policies on urban forest management, how urban landscapes may foster obesity in minority neighborhoods, and the potential impacts of climate change on socioeconomically and ethnically marginalized populations.

Theoretical frames are shifting too as geographers seek out alternative explanations for injustice. Theoretical frames including political ecology, human ecology, cultural landscape, and

ecological modernization are expanding our understanding of how inequalities occur, how they are situated within broader socioecological relations, and how problems might be remedied. For instance, geographers are showing how natural disasters such as Hurricane Katrina are produced through socially mediated ecologies, starkly illustrating how people of color and the poor bear a disproportionate burden of exposure to harm. Katrina has illustrated how the impacts of environmental hazards are increasing not only due to biophysical drivers such as climate change but also due to the intersection of sociodemographic, political, and ideological factors that concentrate vulnerable people in hazardous places and produce harmful nature-society relations.

New analytical techniques such as material flows and lifecycle analyses from fields such as industrial ecology show how environmental harms span commodity chains. They enhance our knowledge of hazards and their spatial and temporal impacts, illustrating, for example, how sites of extraction, production, distribution, and disposal (e.g., mines, factories, railways, and landfills) all potentially generate environmental harms, which affect vulnerable populations in diverse locales. These analyses also show how demographic change, land use planning practices, real estate and property markets, local and national politics, systems of global trade, struggles of access to resources, and war mediate the impacts of environmental harms.

Finally, new research on adaptive capacity and local resilience to hazards is teaching us lessons about when communities are successful in ridding themselves of injustice. Such studies offer us a more nuanced appreciation of why particular environmental laws are not enforced, which lawsuits are successful, where grassroots activism has made a difference, where planning codes have redressed inequality, and whether disaster preparedness programs have actually reduced risks.

Jason Byrne

See also **Cancer, Geography of; Class, Nature and; Differential Vulnerabilities to Hazards; Ecological Justice; Environmental Law; Environmental Racism; Ethnicity and Nature; Industrial Ecology; Justice, Geography of; Landfills; Locally Unwanted Land Uses (LULUs); Nature-Society Theory; Not in My Backyard**



(NIMBY); Race and Nature; Social Construction of Nature; Social Justice

Further Readings

- Agyeman, J. (2005). *Sustainable communities and the challenge of environmental justice*. New York: New York University Press.
- Bullard, R. D. (Ed.). (2005). *The quest for environmental justice*. San Francisco: Sierra Club Books.
- Cutter, S. L., Mitchell, J. T., & Scott, M. S. (2000). Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina. *Annals of the Association of American Geographers*, 90, 713–737.
- Holifield, R. (2001). Defining environmental justice and environmental racism. *Urban Geography*, 22, 78–90.
- Houston, D. (2008). Crisis and resilience: Cultural methodologies for environmental sustainability and justice. *Continuum: Journal of Media & Cultural Studies*, 22, 179–190.
- Iles, A. (2004). Mapping environmental justice in technology flows: Computer waste impacts in Asia. *Global Environmental Politics*, 4, 76–107.
- Low, N. (Ed.). (1999). *Global ethics and environment*. London: Routledge.
- Pastor, M., Jr., Sadd, J., & Hipp, J. (2001). Which came first? Toxic facilities, minority move-in, and environmental justice. *Journal of Urban Affairs*, 23, 1–21.
- Pellow, D. N. (2000). Environmental inequality formation. *American Behavioral Scientist*, 43, 581–601.
- Peluso, N. L., & Watts, M. (Eds.). (2001). *Violent environments*. Ithaca, NY: Cornell University Press.
- Pulido, L. (2000). Rethinking environmental racism: White privilege and urban development in Southern California. *Annals of the Association of American Geographers*, 90, 12–40.
- Pulido, L., Sidawi, S., & Vos, R. (1996). An archaeology of environmental racism in Los Angeles. *Urban Geography*, 17, 419–439.
- Wolch, J., Wilson, J. P., & Fehrenbach, J. (2005). Parks and park funding in Los Angeles: An equity-mapping analysis. *Urban Geography*, 26, 4–35.

ENVIRONMENTAL LAW

Environmental law refers to the array of rules guiding human behaviors that affect the physical and biological world. These rules define what is prohibited, allowed, or required of people in a given situation and the penalties for transgressing those rules. While rules may arise from a wide range of sources from families to governments, this entry outlines the current framework of U.S. environmental law. It ends with a brief overview of the growing trends of criminalization and internationalization in environmental law.

U.S. Common Law

The first U.S. environmental laws existed within the common law, a system of law that originated in England based on the decisions of judges from previous cases as opposed to laws created by legislative bodies. Within common law, tort law provides remedies for injuries to a person's body, property, and rights. For example, a pollutant from one person entering another's property may constitute a violation of the common law rule of trespass, which prohibits invasion of a person's property. Several potential remedies exist for the injured party, including the costs to restore and rehabilitate the damaged environment.

U.S. Federal Environmental Law

Beyond common law, federal, state, and local legislatures and government agencies have created a wide array of environmental laws and regulations. The U.S. federal system limits the national government to those powers expressly stated in the U.S. Constitution, with the remaining powers retained by state governments. States have traditionally handled environmental matters under their police powers, the general authority to regulate for citizens' health and welfare. The federal government has largely developed the legal framework for environmental protection based on its authority to regulate commerce, foreign relations, and federal property. Moreover, federal law is the supreme law of the land, and federal regulation may preempt any conflicting state laws. Nonetheless,



state and local governments continue to play an important role in creating and implementing environmental laws and regulations.

Environmental laws generally address specific problems such as water pollution or hazardous waste; however, one major modern environmental law applies across all environmental issues. The National Environmental Policy Act of 1970 (NEPA) requires identification of environmental, social, and economic effects and alternative courses of action for all federal activities that could “significantly affect” the human environment. This occurs through the creation of environmental impact statements (EIS). Within this process, government agencies elicit and respond to public comments before making a final decision. The record of the final decision must include justification for the decision, but it only requires consideration of alternatives and the public’s comments. Thus, NEPA does not guarantee any protection for the environment, only that environmental effects are considered in government decision making.

Pollution control is the prototypical environmental concern and is exemplified by the Clean Air and Clean Water Acts. The Clean Air Act (CAA) requires the U.S. Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS)—concentration limits for “criteria” pollutants, those likely to pose a danger to human health and welfare. States must then devise implementation plans to meet the NAAQS, with EPA providing final approval of those plans. Air sheds on both ends of the spectrum, those not meeting NAAQS and those with high air quality, generally require stricter emission standards or particular technologies for new or modified sources to either improve or protect air quality in those geographic areas. Additionally, the federal government sets technology standards for pollutant sources not covered under the state implementation plans, hazardous pollutant sources, and mobile sources, including automobiles.

The Federal Water Pollution Control Act, commonly known as the Clean Water Act (CWA), aimed to eliminate water pollution discharges by 1985. While water pollution has decreased, it still exists, and the CWA provides the continuing legal authority for federal management of water pollution. The CWA approach involves technology

requirements for “point sources,” which are discharges via a “discrete conveyance” such as pipes and ditches. The EPA provides grants to projects aimed at reducing nonpoint sources, for example, polluted snow or rain runoff from agricultural operations or parking lots. Additionally, states must set water quality standards and total maximum daily loads for pollutants in specific water bodies.

Two principal laws regulate hazardous wastes. First, the Resource Conservation and Recovery Act (RCRA) created a “cradle-to-grave” approach that governs the generation, transportation, treatment, storage, and disposal of hazardous wastes. Second, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), commonly known as Superfund, funds federal government cleanup of hazardous waste sites, releases, and spills. Superfund also assigns responsibility for cleanup or the costs of cleanup to almost any party even remotely involved with the site, release, or spill, even if their actions occurred before the passage of the Superfund legislation. Additional laws governing toxic substance include the Toxic Substances Control Act, Residential Lead-based Paint Act, and the Federal Insecticide, Fungicide and Rodenticide Act.

Several laws govern the use of natural resources including energy production, water usage, public lands, timber harvest, mining, fishing and hunting, zoning, and soil conservation. Within this body of natural resource issues, two areas are frequently included within the ambit of environmental law, wetlands and endangered species protection. The CWA requires a permit for any discharge into wetlands and as implemented helps prevent many forms of potential wetland degradation, including draining, or at least requires the creation or repair of wetlands to offset any losses. The Endangered Species Act aims to halt the extinction of species and rebuild endangered and threatened species populations, mainly by prohibiting anyone from harming, harassing, or killing listed species.

Criminalization in Environmental Law

Criminalization is playing an increasingly important role in the realm of environmental



law. The law is divided between civil and criminal codes, with the type and severity of penalties (e.g., imprisonment for crimes) constituting the main differences between the two. Many environmental laws include criminal penalties, and governments are increasingly prosecuting polluting activities as crimes. Additionally, criminal prosecutions for activities related to the degradation of the environment have relied on laws not directly pertaining to the environment, such as the organized crime-focused Racketeer Influenced and Corrupt Organizations Act and securities laws.

International Environmental Law

Transboundary pollution has increasingly led to the internationalization of environmental law. International law includes customary law and agreements between nations. International customary law is based on the past practice of states. For example, in the Trail Smelter Case, in arbitration between the United States and Canada over sulfur dioxide pollution, the tribunal recognized the duty of nation-states to prevent harm to other states caused by pollution based on the past practices of nations.

Nations may also agree to limit their environmentally detrimental actions through bilateral or multilateral treaties promoted by the United Nations Environment Programme. For example, the Montreal Protocol on Substances that Deplete the Ozone Layer generally succeeded in reducing the use of chemicals that deplete the ozone layer around the globe. Additionally, other international agreements have ancillary effects on the environment, most notably trade laws that govern the production, transportation, and sale of goods in international markets.

Jeffrey W. Henquinet

See also **Energy Policy; Environmental Impact Statement; Intergovernmental Environmental Organizations and Initiatives; Law, Geography of; Neoliberal Environmental Policy; Regional Environmental Planning; United Nations Environmental Summits; United Nations Environment Programme (UNEP)**

Further Readings

- Adams, D. A. (2007). *Renewable resource policy* (2nd ed.). Washington, DC: Island Press.
- Buck, S. J. (2006). *Understanding environmental administration and law* (3rd ed.). Washington, DC: Island Press.
- Kubasek, N. K., & Silverman, G. S. (2007). *Environmental law* (6th ed.). Upper Saddle River, NJ: Prentice Hall.
- Ostrom, E. (1990). *Governing the commons*. Cambridge, UK: Cambridge University Press.



ENVIRONMENTAL MANAGEMENT

The changing relationships between humans and their environments are fundamental elements of geographical knowledge and research. Humans are in complex and evolving relationships with their surroundings, and species are connected through interlocking relationships. Issues of environmental management are also gaining increasing attention, and communities worldwide are aware of the significant implications of environmental degradation, including accelerated climate change, water scarcity, and decreasing biodiversity. In response to the impacts of humans on the environments in which they live, the disciplines concerned with environmental management have developed a means to assess, control, and manage those relationships. While the discipline of geography is an important contributor to the discourses of environmental management, it relies on specialist knowledge from other environmental sciences and institutional management areas to operationalize environmental management.

In seeking to understand and establish management systems and processes, the dominant institutions and discourses of environmental management have used the natural sciences as a means of classifying aspects of the environment and separating them from each other and from humans. For example, reliance on scientific classifications of environmental components can facilitate the division of responsibility for the environment into



distinct functions and structures across government agencies and community groups. In asserting control over specific human-environment relations, these dominant discourses have created an artificial separation of humans from the “natural” environment. Environmental management is more than simply using science to classify and make sense of the world in order to assert human control as management. Recognizing the connections and inherent relationships among species provides windows for more ethical and contextualized engagements with place. Reorienting and balancing environmental management discourses to recognize the importance of process and connection provides more robust and appropriate approaches to ensuring socially just ecological sustainability.

This entry contrasts this dominant “managing the environment” approach with approaches to human-environment relations that highlight the connectivity and relationships between all species, including humans. In particular, it balances the discourses of environmental management by providing space for marginalized approaches, such as indigenous understandings, which focus on the connections between people and place and the interrelationships between all species. It advocates acknowledgment of and commitment to diversity in understanding and managing human-environment relations in the future.

Managing the Environment

Most dominant discourses of environmental management focus on the need for humans to manage the environments in which they live. Western natural science is often the unquestioned basis for such management decisions and is considered the most important and appropriate mechanism for understanding humans’ relationships with the environment. Many textbooks, for example, argue that science should be the sole approach for making environmental management decisions. Scientific discourses typically allow for unambiguous categorization of the environment into its components, as if those categories are self-evident and universal—an approach that is often displayed by government environmental agencies, which separate, for example, the functions of

water management from air quality, land from sea, and conservation areas from urban spaces. Such a perspective denies the intimate connections among these various environmental domains.

When they are viewed from a scientific perspective that is assumed to be objective and value free, environmental issues and resources can be quantified, understood, and thus managed. Water can be allocated (or overallocated in some areas), commercial species can be harvested to sustainable levels, carbon emissions can be measured and traded, and areas of high biodiversity can be “conserved” in a so-called natural state. Environmental management systems deliver quantified and objective targets, such as the international standard ISO 14000 of the International Organization for Standardization, which establishes targets and milestones for organizations to minimize their environmental impacts. Such approaches have been important for reforming and restructuring modernist resource management regimes.

Eurocentric science was developed on the assumption that experiments that could repeatedly produce the same results provide an understanding of nature regardless of the specificity of context and independent of local place effects (i.e., universal laws). In short, most natural science has treated local geographic context as only marginally relevant to the application of broad theories of how nature works. In developing taxonomic systems, in which the world could be understood and classified, scientific discourses also represented humans as separate from and superior to their environment, in the process justifying management intervention and control. Various elements of the environment, such as forests, wetlands, fisheries, or water bodies, which in reality only exist in intimate connection to one another, could thus be theoretically separated from their context and from one another and managed as discrete units or resources rather than as complex geographical and ecological totalities. By reducing the elements of the environment to “resources,” their functions and values could be separated from their connections to each other. For example, water is generally considered as a quantified input for use in irrigation and for household consumption, and forests and trees are seen as simply a supply source for timber. Yet



these elements are not simply abstract resources but form critical environments for numerous species. By separating such elements from their context, the connections that bind them together are silenced, and in the process, much is lost.

Despite the assumed separation of humans from the environment as managers, dominant discourses typically see the elements of the environment only in relation to themselves, as if they existed independently of human intervention and modification. For example, in Australia, legislative definitions of the environment never allow the biophysical environment to be defined in isolation; it is always defined in relation to people, and therefore, the social aspect is always present. While there is a large body of work about biophysical relations and connections, these understandings must move beyond the biophysical realm to consider its elements in light of their relationships to human beings and social structures. Indeed, many elements of the environment are framed as “natural resources” that are valued and understood for their contribution to humans. In the process, environmental management is easily conflated with natural resource management, as if the governance of human relationships with place is best achieved in terms of managing resource values. For example, governments worldwide have prioritized agricultural, forestry, and the soil sciences to focus on the potential of primary industries, and environmental assessments for proposed developments are often done with respect to how they serve dominant political or economic purposes. Implicitly, the inextricable connections between humans and their environs still exist within these approaches, yet dominant discourses of environmental management position the “environment” as separate from people in a manner that facilitates the use, commodification, and often exploitation of the natural world.

Connectivity and Relationships

Universalizing scientific discourses have often silenced other approaches concerning human relations to the environment. For example, many ecologists, indigenous peoples, and anthropologists and geographers, and even

some environmental managers, argue for a richer and more robust version of environmental management that goes beyond the simple engineering of abstracted resources toward an understanding of the relationships and connections between species and, critically, the embedded nature of humans within these relationships. Such approaches do not view people and the environment as separate, disconnected worlds but rather as two domains inseparable intertwined with one another.

Indigenous perspectives on environmental management typically provide a clear alternative to dominant discourses by acknowledging the connections between, rather than the separation of, nature and culture, a view in which humans are not considered simply as managers. Such views do not perceive environmental “management” as human actions on the environment. Instead, they articulate such activities as taking place within and being accountable to an intricate web of relationships and processes in which humans have important relationships with their environment and, as such, rights and responsibilities in a form of mutual obligation. Indeed, many indigenous groups recognize the role of environmental factors beyond just human needs to include the rights and agency of other species. Indigenous approaches to understanding management often position human activities within the webs of the relationships in which they are embedded, recognizing the inherent codependence of nature and culture. Humans are not separated from, or positioned as superior to, their environments. Their actions are performed as part of an intersecting group of reciprocal rights and responsibilities. There are increasing examples of the ways environmental management can be reconsidered to explicitly incorporate the importance of human and environment relations.

The Great Whale River Hydro-Electric Project, which was proposed for development in Northern Quebec, Canada, in the early 1990s, provides an example of the development of innovative assessment guidelines that explicitly sought a multicultural definition of the environment. The guidelines acknowledged more than simply the ecological components of the proposed development, to include the ethical and practical aspects



as well. While working to understand the various ecosystem elements, they aspired to something beyond a simple encyclopedic account. The focus was on what was referred to as “valued ecosystem components” and recognized that the relevant values were constructed within and were reflective of a “multicultural definition of environment,” which took seriously the concerns, fears, aspirations, and values of all the affected communities (including but not limited to scientists). This approach required an assessment of the environmental effects of the proposal in terms of important scientific, cultural, and health aspects that needed to be understood, documented, and managed to ensure social and ecological sustainability.

The “cultural flow” approach to water management is another innovative approach that recognizes and respects the multiple interests and relationships within environmental systems. Focusing on cultural flows encourages a consideration much broader than the commercial networks of water or simply the constituent elements of the systems. Relationships between humans and place, the core of geographic analysis, are made explicit in these approaches. These examples provide windows of opportunities for envisaging alternative approaches to managing the environment, focusing on the importance of process, engagement, and relationships rather than the abstraction, objectification, and intervention that Eurocentric science provides for within prescribed outcomes.

Conclusion

Albert Einstein once said that we cannot solve problems by using the same kind of thinking we used when we created them. Eurocentric scientific thinking, in its efforts to make sense of the world, has frequently focused on the ways in which the environment can be understood and managed as separate, independent components of a complex whole. Dominant approaches to environmental management have created a large and important accumulation of information about the biophysical nature of the environment and the impacts of human behavior on it. However, in doing so, humans are discursively positioned as separate

from and superior to the environment, which has allowed for the abstraction of elements, such as water, to be quantified, justifying intervention and management control by humans. This separation is in fact what has enabled and encouraged natural resource allocation and exploitation, which at times has led to overallocation and overexploitation. The dominance of Eurocentric science as the appropriate response to environmental degradation has meant that alternative views that focus on connections and relationships have often been ignored. Thinking differently about the ways in which humans relate to their environments, the core of geographic analysis, may provide new ways of addressing today’s environmental problems.

Samantha L. Muller and Richard Howitt

See also **Community-Based Conservation; Conservation; Drylands; Eurocentrism; Governmentality and Conservation; Indigenous Environmental Knowledge; Nature; Nature-Society Theory; Resource Economics; Resource Geography; Resource Tenure; Social Construction of Nature; Soil Conservation; Spatial Strategies of Conservation**

Further Readings

- Howitt, R. (2001). *Rethinking resource management: Justice, sustainability and indigenous peoples*. London: Routledge.
- Howitt, R., & Suchet-Pearson, S. (2006). Rethinking the building blocks: Ontological pluralism and the idea of “management.” *Geografiska Annaler: Series B, Human Geography*, 88, 323–335.
- Muller, S. L. (2008). Accountability constructions, contestations and implications: Insights from working in a Yolngu cross-cultural institution, Australia. *Geography Compass*, 2, 1–19.
- Robin, L. (2007). *How a continent created a nation*. Sydney, New South Wales, Australia: University of New South Wales Press.
- Weir, J. (2008). Connectivity. *Australian Humanities Review*, 42, 153–164.



ENVIRONMENTAL MANAGEMENT: DRYLANDS

Dryland environmental management systems comprise the individual and collective strategies used by resource users to preserve the biological productivity and the economic and social benefits derived from dryland environments. Approaches to managing dryland environments are as diverse as the environmental and social factors that shape human use and management of dryland resources. Drylands encompass a gradient of moisture-deficient zones that span the world's hyperarid, arid, semiarid, and dry subhumid areas. Ecological patterns within drylands exhibit considerable diversity, incorporating woodlands, grasslands, scrublands, and deserts. This diverse ecology supports a range of human livelihood systems, including dryland farming, pastoralism, extractive activities, and large-scale urban settlement. Because dryland resources support the livelihoods of a disproportionate number of people living in extreme poverty as well as growing populations in dryland urban centers, the sustainable management of dryland environments constitutes one of the major global environmental challenges of the 21st century.

Whereas specific management regimes vary by environmental conditions and patterns of resource use, dryland management is typically adapted to extreme temporal and spatial variability of precipitation and water resources and, consequently, variability in patterns of vegetation and wildlife. As a result, human management systems emphasize resilience in the face of climatic extremes and uncertainty. Mobility, flexibility, and opportunism are hallmarks of many local systems of dryland management. Dryland environmental management often involves managing human livelihood activities in relation to limited water resources while addressing the interrelated problems of loss of vegetative cover, soil erosion, salinization, and loss of biological diversity.

Dryland Environmental Management Challenges

Patterns of environmental management reflect the range of institutions, knowledge, practices, and

capacities for realizing environmental and social objectives in dryland environments while limiting the impacts of human production systems. Although drylands are often thought of in terms of their biophysical constraints, dryland environments provide a wide range of services that support the increasingly diversified livelihoods of communities within and beyond dryland areas. Dryland environmental management is thus deeply intertwined with the broader livelihood strategies of dryland populations.

Historically, dryland societies have developed sophisticated strategies for coping with arid conditions and extreme variability. Such coping mechanisms enable pastoralist and dryland farming societies to maintain access to key resources, such as groundwater and surface water for livestock, irrigated agriculture, and human consumption (see first photo). Coping mechanisms may also reflect the economic and political pressures placed on dryland societies and the interaction of dryland communities with state and civil society actors.

In the hyperarid and arid realms, pastoralism is the dominant livelihood system. Pastoralist management strategies have historically relied on the mobility of people and livestock within the ecosystem to gain access to water and vegetation for themselves. Such transhuman movements typically involve movement to upland, wetland, or riparian areas during dry seasons and a return to drier plains during the wet season. Movements further afield may be required during droughts. The seasonal shifting of pressure on vegetation resources allows for regeneration of grasslands because overgrazing and loss of vegetative cover can lead to a series of additional problems, including reduced surface water, reduced groundwater recharge, and severe soil erosion. Pastoralists may also modify savanna ecology through biomass burning or tree planting. For example, silvopastoralism can provide alternative sources of fuelwood and charcoal for dryland communities.

Dryland farmers engage in a variety of soil and water conservation strategies to enhance moisture and soil fertility. In the case of rain-fed agriculture, water harvesting is a critical technique for maintaining crop productivity. Farmers have historically relied on local varieties of



Maasai women of Kenya return home with water for domestic use. Local water harvesting and conservation initiatives can buffer communities against the effects of drought.

Source: Author.

drought-resistant crops, such as millet and sorghum in Africa and South Asia. Soil management is equally important as it determines the extent to which moisture is retained to enhance crop productivity. Mulching, stone bunds, agroforestry, and many other techniques are used by dryland farmers around the world to minimize soil erosion. Where surface water or groundwater resources permit, irrigated agriculture limits the impacts of drought on productivity.

Although dryland management systems are attuned to local environmental conditions, patterns of dryland resource use reflect the roles of dryland areas in broader regional political economies. Just as dryland resources are used by populations in humid zones (e.g., mineral, fossil fuel, and woodfuel resources), dryland populations may also rely heavily on external resources such

as water. Cities located in the dryland realm, such as Los Angeles, Tucson, and Mexico City, demonstrate the potential for large-scale infrastructure to sustain large populations in dryland areas. However, such urban growth faces many limits in terms of long-term water availability due to political uncertainties and physical limitations.

Institutional Dimensions of Dryland Management

Although cases of widespread dryland degradation have been documented throughout history, desertification rose to the status of a global environmental problem relatively recently as a result of international attention to the prolonged drought in the West African Sahel from 1968 to 1973. International concern culminated in the



1977 United Nations Conference on Desertification, which emphasized the role of human land use in accelerating desertification globally. The 1992 United Nations Conference on Environment and Development created new momentum for addressing desertification at international, national, and local scales, eventually leading to the ratification of the United Nations Convention to Combat Desertification in 1996.

At the national level, patterns of dryland environmental management often reflect tensions between local management systems and systems of state and private management, as well as conflict over access to dryland resources. In many cases, dryland areas are economically and politically peripheral or are frontier areas over which states have relatively little political or administrative authority.

Due to the highly variable nature of dryland environments, resource access has historically been subject to tenure systems that provided flexible and negotiated access to common property resources—rather than exclusive rights—within dryland landscapes. Many governments have adopted preservationist policies toward dryland areas as a means of limiting the impacts of human activities on vegetation, soils, and wildlife. The creation of protected areas, such as the extensive national parks systems in Eastern and Southern Africa, has often resulted in the displacement of pastoralist and dryland farming communities and the disruption of traditional management systems. Such policies have often ignored beneficial interactions between livestock, vegetation, and wildlife.

Community-based natural resource management in drylands has been a more recent development and seeks to maintain ecosystem function while recognizing the validity of local knowledge of appropriate environmental management and the complexity of local claims to resources. While environmental monitoring may improve the targeting of environmental policies and programs, broader commitment to community-based resource management may be the most promising means of improving dryland environment management in the face of greater uncertainty associated with global climate change.

Thomas A. Smucker

See also Biome: Desert; Climate: Dry; Common Property Resource Management; Desertification; Drought Risk and Hazard; Indigenous Water Management; Nomadic Herding; Water Needs; Xeriscaping

Further Readings

- Bassett, T. J., & Crummey, D. (Eds.). (2003). *African savannas: Global narratives and local knowledge of environmental change*. Oxford, UK: James Currey.
- Bruins, H. J., & Lithwick, H. (Eds.). (1998). *The arid frontier: Interactive management of environment and development*. London: Kluwer Academic.
- Safriel, U., & Adeel, Z. (2008). Development paths of drylands: Thresholds and sustainability. *Sustainability Science*, 3, 117–123.



ENVIRONMENTAL MAPPING

The process of collecting and visualizing spatially referenced data about our environment is referred to as environmental mapping. Environmental mapping does not refer only to an end product, such as a map of deforestation, but to the whole process of acquiring, preprocessing, storing/archiving, analyzing, and finally displaying information about our physical environment (Figure 1). As such, environmental mapping can be regarded as multidisciplinary. It draws on the expertise of environmental scientists, such as physical geographers, geologists, ecologists, and climatologists, who help define the aspects of the environment to be studied and how to interpret the data collected. It also draws on surveyors, photogrammetrists, and remote sensing specialists to provide expertise in the acquisition of data on the environmental phenomena being studied. Cartographers, modelers, statisticians, graphic designers, and environmental scientists help in the processing and eventual visualization of the environmental data. Environmental mapping can be regarded as underpinning much of the investigation of the physical environment, which is where its importance lies. Scientists and decision makers need to know about the spatial distribution of phenomena in order to be able to research them and

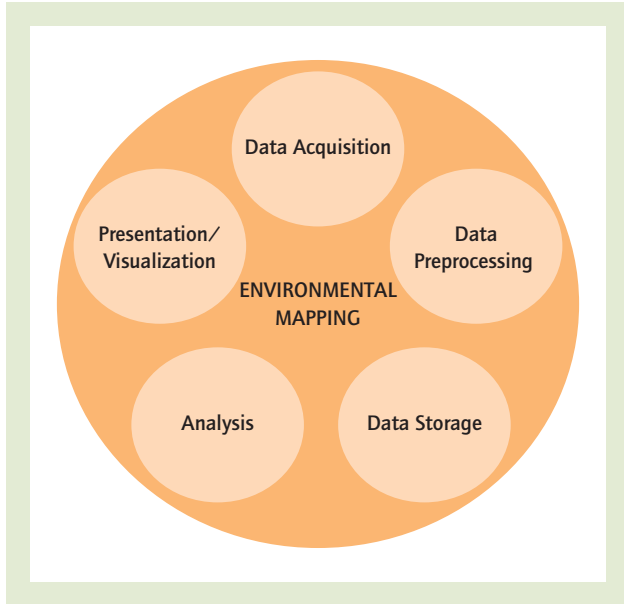


Figure 1 Components of environmental mapping

Source: Author.

develop policies to address environmental problems such as deforestation or climate change. Environmental mapping also has an important role in informing the public and facilitating informed public debate. Environmental mapping is rarely the last stage in the process; it is part of the process of gathering and presenting information for further analysis and interpretation. This stage of investigation then leads to the development of explanations and, when relevant, to the formation of policy and legislation.

The process of environmental mapping consists of a number of stages (Figure 2). The first stage in the process is defining what aspects of the environment are to be mapped. This is then followed by a data collection/acquisition phase. Next, the data may need some form of preprocessing before they can be used. In the case of large projects, or ones where data collection must be repeated numerous times to develop a time sequence of information, some form of data storage or archiving is required. Again, depending on the nature of the data collected and the aspect of the environment being studied, some form of analysis may be required before the data can be displayed for interpretation. The final stage in the environmental mapping process is to create a visual display of the data.

Stage 1: Problem Definition

The first stage in environmental mapping requires making a decision on which aspect of the environment needs to be mapped and what data are required for mapping. This stage will usually be informed by the requirements of the scientific methods behind the project and/or by the policy needs. Ideally, data would be collected for each environmental mapping project, but this is not usually realistic or possible. A key element in the problem definition stage is to assess the fitness of different potential data sets for studying particular environmental phenomena. It is worth noting that the data fitness category is not always limited to identifying the very best data set for a particular application; quite often, it includes criteria such as the data acquisition cost and the availability of resources needed to obtain the data.

Stage 2: Data Acquisition

Once it has been determined what data are to be used, the second stage is data acquisition. This stage of environmental mapping can vary depending on whether existing data sets are to be used or whether new data need to be collected. If existing data sets are to be used, this stage might involve something as simple as downloading data from an Internet site. An example of this might be where a project requires remotely sensed data, which might be accessed from an online archive, such as the one available for satellite remote sensing instruments such as MODIS (moderate resolution imaging spectrometer). The development of the Internet has led to an explosion in the volume of environmental data available, much of it free to download. However, sometimes new data must be collected. In these cases, researchers can use a wide range of technologies and techniques developed specifically for collecting spatially referenced data. Data collection might take the form of direct measurements, such as ecological surveys or measurements made with global positioning systems, or indirect measurements, where remote sensing instruments are used. Depending on the nature of the project, data acquisition might involve a major national or international campaign, observing the whole planet, such as NASA's Earth Observing System, or it may just

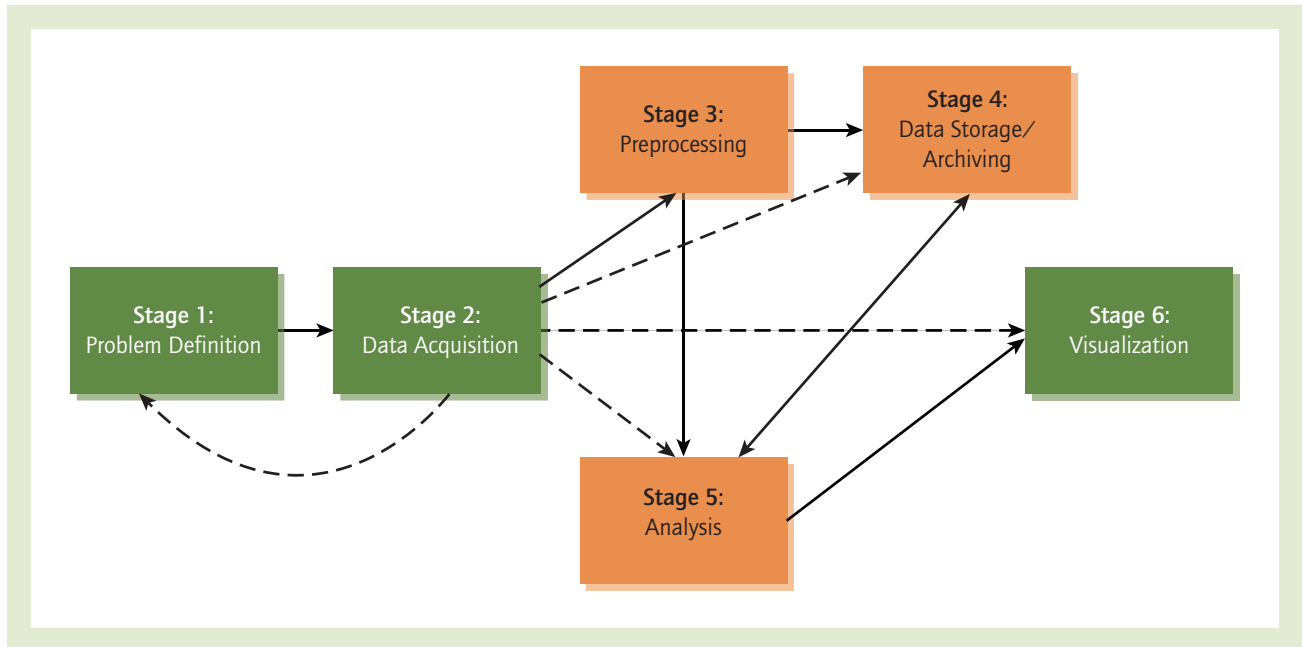


Figure 2 The stages in the process of environmental mapping. Some of the stages in the process, such as problem definition (Stage 1), data acquisition (Stage 2), and visualization (Stage 6), are always carried out. Other stages, such as preprocessing (Stage 3), data storage/archiving (Stage 4), and analysis (Stage 5), are carried out when the mapping project requires them.

Source: Author.

involve an individual going out with a global positioning system to acquire the location of pollution sites or endangered habitats. As indicated in Figure 2, once the data have been collected, there are a number of stages before the final visualization is created.

Stage 3: Preprocessing

Depending on the type and characteristics of the data collected, a certain degree of preprocessing might be required before the data can be used to visualize an environmental problem. The preprocessing can be relatively simple or quite involved. Relatively simple preprocessing might involve changing the map projection and coordinate system for a particular data set. More complicated preprocessing might involve multiple steps. For example, remotely sensed data obtained using satellites are preprocessed using a well-established sequence of steps that range from geometrical corrections of images to atmospheric and radiometric corrections. Preprocessing is really about

making the data usable so that it can be analyzed and/or visualized.

Stage 4: Data Storage/Archiving

The storage of the data in an accessible and logical manner is important, particularly if the environmental mapping project being undertaken continues for a period of time. The storage of large quantities of geographically referenced data has become much easier with the advent of geographic information systems (GIS) and related database technologies. The key issue in the storage of data is determining who will be allowed access to the data and what they are allowed to do with it. These are key concerns if a number of people are involved in a project. The Internet has made the sharing of data relatively easy, but protocols are needed to ensure that the data remain safe. There is also a need for an efficient indexing system that allows the wide range of users who may access the data to search for the data sets they require.



Stage 5: Analysis

The preprocessing of data might be sufficient to make data usable, but in some cases additional analyses might be needed to obtain information on the phenomena or problem being mapped. The analysis might involve the combination of a number of data sets, such as combining layers of information on slope angle, rainfall, and vegetation type to create a model of soil loss. The analysis might involve running hydrological models to create different flooding scenarios. The purpose of analysis is to create information that can be visualized. As noted earlier, the environmental mapping process may be a part of a larger investigation, and so the analysis done as part of environmental mapping may be only a starting point to create derived data and information useful in more complex modeling and simulation.

Stage 6: Visualization

Generally, the final step in the process of environmental mapping is the visualization of the data. Originally, visualization was limited to static two-dimensional representations, usually in the form of a thematic map. However, modern technology makes it possible to visualize environmental entities and their relationships in three dimensions or even to animate entity and relationship changes in time, thus providing the means to visualize processes. Visualizations can comprise a whole range of different data types, including traditional maps, digital elevation models, remotely sensed data, aerial photography, and even virtual reality objects. Technologies such as GIS and the Internet have aided the visualization component of environmental mapping greatly. GIS has provided the framework for storing and displaying the data, and the Internet has made it possible to share that information more widely.

Examples of Environmental Mapping

Environmental mapping can be carried out at many scales, from a very local scale right up to a global scale. A number of examples of environmental mapping-based applications can be found on the Internet. In the United Kingdom, the Environment Agency provides an Internet-based service

where the general public can look up information on their local environment using postal addresses. Information on flooding, water quality, water management, and pollution can all be looked up and displayed as thematic maps. This service provides a basic level of environmental mapping. A similar type of application can be found on the Web sites of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Homes and Communities. On EPA's Web site, the EnviroMapper tool allows the general public to produce interactive maps of various aspects of the environment, including pollution and flooding. Although these examples describe the final stage in the environmental mapping process—visualization—they demonstrate one of the key roles of an environmental mapping project, namely providing a visual record of some aspect of the environment.

Richard Peter Armitage

See also **Adaptation to Climate Change; Aerial Imagery; Data; Aerial Imagery: Interpretation; Biophysical Remote Sensing; Cartography, History of; Climate Change; Database Management Systems; Data Query in GIS; Digital Terrain Model; Digitizing; Ecological Mapping; Forest Degradation; Geostatistics; GIS in Environmental Management; GIS in Land Use Management; GIS Software; Internet GIS; Map Visualization; Remote Sensing; Resource Mapping; Surveying; Three-Dimensional Data Models**

Further Readings

- Environment Agency (UK). (2009). *What's in your backyard?* Retrieved February 17, 2009, from www.environment-agency.gov.uk/homeandleisure/37793.aspx
- National Aeronautics and Space Administration. (2010). *About NASA's Earth observing system.* Retrieved January 6, 2010, from <http://eosps0.gsfc.nasa.gov/index.php>
- U.S. Department of Housing and Urban Development. (2009). *EZ/RC address locator.* Retrieved January 6, 2010, from <http://egis.hud.gov/egis>
- U.S. Environmental Protection Agency. (n.d.). *EnviroMapper for Envirofacts.* Retrieved January 6, 2010, from www.epa.gov/emefdata/em4ef.home



ENVIRONMENTAL PERCEPTION

Originally developed by geographers and psychologists in the 1950s through the 1970s, environmental perception focuses on how people sense, mentally process, and act on patterns they perceive in space and time. In truth, there is no simple definition of environmental perception in that the two components of the concept—environment and perception—are anything but simple. The environment can be defined as the reality around us in which people live and act. William Kirk introduced into geography a dual view of the environment from gestalt psychology of the phenomenal environment, which lies outside a person's perceptions, and the behavioral environment, which is the perceptual environment, in which the phenomenal environment is given meaning through the senses, experiences, culture, and values of the individual. David Lowenthal introduced environmental perception as the medium by which people perceive the reality that they experience and within which they act. He divided the universe of geographic study into three realms: (1) the nature of the environment, (2) what we think and feel about the environment, and (3) how we behave in the environment. The Earth science tradition in geography has focused on developing a strong understanding of the nature or "reality" of the environment. Environmental perception is focused on Lowenthal's second and third realms.

Perceiving the Environment

Humans perceive the environment through their senses. The senses by which we perceive the environment include the hepatic (touch), olfactory (smell), auditory (hearing), and visual (sight). Senses vary in terms of the range of space that can be perceived: The hepatic zone is the immediate perception of differences of pressure and temperature on our skin, while the olfactory, auditory, and visual zones vary with the strength of the surrounding stimuli and the acuity of individual senses. Each person perceives the environment within a personally developed "filter" that incorporates personal history and experiences, which

may also vary with mood, purpose, and focus. The "filter" through which we perceive our environment is shaped through culture, custom, beliefs, and desires.

Reginald Golledge and Robert Stimson outlined the problems in defining perception and how it relates to cognition. Some geographers use perception to describe how aspects of the environment are remembered or recalled. In planning and architecture, perception can refer to common interests between groups and individuals in the design process. In psychology, perception is viewed as a subprocess of cognition. Perception is the immediate stimulus-dependent interpretation of the environment through the senses, while cognition refers to how we link that initial interpretation with past experience and how we may project that interpretation into the future. Robert Lloyd defined perception as the cognitive process that is directly involved with the detection and interpretation of sensory information. Regardless of the varying ways in which researchers in different fields define perception and differentiate between perception and cognition, it can be agreed that perception involves how the mind interfaces with the environment.

Perception also means understanding. Environmental perception under this definition extends the scope of the concept from the act of sensing the environment to the understanding of the environment gained by integrating that which we sense. It also extends into the decisions and actions that people take based on that understanding and thus blends into the study of spatial behavior or behavioral geography. Environmental perception has developed as a field of geography incorporating both the perceptual and the cognitive processes in human relationships with the environment. As a result of the multiple definitions of *perception* outlined above, many geographers use *perception* and *cognition* interchangeably, along with the terms *environmental perception* and *spatial cognition*.

Researching Environmental Perception

In defining environmental perception in geography, one is tempted to apply former U.S. Supreme Court Justice Stewart Potter's famous statement about pornography in *Jacobellis v. Ohio* (1964):



"I can't define it, but I know it when I see it." We can also extend that definition to "I know who does it." The Environmental Perception and Behavioral Geography (EPBG) Group of the Association of American Geographers has been discussing and researching environmental perception since its inception. The mission of the EPBG is to advance the theoretical and applied interests of environmental perception and behavioral geography within the discipline of geography, developing links to related disciplines through communication and organization. EPBG is a broad subarea within human geography that takes a disaggregated approach to the study of human activity, culture, and society. It is concerned with a diverse set of issues about human behavior, perception, attitudes, beliefs, memory, language, intentions, reasoning, and problem solving involving space and place. EPBG research is motivated by two premises—that understanding these issues will help improve traditional models in human geography and that these issues constitute geographic problems in their own right. Furthermore, to an EPBG researcher, people are not interchangeable parts for study but may differ as a function of their culture, socioeconomic status, age, gender, education, travel experiences, differing abilities, and more. EPBG researchers employ a wide array of research methodologies, both qualitative and quantitative, and have interdisciplinary contact with psychology, anthropology, history, phenomenology, microeconomics, computer science, literature, and other disciplines.

Another way of looking at environmental perception in geography is to consider where the research is published. Papers on environmental perception are well represented in mainstream geography journals. Research is also published in the more specialized geographic information science and cartographic journals. In addition, researchers in environmental perception have been publishing in journals in related fields such as psychology, hazards, and planning and architecture, among others. The wide range of publication outlets in these disciplines reflects the multidisciplinary flavor of environmental perception research as well as the multiple perspectives (and definitions) of what research in this field entails.

There are several basic problems that researchers and thinkers in geography and related fields have been investigating and exploring in the area of environmental perception. One of them is how humans perceive the environment. As stated above, a combination of senses and sociocultural experiential filtering is used to perceive and interpret the environment in which we live and act. One variable that has been of particular interest is perspective. Each individual perceives the environment differently, sensing, processing, evaluating, storing, and using information received about the environment. Researchers have been investigating diverse perspectives to determine the differences in perception. Some of the perspectives under investigation include age (both children and the elderly), gender, and disabilities.

Another major area of investigation is the difference between perceptions and "reality." Since individuals have different perceptions of the environment, geographers have tried to investigate these differences and determine some of the mechanisms behind them. The study of mental maps provides insight into how experience changes our understanding of the environment over time. They also give us some insight on how we visualize space. The perception of space varies with the scale of the space perceived. The results of investigations into the relationship between spatial visualization and environmental perception are being applied to spatial learning through cartography, imagery, and geographic information systems.

Our perceptions of the environment also create feelings for places and an aesthetic value attached to those places. This feeling for specific places as a result of our perception and use of these spaces is referred to as sense of place. Yi-Fu Tuan wrote of the combination of perception, experience, and cultural attitude, which he defined as "topophilia"—the affective bond between people and a place or setting. Architects, landscape architects, planners, psychologists, and geographers have researched the sense of place, the design of places, and the influence of culture, gender, and age on the perception of and feelings for places. Research has also been done on how we value our environment and how our perceptions of the environment physically and mentally restore us.



Impacts of Environmental Perception on Behavior

Environmental perception is also at the heart of the investigation of spatial decision making. How we perceive the environment affects how we act within it. For example, transportation researchers have a strong interest in navigation. How we orient ourselves through space is directly related to how well we perceive the spaces through which we navigate. The cumulative perception and cognition of the environment and representations of the environment create a mental map by which we relate, orient, and navigate spaces. Path selection in space is based on our perception of the “best path,” which can be a function of aesthetic perceptions as well as economic utility. The chosen path is not always the shortest path but could also be the path that is the most aesthetically pleasing. Researchers have examined the impacts of culture, gender, age, disabilities, experience, and environment on navigational abilities and orientation.

How we perceive the environment directly relates to the decisions we make about our environment and the actions we take within it. Neo-classical economists typically assume that humans make rational decisions based on their self-interest; however, humans often make what seem to be irrational decisions. One reason for these seemingly irrational decisions is that we tend to base our decisions on locally scaled perceptions of the environment (both in space and time), where perceptions of the environment differ with scale. One example of this tendency is the behavior of humans with regard to climate change. Since the most obvious impacts of the early stages of global warming are evident only in the polar or alpine regions, the majority of people who live in temperate or tropical climates often do not see significant evidence of climatic change in their local landscapes, and they do not notice significant changes locally from year to year. People therefore tend to discount the impacts of climate change on the basis of local perceptions, and they postpone changes in individual behavior (e.g., reducing individual carbon loads through energy efficiency) that could collectively have positive global impacts.

This contrasts with an alternative case where human behavior was modified through a campaign focused on local environmental perceptions. Littering, like climate change, is a global problem, but littering can be easily perceived (and policed) at the local scale. The Keep America Beautiful campaign of the 1970s, with the iconic image of the “tearful Native American,” expanded individual perceptions of litter from a local to national scale in such a way that individual local behavior was changed nationwide. In each of these cases, people are behaving seemingly rationally based on individual local-scale environmental perceptions, although in the former case they are acting in a seemingly irrational manner in relation to larger-scale, long-term impacts that are not directly perceived.

Other examples of this relationship between local and large-scale perceptions that geographers have explored in depth are decisions involving natural hazards (fire, flood, landslide, earthquakes, volcanoes, hurricanes, etc.). People frequently move to, or even move back to, hazardous locations in spite of the risks involved. The actors perceive the benefits of such locations and downplay the risks, especially as time passes after the most recent disaster. Geographers have also been researching the perception of risk and fear in the landscape. We react to perceptions of natural hazards as well as human and societal hazards, such as crimes and violence. Again, people often react to their perceptions of risk. Those perceptions may vary significantly from the actual risks across the landscape.

The future of environmental perception in geography is bright as interdisciplinary research in the field progresses with new tools, new insights, and continuing cross-fertilization with other fields.

Dave Lemberg

See also Behavioral Geography; Childhood Spatial and Environmental Learning; Environmental Imaginaries; Golledge, Reginald; Humanistic Geography; Mental Maps; Natural Hazards and Risk Analysis; Phenomenology; Sense of Place; Spatial Cognition; Spatial Cognitive Engineering; Symbolism and Place; Tuan, Yi-Fu; Wayfinding



Further Readings

- Amadeo, D., & Golledge, R. G. (2003). Environmental perception and behavioral geography. In G. L. Gaile & C. J. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 133–148). Oxford, UK: Oxford University Press.
- Golledge, R. G. (2008). Behavioral geography and the theoretical/quantitative revolution. *Geographical Analysis*, 40, 249–257.
- Jacobellis v. Ohio, 378 U.S. 184 (1964).
- Kitchin, R. M., Blades, M., & Golledge, R. G. (1997). Relations between psychology and geography. *Environment and Behavior*, 29, 554–573.
- Tuan, Y. F. (1974). *Topophilia*. Englewood Cliffs, NJ: Prentice Hall.



ENVIRONMENTAL PLANNING

Urban planning is often referred to as the ordering and design of human settlements. Accordingly, environmental planning then becomes the consideration and analysis of how existing and proposed human settlements affect ecosystems, with subsequent assessment of the extent to which these impacts can be avoided and/or mitigated now or in the future. As our awareness of human impacts on the environment continues to expand, the practice of environmental planning will continue to take on new importance because it provides an important conduit for scientific knowledge to inform policy development and ultimately potentially change human decision making and behavior, leading to better environmental outcomes. While environmental planning is complementary to the study of environmental geography, it differs from the latter and efforts to respond to sustainable development imperatives. These differences evolve, in part, because of the role that professional urban planners play in the practice of environmental planning.

The History of Environmental Planning

The practice of environmental planning has been influenced by the environmental philosophy of

the day. John Randolph has identified three widely recognized phases of evolving environmental values that have fundamentally influenced the practice of environmental planning: the conservation movement, public health, and the ecosystem approach.

The Conservation Movement

The later half of the 20th century gave rise to a philosophical interest in “conserving nature.” Informed by the earlier work of Henry David Thoreau, Aldo Leopold, and John Muir and implemented by nongovernmental organizations such as the Sierra Club, governments began to consider what legislative tools could be employed to protect and preserve vast tracts of undeveloped land or wilderness and the natural resources they held. During this period, environmental planning concerned itself with land outside urban settlements and was applied to vast tracts of land. These preserved or protected areas stood in stark contrast to the increasingly dense urban areas that were home to the infrastructure of the Industrial Revolution.

The Public Health Movement

Responding in part to the negative human health impacts resulting from widespread industrialization located in urban areas, environmental planning’s focus next turned to matters of public health. This movement forged a link in lawmakers’ and decision makers’ minds about the connections between human health and the surrounding environmental conditions. During this phase of environmental planning, there was new urban investment in infrastructure in support of public health, facilitated in part by expanded technological capacity. For example, there were major urban investments in water and sewage treatment, and cities began to explore opportunities to bring “nature” back through the provision of public parks and open spaces.

The transition from this movement to the ecosystem-approach movement was triggered in part by two events. The first was when humankind was first able to view Earth from space—an event widely credited with contributing to our understanding of the planet as a series of connected systems. The second was the release of Rachel



Carson's seminal book *Silent Spring* in 1962, which sensitized us to the impacts that human activities have on ecosystems.

The Ecosystem Approach

Planning based on ecosystem approaches began in the early 1980s in North America but gained prominence in other regions after the United Nations Conference on Environment and Development (the so-called Earth Summit) was held in Rio de Janeiro, Brazil, in 1992. Rather than focusing on the environment as a source of resources or a sink for waste, the ecosystem approach to land use planning emphasized decision-making processes that integrated the consideration of the impacts of human development on land, water, and other resources. Through efforts to assess the impact of current development on future generations, the ecosystem approach requires urban planners to think about the impacts of resource use (or conservation) on current and future generations.

Environmental Planning Is Distinct From Environmental Management

Environmental planning differs from environmental management in part because of the role that the professional urban planner plays. Urban or town planners in many countries are regulated by a professional accreditation body (e.g., The Royal Town Planning Institute, United Kingdom; The Canadian Institute of Planners; The American Institute of Certified Planners, United States; The Institute of Town Planners, India; Planning Institute of Australia). This accreditation process is relevant to the field of environmental planning because it requires its member-planners to adhere to a code of ethics or practice. In many cases (Canada, United States, United Kingdom) this code includes a requirement to uphold ecosystem principles in the practice of planning. For example, the American Institute of Certified Planners' Code of Ethics and Professional Conduct states that planners "shall promote excellence of design and endeavor to conserve and preserve the integrity and heritage of the natural and built environment." By meeting this requirement, the planner can influence the practice of environmental planning

through content and process. Many nonplanners are engaged in research and practice that generate content for environmental planning processes, but their responsibility for the planning process distinguishes planners from other allied professions.

The process by which environmental planning takes place is typically defined by enabling legislation across national, state/provincial, and local governments. The extent to which the local government holds significant power in the environmental planning process varies across countries. Typically there are multiple jurisdictions involved in the regulation of development activities that have an impact on the environment. For example, for a new subdivision to be approved, the developer may be required to complete an environmental assessment (typically mandated by federal or state/provincial governments), complete a plan of subdivision submitted to the local government, and demonstrate compliance with growth management policies (typically mandated by federal or state/provincial governments).

The environmental planning process also typically must include some form of public consultation whereby the public's views on a development proposal are solicited by a planner working for government through a public meeting, submission of a letter, or other means of soliciting input. This public consultation process provides formal opportunities for citizens' groups to raise matters of concern and suggest alternative approaches. Increasingly, there is a growth in the use of online consultation tools to expand opportunities for public comment. Also, citizen groups are turning more to Internet-based spatial analysis tools such as Google Earth and Google maps to create their own sources of data to provide input into the environmental planning process. The increase in the use of public participatory GIS (geographic information systems) tools is likely to continue to grow as these tools proliferate on the Web, the ease of use expands, and the opportunities to integrate multiple data sets expand as well (e.g., mashups).

Current Issues in Environmental Planning

Although the roots of environmental planning were in the protection of undeveloped areas,



environmental planning is increasingly responding to issues in urban, suburban, and exurban environments. As the practice of environmental planning has internalized the ecosystem approach, the challenges arising from attempting to manage suburban growth have become more apparent. Thus, much attention is paid in environmental planning to the protection of agricultural land from suburban sprawl; reducing greenhouse gas emissions resulting from automobile use; improving local air quality, also degraded by air pollution from automobile use; protecting water quality from surface runoff contamination (exacerbated by the proliferation of parking lots and roadways); and protecting biodiversity and preventing habitat fragmentation and destruction, again as a result of low-density, single-land use urban sprawl.

“Smart growth” is the catchphrase of an approach to environmental planning that seeks to respond to the aforementioned issues. Although different jurisdictions may vary in their interpretation of the concept, smart growth principles generally include mixing recreational, residential, retail, and commercial land uses; building new developments that are compact enough to support public transit and other non-automobile-based travel; providing a range of housing types (e.g., single-family homes, town houses, apartments, or condominiums); redirecting growth to underdeveloped areas (as opposed to undeveloped or greenfield lands); protection of open spaces and environmentally sensitive land; protection and enhancement of agricultural land; using “green” infrastructure and green building practices; encouraging the uniqueness of places; and providing meaningful opportunities to engage the public in the planning process. A review of these principles reveals that there are multiple environmental benefits to be gained through the practice of smart growth-type environmental planning. Accordingly, this concept permeates North American planning policy. New urbanism and transit-oriented design are two similar yet distinct planning frameworks that operationalize the principles of smart growth with different emphasis.

In addition to smart growth, other current trends in environmental planning involve exploring how communities can reduce their ecological

footprint (the amount of land required to sustain a person’s lifestyle), reduce greenhouse gas emissions, increasingly localize their food production process, and engage in the revitalization of old industrial sites (brownfields). These issues are all indicative of the elements of environmental planning that distinguish its practice from environmental management or research conducted by environmental geographers. Urban planners who practice environmental planning make significant use of research developed by environmental managers and geographers to inform decision making in the planning process. But planners are also required to mediate interests, negotiate between disparate stakeholders, act as liaisons with politicians, and develop and implement public consultation activities. Environmental planning draws heavily from the spatial analysis that results from the use of remote sensing and GIS, but these data are inputs into a political process that results in mediation between often competing interests.

Are Environmental Planning and Sustainability the Same Thing?

One persistent and unresolved question in environmental planning arises when the concept is compared with that of urban sustainability. Research and practice related to urban sustainability emerge as a subset of the broader issue of sustainable development. With sustainable development’s emphasis on considering the social, economic, and environmental impacts of human developments for current and future generations, there are obvious synergies with the aforementioned ecosystem approach. As a result of these similarities, the terms *urban sustainability*, *environmental sustainability*, and *environmental planning* are often used interchangeably in research and practice. The extent to which environmental planning can be considered the same as planning for urban sustainability depends in large part on the mind-set of the government or practitioner using the terms. In some contexts, environmental planning focuses on ecological impacts (e.g., loss of biodiversity in wetlands), and the planning outcomes respond to these alone (e.g., new zoning requirements for on-site storm water management to reduce overland flow that compromises wetland water quality). In other



cases, environmental planning takes a broader approach that explores the dynamics between social, economic, and environmental impacts and intervenes accordingly (e.g., the creation of buffer zones between new developments and ecologically sensitive areas to reduce the impact of such developments on wetlands).

While the practice of using these terms interchangeably is widespread, research suggests that there are costs to the indiscriminate use of these terms. The most common critique of this practice emerges from a growing body of research that suggests that the equity element of sustainable development gets lost in the translation from definition to practice, with the environmental and economic elements taking precedence. Also common is the concern that the weaknesses of the concept of sustainable development will be used as an argument against all planning intervention, thus serving as a barrier to even the environmental elements being addressed.

As public and professional awareness of the environmental impacts of human development expand and as the world becomes increasingly urbanized, an increase in the demand for environmental planning research and practice can be anticipated.

Pamela Robinson

See also **Brownfields; Community-Based Environmental Planning; Environmental Ethics; Environmental Impact Assessment; Environmental Impact Statement; Environmental Law; Environmental Management; Environmental Protection; Environmental Restoration; Environmental Services; GIS in Environmental Management; Land Use Planning; Multistakeholder Participation; Regional Environmental Planning; Smart Growth; United Nations Conference on Environment and Development; Urban and Regional Planning; Urban Environmental Studies; Urban Sustainability**

Further Readings

- McHarg, I. L. (1995). *Design with nature*. New York: Wiley.
- Randolph, J. (2003). *Environmental land use planning and management*. Washington, DC: Island Press.



ENVIRONMENTAL PROTECTION

Environmental protection is the set of actions or measures that societies take to ensure the health of their life support systems: air, water, land, and biomass. The measures can take many forms, such as passing laws that limit or forbid the use of a certain resource or the performance of some activities in specific areas (e.g., offshore oil drilling, agricultural practices on certain lands), fines for discharging pollutants into the air or water, subsidies for purchasing energy-efficient lighting, heating and cooling technologies, encouraging recycling and waste reduction, emissions trading, and smart growth of human settlements, among others.

Human beings obtain food, energy, and materials from the Earth's ecosphere and lithosphere, water from the hydrosphere, and oxygen from the atmosphere. These resources are termed environmental goods and services. If they are overused, they can be depleted or damaged, depending on the rate at which they can be renewed. For example, air pollution depletes clean air supplies and, if recurrent, can take place at a faster pace than the environment's ability to purify it. This contamination hinders the environmental service of air purification and risks human health. Environmental protection is important since human life is adapted to and depends on the current state of the environment. Furthermore, the rate of depletion of environmental goods and services has a temporal and geographic dimension—temporal in that the depletion of a resource today leaves less of that resource for future generations and geographic in that the use of resources from one region to be consumed in another leads to environmental problems in the region of origin.

All the spheres are interrelated through biological, chemical, and physical processes (such as biogeochemical cycles and temperature gradients). Every living being on Earth is constantly interacting with its environment and altering it. The result of such a transformation is a resource that another being uses or another process transforms. For example, underground carbon and sulfur are released into the atmosphere through volcanic eruptions as a part of the biogeochemical cycles of carbon and sulfur. Sulfur then



contributes to cloud formation, whereas carbon contributes to plant growth. Plants are eaten by animals, which are themselves often eaten by others. Animal wastes become part of the lithosphere through decomposition by bacteria and other creatures to become part of the soil, enriching it with nutrients. In the long run, the tendency is for these processes to interact in a balanced fashion. If there is a disturbance, such as an increase in the population of a particular species, then this system can be thrown off balance as that species depletes its food and water resources and some of its members die until balance is restored.

Humans, like other life forms, play their part in transforming their surroundings and create by-products in the process of procuring their livelihoods. They mine and extract resources, transforming them into goods for consumption. In the process of doing so, they create wastes. As the human habitat expands, it alters land cover and displaces whatever ecosystem was there before. As the human population has expanded, increased its affluence, and developed new technologies, the amount of goods and services that it takes from the environment has increased.

An environmental protection specialist considers the following questions: At what point does the satisfaction of human needs come at odds with what the environment can provide? When this happens, what should be done about it? Can environmental goods and services be used sustainably? To a degree, the amount of protection that can be afforded to the environment has to be justified in terms of costs and benefits. The social benefit of the protection measure has to outweigh the costs it imposes on the polluters. While this approach is extremely helpful in environmental protection, one problem with it is that while damage to buildings and crops can be valued with the price of replacement, it is very difficult to put a price on an ecosystem's goods and services. Ultimately, all areas that are affected by human-caused damage affect the global environmental balance either directly or indirectly through ripple effects throughout several ecosystems and spheres. However, the benefits or costs cannot be measured directly if the environmental damage does not have a direct impact on human health or ecosystems; that is, if the environmental damage has an indirect effect, it is difficult to measure because

its effect cannot be readily isolated from other influences and measured accordingly.

The scale of the environmental problem matters for environmental protection. Some environmental protection takes place at a local level. One example is requiring that a pulp and paper facility limit its toxic discharges into nearby water streams. Other environmental protection objectives need a concerted global effort, such as limiting the ozone layer-depleting production of chlorofluorocarbons (CFCs) in many countries via the Montreal Protocol. This is because, as in the case of CFCs, for example, the emissions generated in one country affect the atmosphere, which is shared by the rest of the planet. There is a similar situation with the emission of greenhouse gases; while a few countries may be responsible for a large share of total emissions, the burden of climate change is shared worldwide. Therefore, there can be conflict and trade-offs in environmental protection at different scales.

Many countries have organizations devoted to environmental research and protection. In the United States, the Environmental Protection Agency (EPA) is tasked with implementing environmental law written by Congress. Such laws include the Clean Air Act, which aims to limit the amount of six pollutants released into the air. The EPA sets its National Ambient Air Quality Standards in two ways. A primary standard is designed to protect public health, including sensitive populations (e.g., asthmatics, the elderly, children). Secondary standards are set to protect public welfare (e.g., decreased visibility due to air pollution, damage to crops and buildings). Similarly, for drinking water, EPA has established the National Primary and Secondary Drinking Water Regulations, restricting pollution in public water systems. The U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration are charged with the administration of the Endangered Species Act, which is designed to protect different species from overexploitation that can lead to extinction. There are also national and worldwide nonprofit organizations that publish information on environmental concerns and propose or take actions toward their resolution, such as the World Wide Fund for Nature, Greenpeace, Sierra Club, and National Wildlife Federation.

Julia A. Gamas



See also **Community-Based Environmental Planning; Conservation; Environmental Ethics; Environmental Impact Assessment; Environmental Impact Statement; Environmental Law; Environmental Management; Environmental Restoration; GIS in Environmental Management; Land Use Planning; Regional Environmental Planning; Urban and Regional Planning; Urban Environmental Studies; Urban Sustainability**

Further Readings

- Mackenzie, F. T. (2002). *Our changing planet* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
- Primack, R. B. (2006). *Essentials of conservation biology* (4th ed.). Sunderland, MA: Sinauer.

ENVIRONMENTAL RACISM

Environmental racism refers to the process and outcome of racial discrimination in the enactment and enforcement of environmental laws, rules, and regulations and in targeting minority communities for the siting of polluting industries. It also refers to the exclusion or restriction of people of color from representation in public and private boards and commissions and from meaningful participation in environmental movement organizations. The broader term, *environmental justice*, refers to environmental inequities in relation to a larger set of social categories, such as social class and gender. Environmental justice also refers to the movement to address environmental injustice and environmental racism. The term *environmental racism* was coined by Reverend Dr. Benjamin Chavis Jr. of the United Church of Christ (UCC) Commission for Racial Justice. Grassroots environmental justice activists have adopted the term to articulate grievances and as a frame to mobilize supporters and claim the right to a clean and healthy environment “where we live, work and play.”

In 1990, the Southwest Organizing Project and the Gulf Coast Tenants Union publicly charged mainstream environmental organizations with environmental racism, that is, with excluding people of color from their boards, staffs, and

memberships and failing to address their concerns programmatically. The growing national presence of the environmental justice movement was manifested at the First People of Color Leadership Summit in 1991, where 17 environmental justice principles were adopted.

Since then, the understanding of racial discrimination in environmental policy making has improved. Environmental racism existed long before it was defined as such. Over time, however, the more blatant forms of discrimination associated with environmental inequality have given way to subtler, institutionalized forms. Recent calls for equal protection and nondiscrimination in environmental decision making have invoked the U.S. Constitution and the Civil Rights Act of 1964 and advanced ideals of environmental rights.

Theories of Discrimination in Environmental Affairs

Some theories of racial discrimination posit that minority communities are intentionally targeted for prejudicial reasons, beliefs in racial inferiority, or a desire to protect racial group privilege. The sense of racial entitlement provides motivation, and socioeconomic power provides the means for systematic oppression based on race/ethnicity, which in turn can result in environmental inequalities in the distribution of environmental burdens and access to natural resources and environmental amenities such as clean air, clean water, and parks.

The traditional perspective views discrimination as more individualistic, sporadic, and episodic than the institutional perspective, which accents the routine, continual character of discrimination. Racial discrimination also can take an institutionalized form not necessarily related to overt racism when, for example, siting and cleanup decision rules, procedures, or the practices of industry and government lead to racially disparate outcomes, even though they appear race-neutral. For instance, decision-making bodies and their governing rules or the way they are carried out may limit access to information or participation of people of color in hazardous waste facility siting, permitting, and decisions.

Discrimination in various institutional domains such as housing, education, employment, and health care can further disadvantage minorities and limit their social and physical mobility. Such



“structured disadvantage” contributes to inter-generational poverty and racially segregated residential land use patterns, which in turn increases minority sociopolitical and economic disadvantages and vulnerability to targeting.

Commonly cited examples of institutional discrimination include government policies and private investment to support suburbanization, coupled with disinvestment in inner cities. Since the 1950s, these policies and practices, coupled with “white flight,” have led to economic decline and a decaying infrastructure in the urban core. Discriminatory real estate and lending practices and expulsive zoning have further concentrated racial-ethnic minorities in areas where locally unwanted land uses (waste facilities in particular) have been increasingly located. Institutional discrimination in environmental policy allows the licensing of polluting industrial facilities and the release of toxic chemicals into the environment without consideration of the disparate impacts on minority and low-income populations.

Empirical Evidence

In the 1980s and 1990s, studies testing various racial explanations for environmental inequality produced mixed results. Among the most influential early studies drawing attention to the problem were a 1983 U.S. General Accounting Office (GAO) study, the UCC’s 1987 landmark study, *Toxic Wastes and Race in the United States*, and Robert Bullard’s *Dumping in Dixie*. Although these studies reported evidence of racial disparities in the location of environmentally hazardous sites, other early studies found only small or insignificant disparities, if any. In some cases, racial disparities appeared to be explained entirely by differences in socioeconomic status.

More recently, studies have examined causal ordering. Some studies reported racial disparities existing at the time of siting; others found evidence of racial disparities developing because of demographic changes occurring after siting, while a few found evidence supporting neither process.

Extensive reviews of the rapidly expanding empirical literature, however, have shown race to be a stronger factor than income or socioeconomic status in explaining the locations of polluting industrial facilities. Improved methods for

assessing locational disparities and identifying affected populations by using geographic information systems have shown that racial disparities are greater than previously found. Using these newer methods, which more reliably count people living in close proximity to the nation’s hazardous waste facilities, the report by Robert Bullard and colleagues, *Toxic Wastes and Race at Twenty: Grassroots Struggles to Dismantle Environmental Racism*, found that race maps closely with the geography of pollution and concluded that racial factors are stronger predictors of facility locations than is the socioeconomic status of host neighborhoods. These findings are consistent with a 2005 Associated Press study showing that African Americans were more than twice as likely as white Americans to live in neighborhoods where air pollution poses the greatest health danger. Hispanics and Asians were also more likely to breathe hazardous air pollutants in some regions of the United States.

Exposure to the heavy metal lead is one type of hazard known to be particularly high in African American children, due to their being concentrated in older housing with lead paint. Harmful exposure to mercury and other bio-accumulating toxins in fish and marine mammals is another risk that is disproportionately high among African Americans, Asian immigrants, and some Native Americans who hunt and fish for subsistence or to supplement protein in their diets. For some risks, the combination of being a member of a minority community and having a low socioeconomic status confers added risks beyond those associated with being a minority member alone.

The “Smoking Gun”

Following the polychlorinated biphenyls landfill protests in Warren County, North Carolina, in 1983, the GAO released a report that found that three of four hazardous waste landfills in the southeastern United States were located in predominantly African American communities. These developments led to charges of racial targeting. While direct evidence of intentional discrimination is nearly impossible to prove, a 1984 report commissioned by the California Integrated Waste Management Board is widely cited as a “smoking gun.” Because of the growing antitoxics



movement in middle- and upper-class white communities, siting new waste facilities had nearly come to a halt in the early 1980s. The report, which became known as the Cerrell Report, sought to identify communities less likely to wage not-in-my-backyard campaigns. In developing the profiles of communities likely to be more accepting of waste facilities, the report did not mention race explicitly, but it employed what many viewed as racial code language and served to confirm the suspicions of many in the environmental justice movement.

Highlighted in the 1983 GAO report, Waste Management, Inc. became identified by environmental justice advocates as a company with a track record of locating landfills in minority communities. In the 1990s, a Waste Management subsidiary operated a hazardous waste landfill in Kettleman City, California, where a proposed expansion has been a frontline environmental justice struggle for more than a decade. Elsewhere, the poor performance of some companies with records of accidents and permit violations harming workers and nearby residents has provided a rallying cry for community groups for stronger enforcement, fines, and penalties.

Perhaps more than any other case, Hurricane Katrina, in 2005, revealed America's racial divides. As documented in a report by the Russell Sage Foundation, Hurricane Katrina has shown the face of institutional discrimination in disaster preparedness and response. The disaster and the increases in hurricane intensity have also heightened awareness of climate justice, that is, concern about the disproportionate impacts of climate change and climate change mitigation on Arctic peoples and atoll nations in particular.

Environmental Racism Remedies

Environmental justice groups, often with assistance from university researchers, students, public health professionals, and faith-based groups, have made great strides in improving environmental conditions in communities overburdened with pollution. Working in diverse coalition, often by using local knowledge, environmental justice groups make use of citizens' right-to-know legislation, citizen science, popular epidemiology, cumulative risk assessment, and legal investigations

to marshal evidence of disparate impacts. As a result, the environmental justice movement has contributed to pollution prevention, toxic substance use reduction, and modest shifts to cleaner production technologies.

Despite these gains, many of the efforts to formulate policies and use existing laws to remedy environmental racism have met with limited success. In 1998, the U.S. Environmental Protection Agency (EPA) issued draft guidance for state environmental agencies investigating civil rights complaints. Although the guidance was revised in 2000, EPA has never promulgated regulations, and EPA's Office of Civil Rights has been slow to investigate and resolve civil rights complaints. State governments have also proposed or adopted environmental justice policies, for example, to conduct disparate impact analyses as part of siting and permitting processes so that existing environmental burdens and health status are taken into account.

A few executive orders have been issued to address environmental justice concerns, most notably Executive Order (E.O.) 12898 of 1994, issued by then U.S. President Bill Clinton: "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," which required federal agencies to take into account potential disproportionate impacts of their policies and program on minority and low-income populations. Various strategic plans were developed by federal agencies. However, recently EPA has removed race as a consideration in its Environmental Justice Strategic Plan, and its Inspector General issued two reports critical of EPA's implementation of E.O. 12898. This has led to recent calls for codification of the order through statute and "environmental communities of concern" to be designated for targeted enforcement and other assistance.

The courts have restricted the ability of disproportionately affected communities to use Title VI of the Civil Rights Act of 1964, which forbids federal agencies from discrimination by "race, color, or national origin." In its *Alexander v. Sandoval* decision in 2001, the U.S. Supreme Court denied a private right of action for racial discrimination cases brought under Title VI, thereby requiring the government to carry cases for aggrieved parties. The Court also held that there must be proof that discrimination was intentional,



not just that a federal policy or action had a discriminatory impact based on race or ethnicity. Although toxic tort claims do not seek to enforce civil rights, they are currently being used as an alternate legal remedy.

Assertion of international human rights and indigenous rights is an avenue being used to combat environmental racism using the international judicial system. For example, claims of human rights violations to the Inuit people resulting from global warming have been heard by the Inter-American Commission on Human Rights.

International agreements such as the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal hold promise for addressing North-South manifestations of environmental racism at the global scale. Nevertheless, illegal “e-waste” and other hazardous waste exports from developed to less developed and developing nations continue due to lax enforcement, and various banned substances also continue to be exported abroad.

Mainstream environmental organizations have begun to respond to these problems. Among the large environmental groups, Greenpeace has vigorously supported environmental justice struggles, most notably under the leadership of the late Damu Smith, with regard to the Shintech Corp. case in Convent, Louisiana, which involved the siting of a large polyvinyl chloride factory. Prominent mainstream groups have made limited progress in diversifying their boards, staffs, and memberships. Nevertheless, several U.S.-based environmental groups, such as Sierra Club, Natural Resources Defense Council, and National Wildlife Federation, have hired staff to work on environmental justice issues. Foundation support for grassroots environmental justice groups continues to lag, with mainstream groups obtaining the bulk of private foundation and corporate grants.

In the United States, environmental justice organizations continue to take matters into their own hands by forming networks and coalitions, such as the Southwest Network for Economic and Environmental Justice, the National Black Environmental Justice Network, and the Indigenous Environmental Network. Although there have been meetings to forge unified multiracial, multi-ethnic, and cross-class alliances, the lack of a national political organization for environmental

justice or a lobbying presence in Washington, D.C., may limit the effectiveness of the movement in the foreseeable future.

The apparent intractability of environmental racism has led to calls to fundamentally restructure systems of production. Various quarters have recommended that government and industry adopt policies informed by the “Precautionary Principle,” which reverses the burden of proof of harm from adversely affected communities to industry by requiring it to demonstrate safety before releasing chemicals into the environment or products into the marketplace.

Environmental racism could be reduced by the phaseout of persistent, bioaccumulative toxic chemicals and the adoption of clean production principles and methods with zero-waste and closed-loop systems that use renewable energy, nontoxic materials, safer chemical practices, and sustainable product design. Also offering promise are green procurement policies and Extended Producer Responsibility, which requires producers to take responsibility for the entire product life cycle, including the postconsumer phase.

Robin Saha

See also **Brownfields; Ecological Justice; Environmental Justice; Ethnicity and Nature; Hurricane Katrina; International Environmental Movements; Justice, Geography of; Locally Unwanted Land Uses (LULUs); Not in My Backyard (NIMBY); Polychlorinated Biphenyls (PCBs); Race and Nature; Race and Racism; Segregation and Geography; Social Justice**

Further Readings

- Boone, C. G., & Modarres, A. (1999). Creating a toxic neighborhood in Los Angeles County: A historical examination of environmental inequality. *Urban Affairs Review*, 35, 163–187.
- Bryant, B. (Ed.). (1995). *Environmental justice: Issues, policies, and solutions*. Washington, DC: Island Press.
- Bullard, R. D., Mohai, P., Saha, R., & Wright, W. (2007). *Toxic wastes and race at twenty: 1987–2007*. Cleveland, OH: United Church of Christ.



- Cole, L., & Foster, S. (2000). *From the ground up: Environmental racism and the rise of the environmental justice movement*. New York: New York University Press.
- Feagin, J. R. (2006). *Systemic racism*. New York: Routledge.
- Hurley, A. (1995). *Environmental inequalities: Class, race and industrial pollution in Gary, Indiana, 1945–1990*. Chapel Hill: University of North Carolina Press.
- Pellow, D. N. (2002). *Garbage wars: The struggle for environmental justice in Chicago*. Cambridge: MIT Press.
- Pulido, L. (2000). Rethinking environmental racism: White privilege and urban development in Southern California. *Annals of the Association of American Geographers*, 90, 12–40.
- Rechtschaffen, C., & Gauna, E. P. (2003). *Environmental justice: Law, policy, and regulation* (4th ed.). Durham, NC: Carolina Academic Press.
- Ringquist, E. (2005). Assessing evidence of environmental inequalities: A meta-analysis. *Journal of Policy Analysis and Management*, 24, 223–248.
- Saha, R., & Mohai, P. (2005). Historical context and hazardous waste facility siting: Understanding temporal patterns in Michigan. *Social Problems*, 52, 618–648.
- Taylor, D. (2000). The rise of the environmental justice paradigm: Injustice framing and the social construction of environmental discourse. *American Behavioral Scientist*, 43, 508–580.

populations that have been displaced or are at risk of displacement associated with environmental change fall outside the ambit of protection provided to those legally designated as refugees by the United Nations High Commissioner for Refugees. The term has been debated and critiqued in academic inquiry rather than accepted as a useful theoretical concept.

Numbers of Environmental Refugees

Environmental change is a broad concept, encompassing short-term disasters such as cyclones, tsunamis, and eruption of volcanoes, as well as progressive phenomena such as land degradation, deforestation, and sea-level rise. It is thus difficult to calculate the numbers of environmental refugees. Norman Myers, however, calculated that in 1995 there were 25 million environmental refugees worldwide, 5 million of whom were in the African Sahel. The same study predicted that some 200 million worldwide would be displaced in the future by climate change impacts. Such estimates are frequently questioned on the basis of a lack of policy or scholarly agreement on what environmental refugee status entails.

Legal Status

Environmental refugees differ legally from political refugees. The latter are defined in the United Nations 1951 Convention Relating to the Status of Refugees and the 1967 Protocol to the Convention. Refugees are defined there as people outside their state of nationality or former residence who, owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, or membership of a particular social group or political opinion, are unwilling or unable to return to it. Environmental factors contributing to migration fall outside this definition. Hence, there is no obligation for state signatories to the above-named convention to recognize or protect even the most destitute displaced persons in the absence of persecution. Nevertheless, the legal definition of a refugee does not depend primarily on whether or how migration is forced but on the crossing of an international boundary and the consequent need for protection that is not provided by the country of origin. Thus, in circumstances where a

ENVIRONMENTAL REFUGEES

Environmental refugee is a term that has gained currency in civil society and the media to describe people who undergo forced migration linked to environmental change. Although migration linked to deteriorating environmental conditions is not a new phenomenon, the concept of environmental refugees has emerged since the 1970s in parallel with environmental crises, particularly desertification in Africa and climate change impacts in the wider developing world. It is frequently used to describe and highlight how



person satisfies the legal criteria for refugee status, the question of environmental degradation as a causal factor is redundant.

Perspectives on Migration and Environmental Change

There are two contrasting perspectives on links between migration and environmental change that are relevant to environmental refugees. Maximalist perspectives posit that environmental degradation is a primary cause of population displacements. Direct causal links between the two are legitimized when the concept of environmental refugees is assumed to possess explanatory power in empirical contexts. For example, Norman Myers defines environmental refugees as people who can no longer gain a secure livelihood in their homelands because of drought, soil erosion, desertification, deforestation, and other environmental problems, together with the associated problems of population pressures and profound poverty.

Minimalist perspectives, in contrast, see environmental change as a contextual variable that can contribute to migration rather than being its primary cause. Such perspectives position environmental change in a way that cannot be analytically and empirically isolated from the economic, cultural, and political fabric associated with migration events. Minimalist views take into account the fact that migration can reflect both long-standing customs and new opportunities and challenges in a globalized world. These views draw on political ecology to problematize the links between environmental change and power relations in migration events. Thus, the term *environmental refugee* is critiqued as vague or misleading, and involuntary migration is understood in terms of complex interrelated factors that may include poverty, unemployment, lack of access to education and health services, persecution, and armed conflict as well as environmental degradation.

Politics of Environmental Refugees

Groups of involuntary migrants crossing international borders can be perceived as negatively affecting the receiving state. Public opinion on

perceived impacts on the environment through urban pollution from refugee settlements, on the economy through welfare systems, and on cultural and social norms and practices can conflict with policies on reception and resettlement of displaced people with claims to refugee status. In this highly politicized context, the concept of the environmental refugee is being used in civil society as a form of advocacy for populations who are vulnerable to environmental change, whether or not migration has indeed occurred. The preemptive labeling of populations as environmental refugees is particularly prominent in climate change debate. "Climate refugees" are understood as a specific class of environmental refugee likely to be affected by climate change impacts such as sea-level rise, drought, flood, and resource scarcity. Migration of people away from low-lying island regions, for example, is at times assumed in environmental campaigns and the popular media to be an involuntary flight, long before these regions have become uninhabitable due to sea-level rise.

The popular currency of environmental refugee discourse has prompted some migration scholars to question the interests that the often well-intentioned deployment of the term *environmental refugee* serves, using minimalist perspectives on the links between environmental change and migration. Maximalist perspectives within civil society are critiqued for promoting the interests of environmental refugees as a proxy for addressing the "real" problem of environmental degradation and potentially failing to advance the interests of populations in environmentally vulnerable locations on whose behalf they claim an advocacy role. From a minimalist perspective, the links between migration and climate change focus on culturally and environmentally appropriate adaptation measures, including but not limited to migration options. For the populations of many small islands in the Pacific, for example, migration is a process embedded in cultures in which seafaring has long been central. Employment on commercial ships and multidirectional migration between the islands and Pacific Rim cities (particularly in New Zealand) is common. It is within these contexts of customary seafaring and high levels of mobility that the issue of the loss of habitability of the Pacific islands is being negotiated



by their inhabitants. For many of these people, the prospect of future environmental refugee status is only one issue among a host of social, economic, and environmental concerns linked to migration.

Carol Farbotko

See also **Climate Change; Desertification; Migration; Political Ecology; Refugees**

Further Readings

- Black, R. (1998). *Refugees, environment and development*. Harlow, UK: Addison Wesley Longman.
- Myers, N. (2002). Environmental refugees: A growing phenomenon of the 21st century. *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences*, 357, 609–613.
- Suhrke, A. (1994). Environmental degradation and population flows. *Journal of International Affairs*, 47, 473–496.



ENVIRONMENTAL RESTORATION

Environmental restoration is an increasingly common management strategy in physical and ecological systems that are viewed as degraded or impaired. Although restoration of environmental systems is defined in different ways by different practitioners, it has grown considerably in recent years in both practice and theory. The term *environmental restoration* itself also represents a complex series of abstractions about the natural world and the human role within it. For example, the environment is a mutable, moldable entity constantly changing in response to different magnitude forces, some subtle and others catastrophic. Change can occur in both positive and negative directions; thus, the effect of these forces may be to degrade or enhance nature or certain elements of natural systems. Last, the role of people and the ways in which we alter the structure of the environment and environmental processes can contribute to constructional changes in a positive direction or destructive changes in a negative direction.

Ecosystem restoration involves attempts to rehabilitate, fix, or heal once common plant communities, habitats that have disappeared or have become disconnected from one another, and the physical and chemical conditions necessary for their reestablishment and survival. It may include active biological manipulation employing techniques such as mowing, burning, planting, fertilizing, revegetation, the removal of nonnative or unwanted species, or the reintroduction of absent or nonviable species. Outside an explicit ecosystem focus, environmental restoration is aimed at the physical elements of landscapes such as watersheds and stream channels, hydrological function, or the removal and remediation of chemical pollutants. Other projects may be undertaken to reinforce unstable landforms to protect them from processes of erosion or mass movement; still others may be pursued with the goal of reestablishing a landscape aesthetic perceived to be more natural or, in the very least, more agreeable.

Historical Roots

Although the practice of environmental restoration may seem to be a very modern phenomenon, the roots of the concept run deep in North American geography. In the preface of *Man and Nature*, one of the most influential works in the history of American environmental thought, George Perkins Marsh expressed the hope that his book would begin to point the way toward understanding three fundamental points about the environmental function of the world around us. First, humans are a significant force at work changing the physical environment of the Earth. Second, many of these anthropogenic changes represent dangerous threats to the organic and inorganic worlds. Last, Marsh wanted to point out that people have the ability to act in the best interest of nature to redress past wrongs and enhance environmental conditions. He pointed to the importance of the restoration of disturbed harmonies and the material improvement of waste and exhausted regions. When Marsh heralded the significance of human agency in forcing environmental change and landscape degradation, he also provided reassurance that people could act as a force to



repair this damage. In a sense, Marsh is the originator of the modern concept of environmental restoration.

The rate of research investigations in environmental restoration has blossomed in recent decades. Prior to 1990, restoration was not a significant focus of explicit investigations, whereas currently, more than 1,000 articles are published each year that include keywords associated with environmental restoration across disciplines. This growth is seen by many to be symptomatic of the future of environmental management and applied environmental science. Like the biologist Edward Wilson, some have referred to the 21st century as the Era of Restoration or the Century of Restoring the Earth. Many of these investigations tend to be interdisciplinary, but specific subject area clusters where scholarly interest is highest can be identified. Areas in which the majority of academic research is being conducted include ecology, environmental science and toxicology, water resources, marine and freshwater biology, and forestry. Work in geography normally falls under one of these broad research umbrellas.

Project Implementation and Contemporary Debates

The scale of environmental restoration activities varies greatly from project to project. Large-scale plans such as the Florida Everglades ecosystem restoration project represent several complex mechanisms designed to redress a variety of ecological, physical, and hydrological changes that people intentionally made to the South Florida landscape in the past century. The enormity, complexity, and contentiousness of the plan has resulted in a project that will likely take decades to implement at a cost of tens of billions of dollars over an area spanning more than 46,000 km² (square kilometers). Others, such as the eradication of invasive species, for example, attempts to eradicate rats from the 26-km² Rat Island in the Alaskan Aleutian Island chain, small-dam removal efforts, or the localized re-meandering of river channels, are more modest in scope and are aimed at changing the circumscribed elements of environmental systems.

One difficulty in describing the totality of environmental restoration is that it is often defined inconsistently and projects may have different goals attached to them. Some of this complexity derives from divergence over what aspect of the environment is to be restored. In 1988, the Society for Ecological Restoration was established in North America with the aim of re-creating indigenous, pre-European settlement conditions. Similarly, in 1992 the U.S. National Research Council defined the restoration of ecosystems as the return of an ecosystem to a close approximation of its condition prior to disturbance. Both descriptions reference a historical landscape, an ahistoric wilderness, of which little is known. In the United States, this historical reference to presettlement conditions and more recent variances such as ecosystem health or integrity is often synonymous with the concept of *natural*, an exceedingly complex term that implies a state where humans play no significant role in ecosystems, geomorphological and hydrological systems, or geochemical nutrient cycling. The human is antipodal to the natural. In this sense, what is being restored is the pristine landscape that existed prior to human manipulation and exploitation of environmental resources, a landscape separated from the imprint of people.

This has raised several concerns about both the practice and the concept of restoration among environmental ethicists. At issue is whether a restored environment is equivalent to the original one that was damaged or lost. In a seminal piece by Robert Elliot, restored environments are equated to art forgeries. They appear similar but do not have the same value of the original primarily because of the role of people in mimicking the natural processes forming these landscapes. Because humans and nature are defined as antithetical to one another, human activity is categorically different from natural activity and will inevitably produce artificial landscapes. As Eric Katz has noted, the result is an artifact. According to this line of reasoning, if the environmental degradation and despoiling that creates the need for restoration is due to human hubris and domination of the natural world, our attempts to actively repair the damage via the same means are yet another extension of this. The hubris is in thinking that it is possible



to repair the environmental damage and restore landscapes to their predisturbance value; the domination is in actively trying to make these changes come about by bypassing or manipulating natural processes for some intentional purpose. Whereas these debates have raised several ethical concerns about the concepts undergirding environmental restoration, they seem to have done little to slow the practical application of these concepts to environmental management.

The specific terminology used in environmental restoration strategies illustrates the subtleties in the intentions or goals of the projects. Restoration, as described above, is a transformation of environmental morphology and function to pre-settlement conditions. True restoration can be an impossible task because of the lack of detailed knowledge of prior states, the extent and magnitude of the biophysical changes that have occurred to landscapes, the impracticality of total removal of human elements from the system, and the lack of technical knowledge or resources needed to recreate relic environmental systems.

Restoration can also be viewed as a more generic umbrella term encompassing more specific terms such as *reclamation*, *rehabilitation*, and *remediation*, which maintain the presettlement environment as the target state but target more modest changes in the existing landscape. *Reclamation* can be viewed as a means of stabilizing highly degraded landscapes, re-creating conditions under which higher-order restoration activities such as rehabilitation can continue. *Rehabilitation* signifies a return of the environmental system to some discrete element of past structure or function that is either no longer present or severely degraded. *Remediation* indicates a focus on restoration activities related to the removal of pollutants or contaminants on sites significantly affected by human activities such as brownfields. All these terms employ “active” restoration strategies, whereby people actively take a role in reshaping the structure of the landscape or manipulating environmental processes to achieve the desired target state. Conversely, “passive” forms of restoration involve letting the environmental system heal itself through biotic regeneration, geomorphic adjustment, or chemical cycling. A critique of passive restoration is that it is too slow and

assumes that the magnitude of degradation can be reversed without a permanent loss of essential elements of the system.

Other concepts broadly subsumed under the umbrella of environmental restoration break from the assumption that the target state should be pre-settlement nature or a historic environmental configuration. For example, naturalization has been used to describe the management of environmental systems to augment certain desirable functions through the manipulation of existing biophysical processes acting within the system. The current state of the landscape is inventoried and used as a baseline for subsequent change to determine progress and success. Whereas naturalization has been used mainly in geomorphic approaches to restoration, this emphasis on functional goals having the ability to self-regulate environmental structure by focusing on process mirrors recent discussions in restoration ecology as well.

Restoration is seen by many as an applied form of sciences such as ecology, toxicology, and geomorphology and as a design science, but one that must transcend scientific considerations. As such, concerns driving environmental restoration projects involve socioeconomic interests such as what people want from the environment, the elements of the system they value as important, and the tools or resources they are prepared to deploy, and these concerns determine the course of action as much as the constraints or techniques of systematic science. Thus, restoration is a cultural activity. In short, the process of determining what aspects of the environmental system are to be restored and how this will be accomplished is a political task, one that involves scientists but also environmental activists and the public.

Identifying success in environmental restoration projects is not always an easy or straightforward proposition. When specific restoration projects have ill-defined or generalized goals such as improvement, rehabilitation, or enhancement, the potential for these projects to be assessed for their effectiveness is limited. Another difficulty in assessing restoration accomplishments is that many projects are small-scale and fragmented from other small restoration projects and their effects are localized. Yet, as Jeffrey Bash and Clare Ryan noted, perhaps the greatest obstacle in the determination of restoration success is that



many of the projects are never assessed at all after completion. Whereas funds exist for the implementation of environmental restoration projects, it is much more difficult to obtain funding for monitoring activities. Although there is a trend of increasing spending in scientific research and public expenditure of funds on restoration activities of all kinds, this lack of monitoring and reliable determination of success represents a potential weakness in the ability of practitioners to learn from both their accomplishments and their failures. For environmental restoration strategies to continue being perceived as viable mechanisms of attenuating the deleterious human impacts on sensitive environments, the effectiveness and social desirability of scientific designs will need to be demonstrated as the field of environmental restoration matures.

Michael A. Urban

See also **Brownfields; Environmental Ethics; Environmental History; Environmental Impact Assessment; Environmental Management; Environmental Planning; Environmental Services; Everglades Restoration; Forest Degradation; Game Ranching; Land Degradation; Landscape and Wildlife Conservation; Landscape Quality Assessment; Landscape Restoration; Marsh, George Perkins; Population and Land Degradation; Prairie Restoration; Soil Degradation**

Further Readings

- Bash, J. S., & Ryan, C. M. (2002). Stream restoration and enhancement projects: Is anyone monitoring? *Environmental Management*, 29, 877–885.
- Bernhardt, E. S., Palmer, M. A., Allan, J. D., Alexander, G., Barnas, K., Brooks, S., et al. (2005). Synthesizing U.S. river restoration efforts. *Science*, 308, 636–637.
- Cunningham, S. (2002). *The restoration economy*. San Francisco: Berrett-Koehler.
- Diggelen, R. van, Grootjans, A. P., & Harris, J. A. (2001). Ecological restoration: State of the art or state of the science? *Restoration Ecology*, 9, 115–118.

- Elliot, R. (1982). Faking nature. *Inquiry*, 25, 81–93.
- Hall, M. (2005). *Earth repair: A transatlantic history of environmental restoration*. Charlottesville: University of Virginia Press.
- Katz, E. (1996). The problem of ecological restoration. *Environmental Ethics*, 18, 222–224.
- National Research Council. (1992). *Restoration of aquatic ecosystems*. Washington, DC: The National Academies Press.
- Pfadenhauer, J. (2001). Some remarks on the socio-cultural background of restoration ecology. *Restoration Ecology*, 9, 220–229.
- Rhoads, B. L., Wilson, D., Urban, M. A., & Herricks, E. E. (1999). Interaction between scientists and nonscientists in community-based watershed management: Emergence of the concept of stream naturalization. *Environmental Management*, 24, 297–308.
- Soulé, M. E. (1986). Conservation biology and the “real world.” In M. E. Soulé (Ed.), *Conservation biology* (pp. 1–12). Sunderland, MA: Sinauer.



ENVIRONMENTAL RIGHTS

Environmental rights refer to the right to what are often referred to as “environmental services.” These include water, food, and materials for shelter. These services are intertwined with the evolving physical and cultural geographies of place. The geographic scope of such linkages has extended far beyond local influences to the planetary scale, and external pressures on both the quantity and quality of environmental services have created tensions and disparities that can be viewed by class, race, and gender at local, regional, and global scales. In this entry, the example of the right to clean water is highlighted as a case study. Environmental rights represent an area of intense debate in both academic and nonacademic circles and are a matter of life and death for the planet’s most vulnerable peoples. This is in large part because such rights lie at the intersection of traditional and “modern” resource management, technology, and economic development.



Systems, Characteristics, and Environmental Justice

The environment has universally, in distinct ways, provided the basis for human existence, and formal and informal management regimes have evolved regarding access to it. Tensions emerge between groups regarding access to natural resources, and this stress is amplified when they are naturally, or made to be, “scarce.” At such times, the hierarchical structure of a given polity (or if global markets are involved, the interlinked capitalist system) may result in redistribution of resources according to the characteristics that determine power in that local system or overlapping multiple scales of systems. Such characteristics can include absolute or relative location, capital or class, connections to important political offices, gender, historical relations, linkages to other places or persons, military power, population size, or adjacency and political and economic linkages to powers outside the immediate region. Thus, environmental services become redistributed by the aforementioned systems at multiple scales to reflect these characteristics and power structures.

Injustices may occur in access to the quality or quantity of environmental services necessary for a certain group because they occupy an unfavorable position in the aforementioned hierarchies. The distribution of resources reflects the inequities in the system(s) they operate within. In addition, if the system extends beyond the local level, then it is not surprising when local people lose their environmental rights or have them stressed but are unable to work to improve their position. Thus, environmental rights are complicated by the multiscale nature of a globalized world, the way we share it, and conflicting paradigms of development—and this can result in entrenched and systematic environmental injustice. Climate change is a high-profile example of this abstract nexus presently being played out from global to local scales.

Water

Arguably, the most well-documented recent battles regarding environmental rights have focused on the use of natural resources for development—the most well-known example being

dams. The work of the World Commission on Dams illustrates this. However, in recent years, authors have increasingly discussed issues related to privatization, political and economic hierarchies, and the “human right to water” movement to address concerns about capitalism, justice, development models, and access to clean drinking water. Much of the well-publicized debate has been centered on the potential impact of free trade agreements on local governance of water, justice, and sustainability.

An important element of the discourse regarding justice and access to safe drinking water (and by necessity, sanitation) has been the rise of the human right to water movement and the need to fulfill “basic needs.” Global civil society has played a large role in advancing arguments that insist on essential levels of safe drinking water being provided regardless of ability to pay or any other characteristic. These advocates refer to such access as a “right” supported in UN documents. Many members of civil society have also insisted that there be a redirection in water development policies toward building local water management capacity through municipalities rather than the use of internationally privatized concessions as in Manila, where the largest privatization has largely failed. Table 1 provides a chronological look at policies developed to support the human right to water.

Environmental rights debates and conflicts are sometimes most starkly defined in the context of less wealthy places, but relevant examples also exist in industrial and relatively wealthy countries. For example, when water conservation is pursued, water conservation-oriented rates may be put in place. However, just as a “flat tax” has variable impacts on different economic levels of stakeholders, the implementation of water conservation structures also has differing impacts depending on the value of a unit of currency to an individual. One way to change the paradigm of water use to incentivize conservation for sustainability, but still protect low-income consumers’ finances and ability to access environmental services, is through the implementation of “inclined” block rate structures to provide “basic needs” levels of services at affordable levels (Figure 1).

As human populations and economic systems grow, and along with them consumption, the



<i>Type and Date</i>	<i>Contribution</i>
Conferences	
1977	The Mar del Plata (Argentina) United Nations (UN) Conference on Water
1992	The Dublin Statement on Water and Sustainable Development
1992	Earth Summit in Rio, Agenda 21 (18.47), global action plan, chapter regarding freshwater
1996	Heads of state and government meeting. Habitat II, Committee on Economic, Social, Cultural Rights
1997	Comprehensive assessment of the world's freshwater resources and discussion of "basic needs," UN General Assembly Under Commission on Sustainable Development
1997/1998	Sixth session of the UN Commission on Sustainable Development (CSD 6)
1998	International Conference on Water and Sustainable Development Paris, France, UNESCO, and Int'l Institute on Sustainable Development (par 9)
2001	Water Resources, Human Rights and Governance, Nepal
2001	Water for People & Nature: Forum on Conservation & Human Rights, Council of Canadians
2001	International Conference on Freshwater—aiming to build on the freshwater-related objectives identified in Chapter 18 of Agenda 21
1997, 2000, 2003, and 2006	Arguably, the World Water Forum conference series
Constitutions	
1994	South Africa Bill of Rights
Covenants, major declarations, international agreements and resolutions	
1948	Universal Declaration on Human Rights, UN
1966	International Covenant on Economic, Social and Cultural Rights, UN
1966	International Covenant on Civil and Political Rights, UN
1979	Convention on the Elimination of All Forms of Discrimination Against Women, Art. 14.2(h)
1980, 1992	"World Water Day" as passed in resolutions, UN
1980s	Declared to be the International Drinking Water Supply and Sanitation Decade, UN
1986	Declaration on the Right to Development, UN
1988	American Convention on Human Rights in the Area of Economic, Social, & Cultural Rights
1988	Inter-American Convention on Human Rights: Additional Protocol to American Convention on Human Rights in Area of Economic, Social & Cultural Rights, Protocol San Salvador (A-52)
1989	Convention of the Rights of the Child, UN (Art. 24)
1989	European Convention on Human Rights, Council of Europe
1990	African Charter on the Rights and Welfare of the Child. The Twenty-Sixth Ordinary Session of the Assembly of Heads of State and Government of OAU, Art. XIV, c
1990	New Delhi Statement, Global Consultation on Safe Water and Sanitation
1990	World Summit for Children Plan of Action (par 5(d))
1997	Convention on the Law of the Non-Navigational Uses of International Watercourses; during an international conflict, "vital human needs" retain primacy over "economic development"
2000	UN Millennium Declaration adopted by the UN Millennium Assembly
2001	Committee of Ministers to Member States on the European Charter on Water (par 5 and 9 14)
2002	"General Comment"; the UN Committee responsible for the Covenant on Economic, Social and Cultural Rights declares water a "human right"
Sample rulings	
1985	Inter-American court of human rights versus pollution of a tributary supply for the Yanomamis
2004	(Case 7615, Brazil)
2008	An Indian state court (Kerala High Court) ruled against industrial overexploitation of a village's groundwater
	A South African court ruled against a prepaid water scheme in the town of Soweto on the basis of the basic right to water

Table 1 Major legal contributions supporting the human right to water

Source: Authors.

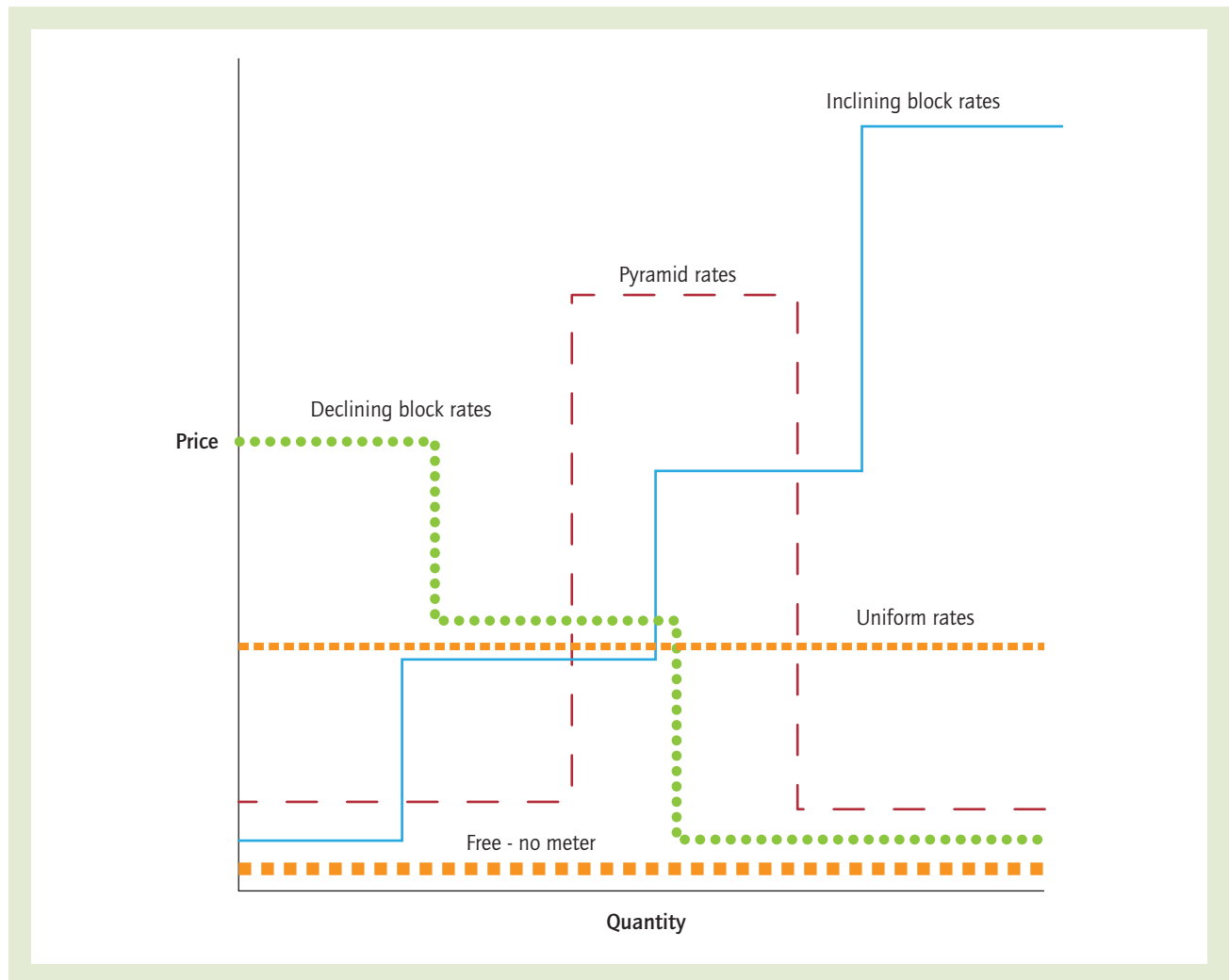


Figure 1 Water rate conceptual model with inclining block rates providing basic levels of water at low cost

Source: Wang, Y. D., Smith, W. J., Jr., & Byrne, J. (2005). *Water conservation-oriented rates: Strategies to extend supply, promote equity, and meet minimum flow levels*. Denver, CO: American Water Works Association. Copyright © 2005 American Water Works Association. Reprinted with permission.

demand for environmental services also grows. Apart from new technologies and new discoveries, the Earth has a stable or declining ability to provide the foundation for these “services,” and so debates and conflicts regarding environmental rights seem likely to intensify.

William James Smith Jr. and Ahmad Safi

See also **Environmental Entitlements; Environmental Justice; Environmental Law; Environmental Racism; Environmental Security; Environmental Services; Human Rights, Geography and; Indigenous Environmental Practices; Water Needs**

Further Readings

- COHRE, AAAS, SDC, & UN-HABITAT. (2007). *Manual on the right to water and sanitation*. Geneva: Centre on Housing Rights and Evictions.
- Jolly, R. (1998). *Water and human rights: Challenges for the 21st century* [Conference address]. Brussels, Belgium: Belgian Royal Academy of Overseas Sciences.
- Petrella, R. (2001). *The water manifesto: Arguments for a world water contract*. London: Zed Books.



- Shiva, V. (1989). *Staying alive: Women, ecology and development*. London: Zed Books.
- Smith, W. J., Jr., & Wang, Y. D. (2007). Conservation rates: The best “new” source of urban water during drought. *Water and Environment Journal*, 22, 100–116.
- Swyngedouw, E. (1997). Power, nature and the city: The conquest of water and the political ecology of urbanisation in Guayaquil, Ecuador: 1880–1980. *Environment and Planning A*, 29, 311–332.
- United Nations. (2007). *The millennium development goals report*. New York: Author. Retrieved June 20, 2008, from www.un.org/millenniumgoals/pdf/mdg2007.pdf
- United Nations Economic and Social Council, Committee on Economic, Social and Cultural Rights. (2002). *The right to water* (Articles 11 and 12 of the International Covenant on Economic, Social and Cultural Rights). Geneva: United Nations.
- Wang, Y.-D., Smith, W. J., Jr., & Byrne, J. (2005). *Water conservation-oriented rates: Strategies to extend supply, promote equity, and meet minimum flow levels*. Denver, CO: American Water Works Association.
- Watts, M. (2001). Petro-violence: Nation, identity and extraction in Nigeria and Ecuador. In N. Peluso & M. Watts (Eds.), *Violent environments* (pp. 189–212). Ithaca, NY: Cornell University Press.
- The World Commission on Dams: www.dams.org

is also debatable. This entry summarizes the ways in which scholars and institutions have conceptualized environmental security and examines debates and dividing points within the literature.

The current literature on environmental security mushroomed in the early 1990s, although the literature on environmental security has precedents predating the collapse of the Soviet Union. The Worldwatch Institute, along with several other environmentalists, argued repeatedly in the late 1970s and 1980s that national security was an outdated concept that needed to be revised in the face of global environmental change.

Environmental security's key institutional moment, however, was the publication of *Our Common Future* by the World Commission on Environment and Development in 1987, which argued that pressing environmental issues and resource scarcities are best addressed through the security orientation that had thus far contained Soviet communism. This was a response to important policy debates about the environmentally disruptive effects of the rush toward “development” in the periphery and helped further instantiate environmental security into the foreign and development policy lexicon. The National Security Strategy statements produced annually by the Office of the U.S. president began incorporating environmental security regularly in 1991 (although the environmental content of these statements waned significantly 10 years later). Although environmental security was a prominent theme in the official policy statements of the Clinton administration, it is questionable to what degree and how it has ever been incorporated as a policy focus. For some of its proponents, environmental security entails state access and control of geopolitically significant resources—securing U.S. access to Caspian Sea oil, for example—although critics sometimes see environmental security as a pretense for neoliberal, capital-driven development policy.

In addition to official policy debates, there are a number of research programs designed to investigate the relationships (causative or correlative) between environmental change, scarcity, and violent conflict, perhaps most notably the Environmental Change and Acute Conflict Project at the University of Toronto. Such research programs are grounded in a case study approach to tracing out relationships between environmental



ENVIRONMENTAL SECURITY

The term *environmental security* suggests that environmental problems should be addressed as threats to human or national security. This can and has taken a number of very different forms, and as such there is no single, indubitable meaning of *environmental security*. It could include, for example, everything from environmentalists employing security rhetoric to draw attention to their political agendas to post–Cold War security officials appropriating new threats to justify exorbitant defense budgets. What an environmentally secure community, state, or world might look like



degradation and violent conflict. Since its inception and increase in visibility, environmental security research in this form has faced (and responded to) a number of criticisms, the most prominent of which is that it typically analyzes *only* case studies in which the dependent variable, violence, occurs. Consequently, critics argue, they offer no control case, such as the existence of peaceful negotiations over a declining resource. Others stress the need to avoid explanations based on models of linear causality, in which independent variables (environmental change) are taken for granted as causes, rather than effects, of dependent variables. The more recent literature has sought to address these issues by focusing on, for instance, the role of natural resources (particularly transboundary water resources) in peace negotiations and pathways to environmental security focused on scales other than the state.

Beyond academic research programs, popular literature accounts of environmental security have been important as well. Another key moment for the environmental security literature was the 1994 publication of an article titled “The Coming Anarchy” in *Atlantic Monthly* by the journalist Robert Kaplan. Kaplan prophesied the spread of environmentally induced chaos from West Africa to other developing countries, and eventually to the developed world, and cited rapid population growth as the central cause. Kaplan’s thesis, and others like it, has at times been unfairly conflated with the research projects described above. It has also been the target of more recent environmental security scholarship, which is more critical of how the link between environment and conflict or security has been deployed and to what ends. Many such critiques come from the subfields of political ecology or critical geopolitics and argue that Kaplan’s neo-Malthusian bent is at some level characteristic of much environmental security scholarship. They also often eschew the construction of generalizable models of environmental conflict in favor of analyses focusing on the site-specific attributes of individual conflicts but situated within broader structures of power, such as international development policy, uneven terms of trade and lending, and consumption patterns in the developed world. Other critics also suggest the need to examine cases of resource abundance (such as diamonds or gold) and violence.

There exists little doubt that the environment and natural resources are important factors in the genesis of certain violent conflicts—the debate is about the nature of this relationship. Does environmental change drive such conflict, with local histories, culture, and political-economic structure at various scales merely the context that influences the form or nature of this conflict? Is the opposite the case, with environmental change something that exacerbates conflict—or for that matter is caused by conflict? Are these debates false constructs in the first place? Regardless, “environmental security” as a label does not have an unquestionable reference point in the real world; it means different things for different people in different contexts. For its various proponents, it can refer to state access to resources, the protection of the environment itself, the protection of people from the consequences of environmental change, or equal access to resources. In the latter case in particular, environmental justice has more recently become a key focal point for environmental security scholarship.

Kolson Schlosser

See also Critical Geopolitics; Ecological Justice; Environmental Entitlements; Environmental Impacts of War; Environmental Justice; Environment and Development; Malthusianism; Military Geography; Neo-Malthusianism; Political Ecology

Further Readings

- Barnett, J. (2001). *The meaning of environmental security: Ecological politics and policy in the new security era*. London: Zed Books.
- Dalby, S. (2002). *Environmental security*. Minneapolis: University of Minnesota Press.
- Kaplan, R. (1994, February). The coming anarchy. *Atlantic Monthly*, pp. 44–76.
- Kaplan, R. (2001). *The coming anarchy: Shattering the dreams of the post Cold War*. New York: Vantage Books.
- Mathews, J. T. (1989). Redefining security. *Foreign Affairs*, 68, 162–177.
- O’Lear, S., & Diehl, P. (2007). Not drawn to scale: Research on resource and environmental conflict. *Geopolitics*, 12, 166–182.



Peluso, N., & Watts, M. (Eds.). (2001). *Violent environments*. Ithaca, NY: Cornell University Press.

World Commission on Environment and Development. (1987). *Our common future*. New York: Oxford University Press.

 ENVIRONMENTAL SERVICES

Environmental services are processes and functions provided by the Earth’s myriad environments and ecosystems that sustain the human condition. The characterization, definition, mapping, and economic valuation of environmental services (also commonly referred to as ecosystem services) constitute a very active research area at the dawn of the 21st century.

One example of these services includes the pollination of crops and nonagricultural plants by bees and other pollinating species. The disappearance or extinction of bees alone would represent

the loss of a nonmarketed ecosystem service that would have profound and painful impacts on the human condition. Another example is the erosion control services provided to various extents by vegetation. This example demonstrates how there can be a spatial dependence of the value of various ecosystem services. For example, a fire can dramatically diminish the erosion control services of a forest. The economic value of these erosion control services can vary based on proximity to capital infrastructure (e.g., reservoirs), agriculture, and vulnerable populations. A highly generalized list of ecosystem services would have to include the various regulatory, production, and control functions that ecosystems provide (Table 1).

The loss and/or degradation of various environmental services has the potential of inflicting significant social, financial, and environmental damage. Some of these damages will be market damages (negative impacts on gross domestic product [GDP]), and some are nonmarket damages (not accounted for in GDP). A clear example of a market damage that could be potentially attributed to a phenomenon such as global climate

Ecosystem Service	Ecosystem Functions
Gas regulation	Regulation of atmospheric composition
Climate regulation	Regulation of global temperature, precipitation, and other climate processes
Disturbance regulation	Regulation related to ecosystem responses to environmental fluctuations
Water regulation	Regulation of hydrological flows
Water supply	Storage and retention of water
Erosion control and sediment retention	Retention of soil within an ecosystem
Soil formation	Soil formation processes
Nutrient cycling	Storage, internal cycling, processing, and acquisition of nutrients
Waste treatment	Recovery of nutrients and removal and breakdown of wastes
Pollination	Movement of floral gametes
Biological control	Trophic-dynamic regulations of populations
Refugia	Habitat for resident and transient populations
Food production	Fraction of gross primary productivity extractable as food
Raw materials	Fraction of gross primary productivity extractable as raw materials
Genetic resources	Sources of unique biological materials and products
Recreation	Providing opportunities of recreational activities
Cultural	Providing opportunities of noncommercial uses

Table 1 Ecosystem services and ecosystem functions

Source: Adapted from Costanza, R., d’Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world’s ecosystem services and natural capital. *Nature*, 387, 253–260.



change is the loss of tourism dollars associated with visits to coral reefs that are destroyed by sea-level rise and or sea temperature change. An example of nonmarket damage is the loss of the ecosystem service of storm protection provided by coastal wetlands in a sea-level-rise scenario. Perhaps ironically, the value of the storm protection services of coastal wetlands (on a per-hectare basis) actually goes up with climate change-induced increases in storm frequency and intensity. Traditional economic paradigms are increasingly challenged by environmental problems, and assessing the costs and benefits of changes to ecosystem services from a strictly economic perspective is particularly problematic.

Evolution of Inquiry in Environmental Services

Research and analysis of environmental/ecosystem services has been a growing area in ecological economics since the mid 1990s. There are many interesting and difficult questions to ask, ranging from foundational theoretical questions to pragmatic policy questions. Challenging questions include issues such as the following: What are the appropriate spatial and temporal scales at which to conduct analyses and implement policies? How do differing levels of economic development and varying cultural values influence and/or dictate methodologies for the valuation of ecosystem services? What ecological functions and processes are reasonable, appropriate, and tractable for economic valuation and quantification? Despite these challenging and contested questions, there is an increasing consensus that ecosystem services are significant and economically valuable phenomena that must be reckoned with. This consensus is demonstrated by the \$24-million, UN-sponsored Millennium Ecosystem Assessment project.

Environmental Services and the Millennium Ecosystem Assessment

On March 30, 2005, the first Millennium Ecosystem Assessment report was released by the United Nations. The major conclusions of this report included the following:

1. Human development has actually increased many ecosystem services; however, it has also significantly damaged or destroyed many others.
2. UN plans to eradicate famine and disease are significantly impeded because of extant and probable damage to ecosystem services around the world.
3. Human demands for food, fresh water, timber, fiber, and fuel have been the driving force of irreversible losses of biodiversity and ecosystem degradation.
4. Facing these challenges effectively will require the establishment and/or creation of policies, institutions, and practices that do not currently exist.

Economic valuation of ecosystem services (whether they are regarded as public goods or common property) is one rhetorical means of clarifying the importance of both ecosystem services as they stand and the consequences of their continued degradation. It is reasonable to argue that the total value of the world's ecosystem services is infinite or incalculable simply because humanity could not exist without these services; however, most attempts to place a dollar value on ecosystem services are made through economic valuations at the margin (e.g., What would the loss of the ecosystem services provided by 1 square kilometer of wetlands cost?). Attempts to make these kinds of global assessments of *marginal* values nonetheless produce global values of ecosystem services in the magnitude of tens of trillions of dollars per year. These likely underestimates of the total value of the world's environmental services nonetheless exceed the total value of the world's marketed economy. We ignore the value of environmental services at our own peril.

Paul C. Sutton

See also **Common Pool Resources; Ecological Economics; Ecotourism; Environmental Entitlements; Environmental Security; Global Sea-Level Rise; Market-Based Environmental Regulation; Neoliberal Environmental Policy; Oceans; United Nations; United Nations Environment Programme (UNEP); Wetlands**



Further Readings

- Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature*, 387, 253–260.
- Daily, G. (Ed.). (1997). *Nature's services: Societal dependence on natural ecosystems*. Washington, DC: Island Press.
- The dynamics and value of ecosystem services: Integrating economic and ecological perspectives [Special issue]. (2002). *Ecological Economics*, 41.
- Farber, S., Costanza, R., Childers, D., Erickson, J., Gross, K., Grove, M., et al. (2006). Linking ecology and economics for ecosystem management. *Bioscience*, 56, 117–129.
- Heal, G. (2000). *Nature and the marketplace: Capturing the value of ecosystem services*. Washington, DC: Island Press.



ENVIRONMENTAL SOCIAL MOVEMENTS

See International Environmental Movements



ENVIRONMENT AND DEVELOPMENT

The concept of environment and development is an attempt to integrate economic development policy-making and environmental considerations. It encompasses an acknowledgment that millions of people worldwide still live in poverty; that there is continued unequal access to the resources needed for a decent livelihood; and that there is a need for economic growth and that many human activities, including the quest for survival, put a strain on the environment. Since the early 1970s, environment and development has gradually gained momentum as an organizing concept for debates and policies on economic development and environmental conservation. It has found its way into the language of international bodies and

agreements addressing environment and development, the policies and legislation of many countries, subfield or related individual courses of study in academic institutions, and academic journal titles or focus areas, as well as becoming a convenient way to link disparate groups in the development-environment nexus.

Like many other concepts within the development discourse (e.g., development, sustainability, participation), the environment and development concept is both loaded and slippery, allowing for multiple interpretations among its users. Perhaps owing in part to the ambivalent implications of the root words that make it up, the concept of environment and development conveys both optimism and a warning. It is optimistic in the sense that it conveys an idea that there can be positive links between economic growth and environmental conservation as long as enabling policies are in place. The concept also carries a warning that the natural resource base is not infinite and that if misguided policies are pursued, economic growth through industrialization and overexploitation or misuse of natural resources could lead to environmental disasters that can negatively interfere with life as we know it today.

Like the concept of sustainable development, environment and development also has been viewed as an oxymoron in that there is an implicit goal of economic growth, but it is to be achieved while remaining within given ecological parameters. Wolfgang Sachs has even characterized the link between environment and development as a “dangerous liaison,” in the sense that, again like sustainable development, the balance is never easy to achieve or even measure.

Institutional Origins of Environment and Development

Unlike some of the most popular development discourse buzzwords, such as *development*, *community*, *gender*, and *participation*, *environment and development* has a fairly clear institutional genealogy. This is in the form of commissions, reports, international seminars, conferences, and agreements over the past four decades. The United Nations (UN) and the World Bank can be singled out as the two institutions that have influenced



global thinking about this concept through their sponsorship of activities where it has received significant attention. Some of these key institutional foundations of environment and development are discussed below.

UN Conference on the Human Environment

The UN Conference on the Human Environment, held in Stockholm in June 1972, can be considered as having laid the foundation for the linkages between environment and development debates and policies on an international stage. First proposed by Sweden, which was concerned about acid rain and industrial pollution, the Stockholm conference's main focus was to forge international cooperation for and on the environment. It is in fact considered as the occasion on which the international community's attention on environmental concerns received serious attention and provided momentum for their ascent to the top of the international agenda. Most significantly, the conference emphasized that environmental problems were caused not only by industrialization but also by poverty and lack of economic development. Thus, development, particularly poverty reduction, was needed for safeguarding the environment. Other significant outcomes of this conference include the establishment of the influential United Nations Environment Programme (UNEP) in Nairobi, the establishment of environmental ministries and agencies in more than 100 countries, and a significant increase in the number of nongovernment organizations dedicated to environmental conservation.

The link between environment and development was further clarified in a follow-up to the Stockholm conference, the Symposium on Patterns of Resource Use, Environment and Development Strategies, held in Cocoyoc, Mexico, in 1974. This symposium emphasized the need to see the development and environment problem as also being rooted in the unequal distribution and misuse of natural resources, rather than scarcity alone. However, despite the gains made by the Stockholm conference and its follow-up, environmental problems continued. Nevertheless, the successes of this conference and the continuing

environmental problems appear to have strengthened the resolve of international agencies to work toward a solution.

The World Conservation Strategy

In 1980, UNEP, one of the notable products of the 1972 Stockholm conference, in collaboration with the International Union for Conservation of Nature and the World Wildlife Fund, produced the World Conservation Strategy. As part of this strategy, the concept of sustainable development was introduced on the international stage. Sustainable development was presented as an attempt to bridge the gap between environmental concerns about ecologically destructive human actions and sociopolitical concerns about human development issues. Significantly, the World Conservation Strategy identified the maintenance of essential ecological processes and life support systems, the preservation of genetic diversity, and the sustainable use of species and ecosystems as the three primary goals of conservation. Even though this strategy had roots in wildlife conservation, it was the first comprehensive strategy to link conservation and sustainable development.

The World Commission on Environment and Development

Whereas the World Conservation Strategy introduced the concept of sustainable development into the international agenda, the World Commission on Environment and Development (WCED) is responsible for popularizing it. This commission produced its report, titled *Our Common Future*, or the Brundtland Report (after the commission's chair, Gro Harlem Brundtland, the former prime minister of Norway), in 1987. *Our Common Future* is arguably the publication that provided institutional legitimacy to international concerns and hopes concerning environment and development. Christopher Barrow has even argued that the Brundtland Report can be singled out as a landmark text of the 1980s and 1990s. Although it has been challenged and modified the world over, the definition of sustainable development that *Our Common Future* offered—economic development that meets the needs of



the present without compromising the ability of future generations to meet their own needs—remains a benchmark in almost all discussions of this issue.

The WCED's main goals were to reexamine critical environment and development problems and to formulate realistic proposals for solutions. Thus, the critical objectives for environment and development policies that were put forward in *Our Common Future* include reviving economic growth; changing the quality of growth; meeting essential needs for jobs, food, energy, water, and sanitation; ensuring sustainable levels of population; conserving and enhancing the resource base; reorienting technology and managing risk; and merging environment and economics in decision making. Poverty eradication was yet again seen as a desirable outcome of a successful development process and a prerequisite for environmental protection.

The World Bank's *World Development Report*

Perhaps a less publicized, yet significant milestone in the institutional history of the environment and development concept is the World Bank's *World Development Report 1992: Development and the Environment*. Although its main message of the need to integrate environmental considerations with development policy making does not differ from those of the Stockholm Conference, the World Conservation Strategy, and the Brundtland Report, the World Bank's apparent endorsement of those earlier observations and goals concerning environment and development is quite significant.

One significant variation between the World Bank's report and the earlier ones was the Bank's primary focus on poverty and developing countries. It emphasized the difference between the environmental problems facing the poor and those of wealthier countries, arguing that whereas industrialized countries need to solve their own problems, they have a role to play in helping improve the environments of developing countries. In its suggestions, the report highlighted the clear links between the environmental problems of developing countries and the economy and lifestyle

activities of wealthy nations. Besides the 1992 report, the World Bank's subscription to the environment and development concept saw it establish an environment department and regional environment divisions as early as 1987. In the *World Development Report 1992*, the Bank articulated its commitment to have environmental considerations more deeply embedded in every aspect of its work.

The UN Conference on Environment and Development

One of the main suggestions contained in the Brundtland Report of 1987 was that the UN should organize an international conference to review progress and promote new initiatives concerning the environment and development agenda. Thus, in June 1992, more than 170 governments, numerous heads of state, more than 1,000 nongovernmental organizations (NGOs), and thousands of other participants and campaign groups assembled in Rio de Janeiro, Brazil, for the UN Conference on Environment and Development, sometimes called the Earth Summit. Of the five key outputs of this conference, which included conventions (treaties) and declarations on forests, climate change, and biodiversity conservation, two specifically relating to environment and development can be singled out. The first one is the Rio Declaration on Environment and Development (the Earth Charter), which is a statement of 27 key principles to guide the integration of environment and development policies. These included statements on the right of every country to have its own policy on the use of its natural resources; the right to development; the necessity to reduce consumption patterns that conflict with the goal of sustainable development; and many others. The second and perhaps most significant output of the conference is Agenda 21 (a plan for the 21st century), which is a plan of action to help with sustainable development efforts following the Earth Summit. In its 40 chapters, the Agenda 21 document sets out objectives and priorities, identifies institutional questions, and assesses the costs of the proposed measures. Despite its ratification by most of the nations present, there were doubts



about whether the plans of Agenda 21 were financially feasible. Nevertheless, Agenda 21 raised much hope, especially because it was envisaged as a more community-led process that relied on local initiatives by governments and people.

World Summit on Sustainable Development

In August and September 2002, the UN held another milestone environment and development conference in Johannesburg, South Africa. This conference was named the World Summit on Sustainable Development (WSSD) but is also referred to as Rio + 10 (10 years after the Rio conference). More than 9,000 delegates from more than 190 governments, more than 8,000 representatives from NGO activist groups, and more than 4,000 media representatives attended the WSSD. Following the Rio Earth Summit, observers noted that environment and development were not easy to reconcile; as a result, there has been unsustainable development, characterized by rising poverty and mounting environmental problems. In the decade between the two UN conferences, many nations had experienced significant challenges in meeting their sustainable development goals, including the key principles contained in Agenda 21. Thus, the main objective of the WSSD was to seek ways of reviving and strengthening the Agenda 21 process and promoting its practical relevance worldwide.

Despite having the term *sustainable development* in its title, observers have concluded that the WSSD contained very little in terms of advancing sustainable development or the environment and development agendas of earlier commissions and conferences. Rather, debates became intense around what—between Agenda 21 (local solutions) and international legal processes (international convention)—succeeded or failed in fulfilling the Rio commitments. Overall, despite the large numbers of participants, the WSSD apparently did not succeed in igniting the enthusiasm of earlier conferences. Ian Scoones, in his interrogation of the term *sustainability*, contends that the sustainable development movement, which was so confident in Rio, had by the 2002 WSSD become muted and fractured.

In addition to stressing the importance of partnerships between countries, as well as between governments and citizen groups within each nation, the WSSD had two significant products relating to environment and development. The first one is the Johannesburg Declaration on Sustainable Development. This political document, which contains 37 articles outlining the path taken from Rio to the WSSD, highlights present challenges, expresses commitment to sustainable development, underscores the importance of multilateralism, and emphasizes the need for implementation. The second significant output of the WSSD is the Johannesburg Plan of Implementation for Sustainable Development. Contained in 10 chapters, the plan is a framework for action to implement the commitments that were agreed on in Rio. There are, arguably, three notable chapters relevant to this discussion. Chapter II is on poverty eradication and is based on goal number one of the eight Millennium Development Goals—of halving the proportion of the world's poor by the year 2015. This chapter also attempted to clarify the complex links between poverty and sustainable development. Chapter IV is on the protection and management of the natural resource base of economic and social development, including action on water resources, natural disaster mitigation, and sustainable use of minerals, metals, and mines, to mention a few. Chapter VIII focuses on sustainable development for Africa. It highlights poverty, violent conflicts, inadequate investment, and human immunodeficiency virus/acquired immune deficiency syndrome as the factors hindering sustainable development in Africa. It offers several recommendations for pursuing sustainable development in Africa, including sustained economic growth, reversing desertification, integrated water management, sustainable agricultural production, strengthened health care systems, and sustainable tourism, among others.

Making Sense of Environment and Development

A review of the conferences and reports on environment and development of the past four



decades easily conveys the notion that this concept is easier to talk about than to put into practice. The years between the Stockholm conference, in 1972, and the WSSD, in 2002, are characterized by what observers see as pedestrian progress on the goal of linking environmental considerations and economic development. There are likely many reasons for this slow pace of change, but only four possibilities are discussed here.

The first challenge for integrating environment and development is that both environmental conservation and development are, individually, characterized by conflicts over meaning, particularly the “how” aspect, as well as about who is responsible. Bringing the two concerns together therefore presents immediate challenges; nevertheless, it is possible to overcome these challenges. It is perhaps safe to acknowledge that linkages between environment and development are dynamic and context specific, reflecting geography, scale, and social and political issues among the groups involved.

The second challenge for integrating environment and development is that even though some countries have single ministries that address environment and development issues, in many other countries environmental issues and development fall under different departments. Facing political and financial pressures, individual ministries are often forced to turn a blind eye to commitments to integrate the two issues.

The third challenge is that given the massive global inequalities and differences in political landscapes between nations, international cooperation on environment and development is not unique in the challenges it faces. Both wealthy and poor countries individually have their own priorities and challenges.

Last, a review of the institutional genealogy of environment and development leaves a strong impression that its goals and those of sustainable development are fairly similar. In that case, one of the major critiques of sustainable development, which is that it is an oxymoron—seeking economic growth but staying within ecological limits—likely applies to the environment and development concept. However, like sustainable development, the environment and development concept has survived for more

than three decades and continues to motivate dialogue, which in turn always has possibilities of leading to positive action.

Thembele Kepe

See also Environmental Entitlements; Environmental Ethics; Environmental Impacts of Cities; Environmental Impacts of Manufacturing; Environmental Protection; Environmental Security; Environmental Services; Malthusianism; Nature-Society Theory; Neoliberal Environmental Policy; Neo-Malthusianism; Polychlorinated Biphenyls (PCBs); Population and Land Degradation; Population and Land Use; Population, Environment, and Development; Sustainable Development; Sustainable Development Alternatives; Sustainable Fisheries; Sustainable Forestry; Sustainable Production; United Nations Conference on Environment and Development; United Nations Environment Programme (UNEP); World Bank; World Summit on Sustainable Development

Further Readings

- Barrow, C. J. (1995). *Developing the environment: Problems and management*. Upper Saddle River, NJ: Prentice Hall.
- Cornwall, A. (2007). Buzzwords and fuzzwords: Deconstructing development discourse. *Development in Practice*, 17, 471–484.
- Hens, L., & Nath, B. (2003). The Johannesburg conference. *Environment, Development and Sustainability*, 5, 7–39.
- Rist, G. (1997). *The history of development: From Western origins to global faith*. London: Zed Books.
- Sachs, W. (1999). *Planet dialectics: Explorations in environment and development*. Halifax, Nova Scotia, Canada: Fernwood Press.
- Scoones, I. (2007). Sustainability. *Development in Practice*, 17, 589–596.
- World Bank. (1992). *World development report 1992: Development and the environment*. Washington, DC: Author.
- World Commission on Environment and Development. (1987). *Our common future*. New York: Oxford University Press.



EPISTEMOLOGY

Knowledge is a type of belief, and epistemology is the study of knowledge, that is, the analysis of how we know the world, as opposed to ontology, which deals with what we take to be real. An epistemology is a worldview with a particular set of assumptions, a definition of truth, and priorities concerning what constitutes valid and important knowledge. Knowledge comprises those beliefs that are both true (they conform to what is real) and justified (the one who thinks them true has sufficient reason to think them true). This formulation attempts to formally distinguish the type of belief we call knowledge from other types of belief, such as errors (untrue beliefs) and lucky guesses (true beliefs held without justification).

Everyone has an epistemology, whether they know it or not. In academic analysis, epistemologies are made explicit as they underlie the rules of knowledge formation. Different epistemologies have different criteria for what constitutes valid knowledge, different definitions of truth, and different priorities in terms of how analysis should be done. Each piece of knowledge can be considered a proposition. Propositions can be sorted (not without remainder) into three epistemic classes: demonstrable propositions (those that can be shown to be true by appeal to logic or fact), defensible propositions (those for which a convincing rational argument can be made), and preferred propositions (those that reflect individual subjective taste and cannot or need not be defended). We hope to win another person's assent to a demonstrable proposition when we can "show" them it is true in a manner that all rational humans will find persuasive. The truth of such statements is given either a posteriori, or as empirically evident to the senses (e.g., "Water runs downhill"), or a priori, that is, by definition and logical deduction (e.g., "A man cannot marry his own widow").

Other propositions may not be clearly demonstrable on empirical or logical grounds, but arguments can be offered in their favor. Dispute over defensible propositions results in agreement only some of the time. This is because their truth or falsehood cannot be conclusively demonstrated beyond the shadow of reasonable doubt. Disputants can only advance arguments for and against

such propositions. Assent (or dissent) follows a judgment, or weighing, of arguments, reasons, and considerations, but unanimity may not be attained. An example of such a proposition is "The death penalty is unjust." Each person believes that the judgment with which she or he responds to a question such as "Is the death penalty justified?" is true and justified but, in the course of dispute with those with a different answer, finds that his or her judgment is, at best, defensible and cannot be "proven" empirically or logically. No one person's argument can carry the day, for other people's judgments are defensible too.

Last, some propositions state preferences that are simply subjective expressions of individual taste. "Wensleydale is the finest cheese" or "Fall is the finest season" are propositions of this sort. In asserting them, people have no empirical evidence or inescapable logic to advance in their favor. Because they simply express a preference, they require no defense. No one knows what I like better than I, thus the famous adage: *de gustibus non est disputandum* ("There is no disputing taste").

Epistemology and Geography

Several epistemologies have shaped geography over time, each rooted in a different conception of truth, valid knowledge, and rules of argument. The word *epistemology* existed in English for more than a century before geographers used it. In the 1960s, the term provoked controversies when it was deployed by a new generation of epistemological puritans, known as logical positivists, who demanded very strict standards of justification (or verification).

Logical positivism is the insistence that only demonstrated propositions (those based on logic or facts) should count as knowledge. It demotes all defensible propositions (those based on rational argument) to mere subjective preferences. For positivists, facts are the most important and incontrovertible form of evidence used to sustain a proposition. The real significance of positivism, though, is that it seeks to separate propositions into just two epistemic classes: (1) demonstrable propositions, which, once demonstrated, cannot be reasonably disputed, and (2) mere expressions of preference. For positivists, only knowledge



grounded in logics and facts counts as “true.” One rub, however, is that positivist claims are not themselves demonstrable propositions but rather are judgments open to dispute.

Post-positivist epistemology developed outside geography, including philosophy and literary criticism. There are a variety of post-positivist schools of thought, including Marxism, humanistic approaches, and various postmodernist or poststructuralist interpretations, which share certain broad features in common. This set of perspectives typically recognizes two things: (1) that every knowledge claim rests on presuppositions that are, at best, judgments and (2) that within the realm of judgment, there is more than one style of valid reasoning (i.e., verification procedure) that humans use and find persuasive. An empiricist cannot, for instance, empirically verify empiricism without begging the question, and theological, historical, and critical arguments employ verification procedures different from (and less conclusive than) those used in science. These considerations lead many to surmise that there are multiple rationalities, each with its own “logic,” or what many today call plural epistemologies. Post-positivist epistemologies tend to focus on knowledge as a social construction, linked to particular interests, with social consequences. Much of this theorizing concerns the origins, nature, and impacts of discursive representations of the world.

Engaged in dispute, each of us attempts to promote our own beliefs while demoting the beliefs of our opponents. We typically present our defenses as demonstrations while treating our opponents’ judgments as preferences or as a mere question of taste. Epistemology in geography is, in short, very often a rhetorical tool employed in the hope that our beliefs will be taken more seriously than those we dispute.

Jonathan M. Smith

See also Discourse and Geography; Ethics, Geography and; Existentialism and Geography; Geographical Imagination; Human Geography, History of; Humanistic Geography; Idiographic; Kant, Immanuel; Logical Positivism; Nomothetic; Ontology; Phenomenology; Positionality; Postmodernism; Poststructuralism; Realism; Situated Knowledge; Structuralism

Further Readings

- Peet, R. (1998). *Modern geographical thought*. Oxford, UK: Blackwell.
- Williams, M. (2001). *Problems of knowledge: A critical introduction to epistemology*. New York: Oxford University Press.



EQUATOR

The equator is the great circle farthest from the north-south spin axis of Earth. The equator is everywhere equidistant from the North and South poles on the surface of Earth, which is a sphere or a reference ellipsoid.

Although the equator is easy to define, it is not easily found and marked on Earth. The gravitational force is lower along the equator since it is the circle on the ellipsoid farthest from the center of mass of Earth. The equator marks the line above which the Coriolis force deflects movement toward the left of the direction of travel and below which the deflection is to the right. While these effects are real and influence weather patterns, ocean currents, and aircraft flight, they are so weak as to be almost immeasurable at the equator. Polaris, the polestar, can be used to find zero latitude, but atmospheric effects make it difficult to observe accurately at the equator.

However the equator is defined by any of more than 100 geodetic datums in use in the world, it is a physically definable origin for latitude. The *geodetic equator* is the circle on the surface of a reference ellipsoid equidistant from the poles of rotation of the ellipsoid. For different ellipsoids, the geodetic equator can be in different places on the physical surface of Earth.

Since there are various definitions for other latitudes, there are other equators found along the line representing 0° of those latitudes. There is a *celestial equator*, defined with respect to celestial latitude, an *astronomic equator*, a *galactic equator*, a *geomagnetic equator*, and others.

The equator has meanings in many contexts. The geostationary weather and communications



satellites orbit Earth above the equator. The tropical sun's rays are at their highest at midday along the line. Along its course, tropical rain forests, massive river systems, and sparse populations are found on land. At sea, sailing ships can be trapped in the equatorial doldrums, and sailors still perform ceremonies for those crossing the line for the first time. Joseph Conrad, Mark Twain, and Herman Melville have used the equator in the titles of their books. There have been over a dozen films with "equator" in the title. There is a region known as Equateur in the Republic of Congo, the Equatorial Channel in the Indian Ocean, the countries of Equatorial Guinea and Ecuador, and the group of Pacific islands known as the Line Islands or the Equatorial Islands.

There are dozens of equatorial monuments in South America, Africa, and Asia, but they are often tourist facilities more than they are accurate markers of the location of the zero for the variously defined systems of latitude. For example, the Mitad del Mundo monument in Ecuador marks the approximate position of zero latitude for a system no longer in use in Ecuador or anywhere else in the world. On Ecuadorian topographic maps, the monument is responsibly placed several hundred meters above the line representing zero latitude for the Provisional South American Datum of 1956. GPS-equipped visitors to the Middle of the World will find the World Geodetic System of 1984 zero latitude a few hundred meters north of the monument.

Peter H. Dana

See also **Datums; Earth's Coordinate Grid; Geodesy; Latitude; Longitude; Poles, North and South**

Further Readings

- Clark, T. (1997). *Equator: A journey*. New York: Avon.
- Cosgrove, D. (2008). Seeing the equator. In *Geography and vision: Seeing, imagining and representing the world* (pp. 203–218). London: I. B. Tauris.

EQUINOX

The term *equinox* (in Latin *aequinocinium*) derives from two Latin words: *aequus*, whose meaning is "equal," and *noctium* (*nox, noctis*), referring to "night." Its definition involves that of the celestial sphere (which is the infinite apparent sphere around the Earth that is imagined to have our planet as its center and that contains the sun, the moon, and all the planets and stars), the ecliptic (the plane on which the orbit of the Earth around the sun lies), and the celestial equator (the huge imaginary circle on the celestial sphere that lies in the same plane as our planet's equator): An equinox, in fact, can be explained as either of two points (equinoctial points) on the celestial sphere where an intersection between the ecliptic and the celestial equator occurs. On the other hand, it can also be defined as either of the two yearly times when the sun crosses the celestial equator. At those specific moments, the sun rises exactly east and sets exactly west, and as can be inferred from the etymology of the word underlined at the beginning, the length of the day (sunlight) and that of the night (darkness) are nearly the same, irrespective of latitude. Vernal equinox is around March 20, and it marks the beginning of spring in the Northern Hemisphere, whereas autumnal equinox is around September 22, and it is the beginning of the cold season. Just the opposite occurs in the Southern Hemisphere. From an anthropological point of view, extremely interesting are those myths and rituals that refer to the equinoxes and are related to ancient cultures all over the world.

Equinoxes are said to have been discovered in ancient times by the Milesian Anaximander, who applied the gnomon (a style fixed on a horizontal plane that projects a shadow) that allowed him to determine them together with the solstices and the inclination of the ecliptic; a few centuries later, the Grecian astronomer and geographer Hipparchus of Nicaea was credited with the discovery of the precession of the equinoxes, which he studied by comparing the results of his observations of the sky with those of his predecessors. He stated that equinoxes are not always the same as they move westward along the ecliptic if compared with the assumed fixed stars on the celestial sphere. This phenomenon is due to the slow movement



(precession) of Earth's rotational axis caused by the gravitational forces of the sun and the moon on the equatorial bulge of our planet. Considering that precession is approximately 1° in 72 yrs. (years), the equinox line moves clockwise and completes its 360° round in 25,800 yrs. As a consequence, every year the dates of equinoxes come slightly earlier.

Susanna Servello

See also **Anaximander; Equator; Hipparchus; Latitude; Solstices**

Further Readings

- Kaler, J. B. (2002). *The ever-changing sky: A guide to the celestial sphere*. Cambridge, UK: Cambridge University Press.
- Millar, W. (2006). *The amateur astronomer's introduction to the celestial sphere*. Cambridge, UK: Cambridge University Press.



ERATOSTHENES (276–194 BC)

Eratosthenes of Cyrene (born in Cyrene 276 BC, died in Alexandria 194 BC) was the first scholar to use the term *geography*, meaning by that the description of Earth. His studies pertained to geography, astronomy, and mathematics and allowed him to confirm the hypothesis about the round shape of the planet and to measure its size with an extremely good approximation. He was also the first to imagine dividing Earth's surface into portions demarcated by meridians and parallels. With a deep interest in nature, he studied tides and their lunar cycle, and by observing the presence of marine fossils far from the sea, he realized the slow transformation of the coastlines.

The starting point that made Eratosthenes estimate the measurement of Earth's circumference was the observation that at noon, on the summer solstice, the bottom of wells located in the Egyptian city of Syene were vertically illuminated by the sun, while

at the same time in the northern city of Alexandria, objects (in particular he was observing an obelisk) were casting their shadows. After noticing that in Syene the sun was at the zenith (he considered it to be crossed by the Tropic of Cancer) and presupposing that the two cities were located on the same meridian, he calculated that the distance between them was around 5,000 stadia, based on the strength of the observed average speed of the caravans of dromedaries. He also correctly asserted that due to the enormous distance that separates the sun from Earth, its rays could be considered parallel when they reach the surface of the planet. Considering that in Alexandria the beams were not perpendicular to the surface but were inclined at an angle of 7.2° relative to the vertical direction, through trigonometry he got the result that the angular distance between the two cities was $1/50$ of Earth's circumference, which let him calculate both its dimension and its distance from the sun. He also succeeded in estimating the inclination of the ecliptic.

As a cartographer, Eratosthenes mapped the river Nile from Khartoum to its delta. He also drew a map of the known world, with Persia at its center and its limits described as follows: Thule (the island, described for the first time by Pytheas, that could be equated with Iceland) in the north, Ethiopia in the south, the Pillars of Hercules in the east, and India in the west. The Caspian Sea was imagined to communicate with the Northern Ocean, and as far as the African continent is concerned, its whole northern part was named Libya. Eratosthenes is also supposed to be the inventor of the armillary sphere (also known as spherical astrolabe), which is a model of the celestial sphere.

Susanna Servello

See also **Anaximander; Aristotle; Cartography, History of; Equator; Hipparchus; Human Geography, History of; Latitude; Longitude; Ptolemy; Solstices; Strabo**

Further Readings

- Dutka, J. (1993). Eratosthenes' measurement of the earth reconsidered. *Archives of the History of the Exact Sciences*, 46, 55–66.



- Eratosthenes. (2010). *Eratosthenes' "Geography"* (D. Rowler, Trans.). Princeton, NJ: Princeton University Press.
- Nicastro, N. (2008). *Circumference: Eratosthenes and the ancient quest to measure the globe*. New York: St. Martin's Press.



ERROR PROPAGATION

Quantitative attribute and geocoded data collection almost certainly entails error that arises from five sources: calculation, measurement, specification, sampling, and stochastic processes. Error propagation may be defined as the transmission of this error from data inputs to output results when performing data manipulations on maps that possess such an error. In extreme cases, this situation is characterized by the maxim “garbage in, garbage out.”

Types of Error

Calculation error refers to mistakes that arise from incorrect executions of arithmetic operations with, or imprecise representations (e.g., rounding) of, numbers. *Measurement error* refers to incorrect numbers in a data set. It arises from the use of the wrong measurement scale (i.e., nominal, ordinal, interval, ratio) or instruments lacking precision (i.e., the number of digits to the right of a decimal point), and/or recording mistakes. *Specification error* refers to the use of incorrect assumptions and/or the application of incorrect mathematical formulae or equations in a data analysis. *Sampling error* refers to differences that are due solely to the use of a subset (a sample) rather than an entire collection of objects (a parent population). Finally, *random noise* in a geographic landscape represents a haphazard (stochastic) disturbance and is characteristic of ignorance or uncertainty about reality or is the outcome of a goodly number of factors that jointly behave in such a way that random disturbances appear to be introduced into attribute and/or geocode measures.

Controlling Error Propagation

Georeferenced data error rarely averages to zero during data manipulations. Rather, error propagation can be controlled by minimizing or eliminating data input and/or analysis error. The widespread use of computers and hand calculators has minimized calculation error, which today tends to be associated almost solely with rounding and the number of significant digits to the right of a decimal point. Improvements in instruments (e.g., decreasing the pixel size in satellite remote sensors, global positioning system [GPS] technology) and the digital rather than manual handling of data, for example, have reduced measurement error. In particular, the development of spatial statistical theory, statistical theory for non-normal data, and resampling techniques has helped diminish the occurrence of specification error, which continues to be the principal source of error propagation. Experimental design and statistical mixed-model approaches (i.e., including random effects terms) furnish controls for sampling error, which because of its random nature is very controllable. Random noise in a geographic landscape refers to model residuals (i.e., the difference between predicted and observed values) and can be controlled by acquiring a better substantive understanding of geographic phenomena.

Relative Importance of the Origin of Error

Error propagation with georeferenced data is complicated by the presence of pairwise attribute correlation as well as positive spatial autocorrelation (i.e., attribute and error values at adjacent locations tend to be similar). Propagation occurs when these data are manipulated within a geographic information system (e.g., overlay, buffering) or used to construct indexes (e.g., linear combinations or ratios of, say, spectral bands). For univariate overlay, overlay-AND, overlay-OR, and overlay-XOR, attribute error and location error tend to dominate error propagation, with spatial autocorrelation of attribute variables often being the single most important contributor to autocorrelation in propagated error. Attribute error tends to be the single most important contributor to error propagation when addition or ratioing is performed, with interattribute



correlation playing a more important role for addition and location error playing a more important role for ratioing. Synchronized attribute and error map patterns frequently obscure the detection of propagated error.

In a multivariate context, either high interattribute correlation or high positive spatial autocorrelation often moderates the overall effects of error propagation. However, summarizing a set of highly correlated variables with only the first principal component, which captures much of the variability in a given data set, tends to exacerbate error propagation.

Digitizing Error

Because so much geospatial information has been digitized manually over the years, researchers have studied the positional error (i.e., the discrepancies between reference and recorded locations) associated with this digitizing process for several decades, finding, for example, that it can be characterized by a bivariate normal distribution.

Today geocodes are typically obtained with global positioning systems or address-matching software. Although these technologies have improved the locational accuracy of georeferenced data, they are not error free. This positional error affects the results of any spatial statistical analysis performed with a georeferenced data set. One outcome of error propagation is the recurrence of spatial clustering in positional error at various geographic resolutions (i.e., aggregations). One empirical study suggests another outcome, namely, the identification of a noticeable but not shockingly large impact from positional error propagation in spatial regression analysis results for the data set analyzed.

A Critique

Error enters into a geographic analysis in many ways and is usually propagated in an unadulterating or amplifying, rather than a diminishing, fashion. Besides the multitude of error propagation possibilities associated with attribute data alone, additional complications are introduced by the presence of spatial dependencies and by positional error. This error propagation can have serious consequences on decision making or knowledge

creation. For the most part, computational error is being managed well. Considerable efforts and investment are being made to manage measurement error, with GPS technology helping reduce positional error. Perhaps the single most problematic feature of this error source concerns confidentiality and the frequent need to geographically aggregate data. Spatial statistics and spatial econometrics, as well as modern advances in statistical methodology (e.g., the generalized linear model, Bayesian map analysis, mixed models), are contributing to better management of specification error. Spatial sampling designs, such as tessellation-stratified random sampling, devised for the Environmental Monitoring and Assessment Program, are enabling more effective management of sampling error for a georeferenced data collection. Random noise in a geographic landscape is, perhaps, the most difficult error source to manage because its management is at the mercy of scientific discovery.

Daniel A. Griffith

See also **Digitizing; Ecological Fallacy; Ground Reference Data; Interoperability and Spatial Data Standards; Metadata; Modifiable Areal Unit Problem; Ontological Foundations of Geographical Data; Spatial Data Integration; Spatial Data Mining; Spatial Data Models; Spatial Data Structures; Spatial Econometrics; Spatial Interpolation; Spatial Multicriteria Evaluation; Spatial Resolution**

Further Readings

- Arbia, G., Griffith, D., & Haining, R. (1998). Error propagation modelling in raster GIS: Overlay operations. *International Journal of Geographical Information Systems*, 12, 145–167.
- Arbia, G., Griffith, D., & Haining, R. (1999). Error propagation modelling in raster GIS: Addition and ratioing operations. *Cartography & Geographical Information Systems*, 26, 297–315.
- Griffith, D., Millones, M., Vincent, M., Johnson, D., & Hunt, A. (2007). Impacts of positional error on spatial regression analysis: A case study of address locations in Syracuse, NY. *Transactions in GIS*, 11, 655–679.



ETHICS, GEOGRAPHY AND

Ethics is an inquiry into the moral values embodied in discourse and practice and a concern for what is good, right, or just in our individual and collective lives. It is an attempt to formulate rules of thumb to help us grasp the ends and means of life, providing insight and guidelines to strive for what the ancient Greeks termed *eudaimonia*, a term sometimes translated as happiness but better understood as “flourishing.” The ancient geographer Strabo referenced this notion when he noted that geographers and ethicists alike are interested in “the art of life, that is, of happiness.”

Ethics can be a subject that is difficult to discuss in geography (and elsewhere) for it raises fears of dogmatic worldviews. There are indeed people who use ethics to scold others, score debating points, or justify doctrinaire approaches to life. But this is not the main tradition of ethics. Rather, as Socrates notes in Plato’s *Republic*, ethics is an exploration of “how we ought to live.” It is a conversation about the moral values that inform (or ought to inform) our way of life. This involves a process of critique and vision. We criticize what detracts from our well-being, and at the same time, we envision how we might improve our lives.

Ethics may be informed or distorted by religion, spirituality, personal experience, or social custom, but it is not reducible to these sources. Instead, it is a reasoned and evidentiary dialogue that bridges cultural and disciplinary positions to improve the well-being of ourselves and others. These others can include different entities (e.g., human or nonhuman) considered at different scales (e.g., local to global, individual to system). Thus, ethics may concern itself with the well-being of people, animals, and the rest of nature, whether they present themselves as individuals or communities, ecological systems or societies, over space or through time.

Ethics and Social Change

Ethics is also a form of discursive power. It helps reveal moral concerns, guide our thoughts and actions in addressing moral problems, and hold people and societies accountable for their actions.

Moral critique and vision are the foundation for all movements of social change, whether these are for animal, environmental, or social causes. It is for this reason that ethics is indispensable in political life generally, as well as in the life of the academy. This is not to say that the moral norms embedded in social customs and laws are always or mostly right. We need only look at the transformation of norms regarding race, gender, and sexual identity for examples of moral progress. Even so, ethics-based arguments motivate struggles for change and spur the evolution of our customs and laws.

If this arc of ethics and social change seems a crooked path, think of it as akin to the development of law, medicine, or any practice-based tradition of knowledge. There is much wrangling, and there are many errors, but over time, trends emerge that point toward better ways of engaging the world. Reason and evidence are key here. They can do much to contest invidious custom and prejudice. They also help adjust our moral compass to distinguish better from worse norms and practices.

Ethics and Geography

It may come as a surprise to some that geography has a strong streak of ethics in its discourse. During the quantitative revolution and the hegemony of logical positivism, ethics was peripheralized by the theoretical and methodological dogmas of a putatively value-free and ethically neutral scientism. With the steady erosion of scientism in geography, however, ethics has been revitalized as a living tradition of geographic thought, and geographers are experiencing a moral turn in their research and practice.

This moral turn began several decades ago with humanists, Marxists, feminists, environmentalists, and others seeking greater engagement with the social and environmental issues of their time. Many geographers began to investigate ethics-laden questions of research practices, protection of human subjects, cultural diversity, social justice, environmental protection, and the like as part of their research. Moreover, they began to speak with a moral voice about what ought to be done to allow people and the planet to flourish in light of the challenges of social injustice, colonialism,



war, uneven development, pollution, resource depletion, loss of biodiversity, climate change, animal rights, and so on.

Yet even as geographers engage in ethical discourse, they still tend to speak about ethics as something external to the field itself, as if it were an extradisciplinary add-on. This is far from the case. Ethics has been part of the geographical tradition since the beginning; the moral turn is both an extension and a recovery of part of our intellectual heritage. For better or for worse, a moral voice has always been present in geographic inquiry.

These moral geographies are of many sorts. They include classical regionalizations of cultural diversity, critiques or justifications of imperialism, teleological explanations of the natural world, and the norms of social Darwinism that underwrote environmental determinism. The contemporary concern with explicitly theorizing and deploying ethical concepts in geography is a welcome addition, representing a more explicit and reflective disposition. As such, these deployments of ethical discourse represent a shift from implicit moral geographies to explicit geographical ethics. Considered in this way, then, moral queries did not somehow infiltrate geography but have been there all along.

Practical Reasoning

One of the reasons for geography's long connection with moral understanding is the field's emphasis on context and contingency. Ethics has historically been a form of practical reasoning, which features context and contingency as central elements of causal explanation and moral justification. Practical reasoning differs markedly from the analytic reasoning that dominates modern moral philosophy. Modeled on the axiomatic sciences of mathematics and formal logic, analytic ethicists seek trans-geographical truth applied acontextually to the world. That is to say, they strive for universal axioms of conduct, derived without reference to the real-world experiences that occur over space and time. They then apply these abstractions to all people, places, and circumstances. The result, of course, is rigorously intended, if rigid, overinterpretations that are out of step with the world.

This is not the case, however, for the practical reasoning that is part of alternative traditions of ethics (e.g., casuistic, feminist, hermeneutic, theological). These alternatives thrive outside philosophy, as well as pose a challenge to analytic ethics within philosophy itself. Practical reasoning seeks to articulate situationally sensitive principles to guide us in moral and political deliberation. In this view, ethics is not a timeless and placeless body of truths but refers to the use of moral concepts as rules of thumb that help us understand how we ought to live. In this respect, geography is constitutive of ethics, generating conceptual and contextual insights that inform moral theory and method. Examples include ideas of space, place, and nature that have been and continue to serve as presuppositions to moral discourse.

Ethics in the Internal and External Domains

When it comes to the use of ethics in geography, there are two domains of ethical significance to consider. The first is the internal domain, that is, the methods of research and the production of knowledge. We often hear this domain explicitly referred to in terms of professional ethics, codes of conduct, or best practices. Ethics in the internal domain helps ensure the integrity and credibility of the field. While there are many ways of discussing this domain, it basically serves to uphold two moral values of science and scholarship—truth and trust. When speaking of truth, we are referring to matters such as the collection, analysis, interpretation, and communication of research. With respect to trust, we are thinking primarily about academic freedom, honesty, transparency, collegiality, and conflicts of interest. Along with upholding truth and trust as prime values, ethics also helps us define best practices for implementing these values in research. Common examples of best practices include the prohibition of plagiarism, falsification of data, and manipulation of research results, as well as guidelines on avoiding or disclosing conflicts of interest, prior restraint of knowledge, and self-censorship.

The second is the external domain, referring to the uses of geographical knowledge and the applications of its theories, methods, and associated technologies. We often hear this domain implicitly referred to when people speak about social



justice, environmental protection, sustainability, protecting local livelihoods, and so forth. Each of these phrases names a vital concern that embodies a substantial moral dimension. The reason for this external domain is that geography, for better or worse, has direct and indirect impacts on the health and well-being of people, animals, and the rest of nature. These impacts have consequences at a number of distinct if interconnected scales on individuals, populations, species, and communities, in natural and social systems, and in geographic space and historical time. Ethics helps elucidate the best uses of geographical knowledge by noting how research practices and knowledge products contribute to well-being in the world.

Although one may be tempted to classify the above domains into technical and critical modes, doing so unreflectively does an injustice to the diversity of intentions manifest in the work of geographers. While it may be true that, on balance, most scholarship in geographic information systems or qualitative research emphasizes the internal domain, there is important work in these areas that references the external domain. Some geographers attempt to balance the two in their research. And some emphasize one domain because they recognize its connection to the other. For example, the transparency of the research process in GIS is crucial if we are to use accurate mappings of nature and society for the greater good. And compliance with internal review boards in research with human subjects is a cumbersome but frequently necessary tool to protect the well-being of people participating in research. The domains should be considered mutually informing distinctions, not boxes into which we categorize (and perhaps dismiss) the full range and legitimate diversity of geographic research.

Challenges for Ethics in Geography

Having said all this, ethics still faces and poses significant problems in the discipline. Two of the more important are highlighted below.

The first of these problems is the empirical objection. The idea behind the empirical objection is that geography is a science committed to empirical research. Ethics is therefore not real geography as it is not “grounded,” “concrete,” “spatial,” “material,” or “factual.” This objection is not

quite a rejection as it allows for a professional ethics enclosed within the internal domain noted above. It does, however, reject “speculative” excursions in so-called theoretical terrains, such as animal ethics, global ethics, and environmental justice. The error behind this objection is that it elides a discredited scientism and its empiricist vision of science with the tradition of geography as an interdisciplinary body of scholarship. This problem is compounded by an implicit facticity that makes invisible the causal relations between tangible and intangible phenomena. Both tangibles (e.g., the spatial patterns and extent of clear-cut forests) and intangibles (e.g., the values behind policy debates about the clear-cutting of forests) are real and thus empirical in any sensible definition of the term. To understand the intangible dimension, much less explain much of the tangible world, one must examine the moral causation that is partially constitutive of what and why humans do what they do.

The second problem is the challenge posed by animals and nature. After the debunking of social Darwinism and environmental determinism in the early 20th century, the field turned away from environmental matters for many decades. This has been redressed to some degree since the mid 1990s through technically focused environmental geographies (e.g., environmental geographic information systems [GIS]) and politically focused critical geographies (e.g., political ecology).

Yet from a moral perspective, these discourses remain stubbornly speciesist and anthropocentric. The reasons for this are many but are partially rooted in the value-free scientism that still stalks aspects of geography, as well as the social reductionism and moral relativism that characterize the social construction of nature thesis embraced by much of critical geography. To be sure, creative efforts to break out of these moral dead ends have emerged, primarily in animal geography and by dissident voices in nature-society relations. Their moral sensitivity to the well-being of people, animals, and nature is forging new insights that honor and extend the insights of technical and critical geographies while at the same time contesting the self-privileging moralities of human exceptionalism.

Overall then, geography is both the root and the fruit of moral understanding. As the root, its



situated knowledge is a necessary element of an ethics engaged with the real world. As the fruit, it is a conceptual space in which a more situationally sensitive ethics might thrive, even if (or because) it lends itself to a different model of practice than is normally pursued in philosophy. In this sense, geography shares with other disciplines (e.g., animal studies, environmental studies, and philosophy) the cotradition of ethics. As such, it also has a responsibility for developing geographical ethics that enrich our moral understanding of the world.

William S. Lynn

See also **Animal Geographies; Critical Human Geography; Environmental Ethics; Environmental Racism; Existentialism and Geography; Humanistic Geography; Human Rights, Geography and; Inequality and Geography; Justice, Geography of; Marxism, Geography and; Phenomenology; Race and Racism; Social Justice; Spatial Inequality**

Further Readings

- Bernstein, R. (1991). *Beyond objectivism and relativism: Science, hermeneutics and praxis*. Philadelphia: University of Pennsylvania Press.
- Lynn, W. (1998). Contested moralities: Animals and moral value in the Dear/Symanski debate. *Ethics, Place and Environment*, 1, 223–242.
- Lynn, W. (2004). The quality of ethics: Moral causation in the interdisciplinary science of geography. In R. Lee & D. Smith (Eds.), *Geographies and moralities: International perspectives on justice, development and place* (pp. 231–244). London: Routledge.
- Sack, R. (1997). *Homo geographicus: A framework for action, awareness, and moral concern*. Baltimore: Johns Hopkins University Press.
- Smith, D. (1994). *Geography and social justice*. Oxford, UK: Blackwell.
- Smith, D. (2000). *Moral geographies: Ethics in a world of difference*. Edinburgh, UK: Edinburgh University Press.
- Wolch, J., & Emel, J. (Eds.). (1998). *Animal geographies: Place, politics and identity in the nature-culture borderlands*. London: Verso.



ETHNICITY

Although there is no definitive definition, most scholars increasingly agree that ethnicity derives from both an internal sense of distinctiveness and an external perception of difference. The category exists to classify various groups of people based on specific social and cultural characteristics, with the most typical identifier being ancestry. Although some researchers continue to assert the emotional, hereditary, and primordial origins of ethnicity, increasingly there is agreement that ethnicity can also be the product of structural forces, social organization, and cultural representation. In other words, ethnicity is a social construction, where individuals are active agents in defining their ethnicity, and at the same time, the category must be negotiated within a reactive, shifting social environment.

Ethnicity is situational and dynamic, with individuals sustaining and asserting their ethnic identities in uneven and differential ways, depending on the social and political environment that surrounds them. So even though individuals may use the same ethnic label, they may construct their ethnicity based on the shifting notions and interpretations of their personal identities. At the same time, ethnicity is not a static concept that remains stable over time; instead, identities can be altered, manipulated, and transformed based on broader spatial, political, social, and economic dynamics. Ethnicity, then, is a creative and complex response to both individual and social forces. The formation and expression of ethnic identity come from both historical circumstances and individual negotiations to endow ethnicity and ethnic symbols with meaning.

Many individual characteristics are considered the building blocks of ethnic identity, including language, dialects, religious faith, literature, folklore, music, food preferences, social and political ties, traditions, values, and symbols, kinship, neighborhood, community links, and/or migratory status. Other external attributes are also thought to be significant in the construction of ethnic identities, including the role of governmental policies and social measures, racial discrimination, residential segregation, occupational concentration, and economic



isolation. Ultimately, each individual conceives, maintains, and makes manifest his or her ethnic identity in numerous ways: For some, the identity may be primordial and unproblematic; for others, ethnicity may be strategic and intentional. But all ethnic identities are transformative, and all ethnic identities have very real consequences in people's everyday lives.

The Role of Race

No conception of ethnicity could explain much if it failed to reckon with the underlying issues of race. In contrast to ethnicity, the definition of which centers on cultural characteristics, race is taken to mean the common physical attributes of a given group, typically including skin color, hair texture, and facial features; however, racial differences are biologically almost meaningless, and race, like ethnicity, is also a social construction. All minorities are considered to have an "ethnic" identity, whereas those in the majority typically view themselves as "nonethnic." But in most situations, this idea of not having an ethnic identity can only work for those in a privileged position. Everyone has an ethnic identity; the question is whether this identity is acknowledged. Nor are all ethnicities equal; for some, ethnicity might appear to be largely symbolic, costless, and voluntary; yet for many, there is no choice when it comes to defining their ethnicity—it is an identity, often conflated with race, that is imposed by the larger society. In other words, the dominant group can enjoy a considerable range of identities, suggesting that race allows it flexibility in choosing its ethnic identity, whereas the "visible" minorities have no such privilege: Even as they gain socioeconomic mobility, they are subject to stigmatization and marginalization based on their ethnic/racial identity.

Dominant groups play a critical role in the social construction and classification of ethnic groups as racialized minorities. Indeed, how the dominant group "sees" others is often more critical in the creation of ethnic/racial categories than how individuals identify themselves. This is primarily because the dominant group reserves for itself the luxury of dismissing ethnic/racial identities, while more oppressed groups are made daily aware of their ethnic/racial identities.

This ethnic/racial "labeling" becomes quite obvious when looking at how ethnic identity formation is intertwined with the process of migration. Immigrants frequently arrive in a new place where the dominant society exercises much power in defining difference. In an effort to not only survive but also prosper and build meaningful relationships, immigrants oftentimes depend on various ethnic attachments to create a sense of belonging. Typically, they become connected to those individuals with whom they share the most commonalities (in terms of locality, dialect, class, and religion, among other things). Yet because the host society relies on its own set of ethnic/racial categories, which generally focus on the country of origin (or even the broader world region), the diversity that characterizes individuals when they emigrate is disregarded for the categories that the host society uses to classify different groups. As a result of interactions with members of the dominant group and other minority groups in the host society, pan-ethnic labels (such as Indian and Mexican, or Asian and Hispanic) become concretized, and individuals of disparate origin oftentimes unite around these simulated categories despite their lack of resonance and meaning for individual immigrants.

Eventually, these distinct ethnic identities and group attachments should disappear as the descendants of immigrants take on the core culture and become assimilated. As members of the second and beyond generations begin interacting with members of the dominant group, particularly on the intimate levels of friendship and family formation, ethnic differences should become less and less significant. Ethnicity should remain important in only the most superficial ways after assimilation occurs, as individuals choose symbols (such as ethnic foods and festivals) that require little effort to maintain and that do not interfere with other social and economic aspects of their lives. This symbolic ethnicity emerges as a nostalgic connection to the culture of the "old" country, whereby individuals carefully and continually (re)choose those ethnic traditions and ideals that serve them in varying contexts. While this idea appears to be valid with regard to ethnic groups that "blend in" with the host society, the reality is that groups that appear to be different (particularly



in terms of physical attributes, religion, and class) have little choice in deciding their ethnic/racial identities. Some “visible” minorities are even forced to appropriate these involuntary labels to use collectively in group actions since society is organized and ruled along ethnic/racial lines.

The Role of Space

Recent work argues that the study of ethnic identities cannot be understood without explicating the relationships between ethnicity, space, and place. This geographic research takes shape in many forms, although only two areas are discussed here: (1) mapping the spatial distributions of ethnic groups and categorizing various ethnic landscapes and (2) identifying how the regulation of space reflects and reinforces ethnic/racial identities.

Many geographers pay special attention to the spatial distributions of various ethnic groups. An entire terminology has emerged to talk about the various forms that ethnic communities take on, including ethnic ghettos, enclaves, and citadels. In this work, typically, the unifying force of ethnic attachment in creating and re-creating ethnic communities is highlighted. Ethnic ghettos, ethnic enclaves, and ethnic citadels are distinguished by their homogeneity, density, and old-country “flavor.” The emotional links of ethnicity bind residents together and refortify the continuation of ethnic communities. Each distinctive ethnic group creates and occupies a place that becomes representative of that group. These places develop into vibrant ethnic centers that not only concentrate and display a distinct group’s way of life but are also supported by specialized institutions and commercial activities.

Often, the spatial distribution of ethnic groups is expected to indicate broader patterns and processes of settlement and adaptation. At the heart of this research is the notion that residential change and social mobility are connected and interlinked. Here, spatial dispersion (and the disappearance of concentrated ethnic communities) is indicative of the weakening of social and structural barriers, thus indicating not only spatial but also social and structural assimilation into the dominant society. This geographic research

illustrates that ethnic distributions are not necessarily stable and that spatial patterns and levels of segregation among and between ethnic groups somehow measure the degree to which groups have become integrated.

Because the primordial and emotional connections of ethnicity tend to be overemphasized in this research, some geographers are revisiting these mappings. Recent critiques and theorizations have exhibited a greater sensitivity to the role of structural forces in reinforcing ethnicity and ethnic landscapes. There is a particular focus on the role of space in creating and re-creating ethnic identities. Scholars articulate how various groups experience places as inclusive or exclusive of them and others and how the regulation of space reflects and reinforces the identities, privileges, and interests of some groups over others. New questions centered around issues of ethnicity focus on (1) the forms of racism and racial privilege and oppression that operate through geographical patterns, processes, and ideas and (2) the ways in which ethnic/racial hierarchies become struggles over space within society. Thus, ethnic ghettos and ethnic enclaves (along with ethnic citadels, which are the ethnic landscapes of the dominant culture) are considered the sites and mediums of privilege, power, and prestige, as well as oppression, minoritization, and disparity. Ethnic groups positioned in the most impoverished and outcast spaces, as well as those living in the wealthiest, most exclusive places, are spatial reminders of broader ethnic/racial divides (and socioeconomic hierarchies as well). Ethnic/racial categories are inhabited and naturalized, both materially and ideologically, through these concrete spaces, primarily as a result of systematic institutional practice and exclusionary spatial codes.

Certain ethnic groups become racially categorized during the time when the neighborhoods they live in become spatially segregated communities. But the spaces of the dominant group, which are usually taken for granted as invisible, ordinary, and mundane, are also spatially segregated landscapes, which in turn reinforce the ethnic/racial category of privilege as one that should be considered normal, taken for granted, and unmarked. This process of differentiation occurs because the members of the dominant group



cannot (or refuse to) acknowledge how they themselves embody particular ethnic/racial categories. By maintaining invisibility, the dominant group remains racially undefined, and social hierarchies remain rigidly reinforced. Thus, the ways in which ethnic spaces in turn both produce and reflect specific racial ideologies become critical. Even though ethnic/racial categories and geographies change with time, they continually matter because groups are relegated to different points along the spatial hierarchy, which in turn reinforces disparity.

Conclusion

It is important to point out that despite its wide usage, ethnicity as an analytical concept in academia still lacks a universal definition. The term *ethnicity* is used with varying meanings in different contexts, and these understandings change over time and across space. Moreover, ethnicity is becoming increasingly complex as the cross-national and transnational movement and connections of people, goods, information, and financial capital become more prevalent. Certainly, ethnicity affects societies deeply and in multiple ways that are not always easily identified or well understood. Identifying the many influences of this categorization scheme (especially the role of race and space), as well as its transformative and dynamic nature, can begin to help untangle the influence of ethnicity in everyday life.

Emily Skop and Wei Li

See also **Environmental Racism; Ethnicity and Nature; Ethnic Segregation; Ethnocentrism; Identity, Geography and; Immigration; Nation; Nationalism; Orientalism; Other/Otherness; Race and Empire; Race and Racism; Racial Segregation; Segregation and Geography; Urban Underclass; Whiteness**

Further Readings

- Allen, J., & Turner, E. (1988). *We the people: An atlas of America's ethnic diversity*. New York: Macmillan.
- Arreola, D. (Ed.). (2006). *Hispanic spaces, Latino places*. Austin: University of Texas Press.

- Frazier, J., & Tettey-Fio, E. (Eds.). (2006). *Race, ethnicity, and place in a changing America*. New York: Academic.
- Li, W. (Ed.). (2006). *From urban enclave to ethnic suburb: New Asian communities in Pacific Rim countries*. Honolulu: University of Hawaii Press.
- Nash, C. (2003). Cultural geography: Anti-racist geographies. *Progress in Human Geography*, 27, 637–648.
- Omi, M., & Winant, H. (1994). *Racial formation in the United States: From the 1960s to the 1990s* (2nd ed.). London: Routledge.
- Schein, R. (Ed.). (2007). *Landscape and race in the United States*. New York: Routledge.
- Sibley, D. (1995). *Geographies of exclusion: Society and difference in the West*. London: Routledge.
- Singer, A., Hardwick, S., & Brettell, C. (Eds.). (2008). *Twenty-first century gateways*. Washington, DC: Brookings Institution Press.

ETHNICITY AND NATURE

The relationship between ethnicity and nature has often focused on a notion of essentialized identities. People and place are linked, in this view, not as mutually constitutive social and cultural constructs but rather as immutable and static objects and subjectivities. Ethnicity has often been viewed, therefore, as a way of expressing assumed relationships between particular communities and specific regional landscapes and resources or through the cultural and economic practices of a given population. Such linkages have sometimes been normalized and reified to the point that the particular racial, national, or ethnic heritage of a group begins to define a landscape itself or vice versa. We begin to talk therefore of an English countryside, a Canadian prairie landscape, or a Rajasthani desert. Similarly, we may begin to describe particular communities as forest dwellers, hill peoples, or desert nomads, privileging a view that echoes with the long-discredited environmentally deterministic theory of human development. It is important therefore to interrogate some of the key discourses that



have linked ethnicity and nature as an expression of essentialized identity. There are three particularly central themes in which this relationship is expressed: (1) nationalism and nature, (2) the noble savage, and (3) environmental racism and environmental justice, which this entry addresses in turn.

Nationalism and Nature

Despite the criticisms that have been levied against environmental determinism for several decades, the power of the assumptions embedded in the relationship between ethnicity and nature remains enduring. Modern nationalist movements, for example, from those of 19th-century Europe to the anticolonial struggles worldwide in the 20th century, have drawn consistently on the idea of inherent and essential connections between people and place as a way of imagining new political communities. We often find in Romanticism, the cultural and intellectual movement that undergirds many of these emerging nationalist visions, an explicit link between an ethnic and a physical nature—pastoral landscapes and an English character or perhaps dark forests and an essentially martial German subject. Similarly, the anticolonial nationalism of the past two centuries has often drawn on the idea that an indigenous population is somehow more legitimately connected to the local landscape than is a “foreign” ruler. Such claims have often been made not only on the basis of justice and equity but also on the assumed authenticity of one group rather than another, an authenticity predicated once again on an essentialized notion of ethnicity and nature. The British, in this view, were not welcome in India, the French in Algeria, or the Dutch in Indonesia, not only because of their repressive behavior as imperial masters but also because the stain of their unfamiliarity with the natural landscape of each place could not be erased through colonialism. The British retreat to hill stations in the summer, the French attempt to re-create metropolises, and the Dutch rejection of the traditional longhouses were all therefore seen as an inability to connect to local landscapes.

In the contemporary period, ethnicity remains a potent fount for articulating “authentic” connections between specific people and places.

Indeed, many of the major political conflicts that have arisen throughout the 20th century have been characterized by struggles to define the “natural ethnicity” of a region. Israel and Palestine, for example, are seen from this perspective as being quintessentially Jewish and Arab, with these ethnicities defining the land and vice versa. So-called ethnic cleansing has also been used in conflicts, from the former Yugoslavia to Rwanda, and many others besides, to remove apparently offending bodies and communities from lands to which it is claimed they do not belong. An essentialized understanding of ethnicity and nature lies once again at the heart of such political categorizations.

The Noble Savage

Romanticism not only celebrated the notion of specific landscapes as touchstones of nationalist identity but also venerated and elevated an earlier cultural archetype of an uncivilized and unspoiled individual or culture for its supposed closeness to and familiarity with nature. In the context of ethnicity, there are two distinct effects of the noble-savage characterization. On the one hand, the archetype has been used to justify paternalism, racism, and colonial subjugation by suggesting that certain ethnic identities are unable to control and manage nature effectively. On the other hand, the notion of the noble savage has at times become a fantasy of purity through which so-called civilized or modernized groups and individuals may lay claim to an unspoiled and natural past. Both views are demeaning, reductive, and pernicious, yet they have had distinct, if related, consequences.

The paternalistic view of the noble savage posits the idea that particular ethnic identities have what amounts to an unsophisticated and immature understanding of nature. This view does not necessarily suggest that these identities are not connected to or situated within nature; paradoxically, noble savages are often glossed with the sheen of a positive and benign association with natural phenomena and space (see below). But the fundamental characteristic that defines these particular understandings of ethnicity and nature is one of inadequacy: an inability to manage resources, to understand—in a scientific, rational



manner—the workings of the natural world, and to preserve and maintain an ecology in a sustainable fashion. Indigenous and tribal communities have suffered in particular because of this characterization and were often labeled as primitive, backward, and ignorant “others.” From the perspective of (self-described) advanced societies, such cultures are often deemed either incapable or unworthy of not only the responsibility of self-rule but also the stewardship of the natural environment in which they are situated. The noble savage in this case may live in nature but is to some degree ignorant of it and its proper use. Throughout the period of European imperialism, but especially during the late 19th century, this particular view of ethnicity and nature helped justify the expropriation of lands and resources from indigenous communities across the world in the name not only of conquest but also of environmental stewardship and the scientific management of natural resources.

Although the ideology of the “white man’s burden” may have faded in the postcolonial period, some critics have argued that primitivist understandings of ethnicity and nature continue to play a substantial role in the contemporary lives of many indigenous, tribal, and marginalized populations across the world. Indigenous communities have consistently found themselves displaced, for example, from traditional lands and livelihoods across the globe. This process has occurred as a result of the projects of nation-states, the profit motives of extractive industries, and the protectionist politics of conservation efforts. Whether because of the building of dams, the logging of forests, or the creation of parks, the same logic that links “primitive” tribal natures to their inability to manage their own environments underlies these displacements. If noble savages are present within so-called natural landscapes, they are often acceptable only as museum pieces or cultural artifacts rather than as active participants. Indigenous communities therefore may be transformed into particular attractions or performers in tourist or ecotourist destinations.

A more celebratory representation of the noble savage presents the reverse view to that of the ignorant and primitive Other, although it arises out of the same essentialized notion of race and ethnicity. In this view, indigenous and tribal

identities are exoticized and fetishized precisely for their apparently deeper and more authentic connection to the natural world. Such Orientalized understandings have become a prevalent lens through which some Native American/First Nations identities have been framed based on an argument that these particular groups may be better stewards of the Earth because of the closeness that their ethnicity provides to nature.

Similarly, ideas regarding Eastern spiritualism—linked variously to traditions in India, China, Japan, or the Middle East—have been a significant source of New Age beliefs and in turn constitute an important influence on some aspects of the modern North American environmental movement. Relying once again on an essentialized view of ethnicity and nature, the positive representation of the noble savage—as both individual and community—has served as a model for environmental activism and the articulation of an alternative ecological vision. Indigenous communities are themselves not ignorant of such reductive views of themselves, in both the positive and negative portrayals as pure or ignorant. Indeed, some groups have engaged in what might be deemed “strategic essentialism,” playing off the stereotypical views to gain necessary support for the social and ecological justice struggles in which they are engaged. The longer-term costs of the accommodation of the noble savage representation by such subjects is, however, difficult to gauge.

Environmental Racism and Environmental Justice

In the same way that the noble-savage characterization has two distinct but related faces, the relationship between ethnicity and nature has a dichotomous form when we look at the issues of environmental racism and environmental justice. On the one hand, the issue of ethnicity is clearly visible when we look at the notion of environmental injustice as it has been popularized over the late 20th and early 21st centuries. Many activists and scholars have alleged that it is on the basis of ethnicity and discrimination in large measure that polluting industries and hazardous materials have been placed within racialized and marginalized neighborhoods, regions,



and countries. Similarly, it is on the basis of assumed linkages between essentialized identities and the natural world that certain groups have been pressed into service through specific forms of labor and exploitation, whether in sweatshops, extractive industries, or fields and factories. On the other hand, a demand for environmental justice has been a rallying cry in recent years for a range of social movements worldwide, many of which base their campaigns in part on the belief that particular ethnic identities—especially marginalized and indigenous communities in the so-called Third World—are especially under environmental threat. Both parts of this equation continue to reify the linkage between ethnicity and nature and similarly continue to have deleterious effects, especially in terms of global environmental politics and change.

Ironically, while the campaigns of many prominent environmental organizations have privileged indigenous struggles across the world, within North America the environmental movement as a whole has often been criticized as being a primarily white, affluent, and urban phenomenon that discounts or denigrates the possible contributions of minority groups. Such populations—including recent immigrants, poorer or working-class communities of color, and historically disadvantaged groups—are often characterized as having less knowledge or interest in environmental issues. At the same time, the increasing internationalization of certain environmental problems—such as global climate change, species endangerment, deforestation, and habitat destruction—has led to the search for transnational solutions, many of which often lead to the disenfranchisement of indigenous and otherwise ethnically identified groups through a process that some observers have described as green globalism or green neocolonialism.

Pablo Bose

See also Colonialism; Environmental Determinism; Environmental Justice; Environmental Racism; Environment and Development; Ethnicity; Indigeneity; Indigenous Environmental Knowledge; Nation; Nationalism; Orientalism; Other/Otherness; Race and Empire; Race and Nature; Social Darwinism

Further Readings

- Baviskar, A. (2004). Between violence and desire: Space, power and identity in the making of metropolitan Delhi. *International Social Science Journal*, 55, 89–98.
- de Wet, C. (Ed.). (2005). *Development-induced displacement: Problems, policies and people*. London: Berghahn Books.
- Guha, R. (2006). *The Ramachandra Guha omnibus: Unquiet woods, environmentalism, saving the civilized*. Oxford, UK: Oxford University Press.
- Pellow, D., & Park, L. (2002). *The Silicon Valley of dreams: Environmental injustice, immigrant workers, and the high-tech global economy*. New York: New York University Press.
- Sachs, W. (Ed.). (1993). *Global ecology: A new arena of political conflict*. London: Zed Books.



ETHNIC SEGREGATION

Ethnic segregation is the enforced or voluntary residential separation of two or more groups on the basis of cultural identity. Usually understood at the local scale among neighborhoods within a city, ethnic residential segregation also occurs at other geographic scales. Regionally, Native Americans have been forced onto reservations encompassing many U.S. counties, and many blacks in South Africa were relocated to several “homelands” during apartheid. The various aspects of ethnic segregation include what causes segregation, how segregation can be measured, and what interpretations can be made from segregated spaces. Overall, the separation of ethnic groups into distinct geographic spaces due to coercion or possible discrimination may illustrate the inequalities found in societies.

Causes of Ethnic Segregation

There are several causes of ethnic residential segregation: housing discrimination, socioeconomic



differences between ethnic groups, ethnic group preferences, and forced ethnic confinement. Housing discrimination, in both public and private sectors, has been proposed to cause ethnically segregated living spaces in American cities. In the past, the U.S. federal government attached provisions to publicly offered home loans that restricted the housing options of various groups of people. Local governments, via their zoning laws, tended to exclude certain ethnic groups from residing in the suburbs. In the private sector (i.e., banks, realtors), limitations to housing for particular ethnic groups were facilitated by redlining and blockbusting. Such formal restrictions are now illegal, but informal practices of housing discrimination may still exist today.

Another prospective cause for ethnic residential segregation deals with differences in socioeconomic status (SES). The basis of the SES argument is that residential segregation is related to class differences rather than to ethnic differences. Here, class issues underlie housing outcomes in determining where people live in a city. If economics were the only factor in determining where people choose to live, then the poor would live in the areas with older housing and the rich in the areas with newer housing, or in the inner city and the suburbs, respectively.

Ethnic group preferences for living in segregated areas are another hypothesized cause of residential segregation. Under this interpretation, ethnic groups differ in the type of neighborhoods they perceive as desirable. Ethnic residential segregation may signify social solidarity, if ethnic members choose to live near each other, or social avoidance, if people prefer not to live near a certain ethnic group. Self-segregation can be a method of creating defensible spaces that maintain “peace” between opposing groups, as the example of Catholics and Protestants in Belfast, Northern Ireland, indicates. The last prospective cause of ethnic segregation deals with the forced confinement of an ethnic group to a particular area. The first “ghetto” in Venice, Italy, was created for Jews by forcing them into a neighborhood that was separate from the residential areas of other Venetians. In terms of regional ethnic segregation, Native Americans and many Japanese Americans during World War II were

relocated and residentially separated from other Americans.

Measuring Ethnic Segregation

Determining the levels of residential segregation is important in monitoring whether cities are becoming more or less segregated over time. There are several segregation indexes that have been disputed over by social scientists, but the most used ethnic segregation index is the dissimilarity index (DI). The DI measures the differential distribution between two population groups in an area and can be calculated using the following formula:

$$\frac{\sum_{i=1}^n |x_i - y_i|}{2}.$$

In this formula, x_i is the percentage of the total x -group population in census tract i and y_i is the percentage of the total y -group population in census tract i . Here, the sum of the absolute values of the differences in percentages between group x and group y values in census tract i is divided by 2. The DI ranges from 0, indicating no segregation between the x and y groups, to 100, indicating complete segregation between the x and y groups. Calculating and mapping this segregation measure between African Americans and whites for American metropolitan areas (Figure 1) illustrates that cities in the Midwest and the northeast have higher segregation levels (with DI greater than 60) than cities in the west.

The drawback of the DI, for quantitative research using enumeration units, is the modifiable areal unit problem. Geostatistical analysis is sensitive to the sizes of the enumeration units used in its calculations, since spatial data can be enumerated for multiple spatial scales (e.g., county level to tract level to block level). Depending on what enumeration unit size or shape is used to measure segregation, different segregation scores can be computed.

Meaning of Ethnic Segregation

There are positive and negative implications of living in ethnically concentrated areas that are

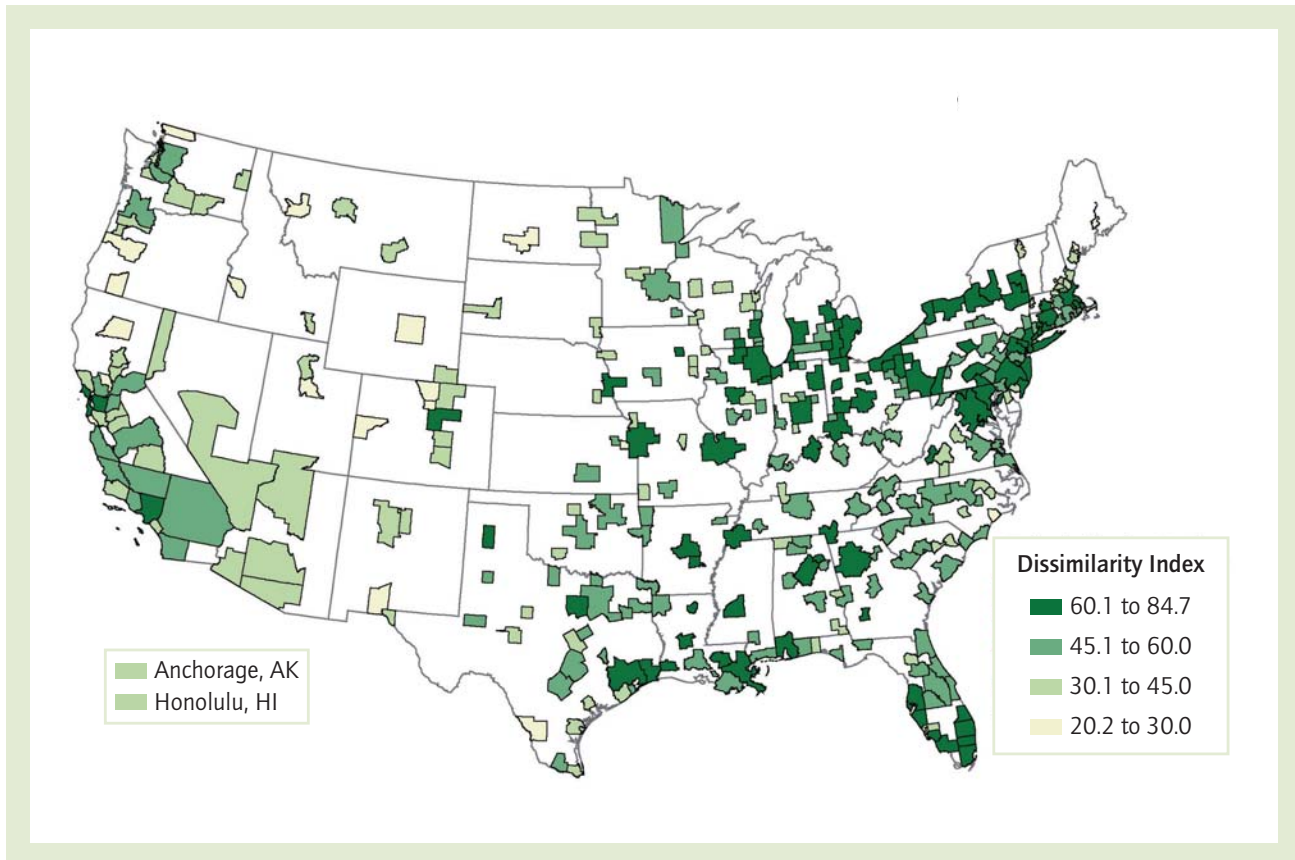


Figure 1 Levels of segregation between African Americans and whites for each American metropolitan area in 2000

Sources: Map created by author, based on data from U.S. Census Bureau, www.census.gov, and Lewis Mumford Center, <http://mumford.albany.edu/census>.

conceptualized in the dichotomy of the ethnic enclave/ghetto paradigm. In other words, there are “good” and “bad” forms of segregation; living in the former provides support for group members, whereas living in the latter hinders future life chances for group members. Ethnic enclaves, or the “good” segregation, have been represented historically in the form of urban places such as Little Italy, Chinatown, and the like, which have provided community support for people with similar ethnic backgrounds. In essence, the ethnic enclave was a “home away from home” for immigrants that made transitioning into another society easier.

In general, the stigmatized ghetto was characterized as a place that had poorer quality-of-life outcomes (e.g., poor education, high poverty and unemployment rates) and where ethnic groups

without choices lived. The ghetto was associated with high crime rates, areas of social vices, and places that housed the most downtrodden in American society. Living in the ghetto was detrimental for its residents, in that trying to make it by moving out was difficult due to the lack of social capital in these neighborhoods. Ghettos were seen to remain on the urban landscape over time since it was too difficult to change the downward spiral of social ills.

Ethnic segregation between African Americans (Figure 2) and whites (Figure 3) in Omaha, Nebraska, can be related to the location of poverty (Figure 4). Areas of “North Omaha” have a high percentage of African Americans and high rates of poverty, while areas of “West Omaha” have a high percentage of whites and low rates of poverty. This spatial association

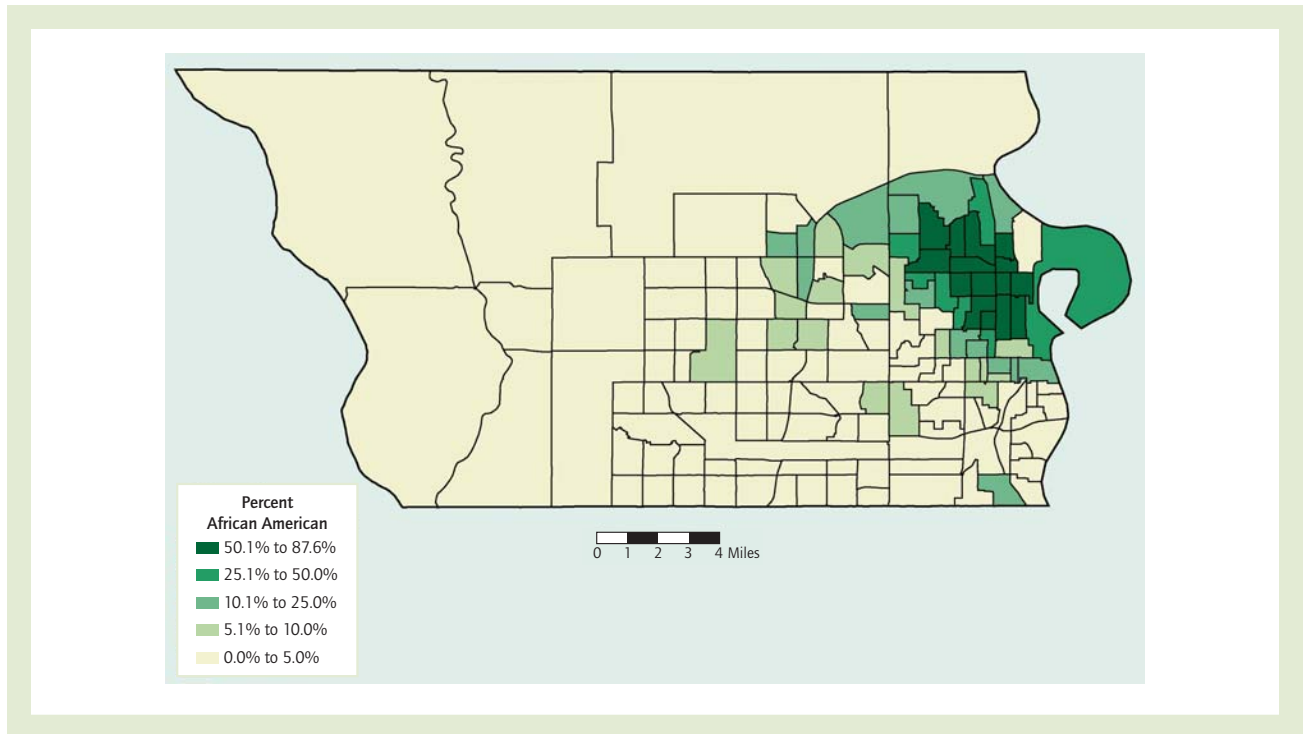


Figure 2 African Americans in Omaha (2000)

Source: Map created by author, based on data from U.S. Census, 2000, www.census.gov.

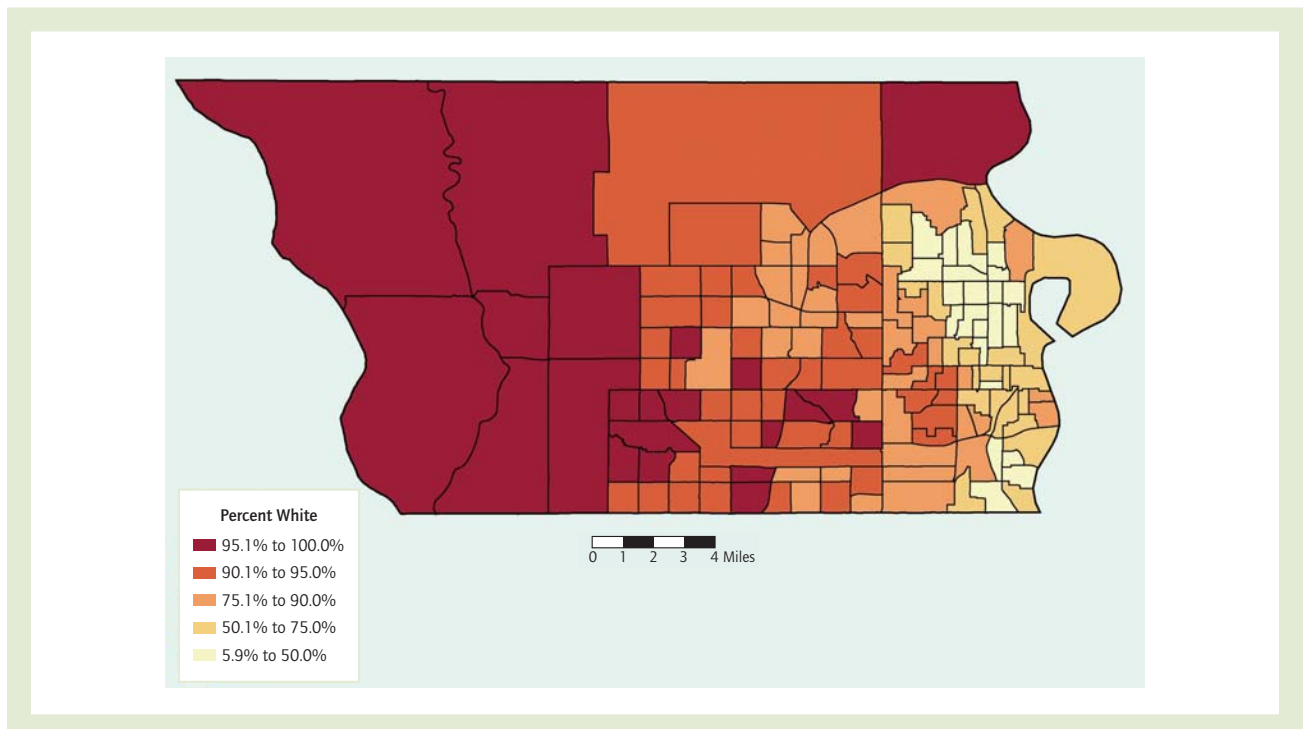


Figure 3 Whites in Omaha (2000)

Source: Map created by author, based on data from U.S. Census, 2000, www.census.gov.

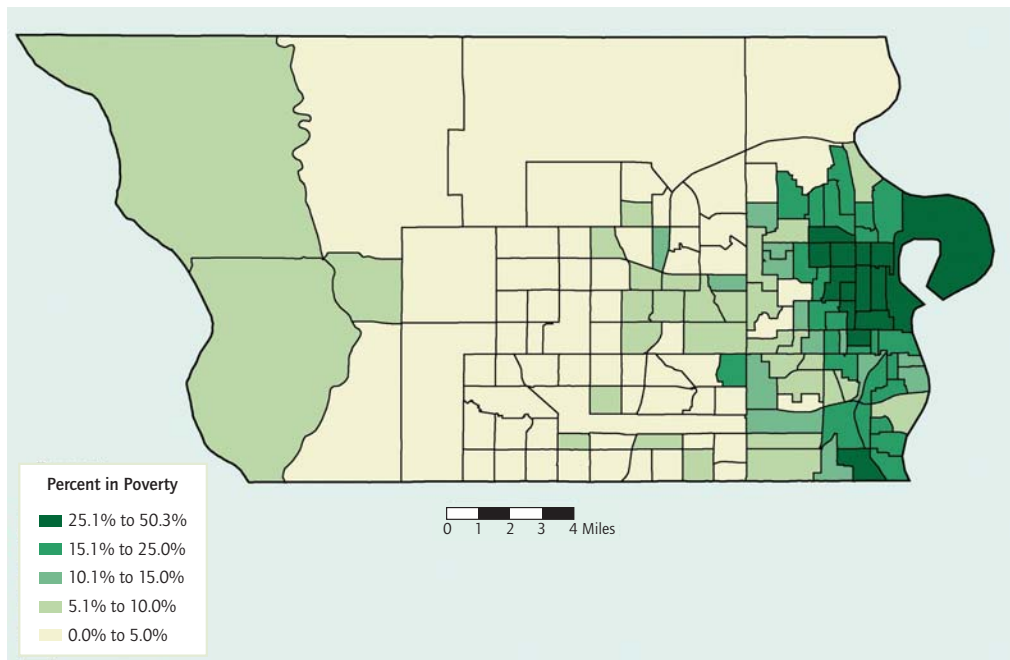


Figure 4 Poverty in Omaha (2000)

Source: Map created by author, based on data from U.S. Census, 2000, www.census.gov.

between ethnicity and one quality-of-life measure indicates that segregation may benefit some ethnic groups over others. However, on the positive side of African American segregation in Omaha, several ethnic businesses and organizations have found a place to flourish in North Omaha. Also, community cohesiveness in ethnically segregated spaces may be high, even with the poor socioeconomic characteristics. Overall, living in ethnically segregated areas can have both advantageous and disadvantageous outcomes for its residents.

Kenneth French

See also **Chicago School; Class, Geography and; Ethnicity; Ghetto; Housing and Housing Markets; Identity, Geography and; Neighborhood; Poverty; Race and Racism; Racial Segregation; Segregation**

and Geography; Urban Spatial Structure; Urban Underclass

Further Readings

- De Souza Briggs, X. (2005). *The geography of opportunity: Race and housing choice in metropolitan America*. Washington, DC: Brookings Institution Press.
- Kaplan, D., & Woodhouse, K. (2005). Research in ethnic segregation II: Measurements, categories, and meanings. *Urban Geography*, 26, 737–745.
- Massey, D., & Denton, N. (1993). *American apartheid*. Cambridge, MA: Harvard University Press.
- Peach, C. (1996). Good segregation, bad segregation. *Planning Perspectives*, 11, 379–398.



ETHNOCENTRISM

Ethnocentrism means that a group of people views the world from its own distinct set of cultural values, or ways of living and thinking. This bias typically leads to feelings of superiority in its relationships with other groups. Ethnocentrism varies widely in type and degree among cultures.

Ethnocentrism makes appreciating cultural diversity difficult if not unattainable. Indeed, most people do not understand that they do not understand other people's cultural values. People may try to be genuinely empathetic to those with different cultural values, but even geographers, anthropologists, and sociologists fail in ridding themselves of subconscious predilections.

Bigotry and racism can emanate from ethnocentrism. Extreme ethnocentrism can cause ethnocide or genocide. Ethnocide is the killing, either unintentionally or intentionally, of a group's culture by another group. For example, the construction of the Trans-Alaska Pipeline in the 1970s inadvertently contributed to the acceleration of ethnocide of the native cultures. The ethnocentric "white man's burden" justified European colonialism throughout Africa, subjugating its cultures and enslaving its peoples. Ethnocentrism sparked the German Nazis to kill 6 million Jews during the Holocaust in the 20th century. Ethnic cleansing is a process by which a dominant group of people expels a minority ethnic group from a particular place. Ethnic cleansing drove Bosnians from their ancestral homes in recent warfare in Southern Europe.

Ethnocentrism inscribes the landscape. China, "the Middle Kingdom," considered itself for centuries as the center of its universe and people located farther from its cultural hearth, for instance, in Inner Mongolia and Outer Mongolia, as increasingly more barbaric. Europeans stamped their "superior" cultural traits onto landscapes around the globe as they conquered and controlled numerous native peoples. Extractive processes, agricultural fields, urban structures, and religious icons changed indigenous homelands indelibly. These cultural conquests

set the stage for a world system of core-periphery relations and hegemonic actors dominating the marginalized aborigines. Ethnocentrism plundered the resources of the peripheral places and decimated native cultures and their natural environments.

Ethnocentrism was central to the idea of "manifest destiny" in U.S. historical geography. In their march westward to the Pacific Ocean, Anglo Americans vanquished the Native American, French, and Spanish ways of living. "The Five Civilized Tribes" were not "civilized" enough to protect their sacred lands and prevent their children from dying along the "Trail of Tears." Anglo-dominated Louisiana legislatures promulgated English-only laws for all government proceedings and school instruction to eliminate the remnants of French culture. Under the Treaty of Guadalupe-Hidalgo, the United States annexed half of Mexico and imposed new mores, especially language and law, on the inhabitants captured in the new country.

Ethnocentrism, then, is an extraordinarily powerful cultural concept that not only leads to misunderstandings among people but is also responsible for devastating natural environments, destroying nations, and killing millions of people.

Lawrence E. Estaville

See also **Discourse and Geography; Ethnicity; Eurocentrism; Identity, Geography and; Nation; Nationalism; Orientalism; Other/Otherness; Positionality; Race and Racism; Social Darwinism; Situated Knowledge; Whiteness**

Further Readings

- Nostrand, R. L., & Estaville, L. E. (Eds.). (2001). *Homelands: A geography of culture and place across America*. Baltimore: Johns Hopkins University Press.
- Said, E. (1978). *Orientalism: Western representations of the Orient*. London: Routledge & Kegan Paul.



EUROCENTRISM

Usage of the terms *Eurocentrism*, *Eurocentrist*, *Eurocentric*, and *Euroseptic* within the social sciences and geography has increased since the 1990s, within the West and in areas of the world that were formally part of the overseas colonial empires of European powers. This entry reviews the definitions, origins, history, and geographical implications of Eurocentrism and its subdivisions. It then describes the counter-Eurocentrism movement.

Definitions of Eurocentrism

There are three interrelated definitions of Eurocentrism. However, it is the third and last definition that reflects by far the most common usage of the term.

Definition 1. In Britain, a Eurocentric or Eurocentrist is a person who supports European integration or the concept or workings of the European Union. The opposite of a Eurocentric is a Euroseptic.

Definition 2. The term *Eurocentrism* is sometimes used to convey the perspective of North Americans (the United States and Canada) and may occasionally be defined as the viewpoint of North Americans of European origin. Some scholars have begun using the specific term *Euro-Americocentrism* or simply *Americocentrism* in this context.

Definition 3. Eurocentrism is a view of the world from a perspective that places Europe and its cultures, concerns, and sociopolitical attitudes at the center of the world. This may be done consciously or subconsciously, but it is always to the detriment of non-Europeans. It can be argued that true Eurocentrism has existed only since World War II and the development of first the European Economic Community (EEC) in Western Europe, followed by the European Union (EU), which has been expanded by the accession of the former Eastern European states. The same argument suggests that prior to World War II there were only national policies and national centrisms.

Since the 16th century there has been a growing socioeconomic and political hegemony of European nations (principally, in chronological order, Spain, Portugal, the Netherlands, Britain, France, Italy, and Germany) over large areas of the world. This status has led to Western European thought permeating many disciplines.

Perhaps the most common form of Eurocentrism is the division of the Eurasian landmass into the “continents” of Europe and Asia at the Ural Mountains—although there is no objective basis for this separation. Indeed, this long-accepted division was the invention of Vasilli Tatischev, an 18th-century geographer for Peter the Great, who used it as part of the Russian elite’s attempt to differentiate Europe from Asia as meaningful entities. By this definition, Europe becomes the only “continent” or major world cultural region that is not separated by water from other so-called continents (although what exactly constitutes a continent is arguable).

In the same vein, within cartography, the Mercator projection distorts the equatorial regions and exaggerates the sizes of polar regions. This projection gives the impression that European nations are larger in areal size (and therefore more important) than countries located nearer the equator.

Toponyms or place names also show a particularly strong Eurocentric resilience. For example, the use of the term *Middle East* (French: *Moyen Orient*) is acceptable only if one assumes that the user of the term is located to the west of this region. Such a term makes the *Far East* (French: *L’extrême-Orient*) another Eurocentric toponym; a region is in the Far East only if one is located in the “West.” In contrast, Arab geography divides Western Asia into distinct geographical and cultural areas and has never viewed the entire region as a culturally homogeneous region. Within political geography, the application of the terms *the West* or *the Western world* is Eurocentric in that they imply a certain political and cultural territorial construct rather than the physical reality. The chronologically and spatially fluid terms *the West* and *the Western world* are often perceived as referring to North America, Europe, Australia, New Zealand, and Japan.

A commonly noted example of a Eurocentric theory is Max Weber’s concept of the Protestant work ethic. Weber held that industrial capitalism



began in Northwestern Europe because its values, stressing hard work and delayed gratification, were inherently superior to those of other cultures such as Islam, Hinduism, and Buddhism. Weber's ideas became widely influential in later modernization discourses.

Origins of Eurocentrism

Eurocentrism has its roots in the European Renaissance, with its celebration of Greek and Roman civilization, often with the omission or denigration of African (e.g., Egyptian, Carthaginian) or Asian (e.g., Sumerian, Assyrian, Persian, Indian, or Chinese) cultures. Eurocentrism has increased since the colonial voyages of discovery and the subsequent period of European colonial and empirical expansion across the world.

In the Iberian peninsula, Eurocentrism reached its zenith during the 17th and early 18th centuries, where it was part of the doctrines of religious and racial superiority (Portuguese, *Raças Infeltas/Limpeza* and *Pureza de Sangue*; English, *Contaminated Races* and *Purity of Blood*). In Northern Europe, similar expressions of Eurocentrism reached a high point in the 19th century, where the notion was seamlessly meshed with theories of European racial superiority, such as social Darwinism, as well as the concepts of race-based slavery and technological, political, and economic domination of non-European peoples. In some cases, Eurocentrism was manifested in illusions of grandeur and exoticism (as in the notion of the noble savage), but by the early 20th century, Eurocentrism had become part of the machinery of empire and European economic and cultural domination over large parts of world. Eurocentrism reflects the relative strength of European economic and sociopolitical power. Europe has always been composed of heterogeneous sociopolitical and economic state entities. Therefore, there is a spatial and chronological fluidity to Eurocentrism. The concept of Eurocentrism has traditionally applied to Western Europe and is rarely inclusive of Russia.

Subdivisions of Eurocentrism

The origin of Eurocentrism lies in the concept that European classical (specifically Hellenic and

Roman) civilization developed in a unique and culturally isolated manner. The contra-Eurocentrist movement has contested this notion for some time. The archaeologist Gordon Childe first challenged Eurocentric theory. In the 1930s, Henri Sée and H. M. Robertson opposed aspects of Max Weber's theory that postulated that only Protestant countries could achieve economic progress.

The end of World War II and the subsequent collapse of European empires marked the start of another political, counter-Eurocentric, movement, including the establishment of the United Nations, with its five permanent members (France, the United States, the United Kingdom, the USSR, and China), in which the European nations were a minority.

Eurocentrism was particularly challenged in the Francophone world by the concept and movement of Negritude, which began in the 1930s and was advocated by the Martinican poet Aimé Césaire, the future president of Senegal Léopold Sédar Senghor, and the Guianan political poet Léon Damas. The Negritude movement, which affirmed the value of African culture and emphasized the shared heritage of blacks through the African Diaspora, voiced a perspective contrary to that of the European colonizing powers.

In the 1970s, a similar movement, termed *subaltern studies*, arose in South Asian historiography. First, *subaltern* was the term used for minor functionaries of the British colonial regime in India, including Indian, Anglo-Indian, and English officials of a low rank in the British military forces. Second, and more important, it is a term often associated with the work of the Italian Marxist political philosopher Antonio Gramsci, who used it to refer to the working class, peasants, and proletariat, who were excluded from, and who stood in opposition to, the dominant historical bloc of a given social formation. More recently, subalternism has given way to the term *Indocentrism*, perhaps underlying the fact that national centrisms are reflections of the increasing socioeconomic power within the regional or world order (Table 1). After the rise in postcoloniality, Eurocentrism has been challenged at its core historical basis by research into the African and Asian contributions to classical European civilization by Martin Bernal.

Regional Centrism	Subregional Centrism	National Centrism	Provincial Centrism
Eurocentrism (Europe)	Iberocentrism (Iberian Peninsula)	Anglocentrism (United Kingdom)	Anglocentrism (sometimes only applied to England/London)
		Francocentrism (France)	
		Lusocentrism (Portugal)	Hispanocentrism (sometimes applied only to Madrid)
		Hispanocentrism (Spain)	
		Germanocentrism (Germany)	
		Italocentrism (Italy)	

Table 1 Structure of Eurocentrism
Source: Author.

Through the 1980s in Europe, especially in France and Britain, Afrocentrism, multiculturalism, and so-called political correctness have challenged Eurocentrism. Much of the force behind these movements has come from the African, Caribbean, and Asian diaspora in Europe.

In geography, Eurocentrism has been strongly criticized by scholars such as James Blaut, who dismiss the “tunnel vision of history,” which he claims asserts privileges for European culture over others. The analysis of Orientalism, initiated by Edward Said, has likewise led to the rise of discourses in which the West is seen as a historically specific configuration of power relations rather than some inherently superior entity. Through the 1990s and the early 21st century, there has been an emphasis on viewing the diaspora and the accompanying culture contacts or cultural (and genetic) interchanges as creating fluid hybrid or “Creole” cultures and peoples of multiple heritage. This notion of hybridity is increasingly perceived as non-Eurocentric, equitable, and diverse and therefore more acceptable as a basis for political and social cohesion.

Clifford Pereira

See also **Blaut, James; Colonialism; Critical Geopolitics; Ethnocentrism; European Union; Hybrid Geographies; Identity, Geography and; Nationalism; Orientalism; Postcolonialism; Race and Empire; Race and Racism; Social Darwinism; Subaltern Studies; Toponymy**

Further Readings

Amin, S. (2010). *Eurocentrism*. New York: Monthly Review Press.

Bernal, M. (1987). *Black Athena: The Afroasiatic roots of classical civilisation* (Vol. 1). London: Free Association.

Bernal, M. (1991). *Black Athena: The Afroasiatic roots of classical civilisation* (Vol 2). London: Vintage.

Blaut, J. (1993). *The colonizer’s model of the world: Geographical diffusionism and Eurocentric history*. New York: Guilford Press.

Blaut, J. (2000). *Eight Eurocentric historians*. New York: Guilford Press.

EUROMARKET

The Euromarket refers to a range of financial markets trading in currencies and bonds. Although there are significant differences between these markets, their common feature is that they trade in products denominated in “national” currencies outside the jurisdiction of the relevant state. Euromarkets are geographically significant because they have altered and extended the meaning of economic space. This entry reviews the origins and evolution of the Euromarkets, their role in the global financial system, and their



implications for the practice and study of economic geography.

There is no precise date for the creation of the Euromarkets, but most commentators agree that they came into existence in 1957, when the Euro-dollar market was created in London. The Euro-dollar market emerged at this time because of a combination of the U.S. dollar's dominance as an international currency, the dynamics of the Cold War, and the strictly regulated nature of U.S. banks. The Marshall Plan had pumped large amounts of U.S. capital into Europe to fund reconstruction, Japan was occupied by U.S. forces and was also being rebuilt, U.S. military spending was rising rapidly, and international trade was growing. Despite this, the U.S. banking system was both bureaucratic and restrictive, placing limits on the profitability of U.S.-based reserves and on the liquidity and flexibility of European banks. Many European banks—particularly in London—wanted an alternative. Further pressure on the system came from Soviet bloc countries, particularly the USSR, with dollar reserves derived from oil production that they did not want to expose to sequestration by a hostile U.S. government.

The Eurodollar market resolved these various problems by allowing banks to use their dollar reserves to make loans to each other and to clear dollar balances entirely outside the U.S. banking system. Because of a peculiarity of English law whereby if money is not formally allocated to a particular legal jurisdiction it is effectively nowhere, the Eurodollar market created an unregulated and untaxed legal “space” within which U.S. currency could be freely traded. Although originally confined to European banks, as the Eurodollar market grew, it quickly attracted U.S. banks wanting to take advantage of the new market's ability to circumvent the Federal Reserve Board. Eurodollars were soon joined by many other Eurocurrencies and by the Eurobond market. The prefix “Euro” no longer refers either to Europe or to the currency euro but to any financial product denominated in any currency outside its formal jurisdiction.

Although it was probably not intended by those involved in its creation, the Euromarkets have fundamentally altered the economic geographies of the 20th and 21st centuries. The markets

have grown exponentially, stimulated by the rise of the petrodollar in the 1970s and the deregulatory policies of many Western governments in the 1980s and 1990s. The Euromarkets are often cited as key drivers of the process of economic “globalization.” Estimates of the values of the markets vary because of their unregulated and volatile nature, but it has been calculated that as much as \$3 trillion to \$5 trillion circulates in the markets daily. The Euromarkets have become key components in the offshore economy, many Euromarket products and reserves being held by companies based in tax havens such as the Cayman Islands, Jersey, or Switzerland. The Euromarkets have also become highly automated, using complex market algorithms and information and communications technologies to reduce transaction times to milliseconds.

For geographers, the Euromarkets are of importance since they operate within an entirely virtual monetary space above and beyond any conventional economic or legal territory. This greatly adds to the complexity of economic geographies since they can no longer be conceived of in simple spatial terms. The majority of the “Russian” economy, for example, which has benefited from many billions of U.S. dollars in aid and oil revenues since the collapse of the Soviet Union, largely resides offshore in the Euromarkets and the world's tax havens. Although the Euromarkets are a relatively new phenomenon, the spaces within which they operate are not. As a number of commentators have argued, the placelessness of the Euromarkets was also a feature of the world economy prior to World War I, when capital was able to move across borders without let or hindrance. As such, the idea of a territorially defined sovereign nation-state managing a bounded economic space appears as historically and geographically anomalous.

This does not mean that the state's role in the economy has been eradicated by the Euromarkets. The virtual legal space these markets occupy is defined in distinction from sovereign state spaces. As such, the Euromarkets need state jurisdictions to create and maintain “national” currencies, to guarantee property title, and to participate in the market for residency and citizenship (personal and corporate), from which much of their profitability is derived. For their



part, although states lose potential tax revenues to the unregulated realm of the Euromarket, they are also significant market participants, holding much of their “national” wealth in the form of extraterritorial financial instruments. Although recent problems in the world financial system have led to calls for greater regulation of the Euromarkets (e.g., the Tobin Tax), these placeless economic spaces remain centrally important to the geographies of the world economy.

Angus Cameron

See also **Circuits of Capital; Economic Geography; European Union; Finance, Geography of; Globalization; Offshore Finance; Money, Geographies of; Telecommunications and Geography**

Further Readings

- Burn, G. (1999). The state, the city and the Euromarkets. *Review of International Political Economy*, 6(2), 225–261.
- Cameron, A., & Palan, R. (2004). *The imagined economies of globalization*. London: Sage.
- Palan, R. (2003). *The offshore world: Sovereign markets, virtual places, and nomad millionaires*. Ithaca, NY: Cornell University Press.
- Pryke, M., & Allen, J. (2000). Monetized time-space: Derivatives—money’s “new imaginary”? *Economy and Society*, 29(2), 264–284.
- Schenk, C. (1998). The origins of the Eurodollar market in London: 1955–1963. *Explorations in Economic History*, 35, 221–238.



EUROPEAN GREEN MOVEMENTS

The European green movements are the individual diverse movements and struggles that emerged in the post–World War II period through explicitly politicizing aspects of the environment. These movements have taken markedly different forms in different places and times and have been organized around multiple grievances. One of the striking aspects of the green movements is their

political heterogeneity, and many green activists have explicitly disrupted notions of left and right. Members of the German Green Party (*Die Grünen*) famously entered the Bundestag in 1983 with the slogan “Neither left nor right—but straight ahead.” The European green movement has made important interventions in the style of doing politics and what counts as politics. It comprises a diverse set of organizational and political forms including direct action, parliamentary parties, nongovernmental organizations, and local environmental campaigns and has had a major impact in making the environment and biopolitics central political issues of our times.

These movements emerged from and have developed a set of plural and contested trajectories. These include the (often rather conservative) conservation groups as well as the more explicitly countercultural politics associated with the New Left. The relations between the European Green Movement and the New Left demand significant attention. Thus New Left activists of the 1960s and 1970s often translated their political activity into emerging social movements such as the German Green Movement and played a key role in articulating green politics away from an authoritarian, conservative agenda. Similarly, the currents of radical politics established in 1968 in Paris had underground afterlives in the work of activists such as Jose Bové, who shaped Left articulations of environmental politics in rural France.

New Left currents also shaped the emergence of environmentalism in Eastern Europe in the postwar period. Dissidents like Rudolf Bahro shaped an independent Marxist/Left politics that had an impact on cross-European debates through its engagement with environmental politics. Under state socialism, conservationists and nascent environmental activists worked under extremely difficult organizing conditions to bring the environmental problems of “actually existing socialism” into contestation. In Czechoslovakia, a movement for “conservation and environmental education” was formed in 1958, which led to some politicization of environmental issues. In Poland, “escape to nature” movements based on a critique of everyday life in the socialist city were prominent in cities such as Katowice, whereas other urban movements politicized the socio-ecological problems of the city. The mobilizing of



Members of the Green Party protest with atomic barrels in front of the Vattenfall customer center in Hamburg, Germany, July 8, 2009. The protest is directed against the operation of the atomic power plant Kruemmel by the energy provider Vattenfall. The plant's reactor was shut down as a result of a short circuit in a transformer on July 4, 2009.

Source: Maurizio Gambarini/EPA/Corbis.

such environmental claims and politics played a central role in the struggles for democratization throughout Eastern Europe in the late 1980s and early 1990s. In the period of transition, however, the conditions for environmental nongovernmental organizations and campaigns have often been fraught with risks. In Slovakia, for example, movements such as Greenpeace Slovakia and *Za Matku Zem* (for Mother Earth) have faced harassment and criticism.

The negotiation of the diverse trajectories and political identities of the different constituents of

the European green movement has often been the subject of contestation. *Die Grünen* has been by far the most successful green party in Europe in parliamentary terms and was involved in government in coalition with the German Social Democratic Party between 1998 and 2005. Despite this, the party's parliamentary strategy was the subject of internal dissension between "fundamentalists" and "realists." Parties such as *Die Grünen* have had to experiment with the organizational structures developed in extraparliamentary social movements and have had to



maintain support and links with diffuse constituencies. Green movements in other national contexts have faced similar challenges. Such practices of institutionalization can be contested and uneven. In the United Kingdom, recent debates over the Green Party's decision to move from a shared to single leadership and concerns over a break with nonhierarchical structures and participatory democracy attest to the continuing character of such tensions. Despite such tensions, environmental movements have been adept at placing environmental issues and regulation on political agendas, including those of the European Union.

Bruno Latour has argued that a possible future for the green movement is for its concerns to become an uncontentious and consensual part of common sense. Left critics of the green movement have long argued that its early focus on issues such as population depoliticized environmental problems and ignored their social components. Such a depoliticization of political ecology continues to be significant. In the United Kingdom, a consensual construction of environmental issues was mobilized as part of the "Third Way" political agenda in the 1990s. What is significant, though, is that despite the institutionalization of many of their core concerns over the past 20 or 30 years, European green movements continue to generate contestation of unequal social and environmental relations in multiple ways. Green activists have been at the forefront of the struggles against neoliberal globalization. Through doing, so they have shaped the politics around "environmentalisms of the poor," which link social justice and environmental issues, and they have outlined alternatives to neoliberalism, such as localized economic practices. Finally, radicalized and assertive nonviolent direct action continues to be an important part of green politics in Europe, most recently demonstrated by the climate change protests at Kingsnorth in the United Kingdom (the proposed site of a new coal-fired power station).

The European green movement was established out of diverse trajectories of political activity and has played out differently in different places. It has had a major impact in making environmental concerns central political issues of our time. The movement has brought such issues into

contestation through multiple ways, and it will surely continue to be diverse and contested.

David Featherstone

See also **Antisystemic Movements; Chipko Movement; Deep Ecology Movements; Environmental Social Movements; International Environmental Movements; Political Ecology**

Further Readings

- Doherty, B. (2002). *Ideas and actions in the Green Movement*. London: Routledge.
- Latour, B. (1998). To modernise or ecologies? That is the question. In B. Braun & N. Castree (Eds.), *Remaking reality: Nature at the millennium* (pp. 221–242). London: Routledge.
- Sarre, P., & Jehlička, P. (2007). Environmental movements in space-time: The Czech and Slovak republics from Stalinism to post-socialism. *Transactions of the Institute of British Geographers*, 32, 346–362.
- Whitehead, M. (2005). Between the marvellous and the mundane: Everyday life in the socialist city and the politics of the environment. *Environment and Planning D: Society and Space*, 23, 273–294.



EUROPEAN UNION

The European Union (EU) was founded in 1992 in Maastricht, the Netherlands. It began functioning as a political organization in November 1993 and has gradually become one of the key actors in international affairs. In Europe, the EU has clearly become a political unit toward which the minor, small, and great powers tend to look before anything else and toward which regional, political, and economic activities increasingly tend to be geared. The EU currently includes 27 European states and is structured around three key institutions: the European Parliament (with 736 members), the European Commission (with 27 commissioners), and the European Council. It is through these political bodies that EU legislation—the driver of integration—is debated, passed, and implemented.



Evolution of the European Union

The EU is the most recent stage of the post–World War II European integration process, which was launched in the early 1950s. Over time, European integration has been legitimated by various dominating discourses. Throughout the process, it has been commonly argued that European integration is aimed at maintaining peace in Europe. From the 1950s up to the 1970s, integration was designed not only to restrain the spread of Soviet communism into Western Europe but also to hinder the rise of fascism.

The institutional dimension of this process has developed step by step during the past decades. The European Coal and Steel Community (ECSC), founded in 1951, first governed the coal and steel industries of the six founder states. In the 1960s, the customs union, a common agricultural policy, and the first seeds of the common market were established for the Community, which now included the ECSC, the European Economic Community, and Euratom. In the 1970s, the political institutions of the Community became stronger; since 1979, the members of the European Parliament have been directly elected every 5 yrs. (years). The late 1980s were a formative time for the development of the European single market, which finally took effect in 1992. After the end of the Cold War, European integration has been increasingly legitimized by the argument that without the EU, the member states would be too small to come to terms with the heightening international economic competition. The establishment of the EU gave more power to the Union, leading, for instance, to the subsequent monetary union based on a common currency (the euro), and a common foreign and security policy. The common currency became reality in 2002 with the adoption of the euro.

In 2008 and 2009, the latest institutional reform, the Lisbon Treaty (also known as the Reform Treaty), was subject to ratification in the member states. This treaty is to a significant degree based on the so-called Draft of the European Constitution, which was signed in 2004 by all the member states but was ultimately rejected 1 yr. later in referenda held in France and the Netherlands. The Lisbon Treaty aims to replace the existing body of treaties of the EU, but it

faced problems as the Irish people rejected the treaty in a referendum in June 2008. This type of crisis often brings to the surface the idea that the EU should be based on flexible integration so that the states that are willing to increase the level of integration are not held back by the “reluctant” members.

The enlargement process has continued steadily, if unevenly, during all but 7 yrs. since the signing of the Treaty of Rome in 1957. Originally, European integration involved only six Western European states: France, Germany, the Netherlands, Belgium, Italy, and Luxemburg. The first round of enlargement took place in 1973, when Britain, Ireland, and Denmark joined the EC. This round was followed by the accession of Greece in 1981. The southern dimension of the integration was strengthened 5 yrs., when Spain and Portugal became members. After the signing of the Maastricht Treaty in 1992 and the consequent establishment of the EU, the expansion, which included Sweden, Finland, and Austria, took effect in 1995. This phase of the EU lasted 9 yrs., after which the eastern expansion of the EU brought in 10 new members in 2004. The expansion was particularly challenging not only given the relatively significant political and economic disparities between the applicants and the member states but also because the expansion also touched on the power politics between the EU and Russia. The eastern expansion was finalized in 2007, when Bulgaria and Romania joined the EU (Figure 1).

Even though the 27 member states all need to fully implement the *acquis communautaire* (the total body of EU legislation), the institutional bonds within the EU vary. For instance, all the member states are not included in the European Economic and Monetary Union (EMU). Only 16 members have entered the EMU and adopted the euro as their currency. Some older member states, such as Britain and Denmark, have stayed outside the “Eurozone,” whereas only three states of the 2004 enlargement (Slovakia, Slovenia, Cyprus, and Malta) have been included in the EMU. Moreover, Ireland and the United Kingdom remain outside the Schengen regulations, which aim to dissolve the physical borders within the EU, whereas some of the nonmembers, such as Norway, currently participate in this system.

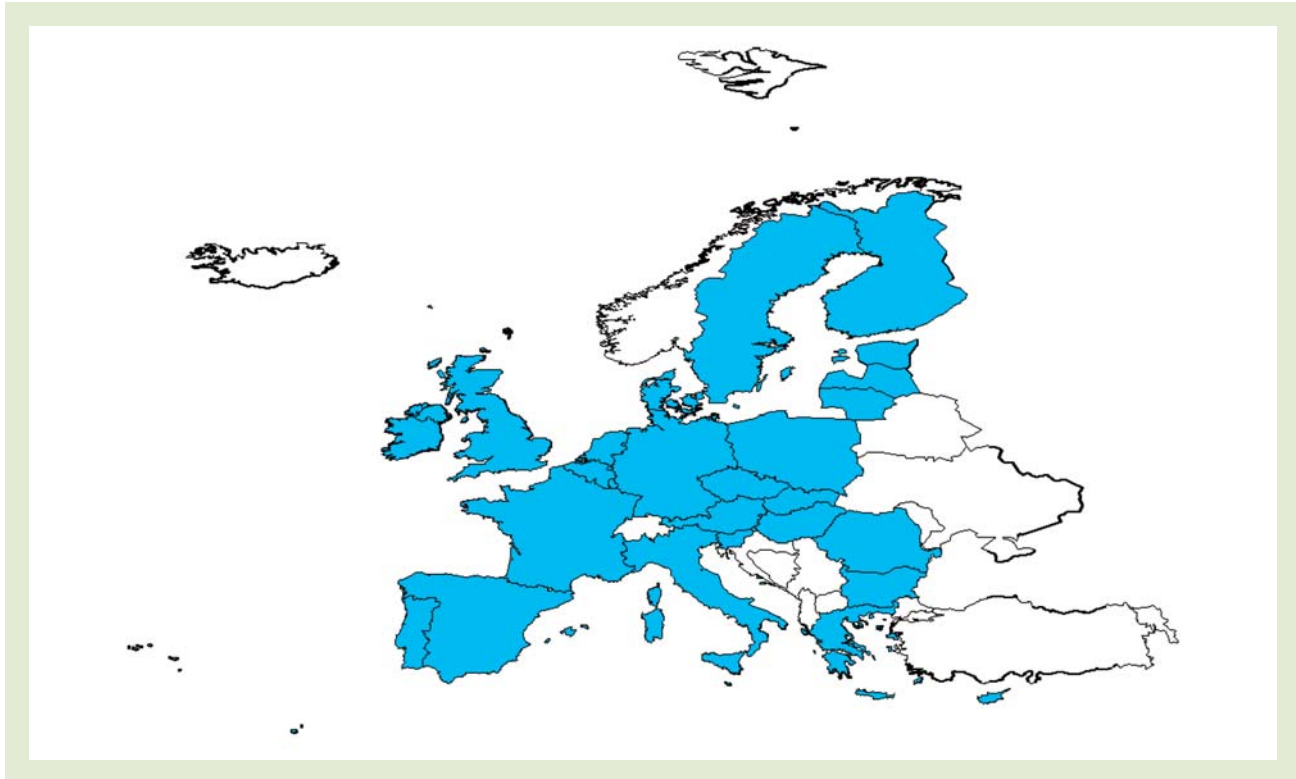


Figure 1 European Union members, 2008. The EU's growth into Eastern Europe has expanded its number of members to 27.

Source: Barney Warf.

The Nature of the Integration Process

There are several schools of thought in European integration studies that seek to explain and understand the successes and failures of the integration process. The early classical theories, such as federalism, were political models targeted toward containing the hostilities between France and Germany by limiting national sovereignty. This process involved rescaling the political power that regulated the strategically important economic sectors of these states. The classical models were followed by theories such as neofunctionalism and liberal intergovernmentalism, which usually emphasize not only political but also economic interdependence. The member states are willing to participate in the integration process because it is both politically and economically rewarding—at least for some segments of society. More recent theories, for example, the social constructivist approach, highlight the importance of both national identities and material interests in the

successes and failures of the EU. The multilevel governance theory has also become a vibrant field that explains the complex rescaling of government and governance within the confines of the EU and beyond.

Despite the steady institutional development of the EU and its predecessors, it is often argued that the EU has remained an elitist project with little significance in the everyday lives of its inhabitants. There has been a lot of debate around the democratic deficit of the EU, indicating that the political decisions made by the EU take away too much decision-making power from member states, local governments, and their citizens. As a result, the EU launched a principle of subsidiarity to limit the powers of the EU and keep more political decision making at the local and national levels. One reason behind such a political move is that the emotional attachment of “Europeans” to the territory of the EU has remained weak.

Seen from the perspective of political competencies, the EU is clearly more than an international



organization but less than a modern Westphalian state, whether federal or unitary. Even though it uses significant power over the member states in sectors such as agriculture and common trade policies, and even though its economy is now partly controlled by the European Central Bank, the EU does not have control over the armed forces and cannot make decisions about war and peace within its territory. The EU thus does not possess a monopoly on legitimate physical violence within its territory, as Max Weber might have put it. In other words, the EU uses significant political power within its borders, but its power has paradoxical limits. For instance, the recent declaration of independence by Kosovo reveals the somewhat amorphous nature of the EU. However, regardless of its significant contribution to the independence process, the EU does not have the ability to recognize Kosovo as a sovereign state.

One of the peculiarities of European integration is that both politicians and scholars tend to have a constant need to redefine the fundamental nature of the EU. At first sight, the EU does not seem to correspond to any previously known polities. As John Pinder stated in 1995, the nature of the EU as a political organization is difficult to understand as it escapes the conventional categories of international relations and federal state. It is sufficient to define the EU as a constant process that does not have self-evident political or geographical finalities. In essence, the institutional and territorial development of the EU is contested to the core and is therefore under serious political debate not only in the European Parliament, the European Commission, and the European Council but also within the member states. Often the territorial and institutional issues of the EU become part of political struggles within the member states, where political opposition is able to pressure government by using various rhetorical resources that integration provides.

In scholarly debates, the EU is frequently conceptualized as a new postnational polity based on multilevel governance. One of the most useful territorial approaches to multilevel governance is offered by Ole Jensen and Tim Richardson, who proposed in 2005 that the gradually evolving spatial policies of the EU form a European “monotopia”: a particular ideology that views the EU territory as one space that should be organized

around large metropolitan areas and the logistic flows that connect these nodes. The emerging territoriality of the EU thus clearly has a particular spatial selectivity that is built into it.

The EU has also been conceptualized as a new type of imperial political subject. Ole Wæver’s treatment of the EU in 1997 as organized around concentric circles is a well-known attempt to look at Europe’s map through an alternative framework. He suggests that the EU is a particular type of empire that pulls other states into its orbit. Wæver points out that the EU is organized around one center and tries to keep this core intact. Simultaneously, the EU implicitly disciplines its immediate outsides, the so-called close outsiders, using various techniques. Wæver also points out that beyond the circle surrounding the core, the EU also seeks to intervene directly in political development—without a significant military capacity.

The models that emphasize the EU’s imperial features should also take into account the often allegedly elitist nature of the European integration. It is widely accepted, for instance, that the EU expansion in 2004 was specifically based on attempts to Europeanize the political elites within the applicant states. One may also treat the politics of conditionally, the effective screening, monitoring, aiding, and gate-keeping practices of the EU institutions that seek to Europeanize the applicants, as a tool through which the EU specifically seeks to influence the various political elites within its neighborhoods. These observations come close to the ideas of John Agnew, who suggests that the EU is a form of hegemony as it has insinuated itself into everyday life not only within the EU but also in its neighborhoods and within its trading partners. Agnew thus defines the EU as a relatively light administration, a network of centers united around common goals and policies that can expand flexibly both in the scope of what it does and in the geographical area in which it operates without collapsing.

The Future of the European Union

All the previous enlargements have put significant pressure on the integration institutions and, therefore, reshaped the nature of the integration. In the history of European integration, territorial



expansions have often been preceded by institutional reforms. The EU is currently preparing for future expansions. The negotiations specifically touch on the Balkan states and Turkey. Ash proposed some years ago that geography and the future of the EU were inseparable. He suggested that the kind of political community the political actors within the EU think the EU will be inevitably determines how far they want to enlarge the Union. And, conversely, how far they want to expand the Union determines what kind of political community the EU can be. The possible Turkish membership of the EU is particularly challenging in this context. There are those who reject the membership as they see it as jeopardizing not only the unity of the EU (or its mythologized and essentialized European values) but also the power structure within the EU. Some opponents script Turkey as a non-European state both geographically and culturally. However, Turkey's EU membership enjoys considerable support within the EU—surprisingly also among federalists. Some of them perceive Turkey as an important strategic location that will stabilize the European geopolitical order.

The EU seems to be a crisis-prone organization that regularly faces serious challenges that jeopardize its very existence. In 2007, Jan Zielonka proposed that the EU suffers from a sort of midlife crisis and that coping with that crisis requires coming to terms with its increasingly diversified cultural, political, and economic space. He asserts that the postenlargement EU is not best described in terms of a Westphalian political unit and that the EU will not work as a Westphalian state. Zielonka thus suggests that the EU should develop in a direction that could be conceptualized as a neo-medieval empire—a sort of metagovernor that distributes decision-making competence between multitudes of territoriality and functionally defined self-governing actors. In such a view, the EU would not impose tight hierarchical control; rather, it would act as a mediator between various European networks and as a facilitator of continuous communication, cooperation, and compromise between such networks. With the neo-medieval empire, the borders of the Union should be flexible and open to those neighbors who embrace the basic set of liberal values and accept the rules operating within it.

European politicians often seem to demand more statelike development from the EU, especially when the process of integration encounters severe institutional difficulties or faces problems in affirming its political legitimacy among the people. Statism represents a particular mind-set according to which proper political life is possible only within statelike polities that are centrally organized, strictly bordered, and territorially homogenized and within which the people share a solid identity that attaches them to the bounded homeland. This form of territorial reasoning is still common within the EU, and the debates on the future of the EU are likely to be plagued by it.

Sami Moisisio

See also **Eurocentrism; Euromarket; European Green Movements; Globalization; North Atlantic Treaty Organization (NATO); Trade; Transnationalism**

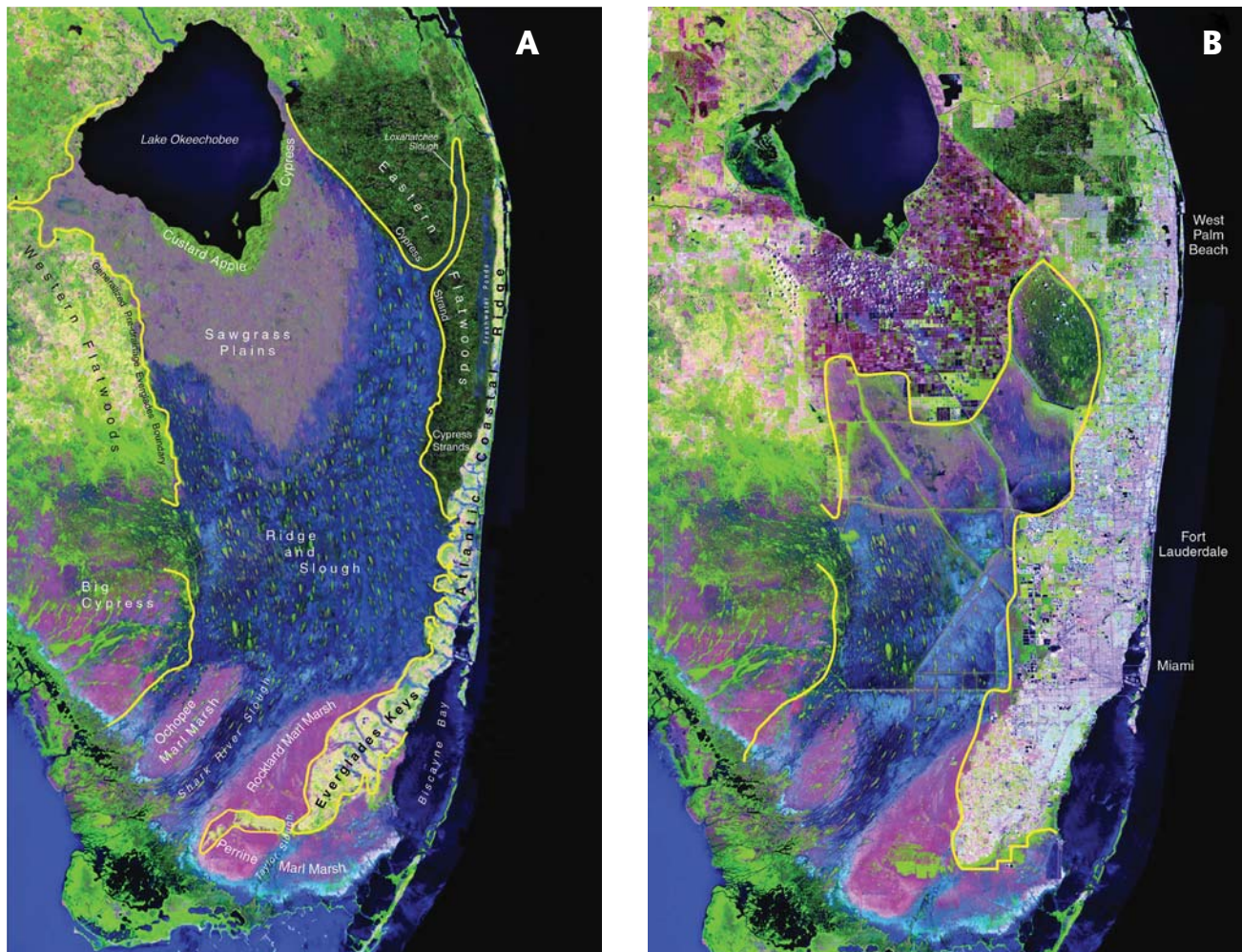
Further Readings

- Aalto, P. (2006). *European Union and the making of a wider Northern Europe*. London: Routledge.
- Agnew, J. (2005). *Hegemony: The new shape of global power*. Philadelphia: Temple University Press.
- Garton Ash, T. (2003). Where on earth will Europe end? *Europaeum Review*, 5, 2.
- Jensen, O., & Richardson, T. (2005). *Making European space*. London: Routledge.
- Pinder, J. (1998). *The building of the European Union*. Oxford, UK: Oxford University Press.
- Zielonka, J. (2007). *Europe as empire*. Oxford, UK: Oxford University Press.



EVERGLADES RESTORATION

Over the past century, much of the Florida Everglades has been transformed from a principally subtropical wetland to a human-dominated system of agriculture and urban development. The present Everglades system is half its predisturbance size, the underlying water table is lower, the cyclical hydro-periods are altered, and the



(A) Reconstructed predrainage (ca. 1850) and (B) current (1994) satellite images of the Everglades ecosystem. The yellow line delineates the historical Everglades ecosystem and the present Everglades ecosystem.

Source: Courtesy of C. McVoy, W. Said, and J. Obeysekara, South Florida Water Management District.

vital freshwater sheet flow is diverted to the Atlantic Ocean and the Gulf of Mexico (see satellite images A and B). These anthropogenic changes have affected the Everglades by isolating and impounding the wetlands, reducing the wildlife habitat, degrading the water quality, and promoting the invasion of nonindigenous vegetation. In recognition of the imbalances created within the Everglades system by humans, the state of Florida is currently undertaking a multi-billion-dollar restoration project as it attempts to repair the degradation. The Everglades Forever Act of 1994 mandated this restoration project to increase freshwater flow back into the Everglades

and to establish minimum pollution levels for phosphorus runoff from the bordering Everglades Agricultural Area (EAA). This 40-yr. (year) restoration plan, approved by the U.S. Congress in 1999, is titled the Comprehensive Everglades Restoration Plan.

Historical Context

Large-scale modifications of the Everglades began with the Swamp Lands Act of 1850, when the state of Florida claimed ownership of more than 20 million acres of the Everglades with the plan to drain the system so as to attract private investment



and economic activity. In 1880, the developer Hamilton Disston initiated the first significant drainage efforts designed to convert the wetlands into fertile agricultural land. In 1904, Napoleon Bonaparte Broward made the Everglades drainage the centerpiece of his successful, gubernatorial campaign as he invested significant political capital into drainage efforts that he promoted as creating vast, economic opportunities for Floridians. From 1906 to 1930, the Everglades experienced the construction of three major drainage canals—North New River, Hillsboro, and West Palm Beach—and completion of the Miami Canal.

To enhance drainage, a levee system was constructed in the 1920s around the southern shore of Lake Okeechobee, which prevented the natural sheet flow of fresh water from Lake Okeechobee south to Florida Bay. Concurrently, the Tamiami Trail highway was constructed to connect the rapidly developing communities on the eastern and western coasts of South Florida, which blocked nearly all surface water flow and divided the enormous, contiguous Everglades into two distinct northern and southern systems.

The second major phase in the human alterations of the Everglades began in 1948, when the Central and Southern Florida Project for Flood Control (C&SF Project) was authorized by Congress to expand greatly the previous drainage canal network for South Florida's booming human population. The Central and Southern Florida Flood Control District, now known as the South Florida Water Management District (SFWMD), was given authority to manage the system, with the primary goal of preventing flooding in the rapidly growing urban areas. The major alterations of the C&SF Project included the construction of more levees and conversion of several hundred thousand acres of natural wetlands to the EAA.

The last large-scale Everglades alterations included a series of flood control levees added in the late 1960s and early 1970s to divide the remaining northern Everglades into three large water conservation areas (WCAs). The WCAs, although they are considered natural areas, are intensely managed systems that have little resemblance to their historical state. The primary purpose of WCAs is not environmental conservation but ensuring adequate water storage and supply for agriculture and coastal development.

Additionally, the water stored in the WCAs contains high phosphorus levels from EAA runoff, which is the main reason why invasive, nonnative plants have outcompeted the once dominant native vegetation in these systems.

Comprehensive Everglades Restoration Plan

After a century of exploiting the natural system, the 1999 Comprehensive Everglades Restoration Plan (CERP) represents an ideological shift in environmental thinking for South Florida, acknowledging that Florida is facing the possible extinction of a unique and vital regional ecosystem. CERP's fundamental hypothesis is that the reduction of environmental stressors such as drainage systems, flood control structures, and pollutant runoff will reinitialize the functional ecosystem processes, thus moving the system toward a more natural state. However, due to the widespread human impacts on ecosystems, it is unlikely that the system can be completely restored to its condition prior to human impacts.

To accomplish the Everglades restoration, CERP established three primary goals. First, and most important, is to restore the natural hydrology. The entire biotic structure of the Everglades system depends on reestablishing the natural water quality and quantity. Second is to restore the natural habitats, including historic populations of key flora and fauna (see photo). Third is to establish a sustainable compatibility between the natural ecosystems of the Everglades and the human-built systems surrounding it. To meet these goals, CERP proposes 68 projects. These projects can be grouped into seven general components that primarily address water storage, conservation, and delivery to both natural and urban areas:

1. *Surface water storage reservoirs*, both within the EAA and in the surrounding counties, will hold more than 1 million acre-feet of fresh water.
2. *Aquifer storage and recovery systems*, constructed around Lake Okeechobee, will store fresh water in deep wells for later recovery.



The Florida Everglades

Source: Anton Oleinik, Florida Atlantic University.

3. *Storm water treatment areas*, consisting of managed wetlands, will reduce pollution from both the EAA and urban runoff.
4. *Seepage management systems* will help raise the water table within the Everglades by reducing groundwater flow from the western natural areas to the eastern built areas.
5. *Freshwater sheet flow*, to the Everglades, will be reestablished by eliminating levees and canals.
6. *Rainfall-driven water management* will be used by the SFWMD to deliver water into the Everglades in a manner that replicates historical hydro-periods.
7. *Water reuse and conservation strategies* will address water quality issues for municipal wastewater discharge.

More than 8 yrs. after its adoption, none of the CERP projects has been completed. Significant programmatic advances have been made, however: four CERP projects are under construction, and several pilot projects are being evaluated. The primary reasons for CERP implementation not moving forward can be attributed to bureaucratic, regulatory, and budgetary impedances. Unfortunately, the delay in CERP implementation means that the Everglades system continues to degrade as the human population and its impacts continue unabated in South Florida.

Tobin Hindle

See also Conservation; Environmental Management; Environmental Restoration; Environment and Development; Landscape Restoration; Population, Environment, and Development



Further Readings

- Blake, N. M. (1980). *Land into water—water into land: A history of water management in Florida*. Tallahassee: University Press of Florida.
- Clarke, A. L., & Dalrymple, G. H. (2003). \$7.8 billion for Everglades restoration: Why do environmentalists look so worried? *Population and Environment*, 24, 541–569.
- Davis, S. M., & Ogden, J. C. (1994). *Everglades, the ecosystem and its restoration*. Delay Beach, FL: St. Lucie Press.
- Gonzalez, G. A. (2005). The comprehensive Everglades restoration plan: Environmental or economic sustainability? *Polity*, 37, 466–490.
- McCally, D. (1999). *The Everglades*. Gainesville: University Press of Florida.
- Walker, R., & Solecki, W. (2004). Theorizing land-cover and land-use change: The case of the Florida Everglades and its degradation. *Annals of the Association of American Geographers*, 94(2), 311–328.



EVERYDAY LIFE, GEOGRAPHY AND

As a basic definition, the term *everyday life* refers to those ordinary, taken-for-granted, habitual thoughts, activities, and settings that are close and familiar to all of us but that are rarely measured by governments or scholars or endowed any particular significance. Henri Lefebvre used the metaphor that everyday life is like fertilizer: It functions as a source of life-giving power, but it largely goes unnoticed as it is tramped underfoot. According to Lefebvre (1991), “a landscape without flowers or magnificent woods may be depressing for the passer-by but flowers and trees should not make us forget the earth beneath, which has a secret life and a richness of its own” (p. 87). Lefebvre also famously coined the phrase “the familiar is not necessarily known” to capture the understanding that while an activity such as shopping or walking may be ubiquitous, it lacks meaning if it is not recognized—by naming, counting, researching, and assigning value to it.

Not only does the essence and substance of the life we live each day largely go by without us consciously thinking about it, but when we do turn to scrutinize ordinary, individual moments, taking these fragments out of their background context, they tend to assume an unrealistically distinct, abstract, and spectacular status. This highlights a tension that has recently emerged in academic scholarship, between descriptions of everyday life as myriad phenomena to be recorded and interpreted from diaries, biographies, ethnographies, and the like; theories of the everyday relating to personal, emotional, and normative compulsions; and the politics of everyday choices and behavior with respect to production, consumption, and social reproduction. For instance, the decision to buy or boycott a particular brand of good or to shop with a reusable shopping bag assumes a symbolic political function in affluent societies today.

Accepting that everyday life is a contested concept, John Eyles implores us never to treat it as unproblematic or unimportant. This plea to name and critically consider the sum of forces and events that create and sustain human existence owes much to efforts by feminist economists to demonstrate that everyday life has to be reproduced—socially and materially. Feminist scholars have long recognized the moral and political significance that what is most frequently omitted from, or trivialized within, the formal economy are the tasks of unpaid, home-based work, largely performed by women, representing all that it takes to keep individual workers, families, and human societies fed, clothed, housed, educated, and cared for. For example, in a book called *The Secret Life of Cities* (alluding to Lefebvre’s metaphor above), Jarvis and colleagues conjoin the concept of everyday life with that of social reproduction to examine them both as a category of practices and as unconscious knowledge supporting the reproduction of human society—and the biographic techniques of analysis required to bring this issue to public attention.

Recent years have witnessed the idea of everyday life entering the popular imagination. For instance, the phrase “part of everyday life” is used to advertise public transport in the English city of Newcastle. Across the social sciences, the term has been variously adopted to convey a shift



in scale (to the body, household, street, and locale), greater emphasis on qualitative methods, and a reconnection of humanistic geography with the temporal rhythms of age, history, calendar, and clock. As with the coinage of any umbrella concept (e.g., *sustainability* or *globalization*), there is potential for precision of meaning to be lost to the illusion of an all-encompassing understanding of the everyday as everything, all the time, everywhere. The definitions provided here identify parameters key to the use of this term.

Origins of the Concept and Language of Everyday Life

By defining everyday life with reference to the reader, along with the author, the concept and language of everyday life is located squarely within a humanistic geographic tradition. Analytically, the term is variously used with reference to the urban sociology of Georg Simmel, the rhythm analysis of Henri Lefebvre, the dramaturgy of Erving Goffman, the phenomenology of Michel de Certeau, the theory of practice of Pierre Bourdieu, the feminist institutional ethnography of Dorothy E. Smith, and the time-geography of Törsten Hägerstrand.

One body of work through which the concept and language of everyday life can be traced far back in time is that of symbolic interaction and an “emotional” or “therapeutic turn,” stimulated in the 1920s by Freudian psychoanalysis. Interest in the people’s compulsion to come together through face-to-face encounters, along with the gendered performance of “emotion work” that this entails, is reflected in the seminal work of Erving Goffman’s dramaturgical approach, elucidated in the 1959 publication *The Presentation of Self in Everyday Life*. Parallels are drawn between everyday life and the staging of a drama, with reference made to a “front-stage” and a “back-stage” “performance” of social activity. The enduring significance of personal, social interaction is associated with growing awareness that people reflexively monitor their own and other people’s emotions in a dynamic process of “learning to fit in.” This reflexivity and the skills required to “pass” as “normal” in a given situation assume particular significance in an age where it is both possible and increasingly expected

that “virtual” communications will replace “real” social contact. Feminist scholars have recently extended this analysis to consider other neglected, less visible, highly gendered “infrastructures of constraint,” including, for example, guilt, love, and obligation. Some commentators argue that these “ties that bind” (and the self-interest of the family as an institution of social organization) disadvantage women as mothers, who are in effect creating a public good (well cared for, socially adjusted youngsters) for intrinsic reward in the absence of pay.

A second body of work traces a shift in emphasis from the extraordinary and the exotic to the ordinary and the mundane. It has been used by cultural geographers to legitimate the study of marginalized groups and discriminatory practices on grounds of gender, class, age, ethnicity, and family form. Caution must be applied in the renewal of interest in “ordinariness.” Just as “everyday life” can appear to encompass everything, everywhere, so too the notion of ordinariness can appear slippery or culturally value laden. Renewed interest in “ordinariness” and “everyday life,” as illustrated in the work of Walter Benjamin and Georg Simmel, for instance, interprets ordinariness through the voyeuristic eyes of the male flâneur, the gentleman stroller of the city. Similarly, the 1960s’ situationist international movement drew attention to the “spectacle” of the everyday, where “situations” were consciously staged as spectacular events intended to disrupt the “alienation and suffering” of capitalist social interaction. The aim of the situationists was to create freedom for the individual through transgressive roles and situations.

When feminist scholars evaluate the writings of Simmel, Benjamin, de Certeau, and the Situationist International on subjects of gender and the family, they reveal the construction of a masculine understanding of the world in which the everyday realities of women and minority groups and the exploitation they frequently experience in the home or street do not register in the philosophical imagination. In contrast, notions of ordinariness have been mobilized by feminist urban planners whose objective is to make the material fabric and institutions of the city as inclusive as possible. Clara Greed, for instance,



The Saturday market stalls at Arnhem in Holland

Source: Morguefile.

draws attention to the inadequate provision of public toilets. She highlights the way poor design and lack of investment in the built environment restricts the everyday mobility and access of older people, mothers with young children, and people with disabilities.

The Geographies of Everyday Life

The academic disciplines of geography and history are crucial to understanding everyday life as a world that we experience directly, through locally proximate, coordinated interaction. The spatial and temporal rhythms of everyday routines and practices were first represented in humanistic time-geography as a theory and method of tracing daily routines as coordinates of time and space. Seminal work by Torsten

Hägerstrand portrayed mundane “projects” of daily life, such as shopping for groceries on the way home from work, as a function of multiple “pockets of local order,” the path or trajectory of which is governed by three contextual constraints relating to capability, coupling, and authority. A striking image associated with this work is a three-dimensional prism, mapping an individual’s path across a morphological map and relating this to a 24-hour daily time budget. Allen Pred described this sequencing and timing as the choreography of existence. More recently, Anthony Giddens developed the theory of structuration to capture and resolve the mutually co-constitutive structures and agency of individual and collective time-space relations.

Apart from time and space, a humanistic geography tradition highlights the importance of an integrated analysis of people-place relations. This



is demonstrated in the work of EuroFEM, a loose affiliation of European feminist scholars committed to promoting and implementing gender mainstreaming in planning policy, job creation, and local initiatives. The EuroFEM model for implementing change is one of participatory engagement, smoothing the barriers to everyday coordination by drawing on historic ideals of collective living.

Renewed interest in everyday life has coincided with innovative methods and techniques to communicate the rhythm of daily life; its seasonal and economic cycles; the dynamics of age, aging, and the life course; and the importance of local history, customs, and language. Methods include the collection of daily diaries and biographies/autobiographies and ethnographic and participatory research. There is a long tradition of looking at time budget analysis in relation to household responsibilities, the provision of child care, and more recently the commoditization of these activities by transnational paid domestic workers. Thus, while everyday life emphasizes micropractices, it also captures the local imprint of global flows and circuits of people and cultural and economic practices.

Today, new advances are being made in the application of geographic information systems and geovisualization to conventional methods of in-depth ethnography. Sophisticated satellite tracking devices can now be applied to the complex problems of everyday life to log not only the time-space coordinates of activities and social interactions but also perceptual experiences felt along the way (fear, discomfort, intimidation, landscape aesthetic, and the like). These innovations suggest a more integrated and nuanced analysis of the social reproduction of everyday life in the future.

Finally, although the term *everyday life* has taken on particular significance in the 21st century, as a result of the “cultural turn” in geography, it is important to note that interest in mundane observations is not new. Back in 1937, mass observation was established in Britain specifically to study the everyday lives of ordinary people. It continues today to focus on different and diverse aspects and views of daily life with a newly commissioned e-mail communications archive. Other projects in the archive include the

National Panel of Diarists, the Bolton Worktown Project, Pub Conversations, and the Cooperative Correspondence Club of young mothers.

Helen Jarvis

See also Behavioral Geography; Chicago School; Class, Geography and; Commuting; Cultural Turn; Discourse and Geography; Emotions, Geography and; Ethnicity; Existentialism and Geography; Feminist Geographies; Gender and Geography; Hägerstrand, Torsten; Home; Humanistic Geography; Identity, Geography and; Positionality; Pred, Allan; Situated Knowledge; Spaces of Representation/Representational Spaces; Structuration Theory; Time-Geography

Further Readings

- de Certeau, M. (1984). *The practice of everyday life*. Berkeley: University of California Press.
- Eyles, J. (1989). The geography of everyday life. In D. Gregory & R. Walford (Eds.), *Horizons in human geography* (pp. 102–117). Basingstoke, UK: Macmillan.
- Gardner, M. (2000). *Critiques of everyday life*. London: Routledge.
- Giddens, A. (1984). *The constitution of society*. Cambridge, UK: Polity Press.
- Goffman, E. (1959). *The presentation of self in everyday life*. London: Penguin.
- Highmore, B. (Ed.). (2001). *The everyday life reader*. London: Routledge.
- Hubbard, P., & Holloway, L. (2001). *People and place: The extraordinary geographies of everyday life*. London: Pearson.
- Jarvis, H., Pratt, A., & Wu, P. (2001). *The secret life of cities: The social reproduction of everyday life*. London: Pearson.
- Lefebvre, H. (1991). *Critique of everyday life*. London: Verso.
- Ley, D. (2004). Transnational spaces and everyday lives. *Transactions of the Institute of British Geographers: New Series*, 29, 151–164.
- Rigg, J. (2007). *An everyday geography of the global south*. London: Routledge.
- Smith, D. (1988). *The everyday world as problematic*. Milton Keynes, UK: Open University Press.



EXISTENTIALISM AND GEOGRAPHY

The term *existentialism* was coined by Jean-Paul Sartre, the most famous of the existentialists, to refer to a range of mid-20th-century European philosophers who studied the conditions of humanity: Sartre, Albert Camus, and Gabriel Marcel in France; Martin Heidegger, Karl Jaspers, and Martin Buber in Germany; and Ortega y Gasset in Spain, as well as myriad novelists and playwrights who promoted a historical genre based on the “existential condition.” These thinkers shared a belief that established philosophical frameworks were insufficient to understand or improve human conditions. The basic premise is that human beings bring their existence into the world or *become* human by engaging a world peopled with other humans. A common referent is Sartre’s idea that “existence precedes essence,” that is, we make ourselves through our human projects.

There are two significant strands of existentialism in geography: (1) existential phenomenology, associated with Heidegger, and (2) existential Marxism, associated with Lefebvre and Sartre. Existential phenomenology arose during the 1970s to contest the spatial determinism of positivist science by emphasizing the subjectivity of human becoming. Profoundly influenced by the Heideggerian concept of *dasein* (“being in the world”), the project of recentering the human subject was addressed by scholars such as Ann Buttimer, Yi-Fu Tuan, and Edward Relph, who advocated a “humanistic” geography that linked phenomenological openness to the project of being with the social and cultural acts of creating, giving meaning to, and sustaining places or landscapes. Buttimer emphasized human creativity and intersubjectivity in everyday, experiential geographies, or “life-worlds”; she held human values as a basis for establishing how people care about one another. Yi-fu Tuan sought to understand how being open to the creative possibilities of human beings affects interactions with the surrounding environment and the struggle to make their landscapes. Edward Relph used phenomenology as a basis for assessing the ways in which humans design and give

meaning to valued landscapes, emphasizing the connection between care for landscape and care for humanity.

Other scholars have made a direct link between a phenomenology of being and a spatial ontology. Marwyn Samuels drew on Heidegger and Sartre to construct a “biography of landscape” as the physical expression of human spatial relations, looking to Martin Buber to understand spatial relations as the project of overcoming the distance between people and to suggest that the recursive act of setting others at a distance and entering into relations is informed by shared belief systems, or worldviews, that define the qualities and normative values of human societies. The inevitable distance that separates humans is thus actively filled with the project of becoming-for-others. For John Pickles, such a spatial ontology defines the scientific paradigm through which we create geographical knowledge.

The ongoing intellectual influences of these humanistic geographers are profound, including the incorporation of meaning and values firmly within the discipline; highlighting questions of ethics in geography, both as a subject of research in understanding human actions and as a normative framework for conducting research; and laying the methodological groundwork for the discursive turn during the 1990s, which views landscapes as repositories of human meaning and spatial relations as centered on the individual and as constituted through human action through which (to paraphrase Derek Gregory) landscapes are *made to mean*.

Existential Marxism came later to human geography. During the 1970s and 1980s, humanism and (structural) Marxism were viewed as oppositional. Humanist geographers objected to what they saw as economic determinism, and Marxist geographers viewed existential phenomenology as romanticist, individualistic, apolitical, and unable to address the complex problems of political economy or the role of power in defining human relations. Since the poststructuralist turn, however, with its emphasis on the active, social construction of meaning, existential Marxism, with its roots in Hegelian rather than Heideggerian dialectics, has had a profound effect. Most notable is the



influence of Henri Lefebvre, who has inspired geographers not only with his dialectical materialism but also with his concept of “space” as a social production. Existentialist in his concern to overcome the rupture in traditional philosophy between theory and practice, Lefebvre posited a triad of representations of space, representational space, and spatial practices (perceived, conceived, and lived space), which has had wide application by geographers in understanding urban processes and, in particular, the question of how “public space” is created and occupied. Don Mitchell, for example, draws on Lefebvre’s notion of the “right to the city” as a starting point to explore the relationship between spatial production, human rights, and class-based locational conflict.

Although he has received negligible attention from geographers, Sartre’s existential Marxism holds great potential for overcoming a tendency to read Lefebvre through an instrumentalist lens—and thus to reify “space,” as well as to extend a spatial ontology. Notwithstanding the many divisions among the French intellectuals that persisted over time, Lefebvre and Sartre shared the designation of existential Marxists, but their interests took different trajectories by the 1970s, when Lefebvre turned his attention to the relationship between cities and rural areas (hence his influence on urban geographies), whereas Sartre was concerned with the social relations of colonialism and oppression, influencing, among others, the work of Franz Fanon and Edward Said. Sartre’s project was to go beyond the individual to understand history as an “accumulation outflow” of spatialized acts and the spatiality of human existence as a dialectically constitutive process of “spatializing-spatialized,” through which human beings become objects to/for one another in a vast social geography of systematically constructed conditions. Using Marxian concepts such as scarcity, seriality, and alienation, he argued that colonialism and capitalism are the major structuring systems that, paradoxically, both situate the possibility of humanity and create alienation, thus preventing humans from achieving their full humanity. Sartre’s quest to overcome history as human oppression is relevant today for understanding how ongoing spatialized systems of

human relationship contribute to the effects of colonialism, Othering, and racialization.

Audrey Kobayashi

See also Buttimer, Anne; Critical Human Geography; Ethics, Geography and; Humanistic Geography; Phenomenology; Relph, Edward; Sense of Place; Tuan, Yi-Fu

Further Readings

- Buttimer, A. (2002). *Geography and the human spirit*. Baltimore: Johns Hopkins University Press.
- Gregory, D. (1994). *Geographical imaginations*. Cambridge, MA: Blackwell.
- Kelly, M. (1999). Toward a heuristic method: Sartre and Lefebvre. *Sartre Studies International*, 5, 1–15.
- Kobayashi, A. (2004). Geography, spatiality, and racialization: The contribution of Edward Said. *The Arab World Geographer/Le Géographe du monde arabe*, 7, 79–90.
- Lefebvre, H. (1991). *The production of space* (D. Nicholson-Smith, Trans.). Oxford, UK: Blackwell. (Original work published 1974)
- Mitchell, D. (2003). *The right to the city: Social justice and the fight for public space*. New York: Guildford Press.
- Pickles, J. (1985). *Phenomenology, science and geography: Spatiality and the human sciences*. Cambridge, UK: Cambridge University Press.
- Poster, M. (1975). *Existential Marxism: From Sartre to Althusser*. Princeton, NJ: Princeton University Press.
- Relph, E. (1981). *Rational landscapes and humanistic geography*. London: Croom Helm.
- Samuels, M. (1978). Existentialism and human geography. In D. Ley & M. S. Samuels (Eds.), *Humanistic geography: Prospects and problem* (pp. 22–40). London: Croom Helm.
- Samuels, M. (1979). The biography of landscape: Cause and culpability. In D. Meinig (Ed.), *The interpretation of ordinary landscapes* (pp. 51–88). Oxford, UK: Oxford University Press.



- Sartre, J.-P. (1943). *Being and nothingness: An essay on phenomenological ontology* (H. Barnes, Trans.). London: Routledge.
- Sartre, J.-P. (1976). *Critique of dialectical reason: Vol. 1. Theory of practical ensembles*. London: New Left Books.
- Sartre, J.-P. (1991). *Critique of dialectical reason: Vol. 2. The intelligibility of history*. London: Verso.
- Schatzki, T. (1991). Spatial ontology and explanation. *Annals of the Association of American Geographers*, 81, 650–670.
- Tuan, Y.-F. (1971). Geography, phenomenology and the study of human nature. *The Canadian Geographer*, 15, 181–192.
- Tuan, Y.-F. (1972). Structuralism, existentialism and environmental perception. *Environment and Behavior*, 4, 319–342.



EXOTIC SPECIES

Exotic species, also termed *nonindigenous*, *non-native*, *alien*, *naturalized*, or *introduced*, are species that are not native to a particular geographic area and were introduced intentionally or unintentionally by human activities. These introductions allow the species to overcome natural barriers to dispersal. In practice, classifying a species as native or exotic can be difficult when it is unclear how or when a species was introduced or if hybridization occurred with native species. Exotic species can be any type of organism, including microorganisms, plants, or animals. It is important to recognize that a species exotic in one area has an area to which it is native and that the behavior of the species in the two habitats can be completely different. Key features of exotic species include their geographic distribution, threats to introduction areas, and amenability to control treatments.

The pervasiveness of human movement and activity means that exotic species are present throughout the world. Even the Antarctic Peninsula is home to an exotic spider crab (*Hyas araneus*) and unknown numbers of exotic microorganisms. Exotics typically become distributed

by long-distance dispersal (e.g., moving from one continent to another by ships or planes), followed by local secondary dispersal (e.g., transportation by cars or animals from one area to another). Multiple introductions can be required for a species to become established, and a slow initial population growth may be followed by exponential growth as invasion proceeds. A classic example of an exotic species, the European rabbit (*Oryctolagus cuniculus*), invaded Australia in this way. Repeated introductions made over a 70-year period beginning in the late 1700s failed, but when establishment did occur in 1859, populations grew exponentially to devastate agricultural crops expansively.

Exotic species vary in their impacts on introduction areas. Some exotics become inert components of their new habitats or provide replacement functions for native species that have become extinct. Many exotics benefit humans and are often purposely introduced (e.g., medicinal plants, food species). Overall, however, exotic species are considered the second largest cause (behind direct habitat loss) of native species extinctions. Exotics also disturb human activities and cause billions of dollars of damage annually. Exotic mussels, for example, clog municipal water intake pipes, reduce the utility of beaches, and alter fisheries.

Competitiveness, invasiveness, and the ability to engineer ecosystems are characteristics that make exotic species threats to native ecosystems. Exotics often have competitive advantages in their new environment because they escape the agents that had kept their populations in check. For instance, the prevalence of the Asian bark fungus (*Cryphonectria parasitica*) remains low in its native habitat because host trees have attained resistance. When this fungus was inadvertently introduced to North America on imported trees near the turn of the 20th century, it eliminated the nonresistant American chestnut (*Castanea dentata*) as an overstory tree.

Many exotics are invasive, readily colonizing and dominating habitats, especially disturbed areas containing open niches available for colonization. Exotics also often invade and thrive in high-resource environments (e.g., nitrogen-enriched soils due to pollution) more than native species do. The ability to invade and usurp



European rabbit (*Oryctolagus cuniculus*), Austin's Ferry, Tasmania, Australia

Source: Wikimedia Commons: <http://www.noodlesnacks.com>.

resources quickly provides exotics with further competitive advantages over native species.

Species that can “engineer” ecosystems by drastically changing disturbance regimes or habitat conditions for indigenous biota are some of the most devastating exotics. Annual grasses of the genus *Bromus*, for instance, have invaded the arid lands of Western North America, engineering a new disturbance regime (frequent fire) by providing fuel to ecosystems where sparse fuel historically limited the spread of fire. Native communities, not adapted to frequent fire, are destroyed, while the exotic grasses exploit this new disturbance regime.

Land and water managers can attempt several techniques to limit the establishment of

undesired exotics, starting with preventing dispersal (e.g., by cleaning ships). If prevention fails, surveys and monitoring can detect new occurrences of exotics. Control treatments are most cost-effective and biologically feasible when exotics are in the early phases of invasion and have low abundance.

Suitable control treatments for exotic species depend on factors such as population sizes and traits of the exotic species, restrictions on the use of some treatments (e.g., herbicides), and economic costs. There are two general classes of treatments: species focused and habitat focused. Species-focused treatments act directly on individuals and include poisons, shooting, physical removal (e.g., hand pulling of plants), genetic engineering (e.g., introducing sterile individuals), and biocontrol (introducing another organism, often derived from the exotic species' native habitat, to control the target species). Biocontrol is risky, and there are examples of the biocontrol organisms themselves becoming troublesome exotic species. Habitat-focused treatments involve manipulating the habitat to be less favorable to the invader. Examples of these techniques include filling potential colonization sites by seeding native plant species, altering soil characteristics to render it outside the limit of an invader's tolerance, or implementing a disturbance regime (e.g., grazing) unfavorable to the exotic. A key condition of habitat-focused treatments is that the treatment should harm the exotic more than resident native species.

There are some dramatic examples of complete eradication of an exotic species, especially when the species threatens agricultural crops. Generally, however, exotics are continuing to expand their populations. Improving our understanding of which exotic species will have severe impacts to enable prioritization of treatments, how to reduce dispersal of exotics and invasibility of potential habitats, and species-specific control treatments is important for effective exotic species management.

Scott R. Abella

See also Biodiversity; Biogeography; Environmental Restoration; Human-Induced Invasion of Species; Invasion and Succession; Land Degradation; Pest Management



Further Readings

- Elton, C. S. (1958). *The ecology of invasions by animals and plants*. Chicago: University of Chicago Press.
- Lodge, D. M., Williams, S., MacIsaac, H. J., Hayes, K. R., Leung, B., Reichard, S., et al. (2006). Biological invasions: Recommendations for U.S. policy and management. *Ecological Applications*, 16, 2035–2054.
- Zouhar, K., Smith, J. K., Sutherland, S., & Brooks, M. L. (Eds.). (2008). *Wildland fire in ecosystems: Fire and nonnative invasive plants* (General Technical Report RMRS-GTR-42, Vol. 6). Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.



EXPLORATION

The history of geographic knowledge is closely bound up with explorations. Exploration is a means by which the geographical horizons and imaginations of cultures and peoples are extended, bringing the unknown world into the known.

Historically, explorations required curiosity and initiative as motivating forces, as well as endurance and force to stand up to the perils that harsh climates, hostile landscapes, and rough waters present; but above all, they require a courageous temperament to face the unknown. As centuries went by, new aims were added to the list of the reasons for exploring other regions and continents: economic and commercial goals, political conquest, or scientific missions that allowed people to acquire a deeper familiarity with the planet. Nowadays, virtually no place on Earth remains unexplored.

When explorations involved territorial conquests, they typically involved territories that were already inhabited by other populations. Explorations under these circumstances often turned into brutal aggression toward the locals. For example, the principle of *Terra Nullius*, a Latin expression meaning “nobody’s land,” was applied during the 16th century by European conquerors in many colonized areas of the world and

neglected the rights of indigenous peoples. Despite those tragedies, however, adventurous travel and mapping of new territories greatly contributed to the development of geographic knowledge.

The history and geography of exploration make up a complex tale in which power and economic and military imperatives are interwoven with the biographies and (often colorful) personalities of individuals. Although the term seems archaic today, *exploration* has long been central to the formation of geographic knowledge. This entry offers a general overview on geographic explorations, focusing on some of the most fascinating protagonists and events.

Prehistoric Exploration

The history of geographic explorations is as ancient as humanity itself and is often entwined with migrations that crossed vast parts of the Earth. Early humans moved to new territories in order to hunt animals or find a more favorable climate and landscape. About 70,000 yrs. (years) ago, human ancestors in Central Africa often faced terrible droughts. To find new sources of food and sustenance, they moved toward the eastern coasts of the continent, learning how to succeed in surviving in different contexts. They essentially followed two directions: One group, thanks to lower sea levels due to the ice age of that period, succeeded in reaching Southern Asia and, millennia later, went ashore in Australia, settling islands in the Pacific Ocean, or continued toward Central and Northern Asia until they found a natural bridge that allowed them to set foot on the American continent; others covered a shorter distance and arrived at Europe after crossing Mesopotamia. Simply by walking, a mode of travel that allowed them to cross a few hundred miles per year, humans exited Africa around 75,000 BC, spreading to East Asia and Europe by 50,000 BC and crossing the Bering Straits into North America between 20,000 BC and 30,000 BC. Boats and the technology for conquering maritime space were particularly well developed among the early Polynesians, who dominated the Pacific Ocean by AD 300, when they reached Easter Island. The final chapter of the diffusion of people to the planet’s remotest regions was the Lapita complex of cultures of the



Bismarck Archipelago, which developed the double-hulled outrigger canoe, an innovation that allowed travel out of sight of land and thus initiated the waves of Polynesian expansion that ended with the settlement of Hawaii around AD 1300.

Ancient History

Around the Mediterranean Sea, several cultures showed an interest in the discovery of new sites. After exploring their main source of sustenance, the Nile River, ancient Egyptians focused on exploring the eastern part of the African continent, in particular the Horn of Africa. By 2500 BC they reached what they considered the legendary Pwenet or Land of Punt, where precious material such as metals and timber, as well as slaves, could be found.

According to tradition, in the 10th century BC, the Phoenicians, who roamed across the Mediterranean, traveled from the Red Sea to Southwestern India and Sri Lanka. Four centuries later, they may have circumnavigated Africa by passing the so-called Pillars of Hercules, which were widely considered to be the end of the world. They also reached the archipelago of Madeira, the Azores, and the Canary Islands, and once in the Atlantic Ocean, they reached Cornwall in the north.

The Greek exploration of the Mediterranean Sea and Asia contributed greatly to the creation of maps and to the rise of cartography. However, they focused their attention on exploring other regions as well. Around 350 BC, for instance, the geographer Pytheas arrived in Britain and Norway. He described, for the first time, the frozen sea and some of the natural phenomena found in the northern parts of the world, such as aurora borealis and the midnight sun, and also provided social and cultural observations. He also described Thule, a mysterious land that scholars later identified either as Iceland or as the Norwegian coast but that at the time of Pytheas, and later throughout the Middle Ages, symbolically represented the northernmost border of the world.

Alexander the Great was a prominent figure in the Greek panorama of military explorations. Geographers and topographers followed him during his travels, and that greatly contributed to the knowledge diffusion of the new conquered world.

In the map later drawn by Eratosthenes of Cyrene, in fact, we can notice that the center of the world was no longer Greece but Persia, which was the core of the empire built by the Macedonian.

The enormous empire created by the Romans between the 1st century BC and the 4th century AD was due to their insatiable thirst for power, which led them to build a dominion that embraced virtually all the Mediterranean countries. Roman space was enlarged by repeated wars of imperial conquest, including the Punic Wars, which annihilated Carthage, and subsequent campaigns that added Gaul, Britain, Thrace, Greece, Syria, Palestine, and Egypt. The term *orbis terrarum* reflected the widespread view that the borders of the empire coincided with the habitable world, the boundaries between order and chaos. However, the Romans enjoyed robust trade with India and even occasional interchanges with China.

The Vikings

During the 8th and 9th centuries, the Vikings played a great role as explorers. On board a type of longship called *drakkar*, they penetrated Russia and the Mediterranean and reached Normandy, Britain, Ireland, Iceland, and a land they called Greenland. Renowned for attacks throughout the coasts of Europe, they perfected the keel by adding the steerboard (from which comes *starboard*), a side rudder that stabilized larger ships when hauling commodities. Their brief arrival in America nearly 500 yrs. before Columbus is a much discussed issue: Various arguments support different, and often contrasting, hypotheses about the European discovery of the continent. Some ancient texts and the results of archaeological excavations in the northwest coast of Newfoundland and the Labrador Peninsula led some scholars to support the theory of Viking journeys from Greenland to the region that the Norse explorer Leif Eiriksson named “Vinland,” “the land of grapes” or “the land of wine,” that is, Newfoundland. Around 1950, a map was discovered, presumably drawn in 1440, which gave new support to the theory of the Norse discovery of America (Figure 1). Besides Europe, Africa, and Asia, it represents the northern islands of Greenland and Iceland and a territory named Vinilanda Insula, which was said to have been discovered in the



Figure 1 The Vinland map, a 15th-century world map purportedly based on a 13th-century original
Source: http://it.wikipedia.org/wiki/Imagine:Vinland_Map_HiRes.jpg.

11th century. However, some recent studies have indicated that the map is false as it was drawn using recent ink. The debate about the authenticity of the Vinland Map continues.

Marco Polo

Early explorations linking Europe and Asia typically centered on the Silk Road (a name coined by the geographer Ferdinand von Richthofen in 1877), the umbilical cord that connected Europe, the Middle East, Central Asia, South Asia, Tibet, and China with ceaselessly flowing caravans of goods, innovations, ideas, merchants, missionaries, and armies. Few individuals traveled the entire distance of the Silk Road; rather, it was served by networks of intermediaries. For 2,000 yrs., its camel caravans formed the primary artery of commerce, linking ports, trading cities, oases, and innumerable different cultures. The Venetian Marco Polo, precapitalist history's most famous adventurer, as noted in his account *The Discovery of the World*, was the eminent figure of Western exploration in the 13th and 14th centuries.

Marco Polo was one of the first Europeans to arrive in China, which he called Cathay. He belonged to a rich family of merchants and began his famous voyage with his father and uncle in 1271. They went to Persia with the aim of embarking to India but then continued their journey until they reached Kashgar in Western China. They went across Hindu Kush and were the first Europeans to reach Pamir. Then they skirted the Taklimakan Desert and arrived in Lop Nuur. After crossing the Gobi Desert and 3 yrs. after their departure, they reached the court of the Mongol emperor Kublai Khan in Khanbalik, now Beijing (Figure 2).

Arab Explorations

The rapid expansion of Islam from the 7th to the 12th centuries unified diverse cultures under the umbrella of a common religion and, inasmuch as Arabic came to dominate governance and religious life in North Africa and the Middle East, a common language. The Arab world's situation intermediate between Asia, Africa, and Europe

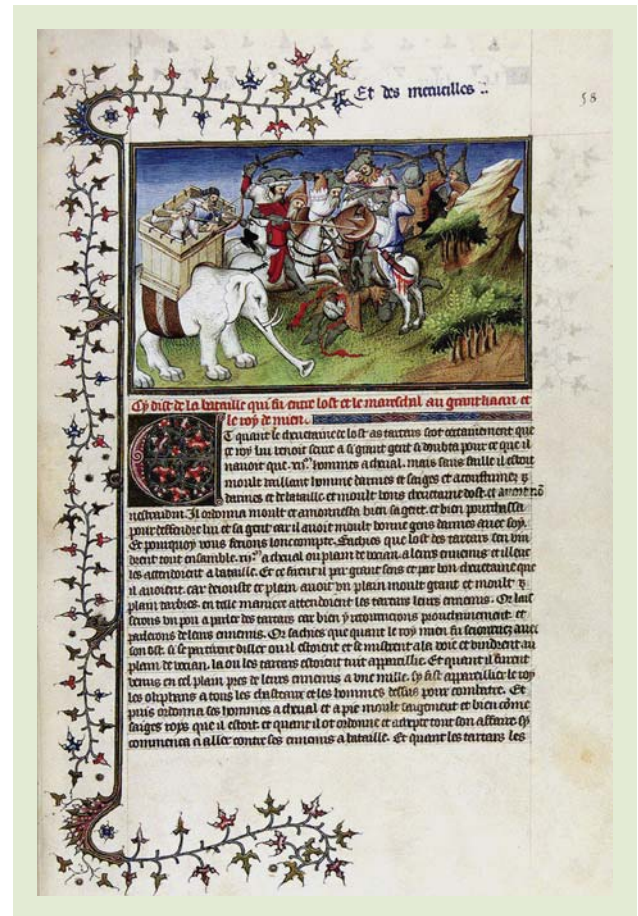


Figure 2 Marco Polo *Il Milione* (chap. CXXIII and CXXIV). From the book *The Travels of Marco Polo* (*Il milione*), originally published during Polo's lifetime, 1298–1299, but frequently reprinted and translated

Source: http://it.wikipedia.org/wiki/Immagine:Marco_Polo,_Il_Milione,_Chapter_CXXIII_and_CXXIV.jpg.

gave it a strategic location within the enormous trade networks that linked together places as far-flung as China, Mozambique, and Belgium. Arabic dhows plied the Persian Gulf and the Indian Ocean for centuries, and Arab shipbuilders invented the mizzen mast, the lateen sail, and stern rudder, all of which shortened times at sea. Unlike the Red Sea, which was notoriously difficult to navigate, the Persian/Arab Gulf emerged as a navigable waterway crossed by innumerable dhows. By the 9th century, when the mechanics of the monsoons (from Arabic *mausim*, “season”) had been deciphered, Arab trade became regularized across the Indian Ocean.



The most famous Arab explorer, Ibn Battuta, born in Tangier in 1304, was a Berber explorer who traveled throughout the Islamic world and wrote a chronicle of his journeys, a precious source of the geographical knowledge of the medieval era. He started his voyages with the ritual pilgrimage, or *hajj*, to Mecca and went on to visit new places for the next 30 yrs., covering more than 70,000 mi. (miles) from Spain to Western Africa and from the Middle East to India and China. During his journey back from Timbuktu, he met nomadic Tuareg people and lived several years with them, reporting on their culture and social structure.

Chinese Discoveries

By far, the most famous example of Chinese exploration occurred during the Ming dynasty. It was, of course, the famous expeditions led by Cheng Ho, one of many royal eunuchs, who made seven voyages across the Indian Ocean between 1405 and 1433 as an emissary for the Ming emperor. The “treasure ships” of the Chinese navy, at 7,800 tons, were three times as large as anything the British had in the water prior to the 18th century. With 317 such vessels and a crew of 37,000, Cheng Ho made Malacca the headquarters for visits to southeast Asia and then went on to Bengal, Persia, Aden, and Zanzibar. In 1407, he conquered Annam. In 1414, he brought a giraffe to the Ming emperor, which caused a flurry of excitement, a sign that the African kingdom of Malindi had become a tributary state. In scouring the Indian Ocean for pirates, the treasure ships provided security and lowered the costs of transport. However, China’s expansionism was short-lived. Japanese pirates subjected Chinese ships to unending harassment. Eventually, Ming China suffered multiple social economic crises that, coupled with the intense internecine battles between conservative Confucian bureaucrats and ambitious eunuchs, ended Cheng Ho’s voyages when all coastal shipping was banned in a fit of xenophobic nationalism. Such moves also reflect the Ming dynasty’s redirection of state resources from foreign expansion to internal security. The Ming withdrawal from the Indian Ocean by the 1430s created a power vacuum later filled by the Portuguese.

The European Age of Discovery

From the beginning of the 15th century till the late 19th century, as capitalism spilled across the world’s oceans and continents, Europeans were very active in the field of exploration. The invention of the sternpost rudder in the 12th century allowed for easier travel in the stormy waters of the North Sea and the Baltic; travel here had been difficult for earlier Greek or Roman ships, which relied on steering oars. Late medieval navigation relied on tables of declination, books of sailing instructions, the astrolabe and quadrant, and a vast oral system of instructions. The astrolabe, long known to Arab and Indian sailors, was introduced into Europe in the 11th century and was designed to solve trigonometric calculations in long-distance navigation. Similarly, feudal Europe was greatly affected by the introduction of the magnetic compass, the first mention of which in Europe dates to 1190; its subsequent adoption facilitated and catalyzed the process of early Western expansion, reducing the uncertainty of travel over both land and water and allowing sailors to sail the Mediterranean during winter. The greatest technical achievement of medieval navigation was the ability to sail against the wind, which was accomplished using sails on the new carack vessels, which were more sophisticated than the square sails used by the Romans. The result was an increase in the velocity and magnitude of trade across the Mediterranean.

In 1453, the Ottomans conquered Constantinople, which caused serious difficulties for non-Muslim merchants who dealt in goods from Asia. The search for new routes to China and India became enormously important for the powerful merchant class in Europe; moreover, innovations in the process of sailing and in cartography allowed great explorers to obtain extraordinary results.

In 1488, the Portuguese captain Bartolomeu Dias rounded the Cape of Good Hope, and 9 yrs. later, the navigator Vasco de Gama reached the Indian Ocean, sailing until he reached India. In 1497, the Italian John Cabot explored Newfoundland. And in the early 16th century, Amerigo Vespucci proved that what Columbus believed to be Asia was in fact a continent previously unknown to the Europeans. Ferdinand Magellan



succeeded in navigating the straits near Tierra del Fuego, and his famous voyage across the Pacific in 1520 remarkably encountered no storms, thus giving the ocean its name. Although he died in the Philippines, his ships ultimately completed the first circumnavigation of the globe. Magellan's crew's feat was not only technically significant, but the very act of global circumnavigation gave rise for the first time to the notion that there was a closed, finite world, an early inkling of the relative spaces yet to come.

Likewise, the European discovery of the Americas initiated a momentous material and discursive transformation. Columbus's narratives of the discovery were drenched in medieval cosmological meanings, including claims that the New World represented Paradise, or heaven on Earth, the site in which saved Christians would enter as promised by Genesis, or, equivalently, a new-found Jerusalem. Spanish imaginary geographies, for example, portrayed the Atlantic as an extension of the Mediterranean and the conquest of the New World—the decisive spatial fix of the 16th century—as an extension of the *reconquista* long after the Moors had been expelled from Iberia. The ideological impacts of the discovery of the New World, as its implications reverberated across Europe, are difficult to exaggerate. The so-called shock of the primitive not only fueled notions of racial hierarchy and European superiority, they also prompted heated debates as to what constituted a human being. O'Gorman (1961) suggests that the discovery of the New World accelerated the incipient secularization of Western society; in his account, the Americas were not simply discovered but discursively invented, a process that obliterated the medieval Christian worldview of a planet with three, and only three, continents and accentuated the division between humans and nature (Figure 3).

As the Enlightenment unfolded, European explorations also served as a means of generating vast quantities of data, in the form of samples of plants and animals as well as scientific observations. The most famous example of scientific exploration was perhaps Captain Cook's voyages to the Pacific in the mid 18th century, which included botanists, naturalists, and scientists studying the transit of Venus and searching for the mysterious *terra australis*.

The Arctic and the Antarctic

The North Pole and the South Pole, with their extremely rigid climate and hostile waters, always represented a formidable challenge for explorers. In 1909, the American explorer Robert Edwin Peary claimed to have been the first person to reach the North Pole, although in 1989 the National Geographic Society stated that he stopped at 5 mi. south of it. Sir Walter William Herbert is now generally considered to be the first person to have achieved that feat in 1969, after having spent years exploring the region.

At the southernmost end of the world, the South Pole was the focus of a competition between the Norwegian Roald Amundsen and the British Robert Scott, who died during his return journey after having reached the South Pole a couple of weeks later than his adversary.

The Northwest and the Northeast Passages

At the beginning of the 20th century, exploration continued for the long sought after Northwest Passage, the sea route that allowed one to reach the Pacific from the North Sea through the Bering Strait. The fact that the Indies could be reached by sailing west from Europe was known shortly after Columbus's famous journey. New routes to reach Asia soon became the priority of merchants and explorers. In 1497 and 1498, John Cabot was the first to seek the Northwest Passage, but the attempt was extremely difficult because of the general lack of knowledge about the area and the perils hidden by ice.

At the beginning of the 17th century, two English navigators accepted the challenge: In 1611, Henry Hudson reached the strait and the bay that were named after him, and William Baffin, in the same period, conducted five voyages in the Arctic Ocean. He became the first European to discover the bay that now bears his name. The passage was navigated for the first time by the Swedish explorer Adolf Erik Nordenskiöld in 1879. Due to the difficult environmental and climatic conditions involved, the dream of reaching the passage was abandoned for some time, but in the 19th century, the Royal Geographic Society charged the Scottish voyagers John Ross and William Edward Parry with



Figure 3 Historical map of the Old World, as Ptolemy knew it, by Johannes de Armssheine, Ulm, 1482

Source: http://commons.wikimedia.org/wiki/Image:World_of_Ptolemy_as_shown_by_Johannes_de_Armssheine_-_Ulm_1482.png.



exploring the northern coastline of America. After discovering the north magnetic pole, Parry explored the Arctic by sled, learning from the Inuit about how to survive in such extreme conditions. But it was again Amundsen who succeeded in crossing the passage during the voyage he undertook from 1903 to 1906.

Explorations in Africa

Africa, of course, was always known to Africans. Its discovery by others, however, is a different matter. The ancient Greeks, Phoenicians, and Romans made numerous exploratory voyages to the African coasts and established numerous colonial settlements there. When in the middle of the 15th century the power of Islam became an obstacle for European trade with Asia, merchants tried to find alternative ways to get to the Indies, including circumnavigating the African continent; however, its interior territories still remained mostly unknown and mysterious, imagined to be inhabited by fantastic and monstrous creatures.

In 1788, the African Association for Promoting the Discovery of the Interior Parts of Africa was founded, which later became the Royal Geographic Society. Its main aim was the exploration of the Niger River and pinpointing the location of the ancient city of Timbuktu. Among the European explorers of African regions was Simon Lucas, who toured Southern Libya. In the 19th and 20th centuries, European colonists were attracted to Africa by its abundant resources and commercial potential. The most famous explorer of the Dark Continent was David Livingstone, a Scottish missionary who dedicated his life to travels in its southern area, starting in 1845. He succeeded in crossing the Kalahari Desert and in reaching Ngami Lake, in Northwestern Botswana. Between 1852 and 1855, he explored the Zambesi River and found the Mosi-oa-Tunya falls, which he named Victoria, in honor of the Queen. He later discovered Lake Niassa (also known as Lake Malawi) and the Tanganyika Lake. Livingstone, like many explorers, focused his attention also on the quest for the Nile's source, a question that had aroused the curiosity of geographers since ancient times. The solution of that enigma

was finally found by the British adventurers Richard Francis Burton (1821–1890) and John Hanning Speke (1827–1864).

Women Explorers

Although they remain too often in the shadows of a male perspective on history and geography, many women can be found in the panorama of explorers. Due to their social marginalization, women explorers have always had to fight against prejudices, sometimes even hiding their identity by disguising themselves.

During the first half of the 19th century, the Austrian Ida Pfeiffer traveled all around the world. Accustomed to independence and physical activity since she was a child, she departed, by herself, and eventually met the indigenous tribes living in the rain forests in South America, whom she considered to be primitive and inferior to Christians. Among her most interesting adventures are the journeys through Mesopotamia and the jungles of Borneo: Such destinations were considered by some to be impossible for a woman traveling alone. Despite her election to the geographical societies of Berlin and Paris, she was not admitted by the British Royal Geographical Society because she was a woman (Figure 4).

Born in Geneva at the end of the same century, Isabelle Eberhardt traveled through the Algerian desert, dressed as a man and pretending that her name was Mahmoud Essadi. She was charmed by the huge open space of the desert and attracted by the Arab culture and way of living.

At the same time, Mary Henrietta Kingsley was interested in Western and Central Africa. She left Britain and was the first European to explore isolated areas of the French Congo and Gabon. During her travels, she did not stop despite numerous difficulties, learning from the locals how to survive in the jungles, discovering new species of fish, and not even hesitating to study cannibal tribes.

In Asia, the Belgian-French writer and explorer Louise Eugénie Alexandrine Marie David, whose pseudonym was Alexandra David-Néel, satisfied her spiritual thirst by traveling first through India, where she studied Buddhism and even lived for



Figure 4 Ida Pfeiffer Illus. [Frontispiece]. (1861). In *The Last Travels of Ida Pfeiffer: Inclusive of a Visit to Madagascar*. London: Routledge, Warne, & Routledge.

Source: [http://de.wikipedia.org/w/index.php?title=Bild:Ida Pfeiffer.jpg&filetimestamp=20081027175947](http://de.wikipedia.org/w/index.php?title=Bild:Ida_Pfeiffer.jpg&filetimestamp=20081027175947).

several years in a cave, and reaching Tibet in 1924, thus being the first European woman to enter Lhasa.

Susana Servello

See also Blaut, James; Bowman, Isaiah; Cartography, History of; Colonialism; Columbus, Christopher; Cook, Captain James; Enlightenment; Eratosthenes; Eurocentrism; Gama, Vasco da; Geographical Imagination; Historical Geography; Human Geography, History of; Humboldt, Alexander von; Ibn Battuta; Ibn Khaldun; Imperialism; Jefferson, Thomas; Lewis and Clark Expedition; Magellan, Ferdinand; National Geographic Society; Orientalism; Pilgrimage; Poles, North and South; Portolan Charts; Postcolonialism; Powell, John Wesley; Ptolemy; Race and Empire; Royal Geographical Society; Russian Geographical Society; Travel Writing, Geography and

Further Readings

- Boorstin, D. (1983). *The discoverers*. New York: Random House.
- Cipolla, C. (1965). *Guns, sails and empires: Technological innovation and the early phases of European expansion, 1400–1700*. New York: Minerva.
- Cunliffe, B. (2002). *The extraordinary voyage of Pytheas the Greek: The man who discovered Britain*. New York: Walker.
- De la Guèreviere, J. (2004). *The exploration of Africa*. New York: Overlook.
- De Porti, A. (2005). *Explorers: The most exciting voyages of discovery—From the African expeditions to the lunar landing*. Richmond Hill, Ontario, Canada: Firefly Books.
- Farrington, K. (2007). *Historical atlas of expeditions*. London: Mercury Books.
- Fernandez-Armesto, F. (2007). *Pathfinders: A global history of exploration*. London: W. W. Norton.
- Hourani, G., & Carswell, J. (1995). *Arab seafaring in the Indian Ocean in ancient and early medieval times*. Princeton, NJ: Princeton University Press.
- Jones, R., & Phillips, R. (2005). Unsettling geographical horizons: Explaining pre-modern and non-European imperialism. *Annals of the Association of American Geographers*, 95, 141–161.
- Larner, J. (2001). *Marco Polo and the discovery of the world*. New Haven, CT: Yale University Press.
- Law, J. (1986). On the methods of long distance control: Vessels, navigation and the Portuguese route to India. In J. Law (Ed.), *Power, action and belief: A new sociology of knowledge?* (pp. 234–263). London: Routledge & Kegan Paul.
- Levathes, L. (1996). *When China ruled the seas: The treasure fleet of the Dragon Throne, 1405–1433*. Oxford, UK: Oxford University Press.
- O’Gorman, E. (1961). *The invention of America*. Bloomington: Indiana University Press.
- Polk, M., & Tiegreen, M. (2001). *Women of discovery: A celebration of intrepid women who explored the world*. New York: Clarkson Potter.
- Riffenburgh, B. (2008). *National Geographic Society exploration experience: The heroic exploits of the world’s greatest explorers*. Washington, DC: National Geographic Society.



- Roller, D. (2006). *Through the pillars of Herakles: Greco-Roman exploration of the Atlantic*. London: Routledge.
- Savours, A. (2003). *The search for the North-West Passage*. New York: Chatham.
- Sigurosson, G. (Ed.). (2008). *The Vinland sagas*. New York: Penguin.
- Steffoff, R. (1994). *Women of the world: Women travellers and explorers*. New York: Oxford University Press.



EXPLORATORY SPATIAL DATA ANALYSIS

Exploratory spatial data analysis (ESDA) is an extension of exploratory data analysis (EDA) to detect and understand the properties of spatial data. ESDA is an important research field in geographic information science (GIScience) because we now live in a data-rich world and a vast and increasing amount of information on geographical phenomena is recorded digitally as spatial data. Adopted by many subdisciplines of geography and other disciplines (e.g., epidemiology), ESDA has made enduring contributions to the development of GIScience and geography. Therefore, ESDA is an important topic in this *Encyclopedia*. This entry discusses three related topics: (1) EDA, (2) traditional ESDA, and (3) the potential future directions of ESDA.

Exploratory Data Analysis

Tukey, who introduced the notion of EDA, thought of it as the first step in a two-step process similar to criminal investigations. The first step focuses on evidence collection, and the second step—the confirmatory analysis—evaluates the strength of the evidence. The difference between the two steps is similar to that between descriptive and inferential statistics: The former produce data descriptions, and the latter draw inferences by assuming some statistical models. Employing descriptive methods, EDA imposes few prior assumptions about the data and attempts to let the data speak for themselves. EDA focuses on

understanding trends and outliers rather than on fitting models. Good defines EDA as a collection of descriptive techniques that summarize data properties, detect patterns and unusual features in data, and formulate hypotheses from data. EDA techniques integrate descriptive statistical methods (e.g., median, mean) with visualization methods (e.g., charts, graphs, and figures). Modern EDA emphasizes human-computer interaction. It employs highly interactive, dynamic statistical graphics that allow the analyst to manipulate the views of the data directly in a simple, intuitive way. The views are often dynamically linked, so that the selection on a subset of data in one view can be immediately reflected in all the other views. Such data manipulation allows investigation of data from various perspectives concurrently and exposing insights that are otherwise hidden.

Exploratory Spatial Data Analysis

Spatial data are special. According to Tobler's First Law of Geography, "everything is related to everything else, but near things are more related than distant things." In spatial data, an observation is referenced to a spatial entity (e.g., a point, line, or areal unit). Because the phenomena represented by neighboring entities interact with each other, samples of spatial data are usually not independent. The dependence in spatial data, often referred to as spatial autocorrelation, conflicts with the basic assumption of independent observations in statistics, making traditional statistics and most EDA methods invalid for spatial data. For example, EDA methods estimating regression parameters and generating measures of fit become invalid in the presence of spatial autocorrelation. Extending the notion of EDA, ESDA methods are geared especially for exploring spatial data—summarizing the spatial properties of data, detecting spatial patterns in data, and generating hypotheses based on the patterns. ESDA techniques consist of a collection of spatial statistics and traditional visual methods including geographic maps.

The special characteristics of spatial data determine the goals and methods of ESDA. For EDA, Tukey (1977, p. 208) modeled any data value with two components:

$$\text{Data} = \text{Smooth} + \text{Rough},$$



where “Smooth” refers to the “predictable” part (i.e., fit) and “Rough” is the “unpredictable” part (i.e., residuals). Haining (2003) extended the Tukey model in spatial terms:

$$\text{Spatial data} = \text{Spatial smooth} + \text{Spatial rough},$$

where “Spatial smooth” includes spatial trend (i.e., the systematic variation of an observation along a region, such as a mountain) and spatial autocorrelation (i.e., in the case of positive autocorrelation, neighboring areas are more similar in attribute than distant areas). This component results from and reflects spatial dependency. The spatial rough component includes localized hot or cold spots and spatial outliers (i.e., places whose attributes are very different in magnitude from the values in their neighboring locations); this component reflects spatial heterogeneity (i.e., the spatial difference and nonstationarity associated with each location). Traditional ESDA techniques focus primarily on detecting and visualizing (a) spatial distribution, (b) spatial association (e.g., autocorrelation and overall clustering), and (c) local clusters and hot spots.

First, visualization of spatial distribution is concerned with displaying the values of a variable observed in a region and exposing the spatial trends and outliers. A simple way to identify spatial clusters is to link a boxplot to a map. The value distribution of an attribute is displayed along the boxplot; data items outside the upper and lower “fences” of the boxplot are considered as outliers and can be highlighted on the map. Smoothing methods are often employed to reveal general trends in spatial data, especially for maps consisting of many small areas. A simple numerical form of smoothing is the spatial average, which averages the original value of a place and the values at its surrounding places. The key issue of map smoothing is to improve the precision of the statistic while not introducing much bias. Spatial averaging based on more surrounding places can increase precision (i.e., with increased sample size), at the cost of introducing more bias since a place “borrows” values from areas farther away.

Second, the focus of ESDA on spatial association primarily involves two aspects: (1) global autocorrelation testing overall clustering (i.e., the null hypothesis states that data values are

distributed randomly across geographical space) and (2) local autocorrelation detecting local clusters. Generally, spatial autocorrelation can be measured from two perspectives, lattice and geostatistical, based on the way in which spatial proximity is conceptualized. Anselin (1994) interpreted the two perspectives in a more intuitive manner: neighborhood view and distance view.

The *neighborhood view*, more commonly found in geography, conceptualizes a place comprising discrete points or areal units and spatial neighbors as spatial units that have a common boundary. The neighborhood is formalized in a *spatial weights matrix* W , with elements $w_{ij} = 0$ when locations i and j are not neighbors and $w_{ij} \neq 0$ otherwise. A location has spatial interaction only with a countable number of its neighbors (when $w_{ij} \neq 0$). The global autocorrelation can be measured by a number of methods including Moran's I , Geary's C , and G statistics. The basic idea is to compare the observation at each location with the average of its neighbors. If most locations have the observation similar to the average of observations at their neighbors (e.g., a high-value location is surrounded by neighbors with high values), a positive spatial association is suggested, otherwise a negative spatial association is suggested (e.g., a high-value location is surrounded by neighbors with low values). Global spatial autocorrelation can be visualized using the Moran scatterplot (Figure 1). A scatterplot plots a variable value against its spatial lag for each location. A spatial lag of a location is defined as the weighted average of observations at the neighboring locations; the weighted average is calculated using the weights in the spatial weights matrix. The method follows the interpretation of Moran's I statistics as a regression of a location's spatial lag on the variable itself. The regression line through the points on the scatterplot reflects the Moran's I , thus indicating the spatial autocorrelation (e.g., a 45° slope indicates strong positive spatial autocorrelation). In addition, local spatial autocorrelation can be detected through the outliers in the scatterplot. The outliers do not follow the same process of spatial autocorrelation of the other points and can be considered as locally nonstationary. A more sophisticated tool is the LISA map (Anselin, 1995). GeoDa, a freely downloadable software application, implements the methods mentioned above.

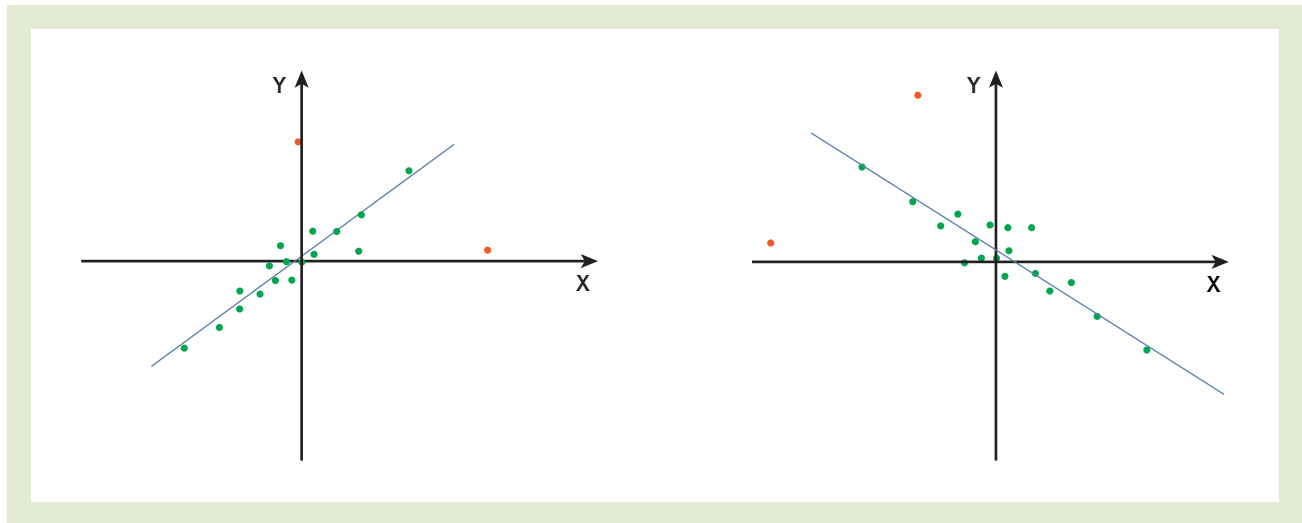


Figure 1 Moran scatterplot to detect spatial autocorrelation and outliers. The x -axis represents a variable, and the y -axis represents the spatial lag of the variable. The left plot shows positive autocorrelation, and the right plot shows negative autocorrelation. The red points are spatial outliers.

Source: Author.

The *distance view* is based on geostatistics. The approach considers spatial observations as a sample of points from a continuous spatial distribution. It conceptualizes spatial interaction as a continuous spatial process. Therefore, spatial autocorrelation is formalized as a continuous function of distance. The global autocorrelation can be measured by comparing the observation dissimilarity (e.g., square difference) at a pair of locations with the spatial distance between the two locations. The autocorrelation can be visualized by a variogram, in which the differences between all pairs of locations are sorted by spatial distance.

Finally, detecting local clusters is important in many contexts, such as epidemiology and crime studies. A local cluster is an unusual concentration of events in an area, where counts or rates are considerably larger than expected values based on an assumption of spatial randomness. Although descriptive statistics methods (e.g., Local Indicators of Spatial Association [LISA]) help identify local hot spots and outliers, many researchers employ inferential statistical methods for detecting clusters. One popular method is the scan statistical method. One of the earliest versions of the spatial scan statistical method was the Geographical

Analysis Machine (GAM) of Openshaw and colleagues. Built on the concept of GAM, Kulldorff's spatial scan statistic gained popularity in recent years because it is both deterministic (i.e., it identifies the locations of clusters) and inferential (i.e., it allows testing of the statistical significance of the clusters). The method assumes the null hypothesis that events are randomly distributed in geographic space. The alternative hypothesis is that there are an unusually high (low) number of events within a subarea as compared with the outside areas. Kulldorff's spatial scan statistic is implemented in publicly downloadable software—SaTScan. Because SaTScan does not provide cartographic output, users need to export SaTScan output into geographic information system (GIS) software to display the geographic location and size of the identified clusters (Figure 2). Chen, MacEachren, and Lengerich (2008) recently developed a visualization technique to facilitate exploratory interaction with SaTScan clusters and tune the clustering parameters.

Potential Future Directions

Computational methods can also be combined with visualization methods to support ESDA.

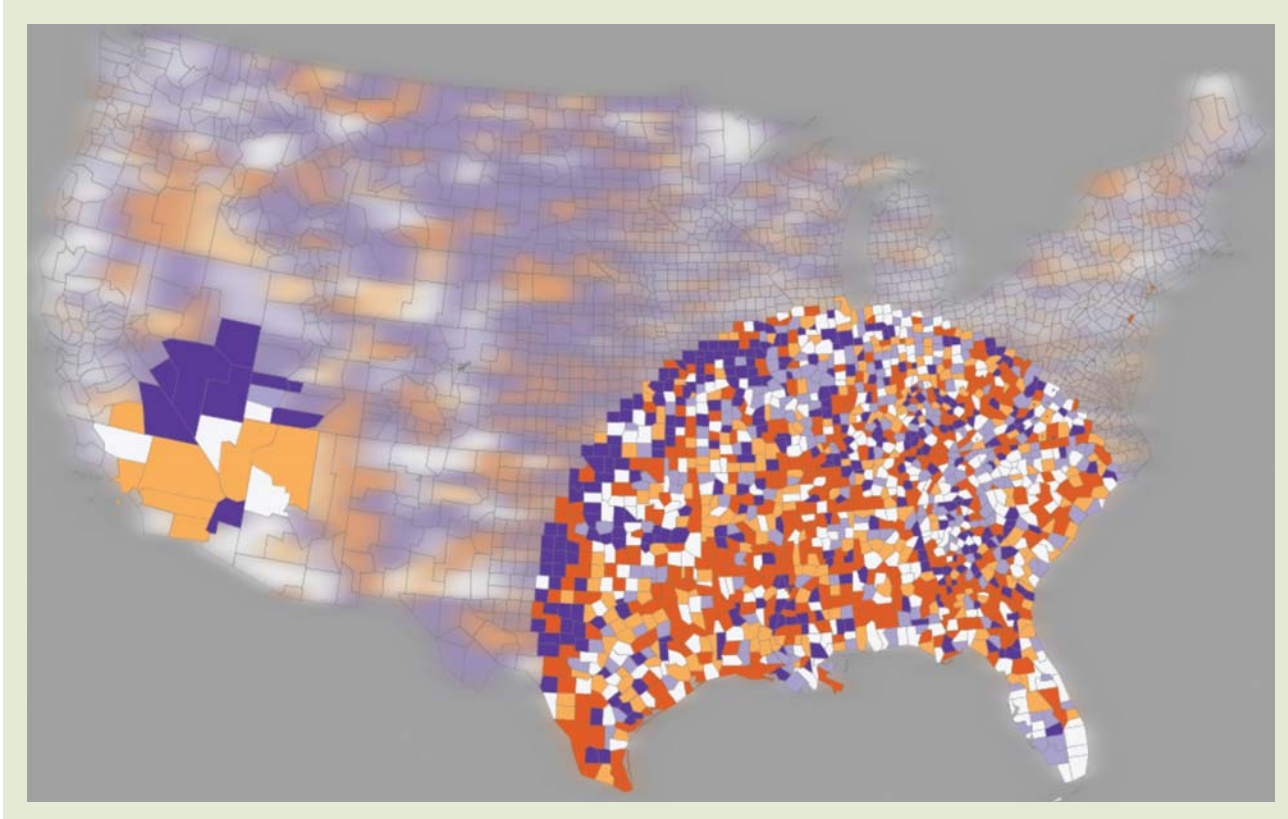


Figure 2 Visualization of high-risk clusters of cervical cancer in the United States (2000–2004) identified by SaTScan

Source: Map created by author, based on data from the National Cancer Institute using the Surveillance, Epidemiology, and End Results (SEER) program via the SEER*Stat software.

Note: Orange = high risk, white = normal, blue = low risk.

Computational methods that are of relevance to ESDA include machine-learning and data-mining methods supporting automatic identification of useful structures, patterns, and clusters in data. Examples of such methods include classification trees, cluster analysis, and neural networks. In recent years, research efforts in ESDA have been extended beyond univariate spatial data to include temporal, multivariate, and moving data as well. Large data volumes and the high multidimensionality of data sets, containing tens of variables, make the traditional ESDA methods no longer satisfactory. Hence, there is a need to develop integrated and more robust visualization and computational methods. Examples and detailed discussions on this topic can be found in Ferreira de Oliveira and Levkowitz (2003); Chen,

MacEachren, and Guo (2008); and Keim, Panse, Sips, and North (2004). Another developing research field that is relevant to ESDA is geovisual analytics (GA). Conceived as an extension of visual analytics (Thomas & Cook, 2005), GA goes beyond ESDA to give more attention to support for both computational and human analytical reasoning processes. GA aims to facilitate a human analyst in his or her direct interaction with visually represented information in order to gain insights, draw conclusions, and ultimately make better decisions (see Keim, Mansmann, Schneidewind, & Ziegler, 2006). GA integrates techniques of visualization, human factors, statistics, mathematics, and data mining.

Jin Chen



See also **Quantitative Methods; Spatial Autocorrelation; Spatial Data Infrastructures; Spatial Data Integration; Spatial Data Mining; Spatial Data Models; Spatial Data Structures; Spatial Econometrics**

Further Readings

- Anselin, L. (1994). Exploratory spatial data analysis and geographic information systems. In M. Painho (Ed.), *New tools for spatial analysis* (pp. 45–54). Luxembourg: Eurostat.
- Anselin, L. (1995). Local indicators of spatial association: LISA. *Geographical Analysis*, 27, 93–115.
- Chen, J., MacEachren, A. M., & Guo, D. (2008). Supporting the process of exploring and interpreting space-time, multivariate patterns: The visual inquiry toolkit. *Cartography and Geographic Information Science*, 35, 33–50.
- Chen, J., MacEachren, A., & Lengerich, E. (2008, September 23). *Visual analytics of spatial scan statistics results*. Paper presented at GIScience 2008, Park City, UT.
- Ferreira de Oliveira, M. C., & Levkowitz, H. (2003). From visual data exploration to visual data mining: A survey. *IEEE Transactions on Visualization and Computer Graphics*, 9, 378–394.
- Good, I. J. (1983). The philosophy of exploratory data analysis. *Philosophy of Science*, 50, 283–295.
- Haining, R. R. P. (2003). *Spatial data analysis: Theory and practice*. Cambridge, UK: Cambridge University Press.
- Keim, D. A., Mansmann, F., Schneidewind, J., & Ziegler, H. (2006). Challenges in visual data analysis. In F. Mansmann (Ed.), *Proceedings of the 10th International Conference on Information Visualization* (pp. 9–16). London: IEEE Press.
- Keim, D. A., Panse, C., Sips, M., & North, S. C. (2004). Visual data mining in large geospatial point sets. *IEEE Computer Graphics and Applications*, 24, 36–44.
- Thomas, J. J., & Cook, K. A. (Eds.). (2005). *Illuminating the path: The research and development agenda for visual analytics*. Los Alamitos, CA: IEEE Computer Society.
- Tobler, W. (1979). Cellular geography. In S. Gale & G. Olsson (Eds.), *Philosophy in geography* (pp. 379–386). Dordrecht, Netherlands: D. Reidel.

Tukey, J. W. (1977). *Exploratory data analysis*. Reading, MA: Addison-Wesley.

EXPORT-LED DEVELOPMENT

Export-led development is a phrase encompassing a number of different economic development strategies—especially export-oriented industrialization (EOI) and the export of primary products—pursued by the developing world. These practices arise from development theories informed by economic and political economic thought. A number of major and conflicting lines of economic and political economic thought, including neoclassical economics, development economics, and Marxist political economy, hold different views on export-led development. Disagreement centers primarily on the role of the state in guiding economic growth through export orientation and the desirability of pursuing comparative advantage versus competitive advantage. Geographers have been prominent in theorizing the uneven development of capitalism and the successes and failures of various nations' attempts at economic development.

Richard Peet makes an important distinction between “strong” development, in which the productive resources of society are used to help the poorest people, and “weak” development, characterized by economic growth that provides more for everyone but primarily benefits the elite and is supposed to “trickle down” to the poor. Beyond this distinction, the concept of development has been subjected to a number of important critiques from the perspectives of sustainable development and poststructuralism. Those who agree that development should be pursued measure it by various criteria, including gross domestic product/gross national product, the Physical Quality of Life Index, and the Human Development Index.

Models and Theories

There are several perspectives on export-led development, which offer differing views on its causes and consequences.



Structuralism

The structuralist perspective, informed by both development economics and critical political economy, including dependency theory and world-systems theory, has viewed state intervention as both useful and necessary to industrialize developing nations and thereby reduce global inequalities. The heterogeneous theories critical of laissez-faire and neoclassical economics generally agree that a lack of state intervention in the economy means that developing countries will not move beyond primary production and simple manufacturing without state intervention and, therefore, that international trade exacerbates international inequalities. In particular, structuralists have pointed to declining “terms of trade”—the value of a country’s exports relative to its imports—for primary product exporters. The declining price of primary products relative to manufactured goods means that primary product-exporting countries must export ever-higher volumes to purchase the same quantity of manufactured goods over time. Additionally, underdevelopment may be entrenched by the “resource curse,” which points to the strong but paradoxical relationship between high stocks of resources such as minerals and oil and low levels of economic development.

Import Substitution Industrialism

After World War II, a structuralist consensus formed in developing economics and became the dominant theory guiding economic policy in developing countries. In the 1950s, most developing countries pursued import substitution industrialization (ISI) to encourage domestic manufacturing to meet domestic needs. ISI drew on the experience of Latin American nations that had pursued these policies since the Great Depression as a solution to export dependency. Under ISI, governments imposed tariffs on imported manufactured goods to limit competition (but did not impose tariffs on inputs for domestic manufacturing) and provided incentives and assistance to the local firms that manufactured these goods. Fiscal policy involved raising the exchange rate of domestic currency, thereby making imports without tariffs cheaper and making exports more expensive (which favored investment in domestic industry).

Nations such as Brazil, the paradigmatic case for ISI, promoted domestic industries through support for domestic firms, state ownership of some sectors, and allowing entry to foreign firms and transnational corporations that the state required to be oriented toward meeting domestic needs. Brazil by the 1970s met the majority of domestic demand for steel, textiles, transportation equipment, and pharmaceuticals. Large nations, with potentially large domestic demand, generally fared best under ISI, while the domestic demand of smaller countries was too small for efficient mass production. But there were several problems with the ISI model. First, ISI did not reduce inequality within the countries that pursued it. Second, ISI did little to reduce imports, as the sectors targeted by ISI required considerable inputs of capital goods such as machinery. This strategy in many instances led to large national debts, which, together with the interest rates hikes of the late 1970s, ushered in the debt crisis of the 1980s.

Export-Oriented Industrialization

The other development model often contrasted with ISI is EOI, although it is important to note that the countries most strongly associated with EOI also pursued ISI, often at the same time. EOI sought industrial growth and structural change in national economies—away from primary products and simple manufactured goods toward higher-technology sectors—by nurturing the conditions domestically that would allow exports to compete successfully in international markets, rather than relying only on domestic demand as promoted under ISI. The newly industrialized countries (NICs)—especially Taiwan, South Korea, Hong Kong, and Singapore—are considered the paradigmatic cases of EOI. They shifted from a largely ISI-oriented approach toward an EOI-oriented approach in the late 1950s and early 1960s. The South Korean and Taiwanese cases, together with their predecessor in EOI, Japan, and their successor, China, have shown that directed state intervention, including what neo-classical economists would call blatantly anticompetitive policies, have created some of the most rapid growth rates and structural changes to national economies that have ever been seen. These countries’ economic growth was strongly



supported by their efforts at exporting manufactured goods, but strong government intervention in prioritizing economic sectors is certainly not in line with neoclassical economics' preferred laissez-faire approach but instead draws on the prescriptions of state intervention promoted by structuralism and other state interventionist thought.

The Heckscher-Ohlin Model

Within the realm of neoclassical economics, and in direct contrast to structuralist and radical political economic thought, the Heckscher-Ohlin model is hegemonic and forms the theoretical basis for global "free trade." Advocates of this model argue that countries should integrate into the world economy by focusing on their comparative advantage—that is, they should specialize in the production and export of goods that rely heavily on the factors of production that they have in relative abundance while importing goods that are intensive in factors of production in which the country is relatively poor. Like laissez-faire arguments at the end of the 19th century, neoclassical economics holds that state intervention in markets is harmful. Neoliberalism draws on neoclassical theory to oppose interventionist economic theories and has been hegemonic in its shaping of economic development in both industrialized and developing countries over the past 30 years. Export-led growth promoted by neoclassical economists and neoliberals eschews the state-led development trajectories that are common to EOI, such as prioritizing sectors by directly or indirectly directing investment, or state-owned industries. Thus, for most developing countries, the neoclassical and neoliberal prescription for national economic growth—along the lines of weak development—is to continue to focus on primary products, in countries with relative wealth in natural resources, and labor-intensive, simple manufactured goods such as textiles because of the low wages prevalent in these countries.

Outcomes of Development

Those promoting neoliberalism have claimed that the experiences of the NICs support the prescription

of pursuing comparative advantage. Thus, since the 1980s, the World Bank and the International Monetary Fund (IMF) have drawn on the successes of the NICs as the basis for structural adjustment as advocated by neoliberalism. With the debt crisis of the 1980s, the World Bank and the IMF imposed structural adjustment policies in return for continued access to loans. Structural adjustment generally required governments to reduce tariffs and quotas on imported goods, privatize state-owned sectors, cut government spending on public services to balance budgets, reorient their economies toward export sectors based on comparative advantage, prevent the overvaluation of exchange rates, create positive interest rates in real terms, and stop the subsidization of capital-intensive industrialization. Structural adjustment has proven to be highly controversial, with particularly fierce opposition among farmers in the developing countries, including members of the Via Campesina movement, who argue that they cannot compete with subsidized agricultural products from the United States and Europe and, as such, are being forced into new forms of exploitation reminiscent of colonialism. The threat of being cut off from the world economic system and the loans that allowed their governments to function proved too much for many developing countries during the debt crisis. Although most developing country governments were often hesitant and resistant, they had to implement structural adjustment programs as designed by the World Bank and the IMF.

In contrast to EOI, structural adjustment has primarily favored two strategies for export-led growth. First, export processing zones closely match the prescriptions of neoclassical economics in that they exploit developing countries' comparative advantage in low wages (labor costs) by focusing on labor-intensive but low-skilled production—such as the textile industry and assembly of simple electronics—rather than attempting to pursue competitive advantage by changing comparative advantage through state intervention. Second, structural adjustment has prioritized exports of primary products as these are generally the resources in which developing countries have a comparative advantage.

The production and export of primary products—including goods from agriculture, forestry, fisheries,



and mining—have therefore flourished under the hegemony of neoliberalism. Export agriculture, often mirroring the large-scale plantations established under European colonialism, has boomed in developing countries to feed industrialized nations' demand for year-round fresh produce. Export agriculture is typically critiqued as being more along the lines of industrialized agriculture in the industrialized world, meaning that it is intensive in its use of pesticides and fertilizers and results in numerous negative environmental and social consequences. Indeed, a large literature exists on the ecological and social crises arising from agroexport-led development.

Chile is used as the paradigmatic case of increased agricultural and timber exports under neoliberalism, beginning with Augusto Pinochet's coup against Salvador Allende. Pinochet and the "Chicago boys," trained in the neoliberal theories of Milton Friedman and others at the University of Chicago, made Chile the world's first neoliberal experiment in 1973. The economic changes involved the liberation of prices and markets, encouragement of foreign investment, the destruction of labor's power, minimization of environmental regulations, and a general commitment to "free trade," making Chile extremely favorable for foreign investment. The goal behind the radical change in policies was to have capitalist enterprises and exports become the driving force for growth. Chile's fruit production for export increased 40-fold, from US\$30 million in 1974 to US\$1.2 billion in 1996. As a result of this very rapid growth, Chile became the leading exporter of fruit in the Southern Hemisphere, servicing markets in both developed and developing countries. Critiques of the Chilean fruit boom include its reliance on the synthetic pesticides and fertilizers of industrial agriculture and the fact that the benefits are primarily distributed to the capitalist classes, whereas fruit workers have received little of the productivity gains and most can only find seasonal employment in the industry.

Ryan E. Galt

See also **Colonialism; Comparative Advantage; Competitive Advantage; Debt and Debt Crisis; Dependency Theory; Developing World; Development Theory; Economic Base Analysis; Export Processing**

Zones; Foreign Direct Investment; Gross Domestic Product/Gross National Product; Import Substitution Industrialization; International Monetary Fund; Political Economy; Neoliberalism; Newly Industrializing Countries; Regional Economic Development; Structural Adjustment; Sustainable Development; Trade; Transnational Corporation; Underdevelopment; Uneven Development; World Bank; World-Systems Theory

Further Readings

- Chang, H.-J. (1993). The political economy of industrial policy in Korea. *Cambridge Journal of Economics*, 17(2), 131–157.
- Evans, P. (1979). *Dependent development: The alliance of multinational, state, and local capital in Brazil*. Princeton, NJ: Princeton University Press.
- Gwynne, R. (1999). Globalisation, commodity chains and fruit exporting regions in Chile. *Tijdschrift voor Economische en Sociale Geografie*, 90(2), 211–225.
- Peet, R., & Hartwick, E. (1999). *Theories of development*. New York: Guilford Press.
- Porter, P., & Sheppard, E. (1998). *A world of difference: Society, nature, development*. New York: Guilford Press.
- Tabb, W. (1995). *The postwar Japanese system: Cultural economy and economic transformation*. New York: Oxford University Press.
- Williams, R. (1986). *Export agriculture and the crisis in Central America*. Chapel Hill: University of North Carolina Press.



EXPORT PROCESSING ZONES

An export processing zone (EPZ) is generally set up by a government to promote and capture foreign direct investment, international trade, technological transfer, and industrial development. These zones provide preferential treatments and incentives to attract foreign enterprises and investors. EPZs are also known as free trade zones (FTZs), special economic zones (SEZs), free zones (FZs), industrial estates, free ports, urban enterprise zones, and other terms.



History and Developmental Functions of EPZs

The concept of EPZs originated in Spain in 1929. In the 1970s, EPZs became a global phenomenon as a developmental tool in low-income nations in Latin America, the Caribbean, Asia, and, to a lesser degree, Africa. By the 1980s, almost all developing countries had established at least one such zone.

The normal provisions are infrastructure, communication and financial services, elimination of trade barriers such as tariffs and quotas, exemptions from production and trade-related taxes and business regulations, friendly and simplified bureaucratic requirements and procedures, elimination of labor laws, and relaxation of environmental protections. Tax holidays, duty-free exports and imports, and unfettered repatriation of profits are regularly offered to foreign firms. EPZs are locations for foreign enterprises and nodes of international transportation.

The main objective for the host nations of EPZs is economic gain. These zones are the instruments to increase foreign currency earnings, upgrade production technology, enter the world market, and provide employment. With foreign investment concentrating in these zones, a multiplier effect to locally linked industries and a dispersal effect to the surrounding regions are expected. Innovation in international transportation and communication in the 1960s and 1970s allowed transnational corporations to lower production costs by outsourcing parts or all of the production to offshore locations. The division of the industrial production process, with corporate headquarters at home nations and production branches overseas, is the basis for EPZs. These zones are designed to absorb international branch operations. Globalization gives rise to selective international economic integration, and EPZs are the transnational connection points in developing nations. The flourishing of EPZ development since the 1970s is a spatial response to globalization.

Shenzhen Special Economic Zone (SEZ)

The Shenzhen SEZ in China was designated in 1979 when that country was transforming from a

socialist to a market economy. It was a “window” through which to observe and learn from the free market operation and a “bridge” to the international economy. Although it has the same set of development objectives and provisions as other EPZs, the Shenzhen EPZ is unusual because it was the one of the first EPZs in China, where it served as an example of radical and systemic economic change.

Adjacent to Hong Kong, an international market economy free port, Shenzhen adopted trade regulations and industrial practices freely from its neighbor. In turn, Shenzhen’s institutions, regulations, administration, and planning are used as models for the rest of China as the country opens up its economy to the world. Connecting to the global economy through Hong Kong initially, Shenzhen has grown with export manufacturing and spread the developmental effects to its northern region, the province of Guangdong. The SEZ has industrialized the province’s economy and uplifted it from being one of the poorest provinces in the socialist era to one of the richest in the market era. Shenzhen not only has fulfilled successfully the promises of the EPZ but is also the transference point of foreign economic ideas and practices to the nation, playing a major role in marketing and internationalizing China’s economy.

Critiques

Developing states embrace EPZs as a developmental tool. Even though there are sufficient successful examples to attest to its effectiveness, there are, nevertheless, many counterarguments. In general, the multiplier effect and regional effects of many EPZs have been weak. The cost-effectiveness of government direct investment and indirect costs in relationship to the revenue received has been poor. Negative externalities have been reported, especially environmental pollution.

One of the most frequently raised issues of EPZs as an instrument of national development strategy is the competition among EPZs themselves. Since transnational firms seek economically advantageous sites for outsourcing and branch locations, and there are many suitable and available EPZs in the world, firms tend to seek



and bargain for the most advantageous zone. EPZs are forced to give their best offers to outbid their rivals. This competitive process is not only limited to international rivalry but also generates intensive contest between EPZs within the same country.

The most controversial issue is labor practice. International firms relocating the labor-intensive production segments are often opposed to labor unions and minimal-wage regulation. To be competitive, EPZs tend to avoid enforcing these institutional practices. Working conditions are substandard, and wages are low. Most of the employment is for young women in “dead-end jobs.” Often, EPZs do not generate new jobs but replicate the existing local jobs. Foreign firms, with better resources than the local firms, compete successfully at the expense of local industries for the “best” workers.

Developmental Trend

Since the 1990s, the World Trade Organization (WTO) has required member nations to eliminate import quotas and trade barriers, which EPZs offer. Export subsidies, which government supplies to the EPZ firms, are also to be repudiated. These WTO conditions have two effects on the member states: (1) making the entire national space more conducive and effective for export-oriented direct investment and (2) making EPZ establishment more difficult and economically less effective.

During the same period, many transnational corporations made a strategic shift from direct investment in low-value-added and labor-intensive segments of production abroad to subcontracting, licensing, and franchising overseas firms. These new transnational tendencies move significantly away from the division of the industrial production process, the basis of EPZ establishment.

With both trends converging at the end of the 20th century, the demand for EPZs has been significantly reduced, and the development of EPZs has subsided.

Reginald Yin-Wang Kwok

See also **Comparative Advantage; Competitive Advantage; Economic Base Analysis; Export-Led**

Development; Foreign Direct Investment; Globalization; Incubator Zones; Import Substitution Industrialization; Industrialization; Neoliberalism; Newly Industrializing Countries; Regional Economic Development; Trade; Transnational Corporation; Underdevelopment; Uneven Development

Further Readings

- Chu, D. (1986). The special economic zones and the problem of territorial containment. In Y. Yao & C. Leung (Eds.), *China's special economic zones: Policies, problems, and prospects* (pp. 21–38). Oxford, UK: Oxford University Press.
- Crane, G. (1990). *The political economy of China's special economic zones*. New York: M. E. Sharpe.
- Jauch, H. (2002). Export processing zones and the quest for sustainable development: A Southern African perspective. *Environment and Urbanization*, 14(1), 101–113.
- Wong, K.-Y., & Chu, D. (1985). Export processing zones and special economic zones as locomotives of export-led economic growth. In K.-Y. Wong & D. Chu (Eds.), *Modernization in China: The case of the Shenzhen Special Economic Zone* (pp. 1–24). Oxford, UK: Oxford University Press.
- Xu, X., Kwok, R., Li, L., & Yan, X. (1995). Production change in Guangdong. In R. Kwok & A. So (Eds.), *The Hong Kong-Guangdong link: Partnership in flux* (pp. 135–162). New York: M. E. Sharpe.



EXTERNALITIES

Broadly speaking, externalities (also known as “spillovers” or “neighborhood effects”) refer to “uncompensated welfare impacts,” that is, the actions and events of one party or person that affect the welfare (positively or negatively) of another without some type of remuneration. These arise when a decision maker does not reap



all the rewards or bear all the costs of his or her actions and can occur in both the production and the consumption of goods and services.

Positive externalities improve the welfare of an individual or group without a cost. For example, if one's neighbor has an attractive garden or plays music that one enjoys, the receiving party derives benefits without paying the costs. Most positive externalities are relatively trivial. However, network externalities, which reflect the rising utility of systems such as telephone networks or the Internet, are important: The more users use a system, the greater the value it has to each user.

Negative externalities, however, which diminish the welfare of a person or a group, are a different story. Examples of negative externalities include the reduction in real estate values created by the location nearby of an unwanted land use (e.g., a toxic waste plant). If a developer erects a high rise that blocks a home owner's view, the latter suffers a negative externality. More general cases involve the creation of air and water pollution, acid rain, noise pollution, or traffic congestion. Because the producers of negative externalities do not have an incentive to worry about the impacts of their actions on others, they generate social and market inefficiencies.

Negative externalities occur when the social costs of an action are not captured in the private costs in the form of the market price and are thus a prime example of market failure. For example, the true costs of operating an automobile include its impacts on highways, the environment, and public health, few or none of which are included in the price of gasoline or car insurance. A logging company may deprive a neighborhood of shade. In this case, and similar ones, the social costs are greater than the sum of the individual costs and lead to the overproduction of goods with high social costs. These are often seen as violations of individual rights and lead to serious ethical and political problems. Negative externalities are thus commonly cited as necessary instances of government intervention, such as zoning ordinances, health and safety regulations, and environmental conservation.

Geographers study the spatial location, frequency, and magnitude of negative externalities, which are unevenly distributed. The presence of a

sports stadium, for example, may generate a field of noise that affects local residents negatively. These factors are particularly important in the analysis of transportation (e.g., congestion), land use (e.g., rural-to-urban land conversion), and natural resource conservation (e.g., hydroelectric dams and their impacts).

Barney Warf

See also **Agglomeration Economies; Development Theory; Economies of Scale; Economies of Scope; Economic Geography; Knowledge, Geography of; Knowledge Spillovers; Location Theory; Neoliberalism; Not in My Backyard (NIMBY); Regional Economic Development**

Further Readings

Cornes, R., & Sandler, T. (1996). *The theory of externalities, public goods, and club goods*. Cambridge, UK: Cambridge University Press.



EXTINCTIONS

Earth is now entering its sixth period of mass extinction, defined as a major decrease in the number of species in a relatively short period of time. Extinctions are a normal part of the evolution of ecosystems. New species evolve, other species die out, and over millennia the diversity of life on the planet has increased.

The previous five mass extinction events are believed to have been caused by prehistoric meteor impacts and/or significant climatic changes (themselves caused by a variety of factors). The fifth event occurred 65 million years ago and wiped out an estimated 50% of Earth's species, including the dinosaurs. In the current time, a similar percentage of Earth's species are again threatened with extinction but this time as a result of the actions of the human species. The main causes include (1) habitat loss, (2) overexploitation, (3) introduced species, and (4) extinction cascades. Through these combined factors, around 70 species are believed to die out every single day; the rate of extinction is approximately 100 to



1,000 times greater than normal levels. In the coming years, anthropogenic climate change is also expected to add increasing pressure to struggling species and ecosystems, further accelerating the rate of extinctions.

Although extinction is a global event, the geographical distribution of extinctions is patchy; critical zones with high rates of extinction are unevenly distributed around the world. In addition, as the 2005 Millennium Ecosystem Assessment points out, the human experience of extinction effects falls disproportionately on rural communities and the poor. A geographical perspective brings a regional specificity to this global event and highlights the interconnections that link and amplify the extinction process. Four brief case studies will draw out connections between the diverse causes of extinctions and provide examples of the way in which a spatial analysis deepens our understanding of the loss and disturbance experienced when species die.

Human/Nonhuman Entanglements in Place

Even before a species becomes extinct, the role that it plays in an ecosystem may be severely impaired by dwindling numbers (called *functional extinction*). A good example is the case of *Gyps* vultures in India and the surrounding regions. Over the past decade, approximately 95% of these vultures have died as a result of poisoning caused by eating cattle treated with an anti-inflammatory drug called diclofenac. With vultures in decline, the millions of cattle carcasses they traditionally “cleaned up” have become a new source of food for growing populations of stray dogs and others. The increase in dog numbers is believed to be a significant cause for the spread of rabies and other diseases to humans, domestic animals, and potentially to some other threatened species. In addition, the vulture deaths are affecting people whose cultural and economic lives are directly connected with the birds, for example, the Parsi community, which traditionally exposes its dead to be consumed by vultures in “sky burials,” and “bone collectors,” who gather vulture-cleaned cattle bones for the fertilizer industry.



An Oriental white-backed vulture (*Gyps bengalensis*) that was brought injured to the Sanjay Gandhi National Park stands inside a cage at the park in Borivili, a suburb of Mumbai, India, September 23, 2008. Several vulture species in Asia have been driven to the brink of extinction after eating cattle carcasses tainted with an anti-inflammatory painkiller given to sick cows. The drug has led to global population declines as high as 99% in slender-billed and other vulture species, especially in India.

Source: AP Photo/Gautam Singh.

The Ecological and Cultural Place of the Species

The loss of “keystone” species has the potential to reduce the long-term viability of whole ecosystems and to reduce the capacity of other species to adapt to changing conditions, potentially leading to “co-extinctions.” For example, the spectacled flying fox (*Pteropus conspicillatus*) lives in the tropical world heritage rain forests of Queensland in Australia and is the major pollinator for the rain forests. These animals are currently under threat from habitat clearance and



the resulting disturbances, including invasive weeds. The loss of flying foxes endangers an ecosystem that is itself of great conservation value. With climate change, the role of these pollinators in maintaining the gene flow within plant species will be increasingly important. Flying foxes also remind us that the human experience of extinctions is local and enmeshed with cultural understandings. For some Australian Aboriginal people, flying foxes, along with numerous other extinct and endangered species, are totemic kin and are the focus of sacred songs, sites, and rituals. As one elder put it, “They’re not just fauna, they’re family.” In this context, local species losses entail the pain of losing nonhuman kindred whose existence in the world gave human life much of its meaning.

Enclosed Spaces, Global Connections

In the midst of so much loss, many of the Earth’s threatened species will survive only in zoos or other conservation centers. Survival is (perhaps) guaranteed inside these spaces, but many of the movements and relationships that organisms were once involved in will no longer be possible; their own lives and those of numerous others may be impoverished. For example, the Svalbard Global Seed Vault, in Norway, draws seed from around the world to provide a “backup” for many of the world’s agricultural plant varieties (which, alongside a great deal of “wild” biodiversity, are disappearing at an alarming rate). But seed in a bank (like animals in a zoo) is not equivalent to real beings living “in situ.” From inside these enclosed spaces, organisms are not able to be a part of the ecosystems they once inhabited, adapt to changing conditions, or be part of human communities. While these issues do not completely undermine the value of these conservation projects, they do highlight the need for critical thought about the enclosed and sometimes privileged spaces within which a great deal of conservation takes place.

Interrupted Spaces

Because the movement and genetic diversity of plants and animals are so important to the health of both individuals and the species, barriers that interrupt these movements are of vital

importance. For example, the European bison (*Bison bonasus*) survives in forests in Poland and Belarus, but the herds are divided by a huge fortified wall. In this “interrupted” environment, fears are raised about the viability of the gene pool and thus about the future of European bison in the wild. In the context of conservation work, barriers can include physical features of the landscape, such as roads, dams, rivers, and fragmented forests, and also less visible barriers, such as the differing ecological, economic, and legal conditions that exist across various political borders.

Conclusion

Many scientists consider the present mass extinction event to be the most serious crisis facing the world today. Its diverse consequences ripple out into ecosystems, drawing in and disturbing the lives of countless humans and nonhumans, in many cases affecting the most vulnerable populations first. A great deal of this scientific knowledge is presented in terms of data and statistics. Although we need numerous ways of engaging with and writing about extinctions, one value of a spatial perspective is that it interrupts the hegemony of numbers. In doing so, geographical approaches facilitate an understanding that includes humans within ecosystems, analyzes both connections and interruptions, and is attentive to the cultural, emotional, and political dimensions of extinctions.

Deborah Bird Rose and Thom van Dooren

See also **Anthropogenic Climate Change; Biodiversity; Biogeography; Conservation; Exotic Species; Game Ranching; Global Environmental Change; Human-Induced Invasion of Species; Keystone Species; Nature-Society Theory**

Further Readings

Elewa, A. M. T. (Ed.). (2008). *Mass extinction*. Berlin, Germany: Springer.

Quammen, D. (1996). *The song of the dodo: Island biogeography in an age of extinctions*. New York: Scribner.



- Weisman, A. (2007). *The world without us*. New York: Picador.
- Whatmore, S., & Thorne, L. (2000). Elephants on the move: Spatial formations of wildlife exchange. *Environment and Planning D: Society and Space*, 18, 185–203.
- Wilson, E. O. (2003). *The future of life*. New York: Vintage.
- World Resources Institute. (2005). *Millennium ecosystem assessment: Current state and trends assessment*. Washington, DC: Island Press.



EXTRACTIVE RESERVES

Extractive reserves are territories dedicated to environmental protection and the sustainable use of nature resources by traditional populations. Reserves follow a traditional land tenure model based on individual family and communal property rights to common areas, such as forest trails used to extract or harvest nontimber forest products. Although the extractive reserve concept originates in the tropical forests of the Brazilian Amazon, reserves have also been created in aquatic, floodplain, and savanna landscapes throughout Brazil. There are now 50 extractive reserves covering more than 10 million hectares, an area larger than Portugal, and more continue to be created. Despite their growing areal extent, the success of these areas for reconciling conservation and development is still being debated. However, the reserves remain popular with policymakers in part because they address both the land tenure concerns of the local people and the environmental concerns of conservationists. This entry focuses on the forested extractive reserves of Amazonia.

The extractive reserve concept originated with the struggle of Amazonian rubber tappers, harvesters of the latex of the rubber tree (*Hevea brasiliensis*), against the encroachment and deforestation practices of cattle ranchers moving into the Brazilian Amazon in the 1970s and 1980s. Tappers developed a resistance strategy combining nonviolent confrontations with the promotion of standing forests as viable development

alternatives and themselves as keepers of valuable forest knowledge. The methods and message of the tappers attracted environmental and human rights groups, who in turn brought international attention to the cause. The rubber tapper movement gained even greater notoriety with the tragic assassination of their internationally known leader, Chico Mendes. Two years later, in 1990, the first extractive reserve, Reserva Extractivista Alto Juruá, was declared.

The creation of extractive reserves generated immediate debate over the economic and conservation viability of both extractivism and organizational units built on the sustainable use of nontimber forest products. Pro-extractive reserve researchers and conservationists found the reserves with great economic and ecological potential for long-term sustainable development, including maintenance of standing forest, biodiversity, and environmental services. Meanwhile, the rubber tappers themselves focused more on the social potential of reserves to generate employment opportunities, preserve subsistence livelihoods, foment local participation in national policy decisions, and support cultural values and local knowledge. Early critics of extractive reserves warned against the idealization of reserves as a panacea for Amazon conservation and cited concerns with the economic sustainability of extractivism (e.g., inelastic supply of the extractive product and low demand), the spatial nature of the targeted resources (extensive nature, low density, and distant from markets), and ecology (potential biotic impoverishment through overharvesting and the deforestation potential of extractivists also pursuing agriculture and animal husbandry). Despite these concerns, extractive reserves gained credence as a means of preserving standing forests and protecting traditional livelihoods.

The complex land tenure arrangement of the reserves, combining public property, community management, and private resource use of designated forest areas, has provided an important refuge for both the forest and the extractivists in the face of continued deforestation and development in the Brazilian Amazon. As road networks, commercial agriculture, and cattle ranching expand into the Amazon basin, extractive reserves increasingly stand out in satellite imagery as



forested islands. However, a closer analysis of the forested reserves reveals some fragmentation taking place as the livelihoods and land use of rubber tappers adjust to new opportunities and constraints.

The traditional livelihoods of rubber tappers included the collection of latex, nuts such as the Brazil nut (*Bortholletia excelsa*), oils such as that from the copaiba tree (*Copaifera* spp.), and even subsistence agriculture and animal husbandry. The collapse of the rubber economy simultaneous to the creation of the reserves forced many tappers to focus on other nontimber forest products and to begin selling agricultural and animal products. Concomitantly, the reserves' united goals of conservation and social justice encouraged international agencies, governments, and nongovernmental organizations to invest resources and research on improving the economic viability of the reserves through initiatives focused on marketing networks, technical innovation, management, and the search for new and diversified extractive products. These initiatives have provided valuable support to residents seeking to continue the extraction of nontimber forest products in the face of alternative income-earning pursuits such as cattle ranching, logging, and farming.

However, extractivist livelihoods, as in Amazonian forests, are characterized by heterogeneity and dynamism. Thus, while the social value of extractive reserves for rubber tappers and the superior conservation value of reserves in comparison with the expanding cattle ranches that spurred their creation are undisputed, some residents are not practicing the same livelihoods envisioned by reserve proponents. In some reserves, this runs counter to the management plan established for the extractive reserve. This begs the question of who should enforce the management plan: reserve residents or the Brazilian environmental agency. To date, enforcement has been infrequent, raising concerns about the long-term future of reserves. Extractive reserves provide an important opportunity to study the dynamism of Amazonian livelihoods and the challenges to reconciling conservation and development within static organizational units. Perhaps most important, these forested units serve as home and workplace for their residents, even as the reserves

become increasingly important to mitigating deforestation and conserving biodiversity in a rapidly developing Amazon basin.

David S. Salisbury

See also Biome: Tropical Rain Forest; Conservation; Environmental Protection; Environment and Development; Forest Fragmentation; Indigenous and Community Conserved Areas; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Forestry; Indigenous Reserves; Indigenous Water Management; Political Ecology

Further Readings

- Allegretti, M. H. (1990). Extractive reserves: An alternative for reconciling development and environmental conservation in Amazonia. In A. B. Anderson (Ed.), *Alternatives to deforestation: Steps toward sustainable use of the Amazon rain forest* (pp. 252–264). New York: Columbia University Press.
- Browder, J. O. (1990). Extractive reserves will not save tropics. *Bioscience*, 40, 626.
- Cardoso, C. A. S. (2002). *Extractive reserves in Brazilian Amazonia: Local resource management and the global political economy*. Hampshire, UK: Ashgate.
- Salisbury, D. S., & Schmink, M. (2007). Cows versus rubber: Changing livelihoods among Amazonian extractivists. *Geoforum*, 38, 1233–1249.



EXTREME GEOGRAPHY

Extreme *human* geography is a critique that celebrates odd juxtapositions; it is not to be confused with extreme *physical* geography, which has its own distinct cabinet of remarkable curiosities. Extreme geography as a recurring subversive idea in the history of geographic thought manifests as fantasy mapping, counterfactual geographies, science fiction spaces/places, and other imaginative social critiques. As an identifiable critical “tradition” in modern Western geographic thought, its convoluted heritage is cross-disciplinary and can



be traced in fits and spurts from Homer, through Diogenes of Sinope, Saint Francis of Assisi, and Athanasias Kircher, to Guy Debord, Ursula K. Le Guin, and recently a conspiratorial core of radical cartographers at Pennsylvania State University, the founders of *Globehead! Journal of Extreme Geography*.

In March 1994, a graduate student, Nikolas H. “Ni4k,” Huffman described himself in *Globehead!*’s founding editorial as a shameless communist who will say anything, especially for money. Huffman and fellow maverick editors exhibited anarchic glee while parading *Globehead!*’s outrageous, often incendiary maps, essays, illustrations, photographs, recipes, and classified ads. The editors invited contributors to push the limits of their own geographical imaginations and, in the manner of extreme sports, to brave the boundaries of the geographical and think the unthinkable. *Globehead!*, spearheading the extreme geography idea, thus set itself out to be geography’s problem child by “aping the Game” and its counterfeit seriousness and playing up to irony and indignation.

By posturing themselves as extreme geography thinkers and practitioners against disciplined academic solemnity and reveling in ridicule and the ridiculous, *Globehead!* participants exuded hyperradical postmodern attitudes at a time in the history of geographic thought when the bloom was new on the rose of the epoch of postmodern geographies. In spite of the initial enthusiastic endorsements and contributions by several prominent academic geographers, including Peter Gould, Michael Dear, and Yi-fu Tuan, *Globehead!*’s second issue was fatally over the top for an academic geography journal in its time. *Globehead!* published the irreverently illustrated article “Fucking Geography” in its second and last issue, proving that extreme geography is forever born a doomed lark destined to become victim to its own exuberance.

Michael Dear, in his epigraph to the founding issue of *Globehead!*, claimed that it was the best idea since postmodernism “came along to confuse everyone.” Yi-fu Tuan wrote that he initially ventured into *Globehead!* because he felt that he belonged there: His own extremism at that time hardly ever touched base with any of the pillars of late-20th-century geography—Marxism,

poststructuralism, feminism, and so on—all of which, from his point of view, were by then recognized (and easily labeled) positions and hence mainstream.

Position-less, dysrational, devoid of lasting appeal, and self-destructive, *Globehead!* extreme geography played a brief nihilistic game at Penn State, in odd juxtaposition to its rational surroundings. However, as a recurrent social critique in the history of geographic thought, the absurdist extreme geography idea—much like radical relativism—is easily refuted though never long retired.

David J. Nemeth

See also **Critical Human Geography; Gould, Peter**

Further Readings

- Globehead! Journal of Extreme Geography*. (1994). State College, PA: Permanent Press.
Nemeth, D. (1997). Extreme geography. *California Geographer*, 37, 10–31.



EXURBS

Exurbia is low-density residential development that occurs at the suburban edge of metropolitan regions. The stereotypical vision of exurban life includes large homes on spacious lots, family life centered on the home, and a desire to escape from the urban ills of crowding, crime, and congestion. However, in contrast to those who see paradise in the guise of exurbia, critics of exurban development contend that such low-density landscapes are simply a form of sprawl where resources are squandered on large lots and long commutes.

Exurban areas are characterized by high commuting flows, low housing density, and rapid population growth. According to the Brookings Institution, about 17 million people, 5.6% of the U.S. population, lived in the exurbs by 2007, compared with 14 million people in 2000. In 2009, the U.S. Census Bureau released a study



called “Population Change in Central and Outlying Counties of Metropolitan Statistical Areas: 2000 to 2007,” which reported that the outlying areas of large cities—those areas beyond the traditional suburbs—grew more than 13% between 2000 and 2007, nearly double the average rate of the closer suburbs.

Why are exurban areas growing so fast? In his 1955 book, *The Exurbanites*, Sectorsky (1955) argued that exurbanites were motivated by a search for a rural environment. The exurban rural dream is a residential landscape in close proximity to environmental amenities such as open space. Sectorsky’s argument was echoed by Leo Marx (1964), who emphasized the role of the rural ideal in shaping the patterns of U.S. landscape development. And Friedman and Miller (1965) argued that exurbia represented a new type of urban form, created by exurbanites motivated by the desire to enact long-standing beliefs in the efficacy of rural landscapes.

The notion that exurbia represents a new settlement form is a controversial one. Thus, much of exurban research attempts to discover whether exurbia represents a “clean break” from previous settlement patterns or whether exurban development is simply suburban development, albeit in a low-density format.

In an effort to discover whether exurbanites are motivated by a different set of residential preferences, Crump (2003) compared the motivations of suburban and exurban residents and found that there are significant differences between the two groups. For example, exurbanites place a significantly greater value on rural characteristics such as open space, while suburban residents express a greater desire for access to transportation and shopping.

In contrast to these findings, other studies find that exurbanites are really no different from suburban residents. Nelson and Sanchez (1999) found that there is little or no evidence to support the “clean-break” hypothesis. Instead, their findings indicate that there is little difference between suburban and exurban residents.

Beyond issues of residential preference, economic factors clearly help fuel exurban development. In particular, the decentralization of employment helps drive exurban growth. Also, the expansion of so-called edge cities, with their

large employment nodes and retail centers, is reflective of the growth of employment at the edge of metropolitan regions.

In addition to the decentralization of employment, exurban growth likely reflects the rising cost of housing in an era of income stagnation for many households. Berube, Singer, Wilson, and Frey (2006) found that many exurbanites are trading lower housing costs for longer commute times. This “drive to qualify” allowed exurbanites to purchase homes that they otherwise could not afford in more expensive suburban locations.

Whatever the forces behind exurban growth, the expansion of exurbia has resulted in large swaths of low-density development at the edge of metropolitan regions. The low-density character of exurban development can be characterized as a form of urban sprawl where developers seek out permissive local governments that exercise little restraint over large-lot development.

Although media images of exurbia rely on stereotypical views of “Realtor Mom” and “Patio Man,” the reality of exurbia is more complex. In a notable attempt to unravel the complexity of exurbia, Hayden (2003) developed a three-way classification of exurban settlement patterns; in her view, exurban towns are reluctant suburbs, hot towns, or Valhallas. Reluctant suburbs are rural places inundated by exurban population growth where newcomers often clash with long-term residents. Hot towns are affluent places populated by wealthy telecommuters, and exurban Valhallas are amenity-based exurbs where the wealthy residents use gates to limit public access and to maintain their prized privacy.

The voting patterns of exurbia were the subject of a great deal of interest during the 2008 presidential contest. In the 2004 election, 57% of exurbanites voted Republican. In contrast, Republicans garnered only 42% of inner-suburban votes. Prior to the 2008 election, pundits wondered whether the largely Republican exurbs could offset the gains the Democrats made in the suburbs. This was, apparently, not the case as the initial results indicated that the Democrats had made significant inroads into exurban precincts.

Today, the viability of exurbia is being tested. In 2008, rising fuel prices greatly increased the



cost of commuting, and the widespread use of exotic (and risky) mortgage products such as adjustable rate mortgages caused foreclosure rates to skyrocket in exurban locations such as the Inland Empire of Southern California. Numerous reports of vacant and blighted exurban properties have appeared as the stagnant pools attract mosquitoes, squatters invade the homes, and skateboarders take advantage of the abandoned exurban swimming pools left behind by the newly dispossessed.

Jeff R. Crump

See also **Commuting; Housing and Housing Markets; Suburban Land Use; Suburbs and Suburbanization; Urban Spatial Structure; Urban Sprawl**

Further Readings

Berube, A., Singer, A., Wilson, J., & Frey, W. (2006). *Finding exurbia: America's fast-growing communities at the metropolitan fringe*. Washington, DC: Brookings Institution.

- Crump, J. (2003). Finding a place in the country: Residential preferences and exurban development in Sonoma County, California. *Environment and Behavior*, 35, 187–202.
- Davis, J., Nelson, A., & Dueker, K. (1994). The new 'burbs and their implications for planning policy. *Journal of the American Planning Association*, 60(1), 45–59.
- Friedmann, J., & Miller, J. (1965). The urban field. *Journal of the American Institute of Planners*, 31, 312–319.
- Garreau, J. (1991). *Edge cities: Life on the new frontier*. New York: Doubleday.
- Hayden, D. (2003). *Building suburbia*. New York: Pantheon.
- Marx, L. (1964). *The machine in the garden*. New York: Oxford University Press.
- Nelson, A. (1992). Characterizing exurbia. *Journal of Planning Literature*, 6(4), 350–368.
- Nelson, A., & Sanchez, T. (1999). Debunking the exurban myth: A comparison of suburban households. *Housing Policy Debate*, 10(3), 689–709.
- Spectorsky, A. (1955). *The exurbanites*. New York: J. B. Lippincott.

ENCYCLOPEDIA OF
Geography

EDITORIAL BOARD

Editor

Barney Warf
University of Kansas

Associate Editors

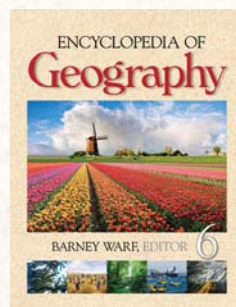
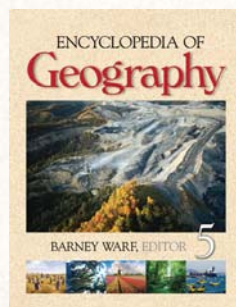
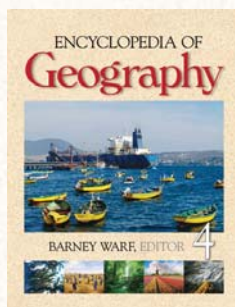
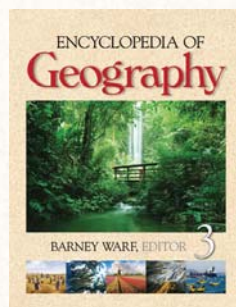
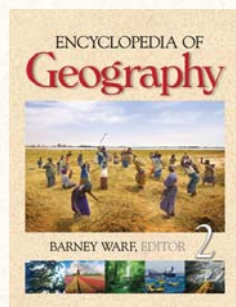
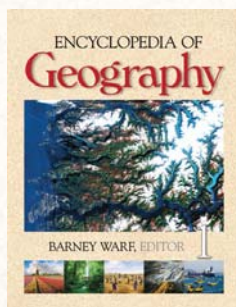
Piotr Jankowski
San Diego State University

Barry D. Solomon
Michigan Technological University

Mark Welford
Georgia Southern University

Managing Editor

Jonathan Leib
Old Dominion University



ENCYCLOPEDIA OF Geography

BARNEY WARF, EDITOR

University of Kansas

3



Los Angeles | London | New Delhi
Singapore | Washington DC

Copyright © 2010 by SAGE Publications, Inc.

All rights reserved. No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

For information:



SAGE Publications, Inc.
2455 Teller Road
Thousand Oaks, California 91320
E-mail: order@sagepub.com

SAGE Publications Ltd.
1 Oliver's Yard
55 City Road
London, EC1Y 1SP
United Kingdom

SAGE Publications India Pvt. Ltd.
B 1/I 1 Mohan Cooperative Industrial Area
Mathura Road, New Delhi 110 044
India

SAGE Publications Asia-Pacific Pte. Ltd.
33 Pekin Street #02-01
Far East Square
Singapore 048763

Printed in Singapore.

Library of Congress Cataloging-in-Publication Data

Encyclopedia of geography, volume I - VI / edited by Barney Warf.

6 v., p. cm.

Includes bibliographical references and index.

ISBN 978-1-4129-5697-0 (cloth)

1. Geography—Encyclopedias. I. Warf, Barney, 1956-

G63.E554 2010

910.3—dc22

2010009453

This book is printed on acid-free paper.

10 11 12 13 14 10 9 8 7 6 5 4 3 2 1

<i>Publisher:</i>	Rolf A. Janke
<i>Assistant to the Publisher:</i>	Michele Thompson
<i>Acquisitions Editor:</i>	Robert Rojek
<i>Developmental Editor:</i>	Diana E. Axelsen
<i>Reference Systems Manager:</i>	Leticia Gutierrez
<i>Reference Systems Coordinator:</i>	Laura Notton
<i>Production Editor:</i>	Tracy Buyan
<i>Copy Editors:</i>	QuADS Prepress (P) Ltd.
<i>Typesetter:</i>	C&M Digitals (P) Ltd.
<i>Proofreaders:</i>	Penelope Sippel, Rae-Ann Goodwin, Annette Van Deusen
<i>Indexer:</i>	Julie Sherman Grayson
<i>Cover Designer:</i>	Ravi Balasuriya
<i>Marketing Manager:</i>	Amberlyn McKay

Volume 3 cover photo: Tropical jungle with a bridge by a waterfall, Singapore. © iStockphoto.com/Jet Tan.

CONTENTS

3

List of Entries

vii

Entries

F 1077

G 1175

H 1395

I 1519

LIST OF ENTRIES

- | | | |
|---|---|--|
| <p> Abler, Ronald
 Absolute Space
 Accessibility
 Acid Rain
 Actor-Network Theory
 Adaptation to Climate Change
 Adaptive Harvest Management
 Adaptive Radiation
 Adiabatic Temperature
 Changes
 Aerial Imagery: Data
 Aerial Imagery: Interpretation
 African Union
 Agamben, Giorgio
 Agent-Based Models
 Agglomeration Economies
 Aging and the Aged,
 Geography of. <i>See</i> Elderly,
 Geography and the
 Agnew, John
 Agricultural Biotechnology
 Agricultural Intensification
 Agricultural Land Use
 Agriculture, Industrialized
 Agriculture, Preindustrial
 Agrobiodiversity
 Agrochemical Pollution
 Agroecology
 Agrofoods
 Agroforestry
 AIDS, Geography of. <i>See</i>
 Disease, Geography of;
 HIV/AIDS, Geography of
 Air Masses </p> | <p> Air Pollution. <i>See</i> Atmospheric
 Pollution
 Albedo
 al-Idrisi
 Altitude
 Ambient Air Quality
 American Geographical Society
 Analytical Operations in GIS
 Anarchism and Geography
 Anaximander
 Animal Geographies
 Annales School
 Anselin, Luc
 Antevs, Ernst
 Anthropogenic Atmospheric
 Change. <i>See</i> Anthropogenic
 Climate Change;
 Stratospheric Ozone
 Depletion
 Anthropogenic Climate Change
 Anthropogeography
 Antiglobalization
 Antipodes
 Antisystemic Movements
 Applied Geography
 Appropriate Technology. <i>See</i>
 Sustainable Development;
 Sustainable Development
 Alternatives; Sustainable
 Production
 Aquaculture
 Archipelago
 Architecture and Geography
 Argumentation Maps </p> | <p> Arid Topography
 Aristotle
 Armstrong, Marc
 Art and Geography
 Asia-Pacific Economic
 Cooperation
 Association of American
 Geographers
 Association of Geographic
 Information Laboratories
 for Europe
 Association of Southeast Asian
 Nations
 Atmospheric Circulation
 Atmospheric Composition and
 Structure
 Atmospheric Energy Transfer
 Atmospheric Moisture
 Atmospheric Particulates
 Across Scales
 Atmospheric Pollution
 Atmospheric Pressure
 Atmospheric Remote Sensing
 Atmospheric Variations
 in Energy
 Atoll
 Automobile Industry
 Automobility
 Avalanches
 Aviation and Geography

 Barrier Islands
 Barrows, Harlan
 Basin and Range Topography </p> |
|---|---|--|

- | | | |
|---|--|---|
| Batty, Michael | Business Models for Geographic Information Systems | Class, Geography and Class, Nature and Client-Server Architecture |
| Bayesian Statistics in Spatial Analysis | Buttimer, Anne | Climate: Dry |
| Behavioral Geography | | Climate: Midlatitude, Mild |
| Berkeley School | | Climate: Midlatitude, Severe |
| Berry, Brian | Cadastral Systems | Climate: Mountain |
| Bhopal, India, Chemical Disaster | CAD Systems | Climate: Polar |
| Biblical Mapping | Câmara, Gilberto | Climate: Tropical Humid |
| Biodiversity | Canadian Association of Geographers | Climate Change |
| Biofuels | Cancer, Geography of | Climate Policy |
| Biogeochemical Cycles | Carbonation | Climate Types |
| Biogeography | Carbon Cycle | Climatic Relict |
| Biome: Boreal Forest | Carbon Trading and Carbon Offsets | Climatology |
| Biome: Desert | Carcinogens | Clouds |
| Biome: Midlatitude Deciduous Forest | Carrying Capacity | Clusters |
| Biome: Midlatitude Grassland | Cartograms | Coal |
| Biome: Tropical Deciduous Forest | Cartography | Coastal Dead Zones |
| Biome: Tropical Rain Forest | Cartography, History of | Coastal Erosion and Deposition |
| Biome: Tropical Savanna | Castells, Manuel | Coastal Hazards |
| Biome: Tropical Scrub | Caverns | Coastal Zone and Marine Pollution |
| Biome: Tundra | Cellular Automata | Cold War, Geography of |
| Biophysical Remote Sensing | Census | Collaborative GIS |
| Bioregionalism | Census Tracts | Colonialism |
| Biosphere Reserves | Centers of Domestication | Color in Map Design |
| Biota and Climate | Central Business District | Columbus, Christopher |
| Biota and Soils | Central Place Theory | Commodity Chains |
| Biota and Topography | Chemical Spills, Environment, and Society | Common Pool Resources |
| Biota Migration and Dispersal | Chernobyl Nuclear Accident | Common Property Resource Management |
| Biotechnology and Ecological Risk | Chicago School | Commons, Tragedy of the Commonwealth of Independent States |
| Biotechnology Industry | Childhood Spatial and Environmental Learning | Communications Geography |
| Biruni | Children, Geography of | Communism and Geography |
| Blaikie, Piers | Chinooks/Foehns | Community-Based Conservation |
| Blaut, James | Chipko Movement | Community-Based Environmental Planning |
| Blindness and Geography | Chlorinated Hydrocarbons | Community-Based Natural Resource Management |
| Body, Geography of | Chlorofluorocarbons | Community Forestry |
| Borderlands | Cholera, Geography of | Commuting |
| Borders and Boundaries | Chorley, Richard | Comparative Advantage |
| Bourghassi, Carmina | Chorology | Competitive Advantage |
| Bowman, Isaiah | Choropleth Maps | Complexity Theory |
| Brownfields | Chrisman, Nicholas | Complex Systems Models |
| Built Environment | Christaller, Walter | Conference of Latin Americanist Geographers |
| Bunge, William | Circuits of Capital | |
| Bush Fallow Farming | Citizenship | |
| Business Cycles and Geography | Civil Society | |
| Business Geography | Clark, Andrew | |
| | Clark, William | |

- Conflation
 Conservation
 Conservation Zoning
 Consumption, Geographies of
 Continental Drift. *See* Plate Tectonics
 Cook, Captain James
 Coordinate Geometry
 Coordinate Systems
 Coordinate Transformations
 Coral Reef
 Coral Reef Geomorphology
 Coriolis Force
 Corporate Voluntary Environmental Initiatives and Self-Regulation
 Cosgrove, Denis
 Cosmopolitanism
 Cost-Benefit Analysis
 Council for Mutual Economic Assistance (COMECON)
 Countermapping
 Counterurbanization
 Coupled Human and Animal Systems
 Coupled Human and Natural Systems
 Creep
 Crime, Geography of
 Crisis
 Critical Geopolitics
 Critical GIS
 Critical Human Geography
 Critical Studies of Nature
 Crop Genetic Diversity
 Crop Rotation
 Cross-Border Cooperation
 Cultural Ecology
 Cultural Geography
 Cultural Landscape
 Cultural Turn
 Cyberspace
 Cyborg Ecologies
 Cyclones: Extratropical
 Cyclones: Occluded

 Dangermond, Jack
 Darby, Henry Clifford
 Darwinism and Geography
 Dasymetric Maps

 Database Management Systems
 Database Versioning
 Data Classification Schemes
 Data Compression Methods
 Data Editing
 Data Format Conversion
 Data Indexing
 Data Querying in GIS
 Datums
 Davis, William Morris
 Dear, Michael
 Debt and Debt Crisis
 Decolonization
 Deep Ecology Movements
 Deforestation
 Deindustrialization
 Delta
 Democracy
 Demographic Transition
 Dendrochronology
 Dependency Theory
 Derechos
 Desertification
 Desert Varnish
 Deterritorialization and Reterritorialization
 Developing World
 Development Theory
 Diamond, Jared
 Diaspora
 Diastrophism
 Difference, Geographies of
 Differential Heating
 Differential Vulnerabilities to Hazards
 Diffusion
 Digital Divide
 Digital Terrain Model
 Digitizing
 Disability, Geography of
 Disaster Prediction and Warning
 Disaster Preparedness
 Discourse and Geography
 Disease, Geography of
 Distance Decay
 Distributed Computing
 Distribution of Resource Access
 Division of Labor

 Domestication Centers. *See* Centers of Domestication
 Domestication of Animals
 Domestication of Plants
 Domino Theory
 Dot Density Maps
 Drought Risk and Hazard
 Drugs, Geography of
 Dunes
 Dynamic and Interactive Displays

 Earle, Carville
 Earthquakes
 Earth's Coordinate Grid
 Eastman, Ronald
 Ecofeminism
 Ecological Economics
 Ecological Fallacy
 Ecological Footprint
 Ecological Imaginaries
 Ecological Justice
 Ecological Mapping
 Ecological Modernization
 Ecological Regimes
 Ecological Risk Analysis
 Ecological Services. *See* Environmental Services
 Ecological Zones
 E-Commerce and Geography
 Economic Base Analysis
 Economic Geography
 Economies of Scale
 Economies of Scope
 Ecoregions
 Ecoshed
 Ecosystem Decay
 Ecosystems
 Ecotone
 Ecotourism
 Education, Geographies of
 Egenhofer, Max
 Elderly, Geography and the
 Electoral Geography
 Electronic Atlases
 Electronics Industry, Geography of
 El Niño
 Emerging Markets

- | | | |
|------------------------------------|-------------------------------------|---------------------------------|
| Emotions, Geography and Empiricism | Environmental Protection | Feminist Environmentalism |
| Endogenous Growth Theory. | Environmental Racism | Feminist Geographies |
| <i>See</i> Knowledge Spillovers; | Environmental Refugees | Feminist Methodologies |
| Learning Regions | Environmental Restoration | Feminist Political Ecology |
| Energy and Human Ecology | Environmental Rights | Fertility Rate |
| Energy Models | Environmental Security | Fieldwork in Human |
| Energy Policy | Environmental Services | Geography |
| Energy Resources | Environmental Social | Fieldwork in Physical |
| Enlightenment | Movements. <i>See</i> International | Geography |
| Enterprise GIS | Environmental Movements | Film and Geography |
| Environmental Certification | Environment and Development | Filtering |
| Environmental Determinism | Epistemology | Filtration |
| Environmental Discourse | Equator | Finance, Geography of |
| Environmental Entitlements | Equinox | Fisher, Peter |
| Environmental Ethics | Eratosthenes | Fish Farming |
| Environmental Footprint. | Error Propagation | Fjords |
| <i>See</i> Ecological Footprint | Ethics, Geography and | Flash Floods |
| Environmental History | Ethnicity | Flexible Production |
| Environmental Imaginaries | Ethnicity and Nature | Flocculation |
| Environmental Impact | Ethnic Segregation | Floodplain |
| Assessment | Ethnocentrism | Floods |
| Environmental Impacts of | Eurocentrism | Flow |
| Agriculture | Euromarket | Flow Maps |
| Environmental Impacts of | European Green Movements | Folding |
| Cities | European Union | Folk Culture and |
| Environmental Impacts of | Everglades Restoration | Geography |
| Manufacturing | Everyday Life, Geography and | Food, Geography of |
| Environmental Impacts of | Existentialism and Geography | Food and Agriculture |
| Mining. <i>See</i> Open-Pit | Exotic Species | Organization (FAO) |
| Mining | Exploration | Footprint Analysis. |
| Environmental Impacts of | Exploratory Spatial Data | <i>See</i> Ecological Footprint |
| Oil Fields | Analysis | Fordism |
| Environmental Impacts of | Export-Led Development | Fordism |
| Pipelines | Export Processing Zones | Foreign Aid |
| Environmental Impacts of | Externalities | Foreign Direct Investment |
| Roads | Extinctions | Forest Degradation |
| Environmental Impacts of | Extractive Reserves | Forest Fragmentation |
| Tourism | Extreme Geography | Forest Land Use |
| Environmental Impacts of War | Exurbs | Forest Restoration |
| Environmental Impact | Factors Affecting Location | Fotheringham, A. Stewart |
| Statement | of Firms | Frank, Andrew |
| Environmental Justice | Fair Trade and Environmental | Frontiers |
| Environmental Law | Certification | Fronts |
| Environmental Management | Famine, Geography of | Gaia Theory |
| Environmental Management: | Faulting | Gama, Vasco da |
| Drylands | Fear, Geographies of | Game Ranching |
| Environmental Mapping | Febvre, Lucien | Gated Community |
| Environmental Perception | Feminist Environmental | Gays and Lesbians, |
| Environmental Planning | Geographies | Geography and/of |
| | | Gazetteers |

- Gender and Environmental Hazards
 Gender and Geography
 Gender and Nature
 General Circulation Model (GCM). *See* Anthropogenic Climate Change; Atmospheric Energy Transfer; Climate Change
 Genetically Modified Organisms (GMOs)
 Genocide, Geographies of
 Gentrification
 Geocoding
 Geocollaboration
 Geocomputation
 Geodemographics
 Geodesy
 Geographical Ignorance
 Geographical Imagination
 Geographically Weighted Regression
 Geographic Information Systems
 Geography Education
 Geolibraries
 Geologic Timescale
 Geomancy
 Geometric Correction
 Geometric Measures
 Geomorphic Cycle
 Geomorphology
 Geophagy
 Geopolitics
 Geosensor Networks
 Geoslavery
 Geospatial Industry
 Geospatial Semantic Web
 Geostatistics
 Geothermal Energy
 Geothermal Features
 Geovisualization. *See* Cartography; Dynamic and Interactive Displays; Three-Dimensional Models
 Getis, Arthur
 Ghetto
 Giddens, Anthony
 Gilbert, Grove Karl
 GIS, Environmental Model Integration and
 GIS, History of
 GIScience
 GIS Design
 GIS Implementation
 GIS in Archaeology
 GIS in Disaster Response
 GIS in Environmental Management
 GIS in Health Research and Health Care
 GIS in Land Use Management
 GIS in Local Government
 GIS in Public Policy
 GIS in Transportation
 GIS in Urban Planning
 GIS in Utilities
 GIS in Water Management
 GIS Software
 GIS Web Services
 Glaciers: Continental
 Glaciers: Mountain
 Global Climate Change. *See* Anthropogenic Climate Change
 Global Environmental Change
 Globalization
 Global Positioning System
 Global Sea-Level Rise
 Global Warming. *See* Anthropogenic Climate Change
 Globes. *See* Cartography; Map Projections
 Glocalization
 Golledge, Reginald
 Goodchild, Michael
 Goode, J. Paul
 Google Earth
 Gottmann, Jean
 Gould, Peter
 Governance
 Governmentality and Conservation
 Gravity Model
 Great American Exchange
 Greenbelts
 Green Building
 Green Design and Development
 Greenhouse Gases
 Green Revolution. *See* Environmental Impacts of Agriculture
 Gregory, Derek
 Gross Domestic Product/Gross National Product
 Ground Reference Data
 Groundwater
 Growth Machine
 Growth Poles
 Gully Erosion
 Guyot, Arnold
 Hadley Cell
 Hägerstrand, Torsten
 Haggett, Peter
 Hanson, Susan
 Harley, Brian
 Hartshorne, Richard
 Harvey, David
 Hate, Geographies of
 Haushofer, Karl
 Hayden, Ferdinand
 Health and Health Care, Geography of
 Heavy Metals as Pollutants
 Hegemony
 Herbicides
 Herodotus
 Hettner, Alfred
 Heuristic Methods in Spatial Analysis
 High-Performance Computing
 High Technology
 Hipparchus
 Historical Geography
 Historicism
 Historic Preservation
 History of Geography. *See* Cartography, History of; GIS, History of; Human Geography, History of; Physical Geography, History of
 HIV/AIDS, Geography of
 Home
 Homelessness
 Hou Renzhi

- Housing and Housing Markets
Housing Policy
Hoyt, Homer
Human Dimensions of Global
Environmental Change
Human Ecology
Human Geography, History of
Human-Induced Invasion of
Species
Humanistic Geography
Humanistic GIScience
Human Rights, Geography and
Humboldt, Alexander von
Humidity
Hunger
Hunting and Gathering
Huntington, Ellsworth
Hurricane Katrina
Hurricanes, Physical
Geography of
Hurricanes, Risk and Hazard
Hybrid Geographies
Hybridization of Plant and
Animal Species
Hydroelectric Power
Hydrological Connectivity
Hydrology
Hydrothermal Energy. *See*
Geothermal Energy
- Ibn Battuta
Ibn Khaldūn
Ice
Identity, Geography and
Idiographic
Image Enhancement
Image Fusion
Image Interpretation
Image Processing
Image Registration
Image Texture
Imaging Spectroscopy
Immigration
Imperialism
Impermeable Surfaces
Import Substitution
Industrialization
Incubator Zones
Indigeneity
Indigenous Agriculture
- Indigenous and Community
Conserved Areas
Indigenous Cartographies
Indigenous Environmental
Knowledge
Indigenous Environmental
Practices
Indigenous Forestry
Indigenous Reserves
Indigenous Water Management
Industrial Districts
Industrial Ecology
Industrialization
Industrial Revolution
Inequality and Geography
Informal Economy
Information Society
Infrastructure
Innovation, Geography of
Input-Output Models
Institute of British Geographers
Interactive Mapping. *See* Map
Animation
Intergovernmental
Environmental
Organizations and Initiatives
International Criminal Court
International Environmental
Movements
International Environmental
NGOs
International Geographical
Union
International Monetary Fund
International Watershed
Management
Internet. *See* Communications,
Geography of; Cyberspace;
Digital Divide;
Telecommunications and
Geography
Internet GIS
Interoperability and Spatial
Data Standards
Interviewing
Invasion and Succession
Isard, Walter
Island Biogeography
Islands, Small
Isopleth Maps
- Jackson, John Brinckerhoff
Jefferson, Thomas
Johnston, R. J.
Journey-to-Work. *See*
Commuting
Justice, Geography of
- Kant, Immanuel
Karst Topography
Kates, Robert
Keystone Species
Knowledge, Geography of
Knowledge Spillovers
Köppen, Wladimir
Köppen-Geiger Climate
Classification
Kropotkin, Peter
Krummholtz
Kuhn, Werner
Kwan, Mei-Po
Kyoto Protocol. *See* Climate
Policy
- Labor, Geography of
Lahar. *See* Volcanoes
Land Degradation
Landfills
Landforms
Land Reform
Landscape and Wildlife
Conservation
Landscape Architecture
Landscape Biodiversity
Landscape Design
Landscape Ecology
Landscape Interpretation
Landscape Quality
Assessment
Landscape Restoration
Landslide
Land Tenure
Land Tenure Reform
Land Use
Land Use Analysis
Land Use and Cover Change
(LUCC)
Land Use and Land Cover
Mapping
Land Use History
Land Use Planning

- Land-Water Breeze
 Languages, Geography of
 La Niña
 Lapse Rate
 Latent Heat
 Latitude
 Law, Geography of
 Learning Regions
 Lefebvre, Henri
 Legal Aspects of Geospatial Information
 Lewis, Peirce
 Lewis and Clark Expedition
 Ley, David
 LiDAR and Airborne Laser Scanning
 Lightning
 Lillesand, Thomas
 Linear Referencing and Dynamic Segmentation
 Literature, Geography and
 Livingstone, David
 Locality
 Locally Unwanted Land Uses (LULUs)
 Location-Allocation Modeling
 Location-Based Services
 Location Quotients
 Location Theory
 Logical Positivism
 Longitude
 Los Angeles School
 Lösch, August
 Love Canal
 Lynch, William
- MacEachren, Alan
 Mackinder, Sir Halford
 Magellan, Ferdinand
 Mahan, Alfred Thayer
 Malaria, Geography of
 Malthusianism
 Manufacturing Belt
 Map Algebra
 Map Animation
 Map Design
 Map Evaluation and Testing
 Map Generalization
 Map Projections
 Map Visualization
- Marcus, Melvin G.
 Marginal Regions
 Marine Aquaculture
 Maritime Spaces. *See* Oceans
 Mark, David M.
 Market-Based Environmental Regulation
 Marsh, George Perkins
 Marxism, Geography and
 Masculinities and Geography
 Massey, Doreen
 Mass Wasting
 Mather, John Russell
 Maury, Matthew Fontaine
 McKnight, Tom L.
 Media and Geography
 Medical Geography
 Meinig, Donald
 Mental Maps
 Mercator, Gerardus
 Metadata
 Metropolitan Area
 Microwave/RADAR Data
 Migration
 Military Geography
 Military Spending
 Miller, Harvey J.
 Minerals
 Mining and Geography
 Mitchell, Don
 Mixed Farming
 Mobile GIS
 Mobility
 Models and Modeling
 Modernity
 Modernization Theory
 Modifiable Areal Unit Problem
 Money, Geographies of
 Monmonier, Mark
 Monsoons
 Morrill, Richard
 Morse, Jedediah
 Mortality Rate
 Most Favored Nation Status
 Movimento Sem Terra
 Multimedia Mapping
 Multispectral Imagery
 Multistakeholder Participation
 Multitemporal Imaging
 Multivariate Analysis Methods
- Multivariate Mapping
 Music and Sound, Geography and
 Nation
 National Aeronautics and Space Administration (NASA)
 National Center for Geographic Information and Analysis
 National Council for Geographic Education
 National Geographic Society
 Nationalism
 Natural Growth Rate
 Natural Hazards and Risk Analysis
 Nature
 Nature-Society Theory
 Neighborhood
 Neocolonialism
 Neogeography
 Neoliberal Environmental Policy
 Neoliberalism
 Neo-Malthusianism
 Network Analysis
 Network Data Model
 New International Division of Labor
 Newly Industrializing Countries
 New Urbanism
 Nitrogen Cycle
 Nomadic Herding
 Nomadism
 Nomothetic
 Nongovernmental Organizations (NGOs)
 Nonpoint Sources of Pollution
 Nonrenewable Resources
 Nonrepresentational Theory
 Nonvisual Geographies
 North American Free Trade Agreement (NAFTA)
 North Atlantic Treaty Organization (NATO)
 Not in My Backyard (NIMBY)
 Nuclear Energy

- | | | |
|---|---|--|
| Nutrient Cycles | Patches and Corridors in Wildlife Conservation | Positionality |
| Nyerges, Timothy | Path Dependence | Positivism. <i>See</i> Logical Positivism |
| Object-Based Image Analysis | Patriarchy, Geography and Peasants and Peasantry | Postcolonialism |
| Oceanic Circulation | Peat | Post-Fordism. <i>See</i> Flexible Production |
| Oceans | Pedology. <i>See</i> Soils | Postindustrial Society |
| Offshore Finance | Peet, Richard | Postmodernism |
| Oil Spills | Penck, Walther | Poststructuralism |
| Okabe, Atsuyuki | Periglacial Environments | Poverty |
| Olsson, Gunnar | Permaculture | Powell, John Wesley |
| Ontological Foundations of Geographical Data | Permafrost | Prairie Restoration |
| Ontology | Pesticides | Prairies |
| Open Geodata Standards | Pest Management | Precipitation, Global |
| Open Geospatial Consortium (OGC) | Petroleum | Precipitation Formation |
| Open-Pit Mining | Peuquet, Donna | Pred, Allan |
| Open Source Geospatial Foundation | Phenomenology | Primate Cities |
| Open Source GIS | Phosphorus Cycle | Prime Meridian. <i>See</i> Longitude |
| Open Space | Photochemical Smog | Privacy and Security of Geospatial Information |
| Organic Agriculture | Photogrammetric Methods | Producer Services |
| Organisation for Economic Co-operation and Development (OECD) | Photography, Geography and Physical Geography, History of | Product Cycle |
| Organization of the Petroleum Exporting Countries (OPEC) | Pickles, John | Production of Space |
| Organophosphates | Pilgrimage | Psychoanalysis, Geography and |
| Orientalism | Place | Ptolemy |
| Ortelius | Place Names | Public Housing |
| Other/Otherness | Place Promotion | Public Participation GIS |
| Outsourcing | Plantations | Public Policy, Geography of |
| Overpopulation. <i>See</i> Malthusianism; Neo-Malthusianism | Plate Tectonics | Public-Private Partnerships |
| | Playas | Public Space |
| | Point Pattern Analysis | Public Water Services |
| | Point Sources of Pollution | Pyrogeography |
| | Poles, North and South | |
| | Political Ecology | Qualitative Methods |
| | Political Economy | Quantitative Methods |
| | Political Economy of Resources | Quantitative Revolution |
| | Political Geography | Queer Theory |
| | Polychlorinated Biphenyls (PCBs) | |
| | Popular Culture, Geography and | Race and Empire |
| | Population and Land Degradation | Race and Nature |
| | Population and Land Use | Race and Racism |
| | Population Density | Racial Segregation |
| | Population, Environment, and Development | Radiation: Solar and Terrestrial |
| | Population Geography | Radical Geography |
| | Population Pyramid | Radiometric Correction |
| | Portolan Charts | Radiometric Normalization |
| | Ports and Maritime Trade | Radiometric Resolution |
| | | Railroads and Geography |
| | | Raisz, Erwin |
| Palimpsest | | |
| Panchromatic Imagery | | |
| Panopticon | | |
| Parks and Reserves | | |
| Parsons, James | | |
| Participant Observation | | |
| Participatory Learning and Action | | |
| Participatory Mapping | | |
| Participatory Planning | | |
| Participatory Rural Appraisal | | |
| Pastoral Herding. <i>See</i> Nomadic Herding | | |

- Rank-Size Rule
 Ratzel, Friedrich
 Real Estate, Geography and
 Realism
 Reclus, Élisée
 Recycling of Municipal Solid
 Waste
 Redistricting
 Refugees
 Regional Economic
 Development
 Regional Environmental
 Planning
 Regional Geography
 Regional Governance
 Regional Science
 Regional Science Association
 International (RSAI)
 Regions and Regionalism
 Regulation Theory
 Relational Space. *See* Relative/
 Relational Space
 Relative/Relational Space
 Religion, Geography and
 Relph, Edward
 Remittances
 Remote Sensing
 Remote Sensing: Platforms and
 Sensors
 Remote Sensing in Disaster
 Response
 Renewable Resources
 Rent-Gap
 Representations of Space
 Research and Development,
 Geographies of
 Resilience
 Resistance, Geographies of
 Resource Economics
 Resource Geography
 Resource Management. *See*
 Environmental Management
 Resource Management,
 Decision Models in
 Resource Mapping
 Resource Tenure
 Restoration Ecology. *See*
 Environmental Restoration
 Restructuring
 Retail Trade, Geography of
 Rill Erosion
 Risk Analysis and Assessment
 Ritter, Carl
 Rivers
 Rock Weathering
 Rose, Gillian
 Royal Geographical Society
 Rural Development
 Rural Geography
 Rural-Urban Migration
 Russian Geographical Society
 Satellites and Geography
 Sauer, Carl
 Scale, Social Production of
 Scale in GIS
 Schaefer, Fred
 Science, Technology, and
 Environment
 Science and Technology Studies
 Scott, Allen
 Sedimentary Rock
 Sedimentation
 Segregation and Geography
 Self-Organizing Maps
 Semantic Interoperability
 Semantic Reference Systems
 Semple, Ellen Churchill
 Sense of Place
 Sequent Occupance
 Services. *See* Producer Services
 Settlement Geography
 Sexuality, Geography and/of
 Shifting Cultivation
 Shortest-Path Problem
 Single Large or Several Small
 (SLOSS) Debate
 Situated Knowledge
 Smart Growth
 Smith, Neil
 Smog. *See* Photochemical Smog
 Social and Economic Impacts
 of Climate Change
 Social Construction of Nature
 Social Darwinism
 Social Forestry
 Social Geography
 Socialism and Geography
 Social Justice
 Social Movements
 Soil Conservation
 Soil Degradation
 Soil Depletion
 Soil Erosion
 Soils
 Soja, Edward
 Solar Energy
 Solstices
 Sovereignty
 Space, Production of. *See*
 Production of Space
 Space of Flows
 Spaces of Representation/
 Representational Spaces
 Spatial Analysis
 Spatial Autocorrelation
 Spatial Cognition
 Spatial Cognitive Engineering
 Spatial Data Infrastructures
 Spatial Data Integration
 Spatial Data Mining
 Spatial Data Models
 Spatial Data Structures
 Spatial Decision Support
 Systems
 Spatial Econometrics
 Spatial Fix
 Spatial Inequality
 Spatial Interaction Models
 Spatial Interpolation
 Spatialization
 Spatially Integrated Social
 Science
 Spatial Multicriteria Evaluation
 Spatial Optimization Methods
 Spatial Resolution
 Spatial Statistics
 Spatial Strategies of
 Conservation
 Spatial Turn
 Species-Area Relationship
 Spectral Characteristics of
 Terrestrial Surfaces
 Spectral Resolution
 Spectral Transformations
 Spit. *See* Coastal Erosion and
 Deposition
 Sports, Geography of
 Squatter Settlements
 State

- Steel Industry, Geography of
- Stereoscopy and Orthoimagery
- Storper, Michael
- Strabo
- Strahler, Arthur
- Stratospheric Ozone Depletion
- Strip Mining
- Structural Adjustment
- Structuralism
- Structuration Theory
- Subaltern Studies
- Suburban Land Use
- Suburbs and Suburbanization
- Sui, Daniel
- Suitability Analysis
- Sunbelt
- Supervised Classification
- Supranational Integration
- Surface Water
- Surveillance
- Surveying
- Sustainability Science
- Sustainable Agriculture
- Sustainable Cities
- Sustainable Development
- Sustainable Development
Alternatives
- Sustainable Fisheries
- Sustainable Forestry
- Sustainable Production
- Symbolism and Place
- Symptoms and Effects of
Climate Change

- Taphonomy
- Taylor, Griffith
- Taylor, Peter
- Technological Change,
Geography of
- Telecommunications and
Geography
- Teleconnections
- Television and Geography
- Temperature Patterns
- Temporal GIS
- Temporal Resolution
- Terrain Analysis
- Territory
- Terrorism, Geography of
- Text/Textuality

- Textile Industry
- Thales
- Thermal Imagery
- Thornthwaite, C. Warren
- Three-Dimensional Data
Models
- Three Mile Island Nuclear
Accident
- Thrift, Nigel
- Thunderstorms
- Thünen Model
- Timber Plantations
- Time, Geographies of
- Time-Geography
- Time-Space Compression
- T-in-O Maps
- Tobler, Waldo
- Tomlinson, Roger
- Topological Relationships
- Toponymy
- Topophilia
- Tornadoes
- Tourism
- Township and Range System
- Trade
- Transhumance. *See* Nomadism
- Transnational Corporation
- Transnationalism
- Transportation Geography
- Trap Streets
- Travel Writing, Geography and
- Tree Farming
- Trewartha, Glenn
- Triangulated Irregular
Network (TIN) Data Model
- Troll, Carl
- Tropical Rain Forests. *See*
Biome: Tropical Rain Forest
- Tsunami
- Tsunami of 2004, Indian
Ocean
- Tuan, Yi-Fu
- Turner, Billie Lee, II
- Typhoons. *See* Hurricanes,
Physical Geography of
- Typography in Map Design

- Underdevelopment
- Uneven Development
- United Nations

- United Nations Conference on
Environment and
Development
- United Nations Environmental
Summits
- United Nations Environment
Programme (UNEP)
- United States Census Bureau
- United States Geological
Survey (USGS)
- University Consortium for
Geographic Information
Science
- Unsupervised Classification
- Unwin, David
- Urban and Regional
Development
- Urban and Regional Planning
- Urban Ecology
- Urban Environmental Studies
- Urban Gardens
- Urban Geography
- Urban Green Space
- Urban Heat Island
- Urban Hierarchy
- Urbanization
- Urban Land Use
- Urban Metabolism
- Urban Planning and
Geography
- Urban Policy
- Urban Solid Waste
Management
- Urban Spatial Structure
- Urban Sprawl
- Urban Storm Water
Management
- Urban Sustainability
- Urban Underclass
- Urban Water Supply
- Usability of Geospatial
Information

- Vagueness in Spatial Data
- Vance, James
- Varenius
- Vectorization
- Vernacular Landscapes
as Expressions of
Environmental Ideas

-
- | | | |
|---|------------------------------------|---|
| Via Campesina (International Farmers' Movement) | Water Needs | Wine Terroir |
| Vidal de la Blache, Paul | Water Pollution | Wise Use Movement |
| Video Games, Geography and | Watershed Management | Wittfogel, Karl |
| Viewshed Analysis | Watershed Yield | Wood, Denis |
| Virilio, Paul | Water Supply Siting and Management | Woodfuel |
| Virtual and Immersive Environments | Watts, Michael | Woodlots. <i>See</i> Forest Fragmentation |
| Virtual Geographies | Wayfinding | World Bank |
| Virtual Globes | Weather and Climate Controls | World Cities |
| Vision and Geography | Weber, Alfred | World Court |
| Volcanic Eruptions as Risk and Hazard | Web Geoprocessing Workflows | World Health Organization (WHO) |
| Volcanoes | Web Service Architectures for GIS | World Summit on Sustainable Development |
| Voronoi Diagrams | Wetlands | World-Systems Theory |
| Vulnerability, Risks, and Hazards | White, Gilbert | World Trade Organization (WTO) |
| | Whiteness | Wright, Dawn |
| Waldseemüller, Martin | Whittlesey, Derwent | Wright, John Kirtland |
| Walker, Richard | Wilderness | Writing |
| War, Geography of | Wildfires: Risk and Hazard | |
| Waste Incineration | Wilson, John | Xeriscaping |
| Wastewater Management | Wind | |
| Water Degradation | Wind Energy | Zelinsky, Wilbur |
| Water Management and Treatment | Wind Erosion | Zoning |
| | Wine, Geography of | |

F

FACTORS AFFECTING LOCATION OF FIRMS

Numerous variables influence the location of individual firms as well as industries, which are aggregations of firms. The locational decision of a firm is important and complicated, and successful companies spend considerable time and effort in choosing the optimal location. Investments in inappropriate locations can be disastrous. Thus, a firm's decision-making process is a rational, if imperfect, one and is subject to the iron laws of market competition. Although personal considerations such as climate or the owner's residential preferences may occasionally be important for the margins, firms cannot choose arbitrarily or they will be forced out of business by their more rational competitors. The major factors of production that shape firms' locations include labor, land, capital, and managerial and technical skills. (Others, such as transport costs, are considered in other encyclopedia entries.) All these topics are necessary for production and distribution, and all exhibit spatial variations in both quantity and quality.

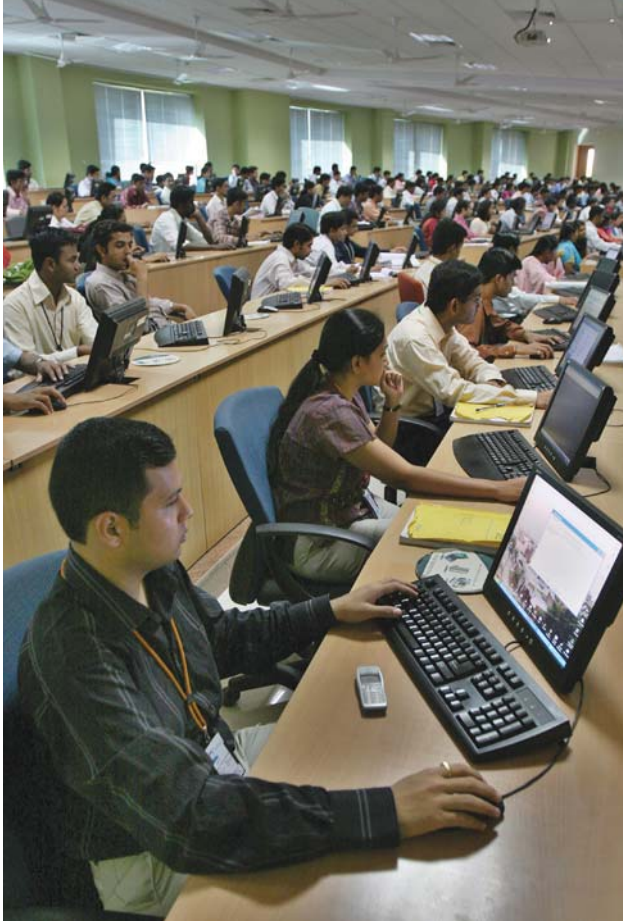
Labor

For most industries, labor is the most important determinant of location, especially at the regional, national, and global scales. When firms make

location decisions, they often begin by examining the geography of labor availability, productivity, and skills. The degree to which firms rely on labor, however, varies considerably among different sectors of the economy and even among different firms, which may adopt different production techniques.

The relative importance of labor varies considerably among industries. The demand for labor depends on the size of the firm involved and how labor intensive or capital intensive a given production process is, as well as the cost. In very capital intensive industries (e.g., petroleum), labor costs may be irrelevant. Thus, it is a mistake, but a common one, to assume that all industries seek out low-cost labor. Over time, most industries have become increasingly capital intensive; that is, they have substituted capital for labor, particularly when production in large quantities justifies the investments involved.

The supply of labor in a given region greatly affects the cost. In countries with high birth rates, the supply tends to be relatively high, and labor costs are low. In economically advanced countries, the birth rate is low, and labor is relatively expensive. Because some firms demand particular types of workers in terms of their age or sex, the demographic structure of a region also shapes the supply of certain types of employees (e.g., teenagers). Finally, since labor is mobile over space (but not perfectly so), migration (or internationally, immigration) also shapes the supply of labor.



Employees attend a class at the training center of the sprawling corporate campus of Infosys Technologies in Mysore, India, in this January 31, 2007, file photo.

Source: AP Photo/Gurinder Osan, File.

In regions that can attract labor easily, wage rates will tend to be low, all else constant. When the supply is limited by, say, immigration restrictions, wage rates tend to go up. At the local level, housing costs can also constrain the supply of labor if they are so high that workers cannot find affordable places to live.

Under capitalism, the real cost of labor is determined by the relative productivity of labor rather than simply the cost of wages and fringe benefits. Thus, cost is hardly the only dimension concerning labor. Productivity is largely a function of the skills present in the local labor force, or human capital, which in turn are derived from formal and informal educational systems, on-the-job training, and years of experience. Firms will pay

relatively high wages for skilled, productive labor. Consider that if labor costs were central to the location of all firms, then very low-wage countries, say Mozambique, should attract vast quantities of capital, which they don't, and high-wage countries, such as Germany or the United States, should see a rapid exodus of jobs. The reality of the geography of labor is much more complex and involves labor markets in which jobs are constantly created and destroyed; skills are produced, reproduced, and change; and new technologies come into play, in addition to other cultural, economic, and social forces.

Moreover, the skill level of a given occupation greatly affects the size of its labor market. Generally, skilled labor markets tend to be geographically larger than unskilled ones. Workers may migrate long distances for well-paying positions, and the market for many skilled jobs is global in reach. Unskilled positions, in contrast, typically draw from a relatively small labor shed; few people would travel cross-country, for example, to take a job as a janitor or retail trade cashier.

The labor process is saturated with politics. Labor is the only "factor input" that is able to resist the conditions of exploitation, to go on strike, to engage in slowdowns or sabotage, or to unionize. Unionization rates vary widely, adding to differentials in the cost of labor. Thus, in addition to the cost of labor, firms must consider the length of the workday, the working conditions, health and safety standards, pensions and health benefits, vacations and holidays, demands for worker training, subsidized housing, and the role of labor unions, all of which shape wage rates and productivity levels.

Land

At the local scale (i.e., within a particular metropolitan commuting area, in which labor costs for a given occupation are relatively constant), land availability and cost are the single most important locational factors affecting firms' location decisions. The cost of land reflects the supply and demand, and different types of firms require different quantities in the production process. Generally, larger firms, particularly in manufacturing, require more land and are thus more sensitive to the costs, although in some sectors, such



as producer services, firms pay very high costs (in rent or by purchasing a site). Firms often engage in intensive examination of several selected possible sites before settling on an optimum location.

The cost of land is heavily influenced by its accessibility. Transport costs determine the location rent of parcels at different distances from the city. Thus, because land downtown is the most accessible, it is by far the most expensive; in most cities, land costs decline exponentially away from the city center. However, not all firms necessarily seek out low-cost land. The imperative to do so depends on the trade-off between land and transportation costs that firms make to maximize their profits. Firms that must have accessible land—generally labor-intensive firms that must maximize their accessibility to labor, to each other, and to urban services—will pay very high rents to locate near the city center. Firms that do not require access to clients, suppliers, and services, on the other hand—such as large manufacturing firms in suburban industrial parks—make a different trade-off, choosing to locate on the urban periphery, where land costs are low but transport costs are higher.

Since World War II, there has been a centrifugal drift of manufacturing to suburban properties. Large parcels of industrialized land are more likely to be available in the suburbs than in central-city locations, where accessibility makes land relatively expensive. More reasons why industrial properties have expanded into the suburbs include these locations being easily accessible to motor freight by interstate highway, and access to suburban services and infrastructure, including ample sewer, water, parking, and electricity. Industries may also be attracted to the suburbs because of nearness to amenities and residential neighborhoods. Suburban locations minimize labor's journey to work.

Capital

Under capitalism, capital plays a major role in structuring the production process. There are a variety of contexts in which the term *capital* is used, such as “natural capital” (i.e., climate and resources) or “human capital” (i.e., skills). In most economic geography, capital takes one of two major forms: fixed capital and liquid, or variable,

capital. Fixed capital includes machinery, equipment, and plant buildings. Besides the installation and construction costs, firms must budget for maintenance and repair, and depreciation. The age of the capital stock of a region greatly affects its overall productivity levels. Liquid capital includes intangible revenues, including corporate profits, savings, loans, stocks, bonds, and other financial instruments. The rate of capital formation reflects variables such as corporate profitability (including market prices, production costs), savings rates, interest rates, and taxation levels.

Liquid capital is theoretically the most mobile production factor. The cost of transporting liquid capital is almost zero, and it can be transmitted almost instantaneously in an electronically wired world. Fixed capital is much less mobile than liquid capital; for example, capital invested in buildings and equipment is obviously immobile and is the primary reason for industrial inertia. Any type of manufacturing that is profitable has an assured supply of liquid capital from revenues or borrowing (depending on its credit rating), and interest rates hardly vary within individual countries. Most types of manufacturing, however, initially require large amounts of fixed capital to establish the operation—or, periodically, to expand, retool, or replace outdated equipment or to branch out into new products. The cost of this capital, which is interest, must be paid from future revenues. Investment capital has a variety of sources: personal funds; family and friends; lending institutions, such as banks and savings and loan associations; and the sale of stocks and bonds. Most capital in advanced industrial countries is raised from the sale of stocks and bonds, although American firms rely on this approach more than do firms in Europe, where banks play a larger role in industrial financing. The total supply of investment capital is a function of total national wealth and the proportion of total income that is saved. Savings become the investment capital for future expansion.

Whether a particular type of manufacturing, or a given entrepreneur, can secure an adequate amount of capital depends on several factors. One factor is the supply of and demand for capital, which varies from place to place and from time to time. Of course, capital can always be obtained if users are willing to pay high enough interest rates.



Beyond supply-and-demand considerations, investor confidence is the prime determinant of whether capital can be obtained at an acceptable rate.

Capital is important as well because firms can substitute capital for labor in a process of capital intensification. The history of capitalism is largely one of capital intensification in different industries, particularly in agriculture, in which only a very small fragment of the labor force in industrialized countries now works. Capital intensification can increase productivity, but it may also displace workers. Only if the cost of goods drops sufficiently to increase real incomes and worker expenditures can it generate job growth in the long run.

Management

Management involves the nuts and bolts of corporate decision making, including allocation of the firm's resources, raising investment capital, keeping abreast of the competition and government rules and policies, making investment decisions, hiring and firing workers, marketing and public relations, and similar types of functions. Corporate management reflects and shapes the organizational structure of a firm, including the pattern of ownership and how decisions are made. Firm management forms may range from sole proprietorships to partnerships and be either publicly or privately owned.

Within firms, management forms an important part of the corporate division of labor, that is, the headquarters as compared with branch plants. Corporate headquarters decide a firm's overall competitive strategy, what markets and products to focus on, labor policies, engagement in mergers and acquisitions, and types of financing. Thus, these tend to be skilled, well-paying, white-collar jobs. Most are in large urbanized areas.

Technical skills are the skills necessary for the continued innovation of new products and processes. These skills are generally categorized as research and development (R&D). The R&D required for new products is typically a large and expensive process, involving long lead times between invention and production, a process that is often beyond the scope of small firms.

Barney Warf

See also Agglomeration Economies; Business Cycles and Geography; Business Geography; Commodity Chains; Economic Geography; Economies of Scale; Economies of Scope; Incubator Zones; Industrial Districts; Innovation, Geography of; Knowledge Spillovers; Labor, Geography of; Location Theory; Technological Change, Geography of; Telecommunications and Geography; Thünen Model; Transportation Geography; Zoning

Further Readings

Stutz, F., & Warf, B. (2005). *The world economy: Resources, location, trade, and development* (4th ed.). Upper Saddle River, NJ: Prentice Hall.



FAIR TRADE AND ENVIRONMENTAL CERTIFICATION

Fair Trade and environmental certification refers to various labeling programs designed to bring accountability to globalized production systems that otherwise obscure a product's sources and conditions of production. Amid food safety scares, environmental concerns, and ethical convictions, consumers and activist groups increasingly turn to certification systems to identify a product's social and environmental qualities.

All certification systems involve standards, inspections, and a logo indicating that the product meets the standard. In the most influential certification projects, third-party auditors conduct inspections and grant the right to use certification logos. Many certification systems have also developed a network of independent organizations that govern inspections, license logos, and develop standards. Such certification networks constitute important new components of global neoliberal environmental policy.

There are a wide variety of environmental certification systems, including, for example, International Standards Organization (ISO) 14001, Blue Angel, Energy Star, the European Union Ecolabel, and the Marine Stewardship Council fisheries certification. Ecolabelling.org provides information



on nearly 300 eco-labels, including more than 70 food labels and 30-plus forest product labels.

Organic products have been third-party certified as produced, stored, processed, handled, and marketed in accordance with product-specific standards designed to maintain the health of soils, ecosystems, and people while avoiding inputs with adverse effects. From its roots as an alternative agricultural movement, organic farming has become increasingly codified and standardized, with recurring controversies about changing standards in ways that make it more convenient for large producers and retailers to offer organic products. In the United States, the sale of organic products increased from about \$1 billion in 1990 to \$17.7 billion in 2006. About 2.8% of food and beverage sales in the United States are organic. Global demand for organics reached \$38.6 billion in 2006, double that in 2000. Forest certification is the process of evaluating forests or woodlands to determine if they are being managed according to an agreed set of standards. The most influential program is the Forest Stewardship Council (FSC), a multistakeholder institution that combines environmentalists, social activists, and private-sector actors involved in forest management and wood product retailing. As of September 2007, FSC certification reached 90,870,769 ha (hectares) and 886 forest management operations in 76 countries, equivalent to about 10% of the world's managed forests. More than 200 million ha have been certified by competing industry- and government-led certification systems, but most environmental groups prefer FSC and question the rigor and legitimacy of the other forest certification systems.

With the goal of improving socioeconomic conditions for poor producers of handicrafts and food, Fair Trade promotes just and direct trading as an alternative to conventional markets. Certified Fair Trade producers must be organized democratically and comply with product-specific standards such as minimum quality and the elimination of certain chemicals. Certified Fair Trade traders must pay a price to producers that covers the regional cost of production, provide a premium that funds local social development projects, and comply with minimum quality and environmental standards. Many Fair Trade producers are also certified organic, especially in coffee.

After many years of direct marketing by faith-based organizations and well-known nongovernmental organizations, certification created new possibilities of selling Fair Trade-labeled products not just in specialty stores but also in conventional retail outlets. Social activist organizations such as Global Exchange and the United Students for Fair Trade pressured big retailers and demanded that on-campus vendors offer Fair Trade coffee and other products. The sales of Fair Trade-certified products grew 40% per year during the past 5 years. By 2007, 632 Fair Trade-certified producer organizations in 58 countries participated in a €2.3 billion worldwide market, directly benefiting an estimated 1.5 million workers and 6 million family members.

Some think that such certification instruments, and the social movements behind them, are transforming the way global corporations do business by making the implications of production and consumption choices clearer to consumers, retailers, and producers. They believe that certification allows activists to shame and also reward corporations for doing the right thing. Other observers suspect that certification's ability to radically transform production processes is diminished when big distributors and retailers get involved. They fear that competing industry-led labels undermine the social and environmental goals of more stringent labels associated with multistakeholder groups or that industries might dominate certification organizations and use their influence to erode standards. Thus, they argue that the vigilance of activist social and environmental organizations is essential for certification projects to affect globalized networks of production and consumption significantly.

Dan Klooster

See also [Agrofoods](#); [Corporate Voluntary Environmental Initiatives and Self-Regulation](#); [Environmental Certification](#); [Neoliberal Environmental Policy](#); [Organic Agriculture](#)

Further Readings

Conroy, M. (2007). *Branded! How the "certification revolution" is transforming global corporations.*



Gabriola Island, British Columbia, Canada:
New Society.
Fairtrade Labelling Organizations International:
www.fairtrade.net
Forest Stewardship Council: www.fsc.org
IFOAM: www.ifoam.org
Organic Trade Association. (2008). *Industry statistics and projected growth*. Retrieved November 5, 2009, from www.ota.com/organic/mt/business.html
PEFC: www.pefc.org

apply meaning can be a powerful tool used to obscure or deny the violence done unto others. Indeed, some of the most destructive famines have been mystified, concealed, and disclaimed by making false and fallacious claims about the precise nature and cause of the disaster.

The definition and meaning of famine have changed with time. In the 18th century, demographer and economist Thomas Malthus argued that because the food supply was relatively inflexible, natural tendencies would increase the population at a much faster rate than the rate at which food could be produced. This propensity for the population to outstrip subsistence could only be avoided through *preventive checks* (i.e., late marriages, celibacy, abortion, and infanticide), by which human populations proactively limited their own progeny, or through what Malthus described as *positive checks* (war, famine, pestilence), which keep population numbers in proportion to the means of subsistence. Malthus’s “population principle,” as it became known, established an enduring association between food

 FAMINE, GEOGRAPHY OF

Anyone attempting to define *famine* must be aware of the significant challenges involved. Definitions involve distinctions, but in the case of famine, such distinctions are especially fraught, not just because relief operations require “definitional clarity” but because the capacity to assign and

	Number of People (millions)						Regional Population in 2001 (millions)
	Living on \$1 per Day			Living on \$2 per Day			
	1981	2001	Change Since 1981 (%)	1981	2001	Change Since 1981 (%)	
East Asia and the Pacific	796	271	−66	1,170	864	−26	1,823
Eastern Europe and Central Asia	3	18	468	20	94	363	474
Latin America and the Caribbean	36	50	40	99	128	30	518
Middle East and North Africa	9	7	−22	52	70	35	300
South Asia	475	431	−9	821	1,064	30	1,378
Sub-Saharan Africa	164	316	93	288	516	79	673
Global Total	1,482	1,093	−26	2,450	2,736	12	6,127

Table 1 Number of people living on \$1 or \$2 per day, 1981–2001. The bench levels of \$1 or \$2 per day are commonly used measures of extreme poverty that point to populations most susceptible to famine.

Sources: World Resource Institute (WRI) in collaboration with the United Nations Development Programme, United Nations Environment Programme, and World Bank, 2005; World Resources Institute. (2005, September). *The wealth of the poor-managing ecosystems to fight poverty*. Washington, DC: Author.

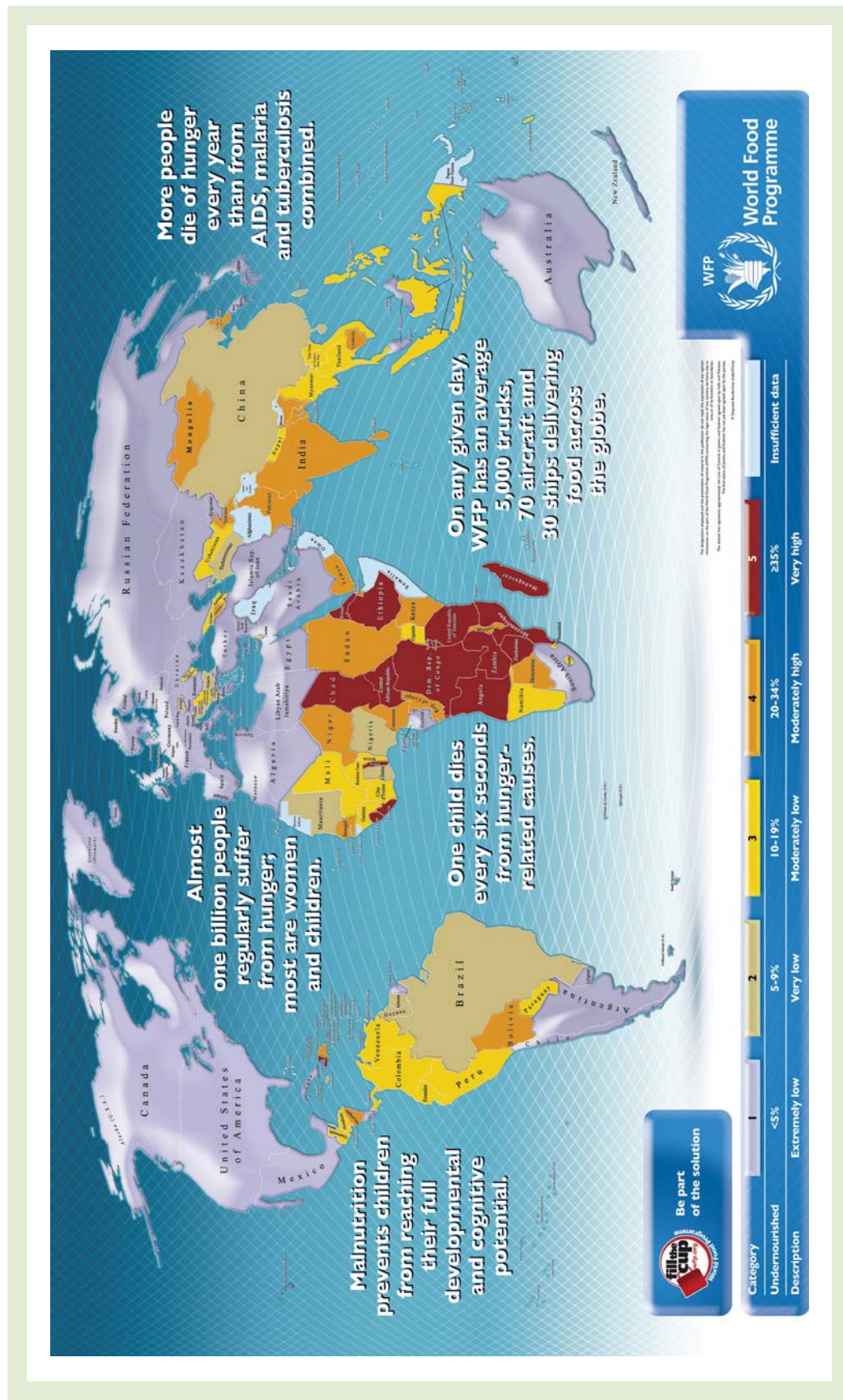


Figure 1 World map of famine-prone regions. Countries in which famine is most common are those with impoverished populations, common malnutrition, and vulnerability to humanly induced or naturally created disasters such as war or drought.

Source: The U.N. World Food Programme.



availability and famine while implying that famines operated as a natural check on human improvidence. Moreover, because only the most advanced European societies were capable of voluntarily restricting population growth, famines would remain an important natural check, especially for subaltern populations lacking social maturity and moral training.

In his groundbreaking book *Poverty and Famines: An Essay on Entitlement and Deprivation*, published in 1981, the Indian economist Amartya Sen directly attacked Malthusian food supply arguments for failing to consider how available foods might be unequally apportioned. Whereas Malthus emphasized “food supply,” Sen focused on the questions of distribution and “demand” within a market economy. To understand starvation, he suggested, it is necessary to analyze the commodity bundles (including foods, goods, and services) that a person can legally command by using his or her available resources and personal capacities. For Sen, famines result from entitlement failures brought about because a person’s assets, capacities, or terms of exchange (within a structure of ownership) shift to such a degree that it is no longer possible for him or her to directly or indirectly obtain the means of subsistence. A dearth of food is thus only one of many possible causes of starvation. Indeed, viewed through Sen’s framework, famines can occur where there is no overall decline in food availability and even in cases where there is an increase in general output—so-called boom famines—as happened in the Great Bengal Famine of 1843.

Sen’s entitlement theory has been widely praised for separating famine from the question of food availability and for debunking the common myth that famines are natural catastrophes. For others, however, Sen’s approach remains entrenched within the modern epistemology of famine. Whereas Malthus viewed mass starvations as the failure to temper the “passion between the sexes,” Sen represents famines as a collapse of entitlements—a failure of another kind. For critics, this view tends to produce a technical or managerial approach to famine that isolates hunger from particular relations of power. This arguably leaves entitlements theory bereft of a concept of justice. Other critics point out that entitlement theory fails to take due cognizance of gender inequalities,

especially entitlement changes among women, who are usually excluded from the historical record of famine. Gender relations are of course embedded within the social relations of society prior to famine and help explain why in times of crisis women can be abandoned, divorced, or sold into prostitution or slavery in the interests of male survival. Recent studies demonstrate that household entitlements are important and that women and children, especially female children, are particularly vulnerable to famine.

Sen is also criticized for focusing only on the “victims” of famine. Recent work has shown that famines—and other disasters—can serve particular political functions as benefits accrue to one section of the community while losses flow to the other. Indeed, it is by no means clear that there has ever been a famine where *all* sections of the population are equally affected. Famines usually leave behind a tense landscape of “winners” and “losers.”

It is also common to situate famine within broader discussions on health, welfare provision, and community access. Despite the customary focus on calories, deaths from starvation account for only a very small proportion of overall famine mortality rates. Most population losses result from a combination of poor diets (including the consumption of unwholesome or indigestible “famine foods”), the breakdown of sanitary conditions, and the spread of infectious diseases. The artificial congregation of populations—in feeding centers, refugee camps, and so on—can also create ideal pathogenic environments for the rapid spread of communicable diseases. On the other hand, traditional coping strategies (nomadic hunting, gathering, pastoral patterns, and migration from affected areas) can increase morbidity by exposing distant populations to famine-related diseases. Although crucial questions remain as to what exactly is epidemiologically distinctive about famine episodes, the simple assumption that famine represents a food crisis has been replaced by a more complex understanding of famine as a health crisis.

Finally, within the critical literature on famine, it is now generally accepted that famines do not necessarily *begin* with crop failures, droughts, or equivalent climatic hazards. On the contrary, their appearance generally occurs much earlier, when a population is made progressively vulnerable or



slowly brought to the point of collapse. Much of this insight is gained from studying colonial contexts, in which famines were often created through the erosion of traditional or customary food systems and the placement of imperial concerns over and above local subsistence needs. For this reason, some scholars prefer to shift their focus away from the “endgame” of famine—mass mortality—to the underlying or structural conditions that contribute to excess mortality. In their view famine is a process, not an event.

Our definition and understanding of famine has changed remarkably in 200 years. Now most social scientists accept that subsistence crises are unnatural social phenomena. Most social scientists also accept that famines are not discrete social events but reflect large and complex issues such as labor rights, gender inequalities, development strategies, state and corporate control of food, colonialism, market capitalism, and racist and institutional prejudices. These new mappings of famine connect seemingly disparate peoples, places, and events and reveal the complex ways in which privilege and suffering are mutually constituted. These lessons are crucial if we are to begin building more socially just and humane food economies.

David Nally

See also **Food, Geography of; Hunger; Malthusianism; Natural Hazards and Risk Analysis; Neo-Malthusianism; Poverty**

Further Readings

- Arnold, D. (1988). *Famine: Social crisis and historical change*. Oxford, UK: Blackwell.
- Edkins, J. (2000). *Whose hunger? Concepts of famine, practices of aid*. Minneapolis: University of Minnesota Press.
- Keen, D. (1994). *The benefits of famine: A political economy of famine and relief in southwestern Sudan, 1993–1989*. Princeton, NJ: Princeton University Press.
- Magdoff, F., Foster, J., & Buttel, F. (Eds.). (2000). *Hungry for profit*. New York: Monthly Review Press.

- Newman, L. (Ed.). (1995). *Hunger in history: Food shortage, poverty and deprivation*. Oxford, UK: Blackwell.
- Sen, A. (1981). *Poverty and famines: An essay on entitlement and deprivation*. Oxford, UK: Oxford University Press.
- Vaughan, M. (1987). *The story of an African famine: Gender and famine in twentieth-century Malawi*. Cambridge, UK: Cambridge University Press.
- Vernon, J. (2007). *Hunger: A modern history*. Cambridge, MA: Harvard University Press.
- Watts, M. (1983). *Silent violence: Food, famine, and peasantry in Northern Nigeria*. Berkeley: University of California Press.
- Weis, T. (2007). *The global food economy: The battle for the future of farming*. New York: Zed Books.



FAULTING

Faulting occurs when Earth's crust ruptures as a consequence of accumulated stress; it is the most common cause of earthquakes. Along with folds, faults are the most obvious results of deformation within the crust and constitute the field of structural geology. While folds are the result of ductile (plastic) deformation, faults indicate brittle behavior and occur only in the relatively cold surficial layers of Earth, generally down to a depth of about 70 km (kilometers; 40 miles). Although faulting may cause vertical uplift, the stresses that lead to rupture are usually horizontal, related to movements along the boundaries that define the plates that make up Earth's crust. Three types of movement predominate—extension, compression, and lateral shear—and lead to three major types of fault, commonly referred to as normal, reverse (thrust), and strike-slip faults. Because the type of fault is directly related to the orientation of stress in the crust, faults (even small or inactive ones) serve as sensitive indicators of those stresses that existed at the time the fault developed.

In defining faults, it is critical to observe the type of motion on the fault plane. Some faults are vertical, but the majority are inclined at some angle to the surface. The orientation of the fault plane (or any other planar surface in geology)



is defined by strike and dip, the strike being the geographic trend of the plane, given as a compass azimuth, and the dip, which is a direction and angular measure of the inclination from the horizontal, measured perpendicular to strike. In strike-slip faults the displacement is parallel to the strike, while in normal and reverse (dip-slip) faults the displacement is parallel to the dip. Faults that combine components of both strike and dip movement are said to show oblique slip. The side above the fault plane is referred to as the hanging wall, which dates from early mining terminology, while the side below is the footwall. A miner observing an inclined fault in a horizontal tunnel would stand with his feet on the footwall, with the hanging wall suspended over his head (Figure 1). The following definitions are based on the foregoing axioms.

Faults and Joints

A fault is a fracture that shows either vertical or horizontal displacement, possibly both. The three major types of fault depend on the orientation of stresses in the crust. A fracture without significant displacement is described as a joint.

Dip-Slip Faults

Normal Fault

When the crust is subject to extension, dip-slip faults develop in which the hanging wall block slides down the fault plane relative to the footwall block. The effect of normal faulting is therefore to lengthen the crust (Figure 2). The Basin and Range Province of Utah and Nevada is dissected by numerous normal faults indicating substantial extension, which continues to the present day. The basins (rift valleys) coincide with the down-dropped blocks (grabens), and the ranges are the up-thrown footwall blocks (horsts). Topographic rift valleys, formed by grabens delineated by normal faults, occur in East Africa and the Middle East, including the Red and Dead Sea rifts, and along spreading centers in the Mid-Atlantic Ridge (visible in Iceland), Mid-Indian Ridge, and East Pacific Rise. In all cases, the presence of active normal faulting signals that crustal extension is under way.

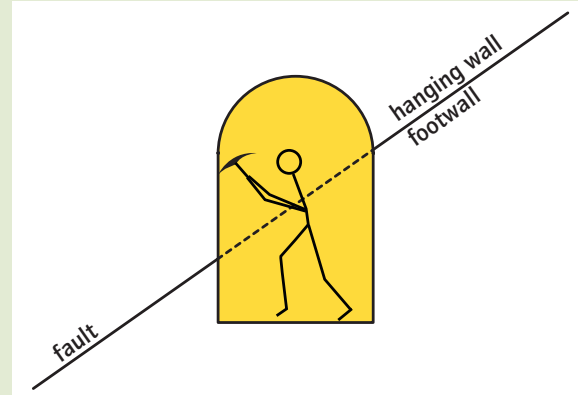


Figure 1 Definition of the terms *hanging wall* and *footwall* adopted from mining vernacular

Source: Author.

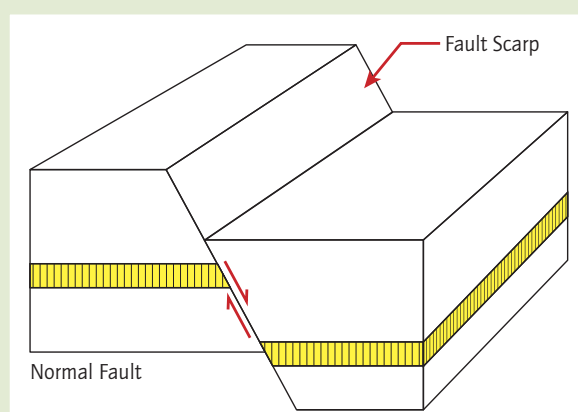


Figure 2 Normal fault in which the hanging wall is displaced downward relative to the footwall as a result of crustal extension

Source: Author.

Reverse Fault

When the crust is subject to compression, dip-slip faults develop in which the hanging wall block slides up the fault plane relative to the footwall block. If the fault is at a relatively high angle to the surface ($>45^\circ$), it is called a reverse fault. It is the reverse of a normal fault and leads to shortening of the crust (Figure 3A). In a high-angle reverse fault, the vertical throw is more pronounced than the horizontal displacement.

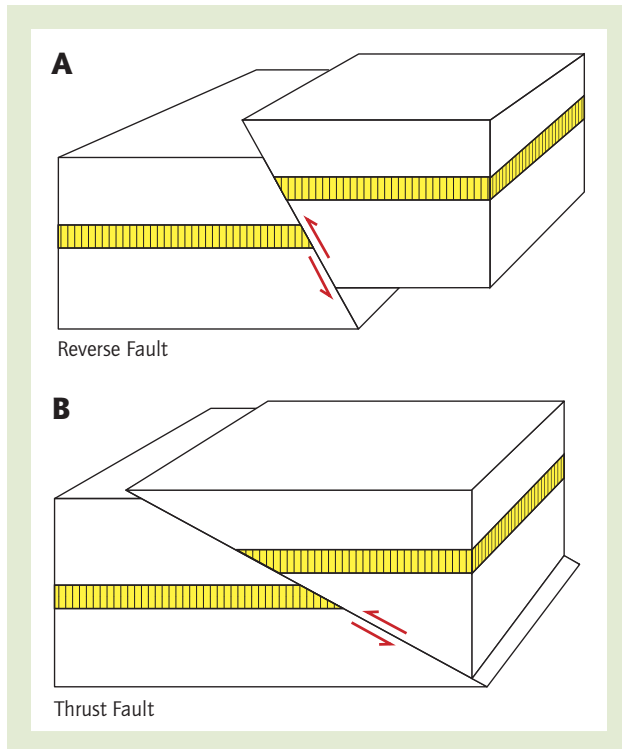


Figure 3 Reverse (A) and thrust (B) faults in which the hanging wall is displaced upward relative to the footwall as a result of crustal compression. The thrust fault is characterized by lower dip than the reverse fault and, usually, much greater horizontal displacement.

Source: Author.

Thrust Fault

If a dip-slip fault developed due to compression shows an inclination less than about 45° , it is called a thrust fault. Again, the hanging wall block moves upward relative to the footwall block, indicating crustal shortening (Figure 3B). However, low-angle thrust faults are capable of producing extremely large horizontal displacements, measured in tens or even hundreds of kilometers. This is much greater than in high-angle reverse faults. Because folds are also a consequence of compression, thrust (and reverse) faults are common in folded mountain terrains. In the Alps, for example, the crust has been shortened and thickened by the stacking of masses of complexly folded rock (nappes) separated by major thrust faults. Similar associations of folds and thrust faults are characteristic of all continental mountain chains formed by compression.

Strike-Slip Faults

Many faults show little or no vertical (dip-slip) movement but show large horizontal displacements parallel to the strike (trend) of the fault. Such faults are referred to as strike-slip faults and are the result of lateral shearing (Figure 4). Depending on whether the sense of displacement is to the left or right as an observer looks across the fault, it is referred to as a left-lateral or right-lateral strike-slip fault. The San Andreas Fault, which separates the coast from the bulk of California, is the most famous of strike-slip faults. In 1906, accumulated stress was released in some 6 meters of right-lateral elastic rebound, which generated the San Francisco earthquake. The cumulative movement on the San Andreas and related strike-slip faults over about 20 million years amounts to at least 550 km or around 20° of latitude. Major earthquakes that occurred in Turkey (North Anatolian Fault) and China (Gobi-Tien Shan Fault) are also related to strike-slip motion.

Transform Faults

The San Andreas Fault belongs to a special group of strike-slip faults, called transform faults, that connect and transform the motion between segments of a plate boundary with

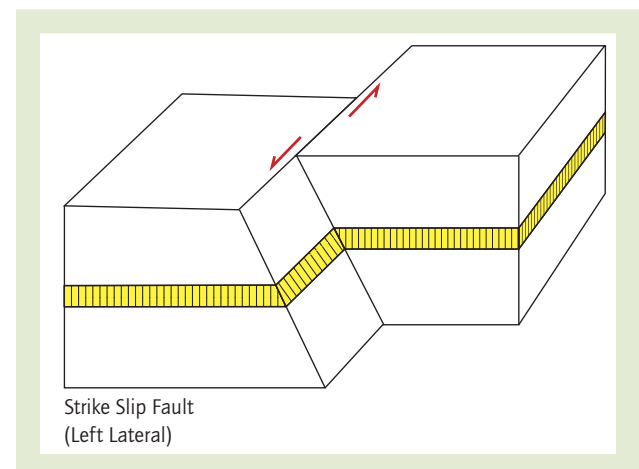


Figure 4 Strike slip fault formed as a result of lateral shear. There is little vertical displacement; the block across the fault from the observer has moved to the left, indicating left-lateral shear.

Source: Author.



slightly different vectors (especially segments of the mid-ocean ridge system). Most transform faults occur in oceanic crust and are necessary to accommodate plate motion and rotation on the surface of a sphere.

Fault Scarps

In some faults of relatively recent age, displacement may be evident at the surface as a *fault scarp* overlooking the down-thrown block. However, in time, erosion obliterates the surface evidence of motion, and changes in elevation across a fault are determined by the relative resistance of rocks exposed on either side. If the down-thrown side of a fault is capped by a resistant rock, it is possible to end up with a *fault line scarp* that overlooks the up-thrown block. To be certain of the type of motion, it is necessary to observe the displacement directly within the rock. This is especially evident when dip-slip faults intersect stratified sedimentary rocks (Figures 2 and 3).

Timothy M. Chowns

See also **Basin and Range Topography; Earthquakes; Folding; Plate Tectonics**

Further Readings

- Schulz, S. S., & Wallace, R. E. (1987). *The San Andreas Fault*. Washington, DC: U.S. Geological Survey.
- Tarbut, E. J., & Lutgens, F. K. (2008). *Earth: An introduction to physical geology* (9th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Twiss, R. J., & Moores, E. M. (2007). *Structural geology* (2nd ed.). New York: W. H. Freeman.



FEAR, GEOGRAPHIES OF

Geographers who study fear are interested in its social and spatial rather than purely psychological qualities. Fear is an emotional reaction to a perceived threat that acquires meaning from its context. It may have positive and negative effects

on people and places. The interest of geographers in fear is long-standing, traditionally associated with studies of landscape and crime and most recently flourishing within the fields of emotional geographies and geopolitics. Fear inhabits, moves between, and shapes particular environments, altering the patterning of social relations. In turn, places may create or reinforce fear. Fear is implicated in restrictions on the use of space but also in reclaiming of space by individuals, groups, and organizations.

The earliest studies of fear in geography focused on subjective aspects of cultural and physical landscapes that interplay with human emotions. From the 1970s, attention was focused on the effects of crime on physical and emotional security in Western cities. The enduring mantra that fear presents as much, or more, of a problem than crime itself was born—arising partly from conservative governments' shifting of responsibility for security to the individual and partly from the growing desire within the social sciences to measure and pin down social problems that seem unknowable. At the same time, the rapid attachment of the label *fearful* to certain people and places traced lines of sociopolitical hierarchy: Women, older people, and children were placed as quintessentially but irrationally fearful victims.

Feminist geographers joined critical realist criminologists in conducting intensive local research to contest such widespread constructions. They showed that fear and crime are concentrated among poorer neighborhoods and among groups with the least social and political capital. Fear is closely associated with systems of privilege that produce systemic violence (e.g., sexual, racist, and homophobic violence and child and elder abuse) that grounds and shapes wider social fears. Much of this violence and fear inhabit private spaces outside the traditional terrain of geographers' focus of attention. Many social "others" who are the subject of cultural fear live with structural vulnerability and insecurity, for example, homeless people, people of color, recent migrants, and teenagers.

A closely related focus of geographical research has been the fortified city. As urban redevelopment has become increasingly corporate, fear has been used to justify exclusionary social and



physical planning. Policies seek to target and exclude “feared” groups whose presence intimidates or interferes with the economic imperatives of city spaces. Recent fears around terrorism have given new life to situational crime prevention through environmental management and surveillance, in opposition to the ideal of peopled, inclusive public spaces. Many such strategies have been criticized as anticomunitarian, easing the fears of some at a high cost to others.

Recently, these localized concerns have been joined by interest in “globalized fear,” relating to issues such as the war on/of terror, the threat of infectious diseases, and international population movement. Geographers have described the use of fear as a tool of governance, particularly the rallying of support for Western military intervention using fears about terrorism. Older anxieties about race are being recast in concerns over religious difference, with Muslims feeling especially insecure in the current geopolitical climate. The media are viewed as having a primary role in whipping up public fears: Long-standing notions about dirt, disease, and the “other” are remobilized as calls grow for a halt on immigration to the West.

The reconceptualization of fear as global, moving between and connecting faraway places in response to geopolitical events and processes, has tended to overlook previous work on the complex patterns of emotionality in local contexts. However, a growing body of geographical research has identified the sharp effects on security and fear among those groups that are themselves demonized, in rejoinder to the whiteness of “globalized fear.” Practices of intersubjectivity, everyday cosmopolitanism, and global social movements are among numerous strategies for resisting, remaking, and remobilizing fear; for security and survival; and to contest oppressive sociopolitical relations and policies.

The ways in which fear moves are currently presenting the most intriguing questions for geographers: whether fear follows people’s journeys through city and home spaces, shifts and fluctuates in tune with international flows of people and materials, or comes alive via the media or firsthand experience. Much research on the everyday and global assumes an uncomplicated, hierarchical movement of fear between

different spatial scales or among different places). Recent reconceptualizations view fear as simultaneously global and everyday, collapsing any idea that emotions are scaled rigidly in experience or constitution. Affective geographies have explored the capacity of bodies to act as unconscious transmitters of feeling; their ability to affect people, places, and events may be deployed through oppressive practices or in forms of resistance. Analysis of the movement of fear in the wider field of emotional geographies evokes perceptions of place, psychotherapeutic landscapes, the structural and responsible aspects of well-being, and the conscientization (knowing, learning, and actioning) of fear.

Meanwhile, following the turn to positive well-being, work on geographies of hope has begun to explore its relation to fear and its place in social and spatial life. Yet stereotypes about Western fearfulness persist—about the motivations of “paranoid parents,” about mass fear during the war on terror, about what drives the overuse of automobiles. Geographers have pointed to the paucity of grounded research; to the dangers of ignoring the central place of social, economic, and political inequality in analysis; and to the need to study emotional landscapes outside Western urban contexts, where most research has focused to date.

Rachel Pain

See also **Crime, Geography of; Emotions, Geography and; Terrorism, Geography of**

Further Readings

- Koskela, H. (2009). Fear and its others. In S. J. Smith, R. Pain, S. Marsden, & J. P. Jones (Eds.), *The SAGE handbook of social geographies* (pp. 389–408). London: Sage.
- Pain, R. (2000). Place, social relations and the fear of crime: A review. *Progress in Human Geography*, 24(3), 365–388.
- Pain, R., & Smith, S. J. (2008). *Fear: Critical geopolitics and everyday life*. Aldershot, UK: Ashgate.
- Tuan, Y.-F. (1979). *Landscapes of fear*. New York: Pantheon Books.



FEBVRE, LUCIEN (1878–1956)

Lucien Febvre, a historian by training, is a central figure in the history of geography as an advocate of the approach of the geographer Paul Vidal de la Blache, particularly after the latter's death in 1918. Born in Nancy in the Lorraine, Febvre received his doctorate in history at the Ecole Normale Supérieure in Paris in 1911. He began teaching at the University of Dijon in 1912, but his career was soon interrupted by World War I. He resumed what would become an illustrious scholarly career at the University of Strasbourg in 1919, where he collaborated with fellow historian Marc Bloch. With Bloch, Febvre founded the soon to be prominent journal *Annales d'histoire et sociale* in 1929, beginning what is now known as the Annales School of history. Febvre was eventually elected to the prestigious Collège de France in Paris in 1933.

Vidal de la Blache was one of Febvre's professors during his time at the Ecole Normale, and, taken with Vidal's geographical approach, Febvre continued attending his lectures even after Vidal moved to the Sorbonne. From his earliest training as a historian, then, Febvre was greatly influenced by what was then the predominant regional approach taken by the early French school of geography. This continuing influence is clear in the Annales School's approach to history, particularly its emphasis on what became known as the *longue durée* of historical evolution, so dominant in the work of perhaps its best-known member, Fernand Braudel.

Along with a corpus of historical works Febvre authored that are imbued with a strong appreciation of the human-environment relationship, his most important book concerning the study of geography is *La terre et l'évolution humaine*, published in 1922 and translated into English in 1925. This book is an extended defense of what Febvre considered to be Vidal's geographical approach against growing criticism of it as merely descriptive. Such attacks came largely from those in the rather new discipline of sociology, influenced by Émile Durkheim, who considered their take on "social morphology" to be a more causal, scientific approach to the

problem Vidalians merely described on the basis of their geographical studies of regional *genres de vie*.

Ironically, Febvre's view came to be considered as the definitive statement of geography as a scientific discipline, and not just in France. The geography Febvre defends focuses exclusively on the human-natural environment relationship as it evolves over long periods of time in unique, regional settings. To Febvre, the regional monograph was the ultimate goal and singular achievement of geography. He completely missed Vidal's emphasis on the causal processes—trade, transportation, and so on—that intersect to form such regions. Since Febvre's work became so prominent a disciplinary reference, the works of the Annales School of history became more a legacy of Vidal's own approach than what was actually followed in departments of geography in France and elsewhere.

Kevin Archer

See also **Annales School; Environmental Determinism; Vidal de la Blache, Paul**

Further Readings

- Claval, P. (2004). Lucien Febvre. *Geographers Biobibliographical Studies*, 23, 35–49.
- Febvre, L. (1922). *La terre et l'évolution humaine: Introduction géographique à l'histoire*. Paris: A. Michel.



FEMINIST ENVIRONMENTALISM

Feminist environmentalisms operate theoretically and politically at the nexus of the feminist and environmental social movements. What unites the multiple branches of feminist environmentalism today is a belief in the fundamental connection between the oppression/domination of women/minorities and the oppression/domination of nonhuman nature. In essence, feminist environmentalists argue that one cannot eliminate human domination of other humans (e.g.,



sexism) without working to dismantle all forms of domination, including human domination of the natural world. This entry outlines the major avenues for connecting feminist and environmental analyses.

In a Western context, the connections between the treatment of women and nonhuman nature have been around since the earliest days of the suffrage and abolitionist movements in England and the United States. Many of the women who took part in these movements were avid vegetarians and argued for better treatment of animals alongside better treatment of women and children, as well as an end to slavery. Women, often acting as “moral mothers,” were also central to turn-of-the-century campaigns to establish natural parks, to protest the decimation of bird populations for women’s hats, and to demand services such as clean water and clean food for their families. Rachel Carson’s 1962 book, *Silent Spring*, galvanized the modern environmental movement and laid the groundwork for many of the issues that feminist environmentalists focus on today.

In 1974, a French philosopher, Françoise d’Eaubonne, coined the term *ecofeminism* to give a label to what many feminists had been starting to feel about both the feminist and the environmental movements. Ecofeminists charged that feminists were not addressing environmental concerns and that women were experiencing a high level of sexism within the environmental movement. Furthermore, for many women, there was a sense that women were, in essence, more closely aligned with nature than were men. As women acted as women and as mothers in campaigns as diverse as exposing the toxic waste at Love Canal, protesting the costs of war with the Women’s Pentagon Action, and reshaping their spiritual connections by recovering ancient, goddess-worshipping cultures and practices, the first academic conferences were held addressing the connections between feminism and ecology, and a flurry of publications appeared challenging the feminisms and environmentalisms of the times.

By the late 1980s, ecofeminism was being challenged from a variety of directions. Many people who saw themselves at the nexus of feminism and environmentalism did not adhere to the essentialist notion that women were “closer” to nature

than were men and preferred to focus on how politically, economically, and socially women were subjected to a closer relationship. This critique went so far as to change the terminology from *ecofeminism* to *feminist environmentalism* or *environmental feminism* in order to emphasize a break from the essentialist tendencies of early ecofeminism. The choice of terms remains an issue for many working at this nexus; while some people see these terms as interchangeable, others disagree and choose the term that most suits how they view the relationship between women and nonhuman nature. Other charges against early ecofeminism focused on how it was developing as a largely white, middle-class, heterosexual movement that focused too much on “luxury” issues such as goddess worship and animal rights. Women of color and women from developing countries raised awareness about the need to focus on immediate survival needs (e.g., access to clean water) and environmental toxins affecting poor, minority communities. They stressed that while there might be significant connections between women, as a category, and the nonhuman world, there were acute differences between women in terms of their capacity to interact with nature and/or affect change.

Today, feminist environmentalisms continue to evolve in multiple directions and are increasingly active internationally. From a community activist standpoint, groups campaign on issues ranging from environmental toxins, green living, and ecosensitive spiritual practices to struggles over wilderness preservation, for local control over resource development, and against capitalist commodification of biodiversity the world over. For example, activists explore the issue of women and nonhuman animals by exposing the treatment of female livestock in industrial systems, the link between domestic violence and animal abuse, and the related objectification of women and nonhuman animals as bodies instead of as whole beings. Additionally, environmental feminists have continued to make tremendous statements about how different women experience or come to know or love nature through art—fiction, poetry, painting, sculpture, and film are all increasingly used formats for connecting gender to the environment aesthetically.



The emphasis varies theoretically as well. A tremendous amount of work has been done in uncovering the historical legacies of linguistic women-environment connections, through the use of terms such as *raping the land*, *virgin forests*, and *mother Earth*—language that reinforces the objectification of both women and the environment. Environmental historians have examined where, how, and when women have related to the environment and where and how those relationships have been constrained by patriarchal practices. Research from a political-economy and political-ecology perspective has highlighted how gender power differentials contribute in local situations (and via international aid) to control women's access to resources and take resources away from women and even how the impacts of global climate change are going to disproportionately affect the world's poor women. Other avenues in political economy focus on the consequences of militarization and wars for local women and environments. In summary, feminist environmentalism is a continually evolving perspective that seeks to dismantle mind-sets of domination that threaten the lives of not only all women but all people and the existence of non-human nature.

Julie Urbanik

See also **Ecofeminism; Feminist Environmentalist Geographies; Feminist Political Ecology; Gender and Nature; Nature-Society Theory**

Further Readings

- Carson, R. (1962). *Silent spring*. Boston: Houghton Mifflin.
- Merchant, C. (1995). *Earthcare: Women and the environment*. New York: Routledge.
- Seager, J. (2003). Rachel Carson died of breast cancer: The coming of age of feminist environmentalism. *Signs: Journal of Women in Culture and Society*, 28(3), 945–972.
- Warren, K. (2000). *Ecofeminist philosophy*. Lanham, MD: Rowman & Littlefield.



FEMINIST ENVIRONMENTALIST GEOGRAPHIES

Feminist environmental geographies seek to make explicit the spatial topographies of gendered relations with the natural world. Studies have focused on the ways in which women's relationships with nature have been enabled or constrained and how male-dominated social-economic power structures have perpetuated environmental harm. This perspective draws on traditions within and outside geographic subdisciplines including political ecology, landscape studies, political economy, animal geographies, feminist geographies, and feminist environmentalisms. Some of the earliest work in this area began in the early 1980s with a focus on landscape studies, but in the early 1990s, a call to focus specifically on the connections between women, nature, and geographies was made by Cathy Nesmith and Sarah Radcliffe. They outlined three major strands of research: (1) nature, culture, and gender; (2) gendered relations of global development and environments; and (3) gendered landscapes and identities. The trajectory of this perspective has generally adhered to these broad categories.

Nature, Culture, and Gender

Feminist environmental geographers, like feminist environmentalists, see a connection between the treatment of women and the treatment of the natural world by male-dominated systems. Feminist environmental geographies, however, differ from the strands of ecofeminist theory that argue that women are essentially, or inherently, closer to nature than are men. Instead, within geography this relationship is seen as one that is mediated by a variety of social and economic factors; so while it is important to uncover the geography of women's experiences with the natural world, it is also crucial to put those experiences in larger, structural contexts. Perhaps no one has been more influential within geography in making explicit the link between nature, culture, and gender than Joni Seager, who was one of the first geographers to articulate a comprehensive feminist *and* environmental analysis. Her research revealed the



structural contexts of environmental harm by highlighting how ordinary people are not degrading the environment and that it is specifically a patriarchal capitalist system that continues to view nature (and women) as expendable commodities. Research in this area has exposed practices such as global militarization, international resource extraction in mining and timber, and food production through international patriarchal capitalist systems—all of which endanger the health of humans and the planet.

In addition to a more straightforward political-economic analysis of gendered environmental issues, another active strand of feminist environmental geography focuses on the nature, culture, and gender intersection specifically through the context of human-animal relationships. In the growing subfield of animal geographies, feminist geographers were the first to call for the opening of the black box of nature to reveal the myriad sentient beings on the planet and humans' relationships to them, which have long been overlooked within geography. The argument is twofold. First, nonhumans have been "othered" by a human-centered society (and geography), that is, seen as objects and/or background to human actions instead of as agents or actors in their own right, and this has resulted in horrific treatment of food, companions, and wild animals. Second, this othering is heavily gendered. Jody Emel's research on gender and wolf eradication is an influential example of this intersection. She highlights how the project of wolf eradication (and return) in the United States was directly correlated to the white male project of eradicating Native Americans and laying claim to dominating the land and removing competitors (both human and nonhuman). The literal and attitudinal violence shown toward wolves dramatically reversed itself with the rise of a men's environmental perspective in the 20th century that suddenly saw wolves as emblematic of the "wild" man—something to be embraced instead of exterminated.

Feminist environmental geographers have gone on to point out how using animals as symbolic foils for humans has repercussions for the treatment not only of nonhumans but also of human groups (such as women or minorities) that get placed in animal-associated categories. In addition,

several studies have continued to point out the ways in which experiences of nonhuman others is gender dependent—whether in relation to categorizing animals or in trying to find alternative, non-hierarchical, and nondominating ways to bring them more visibly as actors into our social, political, and economic systems.

Gendered Relations of Global Development and Environments

A second major strand of research for feminist environmental geographers focuses on issues pertaining to gendered relations of development and environmental decision making. Political ecology examines the causes and consequences of unequal access to, and control over, natural resources, largely in the developing world. Feminist political ecology has emerged as a prominent strand in this field by arguing that gender is a critical variable in exposing the politics of resource use and allocation. In the first anthology of feminist political ecology research, the editors highlighted how a gender analysis helps reveal gendered knowledge about the environment and gendered systems of environmental rights and how gendered environmental activism at the grassroots level is challenging women's historic exclusion from participatory resource use decisions. A plethora of studies have clearly demonstrated that empowering women around the world with respect to resource use is a key part of global environmental sustainability and social justice.

The issue of gendered environmental decision making and resource access is not limited, however, to developing countries. Paralleling feminist political ecology's focus on the global South has been research examining gendered relations in industrialized countries, in particular the United States and Canada. One strand of work has explored gender issues within the environmental justice movement, which strives to expose how people of color and people of low income bear, disproportionately, the costs of environmental pollution and industrial development. Research demonstrates that even in a movement such as this, women do the majority of grassroots activism but hold fewer positions of power and yet in many cases have been able to affect change by successfully bridging traditional gendered and social divides between private and public spaces. Another



strand of studies has examined gendered power relations in participatory decisions around resource use in forestry, mining, and fishing. Leaving women out of decision-making processes not only works to their disadvantage economically but also reinforces problematic power relations between men and women that inhibit widespread implementation of sustainable-use practices. Furthermore, researchers argue that it is not just the “adding in” of women that is necessary but also a fundamental reconceptualization of how environmental actors are defined and incorporated into decision-making bodies that will remedy women’s exclusion.

Gendered Landscapes and Identities

Landscape studies are concerned with how humans experience the built and natural world around them, how they represent it, and how lives are affected by different landscapes. Within geography, the field began to blossom in the 1970s and 1980s as geographers began incorporating insights from literary criticism and art theory to focus on questions of power, colonialism, and different types of landscapes (i.e., rural, wild, urban). Feminist geographers were quick to realize that not only has history been dominated by men’s definition of landscape (and their manipulation of it) but even in geography men have dominated cartography and interpretation. Building on environmental feminist theory about how women and nature have been historically conflated and seen as less than (white) men, feminist environmental geographers brought those insights into landscape studies. One of the most influential pieces along this line of thought comes from Gillian Rose, who argues that the male gaze, or visual masculinity, has not only been the dominant form of “seeing” landscapes but it also hides power relations, conflates nature with women’s bodies (e.g., nature’s bosom, virgin forest), and contributes to notions of human separation from the natural world.

While this line of research is key to revealing the gendered power relations of landscapes, a concern has been voiced by some that this does not go far enough in demonstrating where and how women have actually had agency toward the landscape. Therefore, a parallel line of studies has examined cases such as how women farmers experience their farms as landscapes; how suffragettes in the United

States “rewrote” the masculine western frontier by demanding a more prominent role for Sacagewea, the guide for Lewis and Clark; how women experienced western expansion in the United States; and how males and landscapes can be conflated for women. The aim of all these case studies is to highlight not only where and how women have created their own agency with respect to living in and experiencing the landscape but, more important, that there is no “static” gendered landscape experience. Instead, landscape studies reveal the inherent contextuality of where, how, and by whom landscapes are lived and conceptualized.

In summary, feminist environmental geographies encompass a wide variety of perspectives and avenues of research. They are united, however, in their urgency to reveal the harmful power relations that are affecting both women’s empowerment and survival around the globe and the environmental health and sustainability of the planet itself.

Julie Urbanik

See also **Animal Geographies; Ecofeminism; Feminist Environmentalism; Feminist Political Ecology; Gender and Nature**

Further Readings

- Emel, J. (1995). Are you man enough, big and bad enough? Ecofeminism and wolf eradication in the USA. *Environment and Planning D: Society and Space*, 13, 707–734.
- Nesmith, C., & Radcliffe, S. (1993). (Re)mapping mother Earth: A geographical perspective on environmental feminisms. *Environment and Planning D: Society and Space*, 11, 379–394.
- Rocheleau, D., Thomas-Slayter, B., & Wangari, E. (Eds.). (1996). *Feminist political ecology: Global issues and local experiences*. New York: Routledge.
- Rose, G. (1993). *Feminism and geography: The limits of geographical knowledge*. Minneapolis: University of Minnesota Press.
- Seager, J. (1993). *Earth follies: Making feminist sense of the environmental crisis*. New York: Routledge.



FEMINIST GEOGRAPHIES

Feminism is a political project that asserts the social and political equality of the genders, particularly with regard to the underprivileged status of women in comparison with men. Thus, contrary to much popular opinion, feminism is not concerned simply with women but with gender relations, that is, the webs of masculinity and femininity that shape power, the allocation of resources, and the rhythms of everyday life. Although feminists operate from within a wide spectrum of perspectives, they concur that social reality is gendered, that is, that gender cuts across, intersects, shapes, and is in turn shaped by other lines of social organization such as class, age, ethnicity, sexuality, and geographic location. In denaturalizing gender—in exposing its social origins and power relations—they injected the first non-class-based form of social determination. In this view, to ignore gender and the profound difference it makes is to assume that male lives are the “norm,” a common, if implicit, view embedded in a wide variety of social theories and models. Indeed, for much of the history of geography, women were notable primarily through their conspicuous absence as subjects or producers of geographic knowledge.

At the core of feminist theories lies the notion that gender does not simply consist of the vast differences between males and females in terms of outlook, behavior, speech, movement, and opportunities but that gender differences are all too often constructed around male advantage and female disadvantage. Almost everywhere, today and throughout history, women live in a subordinate social position to men. More often than not, they work more, earn less, enjoy less social autonomy and fewer political rights, and culturally often garner less respect. A core focus of criticism in feminist scholarship is patriarchy, that is, social systems that create male advantage and female disadvantage. Patriarchal social relations penetrate the spheres of both production and reproduction and generally lead to representations of males as strong, rational, and active and females as weak, irrational, and passive. Feminism as a political project seeks not to end gender differences per se (the simplistic stereotype advanced by many conservative antifeminists) but to end

the power relations that accompany gender. In this respect, being a feminist is not the same as being feminine; moreover, while many women are not feminists, and subscribe to traditional, sexist gender roles, some men are feminists.

Feminist Politics

Feminism as a political movement reflects and in turn contributed to numerous changes historically in the status of women. In the United States, its origins may be traced to 19th-century suffragists, particularly to the 1848 Seneca Falls conference, organized by Elizabeth Cady Stanton and Susan B. Anthony, which, among other things, advocated the right of women to vote, own property, and enjoy equal child custody rights in the event of a divorce. A second wave of feminism shook the Western world starting in the 1960s in the wake of the civil rights movement, personified in scholars such as Simone de Beauvoir and Betty Friedan. This second wave led to the growth in the number and power of women's organizations concerned with a wide array of issues related to women's opportunities, health, and safety, such as legalized birth control and abortion (e.g., the *Roe v. Wade* decision of 1973) and challenges to gender-discriminatory laws. The third wave of feminist thought arose in the 1990s, as exemplified in the works of feminists such as Audrey Lorde and bell hooks. It emphasized the diversity of women, particularly class and ethnic differences, as well as differences in sexual orientation.

To understand feminism, it is essential to appreciate its diversity: There is not one, monolithic feminism but many feminisms. Liberal feminists, for example, have long argued that women have intrinsic value and rights as people (“Feminism is the radical idea that women are human beings”). Marxist feminists maintained that the status of women is inseparable from class relations and hence from relations of property and production; in this view, gender inequality is essentially the product of capitalism. Radical feminists suggest that women's experiences are fundamentally different from those of men by virtue of their being marginalized, and they stress “women's ways of knowing,” a notion that critics hold essentializes women. Feminist psychologists such as Nancy Chodorow tend to focus on



gender differences in sex roles and socialization. Postmodern feminists unpack the category “woman” to reveal its enormous diversity. Postcolonial feminists seek to map out the varieties of patriarchy around the world and how Westernized forms of thought naturalized them, such as in the contrast between “rational,” male Europe and an ostensibly passive, feminine developing world that it penetrated and conquered.

Geography and Feminism

Geography has long been a heavily male-dominated discipline, a status that deeply colored its constitution and outlook, although women have joined it in large numbers over the past 40 years. Feminist geographers explore the ways in which space and gender relations constitute and transform one another at many scales and in many contexts.

Initial explorations into this realm included essentially empiricist studies of the geography of women without much attention to the causes of gender inequalities, such as atlases of women (the so-called add-women-and-stir approach). Subsequent views delved more deeply into the vast literature on feminism to ascertain how social relations produced gendered spaces and how space in turn simultaneously sustains, reinforces, and at times challenges gender roles. In this reading, for example, men’s control over space and their power over women are very much intertwined.

In the 1980s, some feminist geographers entered into a heated controversy over the nature of patriarchy, or systems that generate male advantage and female disadvantage. Was patriarchy universal and inevitable? From where do men get their power? If one avoids simplistic biological reductionism, the question remains as to how and why patriarchal relations vary historically and geographically. Many feminists note that gender divisions preceded those of class, as in the sexual division of labor found throughout all hunting-and-gathering societies. Eco-feminists held that the male domination of women arose during the Neolithic Revolution, during which agricultural relations enslaved women on farms, and was accompanied by a simultaneous domination of nature. Whatever its origins, patriarchy clearly preceded the rise of capitalism and exists in many noncapitalist or quasi-capitalist societies today.

The relations between capitalism and patriarchy, in short, are contingent, not necessary.

Feminist geographers have explored the intersection of gender and space in many ways. For example, some have focused on the body, “the most intimate of geographies,” that “closest in” to the self as it plays out over time and space. For most women, the landscapes of fear, particularly fear of violent sexual assault, loom large; sadly, half the human race lives in terror of the other half.

The household as a locus of patriarchal relations and social reproduction has received wide scrutiny from feminists. Indeed, feminism opened up the family as an object of geographic scrutiny. The male-dominated family has been positioned at the core of innumerable studies of domestic violence, gender socialization, and household divisions of labor. Feminist economists note that while the bulk of unpaid housework and child care is done by women, it does not enter into national economic accounts such as gross national product or gross domestic product, which privilege male forms of commodified labor. Feminist geographers note that while women’s spaces are often discursively coded as private and interior, male spaces tend to be equated with the public realm outside the home. Within the home, male chores are often located outside, while women’s work is generally located inside. For some feminists, the entire dichotomy between production and reproduction, the “economic” and the “social,” is itself an inherently patriarchal idea.

The growth of services of many types fostered rising rates of female labor force participation, including growing legions of women in professional occupations, although the common complaint of a “glass ceiling” persists. As women entered the workplace, their changing roles reverberated to change gender relations at home and raised issues for two-income families concerning child care. Feminists challenged, for example, the common assumption in urban models of household commuting that the location of male jobs and the length of male commutes dominated the household location decision process. Moreover, the emphasis on male breadwinners and “stay-at-home moms” ignores the profound differences among women: Latinas and African American women, for example, have long worked outside



the home in greater proportions than have white women. Others have focused extensively on gender differences in commuting, which can be substantial given that a disproportionate share of women work in part-time “pink-collar” positions and assume the bulk of responsibility for child care. Thus, feminist urban geographers have sought to ascertain whether women’s generally shorter commuting times reflect their employment status or their domestic responsibilities.

Other feminist geographers pointed to the feminization of poverty, that is, the disproportionate representation of female-headed households among those living below the poverty level. Feminist political geographers examined gender differences in voting patterns, which vary widely over space and time, particularly the “gender gap,” which leads women to vote more frequently for socially progressive candidates and perspectives. Feminist economic geographers such as Linda McDowell explored the role of gender in industries such as finance, noting how banking circles both drew on masculine pools of labor and in turn produced them in particular locales. Because women are charged with the bulk of household consumption, feminist studies of their shopping behavior hold great import for geographers, economists, and sociologists alike. Yet others point to how public policies ranging from neoliberalism to welfare reform affect women in ways that are often quite different from their impacts on men.

Many feminist geographers focus on women in the developing world, including the numerous disadvantages under which they labor compared with men. The daily rhythms of work for women in Africa, Latin America, and Asia revolve around sets of tasks and nodes of social interaction different from those for men. Many women, for example, are responsible for fetching water and gathering firewood. The propensity of women to migrate tends to be lower than that of men, and they tend to be receivers of remittances rather than senders. Many women suffer extreme difficulties in gaining access to education and other public services. Famines strike women differently than the way they strike men, who may eat while their wives and children go hungry. As global capitalism has spun off a variety of low-wage assembly jobs to the global periphery, it has drawn millions of women into commodified labor markets.

Feminist Methodological and Epistemological Contributions to Geography

Feminism not only profoundly altered *what* geographers study—that is, raising gender to the center of geographical analysis—it also changed *how* they go about understanding men, women, and space. In this sense, feminism elevated gender from the ontological (the “real”) to the epistemological (the “philosophical”). Part of this change involved a novel set of methodologies; feminists were at the forefront in challenging positivist (and arguably masculinist) biases toward quantitative methods and their associated assumptions of objectivity, and in turn, they legitimized the use of methods to explore the subjective worlds of lived experience. Indeed, feminism helped pioneer and popularize the use of a variety of qualitative research methods (e.g., participant observation, standpoint theory, and grounded theory). In this respect, feminists helped clarify the implications of the power relations that exist between researchers and their subjects and helped foster techniques that emphasized the construction of a dialogue in which empathetic understanding loomed large. Feminist scholarship helped force researchers to clarify their own subject positions, limit the scope of their claims, and acknowledge that knowledge is always context bound, that is, that every view is a view from somewhere.

Equally important were the far-reaching implications of feminist epistemology. Some feminist philosophers of science, such as Sandra Harding and Donna Haraway, had long raised devastating critiques of masculinist science as an act of conquest, one that sought to dominate nature rather than understand it, and as a perpetuation of a “phallogocentric” view that equated rationality with masculinity. Among geographers, Gillian Rose pioneered the understanding of geographical knowledge as gendered, particularly its traditional assumption of the neutral Cartesian subject, that is, the active male observer who “knows” and hence controls the passive landscapes of study. In an understanding that became widely popular, to assume that one knows is to assert authority, that is, to code others as simply objects of study whose lives are transparent to the all-powerful, all-knowing male knower. In contrast, feminist methodologies have encouraged geographers to be more patient, more empathetic in their explorations of people’s daily geographies.



Feminism, in short, is simultaneously a mode of inquiry, a political program, and a means to dissect social relations. In making gender differences over space a central topic of inquiry, it also opened the door for the analysis of masculinity and sexuality. Today, virtually no view in human geography lacks a feminist component, and feminist scholarship has markedly changed the perspectives of Marxism, poststructuralism, and postcolonialism, injecting a studied concern with the inequalities of gender throughout.

Barney Warf

See also **Ecofeminism; Feminist Environmentalism; Feminist Environmentalist Geographies; Feminist Methodologies; Feminist Political Ecology; Gays and Lesbians, Geography and/of; Gender and Geography; Gender and Nature; Hanson, Susan; Masculinities and Geography; Massey, Doreen; Rose, Gillian**

Further Readings

- Bondi, L., & J. Davidson. (2003). Troubling the place of gender. In K. Anderson, M. Domosh, S. Pile, & N. Thrift (Eds.), *Handbook of cultural geography* (pp. 325–343). London: Sage.
- Hanson, S. (1992). Geography and feminism: Worlds in collision? *Annals of the Association of American Geographers*, 82, 569–586.
- McDowell, L. (1993). Space, place and gender relations: Part I. Feminist empiricism and the geography of social relations. *Progress in Human Geography*, 17, 157–179.
- McDowell, L. (1993). Space, place and gender relations: Part II. Identity, difference, feminist geometries and geographies. *Progress in Human Geography*, 17, 305–318.
- Moss, P., & Falconer Al-Hindi, D. (Eds.). (2008). *Feminisms in geography: Rethinking space, place, and knowledges*. Lanham, MD: Rowman & Littlefield.
- Peet, R. (1998). *Modern geographical thought* (chap. 7). Oxford, UK: Blackwell.
- Roe v. Wade, 410 U.S. 113 (1973).
- Rose, G. (1993). *Feminism and geography: The limits of geographical knowledge*. Minneapolis: University of Minnesota Press.



FEMINIST METHODOLOGIES

Feminist methodology connotes a way of analyzing and theorizing research methods, principles, and knowledge production from a feminist perspective. In particular, it seeks to render visible the power relations of everyday life and of academic scholarship. Reflexivity and situated knowledge undergird this methodology. Scholars in human geography subdisciplines tend to deploy this methodology and often relate qualitative and quantitative methods. Research strategies driven by a feminist methodology usually hold political and social change as necessary motivations for and outcomes of academic study. By design, this research is frequently multiscalar and attuned to contextual variability.

Much like poststructuralism and postmodernism, the designation of a specifically feminist methodology emerged during the cultural turn. Geographers began to engage more closely with feminist views of knowledge production in the 1990s, and feminist methodology has continued to gain traction and application within the field since then. Notable contributions of feminist methodology to geography include making explicit unspoken or hidden perspectives, legitimizing research into such areas, and examining processes at multiple and fine scales.

Initially, feminist research about women and the category of Woman pioneered the use and development of a feminist methodology. Over time, feminist research broadened its purview and began to unpack meanings and representations of femininity and masculinity. Shifts within the intellectual landscape subsequently led feminists to investigate gender relations and gendered spaces and places. Feminist methodology commanded an important position in many of these research endeavors. In contemporary scholarship, feminist methodology considers myriad power relations, including but not limited to gender. A feminist methodology does not present power as static and passive. Instead, it highlights the relationality of power at all research stages. This emphasis works to disrupt essentialized perceptions of people, places, identities, or experiences. Rather than reproducing singular



or reified representations, a feminist methodology helps scholars foreground micronarratives and dynamic social processes. The joining of feminist methodology and feminist empirical topics throughout the years has led to a greater focus on underexamined geographic scales, especially the household and the body.

Studies informed by feminist methodology draw on a range of research techniques, such as interviewing, focus groups, archival work, participant observation, statistical analysis, and geographic information systems and science. Although feminist methodology has been linked most closely with qualitative methods, current research projects incorporate quantitative and mixed-method approaches as well. What ties these disparate methods together under the heading of feminist methodology is a shared sensibility about how research unfolds and what needs to be accounted for throughout the research process. In short, feminist methodology foregrounds power relations, compels scholars to consider their own roles in all phases of data collection and analysis, and accents the partial and situated nature of knowledge production.

Awareness of the researcher's influential presence in and relationship to knowledge production constitutes reflexivity. Feminist methodology uses reflexivity to make visible the power relations weaving through a study and everyday life. Reflexively considering the gendered, classed, and raced aspects of research, for example, prompts different questions from alleging the perspective of the separate, and purportedly all-knowing, observer. Reflexivity as a process helps illustrate how both researcher and research subjects jointly produce knowledge within and through numerous and unequal power relations.

An explicit recognition that all knowledge comes from someone and somewhere—that it is situated—and that no research project is fully exhaustive—everything is partial—underpins feminist methodology. Rather than discussing situated knowledge as an excuse for shortcomings or as a limitation in understanding, feminist methodology builds on these insights and mobilizes them to fracture assumptions about academic objectivity. This research strategy and style of analysis are political statements because

they explicitly challenge presumed separations between “object” and “knower” and question suppositions about who produces and who consumes what kinds of knowledge.

Teasing out various power relations and norms of authority—evident, for example, between the researcher and the researched and between different sectors of the academy—is central to feminist methodology. Power is understood as contingent, multidimensional, and relational. For example, a study that examines perceptions of race within urban spaces and involves a white woman interviewing women of color might well focus on the structural differences of gendered racialization. At the same time, it will also engage other facets of identity (such as age, socioeconomic class, ability, sexual orientation, and educational background) and spatiality (such as where the interview occurred, what places are described in the conversation, and what race means at different scales). In other words, the co-constitution and relationality of power dynamics within the interview context itself as well as within each phase of the research would require careful analysis when viewed through the lens of feminist methodology.

In recent years, participatory action research (PAR), intersectionality, and transversalism have emerged as new relational and politicized possibilities for feminist research and have informed feminist methodology as a result. While PAR, intersectionality, and transversalism are disparate in theoretical specificity, these approaches all address power relations, the role of the researcher(s), and the situatedness of knowledge production. Thus, they offer new avenues for exploring the central tenets of feminist methodology. The robust debates surrounding these theoretical interventions both within and beyond geography suggest that feminist methodology maintains a growing and vibrant place within the academy.

Serin D. Houston

See also **Cultural Turn; Difference, Geographies of; Discourse and Geography; Feminist Geographies; Gender and Geography; Identity, Geography and; Qualitative Methods**



Further Readings

- Goldberger, N., Tarule, J., Clinchy, B., & Belenky, M. (Eds.). (1996). *Knowledge, difference, and power*. New York: Basic Books.
- Hodge, D. (Ed.). (1995). Should women count? The role of quantitative methodology in feminist geographic research. *The Professional Geographer*, 47(4), 426–457.
- Jones, J. P., Nast, H., & Roberts, S. (Eds.). (1997). *Thresholds in feminist geography: Difference, methodology, representation*. New York: Rowman & Littlefield.
- Moss, P. (1993). Focus: Feminism as method. *The Canadian Geographer*, 37(1), 48–61.
- Moss, P. (Ed.). (2002). *Feminist geography in practice: Research and methods*. Malden, MA: Blackwell.
- Nast, H. J. (1994). Women in the field: Critical feminist methodologies and theoretical perspectives. *The Professional Geographer*, 46(1), 54–102.



FEMINIST POLITICAL ECOLOGY

Feminist political ecology is an emerging interdisciplinary field of study that has grown out of gaps and convergences between political ecology, women's studies, environmental justice, and feminist development studies. It first appeared as a series of dispersed, parallel efforts to address the overlap between theory and practice across the academy and a diversity of social movements, spanning feminist, environmental, and development alternatives concerns. The explicit introduction of the term *feminist political ecology* in the 1990s was a conscious effort to join the ecological feminism and feminist cultural studies of science in Europe and North America with critical approaches to gender and development and sustainable development and to bring a feminist sensibility and analysis to the new and expanding field of political ecology.

As with political ecology in general, feminist political ecology coalesced in part as a broad

critique of early sustainable development efforts. It specifically targeted three trends in the 1980s and 1990s. One was the continuation and proliferation of development programs that threatened forests, water, local food production, and rural livelihood systems as well as women's environmental knowledge, authority, and traditional rights to land and resources. The second trend was the rapid growth of development projects with a shared focus on gender and sustainable development that often resulted in further exploitation of women's labor and "natural resources" and in deepening conditions of poverty and inequality in rural areas. The third trend was the separate treatment of urban and rural environmental and social justice concerns and the widening gulf between parallel pursuits of political ecology (academic, rural, with a focus on "developing areas") and environmental justice (movement driven, North American in origin, urban and/or industrial cases).

As in political ecology, some of the contributors now recognized as foundational did not originally identify themselves as feminist political ecologists. This group includes Judith Carney, Marianne Schmink, Jan Momsen, Cindy Katz, Carolyn Merchant, Val Plumwood, Donna Haraway, Joni Seager, and Betsy Hartmann. Others explicitly coined and embraced the term and invoked a set of shared principles and convergent concerns, as well as distinct theoretical positions and approaches to addressing problems. Several other scholars (including Dianne Rocheleau, Barbara Thomas-Slayter, Esther Wangari, Richard Schroeder, Wendy Harcourt, Arturo Escobar, Lisa Gezon, Susan Paulson, Juanita Sundberg, Alice Hovorka, and Yvonne Underhill) have used the term *feminist political ecology* and framed articles and books and edited volumes around this conceptual framework, with changes constantly introduced along the way.

Feminist political ecology was consciously launched, in the edited volume by the same title, as a platform for discussions across the lines of feminist geography, women's studies, feminist anthropology, gender and development, critical development studies, political ecology, and environmental justice. Academics sought to bring together authors and related social movements already addressing parts of this convergence. They



identified five existing clusters of feminist scholarship and activism defined loosely as ecofeminist, feminist environmentalist, socialist feminist, feminist poststructuralist, and environmentalist. Three major themes were invoked: (1) gendered knowledge and sciences of survival; (2) gendered rights and responsibilities with respect to land, resources, and environmental decision making; and (3) gendered social movements and organizations.

The early works identified with this field were primarily focused on gendered distribution of resources, unequal terms of access to resources, and unequal vulnerability to the depredations of development (what Vandana Shiva calls “maldevelopment”) in rural forest or agrarian settings. The literature has increasingly recognized and analyzed the strengths of women’s organizations and social movements and the contributions of women within broader environmental and social justice movements. Feminist political ecology is also increasingly concerned with multiple kinds of gendered power relations, both positive and negative, entangled with race, class, culture, ethnicity, and other axes of power that suffuse both social and ecological relations. Discourse analysis of gendered institutions in sustainable development has led to in-depth analysis of seemingly simple categories such as nature, women, men, land resources, and ecological systems.

Feminist political ecology entered early into the application of political ecology in urban areas and has begun to extend the insights of feminist urban geography studies on place and space into rural and international contexts where political ecology analysis has been most often applied. Feminist political ecology pioneered the inclusion of urban and industrial case studies in political ecology, although it has not always been recognized and acknowledged. Political ecology has recently expanded to include more work on urban and industrial settings. There is also a strong feminist poststructural and postcolonial element in much of the current feminist political ecology literature, as presaged in the early publications defining the field. Feminist political ecology has acknowledged the role of culture and place in shaping gendered environmental work, knowledge, experience, and perspectives, while also recognizing the reciprocal role of gendered environmental experience in creating distinct places and cultures.

The work of feminist geography has contributed much to theories of place, space, culture, identity, and dispersed power in feminist political ecology, while political ecology has contributed an understanding of the social relations of power at the nexus of culture, nature, and production. Feminist political ecology studies on gendered systems of land and resource tenure have also illustrated the many types of resources, and the diverse rights, uses, and users that may be entangled in the complex landscapes of development projects and programs. The complexity of gendered tenure, livelihoods, identity, and practice has forced open a window that allows us to see beyond simple definitions and maps of property, place, production, and conservation. As noted by Arturo Escobar, the increasing use of poststructural theory in political ecology has been driven in part by feminist and postcolonial insights.

Some of the most illuminating recent works in feminist political ecology have been those that combine culture, race, and gender, such as Juanita Sundberg’s account of indigenous identities emerging, from within and without, in the Guatemalan parks and reserves in Mayan areas south of the Mexico-Guatemala border. Going beyond many critical political ecology studies on parks and conservation policy, Sundberg’s feminist political ecology analysis highlights the complex struggles and manipulation of identity by multiple actors. She uses a feminist poststructural approach to explain how gendered and racialized landscape formations are created through daily practice, as well as by policy, in nature conservation organizations. Wendy Harcourt likewise brings new feminist scholarship on the body to bring bodies back into our understanding of gender, race, nature, and culture. The International Working Group on Women and the Politics of Place, convened by Harcourt and Escobar, defined a series of gendered environments, ranging from the body to the home, the community, and surrounding ecosystems. Because of the emphasis in addressing difference, and questioning categories, feminist political ecology has been able to complicate dualistic visions of the world, especially those relevant to the politics of conservation and development across scales, as well as emerging and complex livelihood systems and landscapes.



Finally, feminist political ecology has been adopted as a working framework for policy and advocacy by an international coalition of women from developing countries, DAWN (Development Alternatives for Women of a New Era), as well as the women's nongovernmental organization caucus that met at the World Summit on Sustainable Development, convened by the United Nations in Johannesburg, South Africa, in 2002.

Dianne E. Rocheleau

See also Chipko Movement; Ecofeminism; Feminist Environmentalism; Feminist Geographies; Gender and Nature; Political Ecology; Sustainable Development

Further Readings

- Carney, J. (2009). Gender conflict in Gambian wetlands. In R. Peet & M. Watts (Eds.), *Liberation ecologies: Environment, development, social movements* (2nd ed., pp. 316–336). London: Taylor & Francis.
- Harcourt, W. (2009). *Body politics in development: Critical debates in gender and development*. London: Zed Books.
- Harcourt, W., & Escobar, A. (Eds.). (2005). *Women and the politics of place*. Bloomfield, CT: Kumarian Press.
- Hartmann, B. (1999). *Reproductive rights and wrongs: The global politics of population control* (Rev. ed.). Boston: South End Press.
- Nightingale, A. J. (2003). A feminist in the forest: Situated knowledges and mixing methods in natural resource management. *ACME*, 2, 77–90.
- Nightingale, A. J. (2006). The nature of gender: Work, gender and environment. *Environment and Planning D: Society and Space*, 24, 165–185.
- Rocheleau, D., Thomas-Slayter, B., & Wangari, E. (Eds.). (1996). *Feminist political ecology: Global issues and local experiences*. New York: Routledge.
- Schroeder, R. A. (1999). *Shady practices: Agroforestry and gender politics in the Gambia* (California Studies in Critical Human Geography, No. 5). Berkeley: University of California Press.

- Schroeder, R. A., & Suryanata, K. (2009). Gender and class power in agroforestry systems: Case studies from Indonesia and West Africa. In R. Peet & M. Watts (Eds.), *Liberation ecologies: Environment, development, social movements* (2nd ed., pp. 273–288). London: Taylor & Francis.
- Sundberg, J. (2004). Identities in the making: Conservation, gender and race in the Maya Biosphere Reserve, Guatemala. *Gender, Place and Culture*, 11, 43–66.
- Underhill-Sem, Y. (2003). “Tragedies” in out-of-the way places: Oceanic interpretations of another scale. In K. K. Bhavani, J. Foran, & P. Kurian (Eds.), *Feminist futures: Reimagining women, culture and development* (pp. 43–54). London: Zed Books.



FERTILITY RATE

The term *fertility*, as used in the social sciences, refers to the actual births of children, and the fertility rate attempts to gauge the number of children being born into a population. The simplest of these rates is the crude birth rate (CBR), which is the number of live births in a year divided by the total midyear population. It is usually multiplied by 1,000 to reduce the number of decimals. The CBR is “crude” because it does not take into account which groups of people in the population were actually likely to have births and ignores the age structure of the population, which greatly affects how many live births can be expected in a given year. Thus, the CBR (which is sometimes called simply “the birth rate”) can mask significant differences in actual reproductive behavior between two populations and, on the other hand, can imply differences that do not really exist.

The general fertility rate (GFR) uses information about the age and sex structure of a population to be more specific about who actually was at risk of having the births recorded in a given year. The GFR (which is sometimes simply called “the fertility rate”) is the total number of births in a year divided by the number of women of childbearing age (typically 15 through 44 yrs. [years]).



One of the more precise ways of measuring fertility is the age-specific fertility rate (ASFR). This requires a rather complete set of data: births according to the age of the mother and a distribution of the total population by age and sex. The ASFR is the number of births occurring in a year to women within a given age group per 1,000 women of that age (usually given in 5-yr age groups). ASFRs require that comparisons of fertility be done on an age-by-age basis, but demographers have also devised a method for combining ASFRs into a single fertility index covering all ages. This is called the total fertility rate (TFR), and it is the sum of the ASFRs over all ages. Note that if the ASFRs are calculated for 5-yr age groups, then the sum of ASFRs must be multiplied by 5, whereas if data by single year of age are available, that adjustment is not required. The TFR can be readily compared from one population to another because it takes into account the differences in age structure and its interpretation is simple and straightforward. The TFR is an estimate of the average number of children born to each woman in her lifetime, assuming that current birth rates remain constant and none of the women dies before reaching the end of the childbearing years. A rough estimate of the TFR (measured per 1,000 women) can be obtained by multiplying the GFR by 30 or by multiplying the CBR by 4.5 and then again by 30. Although there are several other indices that are used as fertility rates, the CBR, GFR, and TFR are the most common.

John R. Weeks

See also **Demographic Transition; Mortality Rate; Population Geography**

Further Readings

- Siegel, J. S., & Swanson, D. A. (2004). *The methods and materials of demography* (2nd ed., chap. 16–18). San Diego, CA: Elsevier Academic Press.
- Weeks, J. R. (2008). *Population: Introduction to concepts and issues* (10th ed., chap. 6). Belmont, CA: Wadsworth.



FIELDWORK IN HUMAN GEOGRAPHY

Fieldwork has long been recognized as an important activity for geographers, in both teaching and research. Carl Sauer, one of the most influential geographers of the 20th century, stated that the principal training of a geographer should come from doing fieldwork. One of the most rewarding and enjoyable aspects of being a geographer is spending time understanding the world through direct experience, gathering data about the world, and leading field experiences as a method of geographical education. This entry briefly reviews the history of fieldwork, examines its characteristics, and considers its role in geography today.

However, despite the recognized importance of fieldwork, many have lamented its decline, particularly in the field of human geography. Wilbur Zelinsky, a respected human geographer, finds the basic explanation to be the ever-greater availability and sophistication of substitute means for gathering physical and social data. He criticizes those who avoid leaving the comfort of the library and believes that the importance of fieldwork will return once again as academic fashion swings the other way. The decline of fieldwork has been attributed to a number of factors, including stringent educational budgets, safety and insurance concerns, pressure for research output in universities, and a growing emphasis on GIS analysis. A further result of this decline in field education is the dwindling opportunity to acquire formal training in field instruction. This lack of formal training is particularly acute at the university level, although one bright spot is the increasing use of computer technologies to provide “virtual fieldtrips.”

Fieldwork in human geography is often linked to the classic work of the Chicago School, which refers to the body of research that emerged during the 1920s and 1930s in urban sociology and geography that combined theory and fieldwork. This early work aimed at understanding the daily world experienced by different subpopulations in Chicago through field research, including, for example, Louis Wirth’s vivid description of life in the ghetto. The fusion of studying spatial form



and more subjective styles of living created the Chicago School's distinctive interactionist sociology, which viewed society not as a stable or fixed structure but one constructed on interaction.

Perhaps one of the best examples of a geography of the human experience is David Ley's description of the inner city as a frontier outpost. Using a wide range of research techniques, including fieldwork, Ley explored the variety of images of an African American inner-city neighborhood in Philadelphia, using those from outside and from within. He viewed the neighborhood as a frontier outpost, having an external environment of hostility and uncertainty and an internal environment that focused on connectivity and cultural separation as a way to meet the challenges imposed by the external environment.

Graham Rowles used fieldwork to explore the geographical experience of the elderly. He went beyond observation in the field to becoming involved. Rather than remaining as the traditional dispassionate observer, he became involved in the experience. Rowles's research techniques involved sharing conversations with older people in their homes, at community meetings, and in other everyday life experiences. The outcome was a collection of five vignettes describing the geographical experiences, combined with a developed theoretical perspective. Rowles discusses five elements of conducting experiential fieldwork. The first element is involvement with participants: Unlike more traditional research, in which no attempt was made to minimize the role of the researcher, emphasis was placed on mutual understanding through dialogue rather than simply observation. The second element is the lengthy time investment required to allow individuals to express themselves in their own way. The third element is the limited number of participants. Because of the small sample size, breadth of generalization is sacrificed for depth of insight. The fourth element is the emphasis on induction as opposed to deduction. The last element is the presentation of the text, which Rowles argued is best presented in a format emphasizing a subtle sensitivity to expression.

Despite the fact that leading schools of geography currently require little training in field methods, fieldwork in human geography has continued and is today more than personal observation and

recording. Today fieldwork involves not just understanding the landscape and includes, for example, interviewing children to uncover their views of space and much of the work that has been done detailing the views of women and their roles within the geographical experience. This wide breadth of work has been undertaken more critically, especially in understanding power relationships between the observer and the observed. Today there is also a necessary and worthwhile discussion concerning reliability issues.

Jennifer Hyndman views fieldwork as an exercise in communication, trust, and timing. Through the learning of language, extended stays, and a slow building of trust and rapport, researchers become part of the field. Despite the intellectual, sociocultural, and economic baggage that field researchers take along, they never return "home" quite the same. The researcher using fieldwork, like the travel writer of the past, is changed by exposure to new places and insights, and he or she returns to a changed place.

Evaluating Fieldwork

The challenges involved in guarding against threats to reliability continue to be discussed in qualitative research and among those conducting fieldwork. Most agree that the key to validity is clarity. Baxter and Eyles have created a set of criteria for evaluating qualitative research that often requires fieldwork and interviewing: credibility, transferability, dependability, and confirmability. They claim that the most important principle for guiding qualitative and field research is the notion of credibility. This credibility is best measured by the degree to which those who are described would recognize their experience and those outside can understand it. Transferability refers to the degree to which findings can fit into contexts beyond the study. The responsibility of a field researcher is to provide data that will allow transfer. Dependability is the degree to which there exists confirmation as opposed to a more idiosyncratic presentation of findings. The degree of dependability can be guaranteed, for example, by triangulation. Triangulation is the process of using different methodological strategies and finding overlap and confirmation of findings from



multiple avenues of research. Confirmability refers to the clear presentation of data-gathering methods and their strengths and weaknesses, and discussion of bias and, through its recognition, of the clarity of the data and the concepts that are derived.

Using fieldwork in teaching geography has a long tradition that continues to this day. Perhaps one of the best references for the creation of field experiences is Kent, Gilbertson, and Hunt, who in 1997 outlined the different approaches, preparation, practice, and debriefing. Field study is often one of the activities that attract students to geography, and it is increasingly important that inclusive field experiences are made possible for students of different identities and abilities. While time pressures and budget concerns have no doubt played a role in the decline of fieldwork, the nature of fieldwork in human geography may also be a reason. Fieldwork in human geography depends on more qualitative methodologies, as opposed to the more quantitative approaches used in physical geography. Such methodologies often take researchers many years of experience to develop, and students may not have the tools to make a field experience instructive. It appears that detailed preparation and debriefing are critical to the success of fieldwork by students.

The Future of Fieldwork

Fieldwork today may not necessarily involve outside participation. With increasingly sophisticated technologies being readily available to observe the Earth's surface from different scales, the notion of what constitutes fieldwork is changing. The roots of fieldwork in contemporary human geography can be found in the explorations that took place in previous centuries. Is virtual fieldwork in the computer laboratory the equivalent of field-based work? Many lament the passage of traditional field-based exploration, but the new virtual explorations allow increased access to students with varying identities and abilities, for example, persons with disabilities, who are unable to navigate a more traditional field-based experience.

Fieldwork is often the face of geography that the public sees, and it is important for geographers

to continue to explore the world using whatever technologies are available to understand the human experience better.

Paul Rollinson

See also Chicago School; Fieldwork in Physical Geography; Humanistic Geography; Interviewing; Participant Observation; Positionality; Qualitative Methods; Writing

Further Readings

- Delyser, D., & Starrs, P. (2001). Doing fieldwork [Special issue]. *Geographical Review*, 91.
- Hyndman, J. (1995). Solo feminist geography: A lesson in space. *Antipode*, 29, 197–207.
- Katz, C. (1994). Playing the field: Questions of fieldwork in geography. *Professional Geographer*, 46(1), 67–72.
- Kent, M., Gilbertson, D., & Hunt, C. (1997). Fieldwork in geography teaching: A critical review of the literature and approaches. *Journal of Geography in Higher Education*, 19, 111–114.
- Ley, D. (1974). *The black inner city as frontier outpost: Images and behavior of a Philadelphia neighborhood*. Washington, DC: Association of American Geographers.
- Rundstrom, R., & Kenzer, M. (1989). The decline of fieldwork in human geography. *Professional Geographer*, 41, 294–303.
- Zelinsky, W. (2001). The geographer as voyeur. *Geographical Review*, 91, 1–8.



FIELDWORK IN PHYSICAL GEOGRAPHY

Fieldwork in physical geography is a standard method in the discipline whereby new understandings of physical phenomena can be obtained most clearly. When combined with other comprehensive mapping tools in the geographic information science (GIScience) laboratory, such as digital elevation models and land cover or land shape data derived from satellite imagery, fieldwork becomes a highly robust means to acquire new



interpretations. Surprisingly, however, in the United States at least, the training of students in the techniques of detailed fieldwork in physical geography is rather limited, although it is taught formally in more universities in Canada and in Europe. The chief reasons for this deficit may be the great diversity of geography and the considerable expense of much modern field equipment, coupled with the difficulty of finding faculty to teach the diverse and interdisciplinary methodologies of fieldwork in physical geography.

Fieldwork in physical geography has been recognized for many years as a central ingredient in the value system of many professional geographers. Some critics have argued that much fieldwork has no theoretical base and that while it may be clearly useful in research, it is not so in teaching; in fact, however, fieldwork in physical geography plays an essential role in both physical geographic research and instruction. A suggested solution to the neglect of fieldwork in much physical geography is improved dialogue between those who are conceptually or theoretically oriented and those who are empirically oriented, as well as between those oriented toward teaching and those toward research. Nevertheless, in spite of numerous publications over the past half-century for improved teaching of field methodologies, problems still occur because of the constant need to recognize new techniques and become skilled in their use. This state of affairs is thus a never-ending quest for improvement of methodologies as physical geographic science marches on.

Methods for Instruction and Research

Empirical and theoretical methods of instruction and research are two sides of the same coin in acquiring geographical knowledge. The three main elements of general geographic research (procedures, techniques, sources of data) range between the empirical and inductive, in the field, for example, and the theoretical and deductive, out of the field. *Procedures* of research include

1. problem formulation,
2. data collection in the field,
3. statistical and cartographic analysis of the data,

4. formulation of hypotheses, and
5. testing of hypotheses.

The *techniques* of research are a spectrum of research procedures that generally include

1. the real-world totality of facts,
2. observations and measurements in that real field world,
3. simulation models of that real world, and
4. mathematical optimization models.

The *sources of data* to accomplish the research task at hand are

1. first and foremost the field observations, whether qualitative observation perceived by sight, hearing, smell, and touch or the many quantitative measurements that should also be made, and
2. archival sources, including maps, aerial photographs, satellite imagery, government records, and the like, which are commonly carried into the field to guide the work.

A third data source can also be the theoretical work, including mathematical or numerical models, but these are rarely useful in the field at the start.

Fieldwork in any discipline is almost always a challenge; in physical geography, the difficulties can be compounded by the very specialized nature of collecting the necessary data in the highly diverse areas of the lithosphere, hydrosphere, biosphere, ecosphere, and atmosphere while at the same time taking care to pay particular attention to the interfaces between these spheres where humans live, such as the soils and landforms of the critical zone. Very few researchers are very knowledgeable in more than one or two of these geospheres, and few can collect reliable data beyond their immediate fields of expertise. Thus, interdisciplinary teams of specialists become necessary to solve interesting field problems. The abilities to fix malfunctioning equipment and to develop alternative methods to “get the data” when some vital piece of field equipment is missing are essential. When field projects involve



complex and physically demanding landscapes in “exotic” foreign countries with tribal people to contend with in a variety of what are generally hoped to be productive and nonthreatening ways, then the requirements for personal skills and cultural sensitivity add further demands on field personnel. Knowledge of foreign languages, the ability to eat odd or unusual foods, and a high tolerance for unforeseen complexities, cultural aggravations, outbreaks of hostilities, bad weather, predatory insects, or aggressive carnivores—all these and more are most helpful in enabling the field researcher to come home with the requisite information and understandings.

Fieldwork in physical geography involves data collection about rock, mineral, and sediment types; measurement of strike and dip of bedrock; stratigraphy; the use of subsurface ground-penetrating radar; collecting information about fossils, rock structures, cosmogenic nuclides, and radionuclides; gathering locational data with global positioning satellite technology; surveying; data collection on weather and climate, glaciers, actively glacierized or previously glacierized terrain, underground water, surficial water, soils, paleosols, vegetation, animals, and geoarchaeological remains; tree ring dating; and geomorphology. This list is a vast panoply of topics across several disciplines, and clearly few geographers have the capability of contributing very much to more than a few of them. Equally clearly, however, working in a multidisciplinary setting where a number of these subdisciplines are part of the mix is something that geographers can fit easily into if they are trained enough to be able to handle the diversity of modern interdisciplinary scientific inquiry.

Fieldwork is best when it has direct and strong linkages to prior training and classroom work, so that the theoretical or the general can be brought to the practical and the specific in the field observation. The ability to discern the essential “signal” in the field from the complex and seemingly random noise of the natural world is an acquired skill that is not easily taught, except by field example. Looking at field landscapes with new eyes for new understandings can be very difficult, however. All too commonly, one’s prior training and experience can also cause one to ignore or gloss over that small bit of field data that just

might be the solution to the problem. “I wouldn’t have seen it if I hadn’t believed it” can be a twist of an old adage that keeps field perspectives fresh and inquiry alive. The ability to formulate multiple working hypotheses on the spot in connection to any particular field inquiry is an essential attribute in any field project.

Formalization of field research problems and their methodologies for analytical solutions is a common technique in physical geography that is taught to many students in classes on research methods or field methods. Students are taught to think in logical pathways using well-known inductive and deductive approaches. Formal analytical procedures involving data collection about certain phenomena in the field are commonly established to enable statistically valid sample data sets that will allow robust correlations. At the same time, however, room for serendipitous discovery of the unforeseen in exploration field situations must be allowed as well. One must not be blind to the new and the unanticipated in the field for the essential answer to an unforeseen problem may be inherently obvious in a new field exposure, an unusual configuration of transient phenomena, or discovery of a long-concealed site.

Means of Instruction in Fieldwork

Four means of instruction in fieldwork in physical geography are employed: the field trip, field course, advanced field seminar, and field camp. Field trips for students are a standard pedagogical technique wherein students can be trained to observe and describe aspects of the physical landscape. The best field trips are well structured, with pre- and posttrip meetings and final reports. Field courses, best delivered in the spring semester as the weather improves, are a means to teach the elementary operational techniques of fieldwork, which include observation and sampling, measuring phenomena in different ways and with different equipment, and recording and mapping through writing, photography, and drawing. Students can learn through doing that none should become so engrossed in the mechanics of the techniques that they lose sight of the problem on which they are working. Advanced field seminars, or proseminars, are rare but may be conducted after an introductory field course. The reasons for



devoting time and effort to such a field seminar are the increased *variety* of field experience that can be offered; the *intensity* of such a “crash” program; the better *insights* that can be obtained by focusing in on different problems; the close *rapprochement* that develops between people in field situations; and the generation of many new *ideas* and working hypotheses that emerge from dedicated field seminars at the advanced level.

Although field camps for students in geological studies are an old story and are generally a requirement for most geology majors, such camps are rare in geography programs. Some geography programs have instituted courses in field studies, commonly to provide skills training in geomorphology, meteorology, or environmental studies, but beyond these efforts, fieldwork for geography students is commonly only done in conjunction with professors in the field as a part of graduate student thesis endeavors. Only rarely is more extensive training desired or required to enable students to become better at fieldwork. In the few examples of field camp research programs that are available, some do research on soil and vegetation, water use, geomorphology, wildlife, and fire histories, for example.

Only a very few field camps attempt to integrate field studies of the physical environment with human geography. Themes of field projects have included things such as (a) the natural environment of certain areas; (b) planning and conservation of parks; (c) human perception of the natural environment; (d) the changing location and morphology of human settlements; (e) patterns of land use and residential segregation; (f) the retail location, transport, and logistics; and (g) tourist perception and management. Field camp learning outcomes have included (a) awareness of the integrated nature of physical and human geography; (b) understanding changes in human-environment interaction; (c) knowledge of the evolution of geomorphology and the cultural landscape; (d) understanding of the spatial variation of human activities and settlements; (e) awareness of the impacts of the natural environment on human perception; and (f) appreciation of the relevance of geographic studies. What has also been taught is developing (a) the capacity to identify regularities in the spatial distribution of key physical features; (b) the ability to find and evaluate the

location of human settlements and economic activities; (c) the analytical skills to logically link the natural environment with human culture and society; (d) the means to compare and contrast human activities in different locations; (e) critical and independent thinking to evaluate geographic concepts and theories; (f) basic skills in map reading, field observation and measurement, and social survey; and (g) essential skills in the identification and solution of geographic problems.

Basic map reading and skill with aerial photographs and satellite imagery are an essential aspect of most fieldwork. A surprisingly large number of field scientists have difficulty in finding their exact location on maps and aerial photographs in the field. Conversions between the magnetic north and true north are difficult for many people, and overreliance on modern global positioning systems for location mapping can be a severe problem in countries that prohibit that technology. Alternative mapping techniques using compass bearings to prominent features on the landscape in classic resection plotting may be required to complete field projects. If too many hours are spent in the field while one is lost or if one is unable to make any entries in the field notebook for lack of observation, it will clearly detract from good fieldwork.

Numerous challenges beyond sheer intellectual effort can occur for researchers and students in foreign countries doing field research. Linguistics, logistics, culture shock, safety, appropriate clothing, inappropriate hand gestures, long periods of time in the field, camping out, personal hygiene, travel sickness, dating, and partying can all be a source of problems. Student participation objectives in field projects can include acquiring

- conceptual and technological understanding and use of appropriate field equipment by participating in the actual data collection in the field,
- familiarity with various quantitative techniques by using multivariate statistical techniques to analyze spatial and temporal data to answer field questions,
- practical experience in information and product generation by producing new information from existing data products by data integration and spatiotemporal analysis,



- familiarity with using remote sensing and GIScience in surveying and solving practical field problems, and
- understanding of the background, development, and implementation of a student thesis or dissertation project.

Student activities to accomplish their objectives in field training, whether foreign or domestic, require a balanced approach with regard to theoretical and conceptual formulations, as well as experiential, and technical education and training to accomplish the project. This generally requires participation in a variety of tasks to ensure understanding of field project objectives, conceptual issues, and the actual nature of the fieldwork and development of new skills and problem-solving capabilities. Large field projects will generally require research meetings of all the participants before and after the field experience, usually at conferences, as well as in hotels or universities before heading into the actual field environment. Papers and research proposals are presented at such meetings to provide everyone an understanding of the tasks to be accomplished in the field.

Field Safety and Security

In too many cases, expeditionary fieldwork in physical geography can run aground when the sheer physical difficulty or danger increases so much that attention to the geographic details is necessarily limited. There is a fine line, however, between the too timid soul who withdraws from doing substantive work because of undefined fears of the unknown in the field and the fool-hardy risk takers who endanger their own selves, as well as others who might have to rescue them, just to get that rare bit of data. “Life before science” is an adage that some field researchers in physical geography have been known to say before a particularly arduous bit of work in crossing a crevassed glacier or mapping in a dangerous underwater speleological expedition, for example. Expeditionary leaders need to be careful to make good decisions, have alternate plans in mind for emergencies, have knowledge of rescue techniques and rudimentary medical procedures, and have plentiful group meetings to keep everyone on track and out of trouble.

Field safety and security are always major concerns, and over the years, seasoned field analysts almost always accumulate a number of negative experiences that can be quite instructive to others. For example, fieldwork in areas in the United States that are known for certain illegal activities (moonshine production, cannabis cultivation, etc.) can be quite dangerous, as can properties inhabited by well-armed people who are just suspicious of outsiders. In general, spending the extra time necessary to find out who owns the areas of desired fieldwork and seeking permission to go there are not wasted effort. Making introductions and inquiries at the local post office and grocery stores is often productive in this regard. Finding local religious figures to talk to is also a good idea. Security may be a major issue in expeditions to remote areas where many poor people live who may be inclined to steal from you. Automatic meteorological stations or other data collection devices that need to be left in place for a time, for example, may have to be protected by hiring a local person as a guard. Camp security can be further guaranteed by such a procedure, and hiring local porters is always a good idea, although care must be taken in tribal areas to ensure that people from the appropriate local tribe are hired and not those from a nearby antagonistic tribe.

Fieldwork and the Media

Many reporters and photographers in the modern communications media are trained to travel with field teams operating in interesting or exotic locales. Many scientists and physical geographers have a distaste for catering to the needs of the media recording field projects, particularly in arduous field situations or when local media representatives intrude (e.g., when trying to get good camera shots) or ask what the scientists may think are naive or unintelligent questions. Media presence, however, may be an important means by which the status and popularity of physical geography can be increased, particularly when the results are broadcast as television or radio specials or make it to the print media. Some larger granting agencies know well the value of the media in increasing the recognition of the importance of good research, as well as ultimately increasing congressional appropriations to conduct it. The



result is that a certain amount of federal agency funding can be used for publicity in big field projects. This funding is applied for by the media group that wishes to accompany the field scientists. In addition, the National Geographic Society is well-known for its desire to have rights of first refusal for all media endeavors associated with its grants. Physical geographers who wish to avail themselves of greater attention from the various media should seek out the publicity directors of their universities or agencies, who may be able to generate the interest necessary to attract the attention of the media for a field project.

John F. Shroder

See also **Fieldwork in Human Geography; Physical Geography, History of; Surveying**

Further Readings

- Cooke, M., Anderson, K., & Forrest, S. (1997). Creating accessible introductory geology fieldtrips. *Journal of Geological Education*, 45, 4–9.
- Fuller, I., Rawlinson, S., & Bevan, R. (2000). Evaluation of student learning experiences in physical geography fieldwork: Paddling or pedagogy? *Journal of Geography in Higher Education*, 24(2), 199–215.
- Jones, A., Duck, R., Weyers, J., & Reed, R. (2000). *Practical skills in environmental science*. Harlow, UK: Prentice Hall.
- Maskall, J., & Stokes, A. (2008). *Designing effective fieldwork for the environmental and natural sciences*. Plymouth, UK: Higher Education Academy Subject Centre for Geography, Earth and Environmental Sciences.

of reality but, rather, is constituted by the industrial practices, social relations, sites, and technologies that produce these cultural products. Film produces a reality effect (a plausible representation of the world that leaves an impression of authenticity) that re-visions, resists, and engages naturalized assumptions of what constitutes reality. Film geographies work to expose these naturalized assumptions, or cultural beliefs that are passed off as natural givens.

The issue of naturalized assumptions became a prominent issue during the late 1980s and was more broadly associated with the crisis of representation. This crisis meant questioning the mimetic belief, or the idea that researchers could achieve absolute realism through representation. Realism is the degree to which any representation *re*-presents what a society believes to be its reality. In other words, the crisis of representation brought into question the ability to which geographic research could accurately *re*-present reality. The impact of the crisis was the acceptance in geography that exploring the cultural politics in films is just as important as exploring them in urban and natural environments because all are sophisticated social constructions. Broadly speaking, cultural politics refers to the ways in which meaning and identity are constructed, negotiated, contested, and literally mediated through space and representation. As such, geographers are not so much studying *re*-presentations when it comes to film as seeking to analyze how cultural politics are encoded, reproduced, and perpetuated through mediated space. One way in which film geography can be characterized is under the analytical model of the author-text-reader (A-T-R model). This model derives from literary and film theory and investigates film as an expression of the cultural politics that are circulating within a particular space and time.



FILM AND GEOGRAPHY

While interest in film geography can be traced to various authors from the mid 20th century (notably, Eugen Wirth in Germany, J. K. Wright in the United States, and Roger Manvell in the United Kingdom), it was not until the 1980s and early 1990s that a sustained geographic engagement with film occurred. Film is not a *re*-presentation

Author-Text-Reader

Geographers have primarily engaged the cultural politics in the space of the *mise-en-scène*, or space within the frame of the movie screen. The focus then has been on understanding how social and spatial meanings combine with narrative and audiovisual representations to produce cultural “texts.” With textual, or hermeneutical, analysis, a researcher seeks to interpret and understand the various



meanings of a cultural text. Different theoretical approaches can be brought to bear on the readings of a text; however, film geography has typically focused on three logical sites of investigation: the author, text, and reader. With a focus on the author, analysis is limited to the production of a film and is often focused on auteur theory, where the director's vision of the meaning within the film is of utmost importance. However, a focus on the author can be expanded to include the cultural era within which the entire production of a film was created.

With a text-centered focus, the researcher becomes an "expert-reader" of the social-spatial meaning embedded within the film. The expert-reader seeks to denaturalize ideologies and expose hidden power relations or social differences within the text. In film, landscape is often a metaphor for a particular type of cultural politics, helping to naturalize ideology, power relations, and social difference. While most expert-reader analysis focuses on the content of the film, some analyses specifically engage with the film's form. Interest in a film's form, or more precisely how the visual and audio elements of film are assembled into a representation, has sparked the interest of many geographers. This is especially of importance since many claim that geography is primarily a visual discipline but little has been done to examine just how the visual works to produce geographic knowledge. Film is *formed* by the frame of the screen, the mise-en-scène, and montage (a technique in film editing, literally meaning "putting together"). Like cartography and landscape painting, film is a product of linear perspective, or a representational system through which one can create the illusion of space on a flat surface. As such, many in film studies, geography, art history, and cultural studies have been interested in film as a modern-day cartography. The central difference between the form of linear perspective in cinema and cartography lies in the angle of the viewer: With film, the camera substitutes for the subject's eye; in cartography, the orthographic view displaces the subject so that she or he is directly above any point on a map.

With a reader-centered approach, geographers are interested in the reception of a film's text, or the socially mediated treatment of meaning. With this approach, the object of inquiry moves away from the film and onto the viewer. Inquiry is

therefore focused on what is meaningful to the viewer and the *affects* of reception on an individual or group's identity, perception, and behavior. At the heart of the affective nature of film is the emotional and (un)intentional response because of the feelings generated by the cultural text. Film has often been called an emotional machine, one that amplifies and modulates affects. These amplifications can occur at various scales (from the individual to the national and the global) and often play on previous feelings resonating within a specific culture and/or era. Affect is more than just a film's impact on our perception of other cultures and places; it also relates to how we formulate our own identity and how we engage with and understand the world around us.

Chris Lukinbeal

See also **Media and Geography; Nonrepresentational Theory; Representations of Space; Symbolism and Place; Text/Textuality**

Further Readings

- Aitken, S., & Zonn, L. (Eds.). (1994). *Place, power, situation and spectacle: A geography of film*. Totowa, NJ: Rowman & Littlefield.
- Clarke, D. (Ed.). (1997). *The cinematic city*. New York: Routledge.
- Cresswell, T., & Dixon, D. (Eds.). (2002). *Engaging film: Geographies of mobility and identity*. Lanham, MD: Rowman & Littlefield.
- Lukinbeal, C., & Zimmermann, S. (Eds.). (2008). *A geography of cinema: A cinematic world*. Stuttgart, Germany: Franz Stienen Verlag.



FILTERING

Filtering is a pattern of residential mobility related to changes in the housing stock, especially new construction and devaluation. Filtering is often described with the metaphors of ladders or escalators: Households move up the housing market ladder as dwellings move down the social ladder. Early use of the term included *filtering up* to denote the former. In recent decades, the use of



the term has been limited to the downward movement of housing units among classes or income groups, associated with the devaluation of dwellings. In housing policy, filtering has long been a key process counted on by advocates of *laissez-faire* politics. The free market, it is argued, supplies housing for lower-income groups through the process of filtering. It is important to distinguish the phenomenon of filtering, which has been empirically researched for nearly a century, from the ideological assumptions of housing policies based on filtering.

Filtering and Urban Social Geography

Filtering as a process of urban social geographic change is commonly associated with the Chicago School of urban studies, particularly Ernest Burgess's 1925 model of urban concentric zones, and even more so with Homer Hoyt's 1939 model of sectoral land use patterns, though observations of the phenomenon predate these models. Urban growth takes place largely in the periphery, where the well-off move to new housing, leaving vacancies that become housing opportunities for households lower down the escalator. These models highlight a spatial dimension of filtering as an outward movement of households generated by new construction, as vacancies move in the opposite direction, ending in low-status neighborhoods in the inner city. The Chicago School, employing concepts of invasion and succession borrowed from ecology, emphasized the push factor of immigrants to the city center creating outward ripples in the urban social geographic fabric. Hoyt instead emphasized market mechanisms, the generative force of upper-echelon demand for new modern dwellings in the periphery, and the opportunities this demand spawned through chains of moves.

Filtering and Gentrification

Filtering is the opposite of gentrification, both at the microlevel of individual moves and at the scale of neighborhoods, both as a pattern of residential mobility and in terms of investment contra disinvestment in buildings. As a particular event, filtering can be said to take place when the household that moves into a dwelling is of lower socioeconomic status than the household that

moves out, while gentrification takes place when the household that moves into a vacancy is of higher socioeconomic status than the household that vacates the dwelling. Though individual changes in occupancy—housing turnover—can be classified as filtering or gentrification, understandings and explanations of these processes of urban change extend beyond the particular, to social structures and mechanisms underlying neighborhood change, housing market dynamics, housing policies, urban politics, and the political economy of space.

Filtering as neighborhood change is characterized by a downward shift in the socioeconomic status of residents through in- and out-migration and by downward movement in relative property values, commonly associated with redlining (designation of the area by financial institutions as ineligible for loans) and disinvestment (e.g., minimal or no maintenance and repair). Gentrification on the other hand is characterized by an upward shift in the socioeconomic status of residents and reinvestment in buildings.

Neighborhood Life Cycles

Defined and explained in terms of housing devaluation, filtering is historically part and parcel of neighborhood life cycles. New housing attracts households of higher socioeconomic status than the same housing does decades later, when quality decline due to physical deterioration, style or technological obsolescence, and the rational behavior of disinvestment by property owners and finance capital has filtered the buildings down the housing ladder. While some high-status areas display near-immunity to such life cycles of decline, other areas already of relatively low status when newly built can experience rapid declines. This suggests that underlying filtering is not only a simple neutral demographics of the built environment, from birth (construction) to death (demolition) to rebirth (gentrification through renovation or renewal), but more important, it is the result of societal stratification, social structures, and struggles for power over urban space, not the least over income from urban space. Indeed, land rent is commonly considered a fundamental driving force behind both filtering and gentrification.

Vacancy Chains

An embryo to the concept of vacancy chains was formulated in 1885 in Ernest George Ravenstein's seminal *Laws of Migration*. Ravenstein noted chain patterns of migration up national hierarchies of central places, those moving higher up in the

hierarchy leaving vacancies filled by others moving from rural centers lower down in the hierarchy. Filtering is a similar pattern but within the socio-economic hierarchy of urban housing markets.

Figure 1 depicts the time-geography of a vacancy chain, sometimes called a chain of moves. A new dwelling is completed at Time 1 (Vacancy

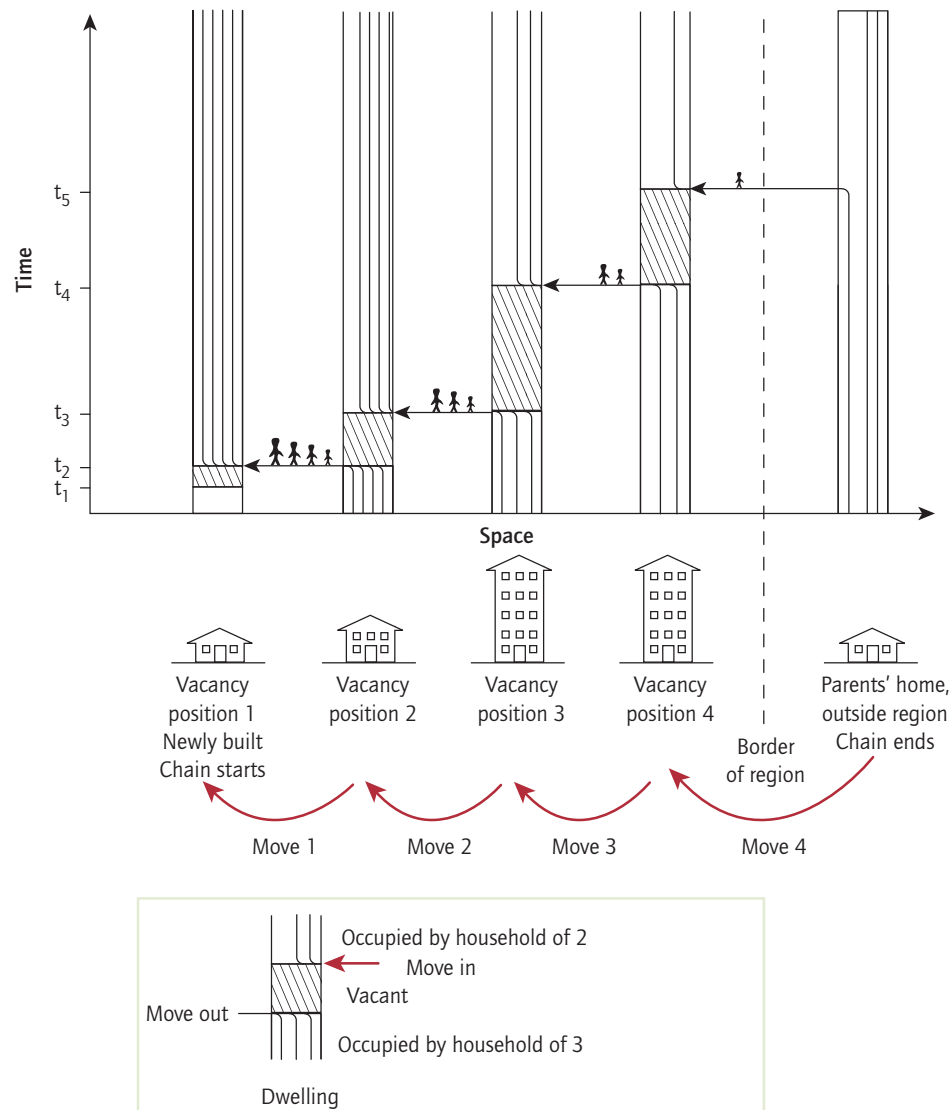


Figure 1 The filtering process. Time-geographic sketch of a vacancy chain initiated by a newly built dwelling, entailing four moves between Time 1 and Time 5 and ending due to a move from the parental home outside the urban parental market.

Source: Clark, E. (1984). Housing policies and new construction: A study of chains of moves in Southwest Skåne. *Scandinavian Housing and Planning Research*, 1, 3–14.



Position 1). At Time 2, a family of four moves in, leaving their previous dwelling vacant (Vacancy Position 2). At Time 3, a family of three moves into Vacancy 2, leaving their previous dwelling vacant in turn (Vacancy Position 3). Later, at Time 4, a couple moves in. The dwelling they left (Vacancy Position 4) is moved into at Time 5 by a young person moving away from the parents' home in another region.

New vacancies in a housing market arise either through change in the housing stock (new construction, subdivision of housing space, or conversion from nonresidential) or through change among households (e.g., death of a household, moving together to share a dwelling, or out-migration to another region). The new vacancy may pass through a number of dwellings as households use openings in the housing market, moving to satisfy their demands for housing characteristics. Ends of vacancy chains may be due to changes in the housing stock (demolition, conversion to nonresidential, merging of housing space, or long-term vacancy) or to changes among households such that the dwelling moved from is not vacant after the move (moving from parental home, divorce or separation, acquiring second home) or involves a new vacancy in another region (in-migration).

Vacancy chain studies that include data on the socioeconomic status of households reveal the extent of filtering. Most studies have focused on vacancy chains initiated by new construction, for the purpose of testing the assumption that construction catering to the demand of the economically well-off can meet the demand of lower-income groups as well. Some studies have instead aimed to evaluate consistency between the stated intentions of housing policies and their actual impact.

Research on Filtering as a Housing Policy

In 1949, Richard Ratcliff concluded that standard housing was the end product of filtering: Filtering produced the very problems housing policies sought to remedy. Filtering came to be critiqued as a euphemism for slum formation. For more than 60 years, housing economists and urban geographers have empirically researched filtering and shown that filtering is an important process through which housing demand is met.

Residential mobility provides many more opportunities in a housing market than does the volume of new construction alone. The research is also highly consistent in showing that filtering is not effective in improving housing conditions for lower-income households. Laissez-faire housing policy commonly assumes that filtering works to the benefit of lower-income households. There is no empirical evidence for this assumption. Under conditions of laissez-faire, filtering benefits middle- and upper-income households, only very marginally reaching the lower-income submarkets. Benefits to lower-income households tend to be greater where new construction occurs in modest-quality submarkets. This requires housing policies that stimulate specific forms of new construction that benefit lower-income households.

Eric Clark

See also **Chicago School; Gentrification; Ghetto; Housing and Housing Markets; Housing Policy; Hoyt, Homer; Real Estate, Geography and; Rent-Gap; Urban Spatial Structure**

Further Readings

- Clark, E. (1984). Housing policies and new construction: A study of chains of moves in Southwest Skåne. *Scandinavian Housing and Planning Research*, 1, 3–14.
- Galster, G. (1996). William Grigsby and the analysis of housing sub-markets and filtering. *Urban Studies*, 33, 1797–1805.
- Gray, F., & Boddy, M. (1979). The origins and use of theory in urban geography: Housing mobility and filtering theory. *Geoforum*, 10, 117–127.



FILTRATION

Filtration is the process by which solid particles dispersed in liquid or gaseous fluids are separated from the fluid. This process is done for two main purposes: (1) removal of suspended solids and (2) thickening. Removal of suspended solids is generally done for the purposes of treatment or remediation of air or water to improve the



quality of the fluid, and thickening is done as a sludge-processing technique. The mechanism by which filtration occurs is a mechanical or physical operation wherein some type of material or medium such as filter screens, filter paper, or some granular material such as sand or other materials is interposed and then gravity or pressure-pumping processes are used to separate the solids from the fluid as they are caught as a retentate and the fluid passes through.

Air Filtration

Smokestacks, garbage incinerators, and other producers of potentially noxious emission are commonly subjected to various types of chemical and water spray scrubbers and baghouse filters to trap undesirable gaseous and particulate pollutants. Homeowners are familiar with replaceable fiberglass air filters that are installed in their home air conditioning or forced-air heating systems.

Water Filtration

Two main types of water filters are in use: (1) granular-medium filters and (2) surface membrane filters. Both types are designed to remove undesirable materials or contaminants, but the membranes can achieve very fine filtration down to 3 Å (angstroms; 1 Å = 10^{-10} meter), which is at the atomic level.

Granular-medium filters are designed with various configurations of materials such as sand, gravel, anthracite coal, activated charcoal, and other compounds. In the filtration process, the water or wastewater is applied to the top of the filter bed so that the suspended matter in the water is removed in various ways, including mechanical and chance-contact straining; inertial impaction and sedimentation; interception; adhesion and absorption, or the sticking of particles to the filtrate; and flocculation, wherein the particles clump together and are too large to pass through the filter's openings. At some point, the granular-medium filters may become clogged with particulates and have to be backwashed or back-flushed with water or air so that undesired particulates can be disposed of.

Semipermeable-membrane processes of filtration involve separation effected by water passing

through the membrane as osmosis or hyperfiltration. The opposite process, wherein solute molecules and ions pass through the membrane, is called dialysis, which is familiar to many as the medical procedure of blood dialysis for those suffering from kidney failure. Membrane processes may be used to desalinize water, treat industrial wastes, or recover economically valuable materials such as precious metals from waste streams. Reverse osmosis is a case in which pressure is applied to a material such as saltwater to drive water without salts through the membrane, leaving the saltier water behind.

Solids and sludge left over after filtration processes need to be further processed and disposed of because they are among the most difficult to deal with in wastewater management. This is because the sludge contains much of the original offensive material of the incoming liquid, only a small part of it may be solid matter, and the waste biological material is organic and will decay. Further filtration may remove more water to thicken the remaining waste. This can be accomplished by vacuum filtration, heating, freezing, pressing, centrifuging, or simple gravity thickening. Drying beds and lagoons may also be employed.

John F. Shroder

See also **Agrochemical Pollution; Atmospheric Pollution; Water Pollution**



FINANCE, GEOGRAPHY OF

Financial geography is a recent subdiscipline within economic geography that is increasingly being recognized as an autonomous research field. While initially the field merely replicated the research objectives of economic geography more generally and aimed to answer questions related to the spatial distribution of finance, more recent contributions to the literature claim that the current rise of financial markets presents important meta-theoretical challenges to the discipline as a whole. In that regard, the fate of the discipline is clearly linked to recent economic transformations, in particular the coming about of a truly transnational financial system that has proven to



be highly prone to booms and busts. This entry briefly discusses the economic preconditions for the rise of financial geography. It then sketches the main strands of research and outlines recent developments within this literature.

The Geography of Finance and the Birth of Financial Geography

“Money makes the world go round!” This phrase neatly encapsulates the intricate link between money and space. Of the three functions of money—storing value, serving as a unit of account, and serving as a medium of exchange—the latter two impinge directly on geography. By providing a single standardized measure for the value of different goods and services, money facilitates the exchange between strangers, annihilating space and crossing cultural, social, and physical boundaries. As such, money is one of the great “space-shrinking” and “border-crossing” techniques of mankind. However, a geography of finance, in the sense of a systematic study of the spatial distribution of financial value production, only came into being when providing money, forwarding capital, intermediating exchange, and settling accounts became specialized economic functions. Banks, brokers, and exchanges owe their existence largely to the increasing division of labor that is the hallmark of modernization. However, these functions were not spread evenly over space but appeared to follow the development of the urban network and the hierarchy of marketplaces it implied. In other words, from the 17th century onward a complex network of local, national, and transnational financial centers came into being that has since become a self-standing object of investigation of what could be termed “financial geography.”

Initially, the study of financial centers and, more broadly, the spatial distribution of financial flows, markets, and products was not exclusively a geographical object of study, even though older geographical theories such as “central-place” theory were widely used to explain the multiscalar nature of financial center networks. During the 1950s, 1960s, and 1970s, the study of the geography of finance was very much a niche topic that was largely the preserve of isolated economists and some historians. Still a classic is Charles

Kindleberger’s 1974 study of the “formation of financial centers,” which, tellingly, was presented by the author as a “study in comparative economic history,” as its subtitle read.

This changed from the 1970s onward, when deregulation, liberalization, and privatization as well as technological changes (the start of the rise of information and communication technologies) unleashed a torrent of liquidity and financial innovation. A financial and economic crisis as well as 6 years of war on a global scale had largely undone the border-crossing entanglements of the “first wave of globalization” that ended so brutally in the trenches of Flanders in World War I. During the first three decades after World War II, exchanges, banks, brokers, and insurers had mainly served a national clientele. Stepwise globalization, starting in production and consumption markets, facilitated a hesitant international deployment of financial functions by some of the largest financial players. The wish to grab these new market opportunities and effective policy lobbying, as well as the demise of the Keynesian underpinnings of the postwar regulatory regime, resulted in the gradual liberalization of national financial markets and the construction of the transnational financial system of today.

Disciplinary Perspectives

With the rise of financial markets as the new centers of economic control and the transformation of financial firms from intermediaries into self-standing sources of economic activity, the research agenda of the geography of finance underwent radical changes in the 1980s and 1990s. Most notable was the influx of economically trained scholars who used econometric modeling techniques to explain (and predict) price formation in integrated financial markets. Now known as “finance,” a prestigious economic subdiscipline that generated a number of Nobel Prize winners whose prize-winning theorems have become common fare for traders worldwide, it has become highly implicated in the workings of the financial markets. A development that is captured by the term *performativity* is that finance does not provide a description of real existing financial markets but has instead stood at the cradle of their construction. Or in the telling simile of Donald



MacKenzie, "Finance is not a camera but an engine." While the perspective of the financial world is highly influential, it does not contain much geography. Geographical phenomena, such as the famed "home bias" of investors, who appear to invest most of their capital in firms of the same nationality instead of diversifying their assets over different countries, are seen as market anomalies that raise interesting questions about investor irrationality but not as geographical issues in their own right.

Second, because of their increasing economic importance and the impact they have on the wider community, financial markets and financial centers have increasingly become objects of policy interventions and have, as a result, spawned a huge amount of quasi-academic reports and rankings. Very popular among policymakers, practitioners, and pundits, "global city indices" give visual overviews of the hierarchical ranking of global, regional, national, and local financial centers. Here we clearly see traces of the older central place theory tradition, for the implication is that financial centers, although located at different geographical scales, are embedded in a global network of central places that is spatially structured. Combined with the notion that financial markets have become truly global and have largely escaped the gravity of the state, this has given rise to what is called "relational geography"; that is, to explain what occurs in any one node of the network, one has to trace its ever-changing relationship with other nodes. Influential examples of this approach are the works of Saskia Sassen and Peter Taylor.

The rise of finance has also caught the attention of economic sociologists and researchers who work in the tradition of the social studies of finance. Most of this research is of an ethnographic or microsociological nature. Although it provides meticulously detailed descriptions of trading floors, trading rooms, bank-client interactions, and the technological interface between traders and the virtual market, it lacks an overarching research agenda. Since financial markets are taken to be the most lifelike realizations of the neoclassical economic paradigm, demonstrating the socially and culturally embedded nature of trader interactions is seen as a disconfirmation of the universal validity of neoclassical assumptions. However, it is unclear what should follow from

this disconfirmation. If the economic perspective is falsified, how should we explain its durability, and what should replace it?

A fourth take on financial geography can be found in the financial-center literature. Building forth on the Marshallian notion of industrial districts that he developed in the late 19th century, which hang together on so-called untraded interdependencies, or positive externalities, an increasing number of economic geographers have shifted their research focus from manufacturing industries to producer service sectors such as advertising, architecture, film production, fashion, and the creative industries more generally. This shift is largely informed by the effects of deindustrialization and the rise of metropolitan service economies. Part of this agenda is a newfound interest in the concentration of complementary financial activities in so-called financial centers. In contrast to the relational approach in geography, the emphasis is less on the relational network *between* financial centers and more on the microgeographical linkages between firms and employees *within* financial centers. Detailed empirical work is used to answer classical geographical questions concerning colocation and proximity and their functional advantages to different agents. However, given the microgeographical focus of this agenda, it frequently loses sight of processes that play out at broader scales.

A final stream of thought comes from comparative institutionalism, where different financial systems are seen to serve crucial aggregating, mobilizing, and allocating functions. The locus classicus of this mode of reasoning is Alexander Gershenkron's 1962 *Economic Backwardness in Historical Perspective*, which distinguished between bank-based and market-based financial systems and related these differences to different growth trajectories. While this approach is rooted in a comparative static and originally failed to see beyond the nation-state, more recent contributions increasingly focus on change and transnational as well as subnational developments. Be that as it may, the hallmark is and remains its focus on institutions and their behavioral effects. While financial markets can be seen to be the most transnational markets of all, this does not imply a regulatory void, as a growing body of comparative institutionalist literature demonstrates. Hence,



the institutional emphasis of this type of literature provides a useful antidote to the tendency of perceiving finance and financial markets as free-floating entities.

Toward a Synthesis?

Currently, the period in which these different research strands could exist in blissful ignorance of one another is ending. There is an increasing awareness that the complexity of the object warrants a multimethod, multitheoretical, and ultimately multidisciplinary approach. The most promising new works in financial geography wed the agent-based approaches of the Marshallian agenda and the social studies finance to a more structure-based approach that focuses on the agency effects of institutions and regulations and add to that a relational perspective that zooms in the interaction effects between different nodes in the globe-spanning network that is the transnational financial system. As such, these works clearly perceive the weaknesses of the different disciplinary perspectives listed above and aim to use the strengths of the one to overcome the failings of the other and vice versa. A fine example of such a multitheoretical approach is found in the works of the Oxford geographers Gordon Clark and Dariusz Wojcik.

Part of the reason why it took such a long time to perform such a synthesis is that the study of the geography of finance has only gradually liberated itself from the normative “a priori” that have too long hindered sober description and analysis. During the long period when financial geographers were working in the shadow of Marxian political economy, descriptions and explanations were too much colored by normative assumptions that were disguised as theoretical premises. Since the mid 1990s, a growing number of younger scholars, accompanied by some less dogmatic elders, have finally succeeded in crawling out of that shadow and are now on the verge of creating an invigorating research agenda that cries out for its own, as yet nonexisting, publication platforms.

Whether that will ultimately result in a true synthesis, in the sense of a new theoretical paradigm with universal validity claims, is unclear. Attempts to do so may well alienate scholars who

feel their approach to be at odds with such a synthesis, resulting in a breakdown of the interdisciplinary cooperation that is now being conducted. Presumably, given the complexity and dynamic nature of the object, cross-disciplinary collaboration is the most we can hope for.

Ewald Engelen

See also **Economic Geography; Money, Geographies of; Telecommunications and Geography; World Cities**

Further Readings

- Cassis, Y. (2007). *Capitals of capital. A history of international financial centres, 1780–2005*. Cambridge, UK: Cambridge University Press.
- Clark, G., & Wojcik, D. (2007). *The geography of finance: Corporate governance in the global marketplace*. Oxford, UK: Oxford University Press.
- Kindleberger, C. (1974). *The formation of financial centers: A study in comparative economic history*. Princeton, NJ: Princeton University Press.
- Leyshon, A., & Thrift, N. (1997). *Moneyspace: Geographies of monetary transformation*. London: Routledge.
- MacKenzie, D. (2006). *An engine, not a camera: How financial models shape markets*. Cambridge: MIT Press.
- Martin, R. (Ed.). (1999). *Money and the space economy*. New York: Wiley.
- Sassen, S. (2001). *The global city: New York, London, Tokyo*. Princeton, NJ: Princeton University Press.
- Taylor, P. (2004). *World city network: A global urban analysis*. London: Routledge.



FISHER, PETER (1955–)

Peter F. (Pete) Fisher is professor of geographical information in the department of geography at the University of Leicester, United Kingdom. He is a prominent geographer and geographic information scientist best known for his long tenure as editor (1998–2007) of the *International Journal of Geographic Information Science (IJGIS)*. His faculty appointments have been at Kingston



Polytechnic, Kent State University, the University of Leicester, and City University London. He holds a PhD in geography from Kingston Polytechnic University, MSc in pedology and soil survey from Reading University, and BSc in environmental science from the University of Lancaster.

After an early specialization in physical geography (mid-Quaternary history, soils studies, and archaeological investigations), Fisher turned permanently to computer applications in geography and in geographic information science in particular. His research interests include uncertainty in geographic information, visibility analysis, and the social impacts of geographic information technology. His publications address uncertainties associated with algorithm design and implementation, database errors, and misunderstandings associated with the actual questions being asked. He has studied probabilistic models of uncertainty in soil maps and elevation models and fuzzy models of uncertainty. Most recently, he examined Type 2 and Type n fuzzy sets in the context of recognizing topographic features.

From 2003 onward, Fisher expressed a strong professional interest in the societal impacts of geographic technologies. In particular, he has focused on privacy, human tracking, and geoslavery. His writings on these topics have led the field in attempting to foster national and international debates on benefits and risks.

As editor of *IJGIS*, Fisher had a notable impact on the emerging field of geographic information science. In the 1980s, geographic information systems (GIS) operated primarily in the domain of specialists in universities, government offices, and corporations. As he took the helm at *IJGIS* in 1994, GIS was in the early stages of its transformation to the popular status that it enjoys today. *Global positioning systems* (GPS) and *Google Earth* became household words, while *IJGIS* advanced the science on which they were based. More than 600 articles were published during his tenure at *IJGIS*.

Fisher has published more than 80 refereed journal articles and 50 book chapters and edited six books: *Innovations in GIS 2* (1995), *Virtual Reality in Geography* (2002, with David Unwin), *Spatial Data Quality* (2002, with John Shi and Michael Goodchild), *Developments in Spatial Data Handling* (2004), *Re-Presenting GIS* (2005,

with David Unwin), and *Classics From IJGIS* (2007).

Jerome E. Dobson

See also **Geoslavery**; **GIScience**

Further Readings

- Comber, A., Fisher, P., & Wadsworth, R. (2004). Integrating land cover data with different ontologies: Identifying change from inconsistency. *International Journal of Geographical Information Science*, 18(7), 691–708.
- Dobson, J., & Fisher, J. (2007). The panopticon's changing geography. *Geographical Review*, 97(3), 307–323.
- Fisher, P., Arnot, C., Wadsworth, R., & Wellens, J. (2006). Detecting change in vague interpretations of landscapes. *Ecological Informatics*, 1(2), 163–178.
- Fisher, P., Cheng, T., & Wood, J. (2007). Higher order vagueness in geographical information: Empirical geographical population of type n fuzzy sets. *GeoInformatica*, 11(3), 311–330.
- Fisher, P., & Dobson, J. (2003). Who knows where you are, and who should, in the era of mobile geography? *Geography*, 88(4), 331–337.
- Fisher, P., & Tate, N. (2007). Causes and consequences of error in digital elevation models. *Progress in Physical Geography*, 30(4), 467–489.



FISH FARMING

Farming a single species of fish through industrial aquaculture processes, as opposed to hunting marine life in the wild or integrating fish farming with subsistence agriculture as is done in Asia and Africa, is a relatively new idea. Farming marine species such as Atlantic salmon and cod emerged slowly in the 19th century, prompted initially by localized overfishing, fluctuating fish landings, and increasing demand from merchants. The Atlantic salmon was domesticated for industrial production in Norway after wild salmon



declined due to overfishing and other anthropogenic assaults. After World War II, the technologies of war were applied to finding and catching fish worldwide. Factory freezer bottom draggers, which scrape the ocean's floor collecting everything in their path, drift nets and monofilament gill nets, hydraulic winches, sonar, radar, diesel engines, and other industrial fishing technologies drove 75% of global fisheries to the brink of commercial extinction by the dawn of the 20th century.

In the wake of the decline in global wild fisheries, industrial fish farming has positioned itself as the solution to the global food crisis and overfishing. The resulting "Blue Revolution," termed so by the industrial aquaculture industry to refer to the domestication and cultivation of aquatic plants and animals for profitable sale in global markets, promises to transform wild marine fish into docile domesticates and fish hunters into harvesters. As commercially fished marine species continue to face extinction in the wild due to overfishing, pollution, global climate change, and a host of other anthropogenic assaults, "culture" has emerged as a keyword in global fisheries. Like the terrestrial dreams and grandiose visions of their Green comrades a half-century earlier, Blue revolutionaries advocate the application of scientific expertise, industrial technology, and transnational capital in their oceanic culturing projects. These culturing projects influence and seek to transform human identity and ways of living as much as they do the genetic makeup, behaviors, and metabolism of the wild fish species that are targeted for industrial domestication and farming.

While marine fisheries have been highly capitalized and industrialized since World War II, it is only since the 1980s that the marine environment has undergone an agricultural transformation such as the one that has been well established on land for many thousands of years.

Culture: Domestication, Development, and Way of Life

The three dominant meanings of *culture* as outlined by Raymond Williams provide an interesting framework to analyze contemporary aquaculture or fish farming.

The meaning of *culture* includes

1. the taming, domestication, and husbandry of wild plants and animals;
2. the development or civilizing of people presented as savage and barbarous by colonizers and administrators; and
3. the anthropological description of distinct human ways of life.

Culture in its original sense referred to cultivation, a process whereby wild plants and animals are brought into a sphere of human influence where stewardship, husbandry, and caretaking take place and cultivator and cultivated each become adapted to conditions and terms dictated by human interests. The various normative and symbolic associations with taming and bringing wildness into the domestic human sphere are complex, ranging from nurturing to exploitation. This complex of meanings spills over into the connotation and operation of the other two meanings of *culture* discussed by Raymond Williams.

Processes of culturing and domestication have framed relations that extend well beyond human relations with wild plants and animals to include the development of hierarchically related groups of people in the context of the civilizing projects of imperial colonization, as well as transformative relations within societies. Contemporary industrial fish-farming projects are often tied to international development, where the production of export commodities is promoted by international banking institutions, state development agencies, and global aid and investment funds.

Romantic and resistance movements against the domestication of wild fish and the subjugation of human otherness and difference grounded in hierarchical dualisms have also deployed "culture." In this third meaning, *culture* stands for diverse and unique ways of living that are valued intrinsically without the need for improvement or eradication through taming, domestication, civilizing, or development. The three meanings of *culture* provide a rich tapestry of relations among and between fish and fishing peoples. What the Blue revolutionaries promise to achieve through industrial fish farming is a complete replacement of harvesting of endangered wild fish with



improved domesticated fishing systems. All three meanings of *culture* associated with fish farming imply different relationships with nature spanning domination, stewardship, and coevolution within natural thresholds. It remains to be explored how some of these relations play themselves out with respect to the culturing of fish and the fishing people in different places worldwide.

Dean Bavington

See also **Aquaculture; Domestication of Animals; Marine Aquaculture; Sustainable Fisheries**

Further Readings

- Coull, J. R. (1988). Fish farming in the Highlands and Islands: Boom industry of the 1980s. *Scottish Geographical Magazine*, 194, 4–13.
- Coull, J. R. (1993). Will a Blue Revolution follow the Green Revolution? The modern upsurge of aquaculture. *Area*, 25, 350–357.
- Food and Agriculture Organization of the United Nations. (2006). *The state of the world fisheries and aquaculture*. Rome, Italy: Author.
- Walters, B. B. (2007). Competing use of marine spaces in a modernizing fishery: Salmon farming meets lobster fishing on the Bay of Fundy. *The Canadian Geographer*, 51, 139–159.



FJORDS

Fjords are one of the more prominent and spectacular landforms found on Earth, formed in areas that have been exposed to extensive glaciations. Fjords are glacially carved valleys, commonly termed *U-shaped valleys* or *glacial troughs*, that have been flooded by the sea during and after the glaciers that formed them retreated. Thus, they demonstrate the erosive powers of outlet glaciers draining continental ice caps and ice sheets. This entry discusses the location of fjords, characteristics of their profiles, and processes of formation.

Fjords are channels of formerly radiating outlet glaciers that drained large continental glaciers

during the ice ages, as seen in Greenland and Antarctica today. Fjords are therefore only found along high-latitude coasts on both hemispheres. Among countries well known for their fjords and fjord regions are New Zealand, British Columbia, Chile, Greenland, Alaska, and Norway. Two Norwegian fjords, Geirangerfjord and Nærøyfjord, are considered archetypical fjords and are therefore on UNESCO's World Heritage List.

Sognefjorden, in Norway, may serve as an example of the size, characteristic features, and dimensions of a fjord system. Sognefjorden cuts its way more than 200 km (kilometers) from the west coast of Norway into the mountain area of Jotunheimen. The maximum depth (1,308 m [meters]) is found more than 50 km inland, giving rise to an overdeepened longitudinal profile (see Figure 1). Adjacent mountains peaks, rising more than 1,700 m above sea level, give rise to extreme reliefs. Commonly, a fjord system consists of several tributary fjords and valleys that coalesce toward the coast, producing a dendritic pattern.

The rate at which glaciers erode depends on the ice thickness and flow velocity; hence glacier troughs will not form in a flat landscape with a uniform ice thickness. Fjord dimensions are thought to be adjusted to the volume of ice that is discharged during maximum glacial conditions. The result is a wide, steep-sided valley, a shape that efficiently conveys glacier ice by sliding and deformation from the source area to lower altitudes, where there is a net ablation. The typical U-shape can be observed in some deep, narrow fjords, but more often the cross-profile of glacial troughs has a parabolic shape, which is favored by ice flow. However, not only glaciological parameters control the trough cross-profile, but the rock mass strength is also found to be an important controlling factor of cross-profile development.

Glacial troughs are likely to have developed in preglacial valleys, which are deepened and widened, while the adjacent mountain plateaus may show limited signs of glacial erosion. The pattern and size of the fjord system are therefore largely inherited from the preglacial landscape. However, ice divides of continental ice sheets may not coincide with the underlying watershed; thus, fjords may drain ice from substantially larger areas than the preglacial fluvial catchment.



Storfjorden, Western Norway, viewed to the south toward Geirangerfjorden

Source: Author.

It has also become increasingly evident that linear geological structures in the bedrock, for example, faults, strongly control the development of glacial troughs. It is suggested that in Patagonia outlet glaciers from repeated glaciations have widened and deepened preexisting geological structures, with less effect on the intervening landscape.

Seen from space, or in a map view, glacial troughs tend to be more linear than those carved by rivers. This relates to the properties of ice compared with water, preventing it from making the same steep turns that rivers are able to do. Thus, a glacier tends to straighten the fluvial preglacial valley.

Glacial fjords also have characteristic irregular longitudinal profiles, consisting of overdeepened troughs with intervening thresholds. An overdeepened trough is a landform where the slope near the mouth is reversed. In other words, the trough is deepest in the middle and shallower toward the ends. This is clearly seen in many fjords, which can be more than 500 m deep in the central part and less than 100 m deep at the fjord mouth. Although ice has a lower density than water and will float, glaciers may grow thicker than the water depth they enter. When the ice thickness exceeds the water depth by approximately 10%, the ice is grounded and can erode the fjord bed. Fjords with depths of many hundreds of meters



thus provide evidence of great ice thicknesses and the fact that fjords conveyed huge volumes of ice during the maximal glacial conditions.

Glacier erosion takes place as glaciers slide over their bed, tearing loose particles from the underlying bedrock and abrading the bed by dragging rock particles along their base. Although glaciers may produce huge quantities of sediment each year, glacier erosion is a slow process taking place over large areas. Glacier erosion is estimated to proceed at rates of the order of millimeters per year. It thus follows that fjords are old landscape elements that have formed during multiple glaciations.

Geir Vatne

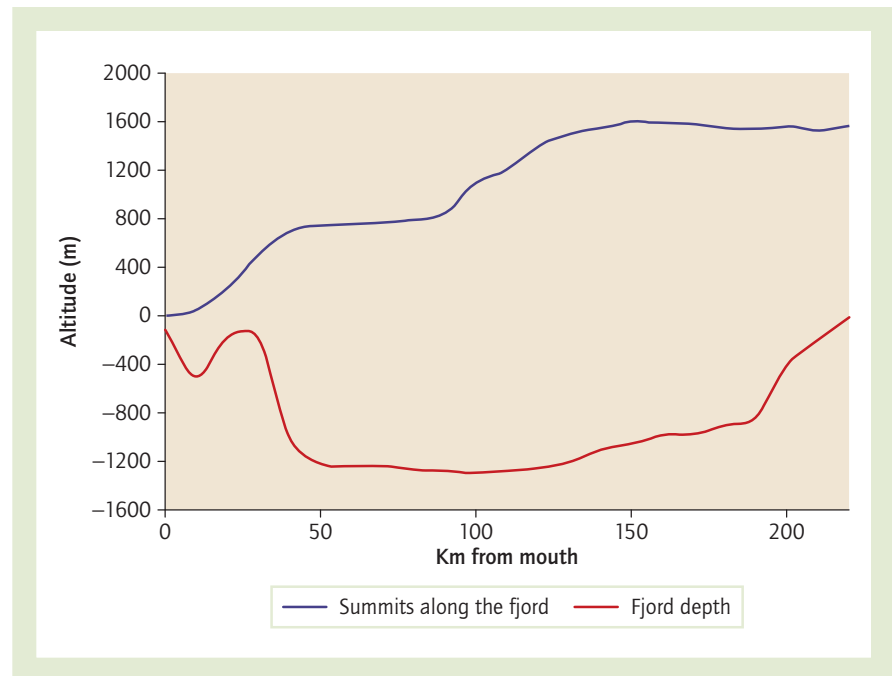


Figure 1 Schematic longitudinal profile of Sognefjorden showing the typical overdeepened profile with reverse slope at the mouth

Source: Author.

See also **Glaciers: Continental**; **Glaciers: Mountain**; **Landforms**

Further Readings

- Glasser, N. F., & Bennett, M. R. (2004). Glacial erosional landforms: Origins and significance for palaeoglaciology. *Progress in Physical Geography*, 28, 43–75.
- Glasser, N. F., & Ghiglione, M. C. (2008). Structural, tectonic and glaciological controls on the evolution of fjord landscapes. *Geomorphology*, 105, 291–302.
- Holtedahl, H. (1967). Notes on the formation of fjords and fjord-valleys. *Geografiska Annaler*, 49A, 188–203.
- Montgomery, D. R. (2002). Valley formation by fluvial and glacial erosion. *Geology*, 30, 1047–1050.
- Nesje, A., & Whillans, I. M. (1994). Erosion of Sognefjord, Western Norway. *Geomorphology*, 9, 33–45.

FLASH FLOODS

Flash floods occur when water levels rise rapidly and inundate low-lying areas. The United States National Weather Service defines flash floods as floods that occur within 6 hours of their cause, which may include heavy rainfall, ice dam breakage, and dam or levee failures. Flash floods cause minor to severe damage, injury, or death, and often disrupt transportation systems. Although some regions are more likely to experience flash floods than are others, they can occur anywhere in the world.

Flash floods often occur when heavy rain falls on less permeable surfaces such as clay soils, soils already saturated with water, and concrete. Urbanization therefore contributes to flash flood hazards in two ways. Instead of infiltrating the ground, the water flows over land surfaces and through streets, increasing human exposure to flash flood hazards as well as the potential for damages and injuries.

Flash floods are a major geomorphological force that erodes soil and rock to create and



Flash flood within a city in Iowa

Source: Lynn Betts, USDA Natural Resources Conservation Service.

deepen canyons, arroyos, and steep valleys, particularly in arid or semiarid regions. Deeper channels confine water and prevent it from spreading across the surface, enhancing the risks associated with flash floods. In a canyon flash flood, the water may appear suddenly and without warning from an unseen source upstream. In such cases, the optimal method of escape is to climb to higher ground, although this is not always possible and many hikers find themselves in danger each year. The Big Thompson River flood of 1976 is one example of a canyon flash flood, in Colorado, that resulted in the deaths of 146 people.

Infrastructural failures may include naturally occurring structures such as ice dams as well as human-made structures such as dams or levees. Although infrastructural failures are often associated with heavy rainfall, this is not always the case. As a result, such flash floods are extremely

difficult to predict and have the potential to devastate extensive areas.

Ice dams are created when water is retained behind a wall of ice. Water pressure builds up behind the dam and may cause it to break, flooding areas downstream. Ice dam failure is a typical event in spring, when rain and warm temperatures combine to melt snow and ice into the reservoir while simultaneously weakening the ice dam. Loss of life from ice dam flash floods is low despite the high frequency of these events because they are relatively predictable. A thaw prediction after one of the heaviest ice accumulations on the Yellow River in China led authorities to evacuate 13,000 people in March 2008. The ice dam burst, but no casualties were reported.

Dam and levee failures present a difficult problem for water managers and residents alike. These types of infrastructure are designed to prevent or



alleviate flooding and usually allow greater development within a floodplain, bringing more people and property under the threat of flash floods. When they do fail, the subsequent flash floods are often devastating to communities downstream because of their suddenness and severity. In 1975, Typhoon Nina produced more than a year's average of rain over the Banqiao Reservoir in China, causing the Banqiao and 61 other dams to fail. Entire communities were destroyed, leaving approximately 26,000 dead from the flash floods and over 100,000 more dead due to subsequent waterborne disease and famine. The storm surge from Hurricane Katrina in 2005 breached 53 flood control levees and caused another 28 to fail outright, rapidly flooding New Orleans and leaving more than 700 dead in the city from flooding alone.

Flash floods frequently cause severe and extensive damage to roads, buildings, and vehicles and frequently undermine infrastructure designed to protect people from danger, such as bridges, culverts, dams, and levees. Swift water often erodes submerged land surfaces to a great extent, which may not be visible to onlookers on account of turbidity. Rapidly flowing water also has the power to dislodge rocks, boulders, branches, trees, and even entire buildings; carry the debris downstream; and damage or demolish anything in its path.

Apart from the damage to infrastructure caused by flash floods, people are vulnerable to the floodwaters themselves. Thousands of people are killed or injured by flash floods each year due to drowning or the debris flowing within the water. In the United States, flash floods kill approximately 100 people per year, more than any other weather-related hazard except for extreme heat. Nearly half of those deaths are of people trapped inside or attempting to escape from their vehicles after driving through high water. Thousands more require swift rescue from emergency response teams. To reduce the number of deaths and injuries, local, state, and federal flood risk management agencies have launched numerous public education campaigns, such as "Turn Around, Don't Drown" from the National Weather Service. Arizona state law has made driving into high waters illegal, and punishment includes fines to cover rescue costs. The National Weather Service

also provides public alerts that include flash flood "watches," which indicate the possibility of flash flooding for a given area, and "warnings," which indicate that flash floods are occurring or imminent in a given area.

The Storm Events database from the United States National Climatic Data Center compiles flash flood data collected by National Weather Service weather forecast offices as reported by media sources and "spotter" networks formed of both officials and citizens. As a result, the reports are incomplete and generally concentrated in urban areas, particularly those with weather forecast offices. However, Storm Events provides the most comprehensive collection of flash flood data that includes meteorological and hydrological information as well as casualty and damage statistics.

Ashley R. Coles

See also **Environmental Perception; Floodplain; Floods; Land Use and Cover Change (LUCC); Natural Hazards and Risk Analysis; Risk Analysis and Assessment**

Further Readings

- Gruntfest, E., & Handmer, J. (Eds.). (2001). *Coping with flash floods*. Dordrecht, Netherlands: Kluwer Academic.
- National Climatic Data Center. (n.d.). *Storm events*. Retrieved December 31, 2008, from www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms
- National Severe Storms Laboratory. (2006, November). *Flash flood safety . . . What you need to know NOW!* Retrieved December 31, 2008, from www.nssl.noaa.gov/edu/safety/flashflood.html



FLEXIBLE PRODUCTION

Flexible production, also called *post-Fordism*, refers to the forms of manufacturing that began to take shape and eventually become dominant throughout the late 20th century. In contrast to Fordism, flexible production allows goods to be manufactured cheaply but in small volumes as



well as large volumes. A flexible automation system can turn out a small batch, or even a single item, of a product as efficiently as it can a mass-assembled commodity.

Flexible production appeared, not accidentally, at the particular historical moment when the microelectronics revolution began to revolutionize manufacturing; indeed, the changes associated with the computerization of production in some respects may be seen as the response of capitalists to the crisis of profitability that accompanied the petro-crises. Flexible production also reflected the imperative of firms to increase their productivity in the face of rapidly accelerating, intense international competition.

The most important aspect of this new, or lean, system is flexibility of the production process itself, including the organization and management within the factory, and the flexibility of relationships among customers, supplier firms, and the assembly plant. In contrast to the large, vertically integrated firms typical of the Fordist economy, under flexible production, firms tend to be relatively small, relying on highly computerized production techniques to generate small quantities of goods to be sold in relatively specialized markets. Microelectronics, in essence, circumvented the need for economies of scale.

The classic technologies and organizational forms of post-Fordism include robots and just-in-time inventory systems. The Japanese developed just-in-time manufacturing systems shortly after World War II to adapt U.S. practices to car manufacturing. The technique was pioneered by the Toyota Corporation (and hence is sometimes called “Toyotism”), which obviated the need for large, expensive warehouses of parts (the “just-in-case” inventory system). *Just-in-time* refers to a method of organizing immediate manufacturing and supply relationships among companies to reduce inefficiency and increase time economy. Stages of the manufacturing process are completed exactly when needed, according to the market, not before and not later, and parts required in the manufacturing process are supplied with little storage or warehousing time required. This system reduces idle capital and allows minimal investment so that the capital can be used elsewhere. The manufacturing run proceeds only as far as the market demands.

Inventories are very small and are only replenished to replace parts removed downstream. Workers at the end of the line are given output instructions on the basis of short-term order forecasts. They instruct workers immediately upstream to produce the part they will need just-in-time, those workers in turn instruct workers upstream to produce just-in-time, and so on. Post-Fordist approaches to production came to dominate much of the electronics sector, automobile production, and the mini-mills of the steel industry.

Flexible production is closely associated with vertical disintegration and increased subcontracting rather than “in-house” production. Many firms engaged in significant “downsizing” in the 1980s and 1990s, often ridding themselves of whole divisions of their companies to focus on their “core competencies.” A large number of companies reversed their old principles of hierarchical, bureaucratic assembly-line (Fordist) processes as they switched to customized, flexible, consumer-focused processes that can deliver personal service through niche markets at lower costs and higher speeds.

In the process, the use of subcontracts accelerated rapidly. Firms always face a “make or buy” decision, that is, a choice of whether to purchase inputs such as semifinished parts from another firm or to produce those goods themselves. Under the relatively stable system afforded by Fordism, most firms produced their own parts, justifying the cost with economies of scale, which lowered their long-run average cost curves. Under post-Fordism, however, this strategy is no longer optimal: Given the uncertainty generated by the rapid technological and political changes of the late 20th century, many firms opted to “buy” rather than “make,” that is, to purchase inputs from specialized companies. This strategy reduces risk for the buyer by pushing it onto the subcontractor, who must invest in the capital and hire the necessary labor.

A key to production flexibility lies in the use of information technologies in machines and operations, which permit more sophisticated control over the process. With the increasing sophistication of automated processes and, especially, the new flexibility of the new electronically controlled technology, far-reaching changes in the process of production need not be associated with increased



scales of production. Indeed, one of the major results of electronic computer-aided production technology is that it permits rapid switching from one process to another and allows the tailoring of production to the requirements of individual customers. Traditional automation is geared to high-volume standardized production; flexible manufacturing systems are quite different. In the business world, flexibility is based on customization of output to individual needs and wants; higher quality and higher value added; rapid response and delivery; and improved service and follow-up. Instead of greater capital investments in infrastructure and machines, software and marketing databases allow firms to estimate the needs of customers and identify niche markets. Such software allows firms to produce in “short runs” for market niches, quickly changing markets without setup costs and avoiding delays of assembly-line systems.

As interfirm linkages grew rapidly in the 1980s, many firms found themselves compelled to enter into cooperative agreements with one another (e.g., joint ventures). Quality control, that is, minimizing defect rates, became very important. Many firms succeed in this environment by entering into dense urban networks of interactions, including many face-to-face linkages, ties that “noneconomic” factors such as tacit knowledge, learning, reflexivity, conventions, expectations, trust, uncertainty, and reputation figure heavily. Geographically, therefore, flexible production is closely associated with the dense concentrations of “high-technology” firms that emerged in the late 20th century, including California’s Silicon Valley, Italy’s Emilia-Romagna region, Germany’s Baden-Württemberg, the Danish Jutland, and the British electronics region, centered in Cambridge. In such contexts, firms can substitute agglomeration economies (or external economies of scale) for (internal) economies of scale achieved by producing in large quantities.

Barney Warf

See also Agglomeration Economies; Electronics Industry, Geography of; Fordism; High Technology; Industrial Districts; Labor, Geography of; Regulation Theory

Further Readings

- Amin, A. (1994). Post-Fordism: Models, fantasies, and phantoms of transition. In A. Amin (Ed.), *Post-Fordism: A reader* (pp. 1–39). Oxford, UK: Blackwell.
- Gertler, M. (1992). Flexibility revisited: Districts, nation-states, and the forces of production. *Transactions of the Institute of British Geographers*, 17, 259–278.
- Linge, G. (1991). Just-in-time: More or less flexible? *Economic Geography*, 67, 316–332.
- Peck, J. (1992). Labor and agglomeration: Control and flexibility in local labor markets. *Economic Geography*, 68, 325–347.



FLOCCULATION

Flocculation is the process by which small primary particles in an aqueous suspension join to form a larger secondary, or composite, particle. Although the term *composite particle* encompasses all multigrain suspended sediment particles, the term *flocculation* refers to all processes by which suspended particles are brought together in water to create larger units termed *flocs*. This distinguishes flocs from *aggregates*, which are composite particles formed in a nonaqueous medium. In engineered systems, flocculation has been referred to variously as aggregation, agglomeration, and coagulation, but the result is still the formation of larger composite particles. In natural systems, flocculation is known best in estuaries and open-ocean environments but has also been documented in freshwater fluvial and lacustrine environments. Flocculation is an important aspect of water quality in both natural and engineered systems, as the floc settling velocity must exceed the settling velocity of the constituent particles due to an increase in mass and as flocs are more easily filtered from water than are primary particles.

Flocculation is a dynamic process controlled by a variety of physical, chemical, and biological factors. The two necessary conditions for flocculation are collision of primary particles and subsequent cohesion. The mechanisms responsible for collision include turbulence within the suspending liquid and differential settling of the particles by size, shape, or



density. Following collision, cohesion can be attributed to electrochemical attraction or the presence of “sticky” organic substances. Larger flocs exhibit increasingly complex arrangements of primary particles, and water or organic material occupies the void space between primary particles. The floc density must therefore be lower than the density of the primary particles (typically considered equal to the density of quartz, 2.65 g/cm^3 [grams per cubic centimeter]) and greater than the density of water (1.0 g/cm^3 at 4°C). Smaller flocs show strong cohesion between closely arranged primary particles and are thus less fragile than larger flocs, which exhibit a more complex geometry, fewer opportunities for cohesion between primary particles, and larger void spaces. Flocs are difficult to sample without disturbance, and floc density is often estimated using measurements of the settling velocity and the diameter and a subsequent rearrangement of Stokes’s law to solve for the density. During laboratory analysis of sediments, samples are often deflocculated using chemical and/or mechanical means. Assuming complete deflocculation, the resulting grain size distribution is representative of the primary particles alone. Analysis of secondary particle size often requires in situ measurements (e.g., laser diffraction), and any difference between in situ and ex situ size distributions can be used as an index of flocculation. Although a positive relationship between floc settling velocity and size is well documented, there is typically a high degree of scatter in this relationship because flocs of similar diameter often exhibit unique geometry, void space volume, or composition of either primary particles or organic substances. Flocs of identical diameter can show settling velocities that range over three orders of magnitude, and scatter typically increases with floc diameter.

Kyle R. Hodder

See also **Sedimentation; Surface Water; Wastewater Management**

Further Readings

Droppo, I. G., Leppard, G. G., & Milligan, T. G. (Eds.). (2005). *Flocculation in natural and engineered environmental systems*. Boca Raton, FL: CRC Press.



FLOODPLAIN

A floodplain is one of the ubiquitous fluvial features found along major rivers. It is a wide, flat plain of alluvium on either side of a river extending to the base of a valley that is seasonally inundated. Inundation may originate from overbank flow due to the high amount of rainfall or spillage from dams (see Amazon and White Volta photos). Geomorphologically, actively inundated areas are the composite fringing floodplains of rivers located near the main channel.

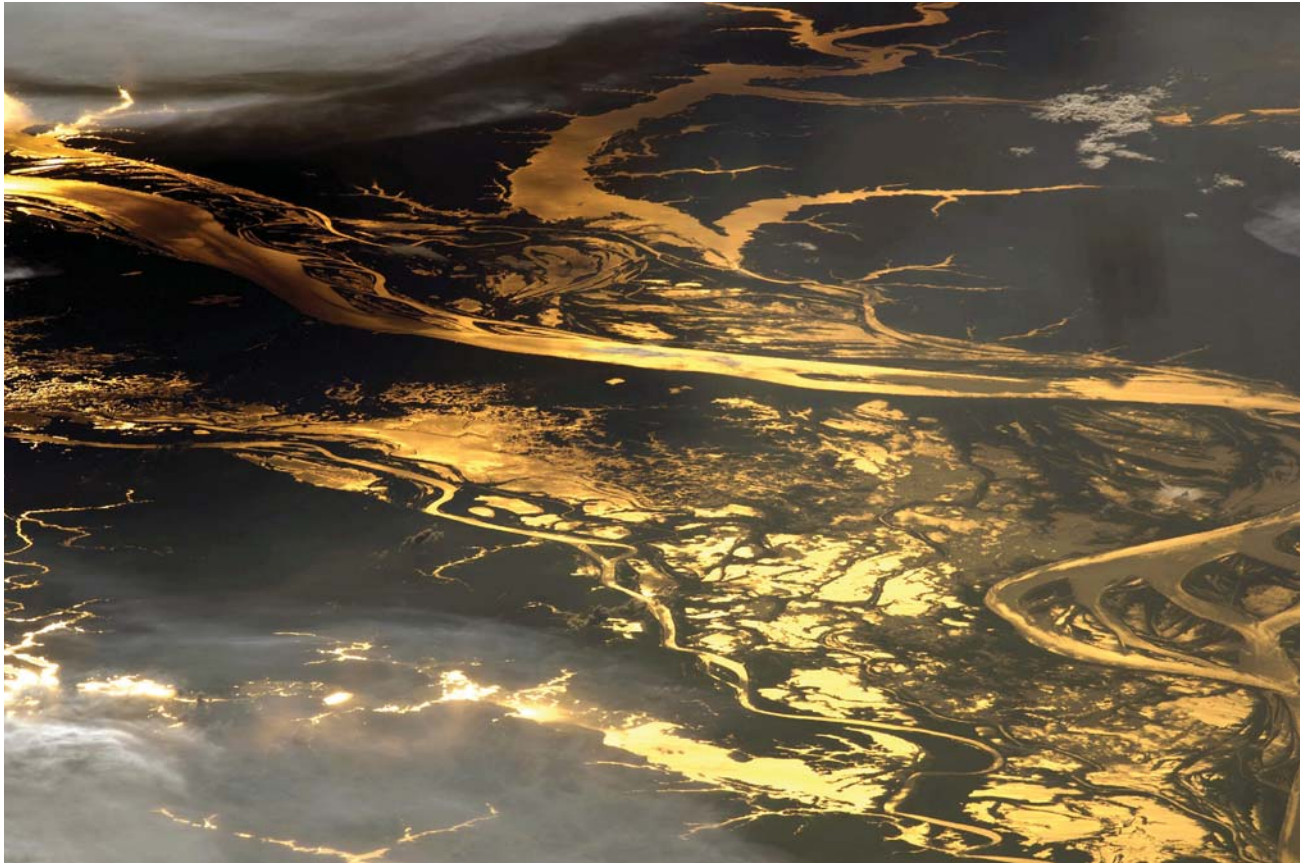
A floodplain is a complex assemblage of landforms (Figure 1) including channel features such as bars; channel edge features such as banks, benches, knickpoints, and levees; and features such as old channels (oxbow lakes), old levees, back swamps, and crevasse splays. The existence, development, and spatial structure of a floodplain and its features are, in effect, a record of the past history of the river and its current activities. Floodplains have natural qualities that provide sites for agricultural production, urban expansion, industrial location, recreational activities, and conservation of nature and sites of cultural and historic value (see Nile and Mississippi photos).

Floodplain Development

Along the longitudinal river profile, tectonic interventions contribute to the formation of floodplains, creating different channel densities and patterns that influence hydraulic connections between lotic and lentic water bodies. Tectonic deformation of a river course leads to raised and subsided blocks displaying different hydrologic patterns (see A and B in Figure 2). Uplift blocks develop large and small lakes, whereas subsided blocks display complex anastomosing drainage patterns with a lot of irregular interconnected lakes.

Base level and climate changes to some extent influence floodplain development. The base level at the coast or valley mouth controls the upstream extent of horizontal and vertical channel migration, creating a landmass that can contain seasonal overbank flow and sediment deposition. Floodplain development is stabilized if there is a final standstill of the base level.

The scientists Wolman and Leopold proposed in 1957 a model of floodplain formation based



The setting sun glints off the Amazon River and numerous lakes in its floodplain in this astronaut photograph from August 19, 2008.

Source: NASA.



Landsat 7 image showing floodplain of a section of the White Volta River in Ghana

Source: Author.

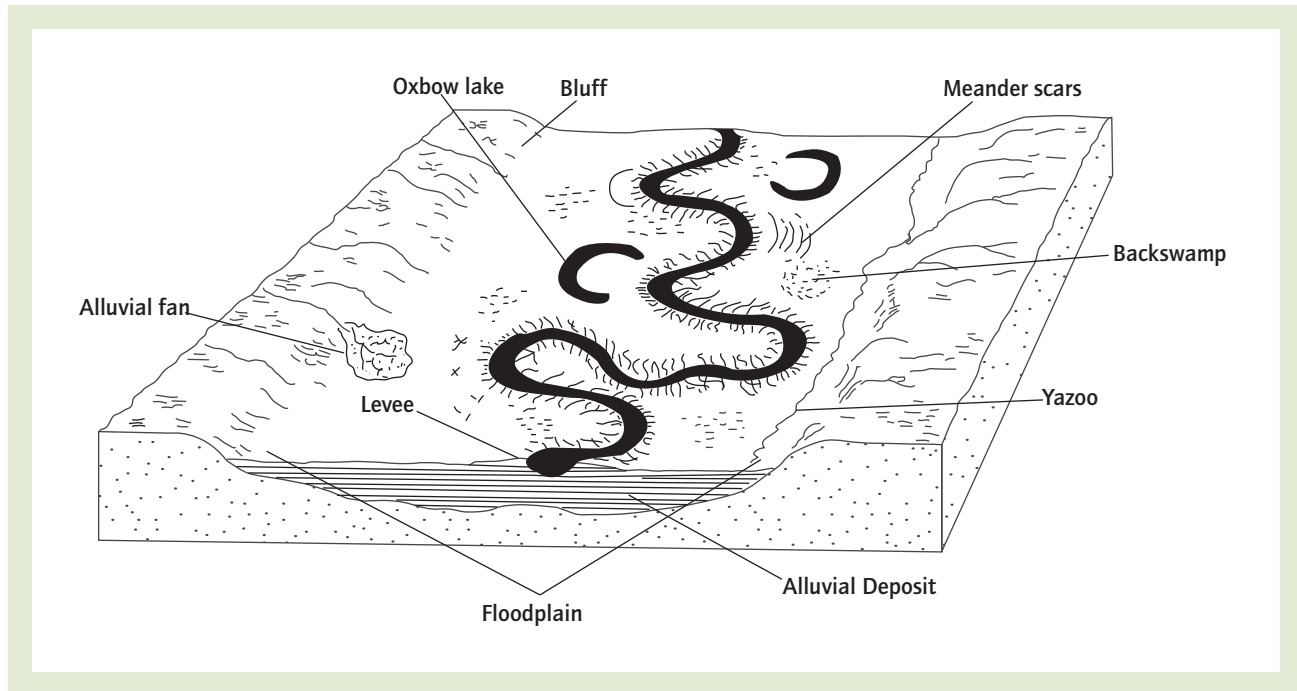
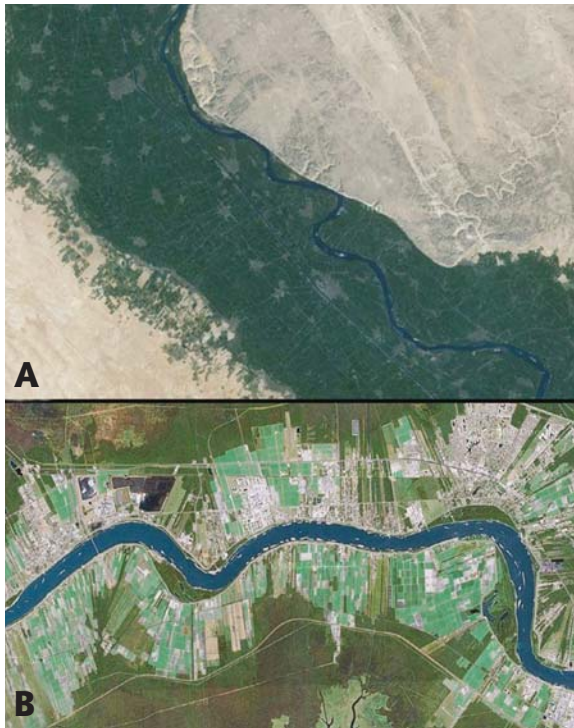


Figure 1 Floodplain and its related features

Source: Retrieved from [www.geog.unt.edu/mcgregor/1710 index.html](http://www.geog.unt.edu/mcgregor/1710%20index.html). Redrawn by J. M. Insaído.



Satellite image showing land use in the floodplains of the Nile River (A) and the Mississippi River (B)

Source: Author.

on geomorphologic reasoning and observation of streams. A floodplain is constructed entirely of horizontal layers of fine-grained sediments interrupted by coarse-grained channel deposit. It is dominated by braids and meanders migrating back and forth over the valley floor, leaving behind a sandy bar deposit.

According to Nevidimova, floodplains are formed due to the simultaneous horizontal and vertical displacement of the river channel. A displaced river in a horizontal plane leaves behind a low surface that gets inundated during high waters but changes with time.

Types of Floodplains

Geomorphologically, two types of floodplains can be distinguished, namely, hydrological floodplains and topographic floodplains (Figure 3). A hydrological floodplain is the land adjacent to the base flow channel residing below the bankfull elevation, which is inundated once every year. Not every stream has such a floodplain. A topographic floodplain is the land adjacent to the

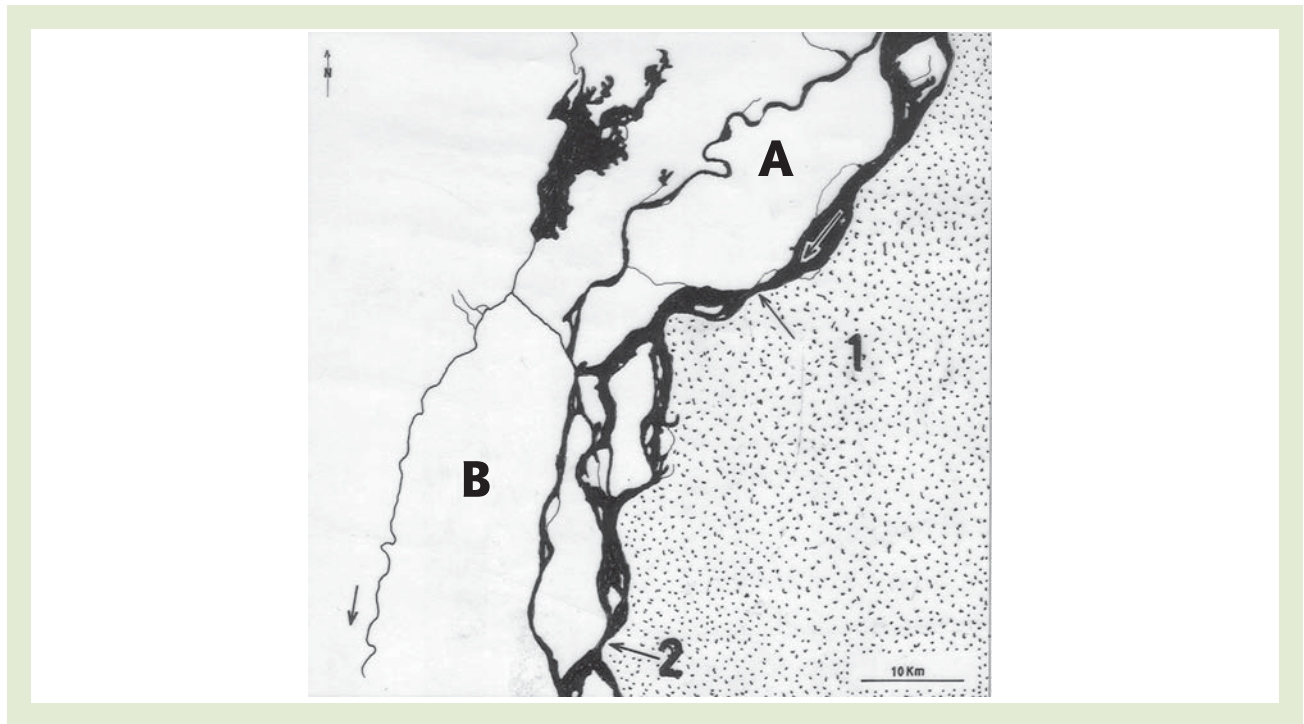


Figure 2 A sketch showing different floodplain water networks in uplifted block (A) and sunken block (B) sectors nodal points (1 and 2)

Source: Based on Paira, A. R., & Drago, E. C. (2007). *Origin, evolution and types of floodplain water bodies, the middle Parana River: Limnology of a subtropical wetland* (pp. 53–81). Berlin, Germany: Springer. Redrawn by J. M. Insaído.

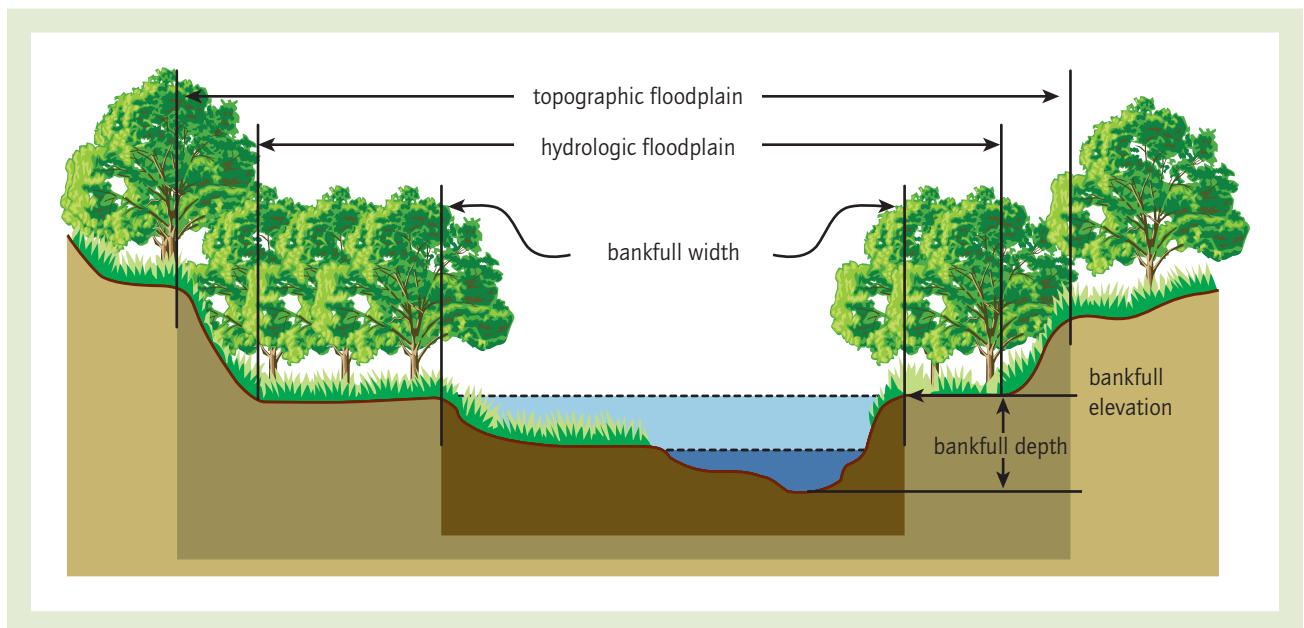


Figure 3 Hydrologic and topographic floodplains. The hydrologic floodplain is defined by bankfull elevation. The topographic floodplain includes the hydrologic floodplain and other lands up to a defined elevation.

Source: Federal Interagency Stream Restoration Working Group. (1998, October). *Stream corridor restoration: Principles, processes, and practices*. Retrieved December 3, 2009, from www.nrcs.usda.gov/technical/stream_restoration.

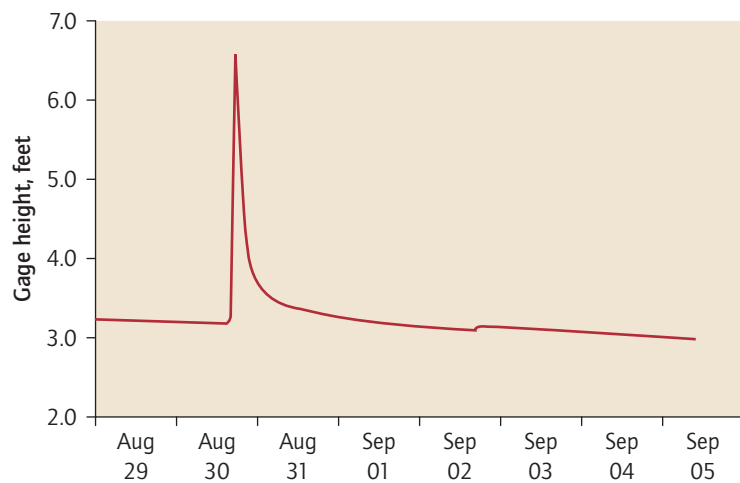


Figure 4 Event hydrograph of water height in a river for the period from August 29, 2005, to September 5, 2005

Source: Author.

channel, including the hydrologic floodplain and other land up to an elevation base reached by a flood peak of a given frequency.

Deposits and Flow Over Floodplains

Floodplain dynamics are determined by the amount of sediment deposited during the period of flooding and the amount of material removed during the time between floods. Water flow and sediment transport are complicated and difficult to evaluate due to variability in floodplain width and surface topography. Understanding the flow and deposition of sediments involves theoretical approaches and numerical modeling. These approaches are based on experiments carried out in flumes rather than on field approaches, largely due to the unpredictability and difficulty in collecting samples and making observations during flood events.

The sedimentation on floodplains consists of millimeter-thick to decimeter-thick strata sets, produced by discrete overbank flooding events. The grain size and internal structures are difficult to specify as they depend on local flow conditions and sediment availability. Many floodplain deposits have varying quantities of fine to very fine sand, silt, and clay.

Floodplain deposits closest to the main channel are comparable with the main channel deposits but decrease in grain size with distance from the main channel.

Methods of Floodplain Delineation

Several methods have been developed to help delineate floodplains. These methods include remote sensing techniques and modeling within the GIS (geographic information system) platform using applicable algorithms. The hydraulic techniques use backwater modeling, based on losses along floodplain reaches. Backwater modeling uses hydrographs of complete events rather than the peak flow rate. Examples of the model include HEC-RAS, TELEMAC,

SOBEK, and LISFLOOD-FP. Information required for these models includes the peak flow rate or event hydrograph (Figure 4), topography, and field data on channel and floodplain characteristics.

Uses of Floodplains

Floodplain resources provide a wide range of benefits to the surrounding communities. Communities use resources found on floodplains for the improvement of their livelihood, for example, firewood, tree stumps for shelter construction, and wood for fencing. Subsurface-water-level fluctuations of floodplains have potential effects on sustenance of stream flows, groundwater recharge, availability of water for livestock, and availability of water for dry-season irrigation. Floodplain use for crop cultivation during the season and off-season exposes the land to environmental hazards, altering its hydrodynamics and affecting the flora and fauna. The increasing use of agro-chemicals has the potential of polluting water bodies, changing the species composition, and entering the food chain. The human occupation of floodplains of major rivers such as the Nile, Mississippi, Ganges, Rhine, and Amazon has led to substantial impacts.

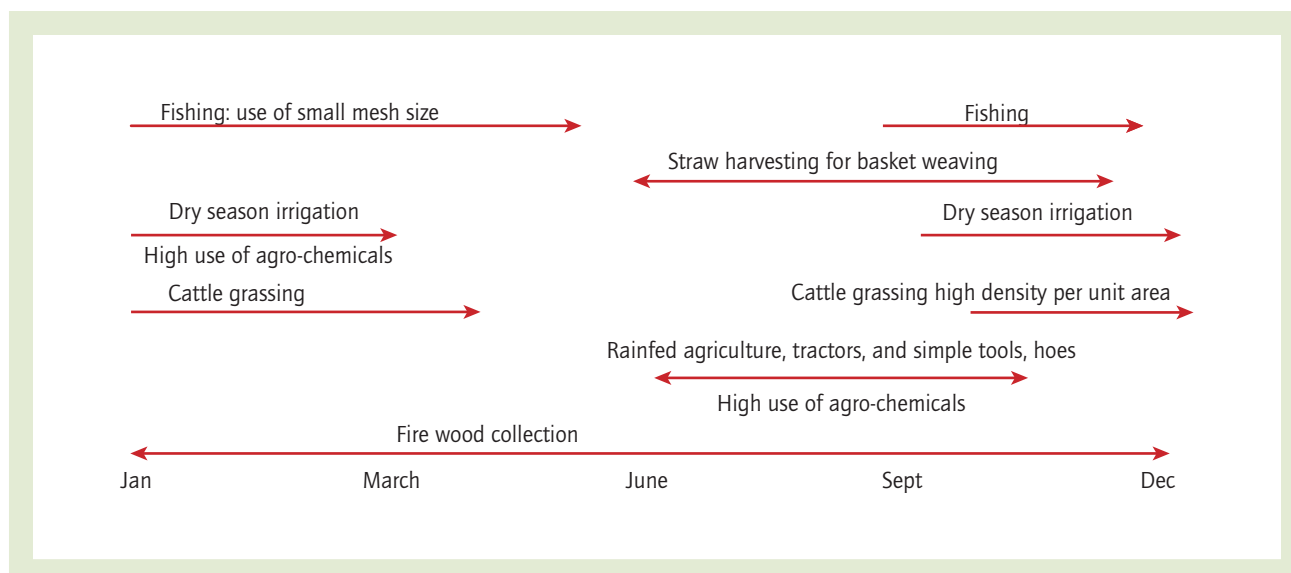


Figure 5 Cycle of land use on floodplains of the White Volta River

Source: Nyarko, B. K. (2007). *Floodplain wetland-river flow synergy in the White Volta river basin, Ghana* (Ecological and Development Series No. 53). Bonn, Germany: Hausdruckerei der Universität Bonn.

Qualitative characterization of the observed cycle of land use activities on floodplains (Figure 5) and parameters such as the magnitude, frequency, areal extent, spatial distribution, and predictability of floods within a floodplain help avert land degradation to some extent.

Benjamin Kofi Nyarko

See also **Coastal Erosion and Deposition; Floods; Rivers**

Further Readings

- Anderson, M. G., Walling, D. E., & Bates, P. D. (Eds.). (1994). *Floodplain processes*. New York: Wiley.
- Bridge J. S. (2005). *Rivers and floodplains: Forms, processes and sedimentary records*. Oxford, UK: Blackwell.
- Nevidimova, O. (2009). Quantitative regularities in floodplain formation. *Geophysical Research*, 11, EGU2009-12797.
- Paira, A. R., & Drago, E. C. (2007). Origin, evolution, and types of floodplain water bodies. In M. H. Iriondo, J. C. Paggi, & M. J. Parma (Eds.), *The Middle Paraná River: Limnology of a subtropical wetland* (pp. 53–81). Berlin, Germany: Springer.

FLOODS

Floods occur when streams and rivers overflow their banks and inundate the adjacent lands, called floodplains. In other instances, localized flooding occurs when drains cannot cope with heavy rainfall and along shorelines from sea surges that can be wind driven or associated with storms. Since all rivers flood and human activities frequently take place on the relatively flat floodplains, the consequences of flooding can be disastrous. Thus, the simple definition of flooding belies a complex of causal mechanisms that involve physical processes of the natural environment and social, economic, and political forces operating in the human environment. It is these factors in combination that determine the magnitude, severity, and ultimately the impacts of flooding. Thus, globally, floods are the most widely experienced natural disaster, causing property damage, economic disruption, and loss of life. At the same time, there are positive outcomes from flooding. Floods provide soil moisture for regions in which flood recession agriculture is practiced and can deposit nutrient-rich sediments to fertilize farmlands.



Causes of Floods

Floods can be understood within the concept of the drainage basin (watershed), often referred to as the fundamental unit of hydrological research. This unit can be viewed as a system, with one part inextricably linked to the next. The basic input to this system is precipitation, and it is how precipitation moves through various storage components that determines downstream discharge, the output to the system. The speed of water moving through the system and the associated “losses” to evaporation, transpiration, and storages in groundwater and lakes will affect the timing and quantity of water in the river channel. If the outcome is flows exceeding bankfull capacity, then there is a flood in that drainage basin (Figure 1).

Determining exactly how individual drainage basins respond to a given input of precipitation is a challenge to hydrologists. The characteristics of drainage basins, including their shape (especially at small scales), geology, soil types, vegetation, and geomorphology, all play a role

in determining discharge. Furthermore, when precipitation occurs, it is the antecedent environmental conditions within the drainage basin that control flood severity. For example, snow cover, frozen ground, wet or saturated soils (or even dry soils on occasion), preexisting high river levels, ice-covered streams, and heavy precipitation can all exacerbate hydrological conditions and lead to floods. The response of a drainage basin to a given input of precipitation, therefore, may be relatively fast, or “flashy,” where flows can be high, peaking rapidly, often with a high velocity (Figure 2). In contrast, some systems may take days or weeks to reach peak discharge and inundate the floodplains, conditions that are termed sluggish. The former systems have a short precipitation-to-flood lag time, the latter, a longer lag time. So while all streams flood, they do not necessarily flood for the same reasons or in the same way.

The extensive flooding in the Midwestern United States in June 2008 demonstrates the role of antecedent conditions. These floods were triggered by a series of storms that crossed the

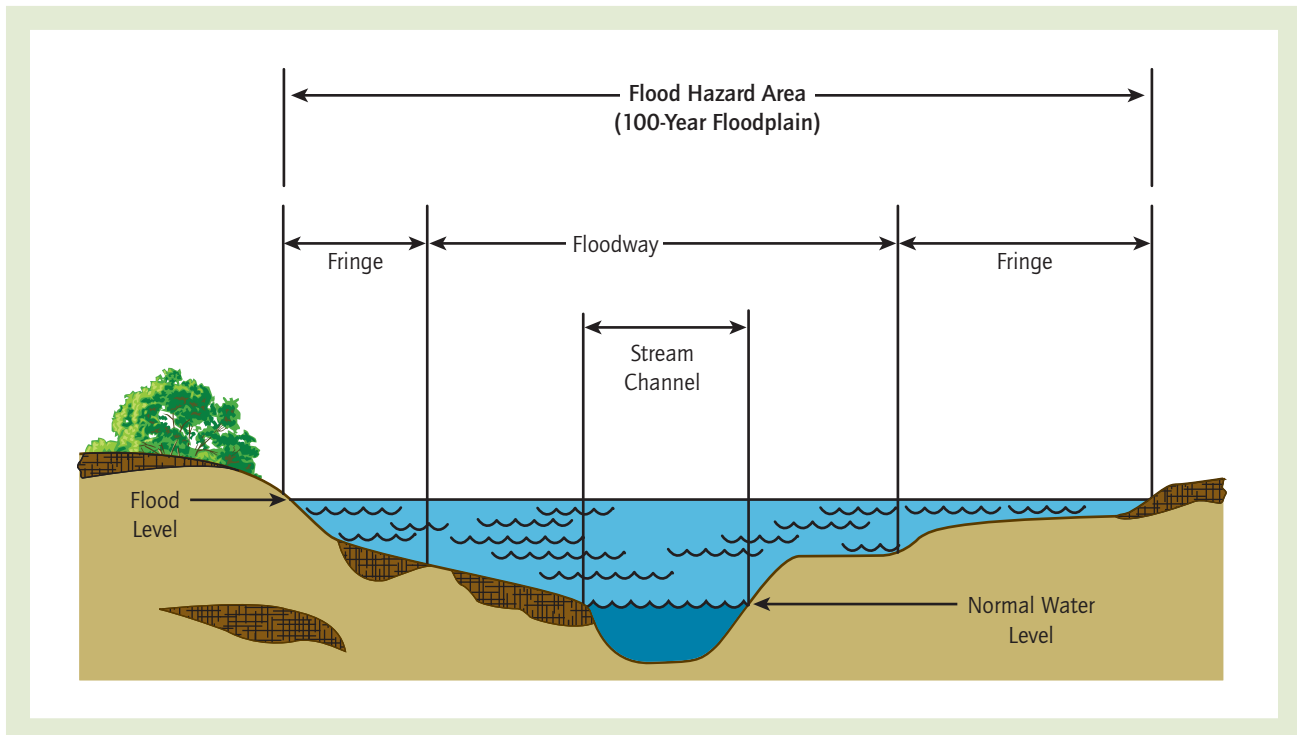


Figure 1 Stream cross-section and floodplain

Source: New Hampshire Office of Energy and Planning. (2007). *Floodplain learning on demand*. Retrieved December 3, 2009, from www.nhflooded.org. Reprinted by permission from the New Hampshire Office of Energy and Planning.



region, dumping in excess of 12 in. (inches) of rainfall on top of already saturated soils following an abnormally wet winter and spring. The result was high streamflows and record-setting floods. Bangladesh, in contrast, regularly experiences flooding during the monsoon season, and consequently, local communities have adapted agricultural practices to these seasonal patterns. The floods of August 2007, however, were exceptional and caused widespread damage even though the total rainfall was somewhat less than normal. The floods occurred because most of the rain fell in just 2 months, June and July.

Under other conditions, severe storms have resulted in flash flooding as water moves rapidly through a drainage basin. For example, in mountainous areas, thunderstorms can concentrate water in narrow valleys, creating a wall of devastation as a flood wave cascades downstream. The Big Thompson, Colorado, flood of 1976, which killed 145 people, is a classic example. Similarly, arid regions can experience flash flooding. Heavy rainfall can exceed infiltration rates and lead to rapid surface runoff filling normally dry streambeds. One such event occurred in August 2008, when almost 4 in. of rain fell in 4 hours near the California-Arizona border, leading to flash floods that killed a number of people.

Shoreline environments add another dimension as coastal processes interact with the hydrological system to exacerbate flooding. In certain circumstances, low-pressure storm systems create a rise in sea level that can be increased further by wind action and high tides. It was just such events that led to the devastation of coastal communities by Hurricane Katrina. The geomorphology of shorelines can also influence flood severity. Bangladesh, for instance, is located where seawater is funneled into a narrow region by approaching storms, which increases sea levels. In addition, much of Bangladesh is situated on the floodplain at the mouth of the Brahmaputra River, so when

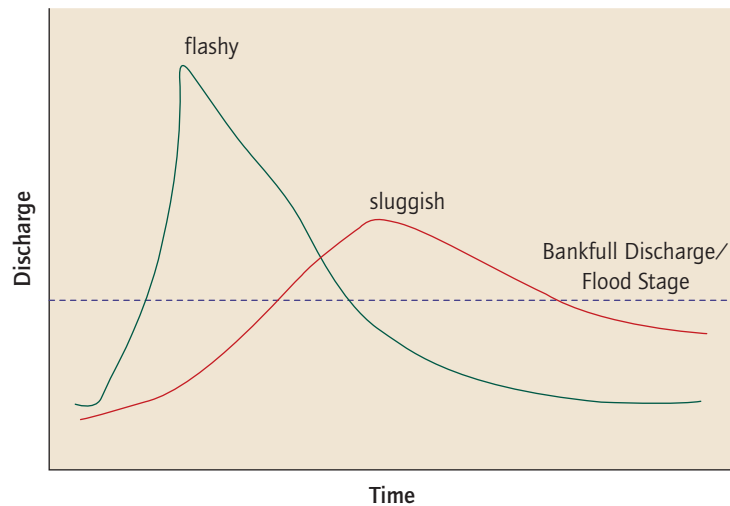


Figure 2 Hydrographs of sluggish and flashy streams

Source: Tobin, G., & Montz, B. (1997). *Natural hazards, explanation and integration*. New York: Guilford Press.

ivers are high and storms approach, the result can be devastating.

Flood Magnitude and Severity

Determining the flood severity from a hydrological perspective is difficult; the metrics used focus on river discharge, water depth, velocity, and frequency. Discharge is measured by the volume of water passing a particular location over a given period of time, usually expressed in cubic meters per second (cms) or cubic feet per second (cfs). These values vary because they are related to the size and other characteristics of the stream and its drainage basin. For instance, the Big Thompson flood had a peak discharge of 883 cms (31,200 cfs), whereas the discharge of the Mississippi River at St. Louis in 1993 was in excess of 28,300 cms (1,000,000 cfs). By comparison, the average discharge on the Mississippi is approximately 16,000 cms (560,000 cfs). Therefore, comparisons of discharges among drainage basins are problematic because data are place specific.

Flood depths provide another metric of magnitude and present a better idea of potential damage than does the discharge. However, depth cannot be considered alone. It is the amount of water (depth) as well as how fast it is moving (velocity) that helps



explain impacts. Flood depths can usually be determined directly using stream gauges and indirectly by trash lines on structures left behind as water recedes. The velocity, on the other hand, has to be calculated from flow measurements along channels or through estimates of the speed of floating debris. Flow velocities in the Big Thompson flood were certainly faster than those in the Mississippi River floods. Hence, it is useful to differentiate between extensive and intensive events. Extensive floods, such as those associated with the Mississippi, can cover large tracts of land and usually allow time for warnings. The response time of the hydrological system to precipitation in these large drainage basins can be lengthy, with hydrographs exhibiting a sluggish time to peak discharge. Flood depths, however, can be considerable, exceeding 3 or 4 m (meters) on occasion. On the other hand, intensive floods, often associated with smaller streams such as those in the Colorado mountains or in smaller tributaries of the Mississippi, may not have great depths but frequently have high velocities that carry debris downstream with devastating impacts.

Flood frequency is another commonly studied component. Estimates of flood frequencies are based on records of flood events and average recurrence intervals. For example, a 100-yr. (year) flood refers to the discharge for a specific drainage basin that is expected to be equaled or exceeded once every 100 yrs. A flood of this magnitude has a 0.01 probability (1% chance) of occurrence in any given year. The greater the discharge, the less chance there is of its occurring because of the extreme conditions required for large-magnitude events. Thus, a 500-yr. flood has an annual probability of occurrence of only 0.002. Unfortunately, this terminology is often misunderstood or poorly perceived. Too often, once a community experiences a 100-yr. flood, residents believe that they are now completely safe, at least in their own lifetimes. In fact, several 100-yr. floods can occur in the same year. Nevertheless, this method of estimating floods is useful for designing flood mitigation structures and for developing land management plans for specific-size events. Because the spatial extent of inundation can be estimated, it provides a guide to flood-prone lands within drainage basins.

Coastal flooding is usually measured in terms of storm surge height, although velocities, set up by strong winds, can make a significant difference.

Water surge elevations in the absence of wind and waves are used to project the 1% event. Although storm surge varied with Hurricane Ike in Texas, in some areas a 5-m storm surge was capped with battering waves, leading to the destruction of entire neighborhoods. Hence, as with riverine floods, depth and velocity work together to help determine destruction potential.

Human intervention in drainage basins can have an important impact on the size, lag time, and frequency of flooding. Activities such as developing land for urban uses, using tile drainage to increase the productivity of agricultural lands, and straightening and channelizing rivers alter natural processes, changing the quantity and velocity of floodwaters and often making the system flashier. Other practices such as constructing storm retention ponds and creating wetlands can have the opposite effect and prolong lag times and thus reduce the impacts of flooding.

Flood Mitigation

While floods can have positive impacts, they are mostly associated with property damage and loss of life, particularly because of our propensity to live near rivers and along coasts. Not surprisingly, then, various approaches have evolved for mitigating these adverse impacts. Such adjustments can generally be divided into structural and nonstructural measures, which operate individually or in combination to minimize losses due to these events.

Structural measures are designed to protect against flooding by separating human activities from floodwater. Through engineering works such as dams, levees, flood walls, and seawalls, floodwater can be stored in reservoirs or confined to channels, at least up to the design levels (standards) of the structures. The discharge for which these mechanisms are designed depends on the drainage basin's flood history, physical characteristics, and social, economic, and political factors. While it is technically possible to protect against a flood with a recurrence interval of, say, 500 yrs. (0.2% chance of occurrence), the cost of such protection frequently outweighs the benefits, measured in flood losses avoided. So flood control structures tend to be designed to protect against floods with recurrence intervals of up to approximately 200 yrs., with local variations.



Flood control structures have been quite successful as a mitigation strategy and have prevented billions of dollars in damage. Nevertheless, some problems have arisen. First, structural design standards may be exceeded, which can lead to catastrophic failures as when dams collapse or levees break, triggering high-velocity floods that completely destroy communities. Flood control works also invariably induce a false sense of security wherein risk is perceived as minimal and design limitations of engineering projects are ignored. Consequently, development continues in risky areas, greatly increasing the exposure of property and lives, because the community is now perceived as protected. When structures fail or when design standards are exceeded, damage can be substantial. A further complication is the changing nature of flooding, whether from global climate change or land use modifications that alter hydrological processes within drainage basins. Flood frequencies and magnitudes may adjust and compromise the effectiveness of structures.

Mitigation through nonstructural measures includes land use zoning, building codes, insurance, and warning systems, among others. Keeping floodplains undeveloped or in low-density uses that are not as likely to incur significant losses is one approach. If construction is permitted, then flood-proofing buildings by elevating them on stilts or fills or temporarily sealing entranceways will reduce damage. In some drainage basins, forecasting and warning systems can mitigate losses by providing time for remedial action, such as protecting property from flooding, and for evacuation. Many nonstructural measures are relatively low cost when compared with flood control structures and can be effective in reducing losses by reducing exposure. However, there are numerous social, economic, and political factors that complicate such practices. For instance, geographical inertia invariably works against relocating residential, commercial, or industrial buildings already located on a floodplain. However, relocation is an option. Valmeyer, Illinois, for example, moved off the floodplain following the 1993 Mississippi River floods, and portions of residential neighborhoods of Conklin, New York, were turned into natural areas following a repeated flooding on the Susquehanna River from 2004 through 2006. Rather than relocating communities, some buildings

can be flood-proofed to keep water out or to let it pass below an elevated structure. However, this may not be cost-effective for some buildings. Also, many nonstructural measures require positive action on the part of floodplain dwellers; they must purchase flood insurance policies or respond appropriately to flood warnings. Unfortunately, promoting such behavioral change is not easy.

Conclusion

Floods are natural physical processes that provide benefits to the surrounding floodplains. The physical and hydrological processes that generate floods are rather well understood, though much remains to be learned about the interaction of atmospheric and hydrological systems. However, when the human environment intersects with these natural processes, disastrous outcomes can result. Flooding is a global concern: It affects communities around the world and normally leads to more death and damage than do all other natural hazards in any given year. Thus, a comprehensive understanding of floods requires incorporation of the social, economic, and political forces that lead to the use of floodplains and coastal areas, in addition to hydrological and atmospheric modeling to determine drainage basin form and process.

Burrell Montz and Graham A. Tobin

See also **Environmental Perception; Flash Floods; Floodplains; Flow; Natural Hazards and Risk Analysis; Surface Water**

Further Readings

- Association of State Floodplain Managers:
www.floods.org/home
- NOAA Watch—Floods monitor: www.noaa.gov/floods.php
- Parker, D. J. (Ed.). (2000). *Floods*. London: Taylor & Francis.
- Smith, K., & Ward, R. (1998). *Floods: Physical processes and human impacts*. Chichester, UK: Wiley.
- USGS—Natural hazards – floods: www.usgs.gov/hazards/floods



FLOW

Flow is a term used to describe fluids in motion. Air and water, fluids ubiquitous in our environment, are of great interest to geographers. Air and water behave in similar ways; the main difference between these respective fluids is their density. Water is close to 1,000 times denser than air. The manner in which flow occurs and the resulting behavior of fluids can be subdivided into two categories, turbulent flow and laminar flow. Both the density and the viscosity of the fluid play an important role in determining which form of flow will occur.

Laminar flow is sometimes referred to as streamline flow. This type of flow refers to fluids moving in parallel layers, with no disruption or mixing between the layers. Such a lack of interactions between the fluid layers elucidates the fact that no eddies or irregular interactions occur in laminar flow conditions. When a flow is either extremely slow or close to a surface boundary, such as a streambed, laminar flow can occur in lower-viscosity fluids. Higher-viscosity flows, such as lava flows, are also likely to be laminar.

Turbulent flows occur in the vast majority of natural streams and are the most commonly encountered flow state. In such waterways, eddies are continuously forming and dissipating. Turbulent flows indicate flows that on an individual-particle level appear to be chaotic or stochastic, with the formation of large-scale eddies being characteristic. Individual water molecules in a turbulent regime follow apparently haphazard pathways that can take each molecule in alternative directions to the overall downstream direction. However, the general downstream flow direction is maintained and is the dominant flow direction superimposed on the random motion of individual molecules.

Rising smoke from a lit cigarette can help us visualize the difference between laminar and turbulent flow. As the smoke exits the cigarette, it rises vertically, in a laminar fashion. However, as the smoke continues to spiral upward, it begins to dissipate and interact with the surrounding air, and turbulent eddies become visible.

The Reynolds number (Re) is a dimensionless parameter that can be used to characterize different flow regimes. Laminar flows occur at low Reynolds numbers ($<2,000$), where viscous forces

are dominant and smooth fluid motion exists, while fully developed turbulent flows occur at high Reynolds numbers ($>4,000$). A transitional zone exists between Re values of 2,000 and 4,000. Here the flow can be either laminar or turbulent, depending on a number of factors, including the roughness of the surface that the flow is in contact with. The Re value at which the flow becomes turbulent is referred to as the critical Reynolds number.

Sarah McCormack

See also **Groundwater; Rivers; Surface Water; Wastewater Management**

FLOW MAPS

Flow maps depict the movement of phenomena between geographic locations, typically using lines of varying widths to depict quantitative data, although different color hues, in the case of qualitative data, may also be used. In the older literature, flow maps are also referred to as dynamic maps. In directed-flow maps, the flow travels along the line only in the direction of the arrowhead. In contrast, in undirected-flow maps, arrows are missing, and movement is possible in both directions.

Flow maps can be categorized into the following five types: distributive, network, radial, continuous, and telecommunications. A distributive flow map depicts the movement of commodities, people, or ideas between geographic regions. Flows within a network, such as the transportation network, are depicted in network flow maps. Radial flow maps possess a distinctive radial or spokelike pattern. Good examples are a street network based on traffic circles and an airline route network based on the airport hub structure. The movement of continuous phenomena, such as wind or ocean currents, is best shown with continuous flow maps, while the flows of information technology, including the Internet, are depicted in telecommunications flow maps.

The earliest flow map dates to 1837 and was created by Henry Drury Harness. Minard of France not only popularized the flow map among statisticians (Figure 1A) but also became known for the flow chart showing the demise of Napoleon's army in Russia. In the early decades of the 20th century, flow mapping became common in

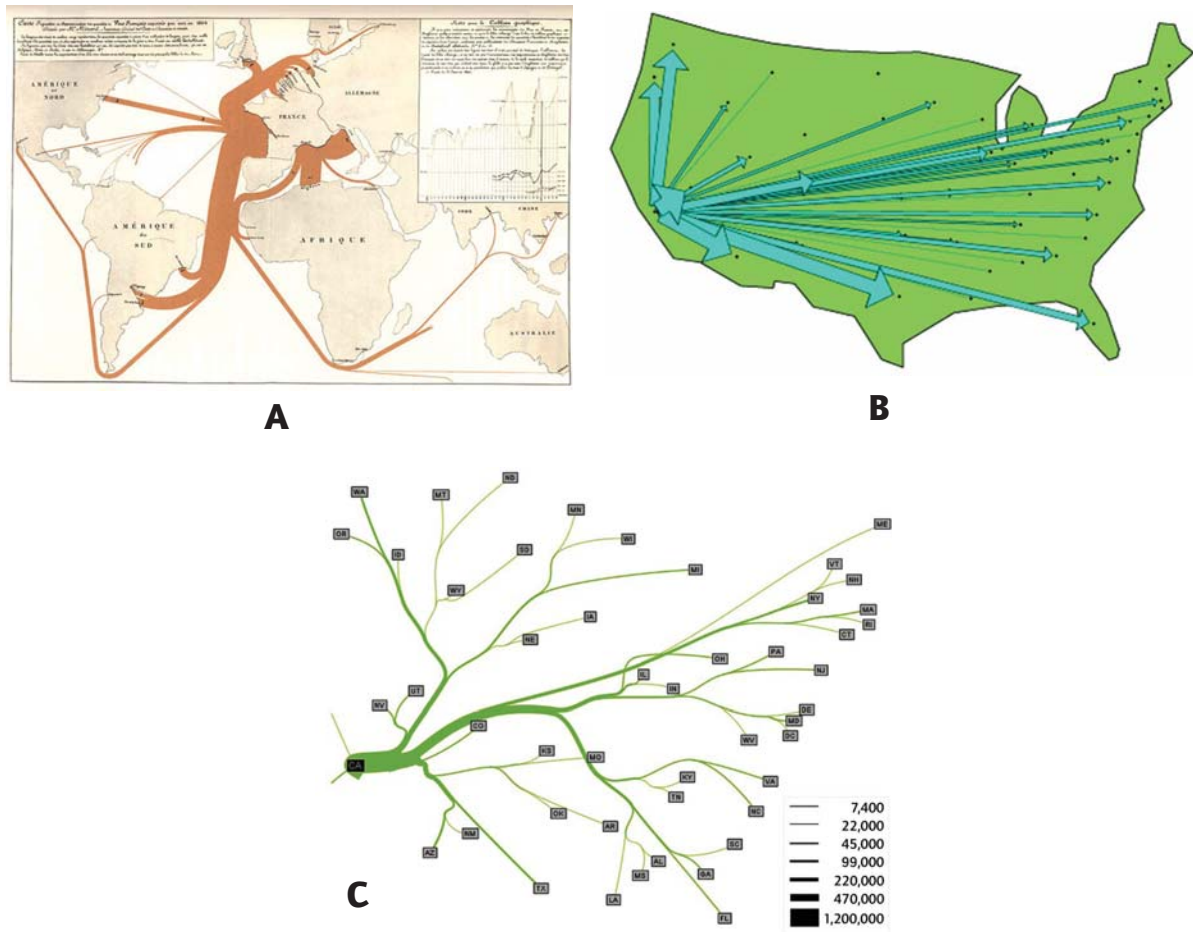


Figure 1 (A) Minard's 1864 flow map of wine exports from France. (B) Tobler's computer-generated flow map of migration from California from 1995 to 2000. (C) A flow map produced by Doantam Phan and his colleagues from Stanford University shows the same migration.

Source: Phan, D., Xiao, L., Yeh, R., Hanrahan, P., & Winograd, T. (2005). Flow map layout. In *INFOVIS '05: Proceedings of the 2005 IEEE Symposium on Information Visualization*. Washington, DC: IEEE Computer Society. Used with permission.

geography textbooks with the impetus supplied by the study of economic geography. Among the first to develop an automatic solution for displaying migration flows was Waldo Tobler, with his Flow Mapper software (Figure 1B). Details about the software, including a free download option, can be found at www.csiss.org/clearinghouse/FlowMapper. A more recent example of a flow-mapping software was developed by Doantam Phan and his colleagues from Stanford University (Figure 1C). Details about their software, including a free download option, can be found at http://graphics.stanford.edu/papers/flow_map_layout.

Recently, Ningchuan Xiao and Yongwan Chun developed the kriskogram, which is a new method to visualize migration flows. In a kriskogram, geographical units are projected as a set of points on a straight line segment called a location line. The migration flow between two points on the location line is represented using a half-circle drawn from the origin to the destination in a clockwise direction (Figure 2, next page).

Michael Leitner

See also **Cartography; Choropleth Maps; Isopleth Maps; Map Design; Map Visualization**

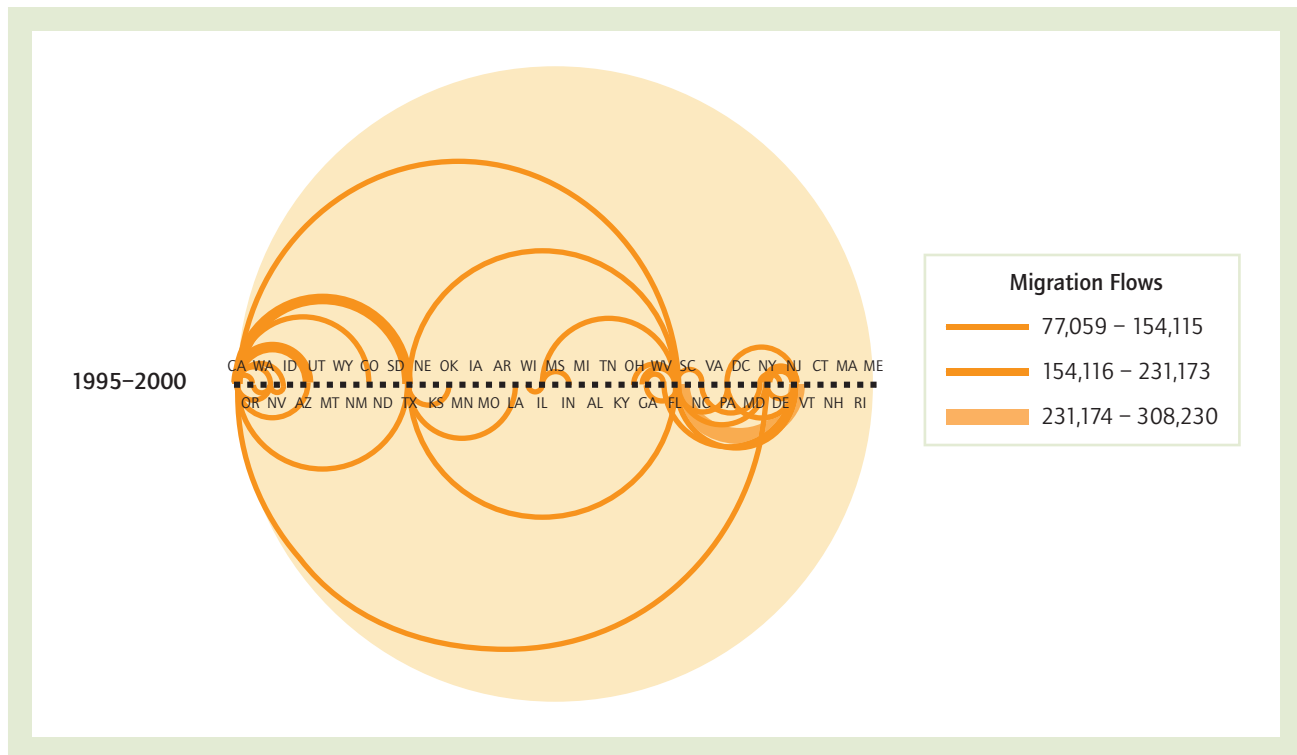


Figure 2 Kriskogram of interstate migration in the conterminous United States

Sources: U.S. Census state-to-state data; Xiao, N., & Chun, Y. (2009). Visualizing migration flows using kriskograms. *Cartography and Geographic Information Science*, 36(2), 183–191. Reprinted with permission from Cartography and Geographic Information Science.

Note: The states are arranged according to the longitude of their centroids. Migration flows with magnitude smaller than 77,059 are treated as background and are not shown.

Further Readings

- Dent, B., Torguson, J., & Hodler, T. (2009). *Cartography: Thematic map design* (6th ed.). Boston: McGraw-Hill.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2009). *Thematic cartography and geovisualization* (3rd ed.). Upper Saddle River, NJ: Pearson.
- Tobler, W. (1987). Experiments in migration mapping by computer. *The American Cartographer*, 14(2), 155–163.
- Xiao, N., & Chun, Y. (2009). Visualizing migration flows using kriskograms. *Cartography and Geographic Information Science*, 36(2), 183–191.



FOLDING

A geologic fold occurs when a flat surface is bent or contorted. For a rock or sediment to show its folds, it must have a set of parallel surfaces or different layers inside it. A very homogeneous rock mass with no internal variation would not show that any force had been applied to it to make it fold. Folds form in sediments and rocks generally from near the surface to as much as 45 km (kilometers) deep in the Earth, where elevated temperatures and the high rock overburden and fluid pressures cause the rocks to be ductile and change shape as they are subjected to tectonic or other forces from glaciers and surface processes. This allows their development in sediments and sedimentary rocks, in a full spectrum of metamorphic



rocks, and even as primary flow structures in some igneous rocks. Folds can even occur in soft sediments, where varied conditions of confining stress, hydrostatic pressure, and pore pressure allow their development. Folds in rocks occur at scales ranging from the microscopic to vast regions best observed by satellites in space. Folds distributed on a regional scale constitute a fold belt, which is a common feature of *orogeny* or mountain-building zones. Folds can also range from aesthetically pleasing, simple waveforms all the way to vital traps for hydrocarbon accumulation; their great variety has excited the curiosity of lay people as well as the geologists and geophysicists who study them intensively. Three main approaches have been used to study folds:

1. The study of the geometry and internal structure of natural folds
2. Theoretical analysis of folding processes
3. The formation of experimental folds in the laboratory

In the course of the study of folds, an extensive and sometimes confusing descriptive terminology of form has been developed to classify them by their size and shape, or geometry and morphology, the tightness of the fold, and the dip of the axial plane, as well as by their mechanics of growth, kinematics, and tectonic frameworks. The first consideration is fold description and classification. The region of maximum curvature of a fold is the *hinge zone* or fold nose, where the limbs of the fold *close*. The *axial surface* of a fold connects the hinge zones of the various folded layers, and an *axial line* connects the points of maximum curvature in any one bedding surface of a fold. Folds that close upward are *antiforms*, and those closing downward are *synforms*. Sedimentary rocks have a variety of structures that show superposition or the right way up (younging direction). If an antiform has its younging direction upward, it can be considered an *anticline*, whereas a synform with the same superposition direction is a *syncline*. Folds *face* in the direction of the stratigraphically younger rocks; *vergence* is the direction in which structures face. If sedimentary rocks are overturned from their original superposition, established when they

were deposited, it is then possible to have synformal anticlines and antiformal synclines. The *plunge* inclination is the attitude of the axial line relative to a horizontal plane.

Many different kinds of folds have been recognized over the years, so that a *symmetrical fold* is one in which the axial surface is everywhere equidistant from the limbs of the fold, whereas an *asymmetrical fold* is one in which the axial surface is not equidistant from the limbs, which commonly dip different amounts. An *upright fold* has a vertical axial surface, whereas an *inclined fold* does not. Fold tightness is the angle between the limbs of a fold. Gentle folds have an interlimb angle of 170° to 180° ; open folds, 170° to 90° ; and tight folds, 90° to 10° . *Isoclinal folds* have an interlimb angle of 10° to 0° , with essentially parallel limbs. An *overturned fold* has one limb that has passed the vertical so that its bedding is upside down from its original superposition order. A *recumbent fold* is so overturned that its axial surface is essentially horizontal. *Fold nappes* are those huge recumbent folds that extend for many tens of kilometers in orogenic areas such as the Alps. A *monocline* is a local steepening of dip in an area of otherwise flat-lying rocks, whereas a *structural bench* is a local flattening in otherwise dipping rocks. A doubly plunging anticline is warped down at both ends, whereas a *structural dome* has rocks that dip down on all sides from a central point. A *structural basin* has rocks that dip upward on all sides from a single point. Folds that maintain uniform layer thickness are classed as *parallel*, *competent*, or *concentric* folds. *Similar* folds have thinning of the limbs and thickening of the hinge zone. Parallel folds are caused by warping that results from deformation of the layers themselves, whereas similar folds usually form by some form of dislocation or flexural sliding between the layers, with extension or thinning in the fold limbs and thickening of rock layers in the hinge zones. Folds can be shaped in various ways, as *chevron folds*, with planar limbs meeting at an angular axis, as cusped with curved limbs, as circular with a curved axis, or as elliptical with an unequal wavelength. *Ptygmatic folds* are formed in high-grade metamorphic rocks and are chaotic, random, or disconnected. Some may have been planar originally, whereas others may have been injected as igneous veins under special circumstances. They



are typical of folding in sedimentary slumps, half-melted migmatites, and decollement detachment zones.

The folding of layered rock is caused when compressional force causes them to buckle, bend, or fold passively. Buckling of rocks occurs when the force is applied parallel to rock layers that are of different strengths. The layers slip past each other as the fold propagates to larger and larger amplitudes. Bending folds occur when the force is perpendicular to the rock layers. This can happen when another mobile material such as rock salt pushes up into overlying rocks and bends them into a dome. In addition, when forces produce fault breaks in the rock, folds can result when the shear surfaces are not planar and change direction. In passive folding, the layering has no mechanical significance, the forces on the rock may be oblique, and the rock records the deformation by changing shape internally and externally.

John F. Shroder

See also **Faulting; Geomorphology; Sedimentary Rock**

Further Readings

- Davis, G., & Reynolds, S. (1996). Folds. In G. Davis & S. Reynolds (Eds.), *Structural geology of rocks and regions* (pp. 372–423). New York: Wiley.
- McKnight, T., & Hess, D. (2000). The internal processes. In T. McKnight & D. Hess (Eds.), *Physical geography: A landscape appreciation* (pp. 409–414). Upper Saddle River, NJ: Prentice Hall.



FOLK CULTURE AND GEOGRAPHY

Folk culture refers to traditional, often rural, cultural production in the form of symbolic practices and cultural artifacts. In geography it is a concept, traditionally linked to the Berkeley

School of cultural geography and Carl Sauer, which fell into disfavor with the rise of critical cultural geography in the 1980s. However, geographers have more recently recovered the concept in the analysis of national identity and commodification of culture and given it a more dynamic meaning.

Prior to the rise of the new cultural geography in the 1980s, cultural geography was focused on rural life and particularly the distribution of cultural artifacts over space. For example, a cultural region could be defined by the style of vernacular or folk architecture found in an area. Geographers located cultural hearth areas and traced the diffusion of particular barn, house, or church styles. This work was based on a relatively static understanding of culture as a coherent “way of life” that changed slowly and could be attached to a particular territory. Urban culture was seen as corrupted and was generally not an object of study. Instead, geographers sought the authentic culture of small isolated groups. With the rise of the new cultural geography under the influence of Raymond Williams and Stuart Hall, geography’s understanding of culture became more sophisticated, and geographers particularly became concerned with culture as a site of struggle. Traditional studies of folk culture fell out of fashion, and geographers concerned with culture focused more on popular culture. However, geographers still found ways to examine folk culture from a critical perspective.

In some ways, popular culture is everything folk culture is not. Popular culture tends to be urban and industrial in nature. There is an explicit recognition of hybridity and change in the study of popular culture. Popular culture is made up of the meanings people create in conversation with mass-mediated, mass-produced, commodified culture. But the distinction between folk and popular culture is not clear-cut. Rural cultures and oral traditions can no longer be seen in isolation from one another and from the world of commodity production. In anthropology, where folk culture and folklore studies are more central than in geography, researchers have moved folklore out of the realm of the static and the rural and begun to concern themselves with the grassroots, oral side of modern life, studying the exchange of folklore via the Internet, for example.



Chinese babies and children are hoisted during the Beizhuang performance in Songxian county in China's Henan Province on February 11, 2006. Beizhuang is a folk art form popular among the people of Zhenxidian Village. Passed down from generation to generation, Beizhuang has developed into a complex performance featuring many aspects of the folk culture of Central China.

Source: AP Photo/EyePress.

The European concern with folk culture goes back to the work of the German philosopher Johann Gottfried von Herder in the late 18th century, and the study of folklore became an important element in the creation of nation-states in the 19th century. Folklorists sought to define national cultures and link them to particular territories by going out into the countryside and collecting examples of authentic folk culture. They collected stories, songs, music, dances, and costumes and selectively interpreted their findings to argue for timeless, essentialist

national cultures attached to particular territories, thereby legitimizing territory-based nation-states. Critical human geographers have analyzed this process of nation building.

Allan Pred coined the term *folk geography* to describe working-class practices of spatial orientation in late-19th-century Stockholm. At a time when modernity swept through Stockholm and the city went through an unprecedented period of sociospatial transformation, the newly emerging working classes developed a folk geography that made the constantly changing city a familiar



and preserved memory and resisted the official, ideologically loaded street names imposed by the nationalist bourgeoisie. Members of the new urban working class practiced oral recalcitrance in stubbornly refusing to utter new names and in continuing to use intergenerationally sedimented place names that referred to the everyday use or history of a place. Pred uses the term *folk geography* interchangeably with *popular geography*, which reflects the ambiguous distinction between folk and popular culture. On the one hand, the urban working classes in late-19th-century Stockholm were recent migrants with one foot in the countryside. Their naming practices were full of the folk humor and sensibilities of village and rural life. On the other hand, they were an industrial proletariat living in a modern cosmopolitan city, and they developed their language of spatial orientation in response to these conditions. Pred is particularly able to conceptualize folk culture as a dynamic practice deployed in the struggles of modern urban life, in contrast to the older, more static conceptions of folk culture.

James Freeman

See also [Architecture and Geography](#); [Berkeley School](#); [Cultural Geography](#); [Popular Culture, Geography and](#); [Pred, Allan](#); [Sauer, Carl](#)

Further Readings

- Hirsch, E. (1997). Voices from the Black Box: Folk song, Boy Scouts and the construction of folk nationalist hegemony in Hungary, 1930–1944. *Antipode*, 29(2), 197–215.
- Mitchell, D. (2000). *Cultural geography: A critical introduction*. Oxford, UK: Blackwell.
- Oakes, T. (1999). Eating the food of the ancestors: Place, tradition, and tourism in a Chinese frontier river town. *Cultural Geographies*, 6, 123–145.
- Pred, A. (1990). *Lost words and lost worlds: Modernity and the language of everyday life in late nineteenth-century Stockholm*. New York: Cambridge University Press.



FOOD, GEOGRAPHY OF

Everyone needs to eat. This basic fact of life is complicated by the rich variety of social meanings and environmental practices associated with food. The result is a complex, almost bewildering, geography of food. Shelves at modern grocery stores around the world are stocked with a vast range of foods, including many exotic foods that were out of reach for most consumers less than a generation ago. At the same time, hunger haunts almost 1 billion people, mostly, but not exclusively, in the global South, while small and subsistence farmers find it harder to sustain their livelihoods amid intense international market competition. Food has been an important object of economic, political, and scientific calculation and manipulation in the long-term development of globalization, as well as the foundation for social movements based on the defense of locality, nature, and culture. Understanding food's multifaceted place thus requires a geographic approach that can make sense of the complexity of food in its social and environmental contexts.

Agriculture, the planned cultivation of plants and animals for human consumption, is one of humanity's oldest markers of "civilization." It has long been the focus of new technological developments that alter the physical environment to suit human needs and has been the necessary obverse of urbanization, which facilitates the storage, trade, processing, and control of food. Geographies of food are therefore geographies of power, and the study of agricultural production in particular was of primary concern in modern geography prior to World War II. Early geographic theories and models, such as the von Thünen model, and descriptive studies of regions, all included some mention of food production and distribution, though often in narrowly economic terms. In the post-World War II period, and especially in relation to concerns with and research on population growth, environmental degradation, and development in former colonies, the study of the geography of food became increasingly interdisciplinary and, in many respects, highly technologized, as did modern agriculture itself.

Social scientists and technical specialists, including geographers, paid special attention to



A young man transports a load of green bananas near the town of Goma, province of North Kivu, Democratic Republic of Congo.

Source: Guenter Guni/iStockphoto.

agriculture's role in the development process in the decades following World War II, aiming to increase yields and efficiency through mechanization and green revolution technologies, such as new hybrid crop varieties. This shift produced more food, as the general lack of food in the developing world was understood as one of the main impediments to successful development. A more technologically and economically sophisticated farm sector would mean more food, more urbanization, and greater political, social, and economic stability. Peasant and subsistence food systems were deemed inadequate to meet the needs of developing societies, and the geography of food was remade to fit the models of development experts and the political mandates of Cold War geopolitics. While aggregate measures of food production and food security showed progress, rural dislocation, widespread environmental

change, and irreversible changes in cultural practices indicated that the geography of food was more complex than net increases in agricultural production alone could describe.

In the developed world, including communist states under the Soviet umbrella, the postwar geography of food became increasingly reliant on technological innovation as well, with industrialized food production requiring massive chemical inputs to keep pace with the increasing demand. By the 1980s, and especially in the 1990s, the technological revolution in food production shifted to the molecular level with breakthroughs in genetic engineering and biotechnology, while at the global scale, the Cold War's end produced an economic environment in which food became central to world trade and its liberalization. These were not unconnected developments, as the international trade regime instituted in the General



Agreement on Trade and Tariffs and, after 1995, the World Trade Organization (WTO), made food subject to the pressures of neoliberal globalization, centered on free trade and dominated by the interests of international investment. Many developing states reversed policies of subsidies for small farmers and food self-sufficiency in favor of increased specialization in production for export and reliance on international markets to meet national food needs. Meanwhile, states in the global North often failed to meet their own WTO obligations to cut agricultural subsidies while investing in further biotechnology research, introducing new genetically modified foods to markets and sparking a contentious debate over globalization's impacts and direction.

While such shifts mean that it is now possible to shop at a Tesco supermarket in Malaysia, enjoy imported mangoes in the convenience of a Chicago home, or eat at McDonald's almost anywhere in the world, understanding the spectacular explosion of global food connections must not neglect the localized and contested networks of people, places, and processes that are the other side of globalization. Numerous food-based challenges to the neoliberal version of globalization have arisen, including consumer advocacy groups in the global North concerned with food safety, organic and "slow-food" movements centered on industrialized food's detrimental ecological and health effects, and calls for "food sovereignty" and localization from farmers' movements around the world, wherein consumers seek to purchase food grown nearby, thus saving transport costs and energy inputs. These critiques and alternatives reassert the importance of the personal, local, and regional scales in our social relationship to food and rely on claims about the centrality of public and ecological health, rather than profit maximization and investor rights, for regulating food.

Geographers examining food today have a wealth of information and examples with which to work. Attempts to reconcile, or even overturn, narrowly economic perspectives on food with theoretical approaches that recognize the vital cultural, social, and political roles of food in daily life have also produced overt challenges to the geography of food underwritten by the institutions of neoliberal globalization. The future of

food remains open to debate, but a food system that can ensure social justice, ecological sustainability, and human security requires taking seriously all aspects of the geography of food and working to understand the ways in which food, place, and society are intertwined.

Jamey Essex

See also **Agricultural Biotechnology; Agriculture, Industrialized; Agriculture, Preindustrial; Agroecology; Agrofoods; Aquaculture; Consumption, Geographies of; Famine, Geography of; Fish Farming; Food and Agriculture Organization (FAO); Hunger**

Further Readings

- Atkins, P., & Bowler, I. (2001). *Food in society: Economy, culture, geography*. London: Arnold.
- Morgan, K., Marsden, T., & Murdoch, J. (2006). *Worlds of food: Place, power, and provenance in the food chain*. Oxford, UK: Oxford University Press.
- Watts, M., & Goodman, D. (1998). *Globalising food: Agrarian questions and global restructuring*. London: Routledge.



FOOD AND AGRICULTURE ORGANIZATION (FAO)

The United Nations' (UN) Food and Agriculture Organization (FAO) is the international organization responsible for improving food security and forest management through the collective efforts of its member states. For geographers it is an important source of international land use statistics.

History and Constitution

The FAO was founded in 1945 at the first session of the FAO Conference, held in Quebec City, Canada. Its Forestry and Forest Products Division was established in 1946. The conference is FAO's supreme governing body, and all member states, which currently number 191, attend its biennial meetings. It elects FAO's director-general, who manages the secretariat, and the



council, a body of 49 member states that meets at least four times between conference sessions and is FAO's executive organ.

FAO's activities are undertaken by the Departments of Agriculture and Consumer Protection, Fisheries and Aquaculture, Forestry, Economic and Social Development, Natural Resources Management and Environment, and Technical Cooperation. The first three departments have their own supervisory committees on which member states are represented.

FAO's staff of 3,600 people are deployed in its headquarters office in Rome, 5 regional offices, 9 subregional offices, 5 liaison offices, and 74 country offices.

Status Within the United Nations System

The FAO is a specialized agency of the UN. As with similar bodies, such as the UN Educational, Scientific and Cultural Organization (UNESCO), it reports to its own member states, not to a UN central organ such as the General Assembly or the Economic and Social Council. In contrast, programs of the UN, such as the UN Development Programme and UN Environment Programme, do report to central organs and receive their budgets from central funds. The World Food Programme, whose mandate is to respond to food emergencies, is jointly responsible to the UN General Assembly and the FAO but is based at FAO headquarters.

Studies of FAO

Organizations within the UN system come under the more general heading of "international organizations" (IOs). These are generally understood in the international relations literature to be sustained groupings of states, convened for a common purpose and operating according to an agreed set of rules or institutions. In the neoliberal theory of international relations, such institutions help reduce the instability caused by the self-interested decisions of states.

The day-to-day operations of an IO are carried out by a secretariat. Few academic analyses of these have been undertaken, and many of them deal with the World Bank. Studies of IOs have

focused on those that maintain peace and security, thereby giving prominence to member states rather than to secretariats. Yet in specialized agencies such as the FAO, which are mainly concerned with technical, not political, matters, the role of the secretariat assumes great importance. Sadly, most IOs do not facilitate external studies, perhaps because they equate critical academic evaluation with negative "criticism."

Two key research questions currently being addressed in this field are the subject of recent books. First, how autonomous are IOs in relation to their member states? Second, how autonomous are the bureaucratic secretariats of IOs?

Role Within the Forestry Profession

The FAO's Department of Forestry provides a global nexus for the reproduction of the common institutions of professional foresters, taking over a role previously exercised by European colonial forest services. Many foresters still work for governments, and at any time a significant proportion of the FAO's staff are seconded by member states. The FAO publishes the journal *Unasylva* and every 6 yrs. (years) convenes the World Forestry Congress, one of the largest international gatherings of foresters.

FAO Statistics on Forests and Land Use

FAO publishes various types of international statistics. Three are particularly relevant to geographers:

1. Statistics on world trade in forest products are published annually in the *FAO Forest Products Yearbook* by the FAO Department of Forestry.
2. Statistics on land use are published annually in the *FAO Production Yearbook* by the Statistics Division of the FAO Department of Economic and Social Development. These include data under the following headings: Arable Land, Permanent Crops (e.g., tree crops), Permanent Meadows and Pastures, Other Land, and, until 1995, Forests and Woodlands.
3. Statistics on global forest resources were published in the *World Forest Inventory* series between 1948 and 1963 by the FAO



Department of Forestry and the joint Agriculture and Timber Division of the UN Economic Commission for Europe (ECE) and FAO in Geneva, Switzerland. Statistics on temperate forest resources were then published periodically by ECE/FAO. In 1981, the FAO Department of Forestry produced an encyclopedic *Tropical Forest Resources Assessment 1980*, which was followed in 1993 by *Forest Resources Assessment 1990 (Tropical Countries)*. In 1995, global coverage was resumed with the publication of *Forest Resources Assessment 1990: Global Synthesis*, which included temperate forest statistics from ECE/FAO. *Global Forest Resources Assessment 2000* was the first to apply uniform definitions to all forests.

The Use of FAO Statistics in Geographical Studies

Statistics on tropical forest areas and deforestation rates in FAO's *Forest Resources Assessments* (FRAs) have been used in 159 academic studies. Of these, 47 involved constructing cross-sectional regression models to make international generalizations about the factors causing and controlling deforestation, 33 entailed monitoring or forecasting trends in carbon stocks and emissions in relation to global climate change, and 18 involved monitoring or forecasting trends in biodiversity. The remainder were generally descriptive in content.

Few of these studies evaluated the quality of the FRA data they used. Regression studies that identified population growth as a significant variable driving deforestation were unreliable because many FRA estimates relied on models including population growth rates. There are numerous inconsistencies among statistics in successive FRAs, for example, between estimates of forest areas and overall trends in forest areas. These stemmed from difficulties in combining large numbers of national statistics in a coherent way. Annual Forests and Woodlands statistics in FAO *Production Yearbooks* have been used in some deforestation studies. But as these statistics are only those reported each year by governments, not measured each year, their quality is not very high.

Alan Grainger

See also **Agroecology; Agrofoods; Agroforestry; Deforestation; Food, Geography of; Forest Degradation; United Nations**

Further Readings

- Barnett, M. N., & Finnemore, M. (1999). The politics, power, and pathologies of international organizations. *International Organization*, 53, 699–732.
- Barnett, M. N., & Finnemore, M. (2004). *Rules for the world: International organizations in global politics*. Ithaca, NY: Cornell University Press.
- Beigbeder, Y. (1987). *Management problems in United Nations organizations: Reform or decline?* London: Pinter.
- Finnemore, M. (1999). *National interests in international society*. Ithaca, NY: Cornell University Press.
- Grainger, A. (2007). The role of end users in an international statistical process: The case of tropical forest statistics. *Journal of Official Statistics*, 23(4), 553–592.
- Hawkins, D. G., Lake, D. A., Nielson, D. L., & Tierney, M. J. (2006). *Delegation and agency in international organizations*. Cambridge, UK: Cambridge University Press.
- Keohane, R. O. (1984). *After hegemony*. Princeton, NJ: Princeton University Press.
- Lambin, E. F. (1997). Modelling and monitoring land-cover change processes in tropical regions. *Progress in Physical Geography*, 21, 375–393.
- Rudel, T., & Roper, J. (1997). The paths to rainforest destruction: Crossnational patterns of tropical deforestation, 1975–90. *World Development*, 25, 53–65.



FOOTPRINT ANALYSIS

See Ecological Footprint



FORDISM

The term *Fordism* was originally invoked by early-20th-century trade union activists to describe the



brutal system of machine-paced production methods deployed in automobile plants owned by Henry Ford. Ford's method radically transformed the conditions and rhythm of work on the shop floor. In the 1930s, *Fordism* was used by the Italian Marxist political theorist Antonio Gramsci to denote the peculiarly American form of modern production prefiguring a new stage of industrial capitalism. For late-20th-century social theorists, the system of production at Ford Motor Company in Michigan, first at the Highland Park plant in the 1910s and then at the massive River Rouge factory beginning in the late 1920s, was often used as the exemplary case of classic Fordism.

A hallmark of classic Fordist production is that large numbers of semiskilled and unskilled workers perform routine standardized tasks arranged sequentially to facilitate the steady and rapid flow of materials from one station to the next. In the Fordist system of mass production, the high volume of output allows the company to spread the cost of expensive, single-purpose capital equipment over a large number of outputs, thereby exploiting economies of scale in the production of consumer goods. This production process contrasted with the small-batch method, in which skilled craft workers would use mostly hand tools to fabricate parts and assemble the product in discrete stages. Machine pacing allowed managers to "speed up" the production process by increasing the pace at which the conveyor moved work through the plant. One of the key characteristics of classic Fordism is the extensive use of mass production techniques that shift control over the pace of work from craft workers to machines and managers. As such, Fordism has come to be seen as the antithesis of craft-based, multiskilled, team-supervised production processes.

Mass production facilities were not only labor intensive, they were land intensive as well. So the central city was no longer a viable site for manufacturing because it could not accommodate the spatial requirements of mass production. The mass production factory layout required a horizontal floor plan to promote the efficient movement of parts and subassembly processes. This technological factor compelled firms to locate outside the central city. In addition, resistance to unionization and fear of spreading strike activity motivated owners to begin to spatially isolate their

massive production facilities. In the auto industry of the late 20th century, a similar set of considerations underlie the construction of "greenfield" facilities by Toyota, Honda, and BMW in Alabama, Southern Ohio, and South Carolina.

The spatial logic of Fordist production relied on the dual requirements of ready access to unskilled and semiskilled labor and relatively inexpensive land. For example, the River Rouge plant, built in the Detroit suburb of Dearborn, was a sprawling facility that internalized the chain of commodity production by fabricating parts on site. In addition, Ford owned copper mines in the Upper Peninsula of Michigan and a rubber plantation in Brazil. So another signal feature of Fordist production is centralized production and direct control of resources. However, the situation at Ford Motor was more complicated than this. At the same time when the Rouge plant was in operation, Ford experimented with the production of decentralized parts under varying technological and social conditions ranging from highly skilled unsupervised work teams to unskilled small-scale versions of mass production and hybrid operations combining aspects of mass production with craft practices. This strategy suggests that classic Fordism was at best partial and incomplete even at Ford Motor and implies that the concept of Fordism serves as an ideal type.

In the early to mid 20th century, the basic characteristics of classic Fordist mass production quickly became synonymous with modernity, rationality, and efficiency. Fordist practices were studied and applied to manufacturing in the non-capitalist countries of Eastern Europe. Fordist principles and aesthetics captivated modern 20th-century architects, notably Le Corbusier. Single-family housing, manufactured using mass production techniques by developers such as Abraham Levitt in Long Island, New York, provided an affordable option to working-class families, allowed suburbanization, and encouraged patterns of spatial segregation by race and class.

The viability of Fordist production depends on the successful synchronicity of mass production with mass consumption. Wages need to be high enough to generate sufficient sales of mass-produced consumer goods. Ford's \$5 per day, introduced in 1914, was a significant increase in wages and is emblematic of this strategy, although



Workers are photographed on a flywheel assembly line at the Ford Motor Company's Highland Park, Michigan, plant in 1913. The use of a moving line reduced a car's assembly time from 12 hours to 93 minutes.

Source: AP Photo/Ford Motor Company.

the rationale for the \$5 day involved reducing costly worker turnover and forestalling the threat of unionization as much as providing workers with a new consumption standard. Union wage demands became defined in terms of the ability of workers to afford mass-produced consumer goods throughout the early and mid 20th century. In addition, the Keynesian welfare state was charged with sustaining consumption in the face of declining employment and stagnant real wages. According to "regulation theory," the creation of a national political economy premised on mass production, mass consumption, collective bargaining,

and a government income support policy characterized the Fordist regimes established in Western Europe, Australia, the United States, and Canada after World War II.

Proponents of post-Fordism or flexible specialization maintain that in light of the breakdown of mass production and unraveling of the Keynesian coalition in the 1970s, new systems of production began to take hold. These alternatives to mass production required access to highly skilled workers able to perform a variety of tasks, participate in team production, and maintain flexible work schedules. This theory assumes a schism between



Fordism and its other (post-Fordism, flexible specialization) that elides any interdependencies between the two forms of production. Instead, mass production and small-batch production, unskilled work and skilled labor, horizontal integration and outsourcing of production are all elements of capitalist production reflecting temporal variations in both the spatial flows of capital and shifts within a global division of labor. Indeed, within contemporary transnational networks of production dominated by neoliberal economic policies, intranational Fordism is being displaced by a global system in which Fordist mass production facilities, located within largely developmental and transitional nation-states, supply consumer markets in core capitalist countries.

Bruce Pietrykowski

See also **Automobile Industry; Economic Geography; Flexible Production; Industrialization; Labor, Geography of; Regulation Theory**

Further Readings

- Aglietta, M. (1979). *A theory of capitalist regulation: The U.S. experience*. New York: Verso Press.
- Biggs, L. (1995). Building for mass production: Factory design and work process at the Ford Motor Company. In R. Asher & R. Edsforth (Eds.), *Autowork* (pp. 39–63). Albany: State University Press of New York.
- Gramsci, A. (1971). Americanism and Fordism. In Q. Hoare & G. Smith (Eds.), *Selections from the prison notebooks* (pp. 277–318). New York: International Publishers.
- Hounshell, D. (1984). *From the American system to mass production, 1800–1932*. Baltimore: Johns Hopkins University Press.
- Peck, J. (1996). *Work-place*. New York: Guilford Press.
- Pietrykowski, B. (1995). Fordism at Ford: Spatial decentralization and labor segmentation at the Ford Motor Company, 1920–1950. *Economic Geography*, 71, 383–401.
- Piore, M., & Sabel, C. (1984). *The second industrial divide: Possibilities for prosperity*. New York: Basic Books.

FOREIGN AID

Broadly speaking, foreign aid implies a transfer of resources from one country, referred to as the donor, for the benefit of another, called the recipient. This transfer can take place directly, through bilateral channels, or indirectly, through multilateral ones. The purpose of aid varies over space and time, ranging from military aid to humanitarian. In more strict definitions, the concept refers exclusively to official development aid, which should be distinguished from humanitarian or relief aid. The former aims at finding long-term solutions that allow recipient societies to meet and generate solutions to their needs, the latter at alleviating human suffering in urgent situations. Flows of resources aiming at generating development are of three types: (1) official development assistance (ODA), (2) foreign direct investment (FDI), and (3) private donations. According to the Organisation for Economic Co-operation and Development (OECD), ODA includes grants or loans to developing countries that are (a) undertaken by the official sector, (b) with promotion of economic development and welfare as the main objective, and (c) at concessional financial terms (if a loan, have a grant element of at least 25%). Grants, loans, and credits for military purposes are generally not included, but it was exactly in this field that the history of aid began. Today, the relevance of foreign aid lies in the fact that it is one of the most important means used to assist the developing world in achieving poverty reduction and economic and social advance.

History

In Western history, the origins of foreign aid can be traced back to when states supported militarily strategic partners, but it is not until the 18th century that foreign aid became more systematic. The best examples are, perhaps, the use of British foreign aid in its rivalry with France or the subsidies of Prussia to some of its allies. The 19th century witnessed the first steps toward foreign aid as we know it today. In 1812, the U.S. Congress passed the Act for the Relief of the Citizens of Venezuela. In the 1870s, the first discussions on the finances for the colonies took place in Britain,



leading gradually to Britain's passage of the Colonial Development Act in 1929, which provided modest government funds to facilitate development in the colonies rather than forcing them to rely on exports of agricultural goods. However, many of the ideas and infrastructure that sustain present foreign aid were born in the post-war period. The Bretton Woods Conference in 1944, the establishment of the United Nations in 1945, the launching of the Marshall Plan in 1947, the creation of the UN Technical Assistance in 1949, and the Development Assistance Committee (DAC) of the OECD in 1961 mark some of the grounds of modern foreign aid. The scale of foreign aid grew bigger with the independence of nation-states in the developing world.

Since its start, modern foreign aid has shifted strategies. The driving forces that lie behind this are to be found in the relationship between foreign aid and development doctrines. Thus, during the 1950s, when belief in industrialization prevailed, foreign aid focused on aggregate large-scale resource transfer to trigger or speed up the Rostovian industrial "take-off." In the late 1960s, economic dualism between the innovative export sector and a traditional, locally oriented one, as well as human-capital issues such as education and technical training, became relevant to development theories, making foreign aid incorporate more issues such as education and rural development. A further shift took place during the mid 1970s, when development theories began pointing at serious hindrances to economic development related to rural-urban migration, unemployment, and mass poverty. In the 1980s, the deep economic stagnation in Africa and the inability of different political regimes to overcome it were hard to ignore. In this state of things, the successful East Asian economies attracted attention and became the central model in development debates. Based on specific interpretations of this success, foreign aid became more conditional and focused on structural adjustment programs that were supposed to discipline the political and economic systems through market mechanisms. Until the mid 1990s, structural adjustment programs were still the main tool for both development strategies and foreign aid. However, since the late 1990s, it became obvious to many, including the World Bank and the IMF themselves, that if foreign

assistance to developing countries was to continue it should retake poverty reduction strategies.

Today, the so-called Millennium Development Goals are the target toward which the United Nations and the international community's endeavors are directed, becoming the actual core of the hegemonic discourse. The first of these goals is to halve global poverty and hunger by 2015.

Geographies of Foreign Aid

Little work in the discipline of geography has been done on the study of spatial distributions of foreign aid. Most of the studies that explored the issue from a geographic perspective are dominated by disciplines such as international relations and political science.

Nevertheless, a brief look at foreign aid flows during the postwar period reveals that the bulk originates from the 22 DAC members, which consist of the 15 original European Union members, Australia, Canada, Japan, New Zealand, Norway, Switzerland, and the United States. Among these, the United States contributes the most, followed by Japan and the EU members.

In absolute terms, foreign aid has grown since the 1960s. There is a clear decline, however, when foreign aid is measured as a proportion of the gross domestic product (GDP). The figure is far below 0.7%, which is the goal set by the OECD. Between 1990 and 1996, the average GDP proportion for the DAC members declined from 0.33% to 0.22%. Today, only a few DAC members, such as Norway, Denmark, Luxembourg, Sweden, and Holland, are fulfilling the goal of 0.7%.

From the recipient perspective, the inflows have been quite diverse for the different regions. The most populated region, Asia, has received much less foreign aid per capita than both Africa and Latin America. Between 1960 and 2004, the inflows to Asia have been very stable and low, always below \$1 per capita. Paradoxically, the material and economic conditions, especially the economic growth, are today far better in East Asia than elsewhere. This observation reemphasizes the idea that foreign aid is only one part of economic development and could never explain the motions of economic development *per se*.

It is worth noting that the practice of foreign aid is no longer exclusive to the developed world



as countries such as China, India, and South Korea are becoming important donors.

Controversies

After more than 50 years and more than \$1 trillion spent on foreign aid, there is still no compelling evidence that aid promotes economic development. Many scholars suggest that foreign aid can only play a modest role. Endogenous factors such as the institutional environment and the competence and goodwill of the leadership are crucial. Much research claims the relevance of the above-mentioned factors; some refer to them as the *absorptive capacity* of recipient countries. However, opinions differ on how the donor community should proceed. There are those who underline the opportunities that an increase in foreign aid could ensure, while others draw attention to the negative effects it might engender. The first group claims that with an increase in foreign aid combined with better donor coordination, foreign aid can improve the economic situation in recipient countries. In opposition, the latter group suggests that with more foreign aid, dependency will grow stronger, while the capacity to mobilize domestic resources, to create a national economic basis, and to compete internationally will be drastically diminished. These critics also warn that corruption may increase in the foreign aid chain.

Yahia Mahmoud

See also **Developing World; Development Theory; Organisation for Economic Co-operation and Development (OECD)**

Further Readings

- Hjertholm, P., & White, H. (2004). *Survey of foreign aid: History, trends and allocation*. Copenhagen, Denmark: University of Copenhagen.
- Kodras, J. (1993). Shifting global strategies of US foreign food aid, 1955–1990. *Political Geography*, 12, 232–246.
- Organisation for Economic Co-operation and Development. (2007). *Development aid at a glance: Statistics by regions*. Bedfordshire, UK: Turpin.

FOREIGN DIRECT INVESTMENT

Foreign direct investment (FDI) occurs when a foreign investor exerts direct control over domestic assets. It normally consists of an international capital flow from the home country to a host country for the purpose of acquiring partial or full ownership of tangible business activity. Technically, it is the book value of the equity held by the foreign investor that is attached to the asset. In most cases, the asset is a firm in a developed country, such as the United States, and the equity consists of two components: ordinary (common stock) and retained earnings. If both foreign and domestic investors own the common stock, then only a portion held by foreign investors is considered to be FDI, and if only a threshold percentage is attained, that is deemed to give the foreign investor control of the business. In the United States, this threshold is 10%, but some countries establish a higher minimum level of stock ownership, usually 25%.

Foreign investment can take place in two ways: Foreign investors can establish new firms overseas, which they control, or foreign investors can acquire controlling interests in the previously established domestic firms, or spin-offs of such firms. FDI as a vehicle of transnationalization is a major contributor of economic development. Transnational corporations (TNCs) act as significant transmitters of economic, social, cultural, and political change into different countries, sectors, and motivations. TNCs take advantage of geographical differences in the distribution of factors of production (natural resources, capital, labor, etc.) and local policies (taxes, trade incentives, subsidies, etc.). Other than FDI, TNCs engage in various kinds of collaborative ventures by which they coordinate and control transactions within geographically dispersed production networks. Resulting from these ventures, the global economy is envisaged as linking together two sets of networks: (1) organizational (in the form of production circuits and networks) and (2) geographical (which include localized clusters of economic activity).



Theories of Foreign Direct Investment

There are several theories that attempt to account for foreign aid. The prevailing ones include Dunning's eclectic approach and the product cycle. John Dunning's eclectic paradigm emphasizes the critical role of geographical location in understanding the complex nature of TNC behavior. The location aspect, as encapsulated in this theory, suggests three primary motivations: (1) foreign-market-seeking FDI, (2) efficiency (cost reduction)-seeking FDI, and (3) resource-seeking or strategic-asset-seeking FDI. In general, a firm's motivations to be transnational can be classified into two categories: (1) market orientation, which pertains to marketing, sales, or production designed to serve a specific geographical market, and (2) asset orientation, when most of the assets required by a firm to produce and sell specific goods and services have an uneven geographic distribution, especially in the natural resources industry. For a TNC to invest successfully abroad, it must possess advantages that no other firm has, the country it wishes to invest in should offer location advantages, and it must be capable of internalizing operations. Internalization tends to become synonymous with the ability of firms to exercise control over operations essential for the exploitation of ownership and location advantages. Raymond Vernon introduced the "locational" aspect to the product life cycle concept, which in the original form had no spatial connotation. First advanced in the mid 1960s, it emanated from the premise that the United States possessed comparative advantage in product innovation. To maximize production flexibility and minimize uncertainties in the early stages of a product's life cycle, firms develop innovations for and introduce them to large high-income domestic markets but eventually set up foreign production facilities in other advanced economies to defend their monopolistic advantages resulting from an innovational lead. This also happens because, as products become more standardized, they get more price sensitive and firms turn to low-cost less developed countries (LDCs) to maximize profits. Vernon describes the phases as revolving around product development, product growth, product maturation, and product standardization.

Impacts of FDI

However, not all FDI is always in the best interest of the host country. Some nations have been increasingly viewing TNCs as a threat to economic autonomy. At times, they tend to be responsible for exerting negative influences on the host economy, for example, crowding out domestic firms and suppressing domestic enterprises. Profit maximization is inherently linked with maximization of efficiency and not necessarily with national, economic, and social goals. From the perspective of TNCs, various decisions have to be taken that can affect their effective working in the country—mainly since they operate in different economic, political, social, and cultural environments.

A lot is said as to why firms choose to transnationalize rather than simply export their products. Two of the reasons commonly cited are that (1) competition is extremely global and volatile and (2) it creates an environment wherein advantages are rapidly created and eroded. Firms increasingly compete not with rivals on a national level but across the globe. Higher sales and profits result from foreign subsidiaries because domestic markets, where the company started, tend to get saturated over time and it is fruitful to conquer foreign markets with more potential consumers than in the home country. The information technology revolution, which began in the United States in the 1980s, was an important source of structural change in the international economic and business environment affecting FDI. There was a sudden upsurge in asset-seeking direct investment in the United States. Foreign companies, chiefly European, were responsible for a gamut of mergers and acquisitions with U.S. companies—primarily with those possessing advanced technology or marketing prowess. The size and growth of the U.S. and Chinese markets have made these countries primary destinations for foreign companies using FDI as a stimulus for profits.

Importance of FDI

FDI has been known to provide a longer-term contribution to GDP and income growth, as against bank loans and portfolio investments.



The long-term perspective of FDI makes it relatively less volatile. FDI is considered to be an important carrier facilitating the spread of technology and is said to contribute to growth in a much wider way than does domestic investment. The contribution of FDI is enhanced due to the interactions with human capital in the host country.

Furthermore, FDI is said to expand the level of know-how in the host country through training and skill acquisition. Summarily, the four basic reasons why companies establish subsidiaries in foreign countries are (1) gaining access to natural resources, (2) protecting or expanding sales in lucrative markets, (3) seeking low-cost production, and (4) acquiring strategic assets. The United Nations, the European Union, and Japan have been the main sources and recipients of FDI for the past several decades. From 1998 to 2000, these three units together accounted for 75% of global FDI inflows. In totality, a country's climate for FDI is built by factors such as relatively accommodative government policies—covering trade barriers and regulation of capital inflows; quality of governance; political stability; presence of laws and regulations; macroeconomic, fiscal, monetary, and industrial policies; and quality of infrastructure.

Foreign Direct Investment in Emerging Economies

The United States continues to be the largest FDI host country, with about US\$2791.3 billion in 2007. The outward investment position increased to US\$336.6 billion. Among the outward investments, about US\$16.1 billion (3.1%) went to Ireland and US\$4.2 billion (3%) to Singapore.

Among emerging economies, China's role as an investor country has been highlighted in the past few years. By 2004, China was the eighth most favored FDI source among developing countries. The liberalization of Chinese FDI policy in 1992 led to increased Chinese outward direct investment (ODI). The growth in Chinese ODI policy developments was driven by cautious internalization, government encouragement, expansion and regulation, implementation of a "go global" policy, and heightened domestic competitive pressures, which led to the opening up of protected industries and markets to foreign and

domestic competitors. A comparative advantage as a manufacturing hub and a firm-specific advantage such as state-ownership of a large part of an industry further stimulate this growth. Chinese ODI has been positively associated with Chinese exports to the host country (the former promoting the latter), a moderate demand of inflation, and rising levels of political risk in the host country. A distinctive feature that remains with China as against other emerging economies is that many of its multinational enterprises remain in state hands, although corporatized to focus on commercial objectives. China's overall FDI inflows stood at US\$82.7 billion, an increase from US\$69.47 billion. The top 10 FDI inflows were mainly from Hong Kong, the British islands, South Korea, Japan, Singapore, and the United States, amounting to about US\$3 billion in 2006 and about US\$2.62 billion in 2007. According to the Ministry of Commerce of the People's Republic of China, the outbound nonfinancial FDI for the first half of 2007 reached US\$7.8 billion, while for the full year in 2006, it was US\$21.2 billion. Of this, 86% was provided by central government sources. Most of China's ODI flowed to 172 destinations, which included Latin America and Asia. In India, the overall record of macroeconomic stability, a sizable domestic market, and a relatively high degree of political stability has attracted large volumes of FDI. The foreign investment in India during 2007–2008 was driven by FDI and portfolio investment inflows. FDI inflows in India increased from US\$9.17 billion in 2005–2006 to US\$22.95 billion in 2006–2007 and US\$34.92 billion in 2007–2008. India emerged as the second most favored FDI destination after China in 2005 and 2006. During these years, investments through Mauritius remained the largest component, followed by Singapore, the United Kingdom, and the Netherlands. Inflows from the United States stood at the sixth position at US\$3.46 billion in 2005–2006, US\$7.06 billion in 2006–2007, and US\$4.86 billion in 2007–2008. Sectorwise, these inflows were mainly directed to financial services, construction, and manufacturing. On the other hand, ODIs from India increased from US\$13.5 billion during 2006–2007 to US\$17.9 billion during 2007–2008 and flowed mainly into the manufacturing sector.



Within the European Union, Ireland is fast emerging as the most FDI-intensive economy in Europe and a global competitor to R&D investment. Since the 1990s, Ireland's economic development policies, which have encouraged greenfield investments by foreign companies in manufacturing and service sectors so as to produce output for export markets, and the establishment of upstream linkages between foreign and indigenous companies and the creation of industrial clusters with them have stimulated an export-led growth of the manufacturing sector. In Singapore, another emerging FDI destination, the total ODI was recorded at US\$406.7 billion in 2005 and US\$484.1 billion in 2006. Financial services and manufacturing have been major draws for Singapore companies venturing abroad. In 2005 and 2006, Singapore invested about US\$9.8 billion and US\$8.5 billion in the U.S. market. The FDI inflow in Singapore was at US\$323.8 billion and US\$363.9 billion, the FDI inflow from the United States alone constituting about 10% of this inflow.

The current scale, proliferation, and importance of collaborative ventures between firms across boundaries have brought out the significance of transnational strategic alliances between firms (especially competing firms). Strategic alliances are formal agreements between firms to pursue specific strategic objectives in order to enable them to achieve specific goals. It involves sharing of risks and rewards. For R&D ventures, for example, cooperation is limited to research into new products and technologies, while manufacturing and marketing remain the responsibility of individual firms.

Globalization, technological advances, and the emergence of new players have propelled a change in FDI movement. Globalization, by removing most of the natural and artificial barriers to cross-border information flows and transactions, has widened locational choice options for firms. By lowering transport, communication, and distribution costs, technological advances have helped overcome many obstacles to overcome space.

Sharmistha Bagchi-Sen and Dipti Saletore

See also **Export-Led Development; Globalization; Neocolonialism; Trade; Transnational Corporation**

Further Readings

- Aliber, R. (1993). *The multinational paradigm*. Cambridge: MIT Press.
- Borensztein, E., De Gregorio, J., & Lee, J.-W. (1998). How does foreign direct investment affect economic growth? *Journal of International Economics*, 45, 115–135.
- Cohen, S. (2007). *Multinational corporations and foreign direct investment: Avoiding simplicity, embracing complexity*. New York: Oxford University Press.
- Dicken, P. (2007). *Global shift: Mapping the changing contours of the world economy*. New York: Guilford Press.
- Dunning, J., & Gugler, P. (2008). *Foreign direct investment, location and competitiveness*. Amsterdam: Elsevier.
- Graham, E., & Marchick, D. (2006). *US national security and foreign direct investment*. Washington, DC: Institute for International Economics.
- Trevino, L., & Upadhyaya, K. (2003). Foreign aid, FDI and economic growth: Evidence from Asian countries. *Transnational Corporations*, 12, 45–72.
- U.S.-China Business Council. (2008). *Foreign investment in China*. Washington, DC: Author.
- Yeung, H. (2007). From followers to market leaders: Asian electronic firms in the global economy. *Asia Pacific Viewpoint*, 48, 1–25.



FOREST DEGRADATION

Forest degradation is not a reduction of forested area but a decrease in its quality, a significant decline of its ecological condition, and/or a shift in its structure. In most cases, human-related activities are the cause of forest degradation. Parameters triggering forest degradation can be local (stand disturbances, insect outbreaks) or regional (climate change). Estimating the extent of forest degradation is challenging because it is difficult to describe the initial state of the forest and the equilibrium state (i.e., climax condition). Also, time-related problems arise due to the



longevity of the trees. It is important to distinguish forest degradation from deforestation. Deforestation involves a decrease in forest cover, a permanent conversion of forested areas to non-forested; there is no deforestation if there is continuity in the forest cover, as with forests that self-regenerate after logging.

Forest degradation occurs in different forested areas all over Earth. The degradation of the Mediterranean Aleppo pine (*Pinus halepensis* Miller) or Holm oak (*Quercus ilex* L.) forests following a significant decline of summer precipitations or the degradation of tropical forests, where the species composition changes after logging, constitute two well-documented examples. In contrast, forest degradation following natural stand disturbance is poorly documented in the literature. This entry describes forest degradation in northern areas.

Forest Degradation in the Northern Hemisphere

As the Pleistocene glaciers began to retreat gradually about 18,000 years ago (BP), species of the boreal forest began to move northward in North America and Eurasia. Around 9,000 BP, milder climatic conditions favored expansion of dense forests in northern areas. Since then, the climate has changed, and the ecological conditions allowing northern expansion of forests no longer prevail. These trees were established during warmer climatic episodes a few hundred to a few thousand years ago and have persisted by vegetative reproduction. Presently, boreal forests occupy about 17% of Earth's total land surface in the Northern Hemisphere.

The North American boreal forest belt is represented by three zones: (1) the closed-crown forest

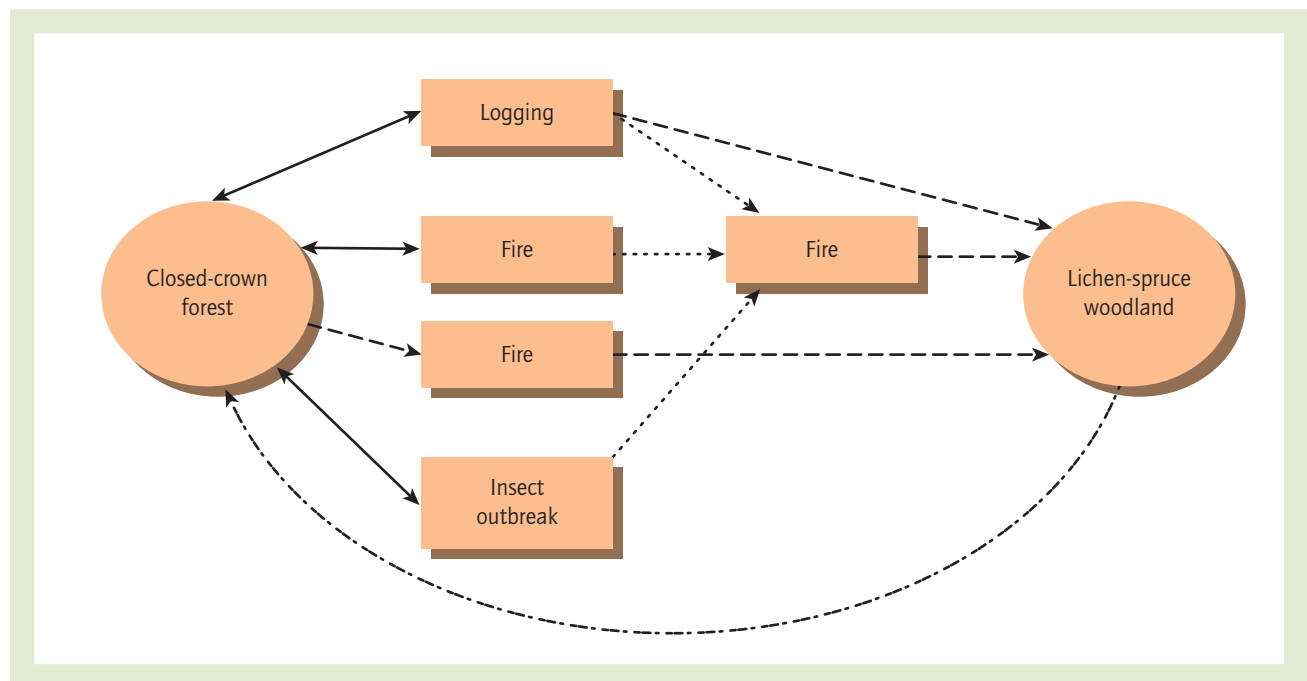


Figure 1 Model of stand disturbances causing the shift of the closed-crown forest to the lichen-spruce woodland in the closed-crown forest zone

Source: Girard, F., Payette, S., & Gagnon, R. (2009). Origin of the lichen-spruce woodland in the closed-crown forest zone of Eastern Canada. *Global Ecology and Biogeography*, 18, 291–303.

Notes: The continuous black arrows indicate good regeneration, whereas the black dotted arrows indicate poor regeneration of the closed-crown forest. The dashed black arrows represent a short interval between two disturbances (compounded disturbances). The dashed and dotted arrow indicates a possible reversion of the lichen-spruce woodland into a closed-crown forest.



zone, (2) the lichen woodland zone (or taiga), and (3) the forest-tundra zone. The closed-crown forest zone is the southernmost portion of the boreal forest. It contains the greatest richness of species, the warmest soils, the highest productivity, and the longest-growing season. North of the closed-crown forest zone is the lichen woodland zone, represented by open, sparse forest. To the north of the lichen woodland is the forest-tundra zone, which occurs along the northern edge of tree growth or tree line. Patches of trees consisting of only a few species form a complex mosaic with the tundra. Boreal forest is characterized by a limited number of conifer species such as pine (*Pinus*), spruce (*Picea*), larch (*Larix*), and fir (*Abies*) and several deciduous trees such as birch (*Betula*) and poplar (*Populus*).

Northern forests do not have a rich and complete vegetative cover due to the extreme environmental conditions, such as harsh winters, a short growing season, a high altitude, and thin soils. This particular characteristic makes them vulnerable to forest degradation. In fact, these stands usually grow and develop under an active disturbance regime including wildfires, insect epidemics, and logging. Both conifer and deciduous species can regenerate after stand disturbance to minimize forest degradation. Following a fire, however, several conditions have to be met to facilitate adequate forest regeneration: (a) the trees have to be old enough to reproduce; (b) the trees have to be in good health, that is, not affected by insects or viruses; (c) the seeds need an adequate seedbed for germination, that is, the mix of mineral soil and organic matter; and (d) there must be a dense prefire tree cover. These conditions are more important for monospecific stands because regeneration failure of the dominant species induces forest degradation.

Closed-crown forest degradation in the black spruce stands of Eastern Canada involves stand disturbances (Figure 1). The transformation of the closed-crown forest in lichen-spruce woodland is the consequence of a regression process of the boreal forest triggered by stand disturbance. Generally, natural or anthropogenic disturbances ensure stand regeneration. At the other end, compounded disturbances cause the degradation of the closed-crown forest. A short interval between two disturbances can compromise

the reestablishment of the closed-crown forest. Disturbances that affect the vitality of trees in the stand, such as an insect infestation, followed shortly thereafter by a fire, can greatly increase the probability of reduced tree regeneration. A reduction in the tree density of a stand can sometimes be caused by a spruce budworm epidemic followed by logging (salvaging of dead timber or affected trees). The passage of successive fires, that is two fires arriving at an interval too short for the trees to attain maturity and reproduce, can equally cause drastic reduction in tree regeneration. Also, the passage of light fires that leave a thick organic matter layer increases forest degradation mainly because seed germination is facilitated on mineral soils where the organic matter was consumed by fire. Finally, degradation of a closed-crown forest into a lichen-spruce woodland appears to be a unidirectional process; to date, the reverse process, the transformation of a lichen-spruce woodland to a closed-crown forest, has not been observed. Once degraded into an open stand, the southern lichen-spruce woodlands resemble the lichen-spruce woodlands situated within the lichen woodland zone. The absence of the full reestablishment of closed-crown forest following a fire is equally characteristic of the regeneration pattern of the forests growing within the lichen woodland zone.

The increasing extent of lichen-spruce woodlands within the southern forest zone is a major problem for forest management, which will intensify if the present degradation trend is maintained (i.e., 9% since 1950 in Eastern Canada). Lichen-spruce woodlands are not economically exploitable for foresters, likely because of their low timber yield, which is below the threshold of durable management. Restoration of degraded forests is possible with plantation, but adequate ground preparation is required (soil scarification). Finally, tree plantation in degraded areas reduces soil erosion and decreases the probability of landslides.

François Girard and Serge Payette

See also [Anthropogenic Climate Change](#); [Biome: Boreal Forest](#); [Biome: Tropical Rain Forest](#); [Deforestation](#); [Ecosystems](#); [Forest Fragmentation](#); [Forest Restoration](#); [Global Environmental Change](#); [Landscape Ecology](#)



Further Readings

- Girard, F., Payette, S., & Gagnon, R. (2008). Rapid expansion of lichen woodlands within the closed-crown boreal forest zone over the last 50 years caused by stand disturbances in Eastern Canada. *Journal of Biogeography*, 35, 529–537.
- Girard, F., Payette, S., & Gagnon, R. (2009). Origin of the lichen-spruce woodland in the closed-crown forest zone of Eastern Canada. *Global Ecology and Biogeography*, 18(3), 291–303.
- Payette, S., Bhiry, N., Delwaide, A., & Simard, M. (2000). Origin of the lichen woodland at its southern range limit in Eastern Canada: The catastrophic impact of insect defoliators and fire on the spruce-moss forest. *Canadian Journal of Forest Research*, 30, 288–305.
- Payette, S., & Delwaide, A. (2003). Shift of conifer boreal forest to lichen-heath parkland caused by successive stand disturbances. *Ecosystems*, 6, 540–550.



FOREST FRAGMENTATION

Forest fragmentation is an aspect of deforestation. It refers to the conversion of relatively continuous forests into a system of isolated forest patches separated by agricultural, urban, or other human land use. The forest remnants may represent areas unsuitable for conversion for economic, physical, political, or cultural reasons (e.g., because of steep terrain or for nature preserve creation). Forest fragmentation is pervasive worldwide. Large-scale forest clearance and fragmentation began in parts of Europe and Asia that had long histories of dense human settlement. It spread to North America during the European settlement about 200 to 300 years ago, beginning with the eastern and midwestern forests (Figure 1). While the abandonment of marginal farmland later facilitated reforestation of some areas, many areas remain where the forest cover represents less than 30% of the landscape. Reforestation has not necessarily reduced fragmentation. In some parts of Southern Ontario, for example, fragmentation has increased in recent decades even while the total

forested area has increased. The tropics are the locale of the most widespread and rapid current or recent deforestation. This is ecologically significant because although tropical forests constitute less than 10% of Earth's land surface, they house more than half of its biological diversity. Much of Central and South America (Brazil) and southeast Asia (e.g., Malaysia, Indonesia, and Papua New Guinea) have rapid current rates of forest loss. Deforestation has slowed in areas such as West Africa, Thailand, the Philippines, and Madagascar, but these places had already lost most of their natural forest cover by the last third of the 20th century.

Forest fragmentation represents a huge change in the biogeographical context of forested systems to which plant and animal species have become adapted. Not only are the configurations of the communities changed and population sizes reduced, they are surrounded by a human landscape that may be inhospitable and intrusive. Forest fragmentation involves changes in (a) the spatial population dynamics of species in fragmented systems and (b) the biophysical environments of fragments.

Changes in Population Dynamics

In many landscapes, including North America and the tropics, fragmentation represents a relatively recent phenomenon in relation to the life spans of tree species, which constitute the bulk of forest biomass. It may take centuries for their populations to adjust to biogeographic changes, and so forest response cannot be deduced from simple measures of species composition in these systems. Theoretical constructs such as the equilibrium theory of island biogeography and other, subsequent, theoretical and computer simulation models of the behavior of disjunct populations or "metapopulations" predict that fragmentation will lead to species extinctions because dispersal among forest "islands" will be rare and insufficient to counteract ongoing local extinctions within fragments. This prediction assumes two characteristics of fragmented populations. First, population sizes in fragments are smaller and more extinction-prone than in continuous forests. Second, the long distances and potentially hostile matrix separating populations will hinder

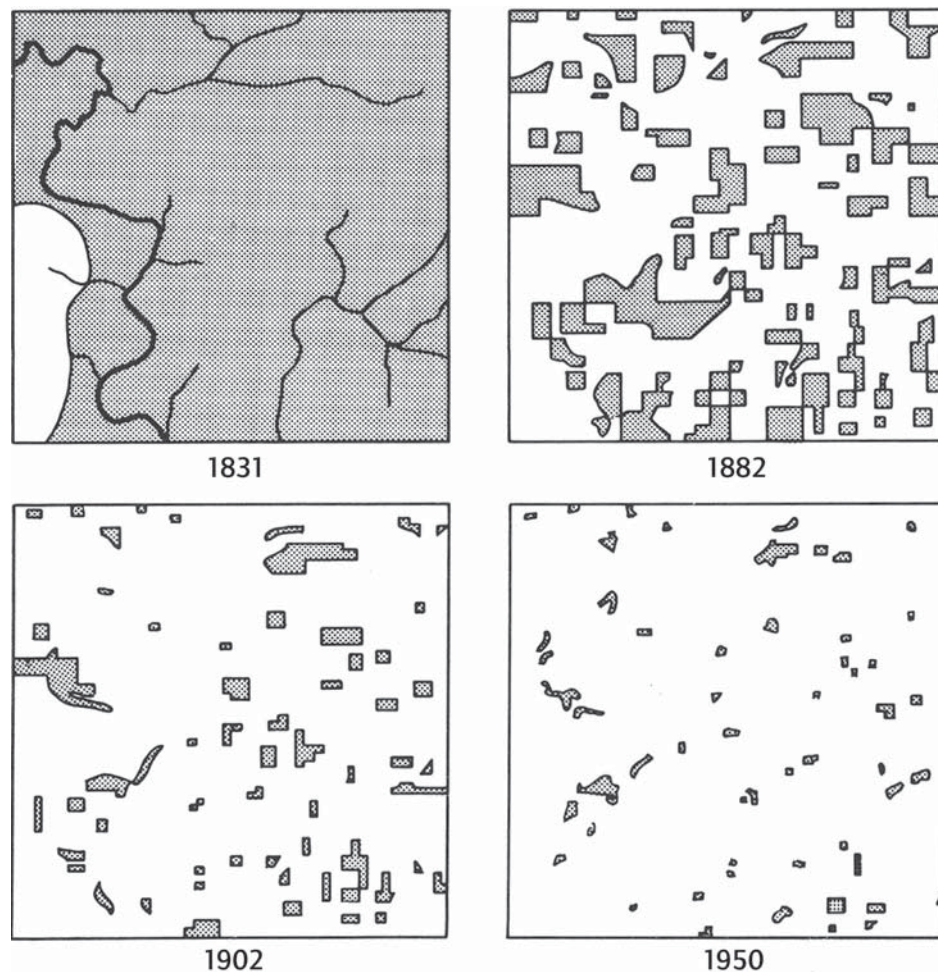


Figure 1 Deforestation and fragmentation between 1831 and 1950 in Cadiz Township, Wisconsin

Source: Burgess, K. L., & Sharpe, D. M. (Eds.). (1981). *Forest island dynamics in man-dominated landscapes* (p. 3). New York: Springer-Verlag. Reprinted by permission of Springer Science and Business Media.

Note: Dark areas are forest.

interfragment dispersal and reestablishment. The combined effect is regional extinctions.

Recent studies show that plant colonization in forest fragments is hindered by limited long-distance dispersal. For many tree species of the eastern deciduous forest biome, for example, dispersal across distances of more than 100 meters is severely limited, especially among wind-dispersed species or heavy-seeded rodent-dispersed species (Figure 2). The former tend to get strewn in the intervening matrix, where they cannot

establish, whereas the latter may be too heavy for animals to carry between fragments. Moreover, many tree species exhibit low rates of seedling establishment and survival in forest fragments (Figure 3). As a result, interfragment tree colonization is rare. Migration of some birds and mammals between fragments is also constrained by the risk of predation in exposed areas. However, connective vegetation structures such as hedgerows, fencerows, or riparian patches promote animal migration.

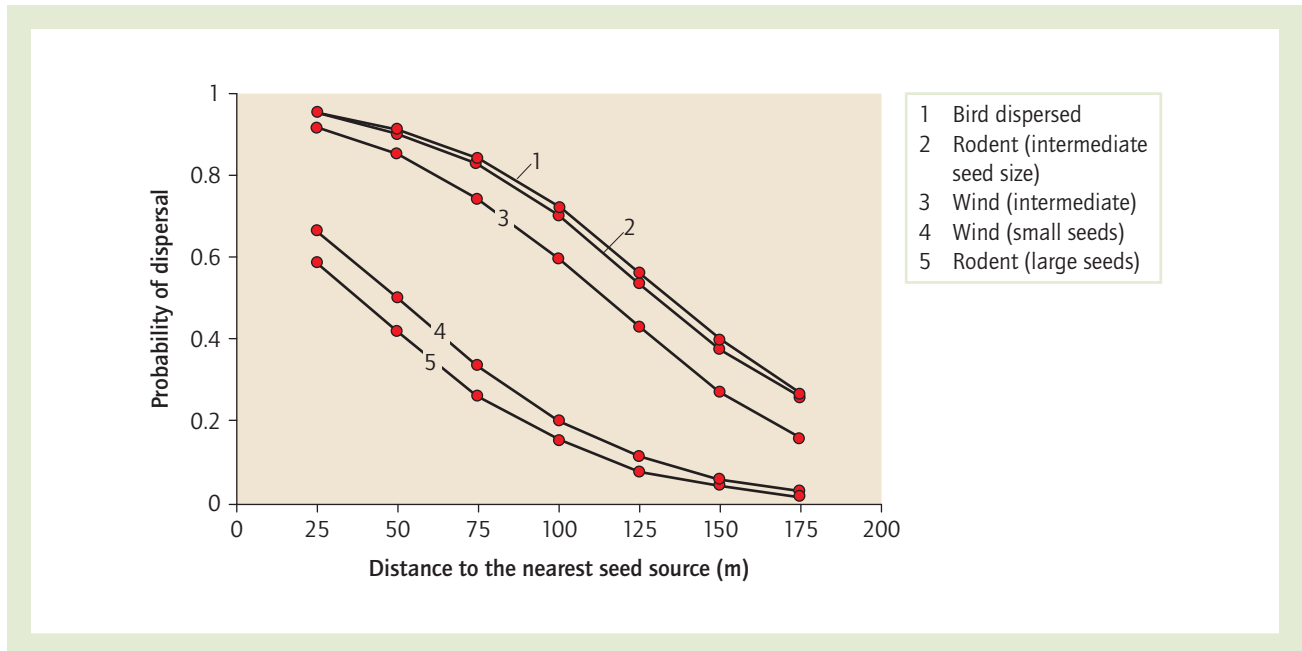


Figure 2 Probabilities of tree species' seed dispersal to and seedling establishment in forest fragments

Source: Hewitt, N., & Kellman, M. (2002). Tree seed dispersal among forest fragments: II. Dispersal abilities and biogeographical controls (Figure 3). *Journal of Biogeography*, 29, 358.

Some research suggests that fragmented habitats may provide compensatory effects that buffer species from regional extinction. This research centers on the design of nature preserves and the question of whether a single large preserve is more likely to sustain species than several smaller ones—the “single large or several small” (SLOSS) debate. Proponents of the “several small” position suggest that populations may be more likely to survive somewhere in the system in the event of disease outbreaks or natural disturbances such as fire and flood. Evidence to support this prediction is mixed. Among animal species, particularly birds, small oceanic archipelagoes with a greater degree of fragmentation have been found to support greater species richness. Similar results have been found for some understory herbaceous species. Beyond the SLOSS debate, studies of naturally patchy systems may help predict long-term effects. Forest patches concentrated along fire-protected river valleys in fire-prone landscapes in Belize and Venezuela exhibit high plant species richness compared with the nearby continuous forest. Conversely, experimental studies in human-fragmented systems indicate that the normal tendency is toward a lower species richness over time.

Changes in Biophysical Environments

Forest fragments are typically surrounded by a “sea” of human land use, whether agricultural, residential, industrial, or urban, which can alter the physical environments within. Much attention has been given to microclimatic changes near fragment edges. These “edge effects” include higher wind speeds and solar radiation at exposed edges than those in the shady, mesic forest interiors, with resultant lower relative humidities and soil moisture at the edges. These desiccating conditions tend to intrude tens of meters into fragment interiors. For plant species that are adapted to interior conditions, the suitable habitat may be restricted to a small “core” at the center of fragments, much smaller than the total forested area. Core species populations may not be large enough to remain viable over the long term, particularly in the case of rare species whose densities are low to begin with. There is, however, evidence that over time, plant species that thrive in sunny conditions may form a band of dense foliage at the edges that buffers the interior from edge effects.

The loss of forest interior habitat may also adversely affect forest bird species. Studies of

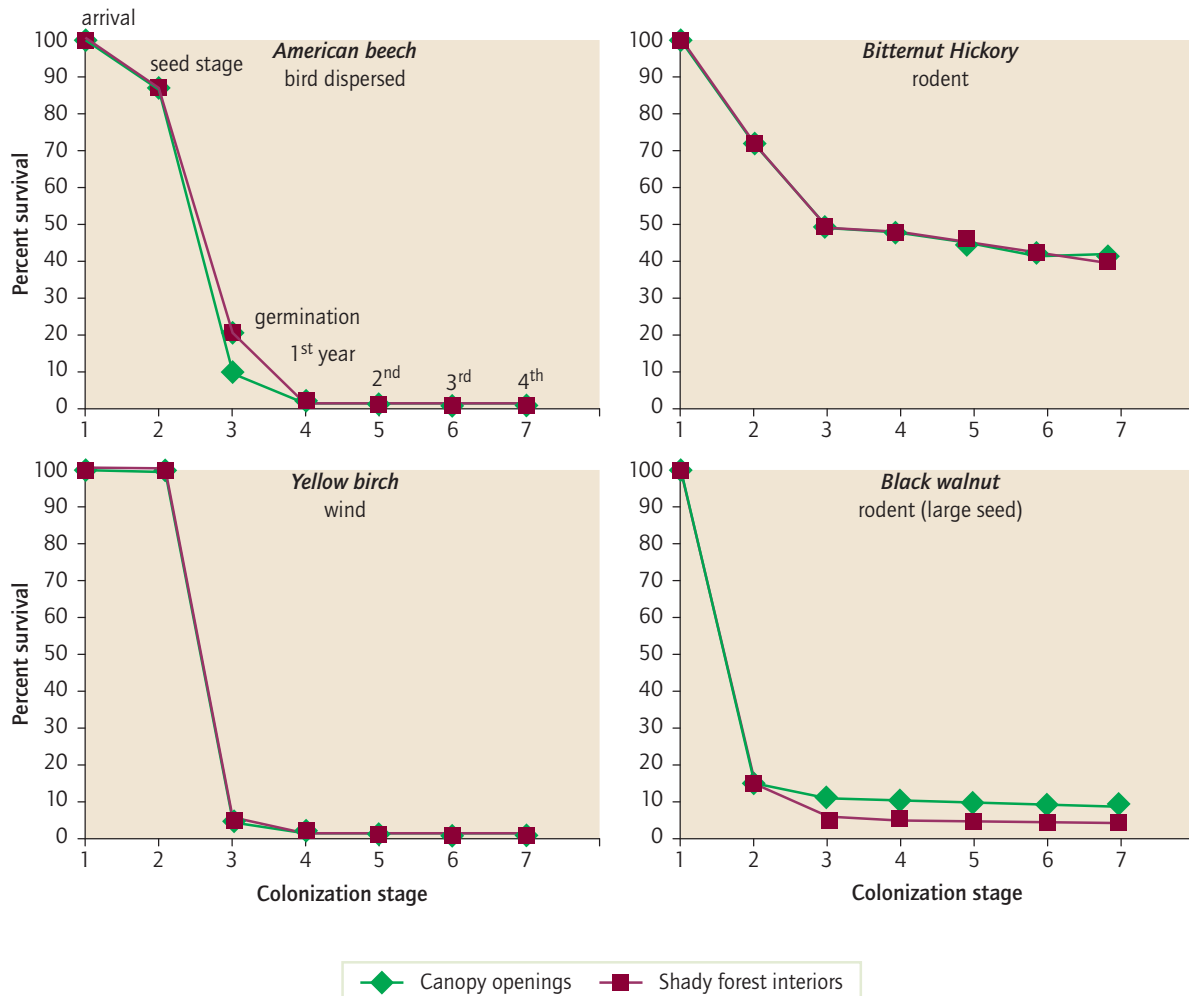


Figure 3 Probabilities of early seedling survival among native eastern tree species in Southern Ontario forest fragments

Source: Adapted from Hewitt, N., & Kellman, M. (2004). Factors influencing tree colonization in fragmented forests: An experimental study of introduced seeds and seedlings (Figure 12). *Forest Ecology and Management*, 191, 53.

midwestern and eastern forests in North America indicate increased predation at the edges by animals, such as raccoons and crows, that are abundant in the adjacent farmland and increased nest parasitism, particularly by invasive cowbirds. The situation may be different in Western North America, however, where logging, rather than agriculture, is a common cause of deforestation

and where forest environments are more naturally patchy as a result of historical fire disturbance and uneven topography. Western bird populations therefore seem to be better adapted to patchiness and have actually been found to experience lower mortality in fragments than in nearby continuous forests that harbor predatory red squirrels.



Other environmental pressures on fragmented populations include the incursion of pesticides and other pollutants into forest habitat. Insect pollinators such as bees may be particularly sensitive to pesticides. These chemicals represent a real, but as yet poorly measured, threat both to insects and to the plant species they pollinate. In built-up areas, moisture conditions may be affected at a landscape level because of the prevalence of impermeable surfaces that prevent rainfall from infiltrating the ground and replenishing soils and water tables. Sites of small-scale human disturbance such as trails, roads, and forest thinning have been correlated with a reduction in native plant species. However, a disturbance such as selective tree cutting may facilitate the establishment of shade-intolerant species in some fragmented systems and so cannot be viewed entirely negatively. Finally, a fragmented forest is more vulnerable to exotic species invasions than is a continuous forest due to the greater edge-to-interior ratio and greater juxtaposition with human activities responsible for exotic species introduction. The problem of plant invasion is compounded by the preponderance of edge habitat, which provides favorable microenvironments for characteristically weedy, shade-intolerant invasive plant species.

Implications of Global Climatic Change

Global climate change and warming will exert further stress on fragmented forests by forcing the migration of species to higher latitudes. While the pollen record shows that temperate genera had remarkably rapid rates of northward migration during the most recent deglaciation in the Northern Hemisphere, they achieved this in a landscape uninterrupted by human land use. Forest fragmentation may represent a formidable barrier to migration in a warming climate.

Nina Hewitt

See also **Anthropogenic Climate Change; Biome: Boreal Forest; Biome: Tropical Rain Forest; Deforestation; Forest Degradation; Island Biogeography; Landscape Ecology; Single Large or Several Small (SLOSS) Debate; Species-Area Relationship**

Further Readings

- Debinski, D. M., & Holt, R. D. (2000). A survey and overview of habitat fragmentation experiments. *Conservation Biology*, 14, 342–355.
- Kellman, M. (1996). Redefining roles: Plant community reorganization and species preservation in fragmented systems. *Global Ecology and Biogeography Letters*, 5, 111–116.
- Laurance, W. F., & Bierregaard, R. O. (Eds.). (1997). *Tropical forest remnants: Ecology, management, and conservation of fragmented communities*. Chicago: University of Chicago Press.
- Lindenmayer, D. B., & Fischer, J. (2006). *Habitat fragmentation and landscape change: An ecological and conservation synthesis*. Washington, DC: Island Press.
- Rodchelle, J. A., Lehmann, L. A., & Wisniewski, J. (Eds.). (1999). *Forest fragmentation: Wildlife and management implications*. Boston: Brill.
- Stutchbury, B. (2008). *Silence of the songbirds*. Toronto, Ontario, Canada: HarperCollins.



FOREST LAND USE

Forests differ from other biomes on the planet because of the large number of trees and shrubs that are found there. The Food and Agriculture Organization of the United Nations (FAO) considers any area with greater than 10% tree canopy cover as a forest. According to this definition, forests cover approximately 44 million km² (square kilometers) of Earth's surface, around 30% of the planet's land area, including a large range of forest types under different types of disturbance regimes. Three main forest types are found in the world: tropical forest, temperate forest, and boreal forest. They differ from each other in terms of tree species, physiology, and the architecture of individual trees. In general, trees are adapted to different climate regimes, but their growth is mostly limited by rainfall. The global spatial distribution of forests (composition and structure) is determined by latitude, altitude, and patterns of dispersion. Locally, forest types are determined by the microclimate, the underlying soils, and the relationship between tree species (e.g., competition).



Forest Types and Spatial Distribution

Tropical rain forests cover approximately 6% of the total surface of the planet (one fifth of the total forest area) and are located across the equatorial line. Tropical forests are considered the most diverse ecosystems in the world: They contain around one half of Earth's plant and animal species. Temperate forests are located in temperate regions of the Northern Hemisphere and are characterized by a combination of deciduous and evergreen trees. Temperate forests grow mostly in the northern latitudes, wherever there is sufficient water and it is not too cold to support the growth of large trees. Boreal forests (called taigas or swamp forests) are dominated by only a few evergreen species (e.g., spruce, fir, and larch), and they occur in a broad band across the northern regions of North America, Europe, and Asia. Boreal forests occupy regions with a cold climate and adequate moisture. They are also present across the mountainous regions of Western North America, all the way to Southern Mexico.

Forests can also be categorized according to the degree of disturbance. There are three types of forests, characterized by different disturbance regimes. Primary forests are composed mostly of native tree species, where there are no clear indications of human activities and the ecological processes (e.g., carbon sequestration, nutrient cycles) are not significantly disturbed. Modified natural forests show some presence of human activities without these forces changing the underlying function of the ecosystem. Forest plantations and seminatural forests are characterized by native tree species that have been planted or by assisted natural regeneration; they comprise very few species that have been mostly introduced and are evenly spaced.

Environmental Services

Forests are critical elements in the climate system and other global and local ecological processes, such as the carbon, oxygen, nitrogen, and water cycles. Forests influence the climate system largely by affecting the amount of carbon dioxide in the atmosphere. When forests grow,

carbon is taken from the atmosphere and absorbed in wood, leaves, and soil. Because forests can absorb and store carbon over an extended period of time, they are considered "carbon sinks." This carbon remains stored in the forest ecosystem but can be released into the atmosphere when forests are burned. Forests are critical to humans not only as providers of ecosystem services (e.g., provision of clean water and air) but also as a critical resource for human livelihoods since forests are also home to other organisms that provide important resources to humans.

Forests are used primarily for their wood and, after forest cover is removed, for agriculture. However, forests play a very important role in subsistence economies across the world, from boreal forests to tropical forests. Communities in Alaska, for example, use boreal forests as a source of food, shelter, transportation, and clothing. In the Amazon, many communities rely on forests not only for their subsistence but also for important market commodities such as rubber and Brazil nuts. In the United States, national forests are considered an important source of local products as in subsistence practices in tropical areas; a specific example is the extraction of edible mushrooms (e.g., morels) in national forests in the Western and Eastern United States.

The use of nontimber products from the forest is considered a sustainable alternative to the conflict between indigenous forest dwellers and conservation practices. Many communities (especially in the tropical regions) depend largely on their ability to gain livelihood resources from their immediate environment. The extraction of nontimber forest products is considered a sustainable activity as long as forest dwellers do not compromise the resource base. One of the major criticisms of the sustainability of nontimber product production is the lack of improvement in the lives of poorer, resource-dependent communities due to the absence of markets, relegating this to a safety net activity and a supplementary income source. The question remains whether resource availability necessarily provides the context for significant contributions to the well-being of communities that rely on forest resources.



Changes in Forest Spatial Coverage

The land area covered with forest has diminished over time. The most common land changes in the world are the transformation of forests into agricultural and urban areas and land under other types of uses. Since 1700, approximately 10 million km² have been transformed mostly into agricultural land used to produce food for human consumption. Forest change is measured by the forest density (the number of individuals and species per area) and by the amount of area covered by it. Based on these two measures, there are four different states or processes of forest transitions: (1) *deforestation*, characterized by decreasing forest area and density; (2) *reforestation*, characterized by increasing forest area and density; (3) *regeneration*, characterized by decreasing forest area and increasing forest density; and (4) *degradation*, characterized by increasing forest area and decreasing forest density.

Such events occur simultaneously in several world regions. Yet deforestation has gained the most attention because of its ecological and social implications. Globally, the net deforestation is greater than any of the other forest transitions described above. The decrease in primary forest is around 12.5 million ha/yr. (hectares per year), and deforestation is around 14.6 million ha/yr. Conversion to forest plantation is growing at 1.5 million ha/yr., around 3.1%; plantations in areas previously removed from forest, however, account for half of the net increase in forest plantations, according to Helmut Geist and his colleagues. Most of the deforestation occurs in the tropics, and most of the regrowth occurs in Western Europe and Eastern North America. Monitoring forest transitions is challenging because it requires the use of different methodologies to reduce uncertainty in the estimates. The most common techniques used to measure deforestation are forest inventories, forest plantation data, and, with technological improvements, the use of remote sensing surveys.

If monitoring the actual change of forest cover is challenging, elucidating the social drivers of such change is even more difficult. For example, the drivers of deforestation are divided into proximate and underlying processes (social and ecological). These drivers also operate at the local,

regional, and global scales. The critical element in understanding forest transitions is to determine how people make land use decisions, how biophysical settings relate to such social processes, and how they interact in specific contexts at different scales of analysis. How much forest is used or transformed relates directly to immediate actions that originate from forest manipulation (e.g., logging, extraction of nontimber products, and development of new infrastructure). It is important, however, to consider the root or the indirect drivers of such complex social, political, economic, demographic, and cultural variables (e.g., agricultural policies, markets, governance). As an example, tropical deforestation is mostly driven by forest commercialization through the growth of national and international timber markets, low domestic costs of land and labor, and fluctuations in the price of agricultural commodities.

Conclusion

The world's forests are critically important to the functioning of the Earth and for sustaining human livelihoods. Forests provide renewable raw materials and energy, maintain biodiversity, and protect land and water resources. However, they are being diminished by agricultural and urban expansion or degraded by wood extraction. Policy mechanisms such as the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries are being sponsored by international institutions such as the United Nations Framework Convention on Climate Change to provide ways to conserve forests and benefit communities that rely on forest resources. How successful such programs are in preserving forests, while not conflicting with the subsistence practices of indigenous communities, remains to be seen.

Laura C. Schneider

See also **Biome: Boreal Forest; Biome: Midlatitude Deciduous Forest; Biome: Tropical Deciduous Forest; Biome: Tropical Rain Forest; Deforestation; Environmental Services; Forest Degradation; Forest Restoration; Indigenous Forestry; Timber Plantations**



Further Readings

- Chapin, F. S., & Whiteman, G. (1998). Sustainable development of the boreal forest: Interaction of ecological, social, and business feedbacks [Electronic version]. *Ecology and Society*, 2. Retrieved December 28, 2008, from www.ecologyandsociety.org/vol2/iss2/art12
- Emery, M., & Pierce, A. R. (2005). Interrupting the telos: Locating subsistence in contemporary US forests. *Environment and Planning A*, 37, 981–993.
- Food and Agriculture Organization of the United Nations. (2005). *Global forest resources assessment 2005: Progress towards sustainable forest management*. Rome, Italy: Author.
- Geist, H., McConnell, W., Lambin, E., Moran, E., Alves, D., & Rudel, T. (2006). Causes and trajectories of land use cover change. In E. F. Lambin & H. J. Geist (Eds.), *Land-use and land-cover change: Local processes and global impacts* (pp. 41–70). Berlin, Germany: Springer.
- Lambin, E. F., Geist, H. J., & Rindfuss, R. R. (2006). Introduction: Local processes with global impacts. In E. F. Lambin & H. J. Geist (Eds.), *Land-use and land-cover change: Local processes and global impacts* (pp. 1–8). Berlin, Germany: Springer.
- Nepstad, D. (2007). *The costs and benefits of reducing carbon emissions from deforestation and forest degradation in the Brazilian Amazon*. Falmouth, MA: Woods Hole Research Center.
- Wadt, L. H. O., Kainer, K. A., Staudhammer, C. L., & Serrano, R. O. P. (2008). Sustainable forest use in Brazilian extractive reserves: Natural regeneration of Brazil nut in exploited populations. *Biological Conservation*, 141, 332–346.

and the welfare of human communities affected by those ecosystems. The Society for Ecological Restoration International defines the practice of ecological restoration as “the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.” Forest restoration represents a particular type of restoration practice.

The Need for Forest Restoration

An extensive body of scientific evidence indicates that preservation of biological reserves is not enough to stem the current biodiversity crisis. While preservation of forests in parks, reserves, and wilderness areas is critical, these landscapes are too fragmented and too small in area. Restoration of degraded and damaged forests is necessary to enable humans to sustainably live and work in ecosystems. Restoration also provides buffers and corridors for added protection and migration of species within protected areas. Forest restoration contributes to poverty reduction and prevention through the protection of water resources, mitigation of soil erosion, and provision of natural resources. Furthermore, restoration of forest ecosystems and corridors will mitigate the impacts of global climate change by enabling forest systems to respond better to stress and change and provide increased carbon sequestration and storage.

Implementation of Forest Restoration

The goal of forest restoration is not to replicate historic forest structure and composition. Given the complexity of forest systems and the multitude of compounding human impacts, it is unlikely that forests can be fully returned to historical conditions. And this is not a desirable goal in the face of uncertainty in predicting the impacts of global climate change and the increasingly multifaceted demands on forest resources (e.g., conservation of biodiversity and poverty alleviation). Rather, the goal of forest restoration is broadly conceived as the restoration of ecological processes and functions that will enable forest recovery.



FOREST RESTORATION

The widespread destruction of habitats and the associated loss of species have resulted in the development of ecological restoration projects worldwide. The restoration of degraded ecosystems can serve to improve not only the conservation of species but also ecosystem productivity



Jon Kyl (R-AZ), left, and Secretary of Interior Gale Norton view the 12-acre Gus Pearson Natural Area, August 8, 2001, in Flagstaff, Arizona. Both Kyl and Norton were surveying the experimental forest inside the Coconino National Forest to see firsthand the forest restoration techniques and how they might be implemented in other states.

Source: AP Photo/Matt York.

Forest restoration represents a long-term management commitment at multiple scales by numerous, often competing stakeholders. The most successful restoration projects fulfill social and conservation needs simultaneously, thereby ensuring the ongoing support needed to sustain the species and people dependent on the forest. Key elements of successful restoration typically include consensus planning, use of local knowledge, educating community members about environmental degradation and restoration, and ongoing monitoring. Forest restoration projects are more effective when they are considered components of continuing land management rather than isolated projects with definitive end points.

A Case Study of Forest Restoration

One of the longest-running and well-documented forest restoration projects exists in Redwood National Park in northwestern California. This national park was the first in the United States mandated to undertake an extensive forest restoration and rehabilitation program. Since 1978, Redwood National Park has used cutting-edge restoration techniques to protect its old-growth coast redwood forests and rehabilitate logged-over lands. Indeed, the national park has been at the forefront in the promotion and development of watershed-scale restoration, gaining international recognition for its forest restoration work.



As in most forest restoration projects, the work in Redwood National Park is facilitative. Restoration begins on the ground with physical rehabilitation of destabilized slopes and degraded soils and new recruitment of existing and reintroduced plants. To the extent to which it is feasible, removal of exotic species occurs concurrently. These steps enable biological restoration activities, such as accelerating the improvement of the habitat for endangered species and the integration of contemporary indigenous values in vegetation management. Restoration silviculture in the park aims to speed the development of old-growth forest wildlife habitat in second-growth forests through selective removal of trees that inhibit recovery. Restoration of ethnographic and cultural landscapes involves encouragement of traditional Native American land uses (e.g., management of hazel patches for basket-weaving materials) while restoring degraded ecosystems (e.g., prescribed burning of prairies and oak woodlands). Redwood National Park's continual emphasis on the reintroduction of processes such as disturbance agents serves the dual mission of the park—preservation and visitor enjoyment of park resources—and enables land managers to respond to changing environmental conditions.

Development of a Landscape-Scale, Geographic Perspective

The World Wildlife Fund and the International Union for Conservation of Nature have broadened the conceptualization of forest restoration to the landscape scale. Forest landscape restoration (FLR) involves landscape-scale assessments to determine where forest restoration is most appropriate and useful from both conservation and social perspectives. It aims to restore a range of forest goods, services, and processes, rather than just forest cover, and seeks a balance between development and conservation to create multifunctional landscapes. Incorporation of macrolevel and fine-scale processes forms the backbone of this strategic approach to forest restoration.

The integration of multiple-scale systems and a place-based approach in FLR has benefits from a geographic perspective. The well-developed human-environment tradition in geography

affords a framework from which to approach forest landscape restoration and provides the tools necessary to carry out such a task. In particular, remote sensing and geographic information systems are critically important tools for identification of areas on the landscape best suited for forest restoration and analyses of interactions between these areas and their surrounding human communities.

Joy A. Fritschle

See also **Adaptation to Climate Change; Biodiversity; Deforestation; Environmental Restoration; Forest Degradation; Landscape Restoration**

Further Readings

- Mansourian, S., Vallauri, D., & Dudley, N. (Eds.). (2005). *Forest restoration in landscapes: Beyond planting trees*. New York: Springer.
- Sarr, D., Puettmann, K., Pabst, R., Cornett, M., & Arguello, L. (2004). Restoration ecology: New perspectives and opportunities for forestry. *Journal of Forestry*, 102, 20–24.
- Sauer, L. J. (1998). *The once and future forest: A guide to forest restoration strategies*. Washington, DC: Island Press.
- Society for Ecological Restoration, Science & Policy Working Group. (2004). *The SER international primer on ecological restoration, version 2*. Retrieved October 20, 2008, from www.ser.org/content/ecological_restoration_primer.asp
- Underwood, S., Arguello, L., & Siefkin, N. (2003). Restoring ethnographic landscapes and natural elements in Redwood National Park. *Ecological Restoration*, 21, 278–283.



FOTHERINGHAM, A. STEWART (1954–)

Alexander Stewart Fotheringham is one of the most active researchers in geographic information science. His research includes spatial statistics, exploratory spatial data analysis, spatial interaction modeling, and spatial analysis. He is



one of the codevelopers of geographically weighted regression (GWR).

Fotheringham received his PhD and MA from McMaster University in Canada and his BSc from Aberdeen University, United Kingdom. Since 2004, he has been Science Foundation Ireland Research Professor and director of the National Centre for Geocomputation at the National University of Ireland, Maynooth. He leads an active research center, which since 2008 includes the Strategic Research in Advanced Geotechnologies group, consisting of researchers from four Irish universities working on four interconnected research strands: sensor integration, spatial algorithms, spatial visualization, and location-based services. Previously, he was professor of quantitative geography at the University of Newcastle, United Kingdom, held positions at several universities in the United States (State University of New York at Buffalo, University of Florida, and Indiana University), and was a member of the National Center for Geographic Information and Analysis. He is one of the founding editors of *Transactions in GIS* and an associate editor of *Geographical Analysis*. He has published numerous books and more than 100 journal articles. He has received numerous awards, including a fellowship from the Center of Advanced Study in the Behavioral Sciences at Stanford University, United States; the PHIAL (Public Health Intelligence Applications Laboratory) Fellowship from Victoria University of Wellington, New Zealand; and a Leverhulme fellowship.

His early work was primarily in spatial interaction modeling. Spatial interaction is defined as movement or communication over space resulting from a decision-making process. This analysis has a wide range of applications, for example, migration modeling, shopping behavior, and commuting. Fotheringham introduced a new type of spatial interaction model, the competing destination model, that linked spatial interaction analysis to spatial information processing.

Subsequently, Fotheringham's research emphasized spatial statistics, and in the mid 1990s, he introduced a new local spatial statistical method, GWR, together with his colleagues Martin Charlton and Chris Brunsdon. GWR is a spatial regression technique that removes the necessity of

assuming that spatial processes are the same everywhere and allows local modeling of such processes. Since its introduction, GWR has become one of the standard spatial analysis tools. Fotheringham continues to work on related topics, such as other geographically weighted spatial statistical methods, spatiotemporal extensions, and methodologies for easier interpretation of GWR output. He is also developing interests in spatial data capture technologies and spatial surveillance.

Urška Demšar

See also **Geographically Weighted Regression; Geostatistics; National Center for Geographic Information Analysis; Quantitative Methods; Spatial Analysis; Spatial Interaction Models; Spatial Statistics**

Further Readings

- Fotheringham, A., Brunsdon, C., & Charlton, M. (2000). *Quantitative geography: Perspectives on spatial data analysis*. London: Sage.
- Fotheringham, A., Brunsdon, C., & Charlton, M. (2002). *Geographically weighted regression: The analysis of spatially weighted relationships*. Chichester, UK: Wiley.
- Fotheringham, A., & O'Kelly, M. (1989). *Spatial interaction models: Formulations and applications*. Dordrecht, Netherlands: Kluwer Academic.



FRANK, ANDREW (1948–)

Andrew U. Frank has been a professor and the head of the department of geoinformation and Cartography at the Vienna University of Technology in Austria since 1999. He has been a leading theoretician and practitioner in the area of spatial data analysis and geographic information science (GIScience).

Frank received his doctoral degree from the Swiss Federal Institute of Technology, in Zurich, in 1982. Prior to joining the Vienna University of Technology, he had been on the faculty of the department of surveying engineering at the University of Maine. He has supervised



nearly 40 PhD students, many of whom are now leaders in GIScience. In 2005, he was awarded the national medal, “Grosses Silbernes Ehrenzeichen,” by the president of Austria for his contribution to science.

Earlier in his academic career, Frank made major contributions to the theory and application of spatial databases through a series of influential works on spatial data modeling, spatial data management, spatial data query, and interface design. Subsequently, his interests expanded into the areas of quantitative reasoning and natural linguistics in search of computational models for representing and processing uncertain and imprecise geographic phenomena. His ideas are expounded in his 1996 article “Qualitative Spatial Reasoning: Cardinal Directions as an Example,” which was selected as one of the 19 “most significant and influential articles ever” published in the *International Journal of Geographical Information Science*.

Frank’s more recent research efforts have been directed toward category theoretic formalization of conceptual models of geographic spaces, objects, and their relations, as well as the ontological aspects of geographic information. In particular, the geospatial information community has found highly insightful his idea of viewing the geographic world from different tiers of ontology, which helps articulate where and how inconsistency between data and reality occurs and propagates in geographic information systems (GIS). Frank has also been recognized as a major contributor to the birth and growth of this relatively new interdisciplinary field, namely, GIScience. Most notably, he is a cofounder of the National Center for Geographic Information and Analysis, a research consortium in GIScience formed by the University of California, Santa Barbara, the University at Buffalo, and the University of Maine. Also, in cooperation with others, he established the International Conference on Spatial Information Theory, a leading conference series on GIScience and related disciplines. In addition, he has served in the committees of a number of international conferences and journals. He is currently editor-in-chief of *Geoinformatica* and coeditor of *International Journal of Applied Earth Observations and Geoinformation* and is on the editorial boards of *Geographical*

Systems, *International Journal of Geographical Information Science*, *Journal of Spatial Cognition and Computation*, and *Annals of the Association of American Geographers*.

Takeshi Shirabe

See also **GIScience**; **National Center for Geographic Information Analysis**; **Ontology**

Further Readings

- Frank, A. (1996). Qualitative spatial reasoning: Cardinal directions as an example. *International Journal of Geographical Information Science*, 10(3), 269–290.
- Frank, A. (2001). Tiers of ontology and consistency constraints in geographical information systems. *International Journal of Geographical Information Science*, 15(7), 667–678.



The frontier is a core concept in geography. Its meaning denotes location at the outer edge of territory, but its use and significance derive from two separate traditions, one associated more with Europe and the other with the United States, although the term applies to regions across the world. The European usage focuses on the frontier as a political boundary between places, a line of separation; the American *frontier* emphasizes interactions within the borderland of settlement. The meanings grow from the different historical experiences and traditions that are involved in their interpretation. A frontier can be a line or an area, its location and extent stable or changing. The relationships along it can be amicable or confrontational, can flow through or across and are easily or tightly controlled. Although a frontier is a spatial periphery, it can be among the most critical of regions in the way it draws interest and resources from the core in the core powers’ attempt to control and manage it.

The European frontier is associated with boundaries between principalities or states—the outer limits of the Holy Roman Empire, say, or



the boundary between Normandy and Brittany. The word *frontier* reflected difference but did not dictate the degree or significance of that difference. As 18th-century Europe became a distinct set of nation-states, with more politically homogenized space and regularized borders, the term denoted regions elsewhere. The word indicated the speaker's perception of a little known, lightly occupied area, potentially rich in resources, possibly an object of colonization. To Europeans, the Americas were frontier territory.

Within North America initially, European settlers, and later Americans, saw the frontier beyond their own permanent settlements, demarcating divisions between Native American space and their own, the boundaries quite close. The term was a European import to the Americas, and like other cultural imports, it gradually transformed in its new home. After independence, the U.S. preoccupation with national expansion made the frontier a central concern. The term meant the area in the process of incorporation into Euro-American settlements. The American frontier crossed the Appalachian Mountains and kept pushing west. It was characterized by spatial elasticity rather than fixity.

Throughout the 19th century, the American government used its decennial censuses to keep track of its population's westward movement. Each census showed the country's center of population and outer edge drifting west. The census even established a clear statistical measure for the frontier: an area with a population density between 2 and 6 people per square mile (a higher density meant that it was settled; a lower density meant a wilderness). Maps showed the national territory divided by settlement category as well as a frontier line, the contiguous edge between frontier and wilderness.

Native American settlements and people became synonymous with the frontier, the whole process of expansion presuming their displacement. Their boundaries, once loosely fixed, kept changing—but in their case, retreating. Throughout the 19th century, references to the frontier increasingly coupled Indians and disputed space. In his famous 1893 essay “The Significance of the Frontier in American History,” Frederick Jackson Turner, the foremost historian of the frontier, described the frontier as “the meeting place of

civilization and savagery,” Euro-Americans and Indians. The frontier drew the former, looking for land and opportunity. Promoters described the frontier as ripe for appropriation and transformation and applauded those moving in as benefiting both themselves and the nation.

By 1890, the frontier area seemed integrated into the rest of the country. Its population was growing. In many places, its native grasslands had been converted to agricultural fields. The whole country became crisscrossed with railroad tracks. Turner saw the moment as transformative, and his 1893 essay described America's frontier as closed. He argued that the country had become more like Europe in its settled borders but that its frontier history made it different in important ways. America was no longer a nation with a frontier, but it was still a frontier nation—its repeated waves of frontier expansion had fostered a buoyant, practical, and unrestrained national character that would persist after the presumed disappearance of the spatial frontier.

Turner was so persuasive that for the next century the frontier's geographical significance received little new consideration. Yet much of the American West and the far northern borderlands never rose above the censuses' frontier densities, and by the late 20th century, the population decline had become so severe in some areas of the Great Plains that they again had frontier densities. Many U.S. frontier communities remain distinctive for their small, isolated populations. Their poor transportation connections meant less access to the usual goods and services other Americans expect from business and government. These frontier regions cannot reliably count on good Internet connections or full-service health facilities.

While the United States has a “hidden” frontier, Amazonia is regularly described as a contemporary frontier. The vast tropical river basin of the Amazon still features a low population density, long-standing communities of native peoples, and ambiguous national borders difficult to police. As with the U.S. frontier, Amazonia's natural resources, particularly rubber and gold, historically lured settlers from elsewhere. The low population density has similarly fed illusions of an unoccupied land that can be given away and cleared for agriculture. Such efforts were sporadic, but the past two decades' soybean cultivation has



transformed sections of Amazonia, changing its landscape and economy, increasing its overall population and infrastructure development. The region's largest city, Manaus, has become an export-processing center. Yet much of Amazonia remains heavily forested, low density, and remote. The region is known for its enormous biodiversity and vital role in global climate regulation and can survive only if conventional development is limited. Although most of the region lies within Brazil, it includes territory from eight other states, each with distant core areas. The borders between them remain areas of potential boundary conflicts and centers of illegal activities, such as cocaine production, that benefit from the peripheral location and weak control, classic features of frontiers.

Deborah E. Popper

See also **Population Density; Settlement Geography**

Further Readings

- Lang, R., Popper, D., & Popper, F. (1997). Is there still a frontier? The 1890 census and the modern American West. *Journal of Rural Studies*, 13(4), 377–386.
- Power, N., & Standen, N. (Eds.). (1999). *Frontiers in question: Eurasian borderlands, 700–1700*. New York: St. Martin's Press.
- Schmink, M., & Wood, C. (1992). *Contested frontiers in Amazonia*. New York: Columbia University Press.
- Turner, F. (1991). *The significance of the frontier in American history*. New York: Continuum.



FRONTS

The most common definition of a front is a “boundary between dissimilar air masses.” While this boundary is typically manifested as a thermal discontinuity, in some cases a moisture discontinuity can also behave as a front. In the plains of the United States, this moisture discontinuity is commonly referred to as a *dryline*, separating continental tropical and maritime tropical air masses.

The classic definition of a *front*, which implies a sharp zero-order boundary, often leads to a misunderstanding of its concept and structure. A front is actually a human construct considered to represent the leading edge of a strong thermal gradient. As a result, it is very difficult to find consistency in its placement on weather maps, even by professional meteorologists. This is especially true with warm fronts.

Zero-order fronts are in fact rare, occurring most frequently during winter in the western high plains and prairies of North America as a result of the ebb and flow of chinook winds. Chinook winds are strong downslope westerly winds that force existing shallow arctic air masses to the east and then allow them to slosh back westward again when the winds weaken. The greatest temperature changes ever recorded in North America are in response to chinook-based zero-order fronts. For example, a 2-minute change of 27 °C (49 °F) was observed in Spearfish, South Dakota, on January 22, 1943, and a 24-hour increase of 56 °C (103 °F), from –47 to +9 °C (–54 to +49 °F) was noted at Loma, Montana, on January 15, 1972.

Compared with zero-order boundaries, most fronts are in reality a transition zone of significant horizontal planar extent, generally up to hundreds of kilometers in width with cross-sectional slopes and depths that vary with each individual air mass. For example, cold fronts generally exhibit slopes of between 30:1 and 50:1, while warm fronts are less steep, with ratios of 100:1 to 200:1. As a result, precipitation shields can extend more than 1,000 km ahead of surface warm fronts, while a cold frontal precipitation is generally of a much smaller horizontal extent and a shorter duration.

Another common misconception is that all fronts extend from the surface to the tropopause, when in fact this is found only with deep baroclinic cyclones. In many cases, upper-level and/or split fronts can pass through a region completely undetected by surface observation stations.

Split fronts exist in cases of differential advection, that is, when multiple air masses are moving through a region at different heights. For example, it is not uncommon for maritime tropical air to be moving north at the surface into the Great Plains of the United States from the Gulf of Mexico at the same time when a shallow layer of hot, dry



continental tropical air aloft is migrating north-eastward from the mountains of Northern Mexico. In many cases, the shallow layer of hot, dry air arrives after the maritime tropical air at the surface, resulting in a split front structure. Split fronts are also common with winter storms in the Eastern United States, where the heaviest snowfall develops northwest of the surface cyclone center in response to frontogenesis at the 700-mb (millibar) level.

The precipitation that occurs in the immediate vicinity of fronts develops in response to baroclinic circulations that form as a result of increasing thermal and pressure gradients, such as with cold fronts, or due to steep isentropic gradients, as with warm fronts. It should be noted that not all precipitation with open-wave extratropical cyclones is *frontal*. This is especially true well ahead of either cold or warm fronts where isentropic lift due to significant south to north advection (tens of degrees of latitude) of moist air produces stratiform precipitation shields.

Fronts, whether they be cold, warm, occluded, or stationary, often trigger deep moist convection in conditionally unstable environments due to enhanced surface convergence. This generally occurs in discrete meso-gamma-scale areas due to the strength of the inversion that typically caps moist surface layers, and vertical directional wind shear. In cases where the inversion is weak and the wind shear is unidirectional, lines of convection quickly develop, in some cases becoming highly organized into a series of interacting cells. This type of organized convection is commonly referred to as a mesoscale convective system (MCS). Most mesoscale convective systems form just north of west-east-oriented warm fronts, migrating east-southeastward along the front and concluding their life cycles in the warm-air sector south of the front. While an MCS can produce large swaths of wind damage and flooding, in Central North America it also provides a significant proportion of the growing-season rainfall.

Cold Fronts

A cold front represents the leading edge of a thermal gradient in which cold air advection is occurring at Earth's surface. Cold air advection typically results in baroclinic circulations that produce precipitation if enough water vapor is present.

Although in some cases the precipitation ahead of cold fronts appears spatially contiguous, much of it is generated by isentropic ascent. *Frontal lift* (due to baroclinic circulations) generally produces a narrow band of precipitation only in the immediate vicinity of the front.

The location of frontal precipitation relative to the location of cold fronts varies a great deal. When the ascent slopes backward against the motion of the front, generally to the west with a typical north-south cold front, the stratiform precipitation shield is found mostly behind the front. This type of cold front is often referred to as an *anafront*. When the lift occurs in response to upright or sheared convection, it is found mostly ahead of the front, in some cases producing very heavy precipitation in spatial pockets, referred to as "maximum precipitation areas."

Warm Fronts

While cold fronts are the most common frontal types, warm fronts are not unusual, especially in Eastern North America, due to the east or south-eastward movement of continental highs or north-westward expansion of the Azores' subtropical high. In many cases, advancing cold air from the Western Cordillera in response to cyclones migrating southeastward from the Gulf of Alaska initiates lee-side cyclogenesis or storm "rejuvenation" east of the Rockies. This results in a warm front due to increasing pressure gradients between the lee-side low and the Gulf of Mexico.

In general, most textbook models of warm fronts imply the existence of only stratiform clouds and precipitation; however, surface convergence along warm fronts frequently triggers the development of cumulonimbus clouds. Given the easterly winds common in the vicinity of warm fronts, these environments are ripe for the development of supercells and tornadoes, given the magnitude of vertical shear.

Occluded Fronts

Occluded fronts typically represent the "merger" of cold and warm fronts in response to the maturity of an extratropical cyclone. In the later stages of the Bjerknes cyclone model, cold fronts are expected to "catch up" with warm fronts due to their more



rapid movement. At this point, cyclolysis is expected to begin as the system becomes quasi-barotropic.

In fact, occluded fronts do not occur with every cyclone and are generally found in or near maritime environments since they represent cyclone maturity. In the middle latitudes of North America, they occur in the Eastern Pacific Basin and along the west coast as cyclones drop southward from the Gulf of Alaska. Along the east coast of the United States, very strong cyclogenesis can occur during the cold season, producing powerful “nor’easters” that move northward along the coast, with occlusion typically in Maine, Newfoundland, or Nova Scotia.

In special situations, especially over the ocean basins, small subsynoptic-scale *polar lows* develop north of the Polar Front jet as midlevel vorticity maximums merge with sections of existing fronts. These lows spin up so rapidly that it appears that the system is occluding almost instantly. As a result, polar lows are sometimes referred to as *instant occlusions*.

Stationary Fronts

Stationary fronts typically represent regions of strong thermal gradients in which neither warm nor cold air advection is occurring over significant periods of time. In reality, the positions of the thermal gradients tend to oscillate back and forth (from north to south with west-east aligned fronts) so that their mean positions appear to remain stationary. The physical structure of stationary fronts is much like that of warm fronts, and in fact, they tend to mark regions of significant isentropic lift, stratiform cloud, and precipitation development.

Lift

Most fronts produce lift in response to surface convergence only up to the 700-mb level (3,000

meters). In some cases, this is high enough to reach a favorable dendritic growth zone for snow; however, it is the transverse circulations in response to an upper-level jet maximum within the vicinity of the front that provide deep lift in which air can ascend from Earth’s surface to the tropopause. These transverse circulations produce a corresponding subsidence in other areas. As a result, there will appear to be an uplift/subsidence couplet within the region of a strong extratropical cyclone.

David L. Arnold

See also **Adiabatic Temperature Changes; Air Masses; Atmospheric Circulation; Atmospheric Composition and Structure; Atmospheric Energy Transfer; Atmospheric Pressure; Atmospheric Variations in Energy; Clouds; Cyclones: Extratropical; Cyclones: Occluded; Differential Heating; Hurricanes, Physical Geography of; Monsoons; Precipitation Formation; Thunderstorms; Tornadoes; Urban Heat Island; Wind**

Further Readings

- Bluestein, H. (1992). *Synoptic-dynamic meteorology in midlatitudes: Principles of kinematics and dynamics*. New York: Oxford University Press.
- Carlson, T. (1998). *Midlatitude weather systems*. Boston: American Meteorological Society.
- Holton, J. (2004). *An introduction to dynamic meteorology* (4th ed.). St. Louis, MO: Elsevier.
- Newton, C., & Holopainen, E. (1990). *Extratropical cyclones: The Erik Palmén memorial volume*. Boston: American Meteorological Society.
- Ray, P. (Ed.). (1986). *Mesoscale meteorology and forecasting*. Boston: American Meteorological Society.



GAIA THEORY

Gaia (or *Gaea*, from its roots *Ge*, “Earth,” and *Aia*, “grandmother”) is the name of the Greek goddess of Earth (cf. *Tellus* or *Terra Mater* [Latin], *Bhumi Mata* [Sanskrit]), who lends her name to geography and all the geosubjects. In Greek mythology, Gaea, born of chaos, gives birth to the sky, hills, oceans, and, eventually, time. Gaia is also the name given to a scientific theory of Earth that has given rise to a new kind of earth systems science, which puts biological processes in the driving seat. First formulated in the 1960s as the Gaia hypothesis by the British Earth scientist James Lovelock, its distinctive feature is that it conceives Earth as a biologically controlled (biocybernetic), self-regulating system. Gaia theory suggests that the biota, the sum of the planet’s living organisms, influences and regulates the global environment: atmosphere, temperature, water, air, soil, and, in effect, the whole global environment. It also suggests that the regulation of Earth’s environment by the combined activity of its living organisms causes the planetary system to behave in ways previously attributed only to individual living organisms, colonies, or ecosystems. Biological processes, tightly coupled with physical processes, control and stabilize global environmental conditions in ways that favor their perpetuation. Gaia theory, at the planetary scale, demonstrates the core notion of the

theory of ecological succession, which is that life creates a better environment for life itself.

Geophysiology and Earth Systems Science

Gaia theory implies that if Earth is a single living system, then planetary science becomes a kind of global physiology (geophysiology) while global environmental management may be conceived as a kind of planetary medicine. It also suggests that the Earth system has a significant capacity to defend itself against a changing external environment. In this respect, it acts like a primitive living creature. When it becomes too warm, it cools itself down, and when it is too cold, it warms itself up. Gaia theorists have collected considerable supporting evidence, but their most powerful single argument involves global temperature.

The traditional scientific argument for the existence of life on Earth is that the planet is perfect for life. This is the so-called Goldilocks hypothesis: Venus is too hot, and Mars is too cold, but the Earth is just right. However, the sun is a star and has the same life cycle. In the past 3.8 billion yrs. (years) of life on Earth, its output has increased by less than 10%. This means that if conditions are just right for life now, they must have been very cold when life began, or if they were perfect when life began, it should be very hot now. However, Earth’s temperatures have remained remarkably constant. The oceans have



neither been so hot that they boiled away nor, in the past 0.5 billion yrs., so cold that the whole Earth froze. The reason is climate regulation by changing levels of atmospheric carbon dioxide (CO_2). Today, this gas makes up more than 98% of the atmospheres on Mars and Venus but only 0.03% of that of Earth. The missing atmosphere is found sequestered into rocks, such as the limestone rocks that cover an eighth of the planet's land surface, and in all the other organic rocks and sedimentary layers. Most limestone rocks are constructed of small shells. It is life that has buried Earth's excess CO_2 .

Viewed as a whole, while the atmospheres of Mars and Venus are chemically stable, Earth's atmosphere is not. Instead, it shows a statistically improbable combination of extreme chemical instability and long-term constancy. Many of the causes of the chemical instability, the amount of free oxygen and methane, are obvious by-products of life. Much of the constancy on Earth is also mitigated by life—biogeochemical recycling being the key. This is why Gaia theorists claim that it is impossible to understand the current physical state of air, the ocean, or Earth without recognizing its biological control. Biological processes keep the planet's physical systems in their condition of dynamic equilibrium, a state that is ideal for life, which needs to process mobile materials, but which would be impossible on a dead planet.

Daisyworld

This gives rise to the question "How does all this occur?" The answer is indicated by Daisyworld, a simple yet powerful mathematical model that at once tames the nonlinear rules of population growth and demonstrates the way in which the tightly coupled feedback between biological and physical processes makes planetary self-regulation by the biosphere possible. Daisyworld is a simplified planet that exists in the mind of a computer. Its surface color is neutral gray, and it rotates in front of a star that, like ours, is getting steadily warmer. The planet is seeded with just two species of daisy, both of which thrive best at one temperature—perhaps 200 °C, which germinate at 150 °C and die at 250 °C. One species is light colored, the other dark colored. Light-colored

daisies cool their local environment by reflecting the sun's rays; dark-colored daisies absorb heat and warm up their locale.

In the model, as temperatures rise, eventually they pass the threshold for germination. At this time, black daisies, which warm their habitat, grow better, so they quickly cover the planet. As they do so, they raise its temperature toward the optimum. Above the optimum, light-colored daisies, which cool the environment, become more favored and begin to replace black daisies competitively, while collectively the two species combine to keep temperatures close to the optimum. Eventually, solar temperature increase means that only white daisies, which cool the environment, remain, and eventually, when they begin to die, the whole system collapses, and Daisyworld dies. Between the two extremes, however, the temperatures on Daisyworld remain remarkably constant. So here is the essence of a Gaia control system. There is no suggestion of conscious control; system regulation emerges as an inevitable consequence of the interactions between the organisms involved and their habitat. Since its creation, Daisyworld has developed its own large literature; there are also several computer models and a spreadsheet version freely available on the Internet.

Gaia Debates

The Gaia concept disturbs many people. One reason is that it considers very long timescales and a relationship between a huge planet (Gaia) (size: $12.76 \times 10^6 = 12,760,000$ m [meters]) and the main life forms that have inhabited the world through its existence, which are the unicellular bacteria of the microcosmos (size: $12.76 \times 10^{-6} = 0.00001276$ m, or much less for the dominant prokaryotic bacteria). Humans (size: $1\text{--}2 \times 10^{-1}$ m), while they may be impressive supercolonies of ca. 19×10^9 cells, exist between the two ruling scales of the Gaia system and across an infinitely small timescale (>0.001 billion yrs.). There is a fertile area of discussion about what, if any, might be the role or effect of humans on Gaia—for example, Are humans a planetary disease? Are they Gaia's organs of reproduction? Will their impacts trigger Gaia's shift to a new warmer system state? and many other speculations.



<i>Eight Gaia Concepts</i>	<i>Different Conceptions of Gaia</i>	<i>Environment-Oriented Geographers Often Regard This View as</i>
Metaphorical	Gaia is a metaphor for the unity of the Earth's environmental system, especially the interlinkages of its biological components.	Romantic but apt and useful
Influential	The biota has a substantial influence over many physical geographical and Earth system processes.	Certain
Coevolutionary	The biota influences the physical environment, and this in turn influences the evolution of the biota by Darwinian processes.	Probable
Homeostatic	The interplay between biota and environment is characterized by self-stabilizing negative feedback loops (Daisyworld model).	Debatable but possible
Teleological	The atmosphere is kept in homeostasis, not just by the biosphere but in some sense "for" the biosphere.	Speculative
Optimizing	The biota manipulates its environment for the purpose of creating biologically favorable conditions for itself.	Improbable
Organismic	Gaia is a living organism composed of many species, much as higher organisms are composed of many cells, and like any organism, it seeks to preserve itself and to reproduce.	New Age
Religious	Gaia is an aspect of the Goddess or of God, who runs the Earth for Her or His own purposes.	Religion

Table 1 Eight conceptions of Gaia

Source: Adapted from Kirchner, J. (1993). The Gaia hypotheses: Are they testable? Are they useful? In S. H. Schneider & P. J. Boston (Eds.), *Scientists on Gaia* (pp. 38–46). Cambridge: MIT Press.

Given these considerations, it is not surprising that Gaia theory has its share of criticisms, many of them based on sound scientific arguments. Of course, the notion is also anathema to fundamentalists ranging from neo-Darwinists such as Richard Dawkins, to reductionist scientists, to the supporters of various, mainly Abrahamic, religious systems. Some of these problems arise because the Gaia hypothesis has been expressed in many ways. John Kirchner, a leading Gaia critic, recognized a spectrum of Gaian hypotheses running from weak to strong in the scientific literature. Table 1 covers the range of views that impinge on geographical inquiry. The last column tries to indicate the current measure of support each notion receives from the scientific community.

Gaia Today

Gaia is an independent scientific theory of the living Earth. It is one of the most important ideas in modern physical geography, with a scientific core and an elegant mathematical base in

Daisyworld. The concept is a logical consequence of the originally organicist, general-system thinking that was in vogue in physical geography for more than two decades in the late 20th century. The romantic and evocative adoption of the name of the goddess "Gaia" has increased both the popularity of the notion and the objections to it. Consequently, Gaia theory is most often taught under the more scientific-sounding strapline "Earth systems science." Its creators and chief protagonists, James Lovelock, Lynn Margulis, and their followers, have shown how science can connect with the Gaia system, perhaps a superorganism. The Gaia concept is also fundamental to deep ecology and is widely used by environmentalists, especially ecofeminists, and the New Age Movement.

Martin J. Haigh

See also [Climate Change](#); [Deep Ecology Movements](#); [Ecofeminism](#); [Physical Geography](#), [History of](#)



Further Readings

- Harding, S. (2006). *Animate Earth*. London: Chelsea Green.
- Kirchner, J. (1993). The Gaia hypotheses: Are they testable? Are they useful? In S. H. Schneider & P. J. Boston (Eds.), *Scientists on Gaia* (pp. 38–46). Cambridge: MIT Press.
- Kump, L. R., Kasting, J. F., & Crane, R. G. (2009). *The Earth system* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.
- Lovelock, J. E. (1979). *Gaia: A new look at life on Earth*. Oxford, UK: Oxford University Press.
- Lovelock, J. E. (2005). *Gaia: Medicine for an ailing planet* (2nd ed.). London: Gaia Books.
- Margulis, L. (1999). *Symbiotic planet*. New York: Basic Books.



GAMA, VASCO DA (1469–1524)

Vasco da Gama was a Portuguese navigator and explorer and the first European who succeeded in reaching India after circumnavigating the African continent. He thus opened the way for new sea routes for trade and laid the foundations for the Portuguese Empire in Eastern Africa, India, and Indonesia, making his homeland for a period the main commercial leader in Europe.

At the time of da Gama's voyages, spices and herbs had enormous importance, and their maritime trade was controlled by the Venetians, Arabs, Persians, and Ottoman Turks; on the other hand, their transport via land was very expensive. For this reason, powerful Western



Figure 1 Map showing Vasco da Gama's voyage routes

Source: Cambridge University Press.



European nations aimed to find an alternative direction to reach Asia by sea. In 1497, King Manuel I of Portugal charged da Gama with an expedition. The navigator left Lisbon in July with four ships. He sailed past the Canary Islands and the archipelago of Cape Verde; then, trying to avoid the currents of the Gulf of Guinea, he crossed the equator. He got to Southern Africa in November, rounding the Cape of Good Hope, which had been previously reached by the Portuguese explorer Bartolomeu Dias in 1488. On Christmas day, 1488, he landed in what is now the province of Natal (in Portuguese, *Natal* means “Christmas”). After several more weeks of navigation, he arrived in Mozambique, where he had to stop because many members of the crew were affected by scurvy, an illness caused by lack of vitamin C, common among sailors who spent long periods on ships. When they finally got to Malindi, da Gama met the Arab expert navigator Ahmed bin Majid, who helped him reach Calicut, on the southwest coast of India, after a 1-mo. (month)-long journey. His journey demonstrated that the Indian Ocean was not an enclosed sea, as imagined by ancient geographers such as Ptolemy. da Gama also provided interesting information about the Eastern African coast (its richness in freshwater and wood that was useful for repairing ships). However, in India, da Gama encountered hostile Arab merchants who tried to prevent trade with the local communities. da Gama used force to counter his opponents.

During his return journey, he faced unfavorable monsoon winds, and it took 5 mos. to get to the coast of Africa near Malindi. Once he reached Portugal in September, 1499, he was proclaimed the “Admiral of the Indian Seas” and, some years later, the Viceroy of India.

Susanna Servello

See also **Colonialism; Exploration**

Further Readings

- Ames, G. J. (2004). *Vasco da Gama: Renaissance crusader*. New York: Longman.
- Subrahmanyam, S. (1998). *The career and legend of Vasco da Gama*. Cambridge, UK: Cambridge University Press.



GAME RANCHING

Game ranches are usually understood to mean an area of land, often enclosed by special fencing, where game animals are kept. There are many purposes for the existence of game ranches. Some owners of game ranches have no commercial motive and are purely interested in conservation and the private enjoyment of the experience of nature. Others acquire and breed animals to profit from live sales, hunting, or tourism. Financial reasons have made the latter type far more common, thus the for-profit type of game ranches is the focus of this entry.

The hunting aspect of game ranching often invokes negative connotations. Some species have become extinct through overhunting. Many people are sickened by reports of the “hunting” of sluggish, drugged lions. The use of dogs in the hunt is also controversial. Negative sentiments toward hunting have influenced impressions of game ranches. However, through hunting, the profitability of game ranches is enhanced. And it is the profit motive that leads to the sustainability and further establishment of game ranches and hence the conservation of wildlife. The rest of this entry addresses the situation in South Africa.

Game Ranching in South Africa

The trend toward transforming livestock production systems into game ranching increased rapidly from the 1990s. The Amalgamated Banks of South Africa estimated that by 2000 there were approximately 5,000 fenced game ranches covering an area of about 100,000 km² (square kilometers), representing a 10-fold increase since 1979. Thus, wildlife can now be found on game ranches that represent an area more than five times the size of the Kruger National Park. Despite the consumptive nature of the activities on most of these ranches, this is a considerable boost for conservation.

What triggered this growth in game ranches? Agricultural Control Boards in South Africa were deregulated, exposing the beef industry to competition from world markets. Consumer preference also shifted toward perceived healthier white meats and away from beef. Venison was also promoted as being low in cholesterol. The



1994 ending of apartheid opened up the potential for tourism, including foreign safari hunters. There was also an amendment in 1988 to the Share Block Control Act of 1980, which facilitated the acquisition of agricultural land for recreational conservation and game ranching.

The initial capital required to establish a game ranch is significant. In addition to the cost of land, capital is needed for infrastructure such as game fencing and tourist accommodation. Initial populations of game also have to be purchased. Not many people have access to sufficient funds for this purpose. The share block scheme, however, allows a coalition of individuals to pool their resources and acquire a game ranch.

Management and Profitability

It would appear that the rate of growth in the number of game ranches is driven mainly by the profit motive. There is some debate as to whether game ranching is more profitable than cattle ranching. Jacobus du P. Bothma and Wouter van Hoven reported a case in the Northern Cape Province where a game ranch yielded a net profit rate that was 7.3 times that of a cattle-only farm. They also reported a case in Zimbabwe where the net income from a 100-km² game ranch was 3.5 times higher than that from an adjacent 200-km² cattle farm. While some farmers are not convinced despite these examples, it seems that the profitability of game compared with cattle increases with aridity. The scientific management of game ranching in Africa is relatively new, and managing for profit is even more recent. *Game Ranch Management*, edited by Jacobus du P. Bothma, was the first significant volume devoted to this topic. The book covers a wide range of topics, such as veld (an elevated open grassland in Southern Africa) management, game capture and transportation, provision of water, buildings, airstrips, game species and their habitat requirements, and monitoring.

With an average game ranch size of about 2,000 ha (hectares), there are many game ranches where it is not viable to maintain a population of large predators such as lions. To prevent damage to the veld, surplus stock needs to be removed either through live sales or hunting. With an increasing emphasis on profits, the following question becomes important: How can

the balance of species be distorted within ecological constraints so as to maximize returns? This question was addressed by John Hearne and colleagues for the Controlled Hunting Area of Mkuzi Game Reserve in Northern KwaZulu-Natal. The authors formulated a linear programming problem (LP) that optimally allocated browse, bulk graze, and concentrate graze to the various species in the area. Hence, the optimal population numbers of each species and the returns from their harvest were calculated. To minimize the large initial capital outlay required, further LP analysis was undertaken to determine an optimal transition plan to a fully functioning game ranch over a 5-yr. (year) period.

Sophisticated mathematical modeling research has continued in an effort to improve decision making for managers of game ranches. This research includes recognition of both the multi-objective nature of managing game ranches and the stochastic aspects of rainfall in determining optimal management strategies. In addition, the stochastic nature of prices and growth rates has been handled by using portfolio selection techniques to determine the optimal target populations for each species. In this approach, food resources are allocated to different species, depending on the returns and the variances and covariances of these returns. Most trophy hunting is marketed as a package. For example, a 7-day buffalo package might include some plains game species and a warthog in addition to a buffalo. For this problem, optimal marketable packages, and hence optimal population levels, for each species have been determined.

Conclusion

Game ranching offers an opportunity to turn marginal lands into profitable ones in Southern Africa. From very little documented knowledge about 40 yrs. ago, increasing scientific activity from fields as diverse as veterinary science and operations research should ensure enhanced profits and thus the use of even more marginal land for game ranching. Advocates of game ranching maintain that this strategy offers Southern Africa its best chance of conserving its priceless wildlife.

John W. Hearne



See also **Hunting and Gathering; Landscape and Wildlife Conservation; Marginal Regions**

Further Readings

- Bothma, J. du P. (Ed.). (2002). *Game ranch management* (4th ed.). Pretoria, South Africa: Van Schaik.
- Bothma, J. du P., & van Hoven, W. (1993). Planning game ranching systems. In C. Maree & N. H. Casey (Eds.), *Livestock production systems, principles and practice* (pp. 281–299). Pretoria, South Africa: Agri-development Foundation.
- Hearne, J. W., Lamberson, R., & Goodman, P. (1996). Optimising the offtake of large herbivores from a multi-species community. *Ecological Modelling*, 92, 225–233.
- Hearne, J. W., Santikay, T., & Goodman, P. (2008). Portfolio selection theory and wildlife management. *ORiON: The Journal of ORSSA*, 24, 103–113.



GATED COMMUNITY

A gated community is a specific form of residential development that is becoming increasingly widespread in many developed and some developing countries. In the most inclusive definitions, a gated community is described as a residential area surrounded by a wall or other means of enclosure, with access controlled at a gate. Specialists require two added criteria. The residential area must be governed by a local governing body, a community association, which is a contractual association responsible for ensuring adherence to regulations and for providing local civic goods and services and whose resources derive from fees paid by the residents. The gated community must also have amenities or infrastructures that are normally publicly owned and operated, such as a park or a street, but are in this case privately held and maintained.

There are different typologies of gated communities. Edward Blakely and Mary Gail Snyder define three main categories: (1) *security zones*—characterized by restricted access alone;

(2) *lifestyle communities*—which offer amenities, most often recreational (tennis courts, golf clubs, etc.), as well as restricted access; and (3) *prestige communities*—which offer their elite membership the distinction of living in an especially desirable location.

There are various forms of gated communities in many widely differing countries such as the United States, China, South Africa, or Brazil. Gated communities are more often located in urban environments but also exist in rural areas (secondary residences). In urban settings, they are found in suburbs as well as in central cities and even inner cities, and in more recent and older neighborhoods. They may include single-family or semidetached homes, apartment buildings, or even residential towers (although many specialists clearly distinguish between gated communities and condominium towers). Their size may range from several dozen to several thousand homes. Their residents generally come from the middle or upper classes, but gated communities inhabited by low-income households also exist. Many retirement communities are adopting the model of the gated community, particularly in the United States.

The opinions on gated communities vary considerably. There are numerous debates on their impacts, more often seen as negative than positive, on local taxation and economies, on social cohesion, and on service provision, and the offer of local collective amenities. Initial analyses of the phenomenon in the 1990s mainly saw gated communities as a source of social segregation on the basis of income especially, because of their capacity to target particular clienteles due to the cost of the housing, the specialized offer of services and amenities, their internal regulations, and the high residents' fees. The analyses also raised the notion of urban secession to describe this new residential form, not only because of the phenomena of enclosure and microgovernance that underlie it but also due to quite vigorous struggles on the part of residents of gated communities, especially in the United States, to obtain local tax reductions.

Supporters of privatization say that gated communities are more efficient in their offer of collective goods and services, which may differ in each gated community, so that households can choose and pay for only those services and amenities that



The security gate outside a prestigious gated residential community in Colorado. There are numerous debates on the impact of gated communities, more often seen as negative than positive, on local taxation and economies, on social cohesion, and on service provision and the offer of local collective amenities.

Source: Rich Legg/iStockphoto.

they are likely to use. Some see gated communities as a way of re-creating neighborhood communities in increasingly diversified (and, in some cases, polarized) urban environments characterized by high residential mobility. This view is, however, contested due to the very constraining regulations found in some gated communities and the tendency for residents to launch legal proceedings when disputes arise, which have nothing in common with the modes of conflict resolution regarding lifestyles and the residential environment found in communities in the sociological sense of the term.

A number of factors—cultural, social, economic, and political—underlie the development of gated communities. One of these is people's feeling of insecurity, whether well-founded or

not, which has been largely exploited by promoters of gated communities. Residents, especially in big cities in developing countries, are said to be looking for a safe environment in these communities, where they are better protected from crimes against individuals or property. In societies that are becoming increasingly socially diverse and polarized, the fear of the Other, of difference, is also a factor: Many people now feel threatened in public spaces. In developing countries, where local administrations have few resources or capacities, gated communities are said to represent a way of ensuring reliable urban services and infrastructures, at reasonable cost, for wealthier inhabitants. In urban peripheries populated by impoverished households, gated communities are seen as enabling very socially and economically



diverse populations to live side by side. Another factor is undoubtedly the attraction for wealthy households of a type of housing and lifestyle in vogue in rich and developed countries such as the United States. In developed countries, promoters present gated communities as a means for middle-class residents to ensure a nonsaturated and efficient offer of specific services and amenities (e.g., recreational facilities) at a reasonable cost. Municipalities can also play an important part as, under certain conditions, gated communities may enable them to attract a solvent clientele without having to make large investments in infrastructures and services. Finally, buyers investing in property in gated communities may feel that they have an additional guarantee of security and profitability in such communities.

Many questions are raised by the study of specific gated communities in various countries due to the great variation in their forms and contexts. What impacts do gated communities have on the surrounding populations and territories? Is the emergence of gated communities enabling a minority to obtain good-quality services and amenities while leaving other inhabitants, particularly less well-off, highly vulnerable populations, in poorly served environments? Or, on the contrary, by developing services and amenities that their residents finance privately, are they allowing municipalities to devote more resources to the rest of the territory? When gated communities are set up, do property values outside these communities rise or fall? Do gated communities in very impoverished areas in large cities in developing countries represent a source of jobs for the highly vulnerable populations around them? Are the barriers established by gated communities significantly affecting the flow of pedestrian and vehicular traffic, and under what conditions? Why are gated communities very popular in some countries and much less so in others?

The realm of gated communities requires a great deal of further study, as there are as yet few definitive answers to these questions. What is known is that in the different contexts in which gated communities exist, there is a wide range of forms, factors, and impacts.

Anne-Marie Séguin

See also **Ethnic Segregation; Gentrification; Housing and Housing Markets; Racial Segregation; Segregation and Geography; Social Geography; Urban Geography**

Further Readings

- Blakely, E., & Snyder, M. (1997). *Fortress America: Gated communities in the United States*. Washington, DC: Brookings Institution Press.
- Le Goix, R., & Webster, C. (2008). Gated communities. *Geography Compass*, 2, 1189–1214.



GAYS AND LESBIANS, GEOGRAPHY AND/OF

Gays and lesbians (but mostly gay men) began appearing regularly in Anglophonic geography in the 1970s. A few brave geographers—including Barbara Weightman, Bob McNee, E. M. Ettore, Jacquelyn Beyer, and Bill Ketteringham—wrote and presented papers that sought modestly to document gay spaces and the impacts of gay people on (mostly urban) landscapes. These early works tended to be isolated and marginalized within the discipline. Meanwhile, more theoretically ambitious work was going on in sociology, anthropology, history, and other social sciences and humanities. One particularly important contribution, published in the early 1980s, was by the famous sociologist Manuel Castells. Along with his graduate students Don Lee and Karen Murphy, Castells mapped and interpreted the development over time of a spatially concentrated gay community in San Francisco. Castells's analysis linked gay community development and political empowerment to spatial concentration and situated its conclusions within a larger theory of urban politics informed by case studies from around the world over several centuries. In addition to taking space seriously, Castells's work posited significant differences between gay



male and lesbian cultures and communities and suggested plausible reasons for these differences.

With the emergence of feminist geography in the 1980s, the shift from gender to sexuality was not much of a leap. Since then, gays and lesbians have become more visible in the discipline (and society at large), both as practitioners and as interesting, and understudied, “objects” of inquiry. A 1995 collection called *Mapping Desire*, edited by David Bell and Gill Valentine, was the first volume to focus specifically on geographies of sexualities, and it concentrated largely on gays and lesbians. Areas of geographic interest then expanded to include, inter alia, the relationship between gay communities and gentrification, the differences between gay male and lesbian lives and communities, rural gays and lesbians, geographies of bisexuality, and intersections between geographies of sexuality, race, and class. By the end of the 1990s, a wide range of traditional geographic preoccupations (e.g., cultural and political geographies, migration studies, medical geographies, travel and tourism) were being regularly reconsidered and reconfigured, at least in part, in light of issues pertaining to gays, lesbians, and other sexual and gender minorities. Furthermore, gay and lesbian geographers were attempting to negotiate new theoretical developments in geography, such as postmodernism and poststructuralism. This turn led to analyses that considered homophobia and heterosexism as part and parcel of larger structures of oppression, including classism, patriarchy, and racism. Concomitantly, the new awareness of gays, lesbians, and broader issues of gender and sexuality led to the emergence of new empirical areas of geographic inquiry, including those surrounding HIV/AIDS, notions such as “closeting,” new forms of popular culture, and “postmodern” social movements (e.g., the “queer” and anti-identitarian political movements).

Indeed, many of geography’s most important theoretical developments over the past two to three decades are inseparable from the more quotidian achievements of gay and lesbian geographies and geographers (as well as others whose lives and experiences have become visible in a post-Fordist, neoliberal, globalized world, such as women, people of color, immigrants/refugees, and postcolonial subjects). In particular, engagements

with feminist, postmodern, poststructural, but especially what has come to be known as “queer” theory have fundamentally transformed both gay and lesbian geographies as well as much of the discipline’s “mainstream.” These perspectives tend to include skepticism about grand theories and reductionism of any kind, along with a distrust of many, if not most, of the established hierarchies of power. Queer theory’s particular lens foregrounds issues of sexuality and desire—especially nondominant and transgressive forms of sexuality and desire—and applies its disrupting insights from this exercise to other domains of geography. The result has been the emergence of new, more sexually sensitive geographies of economy, culture, politics, and the environment.

With respect to gays and lesbians in particular, the focus has shifted away from issues of identity and spatially defined “communities” to fractured and hybridized “subjectivities” whose spatial forms are fluid, always in formation, and enmeshed with similarly fluid and incomplete geographies of race, class, gender, ethnicity, and other forms of difference. In this context, it sometimes becomes difficult to distinguish gay and lesbian geographies (or geographies of gays and lesbians) as something distinct. Still, such geographies continue to be produced, albeit more often under the rubric of “queer” than “gay and lesbian.” Even so, there are recurring debates within queer geography about whether or not the work being produced is “queer enough” (i.e., sufficiently anti-identitarian and intersectional), as well as recurrent, perhaps ironic, debates around whether or not there is enough attention paid to sex and sexual relations per se. Some of the more recent work in queer geography concerns the politics and practice of “seeing” gays and lesbians in government-produced (and other) statistics, the diffusion of queer cultures and politics globally, issues of sexual practice and citizenship, interracial and transnational queerness, the connections between sexuality and health geographies, and a wide range of issues lying at the intersections between gender and sexuality (e.g., drag, transgenderism, queer masculinities/femininities, and queer sexism).

So geographies of and by gays and lesbians have evolved quite substantially over a relatively short period of time. These works continue to grow and



diversify, with attempts to accommodate ever newer theoretical and empirical developments (e.g., actor-network and nonrepresentational theory; the mainstreaming of gays and lesbians through institutions and practices such as marriage, child and elder care, and homemaking). Indeed, it would not be surprising to see this growth and diversification spawn an entirely new set of critiques grounded in a sense of loss of, and nostalgia for, the days when “gay” and “lesbian” were understood as intrinsically radical, and radically distinct, categories.

Lawrence Knopp

See also **Feminist Geographies; Identity, Geography and; Masculinities and Geography; Poststructuralism; Queer Theory; Sexuality, Geography and/of**

Further Readings

- Bell, D., & Valentine, G. (Eds.). (1995). *Mapping desire: Geographies of sexualities*. London: Routledge.
- Browne, K., Lim, J., & Brown, G. (Eds.). (2007). *Geographies of sexualities: Theory, practice and politics*. Aldershot, UK: Ashgate.
- Castells, M. (1983). *The city and the grassroots: A cross-cultural theory of urban social movements*. London: Edward Arnold.
- Castells, M., & Murphy, K. (1982). Cultural identity and urban structure: The spatial organization of San Francisco's gay community. In N. I. Fainstein & S. S. Fainstein (Eds.), *Urban policy under capitalism* (pp. 237–259). Beverly Hills, CA: Sage.
- Ettore, E. M. (1978). Women, urban social movements and the lesbian ghetto. *International Journal of Urban and Regional Research*, 2, 499–520.
- Ingram, G. B., Bouthillette, A.-M., & Retter, Y. (Eds.). (1997). *Queers in space: Communities/public places/sites of resistance*. Seattle, WA: Bay Press.
- McNee, B. (1984). If you are squeamish. *East Lakes Geographer*, 19, 16–27.
- Weightman, B. (1980). Gay bars as private places. *Landscape Research*, 23, 9–16.



GAZETTEERS

Historically, gazetteers served as indexes to place names on map sheets or maps in atlases. A person could look up a place name in the gazetteer and get a page or map sheet number along with a grid reference (e.g., E4) and be able to find it on a map. The gazetteer thus served an important role in information retrieval. In its digital incarnation, a gazetteer serves a similar role as an aid for information retrieval.

One of the most widely used and known gazetteers in the United States is the Geographic Names Information System (GNIS). This digital gazetteer is maintained by the U.S. Geological Survey along with the U.S. Board on Geographic Names. As of December 21, 2009, there were 2,123,538 entries in GNIS covering more than 60 different feature classes. An entry in this gazetteer includes an official place or feature name; alternate feature names; the feature class; the state and county where it is located; the name of a topographic map on which the feature occurs; its latitude, longitude, and elevation; and an entry date.

Recently, the International Organization for Standardization (ISO) 19112 and the Open Geospatial Consortium defined content standards for digital gazetteers and interoperable gazetteer services such that gazetteer services can be executed over the Web. Standard contents for a gazetteer include an official place name; alternate names, including historical or multilingual names; a feature type; and a spatial position most often specified as a point with two-dimensional (2D) or 3D coordinates.

In their digital form, gazetteers are extremely useful for a range of geospatial search functions. Their value lies in their ability to translate between different location representation systems. Locations can be represented textually by place names and addresses or numerically by 2D or 3D coordinates in different spatial reference systems. A person can thus query a gazetteer with a coordinate range and retrieve place names contained within that range. Alternately, a person can query the gazetteer with a place name and retrieve a coordinate location or description for the place name. Location-based services may employ gazetteers to translate a person's coordinate location obtained



by global positioning systems to an address location or to return nearby place names or features of interest. Geospatial information on the Web may have many different location reference forms, so comprehensive searches of the Web for geospatial information will rely more and more on gazetteers to serve as the translators between these diverse reference forms. Suppose a person searches for water-quality data on Sebago Lake. Such data may be referenced using spatial coordinates, or place names, including place names with misspellings. The gazetteer can be used to expand the search from the place name the user enters to alternate names and coordinate descriptions such that the user has a greater chance of finding all the pertinent information.

Gazetteers can also serve as the geographic knowledge source to support automated text processing, spatial grounding of text descriptions, data mining, and information integration. For example, by processing a news article using a gazetteer, one could translate any place name references to coordinate references, plot these on maps, and compare these with place locations in other new articles and with other information sources.

Kate Beard-Tisdale

See also **Place Names; Toponymy**

Further Readings

Hill, L. (2000). Core elements of digital gazetteers: Placenames, categories, and footprints. In J. Borbinha & T. Baker (Eds.), *Research and advanced technology for digital libraries: Proceedings of the 4th European Conference ECDL 2000* (pp. 280–290). Berlin, Germany: Springer.



GENDER AND ENVIRONMENTAL HAZARDS

The human experience of environmental hazards is not only determined by forces in nature but also is contingent on social, political, economic,

and cultural processes. An emergent literature in the hazards field emphasizes the concept of vulnerability, thereby drawing attention away from the “naturalness” of environmental hazards and toward the underlying reasons for the differences in exposure or impact that exist geographically. This work takes seriously several characteristics that mediate the vulnerability of individuals, households, and groups to risks and hazards. One important, yet relatively neglected, socially constructed characteristic influencing vulnerability to environmental hazards is gender. Gender interacts with age, class, caste, ethnicity, religion, economic position, and other underlying social processes to affect the conditions that influence exposure to hazardous situations in the environment. Gender is also a factor in governing the capacity of individuals or groups to respond to and cope with hazards’ harmful and damaging effects. As such, the intersections between gender and other social categories and distinctions need investigation and analysis.

New insights have emerged from research that employs gender as an analytical category in the study of environmental risks and hazards. On a conceptual level, several major gender dimensions have been highlighted. There are some biological and physiological differences between women and men that at times influence their exposure, susceptibility, and response to environmental hazards and their impact. The vulnerability of men and women is influenced by where they are in their respective life courses. Pregnant women and lactating mothers are examples of particularly vulnerable social groups. Moreover, the disproportionate impact of environmental hazards on either women or men is not simply an outcome of biophysiological differences and varying physical exposures; it is an effect of vulnerability as determined by prevailing ideologies of femininity and masculinity that are reinforced through the social construction of gender roles, responsibilities, obligations, and opportunities. Social norms and roles of behavior and responsibility often place either women or men at greater risk from environmental hazards. Recent studies confirm that women generally suffer differential exposure to several serious hazards—fire used for cooking, indoor air pollution, toxic cleaning supplies, water contamination, and seismic activity that can destroy poorly constructed



dwellings—owing largely to the gender division of labor and space at the household scale. These divisions are the outcomes of the micropolitics of power at the household and community scales as well as wider social processes and structural inequalities. On the other hand, men dominate environmentally hazardous and dangerous occupations such as commercial fishing and logging, offshore oil drilling, and underground coal and mineral mining. Some exceptions exist to these patterns, depending on the type of environmental hazard, when gender roles may not affect women or men more adversely. Nevertheless, documentation from many places around the world suggests that gender vulnerability to environmental hazards is to a large extent the product of existing gender-based relations and/or inequalities. Another point in this regard is that prevailing gender norms can influence perceptions of hazards in addition to access to resources, education, information, skills, training, and employment. Hence, there are long-term consequences for individual and community efforts to mitigate hazardous situations and to create safer environments. These gender dimensions are not mutually exclusive but necessarily reinforce each other.

The issues underlying the relationship between gender and environmental hazards are complex. Gender vulnerability must be considered within the context of the physical environment, social structures, and the local-global interactions of pressure-applying forces. In areas where women and/or men are disempowered within the context of modernization theory, live in highly patriarchal or hierarchical social systems, or occupy dangerous built environments, they are more likely to suffer disproportionately in hazardous situations. Internal factors such as political disenfranchisement, poverty, access to education and services, and the outmigration of able-bodied men shape the social fabric of communities and the ability to exercise resiliency in coping with environmental hazards. The combination of these factors makes the everyday roles of social production and reproduction (e.g., growing crops, caring for their children, collecting water, gathering firewood, repairing homes) incredibly demanding for women, who make up a large percentage of the poorest of the poor. Other contributing causes of gender vulnerability include externally driven

forces: large infrastructure projects such as dams and reservoirs, the expansion of industrial agriculture, forest clearing through commercial or illegal logging, mining and mineral extraction, and acts of aggression, war, and displacement. Commerce, construction, urbanization, structural adjustment policies, economic crises, and an eroding resource base have proceeded with little regard to environmental risks and hazards, whereby social and environmental marginalization along gender lines in some places has increased.

It is well documented that women in much of the world bear the primary responsibility of managing the household environment. On account of their sociospatial location, they may be confronted with an entirely different array of environmental deficiencies and risks than men. Urban and rural services and amenities that are deteriorating or nonexistent result in the accumulation of garbage, open defecation, fecal contamination, pest and insect vector habitats, and environmental health risks that pose threats to women, who serve as the principal environmental risk managers, especially in impoverished communities in developing countries. Socioeconomic status, age, and divisions of labor serve as important conditioning factors that render some women more vulnerable to impacts of household-level environmental hazards than others. Water and public health infrastructure and amenities are critical to reducing risk and mitigating the environmental hazards faced by low-income women and their families.

Some researchers suggest that in many places in the world the context within which gender relations are defined is changing, with implications for hazard response and coping. Studies have pointed out the ways in which women and men are attempting to address the multiple and interconnected issues of poverty, underdevelopment, environmental degradation, and hazard through strategies that have the potential to encourage gender equality and tackle other gender-related challenges. Services or amenities supported by the state, such as water infrastructure and environmental rehabilitation, have the potential for improvement of the local environment, health, and economic well-being of the population and for risk reduction. In recognizing the importance of differences based on gender, governments stand to



gain key allies in their efforts to prepare for, mitigate, and respond to the risks and potential devastation associated with environmental hazards.

Sarah J. Halvorson

See also Environment and Development; Feminist Environmentalism; Feminist Environmentalist Geographies; Feminist Political Ecology; Gender and Nature; Political Ecology; Vulnerability, Risk, and Hazards

Further Readings

- Cutter, S. L. (2003). The vulnerability of science and the science of vulnerability. *Annals of the Association of American Geographers*, 93, 1–12.
- Rocheleau, D. E., Thomas-Slayter, B., & Wangari, E. (Eds.). (1997). *Feminist political ecology*. London: Routledge.
- Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (Eds.). (2004). *At risk: Natural hazards, people's vulnerability and disasters* (2nd ed.). London: Routledge.



GENDER AND GEOGRAPHY

The geographical analysis of gender, or simply gender geography, has experienced significant growth since its origins in the 1970s. This field of study has developed from early research on spatial patterns of women's activities to more recent analyses of how spatial processes are linked to gender identities and feminist methodology. Gender and other social relations have been incorporated into nearly all areas of the discipline and brought feminist perspectives to issues such as urban planning, globalization, and, more recently, geographic information science (GIScience).

Gender geography seeks to analyze how gendered social processes are linked to space, place, and scale. In this discussion, gender is defined as a social construct mediated by various axes of power that include race, class, ethnicity, and sexuality. The social construction of gender has often been

compared with sex, which refers to the biological differences between men and women. Geographic analyses of gender underscore how this and other social categories are manifest differently across space and are instrumental in shaping the physical and built environment. Moreover, gender is associated with power relations and access to resources that affect mobility patterns such as commuting and migration as well as divisions of labor in the household and workplace. *Feminist geography*, a term that is increasingly used in connection with gender geography, also entails elements of praxis or engagement with research in a way that incorporates political action and practice. By exposing social and economic inequalities in the workplace, households, and other areas of society, for example, feminist geography has sought to challenge oppressive forces and provide alternatives that include incorporating women's and gender issues in research projects and advocating for social change that empowers marginalized people. In sum, gender geography has expanded the horizons of geographic inquiry to explore alternative perspectives on spatial dynamics, social processes, and power relations.

Evolution of Gender Geography

Early scholarship in gender and feminist geography provided an important critique of traditional assumptions concerning gender roles and the unequal status of men and women in society. Starting in the mid to late 1970s, studies examined how gendered space affects women's employment, commuting, daily time-space patterns, and other common geographical themes. This early work focused on the differences between men and women as explained by gender roles and relations. For example, gender roles profoundly affect labor market participation and commuting patterns for women as they tend to have greater responsibility for household and caretaking tasks. Consequently, limited employment opportunities affect their ability to hold well-paying, full-time, and more secure jobs.

Studies such as these raised a series of questions that launched both theoretical and empirical research on the intersections of gender and geography. One of these projects developed out of Marxist geography, which is based on critical



inquiry of class, capitalism, and uneven development. Radical and socialist feminists have engaged in debates about the relationship between capitalism and patriarchy as separate or interrelated systems. Drawing from this Marxist perspective, feminist geographers such as Jo Foord and Nicky Gregson argued from a realist perspective that gender relations between men and women are built on the necessary conditions of biological reproduction. This position was criticized as ignoring how capitalism affects gender relations. Other dimensions of Marxist feminism developed alongside Walby's *Theorizing Patriarchy*, whereby patriarchal relations are seen as linked to structures in advanced industrial societies that contribute to inequalities between men and women. Examples of these structures include men's exploitation of women's unpaid household labor, segregation in the workplace, and state policies that privilege men. Overall, the issues raised by Marxist and other socialist feminists in geography expanded the scope of and infused gender perspectives into the discipline.

Additional contributions of gender geography in these early decades involved international research on the status of women in countries throughout the world. This research includes empirical analyses of migration, urban planning, and rural development issues. Detailed case studies and maps comparing urban and rural areas, the First and Third Worlds, and regional socioeconomic conditions drew attention to the spatial patterns of gender relations and the status of women. Women's employment activities vary widely throughout the world (data provided in Table 1). This representation of women's involvement in the formal economy raises important questions about scale, accuracy of aggregate data, and alternative measures of economic activity.

The unequal status of women in the discipline through the late 1980s partially explained the lack of attention to gender issues in mainstream geographic research. In a landmark article published in the early 1980s, Janice Monk and Susan Hanson took the discipline to task for failing to consider "half of the human in human geography" and for its masculinist base. This omission was partially explained by the underrepresentation of women among faculty and students in the

discipline and the subsequent lack of research on women's and gender issues. Monk and Hanson and other feminist geographers argued that increasing the number of women in the discipline is bound to improve the amount and quality of scholarship on gender and geography.

Early efforts to address the omission of gender-based research were grounded in analyses of urban and economic geography. A central theme in this literature was the spatial and social separation of home and waged work, which associated the private sphere with women and the public arena with men. Gender-based research contributed to these analyses of the spatial patterns of urban space from early industrial to postmodern cities. The division of public and private space in urban areas provides an interesting comparison of different cultural contexts. In Islamic cities, for example, women's mobility and presence in public spaces are more restricted than in Western ones. Recent feminist analyses of gendered spaces in the city and at work also challenge the social and spatial binaries of paid labor in the workplace and domestic labor in the home. Home-based work, for example, is an important income-generating strategy for many women and thus merges the productive and reproductive spheres. These and other alternative economic practices destabilize mainstream views of the sociospatial separation of home and work.

Social Difference and Gender Geography

The late 1970s and early 1980s marked an important shift in the approach of gender geography in response to critiques about its exclusion of non-Western perspectives and the dominance of white, Western, and middle-class biases in feminist studies as a whole. Third World and non-Western feminism challenged Western feminism to include other social categories such as race, ethnicity, age, and sexuality. Additionally, rather than situating these categories merely as empirical measures, feminist scholars writing about the global South and race were urged to examine the complex intersection of multiple social identities that contributed to discrimination and inequality. Researchers also questioned the "naturalization" of these



<i>Country/Region</i>	<i>Total</i>	<i>Country/Region</i>	<i>Total</i>	<i>Country/Region</i>	<i>Total</i>
Qatar	1	Armenia	23	Afghanistan	40
Kuwait	4	Georgia	24	Congo	42
Palestinian Territory	4	El Salvador	24	Turkey	42
Saudi Arabia	5	Sudan	25	United Kingdom	42
Iraq	5	Azerbaijan	25	Zimbabwe	43
Puerto Rico	6	Yemen	25	Togo	44
United Arab Emirates	6	Tajikistan	26	Canada	44
France	6	Pakistan	26	Mongolia	44
Oman	8	Jamaica	26	Vietnam	45
Jordan	8	Honduras	26	Brazil	47
Bahrain	8	Romania	26	New Zealand	47
Belgium	9	Czech Republic	27	Nepal	48
Peru	10	Albania	27	Australia	49
Libya	10	Finland	27	Benin	50
Algeria	12	Norway	27	Ghana	50
Reunion	12	Fiji	27	Gabon	50
Israel	13	Namibia	27	Guinea-Bissau	51
Japan	13	Paraguay	27	Mauritania	51
Korea, South	13	Costa Rica	27	Papua New Guinea	51
Cuba	14	Uzbekistan	27	Denmark	51
Macedonia	15	Turkmenistan	28	Comoros	52
Lithuania	16	Nicaragua	28	Congo, Dem. Rep. of	52
Bosnia-Herzegovina	17	Uruguay	28	Central African Republic	53
Croatia	17	Mauritius	28	Somalia	53
Greece	17	Germany	28	Ethiopia	53
Trinidad and Tobago	17	Slovakia	28	Madagascar	53
Chile	17	Tunisia	29	China	53
Venezuela	17	Colombia	29	Bangladesh	53
Hong Kong, SAR	17	Malaysia	30	Myanmar	54
Egypt	17	Philippines	30	Senegal	54
Singapore	18	Sierra Leone	31	Gambia	55
Ecuador	18	Swaziland	31	Thailand	58
Bulgaria	18	Guatemala	31	Malawi	59
Ireland	19	Morocco	32	Chad	59
Dominican Republic	19	Cyprus	32	Zambia	60
Sri Lanka	19	Sweden	32	Bhutan	60
Korea, North	20	Mexico	33	Niger	62
Panama	20	South Africa	33	Guinea	62
Estonia	20	Nigeria	34	Mozambique	62
Slovenia	20	Indonesia	34	Mali	63
Spain	21	Netherlands	34	Kenya	64
Latvia	21	Portugal	35	Eritrea	65
Belarus	21	India	35	Burkina Faso	66
Russia	21	Lesotho	35	Angola	67
Ukraine	21	United States	35	Cambodia	68
Syria	21	Botswana	36	Tanzania	70
Guyana	22	Austria	36	Uganda	70
Argentina	22	Hungary	37	Laos	71
Kyrgyzstan	22	Cameroon	37	Burundi	80
Italy	22	Cote d'Ivoire	37	Rwanda	81
Poland	22	Haiti	37	Djibouti	-NA
Moldova	23	Bolivia	37		
Iran	23	Liberia	38		
Kazakhstan	23	Switzerland	39		
Lebanon	23	Cape Verde	40		

Table 1 Percentage of economically active females, ages 15–19, 2005

Source: Adapted from Population Reference Bureau, World's Youth 2006 Data Sheet, <http://prb.org/Datafinder/Topic/Rankings.aspx?sort=v&order=a&variable=32>.



categories in geographical realms of the landscape, everyday language, and spatial practices.

Additionally, other aspects of social difference were incorporated into empirical studies about the journey to work for African American and Latina women, women's experiences throughout the life course, and the performance of sexual identities in place. This research was strongly influenced by poststructural approaches that question the notion of a unified subject and explore the limits of hegemonic discourse. Poststructural theory uses the method of deconstruction to destabilize the hierarchical and oppositional categories that form the basis of Western rational scientific thought. Poststructural feminism has contributed to this field of inquiry by deconstructing the dichotomous categories of male/female, culture/nature, and productive/reproductive labor. Likewise, feminist geography helped advance nonessentializing critiques of the construction of gender and space.

The application of poststructural feminism in geography has been strengthened by the work of J. K. Gibson-Graham's feminist critique of political economy. This groundbreaking research examines how capitalism is part of a hegemonic discourse that has marginalized other noncapitalist forms of economic activity. For example, barter activities and other nonmarket forms of exchange are valid and often sustainable practices in many household and community economies. According to Gibson-Graham, these alternative economic activities open up spaces of resistance in the context of hegemonic capitalist oppression.

Postmodern feminism also created opportunities to critique essentialist views of society and dominant notions of objective truth. In particular, postmodernism's rejection of totalizing views of the world and of progress associated with modernity is consistent with feminism's critique of hegemonic theory and practice. Certain feminists, however, object to postmodernism's refusal to ground critique in the solid foundation of uneven power relations, especially those power relations embedded in oppressive patriarchal structures. In contrast, feminist perspectives on the diversity of representation and truths subscribe to an antiesentialist position where gendered identities are fluid, contested, and negotiated.

Gender Geography and Postcolonial Feminism

Since the early 1990s, efforts to broaden critical perspectives in gender geography drew from postcolonial feminism. According to this approach, regions in the global South once dominated by mostly European colonial powers remain influenced by relations and discourses of powers that stem from Western forms of thinking and politics. For example, the political systems, economic transactions, and cultural practices such as language and religion in many parts of the global South reflect the legacy of European colonization. Under colonialism, these dominant power relations often suppressed local, indigenous forms of knowledge and social relations, including those that affected the status and roles of women. Postcolonial feminism analyzes how patriarchy was shaped by and affected colonial politics and social identities surrounding gender. In many colonial societies, women were placed in submissive positions or not given access to land or property rights under European-ruled administrations. This approach also explores the role of white women who participated in the colonial project as travelers, military personnel, and writers. Journals and travel logs by colonizing women are often diminutive of colonized women in ways that dwell on racial and other discourses of difference. Postcolonial feminism thus disrupts the dichotomies of colonizer/colonized and male/female by recognizing the shifting positions of the subject.

Part of the postcolonial project also entails acts of resistance that challenged the colonial system and questions Western feminism. Subversive interactions between colonizers and the colonized transformed the nature of this unequal power relation and in some instances empowered the colonized to assert their autonomy or gain certain rights. Building on this strategic resistance, some women in the global South have critiqued the idea of feminism as inappropriate for their experiences and perspectives. "Womanism" provided an alternative approach that captures the politics of women's interests and experiences in the global South. Within this approach, issues concerning motherhood and matriarchy have a unique and distinct meaning in many of these societies based on cultural and material practices.



Gendered Transnational Migration

More recent contributions of feminist geography's work on globalization address transnational migration. In this framework, both permanent and temporary migration patterns are affected by gender roles and identities. For example, migrant women take on different roles from men based on the intersection of gender relations in their countries of origin and in the host countries. Studies demonstrate that ties to both places remain important aspects of their livelihoods, social networks, and political organizing. For example, in parts of Asia, women may be more constrained due to restricted mobility, while they are free to travel and commute to work in a European host country. The identities of immigrant women are thus connected to the dominant (host) culture yet complicated by the values and gender relations in their own culture.

Likewise, issues of citizenship and subsequent rights to work and live are restricted for immigrants in many industrialized countries. Thus, concepts such as social and political boundaries, mobility, and production of space raise important questions for feminist researchers studying transnational migration. Feminist studies on the exploitation of women as domestic servants and sex workers, for example, describe the prevalence of often oppressive situations and the basic violation of human rights experienced by these women. Geraldine Pratt's work on Filipina migrants in Vancouver, Canada, explores how these immigrant women's bodies are constructed through their positions as caregivers and, in some cases, undocumented workers. Feminist geographer Melissa Wright also analyzes the violence directed at migrant women in her research on workers in Mexico's *maquiladoras*. Their representation as cheap and docile has contributed to official reactions that minimize the high rates of murder and rape of factory workers in these areas.

Gendered Bodies

The embodiment of power and social identity extends to other areas of gender geography. In this area of research, the scale of the body provides a space or context to explore not only social identity but also spaces of resistance and empowerment. Performance of these social identities

takes place in the body through dress, behavior, and other forms of social expression. Judith Butler's work on gender and performance has been followed up by many feminist geographers who refer to the body as actively involved in the production of subjectivity. Thus, the body is not merely a biological entity but a product of a particular social and cultural context. Michel Foucault expanded this work by theorizing the body as a point of inscription where discourses are represented. From a gender perspective, scholars examine how bodies are marked as male and female through practices and lifestyles such as makeup, physical exercise, and posture.

The field of queer theory and geographic research on sexuality and space has greatly expanded this conceptualization of the body and social representation. In particular, geographical analyses of queer studies approach the body as a site of resistance in efforts to destabilize the dichotomy of a heterogeneous norm. Gay, lesbian, bisexual, and transgender identities and spaces represent important alternatives to heterosexual relations, challenging the dualisms that construct masculinity and femininity as dominant social relations. Research on sexuality and space has addressed a broad range of issues concerning urban politics, gay and lesbian activism, representation and identity, and time-space studies. This field also employs deconstructivist methods of analysis that represent a transgression of heteronormative relations and binaries that oppress nonheterosexual people.

Methodology

The theoretical frameworks and empirical studies discussed above are influenced by methodological approaches in gender geography. These approaches incorporate feminist perspectives in the research process, exploring the positionality of researchers and research subjects, as well as critically reflecting on "the field" as a place of research. Through strategic selection of research topics and emphasis on certain methods of inquiry, feminist geography critiques positivist research for its claim that research can be objective, value-free, and unbiased. In contrast, gender geography recognizes that research is a subjective process that entails biases concerning



the questions asked, conceptual approaches, and methods of analysis.

Feminist methodology also challenges unequal power relations in the research process by destabilizing the relationship between the researcher as “expert” and the participant as informant. These dynamics are considered exploitative and hierarchical by feminist scholars. Debates within the field of gender geography have also raised interesting issues about the use of quantitative and qualitative methods. Some scholars pose questions about whether or not one can “count” or quantitatively analyze issues pertaining to gender relations and feminist inquiry.

Finally, feminist methodology uncovers important dynamics and relations concerning spatial and social processes through a variety of methods such as interviews, focus groups, visual analyses, and participant observation. These methods often empower and provide a voice for the subjects of research and other marginalized voices. Innovative approaches have been used in feminist geography to implement the possibilities of resisting dominant, hierarchical dynamics in the research process. Among these are methods that allow researchers to work with individuals and groups in marginalized communities. For example, using ethnographic methods, Richa Nagar and her collaborators in rural India have conducted activist work with nongovernmental organizations on rural development. This research raises questions about personal identities and the sociopolitical positionality of the institutions in which they are situated. In addition, Nina Laurie works with communities in South America on gender and livelihoods. Her research questions the unequal dynamics often presented in projects in the global South that involve academic researchers from the West. Thus, feminist methodology is an important component of feminist geography in its role of challenging hegemonic assumptions about the research process, providing alternative means of gathering and analyzing data, and incorporating activist or agendas in research.

Many of the themes in feminist methodology highlighted above have affected how feminist geography has contributed to GIScience. For example, work in critical GIScience incorporates social issues of power in the design and implementation of this technology as well as in how data are analyzed.

Likewise, feminist perspectives demonstrate how users of GIScience technology and its applications have been affected by social identity such as gender and particular subjectivities or biases in the research process. Mei Po Kwan and other feminist researchers in this field argue that GIScience can be used to deconstruct binary analyses and construct critical perspectives on sociospatial processes. Recent feminist scholars call for GIScience to be practiced in a more reflexive manner, opening up discursive spaces for alternative visions of the technology and its applications.

Examples of innovative feminist GIScience include Sara McLafferty’s work on breast cancer in Long Island. This project involved cancer victims, policymakers, public health officials, and GIScience practitioners, who developed extensive maps and data in an attempt to reveal causal factors. Although challenges arose, the project was an attempt to empower women and communities affected by the disease with information and regulation of possible environmental hazards. Another example of feminist GIScience research is Kwan’s work on time-space geographies of women in the urban areas of Portland, Oregon, and Columbus, Ohio. She documents the mobility patterns among women of different ethnicities as they undertake employment activities, household responsibilities, and nonemployment travel. Some of this work involves innovative GIScience techniques such as three-dimensional visualization.

The Future of Gender Geography

In sum, gender geography has developed tremendously since its early focus on women’s activity patterns. The growth in this field has borrowed from and contributed to critical analysis of the gendered processes that affect the spatial dimensions of political, economic, and social change. Future directions of research in gender and geography will bring continuing attention to diversity and alternative identities as essential elements in sociospatial processes. An important component of this work will be to continue to explore the intersection of various scales from the body to the global arena. Additionally, the recent growth in feminism and GIScience promises to develop even further as gendered perspectives and methods enhance geospatial technologies. Finally, the



emphasis on activism and social change will lead to growth in the relevance and progressive impact of research in gender geography. This research will in turn strengthen efforts that challenge hegemonic and oppressive tendencies across cultural and political boundaries.

Ann M. Oberhauser

See also **Body, Geography of; Feminist Environmental Geographies; Feminist Environmentalism; Feminist Geographies; Feminist Methodologies; Feminist Political Ecology; Gays and Lesbians, Geography and/of; Gender and Nature; Identity, Geography and; Masculinities and Geography; Sexuality, Geography and/of**

Further Readings

- Geographic Perspectives on Women Specialty Group (Association of American Geographers): <http://atrauger.myweb.uga.edu/gpow/index.htm>
- McDowell, L., & Sharp, J. (Eds.). (1999). *A feminist glossary of human geography*. New York: Arnold.
- Moss, P., & Falconer Al-Hindi, D. (Eds.). (2008). *Feminisms in geography: Rethinking space, place, and knowledges*. Lanham, MD: Rowman & Littlefield.
- Nelson, L., & Seager, J. (2005). *A companion to feminist geography*. Oxford, UK: Blackwell.
- Population Reference Bureau. (2010). *Economically active females, ages 15–19 (%) 2005* [Map]. Washington, DC: Author. Retrieved January 25, 2010, from <http://prb.org/Datafinder/Topic/Map.aspx?variable=32>
- Rose, G. (1993). *Feminism and geography: The limits of geographical knowledge*. Minneapolis: University of Minnesota Press.
- Seager, J. (2003). *The Penguin atlas of women in the world*. London: Penguin.

others. Mutually reinforcing, conceptions of gender and nature are inextricably intertwined. Geographers' interest in these two concepts has been driven by an interest in exploring these connections and, perhaps more important, by efforts to destabilize the assumed nature-given categories of man, woman, and nature.

The term *gender*, as used in contemporary social theory, emerged as part of this denaturalizing impulse. Gender is generally understood to be a social category that can be distinguished from the biological (or nature-given) category of sex. Thus, early feminist theorists delineated gender as a system of meaning that objectifies women, rendering them passive, immobile, and closer to nature. Men in contrast are constructed as agents. Through their gradual subordination of nature, men have been portrayed as on the side of civilization, their historic role being to free humanity from its natural constraints. This system of meaning naturalizes patriarchy through a particular understanding of nature: It places transformative energies in the hands of men as master subjects. In contrast, recognizing gender as a social category suggests that it is open to change. Put at its simplest, even if I am a man, I do not have to act in masculine ways. As this example shows, sex is generally viewed as inescapable: Nevertheless, in recent years, the sex/gender distinction has itself been called into question. This division, it is argued, is a mirror of one of geography's most deeply engrained binaries, the distinction between nature and culture. Within this system of meaning, nature has been framed as the essence of something: It is immutable and historically constant, as opposed to culture, which is viewed as a product of civilization. Questioning the reliance of the sex/gender distinction on both hetero-normative assumptions and dubious dualisms, feminist theorists have sought to historicize and contextualize sex in the same way as gender, showing it to be as much a social construction as the latter. In many respects, this echoes much of the work within critical studies of nature in which long-standing assumptions about the essential characteristics of nature have been progressively undermined. It also builds on a shift from epistemological to ontological questions. Sex, it is argued, is produced, constructed, and performed in ways not dissimilar to nature.



GENDER AND NATURE

Gender and nature are two of the most powerful concepts through which our understandings of the world are shaped. They are central to the framework of meanings through which people tend to view themselves and (human and nonhuman)



Although most of the work reviewed below still relies on a sex/gender distinction, this comes to be questioned in a variety of ways. This entry begins by discussing ecofeminism as a body of work that has placed gender-nature relations at the heart of its work. Then, the entry moves on to a brief consideration of feminist political ecology's contributions before looking at the influence of a broader set of debates within cultural and historical geography. The final section explores the ontological politics in recent moves to question both sex and nature.

Ecofeminism

Within environmental politics, the body of work that has done the most to explore the mutually constitutive relations between gender and nature is probably that on ecofeminism. This work has been driven by an understanding that patriarchy seeks to dominate both women and nature; women suffer the greatest from environmental degradation; and women are at the forefront of efforts to seek better environments. For some, this implied that a feminine conception of nature should be at the heart of struggles for a more appropriate ecological future in opposition to the dominant male-biased frameworks through which environmental conflicts are conventionally understood. Rather than rejecting the association of women with nature, biological and spiritual ecofeminists suggest that there is much of value in this relationship. Indeed, the masculinist domination of nature is contrasted with the deeper immersion of women in the rhythms of nature and the more authentic connections this permits.

Such work has been criticized for its static, singular conception of what it means to be a woman, its inability to contextualize nature as a construct or a product, and its romanticization of the struggles and lives of those in the global South (within much work, the Third World woman is a key figure for the salvation of humanity and nature). Nevertheless, social ecofeminists have begun from a similar starting point, developing a less naturalistic foundation through which the relations between women and nature might be conceptualized. At the heart of such work is the gendered division of labor. For feminist historical materialists—a key influence on

certain conceptions of social ecofeminism—women's work in capitalist patriarchy (cooking, cleaning, bringing up children) mediates the metabolic relation between humans and nature. Nevertheless, this relationship is a historically and geographically specific one that is open to change. Indeed, if the work of social ecofeminists ever proposes a more "feminine" engagement with nature, it is based on a more democratic division of reproductive labor between the sexes. Femininity, in turn, is recognized to be a social construction and not a quality inhering in one sex or the other. While less essentialist than biological ecofeminism, such an approach has still been criticized for implying too sharp a division between the spheres of production and reproduction, for not recognizing the differences among women, and, once again, for romanticizing the tough conditions in which women's environmental knowledge is formulated.

Feminist Political Ecology

While influenced by ecofeminist arguments, geographers' main contribution to gender/nature debates within the field of environmental politics has been through work on feminist political ecology. Once again, the term captures a diverse range of approaches. At the core of work in feminist political ecology is an understanding of the "politicized environment." This politicized environment is both produced out of and serves to reinforce the system of meanings comprising gender. Again, this work has focused on the day-to-day activities of men and women, the gendered division of labor that structures these everyday activities, and the ways in which such work transforms, modifies, degrades, or improves particular environments. Much of the focus of such work has again been on the global South, perhaps because of the apparent directness of the people's engagements with the environments of which they are a part, although there has been an attempt to bring such work into closer conversation with struggles for environmental justice in the global North. Such work has focused more on the discursive ways in which women are understood to be closer to nature. The argument here is that it would be impossible to understand men, women, and nature (or their relationships to one another)



outside any such systems of meanings. Such work has shaped, informed, and transformed work on the social construction of nature.

Landscape and the Masculine Gaze

Within cultural and historical geography, feminists have focused on the dualistic frameworks through which geographical knowledge is produced within and outside the formal discipline. Geographical knowledge, it is argued, depends on the key binaries: nature/culture and feminine/masculine. A particular reading of the relationship between humans and their natural environments emerges because of these dualisms. Geographical knowledge has thereby been subjected to a symptomatic reading: Its silences, absences, assumed dualisms, and hidden assumptions are thereby subjected to much closer scrutiny. Here, some have turned their attention to the heroic figure of the male explorer, demonstrating the manner in which, from the very beginnings of the discipline, a particular relationship between a feminized landscape and a masculine producer of knowledge shaped geographers' approaches to their subject. In questioning the masculine bias to knowledge production, feminist historical geographers have sought to recover the important contributions of women travelers. Their written accounts are important examples of situated knowledge production about human-environment relations in a variety of historical and geographical contexts. Because of their exclusion from most histories of the discipline, focusing on these writings helps unsettle some of the dualisms through which geographical knowledge has been constructed.

Engaging more closely with visual methodologies, feminist geographers have also excavated the systems of meaning through which particular images come to produce and reproduce an association of women with nature, immobility, and passivity (as opposed to men who are associated with culture, movement, and action). Thomas Gainsborough's painting *Mr and Mrs Andrews* has been subjected to some of the most rigorous critique. Here, a passive Mrs. Andrews sits immobile on a bench beneath a tree, while her husband, upright and armed with a rifle, surveys his newly acquired estate. If, as some cultural geographers have argued, landscape is a visual ideology or a

particular way of seeing, it is one that both produces and reproduces a specific relation between the sexes around a relationship with nature: Mrs. Andrews, with space on her lap for a young child, to be added at a later stage, almost becomes part of the tree in Gainsborough's painting.

Gender, Nature, and a New Ontological Politics

In recent years, influenced by queer theory, some feminists have become increasingly troubled by the foundations on which the sex/gender distinction itself rests. The assumption that bodies are anatomical givens over which social constructions are draped relies on particular historical, cultural, and geographical understandings of the body. Indeed, it depends on a particular understanding of what is deemed natural and what is considered social. These debates emerged at the same time as geographers were starting to question the adequacy of arguments about the *social* construction of nature. Society is not a realm discrete from nature that merely constructs at will: Rather, nature is produced, performed, or enacted through a heady mix of human and nonhuman relationships. The argument here is an ontological one: It concerns the makeup of reality itself, seeking to question the very assumptions on which claims about reality have been made. For Marxists, such a framework directs attention to the sensuous activity—structured as it is by specific forms of human and nonhuman forms of organization—on which reality depends: Connections are possible with the ecofeminist argument that the gendered division of labor is central to both the reproduction of inequalities and the possibilities for a liberatory alternative. For actor-network theorists, it implies a multiplication of the different actors out of which the web of life—and in turn sex, gender, and nature—is seen to be woven. In some work, the emergence of new subjects within this technologically mediated socio-natural politics is captured in the figure of the cyborg. In turn, the cyborg becomes a central trope for developing a radical feminist politics adequate to the contemporary moment.

Geographers' engagements with gender and nature have been structured around a series of heated exchanges that have influenced and fed on broader arguments within cultural, historical,



social, and environmental geography. Throughout, the very basis on which understandings of what it means (if anything) to be a man or woman and what it means to develop a critical approach to the study of nature has been subjected to rigorous questioning. While these debates are not likely to lead to any firm conclusions—indeed the impulse is more to destabilize the grounds on which conclusions might be made—they have informed a broadly liberatory agenda. From this, new possibilities for more egalitarian relationships between people and a more sensitive relationship to ecological politics have been opened up.

Alex Loftus

See also *Class, Nature and; Critical Studies of Nature; Ecofeminism; Ethnicity and Nature; Feminist Environmental Geographies; Feminist Geographies; Feminist Political Ecology; Gender and Geography; Nature-Society Theory; Race and Nature; Social Construction of Nature*

Further Readings

- Haraway, D. J. (1991). *Simians, cyborgs, and women: The reinvention of nature*. London: Free Association Books.
- Merchant, C. (1990). *The death of nature: Women, ecology and the scientific revolution*. New York: Harper & Row.
- Rocheleau, D., Thomas-Slayter, B., & Wangari, E. (Eds.). (1996). *Feminist political ecology: Global issues and local experiences*. London: Routledge.
- Rose, G. (1993). *Feminism and geography: The limits of geographical knowledge*. Minneapolis: University of Minnesota Press.



GENERAL CIRCULATION MODEL (GCM)

See *Anthropogenic Climate Change; Atmospheric Energy Transfer; Climate Change*



GENETICALLY MODIFIED ORGANISMS (GMOs)

The term *genetically modified organism* (GMO) is used to refer to plants, animals, and microorganisms whose DNA has been purposefully altered by the direct incorporation (or deletion) of one or more genes to introduce or modify a special characteristic. (Other terms used are *transgenic*, *genetically manipulated*, or *genetically engineered organisms*.) GMOs include pharmaceuticals such as human insulin, which was developed in 1978 and was the first product to show the business potential of the new recombinant DNA technology.

Although the biotechnology industry frequently represents the products of genetic engineering as just the latest stage in a long history of modifications introduced into plants or animals, it is only in recent decades that it has become possible to routinely transfer genes within and across species in ways that are unlikely to occur in nature. A striking difference is that while traditional biotechnology may cross one species with another, these species are always closely related (e.g., apples and pears), whereas genetic engineering has the ability to incorporate genes from one species, including bacteria, viruses, plants, or animals, into a totally unrelated species.

The extent to which GMOs diverge from natural processes has been seen as a great advantage by supporters of the technology, since it enables more effective and precise production of new plants and animals with desired characteristics compared with traditional methods that depend on random or induced mutations and crossbreeding. It has therefore been viewed as having the potential to revolutionize agriculture, food, medicine, environmental remediation, and other fields. However, an alternative view points to the potential risks of adopting a relatively untested new technology and letting its products loose in the world. There are fears that the pace of research and development of new organisms constantly exceeds the ability of policy and regulations to control potential adverse impacts. Genetic modification of animals provokes particularly strong objections for religious, ethical, and animal welfare reasons, except when it is



applied within a medical context. As a result, there has been relatively little interest in developing genetically modified (GM) animals, apart from the “oncomouse,” which was designed for medical use.

Although less contentious than GM animals or bacteria, concerns have also been expressed about GM plants. These revolve around three major issues. First, the control exercised by agricultural biotechnology corporations over farmers, such as restrictions on their right to save seeds; second, the potential environmental risks associated with GM crops, such as the development of herbicide-resistant superweeds and loss of beneficial insects and biodiversity (e.g., bees, wildflowers, and monarch butterflies); and third, the fears associated with consumption of foods derived from GM plants. Opponents point to the possibility that GM foods may result in resistance to antibiotics (due to the use of antibiotic marker genes in the production process) or contain unintended toxins or allergens. Contributing to this negative view is the fact that currently GM crops and foods have no discernible benefits for consumers, since the biotechnology corporations have concentrated on developing traits attractive to farmers and agribusiness, such as insect resistance, herbicide tolerance, and long shelf life.

GM plants developed to date are mainly food crops, notably canola, soy, cotton, and maize. They have been widely adopted in North America and a few other countries but resisted in Europe. Numerous public opinion surveys have revealed that attitudes to GMOs differ between Europe and the United States. For example, the extensive Eurobarometer study (1991–2000) found that Europeans welcomed medical applications of biotechnology to produce pharmaceuticals, vaccines, and diagnostics but were much more skeptical about its use in food production: Only a quarter of those interviewed were willing to eat food from transgenic plants. In contrast, in the United States, food products from transgenic crops have met with far less criticism, although this may partly be attributed to lack of knowledge about what people are eating.

In the United States, GM foods are unlabeled, which Marion Nestle argues deprives consumers of choice and in effect exposes them to an “experiment” in food safety. The industry, supported by regulatory authorities, argues that GM foods are

“substantially equivalent” to conventional foods and therefore do not require mandatory labeling or more rigorous safety testing. In the European Union (EU), in contrast, the precautionary principle is applied: As “Novel Foods,” GM foods are presumed unsafe until their safety has been proved, and any food containing more than 1% GMO content must be labeled. European consumers are highly concerned about potential health risks because of their prior experiences with mad cow disease and other food scares. However, disquiet about GM foods is also increasingly being expressed by U.S. consumers, particularly in relation to milk from cows injected with recombinant bovine growth hormone (rBGH) to increase milk yields. Although widely used in the United States, rBGH was rejected in Canada and the EU because of concerns about adverse impacts on animal welfare and possible human health risks. Recently, opposition has arisen in the United States to the lack of labeling of GM-produced milk. The result has been a growth in demand for organic milk and the supply of GMO-free milk by major retailers. While no direct evidence exists of harm resulting from GM foods, the lack of labeling or long-term monitoring makes this difficult to assess.

Jacqui Dibden

See also **Agricultural Biotechnology; Agrobiodiversity; Biotechnology and Ecological Risk; Domestication of Animals; Domestication of Plants**

Further Readings

- Braun, R. (2002). People's concerns about biotechnology: Some problems and some solutions. *Journal of Biotechnology*, 98, 3–8.
- DuPuis, E. M. (2000). Not in my body: rBGH and the rise of organic milk. *Agriculture and Human Values*, 17, 285–295.
- Lappe, M., & Bailey, B. (2002). *Against the grain: Biotechnology and the corporate takeover of your food*. Monroe, ME: Common Courage Press.
- Nestle, M. (2003). *Safe food: Bacteria, biotechnology, and bioterrorism*. Berkeley: University of California Press.



- Reiss, M. J., & Straughan, R. (1996). *Improving nature? The science and ethics of genetic engineering*. Cambridge, UK: Cambridge University Press.
- Schurman, R. A., & Kelso, D. D. T. (Eds.). (2003). *Engineering trouble: Biotechnology and its discontents*. Berkeley: University of California Press.
- Special issue on biotechnology and the state. (2003). *Geoforum*, 34(2).
- Special issue on environmental economic geography. (2008). *Geoforum*, 39(1).



GENOCIDE, GEOGRAPHIES OF

Geographies of genocide refers to (1) the study of genocide and mass violence within the broad framework of geography as a discipline and (2) the places created and transformed, real or imagined, as a consequence of genocide and other forms of mass violence.

Geographies of Genocide as a Field of Study

Genocide, literally meaning “race murder,” was coined by Raphael Lemkin during his lifelong struggle to garner international support against mass extermination. His crowning achievement, the Convention on the Prevention and Punishment of the Crime of Genocide, was adopted by the United Nations in 1948. The Genocide Convention defines genocide as any action intended “to destroy in whole, or in part, a national, ethnical, racial or religious group.” Significantly, it asserts that recognizing a genocide event is an obligation to intervene, thereby giving genocide legal status as an internationally recognized crime. With a growing awareness of the prevalence of genocide, numerous other terms have been coined in attempts to refine, expand, or focus attention. These include *ethnic cleansing* and the related term *ethnocide* (or *ethnicide*), *democide*, *politicide*, *cultural genocide*, *gendercide*, and *femicide* among others.

Genocide as a topic of study is relatively recent, and most scholars view modern genocide studies

as having roots in the movement to comprehend and explain the Jewish Holocaust that emerged in the 1960s and 1970s in sociology, history, psychology, and political science. Subsequently, scholars expanded their range of interest to include broader issues of genocide in other regions and time periods. In addition to numerous case studies at a variety of scales (e.g., from coverage of an entire genocide to an individual episode of mass killing in a village on a single day), researchers have also sought to address major questions such as the motivation and rationale of the persecutors, the role of bystanders, and the reactions of victims. One recent emphasis is comparative studies across genocidal events with the ultimate goals of prediction, warning, and prevention.

Geography and Genocide Studies

Although researchers outside geography occasionally have made laudable efforts to approach genocide from a geographical point of view, they have frequently fallen short because of failure to understand the complexities of geographic factors such as spatial variation, the flexible meaning of boundaries, place-based identity, and the multiple meanings of territory. Geographers bring to the study of genocide at least three important skill sets and perspectives: (1) in-depth regional expertise, or knowledge of places; (2) an understanding of political geography and geopolitics; and (3) mapping and spatial analysis.

A geographic perspective on genocide has much to contribute. In particular, a political geographic perspective allows for an untangling of the nexus of territory, identity, and power—issues that repeatedly play a central role in contexts of mass violence—complemented by thick, context-specific knowledge of places. It is important to understand the formation, persistence, and changing quality of territory and boundaries, and it is equally important to assess how these spatial arrangements reflect power dynamics and identity formation at multiple scales. Understanding spatial patterns and processes entails thinking outside (or inside) the concept of the state since states are not necessarily the sole or best unit of analysis to consider if we are to understand events of mass violence. A geographic approach avoids the “territorial trap,” as described by John Agnew



As part of its Eyes on Darfur project, Amnesty International (AI) uses high-resolution satellite imagery to provide evidence of the atrocities being committed in Darfur. AI monitors villages in Southern Sudan and Darfur and posts before-and-after satellite images on the Eyes on Darfur Web site to document destruction and the establishment of structures for internally displaced persons. During August and September 2006, Arab militias attacked at least 43 villages inhabited by non-Arabs in the southern tip of Sudan. The top photo shows the village of Ligeidiba before the attacks; the bottom image shows damage as a result of the attacks.

Source: Amnesty International Eyes on Darfur Project, <http://www.eyesondarfur.org/index.html>.

and Stuart Corbridge, of assuming that a focus on state activity suffices to capture or explain events within a state's boundaries. Instead, geographers examine relations and flows across borders, understanding that each reflects changing processes. Additionally, geographers seek to understand patterns of differentiation within state boundaries rather than assuming that a state represents a container of homogeneous identity or evenly distributed access to power and resources.

The critical geopolitical element is perhaps one of the most powerful of geography's contributions to understanding genocide. A critical geopolitical approach examines the geopolitical dimensions of genocide—how genocide is produced, described, promoted, carried out, designated, memorialized, and by whom and with what spatial objectives and results. Such an inquiry can enhance our understanding of the meanings and representations of particular places, identities, and sources of threat linked to genocide events.

A relatively recent initiative by geographers is the application of geographic mapping technologies that provide powerful tools for communicating events as they happened in the past and as they unfold in the present. This approach uses geographic information systems (GIS), aerial photography, and satellite images for digital mapping and spatial analyses. The U.S. Holocaust Memorial Museum has been a leader in applying digital mapping technologies. It hosts the Genocide Prevention Mapping Initiative, which graphically shows the widespread destruction of villages in Darfur, and it has launched its World Is Witness initiative, a "geoblog" that aims to open "a window



into the lives of people affected by genocide and its long-term consequences.”

Most work by geographers on genocide and related topics has been published since 2000. Thus, the geography of genocide is a nascent field that is yet to be fully defined but one that promises to contribute much to cross-disciplinary studies.

Geographies of Genocide as Transformed Space

An illustration from a children's primer published in Nazi Germany in 1936 shows a stereotypical (in Nazi terms) Jewish family standing on a road leading to a bright, sunny land with well-kept farms, children playing, and people fishing. A sign on the road reads “Jews are not wanted here!” the blunt message being that the world of the Germans would be better off without the Jews. This same message, which is inherently geographic, is repeated in every episode of genocide or ethnic cleansing.

Genocides and related crimes against humanity occur in particular places and are targeted at collectivities or identity groups that inhabit those spaces. The creation of an imagined “other” that is dangerous, dirty, degenerate, or in some other way undesirable is a fundamental element of every genocidal event, and the objective of the perpetrating power is to suppress, remove, or ultimately destroy this dangerous, collective other. Thus, space is transformed in the mind of the perpetrator even before any acts of destruction are carried out—indeed, the creation of an imagined space that no longer suffers the influence, presence, or physical being of the other is a key step along the way to actual genocide, which may be viewed as the spatial imaginary made real. From the victims' viewpoint, on the other hand, these spaces to be cleansed represent geographies of exclusion and fear.

Nationalism, Regionalism, and Sense of Place

Often, the geopolitical roots of genocide can be found in nationalism and regionalism, which are, by their nature, attached to place. Sense of place

is variously defined but represents an emotional (and often physical) attachment to place, such as the neighborhood where one grew up or the family farmstead one visited as a child. It evokes powerful feelings of belonging and identity. Sense of place may also attach to regional or national places or even distant places that never have been visited, such as sites of national or religious significance. Mount Ararat in Eastern Anatolia, for example, is an iconic symbol to many Armenians, most of whom have never set foot there. To many it represents lost land, lost ancestors, and lost national glory that perished in the Armenian genocide of 1915. In other words, it is a sacred place and an icon of national identity. Ararat, and many places like it, represent the irredentist impulse—the desire to reclaim lost or “unredeemed” places that, in the national memory, rightly “belong” to an aggrieved group. Likewise, when Slobodan Milosevic spoke in nationalistic terms at Kosovo Pole in 1989, the site of a major battle in 1389 between Ottoman Turks and Serbs, he invoked powerful images of Serbian identity that contributed to the episodes of ethnic cleansing that followed.

Destruction of Place and Erasure of Space

Genocide events not only devastate peoples, they also destroy spaces and places: As a culture is eliminated, its impact on the landscape recedes or disappears altogether, and the place as it once was ceases to exist, except perhaps in occasional relict features on the landscape. This process occurred all over Eastern Europe, for example, where the Jewish impact on both culture and landscape has largely vanished since the Holocaust and is found only in occasional synagogues (often converted to secular uses or abandoned entirely), overgrown cemeteries, or Jewish headstones used as building materials.

Pol Pot's vision for a new Cambodia necessitated the deliberate creation of a new space, and the Khmer Rouge regime applied spatial logic to “delete” or “erase” known and familiar space, as well as those whose ideas reflected the “old” space. Likewise, the Khmer Rouge destroyed family structure to create a spatial vacuum; the space that had been occupied by the home, the family,



and the village society became the space of the collective as the family dynamic disappeared.

Gender, Space, and Genocide

In genocidal events, the roles of men and women as victims, perpetrators, and bystanders vary spatially. It is well known, for example, that the mass rape of women was widely used to produce terror, humiliation, and cultural annihilation in Bosnia, as it was in Rwanda, and as it is in Darfur. In Nazi Germany, on the other hand, soldiers were forbidden to have sexual relations, forced or otherwise, with Jewish and Slavic women, not merely for reasons of discipline but for the purpose of not defiling the “Aryan race.”

Perpetrators of genocide in the main are overwhelmingly male. In Rwanda, however, Hutu women were often active participants as perpetrators, acting as informants, turning over Tutsi children who had been left for safekeeping, looking on as rapes were committed, and even participating in killing. In many or most cases of genocide, mass killing is carried out regardless of the age or gender of victims, while in some cases, as at Srebrenica in Bosnia, men and older boys are selected for extermination (being viewed as potentially more “dangerous” in an immediate sense), while women and children are set free.

Memorialization and Tourism: Contested Postgenocide Space

Memorialization of genocidal events frequently involves the creation of contested spaces, where different experiences and memories vie for attention and remembrance. In a sense, genocide memorials and monuments represent, as Karen Till puts it, “place based politics of memory.” In Ukraine, for example, memorials to the dead of World War II and Stalin’s mass murders, as well as monuments to nationalist heroes, frequently overshadow memorials to victims of the Holocaust, sometimes on the same sites. In other places, though, genocidal events such as the Ovaherero in Namibia are not memorialized at all, resulting in a “null memorialized space,” that is, spaces that are not memorialized despite their historical significance. Genocide tourism also

creates spaces that assert particular memories and narratives. In such cases, a space may become “trapped” by history, as in the case of Oswiecim (Auschwitz) where local Poles’ desires to develop land around Oswiecim have been overruled in deference to the Auschwitz Museum.

Stephen L. Egbert and Shannon O’Lear

See also **Crime, Geography of; Ethnicity; Fear, Geographies of; Hate, Geographies of; Political Geography; Race and Racism; War, Geography of**

Further Readings

- Agnew, J., & Corbridge, S. (1995). *Mastering space: Hegemony, territory and international political economy*. London: Routledge.
- Dahlman, C. (2005). Geographies of genocide and ethnic cleansing: The lessons of Bosnia-Herzegovina. In C. Flint (Ed.), *The geography of war and peace: From death camps to diplomats* (pp. 174–197). New York: Oxford University Press.
- Hinton, A. (Ed.). (2002). *Genocide: An anthropological reader*. Malden, MA: Blackwell.
- Myers, G., Klak, T., & Koehl, T. (1996). The inscription of difference: News coverage of the conflicts in Rwanda and Bosnia. *Political Geography*, 15(1), 21–46.
- Ó Tuathail, G., & Dahlman, C. (2006). The “West Bank of the Drina:” Land allocation and ethnic engineering in Republika Srpska. *Transactions of the Institute of British Geographers*, 31(3), 304–322.
- Till, K. (2005). *New Berlin: Memory, politics, place*. Minneapolis: University of Minnesota Press.
- Tyner, J. (2008). *The killing of Cambodia*. London: Ashgate.
- United Nations. (1948). *Convention on the prevention and punishment of the crime of genocide*. Retrieved from www.hrweb.org/legal/genocide.html
- U.S. Holocaust Memorial Museum: www.ushmm.org
- Wood, W. (2001). Geographic aspects of genocide: A comparison of Bosnia and Rwanda. *Transactions of the Institute of British Geographers*, 26(1), 57–75.



GENTRIFICATION

Gentrification has been the subject of extensive research and debate, with a wide range of definitions and theorizations being advanced. The term is generally traced back to Judith Glass, who suggested that middle-class people were moving into some central working-class areas of London and fixing up run-down houses. Glass highlighted that the in-movement and physical improvement of buildings was accompanied by the displacement of working-class residents, and although there has subsequently been considerable debate about the meaning of gentrification, and the relative emphasis that should be given to in-migration, upgrading, and social displacement, Glass's definition is still encapsulated within many more recent definitions of gentrification.

Although Glass used the term in 1964, it was not until the late 1970s and early 1980s that gentrification became more widely used to refer to change occurring across a range of urban, and indeed some rural, spaces. Since this time, a series of differing forms and theorizations of gentrification have been identified, which may reflect changes in the nature of gentrification itself and/or philosophical/theoretical changes affecting geography and other social sciences. Gentrification was, for example, viewed with skepticism in the 1970s by adherents of logical positivist spatial science who routinely employed urban structural models that implied that both the physical standard of housing and the social status of residents increased with distance from the city center. Much of the early interest in gentrification indeed stemmed from the way it seemed to contradict such models given that middle-class people seemed to be moving into areas close to the center of cities.

Gentrification studies were indeed an important impetus in the critique of positivist urban models and the development of alternative approaches. Behavioral perspectives, for instance, emerged focused on identifying the motivation for inner-city living, while managerial and structuralist approaches were used to consider the role of governmental policy and the availability of finance. By the early 1980s, such differences were often expressed in terms of production-side and consumption-side perspectives, with a trenchant

debate emerging between their exponents, although there has been a subsequent reappraisal of this dualistic construction of gentrification studies, as well as the emergence of new theoretical emphases related, at least in part, to the incorporation of further theoretical perspectives into geography. By the early 1990s, it was possible to identify at least five distinct, albeit overlapping, approaches to gentrification studies, each of which are briefly outlined in this entry.

Gentrification as Class Colonization and Displacement

From Glass's initial comments, notions of class have been central to conceptions of gentrification. Class is, however, a very contested and congested concept, with both widely differing conceptions of class advanced and considerable debate as to the overall significance of class. In the context of gentrification, different concepts of class have been advanced by advocates of production and consumption explanations. Among the former, emphasis is often placed on ownership and control of property and financial resources, with gentrifiers being viewed as people who are able to gain control over areas of space through outbidding others in land markets and investing resources in purchased properties. In consumption-side accounts, class tends to be viewed as an occupation-related concept, it being suggested that a "new middle," "service," or "cultural new" class of creative, professional, and managerial occupations has emerged in association with the growth of postindustrial activities in the second half of the 20th century. It is claimed that this group has been particularly significant in major global cities and a desire for a place of residence close to these locations stimulated the desire for inner-city residence, as well as gentrification of the surrounding towns and rural areas.

Some recent work in class analysis has sought to integrate capital- and occupational-centered concepts of class, suggesting that contemporary class positions are more multidimensional and complex than implied by the dichotomous and gradational concepts of class used in many production and consumption conceptions of class, respectively. Such ideas have been drawn into studies of gentrification, it being suggested that



while some parts of cities such as London and New York may be experiencing so-called super-gentrification by financial services workers with very high levels of economic capital, other areas of these cities, and many other provincial cities, are sites of gentrification by less affluent managerial and professional workers. Earlier, Damaris Rose coined the term *marginal gentrifier* to refer to people who may be undertaking gentrification activities but are far from affluent. People so identified have included artists, first-time house buyers, renters who are forced to become property owners by the sale of properties by landlords, and people who live in gentrified areas due to workplace, transport, or other constraints. It has been argued that marginal gentrifiers may be very important in the early stages of gentrification, although they may themselves be subject to displacement from an area by more affluent social groups. Ideas of diverse middle classes, marginal gentrifiers, and stage processes have also been advanced in relation to the gentrification of rural areas.

While considerable attention has been paid to the class position of gentrifiers, gentrification has a further class dimension in that it classically involved the displacement of working-class residents. Examination of the class position of the displaced has received rather less attention than that of the gentrifiers, an omission that not only may reflect the methodological difficulties surrounding locating the displaced as well as recognition of a range of nonclass differences and identities but may also reflect unacknowledged transformations in working-class living and employment conditions.

Gentrification as Capital Investment

Gentrification appears readily linked to population movement, it being widely portrayed as the “back-to-the-city” movement of people. This understanding of gentrification has been challenged, notably by Neil Smith, who argued that not only were many inner-city gentrifiers migrants from other urban areas but also, and more significantly, that gentrification should be seen as a process of capital rather than population movement. Smith developed what was widely viewed as a production-side theory, in which gentrification was seen as a manifestation of the

uneven circulation of capital and, specifically, the product of processes of devalorization and revalorization in which so-called rent-gaps emerged whereby current use of an area yields financial returns that are significantly lower than those available under some alternative land usage. The existence of such gaps means that there are opportunities for high-level profits by those people or institutions that invest capital—in the broad sense of products and labor power as well as money—in this new use. It was the appearance of rent-gaps in the inner city that created the conditions for a back-to-the-city movement of capital, as resources that were previously flowing out of these areas became attracted back into them because of the opportunity of investing in gentrifying housing (Figure 1). Gentrification was for Smith a process of property investment and gentrifiers in effect property developers who reap the rewards of converting properties from some lower-value activity.

Smith’s capital-centered account of gentrification became the subject of considerable criticism, with at least three lines of debate emerging. First, concerns were expressed about the concept of rent and its relationship with other, largely more neo-classical economic concepts and with empirical data sources. Second, reservations were expressed about the motivational implications of the rent-gap thesis. Studies of residential decision making often suggested that gentrification activity might be stimulated by a range of motivations other than financial profit, including proximity to the workplace and avoidance of escalating commuting costs; access to retail, leisure, and cultural activities; and a desire to live in a location bearing markers of social distinctiveness and status. Third, the rent-gap thesis fostered consideration of the range of agents involved in gentrification. Smith identified types of gentrifiers based on the way refurbishment activity is undertaken and profits realized (Table 1), but his concept of gentrifiers as developers was criticized as being too all-encompassing and stretching the term *gentrification* beyond any meaningful limit. The presence of new-built construction and intersectoral developments encompassing more than housing was also seen to pose definitional problems, although for others, including Smith, these features are indicative of changes in the character and scale of gentrification.

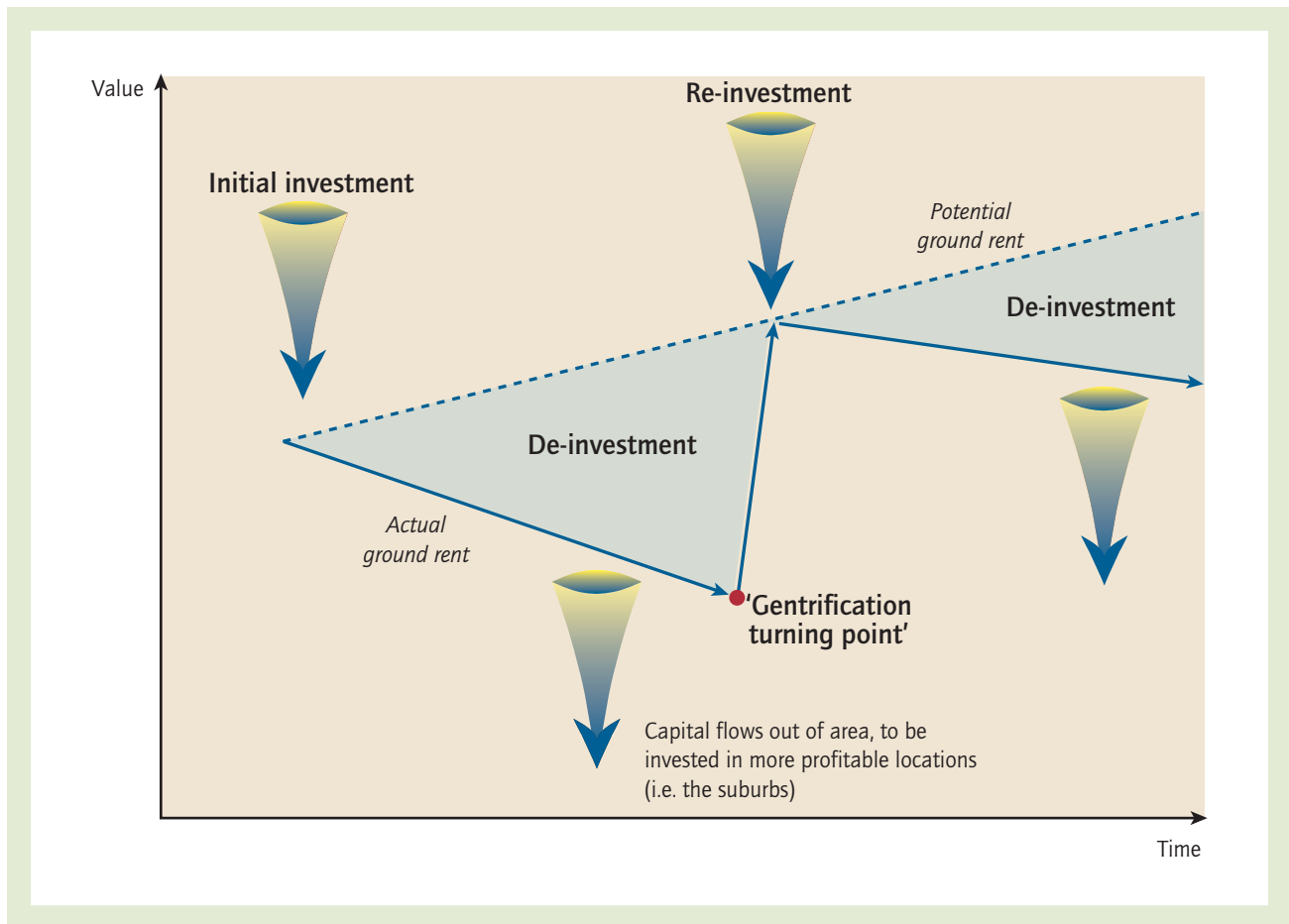


Figure 1 The rent-gap and cycles of investment and disinvestment

Source: Phillips, M. (2005). People at the centre? The contested geographies of “gentrification.” In M. Phillips (Ed.), *Contested worlds: An introduction to human geography* (pp. 317–352). Aldershot, UK: Ashgate. Copyright © 2005 Ashgate Publishing Limited. Reprinted with permission.

Agents of Gentrification and Social Difference

Consideration of agents of gentrification emerged within consumption- as well as production-focused studies. Studies of locational decision making by householders, for instance, suggested that there were significant lines of social difference beyond their class that characterize gentrifiers. For example, retail, leisure, and recreational “consumption” activities identified as significant migrational motivations implied that gentrifiers were relatively young and perhaps living in single-person or childless households. It was argued that the emergence of gentrification might relate to demographic as opposed to class change, with the

postponement/rejection/breakdown of marriage and postponement/rejection of child rearing both leading to the creation of more single-person households and childless couples. More generally, consumption-side studies often argued for disaggregation of gentrifiers beyond a simple designation of being middle class, or indeed from a particular middle class, toward recognizing that a variety of forms of social difference might be of significance. As well as studies highlighting the significance of age and household structure, research emerged linking gentrification to sexuality, gender, ethnicity, and race.

While the recognition of social differences other than class can be seen as simply adding further detail to what is still an essentially class-driven



Type of Gentrifier	Characteristics
Sweat equity gentrifier	Archetypal gentrifier, although not necessarily numerically predominant. Gentrifier is a person who buys a property, upgrades it himself or herself, and then lives in the refurbished property.
Professional developers	Gentrifier is a person or company who purchases properties, develops them, and then resells them for a profit.
Landlord developers	Gentrifier is a person or company who purchases properties, develops them, and then lets them out.
Unmediated owner-occupier developer	Gentrifier is a person who buys a property to live in, but employs some other development agent (e.g., builder, property developer) to undertake the refurbishment work.

Table 1 Types of gentrifiers, as identified by Neil Smith

Source: Created by author, based on arguments presented by Smith, N. (1982). Gentrification and uneven development. *Economic Geography*, 58, 139–155.

process of colonization and displacement, it also led to questioning of whether gentrification should, by definition, be seen to involve class. From the 1980s, a series of studies explored whether gentrification could be explained through factors other than class, and there was also a questioning of the overall value of the term *gentrification*, with some earlier exponents even calling for its abandonment. Other responses, however, included the construction of newer more integrated theories and calls for paying greater attention to the epistemological aspects of gentrification theory.

Gentrification, Reproductive Labor, and Gender

Recognition of difference is of significance to, and was very much fostered by, considerations of gender, where three distinct lines of arguments emerged. First, it was suggested that gentrification was, at least in part, an outcome of rising female participation in paid employment, which led to rising numbers of both high-income single-women households and dual-income households that could afford to engage in gentrification activities. Second, urban gentrification was viewed as a response to the pressure placed on the performance of reproductive labor by rising female paid employment, it being argued that the rising numbers of householders sought to live in inner-city locations in order to minimize journey-to-work

costs and to facilitate the substitution of market-produced commodities for household labor.

These two interpretations have an explicit urban bias in that Western cities tend to have higher rates of female paid employment and contain high levels of accessibility, service, and retail provision. Reproductive labor may also play a role within rural gentrification, with rural in-migration often being stimulated by the onset of child rearing and by perceptions of high levels of personal and community service provision in rural areas. However, service provision, the performance of reproductive labor, and household structures do not necessarily map onto rural-urban differences, with a series of urban studies from the late 1990s highlighting both the presence of children in gentrifier households and the significance of child care and education issues in locational decision making.

A third line of argument relates gentrification to a broad transformation in gender relations, it being suggested that female gentrifiers may be drawn to areas where there is perceived to be a lessening or a dilution of patriarchal relations. Conversely, it has been argued that in a rural context, patriarchal gender relations act to sustain, and are themselves sustained by, middle-class, child-related in-migration. On the other hand, studies have also highlighted how rural locations can be sites for gentrification because they are perceived as localities where nonconventional household and partnering relations are practiced.



Gentrification and Culture

Culture has long been a component of gentrification studies, although it was only in the 1990s that its significance became the subject of extensive reflection and debate. Many early references to culture were linked to the formation of behavioral desires to live in particular locations, such as the inner city or the countryside. Reference to culture was, however, also made in arguments relating to class, where culture was seen to be of significance to both the capital- and the occupational-centered conceptions of class. References to the “cultural new class” in the latter case, for instance, clearly supported that culture was of significance, it being argued not only that there were many occupations in the postindustrial economy centered on cultural work but also that people in this class held particular cultural values. David Ley, for instance, argued that members of this class tended to hold countercultural views associated with the hippy movement of the 1970s, albeit suitably modified to fit within the contours of a middle-class lifestyle. Connections have been drawn from asset-based forms of class analyses that make reference to notions of cultural as well as economic capital, which in turn can be linked to capital-centered concepts of class and gentrification that made reference to the commodification of culture. For example, Sharon Zukin argued that the presence and residential living style of artists who had converted industrial loft spaces in SoHo, New York, were of appeal to the more affluent middle-class group and as a consequence became the subject of marketization by property developers.

Attention has also been drawn to the representations of gentrification by both academics and others. Smith, while renowned for his material emphasis on notions of class and capital, has long made reference to issues of cultural representation, noting how a language of “frontierism” was often employed in descriptions of gentrification. He also highlighted the presence and use of images of nature, adventure, and history in descriptions of gentrification and the relationships and differences between the use of this term and others such as *regeneration*. The significance of place is also highlighted as gentrification is promoted through notions of “city living” and a

“rural idyll.” While seemingly quite contradictory spatial evaluations, it has been argued that they may have a common element—that is, an aversion to suburban space. Attention has also been drawn to the relationships, and differences, between cultural representations of gentrified space and the performance of everyday life in such spaces, through concepts such as the gentrification aesthetic and habitus.

Conclusion

Gentrification has been a term that has been the subject of debate and criticism since its emergence in the mid 1960s, and while there have been repeated calls for its abandonment, it continues to excite interest and contention. Gentrification has been theorized in a wide range of ways. Here, five rather different approaches have been outlined. Not only are there clear lines of overlap between them, but also many nuances within each line of argument have been omitted for the sake of brevity. Furthermore, there are also some further lines of argument that could have been included, including recent discussions related to the role of neoliberalism and the state in contemporary gentrification, the variant forms and locations of gentrification, globalization, the significance of displacement, and the geographies and scales of gentrification. At the present moment, gentrification seems likely to continue to be an important component and catalyst of geographical study and change.

Martin Phillips

See also **Circuits of Capital; Class, Geography and; Ethnic Segregation; Gated Community; Gays and Lesbians, Geography and/of; Housing and Housing Markets; Ley, David; Marxism, Geography and; Racial Segregation; Rent-Gap; Segregation and Geography; Smith, Neil; Urban Geography; Urban Spatial Structure**

Further Readings

Atkinson, R., & Bridge, G. (Eds.). (2005). *Gentrification in a global context: The new urban colonialism*. London: Routledge.



- Butler, T., & Lees, L. (2006). Super-gentrification in Barnsbury, London: Globalisation and gentrifying global elites at the neighbourhood level. *Transactions of the Institute of British Geographers*, 31, 467–487.
- Butler, T., & Robson, G. (2003). *London calling: The middle classes and the re-making of inner London*. Oxford, UK: Berg.
- Lees, L., Slater, T., & Wyly, E. (2008). *Gentrification*. London: Routledge.
- Phillips, M. (2004). Other geographies of gentrification. *Progress in Human Geography*, 28(1), 5–30.
- Phillips, M. (2005). People in the centre? The contested geographies of “gentrification.” In M. Phillips (Ed.), *Contested worlds: An introduction to human geography* (pp. 31–34). Aldershot, UK: Ashgate.
- Smith, D., & Holt, L. (2005). Lesbian migrants in the gentrified valley and “other” geographies of gentrification. *Journal of Rural Studies*, 21, 313–322.
- Smith, N. (1979). Toward a theory of gentrification: A back to the city movement by capital not people. *Journal of the American Planning Association*, 35, 538–548.
- Smith, N. (1982). Gentrification and uneven development. *Economic Geography*, 58, 139–155.
- Smith, N. (1996). *The new urban frontier: Gentrification and the revanchist city*. London: Routledge.
- Smith, N. (2002). New globalism, new urbanism: Gentrification as global urban strategy. *Antipode*, 34(3), 428–450.
- Wacquant, L. (2008). Relocating gentrification: The working class, science and the state in recent urban research. *International Journal of Urban and Regional Research*, 32(1), 198–205.

is useful in many applications, such as responding to emergency calls, mapping and analyzing information from text sources (such as terrorist incidents reported in newspapers), or finding directions to an address. A geocoding process normally has three components:

1. The input features to be geocoded, which are specified as addresses or place names
2. A reference database, which contains a comprehensive collection of addresses or place names and their corresponding coordinates
3. The matching procedure, which finds each input feature in the reference database and retrieves its coordinates

Among the above three components, the organization and structure of the second component (i.e., reference database) may vary from country to country. Each input feature must contain information about its location, such as the street address, the postal code (or at least part of it), or the name of an area. In the United States, there are three main methods of geocoding, according to the reference database that is used: (1) geocoding by street address, using Census TIGER (topologically integrated geographic encoding and referencing system) data files or parcel databases; (2) geocoding by postal code, using databases of zip code areas; and (3) geocoding by place name, using standard geographic name databases.

Geocoding by Street Address

To geocode an address, a reference database of street networks (such as the U.S. Census TIGER data files) can be used, where every existing street segment is stored with its name and addresses at its start and end nodes (for each side of the street). If a given feature address is not at the start or end of a street segment, the geocoding process then interpolates the position of the address, assuming that houses (addresses) are evenly distributed along the length of the street, with odd-numbered addresses on one side and even numbers on the other side. As an alternative to street databases, parcel databases may also be used to geocode addresses. A parcel database contains each parcel (area) and its address. Each input feature address



GEOCODING

Geocoding is the process of finding geographic coordinates (such as latitude and longitude) for a given feature, expressed as, for example, place name, street address, or postal zip code. Geocoding



will be geocoded to the center (centroid) of the parcel that has the same address.

Geocoding by Postal Code

If the input features are specified as zip codes, for example, 5 digits or 5 + 4 digits in the United States, each feature can be geocoded at the centroid (center) of its zip code area. However, since zip code areas are usually much larger than the parcels, the geocoding result with zip codes is not as precise as with parcel data or street networks.

Geocoding With Place Names

The input features may be specified as place names, such as cities, towns, villages, and so on. To geocode such data, a comprehensive geographic name database is needed to find out the coordinates of each feature. In the United States, there are two official geographic name databases, which can be used as the reference data set for geocoding: (1) the GONet Names Server (GNS), which is the official repository of standard spellings of all foreign place names (outside the United States) and their coordinates, and (2) the Geographic Names Information System (GNIS), which is the official repository of domestic geographic names (inside the United States) and their coordinates.

Reverse Geocoding

Reverse geocoding is the process of finding the address for a given pair of coordinates. For example, one may want to find nearby place names or services (such as restaurants or gas stations) for a given latitude or longitude, which may be provided by a GPS (global positioning system) device. The reversed geocoding process is similar to the geocoding process in that both need a reference database. They are different, however, in that the input and output are reversed and the matching procedure is different.

Diansheng Guo

See also **Coordinate Systems; Earth's Coordinate Grid; Geodesy; Ground Reference Data; Place Names; Toponymy**

Further Readings

Dramowicz, E. (2004). Three standard geocoding methods. *Directions Magazine*. Retrieved April 10, 2009, from www.directionsmag.com/article.php?article_id=670&trv=1

Geographic Names Information System:
<http://geonames.usgs.gov>

GONet Names Server: <http://earth-info.nga.mil/gns/html>

Ratcliffe, J. H. (2001). On the accuracy of TIGER-type geocoded address data in relation to cadastral and census areal units. *International Journal of Geographic Information Sciences*, 15(5), 473–485.



GEOCOLLABORATION

Geocollaboration is collaboration among place-based subjects that is facilitated with and through geographic information and technologies. Geocollaboration is a field of study that is multidisciplinary in nature, incorporating theory and methods from human-computer interaction (HCI), computer science, and psychology. Within geography, research on geocollaboration is generally situated within the realm of geographic information science (GIScience). However, it is a topic of cross-cutting relevance to geography as a whole, due to the emphasis that can be placed on either the technological aspects of geocollaboration or the relationship between geocollaboration and social mediation and/or organizational collaboration.

From the technological perspective, the development of systems to support geocollaboration primarily falls under the broader category of computer-supported collaborative work (CSCW), or the study of how people collaborate and the development of computer-based systems that enable people to collaborate in order to achieve common goals and/or make decisions, sometimes referred to as “groupware.” CSCW systems are most often developed based on the use of a given system in terms of the place where collaborators are located (colocated or remote) and the time dimensions of the collaborative work being

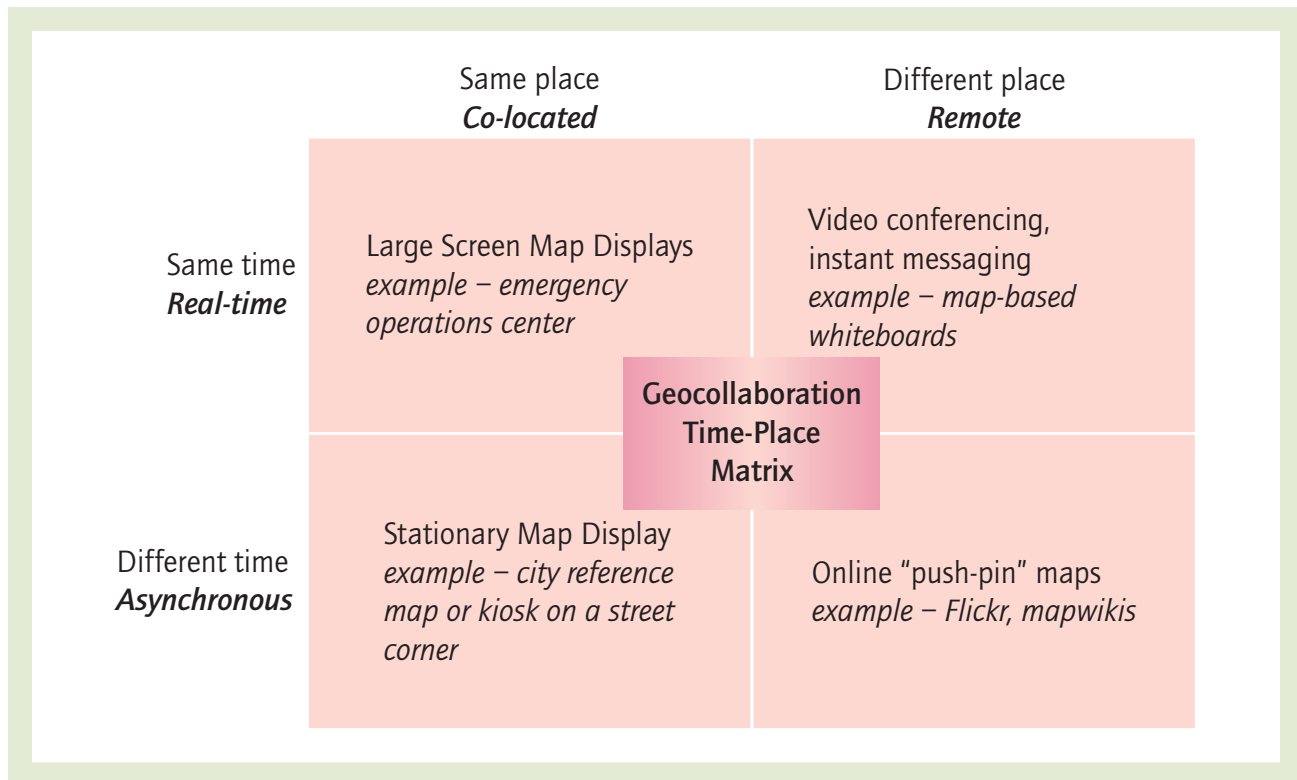


Figure 1 Geocollaboration place-time matrix

Source: Based on Ellis, C. A., Gibbs, S. J., & Rehn, G. L. (2001). Groupware: Some issues and experiences. *Communications of the ACM*, 34, 39–58.

undertaken (in real time or asynchronously). Figure 1 shows the place-time dimensions of geocollaboration in a matrix form and provides brief examples of each dimension.

Additionally, geocollaborative system development takes into account issues of awareness such as co-collaborator presence and activity, the resources available to the group, the status of collective objectives and goals, common ground, and many other CSCW issues that are beyond the scope of this discussion. Unique geographic issues in geocollaborative system development include effective use of geovisual representations such as map-based graphical annotations for representing location-based ideas, the arguments and perspectives of collaborators, the use of geospatial data standards for system interoperability, and group cognition of spatial information.

The research perspective of geocollaboration as a social mediation and/or organizational collaboration de-emphasizes the specific role of

information technology as a mediator for collaboration and looks at the broader social contexts that collaborative processes are occurring within. Social contexts are examined to identify barriers to collaboration such as trust, privacy, and the effects of organizational culture and jurisdictional scale. Using an example from crisis management, collaboration activities across federal, state, and local officials can be examined to understand whether or not officials collaborated effectively across jurisdictional and geographical scales in response to a national disaster.

Another research perspective on organizational geocollaboration activity looks at how geographic information portals on the Internet can potentially encourage organizations to share geographic information resources with the objective of facilitating better collaboration. A primary example of this can be seen in the development of spatial data infrastructures (SDIs). SDIs provide administrative infrastructures such as data-sharing



policies, documentation, and procedures and technological infrastructures such as data interoperability, discovery, and retrieval, which together ultimately allow for the dissemination of geographic information between organizations.

One of the newest research perspectives of geocollaboration as social mediation is examining the integration of geographic information into so-called Web 2.0 technologies. Succinctly, Web 2.0 is the notion of decentralized, user-generated content on the Internet that can be easily shared among people. Examples of Web 2.0 technologies are blogs, wikis, and geotagging of information such as photographs. Geocollaboration from the Web 2.0 perspective thus entails forms of collaboration that do not necessarily have a direct objective such as decision making but rather are decentralized collaborative processes that work toward broader goals that may be of benefit to society. For example, the OpenStreetMap project was developed to create “a free editable map of the whole world” where people can “view, edit and use geographical data in a collaborative way from anywhere on Earth.” In addition to calling this type of activity geocollaboration, the term *volunteered geographic information*, or VGI, has also emerged to describe the development of geographic information by individuals.

One other aspect of geocollaboration activity as social mediation is the use of mapping “mash-ups” to facilitate collaboration. A mashup is a Web-based application that is composed of several heterogeneous components to create a new application. A common example is the use of Google Maps as a base map that is combined with other information that is of prime relevance to the application. From the geocollaboration perspective, mapping mashups are powerful collaborative mediums that can be quickly generated by nongeographic technology experts to fulfill gaps in social needs. For example, during the Hurricane Katrina disaster of 2005, the scipionus.com Web site was a grassroots effort developed to provide location-based information about areas affected by Hurricane Katrina. Using an online mapping mashup, visitors to the Web site were able to enter status information about areas affected by the hurricane. Use of the site grew immensely as the general public sought location-based information on the disaster area that was

not available through regular mediums such as the media.

Brian Tomaszewski

See also Collaborative GIS; MacEachren, Alan; Neogeography; Participatory Mapping; Public Participation GIS

Further Readings

- Goodchild, M. (2007). Citizens as sensors: The world of volunteered geography. *GeoJournal*, 69, 211–221.
- MacEachren, A. M., & Brewer, I. (2004). Developing a conceptual framework for visually-enabled geocollaboration. *International Journal of Geographical Information Science*, 18, 1–34.
- Maguire, D. J., & Longley, P. A. (2005). The emergence of geoportals and their role in spatial data infrastructures. *Computers, Environment and Urban Systems*, 29, 3–14.
- OpenStreetMap Project: www.openstreetmap.org
- Palen, L., Hiltz, S. R., & Liu, S. B. (2007). Online forums supporting grassroots participation in emergency preparedness and response. *Communications of the ACM*, 50, 54–58.
- Schafer, W. A., Ganoe, C. H., Xiao, L., Coch, G., & Carroll, J. M. (2005). Designing the next generation of distributed, geocollaborative tools. *Cartography and Geographic Information Science*, 32, 81–100.



GEOCOMPUTATION

The GeoComputation conference series defines geocomputation as “the art and science of solving complex spatial problems with computers.” This definition highlights the key features of geocomputation that distinguish it from other subdisciplines within geography. First and foremost, it is about solving problems with computers. These problems are also sufficiently complex or involve sufficiently large data sets that a computer is required to solve them. Finally, the conference series definition describes geocomputation as



both an art and a science. Geocomputation is as much about creatively developing new data structures and algorithms for geographical analysis as it is about rigorously testing those algorithms and comparing them with existing algorithms and methods.

Connections to Other Fields in Geography and in Other Disciplines

The problems that geocomputational methods solve span the breadth of geography, including applications in geomorphology, ecology, urban geography, transportation geography, climatology, and medical geography.

In addition to the ties to application domains in which geocomputational techniques and methods are used, the field of geocomputation has connections with several other methodological subdisciplines within geography, including remote sensing, geographic information science, spatial analysis, and geovisualization.

Many data sources for geocomputational data structures and algorithms come from remote sensing, so many of the issues that arise in remote sensing are also dealt with in geocomputation. A prominent issue from remote sensing is the size of data sets that can be involved in this research. Remote sensing satellite systems can generate up to gigabytes of data each day. To best use data sets of this size, especially those that are continually growing in size, data structures allowing for efficient compression of the data and algorithms that can equally rapidly analyze raster data sets of that size need to be developed.

Geocomputation connects with the broader field of geographic information science (GIScience) by contributing to the computational aspects of GIScience. Sample topics in this overlap include data and process modeling with algorithms such as cellular automata and agent-based simulations, how best to represent and analyze uncertainty in spatial data, what data structures and algorithms are effective for representing and analyzing spatio-temporal data, and contributing to the computational aspects of concept mapping and ontologies.

As data sets grow in size and complexity, many of the techniques developed in spatial analysis are entering the geocomputational realm. As data sets get bigger, the statistics used to analyze them

must be performed on a computer. The connection between spatial analysis and geocomputation is more substantial than simple application of previously developed methods; the greater processing power of computers permits new forms of analysis on these data sets. Statistical methods, such as Moran's *I* autocorrelation statistic and regression, can be adapted for spatial data to become the local Moran's *I* statistic and geographically weighted regression. Making even more use of the computer's processing power, artificial intelligence and data mining techniques developed in statistics and computer science are being adapted and applied to geographic data.

Geocomputation has connections with geovisualization and the newly emerging field of geovisual analytics. Geocomputational methods contribute to these fields through the data compression, summarization, and filtering methods needed to reduce very large data sets to a size that is viewable on a computer monitor. Additionally, as ways of visualizing the results from the analytical methods developed in geocomputation are developed, geocomputation contributes to geovisual analytics.

In addition to its ties with other parts of geography, geocomputation has ties with other disciplines, most prominently computer science and statistics. Many of the data structures used in geocomputation originate within computer science, especially computational geometry, although adaptations to fit the constraints of spatial data are common. Likewise, the algorithms developed for analyzing data, especially artificial intelligence techniques, connect geocomputation to computer science. Also, the data mining techniques and analysis methods mentioned above, such as geographically weighted regression, connect geocomputation to statistics.

Topics in Geocomputation

This section gives an overview of the data structures and algorithms that are developed and used within geocomputation. A comprehensive survey of all the topics addressed within geocomputation is beyond the scope of a single encyclopedia entry, so the following section gives a sample of the research issues within geocomputation. For a fuller account of the topics researched within



geocomputation, interested readers should visit the Web site for the GeoComputation conference series to find full-text papers on these topics.

One branch of geocomputation focuses on the development of computational data structures for spatial data. These developments revolve around two themes: (1) the increase in the size of geographic data sets and (2) the difficulties of representing and accessing two-dimensional data when computer disks use a one-dimensional layout, more like a list than a grid.

To cope with the increasing size of geographic data sets, multiple-scale or multiple-resolution data structures have been developed that allow algorithms to access a broad overview of the data quickly and only focus on the detailed data that are necessary for the task being completed. This idea has borrowed the multiple-scale representation from the mathematical concept of Fourier analysis. An example of this is the representation of a demographic variable, such as the percentage of the population that is African American, for all census tracts within the United States. The highest-level overview reports the data aggregated to the state level, giving the percentage for each state. The middle level, at the county level of aggregation, stores not only the aggregated value for each county but also the departure of the county's value from the relevant state's value, so that the sum of the state value and the county departure gives the value for the county. This permits the analysis to look at geographical factors and trends that operate only at the county scale and that may be overwhelmed by the state factors and trends if the true values rather than the departures were used. Similarly, the tract-level departure from the county's true value is stored at the most detailed level of the data set, so that the value for a census tract is the sum of the state value, the county departure, and the tract departure. Another benefit of this type of data structure is that only the detailed data for the area of interest need to be loaded into the computer memory. To examine a variable at the census tract level for a given state, such as Pennsylvania, only the data specific to Pennsylvania are loaded rather than loading the entire file of census tract data for the United States.

The second problem of how to represent geographic data arises from the linear way in which data are arranged on a computer disk, and the

implications that this has for quick access to parts of the file. Computer data are stored as a very long list of bits, and it is easy for a computer to load into memory data that are a contiguous line on the disk. However, it takes longer to load many disconnected lines, even if the lines add up to the same length as the contiguous line. In a geographic setting, it is common to load the data for a geographically contiguous region, such that if data for Place A are being loaded into memory, the data for Place A's neighbors will usually also be loaded into memory. Therefore, it is desired to have the situation whereby two places that are near each other geographically are also likely to be close to each other on the disk to maximize the likelihood of only having to read a single line on the disk. A data structure called a quadtree, along with a way of storing it on disk called the Morton ordering, achieves this goal. While quadtrees are specific to raster data sets, variants for vector data sets have also been developed.

In addition to the data structures developed to address the computational challenges of geographic data, research in geocomputation has developed and examined algorithms to collect and analyze these data.

A growing section of geocomputation involves the collecting and organizing of information gathered from Web sites, RSS (Really Simple Syndication) feeds, and other similar forms of digital media. This research typically involves scanning large amounts of text documents to extract place names and organize texts, such as online news articles, based on where they take place. Challenges encountered in this research center on disambiguation, such as trying to distinguish between place names that are words with nonspatial meanings (such as China—the country and the porcelain) and multiple places with the same name (such as Georgia—the state in the United States and the country in the Caucasus).

Other algorithms, particularly those in the sector of geocomputation connected with geovisualization, focus on enabling decision support for geographic problems. Many of these examine different ways of displaying the data on the computer monitor, to determine what way or ways are most effective at presenting the data so that the user can both understand and explore the data set. A particular approach to decision support specific



to geocomputation is the use of expert systems for geographic decision support. Expert systems are a tool developed within the artificial intelligence community for complex problems such as quickly diagnosing an illness based on a few symptoms. In geocomputation, they can be applied to the challenges of developing effective visualizations and decision support applications for determining whether or not a place is at risk for a hazard, such as landslides. Another research focus for assisting decision support systems examines ways of representing and analyzing the various types of uncertainty in geographic data sets. As the analysis and visualization tools mature to the point of being used to assist decision makers and officials, these tools need to be able to convey not just the information about the problem but also the uncertainty in the information. This uncertainty can take many forms, not just the confidence intervals that are standard in statistics. Some other types of uncertainty include the age of the source—older information about a rapidly changing situation is unreliable—and the trustworthiness of the source; one application domain of these tools is homeland security, where deliberate misinformation is a concern. For these geocomputational tools to be as useful as possible for decision support, they should be able to represent and analyze these types of uncertainty and others in the data set in addition to representing and analyzing the data set itself.

Many algorithms have been developed within geocomputation for the analysis of geographic data, not just the representation of data. Some of these analytical methods, such as geographically weighted regression (GWR), discern trends in the data, much like regression does in standard statistics. While regression finds correlations between two variables across an entire data set, GWR searches for correlations between two variables across only a geographic subset of the entire data set and can then provide an analysis of how the correlation coefficient and its statistical significance varies across the geographic extent of the data set. Similarly, statistics to detect autocorrelation have been adapted to a geographic setting. Autocorrelation statistics were originally developed to analyze time series to determine how likely it is that an observation is similar to observations immediately before and after it in a time sequence. Spatial autocorrelation tests adapt these

ideas to determine how likely it is that an observation is similar to observations in nearby areas.

Similarly, techniques from data mining that facilitate the statistical analysis and exploration of large data sets are being applied to large geographic data sets, such as the U.S. decennial census. These can range from rigorous statistical approaches such as discriminant analysis to computational heuristics such as decision trees and neural networks. A frequent criticism of data mining techniques in geocomputation is that they function much like a “black box.” A large amount of data are given to a computer program, which then applies complex and often hard-to-understand algorithms to the input data and gives an answer about the task being analyzed. Because of the complexity of the algorithm, however, it is hard for most users to understand how the computer program arrives at the answer it gives. This lack of transparency can make some of the algorithms hard to use. Additionally, many geocomputation algorithms require the user to supply parameters that affect the answers they give, yet it can be difficult for a user to determine what the appropriate value of those parameters should be, compounding the difficulty of using these techniques.

Two commonly used sets of algorithms for analysis in geocomputation are for classification and clustering. These two related concepts both create groups of data based on their attributes, and both are often referred to as clustering algorithms. For clarity in this entry, the terms *classification* and *clustering* are used as follows. Classification algorithms, such as K-means divide the data set into a prespecified number of groups and ensure that each individual datum belongs to exactly one group; the groups formed from this algorithm do not need to be geographically contiguous. One application of this type of algorithm is the classification of remotely sensed images into land cover classes. Clustering algorithms search to find groups of data that usually form a single contiguous geographic shape and that have a particular quality that is being searched for, such as a higher than expected rate of a disease. In this example, each cluster is an area of high rates of the disease being studied, and clusters can overlap each other. Thus, each individual datum can belong to zero, one, or more than one cluster simultaneously.



Algorithms for optimization analysis have been developed in geocomputation. These optimization algorithms can include the clustering algorithms described above because they seek parts of the data set that have the highest (or lowest) value of some function. In the clustering example above, the function is the rate of the disease. Typically, the data sets are too large to simply check every possible location within a reasonable amount of time, so a heuristic, or rule of thumb, is needed. These heuristics are frequently borrowed and adapted from artificial intelligence research in computer science. Common examples are genetic algorithms and simulated annealing. In addition to the “black box” and parameter critiques described above, another drawback of these heuristics is that they cannot guarantee that they return the best solution to the optimization problem; because not every part of the data set is examined, it is always possible that a better solution remains in the unexamined portion of the data set.

Last, geocomputation involves methods of modeling geographic processes. Two common approaches to this modeling are cellular automata and agent-based models. Cellular automata operate on a grid of the area being studied, where each grid cell has some geographic attributes assigned to it. An example of this is a physical landscape with the elevation, presence of water, and level of urban development represented. The cellular automata model then has rules governing some process, such as urban growth. As the model runs, the grid cells of the nonurban region get converted to urban cells based on the rules governing urbanization; for example, any cell with five or more urban neighbors will become an urban cell. These models can then be run and compared against the real-world situation to determine if the rules are valid. In this way, cellular automata models can provide valuable insights into the rules governing geographic processes. While cellular automata models work well with raster data, agent-based models are analogous to vector data. In agent-based modeling, which is often applied to objects that move, such as people or wildlife, each person or animal being modeled is considered an agent. Similar to the rules that govern cell behavior in a cellular automata model, there are simple rules that govern agent behavior in agent-based modeling; for example, an agent representing a wild

animal will move toward a river if the animal is thirsty. Both these modeling approaches make use of the idea of complexity, whereby the interaction of a small set of simple rules can create many complicated and interesting patterns.

Conclusion

Geocomputation lies at the intersection of geography and computer science, contributing to and borrowing from a range of subdisciplines both within geography, such as geographic information science, spatial analysis, remote sensing, and geovisual analytics, and outside geography, such as data mining in statistics and artificial intelligence, data structures, and database management in computer science.

Jamison Conley

See also **Agent-Based Models; Cellular Automata; Geographically Weighted Regression; GIScience; High-Performance Computing; Quantitative Methods; Spatial Analysis; Spatial Autocorrelation; Spatial Data Mining; Spatial Data Structures; Spatial Optimization Methods**

Further Readings

- Openshaw, S., & Openshaw, C. (1997). *Artificial intelligence in geography*. Chichester, UK: Wiley.
- Proceedings of the GeoComputation Conference
Series: www.geocomputation.org
- Worboys, M., & Duckham, M. (2004). *GIS: A computing perspective* (2nd ed.). Boca Raton, FL: CRC Press.



GEODEMOGRAPHICS

Geodemographics uses the close links between where a person lives and the lifestyle choices that the person makes for various economic, social, and political applications. It is the analysis of the demographic and socioeconomic characteristics of people based on their location, although it is often viewed as a data exploration tool rather than a method of hypothesis investigation. Developments



in geodemographics go hand in hand with advances in geographic information systems (GIS) as geodemographics heavily uses the mapping of classification schemes. Analysis consists of data acquisition and cluster-based classification to produce profile groupings of similar attributes, which are then assigned to contiguous geographic areas. Marketing companies, academia, and government use these classification schemes for a variety of applications, such as predicting the usage of public services and understanding consumer needs. Current topics of interest within the field of geodemographics are statistical relevance, public accessibility, temporal sensitivity, and combining geodemographics with other geographical fields such as remote sensing.

Data Collection

Data necessary for geodemographic analysis will vary depending on the goals of the project but will always consist of two components—the target group and the geographic unit of study. The target group consists of individuals of specific characteristics and is measured through proxy variables. For example, high-income households might be measured with the proxy of how many cars a household possesses. Proxy variables include but are not limited to information concerning socioeconomic status, demographics, durable goods, usage of public assets, and any other information concerning the lifestyles of individuals and families. The scale of the geographic unit of study will also depend on the goals of the project but will almost always follow preexisting administrative boundaries, such as postal codes, census tracts, or census blocks. GIS is used to tie individual data to locations, assist in analysis, and geographically represent the data. General demographic and socioeconomic data are collected from existing public data sources, such as the census and administrative surveys. Marketing firms often need to buy or privately fund syndicated market research group surveys, which contain extensive detail but do not have many respondents.

Classification

The main goal of a geodemographic analysis is to produce a classification scheme of neighborhood

profiles. Classification takes all the areas under analysis and groups them into a smaller number of classes ranging from 10 to the 150 types offered by some marketing firms. Over time, classes have been offered at increasingly fine scales, ranging down to the household and, at times, even the individual. The number of classes will depend on the needs of the project and how much detail is wanted. Classification is accomplished by placing all proxy variables of interest into a factor or cluster analysis with a predetermined number of classes. The demographic and socioeconomic characteristics of each class are summarized, and often a short label is assigned to each class that gives an impression of what that class represents. Companies selling geodemographic classifications will also usually provide a picture or drawing representing each class. The classes can then be mapped in a GIS, but care should be taken to produce a meaningful and realistic map structure that is easy for the user to understand.

Applications

Applications of geodemographics can be broadly split into public and private interests. Major private companies use geodemographics for profiling of consumers into categories that can then be easily marketed and catered to. This practice is called niche marketing. Companies will often conduct small detailed surveys and buy the geodemographic classifications of those areas from larger companies. They then compare the surveyed customers with the geodemographic baseline for the entire area, allowing them to conjecture information about their customer base. This information is used for a variety of applications, such as further survey designs, product placement, retail planning, development of new shopping centers, site selection, household and rent pricing, and scheduling of television and other media advertising. The main public sector uses of geodemographics are within government initiatives and nonprofit organizations. Local governments can use geodemographics for better planning of resource deployment, such as local policing, food banks, health services, schools, public libraries, and other government-provided services. Often, geodemographics is used to locate and understand where areas of high deprivation are located. Another application



is the use of geodemographics by political campaigns to locate potentially friendly voter blocks. Nonprofit organizations employ geodemographics both to better locate areas of need and for fund-raising purposes.

Criticisms and Future Research

The field of geodemographics has been heavily criticized. Mapping classifications presents limitations by implying that populations are uniformly distributed, both numerically and socioeconomically or demographically. Maps also give the impression that changes occur only at the borders between classed areas, instead of demonstrating the more likely gradual change occurring in neighborhoods. Using GIS methods of overlay with remotely sensed imagery as well as creating boundaries of classifications that are more sensitive to changes over space are some of the methods being explored to correct these issues. Generalization within geodemographics is criticized as a practice that may actually be harmful to neighborhoods. By giving individuals within an area a general label and then marketing to that label, the small changes introduced into a neighborhood based on these marketing decisions may actually further validate the definition and place neighborhood identity beyond the control of residents.

Future work in geodemographics has many potential paths, but most research is being done in academia. Web-based geodemographics has been introduced as a means of easy accessibility and transparency and, more important, as a way of promoting community involvement in classifications by allowing user feedback. As research interests in neighborhood effects increase, geodemographics is proving useful in studying what a neighborhood is, how to define it, and what kind of influences it has on the people living there. There is also some work being done on making geodemographics more statistically relevant and providing some degree of validation. One of the areas that marketing firms are exploring is making geodemographics more in step with the realities of mobility. A geodemographic classification of a city may be completely different in the afternoon, when people are at work, than in the morning or evening, when they are at home.

Marta Jankowska

See also **Applied Geography; Business Geography; Geoslavery**

Further Readings

- Goss, J. (1995). "We know who you are and we know where you live": The instrumental rationality of geodemographic systems. *Economic Geography*, 71(2), 171–198.
- Harris, R. (2005). *Geodemographics, GIS and neighbourhood targeting, mastering GIS*. West Sussex, UK: Wiley.
- Webber, R., & Longley, P. (2003). Geodemographic analysis of similarity and proximity: Their roles in the understanding of the geography of need. In P. Longley & M. Batty (Eds.), *Advanced spatial analysis: The CASA book of GIS* (pp. 233–266). Redlands, CA: ESRI Press.



GEODESY

The literal meaning of *geodesy* is "division of the Earth," and it can therefore be said that at its most fundamental level, the subject is concerned with positioning on the surface of the Earth. More narrowly, the subject is understood to apply principally to applications with an extent or accuracy that demands a consideration of the true shape of the planet (in contrast with surveying, which may be more concerned with flat Earth approximations).

More broadly, however, geodesy necessarily encompasses the range of mathematical and scientific topics that relate to the determination of the shape and size of the Earth, its representation in coordinate terms and computations within these coordinate systems, map projections, positioning, and height determination techniques (in particular satellite-based systems). It can therefore be seen that geodesy is of direct relevance to geography in that it establishes the essential underlying coordinate reference systems for use in mapping and related spatial information activities.

This process can be thought of in a hierarchical fashion or as a logical sequence of required steps. First, one needs to know the shape and size of the



Earth, which one finds from several different types of observation. The surface that it is required to determine is known as the geoid, which is defined as that equipotential surface (one perpendicular to gravity) that most closely corresponds to mean sea level. Its long-wavelength components are generally found from an analysis of the perturbations of satellite orbits from the simple Keplerian model, since these are caused by major gravitational trends. Its short-wavelength components are determined principally from a combination of direct observations of gravity anomalies (on the surface, through airborne gravimetry, and from dedicated satellite missions) and analysis of satellite altimetry data over the oceans. The link between gravity and shape is one of the classical mathematical problems of geodesy, and much research is devoted to the optimization of the algorithms used.

The traditional method for the determination of Earth's size was by terrestrial observations of angles and distances. These were generally made in linked chains of triangulation that were sometimes carried out along a meridian with the specific intention of gaining information on Earth's size; more generally, these were carried out to provide a framework for mapping. While the results of these traditional geodetic observations may still in many parts of the world (and not necessarily the least developed) form an essential component of the coordinate framework, the primary techniques for the determination of the size of the Earth (i.e., determining the relative coordinate values for key global reference points) are space based. These include the following: (a) very long baseline interferometry (VLBI), in which pairs or sets of radio telescopes make mutual observations to extragalactic sources of radiation, and baselines are inferred from time delays; (b) satellite laser ranging (SLR), in which ground stations fire lasers that are returned by retroreflectors aboard satellites; (c) the global positioning system (GPS) or any other similar global navigation satellite system in which receivers make observations of electromagnetic signals broadcast by a system of orbiting satellites; and (d) Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), in which the Doppler shift of a signal received at a dedicated satellite from a ground station is the fundamental measurable.

All these different observations contribute to the establishment and maintenance of the International Terrestrial Reference Frame (ITRF), which is the primary global coordinate system. It is maintained and disseminated by the International Earth Rotation Service (IERS). It is desirable to determine the transformation from any traditionally established coordinate reference system into this international system, as it is this that permits the integration of observations with systems such as GPS into national mapping.

It is an aim of geodesy to determine the complex shape of the Earth and the coordinates of key reference points on it. The uses of the data so obtained are manifold. Geodesy may be used in geophysics or plate tectonics to infer information about the distortions of Earth's crust from time series of observations. It may be used in oceanography, to reveal differences between the mean sea-level surface and the geoid, thereby aiding in our understanding of ocean currents. It may be used in the study of sea-level rise, to separate the effect of vertical land movements from changes observed at tide gauges. It may also be used to establish a coordinate reference frame for mapping. The previous examples cited relate very much to the modern era of space geodesy; the mapping application is one that was traditionally carried out with the triangulation techniques described above (the results of which may still form the basis of the coordinate system) but that is increasingly being established by modern satellite geodesy. In the latter case, computations are largely carried out in simple geocentric Cartesian coordinate systems, and then the results are converted into latitude and longitude in an ellipsoidal system. In the traditional methodology, the ellipsoidal coordinate system was the fundamental system, and computations of coordinates had to be carried out within it. This engendered a branch of mathematical geodesy that has largely been superseded in the satellite era and is now only required in specialist applications such as the determination of international boundaries.

Finally, mention may be made of the science of map projections, a subject that lies somewhere on the boundary between geodesy and cartography. This is the branch of mathematics that deals with the conversion between ellipsoidal

coordinate systems and representations of Earth's surface in two dimensions for mapping and display purposes.

In conclusion, geodesy is a diverse subject that has grown from being historically closely linked to mapping and surveying into a modern science concerned with direct measurement of many of the key defining characteristics of the planet—its shape, size, deformation, and rotation. As such, it is a key component of many of the Earth sciences and is vital for a real understanding of many current concerns such as climate change.

Jonathan Iliffe

See also **Altitude; Cartography; Datums; Earth's Coordinate Grid; Geocoding; Geocomputation; Geometric Correction; Geosensor Networks; Global Positioning Systems (GPS); Latitude; Longitude; Map Projections; Surveying**

Further Readings

- Iliffe, J., & Lott, R. (2008). *Datums and map projections for remote sensing, GIS and surveying* (2nd ed.). Caithness, UK: Whittles.
- Torge, W. (2001). *Geodesy* (3rd ed.). Berlin, Germany: de Gruyter.
- Vanicek, P., & Krakiwsky, E. (1986). *Geodesy: The concepts* (2nd ed.). Amsterdam: Elsevier.



GEOGRAPHICAL IGNORANCE

Media reports periodically highlight an appalling lack of public geographical knowledge, particularly in the United States. The *National Geographic/Roper Public Affairs 2006 Geographic Literacy Study* revealed that two thirds of Americans between 18 and 24 years of age were unable to find Iraq on a world map, almost half could not identify India, and three quarters could not locate Iran or Israel. Seventy-four percent of respondents selected English (rather than Mandarin Chinese) as the world's most widely spoken primary language. Knowledge of the United States itself was shown to be equally scanty, with fewer

Bizarro



Source: "Bizarro" used with the permission of Dan Piraro and King Features Syndicated in conjunction with the Cartoonist Group. All rights reserved.

than half of the respondents able to identify the states of New York or Ohio. Perhaps most worrisome was the finding that most young Americans remained satisfied with their ignorance. Fewer than 30% of those surveyed thought it necessary to know the locations of countries figuring prominently in the news.

Previous *National Geographic/Roper* surveys revealed that the United States is particularly beset by geographical ignorance. In the 2002 effort, which examined Canada, France, Germany, Britain, Italy, Japan, Mexico, Sweden, and the United States, young Americans came in second to last, beating only Mexican students. Respondents in all other countries surveyed more accurately estimated the population of the United States than did American students. Much evidence indicates, however, that geographical illiteracy is by no means limited to the United States. In an extensive 1995 survey based on sketch maps, Thomas Saarinen and Charles MacCabe found that American university students performed at



roughly the global average, trailing Europeans but outperforming many others.

Unfortunately, a disregard for essential geographical distinctions extends to the highest levels of the American body politic. In the 2008 presidential election, candidates from both major parties embarrassed themselves with serious geographical gaffes. The Democratic vice presidential candidate Joe Biden erroneously alleged that the United States had expelled Hizbullah from Lebanon, while the Republican presidential candidate John McCain confused Sunni and Shi'ite Islam. More worrisome were accusations from campaign insiders that the Republican vice presidential candidate, Sarah Palin, could not name the three members of the North American Free Trade Agreement and was unaware that Africa is not a country. Although these assertions were challenged, public interviews revealed that Palin had a meager understanding of international relations and global conditions.

The current lack of concern for geographical knowledge in the United States represents a reversal from historical norms. Before World War II, secondary school students were expected to gain a close familiarity with the basic contours of the world map. To be sure, American isolationism and notions of national exceptionalism militated against the broad acquisition of global knowledge, but educated individuals—and certainly candidates for national office—were expected to be geographically literate.

Ironically, just as the United States found itself embroiled in global geopolitics in the post-World War II period, systematic geographical education was dismantled at the primary and secondary levels. Technological optimists naively assumed that advances in transportation and communication would erase the distinctions among different places, thus rendering geography irrelevant. At the same time, restlessly progressive educators concluded that geography was simply too stodgy and factually intensive. As a result, the subject yielded its place to an amalgam of history, sociology, and political science called social studies. In a 1993 study, J. Chiodo showed that most preservice social studies teachers in the United States lacked even a basic understanding of world geography.

The postwar period also witnessed a massive retreat from geographical instruction at the

university level. Harvard University eliminated its geography department in 1948, and as Harvard led, others followed, eventually including Yale, the University of Michigan, and Columbia University. In several cases, university administrators concluded that geography was insufficiently theoretical to serve as a course of college instruction. Partially in reaction, geographers devised ever more abstract approaches to their subject matter during the quantitative revolution. This movement yielded impressive intellectual dividends, but its more extreme forms tended to disregard factual knowledge, thus perpetuating geographical illiteracy from within the discipline. Geographical ignorance negatively affects a variety of decision makers' actions, including voting, corporate and military strategy, diplomatic efforts, tourism, and international trade.

While basic geographical instruction has been reinstituted at many elementary and secondary schools in the United States, the situation remains discouraging. Without systematic instruction—from kindergarten through college—in the specific, complex, multidimensional spatial relationships that generate geographical patterns, geo-ignorance will remain the norm.

Martin W. Lewis

See also [Geography Education](#)

Further Readings

- Chiodo, J. (1993). Mental maps: Preservice teachers' awareness of the world. *Journal of Geography*, 92, 110–117.
- Eve, R. (1994). Geographic illiteracy among college students. *Youth and Society*, 25(3), 408–427.
- Lewis, M. (2000). Global ignorance. *Geographical Review*, 90(4), 603–628.
- Saarinen, T., & MacCabe, C. (1995). World patterns of geographic literacy based on sketch map quality. *Professional Geographer*, 47(2), 196–204.
- Salter, C. (1990). *Missing the magic carpet: The real significance of geographical ignorance*. Washington, DC: National Geographic Society, Geographic Education Program.



GEOGRAPHICAL IMAGINATION

The geographical imagination is a way of thinking about the world and considering the relative importance of places and the relationships between “our” places and “other” places. The term encompasses a variety of meanings, including individual mental images and socially produced discourses about cultures, spaces, and differences. How people see the world is influenced by many factors, including social class, education, and personal and political philosophies. The particular moments in history in which people live also play a major role in how they view the world around them.

Derek Gregory explains that the geographical imagination plays a significant role in shaping much of the world’s social and spatial thought. Through the geographical imagination, people (both individually and collectively) develop a sense of boundaries, which separate “our” spaces and places from other spaces and places. Geographical imaginations are thus central to the social and spatial constructions of identity. However, few people take the time to contemplate on these issues and think them through thoroughly. The geographical imagination thus forms a part of taken-for-granted everyday assumptions, perceptions, and expectations. Sometimes people gain facets of their geographical imagination through travel, the media, or by sharing travel stories; most people gain the earliest parts of their geographical imagination through what they learn in school about other places. More important, people learn where they fit into the world that they perceive; this is the essence of the geographical imagination. Throughout history, as the particular discourses and social narratives about how the world is structured have been changing so have geographical imaginations.

This entry examines three broad examples of the geographical imagination: (1) the British imperial imagination; (2) manifest destiny and its relation to the American geographical imagination; and (3) Cold War fears in the U.S. geographical imagination.

The British Imperial Geographical Imagination

Empires thrive, in part, because of the geographical imaginations that sustain them. One

important way in which geographical imaginations are represented is through maps. The geographer Denis Cosgrove, among others, examined the role of maps in the formation of Western views of the world during the Renaissance and the Enlightenment and the ways in which they gave some groups a commanding view of the world, that is, a perspective “from above” that integrated the planet’s diverse spaces into a coherent whole. Cartography played a major role in structuring the geographic imaginations of European colonial powers. During the years of colonization, for example, many British colonialists referred to the British Empire as the set of places “where the sun never sets.” This belief was an important part of the British colonial geographical imagination and was reinforced through world maps in which Britain’s colonies were often shaded red.

The British took great pride in their knowledge of the world, but like their maps, their knowledge was colored with the air of superiority and domination. In turn, this knowledge of the world was used to reinforce pride in the empire. Literature, religion, and the social and natural sciences (e.g., social Darwinism) were often closely mingled with imperial discourse. Figure 1, subtitled “God Save the Queen!” shows the relationship between knowledge and the British imperial imagination. Queen Victoria is surrounded by icons of the empire, including the banners of “Commerce,” “Literature,” and “Science.” Each of these banners justified British colonial superiority in the British geographical imagination.

The British colonialists sincerely believed that they were spreading civilization around the globe. The high costs paid by the colonized peoples were not considered. Often, they were grouped into political administrative districts that forced them to compete for resources against other colonized peoples, and families were often broken up. These historical effects still affect many former colonies today. In the British imagination, it was considered an honor to be a part of the empire, even in a subservient role like that of the colonies.

Technology also fueled the British imperial imagination. Many took great pride in the telegraph and its role in connecting the empire by easing communication and the transmission of world news. The British geographical imagination of this time focused out toward the world



Figure 1 Punch cartoon depicting Queen Victoria.

Source: Graves, C. (1922). *Mr. Punch's history of modern England* (Vol. 3, p. 229). New York: Cassell.

and the far reaches of the empire. News reports from abroad transmitted via telegraph reinforced imperial pride, but they also lent an aura of objectivity to British imperial control while legitimizing and naturalizing the empire.

Technology gave the appearance of a unified empire, but in reality, the empire was far from a single unified totality. The colonial subjects had diverse cultures and histories, and they experienced colonialism differently. Some peoples, such as those in India, were looked on more favorably than others, such as the indigenous Australians, who were often considered to be subhuman and were frequently exterminated violently. All colonized peoples, however, were used to further British interests. Two mutually exclusive ideas were held in the British geographical imagination. On the one hand, the diversity of peoples and places was lauded, propping up the British imperial identity. On the other hand, the British assumed a

bond of unity throughout the empire, giving all its servants a common mission. The geographical imagination can gloss over or even ignore differences or ignore other peoples altogether.

Manifest Destiny in the U.S. Geographical Imagination

It bears repeating that geographical imaginations are perceptual and cognitive discourses; they ideologically sustain and justify actions that make reality conform to what is seen in the imagination, linking the “real” to the planned, hoped for, expected, and fantasized. Americans have also had various geographical imaginations throughout their history. Manifest destiny is one such example. Popular during the 19th century, Manifest destiny was the belief that the United States would ultimately extend from the Atlantic to the Pacific, a notion grounded in deeply rooted views of



American exceptionalism. This view shaped the geographical imaginations of many American settlers, who moved to the “empty” West to claim and tame the land. The numerous tribes of Native Americans, who had their own cultures and world-views, did not fit conveniently into the American geographical imagination of manifest destiny. For example, Americans viewed the West as empty and unused land. Many Native American tribes, though, considered it their home. The American interior was thus not “empty” land, despite the fact that it was commonly portrayed that way, but was populated by diverse groups of inhabitants. Through brute force and violated treaties, the United States coerced the Native Americans into smaller and smaller lands and reservations.

The word *imagination* may seem harmless, as if it were some dreamy, impractical idea without material consequences, but geographical imaginations are far from innocent; rather, they are profoundly political and have powerful social and spatial impacts. Geographical imaginations simplify the knowledge of places by making complex and conflicting realities seem simple, with sharp lines of differentiation between one social group and others, often justified on racist, ethnocentric, or nationalist grounds. Thus, the extermination and removal of Native Americans from Western lands made the acquisition of their territories fit better with the doctrine of manifest destiny. According to the popular American historical narrative, the country was a place for immigrants to get a new start in life. In the early 20th century, the United States became popularly known as “the great melting pot.” However, this notion did not include Native Americans, whose connections to the continent long predated the Europeans. The narrative of manifest destiny was an important part of the American geographical imagination, which viewed westward expansion as a positive and necessary thing. The motives for expansion

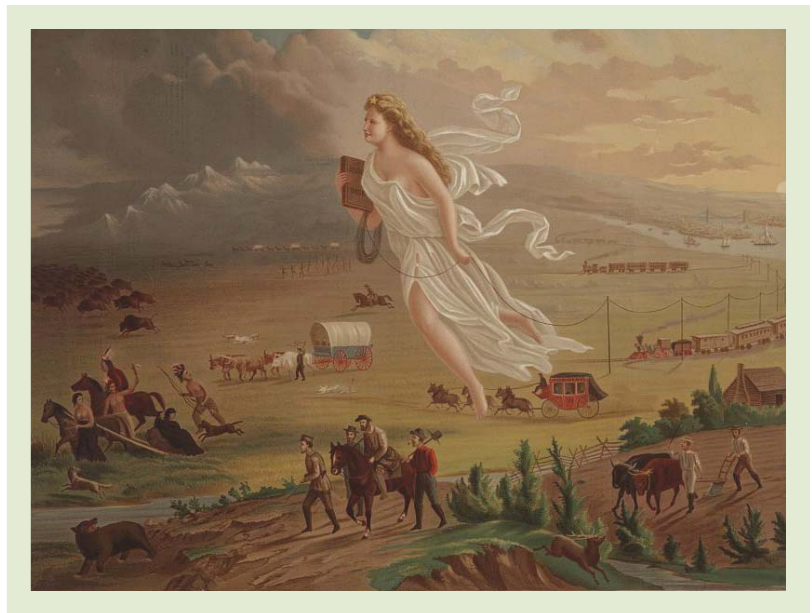


Figure 2 John Gast's 1872 allegorical painting “American Progress” depicts a light-haired woman with the “Star of Empire” on her forehead. Symbolizing progress as understood in terms of the doctrine of Manifest Destiny, she leads settlers west as Native Americans flee. She holds a book in one hand and the transcontinental telegraph cable wire in the other. The painting was commissioned by George Crofutt, a publisher of western travel books and the magazine *Crofutt's Western World*.

Source: An 1873 chromolithograph by George A. Crofutt, after an 1872 painting of the same title by John Gast. Library of Congress Prints and Photographs Division.

were often hidden or justified by narratives that stressed nationalism, racism, or religion; in reality, profit motives and the desire for land contributed greatly to westward expansion, but the American geographical imagination stressed the inevitability of expansion rather than the motives for it and the ensuing conflicts.

Cold War Fears and the American Geographical Imagination

Another important example of the changing American geographical imagination occurred with the Cold War, during which the United States and the Soviet Union were the world's two superpowers. In the geographical imaginations of many Americans, the world was conveniently divided into countries that were free and democratic and those that were oppressed by communism. In the American geographical imagination,



the USSR was a drab and repressive place. During the 1980s, President Ronald Reagan dubbed it the “evil empire.” The Soviet Union, held to be dark, poor, oppressive, and stagnant, was the antithesis of America, which viewed itself as dynamic, wealthy, and free. Accusing enemies of being evil and vile is a common tool in the geographical imagination, which is often deeply moral as well as political in nature.

Such concerns were particularly acute in an age when nuclear missiles could come with little warning and deliver mutually assured destruction, with the threat of violent death looming over both superpowers. During the early years of the Cold War, school children were taught to “duck and cover,” to drop and get under a desk or table to protect themselves from nuclear blasts. Fallout shelters were another means of safety. Threats were global in scale, but safety, it was thought, could come in the smallest of scales. The purpose of discussing the Cold War in terms of the geographical imagination is not to dismiss or belittle Cold War fears but to show that imaginative geographies play an important role in how people think about the world.

Fear of nuclear annihilation was just one aspect of the American geographical imagination during the Cold War. Another fear involved the domino theory, according to which nonallied countries would successively turn communist, and then their neighboring countries would fall, like lines of dominos, into the sway of communism. Many Americans feared that communism would spread in this way throughout southeast Asia from China, Korea, and Vietnam and westward toward India. The domino theory was not limited to southeast Asia but was also used to justify the use of American military force in Central America. With Cuba already viewed as a communist threat, the concern was that Central American countries would follow its lead, bringing communism successively closer to the United States, as suggested by the domino theory. In the geographical imagination of the time, the exaggerated fear that communism would overcome Central America, and eventually Mexico, made the Soviet threat seem all the more urgent and made it imperative to prevent the spread of communism in the region. That is not to say that Americans were unified in their fear of Central America. There was much debate

on the effects and justification of U.S. military and economic interventions in countries such as Panama, Honduras, and Nicaragua.

Conclusion

The geographical imagination continues to play a role in many common geopolitical and social beliefs. With the increasing speed of travel and communication, and thus increasing interconnectedness, geographical imaginations are as important today as ever. Some, such as Thomas Friedman, believe that the world is “flattening,” that is, spatial differences are becoming eradicated or reduced to the point of trivia—and thus proclaim the decline of geography as an important factor in global commerce, trade, investment, communications, and other forms of interaction. However, the belief that the world is flattening is itself an aspect of the neoliberal geographical imagination. British imperialists likewise believed that the world was connected and, like Cecil Rhodes, asserted that it was connected by the British Empire. Proponents of manifest destiny believed that America was destined be connected from coast to coast and ignored Native American claims to the land. Cold War fears of nuclear war and communism were based on the view that the world was connected through a network of mutually assured destruction. Conversely, other geographical imaginations portray contemporary global connectivity in terms of the “global village” of communications networks or cosmopolitan webs of mutual obligations.

Geographical imaginations deeply shape people’s views of other places, and thus of themselves. These views are expressed through a multitude of actions, such as political behavior, military strategy, investments, choices of tourist destinations, consumer choices, and attitudes toward immigrants and foreigners. Geographical imaginations are interwoven with a knowledge of other places, even if such knowledge is inaccurate or misleading. It is important to consider where people get their views of the world, what forms of knowledge they choose over others and what they ignore, who benefits from that knowledge, and who is left out or ignored.

Jessey Gilley



See also Colonialism; Cosgrove, Denis; Discourse and Geography; Domino Theory; Ethnocentrism; Eurocentrism; Globalization; Identity, Geography and; Imperialism; Orientalism; Other/Otherness; Photography, Geography and; Positionality; Race and Empire; Race and Racism; Representations of Space; Sense of Place; Situated Knowledge; Symbolism and Place; Time-Space Compression; Vision and Geography

Further Readings

- Gregory, D. (1994). *Geographical imaginations*. Cambridge, MA: Blackwell.
- Harvey, D. (1990). Between space and time: Reflections on the geographical imagination. *Annals of the Association of American Geographers*, 80, 418–434.
- Harvey, D. (2005). The sociological and geographical imaginations. *International Journal of Politics, Culture and Society*, 18, 211–255.
- Heffernan, M. (2007). *The European geographical imagination*. Berlin, Germany: Franz Steiner Verlag.
- Jarvis, B. (1998). *Postmodern cartographies: The geographical imagination in contemporary American culture*. New York: St. Martin's Press.
- Lestringant, F. (1994). *Mapping the Renaissance world: The geographical imagination in the Age of Discovery*. Berkeley: University of California Press.
- Schulten, S. (2001). *The geographical imagination in America, 1880–1950*. Chicago: University of Chicago Press.
- Schwartz, J., & Ryan, J. (Eds.). (2003). *Picturing place: Photography and the geographical imagination*. New York: I. B. Tauris.

GEOGRAPHICALLY WEIGHTED REGRESSION

Most statistical techniques assume that relationships are constant over space (the assumption of spatial stationarity). Geographically weighted regression (GWR) is a statistical technique that allows relationships to vary spatially within a

study region (it therefore allows spatial nonstationarity). The relaxation of the stationarity assumption in regression has proven to be effective in modeling many spatial processes. This entry summarizes the conceptual and mathematical background to GWR.

Background

Regression analysis, in various guises, is without much doubt the most popular form of statistical analysis practiced. Its popularity arises because it allows researchers to quantify the relationship between two variables while accounting for (holding constant) the potentially confounding relationships between other variables. This is an extremely useful feature that can be employed in a wide variety of application areas. In a linear framework, these relationships can be represented with the following general model:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_n x_{ni} + \varepsilon_i, \quad (1)$$

where y_i is the value of the dependent variable observed at location i ; $x_{1i}, x_{2i}, \dots, x_{ni}$ are the values of the independent variables observed at i ; $\beta_0, \beta_1, \dots, \beta_n$ are parameters to be estimated; and ε_i is an error term that is assumed to be normally distributed.

Within this model, researchers are interested in obtaining accurate estimates of the parameters $\beta_0, \beta_1, \dots, \beta_n$, which inform them of the nature of various statistical relationships that in turn can be used to infer aspects of the determinants of variation in the dependent variable y . The parameter estimates obtained in the calibration of such a model are obtained from the following estimator:

$$\beta^* = (X^T X)^{-1} X^T Y, \quad (2)$$

where β^* represents an estimate of β .

To make clear what is happening here, multiple observations on each of the variables $y, x_1, x_2, \dots, x_n$ are needed to obtain a single estimate of each parameter in the model. It is impossible to determine any set of estimates based on a single observation of $y, x_1, x_2, \dots, x_n$ since then an infinite number of parameter values would fit the equation exactly. Consequently, researchers have to estimate the parameters in the model



statistically from multiple observations of the variables $y, x_1, x_2, \dots, x_n$, and the more observations they have on each of the variables, the more reliable their estimates become as representatives of the true relationships within the model, *ceteris paribus*.

The question then is where do these data come from? If the data are time series, then multiple observations of $y, x_1, x_2, \dots, x_n$ can be obtained at the same location and a regression run for that location (while taking into account serial autocorrelation issues). If the data are spatial (i.e., one has observations at multiple locations), then an estimate of the parameters in the model can be obtained by pooling the data from the various locations at which the data are recorded within a study area. Obviously then, the parameters that are estimated in the regression analysis represent averages of the relationships that exist in each of the locations at which the data are recorded. This is the method by which regression is performed in spatial analysis, and two potential problems arise that are unique to spatial data (although equivalent problems surface in aspatial data, they are not as complex as those found in spatial data).

One of these potential problems is that of spatial dependency in the data, whereby the observations on the variables $y, x_1, x_2, \dots, x_n$ are not independent (a likely scenario with spatial data), and this leads to problems of inference given that the framework for this assumes that independent data are used to estimate the parameters. This topic is covered in Fotheringham, Brunson, and Charlton (2002) and is not the subject of this entry.

The other potential problem is that of spatial nonstationarity (also referred to as spatial heterogeneity), whereby the relationships being estimated by the parameters in the model are not constant over space. In this case, taking the averages of the processes at different locations (how regression with spatial data works traditionally) will lead to biased parameter estimates that do not give any indication of the spatial variation in the processes that generated the data used in the calibration of the model. In this case, describing a spatially nonstationary process with a single parameter estimate would be akin to describing the intricate spatial variation in temperature or

rainfall across the United States with a simple average value. Although researchers would never dream of doing the latter (they would naturally want to describe the spatial variation in temperature or rainfall on a map), they routinely report average parameter estimates from regression performed on spatial data without thinking of whether or not that average is hiding some very important spatial variation in the processes they are investigating.

So how can researchers investigate potential spatial variations in relationships when they typically have only one set of observations on $y, x_1, x_2, \dots, x_n$ at each location within a study area? As stated above, multiple observations of each of the variables are needed to obtain an average set of parameter estimates. GWR does this by defining a location at which a local regression will be performed and then weighting the observed data by the distance each data point is from the regression point, with data locations in closer proximity given more weight than data points farther away (see Figure 1). This regression point is then moved across the study region. Each time this is done, a local regression is performed on the weighted data, generating a set of local parameter estimates (see Figure 2).

Operationalizing Geographically Weighted Regression

The geographically weighted version of the regression model described in Equation 1 is

$$y_i = \beta_{0i} + \beta_{1i}x_{1i} + \beta_{2i}x_{2i} + \dots + \beta_{ni}x_{ni} + \varepsilon_i, \quad (3)$$

where i refers to a location at which data on y and x are measured. In this case, it also depicts locations at which local estimates of the parameters are obtained, but the two sets of locations need not be the same. It is perfectly feasible to obtain local parameter estimates at locations where no data on $y, x_1, x_2, \dots, x_n$ exist (see Figure 3).

On the basis of the notation in Equation 3, the estimator for the local parameters is

$$\beta^*(i) = (X^T \mathbf{W}(i) X)^{-1} X^T \mathbf{W}(i) Y, \quad (4)$$

where $\mathbf{W}(i)$ is a matrix of weights specific to location i such that observations nearer to i are given

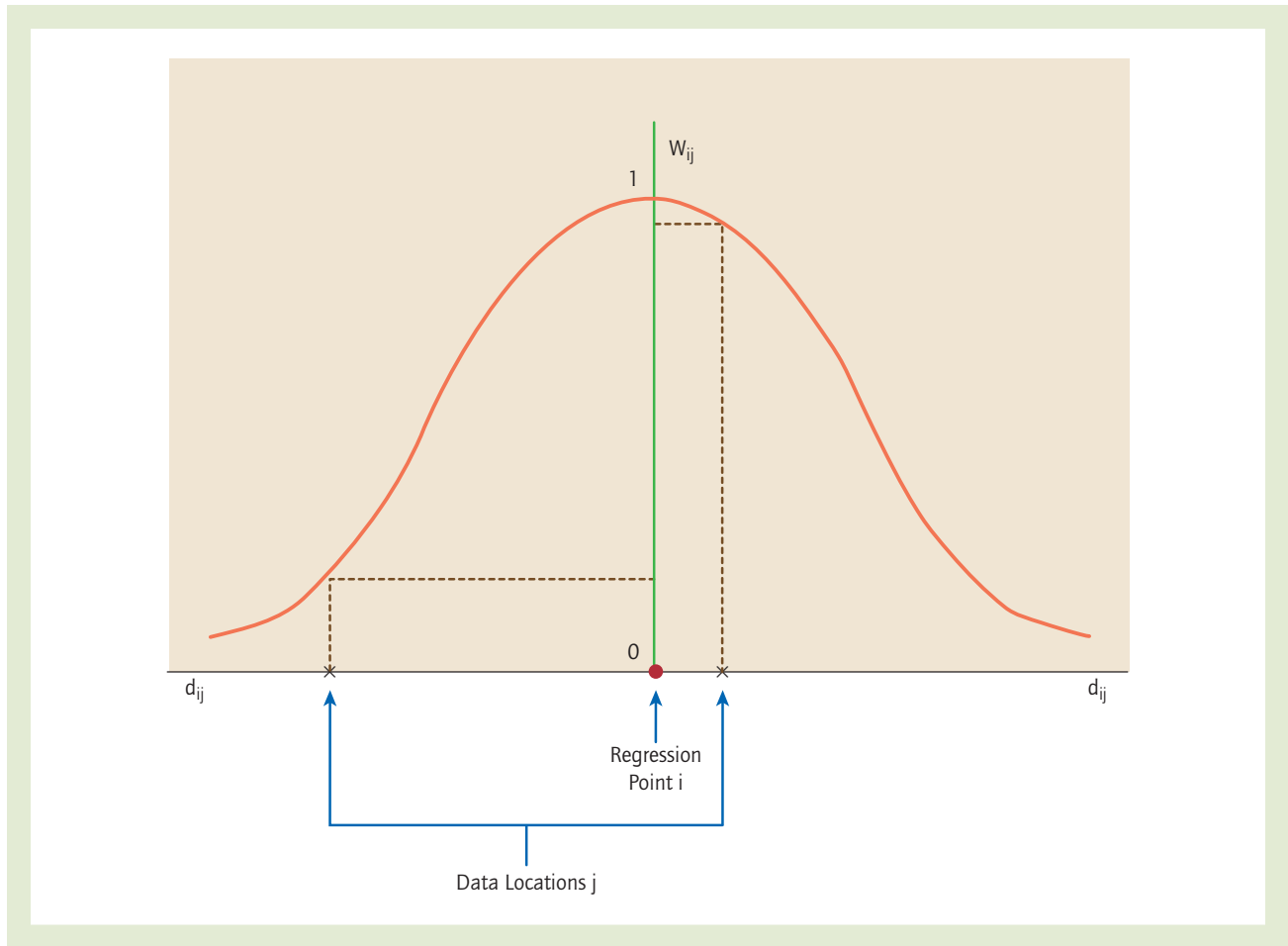


Figure 1 A spatial weighting function

Source: Author.

greater weight than observations farther away. The matrix $\mathbf{W}(\mathbf{i})$ has the following form:

$$\mathbf{W}(\mathbf{i}) = \begin{pmatrix} w_{i1} & 0 & \cdots & \cdots & 0 \\ 0 & w_{i2} & \cdots & \cdots & 0 \\ 0 & 0 & w_{i3} & \cdots & 0 \\ \vdots & & \ddots & & \vdots \\ 0 & 0 & 0 & \cdots & w_{in} \end{pmatrix}, \quad (5)$$

where w_{in} is the weight given to data point n when the estimates of the local parameters are being derived for location at location i . The weighting functions tend to be Gaussian or Gaussian-like, reflecting the nature of many spatial processes, and the results of GWR appear to be relatively insensitive to the choice of weighting function. However, the results will be sensitive to

the degree of distance decay in the weighting function, so that it is necessary to determine an optimal distance decay value by examining the goodness of fit of the local models using different bandwidths.

Bandwidth and Scale

The bandwidth in whatever weighting function is selected in GWR is clearly an important operator. It controls the degree of localization of the resulting parameter estimates: A large bandwidth relative to the size of the study region implies only a broad regional variation in relationships (or no spatial variation); a small bandwidth relative to the size of the study region implies considerable local variation in processes (see Figure 4). Hence, the optimal bandwidth is an indicator of the scale

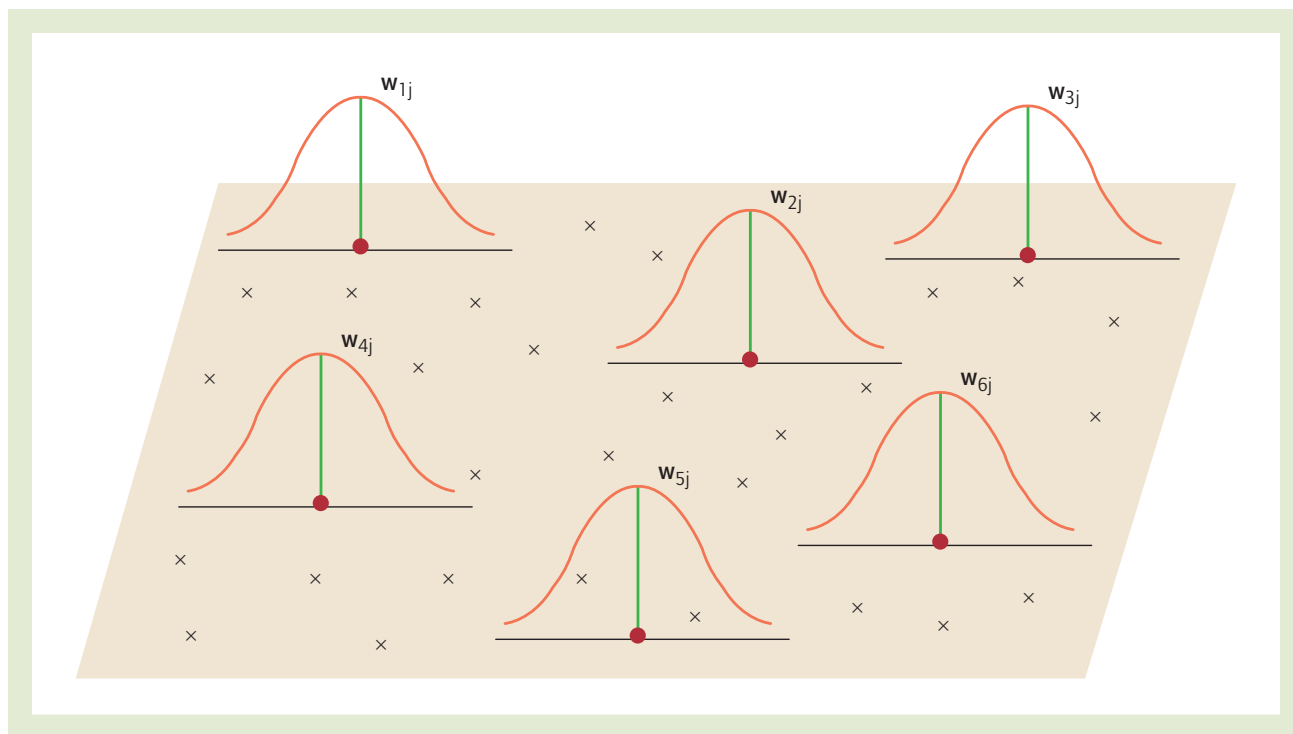


Figure 2 The process of geographical weighting

Source: Author.

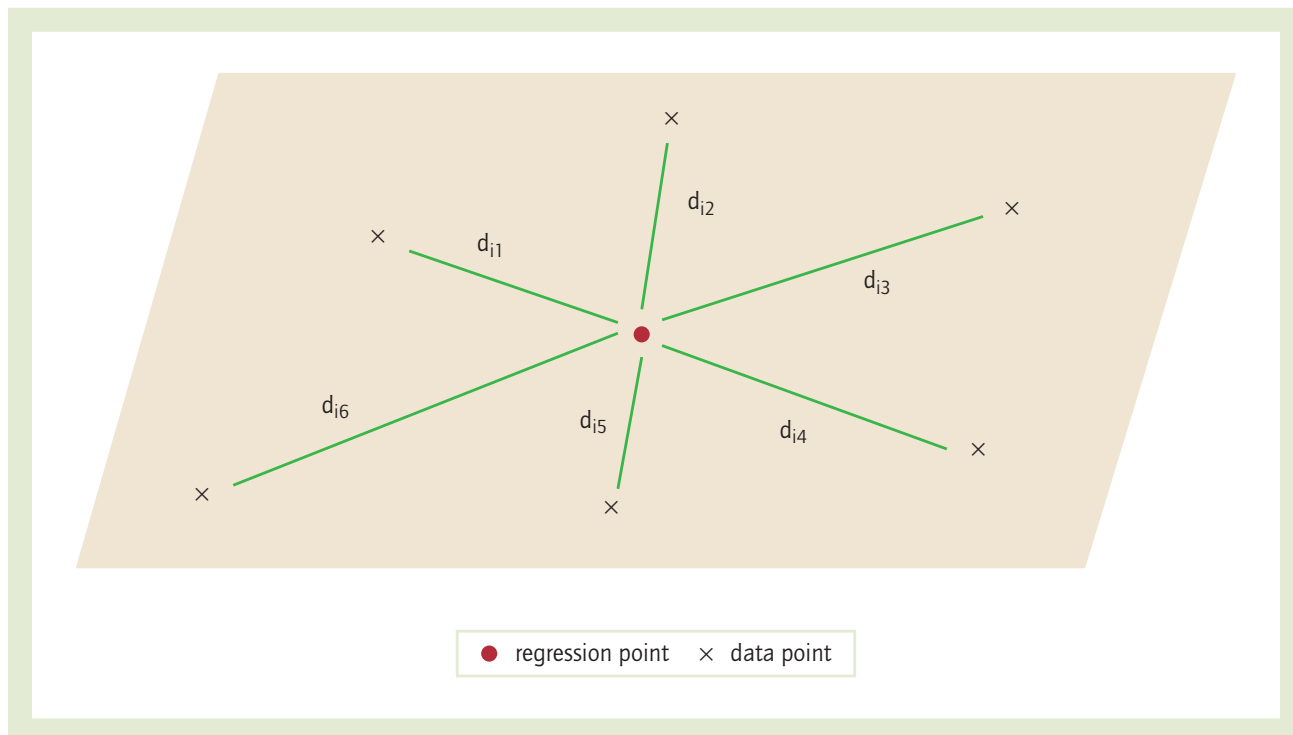


Figure 3 Geographically weighted regression undertaken at locations where no data exist

Source: Author.



at which the processes that are being investigated operate.

The optimal bandwidth in a GWR calibration results from a trade-off between bias and variance of the local parameter estimates. Too small a bandwidth leads to a large variance in the local estimates because of the relatively small number of data points that will be used in the local calibration. In the extreme case, as the bandwidth approaches 0, the local model will wrap itself around the data, so that only the local intercept will have a nonzero estimate that will be equal to y_i and the remaining parameter estimates will all be zero. In this case, the number of parameters in the local model is equal to the number of observations, n . Conversely, too large a bandwidth leads to large bias in the local estimates because data are drawn from locations farther away from the regression point. Ideally, researchers would like to have repeated observations at the same location so that they can calibrate separate models for each location, but this is rarely possible, and hence, they have to “borrow” data from the surrounding locations. The farther away they “borrow” data from, the more bias they introduce into the local parameter estimates. As the bandwidth approaches ∞ , the local model will tend to the global model as all the local estimates will be based on the same data set and the number of parameters will equal k , the number in the global model.

For all practical applications of GWR, the bandwidth will be greater than 0 and less than ∞ , and the effective numbers of parameters in the resulting GWR model will lie between a minimum of k and a maximum of n , depending on the bandwidth. This number need not be an integer and is referred to as the *effective number of parameters* (ENP). Although it may seem strange that the ENP estimates in a GWR calibration is not necessarily an integer (indeed, it will rarely be an integer), a little thought demonstrates why this is the case. Suppose a global model is calibrated using data distributed across a region (the traditional application of regression analysis to spatial data) and the number of parameters estimated in the calibration of this model is k . Furthermore, suppose the region is divided into two and the same model is calibrated separately for both subregions. The number of parameters then

estimated is $2k$. Similarly, if the region is segmented into three areas and the model calibrated separately for each of the three distinct regions, the number of parameters estimated is $3k$, and so on. Now suppose that the same model is calibrated by GWR in this region and there are n data locations at which the model is calibrated. Shouldn't the number of parameters estimated then be nk ? Strictly speaking, the answer is yes—we do have nk parameter estimates, *but* this is not what the formula for ENP measures. The formula measures the equivalent number of *independent* parameter estimates—that is, the number of parameter estimates that would be generated if the samples of data on which the estimates are based were independent (as in the example where the region was separated into distinct areas). In GWR calibration, one is not separating the data into distinct regions where the data are only used once to produce one set of parameter estimates. The same data will be used in the calibration of parameter estimates at different locations, albeit with different weightings in each of the location regressions, depending on the location of the data points with respect to the location of the regression points. Consequently, GWR parameter estimates for the same relationship but produced for different locations are *not* independent of each other; the degree of dependency will depend on how close the regression point locations are to each other. The ENP thus measures the equivalent number of independent parameters estimated in a GWR calibration, and this will always be between k and n and will rarely be an integer.

Applications

As of January 2010, the number of Google references to GWR was more than 109,000 and was increasing exponentially. The number of applications of GWR to social, health, and environmental data is now huge and increasing with each month. The technique has proven to be popular in a wide variety of application areas in academia, government agencies, and the private sector. There are several reasons for this popularity.

First, there is now a selection of software for GWR that makes it very easy to apply the

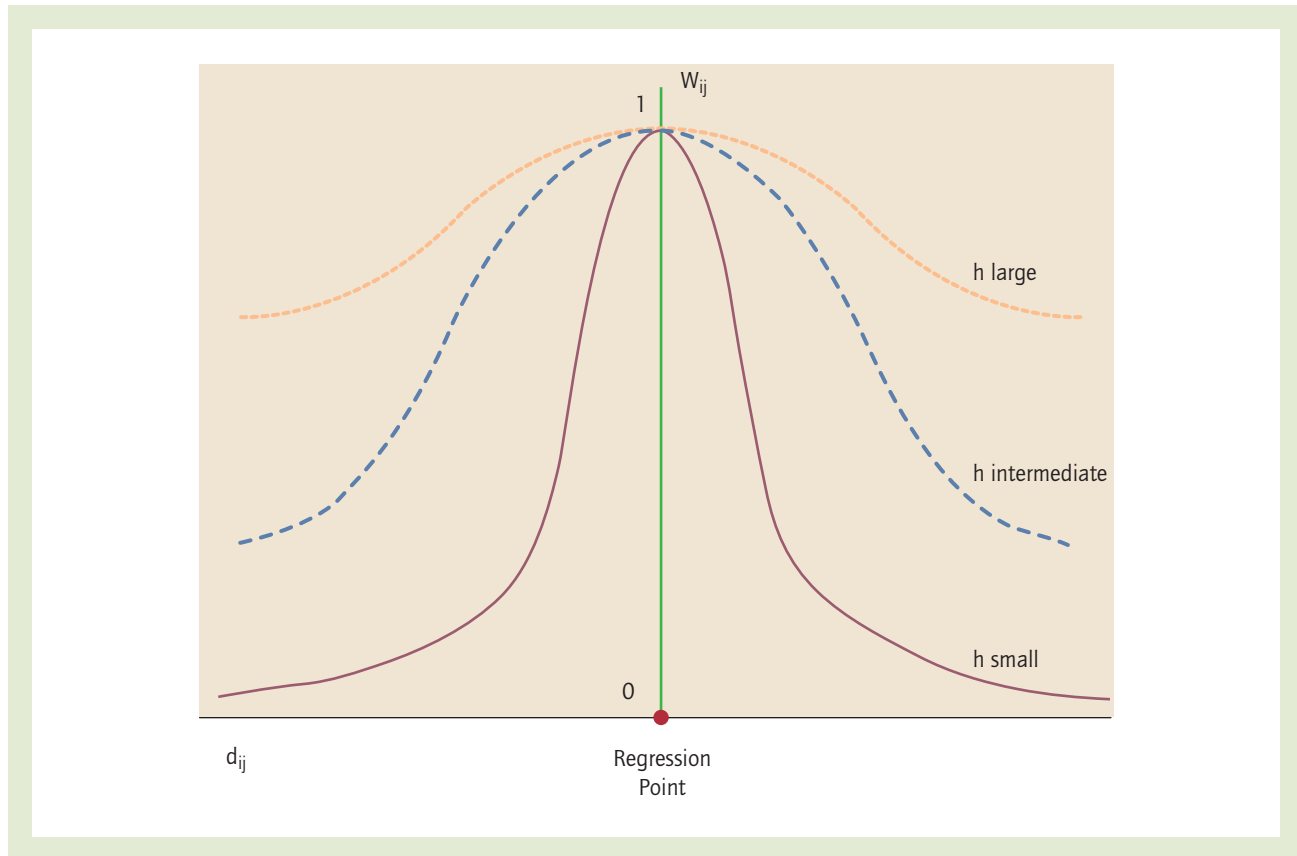


Figure 4 Spatial weighting functions and bandwidths

Source: Author.

technique to almost any form of spatial data. The most well-known perhaps is GWR 3.0, the software supplied from the National Centre for Geocomputation at the National University of Ireland Maynooth, which is described elsewhere (Fotheringham et al., 2002). A new version of this software, GWR 4.0, which includes the facility to run mixed GWR models, is due to be released soon. Others include the GWR module in the Environmental Systems Research Institute's (ESRI) ArcGIS 9.3; the GWR module in R; the SAM ecological software package; Terra-seer's version; and a Stata version from Mark S. Pearce.

Second, the technique can be applied to almost all spatial data sets in which a form of regression relationship can be established. As long as some model can be established of the type shown in Equation 1 and the coordinates of the data points are known, then a geographically weighted

version of this model can be formulated. In practice, however, some problems might be encountered in obtaining sensible GWR results. The most common of these are as follows:

- Too few data points for sensible GWR calibration: GWR is a “data-hungry” technique. It is difficult to define a precise minimum number of observations needed for GWR, but recognizing that each local regression needs to have a sufficient number of data points with a reasonable weight to make the estimated coefficients reasonably reliable suggests that GWR should not be performed when there are fewer than 150 data points. Even with this size of data set, only very broad regional trends in relationships can be observed; data sets with more than 1,000 observations are generally needed to have a chance at uncovering fine-scale spatial variations in relationships.



- Data that are spatially isolated or separated by large areas over which no data are recorded, such as a string of island communities: To reduce excessive bias in the local parameter estimates, GWR needs data in relatively close proximity to each regression point. Having data spread out over large distances creates excessive bias.

- Data that have relatively little local variance: Recall that GWR is essentially a series of local regressions and each local regression needs to conform to the usual regression requirements, including having sufficient variation in each variable. A common problem occurs when a GWR Poisson or binary logit model is calibrated and the dependent variable is either a count or a binary variable. In such cases, locally it might be that all the values of the dependent variable are 0, so that a local regression cannot be run.

- Other problems that affect global regression will also affect local regressions—GWR is not a panacea for all ills. Indeed, because the local regressions use only a small sample of the overall data set, problems can be compounded in some local regressions while being ameliorated in others.

- Starting with a poor global model: GWR is not a magic formula that corrects poor global model specification. It is very important to start with as good a global model as possible and only then perform GWR to examine for possible nonstationary relationships. Where relationships are strongly nonstationary, there will be impressive improvements in goodness of fit, but some improvements can be spurious, especially if the global model is a poor one to start with. Under such conditions, as mentioned above, the local model can simply wrap itself around the data, creating the misleading impression of increased understanding of the processes underlying the creation of the observed data.

A third reason for the popularity of GWR is that the results of GWR, because they are geocoded, lend themselves to visual interpretation and to further spatial analysis. Instead of having a single parameter with which to represent a relationship between two variables, researchers now have a surface of such values that can be

mapped in a variety of ways and subjected to further spatial analysis. For instance, it is possible to create pseudo-three-dimensional surfaces, interpret a whole new geography—that of relationships rather than variables, and ask questions that were previously unthinkable. Why is a particular relationship significantly positive in some areas but significantly negative in others? Why do some areas exhibit similar relationships? Are there regions where sets of different relationships seem to exhibit similar patterns? All these questions are only possible when researchers view the output from local, rather than global, models. Of course, not only local parameter estimates can be mapped, but output from GWR researchers can also map local standard errors, local goodness-of-fit measures, and local t values; indeed, any diagnostic from global regression has a local equivalent.

Conclusion

GWR is a simple yet powerful statistical technique for uncovering spatial variations in relationships. While certainly not all relationships are expected to vary over space, it seems reasonable to assume that some might. For instance, in hedonic price modeling, spatial variation in the supply of some attribute that affects house prices would suggest that the effect of that attribute on house prices would vary spatially: In areas where the attribute is relatively scarce, its effect on house prices would be greater than where it was plentiful.

GWR thus allows us to examine potential spatial variations in *relationships* and consequently allows us to examine a whole new geography. It prompts us to ask questions we would not normally consider, and it brings the role of space and spatial diversity very much to the fore in statistical analysis. It is a quintessential spatial statistical technique having as inputs spatial data, applying a spatial weighting function to the data, and producing geocoded outputs that can be mapped.

A. Stewart Fotheringham

See also **Fotheringham, A. Stewart; Quantitative Methods; Spatial Autocorrelation**



Further Readings

- Bivand, R., & Yu, D. (2009). *Geographically weighted regression*. Retrieved from <http://cran.r-project.org/web/packages/spgwr/spgwr.pdf>
Environmental Systems Research Institute:
www.esri.com
- Fotheringham, A. S., Brunsdon, C., & Charlton, M. E. (2002). *Geographically weighted regression: The analysis of spatially varying relationships*. Chichester, UK: Wiley.
- Geographically weighted regression: www.terraseer.com/help/stis/Statistics/Regression/About_geographically_weighted_Regression.htm
- National Centre for Geocomputation at the National University of Ireland Maynooth: <http://ncg.nuim.ie/GWR>
- Pearce, M. S. (n.d.). *Geographically weighted regression: A method for exploring spatial nonstationarity*. Retrieved from www.staff.ncl.ac.uk/m.s.pearce/stbgwr.htm
- Spatial analysis in macroecology: www.ecoevol.ufg.br/sam



GEOGRAPHIC INFORMATION SYSTEMS

Geographic information systems (GIS) are a specialized category of information systems, in which data and information have an explicit spatial component given by location. A GIS comprises data, software, hardware, people, and operational procedures. GIS does not exist in a vacuum, it is always a part of a larger information infrastructure, where it fulfills specific functions aimed at responding to users' information needs. The users of geographic information involve public organizations, such as local, regional, and national governments; private companies; and individual members of the public. Since much of the information generated by GIS is used to support decision making, GIS have been sometimes referred to as spatial decision support systems. GIS share a core set of functions enabling spatial data input, storage, editing and management, data analysis, visualization, and report generation. Traditionally, GIS have been centralized

and operated by GIS professionals, responding to the information needs of end users. With the proliferation and advancement of networking and Web-based technologies, a parallel (to the centralized) model of GIS has emerged, in which software engineers and GIS professionals develop geographic information (GI) Web-based services and GI-savvy users access the services using proliferating points of network access.

Application domains of GIS are numerous and include diverse areas such as disaster and hazard management, retailing, homeland security, crime prevention and community policing, environmental management, city planning, regional development, transportation programming, logistics, construction management, public health and epidemiology, and natural resource development.

Piotr Jankowski

See also **GIS, Environmental Model Integration; GIS, History of; GIScience; GIS Implementation; GIS in Archaeology; GIS in Disaster Response; GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Land Use Management; GIS in Local Government; GIS in Public Policy; GIS in Transportation; GIS in Urban Planning; GIS in Utilities; GIS in Water Management; GIS Software; GIS Web Services; Spatial Analysis; Spatial Decision Support Systems**

Further Readings

- Berhardsen, T. (2002). *Geographic information systems: An introduction*. New York: Wiley.
- Langley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science* (2nd ed.). New York: Wiley.



GEOGRAPHY EDUCATION

Geography education is a teaching and research subfield focused on educational purpose, practice, and theory in geography, from prekindergarten through the postgraduate life span, in both formal and informal contexts. Though much of the



research in geography education has tended to investigate problems in kindergarten through Grade 12 (K–12) curriculum and instruction, since 2000 there has been a noticeable trend toward research activity exploring teaching and learning issues in higher education, especially in the areas of spatial cognition, computers and multimedia, graduate education, and faculty development.

Geography in Elementary and Secondary Education

During the past two decades, geography has made considerable progress in the American school curriculum, having gained a discernible presence apart from social studies and a growing cadre of teachers skilled in modern analytical concepts and technologies. Improving the quality of geography teaching and learning in American education was the focus of a national reform movement that dates back to the early 1980s and that marshaled the talents of some of geography's leading scholars and professional organizations. In 1984, the Association of American Geographers (AAG) and the National Council for Geographic Education established a Joint Committee on Geographic Education to publish *Guidelines for Geographic Education*, a document that informed teachers, school districts, local and state education authorities, and the general public of the importance of geography in K–12 education through the use of “five fundamental themes” and associated learning activities. Since its publication, more than 100,000 copies of the *Guidelines* have been disseminated in the United States. This period also witnessed the establishment of the state geographic alliances, a network of organizations whose primary purpose is to promote collaboration between university geographers and in-service teachers. The majority of these alliances were established during the late 1980s and early 1990s, with grants from the National Geographic Society to set up an alliance in each state. Most of these alliances are still actively in operation, in many cases funded through endowments that were matched by the National Geographic Society and other organizations.

Perhaps the crowning achievement of the geographic education infrastructure building during the 1980s was the designation of geography as

one of five core subjects under the National Education Goals, formulated by the National Governors Association in 1990 and set into law by the Goals 2000: Educate America Act of 1994. The Goals 2000 Act prompted geographers to develop national standards for K–12 teaching and learning, published in 1994 as *Geography for Life: The National Geography Standards*. By 2004, geography was present in the curriculum standards of every state except Iowa. Although the reform movement was successful in raising the status of geography in American education, it has yet to make significant headway in raising student achievement and teacher preparation in the subject. The 2001 geography assessment by the National Assessment of Educational Progress (NAEP) found that more than two thirds of American students in Grades 4, 8, and 12 did not meet proficient competency standards. This situation is likely to continue until concerted efforts are made to reform the pedagogic content knowledge of geography teachers, especially at the pre-service stage of the professional continuum.

Another noteworthy development since 2000 has been the increase in enrollment for the advanced placement (AP) course in human geography. The number of high school students taking AP human geography grew from 3,272 in 2002 to 28,239 in 2007. An updated version of the national geography standards will be published in 2010. The next NAEP geography assessment is scheduled for 2010.

Geography in Postsecondary Education

Geographers have also dedicated a considerable amount of effort to the improvement of teaching and learning in higher education. Some of the earliest efforts in this regard include the AAG's Commission on College Geography, established during the 1960s to focus on faculty development and instructional issues in undergraduate education. It published an extensive paper series on the teaching and learning of geography and, during the 1970s, initiated a number of professional development programs to promote innovative practice in curriculum and instruction, including the Commission on Geographic Education and the Teaching and Learning in Graduate Geography projects.



During the 1980s, an informal effort known as the Phoenix Project, led by some of geography's most influential scholars, was successful in providing support and networking for another cohort of early-career geography professors. The Committee on the Status of Women in Geography has a substantial record of organizing conference sessions to address career issues for women graduate students and faculty. Since 2002, the AAG has supported two broad-based initiatives to enhance career preparation in geography. One of those is the Geography Faculty Development Alliance (GFDA), funded by the National Science Foundation (NSF) between 2002 and 2007 and since institutionalized by the AAG to provide early-career faculty with the theoretical and practical knowledge needed to succeed in their careers of research, teaching, and service. Complementing and extending the GFDA is Enhancing Departments and Graduate Education (EDGE) in Geography, a research and action project funded by NSF to examine issues affecting the professional development of master's and doctoral students in geography programs.

Since the mid 1990s, geographers have also pursued a wide range of federally funded projects in undergraduate education, including the Core Curriculum in GIScience (geographic information science) and Core Curriculum in GIS (geographic information systems) for Technical Programs, the Geographer's Craft Project, the Virtual Geography Department Project, Hands-On: Active Learning Modules on the Human Dimensions of Global Change project, and the AAG Center for Global Geography Education project. Many of these projects have explored strategies to internationalize teaching and learning. In 1999, an International Network on Learning and Teaching Geography in Higher Education was formed with the aim of building an international community of geographers dedicated to collaborative teaching and research on postsecondary education issues.

Undergraduate degrees in geography awarded by U.S. institutions of higher education grew by about 66% (from approximately 2,900 to 4,800) between 1987–1988 and 2003–2004. During that same time period, master's degrees in geography grew by about 33% (from approximately 580 to 770), and doctoral degrees grew by about 33% (from approximately 150 to 200). Much of

this growth coincided with the discipline's broader recognition in scientific and academic communities and the increased demand for geographically skilled professionals in the workforce, particularly in the area of GIS technology. A recent NSF report, *Complex Environmental Systems: Synthesis for Earth, Life, and Society in the 21st Century*, presented a 10-year outlook for environmental research and education and cited geography as a key source of concepts and technologies to synthesize research questions and data acquisition across spatial, temporal, and societal scales. In 2004, the U.S. Department of Labor and U.S. Department of Education listed GIS technology as one of the three most important emerging areas for job growth alongside nanotechnology and biotechnology.

Michael Solem

See also **Education, Geographies of; Geographical Ignorance; National Council for Geographic Education**

Further Readings

- Geography Education Standards Project. (1994). *Geography for life: National geography standards 1994*. Washington, DC: National Geographic Research and Exploration.
- Gersmehl, P. (2008). *Teaching geography* (2nd ed.). New York: Guilford Press.
- Solem, M., Foote, K., & Monk, J. (Eds.). (2009). *Aspiring academics: A resource book for graduate students and early career faculty*. Upper Saddle River, NJ: Pearson Prentice Hall.



GEOLIBRARIES

The term *geolibrary* was introduced in 1998 by the geographer Michael Goodchild to explicitly identify an emerging class of digital system, the "library filled with georeferenced information," as an important element of the growing global spatial data infrastructure. The geolibrary concept grew out of efforts at organizing and providing shared access to the digital holdings of map



libraries and spatial data repositories. These collections typically include scanned paper maps, satellite imagery, aerial photographs, and geographic information systems (GIS) data files. A key distinction was drawn between this “geographical information,” as representations of the surface and near surface of the Earth, and the vastly broader category of “georeferenced information,” defined as any information referring to or about particular places.

A geolibrary indexes its holdings by location, specified by one or more place names and a geographic “footprint” of any complexity, as well as by the traditional library catalog keys of title, author, and topic. Many digital map libraries and spatial data clearinghouses are then by definition geolibraries, in that their holdings may be browsed and searched by location. It became increasingly apparent that the methods developed for accessing those data could be applied to *any* digital information objects associated with locations specified by name or footprint. In principle, any library would become a geolibrary if its holdings were comprehensively georeferenced. At its furthest extension, such functionality resembles the *Digital Earth* vision of systems providing access to all available digitized information related to any specified location.

Geolibrary development—particularly as distributed systems—has raised numerous research challenges and is a valuable context for their solution. These include the following: (a) interoperability for data sharing by means of metadata standards, authority lists, and ontologies; (b) gazetteer development, that is, the association of a particular spatial footprint with potentially numerous place names; (c) efficient spatial indexes for databases and related issues of scale, resolution, and generalization; (d) georeferencing, including the parsing of textual material for named places and related temporal issues; (e) spatiotemporal query algorithms; and (f) interface usability for spatial browsing and search informed by cognitive principles. Significant incremental progress in all these areas has made the prospect of very large, distributed geolibraries increasingly realistic.

In 2004, Goodchild suggested that the next stage of progress in geolibrary development might be from simply delivering information

objects (maps, imagery, and other documents) to adding some ability to open and process those objects. In addition to answering the basic query “What do you have about this place?” it could answer many of the type “What is (or was) so interesting about this place?” Such extensions are likely to blur distinctions between the geolibrary and other emerging classes of information systems, including digital atlases and georeferenced digital encyclopedias.

Karl Grossner

See also **Gazetteers; Geocoding; Goodchild, Michael; Interoperability and Spatial Data Standards; Spatial Data Infrastructures**

Further Readings

- Goodchild, M. F. (1998). The geolibrary. In S. Carver (Ed.), *Innovations in GIS 5* (pp. 59–68). London: Taylor & Francis.
- Hill, L. L. (2006). *Georeferencing: The geographic associations of information*. Cambridge: MIT Press.
- National Research Council. (1999). *Distributed geolibraries: Spatial information resources*. Washington, DC: National Academies Press.



GEOLOGIC TIMESCALE

The geologic timescale divides the 4.5-billion-year history of Earth into unequal divisions of time. Originally, these divisions were based on sedimentary rocks and their corresponding fossils. Each time interval has its own unique fossil assemblage, and the boundaries between many intervals of geologic time correspond to mass extinction events. The most famous of these was at the boundary between the Mesozoic and the Cenozoic eras. At that time, land-dwelling dinosaurs became extinct, likely due in part to the impact of a large asteroid near the present-day Yucatan Peninsula.

The intervals of the geologic timescale are hierarchic—eons include eras, eras include periods,



<i>Era</i>	<i>Period</i>	<i>Epoch (Cenozoic only)</i>	<i>Age (Millions of years)</i>	<i>Major Biological & Geologic Events</i>
CENOZOIC	Quaternary	Holocene (Recent)	.01	Ice Age begins and evolution of modern mammals; man reaches N. A.; general uplift of continent.
		Pleistocene	3	
	Tertiary	Pliocene	5.5	Evolution and Development of major mammal groups; Cascadian Orogeny in northwestern United States; in latest Cenozoic, Eocene lake system.
		Miocene	25.5	
		Oligocene	36	
		Eocene	54	
		Paleocene	65	
MESOZOIC	Cretaceous	Epochs for these periods are not definitely established	130	Extinction of dinosaurs; flowering plants flourish; height of Cordilleran Orogeny.
	Jurassic		185	First birds, dinosaurs and mammals continue to evolve; beginning of Cordilleran Orogeny which formed the Rocky Mountains.
	Triassic		230	Conifers evolved; first dinosaurs; first mammals; Appalachian Orogeny; some orogeny in Cordillera.
PALEOZOIC	Permian		265	Archaic reptiles and mammal-like reptiles evolve. Appalachian Orogeny.
	Pennsylvanian		310	First reptiles; cool swamps formed; beginning of the Appalachian Orogeny.
	Mississippian		355	Expansion of amphibians; much carbonate deposition; Antler Orogeny in Cordilleran Mobile Belt (Rocky Mountain area).
	Devonian		413	First land plants; first jawed fishes, sharks and bony fish; amphibians appear; Acadian Orogeny in the Appalachian belt.
	Silurian		425	Jawless fishes evolved; much reef development; evaporite mineral development.
	Ordovician		475	First vertebrate remains known from this time; Taconic Orogeny in Appalachian belt.
	Cambrian		600	First shelled invertebrates; major flooding of North America.
Precambrian time began 5 billion years ago.				

Table 1 Geologic timescale

Source: National Park Service.



and then periods are divided into epochs. Epochs can be further subdivided into stages. In developing the geologic timescale, geologists frequently relied on the law of superposition, which states that younger sediments were deposited on top of older sediments. Thus, by applying this principle to a single exposure, one can determine the relative sequence of events visible in the geologic record. Unfortunately, only a small part of the entire expanse of geologic time is recorded in one place, either because the older parts of the record are still buried or because much of the record has been destroyed by erosion. Thus, the geologic timescale was created by combining records from many different places using the process of correlation, where the relative ages of rocks in different areas are determined, often by matching the fossil species they have in common. Most of the periods in the currently accepted geologic timescale were named by the 19th-century European geologists, and they were frequently named after the places where the rocks are exposed. For example, the Devonian Period was named by Adam Sedgwick and Sir Roderick Impey Murchison after Devonshire, England. In discussing geologic time, geologists distinguish between the time intervals themselves (geochronologic units) and the rocks deposited and formed during those times (chronostratigraphic units). So the Devonian Period, a geochronologic unit, is now represented on Earth by the rocks of that age, referred to as the Devonian System, a chronostratigraphic unit.

One unfortunate outcome of the patchy record of Earth's history is that geologists working in different areas have at times developed separate and incompatible versions of the geologic timescale. Such disputes are resolved by the International Commission of Stratigraphy (ICS). In one recent case, many Russian scientists used the term *Vendian* for the interval of time between 632 and 542 mya (million years ago), while many Australian scientists used the term *Ediacaran* instead. Arguments were made for both names, and in 2004, the ICS decided on the Ediacaran Period, which is now a part of the internationally recognized geologic timescale.

Although the law of superposition and the use of fossils in correlation allowed for a relative geologic timescale to be developed, throughout

the 19th century, the durations of geologic time intervals, the age of their boundaries, and the age of the Earth were speculative. This changed shortly after the discovery of radioactivity by Henri Becquerel in 1906, and by 1913, Arthur Holmes published the first geologic timescale with absolute ages determined by isotopic abundances as a result of radioactive decay. In addition to the well-known method of carbon-14 dating applied to organic material, many rocks include radioactive isotopes whose rates of decay are exceedingly slow (e.g., ^{238}U [uranium], ^{147}Sm [samarium], ^{187}Re [rhenium]). By using radioactive isotopes with low rates of decay, scientists have determined that some meteorites are 4.5 billion yrs. (years) old and record the composition of the early solar system.

Although the age of some volcanic rocks can be determined using radioactive dating, the same cannot be done for nearly all sedimentary rocks, the very places where much of Earth's geologic history is recorded. Thus, areas where volcanic rocks, such as ancient lava flows or ash falls, are interbedded with sedimentary rocks are particularly important for adding absolute ages to the geologic timescale. Much of the timescale for the past 65 million yrs. has been developed using two additional sources of data to interpolate between known ages: paleomagnetism and cyclic stratigraphy. Earth's magnetic field has undergone numerous reversals during geologic time, so that at some times in Earth's history a compass would have pointed south, while during others it would have pointed north, like today. These magnetic reversals have been recorded in many sedimentary rocks and also in the volcanic rocks that make up the oceanic crust. As new crust cools, it acquires a copy of Earth's magnetic field. Old crust is pushed away from the midocean ridges as new crust forms, causing a series of stripes of north-pointing oceanic crust alternating with south-pointing oceanic crust. The development of new oceanic crust at midocean ridges occurs at a fairly constant rate, thus the widths of the magnetic stripes on the ocean floor are directly proportional to the actual durations of each direction for Earth's magnetic field.

In places where sediment is continuously deposited, cyclic patterns in the layers deposited may develop in response to climate change. In some



cases, these climatic changes can be tied to subtle yet important changes in Earth's orbit called Milankovitch cycles, after the Serbian astrophysicist Milutin Milankovitch. The three most prominent Milankovitch cycles occur in periods of 24, 40, or 100 ky (kiloyears, or thousand years). The periods of these cycles are remarkably regular, and by counting cycles back through the geologic record, the precision and potentially the accuracy of some events can be determined within 40,000. Again, no such continuous record exists, so it requires many separate geologic sections to be correlated for this process of "orbital tuning." These more precise dates have been extended back to 34 mya, and will likely be extended back to 75 mya in the near future. Although further refinements in the geologic timescale are expected, changes for the ages of most boundaries will be on the scale of less than 2 mya.

Jonathan Henry Geisler

See also **Geomorphology**; **Plate Tectonics**

Further Readings

Dickin, A. P. (2005). *Radiogenic isotope geology* (2nd ed.). Cambridge, UK: Cambridge University Press.

Gradstein, F. M., Ogg, J. G., Smith, A. G., Agterberg, F. P., Bleeker, W., Cooper, R. A., et al. (2004). *A geologic time scale 2004*. Cambridge, UK: Cambridge University Press.

International Commission of Stratigraphy:
www.stratigraphy.org

Winchester, S. (2002). *The map that changed the world: William Smith and the birth of modern geology*. New York: HarperPerennial.

predict the future. Geomancy literature and its applications constitute the oldest continually practiced scholarly geographic tradition in the world. East Asian variants of geomantic applied arts have had major impacts in shaping some of the world's most populated cultural landscapes during ancient and medieval times.

The two major exemplars of geomancy in human history are the "African" (or Western) "science of sand" and the "Chinese" (or East Asian) "wind-and-water" variant, popularly known as *feng shui* (various spellings). Geomantic configurations divined in both systems relate to celestial phenomena. The Islamic variation of African geomancy, which interprets geometric designs formed by casting pebbles, diffused through the Byzantine and Latin worlds across Europe and into England, to gain popularity during the medieval and Renaissance periods. The telluric medium divined in East Asian *feng shui* geomancy is terrain itself. Due to its preoccupation with landform divination, *feng shui* is known alternatively in English as topomancy and terrestrial astrology. Esoteric ideas related to correspondences and reciprocities between Earth and heaven as human habitat are highly symbolized and deeply embedded in *feng shui* theories and applications. *Feng shui* surveying in the field involves skill, intuition, instrumentation (principally its complex astrobiological model and compass), and cartographic skills.

Feng shui geomancy, aptly described a century ago by Herbert Chatley, is the art of adapting the residences of the living and the dead so as to cooperate and harmonize with the local currents of the cosmic breath. Motivating the effort are expectations of propitious outcomes for nature and humanity. Where *feng shui* surveys are diagnostic and remedial, skilled surveyors are perceived to be "Earth doctors." Two distinct traditional schools of *feng shui*—"landscape" and "compass"—are discernable, but their skills seem complementary and overlapping. The mass popularity of Chinese geomancy reached its pinnacle under the Qing dynasty (AD 1644–1911) but then faded dramatically throughout East Asia wherever modernization and communism became entrenched. However, among the unforeseen impacts of economic liberalization and globalization over the past few decades is the unexpected



GEOMANCY

The mantic arts employ diverse mediums for purposes of divination. Geomancy (*geo-* for "Earth," *-mancy* for "divination") is the mantic art that divines earthy, terrestrial, or telluric mediums to discover hidden knowledge and/or



new demand throughout East Asia for traditional feng shui skills, services, and products.

Related to this resurgence, and even more remarkable, is the diffusion to and sudden growth and persistence of a popular wave of interest in Asian geomancy throughout the West, and especially in the United States. This trend has had some major economic impacts in high-end residential and commercial West Coast real estate markets, meanwhile generating a variety of geomancy-related “New Age” products and services in mass markets nationwide. Higher-education programs, including those in geography, planning, and Africana studies, have meanwhile increasingly incorporated the topic of geomancy into their curriculums.

David J. Nemeth

See also **Cultural Geography**; **Cultural Landscape**; **Landscape Interpretation**

Further Readings

- Pogacnik, M. (2008). *Sacred geography: Geomancy: Co-creating the Earth cosmos*. Great Barrington, MA: Lindisfarne Books.
- Yoon, H.-K. (2006). *The culture of fengshui in Korea: An exploration of East Asian geomancy*. Lanham, MD: Lexington Books.



GEOMETRIC CORRECTION

Geometric correction is the preprocessing method of removing positional distortions in remotely sensed data caused by the movement of the sensor. Unrectified images contain distortions in their planimetric (x, y) map locations due to variations in sensor parameters (altitude, attitude, and velocity), in the Earth's curvature, and in remote sensing systems. Geometric correction seeks to eliminate these distortions and to transform the image into a map projection system, so that the image could be used as a map and integrated with other thematic information and other maps.

Sources of Geometric Distortions

Geometric distortions are typically classified into (a) internal distortion resulting from the geometry of the sensor and Earth rotation or curvature characteristics and (b) external distortions resulting from the attitude of the sensor or the shape of the object. Geometric distortions can be divided into systematic (predictable) source of the error or nonsystematic (random). Internal errors include errors of skew, scanning system, and relief displacement. External errors include altitude alterations and attitude changes (roll, pitch, and yaw).

Methods and Procedure

Some internal distortions are predictable or systematic and are generally corrected at the ground station or by image vendors. There are two types of correction: (1) image-to-map rectification and (2) image-to-image rectification. In the image-to-map rectification, a map (with correct projection) is used to correct images and convert them into a planimetric system. This method should be used when area, direction, or distance measurements are needed after correction. Image-to-image correction involves matching the coordinate systems or column-and-row systems of two digital images. In this case, both images should cover the same geographic area.

The general procedure involves (a) registration: selecting ground control points (GCP) and image pixel coordinates (row and column) with their map coordinate counterparts (e.g., meters northing and easting in a UTM [Universal Transverse Mercator] map projection); (b) spatial interpolation (also called transformation): identifying the geometric relationship between input coordinates and output coordinates; and (c) intensity (or pixel value) interpolation (also called resampling): determining the pixel value of the output image from the input image. For the registration, GCPs can be easily identified on the imagery and located accurately on a map (e.g., road intersections, lake edges, river junctions). For spatial interpolation, the paired coordinates (i, j and x, y) from many GCPs (e.g., 20) can be modeled to derive geometric transformation coefficients. These coefficients



are then used in polynomial equations for computing root mean square error (RMSE). RMSE ideally is to be within 1 pixel. For intensity interpolation, new values are assigned in one of three ways: (1) nearest neighbor, (2) bilinear, and (3) cubic.

Sunhui Sim

See also **Coordinate Systems; Coordinate Transformations; Image Registration; Radiometric Correction; Spatial Interpolation**

Further Readings

Jensen, J. R. (2005). *Introductory digital image processing* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

Toutin, T. (2004). Review paper: Geometric processing of remote sensing images: Models, algorithms and methods. *International Journal of Remote Sensing*, 25(10), 1893–1924.



GEOMETRIC MEASURES

A great variety of measures, many still in their early development, are used to describe the geometric properties of an object/distribution in geographic space. Some are derived directly from geometry, such as length, perimeter, and area, whereas others have evolved in the study of geography, for example, the compactness index. Unlike their geometric counterparts, objects/distributions in geographic space appear complex and diverse, depending on their point composition (e.g., cities), lines (railway networks), or areas (e.g., the territory of the Philippines). Furthermore, little agreement exists among spatial analysts on the classification of the various geometric measures. The history of these measures dates to the “Common Era,” when Strabo recognized the difficulty of measuring the shape of Italy. Five categories of geometric properties are recognized in the literature: (1) centroid, (2) orientation, (3) range, (4) intensity (or compactness), and (5) shape. Centroid is the center point

of an object/distribution in geographic space, the point at which the object/distribution attains balance; orientation is the direction along which an object/distribution is arranged over space; range is the two-dimensional (2D) scope (spread) of an object; intensity is the extent of compactness (closeness) among elements of an object/distribution; and shape is what is left after the effects of position, orientation, and size are removed.

Various indices are used to measure each of these geometric properties. Centroid measures include the mean center and its extensions to global coordinate systems; orientation measures include the direction of the major axis of the standard distance ellipse; range measures include the mean distance, standard distance, standard distance deviation, and standard distance ellipse; intensity measures include compactness and spatial intensity indices; and shape measures include the elongation, circularity, overlap indices, ratio of the length of the major to the minor axis of the standard distance ellipse, and others. Notably, the standard distance ellipse can show simultaneously all the five geometric properties on a map except shape; and the centroid usually serves as a reference for calculating the other geometric measures.

Enormous difficulties have been encountered in examining the geometric properties of spatial objects, including the creation of a coherent framework. It has also been difficult to separate some properties from others; for example, measures of shape, compactness, and orientation are often mixed. Furthermore, geometric properties vary with scale; for example, the length of a river increases as scale decreases. Finally, the curvature of the globe creates problems; for example, the standard distance ellipse does not apply to spatial analysis in spherical space.

These geometric measures follow to varying extents the laws of addition and transitivity. Unlike length and area, each of which are additive across spatial objects, the five categories of geometric measures are not additive. But the rule of transitivity generally applies, except in the case of the shape indices. Transitivity, for instance, increases with the levels of similarity between two shapes.

Roger R. Stough and Dennis Zhao



See also **Cartography; Coordinate Geometry; Earth's Coordinate Grid; Map Projections; Surveying**

Further Readings

- Aboufagel, E., & Austin, D. (2006). A new method for computing the mean center of population of the United States. *The Professional Geographer*, 58, 65–69.
- Coffey, W. J. (1982). *Geography: Towards a general spatial systems approach* (pp. 78–117). London: Methuen.
- Gong, J. (2002). Clarifying the standard deviational ellipse. *Geographical Analysis*, 34, 155–167.
- Griffith, D. A. (1982). Geometry and spatial interaction. *Annals of the Association of American Geographers*, 72, 332–346.
- Johnston, R. J. (1997). *Geography and geographers: Anglo-American human geography since 1945* (5th ed., pp. 102–146). London: Arnold.
- Jones, B. G. (1980). Applications of centrographic techniques to the study of urban phenomena: Atlanta, Georgia 1940–1975. *Economic Geography*, 56(3), 201–222.
- Kendall, W. S. (1999). Geometry, statistics, and shape. In O. E. Barndorff-Nielsen & E. B. V. Jensen (Eds.), *Geometry in present day science* (pp. 143–163). Singapore: World Scientific.
- Neft, D. S. (1966). *Statistical analysis for areal distributions*. Philadelphia: Regional Science Research Institute.
- U.S. Census Bureau. (2001). *Centers of population computation for 1950, 1960, 1970, 1980, 1990 and 2000*. Washington, DC: Author.
- Warntz, W., & Neft, D. (1960). Contributions to a statistical methodology for areal distributions. *Journal of Regional Science*, 2, 47–66.
- Wentz, E. A. (2000). A shape definition for geographic applications based on edge, elongation, and perforation. *Geographical Analysis*, 32, 95–112.
- Zhao, Z. (2008). *Spatial distribution and economic growth*. Saarbrücken, Germany: VDM Verlag Dr. Muller.
- Zhao, Z., & Stough, R. R. (2005). Measuring similarity among various shapes based on geometrical matching. *Geographical Analysis*, 37, 410–422.



GEOMORPHIC CYCLE

The geomorphic cycle was introduced by William Morris Davis as a comprehensive model of the way in which natural landscapes develop at a regional scale. Although initiated somewhat earlier, it emerged as a largely finished product in 1899 and quickly became the dominant way in which landscapes were viewed academically for several decades. While its dominance in the world of research was challenged in the late 1930s and substantively soon after World War II, it remained an important teaching framework much longer. Today, the comprehensive model is passé, but discrete elements and terms remain and are often used shorn of their original critical conceptual underpinnings.

Context and Objectives

The geomorphic cycle was launched into the scientific world at a time when Charles Darwin's work was an overt and pervasive influence. The "cycle" is largely biological in tenor. However, Darwin's concept of evolution, dominated as it is by the concept of randomness, was modified by Davis into a concept of inevitable change over time, that is, mathematical probability became deterministic. This was also the period when eustatic theory, isostasy, and epeirogeny were all in their introductory phases within geomorphology. Davis did not accept all these new ideas but clearly embraced some of them.

Davis's objective was to develop and present a model of landscape development that was deductive and theoretical. Just how deductive Davis's formulation of the model really was has been widely debated. Davis wanted his model to be not only theoretical but also genetic, so the model was designed both to describe and to explain landforms. He did not attempt to describe the fundamental geologic origin of landscape but rather the subsequent geomorphic development. For example, he was not particularly interested in the initial uplift of a plateau or mountain system; rather, he sought to explain its development subsequent to uplift.

Essential Components

Initially, Davis forwarded five controlling factors for landscape development: (1) structure,



(2) process, (3) stage, (4) relief, and (5) texture of dissection, and he also initially invoked the rate of uplift as important. However, he pruned his model vigorously, and structure, process, and stage are the three variables with which it is most widely associated. Even they are not coequal as stage was Davis's preeminent preoccupation. Stage is a relative, not absolute, temporal concept, being the amount of time elapsed since uplift. Consequently, a landscape may exhibit different stages in different parts.

The Davisian concept of stage was widely discussed in anthropogenic terms of *youth*, *maturity*, and *old age*. Youth follows uplift immediately and is a period when the relative relief of the landscape (i.e., the local difference between the valley bottom and the abutting mountain or ridge tops) increases. Youth ends when all the original landscape surface has been removed by erosion; specifically, this implies that valley sides have eroded so greatly as to have removed the original summits. During maturity, the landscape attains maximum relative relief, and valleys are V-shaped. As maturity advances, the landscape becomes more rounded and the valley system more extensive and better integrated, while floodplains emerge and expand. During old age, relative relief is greatly reduced. The surface becomes gently rolling with broad valleys with floodplains, ultimately producing a plain without relief. However, Davis chose to highlight the stage immediately prior to the ultimate landscape, thus the world famous "peneplain," which should reflect little or none of its geologic structure and bear infrequent resistant elements standing up as "monadnocks" (these are hills or mountains descriptively, but their origin is specifically derived from a Davisian view of landscape development).

The geomorphic cycle really incorporates three cycles: (1) a cycle of landscape development, (2) a cycle of river development (both individually and as networks), and (3) a cycle of slope development. The cycle of landscape development is very slow and is initiated by uplift, proceeded by erosion, and terminated by renewed uplift (this is why stage is a relative, not absolute, temporal concept). The cycle of river development has a youthful stage with few major rivers and few major tributaries but numerous minor rivers. Floodplain expansion marks mature and later

stages, as well as network integration. During old age, very extensive floodplains and broad gentle slopes predominate, and generally speaking, landscape domination by fluvial processes gives way to domination by mass wasting.

Slope development is not present as a discrete focus in many of Davis's papers; however, it emerges frequently as an element. His most important idea concerning slope development is that the slope angle declines with time. This perspective stems from two rather fuzzy and weakly integrated ideas: (1) more material is removed from the top of a slope than from the toe or bottom and (2) as particle size decreases downslope, so does the angle needed to mobilize the material. The first idea is founded on rate of removal, the second on a weathering rate. The resulting slope is sigmoidal (convexo-concave), with an upper convexity and a lower concavity. The Davisian sigmoidal slope profile has been widely debated in slope geomorphology. Basically, Davis's notion that the upper convexity ensues from dominance by creep processes has survived; his lower concavity explanation is less satisfactory. The universal validity of the sigmoidal slope profile has been hotly debated; for example, it was explicitly rejected by Lester King, who viewed it as a degenerate slope form. The matter was frequently debated also in terms of specific climatic zones, with the Davisian profile usually being categorized as widespread in temperate, as opposed to tropical, environments.

A number of other salient components of the geographical cycle merit separate identification and discussion because the cycle became so pervasive that for many years virtually all English-speaking geomorphologists discussed landscape development exclusively within its framework. A very important reality is that the geographical cycle and "denudation chronology" fitted one another hand in glove. Denudation chronology is a view of landscape development that reconstructs it as a series of dated stages, although the dating was usually only relative and/or extremely broad (this was an era prior to isotope dating). While denudation chronology predated the geographical cycle in origin, the two became inseparable for decades.

Davis infused geomorphology with a welter of "morphogenetic terms," the overwhelmingly majority of which were part and parcel of the



geographical cycle. A morphogenetic term is a single word that incorporates a description of the shape of something (the “morpho-” component of the word) while also purporting to explain its origin (the “genetic” component of the word). For example, a peneplain is a gently rolling eroded landscape, with occasional erosional remnants upstanding (i.e., monadnocks [another morphogenetic term]), that is the penultimate stage of the geographical cycle. It is not just a near-flat erosional surface but one specifically produced by progression of the geographic cycle. To draw the illustration even more explicitly, a Davisian peneplain, with monadnocks, is a fundamentally different intellectual view of landscape and its development from King’s pediplain, with inselbergs, bornhardts, or koppies (there is terminological overlap among these latter three terms, all of which are essentially erosional remnants). The Davisian landscape has been lowered and is essentially temporally all of one age, while the Kingian landscape is of necessity time-transgressive given its mode of development, which is by the parallel retreat of slopes.

Davis took up the long-used concept of “grade” and transformed it in a fundamental manner. Grade, essentially an equilibrium concept, is of very old origin and was originally used to designate a time-independent balance between a stream’s energy and its erosive and transporting power. What Davis did was to take a time-independent term and make it time dependent, that is, developed over time. So grade was absent in rivers during youth, acquired during maturity, and maintained thereafter. Grade was attained first at a river mouth and advanced upstream, producing a smooth concave longitudinal profile to the river. This profile was anchored by the ultimate base level (sea level) overall but might also be anchored locally, for example, a lake. River grade became a major issue in fluvial geomorphology. Davis invoked a parallel grade concept and applied it to slope development. Here, decreasing particle size was also invoked as an explanatory factor for decreasing slope angle, hence a lower concave slope profile. However, there was no reason to expect slope and river grade to emerge in the landscape at one and the same time.

On a related, but essentially independent, note it is worth appreciating that Davis was a

remarkably skilled sketch artist. The quality of his sketches, read explanatory diagrams, provided support for his argumentation in what amounted to a second language. Of course, sketching has the inbuilt advantage of being editorial in and of itself.

Criticisms of the Cycle

In essence, the initial criticism of the geomorphic cycle came from Davis himself. The idea was launched as a universal concept, that is, one unconstrained by climatic variability; however, it took Davis only a few years to appreciate that a model of cycle development in the temperate mid-latitudes would need substantial modification if it were to be used in other climes. Consequently, Davis added to his concept of a “normal” or mid-latitude climate a version of landscape development in an arid climate; other special cases were subsequently forwarded by disciples of his views. In many ways, this need can be viewed as the birth of climatic geomorphology.

The most pervasive problem with the geographical cycle rests in the manner in which Davis himself pursued and proselytized it. A model of landscape development is essentially a hypothesis; as such, it needs to be tested against empirical evidence, that is, landforms and landscapes. However, Davis took his model as an established and/or foolproof explanation of landscapes and then proceeded to see landscapes exclusively in terms of that model. Where real landscapes failed to substantiate his expectations, he invoked special circumstances of numerous kinds. A simple example would be the frequent invocation that a peneplain had been warped subsequent to its initial formation. Given his immensely influential position at Harvard University and in the geomorphological community at large, his cause was also taken up by influential disciples. It seems reasonable to assert that because Davis did not pursue process geomorphology vigorously, those who challenged him and later geomorphologists tended to do so. In turn, the pursuit of process geomorphology necessitated much greater attention to detail and direct measurement; consequently, process geomorphology came to function at the slope scale rather than at the regional scale. Consequently, much of Davisian geomorphology has



been bypassed by contemporary process geomorphology, some portions of it having been demonstrated to be wrong, while other portions are deemed irrelevant. Some large-scale modeling in recent years has suggested that the geographical cycle contains important truths, but it is no longer a model that carries much credibility with the majority of geomorphologists. Nevertheless, it should be seen as a towering, pioneering effort that shaped geomorphology both by what it aspired to do, a lengthy period of disciplinary domination, and by the enormous intellectual effort that was required within the discipline to oppose and overcome it.

Colin Edward Thorn

See also Davis, William Morris; Geomorphology; Gilbert, Grove Karl; Penck, Walther; Physical Geography, History of

Further Readings

- Chorley, R. J., Beckinsale, R. P., & Dunn, A. J. (1973). *The history of the study of landforms: Vol. 2. The Life and Work of William Morris Davis*. London: Methuen.
- Davis, W. M. (1899). The geographical cycle. *Geographical Journal*, 14, 481–504.
- Knox, J. C. (1975). Concept of the graded stream. In W. N. Melhorn & R. C. Flemal (Eds.), *Theories of landform development* (pp. 169–198). Boston: Allen & Unwin.
- Rhoads, B. L., & Thorn, C. E. (1996). Observation in geomorphology. In B. L. Rhoads & C. E. Thorn (Eds.), *The scientific nature of geomorphology* (pp. 21–56). Chichester, UK: Wiley.
- Young, A. (1972). *Slopes*. Edinburgh, UK: Oliver & Boyd.

processes that form, maintain, and change them over time. Geomorphology has long been recognized as a major subfield of geography and geology, but in recent decades, concepts and techniques from geomorphology have been applied widely in engineering (e.g., restoration of damaged streams), ecology (e.g., estimating fish abundance as a function of physical habitat features), forestry (e.g., evaluating the stability of hillslopes), agriculture (e.g., modeling soil erosion), hydrology (e.g., assessing flood hazards, finding groundwater), archaeology (e.g., reconstructing past environments), pedology (e.g., explaining the movement of heavy metals, relative age dating of geomorphic surfaces using soils), space science (e.g., landforms on Mars), and environmental planning (e.g., evaluation of geomorphic hazards such as dust storms, coastal erosion). Many opportunities exist in geomorphology to share concepts and techniques with practitioners in other branches of physical geography (“integration”) and in human geography (“synthesis”). Geomorphology is an intimate part of the emerging, interdisciplinary field known as Earth system science, a scientific approach to describe, explain, and predict biogeochemical phenomena at or near the surface of the Earth. A significant number of geomorphologists practice Quaternary geomorphology, the reconstruction of past environments. This part of geomorphology has received new vigor in light of the need to predict the effects of climate change, a task that profits from the ability to decipher past adjustments between form and process.

On the one hand, geomorphology is a basic science in that it seeks to understand the diversity of landforms without necessarily having any direct implications for human activities. On the other hand, geomorphology is an applied science because concepts and techniques from geomorphology are applied to practical problem solving in engineering, resource evaluation, and environmental planning.

Geomorphologists study landforms on a variety of spatial scales, ranging from regional/continental (e.g., stream networks, mountain building) down to microscopic (e.g., development of soil crusts, cosmogenic dating of earth materials). A reductionist approach, which relies on principles from physics and chemistry, has proven useful in explaining small-size phenomena, for instance, in



GEOMORPHOLOGY

Geomorphology is the science that studies landforms, including their shape (morphology) and spatial distribution (location and position in the landscape), the materials of which they are composed (bedrock, soils, sediment), and the



understanding the factors that affect the initial movement of an individual particle by wind or water. However, for larger-size phenomena, probabilistic modeling approaches have provided more explanatory power. What is ordered and regular at one spatial or temporal scale may be disordered and irregular at another scale. Some exciting new developments in mathematical modeling in geomorphology have emerged from the application of complexity and chaos theory.

Geomorphologists rely on an amazing array of field methods for the collection of primary data, supplemented by secondary data sources: topographic maps, digital elevation models, land surveys, soil surveys, geologic maps, aerial photography, satellite imagery, and numerical dating techniques. Data are also collected in laboratory settings with physical models (e.g., wind tunnels, flumes) and lab analyses of soil and sediment samples (physical-chemical analyses, dating). Data are analyzed using geographic information systems, computer simulation models, and geospatial statistics.

History of Geomorphologic Thought

To understand geomorphology requires an examination of how fundamental, guiding ideas in geomorphology changed over time. The discipline of geomorphology was not recognized as a distinct subdiscipline of geology and geography until the 19th century, but early writings on landforms can be traced to classical Greek, Roman, Arab, and Chinese scholars. For example, Herodotus is attributed with the observation that “All Egypt is the gift of the Nile,” a recognition that the fertility of floodplain soils depends on annual floods, more specifically the deposition of silt and leaching of salts. Herodotus also believed that the sea level had changed over time. Aristotle believed that stream erosion was a dominant process in forming landscapes. Strabo found that the size of river deltas depends on the drainage area, the resistance of the source rock, and the erosional strength of tides.

During the European Renaissance, contributions were made by Leonardo da Vinci, among others. Leonardo used glass flumes to study stream erosion, transport, and deposition. However, much of his work was not published until the

18th century. The Church exerted powerful control over academic thinking at this time, so scientists had to reconcile their scientific observations with religious orthodoxy. During the 17th and 18th centuries, theories of landform development focused on catastrophic processes of origin, including sea-level change (Abraham Gottlob Werner), floods (William Buckland, Adam Sedgwick), vulcanism (e.g., Horace-Bénédict de Saussure), and endogenic processes (e.g., John Phillips).

The concept of uniformitarianism came to dominance in the 18th century and persisted until the mid 19th century. This concept is generally attributed to James Hutton, although it was his colleague, John Playfair, who popularized Hutton’s ideas in a book published in 1802. By the mid 1800s, geomorphology was coined as a new word and was often taught under the name *physiography*. Western literature was dominated by uniformitarianism in the writings of Charles Lyell and the Frenchman Jean Baptiste Perrault; Georges-Louis LeClerc, Comte de Buffon; and Nicolas Desmarest. In the late 19th century, the concept of uniformitarianism was modified into the term *gradualism*, which allows for the changing rates of geomorphic processes over time (Andrew Crombie Ramsey, Ignaz Venetz, Jens Esmark, Louis Agassiz).

In the late 19th century, geomorphology was given renewed attention thanks to the detailed explorations of the Western United States by John Wesley Powell, Grove Karl Gilbert, and Charles Dutton. Powell classified streams by their relation to the geologic structures they cross—an idea that has stood the test of time. Gilbert conducted lab experiments on sediment transport and wrote on a wide range of geomorphic topics: intrusive igneous landforms, fault scarps, Pleistocene lakes, craters on the moon, barrier islands, glaciers, and more. Gilbert is attributed with several key concepts that persist to this day: the graded stream, lateral planation, stream competence, the origin of pediments, controls on drainage patterns, and the effects of geologic structure. Dutton’s studies of the Grand Canyon region are legendary for a number of reasons, not the least of which are the spectacular drawings of the Grand Canyon by William Holmes that were included in Dutton’s U.S. Geological Survey publications on the region. Dutton also recognized evidence in the field for



old erosion surfaces, which he said could be subject to uplift and new episodes of erosion.

The first half of the 20th century was dominated by William Morris Davis and his disciples (Eliot Blackwelder, Charles Cotton, Oscar Diedrich von Englyn, Nevin Fenneman, Armin Kohl Lobeck, J. Hoover Mackin). Based on deductive reasoning, and extending the earlier work by Powell and Dutton, Davis developed the “cycle of erosion” to characterize landscapes as progressing through stages of youth, maturity, and old age, until rejuvenated by uplift. The Davisian cycle was popular at first because it was simple, ordered, unified, and harmonious. However, it quickly came under criticism in Europe, notably by the German geomorphologist Walther Penck. The German Herbert Louis Büdel and the Frenchman Jean Tricart promoted climatic geomorphology as an alternative. Davisian concepts were replaced in the latter half of the 20th century by empirical, quantitative geomorphology (Robert Horton, Arthur Strahler, William Rubey, Luna Leopold, M. Gordon Wolman), the systems approach (Richard Chorley, Stanley Schumm), and a focus on human impacts. The development of new techniques, notably in the field and with remote sensing, led to an emphasis on direct measurement of processes. Specialties developed within geomorphology based on the dominant process being studied: tectonic, volcanic, fluvial, glacial, periglacial, aeolian, coastal, weathering, mass movement, karst, and biogeomorphology.

Geomorphological research is currently published in a variety of journals, but most notably in several that are dedicated to the discipline: *Geomorphology* (since 1987), *Earth Surface Processes and Landforms* (since 1976), *Journal of Geophysical Research-Earth Surface* (since 2003), and *Zeitschrift für Geomorphologie* (since 1957). Geomorphologists in the United States are affiliated with the American Geophysical Union, Association of American Geographers (AAG), Geological Society of America (GSA), and International Association of Geomorphologists. Incidentally, Davis was the first president of both the AAG and the GSA. Geomorphologists from multiple disciplinary backgrounds have come together each fall since 1970 for the Binghamton Geomorphology Symposium, which highlights a different theme every year.

Fundamental Concepts and New Directions

The most fundamental concept in geomorphology is that landforms develop as the result of the interplay of the resisting framework, driving forces, and time. The resisting framework refers to the effects of lithology (differential resistance to weathering and erosion), stratigraphy (layered sequence of lithologic units), structure (geometric arrangement of geologic units—strike and dip, faults, folds, joints, etc.), and vegetation (e.g., soil-binding effect of roots, roughness caused by vegetation on wind and water). The driving forces in geomorphology include endogenic processes (diastrophism, volcanism), exogenic processes (weathering, erosion transport, and deposition), and extraterrestrial processes (impact of asteroids and meteorites). It is perhaps more prudent to state that geomorphologists pursue their studies by examining the spatial distribution of the resisting framework and driving forces over time.

Recent developments in techniques to provide absolute dates of landforms have provided a new impetus for the discipline of geomorphology. Several forms of radioisotope dating are available to date earth materials over a range of timescales, depending on the materials available. For example, ^{14}C (carbon) is used to date carbon-bearing materials back to about 40,000 yrs. (years); ^{40}K (potassium) is used to date potassium-bearing materials from approximately 20,000 yrs. old to the oldest rocks on Earth. Dating with cosmogenic isotopes and optically stimulated luminescence (OSL) are two rapidly developing, lab-intensive methods. Cosmogenic isotope dating is based on the accumulation of in situ, stable, radioactive isotopes in rocks that have been bombarded by cosmic radiation. Cosmogenic isotopes accumulate over time on exposed rock surfaces, thus providing a means by which the surface can be dated, subject to a number of constraints. The most often used isotopes are ^{36}Cl (chlorine), ^{10}Be (beryllium), and ^{26}Al (aluminum), which can provide ages back to 500,000 to 1 million yrs. OSL dating is based on the absorption and storage of radiation in the form of electrons trapped in the impurities and defects of mineral crystals. Dating is related to the last exposure of a mineral to sunlight prior to being buried. Other breakthroughs



with dating landforms have occurred with fission track dating, paleomagnetism, obsidian hydration dating, dendrochronology, and lichenometry.

Geomorphologists focus on time in another regard. When examining the adjustment between landforms and processes, it is meaningful to compare the time between major disturbances to landforms (natural or human) with the time required for landforms to adjust to the disturbance. It is typical for a reaction (lag) time to exist between the disturbance and when the landform begins to adjust. Then the adjustment toward a new equilibrium will begin and span a period of time known as the “relaxation time.” If the major disturbances are spaced over an interval of time greater than the response time (reaction + relaxation time), a new equilibrium can be achieved. If, however, the next major disturbance occurs before the completion of the response time, equilibrium cannot be achieved. Thus, it is possible for some landforms to achieve a dynamic equilibrium, whereas other landforms may never achieve equilibrium.

Geomorphology is a key element in separating environmental change due to human activities from change that would have occurred without human interference. Journal articles and textbooks abound that describe the impact of humans on the delicate adjustment between landforms and geomorphic processes, through the effect of forestry, agriculture, grazing, mining, urbanization, wildfires, military maneuvers, dams, channelization, climate change, and more. Roger L. B. Hooke estimated that worldwide humans move 45 Gt (gigatons; 1 Gt = 10^9 tons = 10^{12} kilograms) of earth materials each year. This compares with rivers (14 Gt/yr. excluding human effects + 39 Gt/yr. from meander migration = 53 Gt/yr.). Glaciers move 4.3 Gt/yr. at present, compared with 10 Gt/yr. during the Pleistocene. Hillslope processes move 0.6 Gt/yr.; waves move 1.24 Gt/yr.; wind and volcanoes together move 1.0 Gt/yr. Mountain building moves 14 Gt/yr. on continents and 30 Gt/yr. in the oceans.

Jonathan Phillips has proposed that geomorphologists recognize that the development of landforms is controlled by a combination of global factors (i.e., independent of time and place, governed by the laws of physics and chemistry) and local factors. Each landscape has an inherited history—from biophysical and human influences—which

will almost certainly vary from place to place. The historical legacy of local disturbances leads to increased divergence in landform development, while global controls lead to convergence. One approach, therefore, is to increase the generality of models, concepts, and research in geomorphology and to reduce the number of variables and factors considered, while others continue to seek deterministic models to describe landscapes in all their complexity.

In his book *To Interpret the Earth: Ten Ways to Go Wrong*, Stan Schumm has described the factors that confound geomorphologists as they seek to interpret landforms:

Time: Whether a landform can be considered to be in equilibrium depends on the time frame over which observation occurs.

Space: The difficulty in explaining geomorphic phenomena increases as the size of the phenomenon increases; and the length of time needed for a geomorphic feature to adjust is directly related to the size of the feature.

Location: It is difficult to extrapolate cause and effect from one location to another.

Convergence: Similar landforms can be created by different initial combinations of processes and materials.

Divergence: Different landforms can be created from similar initial combinations of processes and materials.

Efficiency: Explanations of cause and effect may be confused by nonlinear relationships.

Multiplicity: A single explanation will rarely provide total understanding; it is likely that multiple cause-and-effect linkages are operating to create geomorphic phenomena.

Singularity: A large natural (and unexplained) variation exists between similar geomorphic systems.

Sensitivity: Geomorphic systems vary in their sensitivity to disturbances. Some systems have thresholds of change, where perturbations (in form or process) up to a certain level produce no change but after that threshold value is exceeded, rapid change begins.

Complexity: Geomorphic systems can respond to a disturbance in opposite ways at different times or places.



Geographers offer three special insights in geomorphology. First, the mixed methods and theories that geographers employ—quantitative and qualitative, post-positivist science and social theory, muddy-boots fieldwork linked with geographic information science (GIScience)—together position geographical geomorphologists to resolve the debate over human-triggered change in landscapes and to explain the frequent disconnect between geomorphology, policy making, and resource management. Second, many problems in geomorphology require training, experience, and expertise in understanding coupled physical-human systems. Third, modern techniques of measuring the rates of geomorphic change help place the human factor in perspective and explain the spatial variability of natural hazards.

Richard A. Marston

See also **Atoll; Barrier Islands; Biota and Topography; Carbonation; Coastal Erosion and Deposition; Davis, William Morris; Dunes; Faulting; Fieldwork in Physical Geography; Fjords; Folding; Geologic Timescale; Geomorphic Cycle; Gilbert, Grove Karl; Glaciers; Continental; Glaciers: Mountain; Gully Erosion; Hydrology; Impermeable Surfaces; Karst Topography; Landforms; Landslide; Periglacial Environments; Permafrost; Physical Geography, History of; Plate Tectonics; Powell, John Wesley; Rill Erosion; Rivers; Sedimentary Rock; Sedimentation; Soil Erosion; Volcanoes; Wind Erosion**

Further Readings

- Butler, D. R. (2003). Geomorphology. In G. L. Gaile & C. J. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 56–71). New York: Oxford University Press.
- Easterbrook, D. J. (1999). *Surface processes and landforms*. Upper Saddle River, NJ: Prentice Hall.
- Hooke, R. L. B. (1994). On the efficacy of humans as geomorphic agents. *GSA Today*, 4(9), 224–225.
- Marston, R. A. (1989). Geomorphology. In G. L. Gaile & C. J. Willmott (Eds.), *Geography in America* (pp. 70–94). Columbus, OH: Merrill.
- Phillips, J. D. (2007). The perfect landscape. *Geomorphology*, 84(3/4), 159–169.
- Schumm, S. A. (1991). *To interpret the Earth: Ten ways to be wrong*. Cambridge, UK: Cambridge University Press.



GEOPHAGY

Geophagy, literally “earth eating,” also known as *pica* (technically the consumption of all inappropriate materials), is the practice of consuming dirt, typically clays. Geophagy may be practiced for either health or religious reasons. Devout Christians and Muslims have engaged in ritualized forms of geophagy for centuries, typically in the form of wafers ostensibly derived from holy sites.

Geophagy was widely practiced in many pre-industrial societies, particularly in tropical environments and most commonly by pregnant women to relieve the nausea of pregnancy. Through trial-and-error experimentation, many cultures learned to compensate for nutritional deficiencies of trace minerals or vitamins, particularly sulfur, zinc, calcium, phosphorus, potassium, magnesium, and manganese, by consuming certain forms of clay. Consumption of dirt rich in iron is helpful in regions where people suffer from iron deficiency due to the high prevalence of hookworm disease. Soil may be added as well when salt or calcium are deficient in the local diet (especially among non-milk-drinking peoples), or kaolin may be added as an antidiarrheal or gastric disorder treatment, especially for infants. Some Native American tribes, as well as Sardinians, mixed dirt with corn or acorns to neutralize the acids. South American Indians regularly used clays for their alkaloid-binding properties when consuming bitter potatoes. When viewed in this light, geophagy is a rational nutritional adaptation to dire mineral deprivation. However, severe geophagy also carries health risks such as growth retardation and liver enlargement. When it occurs as a regularized social practice, dedicated clay pits and specialized workers are used to harvest, clean, and process the clays consumed, and they may be traded over wide areas. Geophagy is also often prevalent during times of extreme famine.

Although it carries risks of bacterial infection or parasites, in many non-Western cultures, geophagy was culturally sanctioned as healthy and beneficial. Sometimes called “calabash chalk” in much of Africa, clays were consumed by up to half of the population of pregnant or breast-feeding women, either to alleviate morning sickness



or to improve lactation. Geophagy was imported from West Africa to the Southern United States via the institution of slavery. Sometimes known as “Cachexia Africana” in the slave-based South, geophagy among slaves was sometimes prevented through the use of mouth locks.

Despite centuries of attempts to eliminate it and increasingly severe social stigmatization, geophagy persisted in the South. White clay consumption was traditionally confined mostly to impoverished rural black women and children (although some whites too practiced it). A survey in 1942 in Mississippi found that 42% of schoolchildren regularly consumed clays. Sometimes other materials such as starch, chalk, or ash were substituted for clay. Although widely discredited as a practice of poor people (and today, as an eating disorder), in some locales it was institutionalized, and baked or processed clays and dirt are occasionally still found in the South today. Migration from Africa to former colonial countries introduced geophagy into Britain and France.

Barney Warf

See also **Food, Geography of**

Further Readings

- Hunter, J. M. (1973). Geophagy in Africa and in the United States: A culture-nutrition hypothesis. *Geographical Review*, 63, 170–195.
- Vermeer, D. (1966). Geophagy among the Tiv of Nigeria. *Annals of the Association of American Geographers*, 56, 197–204.
- Vemeer, D. (1971). Geophagy among the Ewe of Ghana. *Ethnology*, 10, 56–72.
- Vermeer, D., & Frate, D. (1975). Geophagy in a Mississippi county. *Annals of the Association of American Geographers*, 65, 414–424.

of the state and national power with reference to natural resources, population, and geographical location. Like other terms that gain academic and political popularity, a geopolitical way of thinking was judged to be timely in the sense that Europe in particular was undergoing a series of political, economic, and cultural transformations, including regional alliance formations, imperial change, and conflict over trade and resources. Later, geopolitics was implicated with Nazism and became deeply controversial as a consequence of such an association. Notwithstanding the opprobrium, the term proved to be resilient and has even enjoyed a revival in many parts of the world, especially in the post–Cold War era.

Origins of the “Science” of Geopolitics

In the earliest phases of its scholarly history, geopolitics was taken up with great interest in Germany, Italy, Japan, and the United Kingdom. As a portmanteau adjective, geopolitics attracted interest because it hinted at novelty. It was intended to convey an interest in the often unremarked geographical dimensions of states and to posit “laws” in international politics based on a series of geographical facts such as the relationship between land- and sea-based powers. Informed by social Darwinism, the struggle of states and their human creators was emphasized, as was the need to secure the “fittest” states and peoples. According to Ratzel, the state should be conceptualized as a super-organism that existed in a world characterized by struggle and uncertainty. To prosper, let alone survive in these testing circumstances, states needed to acquire territory and resources.

Strikingly, in Germany after World War I, an influential figure, General Karl Haushofer, was pivotal in the creation of a journal of geopolitics in 1924. As a former aide-de-camp to Rudolf Hess and an established expert on Japan, Haushofer became professor of geography at the University of Munich. Like earlier writers such as Ratzel, he believed that German survival, let alone consolidation, in the aftermath of the 1919 Peace Conference would depend on the country understanding the geographical realities of world politics. As a defeated nation, Germany’s national boundaries had changed, and empires such as the Austro-Hungarian and Ottoman were dismantled. Europe



GEOPOLITICS

Coined in the late 1890s, the term *geopolitics* has had a controversial scholarly history. The Swedish political geographer, Rudolf Kjellen and other early-20th-century writers such as Friedrich Ratzel considered the geographical foundations



was in a state of flux, and the alleged scientific status of geopolitics was important in establishing intellectual legitimacy and policy relevance in Germany and elsewhere.

For Germany to prosper, Haushofer opined that interwar Germany needed to appreciate five issues: (1) physical location, (2) resources, (3) territory, (4) morphology, and (5) population. If Germany was, what he termed, a “space-hopping” country rather than “space bound,” then it might be able to capitalize on all available resources and territorial opportunities. He also contended that if the world were organized into a series of pan-regions, then it might be possible for Germany and other states such as the United States and Japan to exercise global leadership. Under his global model, Germany would dominate the Euro-Asian landmass and Africa. He was a keen supporter of the proposed Berlin-Baghdad railway and of German colonies in Africa. As a consequence of his close relationship to Hess, these ideas have been credited with informing Hitler’s plans of spatial expansionism in the East and were even seen as contributing to the final solution involving Jews, communists, and others, including the disabled. While Haushofer was fascinated by spatial relationships and Germany’s reemergence after World War I, there is neither any evidence that he shared Hitler’s hatred of European Jewry nor evidence that he viewed the world as being controlled by an international cabal of Jews and communists. By the late 1930s, Haushofer’s influence was on the wane, and he thought the invasion of the Soviet Union in 1941 was a geostrategic error. He later committed suicide in 1946, after being sidelined in academic and policy-making terms.

While the relationship between geopolitical thinking and Nazism was never as clear-cut as some may have believed, it did not prevent a new generation of émigré intellectuals such as Hans Weigert, Andreas Dorpalen, and Robert Strausz-Hupe from warning American audiences about the dangers of the “science” of geopolitics. The latter was invested with great scientific potential, and popular magazines such as *Reader’s Digest* warned about the shadowy Institute of Geopolitics at the University of Munich. The truth was less prosaic, and German engagement with geopolitics was, in different ways, being replicated in other countries, including not only fascist Italy

but also Portugal and Spain. In each case, geopolitics appears to have been popular because it offered a way of looking at the world that tied a country’s destiny to an analysis of resources, territory, and population. Maps, including those found in school textbooks, were important in communicating those ideas to both popular and scholarly audiences.

Germany’s and Japan’s defeat in 1945 had consequences not only for global geopolitics but also for the academic study of geopolitics itself. One important figure in the case of the latter was Father Edmund Walsh, Jesuit priest and American colonel, who interviewed Haushofer in the aftermath of the conflict. While Walsh was convinced that the German professor and former general should not be tried for war crimes, he described the latter as a “master geopolitician.” Although he did not blame German geopolitics for Hitler’s racist and expansionist policies, the “science” of geopolitics was damned in the eyes of many observers. A new generation of American political geographers (and their Soviet counterparts) spurned the term *geopolitics* and were careful to distinguish their own activities as intellectually objective and less deterministic with regard to the spatial and environmental parameters influencing states. With very few exceptions, the term *geopolitics* disappeared from the American academic scene and was not revived until the 1970s. Distinguished geographers such as Isaiah Bowman and Richard Hartshorne had warned their colleagues about the poisonous reputation of the subject matter.

One partial exception to this generalization was the geographer Saul Cohen, who for about 40 years has been reminding colleagues of the importance of understanding the changing global political map. Inspired by a Dutch American geographer, Nicholas Spykman, Cohen sought to convey how the onset of the Cold War made it even more important that Americans understood the geographical basis of the struggle between the United States and the Soviet Union. In his pioneering work, *Geography and Politics in a Divided World*, he explored how the world was composed of a series of shatterbelts and showed how the two superpowers were locked in conflicts over territory, resources, and access. He also emphasized the importance of understanding regional differences and not assuming



that the Cold War struggle against communism was occurring against a backdrop of uniform political, economic, and cultural geographical relationships.

Geopolitical Revival: The Kissinger Factor

Former Secretary of State Henry Kissinger, a German-born émigré and intellectual, has been credited with reviving American interest in geopolitics even if his use of the term was more informal than that by academic scholars. In the midst of the Cold War, Kissinger was involved with President Nixon in some highly significant geopolitical maneuvers, including negotiating a more cordial relationship with China and relative détente with the Soviet Union. The United States was also in the process of leaving Vietnam. Kissinger's use of the term *geopolitics* was in part a way of coming to terms with these changes and in part to underscore the significance of global balance and permanent national interests. He was particularly mindful of the Soviet Union's "geopolitical ambitions" and "geopolitical aspirations" with regard to the Euro-Asian landmass. The United States had to maintain its presence in the region and seek to contain its ideological challenger.

Although Kissinger's use of the term *geopolitics* was often vague, it did invoke earlier writers such as Halford Mackinder, a former director of the London School of Economics and Reader in Geography at the University of Oxford, who had drawn attention to the importance of the Euro-Asian landmass (the Heartland, to use his term) before and after World War I. Although not cited by Kissinger, another leading policy figure and intellectual under the Carter administration was informed by Mackinder's legacy. The Polish-born National Security Advisor, Zbigniew Brzezinski, was a keen advocate of geopolitics and wrote about the need to contest Soviet expansionism in the Euro-Asian landmass. After the Soviet invasion of Afghanistan, this call took on an added sense of urgency as America looked to the anti-Soviet resistance and regional allies such as Pakistan to contest the occupation. Some political analysts assert that American military and financial support throughout the 1980s not only helped defeat the Soviet war machine but also,

paradoxically, created the conditions for the al-Qaeda terror network to later rely on the battle-hardened veterans in Afghanistan to carry out deadly attacks from the 1990s onward.

During the last years of the Cold War, some policy intellectuals and academics in the United States came together to establish the Committee on the Present Danger (CPD), which used geopolitics and other academic pursuits to argue that the United States needed to ditch policies such as détente and take up a more aggressive foreign policy committed to achieving victory in this titanic struggle. The Reagan administration epitomized this geopolitical worldview and committed the United States to intervening all over the world, including Central America and the Middle East, in an attempt to secure such a victory. This strategy frequently resulted in American support for dictators such as Saddam Hussein in Iraq and countless military regimes in Asia, Africa, and Latin America. The bigger geopolitical picture involved the defeat of the Soviet Union and its allies. In 1989, Eastern European socialist allies such as East Germany and Czechoslovakia folded, and the Cold War was considered terminated. Two years later, the Soviet Union collapsed, and the realist and geopolitical approaches advocated by the CPD appeared triumphant.

Toward a Critical Geopolitics

At the same time that the Cold War was entering a more confrontational phase, a new generation of geographers was preparing the ground for the emergence of a more critical engagement with geopolitics. For some geographers, this meant exploring the peace literature, and for others, it entailed an engagement with world-systems theory and a more politico-economic understanding of global capitalism. During the 1980s, political geography and geopolitics were revived in the universities. While Henry Kissinger had repopularized the term, world events coupled with 40 years of its absence from the political forum made it easier in the English-speaking world for a new generation of scholars to reclaim the term. In other parts of the world, this option was either less straightforward or simply not relevant. In the Soviet Union, for instance, the term *geopolitics* was



still considered to be deeply problematic and offensive. While in Latin America, scores of mainly military officers were using geopolitics with little to no apparent concern for its alleged associations with Nazism.

American-based scholars such as Gerard Toal, Simon Dalby, and John Agnew began to reengage with this controversial intellectual train, later to be dubbed critical geopolitics. Rejecting the notion that geopolitics was an objective “science,” they conceptualized geopolitics as a discourse and political practice. In other words, attention was drawn to how geopolitics is performed and the manner in which it constructs representations of the geographies of global politics. If geopolitics is a discourse capable of producing and circulating spatial understandings of world politics, then it is imperative that we consider, so they contended, the consequences of such representations. For one thing, we might explore how certain geographical understandings of Cold War America were critical not only in securing a sense of political identity (as the leader of the free world) but also in justifying a vast investment in military and technological resources (the military-industrial complex).

Since the 1990s, these writers have maintained that geopolitics can be considered to exhibit three forms: (1) a form concerned with academic manifestations of the term, (2) a practical form that involves the policy-orientated geographical templates used by presidents and prime ministers in their policy discourses, and (3) finally a popular geopolitical variety that notes how the media is central in creating and reproducing geographical understandings of local, regional, and global politics. In the case of the latter, recent research has explored how cartoons, television, films, newspapers, and the Internet contribute to the geographical socialization of citizens in the Euro-American world and beyond.

Conclusion

Geopolitics has had a varied and at times controversial history. Shunned by some, it has also been embraced by others, especially in the aftermath of the September 11, 2001, attacks on the United States when pundits and journalists embraced the term. What geopolitics offers to

many is a convenient term that seems to promise a rugged respectability and a willingness to ponder the grim realities of world politics. It also frequently attracts commentators anxious to make predictions about the world, usually for the benefit of one country as opposed to others. For critical geopolitical scholars, these kinds of claims need to be scrutinized and challenged, not the least because they neglect the persistent inequalities between the North and the South, the highly gendered geographies of human security, and the environmental consequences of global political and economic patterns.

Klaus Dodds

See also **Critical Geopolitics; Haushofer, Karl; Mackinder, Sir Halford; Mahan, Alfred Thayer; Nation; Nationalism; Political Geography; Ratzel, Friedrich; State**

Further Readings

- Cohen, S. (1973). *Politics and geography in a divided world*. New York: Oxford University Press.
- Dodds, K. (2007). *Geopolitics: A very short introduction*. Oxford, UK: Oxford University Press.
- Hepple, L. (1986). The revival of geopolitics. *Political Geography Quarterly*, 5(Suppl.), S79–S90.
- Ó Tuathail, G. (1996). *Critical geopolitics*. London: Routledge.
- Ó Tuathail, G., Dalby, S., & Routledge, P. (Eds.). (1998). *The geopolitics reader*. London: Routledge.



GEOSENSOR NETWORKS

Advances in miniature, low-cost microelectronic and mechanical systems (MEMS) with limited onboard processing capabilities, storage, and short-range wireless communication links, together with the development of novel microsensors and sensor materials, enable us to build a new generation of technology that consists of large collections of tiny, untethered, battery-powered computing nodes with various sensing functions. With the continued trend toward miniaturization and the inexpensiveness of such sensor nodes, it is expected that sensor nodes will be



less than a cubic millimeter in size in the near future and that sensor networks can be made up of thousands or even millions of sensors (“smart dust”). Geosensor networks (GSNs) are a specialized application of wireless sensor network technology in geographic space to detect, monitor, and track environmental phenomena and processes at a novel spatial and temporal scale. Considering remote sensing instruments such as “telescopes,” which are commonly used to monitor environmental processes on Earth, a GSN can be viewed as an “environmental microscope” providing a spatiotemporal resolution of observations and near-real-time information never available before.

The technology of GSNs has the following constraints that pose new challenges from an infrastructure system and application development standpoint:

Power consumption: Sensor nodes are limited with regard to their battery supply, and energy conservation is a major system design principle. Also, communication is a much larger battery drain than local computation on a computing node.

Low-range communication: The bandwidth of a wireless communication link of a node is limited and its range is short. Messages from nodes at different regions of the network are typically communicated with a multihop routing strategy. Since communication energy cost is a significantly higher drain on energy consumption than the energy needed for onboard processing, optimizing and minimizing communication within the sensor network are a major system design consideration.

Limited computing and storage capabilities: Sensor nodes have, at least for the foreseeable future, limited onboard computational, and volatile and persistent storage capabilities. Thus, onboard data processing using the available memory and CPU capacity is also limited.

Self-organization: Due to the large number of sensor nodes, the vulnerability and failure rates of nodes and communication links, and the often unattended deployment, task management and handling in sensor networks need to be decentralized and self-organizing. Thus, some level of local autonomy must be provided for the devices.

Since the mid 1990s, much research in sensor networks has focused on the design of tiny computing platforms, operating systems, and programming languages for resource-constrained computing environments (e.g., TinyOS, Contiki, and nesC). A major task of GSNs is intelligent data collection and processing. Despite their powerful and novel capabilities to observe the physical world, programming sensor networks for specific observation and actuation tasks is cumbersome today due to the failure-prone nature of nodes and communication links and the vast parallel computational nature of such systems. A domain scientist interested in deploying a GSN needs to be able to define the necessary tasks in a user-friendly way and delegate the optimization and ultimately self-adaptive execution to the run-time system without having to worry about the details.

Today, it is a popular abstraction to view a GSN simply as a distributed spatial database system (DBS) with sensor nodes running tiny footprint DBS software locally, responding to queries and performing local processing and collaboration with other nodes. Each sensor node supports a single sensor table, and the attributes match the attached sensors, such as temperature, humidity, location, and so on. The query language is similar to structured query language (SQL)-style spatial queries, and it is extended with sampling epochs for continuous queries. Using this abstraction, a user can interact with the GSN as a single virtual sensor. One of the first sensor database management system prototypes is TinyDB.

Typical sensor network data collection tasks are spatiotemporal in nature. For example, a user might be interested in hourly sampled values of the light profiles around tomato plants in an industrial greenhouse to monitor and optimize the microclimate around the plants. Nowadays, spatiotemporal queries over GSNs often retrieve discrete information measured at the locations of sensor nodes. Many environmental phenomena, such as a temperature field or a gas concentration field in an open space, however, are *continuous*. The challenge exists to provide an accurate and precise estimation of all points or regions of a dynamic spatial field based on limited discrete point samples collected by the sensor nodes. Due



to the constrained nature of sensor nodes, estimation algorithms need to be lightweight and processed in a distributed, decentralized way “in the network.” Typically, streaming all sensed values out of the network to provide offline data analysis is not an option, since the raw, unprocessed data collection drains the energy resources of the network and reduces the GSN application lifetime by 90%. A valid option of data processing today is decentralized, localized event detection and decision making. For example, to detect a toxic plume, it is sufficient to detect and track the boundary of the plume, while reducing any kind of processing, sampling, and communication elsewhere in the network.

GSNs can also be deployed in a mobile way such that sensor nodes are attached to automobiles or used by pedestrians, mounted onto animals, or floating on the ocean. Here, relevant real-time sensed information is collected in a local context and only exchanged in an ad hoc way between other mobile sensor nodes currently located in the region and in (communication) proximity to each other. For example, in intelligent transportation systems, collocated sensor nodes can inform other nodes in the same region about environmental threats such as icy patches on the road or other unexpected road hazards that can be sensed on the road.

The application areas for GSNs are plentiful—for example, biodiversity, biogeochemical cycles, precision agriculture, habitat monitoring, flood monitoring, landslide monitoring, tsunami warning systems, coral reef observations, and coastal and ocean observations.

Today, a large variety of comparatively large-sized sensors with onboard processing are already in use in geographical applications. Characteristically, such sensors are stationary, expensive, and, thus, sparsely distributed over a large geographic area (e.g., a single sensor for a square-mile region). Data are logged and stored locally and retrieved in batch mode either manually or via satellite link. GSNs add the ability to monitor dynamic complex processes, at a very small and local scale, that are more difficult to observe by existing instruments due to their scale. It is, however, typical of geosensor networks that the technology is integrated with existing, larger-scale sensing platforms such as remote sensing

instruments, buoys, autonomous underwater vehicles, windmills, weather stations, and so on. When combining sensor networks with the existing sensing platforms, so-called sensor webs are created. Similar to the idea of the World Wide Web, the vision is that sensors and sensor networks should be accessible and usable in a uniform way, so that scientists can find, combine, and query real-time sensors in a geographic region for a specific application. This results in the (often expensive) sensor platforms being reusable for different purposes. The Open GIS Consortium provides a standardization approach for sensor platform interfaces and data exchange (Sensor Web Specifications) for sensor webs. Today, several research networks have been established, including NEON (National Ecological Observatory Network), GLEON (Global Lake Ecological Observatory Network), CREON (Coral Reef Environmental Observatory Network), and the NEPTUNE Cyberinfrastructure.

Currently, the actual application and deployment of GSNs is in its infancy. With the increasing robustness of sensors, wireless communication, improved battery life and technology, and software developments, GSNs will become a powerful technology, an extension of the existing environmental sensing platforms.

Silvia Nittel

See also **Neogeography**; **Remote Sensing**

Further Readings

- Hsu, V., Kahn, J. M., & Pister, K. S. J. (1998). *Wireless communications for smart dust* (Electronics Research Laboratory Technical Memorandum No. M98/2). Retrieved January 15, 2010, from <http://robotics.eecs.berkeley.edu/~pister/SmartDust>
- Madden, S., Franklin, M., Hellerstein, J., & Hong, W. (2002). TAG: Tiny AGgregate queries in ad-hoc sensor networks. In *Proceedings of the USENIX Symposium on Operating Systems Design and Implementation*, Boston. Retrieved January 15, 2010, from www.usenix.org/events/osdi02/tech/full_papers/madden/madden.pdf



Nittel, S., Stefanidis, A., Cruz, I., Egenhofer, M., Goldin, D., Howard, A., et al. (2004, March). Report from the first workshop on geo sensor networks. In *Sensor network technology infrastructure, security, data processing, and deployment* [Special issue]. *SIGMOD Record*. Retrieved January 15, 2010, from www.sigmod.org/sigmod/record/issues/0403/R4.GSN03_report_nittel.pdf

Stefanidis, A., & Nittel, S. (Eds.). (2005). *GeoSensor networks*. Boca Raton, FL: CRC Press.

Zhao, F., & Guibas, L. (2004). *Wireless sensor networks: An information processing approach*. Amsterdam: Morgan Kaufmann.

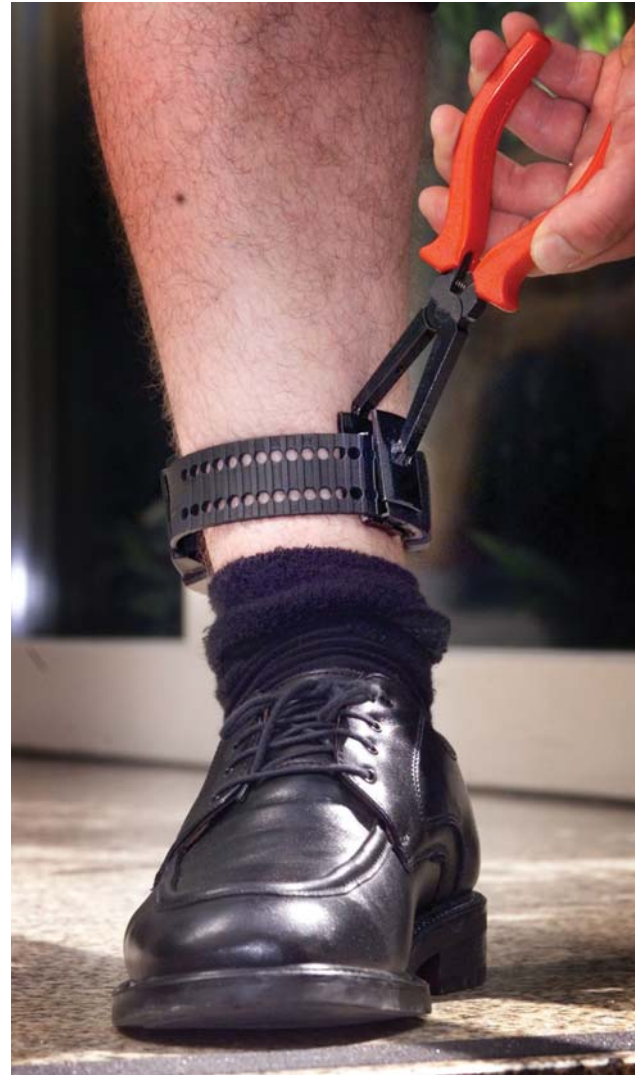


GEOSLAVERY

Stated simply, geoslavery occurs when a person or an institution takes control over the spatial activity of another person. The history of such control is long and has usually involved chains and walls to restrain and contain the victims. It is perhaps epitomized by the restriction of Jews to ghettos in Nazi-occupied Europe. In the early 21st century, with the advent of personal location devices such as mobile phones and global positioning systems (GPS), this control has become very personal, enabling one individual to easily monitor the location of another, control being achieved by threat or by retribution.

Tracking of individuals can be sanctioned by law and is enabled through criminal justice systems. Thus, offenders, who are released on license, can be tagged to ensure that they stick to the terms of their curfew. This has been part of offender management for a number of years. The technology to do this initially relied on a base station that simply recorded the distance the offender wandered away from the station. This approach is being replaced by GPS and mobile communication devices that report the movements of the offender and raise an alarm when the offender moves outside his or her curfew area.

Geofencing is a term used to describe the corporate use of this same technology. Many employees need to be mobile over large areas as part of



The information scientist Christoph Seifert demonstrates how to apply an electronic ankle bracelet at the district court in Frankfurt/Main, Germany, May 2, 2000. The federal state of Hesse is the first in Germany to introduce the device to control convicts under probation and house arrest.

Source: AP Photo/Frank Rumpenhorst.

their work, but employers may require them to stay within specific territories during working hours. Their locations can be monitored and alerts sounded at a monitoring office when they stray outside their assigned territories. Initially, this type of application used software to identify routes for delivery van drivers, and managers compared the recommended route with the distance driven; but this has evolved into constant



monitoring of the van's location as well as of the locations of many other mobile employees. It is known when employees take too long to traverse a road, when they speed, and for how long they stop. This issue, however, raises questions of trust and appropriateness in the workplace.

The same approach is available for child monitoring. Watchlike GPS devices with mobile communications that can be locked onto a child's wrist are available, with Web-based inspection of real-time mapping of the child's location. Indeed, subcutaneous implanting of chips with GPS and communication devices has been suggested. Child tracking is also available through normal mobile phone systems without the GPS enhancement, although this is less accurate.

Another acceptable application of this technology is to monitor the locations of patients suffering from Alzheimer's disease in their home or in sheltered accommodation. Devices for this application can have the additional advantage of monitoring a patient's vital signs.

Such location services, which aim to monitor and control the location of offenders, contracted employees, children, and elderly patients, are probably socially acceptable applications of this technology. Increasing numbers of cases are coming to light, however, where the use of location services is not socially acceptable, where, indeed, they can be criminal, for instance, when the technology is applied to adults with no record of offending by those who wish to monitor their location in order to exercise control. People are using the technology for stalking others, for monitoring the location of spouses without their permission, and for checking on the locations of employees even when there is no contractual obligation regarding location.

An appropriate framework for practice of these services is essential for their control. In the United Kingdom, for example, there is a code of practice for mobile phone-based location services that states that anyone being monitored should be notified when any monitoring session starts, be notified at intervals during the monitoring, and be able to refuse the monitoring whenever they wish. Similarly, a bill was proposed to the British Parliament that would require all child-tracking services to be registered and to abide by certain codes of practice. However, it was not approved.

Geoslavery refers to all these applications, many of which are legal. However, geoslavery can also be applied in a manner that is a clear abuse of this technology. Such uses and abuses of geoslavery can be controlled through compliance with legislation and industry codes of practice.

Peter Fisher

See also **Global Positioning System; Location-Based Services; Mobile GIS; Panopticon; Surveillance**

Further Readings

Dobson, J., & Fisher, P. (2003). GeoSlavery. *IEEE Society and Technology*, 22(1), 47–52.

Dobson, J., & Fisher, P. (2007). The panopticon's changing geography. *Geographical Review*, 97(3), 307–323.

Fisher, P., & Dobson, J. (2003). Who knows where you are, and who should in the era of mobile geographies? *Geography*, 88(4), 331–337.



GEOSPATIAL INDUSTRY

The geospatial industry encompasses the production and consumption of geospatial data and technologies. The relevance of the geospatial industry to geography stems from the fact that the production and use of geospatial technologies and data represent the practical side of the geographic theory, inquiry, and analysis that define the discipline. Furthermore, geospatial technology and data have become ubiquitous throughout academia, industry, business, and modern society. This entry describes the components of the broad suite of geospatial data and technologies in the geospatial industry, their production and application, and their transition from isolated, expert systems to integral parts of mainstream information technology.

One way to categorize the geospatial industry is to first consider a separation of data from functionality. Although they are often discussed in tandem or interchangeably, data are separate entities from the software and tools that are used to analyze and visualize them, and both data and functionality are necessary for a successful geospatial



solution. Accordingly, the first sections of this entry are devoted to a discussion of geospatial data, followed by sections about geospatial software and functionality.

Geospatial Data

Data Production Technologies

Geospatial data are the spatially referenced, geometric features, images, and associated attribute values that can be visualized on a hard-copy or digital map. Traditional methods for creating spatial data, such as land surveying and manual drafting and digitizing, are still practiced; however, many techniques are being replaced by automated or computer-aided data capture and processing. Remote sensing, in particular, has revolutionized the way in which many forms of spatial data are created.

Remote sensing is predominantly accomplished by means of two platforms: aerial sensors and satellite sensors. The initial product of most remote sensing instruments is a raster (a regular array of grid cells) image of Earth's surface. By themselves, satellite and aerial imagery are critical components of most data consumers' libraries of information. In addition, aerial imagery has become the foundation from which other data are derived. In particular, vector data (geometric features composed of points, lines, and polygons) such as roads, streams, and building footprints can often be manually or automatically digitized from imagery with greater accuracy, speed, and convenience than can be achieved by traditional methods. The advantages of raster imagery combine to make the remote sensing industry an indispensable asset to nearly all geospatial endeavors.

Another data production technology that has revolutionized the geospatial industry is the global positioning system (GPS). The GPS is, in essence, a data production technology, due to the fact that its fundamental role is to produce the coordinate location of a receiver. With the addition of differential GPS and the Wide Area Augmentation System (WAAS), receivers can yield ground coordinates within fractions of an inch of their true position. GPS satellites were initially launched by the U.S. government for military applications, and an intentional degradation of the positioning

accuracy, called Selective Availability, was installed to prevent nonmilitary receivers from attaining high accuracies. Selective Availability has since been deactivated, allowing commercial and recreational receivers to achieve higher accuracies, thus enabling the expansion of the geospatial industry into the realm of location-based services (LBS), which are discussed later in this entry.

Sectors of Data Production

The data production sectors of the geospatial industry span private industry, government, and, increasingly, the general public. Many of the most accurate data used in production applications are created and sold by private companies. Aerial photography and national-scale transportation data, in particular, are commonly produced and sold by private companies due to the extreme costs and labor power necessary to create them. Companies such as Tele Atlas produce transportation data products with the necessary address attribute information that are sold to others, such as in-car navigation companies, for use in routing and geocoding applications.

Government agencies at the federal, state, and local levels produce large quantities of spatial data, which are often distributed free of cost. The U.S. federal government has been a leader in the production of satellite data, including the Landsat land cover imagery program and the Shuttle Radar Topography Mission (SRTM) elevation product. State and local governments often generate highly accurate data particular to their area. Specifically, parcel or tax assessment data are highly coveted products, almost always produced and maintained by local entities. Due to the indigenous knowledge and proximity of local data producers, attributes, such as addresses, are often created with more care and accuracy than is possible from commercial organizations with a national scope.

Internet trends, exemplified by sites such as Wikipedia, have influenced the data production industry by enabling public communities to easily create and share information. Through services such as Google Earth, individuals can create spatial data by plotting areas and locations on a Web-based interactive map and attributing them with contextual information. Also, many Web sites that facilitate the publishing of personal photographs



on the Internet (e.g., Picasa) include the capability to tag photos with the spatial location at which they were captured. This sector of the data production industry has the potential to proliferate and become a dominant source of spatial data. Consequently, this open style of data production may introduce new and complex issues relating to data integrity, liability, and ownership as it is more widely used.

Modes of Data Distribution

Data are a critical component of every geospatial project, and a user's acquisition of data is therefore a critical consideration. A traditional mode of digital data distribution is via media such as floppy disks, CDs, DVDs, and portable hard drives. Increasingly, however, the quantity of data desired and the speed at which they need to be acquired preclude the use of physical media. In response to this need, entities such as Web-based spatial data clearinghouses make data available via the Internet. For example, Pennsylvania Spatial Data Access (PASDA) provides free access to thousands of spatial data sets either for download or in a number of interactive ways, which are described in later sections of this entry. Other local, state, and federal clearinghouses exist, such as the U.S. federal government's Geospatial One Stop and National Spatial Data Infrastructure (NSDI) efforts, which aim to facilitate online access to nationwide framework data.

Geospatial Software Functionality

Database Capabilities

Spatial data storage takes two primary forms: file and database. For raster data, file storage typically takes the form of common image file formats, for example, tiff, jpeg, and MrSID. Vector data consist of a more unique data structure, so more proprietary file data formats are commonly used to handle the spatial geometry component. For example, the Environmental Systems Research Institute (ESRI) supports a vector data format, called the *shapefile*, that is widely used and is compatible with many software products.

The ability to store spatial data in a commercial database, thereby taking advantage of the

benefits of database operations, is a more recent development. Many common commercial database products operate on a relational data model, which is not inherently accommodating of spatial data structures. Database vendors such as IBM and Oracle have produced extensions to their relational database products to accommodate spatial data—DB2 Spatial Extender and Oracle Spatial, respectively. In addition, geospatial software companies produce database add-ons that spatially enable relational databases. For example, ESRI's Spatial Database Engine (SDE) can be installed into commercial database products such as IBM DB2, Oracle, and Microsoft's SQL Server to accommodate spatial data.

Software Capabilities

The analysis and visualization of geospatial data are most commonly performed in geographic information system (GIS) software. Computer-aided design (CAD) tools perform similar functions and are commonly used in the engineering and drafting industries. Early GIS software products ran on mainframe hardware architectures and presented command line user interfaces. Due to these conditions, early GIS was relegated to expert users. Modern GIS software, however, is developed to run on more accessible operating systems, such as Microsoft Windows, and uses graphical user interfaces (GUIs) in place of the command line. These developments have made modern GIS software accessible to a wide user base of both experts and novices. Furthermore, the production of GIS software has expanded beyond GIS-specific commercial software vendors to untraditional sources. For example, Internet application providers such as Google, MapQuest, and Microsoft have entered the geospatial realm by developing desktop and Internet-based GIS programs that are specifically targeted toward a general, nonexpert audience. These advancements have transitioned GIS from a fringe, specialized technology into a core component of mainstream information technology and society.

Internet and Mobile Capabilities

A particularly influential geospatial software development is the use of Web services to deliver geospatial data and functionality over a network.



Web services are a computer programming technique where functionality located at remote locations is consumed over the Internet and used as if stored locally. This technique is commonly used for geocoding, routing, and coordinate conversion. For example, Google Maps offers an application programming interface (API) for embedding an interactive map in any Web site.

Spatial data can be published and consumed over the Internet via map services, which are a type of Web service specific to geospatial data. Map services can be consumed by either a GIS software program or a custom utility, without the need to download and store the actual data locally. Map services make possible the sharing, viewing, and analyzing of large quantities of data, including raster imagery and vector data, seamlessly in a fraction of the time it would take to download the corresponding data files to the local computer. For example, PASDA publishes map services for immediate online viewing or use in a desktop GIS. Other programs, such as Google Earth and NASA World Wind, offer user-friendly interfaces for visualizing and overlaying geospatial data sets, which are stored on remote servers distributed across the Internet.

A burgeoning part of the geospatial software industry involves mobile devices such as personal digital assistants (PDAs), cell phones, and in-car navigation units. These devices use integral GPS receivers and location-based services to provide information relative to their current location. Beyond simply displaying a coordinate location, these GPS-based appliances contain software for displaying other data, such as imagery or roads; performing routing from the current location to many points of interest stored within the receiver's memory; and using mobile Internet connections to incorporate ancillary information from the Web. Most commercial GPS receiver companies, such as Garmin and Magellan, are producing increasingly sophisticated and compact devices that take advantage of cutting-edge antenna technology and the increasing availability of location-based services.

Sectors of Software Production

Private industry remains a dominant producer of geospatial software, including companies such

as ESRI, Intergraph, and Autodesk. Commercial products are typically sold at a cost and span the complete range of functionality and platform (i.e., server, desktop, Internet, and mobile). Increasingly, other commercial enterprises that are not traditional geospatial providers are developing products targeted to a more general audience. Google, primarily an Internet search engine, provides basic data visualization tools through a deliberately user-friendly interface in its Google Earth product. Government agencies also provide specialized geospatial software products, such as the U.S. Department of Agriculture's Fusion program for working with LIDAR (light imaging and ranging) elevation data. Many popular geospatial software applications are produced in an open manner by community-supported efforts, such as the University of Minnesota's Web-mapping program called Map Server.

In response to a proliferation of geospatial software and data formats, the Open GIS Consortium (OGC) was conceived in an effort to make the diverse geospatial industry more interoperable. In particular, OGC is publishing common communication and format standards for Internet map services, such as the Web Mapping Service (WMS) specification, so that they can be consumed regardless of the client software used.

Ryan E. Baxter

See also **Applied Geography; Business Geography; Business Models for Geographic Information Systems; Dangermond, Jack; Enterprise GIS; Geodemographics; Geospatial Semantic Web; GIS Software; GIS Web Services; Global Positioning System; Google Earth; Legal Aspects of Geospatial Information; Location-Based Services; Neogeography; Privacy and Security of Geospatial Information; Remote Sensing; Usability of Geospatial Information**

Further Readings

Bossler, J. D. (Ed.). (2002). *Manual of geospatial science and technology*. New York: Taylor & Francis.

Global Marketing Insights, Inc. (2005). *Survey and analysis of remote sensing market aerial and spaceborne* (Solicitation No. NEEA2000-4-00028).



Silver Spring, MD: National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

Jiang, B., & Yao, X. (2006). Location-based services and GIS in perspective. *Computers, Environment and Urban Systems*, 30, 712–725.

Thurston, J., Poiker, T. K., & Moore, J. P. (2003). *Integrated geospatial technologies*. Hoboken, NJ: Wiley.



GEOSPATIAL SEMANTIC WEB

The term *geospatial semantic web* has been coined to describe the convergence of three distinct concepts in computing and geographic information science. The first is a *geospatial web* composed of geospatial information Web services. The second is *geospatial semantics*—the formal and computable definition of the meanings of geospatial terms. The third concept is the *semantic web*—representing the growth of the World Wide Web from a web of human-accessible content into a web of data traversed by machine agents.

Geospatial Web

Almost as soon as the World Wide Web came into being, so too did the idea that content on the Web might have a counterpart in the real world with a corresponding geospatial position, referred to as the *spatialization* of the Web. Position coordinates alone provided little benefit, though, without capabilities for making maps and forming location-relevant hyperlinks. In the late 1990s, standards organizations such as the Open Geospatial Consortium and vendors such as ESRI and MapQuest began to define, build, and offer geospatial services. Services allowed Web sites to provide dynamically rendered maps of useful information and geospatially relevant links, such as hotels close to a user location, that can be used without much specialized expertise. The usefulness and volume of geospatial data and functionality on the Web has since grown with the deployment of extensive geospatial Web services

that allow such resources to be maintained locally and yet accessed globally over the Internet. Even with the development of geospatial catalogs and registries, however, the interconnectedness and hence the value of the resulting “GeoWeb” has been constrained by the difficulty of meaningfully relating data elements from disparate localities and knowledge communities to one another and to Web users at large. The “pushpin on a road map” paradigm has proved a difficult one to move past in terms of large-scale accessibility to geospatial knowledge.

Geospatial Semantics

The challenge of making meaningful connections between disparate pieces of information is being addressed by the growing field of formal and machine semantics, using formally defined, logically tractable knowledge representations such as OWL (Ontology Web Language) and explicit expressions of connected data such as RDF (Resource Description Framework). In the geospatial domain, developments such as RCC8 (Regional Connection Calculus) have provided formal definitions of the ways in which the relations between real-world features can be represented. The goal of geospatial semantics has been to provide standards, representations, and tools that allow localized geographic understanding to be communicated universally.

Semantic Web

The remaining challenge to the emergence of the geospatial semantic Web has been to apply geospatial semantic tools and technologies on a Web scale. The means to address this challenge is just beginning to come from geospatial extensions to technologies supporting the development of the semantic Web, including geospatially enabled query languages, spatial inference engines, and geospatial ontologies. Their goal is a Web of geospatial knowledge in which computers create and leverage as well as host connections both between geospatial data elements and with the parts of the physical world they represent.

Joshua Lieberman



See also **Geospatial Industry; Open Geospatial Consortium (OGC); Semantic Reference Systems**

Further Readings

- Antoniou, G., & van Harmelen, F. (2008). *A semantic web primer* (2nd ed.). Cambridge: MIT Press.
- Cohn, A. G., Bennett, B., Gooday, J., & Gotts, N. M. (1997). Qualitative spatial representation and reasoning with the region connection calculus. *GeoInformatica*, 1, 275–316.
- Scharl, A., & Tochtermann, K. (Eds.). (2007). *The geospatial web*. Berlin, Germany: Springer.
- van Oosterom, P., & Zlatanova, S. (Eds.). (2008). *Creating spatial information infrastructures: Towards the spatial semantic web*. Boca Raton, FL: CRC Press.

GEOSTATISTICS

Geostatistics has been defined broadly as the study of phenomena that vary over space. Developed originally to address problems of spatial prediction in the mining industry, the generality of the approach has led subsequently to its application in a diverse range of settings across the geographical, geological, atmospheric, environmental, and epidemiological sciences, among others. Geostatistics offers a collection of primarily probabilistic tools that have been developed to aid the understanding and modeling of spatial variability, with the principal motivation of predicting unsampled values dispersed in space (also termed *interpolation*). The origins of the discipline are generally traced back to the work of Daniel Krige and others on methods for gold and uranium reserve valuation in the Witwatersrand, South Africa, during the 1950s. These ideas were extended and formalized during the 1960s by the French statistician Georges Matheron, who coined the term *geostatistics* and, with the publication of a series of seminal texts throughout the 1960s and 1970s, laid the foundations for the modern, and still evolving, discipline practiced today by scientists and engineers worldwide.

Theoretical Background

Deterministic and Probabilistic Modeling

The problem motivating the early pioneers of geostatistics, and still the most common goal of contemporary geostatistical analyses, can be stated in the simplest terms as the prediction of a variable (e.g., the concentration of an ore grade) at locations where it has not been sampled (e.g., across a potentially minable deposit). Such predictions require, at least implicitly, the use of a model describing in some way how the phenomenon of interest behaves at these unsampled locations. Various conceptual approaches exist for the formulation of such a model, and a useful categorization is between deterministic and probabilistic models. In a deterministic model, each unknown value is predicted as a single value with no associated prediction error. Such models are best employed when the physical mechanisms that govern the variable of interest are well understood and established physical equations exist that allow calculation of the unknown value with negligible or no error. In fields such as environmental, epidemiological, and public health sciences, however, the systems of interest are often of such complexity and scale that they retain an inherent unpredictability, even when many of the constituent processes are understood in detail, meaning that a deterministic model may be neither feasible nor appropriate. Probabilistic models represent an alternative paradigm to deterministic approaches by considering the underlying mechanism that generates observed data and, by extension, that determines values at unsampled locations, as a random process. Although the mechanism in question is rarely, if ever, entirely random, the adoption of a probabilistic model provides a framework that can prove extremely useful in both predicting unsampled values and assessing the uncertainty of those predictions. Instead of predicting a single value for each unsampled location with assumed zero error, probabilistic models allow the prediction of a set of possible values with corresponding probabilities of occurrence. Unlike deterministic models, probabilistic models do not necessarily require knowledge of the physical process that generated sample data. Rather, most of the information used is derived from the data.



The Random Field Model

While geostatistics is today a broad and multifaceted statistical toolbox, a core conceptual component—the random field model—underpins its many constituent techniques. A spatial random field (also known as a *random function*) is defined as a set of usually dependent random variables $F(\mathbf{x})$, one for each location $\mathbf{x}$ in a study area of interest. Just as a univariate probability distribution can be used to represent uncertainty around the unknown outcome value of a random variable, a multipoint probability distribution can be used to represent the joint uncertainty around outcome values at any given set of n locations spatially distributed across a study area. Treating spatial data as observations from a random field, and using those observations to characterize the field's properties, provides a framework for estimating values at unobserved locations. Strictly, a random field is only characterized fully by what is known as its *complete spatial law*: the theoretical set of multipoint probability distributions for every possible set of locations across the field. In practice, such complete characterization is both infeasible and unnecessary for the prediction of unsampled values. As a practical alternative, the much simpler joint relationship between random variables at just two locations at a time, say $F(\mathbf{x})$ and $F(\mathbf{x} + \mathbf{h})$, can be characterized by the one- and two-point probability distributions. The symbol $\mathbf{h}$ in this context refers to *lag*, the separation distance (and direction) between the two locations in question. Under conditions of stationarity (discussed in more detail below), the degree of dependence between two random variables separated by the same lag is the same for any such pair $F(\mathbf{x})$ and $F(\mathbf{x} + \mathbf{h})$ across the study area. Under these conditions, a number of parameters of the random field exist that summarize this bivariate dependence, including the *covariance function* and the *semivariogram*. The latter can be expressed as

$$\gamma(\mathbf{h}) = 0.5(E\{[F(\mathbf{x}) - F(\mathbf{x} + \mathbf{h})]^2\}),$$

which defines *semivariance* γ between two random variables separated by a lag $\mathbf{h}$ as half their expected squared difference. The adoption of a random field model and its parameterization via

the semivariogram provides a powerful framework for the prediction of unsampled values dispersed in space. The following section describes the principal considerations and tools by which this framework is implemented.

Spatial Prediction With Geostatistics

Stationarity

Strict stationarity entails that the multivariate probability distribution for random variables at any arbitrary set of locations across the field is spatially invariant, such that the set of locations could be translated to anywhere else on the field without modifying the probability distribution, that is, the statistical properties of the field are the same throughout. A less stringent definition of stationarity, known as *second-order stationarity*, has two requirements: (1) that the underlying expectation (the theoretical mean value) of the field is invariant with location and (2) that any pair of random variables separated by the same lag $\mathbf{h}$ share the same two-point probability distribution, regardless of the absolute location of the pair. In a further weakened definition known as *intrinsic stationarity*, this latter requirement is relaxed so that it is sufficient that the *increments* of the random field, that is, the *differences* between values in a pair separated by a given lag, are second-order stationary. One reason for the centrality of the variogram for characterizing the random field in geostatistics is that, unlike the covariance function, its existence and inference require only intrinsic stationarity, a modeling assumption that can be justified in a wider range of settings than the more rigorous definitions of strict or second-order stationarity.

Variography: Inferring the Structural Properties of a Random Field

There are two related motivations for aiming to characterize a random field by estimating its variogram from observed data. First, semivariance can be thought of as a measure of dissimilarity between values of the random field as a function of their separation distance and direction. By describing semivariance across a range of possible lags, the semivariogram acts as a useful



exploratory and descriptive tool, providing a summary of the second-order properties (i.e., the spatial autocorrelation structure, or texture) of the phenomenon under study that may provide insight into the underlying physical or biological processes. Second, prediction algorithms such as kriging, described in more depth below, require that the dependence between random variable pairs at different lags be characterized. In both cases, the semivariogram must be estimated from a sample of data obtained at locations dispersed across the area of interest. The most common approach taken is to estimate the semivariogram from n sample data using a straightforward method-of-moments approach. For each lag $\mathbf{h}$, the sample semivariogram $\hat{\gamma}(\mathbf{h})$ can be estimated as half the mean squared difference between all $i = 1, 2, \dots, l$ data pairs separated by that lag:

$$\hat{\gamma}(\mathbf{h}) = \frac{1}{2l(\mathbf{h})} \sum_{i=1}^{l(\mathbf{h})} [f(\mathbf{x}_i) - f(\mathbf{x}_i + \mathbf{h})]^2.$$

Semivariance values can be calculated for every data pair in the data set and compared with the corresponding lags by plotting the resulting *variogram cloud*. An alternative approach is to pool data pairs according to a finite set of regularly spaced lags, with each value of $\mathbf{h}$ actually representing a defined range of lag separations. The latter approach allows a larger sample, and hence a more stable estimate, for each estimated value of $\hat{\gamma}(\mathbf{h})$. A further issue is the effect of direction on the variogram. Where semivariance is dependent only on the separation distance, the variogram is deemed *isotropic*. Where the direction of separation also has an effect, the variogram is deemed *anisotropic*. In the latter case, data pairs are generally pooled by both distance and direction, and separate sample variograms are estimated for each direction. Interpolation algorithms such as kriging require semivariance values for any possible lag. As such, it is necessary for these purposes to fit a continuous model $\tilde{\gamma}(\mathbf{h})$ to the sample semivariogram.

Simple Kriging

The term *kriging* was introduced by Georges Matheron (in recognition of the earlier work of

Daniel Krige) to describe a family of generalized linear regression techniques that provides an approach by which a set of spatial data $f(\mathbf{x}_d)$, collected at spatially dispersed locations across a study area, can be used to predict the values, $f^*(\mathbf{x}_p)$, at a set of unsampled locations (where the asterisk denotes a predicted value). Kriging techniques operate within the conceptual framework provided by the random field model and exploit *spatial autocorrelation* (also termed *spatial dependence*) in the phenomenon of interest, as modeled by the covariance function or semivariogram. The theoretical difference (or error) between the predictions and the unknown true values at those locations is defined as $F^*(\mathbf{x}) - F(\mathbf{x})$. Kriging is known as a *best linear unbiased predictor*, which implies two properties with regard to this error: (1) that the expectation of the error is zero (i.e., the predictor is unbiased) and (2) that the expected variance of the error, $\sigma_E^2(\mathbf{x})$ (also termed the *kriging variance*), is minimized (i.e., the predictor does the “best” job possible by minimizing the expected magnitude of prediction errors given the available data and the parameterization of the random field). Numerous variations of kriging exist, each targeted at subtly different prediction problems. In *simple kriging*, the random field $F(\mathbf{x})$ is considered to consist of a trend component with a known mean $m(\mathbf{x})$ and a residual component $R(\mathbf{x})$. The simple kriging estimator $F_{SK}^*(\mathbf{x})$ can be defined as

$$F_{SK}^*(\mathbf{x}) = \sum_{d=1}^{n(\mathbf{x})} \lambda_d(\mathbf{x}) F(\mathbf{x}_d) + \left[1 - \sum_{d=1}^{n(\mathbf{x})} \lambda_d(\mathbf{x}) \right] m,$$

where λ_d are termed the *kriging weights* and determine the influence of each observed datum on the predicted value. A minimization procedure can be implemented to derive the set of kriging weights in order to minimize the error variance, $\sigma_E^2(\mathbf{x})$. In matrix notation, this procedure can be summarized as

$$C_{dd} \cdot \lambda_{SK} = C_{dp},$$

where C_{dd} is an $n \times n$ matrix of the covariances between random variables at the data locations, C_{dp} is a vector of the n covariances between random variables at data locations and the prediction location, and λ_{SK} is a vector of the n kriging



weights. Covariance values to populate these matrices can be derived, using the assumption of stationarity, from the model fitted to the sample semivariogram. The vector of kriging weights is obtained by the matrix product of the inverted data-to-data covariance matrix C_{dd}^{-1} and the data-to-prediction covariance vector, C_{dp} :

$$\lambda_{SK} = C_{dd}^{-1} \cdot C_{dp}.$$

Multiplying this vector of weights with the corresponding vector of data values $f(\mathbf{x}_d)$ and summing across the resulting vector provides the final simple kriging prediction.

The Kriging Variance

The attractive qualities of kriging as an interpolation technique lie in its minimization of the error variance under the constraint of unbiasedness. As well as being a critical intermediate stage of the kriging computation, the calculation of this error, or kriging variance, is extremely useful in its own right because it acts as an objective measure of the uncertainty associated with each prediction. The simple kriging variance, calculated using the same covariance matrices described above, is defined as

$$\sigma_{SK}^2(\mathbf{x}) = C(0) - C_{dp}^T \cdot C_{dd}^{-1} \cdot C_{dp},$$

where $C(0)$ denotes the covariance at lag zero. The kriging variance is dependent on the variogram or covariance model and on the spatial configuration of the data in relation to the prediction location. Because of this dependence, the kriging variance provides a measure of the uncertainty of each prediction, with uncertainty increasing for random fields with large spatial variability and for predictions that are made at locations more distant from data. Kriging variance is not dependent, however, on the data values, such that any two sets of data with different values but the same spatial configuration would yield a prediction with the same kriging variance. This independence reduces the utility of the kriging variance as an absolute measure of uncertainty since, for example, it is intuitive that a local set of data with large variability will result in a less certain estimate than a less variable set with the same spatial configuration. As such, the use of kriging

variance is generally restricted to a relative measure of uncertainty, allowing relative comparison of the uncertainty of individual predictions and different data configurations. The kriging variance is often used in this context for the design and evaluation of different sampling schemes prior to data collection. Because the kriging variance is independent of the actual observed values, different schemes can be assessed on paper before any data are collected. Assuming that a reasonable model for the variogram can be inferred, either from a small pilot survey or from existing knowledge, then the relative efficiency and cost of candidate sampling schemes can be evaluated and potentially optimized using the kriging variance as a measure of the predictive accuracy that can be expected at each location to be predicted.

Other Common Kriging Algorithms

A second and perhaps more widely used member of the kriging family of algorithms, known as *ordinary kriging*, differs conceptually from simple kriging in the way the trend component of the random field $m(\mathbf{x})$ is modeled. Rather than considering this component as known, ordinary kriging considers the mean to be unknown and limits its domain of stationarity to a local neighborhood centered on the location $\mathbf{x}$ to be predicted. This approach has the important practical implication that the local mean may vary considerably over the study area, which, in practice, is often considered a more appropriate modeling strategy. The rationale of incorporating a varying mean is extended by *kriging with a trend model*, sometimes called *universal kriging*, in which the trend component $m(\mathbf{x})$ is modeled by the automatic estimation within each local neighborhood of a simple linear or low-order polynomial function. In many settings, the target variable to be predicted is related, at least empirically, to one or more secondary variables that coexist within the study area of interest, implying that the variation in the primary variable may be partially explained by the variation in these covariates. If covariate data are available, it may be helpful to incorporate them in the prediction of the primary variable. If such data are available at both the data locations and all locations to be predicted, a technique called *kriging with an external drift* can be used. This can be



considered a straightforward extension to kriging with a trend model, in which the local trend components are defined not as linear functions of location but as functions of the covariate data. *Cokriging* acknowledges the separate spatial structures of the primary and any secondary variables, as well as their cross-correlations, to provide an elegant method for incorporating covariate data not necessarily collocated with the available data or available at all prediction locations.

Quantifying Prediction Uncertainty

A key limitation of kriging for certain applications is that while the kriging variance provides a useful measure of relative prediction accuracy, it cannot in general be treated as an absolute measure, as required, for example, in the definition of confidence intervals around predictions. A family of geostatistical algorithms has been developed to address this limitation. In *multi-Gaussian kriging*, observed data are subjected to a *normal-scores transform* before the standard procedure of variogram estimation and modeling, and prediction via simple kriging. Because the transformed random field can, subject to a number of assumptions, be considered multivariate Gaussian, the value of the field at each prediction location can be considered to have a univariate Gaussian distribution fully specified by the kriging prediction (which parameterizes the mean of the distribution) and kriging variance (parameterizing the variance of the distribution). Values can be simulated from each of these predictive distributions and subjected to a back-transform to provide, for each prediction location, a set of realizations that together constitute a model of the posterior predictive distribution from which summary point estimates and confidence intervals can be calculated. The *sequential Gaussian simulation* algorithm extends this procedure to allow joint realizations of all prediction locations simultaneously rather than independently. The resulting set of back-transformed realizations provides a model of uncertainty that can be averaged or summed spatially to obtain posterior predictive distributions of regionally aggregated quantities. *Indicator kriging* and the *sequential indicator simulation* algorithms provide parallel nonparametric approaches.

Peter Gething

See also **Analytical Operations in GIS; Bayesian Statistics in Spatial Analysis; Geocomputation; Geographically Weighted Regression; Quantitative Methods; Spatial Analysis; Spatial Autocorrelation; Spatial Interpolation; Spatial Statistics**

Further Readings

- Chilès, J. P., & Delfiner, P. (1999). *Geostatistics: Modeling spatial uncertainty*. Toronto, Ontario, Canada: Wiley.
- Christakos, G. (2000). *Modern spatiotemporal geostatistics*. New York: Oxford University Press.
- Cressie, N. (1993). *Statistics for spatial data*. New York: Wiley.
- Deutsch, C. V., & Journel, A. G. (1998). *GSLIB: Geostatistical software library and user's guide* (2nd ed.). New York: Oxford University Press.
- Goovaerts, P. (1997). *Geostatistics for natural resource evaluation*. New York: Oxford University Press.
- Isaaks, E. H., & Srivastava, R. H. (1989). *Applied geostatistics*. New York: Oxford University Press.
- Journel, A. G., & Huijbregts, C. J. (1978). *Mining geostatistics*. New York: Academic Press.
- Matheron, G. (1971). *The theory of regionalized variables and its applications*. Fontainebleau, France: Ecole Nationale Supérieure des Mines de Paris.
- Olea, R. A. (Ed.). (1991). *Geostatistical glossary and multilingual dictionary*. New York: Oxford University Press.



GEOTHERMAL ENERGY

Geothermal energy is the heat contained within Earth that generates geological phenomena on a planetary scale. The term *geothermal energy* is often used to indicate that part of Earth's heat that can, or could, be recovered and exploited by humans. The presence of volcanoes, hot springs, and other thermal phenomena clearly demonstrates that the interior of Earth is hot: Earth's temperature increases with depth.



This heat is continually generated by the decay of the long-lived radioactive isotopes of uranium (^{238}U , ^{235}U), thorium (^{232}Th), and potassium (^{40}K), which are present in Earth, in addition to the primordial energy of planetary accretion. The total heat content of the crust of Earth can be estimated in the order of 5.4×10^{21} MJ (megajoules). As a comparison, the total world electricity need per year is about 6×10^{13} MJ, that is, 100 million times lower. The thermal energy of Earth is therefore immense, but only a modest fraction can be used by people. Human use is limited to areas in which geological conditions permit a carrier (water in the liquid phase or steam) to “transfer” the heat from deep hot zones to or near the surface, thus giving rise to the geothermal resource.

Geothermal System

A geothermal system can be described schematically as convecting water in the upper crust of Earth, which, in a confined space, transfers heat from a heat source to a heat sink, usually the free surface. A geothermal system is made up of three main elements: a *heat source*, a *reservoir*, and a *fluid*, which is the carrier that transfers the heat (Figure 1). The heat source can be either a very high-temperature ($>600^\circ\text{C}$) magmatic intrusion that has reached relatively shallow depths (5–10 km [kilometers]) or, as in certain low-temperature systems, Earth’s normal temperature. The reservoir is a volume of hot, permeable rocks from which the circulating water is generally overlain by a cover of impermeable rocks and connected

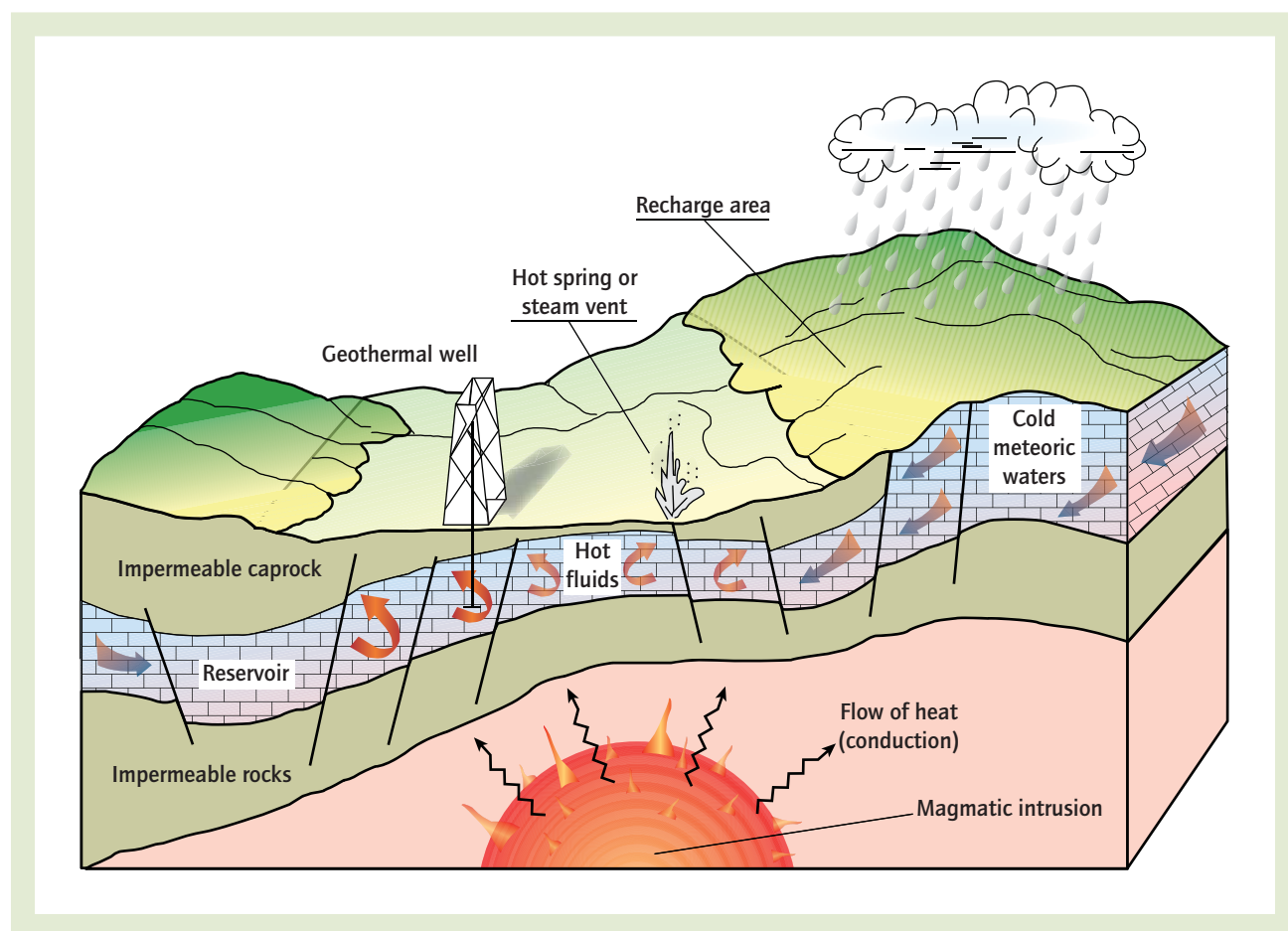


Figure 1 Schematic representation of a typical geothermal system

Source: Dickson, M., & Fanelli, M. (1995). *Geothermal energy* (UNESCO Energy Engineering Series). Chichester, UK: Wiley.



to a superficial recharge area through which the meteoric waters can replace or partly replace the fluids that escape from the reservoir.

Geothermal History

In the early part of the 19th century, geothermal fluids were already being exploited for their energy content. A chemical industry was set up in that period in Italy, in the zone now known as Larderello, to extract boric acid from the hot waters issuing naturally or from specially drilled shallow boreholes. In 1827, Francesco de Larderel developed a system for using the heat of the geothermal fluids in the evaporation process, rather than burning wood from the rapidly depleting forests. Between 1910 and 1940, the low-pressure steam in this area of Tuscany was brought into use to heat the industrial and residential buildings and greenhouses. In 1928, Iceland, another pioneer in the use of geothermal energy, also began exploiting its geothermal fluids for domestic heating.

The first attempt at generating electricity from geothermal steam was made at Larderello in 1904. The success of this experiment indicated the industrial value of geothermal energy. By 1942, the installed capacity had reached 128 MWe (megawatts electrical). The example set by Italy was followed by several countries. The first geothermal wells in Japan were drilled at Beppu in 1919 and in the United States at The Geysers, California, in 1921. In 1958, a small geothermal power plant began operating in New Zealand, in 1959 in Mexico, in 1960 in the United States, and in many other countries in the years to follow.

Present Use of Geothermal Energy

After World War II, many countries were attracted by geothermal energy, considering its economical value: It did not have to be imported, it was available 24 hours per day, it was independent of external weather conditions, and, in many cases, it was the only energy source available locally for the benefit of local populations. Geothermal resources

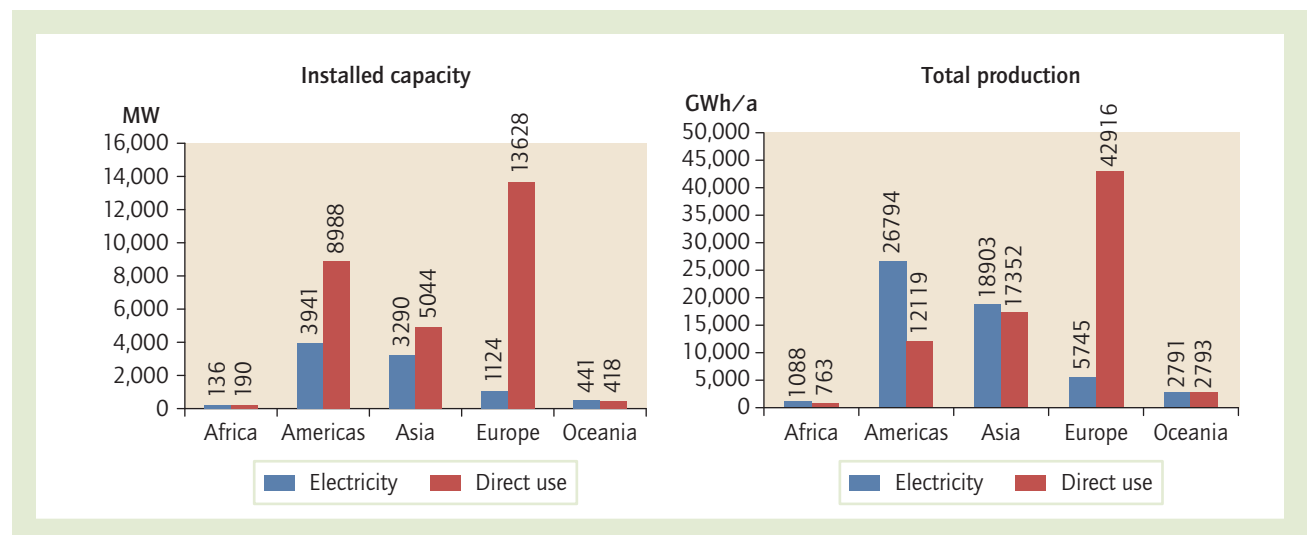


Figure 2 Installed capacity (*left*) and energy production (*right*) for geothermal electricity generation and direct use (heating) in the different continents. The Americas include North, Central, and South America.

Sources: From Fridleifsson, I., Bertani, R., Huenges, E., Lund, J., Ragnarsson, A., & Rybach, L. (2008, January 20–25). The possible role and contribution of geothermal energy to the mitigation of climate change. In O. Hohmeyer & T. Trittin (Eds.), *Proceedings of the IPCC Scoping Meeting on Renewable Energy Sources* (pp. 59–80). Luebeck, Germany: Intergovernmental Panel on Climate Change. Based on data from Bertani, R. (2005). World geothermal power generation in the period 2001–2005. *Geothermics*, 34, 651–690; Lund, J. W., Freeston, D. H., & Boyd, T. L. (2005). Direct application of geothermal energy: 2005 worldwide review. *Geothermics*, 34, 691–727.

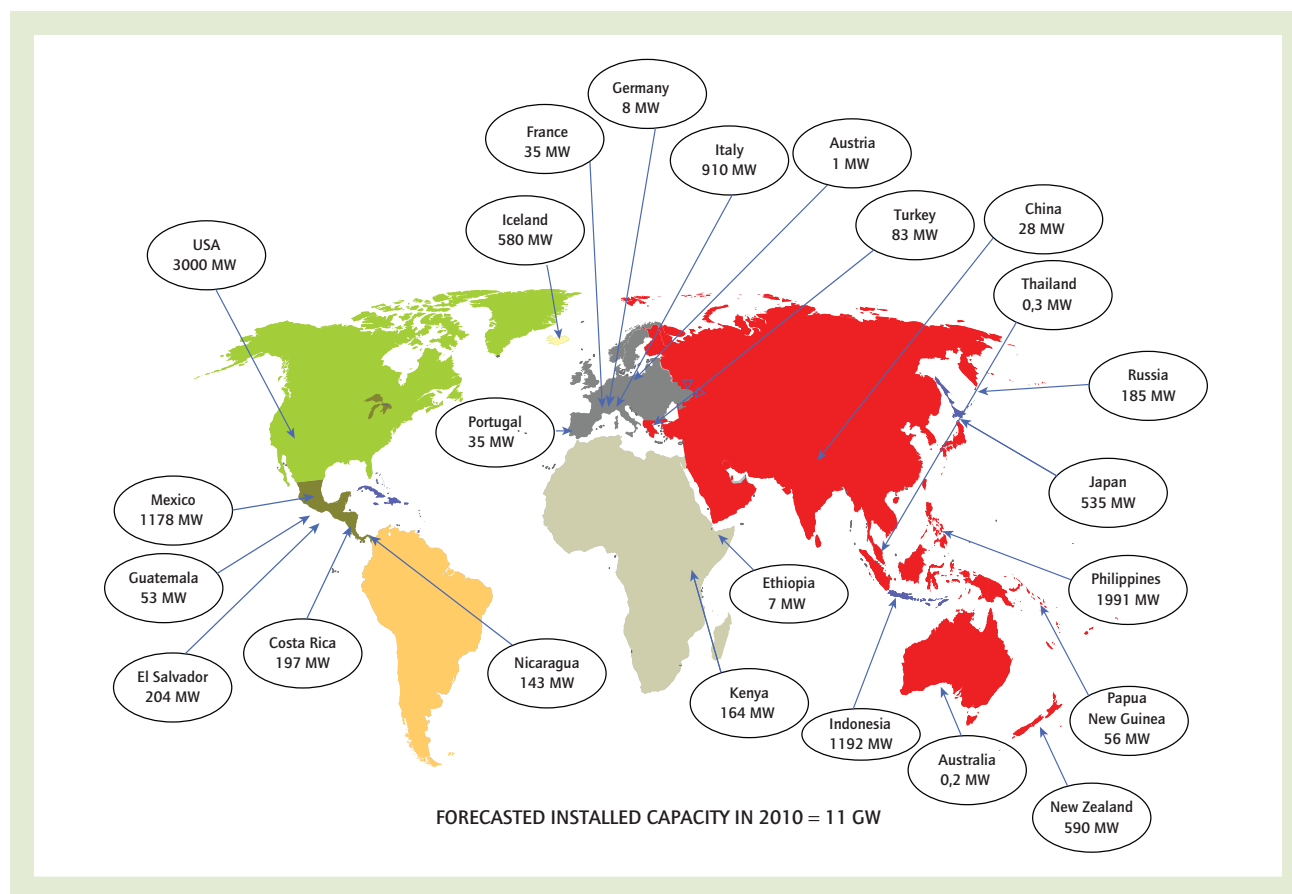


Figure 3 Forecast of the installed capacity for electricity production in 2010 in different countries

Sources: Bertani, R. (2005). World geothermal power generation in the period 2001–2005. *Geothermics*, 34, 651–690; Fridleifsson, I. B., Bertani, R., Huenges, E., Lund, J. W., Ragnarsson, A., & Rybach, L. (2008, January 20–25). The possible role and contribution of geothermal energy to the mitigation of climate change. In O. Hohmeyer & T. Trittin (Eds.), *Proceedings of the IPCC Scoping Meeting on Renewable Energy Sources* (pp. 59–80). Luebeck, Germany: Intergovernmental Panel on Climate Change; Lund, J. W., Freeston, D. H., & Boyd, T. L. (2005). Direct application of geothermal energy: 2005 worldwide review. *Geothermics*, 34, 691–727.

have been identified in 90 countries, and there are quantified records of geothermal use in 72 countries. Summarized information on geothermal use in the individual countries for electricity production and direct use (heating) is available. In 2004, the worldwide use of geothermal energy was about 57 TWh/yr. (terawatt hours per year) of electricity and 76 TWh/yr. for direct use. The installed electric capacity in 2004 was 8,900 MWe. The installed capacity for direct applications in 2004 was 28,300 MWth (megawatts thermal). Figure 2 shows the installed capacity and the geothermal energy in the different continents in 2004. Figure 3 shows the short-term forecasting of the installed capacity for electricity production in 2010 in different countries.

Geothermal Potential

Geothermal energy sources have been considered exploitable, until recently, only in areas where the fluid is found at depths less than 4 km with temperatures above 180 °C. This has changed in the past two decades with the development of power plants that can economically use lower temperature resources (down to 100 °C) and the emergence of ground source heat pumps using Earth as a heat source for heating or as a heat sink for cooling, depending on the season. This has made it possible to use the heat of Earth for heating and/or cooling, as appropriate.

It is difficult to estimate the overall worldwide potential because of large uncertainties.



Nevertheless, it is possible to identify a range of estimations, taking also into consideration the possibility of new technologies, such as permeability enhancements, drilling improvements, enhanced geothermal systems (EGS) technology, low-temperature electricity production, and the use of supercritical fluids. One estimate of the expected geothermal electricity potential is 35–70 GW (gigawatts) to 140 GW (Figure 4).

It is considered possible to produce up to 8.3% of the total world's requirement of electricity with geothermal resources, serving 17% of the world population. Thirty-nine countries (located mostly in Africa, Central/South America, and the Pacific) can potentially obtain 100% of their electricity from geothermal resources.

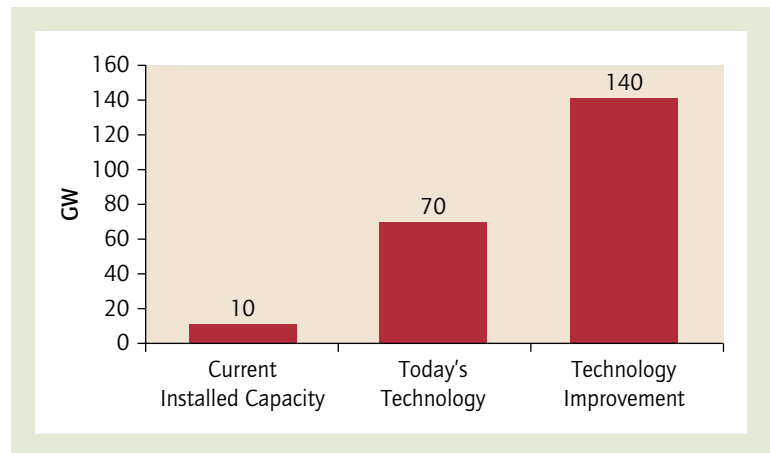


Figure 4 Estimated world geothermal electricity potential

Source: Bertani, R. (2007, May 30–June 1). World geothermal power generation in 2007. In *Proceedings of the European Geothermal Congress 2007*, Unterhaching, Germany. Retrieved January 15, 2010, from <http://geoheat.oit.edu/bulletin/bull28-3/art3.pdf>.

Geothermal Field Classification

Frequently, a distinction is made between water- or liquid-dominated geothermal systems (also called *hydrothermal energy*) and vapor-dominated or dry steam geothermal systems (including hot, dry rocks). In *water-dominated systems*, liquid water is the continuous, pressure-controlling fluid phase. These geothermal systems, whose temperatures may range from 100 to 225 °C, are the most widely distributed in the world. In *vapor-dominated systems*, liquid water and vapor normally coexist in the reservoir, with vapor as the continuous, pressure-controlling phase. Geothermal systems of this type, the best known of which are Larderello in Italy and The Geysers in California, are somewhat rare and are high-temperature systems (>300 °C).

Direct Use of Geothermal Heat

Electricity generation is the most important form of use of high-temperature geothermal resources (>150 °C). The medium-to-low temperature resources (<150 °C) are suited to many different types of application.

Space and district heating systems have made great progress in Iceland, where the total capacity

of the operating geothermal district heating system had risen to about 1,200 MW_{th}, but they are also widely distributed in the East European countries as well as in the United States, China, Japan, France, and so on.

Space cooling is a feasible option where absorption machines can be adapted to geothermal use. The technology of these machines is well-known, and they are readily available on the market. The absorption cycle is a process that uses heat instead of electricity as the energy source. The refrigeration effect is obtained by using two fluids: (1) a refrigerant, which circulates, evaporates, and condenses, and (2) a secondary fluid or absorbent.

The *agricultural applications* of geothermal fluids consist of open-field agriculture and greenhouse heating. Thermal water can be used in open-field agriculture to irrigate and heat the soil. The most common application of geothermal energy in agriculture is, however, in *greenhouse heating*, which has been developed on a large scale in many countries. Greenhouse heating can be accomplished by forced circulation of air in heat exchangers, hot water-circulating pipes or ducts located in or on the floor, or other methods. Exploitation of geothermal heat in greenhouse heating can considerably reduce operating costs, which in some cases account for 35% of the product costs.



Aquaculture, which is the controlled breeding of aquatic forms of life, is gaining worldwide importance nowadays. By maintaining an optimum temperature artificially, we can breed more exotic species, improve production, and even, in some cases, double the reproductive cycle.

Conclusion

Geothermal energy is a renewable energy source that has been used economically in many parts of the world for decades. The geothermal exploitation is renewable because of the total reinjection of the cold water after its use, so that only the heat is mined out of the rocks, but it is continuously recharged (directly or indirectly) by Earth's heat flux. A great potential for an extensive increase in worldwide geothermal use has been proven. This is a reliable energy source that serves both direct-use applications and electricity generation. Geothermal energy is independent of weather conditions and has an inherent storage capability, which makes it especially suitable for supplying base load power in an economical way, and can thus be used along with energy sources that are only available intermittently. The renewable energy sources can contribute significantly to the mitigation of climate change and more so if they are used in combination, rather than in competition, with each other.

Geothermal exploitation techniques are being rapidly developed, and knowledge of the reservoirs has improved considerably over the past years. Combined heat and power plants are gaining popularity, improving the overall efficiency of geothermal use. Also, low-temperature power generation with binary plants has opened up the possibility of producing electricity in countries that do not have high-temperature fields. EGS technologies, where heat is extracted from deeper parts of the reservoir than in conventional systems, are under development. If EGS can be proven economical at commercial scales, the development potential of geothermal energy will be limitless in many countries of the world.

Ruggero Bertani

See also **Energy Resources; Geothermal Features; Renewable Resources; Volcanoes**

Further Readings

- Bertani, R. (2005). World geothermal power generation in the period 2001–2005. *Geothermics*, 34, 651–690.
- Bertani, R. (2007, May 30–June 1). World geothermal power generation in 2007. In *Proceedings of the European Geothermal Congress 2007*, Unterhaching, Germany. Retrieved January 15, 2010, from <http://geoheat.oit.edu/bulletin/bull28-3/art3.pdf>
- Cataldi, R., Hodgson, S. F., & Lund, J. W. (1999). *Stories from a heated Earth: Our geothermal heritage*. Sacramento, CA: Geothermal Resource Council and International Geothermal Association.
- Dickson, M., & Fanelli, M. (1995). *Geothermal energy* (UNESCO Energy Engineering series). Chichester, UK: Wiley.
- Lund, J. W., Freeston, D. H., & Boyd, T. L. (2005). Direct application of geothermal energy: 2005 worldwide review. *Geothermics*, 34, 691–727.
- Wright, P. M. (1998). The sustainability of production from geothermal resources. *Geo-Heat Center Quarterly Bulletin*, 19(2), 9–12.



GEOTHERMAL FEATURES

Geothermal features are surface manifestations of the internal heat of Earth interacting with groundwater. Earth's internal heat developed during the early evolution of the planet, and additional heat is generated by the decay of radioactive elements, primarily uranium, thorium, and potassium. However, the most important heat source is shallow magma bodies and associated volcanic activity.

Geothermal areas can be classified into high temperature and low temperature, based either directly on subsurface water temperatures or indirectly on the geological settings. High-temperature geothermal areas have water temperatures in the uppermost 1,000 m (meters) of greater than 200 °C. Low-temperature geothermal areas are characterized by water temperatures ranging from close to 20 to 150 °C and can be found in formerly active volcanic regions, on the margins of



active volcanic regions, or in areas where there is a deep component of groundwater flow, combined with geological features, such as faults or fracturing, that allow the upward movement of heated water to the surface. The primary water source for most geothermal regions is meteoric water, usually as recharge to an aquifer.

High-temperature geothermal areas form where there is a high-temperature gradient due to the presence of a shallow magma body (typically at around 15–5 km [kilometers], i.e., 9–3 mi. [miles] depth). Because groundwater at depth is subjected to greater pressures than shallow groundwater, it can remain in a liquid state while reaching temperatures greater than 100 °C. Consequently, in high-temperature geothermal areas, groundwater typically reaches temperatures of around boiling point at 1 km (0.6 mi.) depth, and it can reach temperatures of more than 350 °C at 3 km (2 mi.) depth. Groundwater that is heated at depth becomes less dense and rises to the surface. If the temperature exceeds the boiling point as it reaches the surface, then it is emitted as steam. Most high-temperature geothermal fields are associated with young and active rhyolitic volcanism. A faulted, fractured, or porous host rock is necessary to allow water to move from the heat source to the surface. Depending on the temperature at which the water emerges, and the surface conditions, it can form a range of geothermal features, including fumaroles, mud pots, hot springs, and geysers.

Fumaroles

A *fumarole* is any vent in Earth's surface from which steam is emitted. Fumaroles form in geological settings where groundwater is maintained at temperatures in excess of the boiling point close to the surface. Steam temperatures can range from 98 °C to as high as 1,000 °C, but commonly in the range of 200 to 300 °C. As such, fumaroles are always found in association with active volcanism or in high-temperature geothermal fields associated with very shallow magma chambers. Where there is no well-defined vent, a steam field may develop, where steam is emitted from porous ground over a wide area.

The steam from fumaroles is generally composed of a range of gases in addition to water



Oblique aerial view of secondary steam fumarole near Spirit Lake, Kamania County, Washington, 1980. The fumarole was 300 feet in diameter. Eruptions occurred hourly and continued for 2 months after May 18, 1980.

Source: U.S. Geological Survey.

vapor. Typically, these include carbon dioxide (CO₂), sulfur dioxide, hydrochloric acid, and hydrogen sulfide. The ratio of water vapor to gas varies depending on the temperature of the steam, rising to more than 20% at temperatures of approximately 300 °C but falling again at higher temperatures (>500 °C). Fumaroles that emit sulfurous gases are sometimes referred to by the term *solfatara*, particularly in Italy. Hydrogen sulfide present in the steam (which produces the distinctive “rotten egg” smell common in geothermal areas) tends to be oxidized at the surface by atmospheric oxygen, either into elemental sulfur,



which is deposited around the vents, or into sulfuric acid. For this reason, surface water around steam vents can be highly acidic, with pH values as low as 1. This acidic surface water reacts easily with volcanic material to form fine-grained silica and clay mixtures.

Mud Pots/Mud Pools

Mud pots and *mud pools* are often found in close association with fumaroles, as they form in areas of relatively limited water supply but with abundant steam being vented. As described above, hydrogen sulfide in venting steam reacts with atmospheric oxygen to form sulfuric acid, which breaks down surface material into a fine clay. Mixed with the water from low-discharge hot springs, and venting steam, this fine-grained mixture produces the effect of a boiling mud pot in which bubbles of mud slowly grow and then “pop.” Usually, the mud is a dark gray color, but depending on the chemical composition of the source rocks, it can be brightly colored and is sometimes referred to as a *paint pot*.

Hot Springs

Hot springs form where geothermally heated water emerges from Earth. Depending on the geological setting, the temperatures in a hot spring can range from just above ambient to nearly boiling. There is no widely accepted definition of exactly what a hot spring is. The most commonly accepted definition is that a hot spring is any spring where the water temperature is above the ambient temperature, where *ambient* is loosely defined as the “temperature of the surroundings.” Another common definition is water temperature above 36.7 °C (the human body temperature), although this is often considered to be too anthropocentric.

Hot springs can be found on all continents and in both terrestrial and marine settings. Low-temperature geothermal springs usually have deep water sources and are connected to the surface by faults or fractures. Geothermal water typically has a high dissolved mineral load. The exact composition of geothermally heated water depends on the host geology. Low-temperature geothermal systems are usually dominated by carbonates, while high-temperature geothermal systems are

usually enriched in silicic minerals due to their close association with volcanic rocks, especially rhyolite. As mineral-rich water overflows the edge of a hot spring, or flows over the adjacent ground, it precipitates its dissolved load, leading to the deposition of distinctive deposits called *sinters*. Sinters formed from carbonate minerals are called *travertines*, while those formed from silicic minerals are referred to as *siliceous sinters*. Extensive silica terraces are a common feature of many geothermal areas. The warm and mineral-rich conditions in hot spring sinter deposits encourage colonization by a variety of microbial organisms, primarily cyanobacteria. The uptake of CO₂ by bacterial photosynthesis may encourage rates of sinter precipitation, although generally, the loss of CO₂ to the atmosphere is the primary mechanism of precipitation. Bacteria may also play a role in controlling the internal structure of some sinter deposits.

Geysers

Geysers are hot springs that periodically “erupt,” forcing water into the air. Geysers are relatively rare, with only around 1,000 of them occurring globally. This is because in addition to the heat source and water supply necessary for other geothermal features, they also require a distinctive reservoir and plumbing system. Almost all geysers occur in areas of rhyolitic volcanic rock, although a small number are hosted in other igneous rocks. Rhyolites are especially common because their high silica content encourages the deposition of siliceous sinters on the inside of their vents, creating a watertight plumbing system that allows high pressures to be reached. The structure of a geyser consists of a standpipe, which terminates at the surface in a cone or shallow pool, and one or more reservoirs. The water in a geyser plumbing system consists of deep-circulating high-temperature geothermal water entering the system from below and cooler surface water entering from above. Where the two water sources meet, the hotter, less dense water will begin to condense and gradually heat the cooler water until it also reaches boiling point. At this point, steam bubbles from the hotter water will begin to move upward through the cooler water. In geysers with a constrictive



opening, the pressure of the rising steam will build up behind the constriction, eventually lifting the overlying water to allow the steam to escape, thus lowering the pressure, allowing the already boiling water to boil even more vigorously, and turning more water to steam as it does so. This process causes a rapid expansion of steam and water that ejects violently through the constriction. The explosion continues until there is no more water in the reservoir or the water temperature drops below boiling. Depending on the size of the geyser and the available heat source, this cycle of filling, heating, and erupting can take from minutes to days.

Geographical Distribution of Geothermal Features

The distribution of geothermal features is strongly controlled by the distribution of available heat sources and is consequently closely related to the distribution of volcanic activity across the globe. The distribution of volcanoes is primarily determined by the distribution of Earth's tectonic plates, and many geothermal areas occur in association with the volcanism that occurs along plate boundaries. High-temperature geothermal areas occur at divergent plate boundaries (mid-oceanic ridges and rift valleys) and convergent boundaries (along cordilleras, volcanic arcs, and back-arc basins). Continent-to-continent collision zones usually develop only low-temperature geothermal areas. Most of the major geothermal areas on the Pacific Ring of Fire are associated with convergent boundary subduction zones. Other geothermal areas occur in conjunction with volcanic hot spots (volcanic areas formed by mantle plumes), primarily in locations away from plate boundaries, such as the Yellowstone geothermal area or the Hawaiian volcanic islands. Iceland is located on a divergent plate boundary (a midocean ridge) that is coincident with a hot spot. As volcanic areas become dormant or extinct or a tectonic plate moves over a hot spot, changing the center of volcanic activity, a geothermal area can change in character from high temperature to low temperature.

The most famous geothermal area is Yellowstone National Park in the United States. Yellowstone contains a total of 10,000 geothermal

features distributed across seven geothermal basins within the region, including approximately 500 geysers (around one half the world's total) and 4,000 fumaroles. Other geothermal areas in the Western United States include the Beowawe Geyser Field, Nevada, and Steamboat Springs, Colorado, but the geyser activity at these sites has been damaged by geothermal power exploitation. A small geothermal area with geysers exists on Umnak Island, an Aleutian Island close to the Alaskan mainland.

Iceland is famous for the geyser "Geysir," from which all other geysers are named. The name *geysir* is derived from the Icelandic verb *gjósa* (meaning "to erupt"). Geysir is the world's oldest recorded geyser, with accounts dating back to 1294. During the 19th and 20th centuries, Geysir was relatively inactive. Geysir has been reactivated by major earthquakes (most recently in 2000) and during the 1980s by pouring soap into the vent, a practice that has since been discontinued due to environmental concerns.

All of New Zealand's active high-temperature geothermal fields are on the North Island. The Taupō volcanic zone lies in the center of the North Island and extends from the southwest to the northeast for 350 km (217 mi.). There are more than 100 low-temperature geothermal areas across both North and South Islands, associated with older volcanic regions. In the 19th century, there were five major geyser fields within the Taupō volcanic zone: Rotomahana, Whakarewarewa, Ōrākei Kōrako, Wairākei, and Taupō Spa. The Rotomahana geyser field was destroyed by the 1886 eruption of Mt. Tarawera, and most of the remaining geyser fields have been damaged by geothermal power development, such that the number of recorded geysers in New Zealand had decreased from 220 in the 19th century to 58 in 2004. Whakarewarewa is the largest of the active geothermal areas, with some 500 hot springs and 65 geyser vents, 7 of which are active.

Other geothermal areas include the Valley of Geysers in the Kamchatka Peninsula, Siberia, and El Tatio in the Chilean Andes.

Philip M. Marren

See also Earthquakes; Geothermal Energy; Groundwater; Plate Tectonics; Volcanoes



Further Readings

- Arnórsson, S. (1995). Geothermal systems in Iceland: Structure and conceptual models—I. High temperature areas. *Geothermics*, 24, 561–602.
- Bryan, T. S. (2001). *The geysers of Yellowstone* (3rd ed.). Boulder: University Press of Colorado.
- Renaut, R. W., & Jones, B. (Eds.). (2003). Sedimentology of hot spring systems [Special issue]. *Canadian Journal of Earth Sciences*, 40(11).
- Rhinehart, J. S. (1980). *Geysers and geothermal energy*. New York: Springer.



GEOVISUALIZATION

See Cartography; Dynamic and Interactive Displays; Three-Dimensional Data Models



GETIS, ARTHUR (1934–)

Arthur Getis is Distinguished Professor of Geography, Emeritus, at San Diego State University. He received his BS and MS degrees at the Pennsylvania State University and completed his PhD in geography at the University of Washington in 1961. Getis was a student of William Garrison and, together with his fellow graduate students, took part in the “quantitative revolution” in geography. He is widely known across disciplines for his research in spatial statistics and has made significant contributions in all aspects of academic geography.

Getis’s early work analyzed the patterns of economic activity using map transformations and pattern analysis techniques borrowed from ecology. His manuscript titled “Temporal Land Use Pattern Analysis With the Use of Nearest Neighbor and Quadrat Methods” appeared as the first discussion paper in the *Michigan Inter-University Community of Mathematical Geographers* (MICMOG) series in 1963. The paper reached a wider geography audience a year later, when it was reprinted in

the *Annals of the Association of American Geographers*. He has since published scores of scholarly articles in the top journals of the field. Two books, coauthored with Barry Boots, examine the connections between process and spatial pattern and demonstrate pattern analysis techniques.

Much of Getis’s recent work has focused on the development of methods for spatial analysis and spatial econometrics. He has been influential in advancing local methods of spatial analysis, and his most often cited research is the development of local spatial clustering statistics with J. Keith Ord. He has also employed local spatial statistics to account for and incorporate spatial dependence in regression analysis. The subject matter of his work has shifted to understanding and improving the health of populations. He is currently conducting research on dengue fever transmission, fertility, and women’s health in developing regions.

Getis has received several awards honoring his scholarship, including the Walter Isard Award from the North American Regional Science Association and Distinguished Scholarship Honors from the Association of American Geographers. He held the Stephen and Mary Birch Foundation Endowed Chair of Geographical Studies at San Diego State University from 1992 to 2004.

Getis has worked to advance geographic education at all levels. He has written several popular textbooks, including *Introduction to Geography*, coauthored with Judith Getis and Jerome Fellmann, which is now in its 12th edition. He has taught at a number of prestigious universities and in several interdisciplinary workshops. His graduate advisees include Barry Boots of Wilfrid Laurier University, Kingsley Haynes of George Mason University, and Marc Armstrong of the University of Iowa.

Getis also has an extensive record of service at departments, universities, and professional organizations. Past leadership roles include head of the department of geography and director of the School of Social Sciences at the University of Illinois. He has served as president of both the Western Regional Science Association and the University Consortium for Geographical Information Sciences. He is a founding editor of the *Journal of Geographical Systems*, together with Manfred Fischer.

Jared Aldstadt



See also **Quantitative Methods; Quantitative Revolution; Regional Science; Spatial Autocorrelation; Spatial Statistics**

Further Readings

Getis, A. (1964). Temporal land-use pattern analysis with the use of nearest neighbor and quadrat methods. *Annals of the Association of American Geographers*, 54, 391–399.

Getis, A., & Boots, B. (1978). *Models of spatial processes: An approach to the study of point, line, and area patterns*. Cambridge, UK: Cambridge University Press.

Getis, A., & Ord, J. (1992). The analysis of spatial association by distance statistics. *Geographical Analysis*, 24, 189–206.

GHETTO

The concept *ghetto* is much debated and controversial in Anglophone geography, the social sciences, and public policy. Conflicting and clashing ideologies—conservatism, liberalism, and radicalism—all proclaim a definitive unearthing of its essence. Many agree that the concept today references a distinctive space inhabited by one stratum of the American population: the poor and relatively isolated. This space, almost universally associated with U.S. cities, identifies a core of underemployed and unemployed persons whose limited social and spatial mobility confines them to the inner city. In this context, a population disproportionately black and Latino is distinguished on the basis of material deprivation, lack of opportunities for upward mobility, limited spatial mobility, and immersion in disinvested neighborhoods. The pathbreaking exposition of black ghettos in urban America by Harold Rose in 1971 was pivotal to centering this notion within contemporary Anglophone human geography.

Yet there is much disagreement about the ghetto's specifics, that is, the causes for its existence and perpetuation and for its precise social attributes. Neoconservatives posit a space-trapped

population who fall prey to their own production of a pernicious, ensnaring “ghetto subculture.” Poor people, in often dire realities, reflexively and consciously opt for a lifestyle of limited responsibility, peripheral commitment to wage labor, and adherence to short-term, hedonistic pursuits, as place-specific, “ghetto” values are mediated and acted on. Ghettos here evolve as increasingly separate, distinctive social worlds whose unique values seamlessly circulate in life’s everyday circuitries to produce a problematic type of being: “ghetto people.”

Alternatively, liberal and radical perspectives chronicle a contemporary ghetto with different social attributes. Both are remarkably similar in identifying a resource-deprived space that embeds a population and institutional fabric bearing hopelessness, the struggle to achieve against great obstacles, and discord in the face of class and racial oppression. A reality comprising barriers, racism, discrimination, and lack of access to resources and facilities is seen to be ceaselessly mediated by and shaping a population’s everyday life and sense of future material prospects. Ghettos, then, are seen to house a population struggling to be the same rather than choosing change, opting for an alternative demographic. What ghetto residents most desire—decent material foundations, steady jobs, meaningful lives, resource-rich communities—is identical to the desire of every other population group but is extremely difficult to obtain in these isolated, deprived, and stigmatized spaces. Where there is deviance and deformity, it is suggested, there is the debilitating impact of hopelessness spawned by racism, grinding poverty, and the everyday struggle to survive.

At the same time, much disagreement exists about the reasons for this space’s continued existence. Neoconservatives emphasize the driving power of a humanly created subculture: “the subculture of poverty.” This perspective emphasizes the interconnection between human choice, created cultural traditions, and individual character, which places cause in the realm of human actions and choices. Here, the creation and sustaining of ghettos is a culturally driven affair. Faced with difficult everyday realities, people create their own social worlds via conscious decision making to adapt to marginal circumstances. The



South Bronx ghetto neighborhood, 2002

Source: Marc Asnin/Corbis.

construction of different norms allows people to attain goals, ones that are frequently impugned by the larger society. Amid pervasive feelings of resignation, passivity, fatalism, and powerlessness, the failure to self-discipline, an unwillingness to defer gratification, and the marginalization of the work ethic propel the formation of a distinctive population and space. In the end, people have difficulty holding jobs, fail to see the utility of working hard, and become transient economic actors who perpetuate poverty, reduce life chances, and sustain the economic and social environment of a ghetto.

Liberal and radical visions dispute this explanation. The liberal stance posits that everyday realities are a product of human choices but within a powerful causal force: bounded and constrained circumstances. Human choice, then, is anything but “pure” and unfettered. In this context, poverty and deprivation are complex end products of people having to routinely negotiate a litany of structural forces—for example, low-income-punishing labor markets, a distant and

hostile government, identity-punishing everyday realities, and degrading social welfare programs. At issue are the powerful realities of a postindustrial economy with declined numbers of decent-paying jobs, aloof public bureaucracies, and minority and low-income hostilities embedded in the common institutional actions and common affairs that sear everyday ghetto life.

The radical vision more deeply contextualizes the realities of these spaces by situating them within the totality of capitalist social and economic organization. Its starting point is the notion that inequality is inherent in the capitalist mode of production. Inequality is inevitably produced in the normal operation of capitalist economies and social processes and cannot be eradicated without fundamentally altering the mechanisms of capitalism. Thus, capitalist economies need pools of low-wage workers as both regular and sporadic participants, the latter being deployed periodically to drive wage rates down. In this setting, spatial divisions of labor form in cities that isolate such residual



low-income workers (and other segments of workers) in their own communities to be socially reproduced and deployed. The end result is the creation of mosaics of communities—ghettos, working-class neighborhoods, middle-class districts, upper-income enclaves—that reflect the actions of complex institutional operations working through the structural logic of creating packets of workers on landscapes.

This stratification—essential to reproducing local labor—is sustained through realtor steering, bank redlining, government constructing low-income social spaces, and the like. While these actors do not conspire to promote residential differentiation, the short-term pursuit of profit collectively has this effect. Space, as a socially constructed apparatus, encourages labor slot reproduction into future generations. Every segregated social group operates within a kind of daily prism that, for ghetto residents, closes into a prison of space and resources. In this way, individuals inadvertently carry an imprint of a given environment, even under conditions of active contemplation and reflexiveness, as they engage a daily-life environment that acts to transmit inequalities.

David Wilson

See also Ethnic Segregation; Housing and Housing Markets; Poverty; Race and Racism; Racial Segregation; Segregation and Geography; Urban Geography; Urban Spatial Structure; Urban Underclass

Further Readings

- Jakle, J., & Wilson, D. (1992). *Derelict landscapes: The wasting of America's built environment*. Lanham, MD: Rowman & Littlefield.
- Rose, H. (1971). *The black ghetto: A behavioral perspective*. New York: McGraw-Hill.
- Wacquant, L. (2008). *Urban outcasts*. New York: Polity Press.
- Wilson, D. (2007). *Race and cities: America's new black ghetto*. London: Routledge.
- Wilson, T. (1990). *The truly disadvantaged: The inner city, the underclass, and public policy*. Chicago: University of Chicago Press.



GIDDENS, ANTHONY (1938–)

Anthony Giddens is one of the most influential social theorists of the late 20th and early 21st centuries and the inventor and most prominent proponent of the theory of structuration. He was also a leading figure in British “third-way” politics in the 1990s. He has published at least 35 books, which have been translated into 30 languages, and more than 200 articles. Within human geography, he played a key role in debates about the “new regional geography,” the emergence of critical human geography, and theoretical developments in European social geography.

Giddens was born in Edmonton, a working-class area in northeast London. From the mid 1950s onward, he studied, at the University of Hull, Yorkshire, philosophy and sociology under Peter Worsley, an active member of the Socialist Society. He completed his master's degree from the London School of Economics, where noted theorists such as Karl Popper, Ernest Gellner, Peter Winch, and Ralf Dahrendorf were lecturing at the time. Their theoretical debates inspired Giddens's interest in social theory, as unveiled in his first book *Capitalism and Modern Social Theory: An Analysis of the Writings of Marx, Durkheim and Max Weber* in 1971. He was appointed as a lecturer at Leicester University, where he worked with Norbert Elias and Iliya Neustadt, and he spent several terms at Simon Fraser University (Vancouver) and at the University of California at Los Angeles. In 1969, he was appointed as a lecturer in sociology at Cambridge University, where he also received his PhD from King's College, and he cofounded Polity Press in 1985. He was promoted to a full professorship of social and political theory in 1987. Ten years later, Giddens was elected director of the London School of Economics. In June 2003, he was given a lifetime peerage in the House of Lords.

In the 1970s and 1980s, Giddens developed the theory of structuration, which elaborates on classic social theory. Giddens argued that Karl Marx, Émile Durkheim, and Max Weber were all equally important founding figures of modern sociology. These three scientists shared more



similarities than was usually claimed. They all dealt with the emergence of modern society under the influence of industrialism and Western capitalism. Each of them presents specific analytical foci for the study of modern societies. As these foci are rooted in the 19th century, they need critical elaboration if social theory is to keep its relevance for the analysis of late modern societies. This is the starting point of Giddens's approach, which incorporates three main lines of argument: (1) an ontology of late modern societies, (2) the elaboration of an adequate social theory of late modern societies, and (3) a theory-based intervention in politics as a "third way" between capitalism and communism for the renewal of social democracy.

Giddens's ontology of contemporary societies reaches the conclusion that social reality changed so dramatically during the 20th century that none of the theories of the classics of social thought can continue to grasp it in a satisfying manner. The two most important dimensions of transformation are the shift from the temporal and spatial embeddedness of traditional societies to the disembeddedness of posttraditional or late modern societies and, based on the processes of disembeddedness, the ongoing process of subjectivation/individuation, implying most of all a radical transformation of intimacy and emancipatory politics. The elaboration of structuration theory, quite different from those of Pierre Bourdieu or Roy Bhaskar, takes the new socio-ontological conditions of late modern societies explicitly into account. Giddens's approach redefines the relations between agency, structure, and social system. In doing so, he draws attention to the duality of social structures, in other words, to the fact that social structures are constituted by human agency while at the same time they are a medium of social agency, enabling as well as constraining it. Based on this constitutive conceptual frame, structuration theory suggests investigating societies first of all in terms of agency and institutionalized practice and not in terms of structural categories. Accordingly, processes of structuration, that is, the interrelations of agency and (enabling/constraining) structures, should form the center of social research, not simply the analysis of structure.

It is important to note that the use of the terms *agency* and *structure* differs considerably from their use in the classics of social theory. Agency as conceptualized in human activities differs from action as conceptualized by Max Weber. Weber's concept of action was conceptualized in its pure form as a purposive-rational form of social activity, based on a rational consciousness. Giddens's concept of agency includes also social practices based on a practical consciousness constituted primarily by tacit knowledge. Therefore, agency refers not to rational, goal-oriented activity but rather to a more general steering capability of social practice. Structure, as a form of conceptualizing social relations, differs in Giddens's theorizing decisively from Durkheim's and Marx's theories. Giddens does not interpret structure in a static and deterministic way but rather as the medium of action, enclosing the core elements, rules, and resources. *Rules* denote guidelines of conduct as well as schemes of interpretation that enable the understanding of the culturally specific meanings of the activities of human agents and of sociocultural events. *Resources* refer to the capability of control over the object world, the means of production, and nature (allocative resources) and to the capability of control over (present and absent) persons (authoritative resources). The varying degrees of control thus display the differing power potentials of the agents.

According to Giddens, the social world is constituted by every concrete interaction. Agency referring to social structures then constitutes structuration processes in the sense of reproducing and transforming social reality. Structure and agency are neither the same, nor can they be regarded as dualistic (i.e., as two separate entities); but rather, they should be regarded as a duality, that is, deeply interwoven with one another. They are two aspects of the same thing, that is, social praxis. Social praxis should then be understood as simultaneously structuring and structured by human agency.

Benno Werlen

See also **Critical Human Geography**; Pred, Allan; **Structuration Theory**; Thrift, Nigel; **Time-Geography**



Further Readings

- Giddens, A. (1971). *Capitalism and modern social theory: An analysis of the writings of Marx, Durkheim and Max Weber*. Cambridge, UK: Cambridge University Press.
- Giddens, A. (1976). *New rules of sociological method: A positive critique of interpretative sociologies*. London: Hutchinson.
- Giddens, A. (1979). *Central problems in social theory*. London: Macmillan.
- Giddens, A. (1984). *The constitution of society*. Cambridge, UK: Polity Press.
- Giddens, A. (1985). The nation-state and violence. In *Contemporary critique on historical materialism* (Vol. 2). Cambridge, UK: Polity Press.
- Giddens, A. (1990). *The consequences of modernity*. Cambridge, UK: Polity Press.
- Giddens, A. (1998). *The third way: The renewal of social democracy*. Cambridge, UK: Polity Press.
- Giddens, A. (1999). *Runaway world: How globalization is reshaping our lives*. London: Profile.



GILBERT, GROVE KARL (1843–1918)

Time and space represent perhaps the two most fundamental inputs to the explanation of landscape development and differentiation. In traditional qualitative models, time is the preeminent variable. However, if the landscape and/or its constitutive elements reflect some sort of instantaneous balance between the forces acting on it, or them, and surface resistance, then we are offered a fundamentally different starting point from which to examine their development. Geomorphological models dominated by a temporal perspective have been largely biological in tone; however, Grove Karl Gilbert, a contemporary of William Morris Davis, viewed landscapes from the perspective of physics and engineering. The great contrast between the two approaches is that a Davisian approach results in a time-dependent model of development, while that of Gilbert favors time-independent modeling. In

the former, spatial variation is essentially a form of contamination; in the latter, time, be it absolute or relative, contaminates. Clearly, both time and space must be considered; however, the relative weight assigned to each influences the resulting perspective enormously.

Gilbert received enormous professional recognition while alive; however, his professional life followed a very different path from that of Davis. Working for the U.S. Geological Survey, he served as an administrator for lengthy periods. He also was not apparently very interested in integrating his ideas into a comprehensive model of landscape development. Finally, his profound commitment to physical and engineering principles did not resonate greatly with the dominantly qualitative and biologically inspired views of the time. Consequently, his enormous insights, while lauded during his professional lifetime, lay fallow for a long time after his death. It was not until the 1960s that John T. Hack reinvigorated Gilbert's legacy when he invoked it as the foundation for his own ideas of dynamic equilibrium.

Present-day geomorphology would not be what it is without Gilbert's seminal paper "Report on the Geology of the Henry Mountains." Among Gilbert's many important conceptual contributions are "the law of uniform slope," "the law of structure," "the law of divides," and "the tendency to equality of action, or to the establishment of dynamic equilibrium." He also produced important methodological papers that may be seen as the clear forerunner of the concept of "multiple working hypotheses," more commonly associated with its later formulation by T. C. Chamberlin.

Colin Edward Thorn

See also Davis, William Morris; **Geomorphic Cycle**; **United States Geological Survey (USGS)**

Further Readings

- Gilbert, G. K. (1877). Report on the geology of the Henry Mountains. In *U.S. geographical and geological survey of the Rocky Mountains* (p. 160). Washington, DC: Government Printing Office.



- Gilbert, G. K. (1886). The inculcation of scientific method by example, with an illustration drawn from the Quaternary geology of Utah. *American Journal of Science, Third Series*, 31, 284–299.
- Higgins, C. G. (1975). Theories of landscape development: A perspective. In W. N. Melhorn & R. C. Flemal (Eds.), *Theories of landform development* (pp. 1–28). Boston: Allen & Unwin.
- Pyne, S. J. (1980). *Grove Karl Gilbert: A great engine of research*. Austin: University of Texas Press.



GIS, ENVIRONMENTAL MODEL INTEGRATION AND

Environmental process models describe the exchange of energy and materials through space and time and assess their impact on the environment. Many environmental process models are closed monolithic systems that cannot be easily modified. When dealing with increasingly complex environmental problems, multiple models are often involved in a single project, but only parts of each model are relevant. An ideal approach is to integrate only the relevant parts into a customized model or an interoperable model.

The interoperable modeling approach may fundamentally change the way environmental models are developed and used, as well as the way they integrate with geographic information systems (GIS) and other tools. This development is supported by both the research community and government agencies and is foreseen as an inevitable direction for future generations of environmental process models.

Interoperation allows data and functions to be used freely across systems. At the core is the semantic interoperability, which allows for meanings of data and functions to be shared between users. Computing techniques are already available to support interoperable models, such as component-based modeling. Components are independently developed, ready-to-use software units. They can be assembled to form functional systems. The challenges lie in the conceptual issues, including the principles to guide the delineation of components, the meta-information needed to

describe a component, and the semantic compatibility between components.

The first issue is to identify the primitive components, the building blocks of an interoperable model. Because the existing process models embody accumulated knowledge and time-tested coding, it is sensible to respect these developments and identify the common elements contained in them in order to delineate the primitive components. The semantic reference system can serve as a conceptual framework to guide the delineation. This system consists of (a) a semantic datum that contains the most basic terms and their meanings, (b) a semantic reference frame that organizes the semantic datum, and (c) translation functions that relate a concept in an application to the semantic reference frame and annotate the concept by the semantic datum.

Methods such as formal concept analysis can help translate the concepts (e.g., equations, processes) in heterogeneous environmental models to the discipline datum, identify the common elements embedded in the local concepts, and subsequently identify the primitive components.

Several types of meta-information are needed to describe a primitive component. One type is spatial and temporal scale, such as spatial and temporal continuity (i.e., discrete vs. continuous), spatial and temporal extent, and spatial and temporal resolution. Another type of information is the scale of processes, represented as entity hierarchy, process hierarchy, and the relationships within each and between them. A third type of information addresses parameters and their values for environment conditions, initial conditions, and boundary conditions. The fourth type is concerned with model development, such as information about model creation, validation, and referencing.

The third issue, semantic compatibility between components, addresses whether environmental process components can be assembled together. The meta-information associated with each component is critical for this step. A number of approaches can be used to evaluate the semantic similarity between components. These include trees and conceptual graphs and associated methods to evaluate compatibilities.

Ling Bian



See also **GIScience; Interoperability and Spatial Data Standards; Semantic Interoperability; Semantic Reference Systems**

Further Readings

- Bennett, D. A. (1997). A framework for the integration of geographical information systems and model base management. *International Journal of Geographical Information Science*, 11, 337–357.
- Bian, L., & Hu, S. (2007). Identifying components for interoperable process models using concept lattices and semantic reference system. *International Journal of Geographical Information Science*, 21, 1009–1032.
- Szyperki, C. (1998). *Component software: Beyond object-orientation programming*. Boston: Addison Wesley.



GIS, HISTORY OF

Geographic information systems (GIS) benefited from a range of parentage disciplines. The advent of spatial information management and decision support systems can be traced to a range of development push disciplines, including transportation engineering, automated cartography, computer science, aerospace engineering, and remote sensing. A litany of disciplines further created the applications environment for these systems to succeed, including demography, agricultural science, forestry, urban and regional planning, ecology, rangeland management, and geography. Common to these push and pull disciplines was the influence of 1960s space age technology and the computerized information age. Two decades of GIS development occurred prior to geographers formally recognizing GIS as a field in geography. Geographers began in the 1980s to investigate the underlying scientific principles and the framework for the success of these automated spatial information systems. At the turn of the 21st century, GIS became prevalent throughout society, and usage expanded exponentially among the general public, with Web-enabled facilities for viewing any location on Earth or easily selecting optimal

routes for travel destinations anywhere on the planet. Virtual worlds on the Internet, or digital Earths, can be directly traced to the pioneering work of a finite set of individuals and laboratories, predominately located in North America.

Conceptual Landscape

The prowess of spatial analysis had been recognized for millennia in the use of maps to illustrate records, beginning with petroglyphs of optimal hunting areas and extending to Sumerian clay tablets for agricultural and land taxes. Mercator's map projections provided the first global standard for cartographic representations and hence can be viewed as one of the first "systems" for geographic information. Prior to the age of automation, examples of using overlay maps (i.e., space) to depict different object themes or time sequences for a geography were demonstrated in 1781 in the "Siege of Yorktown" sketches by Louis Alexandre Berthier (and the 1874 Louis van Blarenberghe painting based on the sketches) and in 1838 for the *Atlas to Accompany the Second Report of the Irish Railway Commissioners*. In 1912, the benefits of spatially overlaid maps were documented for both thematic maps of Billerica, Massachusetts, and time series maps of Düsseldorf, Germany. Spatial data overlay mapping methods were proving to be valuable analytic tools for large landscape projects. In 1969, Ian McHarg's seminal book *Design With Nature* formally introduced to a national audience of landscape architects and thoughtful managers the comprehensive power of systematic spatial analysis using transparent Mylar overlay maps for human development design and engineering. It remained for the influence of automated methods in the 1960s to establish the quantitative framework for the genesis of computer-based GIS.

Technology Prerequisites

Technology was a paramount factor in the creation of modern GIS, beginning with the confluence of Herman Hollerith's Census Bureau's data and command language punch cards operating on electronic computers from the postwar era of the late 1940s. Translating geographically referenced data, or geodata, into computers required many



inventions to facilitate this basic need. Geocoding techniques using Cartesian reference systems were required to keep links of data to geography. Database methods were created to capture the georeferenced files using various schemas. Manually typing in these records proved to be an onerous task, and capturing irregular grid-shaped features from maps necessitated scanners to digitize data, both from drum-based and from flatbed technologies, to create vector files. Visually displaying the results required the advent of cathode ray tubes (CRTs) to project maps and their layers. Collecting data for larger areas traditionally relied on aerial photographs (analog format) that were manually annotated and then digitally scanned (vector format). Digital remote sensing tools, beginning in the 1970s with the Landsat series of satellites, provided raster data format. Computer scientists created a variety of algorithms to frame the schema used to collect, store, and manipulate the digital data. Innovators designed and built automated systems to handle the challenges of acquiring spatial information and subsequently printing maps using the rapidly evolving computational tools of the space age. This progression followed the quantum leaps in computing power, beginning with large mainframe computers and leading up to laptops and field-portable, handheld display phones, enabling GIS mapping information to be transported anywhere on the globe.

Pioneering Centers

Government organizations were the main agents responsible for collecting, analyzing, and managing large volumes of land ownership and census records, often in collaboration with universities, which were keen to attempt creative approaches to automating the increasingly large records. Roger Tomlinson led the development of the Canadian GIS in the 1960s and is credited with establishing the first operational automated spatial information system, as well as with coining the GIS moniker for these technologies. Tomlinson's team automated Canada's natural resources information files for a number of thematic data layers for the purpose of reading digitally encoded maps, to then measure, compare, combine, and analyze the data for useful decision making. To encode map data, the flatbed digitizer, Morton Matrix tiling

structure, and geocoding coordinate system methods were created for this pioneering enterprise. Basic data manipulation and retrieval commands and algorithms were created that enabled the earliest automated spatial analysis, including topological overlay. These fundamental elements remain the foundations for vector GIS software.

During the same period, the U.S. Census Bureau was addressing the requirements for automated address matching. Working with a network of New England organizations, the Census introduced data structure models and methods for computer mapping and small-area data analysis with address-matching data, which led to DIME (Dual Independent Map Encoding) in 1967. DIME can be viewed as the information fuel that fed many of the early state and local GIS developments throughout the 1970s. DIME was promulgated via the 1967 URISA (Urban and Regional Information Systems Association) conference and the New Haven Census Use Study of the same year, whereby recognition of its topology functions for address location and analysis influenced further developments at the Harvard Laboratory for Computer Graphics. The Harvard Lab served as a unique incubator for the modern GIS landscape. Harvard's Center Laboratory for Computer Graphics invented GRID, which begat Odyssey and then SYMAP, which was used to form both Synercom and Intergraph corporations. A separate path from Harvard was the creation of Arc/Info and ESRI, Inc. (Environmental Systems Research Institute). ESRI and Intergraph are market leaders in the 21st-century GIS and computer-aided drafting (CAD) industry. Other academic centers that were also seminal incubators of conceptual models, software systems, and young pioneers include the University of Washington, University of Oregon, Purdue University, University of California (UC) at Berkeley and at Santa Barbara, Pennsylvania State University, and University of Wisconsin.

Raster-based GIS was borne of two major paths that can be traced to the use of grid (matrix) data structures for land records and the development research for remotely sensed data and engineering systems, more commonly called *remote sensing*. Raster and vector data formats are inherently different structures for storing spatial information. Notable early pioneers for raster-based GIS included the Minnesota Land Management



Information System (1967–1971), the Land Use and Natural Resources Inventory of New York State (LUNR, based on Harvard's SYMAP), and the Oak Ridge Regional Modeling Information System (ORRMIS), started in 1970. The Harvard Lab also developed the first interactive geographic analysis tool, IMGRID (Interactive Manipulation GRID), considered the forerunner of all raster GIS, including Map Analysis Package (MAP). Image-processing systems also handled the manipulation of raster data for the remote sensing (airborne and satellite) community. The National Aeronautics and Space Administration (NASA) worked in collaboration with a variety of centers, such as UC Berkeley, Jet Propulsion Laboratory/Cal Tech, University of Michigan (Environmental Research Institute of Michigan), University of Kansas, and Purdue University (Laboratory for Agricultural Remote Sensing). NASA funding supported many early raster systems, including VICAR/IBIS (Jet Propulsion Laboratory) and LARSYS (Purdue). Industry also created systems for mineral exploration and forestry, such as IDIMS (ESL, Inc.), MDAS (Bendix Corporation), Image 100 (General Electric), and ERDAS (ERDAS, Inc.).

GIS vendors of this century offer systems that easily handle vector and raster data structures, with interchangeable data formatting that makes many of the early distinctions moot. However, the development pathways for these systems were fundamentally separate until the late 1980s.

Other pioneering efforts were evolving in the 1970s outside North America, as demonstrated in centers such as the Experimental Cartography Unit of the Royal College of Art in the United Kingdom and the Commonwealth Scientific and Industrial Research Organization in Australia and the work led by Chen Shupeng at the Chinese Academy of Sciences. While no commercial ramifications of these efforts can be documented, important research applications furthered understanding of automated mapping and cadastral systems as well as assessment methods for disaster and humanitarian response.

Fuels for Development

The bane of early GIS operations, often heard in the laments of technicians and graduate students, was the labor-intensive nature of digitizing data

for input into the automated spatial databases. With the onset of flatbed free-cursor digitizing tables (a result of Ray Boyle's contribution to the Canadian GIS), long hours were required to translate the lines, points, and polygons from paper or Mylar maps into computer records. Alternatives to this laborious and error-prone method were well received and were responsible for the rapid increase in commercial acceptance of the early vendor software packages. Beginning with the digital DIME files, GIS users could now rapidly build large-area databases with street centerlines to define the geography along with spatial encoded knowledge (i.e., topology) of street ranges, left and right, and directionality. This fuel for GIS can be credited in large part for the expanded user base, an exponential curve that began in the 1980s. The Census Bureau's upgrade to these digital data files for the 1990 census was TIGER (Topological Integrated Geographic Encoding and Referencing). Digital TIGER files for the nation were demonstrably the fuel for business applications with GIS.

A second pathway that fueled GIS development and applications was the NASA/U.S. Geological Survey Landsat series of satellites. With Landsat digital raster data, large areas of the landscape, over 9 million acres per image scene, were captured with a pixel resolution of 1.1 acres. Land managers, biologists, foresters, and mineral scientists could use Landsat data to populate land management GIS for myriad applications with timely and precise digital input. Topology for raster systems is inherent in the Cartesian matrix of the gridded data structure and has proved to be extremely valuable in determining questions of adjacency, buffers, and best-route analysis. Systems such as ERDAS were early pioneers in desktop computer systems using raster-based systems with digital satellite data. Without the TIGER and Landsat digital data fuel, GIS growth in the commercial markets would have been significantly set back in time.

Mainstream Implementation

Canada's GIS paved the way for cost-effective automated inventory and data management approaches for agencies entrusted with large-acreage stewardship. In the United States, the



impetus for automated GIS was borne out of state governments' requirements for planning and natural resources inventory systems. Many of these initiatives were stimulated further by the federal government's 1969 National Environmental Policy Act (NEPA). NEPA's mandate clearly required a new level of awareness by federal and state agencies regarding mitigation of environmental impacts. Early GIS developments included the Maryland Automated Geographic Information (MAGI), the Minnesota Land Management Information System (MLMIS), New York's Land Use and Natural Resources (LUNR), the Ohio Capability Analysis Program (OCAP), North Carolina's Land Resources Information Service (LRIS), and the Arizona Land Resource Information System (ALRIS). The influence across a broad sector of government and scientists of the natural resource inventory systems development efforts of the late 1970s and early 1980s cannot be overstated. These pioneering system implementations incorporated government agencies, vendors and consultants, and university researchers who created careers, new technology, and new policies for land management through trial and experiment, setting the framework for the commercial successes of the 1980s, the maturing decade of the best-known modern GIS.

The engineering world of automated mapping and facilities management (AM/FM) quickly matched the GIS systems development, but for a distinct class of engineering stakeholders. Computer-aided drafting and mapping (CAD/CAM) did not possess topology but was responsible for many developments in 2D (two dimensional) and 3D visualization that hybridized GIS software systems quickly adapted.

The latest chapter in GIS history is exemplified in the visual rendering of spatial information on virtual globes or Earths. Geographically referenced tessellation engines, or geobrowsers, became visible beyond research centers and NASA's Digital Earth initiative and came into the public view in the early 2000s. GIS functionality became increasingly popular with users of Web-based platforms, beginning with 2D mapping viewers in Mapquest and extending to 3D with Google Earth. Simple as well as sophisticated GIS analytic tools are available for a host of virtual Earth geobrowsers, including NASA's WorldWind,

Microsoft's Virtual Earth, ESRI's ArcGlobe, Geofusion's GeoMatrix, and Google Earth. GIS capabilities to query, conduct analysis, and generate useful maps and data are available anywhere on the globe with access to the Internet. This represents a truly remarkable geographic revolution over the past four decades.

Timothy W. Foresman

See also Batty, Michael; **Business Models for Geographic Information Systems; Critical GIS; Dangermond, Jack; Egenhofer, Max; Fisher, Peter; Frank, Andrew; Geodemographics; Geodesy; Geographic Information Systems; Geoslavery; Geospatial Industry; GIScience; GIS in Archaeology; GIS in Disaster Response; GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Land Use Management; GIS in Local Government; GIS in Public Policy; GIS in Transportation; GIS in Urban Planning; GIS in Utilities; GIS in Water Management; GIS Software; GIS Web Services; Goodchild, Michael; Google Earth; Humanistic GIScience; Tomlinson, Roger; University Consortium for Geographic Information Science**

Further Readings

- Foresman, T. (Ed.). (1998). *The history of geographic information systems: Perspectives from the pioneers*. Englewood Cliffs, NJ: Prentice Hall.
- Maguire, D., Goodchild, M., & Rhind, D. (1991). *Geographic information systems: Principles and applications*. New York: Wiley.



GISCIENCE

GIScience (geographic information science) is a scholarly discipline that addresses fundamental issues surrounding the use of a variety of digital technologies to handle geographic information, namely, information about places, activities, and phenomena on and near the surface of the Earth that is stored in maps or images. GIScience includes the existing technologies and research areas of GIS (geographic information systems, or



GISystems), cartography (mapmaking), geodesy (measurement of the Earth itself), surveying (measurement of natural and man-made features on the Earth, also called *geomatics* in the United States), photogrammetry (measurement from photographs or images), global positioning systems (GPS, precise and accurate positioning on the Earth's surface aided by satellites), digital image processing (the handling and analysis of image data), remote sensing (observation of Earth from space or under water), and quantitative spatial analysis and modeling.

GIScience therefore includes questions of spatial data structures, analysis, accuracy, meaning, cognition, visualization, and many more and thus overlaps with the domains of several traditional disciplines that are concerned with Earth's physical processes and how humans interact with the Earth (e.g., geography, geology and geophysics, oceanography, ecology, environmental science, applied mathematics, spatial statistics, physics), as well as disciplines that are concerned with how humans interact with machines (e.g., computer science, information science, cognitive science, cognitive psychology, artificial intelligence). However, GIScience is not central to any of these fields, representing instead a new kind of scientific collaborative that is defined by researchers from many distinct backgrounds working together on particular sets of interrelated problems, problems that are not only scientific in nature but also serve the needs of natural resource management, government, industry, and business.

It is important to make a distinction between GIS and GIScience. While GIS is concerned primarily with the hardware and software for capturing, manipulating, and representing geographic data and information (e.g., as a container of data, maps, and software tools), GIScience is essentially the "science behind GIS" or the "science behind the systems." It can be defined further as the scientific research that is done both on and with GIS, ranging from the fundamental issues arising from the use of GIS (e.g., how to improve the interface to the system, improve its overall design and usability, or track error through the system) to the systematic study of geographic information using scientific methods (i.e., methods based on issues of scale, accuracy, and quantitative analysis of spatial data) and even to the science that is

done with GIS (e.g., the development of spatial models for predicting landslide susceptibility in a region, agent-based models for simulating the actions or interactions of vehicles in a transportation network, or a map, table, or spatial statistic expressing the environmental impacts resulting from the decision to commercially develop a piece of land).

A Brief History of GIScience

The origin of GIScience is traced back to two keynote addresses presented by Michael Goodchild of the University of California at Santa Barbara at conferences in Europe: one titled "Spatial Information Science" (to the Fourth International Symposium on Spatial Data Handling, Zurich, Switzerland, in July 1990) and the other, "Progress on the GIS Research Agenda" (to the Second European GIS Conference, Brussels, Belgium, in April 1991). In both of these keynote addresses, Goodchild challenged the academic GIS community to move beyond a focus primarily on the technical capabilities of GIS to the more substantive intellectual challenges and scientific questions posed by the use of GIS or by the impediments to its use. This fundamental shift would thereby ensure the acceptance and longer-term survival of GIS within broader academia. These important presentations were later published in 1992 in a seminal paper for the *International Journal of Geographic Information Systems*, a paper that has since defined the field of GIScience. In 1988, a few years prior to Goodchild's presentations in Europe, the National Science Foundation (NSF) awarded a multiyear, multimillion-dollar grant to the University of California at Santa Barbara, the State University of New York at Buffalo, and the University of Maine to form the National Center for Geographic Information and Analysis (NCGIA). This was the first major consortium of academicians formed to define and conduct research in the field, laying the foundation for current and future scholarly inquiry by way of its Initiatives 1–21 on topics ranging from the accuracy of spatial databases to visualization of spatial data quality, to the social implications of GIS, to the multiple roles of GIS in global change research, to collaborative spatial decision making. Following on the success of the NCGIA, but



seeking to realign its research, education, and outreach agendas on the more basic, fundamental issues of GIScience, the NCGIA spawned Project Varenus in 1997. Project Varenus focused on several strategic areas of GIScience deemed among the most fruitful for advancing the field in the new context of 21st-century information technology. These strategic areas were cognitive models of geographic space, geographies of the information society (including spatial data infrastructures), and computational implementations of geographic concepts (including overcoming the duality of spatially continuous fields vs. discrete objects). A series of Varenus specialist workshops were held on these topics, generating publications from 1997 to 1999.

In a somewhat parallel effort, in 1990 the NCGIA board of directors recommended that a more broadly based organization be established to engage the long-term participation of excellent researchers beyond the three-university consortium of the NCGIA, thereby supporting and promoting GIScience even further. The NCGIA responded by forming an ad hoc committee of researchers from 16 institutions with prominent programs in GIS and representing seven different academic disciplines. These individuals gathered sufficient momentum to spawn a national meeting in Boulder, Colorado, in 1994, which was attended by 42 individuals representing 33 universities, research institutions, and the Association of American Geographers. This meeting established the University Consortium for Geographic Information Science (UCGIS) as a formal nonprofit organization charged, as indicated on UCGIS's Web site, with "advancing the understanding of geographic processes and spatial relationships through improved theory, methods, technology and data, and to promote the informed and responsible use of geographic information systems and geographic analysis for the benefit of society." The UCGIS has since grown to a membership of more than 80 (as of 2008, 73 universities, three professional organizations, and eight corporate, government, and international members). The organization continues to seek ways to unify the academic GIScience research and education communities to speak with a strong voice on matters affecting resources and policies, particularly where the U.S. Congress and federal

agencies such as the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), the National Geospatial-Intelligence Agency (NGA), the Federal Emergency Management Administration (FEMA), the Department of Homeland Security (DHS), and the National Oceanic and Atmospheric Administration (NOAA) are concerned. Over the years, the organization has formulated dozens of research and education priorities in GIScience; disseminated these via white papers, brochures, and occasional scholarly monographs; and assessed progress in relation to major federal programs and national interests.

In Europe, a similar effort was launched to form the Association of Geographic Information Laboratories for Europe (AGILE). AGILE was established in 1998 with a mission and goals similar to those of UCGIS and with an eye toward continuing momentum from the European GIS conference series, as well as new research initiatives developing within the European Science Foundation's GISDATA scientific program. AGILE promotes and develops GIScience initiatives in a manner similar to UCGIS, with working groups, research initiatives, and small conferences and workshops for the exchange of ideas and strategic planning on promoting GIScience initiatives.

GIScience as a field of study has now reached a mature level, with its own scholarly journals, research monographs, blogs, textbooks, core curricula, degree and certificate programs, research institutes, professional organizations, and conferences. For example, in addition to the UCGIS and AGILE, there are related organizations such as the Cartography of Geographic Information Society, the Open Geospatial Consortium, and the International Spatial Accuracy Research Association and leading peer-reviewed journals such as the *International Journal of Geographical Information Science* and *Cartography and Geographic Information Science* as well as *Transactions in GIS* and *Geoinformatica*. The GIScience series of conferences has convened biennially since 2000, and several new conferences that have emerged in recent years, such as GeoWeb, the International Conference on Geospatial Semantics, and the Where 2.0 and OSCON conferences of O'Reilly Media, now regularly feature GIScience themes and research topics.



Examples of Research Topics in GIScience

Research in GIScience is now represented by literally scores of different topics and specialties, all arising from the questions raised by GIS and the other kinds of geographic technologies mentioned above. For example, there are questions of representation. How should the varied and infinitely complex features on the surface of Earth be represented? What criteria should be used to select a representation? How can a representation be best assessed in terms of its accuracy and completeness? How should one store a given representation efficiently—what is the best data model to use conceptually and the best data structure to use computationally? How should a representation be extended from the well-known two dimensions of a flat surface to the three, four, and n dimensions needed to capture and understand dynamic processes in the atmosphere, in the ocean, and on Earth's surface?

There are research questions in the realm of *scale*, which refers to the level of detail at which information can be observed, represented, and analyzed. How does changing the scale of data affect our understanding of the processes or patterns generating the data? Do processes always scale linearly or uniformly, and if not, how do we characterize or understand them? What are the best ways to describe scaling behavior? Should one use a fractal dimension or multifractals? Is there scale within the digital world of the computer (i.e., does a cartographer's representative scale for a paper map really matter for data sets that may never exist in paper map form)?

Research questions abound in other areas, such as spatial data acquisition and integration, cognition of geographic information, interoperability of geographic information, spatial information policy and privacy, error and uncertainty of spatial data and analyses, and many more. Table 1 summarizes the many interesting areas that have persisted in GIScience as well as those now emerging. Most of these have been identified and refined by the UCGIS over the course of their summer and winter assemblies of the past decade. Of note once again is that these do not focus on geographic technologies such as GIS, GPS, remote sensing, and so on but on several fundamental issues raised by the technologies, especially those

impeding its more effective use. The science done with the technologies is motivated by the need for improved practice, observation, and spatially explicit problem solving.

Education in GIScience

As the adoption of GIS technology and the principles of GIScience have continued to increase across academic, government, and commercial sectors, there has been an increasing emphasis on ensuring an adequately trained and educated workforce in GIScience. Each year, the demand by university students for courses not only in GIS but also in GIScience has increased, as has the demand for this coursework by geospatial professionals. Furthermore, the advances in the technology and the research have spawned a national demand for sequences of courses external to traditional degree programs, hence the proliferation of certificates in GIS, in remote sensing, in surveying, and the like. In the late 1990s, it became the view of many professionals within the GIScience community that the time had come to synthesize, articulate, and put into appropriate intellectual context the recent advances of this research for use in the classroom at both the undergraduate and the graduate levels. As such, the UCGIS developed a set of national priorities to advance GIScience education. Among these was a focus on emerging technologies for delivering GIScience education, including distance education (e.g., the Web, multimedia audio and video files, digital libraries, tele-immersion, digital video, Internet2, and distributed classrooms connected by digital audio and video for two-way interactive lecture sessions). Supporting infrastructure to support GIScience instruction was a related priority, covering issues of facilities administration and staffing, design and maintenance, safety and security of labs and classrooms, and financial resources. Other priorities included access and equity issues (e.g., for students with physical or learning impairments or those from disadvantaged or disenfranchised groups of society), alternative designs for curriculum content and evaluation, research-based graduate GIScience education, and learning with GIS (emphasizing the use of both GIS and GIScience to help students learn about other subjects, such as environmental science).



<i>Long-Term Research Challenges</i>		
Spatial ontologies	Geographic representation	Spatial data acquisition and integration
Scale	Spatial cognition	Space and space-time analysis and modeling
Uncertainty in geographic information	Geovisualization	GIS and society: Interrelation, integration, and transformation
Geographic information engineering: Distributed and mobile computing	Geographic information engineering: Spatial information infrastructures	Geographic information engineering: Geospatial data mining and knowledge discovery
<i>Short-Term Research Priorities</i>		
GIS and decision making	Geospatial Web service interoperability	Location-based services (including ethical and privacy dimensions)
Identification of spatial clusters	Geospatial semantic Web and information semantics	Geographic information resource management
Emergency data acquisition and analysis	Gradation and indeterminate boundaries	Geographic information security
Geospatial data fusion	Institutional aspects of spatial data infrastructures	Geographic information partnering
Geocomputation	Global representation and modeling	Spatialization
Pervasive, ubiquitous computing and geoinformation	Geospatial cyberinfrastructure, including design of service-oriented architecture (SOA)	Dynamic modeling
Public participation GIS	Temporal GIS	Geospatial visual analytics

Table 1 Examples of high-priority research topics of GIScience

Source: Based on information from the University Consortium for Geographic Information Science and the Association of Geographic Information Laboratories for Europe.

Soon after developing its national education priorities, the UCGIS embarked on an ambitious project to develop visionary model curricula for GIScience, designed to further aid in the development of an adequate supply of well-educated and well-prepared GIScientists and technologists. Desired outcomes of a model curriculum included the following: (a) demonstrated skill in integrative spatial thinking and effective implementation of various spatial analysis methods, as well as collaborative learning across several subdisciplines within the GIScience field; (b) solid grounding in the appropriate application of related geospatial technology (software, data collection instruments and devices); and (c) familiarity with a wide variety

of research applications, management, and decision support scenarios, with the capacity to apply knowledge to scientific and management problems at a variety of spatial and temporal scales.

Over an 8-yr. (year) period (1998–2006), dozens of GIScience researchers and educators participated in workshops and related activities to develop an initial comprehensive inventory of knowledge and skills defining the field. The result was the first edition of the *GIScience & Technology Body of Knowledge* resource book and brochure, published in 2006 and detailing hundreds of topics and thousands of formal educational objectives, all organized into more than 70 units within 10 major knowledge areas.



The *Body of Knowledge* serves not only as a resource for course and curriculum planning but also as a basis for professional certification, program accreditation, and articulation agreements between 4-yr. universities and 2-yr. community colleges. Issues of certification where GIScience is concerned and, to a lesser degree, accreditation and licensure will be the subject of vigorous discussion and debate in the foreseeable future. As yet, there is still no authoritative body that accredits a GIScience major, minor, or certificate program, as currently exist for engineering, urban planning, architecture, and other professionally oriented programs (keeping in mind that accreditation refers to programs to establish professional and ethical standards, whereas certification refers to individuals). This differs from licensure, which is meant to protect the public from any harm that an incompetent professional may cause (e.g., as is the case with the licensing of land surveyors). Organizations such as the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology accredit traditional disciplines such as civil engineering and forest engineering. But these organizations are highly disciplinary in orientation and commonly review entire departments or colleges rather than their components. The Urban and Regional Information Systems Association (URISA) piloted a national program in 2003 to certify GIS professionals via a new GIS Certification Institute (GISCI), including an ascription to a GIS code of ethics. GISCI produced the first group of certified GIS professionals (GISPs) in 2003 and has since certified over 2,000 more by way of a nonexamination, portfolio-based system. GIScience coursework offered throughout the United States supports eligibility for this national certification. The American Society for Photogrammetry and Remote Sensing certifies a range of GIScience professionals (mapping scientists and technologists in GIS/land information systems, remote sensing, and photogrammetry) via a peer-reviewed application and written-examination system.

Dawn J. Wright

See also **Analytical Operations in GIS; Association of Geographic Information Laboratories for Europe; Critical GIS; Geocomputation; Geographic Information**

Systems; Geospatial Industry; Geoslavery; GIS, Environmental Model Integration; GIS, History of; GIS Design; GIS Software; Goodchild, Michael; Google Earth; Humanistic GIScience; Neogeography; Spatial Analysis; Spatial Data Models; Three-Dimensional Data Models; University Consortium for Geographic Information Science

Further Readings

- Association of Geographic Information Laboratories for Europe: www.agile-online.org
- DiBiase, D., DeMers, M., Johnson, A., Kemp, K., Luck, A. T., Plewe, B., et al. (Eds.). (2006). *Geographic information science & technology body of knowledge*. Washington, DC: Association of American Geographers and University Consortium for Geographic Information Science.
- GeoWeb: www.geowebconference.org
- GIScience series of conferences: www.giscience.org
- Goodchild, M. F. (1992). Geographic information science. *International Journal of Geographical Information Science and Systems*, 6(1), 31–45.
- Goodchild, M. F. (2006). Geographical information science: Fifteen years later. In P. F. Fisher (Ed.), *Classics from IJGIS: Twenty years of the International Journal of Geographical Information Science and Systems* (pp. 199–204). London: Taylor & Francis.
- Goodchild, M. F. (2006). GIScience ten years after *Ground Truth*. *Transactions in GIS*, 10(5), 687–692.
- McMaster, R. E., & User, E. L. (Eds.). (2004). *A research agenda for geographic information science*. Boca Raton, FL: Taylor & Francis-CRC Press.
- O'Reilly Conferences: <http://conferences.oreillynet.com>
- University Consortium for Geographic Information Science: www.ucgis.org
- Wilson, J. P., & Fotheringham, A. S. (Eds.). (2007). *The handbook of geographic information science*. Malden, MA: Blackwell.
- Wright, D. J., Goodchild, M. F., & Proctor, J. D. (1997). Demystifying the persistent ambiguity of GIS as “tool” versus “science.” *Annals of the Association of American Geographers*, 87(2), 346–362.



GIS DESIGN

Geographic information system (GIS) design refers to a process of developing a spatially explicit computer information system to provide a simplified representation of geographical entities and phenomena and support relevant spatial analyses. Since its formative years in the 1960s, GIS has experienced rapid progress in its capacity to handle spatial information, and it has become a powerful research tool for various study fields inside and beyond the discipline of geography. For example, GIS has been widely used in agriculture and land use planning, natural resource management, transportation, geology, municipal applications, and business, among others. These application domains have quite different requirements in spatial modeling and analysis. A GIS design process aims at helping system developers identify unique data needs and develop an effective model to support data analyses.

A GIS comprises five key components: data, people, hardware, software, and procedures. Geographic data, which include both spatial information and nonspatial attributes of geographic entities, are considered as the most important component of GIS. They are often stored and maintained in a database management system (DBMS) and provide the basis for data query and spatial analysis. The people component covers a wide variety of individuals who are related to a GIS application at different levels. They can be GIS professionals who design, develop, and manage the system; general GIS users who use the system to complete their everyday work; or geographic data viewers who simply browse a GIS database occasionally for information. The hardware component consists of equipment that supports the operation of a GIS application and other devices that facilitate the input/output of geographic data (e.g., global positioning system [GPS] data loggers, digitizing tablets, scanners, and plotters). The *software* component refers to computer programs and user interfaces that provide for the spatial data handling capabilities of the system. Finally, procedures define the specific steps of manipulating and analyzing the geographic data to solve domain-specific application problems. All five components interact with one another to form

a functioning system. Therefore, an effective integration of these components is paramount to creating a successful GIS application. A GIS design process can help ensure the effective integration of the components in a specific application domain by identifying the domain-specific requirements and incorporating the components to meet the application data-processing needs. Similar to the development of other information systems, a GIS design process follows standard steps. In general, these steps include identifying and analyzing user information needs, defining the system scope, making choices about data and database models, determining the system requirements, and, finally, implementing the system.

User needs analysis, which is the first step in developing a GIS application, presents an important task to help system developers understand the purpose of a proposed system. As each GIS application is created to support spatial decision making in a particular problem domain, there are specific requirements to integrate the five GIS components. System developers need to examine the following questions: Who are the end users of the system? Do they all share the same needs? If not, how many different user groups are there, and what are the major functions demanded by each user group? What are the final information products of the system? Detailed answers to these questions can provide proper guidance for the application development.

After the user needs and the goals of GIS applications have been identified, the results need to be further organized and processed to define the system scope. At this stage, developers pinpoint all the data needed in the application (e.g., socioeconomic data, environmental data, political boundaries) and address the corresponding hardware/software requirements to support the data collection and storage. A master input data list is compiled to enumerate all the data sets that are necessary to produce the information products identified in the application. The list contains detailed information of each required data set, including its name, source, spatial reference (scale, datum, and coordinate system), temporal characteristics, size, and cost. The information will guide the effort of creating an effective database design to manage the data in a later step. Since a wide variety of data sets could be used in



a GIS application, some data sets may require specific hardware/software configurations to facilitate the data input process. For example, a digitizer, scanner, or GPS receiver may be used to collect the data, and corresponding software procedures will be used to enter the data into the system. Therefore, it is necessary to evaluate the appropriate hardware configurations and functions to support the data input of the data sets.

Selecting a proper spatial data model for a GIS application is the next important step in GIS design. Different models may be needed to effectively represent and analyze geographic entities and processes in different application domains. Over the years, geographers have developed two fundamental views of geographic entities and processes, viewing them as either discrete objects or continuous phenomena. Accordingly, two representation approaches have been developed. The *object-based approach* views the world as an empty space populated with discrete geographic features, such as wells, buildings, roads, and administration units, and represents them as objects with well-defined boundaries. Each object can have multiple attributes to describe its nonspatial characteristics. The *field-based approach* views the world as composed of entities and phenomena that are distributed continuously across space, such as elevation and precipitation, and focuses on representing the transitional variations of a geographic phenomenon across space. In general, the object-based approach is chosen to represent man-made features, since they usually have well-defined boundaries. For modeling natural features, the object-based approach can be used to describe objects with distinguishable boundaries, and the field-based approach can represent features with fuzzy boundaries and gradually changing characteristics. According to the specific requirements of a GIS application, one or both views could be adopted to model geographic entities and processes.

The *vector data model*, which uses sets of coordinates to record the shape and locations of geographic features, provides a straightforward implementation of the object-based view. In this model, geographic coordinates are directly used to record spatial information and construct three basic geometric types: points, lines, and polygons. These geometric objects then are used to represent

discrete geographic features (e.g., landmarks as points, streets as lines, and water bodies as polygons). Depending on specific spatial modeling purposes, various versions of the vector data model have been created. For example, an early vector data model called the *spaghetti data model* stores geometric elements as unstructured data and provides a simple but effective approach to cartographic representation of geographic features. However, because of the lack of topological information, it has very limited capability to support spatial analysis. To address the limitations of the spaghetti data model, topological data models have been developed. For example, the *arc-node data model* maintains the topological relationships (e.g., containment, adjacency, and connectivity) of geographic features, besides their locations and shapes. This model is needed if an application requires network or adjacency analysis.

The field-based view focuses on the spatial variations of one particular phenomenon and requires a continuous representation of space. Different tessellation methods have been developed in GIS to cover an area and record the spatial variations of a phenomenon. A regular tessellation method usually divides space into an array of rectangular (or more commonly, square) cells. An attribute value is then stored for each cell to represent the variations of the phenomenon. This method is widely known as the *raster data model*. Some common examples include the digital elevation model (DEM), which stores elevation values in grids that cover an area, and satellite images, which record the spectral data in pixels. An irregular tessellation method, which uses a set of irregular shapes that do not overlap to cover an area, also has been widely used to divide the space. The triangulated irregular network (TIN) representation, which uses a collection of nonoverlapping, irregularly shaped triangles to cover an area and stores attribute data at the nodes of the triangles, represents a well-known irregular tessellation method. Since the triangles consist of nodes (points), edges (lines), and facets (polygons), TIN is a collection of composite features and a specialized type of vector data model.

Selection of a data model for each specific data set should be guided by GIS user information needs, the characteristics of entities and phenomena



represented by the data set, and the data requirements of spatial analysis workflows dictated by specific application domains.

Once the appropriate data models are chosen for spatial data sets, the next step involves choosing a logical data model to structure the data in a database. Since geographic information is composed of spatial (geometric primitives with coordinates) and nonspatial (attributes of geometric primitives) data components, a logical data model needs to handle both components. Currently, three logical data models, including *georelational*, *object oriented*, and *object relational*, are commonly used to manage geographic data. In a georelational approach, spatial data are maintained in files, and attribute data are managed in a separate relational database management system. A unique ID is assigned to each entity, and the ID is attached to a data record representing the entity's geometry and the corresponding record representing the entity's attribute. Operations on geographic entities are performed independently of the storage of geographic data. Such an approach limits the possibilities of representing complex geographic entities and their relationships.

Recently, the object-oriented data model has emerged as a new approach in GIS to overcome some limitations of the georelational approach. The object-oriented data model conceptualizes the real-world features as objects and uses various relationships to capture the interactions among the objects. In this model, the concept of *object* denotes an integrated package that contains geometry, properties, and methods associated with a geographic entity. Thus, the spatial information and attributes of a geographic entity and the operations defining the behaviors of the entity are encapsulated in one object. Also, a hierarchical structure can be constructed to organize objects representing different levels of real-world entities (e.g., states, counties, and census tracts). Through the hierarchical relationship, the properties and methods defined for the objects at a higher level can be inherited and reused by the objects at a lower level. Furthermore, a method in this model can adapt itself to different objects to produce different results or effects. These characteristics distinguish the object-oriented data model from other geometry-oriented models and support a more intuitive approach to the representation of

geographic entities and their relationships. However, due to the difficulties in implementing its complex design, the use of the object-oriented approach has been limited. The most recent development in logical data models is the object-relational data model, which implements object-oriented concepts in a relational database environment. By recording spatial data in a binary large-object (BLOB) field in a relational database, this model enables an integrated approach to the storage of spatial and attribute data of geographic entities. The model has many advantages because it combines the features of both relational and object-oriented approaches. Due to the ease of its implementation, the object-relational data model has become the dominant logical data model for various GIS applications.

Another step in GIS design involves determining the system requirements. This step usually accompanies the selection of data models. In this step, system designers will identify functions that are crucial to the workflows for processing the data to produce the final information products. Based on data-processing requirements, the designers will select software programs (e.g., DBMS and spatial analysis packages) that can provide the needed functionality and choose hardware components (e.g., computers, Web servers, and network connections) that provide the data-processing performance required for the application at hand. Also, if there is no existing software package that can provide the needed functionalities, customized programming will be required to achieve the functionalities.

The final step of GIS design is system implementation. After procurement of the required data, software, and hardware, all GIS components are integrated to build a functioning system. When developing a large and complex system, a prototype system—a mini version of the full GIS system—is usually implemented to test the feasibility of the design before the design is finalized. Also, testing of the full system should be conducted to ensure its functionality, performance, and reliability.

Hongbo Yu

See also **Analytical Operations in GIS; Collaborative GIS; Database Management Systems; Data Querying in**



GIS; GIS Implementation; GIScience; GIS Software;
GIS Web Services; Spatial Data Models; Spatial Data
Structures

Further Readings

- Chang, K.-T. (2008). *Introduction to geographic information systems* (4th ed.). New York: McGraw-Hill.
- Lo, C. P., & Yeung, A. K. W. (2007). *Concepts and techniques in geographic information systems* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Longley, P., Goodchild, M., Maguire, D., & Rhind, D. (2005). *Geographic information systems and science* (2nd ed.). West Sussex, UK: Wiley.
- Tomlinson, R. (2007). *Thinking about GIS* (3rd ed.). Redlands, CA: ESRI Press.



GIS IMPLEMENTATION

A geographic information system (GIS) should be considered as an information system rather than as a software product when planning GIS implementation in an organization. Different organizations that implement identical GIS software could experience very different outcomes with respect to their success. An information system involves not only software but also other components, such as data, hardware, procedures, people, and organizational settings. These components must work together to create a successful implementation. As a result, management and organizational considerations are often at least as important as technology in a successful GIS implementation.

Before an organization makes a commitment to GIS implementation, it is critical to identify its business needs and find out if GIS can help the organization meet its needs in more efficient and effective ways. At the minimum, every GIS implementation should begin with a *needs analysis* that assesses the current and future needs of various units in an organization. Findings from the needs analysis assist an organization in determining if GIS can improve the current system and/or offer new solutions that are not currently available. It is good practice to develop a GIS *strategic plan* at

this stage to provide a framework for managing the changes and challenges associated with introducing GIS into the current work environment. Once an organization reaches an initial decision of pursuing GIS, the next step is to plan for GIS implementation. The outcome of this implementation planning process should be a well-documented *implementation plan* that represents an organization's commitment to GIS and establishes a process and schedule to implement GIS.

One critical component in GIS implementation planning is the *system design* that identifies the changes needed in an organization to achieve the goals of GIS implementation. System design attempts to address the specific needs related to data, software, hardware, procedures, staff, and organizational issues. With the information collected from a needs analysis, it is feasible to identify the specific products required by various units in an organization, the different kinds of data needed to generate those products, GIS software and hardware with capabilities of supporting different applications, procedures to meet various user needs, trainings for different user groups, and the organizational changes needed to maximize the benefits of GIS implementation.

After identifying the scope of information products and data for a GIS implementation, it is time to consider a *GIS database design* that attempts to capture and represent the user's view of specific tasks. For example, a particular user group wants to be able to display maps showing property parcel boundary lines with building footprints based on a user query and to easily identify those properties that are within 1,000 ft. (feet) of each other and have a difference of more than \$100,000 in their assessed values. Data available for this particular application may be in different formats, scales, map projections, and geodetic datums. Furthermore, different data sets may be created and maintained by different groups, and they may be shared by several different applications. GIS database design must consider all these factors to choose appropriate logical data models and to design specific physical database schemas to support various user needs. To maximize the benefits of GIS data sharing, it is often necessary to establish standards for data and other related procedures when implementing an enterprise GIS. Coordination and



communication among various groups therefore play critical roles in GIS implementation.

Workflow is another important consideration in GIS implementation. Data must be processed through specific procedures to generate useful products. A GIS application may involve multiple units with staff of varying levels of GIS knowledge. It is important to consider the workflows in an organization such that the GIS implementation can design user interfaces and procedures to accommodate the business logic behind various applications in a manner intuitive to the users. Once the information about user data needs, application requirements, and GIS database design requirements is collected, a design team can proceed to evaluate alternative GIS software and hardware products and determine which software and hardware configurations will best serve the organization's needs. A common practice in the selection of GIS software and hardware is to develop functional specifications of the planned GIS implementation and then prepare requests for proposals for vendors to respond with their solutions to the functional specifications. A benchmark test could be included in the evaluation process to help choose among the competing proposals.

One must keep in mind that GIS does not exist for its own sake. GIS is implemented to help people solve problems. In the meantime, people are needed to operate GIS. As a result, people are an integral part of GIS implementation. In fact, most failures of GIS implementation have been attributed to user issues—whether they are due to lack of understanding, lack of coordination, lack of training, or turf wars. It is essential to consider, in a GIS implementation, the technical staff who will manage and operate the system, the potential users who will benefit from the system, and the administrators who manage the system and communicate with decision makers. A successful GIS implementation must communicate with all stakeholders, offer proper training to different user groups, and design an organizational structure to facilitate data sharing and workflows across different units.

Even if an implementation plan suggests that GIS can improve the current system, the costs associated with a GIS implementation may outweigh the potential benefits. Cost-benefit analysis

is a method available for an organization to compare the expected costs with the expected benefits before executing a GIS implementation plan. Finally, GIS is a rapidly evolving technology, and user needs may change over time. A successful GIS implementation must be able to make necessary adjustments to the changing technology and organizational needs.

Shih-Lung Shaw

See also [Business Models for Geographic Information](#); [Geographic Information Systems](#); [Geoslavery](#); [Geospatial Industry](#); [GIScience](#); [GIS Design](#); [GIS in Archaeology](#); [GIS in Disaster Response](#); [GIS in Environmental Management](#); [GIS in Health Research and Health Care](#); [GIS in Land Use Management](#); [GIS in Local Government](#); [GIS in Public Policy](#); [GIS in Transportation](#); [GIS in Urban Planning](#); [GIS in Utilities](#); [GIS in Water Management](#); [GIS Software](#); [Spatial Data Integration](#); [Spatial Data Models](#)

Further Readings

- Huxhold, W., & Levinsohn, A. (1995). *Managing geographic information system projects*. New York: Oxford University Press.
- Obermeyer, N., & Pinto, J. (2008). *Managing geographic information systems*. New York: Guilford Press.
- Tomlinson, R. (2007). *Thinking about GIS: Geographic information system planning for managers*. Redlands, CA: ESRI Press.



GIS IN ARCHAEOLOGY

Since its origins in the 19th century, the modern discipline of archaeology has been based on an understanding of spatial phenomena at a range of interconnecting scales. Whether plotting distributions of artifacts and structures across a site or sites within a landscape, spatial relationships have been fundamental to thinking about past human lives and about social structures and relationships. Archaeology has also had a long and fruitful relationship with geography through the exchange of



methods, techniques, and theoretical approaches; and it is not surprising, therefore, that geographic information system (GIS) technology was rapidly adopted by archaeology and has formed the basis of much analysis since the early 1990s.

The use of GIS in archaeology can be broadly divided into the two areas of cultural resource management (CRM) and landscape archaeology. Most countries have national or regional inventories of archaeological and historical sites and monuments often integrated into development legislation and planning control. Traditionally, these records have consisted of information about archaeological sites tied to maps and so are ideally suited to GIS technology. One of the strengths of GIS is the ability to integrate and manage large amounts of diverse data, and that capacity is well demonstrated within CRM, where written information, map data, and various types of images all need to be readily available for a specific place to respond rapidly to a development threat. Another aspect of CRM, one that is particularly important in North America, is the predictive modeling of the location of archaeological sites. GIS is used to analyze the locations of known sites and produce predictive maps that indicate where sites may be found, a procedure of great value when large areas of landscape cannot be surveyed and evaluated through fieldwork. In many countries, the move toward online CRM databases is well under way, enabling easier public access.

Much archaeological work these days is conducted at the landscape scale, and an interest in *landscape*, often a rather vague and contentious term that can involve a range of different approaches and understandings, is something that unites today's archaeology and geography. Again, the data sets used here can be large and diverse, consisting of various surveys, including aerial photographic, geophysical, and surface walking and earthwork details, as well as environmental information and targeted excavation. GIS technology is now considered essential to correlate and manage all these georeferenced data together with the attribute data sets that link with them. Archaeology is not just about gathering data, although this is an important aspect of most archaeologists' work, and many field-based data these days originate as digital information ("born digital"), so inputting it into a GIS is part of the

process. Once collected, data have to be analyzed and presented as an interpretation of some aspect of past people's lives.

The adoption of GIS in archaeology in the early 1990s was not entirely uncontroversial and has generated considerable debate, again similar to that within geography. A popular early use of GIS was to model the "catchment" areas of archaeological sites, using buffering to try and establish their areas of economic control. Another was the modeling of site territories and hierarchies using Thiessen polygons and the principles of central place theory. Although still occasionally used, with some interesting results, these were generally criticized as being environmentally deterministic, and, so it was argued, such models were rooted in a mode of positivist interpretation that underwent severe criticism by the developing postmodernist archaeology of the late 1970s and early 1980s. The response by GIS-using archaeologists was to try and develop approaches that humanized the modeled landscape by attempting to position the analyst within it, the two most popular areas of work being visibility and movement studies.

An essential aspect of both visibility and movement modeling is the use of a digital terrain model (DTM), which is a cell-based representation of altitude and, therefore, a model of the topography. Visibility modeling uses line-of-sight and the more encompassing viewshed to try and establish the visibility characteristics of an area of landscape. Archaeological sites can then be explored to see which are intervisible, which landscape features are visible from particular places within a site, and a whole range of other possible visibility relationships that may help the understanding of how people lived in and used those places in the past. Recent work on visibility has attempted to move beyond the simple binary viewshed (is something in view or not?) to model more subtle understandings of how visibility is affected by distance, direction, and other factors. Similarly with movement, either linear cost paths, from a given start and to a given end point, or a cost surface can help think about how people moved across and accessed various landscapes. The "cost" of moving can be modeled using slope and/or other environmental variables such as ground cover and/or cultural variables such as



not wanting to go near cemeteries or other taboo places. The combination of visibility and movement has gone some way toward enabling the understanding of past landscapes.

At a very different scale, GIS is also now often used for excavation recording, where individual pits, ditches, postholes, and other structures are digitally planned, and the artifacts contained within them are linked through the database. Because GIS is multiscalar, individual site plans can be integrated into wider landscape studies so that a wealth of detail can be accessed at both the landscape and the site scale. Archaeology is a discipline that has the understanding of space at its core, and the tremendous power and flexibility of GIS goes a long way toward meeting its spatial needs.

Gary Lock

See also **GIS Implementation; GIS in Environmental Management; GIS in Land Use Management**

Further Readings

- Chapman, H. (2006). *Landscape archaeology and GIS*. Stroud, UK: Tempus.
- Lock, G. (2003). *Using computers in archaeology: Towards virtual pasts*. London: Routledge.
- Wheatley, D., & Gillings, M. (2002). *Spatial technology and archaeology: The archaeological applications of GIS*. London: Taylor & Francis.



GIS IN DISASTER RESPONSE

Geographic information system (GIS) technology is used in many phases of disaster management, principally for risk mitigation information and damage assessment, as a tool for supporting decisions during the impending crisis, for sharing information, and as a basis for emergency plans. It should be noted in advance that while rescue, relief, and recovery are aimed at coping with the crisis, reconstruction and preparedness should be devoted to the mitigation of possible future disasters in terms of realization of adequate settlements and community innovations. Currently, the potential, performances, and presence of GIS

in all disaster phases are expanding. This has emerged because GIS potential is fostered in combination with ubiquitous information and communication technologies, the increasing availability of geospatial technologies (e.g., the Spatial Video Acquisition Systems, global positioning systems [GPS] incorporated in mobile phones, Google Earth imagery), and the number of hazard data sets. The use of GIS in disaster response is also expanding because of the increasing number of disastrous events and the various sources of such disasters (natural, technological, security) in current societies.

Examples of GIS in Disaster Response Phases

In the first stage of the response phase, GIS can assist decision makers in understanding the scope of the damage; analyze critical infrastructures for health services, food and goods supply, and transportation routes for potential evacuation and operations management; identify suitable locations for rescue officers and civil protection command posts, in case these areas have not yet been identified in emergency territorial plans; identify locations where people may be trapped or require rescue and medical assistance; and identify shelters and possible camps for refugees.

In the recovery phase, GIS can identify locations and best paths for obtaining and delivering supplies, communicate with people to reduce their sense of uncertainty on the condition of their homes and rescued people, and keep participants informed about the status of operations. If the disaster persists, GIS can assess and model the secondary effects of the event to warn people and organize a public safety response. GIS can produce mapping for the media, communicate the extent of damage, and enable field operations for outsiders. GIS can produce maps and documentation for all responsible levels of public safety in both logistical and financial resource support.

During the reconstruction phase, GIS can be used to support decision making and monitor land planning and to redefine hazard zones and distribution of risks both equal and unequal across various residents.



During the preparedness phase, GIS-based applications may include indicators of vulnerability at specific places, early warning systems, and systems to ease emergency response as well as community learning, simulations with citizens to build their awareness, communicating risk and proper behavior, and also receiving data and information from citizens.

In all stages, GIS can help track, assess, and visualize the status of the response and of relief and recovery efforts.

Criticisms and Further Development

Although GIS developments in disaster response have been noteworthy, there are weaknesses that ought to be overcome if further development is to follow. Some criticism comes from recent experiences with disaster management in the United States and abroad. It has been noted that during the emergency response phase of rescue and relief, the majority of first responders are not sufficiently familiar with GIS, nor are they likely to use GIS tools in the immediate rescue phases. In this regard, the major criticism of GIS involves the lack of intuitive user interfaces and the need for widespread adoption of GIS among governmental entities to increase awareness and their willingness to adopt GIS tools. A second issue is the need to organize and deliver effective training in GIS use to personnel of government agencies involved in disaster preparedness, response, and management, so that spatial data and their derivatives become a common language for operations. Data quantity, quality, availability, integration, and interoperability are in many instances underdeveloped, thus hampering the effectiveness and increasing the time of the response. Especially for rural areas, some data sets important for disaster response often do not exist. There is an increasing need for integrated spatial data systems linking local georeferenced data with national spatial data and a need to provide updated data on local building inventories, geology, and critical infrastructure as well as better temporal and spatial estimates of tourists, homeless people, undocumented workers, and daytime populations. More research efforts should be invested in integrating physical processes and social models for

enhanced predictions of impacts. Another need relates to developing GIS workflows, enabling cooperation among agencies.

Some scholars have investigated the potential for using real-time 3D GIS for the implementation of intelligent emergency response systems to facilitate quick emergency response in multi-level structures (e.g., multistory office buildings). Others have pointed out that the postdisaster recovery phase has received little attention from the GIScience community, partly due to the difficulties in gathering data in a postdisaster environment. The GIScience community has to pay more attention to all scales of rebuilding and their spatial dimensions (individual, community, wider city, and regional scales) within a GIS environment.

Methods should include community-focused information dissemination as well as data archiving for comparative research among events and geospatial technologies, such as capturing GPS-encoded digital video for dynamic collection of recovery indicators, and they should provide mechanisms for spatial data to be shared in publicly accessible formats.

GIS should be used in a participatory fashion: not just communicating risk to a community but also integrating information about hazard and assets from citizens. Information sharing for decision support and risk communication can be enhanced by interactive mapping rather than static Web data portals.

Maria Paradiso

See also **Geographic Information Systems; GIS Design; GIS in Environmental Management; Humanistic GIScience; Internet GIS; Natural Hazards and Risk Analysis; Remote Sensing in Disaster Response**

Further Readings

Boyd, K. A., & Mills, J. W. (2007, May 17). GIS applications during response to Hurricane Katrina: Small, local government and state government experiences. *Directions Magazine*. Retrieved January 6, 2010, from http://lbs360.directionsmag.com/articles/index.php?article_id=2466



- Curtis, A., Mills, J. W., Kennedy, B., Fotheringham, A. S., & McCarthy, T. (2007). Understanding the geography of post-traumatic stress: An academic justification for using a Spatial Video Acquisition System in the response to Hurricane Katrina. *Journal of Contingencies and Crisis Management*, 15, 186–197.
- Cutter, S. L. (2003). GI Science, disasters, and emergency management. *Transactions in GIS*, 7, 439–445.
- Kar, B., & Hodgson, M. E. (2008). A GIS-based model to determine site suitability of emergency evacuation shelters. *Transactions in GIS*, 2, 227–248.
- Kwan, M. P., & Lee, J. (2005). Emergency response after 9/11: The potential of real time 3D GIS for quick emergency response in micro spatial environments. *Computers, Environment and the Urban Systems*, 29, 93–113.
- Mills, J. W. (2008). Understanding disaster: GIScience contributions in the ongoing recovery from Katrina. *Transactions in GIS*, 1, 1–4.



GIS IN ENVIRONMENTAL MANAGEMENT

Since the early 1970s, geographic information systems (GIS) have been used extensively in environmental management using spatially intensive and extensive databases in an integrated manner. The geographic database includes the collection of samples that are truly representative of any large irregular regions. These samples are turned into useful information to monitor environment that might otherwise be invisible. GIS works on the principle that by bringing together geographic data from different sources and using them in an integrated manner, proper communication among the public and policymakers becomes possible, enabling them to engage in complex environmental decision making. Simply put, GIS bridges the gap between the hard and soft sciences in environmental decision making. It plays a vital role in data validation, digital data transfer standards, and data retrieval, dissemination, and analysis. The evolution of spatial data standards, the

Internet, and the next generation of GIS technology will allow all types of users to access environmental information in its proper spatial context in a cost-effective manner. GIS can help deal with location issues and understanding why and how certain things happen at certain locations and how to allocate demand for services.

Though GIS use in environmental management started with the visualization of different layers in the late 1970s, today, it ranges from land surface analysis to emergency services such as forest fire prevention, to hazard mitigation and planning, monitoring air pollution and control, disaster management, precision farming and animal litter applications, human health issues, planning and managing natural resources, and assessing the environmental consequences of economic development. These applications of GIS involve hypothesis testing and geovisualization.

Other applications of GIS in environmental management that are related to land surface and subsurface include terrain modeling, mine exploration, land reclamation, and mapping areas of rehabilitation. Through the overlay of various thematic layers representing spatial distributions of environmental variables and the mathematical modeling changes in these variables, GIS helps in calculating and visualizing the spatial relationships of biophysical factors directly influencing the environment. Factors such as steepness of slopes, aspects, and vegetation density can be viewed and overlaid together to determine various environmental parameters and to conduct impact analyses. The integrated information system used in GIS leads to better decision making within the geographic framework through an understanding of how elements of the environment interact across a landscape. This understanding helps not only to display relationships among key variables but also to test hypotheses concerning, for example, the status of habitats, wetlands, water quality, channel characteristics, adjacent land uses, and natural features in an environment.

GIS applications touch all our daily activities; GIS links environment regulations with human day-to-day activities. Its use to monitor human-environment interactions results in the production of more effective, efficient, equitable, and predictable outcomes. For example, GIS is used in



the analysis of discharge contents of streams and rivers, hazardous substance tracking, landfill sites, waste transfer treatments, disposal sites, and enforcement and prohibition notices brought against organizations as per environment regulations.

In monitoring air and water pollution and in pollution control, disaster management GIS tools can be used in profiling pollution levels using pollution gradient maps. They are used to locate devastation sites and to estimate the amount of devastation. By using GIS, an analyst can rapidly map waste storage sites; describe the volume, content, and state of waste containers; retrieve previous inspection records to compare them with existing environmental conditions; and view environmental data in relation to adjacent geographic features such as waterways, neighborhoods, or other sensitive areas (e.g., high-risk zones for landslides) and in relation to local water pollution levels.

In precision farming, a field crew can use GIS in conjunction with a global positioning system (GPS) to accurately ground truth high-resolution satellite imagery to locate areas that need specific fertilizer applications and areas that need attention in terms of eutrophication. GIS also is useful to locate oil spills, volcanic activities, and their effects on the surrounding ecosystem. Digital information can be overlaid on aerial photographs or satellite images to provide environmental data analysts with familiar views of landscapes to enable them to reach a quick decision.

To monitor environmental problems, the assessment of hazards and risks becomes the foundation for decision making and for mitigation activities. GIS supports activities in environmental assessment, monitoring, and mitigation that can be used for generating environmental models. GIS can be employed to deal with issues of spatial error and uncertainty through the use of statistical modeling, fuzzy sets, and fractal analysis at different scales over time.

In planning and managing natural resources, GIS has been instrumental in inventorying and mapping vegetation across landscapes to better understand the nature of threatened and endangered species for scientific and management purposes. GIS maps are helpful for estimating forestry species stocks, monitoring land clearing, examining farming systems, and estimating carbon

sequestered by various plant species. Likewise, GIS helps farmers in performing site-specific spatial analyses of agronomic data, mapping and managing timber resources, and maintaining sustainable forest management. GIS is also useful in land valuation, timber market analysis, harvest route planning, and landscape visualization.

Despite the diverse uses of GIS in environmental management, there are challenges to a more extensive use of GIS technology, especially in Third World countries. Some of the notable problems include nonavailability of high-resolution spatial data; lack of a proper infrastructure, such as a working environment within government bodies; meager-skilled manpower in government planning and development departments; and expensive and unaffordable GIS software and hardware. Nonetheless, GIS technology will continue to play a vital role in environmental system management, and it will likely become the primary information repository, which can be quickly accessed and viewed when required. GIS is becoming more suitable for environmental management requiring real-time display of information. In conclusion, GIS helps rapidly access information for safe, efficient, and sustainable environmental management and decision making.

Keshav Bhattarai

See also [Environmental Management](#); [GIS in Disaster Response](#); [GIS in Land Use Management](#); [GIS in Water Management](#)

Further Readings

- Aronoff, S. (2005). Introduction: Remote sensing and GIS. In S. Aronoff (Ed.), *Remote sensing for GIS managers* (pp. 1–7). Redlands, CA: ESRI Press.
- Burrough, P. A., & McDonnell, R. A. (2000). *Principles of geographical information systems*. New York: Oxford University Press.
- Chang, K. (2010). *Introduction to geographic information systems* (5th ed.). Columbus, OH: McGraw-Hill Higher Education.
- Demers, M. N. (2003). *Fundamentals of geographic information systems* (2nd ed.). New York: Wiley.



Environmental Systems Research Institute. (2009). *GIS for environmental management*. Retrieved June 10, 2009, from www.esri.com/industries/environment/index.html

Langley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science* (2nd ed.). New York: Wiley.

Wulder, M., Hall, R. J., & Franklin, S. E. (2005). Remote sensing and GIS in forestry. In S. Aronoff (Ed.), *Remote sensing for GIS managers* (pp. 351–356). Redlands, CA: ESRI Press.



GIS IN HEALTH RESEARCH AND HEALTH CARE

A burgeoning area within the subdiscipline of medical geography, research on geographic information systems (GIS) and health has increased dramatically in recent years. Importantly, the use of GIS in health research has become common in areas outside geography, including public policy, public health, health informatics, and biomathematics, and in medical and nursing schools. GIS techniques are now embedded in health surveillance systems and are used to produce cartographic representations of disease distributions and patterns. In the arena of analysis, pattern and cluster analysis have been the primary techniques employed in most published research in GIS and health. Finally, cutting-edge GIS and health projects are experimenting with participatory GIS methods to improve simulated pandemic responses and early warning systems and to promote the adoption of critical perspectives within work on health and GIS.

Surveillance Systems and Emergency Management

Electronic tracking of infectious disease and environmental public health has become commonplace in much of Western Europe and is increasingly a part of public health practice in the United States. Figure 1 illustrates infectious disease tracking systems before and after electronic

documentation was implemented in the state of Florida. Essentially, health workers can now quickly access and analyze spatial information on infectious diseases. With the emergence of health digital surveillance systems, techniques for ethically masking sensitive individual data have been developed, as have mechanisms to communicate spatial distributions of a disease over the Internet. Emergency management systems have also made significant inroads in incorporating GIS in all emergency vehicles. Using GIS for deciding new hospital and clinic locations and assessing accessibility to care is now ubiquitous.

Cartographic Visualization

Some of the earliest work in medical geography has involved mapping diseases and their environmental correlates. Historical and modern atlases facilitate spatial pattern analysis and inquiry. Several federal and state health agencies now provide Internet atlases, a few of which maintain real-time or close to real-time information.

Pattern Analysis

Many innovations in the area of spatial analysis have risen in response to public health challenges, particularly in identifying significant evidence for the spatial clustering of cancer. Several specific GIS applications have been developed for the investigation of pattern analysis in health data, including GeoDa and SaTScan. Such tools help prioritize areas for funding and help direct targeted public health programs. As data specificity has expanded from general regions, such as counties, to exact residences and places of work, a number of simulation techniques, including agent-based modeling, propose to model the human-to-human diffusion of infectious diseases. These simulations suggest strategies for rapid response in the form of selective urban quarantines in the event of a pandemic, such as the highly anticipated influenza pandemic.

Early Warning and Prediction Systems

Several early warning systems predict the diffusion of disease vectors, such as mosquitoes (in

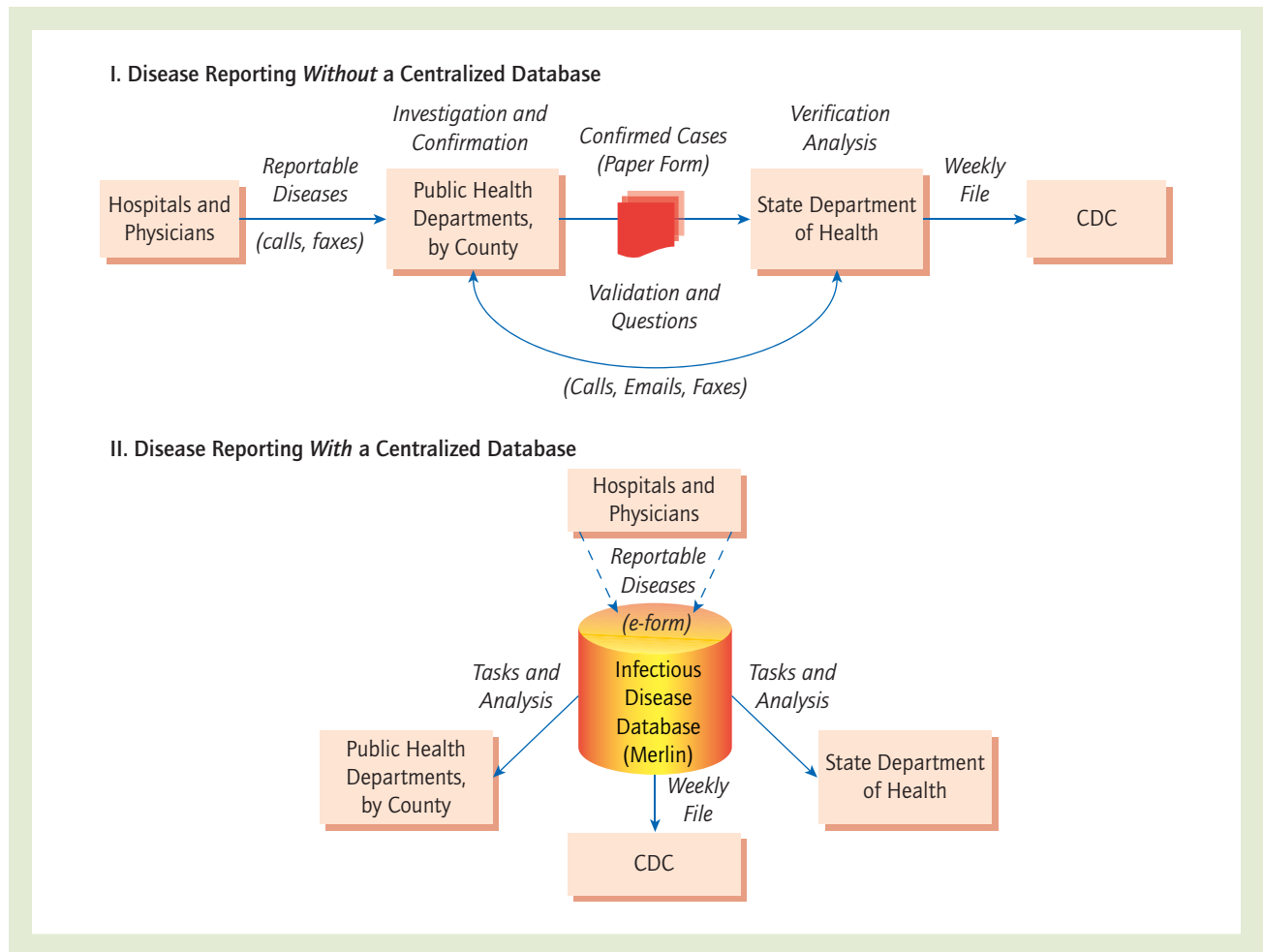


Figure 1 Chain of infectious disease reporting before and after digital database usage

Source: Adapted from Gutierrez, J. B., & Loomis, C. (2006). *Infectious disease reporting: GIS for health decisions*. Paper presented at the Seven Hills Regional User Group Workshop, Tallahassee, FL, November 15–16.

anticipating West Nile virus, dengue fever, and malaria cases) and tsetse flies (in trypanosomiasis cases). These early warning systems rely on GIS and remote sensing to detect changes in the environmental correlates of vector habitats (vegetation, humidity, rainfall, and temperature). For diseases in which the diffusion patterns are less clear, such as meningitis, environmental correlates (such as proxies for the level of dust in the air) are being used to predict outbreaks. Last, although they are more than a decade in the making, early warning systems for famine continue to be developed by integrating spatial population data, information on livelihood zones, and

environmental correlates such as rainfall, temperature, and crop yield.

Adoption of Critical Perspectives in Health and GIS

Scholars and public health practitioners increasingly choose to adopt public participation GIS techniques to promote community alliances with public health departments, particularly to investigate environmental health and justice concerns. Of specific priority, many GIS and health projects seek to raise awareness of health differences



across racial and ethnic groups, between men and women, and within countries, states, and cities. Mapping of geographic disparities in life expectancy and quality and access to health care highlights the disadvantage for populations living in the southeastern United States experiencing the highest mortality rates. The geographic disparities are so remarkable that the reduction of such differences has become a stated goal of the federal initiative Healthy People 2010. Travel logs, combined with photographs and narratives, have been mapped as a way to complicate and enrich traditional GIS techniques that seek to understand spatial patterns of inequities in health. GIS assessment of access to not only health care but also healthy food sources, recreation, and green space contributes significantly to research on obesity in urban settings. Health metrics, especially infant mortality and child malnourishment, have been used to critique the strictly economic metrics of development and now appear widely in atlases and development reports.

Lisa Jordan

See also **Critical GIS; GIScience; Health and Health Care, Geography of; Medical Geography**

Further Readings

- Albert, D. P., Gesler, W. M., & Levergood, B. (2000). *Spatial analysis, GIS, and remote sensing applications in health sciences*. Chelsea, MI: Ann Arbor Press.
- Anselin, L. (2007). *GeoDa: An introduction to spatial data analysis*. Retrieved December 4, 2008, from www.geoda.uiuc.edu
- Cromley, E. K., & McLafferty, S. (2002). *GIS and public health*. New York: Guilford Press.
- Gatrell, A. C., & Löytönen, M. (Eds.). (2003). *GIS and health* (GISDATA Series, 6). London: Taylor & Francis.
- Kulldorff, M. (2005). *SaTScan: Software for the spatial, temporal, and space-time scan statistics*. Retrieved December 4, 2008, from www.satscan.org



GIS IN LAND USE MANAGEMENT

Land use refers to the various ways in which land may be employed for human or other activities. Inventorying, classifying, and analyzing land resources and their use have always been important themes in applied geographical research, with significant implications for urban, rural, and regional planning activities. The use of geographic information systems (GIS) and related geospatial technologies in land use management is both well established and diverse, with widespread applications related to agriculture, forestry, wildlife, outdoor recreation, energy development, transportation, and urbanization. GIS applications in land use management vary in terms of function from inventory and mapping to suitability analysis and spatial decision support.

Land Use Inventory and Mapping

The first “named” GIS—the Canada Geographic Information System (CGIS), pioneered by Roger Tomlinson in the mid 1960s—was, in fact, part of the Canada Land Inventory, largely undertaken to address the need for improving national land use policies. In addition to the CGIS, other prominent North American examples of GIS-based inventory and mapping from the 1960s include the Minnesota Land Management Information System and New York’s Land Use and Natural Resources Inventory System. These efforts were all significant in their pioneering use of digital computers to store, manipulate, update, and display geographically referenced land use data and integrate it with other types of similarly mapped environmental and socioeconomic information.

In the 1970s, the U.S. Geological Survey (USGS) undertook a nationwide inventory of land cover and land use for the development of a remote sensing-based series of intermediate-scale map products. To address the data management and analysis challenges of such a large undertaking, the Geographic Information Retrieval and Analysis System (GIRAS) was developed. In addition to producing computerized cartographic output, GIRAS also supported storing and querying



NRCS employees digitizing soils for soil survey information. Digitized layers are used in GIS.

Source: Bob Nichols, USDA Natural Resources Conservation Service.

hierarchical land use attributes representing multiple levels of mapping detail.

Another, more recent example of a GIS-based land use data inventory was the digitization of soil surveys by the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS). Initiated in the early 1990s and designed for use by landowners and local government managers, this effort resulted in highly detailed and richly attributed county SSURGO GIS databases and the more generalized state-level STATSGO products.

Today, GIS-based land use inventory and mapping activities are widespread in state and federal land management agencies as well as local tax assessment departments and planning offices. Combined with land ownership (i.e., cadastral) data, such specialized GIS is sometimes referred

to as *land resources information systems*, or simply *land information systems*.

GIS-Based Land Use Suitability Analysis

Land use suitability analysis involves identifying the most appropriate geographic pattern for future land use activities. Contributing factors may include both the fitness of the land for particular uses as well as the cultural and socioeconomic values and interests of the individuals, groups, and/or organizations involved. GIS-based methods for land use suitability analysis are historically tied to the concept of hand-drawn overlay mapping in landscape architecture, applied first as "sieve mapping" techniques in the late 1800s and early 1900s and advanced with Ian McHarg's ecological inventory process in the 1960s.



In the 1960s and 1970s, computer-assisted overlay techniques were developed to address the cartographic and data management limitations of manual overlay mapping methods. Many of these advancements were associated with the development of pioneering cartographic modeling software applications by Carl Steinitz and others at Harvard University's Laboratory for Computer Graphics.

As GIS continued to evolve in the 1980s, the "map algebra" concept formalized by C. Dana Tomlin at Harvard and Yale became the basis for much of the GIS-based land use suitability modeling that continues today. With map algebra, mapped data layers are overlaid or combined in equation-like fashion using operations such as "add," "subtract," and "multiply." Common types of map algebra overlays include union operations—where conditions for only one input datum must be met; intersection operations—where conditions for all input data layers must be met; and weighted linear combination functions—where weights of relative importance are assigned to various input data layers and then combined to generate an overall suitability score layer output.

Spatial Decision Support

In general, spatial decisions are those in which geographic conditions either influence, or are influenced by, the decisions being made. Spatial decisions are inherent in management of land use. As GIS became more directly accessible to planners, managers, and decision makers in the 1990s, the technology and its associated geographic methods were more widely applied to support spatial decision-making activities, including those involving land use. The most common approach has been the weighted linear combination (WLC) method of combining (i.e., overlaying) multiple thematic decision factor data layers to identify suitable or unsuitable locations for future land use allocations. While relatively easy to parameterize and generate results, WLC methods have been criticized for not addressing the assumptions inherent in weighting procedures and the potential interdependency among input factors, often oversimplifying solutions for complex situations.

To address concerns with standard map algebra methods such as WLC and to better incorporate stakeholder value judgments in decision processes, multiple-criteria decision-making (MCDM) methods have increasingly been integrated with GIS-based land use management analysis and decision making. Additional spatial decision support approaches may be categorized as indicator-based scenario evaluations or as artificial intelligence methods, including fuzzy logic techniques, neural networks, genetic algorithms, and cellular automata and related agent-based methods.

Other Applications and Future Prospects

Challenging land use management issues continue to foster further advancements of GIS technology and its application, especially in the areas of data development and software accessibility. For example, land use inventories are improving in terms of completeness, accuracy, and timeliness as a result of more standardized and higher-resolution remote sensing programs and platforms. Furthermore, the evolution of Web-based GIS has both increased the accessibility and use of data and provided for wider public participation in land use decision-making processes.

Jeffrey D. Hamerlinck

See also **GIS in Environmental Management; GIS in Urban Planning; GIS in Water Management; Land Use Analysis; Land Use and Land Cover Mapping; Remote Sensing; Resource Mapping; Spatial Decision Support Systems**

Further Readings

- Bojorquez-Tapia, L. A., Diaz-Mondragon, S., & Ezcurra, E. (2001). GIS-based approach for participatory decision making and land suitability assessment. *International Journal of Geographical Information Science*, 15, 129–151.
- Collins, M., Steiner, F., & Rushman, M. (2001). Land-use suitability analysis in the United States: Historical development and promising technological achievements. *Environmental Management*, 28, 611–621.



Hill, M., & Aspinall, R. (Eds.). (2000). *Spatial information for land use management*. Amsterdam: Gordon & Breach.

Malczewski, J. (2004). GIS-based land-use suitability analysis: A critical overview. *Progress in Planning*, 62, 3–65.

Ventura, S., Miller, T., & Barry, G. (2003). Community engagement in land use planning through Web-based technologies. In S. Geertman & J. Stillwell (Eds.), *Planning support systems in practice* (pp. 87–98). Berlin, Germany: Springer.

GIS IN LOCAL GOVERNMENT

Geographic information system (GIS) technology in local government has been implemented to support many government functions, and its use is expanding every day. GIS implementation at the local level depends on several factors. These factors and functions are described in more detail below.

Distributed Versus Centralized Environments

A local government GIS may be implemented in either a distributed or a centralized environment. In the distributed environment, GIS exist in different departments, each of which provides tools and analysis for their own use. In the distributed environment, practitioners may share all, some, or none of their data between departments. In the centralized environment, most spatial data are provided on a common platform for storage and dissemination that adheres to standards set by the jurisdiction. A centralized environment accommodates the workflows of multiple departments, establishes responsibilities for individual data themes, and avoids the duplication of efforts by separate departments with the trade-off being the cost of compromise in the development of a standardized data frame and the loss of individual control over data. Although a local government may have a centralized implementation of GIS, it does not always mean that *all* spatial data are

stored in a central repository. There may be issues associated with certain data themes that prevent them from being stored with the jurisdiction's centralized data. Examples are data pertaining directly to law enforcement, health and human services, or homeland security.

Department Location and Staff

GIS may fall under the purview of the information technology department, may be an independent department, or may exist under another department, such as Planning or Public Works. GIS is data and technology resource intensive, use a variety of software, and contain applications for internal and external (public) use. Each jurisdiction must examine its needs and organizational capacity to best locate the management of their GIS.

GIS implementation at the local level often depends on the size of the jurisdiction. Large jurisdictions typically have a more centralized system with support from programmers, IT staff, and administrators. In small jurisdictions, the GIS staff is usually composed of one or two people who perform all functions in support of their GIS instance.

GIS Functions and Applications at the Local Level

GIS in local government supports many different governmental functions.

Public Facility and Infrastructure Management

In 1999, the Government Accounting Standards Board made changes to the way infrastructure must be tracked and accounted for. This standard is commonly referred to as GASB34. As a result, many local governments moved to asset management systems that interface with GIS, to create a current inventory of assets and their locations. Integrating asset management with GIS has given governments the ability to more efficiently manage their work orders, assess areas for capital improvements, track infrastructure conditions, assist with budget projections, and



improve customer service through online mapping applications.

Planning and Zoning

The maps and associated data are used visually or through models to assess current and future needs. Frequently, this information is then used in GIS-based transportation models to assess what transportation infrastructure might be needed to support land use changes. Some governments have made this information available through online mapping applications that citizens can use to identify the zoning regulations for specific properties or that businesses can use to site new locations. In addition, GIS is used to track building permits and business licenses so that planners can assess the types of activities that are taking place in various neighborhoods.

Emergency Services and Law Enforcement

Computer-aided dispatch (CAD) systems use GIS to route personnel to incident locations. GIS analysis is used to identify what fire stations would most appropriately serve individual properties and what infrastructure, facilities, or hazardous materials are within the vicinity of an incident. Evacuation routes can be generated through GIS. Law enforcement analysts use GIS to look at overall or specific crime trends, track individual criminals, and analyze the effects of streetlights or the local economy on neighborhood crime. During an incident, GIS is used to generate data and maps for decision makers and the media.

Environmental Management

Parks and recreation departments use GIS to identify the locations of parks, what functions they support, and specific maintenance requirements. GIS is also used to track agriculture and the types of crops that are grown, pests and pesticide management, water use and runoff, habitat management and mitigation, invasive weed locations and abatement, and air quality and to analyze energy use and potential solar radiation or wind production within the jurisdiction.

Health and Human Services

Health and Human Services (HHS) personnel use GIS to identify special needs and care facilities, hospitals, and clinics and to track disease outbreaks. Some local governments have GIS-based self-registration Web sites that allow individuals with special needs to identify themselves and what services they might need, such as power during an emergency or assistance required for evacuation.

Public Information and Education

Many local governments have set up online mapping applications that provide a visual tool that allows the viewer to see not just a location on a map but also information associated with that item or location. More and more local governments are opening their GIS to allow public input. Local governments are creating applications that ask the public to input the location of items of interest, such as city trees, streetlights, potholes, or storm drains. Some local governments have made the results of urban planning or habitat models available for public comment; others have made models within their applications that allow the citizens to alter model parameters and offer their own interpretations of what is needed in their community. Such interactive GIS applications can lead to a better-educated public, who more fully understand the parameters and the trade-offs that are part of the policy decisions under consideration.

No matter how implemented, the adoption of GIS has allowed local governments to improve their workflows, better track their assets and work orders, enhance public health and safety, and enhance their understanding of their decisions on the surrounding environment.

Paul E. Hardwick

See also **GIS in Disaster Response; GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Public Policy; GIS in Transportation; GIS in Urban Planning; Spatial Decision Support Systems**



Further Readings

- Fleming, C. (Ed.). (2005). *The GIS guide for local government officials*. Redlands, CA: ESRI Press.
- Maantay, J., & Ziegler, J. (2006). *GIS for the urban environment*. Redlands, CA: ESRI Press.
- O'Looney, J. (1997). *Beyond maps: GIS and decision making in local government*. Washington, DC: ICMA.
- Pamuk, A. (2006). *Mapping global cities: GIS methods in urban analysis*. Redlands, CA: ESRI Press.



GIS IN PUBLIC POLICY

Since the late 1980s, geographic information systems, or GIS, have become almost ubiquitous in public organizations and throughout the nonprofit sector. Over this period, geospatial capability has become essential. The powers of GIS, including the assimilation, analysis, and graphical display of large volumes of geographically coded (geocoded) information, are widely recognized. They are typically used for purposes such as managing planning and zoning, geodemographic service management, emergency response system optimization and path selection, targeted-facilities location, and many others. Much of the innovation has been driven by the use of GIS for private sector marketing and spillover functionality that public organizations have capitalized on. At the same time, some functional areas, such as more reflexive data capture for GIS using Internet applications, are being targeted by both academic researchers and public sector developers and practitioners.

But why does—or should—GIS matter for public policy? Normatively, this entry assumes that the purpose of GIS in public policy is to increase spatial justice, that is, the distribution of costs and benefits across regions, areas, and populations. This justification is often presented by public organizations charged with improving the quality of public goods allocation. As Paul Longley (2005) argues,

In policy terms, these developments [widespread adoption and use of GIS by governing institutions]

also arise out of greater recognition of the importance of preventative communications programmes (e.g., in health and policing) and the opportunity to improve efficiency by targeting them to those most at risk. (p. 59)

This entry presents a brief overview of significant trends within GIS literature in geography, planning, and critical GIScience literature and connects these with the public policy field. The range of public policy applications considered includes policy, environmental management, transportation and land use planning, and infrastructure design. Rather than presenting a laundry list of citations and examples of technical applications, this entry highlights several current trends in the deployment of GIS for public policy, to illustrate some technical developments that promise to increase functionality and to outline some structural impediments to the achievement of better spatial justice in public policy application.

Overview

A deep-rooted but rather thinly supported and almost ideological set of assumptions governing the utility and value for money of GIS generates significant enthusiasm among policymakers and government officials. Almost all the claims advanced in relation to public policy applications of GIS have focused on its potential to “improve” collaborative decision making in some way or another, either by including more stakeholder valuations and more data or by analyzing them in more effective ways, or both. Other advantages include supporting decision making and improving communication and collaboration. Improved spatial justice is imputed from this performance. The practical justifications offered by software vendors focus on efficiency. For example, the GIS developer and vendor ESRI (Environmental Systems Research Institute) lists 10 advantages of GIS for state and local governments, 5 of which involve revenue maximization or cost avoidance. Similar claims have been made by IT vendors with respect to their products for more



than 30 years. In this regard, as with most IT domains, even the more limited efficiency claims advanced by software vendors are hard to quantify because focused life cycle benefit-cost analysis does not exist. Indeed, in a 2002 survey of the public sector GIS user base, Gregg Kreizman found that 37% of respondents stated, “No financial analysis is used to justify GIS implementation.”

Nevertheless, a rather technotopian view of “efficiencies” associated with GIS adoption has acquired currency, at least among many public officials and organizations. These enthusiasms are evident in the wide-ranging presentation of GIS applications at conferences such as those of the URISA and ESRI. The size of this sector is clear from the magnitude of the annual ESRI User Conference, which is one of the world’s largest professional GIS gatherings: In 2008, it hosted 14,500 attendees. In the higher-education sector, GIS certificate programs have proliferated in response to the market developed by working professionals who wish to upgrade their skills and secure geospatial certification. Many participants are working in fields related to public policy. Undergraduate class offerings have expanded similarly, and in fields such as urban growth modeling and environmental management, there is a consciousness among students that a GIS credential is a strong asset in the job market.

Trends

Examining the broad sweep of the GIS field, three trends are evident. The first is the apparent democratization of GIS technology. In geography, researchers have coined terminology such as *public participation GIS* (PPGIS) or *participatory geographic information science* (PGIS). Methodologically, this democratization takes the form of efforts to allow more decentralized data definition, capture, and input to GIS databases, for example, to encourage recreational users and stakeholders to define their areas and types of use with the intent of developing more inclusive and reflexive management policies for common resources such as national parks. This involves researching improvements in the way geospatial data are thought of and handled. These projects

have sometimes entailed community factions at loggerheads with public offices, and there is little doubt that these uses of GIS have modified the way in which public policy is developed and managed using GIS.

A second significant trend is the convergence of geospatial technology with (geo)visualization, particularly real-time visualization and virtual reality display modes. GIS vendors compete to add real-time visualization capacities to their platforms and to facilitate interoperability with high-end rendering and graphical packages, allowing pseudorealistic visualization of urban environments with geocoded data such as parcel boundaries and locations. CommunityViz and WhatIF? seek to increase analytic functionality. At the local or urban scale, planning support systems are one of the most high-profile types of GIS application to public policy.

A third trend is improved accessibility with respect to geospatial information, both upstream and downstream. This accessibility enhancement is conceived in physical terms such as miniaturization and overhead reduction; palmtop devices and mini laptops, without full functionality, have spurred the development of software such as ArcPad, allowing a subset of GIS operations to be performed on the road. Accessibility is also enhanced through new media dissemination systems, such as integrated Web delivery of geospatial and visualization data, permitted by increasingly interoperable GIS/database and visualization software. Nevertheless, Web functionality is still extremely limited. For example, although GIS output is displayed in real time on MapQuest in response to user queries, the capture, geocoding, and upload of spatial information from users are still not feasible without specialized equipment. Once their GIS divisions exceed a certain size, authorities in any case tend to develop and maintain proprietary geospatial databases.

Applications and Impact of GIS in Public Policy

Despite efforts to reduce their resource overhead, GIS platforms remain rather cumbersome and inaccessible. As Peter Kwaku Kyem (2004) notes,



Short of a conscious effort to ensure equal participation, those participants who have prior knowledge of the conflict situation, those with some experience of spatial data analysis, or those close to positions of power would dominate the discussion and alter the results. (p. 52)

This situation is worse in larger-scale public policy questions, where the networks of control are more complex and diffuse and the objectives of GIS deployment vary between stakeholders. As the scale and social complexity of the problem domain increase, public policy applications of GIS become less successful. Even at the urban scale, problems exist. Raul Lejano, for example, argues that GIS use in local planning “increases alienation.” Compared with PPGIS applications, which typically are organically driven by local neighborhood participants and groups to address their concerns and which operate at relatively small spatial scales, the structural problems of power are, if anything, exacerbated by GIS in public policy applications. These problems involve multiple actors.

The impact of GIS on public policy has been clearest in public service delivery involving clearly focused public goods applications such as epidemiology or emergency service provision. This is accounted for by the knowledge structure within which these are used: Technical experts and GIS analysts play a significant role in deciding how to define and harvest information and then to geocode and analyze it. Performance criteria in these focused applications are clearly defined: to minimize the response time of environmental management systems (EMS), for example, subject to certain system constraints.

In the mid 1990s, a strongly critical current of thought emerged among geographers and others concerned with the uncritical and sometimes exuberant application of GIS to social, environmental, and economic problems. In public policy, if not in marketing and private sector applications, it might appear that the systems’ potential as a panopticonic technology is checked to some degree by various laws and requirements that constrain the offices and departments that use GIS. But the social reflexivity with which the systems are deployed is typically limited. For example, although GIS may be used for the management

of large-scale public lands by federal bureaus, it is not clear how stakeholder knowledge is incorporated into the decision system. And not all public policy and planning uses of GIS to increase transparency are welcomed by community members. Residents in one local community, for example, were shocked to discover that the local county assessor’s office had, in the process of GIS and property assessment database integration, offered online access not only to the purchase price of their houses but also to their purchase deposit percentages.

Moreover, GIS can only influence public policy to the extent that political ideology permits. The predilections of system managers may, or may not, accord with the stated goals of the offices within which they work. Even with the best will, making the rather exclusive and cumbersome GIS software more socially responsive is not an easy task. Large volumes of data are stored on secure servers, and the actual functionality of the system is managed by departments within local government.

In one example, a large-scale highway-routing project, an analytic method for integrating disparate social, environmental, and human factors into a participatory geospatial decision platform based on ArcView was developed. Having run the model and analyzed the output, the responsible officials were concerned that the routings did not accord with their notions of where the line should be. The lowest net social cost corridors proposed by the GIS-based multicriteria model were considered inappropriate, and the recommendations were not implemented; and the original analytical team moved to other projects. After some years of fits and starts, with various phases of decision making, opposition, resistance, and realignment, the actual routing of this project followed closely the original solution corridors proposed by the model. Given that the original decision criterion was that the system was designed to minimize net social impedance by integrating a broad range of decision criteria generated by a range of stakeholders, this is not surprising.

In the past few years, geographers have applied postructuralist Foucauldian and Latourian analyses of the nature of power in complex, multi-stakeholder systems. The advantages of this



approach include a more nuanced and complex notion of how power flows and how GIS and geovisual technologies fit within this power structure as active agents. This allows researchers to understand more clearly the barriers to implementation in a more geopolitical context and therefore gives insight into how and why GIS fails to realize its potential in terms of increasing stakeholder input quality. These analyses help clarify the differentials between the stated spatial justice improvement objectives and the mundane nature and contingency of organizational practices that, often, confound the will of participants and sponsors. Unfortunately, without large-scale and meaningful GIS applications in the field of public policy to refer to, it is hard for academics to legitimate these critical analyses in ways that work to improve policy over the medium term.

It is not necessary to be a formal technoskeptic, as perhaps some critical GIS and society theorists have appeared to be, to be wary of, and unconvinced by, some of the more optimistic assertions. Nor is it necessary to be such a technoskeptic to know that the core premise of improved spatial justice cannot be assessed readily because the indicators of performance such as “improved collaboration” or “better stakeholder understanding” are not even defined, much less measured and published. In this respect, some argue that the rather utopian promise of GIS, like that of much technology, remains at best largely unrealized and at worst is being undermined by the deployment of these systems within anti- or nondemocratic and non-transparent power structures. For critical theorists of GIS in public policy, seeking to improve the quality of public participation, and ultimately the justice, sustainability, and durability of collaborative decision making, the way forward may include a closer coupling of theories of power with geospatial analyses. It is important to understand how uncritical notions of democracy, consensus, fairness, and justice erode, or even confound, the promise of increased transparency, inclusion, and equity that technotopian advocates believe GIS holds. Beyond learning from this work, it is even more critical for geographers, planners, and other critical theorists of GIS to find ways to influence GIS and public policy in the interests of spatial justice by

establishing a meaningful dialogue with those who deploy the systems in daily use.

Keiron Bailey

See also GIS in Disaster Response; GIS in Health Research and Health Care; GIS in Local Government; GIS in Transportation; GIS in Urban Planning; GIS in Utilities; GIS in Water Management; Public Participation GIS; Spatial Decision Support Systems

Further Readings

- Andrienko, G., Jankowski, P., Keim, D., Kraak, M.-J., Maceachren, A., & Wrobel, S. (2007). Geovisual analytics for spatial decision support: Setting the research agenda. *International Journal of Geographical Information Science*, 21(8), 839–857.
- Brail, R., & Klosterman, R. (2001). *Planning support systems: Integrating geographic information systems, models and visualization tools*. Redlands, CA: ESRI Press.
- Elwood, S., & Ghose, R. (2003). Public participation GIS and local political context: Propositions and research directions. *Journal of the Urban and Regional Information Systems Association*, 15, 17–24.
- Environmental Systems Research Institute. (2008). *GIS for state and local government*. Retrieved July 30, 2008, from www.esri.com/industries/localgov/business/roi.html
- Geertman, S. (2002). Participatory planning and GIS: A PSS to bridge the gap. *Environment and Planning B: Planning and Design*, 29, 21–35.
- Greene, R. (2000). *GIS in public policy: Using geographic information for more effective government*. New York: ESRI Press.
- Grossardt, T., Bailey, K., & Brumm, J. (2001). AMIS: Geographic information system-based corridor planning methodology. *Transportation Research Record*, 1768, 224–232.
- Jankowski, P., & Nyerges, T. (2001). *Geographic information systems for group decision making: Towards a participatory geographic information science*. London: Taylor & Francis.
- Jankowski, P., Nyerges, T., Robischon, S., Ramsey, K., & Tuthill, D. (2006). Design consideration and evaluation of a collaborative, spatio-temporal decision support system. *Transactions in GIS*, 10(3), 335–354.



- Kreizman, G. (2002, December 3). *U.S. public sector GIS survey: Key issues and trends* (Gartner Research Strategic Analysis Report). Retrieved January 21, 2010, from http://ontogeo.ntua.gr/nagii/US_Public-Sector_GIS_Survey.pdf
- Kyem, P. (2004). Of intractable conflicts and participatory GIS applications: The search for consensus amidst competing claims and institutional demands. *Annals of the Association of American Geographers*, 94(1), 37–57.
- Lejano, R. P. (2008). Technology and institutions: A critical appraisal of GIS in the planning domain. *Science, Technology and Human Values*, 33(5), 653–678.
- Longley, P. (2005). Geographical information systems: A renaissance of geodemographics for public service delivery. *Progress in Human Geography*, 29(1), 57–63.
- Nedovic-Budic, Z. (1998). The impact of GIS technology. *Environment and Planning B: Planning and Design*, 25(5), 681–692.
- Sieber, R. (2003). Public participation geographic information systems across borders. *The Canadian Geographer*, 47(1), 50–61.



GIS IN TRANSPORTATION

Geographic information system (GIS) technology is often used in improving transportation. Transportation applications of GIS, also referred to as *GIS-T*, are popular and extensive in scope. Transportation problems range from day-to-day operations (in-vehicle global positioning system [GPS] navigation, the North American E-911 emergency response system) to large-scale efforts (prioritizing policy alternatives, long-range transportation planning) by metropolitan planning organizations. This entry reviews the policy contexts and market forces that influence the way institutions approach transportation problems. Then, data models and operations (with a focus on analysis and modeling) unique to GIS-T are reviewed.

Policy-wise, the span of policy goals has stretched from improving efficiency and mobility (e.g., the interstate highways) to embracing sustainable development, including mitigating

negative externalities (e.g., air pollution, safety, congestion), as indicated in the passage of legislation such as the Clean Air Act, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), and the Transportation Equity Act for the 21st Century (TEA-21). Along with the changing policy context (as well as advances in geotechnology), GIS-T in the public sector has widened from the inventory of infrastructure and travel demand forecasting to Web-based public participation tools and decision support systems.

Market forces driven by advances in technology (e.g., the Internet, positioning technology, wireless sensor networks) are reshaping the way GIS handles transportation problems. They not only change the way geographic information is *served*, or disseminated, but also change the way geospatial data are captured. The era of what some call geonomadism or geosurveillance has already arrived. GIS-T in the private sector encompasses location analysis, logistics, and location-based services.

To understand how GIS in transportation works, it is necessary to have a grasp of basic data models and operations in GIS-T. Data models and operations are dependent on application needs, and they are interrelated. For example, spatial mapping of the fixed transportation infrastructure, monitoring the pavement conditions of sections of highway, and finding the best route for ambulance dispatch require different specifications of data models and operations.

A universally adopted approach to representing a transportation network is to break down the network to links and nodes where links correspond to linear segments and nodes correspond to intersections. Links and nodes are different from lines and points in that they are topological constructs (e.g., they possess connectivity). As many events occur along linear features, it is common to identify their location using a linear referencing system (LRS). LRS uses offset distance (how far) from a reference point along the route. For example, police officers can locate accidents on the highway using an LRS. The link-node model conveniently (but redundantly) stores transportation networks in files, but it is not amenable to representing something of the dynamic nature that is referenced using an LRS (e.g., accidents, pavement conditions, bus routes) and that does not



necessarily begin or end at the node. GIS has capabilities to dynamically generate those events tied to links based on their attributes (dynamic segmentation). Origin-destination matrices are used to store spatial interaction data (e.g., traffic flows among traffic analysis zones), although this is not well supported in generic GIS software due to the dominance of relational databases.

As more GIS-T applications are geared to servicing geographic information in the distributed environment (e.g., location-based services and intelligent transportation systems [ITS], such as the provision of real-time travel information in vehicles, the navigation of vehicles, and automated piloting), further requirements of GIS-T data models are being added. For example, high-resolution (e.g., lane based), dynamic (e.g., moving objects), and multidimensional (e.g., 3D) representations have been proposed. This trend poses challenges in managing, exchanging, and integrating geospatial data of disparate sources. For example, data stored in different location reference systems should become compatible. Strategies for promoting interoperability are being proposed.

Shortest-path problems are at the core of many GIS-T operations. The generic shortest-path algorithm is used in developing least-cost routes for deliveries (the traveling salesman problem) and determining optimal facility locations given the configuration of demand and facility (location-allocation). For example, planners may be interested in maximizing the coverage of health care clinics to the general public and minimizing the distance to demand in deploying ambulances.

Accessibility, as a core concept of transportation, has been a mainstay of geographers' contribution to this multidisciplinary field. Accessibility can be measured in several ways in GIS. These range from simple buffering (e.g., the number of facilities that can be reached from origins within a certain distance) to spatial interaction models that predict aggregate flows (or the potential of spatial interaction) among zones. Recently, much effort has been devoted to measuring individual space-time accessibility (based on Hägerstrand's time-geography) in GIS. GPS-enabled travel diary data collection would render this approach more practical.

GIS is used in the four-step urban transportation modeling system (UTMS) universally employed in transportation planning agencies. UTMS that aims at forecasting travel demand consists of trip generation (where trips come from), trip distribution (where trips go), modal split (which modes to take), and traffic assignment (the routes to be taken). The functionality of UTMS is provided in specialized GIS-T packages such as Caliper's TransCAD. GIS can improve the UTMS features that have been criticized for empirical inconsistency through including better land use modeling as input, visualization for alternative analysis as output, and refining the modeling procedures of the four steps.

GIS-T data can be obtained from the Census Bureau's TIGER files, the Department of Transportation, GIS software vendors, and specialized data vendors such as NAVTEQ and Tele Atlas. The Network Analysis functionality is provided in ESRI's (Environmental Systems Research Institute) ArcInfo Workstation and Network Analyst, an extension of ArcGIS and ArcView 3.x, while users can customize functionality using macro-language or componentware.

Sungsoon Hwang

See also [Accessibility](#); [Commuting](#); [GIS in Urban Planning](#); [Global Positioning System](#); [Gravity Model](#); [Location-Allocation Modeling](#); [Location-Based Services](#); [Spatial Interaction Models](#); [Transportation Geography](#)

Further Readings

- Miller, H., & Shaw, S.-L. (2001). *Geographic information systems for transportation: Principles and application*. New York: Oxford University Press.
- Thill, J.-C. (2000). Geographic information systems for transportation in perspective. *Transportation Research Part C*, 8, 3–12.
- Waters, N. (1999). Transportation GIS: GIS-T. In P. Longley, M. Goodchild, D. Maguire, & D. Rhind (Eds.), *Geographic information systems: Principles, techniques, management and applications* (pp. 827–844). New York: Wiley.



GIS IN URBAN PLANNING

Urban planning is greatly enhanced by the use of modern technology such as geographic information systems (GIS), which are uniquely suited to capture the many spatial layers and dimensions of the contemporary city and provide analytical tools to model its growth and change. Cities, counties, regional planning agencies, and other planning units frequently undertake what-if analysis and problem solving with GIS. GIS are a helpful tool for urban planners because it not only goes beyond just forecasting the magnitude of a problem but also visually displays the spatial distribution of the phenomena being examined.

GIS has been especially popular for smart growth initiatives, sometimes called *new urbanism* or *neo-traditional planning*, which encourage compact development with mixed uses, redevelopment of infill areas, pedestrian-friendly walkways, public transportation, open space connecting neighborhoods, and architectural designs that encourage social interaction. The principles of smart growth are articulated with terms such as *compactness*, *connectedness*, and *interaction*, which are all spatial terms, and therefore, GIS becomes the natural tool for implementing such plans.

Consider the contrasting example of what-if planning applied to population growth impacts in an urban fringe watershed west of Chicago (Figure 1, next page). The urban fringe of Chicago has been affected by many negative consequences of sprawl due to rapid population growth. The Chicago Metropolitan Agency for Planning (CMAP) has developed GIS data sets and tools to cope with the impacts of this growth on metropolitan Chicago's environment, land use, and economic development. Inputs from federal, state, and local planning agencies included cadastral land parcels, land use, extent of prime agricultural land, and open space. In the watershed example, assumptions were entered into the GIS about how growth would occur in the future. For instance, assumptions were made about the nature and policies of land use and whether new development should be kept compact or allowed to be scattered throughout the watershed.

In the first scenario, the GIS assumed no land use controls, and the growth continued to occur

in a scattered fashion. In the smart growth scenario, the growth was made compact and took place adjacent to existing development, particularly filling in many bypassed sites from an earlier development period and protecting prime farmland and other green areas. Similarly, the CMAP has undertaken a more comprehensive study of available infill areas throughout the entire Chicago metropolitan area and has held community meetings encouraging a participatory planning process aided by GIS.

Urban planning researchers often apply more complex GIS modeling and simulations referred to as *cellular automata*. Cellular automata models in a GIS are designed as a grid of cells where the state of each cell depends on the previous state of the cells within a neighborhood according to a set of transition rules. For instance, Jose Barredo and Luca Demicheli, working with the European Commission's MOLAND (Monitoring Land Cover/Use Dynamics) project, developed a large-scale cellular automata urban growth model for the megacity of Lagos, Nigeria. The city was divided into grid cells of 100 m (meters) by 100 m, with particularly strong land use factors that could be calibrated through the use of time series data. As a developing-world megacity, Lagos experienced very rapid growth in its population and land extent from 1962 to 2000. The model was run, and the city's urban spatial distribution was projected for 20 years, from 2000 to 2020. It projected that Lagos in 2020 would become a megacity with 27 million persons, encompassing an area of 969 square kilometers, which is more compact than Mexico City today. The model projected rapid growth of the urban area, although with considerable consolidation and infill. The model demonstrated the need for better infrastructure to provide the key needs of water, energy, and communications.

In short, all aspects of GIS have been applied in the field of urban planning, ranging from its use in the inventory of essential planning map layers all the way to sophisticated simulation models of urban development.

Richard P. Greene

See also GIS in Environmental Management; GIS in Health Research and Health Care; GIS in Public Policy; GIS in Transportation; GIS in Utilities; GIS in Water

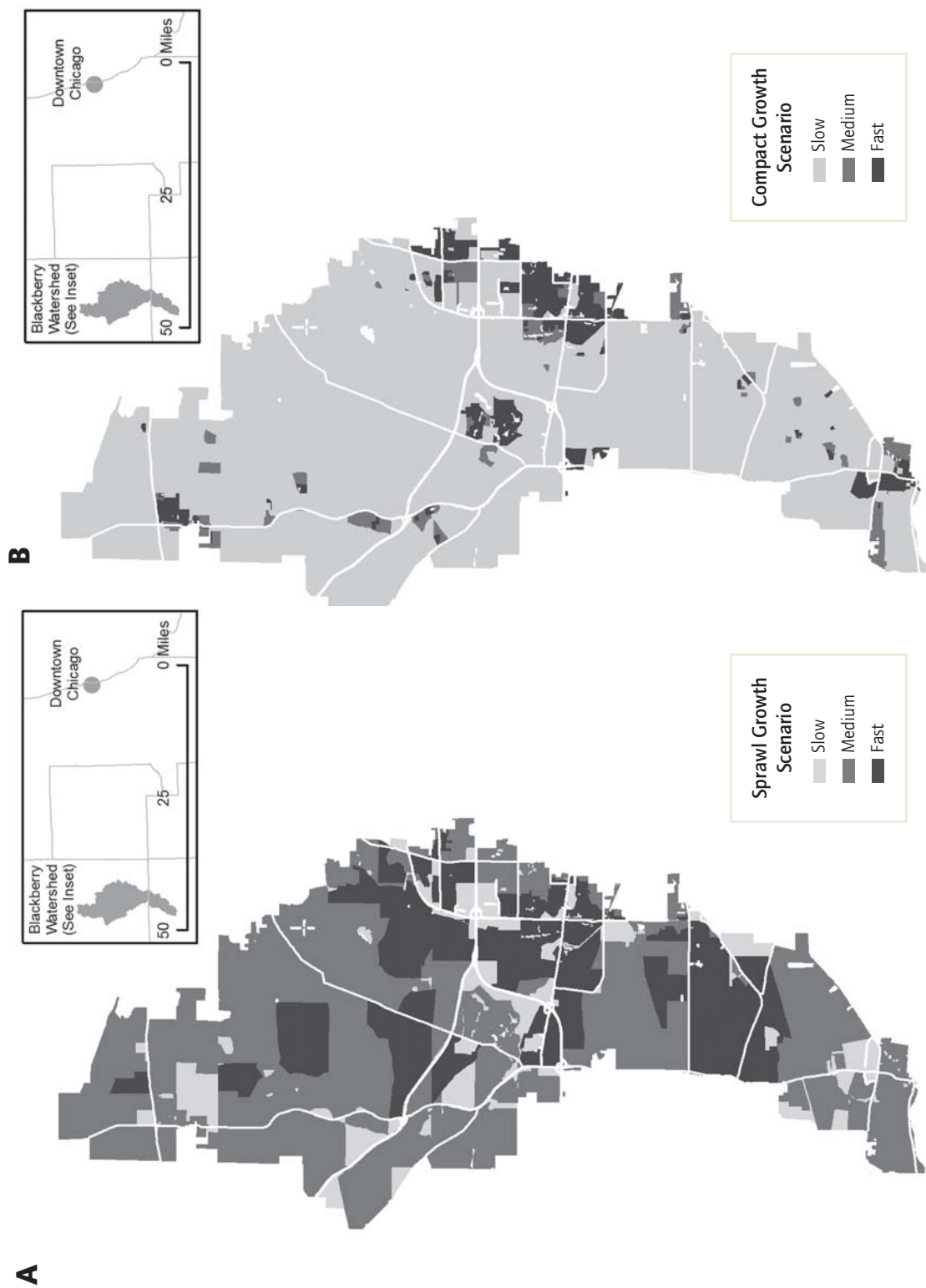


Figure 1 Urban growth scenarios for the Blackberry watershed up to the year 2020: (A) sprawl growth, (B) compact growth
 Source: Adapted from Greene, R. P., & Pick, J. B. (2006). *Exploring the urban community: A GIS approach* (p. 468). Upper Saddle River, NJ: Pearson/Prentice Hall.



Management; Land Use Planning; Smart Growth; Spatial Decision Support Systems; Urban and Regional Planning

Further Readings

- Barredo, J., & Demicheli, L. (2003). Urban sustainability in developing countries: Modeling and predicting future urban growth in Lagos. *Cities*, 20, 297–310.
- Clarke, K. (2008). A decade of cellular urban modeling with SLEUTH: Unresolved issues and problems. In R. Brail (Ed.), *Planning support systems for cities and regions* (pp. 47–60). Cambridge, MA: Lincoln Institute of Land Policy.
- Greene, R., & Pick, J. (2006). *Exploring the urban community: A GIS approach*. Upper Saddle River, NJ: Prentice Hall.

GIS IN UTILITIES

A utility is a private company, a public agency, or a cooperative of organizations that provide a service to the public. Some services commonly thought of as utilities are electricity generation and distribution, oil and natural gas distribution, telephone and other communication services, cable television, and water and wastewater management. More recently, high-speed Internet services and cell phone provision have become increasingly important utilities. Geographic information systems (GIS) are one of the most important technologies for the efficient operation and management of utilities.

Utility Networks Modeled in GIS

One of the primary reasons why GIS has been thoroughly integrated into utility operations is the development of vector and network data models within GIS. Topological data models were a revolutionary component of GIS, and many of the most common utilities are structured as networks, comprising of topologically connected sets of edges and junctions. As an example, natural gas transmission systems largely consist of sets of

connected pipes, where the connections occur at points where the gas is either split from one pipe to many or collected from many pipes into one. At any point along the network, there may be junctions that contain valves, pressure gauges, compressors, or storage facilities. Of course, there must be a production facility (or facilities) and distribution points (homes or businesses) that act as sources and sinks in the gas distribution network. Each of these network elements may have many different attribute values. In the case of the pipes that compose a gas transmission network, attributes include the pipe diameter, its capacity for flow, the date of its last inspection, and perhaps hundreds of other attributes. Similar network structures exist for most of the other utilities mentioned above. The well-developed topological and network data structures that have been integrated into GIS, the network analytical capabilities that are continually being developed, and the underlying relational database management system have combined to make GIS an essential element of utility operations.

Advantages of GIS for Utility Management and Operations

Beyond the clear correspondence between fundamental GIS data structures and utility network systems, GIS holds several other advantages for utility management and operations. Perhaps most important among these is the ability to analyze systems at a wide range of geographic scales. Utilities operate at local or metropolitan (e.g., water and sewer systems), regional (e.g., cable television providers), national (e.g., some telephone systems), international (e.g., natural gas and oil pipeline systems), and even intercontinental (e.g., undersea cable and pipeline systems) scales. At a microscale, GIS can assist with operations within single facilities, and at a macroscale, GIS can assist in global resource planning. The flexibility of a GIS to operate at all these scales allows utility operations to employ spatial technologies throughout their enterprise.

A second advantage of GIS for utility management is the close correlation between traditional GIS data layers and the data needs of utilities. Utilities manage both their own landholdings and the locations of their customers through the use



of cadastral databases. They manage regulatory reporting in part through the use of administrative boundaries (e.g., city, county, state, national). They target markets through the use of both census data and ZIP codes. They plan access to their facilities through the use of street centerlines, and they manage environmental impacts in part through the use of hydrographic, topographic, and land cover data sets. Orthophotography is used increasingly in the planning of new utility construction or expansion.

The ability to integrate GIS with other business systems is a key factor in the wide acceptance of GIS in these industries. Address-geocoding functionality in GIS allows utilities to respond to customer needs for service, particularly in emergency situations, when access to services can literally be a matter of life and death. The network analytic functions built into the GIS can assist in the dispatching of emergency crews in the most efficient manner possible. More routine operations such as meter reading or inspection of facilities are enhanced by the ability to use GIS in the field with handheld user interface devices. The ability to integrate database systems allows for diverse activities such as bill and payment processing, asset and equipment management, and engineering planning through integration with computer-aided design systems.

While even routine GIS techniques such as editing, metadata creation, and cartographic production are essential for many utility operations, more advanced GIS technologies hold great promise for these organizations. Three-dimensional (3D) analysis can assist in the modeling and analysis of systems that exist not only on the surface of the Earth but also above it (e.g., raised wires) and below it (e.g., underground pipelines). The process of linear referencing can be used to go beyond traditional coordinate location to identify measure locations along a network and permit the network to be the spatial platform for analysis. The advances in network analysis in GIS, including finding multiple routing solutions and determining flow patterns through networks, bring the field of operations research into utility management.

Since utilities have such a diverse range of activities across the enterprise, since their systems are extremely capital intensive, and since their

operations are so vital to society in many ways, the use of GIS to improve operations and more efficiently provide service is a vital contribution. To the extent that GIS can reduce the cost of operations, improve customer service, and help make wise, safe, and secure operational decisions, it will help in reaching a suite of both financial and social goals.

Kevin M. Curtin

See also *Applied Geography; Business Models for Geographic Information Systems; Environmental Impacts of Pipelines; Flow; Geographic Information Systems; GIS in Urban Planning; GIS in Water Management; Linear Referencing and Dynamic Segmentation; Network Analysis; Network Data Model; Public Water Services; Spatial Decision Support Systems*

Further Readings

- Curtin, K. M. (2007). Network analysis in geographic information science: Review, assessment, and projections. *Cartography and Geographic Information Systems*, 9, 103–111.
- Curtin, K. M., Arifin, R. R., & Nicoara, G. (2007). A comprehensive process for linear referencing. *URISA Journal*, 19, 41–50.



GIS IN WATER MANAGEMENT

Water is an essential resource for sustaining life and the economy, but water resources are scarce. Virtually all human uses of water require freshwater. However, of all water on Earth, 96.7% is saltwater, while over two thirds of freshwater is frozen in the glaciers of Antarctica and Greenland. Thus, we are left with only 0.9% of the globe's water for our use. This fact, combined with the needs of the growing population, obliges efficient management of water resources. Well-organized water management systems may help people use the limited water resources wisely. Applying geographic information systems (GIS) in water management greatly improves its effectiveness. To facilitate water management, many



hydrologically oriented pieces of software have been developed. Together with an abundance of spatial data generated specifically for hydrologic analyses, such software offers the necessary environment for using GIS in water management.

The management of water resources involves the design, implementation, and development of an organizational, technical, and legal structure for optimizing the exploitation, protection, and monitoring of water systems. Water management tasks range from preserving water for environmental protection and irrigation, to maintaining sewage systems in towns, to the supervision of international water resources on the surface (rivers, lakes, and wetlands) as well as underground (aquifers). Some highly complex water resources are managed under defined local regulations and/or international treaties. The World Bank projects that by 2030, 3 billion people will be living under conditions of severe water shortage. Countries receiving their water supply from across national boundary waters with limited availability experience increasing tension over water rights. Such stress over scarce water resources creates the risk of conflict.

Water management practices may be organized into the following major categories:

- Water treatment for drinking water and wastewater
- Water resources for agricultural, industrial, transportation, domestic, environmental, and recreational purposes
- Flood protection practices along rivers exhibiting flood dangers caused by sustained rainfall or rapid snowmelt and along seacoasts exhibiting flood dangers caused by severe sea storms, tsunamis, or hurricanes
- Irrigation for assisting the growing of crops in dry areas and in periods of rainfall shortfalls
- Groundwater, aquifers, and water tables

In all the above categories of water management, GIS is applied. Management of water resources and flood protection are the two main areas where GIS has been used for many years. For hydrologic analyses, GIS is an essential and indispensable tool.

GIS facilitates the ability to store, retrieve, process, and display spatial data, including data

related to surface and groundwater resources and water utilities. GIS-based watershed resource inventories provide information about elevation, slope, topography, soil properties, geology, land cover, flood zones, water reservoirs and their capacity, water quality, precipitation and other relevant climate variables, and demographic and socioeconomic issues. Data management of any watershed would not be feasible without a well-designed database, which is provided by GIS.

GIS is critically important when the spatial dimension of phenomena and their dynamic changes need to be modeled. GIS technology can help with finding spatial relationships in complex systems, with locating problems, and with planning alternative solutions using a variety of means, including simulations. With this, GIS provides a framework for a computer-based water management system that can be effectively applied to both large and small scales.

During the 1990s, GIS emerged as a major support tool for hydrologic analysis and modeling. For instance, GIS provided a reliable method for watershed and stream network delineation based solely on the information derived from a digital elevation model (DEM). Many GIS software vendors offered specialized tools for pre-processing the DEM required for more advanced hydrologic analysis (e.g., filling so-called sinks in the DEM to ensure continuous flow within a stream network, calculating the flow direction at every cell, and providing a foundation for deriving a stream network from creating a flow accumulation raster). These resulted in the creation of a community of GIS-based hydrologic modeling specialists who keep developing both increasingly accurate primary and collateral input data, which are critically important components of GIS in water management, and the know-how for more sophisticated hydrologic analysis and modeling.

To provide high-quality standards for the data and to facilitate water management applications, the U.S. Geological Survey (USGS) has developed a hydrologically correct National Elevation Dataset and National Hydrography Dataset of various fine resolutions for the territory of the United States. For the entire globe, the HYDR01K data (also developed by USGS) consists of a DEM



with 1-km (kilometer) resolution preprocessed for hydrologic analysis. HYDR01K provides a suite of georeferenced data sets, both raster and vector.

In the United States, various thematic GIS data layers are available online in open-access mode. The National Spatial Data Infrastructure focuses on the distribution and access of geospatial data, encourages spatial data sharing, avoids costly duplication of data sets, and directs all federal agencies to work cooperatively with other sectors to ensure the infrastructure's growth and evolution.

The development of data and the proficiency of hydrologic analyses have stimulated the GIS industry to further extend their software. This new "generation" of software enables progressively advanced GIS-based analyses, which by the end of the 20th century became the core of water management. With this, many companies have developed GIS packages for sophisticated hydrologic analysis and simulations that are essential for water management, including the evaluation of alternative water management options. Some of these, such as HEC-1, HEC-RAS, HEC-HMS, StormDrain, GSSHA, TR-20, TR-55, NFF, Rational Method, HSPF, DAMBREAK, MODFLOW, EMS-i, and MIKE21, were developed on top of the basic functionality of larger, generic packages of GIS, such as ArcGIS. Others, such as the HSPF, MT3DMS, MIDUSS, SWMM, XPSWMM, and QHM, are stand-alone pieces of hydrologically oriented software.

There is no alternative to the application of GIS in water management and in water-related information and decision support systems. The growth of GIS, together with the development of data and the continuous advancement of techniques for hydrologic analysis, offers an important resource for those involved in water management to meet global water needs.

Witold Fraczek

See also Floods; Hydrology; International Watershed Management; Public Water Services; Surface Water; Urban Storm Water Management; Urban Water Supply; Wastewater Management; Water Management and Treatment; Water Needs; Watershed Management; Watershed Yield; Water Supply Siting and Management

Further Readings

- Bedford, M. (2004). *GIS for water management in Europe*. Redlands, CA: ESRI Press.
- Gurnell, A., & Montgomery, D. (2000). *Hydrological applications of GIS*. New York: Wiley.
- Maidment, D. (Ed.). (2002). *Arc Hydro: GIS for water resources*. Redlands, CA: ESRI Press.
- Shamsi, U. (2005). *GIS applications for water, wastewater, and stormwater systems*. Boca Raton, FL: Taylor & Francis.



GIS SOFTWARE

Software that is used to create, manage, analyze, and visualize geographic data, that is, data with a reference to a place on Earth, is usually denoted by the umbrella term *geographic information system (GIS) software*. Typical applications for GIS software include the evaluation of places for the location of new stores; the management of power and gas lines; the creation of maps; the analysis of past crimes for crime prevention; route calculations for transport tasks; the management of forests, parks, and infrastructure such as roads and waterways; and applications in risk analysis of natural hazards and emergency planning and response. For this multitude of applications, different types of GIS functions are required, and different categories of GIS software exist that provide a particular set of functions needed to fulfill certain data management tasks. This entry first explains important GIS software concepts; then it lists the typical tasks accomplished with GIS software and describes different GIS software categories; finally, it provides information on software producers and projects.

GIS Software Concepts

To represent a geographic object in a GIS, for example, a building or a tree or a forest, a data representation has to be established first. GIS usually provides two different possibilities to represent a geographic phenomenon: the raster representation and the vector representation. In the raster

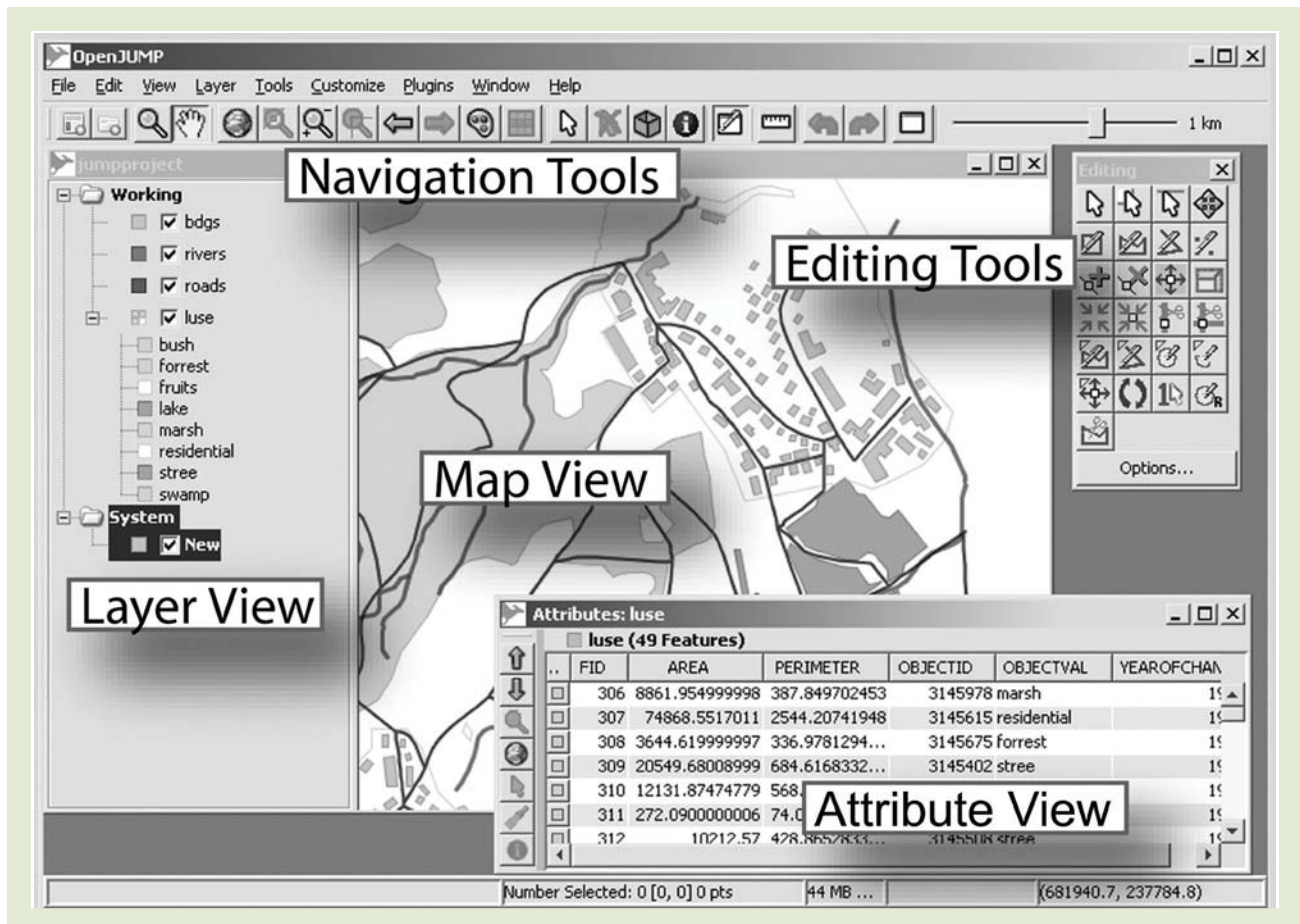


Figure 1 A typical desktop GIS user interface with map view, layer view, attribute view, and tools for navigating and exploring data, as well as tools for creating and modifying geometries

Source: Stefan Steiniger.

representation, a regular mesh of cells is used, where every cell records the value of the attribute that describes the phenomenon—such as the red/green/blue values in a digital image. Rasters are typically used to represent variables that are continuous over space, such as terrain elevations or land cover. In the vector model, which is commonly used to store objects that are spatially discrete, every object is represented by a (vector) geometry (e.g., a point, a line, or a polygon) and by value fields that describe the nonspatial object properties, the so-called attributes, in a table. For instance, a building might be represented by a rectangle geometry and have attached two fields that describe the construction year and the owner.

In GIS software, geographic objects that have the same geometric and attribute representation

are typically grouped in so-called layers to simplify data management tasks. For instance, all buildings that are represented by polygons and have information on owner and construction year are grouped in a layer labeled “buildings.” Figure 1 shows the typical graphical user interface of a GIS software package that includes the concept of geometries (map view) connected to values in tables (attribute view), as well as layers that contain one class of objects (e.g., rivers).

Typical Tasks Accomplished With GIS Software

Before any geographic analysis can take place, the data need to be derived from fieldwork or from maps or satellite imagery, or acquired from data

providers. Hence, data need to be created and—in case something has changed—edited and then stored. If data are obtained from other sources, they need to be viewed and eventually integrated (conflation) with existing data. To answer particular questions—for example, Who is living at Address X and is going to be affected by the planned renewal of a power line?—the data are queried and analyzed. However, some specific analysis tasks may require data transformation and manipulation before any analysis can take place. The query and analysis results can finally be displayed on a map.

GIS Software Categories

Different types of GIS software exist with different functionality, as not every GIS user needs to carry out all the above tasks. For instance, an

employee in the public services department of a city may only provide information on house owners to construction companies and may not need to edit the cadastral data set.

Figure 2 summarizes commonly used GIS software categories. Desktop GIS usually serves all GIS tasks and is sometimes classified into three functionality categories: (1) GIS Viewer, (2) GIS Editor, and (3) GIS Analyst. Spatial Database Management Systems (DBMS) are mainly used to store the data but often also provide (limited) analysis and data manipulation functionality. Web-Map Servers are used to distribute maps over the Internet. Similarly, WebGIS Clients are used for data display and to access analysis and query functionality from Server GIS over the Internet or intranet. Libraries and Extensions provide additional (analysis) functionality that is not part of the basic

GIS Task vs. Software	viewing	creation	editing	storage	conflation	transforming	query	analysis	create maps
Desktop GIS									
Viewer	●			●			●		○
Editor	●	●	●	●		○	●		●
Analyst	●	●	●	●	●	●	●	●	●
Spatial DBMS				●		●	●	○	
WebMap Server	●	○	○				●		●
Server GIS				●	●	●	●	●	●
WebGIS Clients									
Thin Client	●						●		
Thick Client	●	●	●	●			●	●	●
Mobile GIS	●	●	●	●			●		
Libraries/ Extensions				●	●	●		●	●

Figure 2 Typical tasks accomplished with different GIS software

Source: Stefan Steiniger.

Note: ● = standard functionality; ○ = optional functionality.



GIS software—for instance, functions for network and terrain analysis or functions to read specific data formats. Finally, Mobile GIS is frequently used for field data collection.

Software Manufacturers and Projects

GIS software is provided not only by companies but also increasingly by free and open-source software projects. While commercial vendors usually offer products for all software categories, open-source software projects often concentrate on a single category, for example, desktop GIS or WebMap server. The key players in the GIS software market today are Autodesk, Bentley, ESRI, Inc. (Environmental Systems Research Institute), GE (Smallworld), Pitney Bowes (MapInfo), and Intergraph. GIS software companies tend to target specific application domains. For instance, ESRI's ArcGIS product tends to be mainly used for business analysis, planning, and environmental applications, while Autodesk, GE, and Bentley products are used in utility and facility management. Competitive GIS software that is developed by free software projects exists as well—especially with respect to server applications (MapServer, GeoServer) and spatial DBMS (PostGIS). Free desktop GIS projects, such as Quantum GIS and gvSIG, currently have growing user communities.

Stefan Steiniger and Robert Weibel

See also Database Management Systems; Data Querying in GIS; Geospatial Industry; GIS, Environmental Model Integration and; GIS Implementation; GIScience; GIS Web Services; Open Source GIS; Spatial Analysis; Spatial Data Integration; Spatial Data Models; Spatial Decision Support Systems; Web Geoprocessing Workflows; Web Service Architectures for GIS

Further Readings

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic Information Systems and Science* (2nd ed.). Chichester, UK: Wiley.

Sherman, G. E. (2008). *Desktop GIS: Mapping the planet with open source tools*. Lewisville, TX: The Pragmatic Bookshelf.

Steiniger, S., & Bocher, E. (2009). An overview on current free and open source desktop GIS developments. *International Journal of Geographical Information Science*, 23(10), 1345–1370.

GIS WEB SERVICES

Geographic information system (GIS) Web services represent an evolution of traditional stand-alone GIS applications available in desktop environments with database back-ends for storing data, and they provide the components for a spatial data infrastructure (SDI). GIS Web services are self-contained application components that are published and accessed over the World Wide Web using standard protocols such as HTTP, SOAP, and XML. Each service performs a specific GIS function as part of a loosely coupled and distributed geographic application (also called a *distributed GIS*).

The functionalities provided by GIS Web services can be classified into four basic categories—geographic data discovery, access, computation, and visualization—which are described in the following sections. Additional functionality is required to orchestrate the interaction among several services in order to provide specific applications. GIS Web services categories and orchestration are illustrated in Figure 1.

The main challenge in using GIS Web services is that they require an agreement on a common architecture and a portfolio of standard Web services to support reusability and create applications that share the use of services. Emerging interoperability specifications, in particular from the Open Geospatial Consortium (OGC), have addressed this challenge.

Discovery

Discovery services enable the ability to publish, query, and retrieve descriptive metadata for

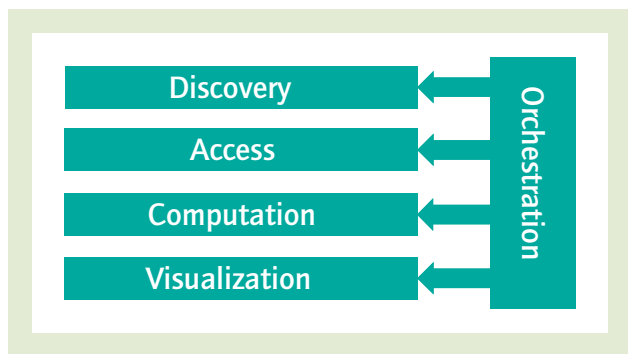


Figure 1 GIS Web services categories

Source: Author.

resources, which can be data and services. A discovery service is significant for the establishment of an SDI, as it enables users to discover which data and services exist and could potentially be used in a given application. Metadata offered by such a service should include descriptions of the content and functionality, quality information, and access details and/or restrictions that enable a user to evaluate fit for the purpose of the resource.

A prominent specification of discovery services is the OGC's Catalogue Services Specification, which offers a range of service interfaces that support the discovery, access, maintenance, and organization of catalogs of geospatial resources. Various profiles of the catalog specification offer different bindings for protocols—among others, HTTP and SOAP.

Current catalog implementations mainly rely on matching keywords with metadata entries, leading to low recall and/or precision during search. They do not yet make use of semantic Web technologies.

Access

A prerequisite for a distributed GIS application is the possibility to access geographic data through services. This type of service provides access to any kind of geographic data (represented both as vector and as raster) and enables queries to provide subsets of data, for example, based on types, attribute values, or spatial or temporal extent. In addition, it can provide functionality for inserting and updating.

OGC provides several specifications of services for geodata access. The Web Feature Service (WFS) and Web Coverage Service (WCS) provide access to vector data and coverages, respectively. These services provide access (read and write) and enable querying of geographic data using a standardized interface. To support exchange of data between a client and a service, the Geography Markup Language (GML) has been proposed by OGC as an encoding of geographic data. GML is an XML (EXtensible Markup Language) grammar that can be used to represent both discrete features (vector) and continuous-coverage surfaces (raster). Keyhole Markup Language (KML) is an alternative XML-based encoding, now also an OGC standard. WFS uses GML as data exchange encoding, and WCS can use GML but also supports traditional binary formats such as JPEG, (geo)TIFF, and PNG.

Computation

The computational capability of GIS is important for any kind of geographic analysis. Traditional GIS offer a vast amount of computational functionality, which needs to be transposed into the Web services platform to enable distributed GIS. In principle, any kind of GIS functionality can be exposed on the Internet as a Web service, using standard protocols and bindings such as HTTP and SOAP. The main challenge is to standardize these components in order to facilitate interoperability, that is, standard ways to invoke services and encode data and messages among services.

Standardized encoding of data, such as GML and KML, enables interoperable exchange of data not only between a client and a service but also among Web services, for example, for geographic data computation. In addition to the encoding of data, OGC has published the Web Processing Service (WPS) specification for standardizing an interface for geographic data computation. It offers a generic interface that can be used to invoke a variety of computational functionalities for geographic data (vector as well as raster). Examples of computational functionality are statistical or geospatial calculations, image processing and analysis, and, in general, computer algebra operations.



Visualization

A fundamental requirement for working with GIS is the possibility of displaying and portraying geographic data as maps. For a distributed GIS, visualization services are required to visualize data or results from computation services. OGC specifies the Web Map Service (WMS) interface, which can be used to visualize data accessible through data access services such as WFS or data stored within the WMS itself. The data can be visualized using a predefined or user-defined symbology.

Orchestration

To support a distributed GIS, there is a need for controlling the interaction among various GIS Web services. An example here may be an application where data are retrieved from a geodata access service, manipulated by a computation service, and finally portrayed in a visualization service. This workflow can, in its most simple form, be controlled by a client. However, more advanced technologies are available. Workflow languages such as Business Process Execution Language support the (parallel or sequential) execution of different service invocation activities, conditional behaviors, activities related to events, and the definition of new service interfaces used to exhibit the implemented functionalities. Therefore, workflow languages enable the definition of new GIS Web service interfaces with their own interfaces based on distributed service components.

Anders Friis-Christensen

See also Distributed Computing; Geocomputation; Geospatial Semantic Web; Interoperability and Spatial Data Standards; Metadata; Mobile GIS; Neogeography; Open Geospatial Consortium (OGC); Spatial Data Infrastructures; Web Geoprocessing Workflows; Web Service Architectures for GIS

Further Readings

OGC—OpenGIS Standards and Specifications:
www.opengeospatial.org/standards



GLACIERS: CONTINENTAL

The term *glacier* originates from the Latin word *glacies*, meaning “ice,” and refers to any body of perennial ice originating on land through the densification and recrystallization of snow that is massive enough to be flowing under its own weight. Generally, glaciers form in areas where the annual accumulation of snow, through precipitation and deposition, is greater than the annual mass loss due to melting, sublimation, and the calving of icebergs at the glacier margin. Glaciers provide important stores of water to more than 40% of the world’s population, maintain the temperature of the planet through a high albedo (they reflect sunlight back to space), and, in the case of the largest bodies of ice, even affect local and regional climate.

Glaciers form where the snow accumulates for hundreds to thousands of years. As the snow accumulates, older layers of snow are buried beneath more and more mass and are eventually compressed and recrystallized into dense glacial ice (density = 917 kilograms per cubic meter). If enough mass accumulates, the ice begins to flow downhill and outward toward the margins, where mass is lost.

Mass loss on a glacier is known as *ablation*. Anywhere on the glacier or ice mass where annual ablation exceeds accumulation is included in the ablation zone. Areas where accumulation exceeds ablation are included in the accumulation zone. The equilibrium line separates the accumulation and ablation zones and marks where accumulation and ablation are equal. This occurs at the equilibrium line altitude, which typically varies with latitude and the prevailing climatic conditions. On some glaciers, the highest elevation area may experience no melt at all. This area is referred to as the *dry snow zone*.

Glaciers occur in many places and in many different morphologies. The largest ice masses are ice sheets. Ice sheets cover continent-sized areas and are typically dome shaped. The surface morphology of ice sheets, unlike that of mountain glaciers, is relatively unaffected by the underlying topography. The flow of ice from these domes is outward from the summit, terminating in many outlet glaciers along the ice sheet margins. These outlet glaciers typically are constrained by the topography.

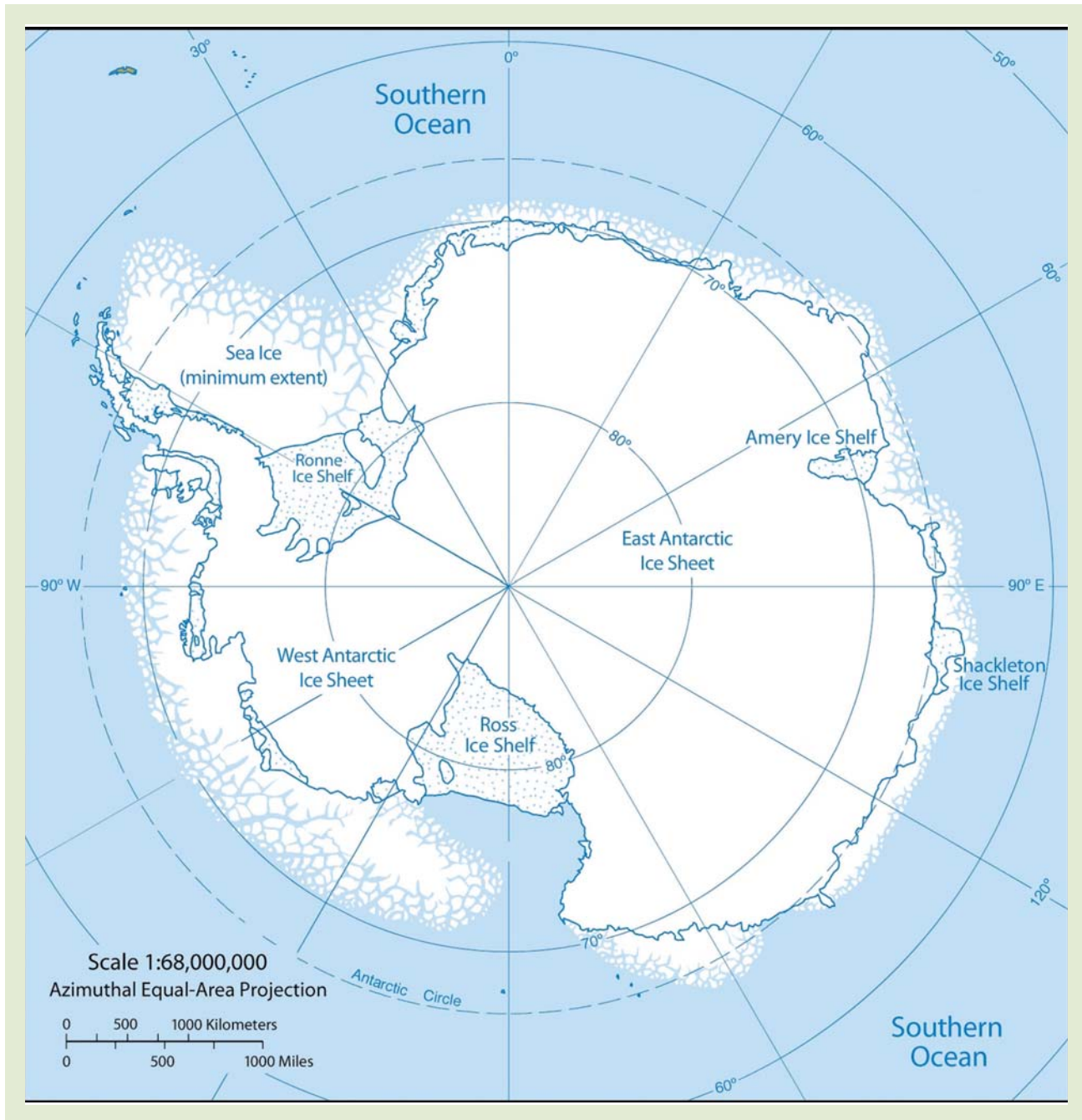


Figure 1 Map of Antarctica showing areas of sea ice, ice shelves, and the two ice sheets

Source: Adapted from Central Intelligence Agency. (2009). *The world factbook*. Washington, DC: Author.

At present, there are three large ice sheets on Earth, namely the West Antarctic Ice Sheet, the East Antarctic Ice Sheet (Figure 1), and the Greenland Ice Sheet (Figure 2). Combined, these ice sheets contain more than 90% of the estimated 33,000,000 km³ of ice contained in

all the glaciers in the world. The ice thickness on the East Antarctic Ice Sheet exceeds 4,200 m (meters) in places, while the West Antarctic Ice Sheet is grounded mostly below sea level and may be up to 2,500 m below sea level in places.



Figure 2 Blue Marble image of the Greenland Ice Sheet showing accumulated melt area from 1979 to 2007 from passive microwave data

Source: NASA/Goddard Space Flight Center Scientific Visualization Studio. Next Generation Blue Marble data courtesy of Reto Stockli (NASA/GSFC).

Ice caps are also dome shaped but are much smaller in scale. They typically occur at higher elevations but have morphologies similar to those of ice sheets, also terminating in outlet glaciers. In fact, very little differentiates ice caps from ice sheets, other than their size; their dynamics and flow characteristics are nearly identical.

Outlet glaciers from ice sheets and ice caps may terminate on land or in the ocean, where they are referred to as *tidewater glaciers*. A glacier becomes tidewater at the grounding line, the point where the base of the glacier becomes ungrounded, or disconnected from the land beneath. As glaciers flow out over the water, there is less friction at the base, and their flow accelerates. This divergence

of mass leads to thinning and spreading of the glacier where it is unconfined.

In some cases, particularly around the Antarctic ice sheets, many tidewater glaciers terminate in a single bay, gulf, or sea. There, the ice may combine and flow out in a large sheet over the water, called an *ice shelf* (Figure 1). Ice shelves continually grow through the flow of ice out from the ice sheet and shrink through calving and breakups of the ice shelves at their edges, through surface melt and sublimation, and largely through basal melt. Studies of tidewater glaciers in Greenland suggest that more than 90% of the mass lost is through melt at their bases.

Ice shelves are thinner than the continental glaciers from which they are born but are much thicker than sea ice (Figure 1), which is ocean water that is frozen at the surface. While not technically a glacier, sea ice is also an important component of the cryosphere, particularly in how it reduces the coupling of the ocean and the atmosphere and alters the salinity of the ocean (salt sinks out of the ice, making the water both more saline and more dense); sea ice has a much higher albedo than the underlying water, affecting the radiation balance of the planet.

Glacier ice behaves as a slowly creeping fluid but also exhibits nonlinear flow like a brittle material. As a fluid, it deforms in a uniform fashion without momentum or turbulence. The glacier slowly changes shape as it deforms. Occasionally, the deformation speeds up, and fracturing may occur, resulting in the formation of crevasses.

In a joint meeting of glaciologists and metallurgists in England in 1948, it was realized that ice is a polycrystalline solid and should deform like polycrystalline metals and rocks close to their melting points. Prior to that, it was assumed that ice deformed like a Newtonian viscous body. As a polycrystalline solid with randomly oriented crystals, the deformation rate initially decreases with time as crystals with different orientations interfere with each other. As these crystal matrices deform and align more favorably for deformation (i.e., parallel to the applied strain), the deformation rate tends to settle into a steady-state value. The eventual recrystallization of the ice leads to an orientation more favorable for deformation,

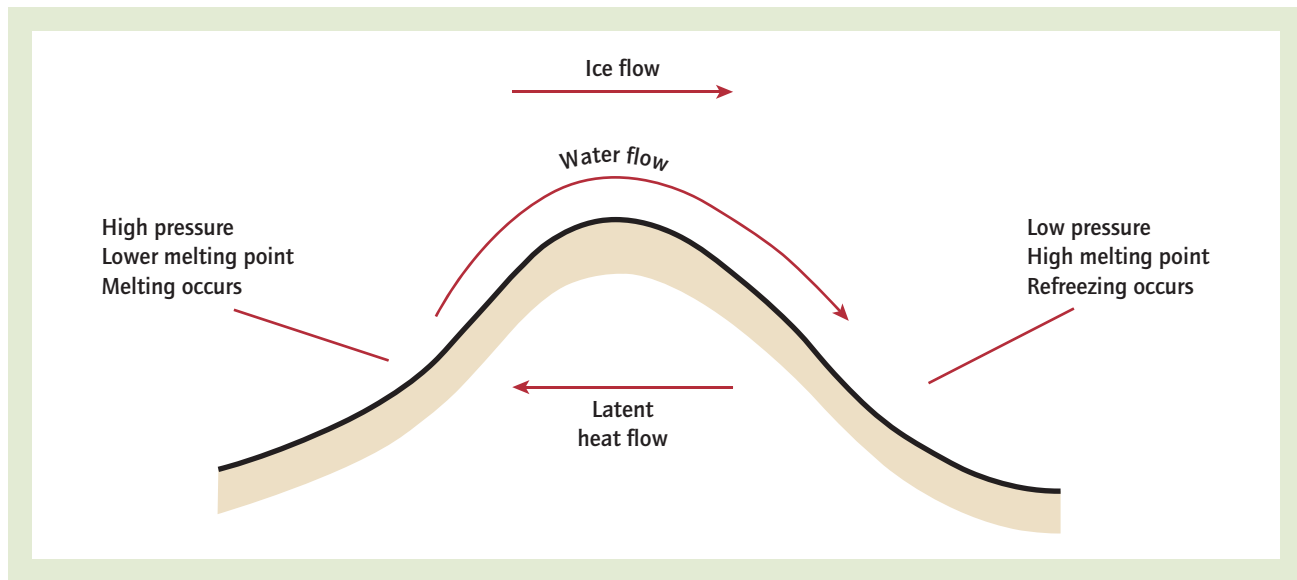


Figure 3 The process of basal sliding over an obstruction via regelation

Source: Adapted from Paterson, W. S. B. (1994). *The physics of glaciers* (3rd ed.). Tarrytown, NY: Elsevier.

during which time there is often a tertiary acceleration in the deformation rate.

Apart from internal deformation, glaciers also slide along their boundaries. Basal sliding rates are controlled by many variables, including bed roughness and composition and subglacial water content. Basal water occurs as the ice approaches the pressure-melting point at the base. Water is also delivered to the base from surface meltwater through finger-like channels and through large pressure-melt tunnels called *moulins*. Differential global positioning system (GPS) measurements in west-central Greenland, for example, show that the surface of the ice sheet actually rises up during the melt season, as surface melt reaches the base of the ice sheet, resulting in a dramatic increase in the flow rate of the ice sheet.

As ice flows toward the margins of ice sheets, ice streams may form where the ice flows faster than the surrounding ice. Ice streams are different from outlet glaciers in that they are not constrained by the bedrock topography. Nearly 15% of the Antarctic coastline consists of ice streams that drain as much as 90% of the ice sheet interior. On the Greenland ice sheet, almost 10% of the ice is drained by a single ice stream, the Jakobshavns Isbræ, which becomes an outlet glacier at the coast.

As glaciers slide over their beds, they encounter bumps and other obstacles to flow. While the ice is driven around larger bumps through plastic flow, sliding over smaller bumps is usually achieved through an exchange of heat and water around the bump. As the ice hits the upstream side of the obstacle, pressure builds up, lowering the pressure-melting point. This allows a layer of ice to melt and the water to flow past the obstacle. As the ice passes the downstream side of the obstacle, the pressure lowers, raising the pressure-melting point. This allows the water to refreeze, releasing latent heat. The latent heat released is absorbed on the upstream side as melting occurs. This process, known as *regelation* (see Figure 3), is only possible where the obstacle is small enough to allow for the efficient transfer of latent heat across it. Once the obstacle becomes too large, plastic flow occurs.

The rate of deformation on a glacier is strongly dependent on the internal temperature of the ice. Temperature at the base of the glacier helps control erosion. When ice is frozen to the bed, it is protected from erosion. As basal temperatures increase, melt increases, increasing the basal sliding rate and allowing more erosion.

At any given point on a glacier, the temperature profile may be considered “cold,” where all



ice is below the melting point, with the possible exception of the base; “polythermal,” where a finite layer at the base is at the melting point; or “temperate,” where the ice in the top 10 to 15 m is below the melting point. The temperature distribution within the glacier is controlled by heat transfer into, out of, and within the ice mass. The main controls on ice temperature include the shortwave and long-wave radiation balances at the surface, the exchange of latent heat at the surface mainly from sublimation and deposition on cold glaciers, the turbulent transfer of sensible heat between the air and the ice surface, and the subsurface heat flux, particularly from geothermal heat and friction from sliding. The refreezing of percolating meltwater liberates additional latent heat, while melt at the surface results in the absorption of latent heat from the surface.

Seasonal variations of temperature at the surface are dampened with depth in the ice. By a depth of 10 to 15 m, the ice temperature often resembles the mean annual surface temperature. In dry-snow zones, where the surface temperature remains below freezing all year, this mean annual temperature is generally reached at a depth of 10 m. Where melt does occur, the refreezing of percolating meltwater at depth releases latent heat, significantly inflating the 10-m temperatures. The amount of temperature added to depth varies from year to year depending on the amount of melt. In the ablation zone, all the superimposed ice that forms melts off by the end of the ablation season, so any increase in the 10-m ice temperature is temporary as the excess heat is reabsorbed by the ice as it melts. Accordingly, 10-m temperatures may be colder in the ablation zone, even though the air temperatures are warmer.

As glaciers melt or grow, they have a direct effect on sea level. At the height of the last glaciation, 20,000 yrs. (years) ago, mean sea level was approximately 120 m lower than at present, mainly due to the presence of the Laurentide Ice Sheet over North America but also due to the Scandinavian Ice Sheet and the expansion of the Greenland and Antarctic ice sheets. As the last glaciation gave way to the present interglacial stage, sea levels rose at an average of 10 mm yr.⁻¹ (millimeters per year), from 15,000 yrs. ago to 6,000 yrs. ago. This rise was not steady, but episodic and dynamically driven. In contrast, sea

levels have not fluctuated much more than 50 centimeters in the past 6,000 yrs. In the 20th century, sea levels rose at an average rate of 1.5 mm yr.⁻¹, the fastest rate in the past 6,000 yrs. Approximately half of this rise is attributed to thermal expansion of the oceans. The other half is attributed to the melting of glaciers and ice caps.

Evidence of past glaciations is found in the isostatic response of Earth's crust as well as in the remnant glacial features. As a large ice sheet grows, it depresses Earth's viscoelastic crust beneath it. When the ice melts, the crust rebounds over thousands of years, leaving evidence of prior loading, which can help determine the size of the ice sheet but complicates determining the changes in sea level.

Glaciations also leave behind telltale geomorphic features such as *moraines* and *striations*. Moraines are localized deposits of material carried by a glacier. As glaciers advance, material is pushed forward. When they retreat, they frequently leave a mound of material at the maximum extent of their snout. These deposits can help determine the maximum extent of the glacier or ice sheet. Lateral moraines, occurring on hillsides or mountains, yield evidence of the elevation of past glaciers. Glacier striations, gouges in rock from the sliding of a glacier with entrained material, can indicate the flow or orientation of former ice motion.

Todd Albert

See also **Fjords; Glaciers: Mountain; Ice; Permafrost; Poles, North and South**

Further Readings

Central Intelligence Agency. (2009). *The world factbook* [Online]. Washington, DC: Author. Retrieved July 13, 2009, from www.cia.gov/library/publications/the-world-factbook/index.html

Glen, J. W. (1955). The creep of polycrystalline ice. *Proceedings of the Royal Society of London, Series A*, 228, 519–538.

Jaeger, J. C. (1962). *Elasticity, fracture and flow* (2nd ed.). London: Methuen.



- Nye, J. F. (1951). The flow of glaciers and ice-sheets as a problem of plasticity. *Proceedings of the Royal Society of London, Series A*, 207, 554–572.
- Paterson, W. S. B. (1994). *The physics of glaciers* (3rd ed.). Tarrytown, NY: Elsevier.
- Thomas, R. H. (1993). Ice sheets. In R. J. Gurney, J. L. Foster, & C. L. Parkinson (Eds.), *Atlas of satellite observations related to global change* (pp. 385–400). London: Cambridge University Press.



GLACIERS: MOUNTAIN

In mountainous locations where more snow crystals accumulate annually than melt, a glacier will form. Glaciers develop from the accumulation of snow; when this accumulation reaches a sufficient thickness, glacier ice forms. Under its own weight and the force of gravity, the snow and ice begin to move, and a glacier is born. Mountain glaciers attract our attention because they have created much of the beauty of alpine regions, creating cirques, alpine lakes, U-shaped valleys, horns, and arêtes. These glaciers are important in many alpine regions, as they are a key component of summer stream flow, providing runoff for irrigation, hydropower, and drinking water during the driest months of the years to many of the world's largest rivers. Mountain glaciers affect the sea level, lowering it as they expand and raising it as they contract. Glaciers are also noteworthy for their sensitivity to climate, as indicated by their response to the recent rise in global temperature, which has prompted widespread and ubiquitous retreat in the alpine regions.

Glacier Formation

Glaciers form where snow and ice accumulation exceed snow and ice melt. As the snow and ice thicken, there will be a point where the mass begins to move due to a combination of the slope the snow is lying on and the pressure of the overlying snow and ice. On steeper slopes, this can occur with as little as 20 m (meters) of snow-ice. There are two types of mountain glaciers, based on their temperature: polar and temperate. A

polar glacier has cold ice throughout, never reaching the melting point; these glaciers are confined to the Arctic region and very high-altitude locations with dry climates. A temperate glacier is at the melting point throughout. The snow that forms temperate glaciers is subject to repeated freezing and thawing, which quickly changes it into rounded granular ice, or *firn*. Over a period of years, the firn undergoes further compaction, as well as grain growth via melting and refreezing, and sinters together with neighboring firn grain, creating glacier ice with air bubbles trapped between the grains. This process takes from 3 to 10 years on temperate glaciers, depending mostly on the accumulation rate—the higher the accumulation rate, the faster the process. On a polar glacier, without the melting and refreezing, the process takes much longer. The accumulation rate is lower on polar glaciers as well, further slowing the process of firn and glacier ice formation, which now must occur mainly via compaction.

The smallest alpine glaciers form high on the mountain slopes and are niche, slope, or cirque glaciers. These glaciers occupy locations that favor snow accumulation from drifting or avalanching and/or provide some radiational shading. As a mountain glacier increases in size, it can begin to flow downvalley, creating a valley glacier. Larger alpine glaciers can merge into a large area, covering a portion of a mountain range; these are ice caps or ice fields, such as the Barnes Ice Cap, Baffin Island, or Juneau Icefield, Alaska. In Patagonia and Alaska, large outlet glaciers from ice fields reach the ocean, to become tide-water glaciers. The larger glaciers, like rivers, are formed from tributary glaciers joining together into a larger trunk outlet glacier.

Glacier Movement

Mountain glaciers tend to have high slopes, as the terrain they exist in has substantial relief. Flow rates range from a few meters per year on small cirque glaciers to 10 meters per day on large tide-water glaciers such as Columbia Glacier, Alaska, and San Rafael Glacier, Chile. Surging glaciers are an unusual exception; they flow relatively slowly for many years and then flow quite quickly for a few weeks to a year. Glaciers move by sliding



Lyman Glacier, Washington. The lake in the foreground is colored green by glacier flour from glacier erosion. This is a small cirque glacier fed by avalanches from the mountain above. Crevasses indicate glacier flow. The separation between bare blue glacier ice and snow cover is also evident. The photograph, taken in 2008, is from the 1944 terminus position of the glacier.

Source: Author.

over their bed and by internal deformation. Steeper slopes and thinner ice increase the percentage of motion from sliding, thick glaciers, and low slopes increase the role of internal deformation. Sliding occurs when a thin layer of water at the bottom of the glacier sufficiently reduces friction. This water may come from basal melting due to the pressure of the overlying ice or from surface meltwater that has worked its way through cracks in the glacier. Velocities are highest at the surface and in the middle of the glacier, where frictional impacts are at a minimum. This leads to the highest erosion in the center of the glacier and the valley or basin underneath. Many

glaciers flow faster during summer, when more meltwater is produced; this is a sure sign that basal sliding is the main mode of flow.

The active glacier flow results in the formation of crevasses. Crevasses form where a differential in glacier motion leads to the development of surface separation. If a glacier accelerates as slopes steepen, transverse crevasses form. When a glacier can expand laterally, longitudinal crevasses will develop. At the lateral margin of a glacier, the friction of the sidewalls slows a glacier, resulting in splayed crevasses. If a glacier is sufficiently thick and descends a steep slope, an icefall will develop.



Gilkey Glacier, Alaska, where several tributaries separated by medial moraines join and flow downvalley. The ice waves in the center foreground are ogives. One ogive forms per year at the base of some icefalls where seasonal velocity and melting fluctuate. There are few small ponds between the ogives.

Source: Author.

Glacier Mass Balance and Terminus Response

As a glacier develops and flows downslope, it balances the excess accumulation that created it with additional ablation, terminating where there is a balance between accumulation and ablation. A glacier is divided into the accumulation zone, where accumulation persists through the summer season, and an ablation zone, where snow cover is seasonal. The two zones are separated by the equilibrium line. A typical mountain glacier must have an accumulation zone that is at least 60% of its total area. If a glacier is calving, the percentage increases.

The health of a glacier is determined by monitoring the behavior of the terminus and/or its mass balance. Glacier mass balance is the difference between accumulation and ablation (melting and sublimation). Climate change may cause variations in temperature and snowfall, altering the mass balance. A glacier with a sustained negative balance is out of equilibrium and will retreat. A glacier with sustained positive balance is out of equilibrium and will advance to reestablish equilibrium. Glacier advance increases the area of a glacier at lower elevations, where ablation is highest, offsetting the increase in accumulation.

Glacier retreat results in the loss of the low-elevation region of the glacier. Since higher



Transverse crevasses in the ablation zone of Easton Glacier, Washington, formed from the glacier's acceleration as its slope increases.

Source: Author.

elevations are cooler, the disappearance of the lowest portion of the glacier reduces the total ablation, increasing the mass balance and potentially reestablishing equilibrium. If the mass balance of a significant portion of the accumulation zone of the glacier is negative, the glacier is in disequilibrium with climate and will melt away without a climate change toward cooler, wetter conditions.

Glaciers and Water Supply

Temperate mountain glaciers are an important water resource. The meltwater generated above the equilibrium line percolates through the snowpack, slowly reaching the internal drainage

system of the glacier. In the ablation zone, meltwater flows in supraglacial streams on the surface, usually descending into the glacier via a moulin or a crevasse. The water then is carried through the glacier englacially or may reach the base of the glacier. The internal drainage system develops during the course of the summer and is quite remarkable in that the majority of the runoff will congregate into a single outlet stream at the glacier terminus. The glacier runoff that is discharged peaks during dry, warm periods during the summer melt season, when other contributors to runoff are at a minimum. The runoff is also rich in glacier flour, generated from erosion of rock at the base of the glacier. Glacier runoff often provides up to 50% of flow during

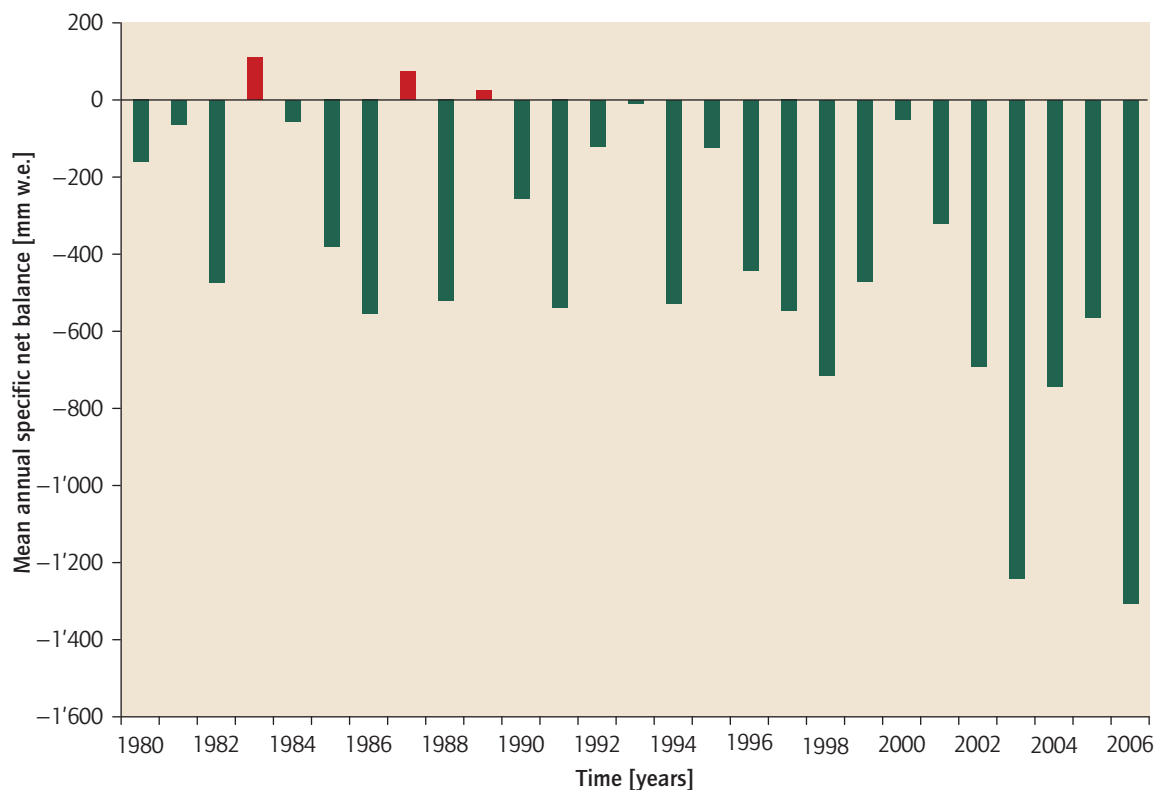


Figure 1 Annual mean glacier mass balance in water equivalent to glacier thickness gained or lost, as reported to the World Glacier Monitoring Service

Source: Created by author, from data compiled by World Glacier Monitoring Service.

late summer in rivers draining glaciated mountain regions.

Glacier Distribution

Glaciers exist on every continent. In Oceania, glaciers exist on New Zealand's South Island; the New Zealand Alps are host to numerous glaciers. New Zealand has more than 3,000 glaciers covering 1,160 km² (square kilometers). In New Guinea, several small glaciers are located on its highest summit massif, Puncak Jaya, with an area of 3 km², though these glaciers are rapidly disappearing. Africa has glaciers on Mount Kilimanjaro in Tanzania, on Mount Kenya in Kenya, and in the Ruwenzori Range of Tanzania. African glaciers have an area of 6 km² and are all

retreating. South America has 25,000 km² of mountain glaciers, 90% in Chile and Argentina. Glaciers occur along the entire crest of the Andes from Colombia south to Chile and Argentina. In the northern portion of the Andes, many of the glaciers are at very high elevations, with snowlines from 4,500 to 5,000 m, existing in a dry climate with little snowfall or melting. At the southern end of the continent, large outlet glaciers of Patagonia's ice fields terminate in the ocean, with snowlines ranging from 300 to 1,500 m. In Central Asia, ice cover is estimated at 115,000 km². The majority of glaciers are in the Himalaya and adjacent mountain ranges, Karakoram, Kunlun Shan, Pamir, and Tien Shan. These glaciers are key sources for the largest rivers of Asia, the Ganges, Brahmaputra, Indus, and Yangtze Rivers, for example. Kamchatka



has nearly 3,000 km² of glaciers, mostly on the flanks of volcanoes.

Glaciers are a key aspect in the development of the environment of the Alps in Europe. The glaciers carved the mountain valleys, gouging out the alpine lakes, steepening the famous mountains, providing key water resources for hydropower and drinking. The Alps and the Caucasus have 3,800 km² of glacier ice. In the Pyrenees, two thirds of the ice cover has been lost since the 19th century, with retreat particularly rapid since 1980. Norway and Sweden lost 2,900 km² of glacier-covered area. In Norway, 15% of the water used is from glacier runoff, particularly for hydropower. In North America, glaciers occupy the coastal ranges from the Sierra Nevada, California, north through the Cascades to the Coast Range of British Columbia and Alaska. The Rocky Mountains and affiliated ranges are glaciated from Mexico north to the Yukon; there is 124,000 km² of glacier cover. Much of the glacier cover is remote, but many glaciers are crucial to water supply. The Columbia River, renowned for its salmon and hydropower, is heavily fed by glacier runoff. In the Arctic, glaciers are a mixture of ice caps in nonmountainous areas and mountain glaciers. From Iceland to Baffin Island and Novaya Zemlya, glaciers cover 275,000 km². Except on Iceland, the Arctic glaciers are not much used as a water resource.

Recent Glacier Behavior

Repeated observations of a glacier's terminus allow determination of its behavior. Glacier termini that lack active crevassing indicate a lack of active flow in the terminus area; these glaciers will be retreating. The World Glacier Monitoring Service (WGMS) collects terminus change data throughout the world. In 2005, of the 442 glaciers examined and reported, 388 were retreating, 18 were stationary, and 26 were advancing. The 90% retreating figure is less than the total percentage of retreating glaciers, as the number of glaciers in the Himalayas and Alaska, where retreat has been widespread, is underreported.

Mass balance is also assessed on a number of glaciers by measuring both the accumulation and the ablation across a glacier. The WGMS collects these data annually; from 1975 to 2005, the

average glacier lost 0.30 m of thickness annually. This cumulative loss of 10 m sliced off the average glacier is a modest amount on large glaciers but a critical amount on small glaciers averaging 20 to 40 m in thickness. This loss also contributes substantially to global sea-level rise (see Lyman Glacier image).

During the Little Ice Age, from about 1550 to 1850, the world experienced relatively cooler temperatures compared with the present, and glaciers advanced. Subsequently, until about 1940, glaciers around the world retreated as the climate warmed. Glacial retreat slowed and even reversed, in many cases, between 1950 and 1980, as slight global cooling occurred. However, since 1980, significant global warming has led to glacier retreat becoming increasingly rapid and ubiquitous. This has led to the disappearance of some glaciers, and the existence of a great number of the remaining glaciers of the world is threatened. In locations such as the Andes of South America and the Himalayas in Asia, the decline of glacier area will reduce summer water supplies. Glaciers act as large natural reservoirs, slowly melting during dry warm periods. As their size is reduced, the area exposed for melting decreases, reducing the capacity of these frozen reservoirs.

Mauri S. Pelto

See also **Anthropogenic Climate Change; Climate Change; Fjords; Geomorphology; Glaciers: Continental; Ice; Permafrost**

Further Readings

- Hambrey, M., & Alean, J. (1992). *Glaciers*. Cambridge, UK: Cambridge University Press.
- United Nations Environment Programme, & World Glacier Monitoring Service. (2008). *Global glacier changes: Facts and figures*. Zurich, Switzerland: Authors.



GLOBAL CLIMATE CHANGE

See **Anthropogenic Climate Change**



GLOBAL ENVIRONMENTAL CHANGE

Throughout geologic history, Earth has experienced dramatic environmental changes from forces such as plate tectonics and glaciation. However, recent human activities have accelerated the rate and scale of global changes immensely—so much so that many authorities now suggest that the Holocene is ended and a new geologic epoch has been entered: the Anthropocene. Human impacts on Earth have multiplied as technology develops and populations grow. The rate of change has increased much faster than just the population growth rate, as humans have moved from merely procuring food and shelter to exploiting Earth for myriad products to add comfort to their lives and to using increasingly advanced technology that creates a variety of waste products. Global environmental change encompasses the study of all these anthropogenic impacts on Earth. Global environmental change includes global climate change and more regional changes such as urbanization, ozone depletion, soil erosion and land degradation, desertification, habitat alterations, deforestation, hydrologic perturbations, and other changes that directly affect ecological systems.

Institutions and governance of local societies often dictate the rate and regional impacts of global environmental change. These changes manifest themselves at multiple spatial, temporal, and sociopolitical scales, and it is this complexity that makes examining the entire phenomenon so difficult. Current research in global environmental change is concerned both with documenting change and the interactions of forcing mechanisms as well as with mitigating their impacts. Environmental change mitigation is accomplished by reducing societal and ecological vulnerability to disruption by maximizing the resilience and adaptive capacity of the systems.

Human activities affect the majority of natural global environmental systems, and often these impacts interact to create ramifications far larger than their sums. Specific manifestations of global environmental change in regions of the Earth differ depending on an area's society and its economic capabilities, but ultimately, they always

have biodiversity impacts. For example, when discussing agricultural impacts on water quality, Guatemala must cope with primarily sediment erosion, while the United States also has to address agricultural pesticides and fertilizers, and each of these pollution types affects aquatic ecosystems in different ways. A century or more ago, Earth's biogeochemical cycling could accommodate human waste products and extraction. But the exponential growth of human populations has depleted or exceeded the resilience of natural systems, and thus today, global environmental change impacts are growing exponentially. While technology accelerates the rate and severity of impacts, it also offers the potential to remediate much of the damage, if society demands and is willing to pay for such remediation.

Global climate change is the overriding factor that affects all other anthropogenic alterations. To avoid duplication, this discussion focuses on the other regional forces that interact with climate change to create global environmental changes and biodiversity impacts. These forcing mechanisms include land-cover changes, soil degradation, hydrologic perturbations, and both ocean and atmospheric changes. No part of the Earth is untouched—from the stratosphere and its new gases to the deepest ocean trenches with warmer, more carbon dioxide-rich waters and trash disposal—even the moon and other planets have space vehicle wreckage. The physical impacts on the landscape in turn have major social impacts—especially for food security and human health.

Land Cover and Land Use

Every organism changes its immediate environment to suit its habitat needs. However, humans change Earth as no other species in the geologic record has done. Throughout history, deforestation has been driven by the local civilization's land use intensity, as the demand for timber products has often intersected with the demand for agricultural land to dramatically alter landscapes. These impacts are exacerbated by climate, fire, and insect disturbances. Human impacts on land cover have a variety of climatic, ecological, and socioeconomic drivers, and landscape fragmentation often results. Biological impacts such as



changes in the assemblage of species, local extinctions, dispersal, and relocation also result from local changes in habitat parameters. Land use changes transform the land's productivity and biochemical/hydrologic cycling. The most profound alteration has been the conversion of various land types to agricultural uses, so that now, over one half of Earth's potential agricultural land is already in use.

At a global level, change from a dark forest to lighter soil changes the albedo of Earth's surface and the resultant radiative forcing. Carl Sagan theorized that the Little Ice Age in Europe was partially caused by such a regional clearing of forest for agriculture and the resultant albedo effect. In addition to albedo, land cover changes affect runoff rates, soil erosion and sediment deposition, habitat availability, and local microclimates. These processes also affect transpiration (through the loss of vegetation) and surface latent and sensible heat fluxes. Local sources of precipitation, or recycled rain, can account for one third or more of rainfall—the Amazon has the highest values in the world—and deforestation reduces transpiration, which in turn reduces local precipitation.

The most significant causes of land cover change globally, ranked by area affected, are grazing (because it uses marginal lands across nearly 50% of the planet—from deserts to mountains to subpolar regions), agriculture, timber activity, and urbanization. Combined, these impacts have accelerated the global extinction rate by fragmenting habitat, and this favors rapid growing of pioneer species that are adapted to the broadest range of physical conditions. It is estimated that one third or more of Earth's species may go extinct in modern times due to global environmental changes in species habitat.

Soil Degradation

Soil quality is the inherent capability of soil to perform environmental functions, and degradation may result in the partial or complete loss of soil's productive capacity. Global soil degradation includes erosion, compaction, acidification, soil organic matter and fertility losses, and salinization. Mismanagement of soils for agriculture, timber activity, and by livestock owners is the

major cause of soil degradation. Estimates of global soil degradation suggest a 25% to 50% loss of global productivity resulting from human impacts on soils. The most well-known example of soil degradation is *desertification*, which is the degradation of formerly productive lands into deserts. This process was addressed by the United Nations Convention to Combat Desertification in 1994, but other aspects of soil degradation have not been addressed at the international level.

Water Resources

Humans affect water quantity and water quality both above- and belowground, and these issues are interrelated. In the case of water quantity, water diversion for irrigation consumes 70% of the water used globally and has stopped or impaired the flow of many rivers worldwide. To regulate water supplies, dams, canals, and dikes have been constructed, and river channel alterations have been undertaken on nearly every river of the world. Engineering channel processes significantly alters hydrologic function, changes sediment delivery patterns, and disrupts riparian habitat stability. Land use changes affect water resources, as deforestation impedes hydrologic processes, leading to local decreases in precipitation and more rapid runoff, which, in turn, lead to greater flooding and increased soil erosion.

There are several other major issues of water quality as well. Grazing, agriculture, forestry, and construction all contribute sediment to rivers and disrupt channel morphology and aquatic photosynthesis. Agricultural chemical runoff includes both pesticides and fertilizers: Nitrates and potassium come from fertilizer application and livestock fecal matter. Storm water runoff from roads and parking lots is another major source of non-point water pollution. Point source pollution from urban areas is still widespread in much of the world and includes sewage and industrial waste disposal. Groundwater depletion from overpumping of wells is a growing problem as precipitation uncertainty grows with climate change and societies try to find more "secure" water supplies. The use of underground injection wells for storm water removal increases the risk of groundwater contamination in some areas. Polluted water is effectively unavailable for many uses, and thus water



quantity is intimately tied to water quality for human use and ecosystem functions.

Urbanization

Urbanization's most immediate impact is habitat fragmentation and loss of agricultural lands and forests as they are covered in impervious surface. These surfaces retard infiltration and, combined with storm sewers, maximize runoff into downstream waterways, which exacerbates flooding. Additionally, oil, natural gas, sediment, and other contaminants in storm water compromise water quality and impair aquatic habitat. A second major effect of increased impervious surface is to create an "urban heat island effect." This localized elevated temperature potentially leads to air temperature inversions and related air quality impairment. Also, elevated precipitation develops downwind from the urban area due to convective effects and elevated cloud condensation nuclei from particulate matter pollution. Urbanization changes surface roughness, which affects air momentum and heat transport.

Ocean Change

The vast size of the oceans has hindered quantification of oceanic biogeochemical characteristics and of recent environmental changes. The oceans redistribute large amounts of heat around the globe, and perturbations to ocean currents or giant ocean gyres could change regional climate patterns. The Younger Dryas was a cooling of the Northern Hemisphere approximately 12,000 years ago, at the end of the Pleistocene. It was marked by a slowdown of the global thermohaline ocean circulation (also known as the *meridional overturning circulation*), and a similar event is expected under most climate change scenarios, as the Greenland ice cap contributes massive volumes of freshwater to the North Atlantic and disrupts this ocean current. Recent studies indicate that the subpolar North Atlantic gyre is in fact slowing and cooling, but future trends are uncertain. El Niño/Southern Oscillation is a quasi-periodic reversal of equatorial winds along the equator in the Pacific. This cyclic instability disrupts precipitation patterns and fisheries across much of the world, and recent decades have seen

disruptions in the periodicity of the normal 3- to 5-year pattern.

Sea-level rise has been occurring for several decades as ice caps and glaciers melt globally. Sea-level rise is increasing coastal erosion and leads to greater storm impacts inland. Ecosystem and biodiversity impacts are driven by fishery depletion from by-catch losses and pollution, including sewage disposal, floating trash, and oil spills. Recent uses of high-power sonar systems for military purposes are expected to have catastrophic impacts on ocean mammals. Ocean waters have become more acidic by more than 0.1 pH units, and increasing carbon dioxide atmospheric partial pressure will further acidify seawater. This leads to a reduction in aragonite saturation in seawater and weakens carbonate-secreting organisms' shell structures, including coral reefs. Ocean hypoxia is occurring in deltas and estuaries of the world, as agricultural pollutants and other chemicals reduce dissolved oxygen partial pressures in seawater to near zero. The occurrence of this phenomenon has increased exponentially in recent years, and there are fears of sterilization of some fisheries and ecosystems.

Atmospheric Change

Other atmospheric changes include ozone depletion in the polar regions and acid rain. Anthropogenic chlorofluorocarbons (CFCs) and bromine compounds reduce stratospheric ozone concentrations in the presence of very cold temperatures and have created ozone "holes" in both polar regions. Ozone depletion impacts for terrestrial species include sunburn, skin cancer, cataracts, and loss of plant productivity. The impacts on aquatic life in the Southern Ocean have not been quantified but are expected to be equally severe. Documented impacts on human and animal populations are increasing exponentially in these regions, even though CFC use has been phased out globally under the Montreal Protocol on Substances That Deplete the Ozone Layer.

Acid rain is a regional phenomenon downwind from major industrial areas burning fossil fuels. Nitrogen oxide and sulfur dioxide emissions remain in the atmosphere until they encounter rain, snow, or fog to form sulfuric and nitric acids and fall to the Earth as precipitation. Normal



rainfall is slightly acidic due to the presence of carbon dioxide in the atmosphere, but acid rain can exceed the pH of battery acid. This phenomenon can kill vegetation and sterilize water bodies—the German phrase for the phenomenon is “forest death.” Atmospheric deposition of compounds is not limited to acid rain; lead, mercury, radioactive fallout, and many other substances are delivered to the world’s ecosystems by air currents—there is no part of the world untouched by these human wastes.

Biodiversity

Human-caused extinctions have occurred since at least the Pleistocene, when a large number of terrestrial megafauna disappeared as humans expanded their range into North America. Contemporary extinction rates and modeled future extinction rates are much more severe than past events and are not limited to a few organisms. Changes in habitat beyond environmental tolerance will cause more widespread taxa extinctions than past geologic events, because now there are fewer species dispersal routes. Life forms can respond to environmental changes through evolution, but the current rates of environmental change are far too fast for species’ response through such a mechanism. Extinctions result in the loss of genetic resources and also may impede future scientific research.

New ecosystems and assemblages of species are predicted to occur in the decades ahead in conjunction with massive species extinctions. Alien or invasive species are organisms that thrive when introduced into a new ecosystem and that often displace and even exclude many of the endemic species. The success of invasive species leads to a loss of biodiversity in an area and globally. Because they lack predators and competitors that have coevolved with them, they can spread rapidly and aggressively. Declines in biodiversity lead to a loss of natural capital and genetic material and, more important, a reduction in the ecosystem services that society critically depends on for survival. Ecosystem services do not have explicit values in our market-based economy, but steady losses will eventually make them infinitely valuable and ultimately unattainable. Habitat fragmentation is destructive to ecosystem services because trophic

levels are more likely to be impaired or lost, especially in the upper trophic levels.

Societal Implications

Humans affect the planet directly through resource extraction and waste release and indirectly through social systems including laws, regulations, and economic incentive systems. Social organizations and transnational resource flows have intertwined to determine local environmental change since colonization began. Humans extract up to 40% or more of global net primary productivity through grazing, logging, and agricultural systems, and a new societal emphasis on sustainability aims to ensure that these extraction rates do not have net global and local increases. Sustainable agricultural and forestry systems are affected as much by governmental policies and subsidies as climate parameters. Governments are searching for ways to balance economic needs with long-term social stability to mitigate global environmental change. Disruptions of socioeconomic activities in sensitive regions will cause migration as peoples flee inhospitable conditions and places and seek greater opportunities. These human migrations will inevitably, in turn, cause more rapid environmental change in the receiving areas. Governments are examining the military and political ramifications of these migrations and their expected increase as additional global environmental changes occur.

The major concern for society must be irreversible global environmental changes, because these mistakes cannot be remedied. Exploding species extinction rates are the most critical of the anthropogenic impacts because extinction is permanent and irreversible. Other changes are reversible but unlikely to be achieved (e.g., restoration of major temperate forests is very difficult because cities, homes, and farms would need to be removed). Soil losses are irreversible in many areas (within human lifetimes), but new soil can develop in other, less sensitive areas. Societal management of future environmental change will focus on understanding the role of global climate change in exacerbating environmental changes and on reducing the uncertainties in predicting the trajectory of future forcing mechanisms and the resulting changes.

John All



See also **Acid Rain; Adaptation to Climate Change; Anthropogenic Climate Change; Biodiversity; Biogeography; Biota and Climate; Biota Migration and Dispersal; Carbon Cycle; Climate Change; Climate Policy; Climatology; Coastal Zone and Marine Pollution; Complexity Theory; Complex Systems Models; Desertification; Environmental History; Exotic Species; Extinctions; Global Sea-Level Rise; Great American Exchange; Human Dimensions of Global Environmental Change; Human-Induced Invasion of Species; Land Use and Cover Change (LUCC); Oceans; Plate Tectonics; Resilience; Symptoms and Effects of Climate Change**

Further Readings

- Blaikie, P., & Brookfield, H. (1991). *Land degradation and society* (New ed.). London: Routledge.
- Crutzen, P. J., & Stoermer, E. F. (2000). The "Anthropocene." *Global Change Newsletter*, 41, 17–18.
- de Sherbinin, A. (2002). *Land-use and land-cover change*. Palisades, NY: Center for International Earth Science Information Network of Columbia University. Retrieved November 19, 2008, from http://sedac.ciesin.columbia.edu/tg/guide_main.jsp
- Stein, B. A., & Flack, S. R. (Eds.). (1996). *America's least wanted: Alien species invasion of U.S. ecosystems*. Arlington, VA: The Nature Conservancy.
- U.S. National Research Council. (1999). *Global environmental change: Research pathways for the next decade*. Washington, DC: National Academies Press.
- Zalasiewicz, J., Williams, M., Smith, A., Barry, T. L., Coe, A. L., Bown, P. R., et al. (2008). Are we now living in the Anthropocene? *GSA Today*, 18(2), 4–8.

involves an increase in the scope, volume, and velocity of transactions across national borders, not all of which occur on a worldwide basis.

It is misleading to speak of globalization as a linear development, a fixed situation, or an undifferentiated worldwide phenomenon. Certain processes are, depending on world regions, globalized (such as trade, production, and labor and financial markets in the industrialized world), while others are constrained by local, regional, and national identities and policies (such as identity and border politics in sub-Saharan Africa; Central, East, and southeast Asia; and large parts of the greater Middle East). However, this status changes over time because the process of globalization is historically contingent. To take account of geographical differences, geographers have found the idea of globalizations (in the plural) increasingly relevant in recent years. Therefore, careful observation is necessary both to identify globalized arenas and to recognize the existence and assess the continuing relevance of national(ized) politics and (re)asserting statehood. Thus, the idea of a "borderless world" signifies some of the tendencies of contemporary hyper-globalization; depending on an individual's standpoint, such globalization may be seen as either a positive or a negative development. Those arenas that can be made out as globalized, however, are characterized by three single, though interconnected, processes: transnationalization and, in its consequences, denationalization and deterritorialization. These processes are not linear but are contested and resisted by governments, regional organizations, and nonstate antiglobalization movements. Such resistance is directed at all kinds of globalizations, but it typically emphasizes economic issues such as labor rights, economic injustices, environmental degradation, and human rights violations. This entry examines these processes and their implications for local places.

The most far-reaching impacts of those transformations relate to (a) shifts in the structure of time and space; (b) conceptualizations of human agency, including power; and (c) political and geographical imaginaries of statehood. Although those impacts appear to be historically novel, they are comparable with earlier historical periods of social and political upheaval, including their geographical distinctiveness and impacts and their complexities.



GLOBALIZATION

Globalization is a historical process of transnationalization, denationalization, and deterritorialization that encompasses different arenas, such as the economy, society, politics, culture, academia, and so on, with varying intensities and geographical differences. Loosely defined, it



Globalization and the Compression of Space and Time

Geographical distances can be overcome more easily and rapidly than ever before in history. The resulting compression of time and space has influenced the nature of the processes associated with globalization. This compression is largely due to new technologies of transportation and communications (e.g., developments in aircraft, telegraphic and telephone communication, and computer-based information technologies), the roots of which go back to at least the mid 19th century. These innovations allow for global coordination of social and political actions in simultaneous time; for example, through synchronized communication, people from (nearly) every corner of the world can get news of events at (nearly) the same time when they occur. Empirically, however, participation in those forms of communication and information flows is a question of their accessibility—that is, of social status and power; globalizations are much more widespread in the industrialized world than in less developed regions. However, the potential use of these innovations is, in principle, unrestricted. The compression of time and space also increases the permeability of borders in a wider sense—of territorial borders that control flows of people, goods, and information across nations and states. The porosity of borders also shapes transnational social organizations and movements. Because in democratic and pluralist political cultures the use of communications technologies is generally not restricted to certain classes or the elites, social participation in and use of their advancements in the industrialized world resulted in a massive increase of substate, global organizations during the late 20th century, for example, nongovernmental organizations. The growth in the number of such nonstate actors led to an increase in transborder social, political, and economic activities worldwide. These actors and their transborder activities, enabled by modern technology, play a key role in contemporary transnationalization and denationalization. The critical relevance of these two processes of globalization is that they call into question two major modern concepts of social, political, and economic order: the nation-state and international politics.

Transnationalization and Denationalization

Transnationalization (the emergence and increasing relevance of nonstate actors and their transborder activities) causes denationalization (shifts in decision-making power from nation-states to nonstate actors). Accordingly, the role, status, and power of states are increasingly uncertain and contested in the face of globalizations. This process has recently unfolded to a degree that is qualitatively new in world history. Since the Treaty of Westphalia in 1648, the nation-state and the international order in which it is embedded have formed the guiding principle of socioeconomic and political order for the past 350 yrs. (years) of Western and Westernized modernity. Thus, transnationalization represents a revolutionary upheaval in the conceptual focus that saw the world as divided by and compartmentalized into nation-states, world politics as limited to nation-states as actors, and the world as international, that is, involving interrelations only of and between nation-states (*inter* and *nations*). This focus on the nation-state, which dominated not only academic disciplines such as politics, sociology, geography, law, and economy but also non-academic perceptions, became insufficient for understanding and managing globalizations. Globalizations forced the social sciences as well as people in everyday life to develop new concepts that grasp the threefold reality of social and political agency situated *beyond* the state, residing *in* and *between* states (including national politics of territorialization and reterritorialization), and constituted by tensions between states and global nonstate actors. This idea not only presents conceptual challenges for the social sciences and law and jurisprudence, whose basic ontological unit, the nation-state, is in a profound process of transformation, it also creates the epistemological necessity for large segments of society to identify and imagine normatively patterns of world order in which this ontological unit is becoming blurred.

The most common ontological unit discussed as a replacement, or substitute, for the nation-state and the international in globalized politics is that of networks. Transnational, global networks are replacing and acting concurrently alongside the nation-state and the international



order. Networks are functionally differentiated relations among a multitude of actors—nation-states, their governments, and public authorities; nonstate actors and transnational societies and movements; and individuals—that cooperate globally on specific issues. Actors gain access to networks or are recruited as network members as a result of their functional contribution to the overall network targets and their specific resources. Because networks transcend the nation-state and the international order, they contribute to the third component of the globalization process, namely, deterritorialization.

One important aspect of globalization is that it is fundamentally different from internationalization. Whereas globalizations rest on and create transnational (and deterritorial) networks of social exchange and politics, internationalization (and international politics and society alike) remains within the territorial framework of nation-states, referring to cooperation among, and solely between, nations and national subunits. Thus, while the terms are often used interchangeably, they properly refer to different, if related, phenomena.

Deterritorialization

Deterritorialization, the third component of the globalization process, is a profound transformation of another basic ontological unit of the social sciences and common perceptions: territory and territoriality. In the 17th century, the primary form of political and social organization became associated with the nation-state, and this association became much stronger in the 19th and 20th centuries, when it was anchored in, and fixed to, the territorial framework of the sovereign state. Neither society, or politics or law in particular, nor human agency was perceived as possible without territorial fixation and a clearly demarcated geographical space where it was located and situated. The framework for territoriality was provided by the state, leading to geographical imaginations that equated statehood and national society. The basic *political* concept derived from this intellectual construction is sovereignty, which by definition is national sovereignty based on the geopolitical idea of a clearly demarcated territory; the basic *sociological* concept is integration, which

is by definition the integration of a national society within a certain territory. Substantively intertwined with transnationalization and denationalization, the deterritorialization of distinct globalized geographical units such as nation-states fundamentally challenges the concept of territoriality so basic to political, social, economic, juridical, and geographical modernity. Transnationality and the exercise of human agency in globalized networks are not limited to territorial frameworks but frequently transcend the geographical spaces of nation-states and the international order. Transnational politics does not occur within individual states and cannot be understood by applying the concept of territorial sovereignty. However, it is too vague to speak of deterritorialization as such, and careful analysis is necessary to spell out its consequences and implications, which vary widely across the globe.

The consequences of deterritorialization can be specified by investigating the changing functions of borders. For the past 350 yrs., borders have been thought of primarily as territorial borders according to the paradigm of modern statehood. The functions of such borders have been defined in terms of ideology, sociopsychological considerations, legal issues, and the provision of military security. With regard to distinct multilevel forms of transnational activities, deterritorialization results in the partial dissolution and blurring of these traditional four rationales for borders. Empirical studies, however, reveal the ambivalent character of this transformation. While they typically retain their ideological and sociopsychological meanings, territorial borders have been increasingly replaced by the functional ties of transnational social, political, and economic networks; their relevance to national legal and security issues seems to have widely diminished. Territorial borders and frameworks are still important for legal stability and military security, because global law, transnational arbitration, and state-led privatization of security are without legislative power, ambivalent, and/or still underconceptualized, and from the perspective of democracy, they often lack transparency and accountability. Thus, there still seems to be no substitute for the effectiveness, steadfastness, and reliability that have traditionally characterized territorialized and geographically delineated



(state) borders in (inter)national politics, society, and economy. Another indication of the continuing significance of territorial borders is that an estimated 80% of international wars have been and still are caused by border conflicts and territorial claims. Nevertheless, global (in)security, law, and jurisprudence are indeed borderless. Thus, there are large gray zones of lawlessness and insecurity both in the globalized arenas themselves and when the activities of globalized networks permeate into national and local societies. There are varying normative assessments of the development of borderless worlds; some see the potential for increased conflict as territorial boundaries become blurred, while others argue that de-bordering can foster new, grassroots-like forms of societal self-organization and transnational democracy.

Globalization, Networks, and the Human Subject

The most dramatic (and unresolved) philosophical consequences of the global transformation of time and space (dissolution of borders, compression of time and space) go hand in hand with those processes and are simultaneously reinforced by them. Globalization has had important implications for the nature of human identity and subjectivity. In most conceptualizations of modern political, social, and legal order, the human being is viewed as a self-contained subject, an autonomous person, and a unified (integrated) actor. This view assumes that the human subject is easily identifiable and is geographically and spatially constrained in terms of his or her inability to act simultaneously at two different locations. The rise of globalized networks, however, implies that the spatial and temporal scope of individual action is greatly increased and enhanced by new information and communications technologies, which allow individuals and networks to operate at multiple spatial scales. This transformation in potential geographical horizons can diversify the concept of the individual from an ostensibly self-contained subject, allowing him or her to occupy multiple, spatially different, contemporaneous spheres of being. When involved in globalized networks, individuals may multitask in several different contexts at

the same time. While neoliberal imaginations of an independent economic subject whose primary function and identity are based solely on consumption sustain this discursive logic of globalization, and vice versa, there are in fact massive ruptures between the reality of functionally diversified individuals embedded in transnational networks and dominant existing concepts of human action with regard to political rights, legal claims, and social norms and values. Thus, one of the greatest challenges for the social sciences concerning globalizations appears to be imagining and normatively conceptualizing a deterritorialized society and politics, including the development of a theory of human action that lives up to the multifaceted realities of borderlessness and the globalized subject.

Globalization: Historical Context and Implications

When specifying globalization as a process of transnationalization, denationalization, and deterritorialization, it has to be acknowledged that such processes are not new phenomena but have many historical roots. Outstanding historical examples are world religions such as Protestantism and the Catholic Church; premodern political systems such as the Persian, Mongol, Chinese, Ottoman, and Roman empires, the Hanseatic League, and the 14th-century world system; and the globalization associated with European colonial conquests. Consequently, the question arises whether globalizations in the 21st century signify a mere *quantitative proliferation* or (also) a *qualitative transformation*—of transnationalizing, denationalizing, and deterritorializing political, social, and economic processes—as compared with their earlier historical forms.

A necessary awareness of and sensitivity toward historical and empirical differentiation must not overshadow the fact that there are influential and highly transforming globalizations taking place in the early 21st century, bringing about qualitative transformations in world politics and geographies. Those qualitative changes are primarily due to revolutionary innovations in information, communications, and transport (technologies) that contribute to the three components of the globalization process (transnationalization, denationalization, and



deterritorialization) and the subsequent emergence of network societies and global flows of sociopolitical and economic communication and agency. The consequences of those upheavals are always in abeyance and ambiguous and can be identified only as transient, nevertheless eventually crucial, sociopolitical and geopolitical formations.

Hartmut Behr

See also **Antiglobalization; Antisystemic Movements; Borders and Boundaries; Castells, Manuel; Colonialism; Debt and Debt Crisis; Decolonization; Dependency Theory; Deterritorialization and Reterritorialization; Developing World; Development Theory; Economic Geography; Emerging Markets; European Union; Export-Led Development; Export Processing Zones; Finance, Geography of; Glocalization; Gross Domestic Product/ Gross National Product; Immigration; Imperialism; Import Substitution Industrialization; International Environmental Movements; International Environmental NGOs; International Monetary Fund; Marxism, Geography and; Modernization Theory; Nation; Nationalism; Neocolonialism; Neoliberalism; Newly Industrializing Countries; North American Free Trade Agreement (NAFTA); Offshore Finance; Organisation for Economic Co-operation and Development (OECD); Orientalism; Political Geography; Sovereignty; Space of Flows; Structural Adjustment; Supranational Integration; Telecommunications and Geography; Time-Space Compression; Tourism; Trade; Transnational Corporation; Transnationalism; Underdevelopment; War, Geography of; World Bank; World Cities; World-Systems Theory; World Trade Organization (WTO)**

Further Readings

- Barber, B. (1995). *Jihad vs. McWorld: How globalism and tribalism are reshaping the world*. New York: Ballantine.
- Dicken, P. (2007). *Global shift: Mapping the changing contours of the world economy* (5th ed.). London: Sage.
- Ferguson, Y., & Mansbach, R. (2004). *Remapping global politics: History's revenge and future shock*. Cambridge, UK: Cambridge University Press.
- Frank, A. (1998). *ReOrient: Global economy in the Asian age*. Berkeley: University of California Press.

- Friedman, T. (2005). *The world is flat: A brief history of the twenty-first century*. New York: Farrar, Straus & Giroux.
- Held, D. (1996). *Models of democracy*. Cambridge, UK: Polity Press.
- Herod, A. (2009). *Geographies of globalization*. Malden, MA: Wiley-Blackwell.
- Marks, R. (2007). *The origins of the modern world: A global and ecological narrative from the fifteenth to the twenty-first century*. Lanham, MD: Rowman & Littlefield.
- Pomeranz, K., & Topik, S. (1999). *The world that trade created: Society, culture, and the world economy, 1400–the present*. Armonk, NY: M. E. Sharpe.
- Smith, N. (2005). *The endgame of globalization*. London: Routledge.
- Stiglitz, J. (2003). *Globalization and its discontents*. New York: W. W. Norton.
- Wallerstein, I. (1979). *The capitalist world-economy*. Cambridge, UK: Cambridge University Press.



GLOBAL POSITIONING SYSTEMS

The *global positioning system* (GPS) is a satellite-based navigation system designed and operated by the U.S. Department of Defense (DoD). GPS can provide three-dimensional (3D) position and guidance in any weather and at any time of the day over the entire surface of the Earth, in the air, and in low space orbits. GPS consists of a control segment run by DoD, a space segment consisting of 24 or more satellites, and a user segment that includes military and civilian receivers.

GPS evolved from earlier regional and global radio navigation systems such as the Navy Transit System, Omega, and Loran-C. It was first described in the mid 1970s, and by 1985, there were enough satellites to allow development and testing of receivers for land, sea, and air navigation and guidance as well as for time and frequency dissemination and for both geodetic and plane surveying. The system was declared fully operational in 1995.

There is a wide range of GPS services and techniques with different capabilities, limitations, and



costs. There are two primary services that are provided by GPS and controlled by DoD. The Precise Positioning Service (PPS) is for use by the U.S. military, approved allied armed forces, and some agencies of the U.S. government. The PPS provides for encryption of the PPS bit stream (the P-Code) that is transmitted by the GPS satellites, mitigating the threat of spoofing, or tricking, a military receiver into tracking GPS-like signals transmitted by an adversary. Decrypting the PPS signals requires authorization and access to secure cryptographic keys.

The Standard Positioning Service (SPS) is now available, without restriction or charge, to everyone. For a time, between 1990 and 2000, the SPS bit stream (the C/A code) was intentionally degraded by Selective Availability to deny high-accuracy positioning to non-DoD users. The SPS, sometimes known as civilian GPS, is used throughout the world by a wide range of users in a wide variety of applications. Recreational hikers and boaters, users of automobile navigation systems, general aviation pilots, and data attribute collectors use inexpensive receivers to track the SPS signals.

The 24 or more GPS satellites orbit the Earth every 12 hrs. (hours). Earth rotates beneath the constellation, so the ground track of the satellites repeats in just less than 24 hrs. Monitored, adjusted, and provided with orbital and clock information by the control system, the satellites send their positions, their atomic clock errors, and complete system information on a bit stream called the Navigation Message. Relative ranges to satellites are determined within the receiver by lining up bit streams (P-Code and C/A code) sent by the satellites with identical codes produced in the receiver. The Navigation Message is sent from the satellites to the receiver over microwave frequency carrier signals that “spread” the SPS and PPS codes to resemble noise. When the receiver aligns its version of the codes with the noiselike GPS signals, the carrier frequencies are “despread,” providing the receiver with the contents of the Navigation Message and a code-phase relative arrival time for each satellite signal. Using at least four satellite messages and code-phase arrival times, a GPS receiver can produce a full 3D position solution and a correction for the receiver’s inexpensive clock.

SPS GPS can provide GPS receivers operating under optimal conditions with horizontal positioning errors of 3 m (meters) and vertical accuracies of 5 m. These levels of accuracy are 95% figures and require an antenna with a full and unobstructed view of the sky so that sufficient numbers of satellites and good enough geometry (satellites must be evenly spread out in the sky for robust positioning) can be obtained. Local reflections from building and ground surfaces can interfere with GPS tracking. Trees, some foliage, metal, many building materials, and even the human body can block GPS signals from getting to the GPS antenna with sufficient signal strength to allow for position determination. While there are some assisted and low signal-strength approaches to GPS receiver design, GPS remains an outdoor system requiring care on the part of the user to obtain useful position information.

Some GPS bias errors, including signal delays introduced by the ionosphere and troposphere, orbital parameter errors, and GPS satellite clock errors, can be reduced by applying corrections for each tracked satellite signal. Differential GPS (DGPS) uses corrections produced by one or more reference GPS receivers to improve the position accuracy of a remote receiver at an unknown position. The precisely located DGPS reference receiver produces corrections in the form of time-tagged range error and rate-of-range error parameters for each satellite along with codes identifying which orbital and clock parameters the corrections relate to. DGPS is not based on position corrections. The remote receiver position is computed after applying the range corrections for each satellite used in the remote receiver position solution.

DGPS is the basis for a wide variety of GPS approaches. Real-time, code-phase DGPS can make use of range corrections transmitted from ground-based or communications satellite radio transmitters. These real-time DGPS systems can provide 1-m accuracies when the receiver is within a few hundred kilometers of a DGPS reference station. Other systems such as the U.S. Federal Aviation Administration Wide Area Augmentation System provide corrections based on models for signal biases computed from a network of monitor receivers. These network solutions can result in 3-m accuracies anywhere within the national airspace service area of the system.



DGPS postprocessing can be accomplished if both remote and reference receivers store sufficient information to couple corrections with measured arrival times and orbital and clock data sets. Many commercial and public agencies provide Internet access to DGPS data for postprocessing. Geodesists use receivers separated by thousands of kilometers to measure tectonic movement by measuring over many hours. Surveyors make use of de-spread GPS carrier signals, low-noise receivers, special software techniques, and continuous tracking to produce relative position estimates over baselines of 10 to 30 kilometers.

Peter H. Dana

See also [GIScience](#); [GIS Web Services](#); [Location-Based Services](#); [Mobile GIS](#); [Neogeography](#); [Surveying](#)

Further Readings

- El-Rabbany, A. (2006). *Introduction to GPS: The global positioning system*. Norwood, MA: Artech House.
- Hofmann-Wellenhof, B., Lichtenegger, H., & Collins, J. (2004). *Global positioning system: Theory and practice*. Berlin, Germany: Springer.
- Parkinson, B. W., & Spilker, J. J. (Eds.). (1996). *Global positioning system: Theory and practice* (Vols. 1 & 2). Washington, DC: American Institute of Aeronautics and Astronautics.



GLOBAL SEA-LEVEL RISE

Global sea level (i.e., the mean sea level averaged across the globe) has risen by 1.6 ± 0.2 mm/yr. (millimeters per year) in the period 1961 to 2003 and by a similar amount (1.7 ± 0.3 mm/yr.) when calculated over the entire 20th century. These rates are based on tide gauge measurements and, since the early 1990s, also on satellite altimetry. Satellite measurements have shown that global sea-level rise has not been uniform, either in time or in space.

The average global sea-level curve shows distinct temporal fluctuations. In the 1920s and

1930s, sea-level rise speeded up, while in the 1960s, sea-level rise slowed down. Since the 1970s, the maximum decadal rate of sea-level rise has increased from about 3 mm/yr. to more than 5 mm/yr. Averaged over the past 15 yrs., the global rate is about 3 mm/yr. The spatial pattern of sea-level rise shows large variability. Between 1993 and 2003, parts of the North Atlantic and Western Pacific oceans experienced rates of sea-level rise in excess of 10 mm/yr., but in the Eastern Pacific and Western Indian oceans, sea level fell by similar amounts. When averaged over the past 50 yrs. the pattern is also complex (Figure 1). Large parts of the world's oceans have been subject to sea-level rise, but there are places, most notably in the Indian Ocean and the tropical Pacific, where sea level has fallen, albeit by a small amount.

Spatial variability in patterns of sea-level rise is strongly correlated with changes in oceanic heat content that affect the density of ocean water and produce so-called steric sea-level change. Thermal expansion is the predominant contributor to steric sea-level change; salinity variations are less important. Thermal expansion was responsible for about 45% of global sea-level rise in the period 1961 to 2003, with glaciers and ice caps contributing about 30% and ice sheets in Greenland and Antarctica a little over 10% each. Building of dams and mining of groundwater may be significant additional factors in the global sea-level budget but are believed to cancel each other out.

The melting of ice sheets, ice caps, and glaciers also produces regional sea-level variability, albeit on a larger wavelength than do the steric effects. The diminishing gravitational attraction exercised by a shrinking polar ice mass on the ocean surface causes sea-level rise to be greater in the "far field" (i.e., equatorial regions and the oceans in the opposite hemisphere) than nearby. This effect means that coastlines on both sides of the North Atlantic Ocean, for example, are more vulnerable to the melting of the Antarctic Ice Sheet than to melting of the Greenland Ice Sheet. The sloping pattern of sea-level rise produced by melting ice is known as the *sea-level fingerprint* of the melt source.

Coastal sea-level change is measured by tide gauges, but these instruments measure simultaneously the movement of the coast to which the

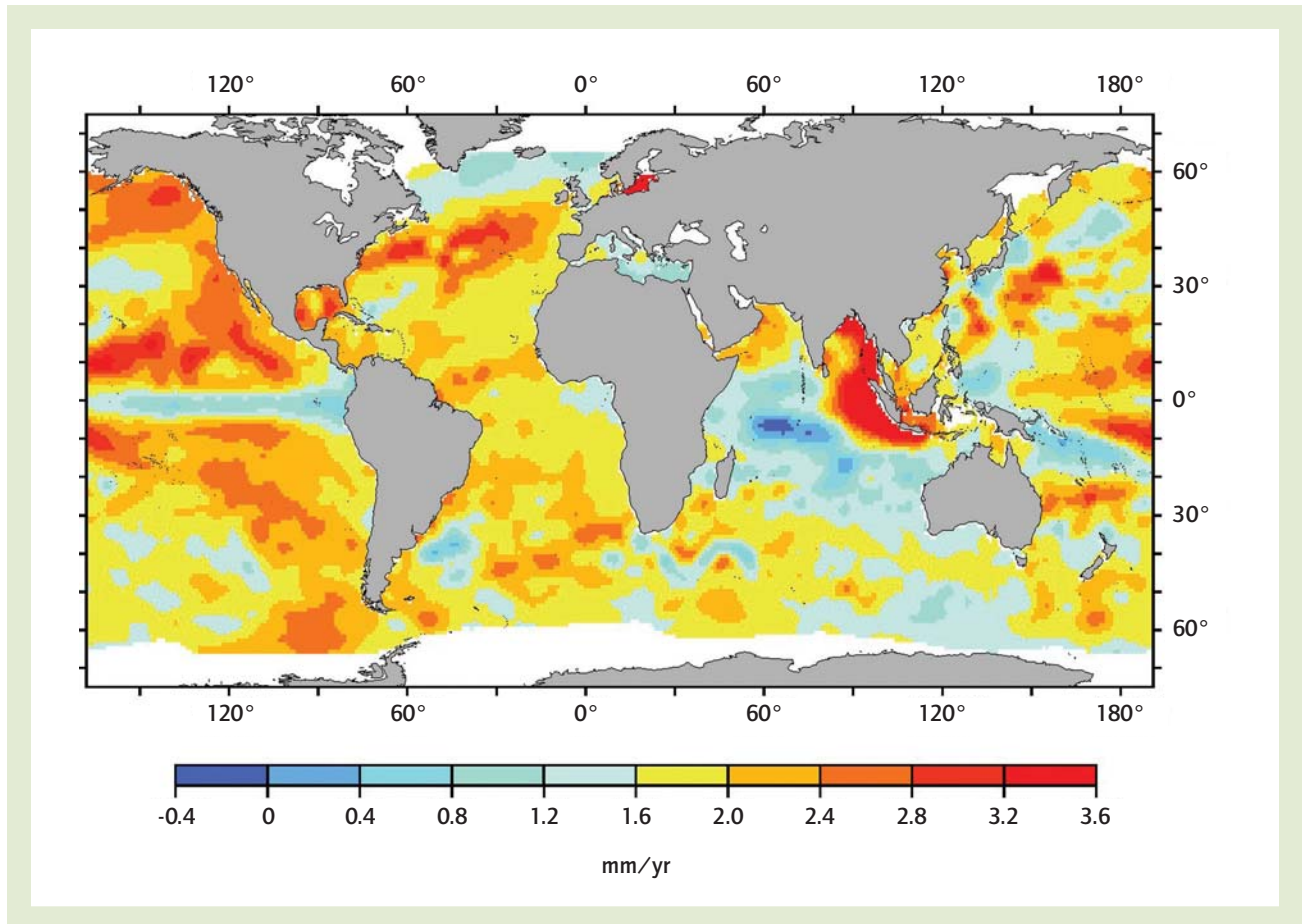


Figure 1 Linear trends in mean sea level between 1955 and 2003 determined from tide gauge data and satellite altimetry

Source: Adapted from Woodworth, P. L., White, N. J., Jevrejeva, S., Holgate, S. J., Church, J. A., & Gehrels, W. R. (2008). Evidence for the accelerations of sea level on multi-decade and century timescales. *International Journal of Climatology*, 29(6), 777–789.

tide gauge is attached. Globally averaged rates of sea-level rise based on tide gauge records should therefore be corrected for isostatic and tectonic effects. The global glacial isostatic adjustment (GIA) process has been extensively analyzed with the help of sophisticated Earth models. These studies have revealed that GIA produces not only land-level changes but also a slow increase in the global ocean volume in areas where the ocean floor is subsiding due to glacial forebulge collapse and hydro-isostatic loading. The global sea-level fall due to this “ocean-syphoning” effect is about 0.3 mm/yr. and is important because it partly offsets the global acceleration of sea-level rise that has occurred between the 19th and the 20th centuries.

It is now becoming clear that humans are having a distinct impact on global sea-level rise. Computer simulations have shown that anthropogenic sea-level forcing took effect around the beginning of the 20th century. Since the 1950s, anthropogenic forcing has become more dominant than natural forcing. During the 19th century, sea-level rise was “natural” and slower. The climatic recovery following the volcanic eruption of Tambora in 1815 marked the onset of the global increase in oceanic heat content and the resulting thermal expansion. Aerosols produced by other large volcanic eruptions, including Krakatoa (1883), El Chichon (1982), and Pinatubo (1991), have temporarily cooled the ocean and halted global sea-level rise.



The rates of global sea-level rise during the 20th and 21st centuries are small when compared with the episodes of sea-level rise during the last deglaciation. Around 14,000 yrs. ago, the event known as *Meltwater Pulse 1a* produced a short-lived sea-level rise in excess of 40 mm/yr. However, contemporary rates of global sea-level rise probably exceed the highest rates known to have occurred during the past 8,000 yrs., while during the Last Interglacial, when sea level was 4 to 6 m (meters) higher than today, rates of sea-level rise may have been as high as 0.6 to 2.5 m per century. These rates are comparable with the highest forecasts made for the remainder of the 21st century.

The Intergovernmental Panel on Climate Change (IPCC) has predicted that by the year 2100, global mean sea level will have risen by 0.18 to 0.79 m. This range reflects the possible greenhouse gas emission scenarios and their effects on the oceans and the cryosphere. These forecasts are made by sophisticated climate models, but higher rates have been predicted from extrapolating the empirical relationship between temperature and sea-level rise observed during the past century. However, these high rates have been challenged based on glaciological grounds, and it is considered unlikely that sea-level rise in the next 100 yrs. will exceed 1 m. Incorporating the dynamics of rapid ice decay into the modeling of sea-level change is required to improve future predictions of global sea-level rise. The regional variability of sea-level rise, so evident in the patterns of recent sea-level change, also needs to be included in future model predictions. In addition to rising sea levels, the frequency of extreme sea levels and storm surges is predicted to increase. The “smooth” line predictions of the IPCC can therefore be somewhat misleading. It is to be expected that in future decades, as in the 20th century, global sea-level rise will be of a fluctuating nature and the magnitude of local sea-level rise will be site specific.

Roland Gehrels

See also **Anthropogenic Climate Change; Climate Change; Coastal Hazards; Floods; Glaciers, Continental; Glaciers, Mountain; Global Environmental Change; Oceans**

Further Readings

- Church, J. A., White, N. J., Aarup, T., Wilson, W. S., Woodworth, P. L., Domingues, C. M., et al. (2008). Understanding global sea levels: Past, present and future. *Sustainability Science*, 3, 9–22.
- Gehrels, W. R., & Long, A. J. (2008). Sea level is not level: The case for a new approach to predicting UK sea-level rise. *Geography*, 93, 11–18.
- IPCC. (2007). Summary for policymakers. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, et al. (Eds.), *Climate change 2007: The physical science basis* (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, UK: Cambridge University Press.
- Woodworth, P. L., White, N. J., Jevrejeva, S., Holgate, S. J., Church, J. A., & Gehrels, W. R. (2008). Evidence for the accelerations of sea level on multi-decade and century timescales. *International Journal of Climatology*, 29(6), 777–789.



GLOBAL WARMING

See Anthropogenic Climate Change



GLOBES

See Cartography; Map Projections



GLOCALIZATION

At its most superficial level, *glocalization* connotes the combination of *global* and *local*, two spatial terms of great importance to geographers. While the term apparently derives from a traditional Japanese word now used to describe the spatial niche marketing of commodities in the business literature, in more scholarly literature, *glocalization* has come to mean something more complex: that globalizing processes only manifest

themselves in various ways in local contexts. That is, the global and the local are not separate spatial phenomena somehow interacting with each other, but rather, what is considered a “global” process is always already enacted variously in local settings. In this view, all cities in the world are global cities in that they all include globalizing economic, political, and cultural processes. How, to what extent, and to what possible future these globalizing processes manifest themselves, however, depends on local socioeconomic characteristics and trends.

This is a vision of spatial hybridity that sees the global and local as mutually formative. Unlike commentators who suggest that globalization is inevitably leading to a flatter, more homogeneous economic, political, and cultural world, glocalization scholars argue that, in fact, so-called globalizing processes are not only spread quite unevenly across the world, they also serve less to homogenize than to diversify this world as a result of hybrid glocal formations. The key is to observe each glocal context more closely to determine what globalization really entails. Cultural geographers thus consider globalization not as a convergence of global cultures but as the creation of new, heterogeneous, hybrid glocal cultures and individual identities. Political and economic geographers place more emphasis on the capacity of differential social power to create certain types of glocal hybridities as opposed to others as well as on the overall decline in the power of the nation-state to regulate global processes.

With respect to the latter, financial capital as well as some forms of productive capital clearly have transcended nation-state boundaries in terms of markets and investments. To conduct such business has necessitated the emergence of supranational governance institutions such as the World Trade Organization, the North American Free Trade Agreement, the European Union, the



Indian youths queue at the opening of the first McDonald's family restaurant in New Delhi, October 13, 1996. Officials of the giant U.S.-based chain announced that this is the only McDonald's restaurant in the world with no beef on the menu, as most of the people of India do not eat beef.

Source: AP Photo/Ajit Kumar.

World Bank, and the International Monetary Fund, which necessarily reduces the sovereign decision-making powers of member states. At the same time, growing supranational economic activity has increased the competition among nations, regions, and localities to capture this activity, which is no longer regulated at the national level. To be successful at this process necessitates, in turn, the restructuring of internal social and economic governance to make it more conducive to the “free market” business practices of footloose supranational capital.

This idea is the source of the currently hegemonic neoliberal ideology of governance. Of interest is that the increasing deregulation of national spaces as well as the growing power of supranational governing institutions and transnational corporations have entailed the rising importance of governance at the subnational level of regions and metropolitan areas. As the free market nation-state relinquished its spatially “uncompetitive” role of equalizing development over the whole national territory, such subnational entities



were increasingly left to their own devices in terms of successful economic development and social reproduction. Not surprisingly, subnational elites largely follow the neoliberal recipes for success adopted at the national level, thereby increasing place competition and social inequality at the subnational level. Viewed glocally, this is a direct result of the growing discursive and real hegemony of national and subnational agents of increasingly powerful supranational processes. The weakening of nation-state regulation is thus consciously enacted by glocal agents and is not something forced by an inexorable, somehow external pressure of globalization.

The profound insight of the glocal approach is that by unreflectively thinking the global situation to be so, humans are acting to make it so. But, in fact, it is not actually so or, better, real globalization could be otherwise. This general glocal vision thus focuses on the ways in which not only this hegemonic discourse but also the emerging reality of globalization can be resisted. If globalization is really not a monolithic, homogenizing force but an uneven glocal phenomenon, then there are always openings for such resistance via both active hybridization and sociopolitical movement. In terms of the former, the focus is on the hybridization of individual and group identities as a result of the global movement of people and ideas, with the key concept of cultural transnationalism replacing internationalism. In terms of the latter, the focus is on how to negotiate differential power within and among the different spatial scales of productive activity and political governance that have emerged as a result of the weakening of nation-state regulation.

Viewed glocally, then, nothing about “globalization” is necessary, but globalization is rather the result of conscious decisions made by some to the economic and social detriment of others. Globalizing processes are neither as strong as they seem nor should they be discussed as such. The political optimism of this approach is that once this is understood, one can imagine and enact a wholly different kind of globalization, less inequitable and more participatory. That this will entail a difficult discursive and real battle is certain. In fact, paying attention to the glocal makes it clear that some individuals and institutions have more power over space and place and other people than do others.

In geography, this is where the focus on globalization merges with the discussion of the significance of geographical scale in social relations. In short, paying attention to the glocal makes it clear that the currently hegemonic imagining and enactment of the “global” is but a specific social construction that can be deconstructed as a result of conscious re-imagining and the accompanying re-enactment.

Kevin Archer

See also Globalization; Hybrid Geographies; Locality; Neoliberalism; Regional Geography; Scale, Social Production of; Transnationalism

Further Readings

- Peck, J., & Tickell, A. (1994). Searching for a new institutional fix: The *after*-Fordist crisis and the global-local disorder. In A. Amin (Ed.), *Post-Fordism: A reader*. Oxford, UK: Blackwell.
- Robertson, R. (1995). Glocalization: Time-space and homogeneity-heterogeneity. In M. Featherstone, S. Lash, & R. Robertson (Eds.), *Global modernities* (pp. 25–44). London: Sage.
- Swyngedouw, E. (2004). Globalisation or “glocalisation”? Networks, territories and rescaling. *Cambridge Review of International Affairs*, 17, 25–48.



GOLLEDGE, REGINALD (1937–2009)

Reginald Golledge was a professor of geography and the director of the Research Unit on Spatial Cognition and Choice at the University of California, Santa Barbara (UCSB). His extensive body of work spanned more than 40 years of outstanding scholarship in the service of geography. As a senior faculty member at UCSB, he joined the geography department in 1977, only a few years after its inception. His efforts significantly contributed to the flourishing of geography at UCSB and helped establish one of the top geography departments in the United States.



Golledge was born in Australia in 1937. He received his BA (1959) and MA (1961) in geography from the University of New England in Australia and his PhD (1966) from the University of Iowa. During the following decades, he pursued a vast array of research projects. Golledge was highly regarded for his pioneering work in behavioral geography and disability geography. A noncomprehensive list of his research interests includes spatial decision making, migration, travel behavior and activity planning, spatial cognition, cognitive mapping, spatial abilities and spatial knowledge acquisition, wayfinding and navigation, visual impairment and other disabilities, and geography in K–12 (elementary and secondary) education.

Golledge wrote or edited 16 books, contributed to more than 100 book chapters, and was the author or coauthor of more than 100 academic papers. Just as his prolific publications speak of his devotion to geography and academia in general, an extensive number of honors and accolades have accompanied his distinguished career. Apart from holding an honorary PhD from Göteborg University in Sweden and an honorary LLD from Simon Fraser University in Canada, Golledge was named a Fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science, and the Guggenheim Foundation. In addition, he received numerous awards, such as the Lifetime Award of the Association of American Geographers (AAG), the Gold Medal of the Institute of Australian Geographers, and the UCSB Award for Outstanding Graduate Mentor. Between 1998 and 2000, he first held the position of vice president of the AAG, followed by a term as president of the same organization. More recently, Golledge was the recipient of the Enhancing Diversity Award of the AAG in recognition of his work on geography and disability, actively striving to extend the notion of diversity to include those with disabilities. In early 2009, he was selected as the Annual Faculty Research Lecturer at UCSB, the highest honor given out by the UCSB Academic Senate.

Golledge earned respect and veneration within the discipline, not just due to his extraordinary academic record and scholarly work but also as a result of his lifelong commitment to his students. As an advisor, teacher, and mentor, he has had

an impact on the lives and careers of numerous geographers.

Martin Swobodzinski

See also Behavioral Geography; Blindness and Geography; Disability, Geography of; Spatial Cognition; Wayfinding

Further Readings

- Golledge, R. (Ed.). (1999). *Wayfinding behavior: Cognitive mapping and other spatial processes*. Baltimore: Johns Hopkins University Press.
- Golledge, R. G., & Stimson, R. J. (1997). *Spatial behavior: A geographic perspective*. New York: Guilford Press.

GOODCHILD, MICHAEL (1944–)

Michael Frank Goodchild is a well-known British-American geographer and educator and an influential theorist and pioneer in geographic information science (GIScience). As a professor of geography at the University of California, Santa Barbara (UCSB) since 1989, and codirector (1991–1997) and executive committee chair (1997–) of the National Center for Geographic Information and Analysis (NCGIA), Goodchild has led the development of GIScience from its origins within the technical specialty of geographic information systems (GIS) to the status of a full-fledged academic field. GIScience studies the fundamental principles underlying the acquisition, handling, analysis, and dissemination of geographic information, addressing issues of representation, computation, visualization, and societal impact.

Apart from the vision that helped shape a nascent discipline, Goodchild's notable contributions to geography include his persistent attention to the quality of geospatial data, uncertainty in their representation and interpretation, and resultant impacts on geospatial analyses. He has played a significant role in the global Digital Earth



initiative begun in 1998 and has led discussion and research on a succession of related efforts, including the digital geolibrary (codirecting the Alexandria Digital Library since 1994), applications of virtual-globe technology, and the emerging field of volunteered geographic information. An increasing focus of interest has been spatial literacy and applications of spatial thinking in all knowledge domains.

Goodchild's appointment at UCSB, followed 20 years as a professor of geography at the University of Western Ontario (UWO; 1969–1989). He served as department chair at both institutions (UWO, 1982–1985; UCSB, 1998–2000). He earned his BA in physics from Cambridge University in 1965 and his PhD in geography from McMaster University in 1969.

Goodchild has published more than 400 scholarly articles and coauthored or coedited 11 books, including *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools* (2007), *Geographic Information Systems and Science* (2005), and *Uncertainty in Geographical Information* (2002). He was the editor of *Geographical Analysis* (1987–1990) and the “Methods, Models, and Geographic Information Sciences” section of the *Annals of the Association of American Geographers* (2000–2006) and has served on the editorial boards of several other journals. As of 2008, he had supervised 21 doctoral and 25 master's theses.

Goodchild has been a member of the National Academy of Sciences since 2002, a Foreign Fellow of the Royal Society of Canada since 2002, and a member of the American Academy of Arts and Sciences since 2006. He was the 2007 recipient of the Prix Vautrin Lud, widely regarded as the highest award in the field of geography, and has received honorary doctorates from Université Laval (1999), Keele University (2001), McMaster University (2004), and Ryerson University (2004). His numerous awards include Royal Geographical Society Founder's Medal (2003); Educator of the Year, University Consortium for Geographic Information Science (2002); Canadian Cartographic Association's Award of Distinction for Exceptional Contributions to Cartography (1999); Association of American Geographers' Award for Outstanding Scholarship (1996); and the Canadian Association of Geographers' Award

for Scholarly Distinction (1990). He received Lifetime Achievement awards from the Geospatial Information and Technology Association (2007) and the Environmental Systems Research Institute (2001) and was inducted into the GIS Hall of Fame of the Urban and Regional Information Systems Association (2007).

Karl Grossner

See also **Geographic Information Systems; GIScience; National Center for Geographic Information and Analysis**

Further Readings

- Goodchild, M. (1992). Geographical information science. *International Journal of Geographical Information Systems*, 6(1), 31–45.
- Goodchild, M. (2004). A general framework for error analysis in measurement-based GIS. *Journal of Geographical Systems*, 6(4), 323–324.
- Goodchild, M. (2004). GIScience, geography, form, and process. *Annals of the Association of American Geographers*, 94(4), 709–714.
- Goodchild, M., & Mark, D. (1987). The fractal nature of geographic phenomena. *Annals of the Association of American Geographers*, 77(2), 265–278.
- Goodchild, M., Yuan, M., & Cova, T. (2007). Towards a general theory of geographic representation in GIS. *International Journal of Geographical Information Science*, 21(3), 239–260.
- Maguire, D., Goodchild, M., & Rhind, D. (Eds.). (1991). *Geographical information systems: Principles and applications* (2 vols.). London: Longman Scientific and Technical.



GOODE, J. PAUL (1862–1932)

John Paul Goode played a key role in the development of 20th-century American cartography. Born in Minnesota in 1862, Goode received his bachelor's degree from the University of

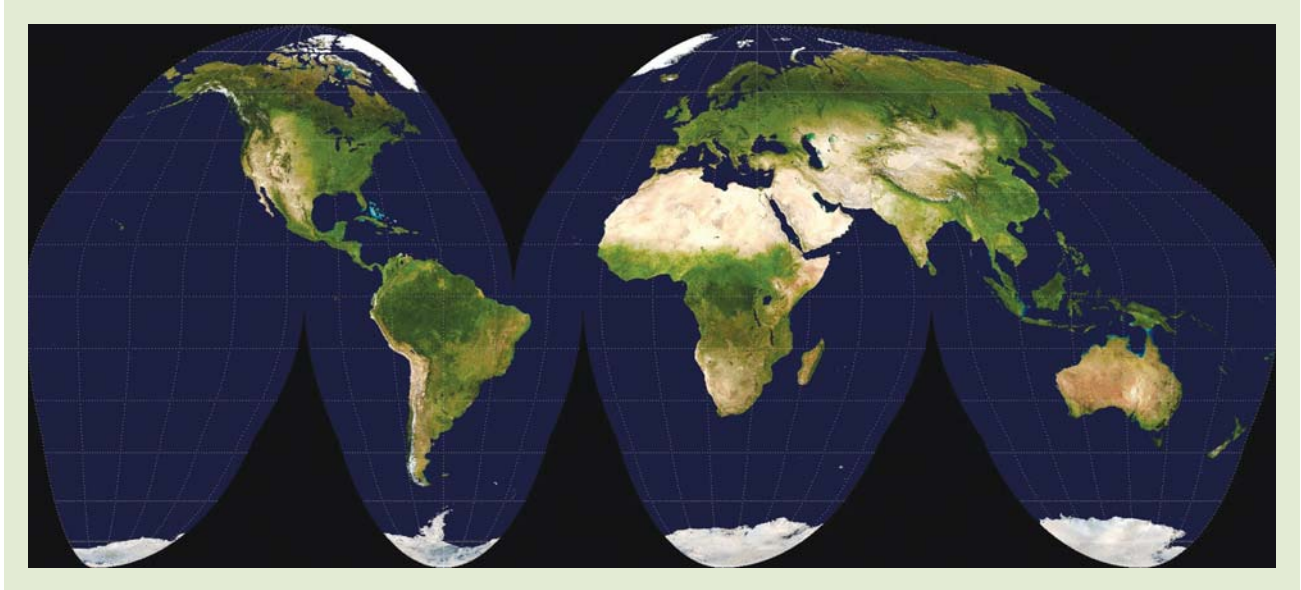


Figure 1 Goode's Interrupted Homolosine projection. This famous projection preserved the relative sizes of places by revealing them in a series of disconnected parts.

Minnesota in 1889 and taught at the Minnesota Normal School in Moorhead from 1889 to 1898. In 1901, he completed his doctorate in economics at the University of Pennsylvania, and he subsequently played an important role in the cultivation of the nascent subdiscipline of economic geography, then called “commercial geography.” He taught geography at the University of Pennsylvania from 1903 to 1917 and at the University of Chicago (then a leading center of geography) from 1917 to 1928, where he taught a variety of courses, including cartography and graphics. Indeed, he is occasionally called the first true American academic cartographer; his students included Henry Leppard and Edward Espenshade. Goode was interested in advancing geographic education in a variety of respects and published widely on the topic. He also served as an “expert investigator” of the Chicago Harbor and for harbors in other cities.

Goode contributed to geography and related disciplines in several respects, including coediting the *Journal of Geography* from 1901 to 1904, helping organize and head the Geographical Society of Chicago, and serving as General Secretary of the American Association for the Advancement of Science in 1907–1908. He was

a founding member of the Association of American Geographers in 1904 and served as its president in 1926–1927, giving as his presidential address a talk titled “The Map as a Record of Progress in Geography.”

Goode was well-known for his opposition to the widely used Mercator projection, particularly for its areal distortion at high latitudes, a problem that prompted him famously to label it the “evil Mercator.” In response, in 1916, he famously combined two other projections, the equal-area Homolographic (or Mollweide) and the Sinusoidal, which Goode noticed coincided at roughly 40°44' latitude, to invent the Goode Interrupted Homolosine projection, a quasi-cylindrical view that depicted the globe in irregular joined parts, yielding a “peeled-orange” effect (Figure 1). By placing the interruptions over the oceans, the map could reveal continents relatively well; later, Goode made a similar map emphasizing global water space. The result effectively combined the Sinusoidal's superior representation of equatorial regions with the Mollweide's better view of polar areas. Unlike the Mercator, this approach preserved proportionate areal sizes, and it became widely popular for the representation of global thematic distributions. Goode was criticized at



times, however, for not positioning the United States in the center of the map, as was the custom at the time. He also developed the polar equal-area projection in 1928.

Goode also became widely known for initiating and editing *Goode's School Atlas*, later renamed *Goode's World Atlas*, which first appeared in 1922. Originally designed for use in schools, where it became a standard text in high schools and colleges, it also became enormously popular among the lay public. Over the following decades, often edited by his students, it reappeared in more than 21 editions to become one of the most commonly used atlases in the world, greatly accelerating the popularity of thematic cartography and powerfully influencing the geographic imagination of millions of people.

Barney Warf

See also **Cartography; Cartography, History of; Map Projections**

Further Readings

Goode, J. (1929). The polar equal area: A new projection for the world map. *Annals of the Association of American Geographers*, 19, 157–161.

Haas, W., & Ward, H. (1933). J. Paul Goode. *Annals of the Association of American Geographers*, 23, 241–246.

McMaster, R., & McMaster, S. (2002). A history of twentieth-century American academic cartography. *Cartography and Geographic Information Science*, 29, 305–321.

information system), an advanced visualization technology, and a tool for teaching, learning, and entertainment (Figure 1).

Google Earth was originally developed by Keyhole Corporation, which Google purchased in October 2004. In early 2005, the basic version of Google Earth became available to the public. Google Earth enables exploration of the terabytes of images and information served by Google within the spatial context of Earth. In addition to Earth, the software includes a virtual rendering of the sky, a bathymetry of the ocean floor, and a virtual globe of the planet Mars.

The Google Earth virtual globe is covered with layers of satellite and aerial imagery of Earth displayed at various resolutions and scales. In certain areas, multiple images acquired on different dates can be viewed sequentially. Google Earth provides the user with numerous layers of information related to the location being viewed that can be optionally shown, such as Web links to articles, high-resolution and panoramic ground-based photography, 3D models of terrain and buildings (Figure 2), weather, traffic, road and street names, 360° photography of street views, points of interest, information related to organizations, and many other features that are continuously updated by Google and the Google Earth community.

In Google Earth, one can search for geographic features using Google's search technology by simply entering the name of a geographic feature, an address, a place name, or a set of coordinates or by browsing with the mouse. The built-in DEM (digital elevation model) enables one to view the relief of mountains and valleys or dive below the surface of the ocean to observe the deep trenches and canyons (Figures 3 and 4). The user can fly over the terrain, pan, rotate, tilt, spin, or jump to another place on the globe.

Google Earth enables some basic functions of a GIS. Tools for measuring distances and areas and for creating lines and polygons that the user may save on his or her computer are all included. Users can also add their own information, which can be a place-mark, text, images, video, or links to other information on the Web. Users may also import GPS (global positioning system) data such as waypoints or tracks and create multiple layers of their own raster or vector data. Layers of



GOOGLE EARTH

Google Earth is a virtual globe that is available for free through the Internet to anyone in the world who has an Internet connection and a computer with the minimum requirements. Google Earth is many things in one: a virtual globe, a 3D (three-dimensional) geobrowser, an interactive geospatial encyclopedia, a basic GIS (geographic

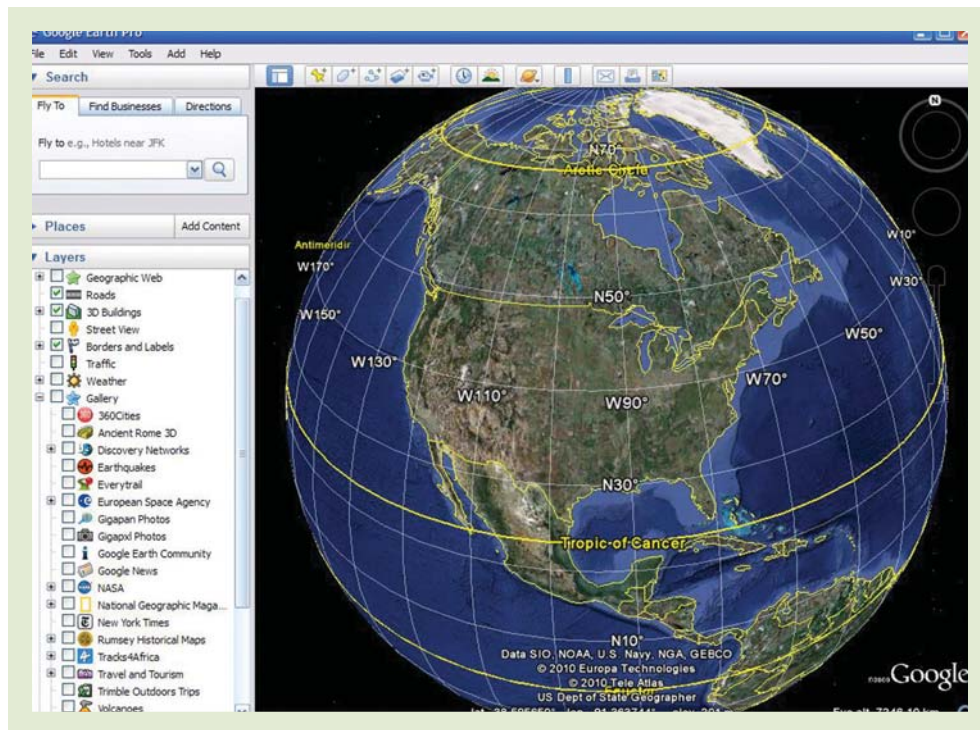


Figure 1 Google Earth with the borderlines in yellow and the layers of information on the left

Source: Google Earth.

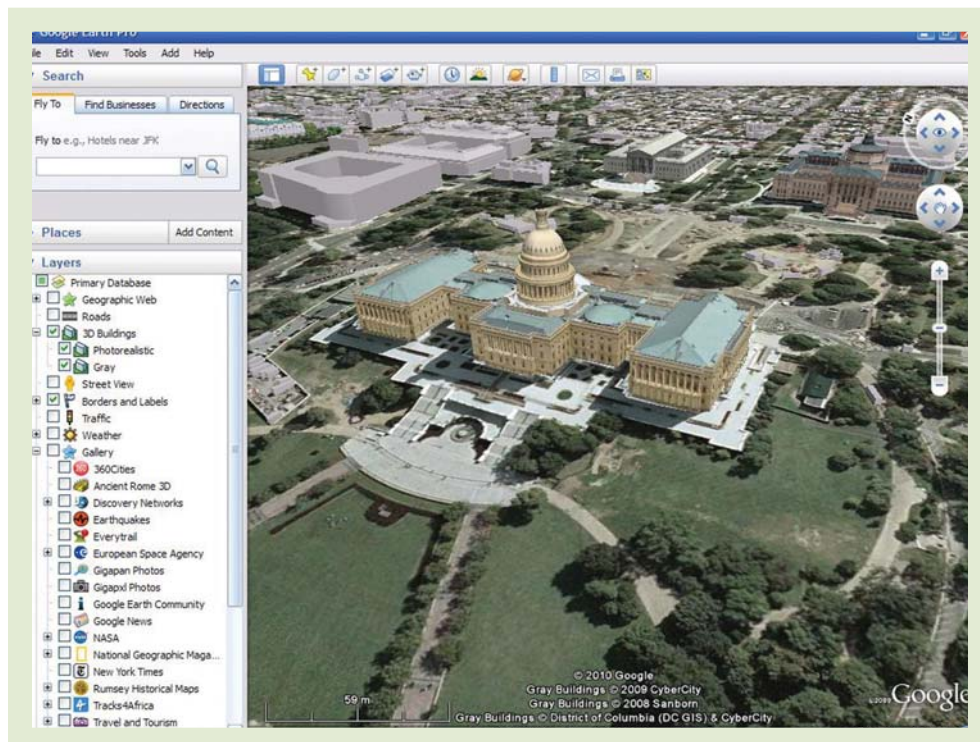


Figure 2 The Capitol as a photorealistic 3D building

Source: Google Earth.

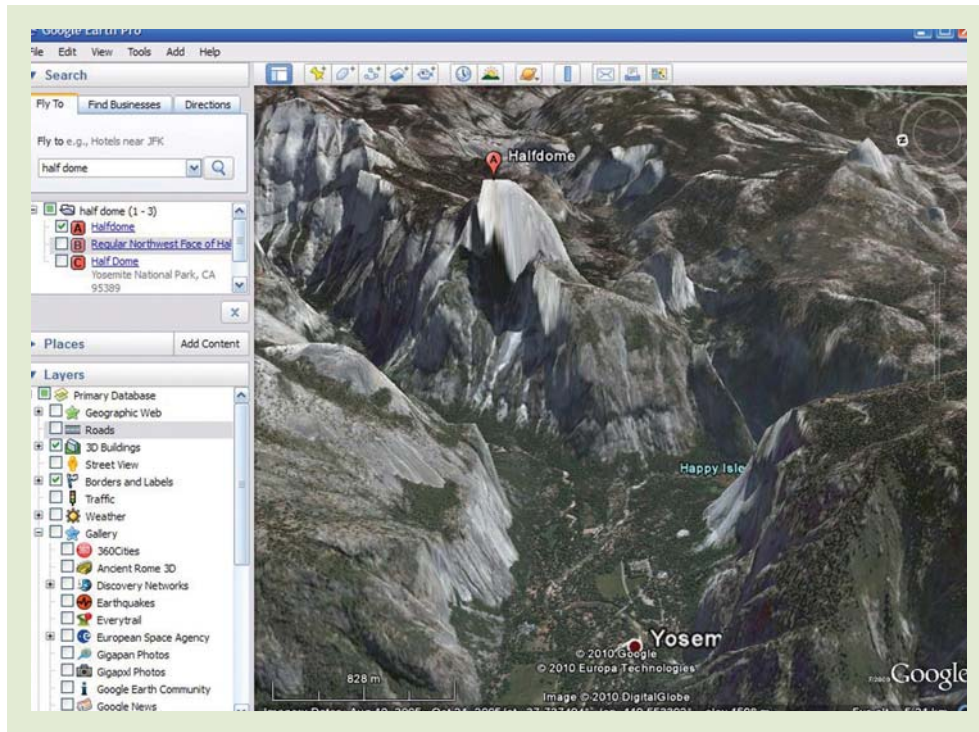


Figure 3 DEM (digital elevation model) of Half Dome in the Sierra Nevada

Source: Google Earth.

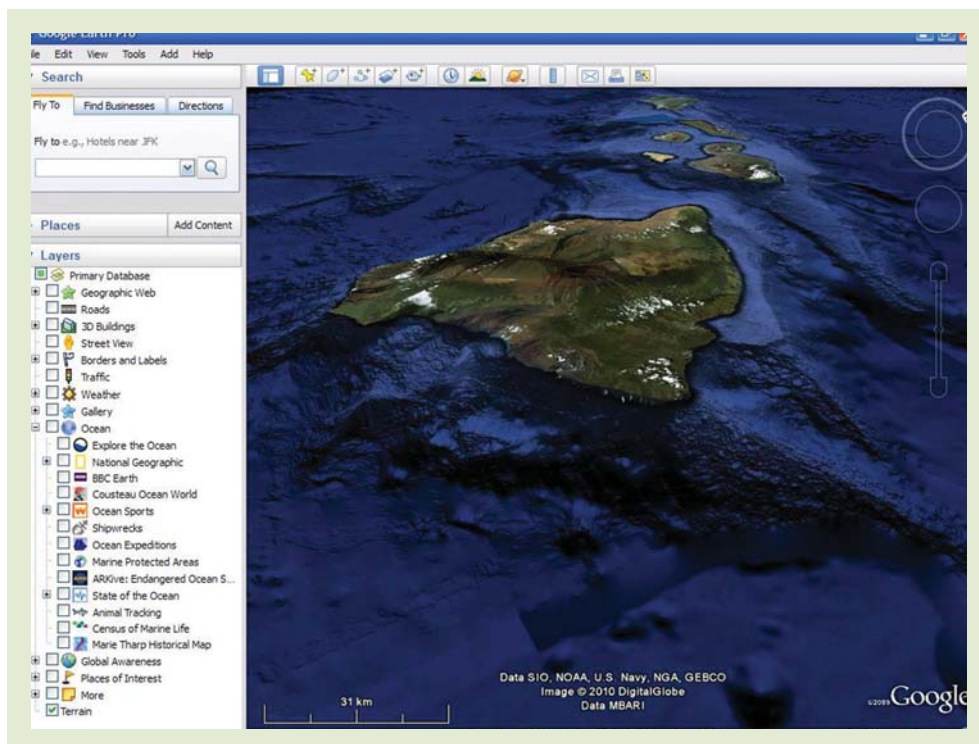


Figure 4 Earth's tallest mountain: Mauna Kea from the sea bottom shown in 3D

Source: Google Earth.

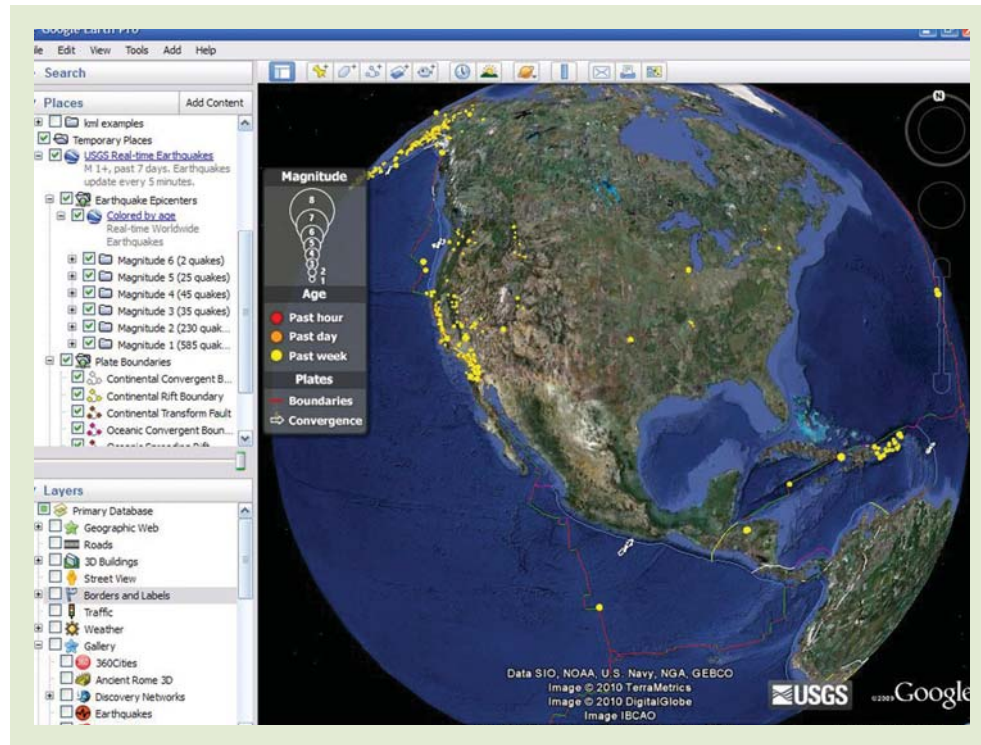


Figure 5 Real-time earthquakes layer made by the U.S. Geological Survey (USGS) and uploaded in KML to Google Earth

Sources: Google Earth and USGS.

information may be saved to files using the KML (Keyhole Markup Language) and shared with other users using Google Earth as a posting board (Figure 5). With or without the use of KML, Google Earth can be an effective learning experience. Google Earth provides a way to visualize complex geographic information to make it more easily understood by the general public.

Katarina Doctor

See also Digital Terrain Model; Geographic Information System; Global Positioning System; Virtual and Immersive Environments; Virtual Globes

Further Readings

Google Earth: <http://earth.google.com>



GOTTMANN, JEAN (1915–1994)

Jean Gottmann was one of the premier urbanists of the 20th century. Born in the Ukraine, Gottmann was raised in France. After a traditional French education, he studied geography within the French regional tradition of Paul Vidal de la Blache. It is from this tradition that Gottmann started to develop his own ideas on the nature and meaning of geography, including the spatial theory that eventually led to his most famous work.

It was through the 1961 publication of *Megalopolis: The Urbanized Northeastern Seaboard of the United States* that Gottmann established himself as one of the most influential geographers of the 20th century. While he used the term *megalopolis* to refer specifically to the 600-mile-long metropolitan corridor between Boston, Massachusetts, and Washington, D.C., the term has been used to refer to any similar agglomeration of large



urban areas. The idea of a megalopolis is more than just a descriptive term for a system of functionally integrated cities; it is also a concept that embodies the notion of how and why space is organized. In *Megalopolis*, Gottmann's view of space is presented as a dialectic between a constantly changing circulation of goods, information, and people and the attempt by individuals/groups to offset the tenuousness of change with the stability of a partitioned, iconographic territory. What *Megalopolis* represented was a new form of this ongoing dialectic away from the political nation-state to the economic urban region.

Two other aspects of *Megalopolis* make Gottmann's contribution to the discipline of geography important. First, *Megalopolis* was published at the nexus of the transition in geography from the traditional descriptive, regional (idiographic) approach to the more "scientific" approach using deductive logic and the scientific method. Some argued that *Megalopolis* had too much description and not enough explanation. What Gottmann did in *Megalopolis* was bridge the gulf between the idiographic and nomothetic traditions in geography, which is why this work is still relevant today. Second, Gottmann's observations concerning the formation of a megalopolis seem prescient. For example, in *Megalopolis*, he posits the idea that communications technology may, at some point, offset the "need" for businesses and populations to cluster. This idea continues to be one of the fundamental themes explored in both urban and economic geography. This is just one example of the remarkable work of the geographer Jean Gottmann.

J. Matthew Shumway

See also **Exurbs; Metropolitan Area; Suburbs and Suburbanization; Urban Geography; Urban Hierarchy; Urbanization; Urban Sprawl**

Further Readings

Gottmann, J. (1961). *Megalopolis. The urbanized northeastern seaboard of the United States*. New York: Twentieth Century Fund.

Johnston, R. (1996). Jean Gottmann: French regional and political geographer extraordinaire. *Progress in Human Geography*, 20(2), 183–193.



GOULD, PETER (1932–2000)

One of the discipline's most creative and diverse thinkers, Peter R. Gould wrote about a wide variety of topics in geography, ranging from transportation to AIDS to television to critiques of Marxism. During his career, he authored 20 books and monographs and 170 journal articles. Fluent in French, he also published in that language.

Born and raised in England, he was evacuated to the United States during World War II. Returning to England afterward, he attended the Nautical College, graduating in 1951. Immediately thereafter, he served with the British military against communist guerrillas in Malaysia. In 1956, he graduated from Colgate University, and he went on to do graduate work at Northwestern University, completing his PhD in 1960. Initially an Africanist, he journeyed widely and conducted fieldwork in that continent before assuming a faculty position at Syracuse University. In 1963, he moved to the Pennsylvania State University (Penn State), where he remained for the next 35 years, taking sabbaticals in a variety of countries. He retired in 1998 and died of cancer shortly thereafter.

Gould was eclectic in his research interests. He maintained a fascination with the structure of cognition, and his early work included the study of mental maps and residential preference surfaces. He was also deeply interested in issues of geographic philosophy. Although he was certainly not an empiricist, he exhibited a deep distrust of armchair theorizing and rigidly held views that led inexorably to predetermined theoretical conclusions, a fault he often attributed to Marxism. He pursued Heideggerian phenomenology as a means of comprehending human experience. He could be polemical, and he challenged feminist geographers and postmodernists in ways that were often disconcerting and earned him considerable criticism. Gould had an abiding love for mathematics, which he deployed in novel ways, and helped propel the quantitative revolution. Among his favored techniques were linear programming, game theory, entropy maximization, and eigenvalues. He was an enthusiastic advocate of Q-analysis, a sophisticated combinatorial technique derived from set theory, as a means of



uncovering the deep structure of empirical reality, and he applied this method to different topics, including the international diffusion of television shows. He wrote about the diffusion of AIDS, employing novel forms of cartography to explore its temporal and spatial dimensions. Gould also authored a volume on the nuclear accident at Chernobyl and the wide cloud of radioactive material it unleashed.

Finally, Gould was a highly committed and innovative teacher greatly concerned about issues of pedagogy. *Spatial Organization: The Geographer's View of the World*, coauthored with Ronald Abler and John Adams, was pioneering in integrating diverse strains of the discipline for undergraduate students. Drawing on a lifetime of experience, his volumes *Geographer at Work* and *Becoming a Geographer* earned him great acclaim. On his death, Penn State created the Peter Gould Geo-Center for the promulgation of geographic thought and teaching.

Barney Warf

See also **Epistemology; HIV/AIDS, Geography of; Mental Maps**

Further Readings

- Abler, R., Adams, J., & Gould, P. (1971). *Spatial organization: The geographer's view of the world*. New York: Prentice Hall.
- Gould, P. (1979). Geography 1957–1977: The Augean period. *Annals of the Association of American Geographers*, 69, 139–151.
- Gould, P. (1981). Letting the data speak for themselves. *Annals of the Association of American Geographers*, 71, 166–176.
- Gould, P. (1985). *Geographer at work*. London: Routledge.
- Gould, P. (1986). *Mental maps*. London: Routledge.
- Gould, P. (1990). *Fire in the rain: The democratic consequences of Chernobyl*. Baltimore: Johns Hopkins University Press.
- Gould, P. (1993). *The slow plague: A geography of the AIDS pandemic*. Cambridge, UK: Blackwell.
- Gould, P. (1999). *Becoming a geographer*. Syracuse, NY: Syracuse University Press.

- Gould, P., Johnson, J., & Chapman, G. (1984). *The structure of television*. London: Pion.
- Gould, P., & Olsson, G. (Eds.). (1982). *A search for common ground*. London: Pion.
- Gould, P., & Pitts, F. (Eds.). (2002). *Geographic voices*. Syracuse, NY: Syracuse University Press.
- Haggett, P. (1993). Peter Robin Gould, 1932–2000. *Annals of the Association of American Geographers*, 93, 925–934.



GOVERNANCE

The idea of governance has traditionally been understood as the pursuit of the activities of government or the actions taken by political leaders and government bureaucrats for the benefit of people. During the late 20th century, the term *governance* began to be used more broadly by geographers, political scientists, and other social scientists to refer to activities that not only included government actors and institutions but also notably extended beyond government. The wider actors and institutions involved include civil society, such as nongovernmental organizations, as well as, increasingly, corporate interests. Individual citizens have also been encouraged to actively participate in community-based planning processes. The notion of “good governance” in social science parlance signifies the inclusion of the multiple stakeholders who share a common concern, albeit often from conflicting perspectives, toward finding a workable and equitable way forward to manage that shared concern. This idea has become an important metanarrative for policy analysis in geography and political science. Conceptually, the idea of good governance can be applied at various scales and to a range of different concerns. This entry explores the ideas of environmental governance, local governance, global governance, and multilevel governance.

Environmental Governance

The term *environmental governance* signifies the pursuit of governance with reference to issues that broadly pertain to sustainability issues. The



concept of environmental governance can occur at the global scale, as with concern about climate change; at the regional scale, as in transboundary watershed management; and at the local scale, as in decision making on recycling initiatives, landfills, or other local environmental issues. The appropriate scale for addressing environmental governance concerns is often influenced by the biophysical limits of the resource in question, with the stakeholders who are then involved defined by their interest in the resource in question. For example, while good governance of water is a concern shared by many people, the practical challenges of managing water vary greatly in different locations based on factors such as water availability, population, climate, and biogeography. Water's biophysical boundary is the watershed, which often complicates establishing effective governance institutions because the biophysical boundary often does not correspond to political boundaries. Hence, good governance at the watershed scale could include planners from multiple government jurisdictions and the range of often conflicting nongovernmental interests with competing demands for limited water.

For shared environmental resources, an underlying concern is to devise workable and equitable solutions that encompass both intergenerational and intragenerational equity. Intergenerational equity is particularly challenging because, while future generations have a stake in the protection of resources for the future, they (as well as the resources, wildlife or a habitat) cannot participate on their own behalf and depend on the advocacy of stakeholders such as environmental nongovernmental organizations. Part of the rationale for widening participation through environmental governance is that politicians and bureaucrats lack the mandate to take into account the needs of future generations or of nature itself (often popularly explained as "people vote and bunnies don't") and that, through governance with involvement that extends beyond government, these considerations can be better integrated into decision making.

The institutions of a governance process can manifest in different forms depending on the nature of the resource and the controversy surrounding a given issue. One form is the idea of managing common pool resources through collective action,

but other institutional structures can also be deployed. While the institutions and the form of the process may vary, the principles of good governance require that wider stakeholders, through some institutional structure, either formal or informal, have an opportunity to participate in decision making.

Different Scales of Governance

As mentioned above, governance can occur on different scales. The term *local governance* describes activities involving shared concerns at a local level and conceptually and practically encourages the involvement of the individual in shared community concerns. This process can include formal roles for individual citizens, such as sitting on decision-making committees, or more informal roles. The idea of governance is linked to encouraging individual and collective citizenship in the pursuit of common goals such as safer or cleaner communities.

At the global scale, the idea of good governance seeks to provide an organizing framework for issues that extend beyond the limitations of national boundaries, such as poverty, international trade, and climate change. The United Nations and the International Monetary Fund are examples of formal institutions that increasingly seek involvement beyond government. One current example of an attempt at global governance is the agreement on the Millennium Development Goals.

Some issues may lead to multilevel governance, which links initiatives across scales to enhance governance solutions. One example is the Kyoto Protocol, where many nations agreed to national targets for emissions reductions; when the United States did not enter this global-scale agreement, many mayors of major U.S. cities (i.e., an ad hoc collective action of local governments) made commitments to targets for their individual cities.

Mary Dengler

See also **Civil Society; Common Property Resource Management; Community-Based Environmental Planning; Environmental Law; Environmental Management; Environmental Planning; Governmentality and Conservation; Multistakeholder Participation;**



Neoliberal Environmental Policy; Neoliberalism; Nongovernmental Organizations (NGOs); Participatory Planning; Regional Governance; Urban and Regional Planning; Urban Planning and Geography; Urban Policy

Further Readings

- Bulkeley, H. (2005). Reconfiguring environmental governance: Towards a politics of scales and networks. *Political Geography*, 24, 875–902.
- Dengler, M. (2007). Spaces of power for action: Governance of the Everglades restudy process (1992–2000). *Political Geography*, 26, 423–454.
- Kjaer, A. (2004). *Governance: Key concepts*. Cambridge, UK: Polity Press.
- Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge, UK: Cambridge University Press.
- Stoker, G. (1998). Governance as theory: Five propositions. *International Social Science Journal*, 50, 17–28.



GOVERNMENTALITY AND CONSERVATION

Governmentality and conservation is a developing area of scholarship that addresses the alignment of nature conservation initiatives with political, economic, and social change. It draws heavily on the French philosopher Michel Foucault's analytics of government to describe and critique some of the shifts occurring in the relationships between government, corporate, and community actors concerning nature conservation, emphasizing the roles played by both individual and collective subjects within broader networks of power relations that operate on multiple geographical scales.

From his studies of government transformations in Europe between the 15th and 18th centuries, Foucault observed that new political rationalizations emerged in particular sites at particular historical moments, underpinned by coherent systems of thought. While beginning as new sets of ideas and systems of thought, these

practices eventually became linked to a range of new regulatory practices. Although Foucault himself never applied these ideas to environmental governance or nature conservation, there has been particular interest among geographers, political ecologists, and others in the social sciences in drawing on ideas of "governmentality" for understanding new approaches to environmental management, the management of natural resources, and human-environment relations more generally. These approaches are linked to shifts in the role of the state, but they also operate at a more epistemological level.

While the literature on governmentality and conservation has largely developed since the 1990s, it has strong connections with the more established literature about the role of the commons versus individual property rights in the management of natural resources. While, on the one hand, contemporary environmental governance initiatives seek to create new forms of individual property rights in nature, on the other hand, many environmental programs emphasize collective responsibilities for good environmental conduct in the common interest.

Governance

Foucault's use of the term *governance* takes in a much wider cast of actors than formal agents of government, including nonstate actors such as environmental nongovernmental organizations (NGOs), corporations, community organizations, and so on. Power relations are construed on different but overlapping scales ranging from individual social identities to transnational organizations and the operations of international treaties and trade agreements. This represents a significant departure from analyses of power that simply focus on institutions of formal government.

A particular contribution is the insight provided into the internalization of power relations by individuals as norms of social conduct. The discourse and practices promoted by various forms of environmental governance carry new forms of social and environmental ethics and associated responsibilities, which ultimately influence the way in which individuals understand their own identity in relation to both society and nature. Some scholars have used the term *environmental citizenship*



to describe this phenomenon. For example, concerns about rising levels of atmospheric carbon dioxide and their implications for global climate change give rise to new sets of assumptions about the responsibility of individual householders to reduce energy use in the home.

Governmentality

The term *governmentality* refers to a broad range of tactics and strategies of government that includes the structures and procedures of institutions as well as the technical means of implementing these procedures. These are concerned with what Foucault termed “the conduct of conduct,” or the establishment and oversight of norms of social practice and behavioral conduct. For example, these might include the definition of new forms of property, such as carbon emission permits or quantum measures of biodiversity, along with the establishment of new market mechanisms for trading in them. It might also include the forms and procedures that government agencies require community organizations to complete when applying for funding grants. A key contribution of Foucault’s analytics of government is its central concern with the exercise of power through such procedures and practices.

Measurement and statistics are key tools for the representation of human populations, specific aspects of nature, and the humanity-nature relationship more generally. For example, statistics about population growth, climate change, and biodiversity loss have become key to the representation of the humanity-nature relationship. They form a specific technology of governance, referred to as biopolitics, and are used by different kinds of organizations to frame discourse on sustainable development and the limits to human existence. This discourse conveys specific knowledge and understanding of the status of environmental entities such as the global atmosphere that provides the rationale and imperative for new regulatory regimes.

Space and Scale

Concepts of space and scale are critical to the analytics of environmental governance, and geographers have played an important role in

demonstrating how they are deployed in a wide range of governance contexts. Specific environmental entities, ranging from the genetic makeup of organisms to entire river basins or the global atmosphere, become referents for environmental governance initiatives. As such, environmental entities that exist at quite different geographical scales are construed as “governable spaces” and form the locus for new forms of responsibility and ethics expressed in standards or norms of behavior. There are strong links between these ideas of governable spaces, and recent scholarship in geography emphasizes the need to think of place in terms of its ongoing production through different sets of social relations that bring with them different dynamics of power. While it is clear that the transformation of nature is associated with social transformation, geographers such as Eric Swyngedouw and David Harvey highlight the complexity of the scalar dimensions within each form of transformation and argue the need for caution in drawing connections between them.

Ruth Lane

See also **Common Property Resource Management; Environmental Ethics; Environmental Law; Environmental Management; Environmental Planning; Neoliberal Environmental Policy; Neoliberalism; Place; Political Ecology; Production of Space; Regional Governance; Scale, Social Production of**

Further Readings

- Bulkeley, H. (2005). Reconfiguring environmental governance: Towards a politics of scales and networks. *Political Geography*, 24, 875–902.
- Foucault, M. (1991). Governmentality (R. Braidotti, Trans.; C. Gordon, Rev.). In G. Burchell, C. Gordon, & P. Miller (Eds.), *The Foucault effect: Studies in governmentality* (pp. 87–104). Chicago: University of Chicago Press.
- Rose, N. S. (1999). *Powers of freedom: Reframing political thought*. Cambridge, UK: Cambridge University Press.
- Rutherford, S. (2007). Green governmentality: Insights and opportunities in the study of nature’s rule. *Progress in Human Geography*, 31, 291–307.



GRAVITY MODEL

The gravity model is a popular mathematical model used to predict the interaction between two or more places. In geography it has been used to simulate a variety of flow patterns, such as traffic and mail flows, telephone calls, and migration. Essentially, the gravity model can be used to account for any interaction or flow that is expected to move from one place to another. This idea has generated many mathematical manipulations of the model.

The original gravity model is based on Newton's law of gravitation, expressed as

$$G_{ij} = G \frac{M_i M_j}{d_{ij}^2},$$

where G_{ij} is the gravitational bond between objects i and j , G is the gravitational constant, M_i and M_j are measures of the attractiveness of masses i and j , and d_{ij}^2 is the square of the distance between objects i and j . The theoretical principle of the gravity model is twofold: (1) the degree of interaction is directly proportional to the size of the masses and (2) the degree of interaction is indirectly proportional to the distance that separates them. E. G. Ravenstein later applied these principles and the gravity model concept to the social sciences with a study of migration patterns during the 19th century.

Generally, three types of gravity model have evolved since Ravenstein's formulation: (1) origin-specific, (2) destination-specific, and (3) network or potential models. The basic gravity model formulation is the foundation of origin- and destination-specific models. It takes the following form:

$$I_{ij} = k \frac{P_i P_j}{d_{ij}^b},$$

where I_{ij} is the interaction between places i and j , k is a constant, P_i and P_j are measures of the size of places i and j (e.g., populations), d_{ij} is the distance between places i and j , and b is the friction of distance. Larger values of b indicate that the interaction between i and j declines more rapidly

with increased distance. Commonly, origin-specific models are used to predict flows from one place of origin to several destinations. With destination-specific models, flows are predicted from several origins to one destination. The gravity model was later reformulated to account for a network of interactions between places. These are known as potential models, expressed as

$$V_i = \sum (M_j / d_{ij}),$$

where V_i is the population potential of place i , M_j is the population of j , and d_{ij} is the distance that separates place i and j . Results of the potential model show the position of each place relative to all other places. Often, the results are illustrated spatially with a potential surface map.

Most criticism of the gravity model has concerned its use as a predictive tool. Some note that the model is not based on observation and therefore cannot be substantiated scientifically. Others believe that the model is biased toward existing spatial patterns and that this will perpetuate the status quo.

Todd Sink

See also **GIS in Transportation; Migration; Mobility; Spatial Interaction Models; Transportation Geography**

Further Readings

Haynes, K., & Fotheringham, A. (1984). *Gravity and spatial interaction models*. Beverly Hills, CA: Sage.

Ravenstein, E. (1885). The laws of migration. *Journal of the Statistical Society of London*, 48, 167–235.



GREAT AMERICAN EXCHANGE

The Great American or Columbian Exchange refers to the transmission of agricultural crops, domesticated livestock, technology, and disease between the Afro-Eurasian region and the Americas that occurred after the voyages of Christopher Columbus to the New World reestablished



<i>From the New World</i>	<i>From the Old World</i>
Corn	Horse
Potatoes	Sugar
Sunflowers	Cattle
Tomatoes	Pigs
Peppers	Chickens
Chocolate	Sheep
Peanuts	Wheat
Pineapples	Citrus fruits
Blueberries	Bananas
Tulips	Olives
Tobacco	Okra
Syphilis	Smallpox

Table 1 Some major plants and animals of the Great American Exchange
Source: Author.

contact between the two continental systems and their respective populations (Table 1). The most prominent impacts were in the areas of disease transmission and new agricultural crops. These transfers were by no means equivalent. The New World, with its relatively lower population density, did not acquire immunity to the diseases imported from Europe, Asia, and Africa. Native American resistance to malaria, measles, smallpox, tetanus, and typhus was nonexistent, and this resulted in an estimated loss of up to 70% of the population of Middle and Southern America, while the populations in the Americas overall are estimated to have decreased between 50% and 70% following contact. Europeans were introduced to a new form of syphilis in the course of opening up the New World to commerce and settlement.

The exchange of crops and livestock were, however, more balanced. Europe gained tobacco, maize, beans, peanuts, several kinds of potatoes, manioc (which has since become a staple in parts of Africa), squashes, pumpkins, chocolate, papayas, guavas, avocados, pineapples, tomatoes, chili peppers, and cayenne. The Americas received chickens, cattle, goats, pigs, sheep, horses, wheat, grapes, bananas, rice, sugar, and honeybees. However, the impacts of crop exchange were also differential. For Americans, the European crops were somewhat less efficient users of arable land. Their origin in higher latitudes meant that they were

adapted to a shorter growing season than that of the tropics, hence they could not be harvested as often as native crop species. In addition, the sudden release of more grazers on natural crops led to famine. In the years that followed, the impact of American silver and gold on the policies of Spain and the general rush to colonization cannot be understated either. In Asia, the impacts of New World crops were remarkable. In China, for example, more than a third of the crops currently grown are of American origin.

Finally, there was an exchange of ideas and people. Some scholars contend that notions of democracy in European societies were reawakened and strengthened by the discovery of relatively egalitarian Native American societies and the corresponding development of Rousseau’s “noble savage.” However, the stronger impact was by far the imposition of the plantation model of society on Southern and Central America. The mass movement of millions of Africans into the Americas forever changed the political landscape. The notion of racially based hierarchies of power and wealth eventually prevailed over indigenous power structures based on religion, wealth, and lineage. The Columbian exchange also forced the European colonizers, especially the Spanish and Portuguese, to modify their religiously based mandates for colonization and refine the notion of a “mission to civilize the world,” which would later be spread to African and Asian colonies.

Edward Rice

See also **Biodiversity; Biogeography; Exotic Species; Human-Induced Invasion of Species**

Further Readings

Christian, D. (2005). *Maps of time: An introduction to big history*. Berkeley: University of California Press.

Crosby, A. (2003). *The Columbian exchange: Biological and cultural consequences of 1492*. New York: Praeger. (Original work published 1972)

Winn, P. (2005). *Americas: The changing face of Latin America and the Caribbean* (3rd ed.). Los Angeles: University of California Press.



GREENBELTS

A greenbelt is a section of land deliberately left undeveloped as either forest or agricultural space, often near urban centers, generally for purposes of environmental conservation.

Historical Formation of Greenbelts

In 1829, an etching by the artist George Cruikshank showed London literally “going out of town,” with development spewing onto the countryside and threatening the tranquility of pastoral England. Britain’s Industrial Revolution had prompted unprecedented urban growth, triggering two areas of critical concern for future generations of planners: (1) the well-being of urban centers and (2) the relationship between these centers and their rural hinterlands. In the preindustrial era, many significant settlements had been contained by fortification. Across Europe and Asia, towns and cities were frequently enveloped by man-made or natural barriers—walls, the sea, rivers, or mountains—by anything, in fact, that afforded some protection from the incursion of rival powers. The nearby countryside provided sustenance for the urban population, such as it was, in a largely agrarian world dominated by an urban nobility and populated by a rural peasantry.

But industrialization and the subsequent urbanization changed the world forever. Britain—the first industrial nation—was also one of the first to take note of the environmental and aesthetic consequences of this change. Cruikshank’s imagery was one of a number of comments—artistic, poetic, and political—to gradually raise the profile of this issue in the public mind. Threats to the countryside in 19th-century Britain were taken seriously. Conditions in the major urban centers were often so dire, so unsanitary, that adjacent rural areas were justifiably concerned about urbanization, though they were powerless to prevent it.

By the end of the 19th century, a few visionaries—Ebenezer Howard being the most notable—had become convinced of the need to reconnect urban populations to the fresh air and other health benefits of the open, green

countryside. For Howard, this could be achieved through the creation of Garden Cities: planned centers covering areas of 1,000 acres and with populations of no more than 32,000 situated within at least 5,000 acres of agricultural land that would be protected from further encroachment. In the absence of fortification, cities still needed to be contained—fortified against their own expansion rather than the actions of foreign armies.

At various points throughout the 20th century, different countries reached this same conclusion. But because of its 19th-century experiences, and the lobbying of a number of key individuals (Howard being an early trailblazer), Britain led the way in the development of urban containment tools as part of a broader rural development intolerance, aiming to protect the interests of farming and what became regarded as the rural idyll. Two prominent figures in the evolution of British town planning—Patrick Abercrombie and Raymond Unwin—played crucial roles in promoting the idea of statutory greenbelts. In 1926, Abercrombie highlighted the danger posed by urban decentralization, arguing for a concerted effort to preserve rural England. His writing inspired the creation of the Council for the Preservation of Rural England (CPRE), which campaigned for stricter rural development controls. Planning legislation in the 1930s took up this theme, introducing new restrictions on “ribbon” development (residential development along roads and railway lines extending from urban centers). But it was Unwin who, in 1933, proposed the creation of a “green girdle” around London primarily for recreational purposes. Two years later, the municipal authorities were supporting Unwin’s idea of a “London Greenbelt”; but it was not until 1938 that Parliament legislated for its creation. This prewar greenbelt could only be realized through the purchasing of privately owned open spaces on the edge of the city. Only through a nationalization of development rights—still 9 yrs. (years) away—would it be possible for planning authorities to draw lines on maps and tell landowners and prospective developers that further land use change would be effectively prohibited.

The development of this urban containment approach gained real momentum after the war. Abercrombie incorporated a greenbelt into his 1944 Greater London Plan, and 3 yrs. later, the



Town and Country Planning Act of 1947 created a system of comprehensive land use control, built on a nationalization of development rights and the transfer of planning power to local councils. The stage was set for a comprehensive system of greenbelts, and this duly arrived in 1955, with the British government urging local authorities to formally designate clearly defined greenbelts, where these were considered necessary and appropriate. According to the Ministry for Housing and Local Government, these were to have the objective of “checking the unrestricted sprawl of the built-up areas, and of safeguarding the surrounding countryside against further encroachment.”

Contemporary Greenbelts

The evolution of this approach to urban containment in Britain is the first chapter in the story of the greenbelt. It has since been lauded by the CPRE as “planning’s most celebrated achievement.” The regularity with which other countries have duplicated the British approach—at least in name—is held up as evidence that Britain “got it right” and that this form of growth management is the best way to serve the interests of cities—concentrating urban regeneration efforts within the existing urban footprint while checking sprawl and protecting the countryside from encroachment. Numerous countries have imported the greenbelt idea. In North America, both the United States and Canada have adopted this containment approach as a means of preserving agricultural land and setting urban growth boundaries.

In Canada, a complete greenbelt encircles the city of Ottawa, while a horseshoe-shaped greenbelt has been designated around the Greater Toronto Area and the Niagara Peninsula, aiming to protect this environmentally sensitive area from future sprawl.

The development of greenbelts in the United States has a particularly interesting and varied history. In a move reminiscent of—and inspired by—the British Garden Cities movement, a number of “green towns” were planned and built as part of President Franklin D. Roosevelt’s New Deal. The first of these towns was the City of Greenbelt, Maryland, built on the edge of Washington, D.C., in 1937 and designed as a cooperative, walkable,

garden suburb that would be a model of modern town planning in the United States. Many other such towns were planned, but only two were built: Greenhills on the fringe of Cincinnati, Ohio, and Greendale, outside Milwaukee, Wisconsin. The government-sponsored green towns inspired a number of private projects across the country, but like the City of Greenbelt, many have since lost their original cohesiveness and character, often as a consequence of freeway development and associated sprawl. General containment tools—which might have provided some protection to these exemplars of greener living—arrived too late to save the Green Towns, while, in comparison, the two Garden Cities developed in the United Kingdom have been afforded some protection by London’s greenbelt and by exclusive environmental safeguards.

Although not strictly greenbelts, many U.S. states have used urban growth boundaries as a means of controlling the spread of high-density development with a defined urban edge. Oregon, Washington, and Tennessee require cities to define boundaries beyond which only lower-density development of specified types will be permitted. Recent analyses of the urban growth boundary approach have highlighted the effect that this zoning has on land prices and on residential property values, arguing that this form of growth management—like greenbelts elsewhere—serves the interests of existing property owners and restricts access to housing among new buyers.

Similar tools have been used to manage the outward spread of cities in other locations around the world. A notable and much studied example is that of restricted development zoning around Seoul, South Korea. Although this is sometimes referred to as a greenbelt, it has far more in common with the U.S. urban growth boundary approach. Set within a system of zonal planning in which higher-tier strategic authorities claim jurisdiction over the policies affecting local areas (as opposed to the system of local political “discretion” that operates in the United Kingdom), restricted development zoning is a means of reducing development densities and giving South Korea’s overheating capital region an identifiable urban boundary. The hope has been that growth in Seoul will not merely be contained but will be diverted



to other centers. This is yet to happen: Urban pollution and traffic congestion remain weaknesses of Korea's economic miracle but have now been joined by the added problem of low-quality development leapfrogging Seoul's greenbelt.

It is perhaps fitting that the United Kingdom—the earliest greenbelt pioneer—is now the setting for an intense debate on the future direction of containment policy. The creation of a comprehensive planning system in 1947 provided the backdrop for the development of the greenbelt; comprehensive reform of that system in the 2000s provides another backdrop, but this time for calls to rethink the role and purpose of the greenbelt (Figure 1). The last time the policy was most recently rewritten, in 2001, it essentially retained its postwar focus: checking sprawl, serving regeneration efforts, preventing urban coalescence, preserving the settings of historic towns, and safeguarding the countryside. Beneath this list of purposes sits another list of ways in which greenbelt land might be used: for general access, sport, and recreation; for farming and forestry; and as a resource that can be beautified, serve conservation interests, and undergo improvement where there is evidence of postindustrial scarring.

Since the 1990s, both the central purpose of greenbelts, and how their use is promoted (for recreation, conservation, and enhancement), have been continually questioned. Representatives of the planning community—the professional bodies—have argued that it is out of step with reform of the wider system and a barrier to providing the growth and infrastructure that the United Kingdom now needs and that general planning reform is designed to deliver. It has been called an inert green blanket, smothering the countryside and preventing the diversification of rural economies that are today struggling to find a postagricultural future. A central criticism is that greenbelts should become a positive force in leading change within peri-urban environments and not simply an inflexible barrier to the necessary transformation of the urban fringe.

Criticisms of the greenbelt's purpose are well rehearsed: Tightly drawn boundaries promote town cramming rather than regeneration; pressure builds and can only be released through leapfrogging over the greenbelt to distant locations

where car-dependent developments, isolated from existing infrastructure and inherently unsustainable, are promoted. It is argued that a logical alternative would be to use the planning system to support sustainable urban extensions, keyed into existing infrastructure, and to transform the greenbelt into a framework for projects that exemplify the highest standards in green, zero-carbon development.

The idea that the greenbelt could become a framework for promoting something positive is a more recent aspect of the debate. A comprehensive review of land use planning (paving the way for further reforms) recently concluded that despite their published objectives, greenbelts are understood, primarily, to be control tools. Far less consideration is given to the delivery of valued environmental and social objectives. The label *greenbelt* is somewhat of a misnomer: Land under this designation is often somewhere on a continuum between gray and green, frequently subject to postindustrial scarring. In the United Kingdom—and also in the United States—there are calls to make the greenbelt more proactively green, delivering a program of social and environmental benefits within areas of urban fringe (returning to the ambitions of Howard's Garden Cities and Roosevelt's Green Towns) while retaining its role in restricting unchecked sprawl, though sometimes by permitting the planned release of land for residential and associated development.

Many countries have taken note of the development of greenbelt policy in the United Kingdom. While the tool is not always well understood, there is some hope that it will evolve to face the challenges of the century ahead. Cities around the world share a concern over development sprawl and unsustainable, sporadic urban growth. Greenbelt is likely to survive, in one form or another, with shared concerns prompting shared efforts to evolve containment into a growth management approach that can bring positive benefits.

Nick Gallent

See also **Green Design and Development; Parks and Reserves; Smart Growth; Urban Gardens; Urban Green Space; Urban Sprawl**



Figure 1 Britain's greenbelts in 2008

Source: Adapted from Department for Communities and Local Government. (2008). *Local planning authority green belt statistics, 2007*. London: Author.



Further Readings

- Bruegmann, R. (2005). *Sprawl: A compact history*. Chicago: University of Chicago Press.
- Elson, M. (1986). *Greenbelts: Conflict mediation in the rural-urban fringe*. London: Heinemann.
- Freilich, R. (1999). *From sprawl to smart growth: Successful planning, legal and environmental systems*. Chicago: American Bar Association.
- Gallent, N., Andersson, J., & Bianconi, M. (2006). *Planning on the edge: The context for planning at the rural-urban fringe*. London: Routledge.
- Hannah, L., Kim, K. H., & Mills, E. S. (1993). Land-use controls and housing prices in Korea. *Urban Studies*, 30(1), 147–156.
- HM Treasury. (2006). *Barker review of land use planning: Final report—recommendations*. London: Author.
- Howard, E. (1898). *To-morrow: A peaceful path to real reform*. London: Swan Sonnenschein.
- Ministry for Housing and Local Government. (1955). *Circular 42/55: Greenbelts*. London: Author.



GREEN BUILDING

Green buildings are structures that are designed to have a reduced environmental impact compared with standard construction methods and materials. When the concept was introduced in the 1970s because of concerns over rising energy use and environmental pollution, green building was largely carried out by people constructing their own homes. Since 2000, however, the growing concern over global warming, water resources, and sustainability has led to a movement that is influencing development in the public and private sectors across the world, from houses to skyscrapers. The standards that have been developed to certify green buildings are part of the general 21st-century shift away from government regulation and toward voluntary, performance-based standards. Because of the focus on economic and environmental but not social issues, green buildings do not generally fit the traditional definition of sustainability; instead, they are sometimes called high-performance buildings.

According to the nonprofit U.S. Green Building Council (USGBC), buildings within the United States produce nearly 40% of global carbon dioxide emissions and 30% of waste output, while consuming 7% of the world's electricity, 40% of its raw materials, and 14% of the potable water. In most cases, there is relatively little that building inhabitants can do to reduce these figures once the structure is in place. The responsibility for producing more environmentally friendly buildings is therefore placed on the shoulders of those who design and construct them. At the same time, there is tremendous potential for reducing resource consumption and waste production by better building designs and construction practices.

There are three general approaches to greening buildings. The first is to rely on existing vernacular building practices and materials, such as adobe structures in desert climates to take advantage of large temperature fluctuations or raised floors in hot and humid climates to allow for airflow. The second approach is high-tech, relying on new materials and processes to reduce resource use and minimize waste. The third is biomimicry, imitating natural processes and using natural materials. Each has different implications in terms of capital requirements, marketability, and effectiveness. The technological approach dominates the industry at the present time, as seen by the term *high-performance buildings*.

There is no single definition of what makes a building green. The Leadership in Energy and Environmental Design (LEED) standards of the USGBC considers six dimensions: (1) sustainable sites, (2) water efficiency, (3) energy and atmosphere, (4) materials and resources, (5) indoor environmental quality, and (6) design innovation. The idea is to go beyond simply using less water or energy, by considering how multiple components of a building's design work together in a mini-ecosystem that consists of the site and its relationship to the surrounding networks of transportation, wildlife habitat, and urban space; the indoor environment, including emissions from paint and carpet; and the sources and sinks for the materials that go into the building and the wastes that come out. The complexity of a green building means that architects, engineers, and construction managers have to work closely together to achieve the goals of the project.



Modern building using energy-efficient measures, including solar panels and reflective glass

Source: David Hills/iStockphoto.

Most green building certification systems are point based, designed to be flexible and allow project owners to decide the level of certification and which points or credits they want to earn to achieve that level; this flexibility is one reason why green building standards have been widely embraced. Various categories of certification focus on different building types such as schools, hospitals, and homes to broaden the range of categories and incorporate uses such as laboratories that may have special energy or water needs. At the same time, many jurisdictions from local to national levels are implementing requirements that certain types of development must achieve a set level of certification. Some jurisdictions use incentives such as expedited permitting or tax breaks rather than requirements, creating a patchwork of regulation from one place to the next.

U.S. studies have found that while the perception exists that green buildings are considerably

more expensive than conventional structures, data on finished buildings indicate an increased cost of about 5%, which is usually earned back within a couple of years through increased energy savings. Additionally, employees have been shown to have fewer sick days and schoolchildren to have higher test scores when they work and learn inside certified green buildings. Other studies have found that green buildings under operation not only use less energy, as predicted, but also bring in higher rental value.

Globally, programs such as the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan, Green Star in New Zealand and Australia, and the Green Globes in North America serve a similar function to the USGBC's LEED. The LEED standards have been adopted in over 40 countries,



including Brazil, China, and India, while BREEAM International has been employed in countries across Europe and Asia. The major differences between the systems are in terms of how certification is approved (onsite inspection for BREEAM, documentation for LEED) and in percentage reductions from a baseline (LEED) as compared with quantitative targets (BREEAM).

Green building is increasingly tied to green-collar jobs in some locations: manufacturing and installing materials such as wind turbines, low-emissions paint, and photovoltaic panels. Particularly within the United States, concern over the outsourcing of manufacturing and the concomitant loss of jobs for skilled laborers is part of the green-collar job movement. Green building programs contribute to this movement by, for example, designating credits for using materials produced within 500 miles of the building site, which is meant to encourage economic development as much as environmental responsibility.

Criticisms of green building include its failure to incorporate life-cycle analysis, although that is changing; higher costs, although that is under debate, as described above; and epitomizing ecological modernization by continuing business as usual with a green façade. Nevertheless, green buildings are gaining a greater share of the market worldwide and are at least in a small way reducing the ecological impact of the built environment.

Julie Cidell

See also **Architecture and Geography; Built Environment; Environmental Impacts of Cities; Green Design and Development; Smart Growth**

Further Readings

- Guy, S., & Moore, S. (2005). *Sustainable architectures*. New York: Spon Press.
- Kibert, C. J. (2007). *Sustainable construction* (2nd ed.). Hoboken, NJ: Wiley.
- U.S. Green Building Council: www.usgbc.org
- Van der Ryn, S. (2005). *Design for life*. Layton, UT: Gibbs Smith.
- Yudelson, J. (2007). *The green building revolution*. Washington, DC: Island Press.



GREEN DESIGN AND DEVELOPMENT

The terms *green design* and *green development* are open to several interpretations and associated with a series of other terms, including *sustainable development*, *sustainable design*, *eco- or ecological design*, and *environmental design*. Two ways in which these terms have been employed can be identified. First, they refer to the design and/or construction of objects, environments, and services that have minimal detrimental impact on their surrounding environments, are sustainable, and, in some cases, may potentially have beneficial impacts. Second, they refer to designs and/or developments that draw inspiration from understandings of nature and its operation. In this sense, green designs/developments are viewed as being constructed such that they work within or learn from the rules, limits, designs, or ethos of nature. These two senses of green design/development connect to differences in broader attitudes and practices, such as the distinction between technocentrism and eco-centrism or the differentiation between light or shallow green and deep green, as made by people such as Arne Næss; or even the difference between ecological modernization and counterproductivity theories, as outlined by Gert Spaargaren and Arthur Mol. Technocentric and light green perspectives, for instance, can be seen to focus predominately on the first sense of green design/development, while eco-centrism and dark green perspectives often make much of learning from nature and are often critical of technological/design-focused approaches to nature. For this reason, the two perspectives on green design/development are discussed separately in this entry, although it is important to recognize the considerable overlap between them and the variability within each.

Light Green Design and Development

Green Design as Appropriate Technology

While much design and development has proceeded without consideration of its environmental basis and consequence, the growth of environmental concern, particularly from the



1960s and 1970s, saw growing attention to the level of environmental resource extraction and the impacts of human activities on the environment. Geographers were heavily involved in the formation of means to assess levels of resource use and environmental impacts and in consideration of the meaning of terms such as *resource*, *environment*, and *nature*. Other professionals, including engineers, planners, economists, and architects, as well as environmental activists, began to consider the environmental resource and impact dimensions of object and building design and construction.

In 1973, for instance, the economist Ernst Schumacher published *Small Is Beautiful*, a book that criticized existing models of economic development for fostering reliance on Western technology and thereby heightening dependency relationships. Schumacher argued that Western technologies were often highly inappropriate for many poor/developing/underdeveloped countries, both socioeconomically and environmentally. Schumacher advocated the development of more appropriate forms of technology, which he described as being intermediate technologies, lying somewhere between the technologies of the developing and the developed world in terms of capital and labor intensities. Schumacher sought to put his ideas into practice through the Intermediate Technology Development Group (now Practical Action), and they were also influential within organizations such as the Centre for Alternative Technology at Machynlleth, Wales. Schumacher's ideas were picked up by designers such as Victor Papanek and Gui Bonsiepe, who were influential in the "design for need" movement of the 1960s and 1970s. His ideas were also influential in development studies, where they were connected to, and critiqued within, debates over the meaning of development.

Sustainable Development and Green Capitalist Design

Differential understandings of development were equally significant to the concept of sustainable development that emerged strongly after the 1987 report of the World Commission on Environment and Development, *Our Common Future* (or the Brundtland Report, as it came to be more

commonly known). The Brundtland definition of sustainable development as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs was compatible with technocentrism in that it did not provide any direct challenge to conceptions of development as economic growth. Indeed, *Our Common Future* can be seen to have espoused an ecological modernization perspective in that it portrayed economic growth as a mechanism for improving environmental protection, as well as proposing that environmental resources were essential for continuing economic growth.

While the Brundtland conception of sustainable development was criticized, by the 1990s it had become widely adopted in international, national, and local policy making. This was particularly so when the concept was conjoined with growing concerns over global environmental changes such as atmospheric ozone depletion and climate change, along with localized concerns over pollutants. Technological development was a key element in the espousal of "green capitalism" in the late 1980s and early 1990s, whereby it was argued that new "environmentally friendly" products were being created, often by businesses that were otherwise seen as producers of considerable environmental pollution, such as petrochemical companies, power producers, and car manufacturers.

Examples of new environmentally friendly products cited as illustrations of green capitalism include low-energy light bulbs, biodegradable oils, nonchlorofluorocarbon (CFC) propellants for aerosols, lightweight and low-noise aero-engines, and more fuel-efficient and less polluting car engines. In some cases, the environmental design dimensions of products only extended to labeling and marketing, as with the case of "environmentally friendly, phosphate-free" dishwashing liquids, which emerged in the 1990s, even though phosphates were not generally constituents of ordinary dishwashing liquids. However, even product designs that have clear environmental benefits, such as low-energy light bulbs and solar energy/heating panels, do not necessarily qualify as being environmentally friendly, given that the products and processes used to manufacture, package, market, and distribute them consume energy and resources as well as generating



waste materials that can become pollutants. Concepts such as carbon miles, environmental and ecological footprints, and cradle-to-grave product life cycles emerged as ways of assessing the multiplicity of impacts a single product can have on the environment.

These techniques have been quite widely employed by environmental pressure groups and consumers, plus incorporated into product design practices, although their use has often been viewed as a matter of individual preference and environmental consciousness, coupled with the attractiveness of certifications of environmental standards, such as the USDA Organic Seal, to green consumers. However, with growing governmental concern over issues such as global warming and energy security, more regulative approaches have been adopted that could be viewed as indicative of an institutionalization of environmental concern such that it constitutes a policy regime, mode of social regulation, or mode of governmentality.

Low-Carbon Design and Eco-Housing Development

Governmental regulation and promotion, in many cases associated with meeting requirements to reduce greenhouse gas emissions, have fostered significant developments in product design in many areas, much of it oriented toward the creation of low- or zero-carbon energy products. For instance, there has been a significant increase in investment in carbon-free and renewable energy supplies, with a range of new technologies being developed and improved, including wind turbines, photovoltaic panels, ground source heat pumps, and biofuels, as well as developments in emissions reduction and energy conservation.

Many of these technologies have been employed in connection with housing, where there have been numerous developments not only in energy production and conservation but also with respect to resource use and waste production and disposal. Some of these technological developments employ materials and production techniques that were previously in use but had come to be seen as obsolete in modernist production, as with the use of earth and straw cob or natural ventilation. Other technologies, such as so-called smart

homes, adopt an ecological modernist approach centered on the use of newly emergent electronic, computing, and communication technologies to monitor and adjust energy and resource use.

Figures on the number of eco-house developments are difficult to obtain, but it has been suggested that they form important “green niches” where new technologies, designs, and social practices are assembled and tried out by small groups of committed practitioners in bespoke developments, whose learning experiences and practical successes can then be disseminated more widely. A series of model or exemplary developments have long and widely been identified, such as the Beddington Zero Emission Development (BedZED) in London; the B001 development in Malmo, Sweden; Ecolonia in Alphen aan den Rijn, the Netherlands; the Schlierberg estate in Freiberg, Germany; Drake Landing Solar Community in Alberta, Canada; and Crystal Waters, in Brisbane, Australia.

These initial efforts were subsequently recognized and emulated in some degree by other individuals, businesses, and governmental agencies. Illustration of such diffusion of green design includes the movement of double-glazing installation firms into solar energy/heating provision, as well as the construction of eco-housing by mass house-building companies. Another form of diffusion from niche developments has been the emergence of planned eco-neighborhoods, or sustainable communities, that constitute variously scaled collections of eco-housing, often in combination with production, consumption, and recreational facilities. Such developments range from groupings of a few houses and associated buildings, through eco-villages such as Findhorn in Scotland, which has around 55 buildings, to “eco-towns,” which in the case of the United Kingdom include prospective settlements of 5,000 to 20,000 homes.

The increasing scale of developments has at least two significant implications. First, it has involved a widening of design focus beyond buildings to encompass wider activity spaces and travel patterns. Concepts such as sustainable neighborhoods, eco-towns, and sustainable cities have often involved a concern to design out environmentally damaging activity, such as extensive commuting for work, retailing, and leisure.



“Smart growth” planning has been promoted as a mechanism for minimizing the use of cars and associated resource consumption and pollution. It does this by encouraging population concentration rather than dispersal and the creation of public transport/nonhydrocarbon transport-oriented designs that reduce the need for private petroleum-powered vehicles. These approaches, again, often adopt an ecological modernist perspective, although they have also been linked to the new urbanism movement (which has a range of non-environmental and antimodernist constitutive elements). A second feature of the growing scale of eco-developments has been increasing governmental and corporate business involvement, which has been accompanied by criticisms that they are becoming used as a green marketing or policy gloss to make quite conventional/neoliberal business and policy concerns, such as the construction of new housing, more palatable. On the other hand, it is important to recognize the continuing presence, and innovative role, of a series of less commodified, less state-sanctioned eco-housing developments, many of which, although often drawn into ecological modernist developments, owe their origins to deeper green perspectives on design and development.

Deep Green Design

Among the features identified as key elements of eco-centric or deep green attitudes is a concern to establish nonexploitative relations with nature and a sense that people are linked to and are a part of nature, such that it not only provides material limits to human activity but is also a source of behavioral obligations and prescriptions and, indeed, of design ideas and ways of thinking. Advocates of deep green perspectives also tend to be highly critical of the technology and economic growth-focused perspectives on design and development, even though some of them have been influential agents in the construction of such perspectives.

Victor Papanek, for example, whose work has been discussed in relation to ideas of appropriate technology, can be viewed as adopting a deep green sense of holism in his promotion of green design as “design for the real world.” By this, he meant that there are not only unaddressed human needs but also an environment that, although in

the process of being defiled by poorly designed objects and structures, he viewed as productive of a collective unconsciousness or spirituality to which designers needed to become attuned. Papanek also espoused the view that biological systems could provide prototypes for human product designs, a concept he described as bionics and that has also been characterized as biomimicry and biomimetics. These ideas have subsequently been widely applied in mechanical, biochemical, and genetic engineering; architecture; and computing and information/communications technologies. Even Schumacher, whose orientation toward technology exhibited a clear anthropocentric focus, suggested that human societies needed to learn from the principles and laws of nature.

A further feature identified as significant in many eco-centric perspectives is an emphasis on self-reliance and communality. These concerns can again be seen as important elements in the writings of Schumacher and Papanek, but they have also long been articulated in the anarchist and socialist writings of Peter Kropotkin and Robert Owen as well as by environmentalists. They were also significant in Western countercultural movements of the 1960s and 1970s, through which a series of experiments in autonomous living were conducted in many Western countries. David Pepper has argued that although these linked self-reliance and communal living to environmental issues, they were not of central significance within them, although some of the settlements established during this period, such as Findhorn, have subsequently been viewed as important practical demonstrations of eco-housing design.

Environmental activists often placed an emphasis on autonomy and communality in discussions of sustainable development and green capitalism in the 1980s and 1990s. Many environmentalists frequently espoused counterproductivity arguments, suggesting that any gains from environmentally friendly design would be more than negated by the requirements of capitalism for continuing economic production. In addition, there were also repeated calls to view sustainable development in ways that encompassed social dimensions as well as the environmental and economic aspects emphasized within ecological modernist perspectives. The degree to which these calls reflected a diminution



or deepening of environmentalism has been subject to much debate, particularly when many governmental policy initiatives seem to emphasize economic and social sustainability issues over environmental ones. It is, however, important to note that away from the policy arena, notions of autonomy and communality were often being practically integrated with notions of environmentalism and sustainable development through the design and construction of eco-housing and low-impact residential developments. Many of these developments sought to be self-sufficient or operate “off-grid” through becoming independent of any external inputs of energy and resources. Moreover, in many instances, the concern for ecological independency was linked to notions of social independence/autonomy, with residents seeking to exercise dweller control over the house-building process. Many of these developments have intentionally sought out marginal positions. Additionally, as noted above, they have also become used as models by ecological modernist design movements, even though the latter’s emphasis on technology and economic growth is often explicitly rejected by their designers, who adhere to deep green or other antimodernist values.

Martin Phillips

See also **Deep Ecology Movements; Ecological Modernization; Greenbelts; Green Building; New Urbanism; Smart Growth; Sustainable Cities; Sustainable Development; Sustainable Development Alternatives; Sustainable Production**

Further Readings

- Elkington, J., & Burke, T. (1987). *The green capitalists*. London: Gollancz.
- Halfacree, K. (2006). From dropping out to leading on? British counter-cultural back to-the-land in a changing rurality. *Progress in Human Geography*, 30, 309–336.
- Lovell, H. C. (2004). Framing sustainable housing as a solution to climate change. *Journal of Environmental Policy and Planning*, 6, 35–55.
- MacKenzie, D. (1997). *Green design* (2nd ed.). London: Books Nippan.

- McHarg, I. L. (1995). *Design with nature* (25th anniversary ed.). New York: Wiley.
- Naess, A. (1973). The shallow and the deep, long range ecology movements. *Inquiry*, 16, 95–100.
- O’Riordan, T. (1976). *Environmentalism*. London: Pion.
- Papanek, V. (1972). *Design for the real world*. London: Thames & Hudson.
- Papanek, V. (1995). *The green imperative: Ecology and ethics in design and architecture*. London: Thames & Hudson.
- Pepper, D. (1990). *Communes and the green vision*. London: Greenprint.
- Schumacher, E. F. (1973). *Small is beautiful*. London: Blond & Briggs.
- Smith, A. (2007). Translating sustainabilities between green niches and socio-technical regimes. *Technology Analysis & Strategic Management*, 19, 427–450.
- Spaargaren, G., & Mol, A. (1992). Sociology, environment and modernity: Ecological modernization as a theory of social change. *Society & Natural Resources*, 5, 323–344.



GREENHOUSE GASES

Many chemical compounds found in Earth’s atmosphere act as greenhouse gases (GHGs). These gases allow sunlight to pass through the atmosphere; however, when the sunlight is reradiated back toward space as infrared radiation, GHGs absorb the infrared radiation and trap the heat in the atmosphere and at Earth’s surface. GHGs allow Earth to be habitable—without them, the average temperature of the planet would be -18°C instead of 15°C . However, human actions are increasing the atmospheric concentrations of GHGs, resulting in an enhanced greenhouse effect that is warming Earth’s climate and increasing the incidence of extreme weather events.

The most abundant GHGs are naturally occurring: water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). There are also many other, highly potent, anthropogenic GHGs. Three of these also deplete the stratospheric ozone layer: chlorofluorocarbons



(CFCs), hydrochlorofluorocarbons (HCFCs), and bromofluorocarbons (i.e., halons). These ozone-depleting substances (ODSs) are controlled under the Montreal Protocol on Substances That Deplete the Ozone Layer of 1987, and as a result, their impact on both ozone and the greenhouse effect has been greatly reduced. Other anthropogenic fluorine-containing halogenated substances do not deplete stratospheric ozone but are potent GHGs. The most important of these are collectively called the F-gases and include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Numerous other minor trace gases complete the inventory of GHGs.

The contribution of a gas to the greenhouse effect is a result of both its characteristics and its atmospheric concentration. For example, on a molecule-by-molecule basis, CH_4 is a much stronger greenhouse gas than CO_2 , but it is present in much lower concentrations, so that its total contribution is smaller. When these gases are ranked by their contribution to the greenhouse effect, the most important ones (excluding ODSs) are water vapor, CO_2 , CH_4 , and O_3 , followed by N_2O and the three F-gases.

Institutional Framework

In 1992, 157 countries signed the United Nations Framework Convention on Climate Change (UNFCCC) and agreed to a common objective: “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.” As of 2009, 192 parties, including the European Union, have ratified the UNFCCC. This treaty focused attention on “anthropogenic” GHGs, that is, those GHGs that are either the direct result of human activities or the result of natural processes that have been affected by human activities.

The Kyoto Protocol (Japan) to the UNFCCC was negotiated in 1997; it focused on six GHGs (CO_2 , CH_4 , N_2O , SF_6 , HFCs, and PFCs). This treaty established legally binding commitments for the reduction of these six gases by the industrialized nations, as well as general commitments for all member countries. The Kyoto Protocol went into force in 2005, and as of 2009, 181 parties, including the European Union, had ratified

it. Under the Kyoto Protocol, the industrialized countries agreed to reduce their collective emissions of the six GHGs by 5.2% relative to the year 1990. Because of its dominant influence in global warming and climate change, the rest of this entry focuses on CO_2 .

Radiative Forcing and Climate Sensitivity

Radiative forcing is used to quantify the effect of increased concentrations of GHGs on the climate. It is a measure of the global energy balance, relative to preindustrial times. *Forcings* are influences that “push” the climate toward overall warming (positive forcing) or cooling (negative forcing). This phenomenon is measured as the alteration in global average atmospheric radiation flow in watts per square meter (W/m^2). The *sensitivity* of Earth’s climate to forcings is defined as the change in average surface temperature produced by a forcing of $1 \text{ W}/\text{m}^2$.

Through the study of ancient ice cores from Antarctica, it is possible to compare concentrations of CO_2 in the atmosphere with temperature variations over the past 400,000 yrs. (years). These records support a sensitivity of $\sim 0.75 \text{ }^\circ\text{C W}^{-1} \text{ m}^{-2}$. Sensitivity is also sometimes expressed as the change in average surface temperature that would be produced by a doubling of CO_2 from its preindustrial concentration of 278 ppmv (parts per million by volume), which corresponds to a forcing of $3.7 \text{ W}/\text{m}^2$, or $\sim 2.7 \text{ }^\circ\text{C}$. Such analysis has led researchers to conclude that most of the observed increase in globally averaged temperatures since the mid 20th century is “very likely” due to the observed increase in anthropogenic GHG concentrations. In the terminology of the Intergovernmental Panel on Climate Change (IPCC)—the international scientific organization that assesses the scientific, technical, and socioeconomic information relevant for understanding the risk of human-induced climate change—“very likely” implies a 90% or greater probability of occurrence.

The global increases in CO_2 concentration are due primarily to fossil fuel use and land use change, while those of CH_4 and N_2O are primarily due to agriculture. Reducing emissions of GHGs affords significant near-term opportunities for addressing the underlying causes of climate change. Many of

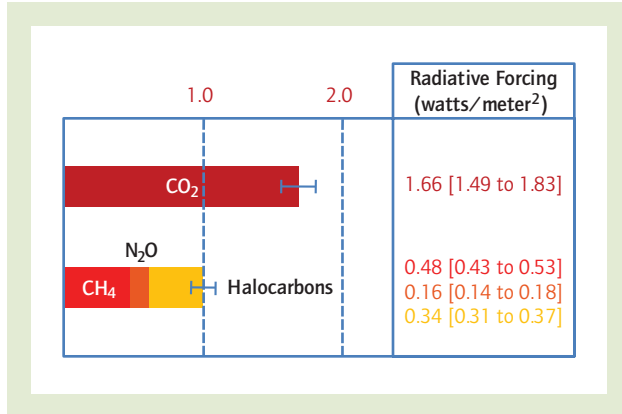


Figure 1 Global mean radiative forcing of the climate system in 2005 by long-lived greenhouse gases (measured in watts per square meter)

Source: Adapted from Intergovernmental Panel on Climate Change. (2008). *Climate change 2007: The physical science basis summary for policymakers*. Geneva: Author.

these GHGs have global warming potentials (GWPs) far higher than that of CO₂.

According to the IPCC, long-lived anthropogenic GHGs in 2005 exerted a total radiative forcing of ~2.64 W/m² (Figure 1). CO₂ accounted for 63% of this total, and non-CO₂ global GHG emissions of CH₄, N₂O, and high-GWP gases accounted for the remaining 37% (including ODSs). Since the Industrial Revolution, GHG concentrations in the atmosphere have risen rapidly, with CO₂ concentrations increasing from 280 ppmv in the early 1800s to a current level of ~375 ppmv. From just 1995 to 2005, CO₂ radiative forcing increased by 20%, the largest change for any decade in at least the past 200 yrs.

About 80% of anthropogenic GHG emissions are energy related, principally from fossil fuel combustion. As a greater portion of the world's population gains access to electricity and commercial fuels and with continued population growth, GHG emissions and concentrations in the atmosphere are expected to continue to increase over the 21st century. Numerous scenarios have been developed, with concentrations ranging from 350 to 650 ppmv and higher in the year 2100. As scientists begin to characterize the consequences of such unprecedented interference with the global climate, attention is being focused on mitigation actions. Technology, policy, and behavioral

options to reduce GHG emissions are numerous, mirroring the complex of emission sources that exist. GHG sources and mitigation options are summarized below. Types and sources of U.S. GHG emissions are summarized in Figure 2.

Sources of CO₂ and Their Control

CO₂ emissions come principally from the burning of fossil fuels, although land use changes, forestry, and other industrial activities such as cement manufacturing are also important. There are three strategies for addressing CO₂ emissions from fossil fuels: (1) improving energy end-use efficiency, (2) de-carbonizing the energy supply sector, and (3) capturing and storing carbon to prevent its release into the atmosphere. These are addressed in turn.

Energy End-Use Efficiency

End-use energy efficiency offers some of the largest and least-cost near-term opportunities for large-scale GHG mitigation. Numerous energy efficiency improvements are currently available and cost-effective and are already displacing CO₂ emissions.

On a global scale, combustion of transportation fuels accounts for 20.3% of CO₂ emissions. Over the next few decades, the transportation sector is expected to be one of the fastest-growing sources worldwide of GHG emissions. Promising technologies to reduce transportation energy use include lightweight materials, improved vehicle efficiency, electric fuel engine hybrids, clean diesel engines, and hydrogenated low-sulfur gasoline. Other options include alternative fuels such as ethanol, natural gas, electricity with storage, and biodiesel. In aviation, the next largest category of transportation energy demand after highway use, GHG emissions could be lowered through new technologies, including improved engine designs, fuel blends, and air traffic management systems. Finally, reductions could result from curbing the growth in vehicle miles traveled (VMT), modal shifts, and optimized transportation logistics.

The built environment accounts for about one third of primary global energy demand and is a major source of energy-related GHG emissions. Over the long term, buildings are expected to

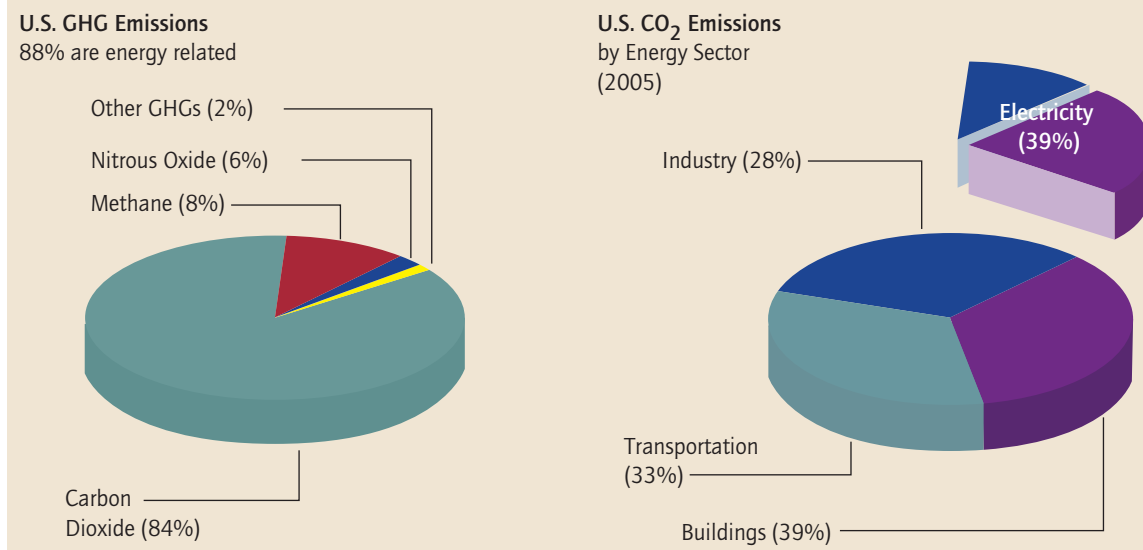


Figure 2 U.S. greenhouse gas emissions in 2005 by type and source

Sources: Energy Information Administration. (2007). *Annual energy outlook 2007 with projections to 2030* (Table A18). Washington, DC: Author; Environmental Protection Agency. (2008). *Inventory of U.S. GHG emissions and sinks: 1990–2006*. Washington, DC: Author.

continue to be a significant component of increasing global energy demand and a large source of CO₂ emissions, driven in large part by the continuing trends of urbanization, population and income growth, and longevity of building stocks. In the United States, the energy services required by residential and commercial buildings contribute ~38% of CO₂ emission. Technologies to reduce GHG emissions include the following:

- Advanced appliances, lighting, and heating and cooling equipment
- Advanced building envelope components, including roofs, walls, windows, and foundations
- Integrated building design, construction, and operation, including the optimal integration and control of components

The industrial sector is the largest of the end-use sectors, consuming more than 50% of the delivered energy worldwide and producing a

commensurate share of CO₂ emissions. Global energy consumption in this sector is projected to increase by an average of 1.8% per year from 2004 through 2030. GHG-intensity-reducing concepts for industry include technologies that increase the efficiency of process heating and process and design enhancements that can improve quality, reduce waste, reduce the intensity of material use, and increase in-process material recycling. Industrial facilities can implement direct manufacturing processes, which can eliminate some energy-intensive steps, thus both avoiding emissions and enhancing productivity. On the supply side, industry can self-generate clean, high-efficiency power and steam; it can also create products and by-products that can serve as clean-burning fuels, including the use of combined heat and power and cascaded heat.

Low-Carbon Energy Supply

Transforming the energy supply sector to reduce GHG emissions will require deployment



of innovative GHG-reducing technologies. For example, low-emission fossil fuel technologies, such as integrated gasification combined cycle power plants, can improve the efficiency of coal combustion by a few percentage points and have a significant impact on aggregate GHG emissions. Hydrogen has the potential to supplant hydrocarbon fuels and deliver net GHG reductions, though this depends on the source of hydrogen. Renewable power and fuels constitute a class of technologies that vary widely in terms of market readiness and penetration but have large GHG mitigation potential as a whole. In addition, nuclear fission substantially contributes to low-carbon power production and has significant potential to supply more in the future.

Carbon Capture, Storage, and Sequestration

Carbon capture and geologic storage technologies are expected to work in conjunction with the transition of low-carbon fuels to reduce GHG emissions from large concentration sources such as fossil power plants and industrial facilities. Capture and storage are supported by domestic demonstration projects, international collaboration efforts, and information programs. Terrestrial sequestration in soils or trees offers a potential sink for CO₂ that cannot be stored in geologic formations, and the large U.S. land base offers considerable potential for increasing terrestrial sequestration capabilities. However, this great opportunity comes at a relatively high cost for the many individual landowners who must change their practices and acquire additional skills or equipment to increase their land's sequestration capacity.

Comparisons Between Developed and Developing Countries

The global contribution of CO₂ emissions is dominated by the developed nations. In 2005, members of the Organization for Economic Cooperation and Development (OECD) were responsible for 48% of global CO₂ emissions, and the United States alone was responsible for 21%. According to the U.S. Energy Information Administration, world CO₂ emissions will grow

from 28 billion metric tons in 2005 to 42 billion metric tons in 2030. A majority of this growth will take place in non-OECD countries—especially China, India, and the Middle East. As a result, by 2030, OECD countries will account for only 37% of the total CO₂ emissions.

The global contribution of non-CO₂ GHGs is also highest in developed nations (Figure 3). While there have been reductions in CH₄ emissions, for instance, from coal mining and landfills in industrialized nations due to the restructuring of key industries, the emissions of the developed world remain much higher than those from developing countries. The ranking of regions from 1990 through 2020, in descending order, is forecast to be member countries of the Organization of Economic Cooperation and Development (OECD) and the European Union (EU), China, southeast Asia, non-EU countries of the Soviet Union, Latin America, Africa, and the Middle East. As with CO₂, the growth rates of non-CO₂ GHGs are higher in the developing nations than in the industrialized nations because of their rapid industrialization, expanding economies, and more rapidly growing populations.

The Urban Geography of Greenhouse Gas Emissions

Attention is beginning to focus on the urban geography of GHG emissions as community leaders realize that they need to play a critical role in the push to restrain emissions. Fortunately, many metropolitan areas offer major advantages for doing that, as illustrated in a recent study funded by the Brookings Institution that quantifies, for the first time, the carbon footprints of the 100 largest U.S. metropolitan areas. Topmost among the stories told by the study is the large degree of variation between the carbon footprints of U.S. metropolitan areas, based on the energy used in residential buildings and for surface transportation (i.e., cars and trucks). In 2005, per capita CO₂ emissions were highest in Lexington (Kentucky) and lowest in Honolulu—the average resident in Lexington emitted 2.5 times more carbon from transport and homes than the average resident in Honolulu.

Along with this dramatic variation between metropolitan areas, the study also reveals

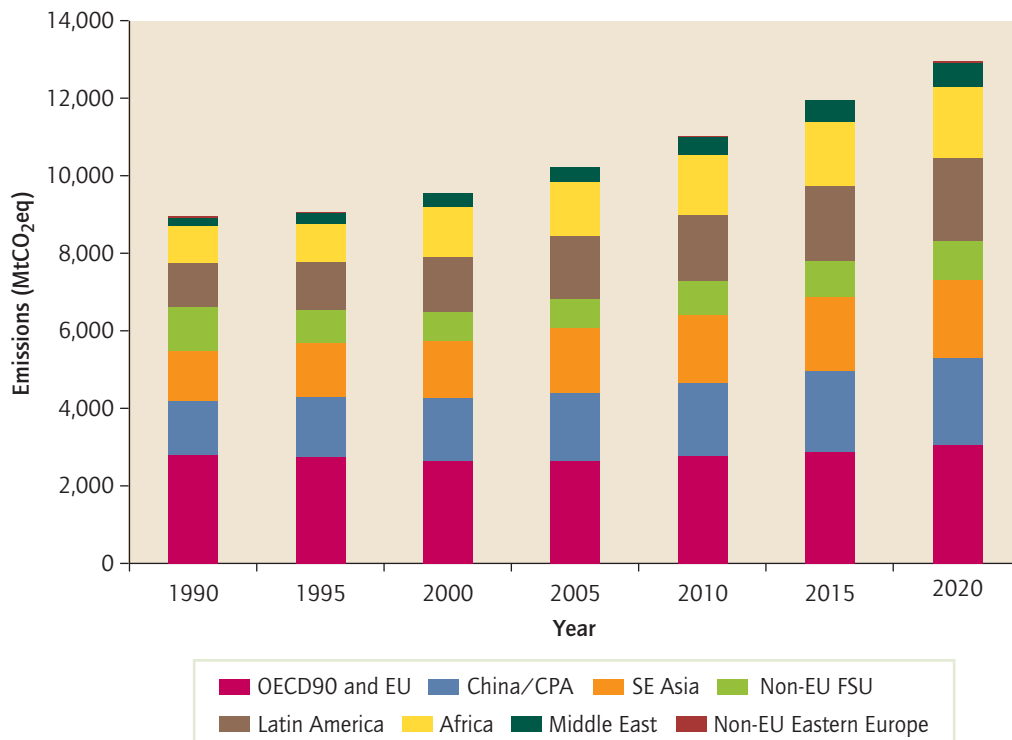


Figure 3 Total non- CO_2 emissions by region (metric tons of CO_2 equivalent). These geographic statistics highlight the fact that mitigation measures and strategies are needed worldwide.

Source: U.S. Environmental Protection Agency. (2006). *Global anthropogenic non- CO_2 greenhouse gas emissions: 1990–2020*. Washington, DC: Author.

that urban areas with high-density, compact development and rail transit offer a more energy- and carbon-efficient lifestyle than sprawling, auto-centric areas. For example, many metropolitan areas with small per capita carbon footprints, such as New York, San Francisco, San Diego, and Los Angeles, have sizable rail and mass transit riderships, while low-density metro areas such as Nashville and Oklahoma City are prominent among the 10 largest per capita emitters. There are exceptions, however. Washington, D.C., Baltimore, and Atlanta all have high rail transit ridership but also have larger than average carbon footprints, illustrating that other factors can offset the GHG savings from rail transit ridership, such as large emissions

from freight transportation and coal-dominant electricity.

Twenty-four percent of all highway fuel consumed and CO_2 emitted within the 100 largest U.S. metro areas comes from trucks, as opposed to cars. Growth in truck traffic is now outpacing growth in car traffic, and truck VMT (vehicle miles traveled) is expected to grow by more than 2% annually through 2020 in the United States.

Heavy reliance on coal-generated electricity for air conditioning and heating also contributes to the large per capita carbon footprints characteristic of many urban areas in the American South and Midwest. For example, the Washington, D.C., metropolitan area's residential electricity footprint was 10 times larger than Seattle's

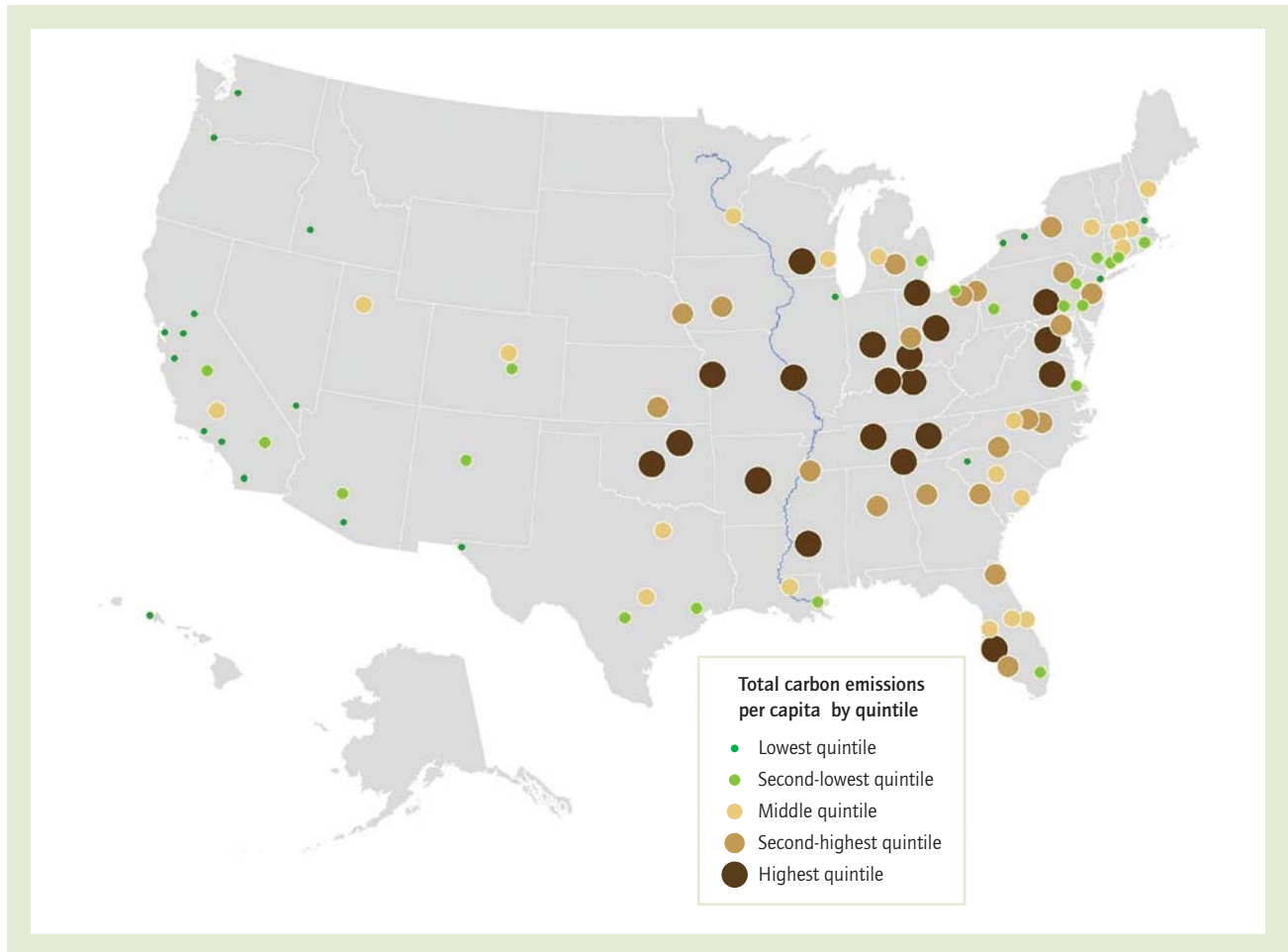


Figure 4 The urban geography of carbon footprints

Source: Brown, M. A., Southworth, F., & Sarzynski, A. (2008). *Shrinking the carbon footprint of metropolitan America*. Washington, DC: Brookings Institution. Reprinted with permission.

footprint in 2005, partly because the area's mix of fuels includes high-carbon sources of electricity such as coal, while Seattle draws its electricity largely from carbon-free hydropower.

CO₂ emissions show strong regional trends. The Mississippi River roughly divides the country into high and low emitters. In 2005, all but 1 of the 10 largest per capita emitters were located east of the Mississippi. Most of the metro areas with the smallest per capita footprints were located in the west. A north-south divide is also apparent, with seven of the highest per capita emitters located south of the Mason-Dixon Line, including two each from Tennessee, Ohio, and Kentucky. Thus, the passage of climate legislation aimed at curbing GHG emissions in the United

States would have highly geographically differentiated impacts (see Figure 4).

Altogether, federal prometropolitan climate policies could place large urban areas at the forefront of problem solving on energy and climate challenges. Just as there are strong geographic variations in GHG emission trends at the global scale, so too are there variations at the regional and urban scales.

Marilyn A. Brown

See also [Anthropogenic Climate Change](#); [Atmospheric Pollution](#); [Carbon Cycle](#); [Carbon Trading and Carbon Offsets](#); [Climate Change](#); [Climate Policy](#); [Energy Policy](#); [Energy Resources](#)



Further Readings

- Brown, M. A., Southworth, F., & Sarzynski, A. (2008). *Shrinking the carbon footprint of metropolitan America*. Washington, DC: Brookings Institution.
- The Committee on Climate Change Science and Technology Integration. (2009). *Strategies for the commercialization and deployment of greenhouse gas intensity-reducing technologies and practices* (DOE/PI-0007). Washington, DC: U.S. Department of Energy.
- Energy Information Administration. (2007). *Annual energy outlook 2007 with projections to 2030* (DOE/EIA-0383, 2007). Washington, DC: U.S. Department of Energy.
- Energy Information Administration. (2008). *International energy outlook 2008* (DOE/EIA-0484, 2008). Washington, DC: U.S. Department of Energy.
- Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: The physical science basis summary for policymakers*. Retrieved February 21, 2009, from http://ipcc-wg1.ucar.edu/wg1/docs/WG1AR4_SPM_Approved_05Feb.pdf
- United Nations. (n.d.). *The United Nations framework convention on climate change*. Retrieved December 30, 2009, from http://unfccc.int/essential_background/convention/background/items/1349.php
- U.S. Climate Change Technology Program. (2006). *Strategic plan* (DOE/PL-0005). Washington, DC: U.S. Department of Energy.
- U.S. Environmental Protection Agency. (2006). *Global anthropogenic non-CO₂ greenhouse gas emissions: 1990–2020* (EPA Report 430-R-06-003). Retrieved February 21, 2009, from www.epa.gov/climatechange/economics/downloads/GlobalAnthroEmissionsReport.pdf
- U.S. Environmental Protection Agency. (2006). *Global mitigation of non-CO₂ greenhouse gases* (EPA Report 430-R-06-005). Retrieved February 21, 2009, from www.epa.gov/climatechange/economics/downloads/globalMitigationFullReport.pdf
- U.S. Environmental Protection Agency. (2008). *Inventory of U.S. greenhouse gas emissions and sinks: 1990–2006* (USEPA 430-R-08-005). Washington, DC: Author.



GREEN REVOLUTION

See Environmental Impacts of Agriculture



GREGORY, DEREK (1951–)

Derek Gregory is one of contemporary human geography's leading theoreticians. His early career was marked by critiques of location theory, spatial diffusion, and humanistic geography. In the 1980s, he introduced geographers to Anthony Giddens's theory of structuration, linking it to the tradition of time-geography. He also injected social theory into historical geography, including studies of the uneven spatiality of class struggle in England during the Industrial Revolution. Such studies of the origins of modernity enticed geographers to unveil its historically specific nature and reveal it as a particular power-knowledge configuration.

Gregory's exploration of postmodernism, including its general distrust of broad, overarching theoretical paradigms, raised the importance of spatiality to new heights: Geographies, he insisted, are not simply passive reflections of some aspatial social structure; rather, space is inevitably an active participant in the formation of social relations and their changes over time.

The book *Geographical Imaginations*, published in 1994, was a well-received elaboration on the ways in which seemingly different theoretical approaches reflected historically specific "scopic regimes," ways of seeing and knowing the world that appear consistent and complete within their own frames of reference. Since the Enlightenment, Western social science, including geography, has subscribed to the notion of a Cartesian observer, who is detached, all-knowing, and objective, a view that led to what Gregory calls the "world-as-exhibition." This notion underlies many seemingly disparate perspectives, including Marxism and positivist conceptions, and confers the power to know and define the world—both social and natural—on a rational, presumably male, all-knowing ego. Within geography, it was reflected in the triumph of abstract



space over lived experience, a position made possible only if representations of the world are held to be detached from the world they reflect. In contrast, Gregory argues that every theoretical position is necessarily incomplete and situated, linked to a power interest, and reflective of its utility in social life.

More recently, drawing on works concerning Orientalism, Gregory has focused on European colonial representations of non-Western spaces and peoples. As a power-knowledge relation, the active “geo-graphing” of various parts of the globe was an integral part of Western administrative control of colonized regions. The colonial geographical imagination demarcated space and brought alien territories into Western frames of understanding in a manner that drew critical boundaries between identities, the self and the other, whites and nonwhites, and so on. Empirically, Gregory’s postcolonial work focused largely on the Middle East, particularly European and American representations of Egypt in the late 19th and early 20th centuries. In the 19th century, as Egyptology became fashionable, Egypt occupied a central ideological position in the evolving self-conception of the West as both near and distant, foreign and familiar, ancient yet stagnant. Gregory reveals how Western imaginative geographies were laced with patriarchal, sexualized, and often racist imagery that effectively “othered” Arabs in their own lands as Egypt was thoroughly “geo-graphed” by a panopticonic foreign authority. In *The Colonial Present*, he extended postcolonialism into a critique of the so-called war on terror in Iraq, Palestine, and Afghanistan, revealing it to be a war of terror against people rendered invisible by Western discourses that marginalize Muslims.

Continuing in this vein, Gregory has more recently explored the spatiality of U.S. human rights abuses at the military base and prison at Guantanamo, Cuba, drawing on the work of the Italian philosopher Giorgio Agamben. The dominant discourses defending American policies portrayed Guantanamo as a necessary corrective to the unjustified and irrational actions of insurgents. The volume *Violent Geographies*, which Gregory co-edited with Allan Pred, offered an in-depth overview of how political terror, daily life, and space were intertwined in a variety of

different contexts, including Hindu and Muslim fundamentalism, the geographies of the terrifying war on terror, and the ways in which violence of all types is discursively sanitized.

Gregory has emphatically stressed the importance of historical context in academic work, a move that thwarted the aspirations of Enlightenment modernists to construct universal interpretations independent of time and space. He has remained steadfast in his insistence that geographies are peopled, that time and space are made by ordinary folk, and that the outcomes are always contingent and never predetermined, even if, in contrast to overly structuralist interpretations, they are likewise never random or chaotic. His works have decisively demonstrated the need to understand capitalism in discursive terms, and he has been an acute observer of the roles played by language in the process of representation. He has remained sensitive to the politics of representation, the ways in which all forms of understanding are inescapably entwined with temporally and spatially varying regimes of power-knowledge: Discourses simultaneously reflect and constitute the relations they depict and that give rise to them. Finally, Gregory’s turn to postcolonialism has helped awaken the discipline to the profound but often invisible ways in which geography as discourse was complicit in the systematic othering and dehumanization of non-European peoples, a process that continues today in Western policies toward the Muslim world.

Barney Warf

See also Agamben, Giorgio; **Critical Human Geography**; **Geographical Imagination**; Giddens, Anthony; **Postcolonialism**; Pred, Allan; **Structuration Theory**; **Time-Geography**

Further Readings

- Gregory, D. (1978). *Ideology, science and human geography*. London: Hutchinson.
- Gregory, D. (1981). Human agency and human geography. *Transactions of the Institute of British Geographers*, 6, 1–18.
- Gregory, D. (1994). *Geographical imaginations*. Cambridge, MA: Blackwell.



- Gregory, D. (1995). Between the book and the lamp: Imaginative geographies of Egypt, 1849–50. *Transactions of the Institute of British Geographers*, 20, 29–57.
- Gregory, D. (1995). Imaginative geographies. *Progress in Human Geography*, 19, 447–485.
- Gregory, D. (2001). (Post)colonialism and the production of nature. In N. Castree & B. Braun (Eds.), *Social nature: Theory, practice, and politics* (pp. 84–111). Oxford, UK: Blackwell.
- Gregory, D. (2004). *The colonial present: Afghanistan, Palestine, Iraq*. Oxford, UK: Blackwell.
- Gregory, D. (2006). The black flag: Guantanamo Bay and the space of exception. *Geografiska Annaler B*, 89, 405–427.
- Gregory, D. (2008). The biopolitics of Baghdad: Counterinsurgency and the counter city. *Human Geography*, 1, 6–27.
- Gregory, D., & Urry, J. (Eds.). (1985). *Social relations and spatial structures*. New York: St. Martin's.



GROSS DOMESTIC PRODUCT/ GROSS NATIONAL PRODUCT

Gross domestic product (GDP) and *gross national product* (GNP) are widely used measures of the value of total economic activity of a region in a given period of time, typically a year. While these indices may be estimated for subnational regions, they are most commonly used in reference to countries. Thus, while GDP and GNP are primarily economic measures, they are also inherently spatial because they vary in absolute and per capita terms widely across the world.

GNP assesses the total value of the goods and services produced by a given national group of people in a given year. Because statistically total output must equal total income and expenditures, it is also a measure of those two other dimensions of the economy. In typically macroeconomic accounting, GDP is the sum of consumption, gross investment (not counting depreciation), government spending, and net exports. This measure is also equal to total employee income (wages and salaries) and profits (returns to businesses);

thus, GDP is sometimes called *gross domestic income*. GDP may also be regarded as the sum of all profits added at different stages in production from raw material to final good.

GDP differs from GNP in that the former refers only to the output of a country rather than to its nationals, who may live beyond its borders. GNP, in contrast, includes the output of nationals abroad. Given the growing significance of extranational production, GDP has slowly replaced GNP as the most common measure of national output. For example, in 2006, the U.S. GNP was \$11.059 trillion, including \$55 billion in receipts from abroad, making the U.S. GDP equal to \$11.01 trillion. As foreign incomes have increased around the world, the use of GDP as a measure of economic activity has gradually declined in favor of GNP.

In 2007, the world's GDP was roughly \$54.6 trillion; of these, the GDP of the United States was about \$13.9 trillion (Figure 1), followed, in order, by China (\$7 trillion), Japan (\$5 trillion), Germany (\$2.8 trillion), and France, Russia, the United Kingdom, and Italy at approximately \$2 trillion each.

GDP divided by the total population of a region at a given moment yields GDP per capita, the most common measure of average individual income (or lack thereof), productivity, and economic development. GDP varies widely among the world's states (Figure 2), ranging from a high of more than \$40,000 in Scandinavia in 2007 to a low of less than \$300 in Mozambique, Congo, and Niger. Roughly one half of the world's population lives on a GDP per capita of less than \$2 per day, although this measure excludes the informal economy and noncommodified forms of activity such as subsistence production. GDP per capita is thus a widely deployed metric of uneven spatial development, and its map reflects the pronounced bifurcation between the First and Third Worlds. Growth rates of GDP per capita measure the extent to which average incomes are changing.

However, as with GNP, GDP has been criticized as a measure of economic wealth in that it only includes commodified activity and ignores substantive areas of activity such as subsistence production, unpaid activities such as housework, and the informal economy and that it is vulnerable to both exchange rate fluctuations and inflation rates. Feminists have criticized these measures

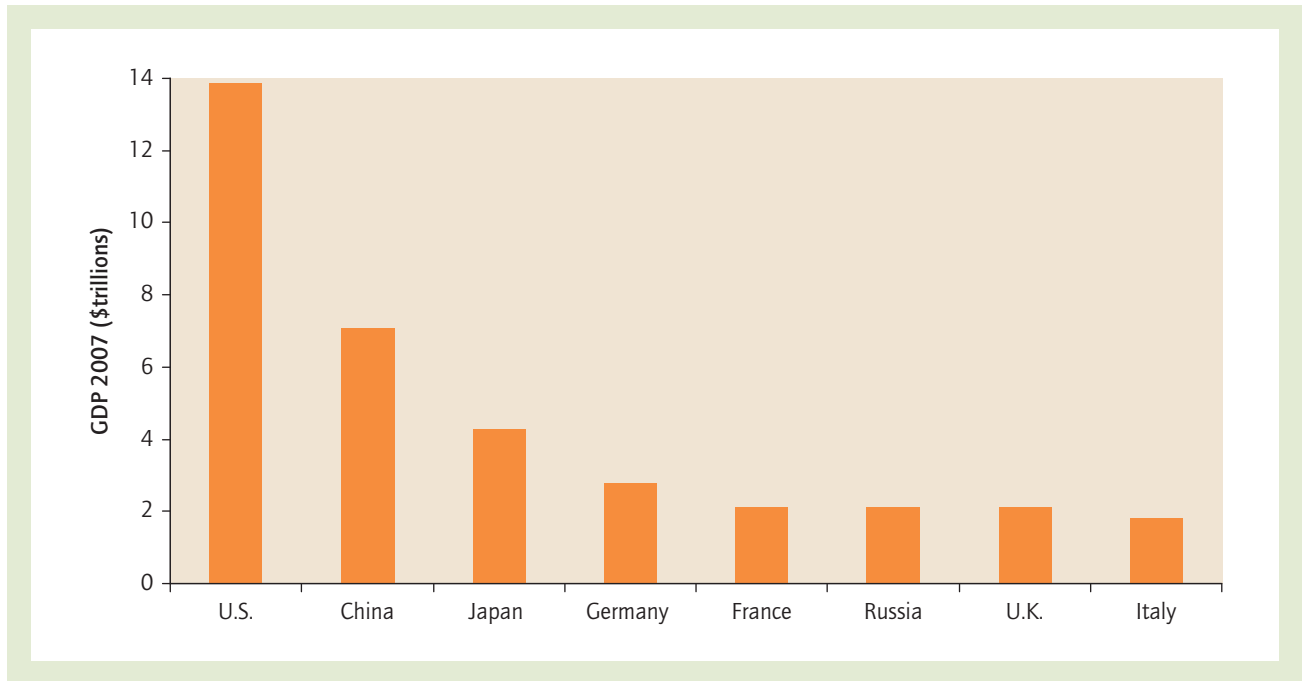


Figure 1 Major world GDP, 2007 (in U.S. dollars). GDP reflects, among other things, the size of a country's population, its resource base, and productivity. The United States is the only country that is simultaneously large and productive.

Source: Created by author, from data in *The World Factbook* (www.cia.gov/library/publications/the-world-factbook/index.html).

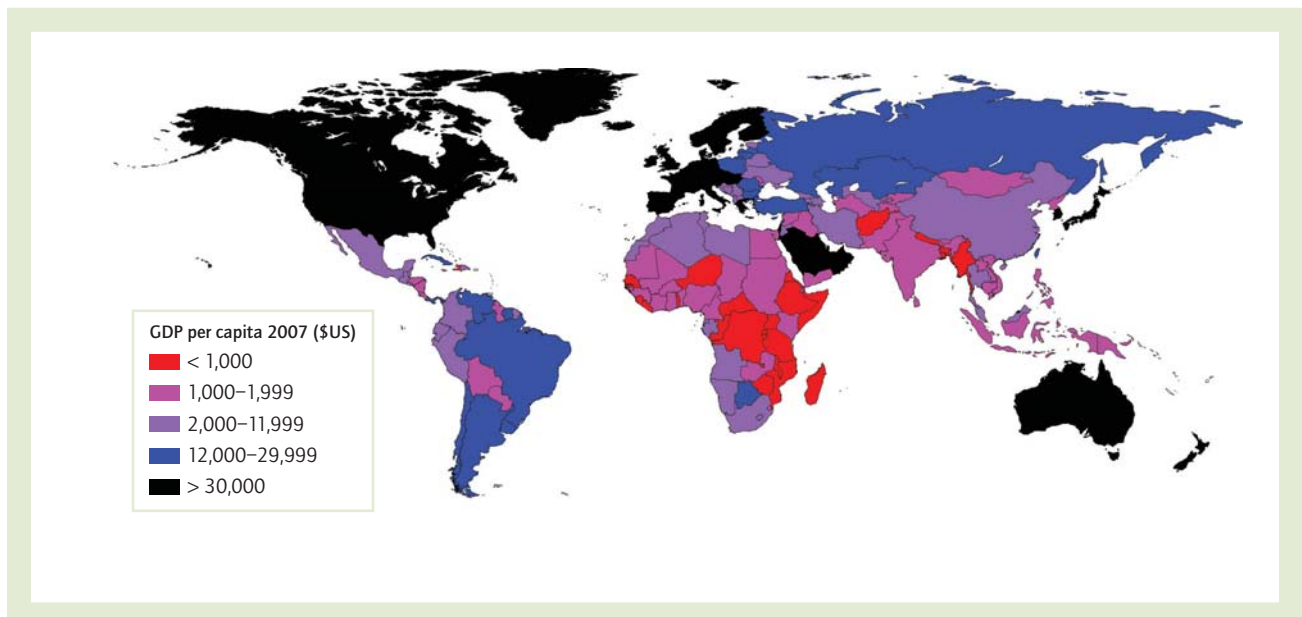


Figure 2 Map of GDP per capita, 2007. Although it is an imperfect measure of average incomes, GDP per capita is the most widely used. Its spatial variations reflect the world's wealth and poverty (i.e., uneven development).

Source: Created by author, from data in *The World Factbook* (www.cia.gov/library/publications/the-world-factbook/index.html).



as valuing only male labor relative to female labor. Neither does GDP per capita include the cost of living; for this reason, some researchers prefer measures of purchasing power parity. Moreover, GDP per capita is an average that may conceal large internal inequalities in income. Both GNP and GDP, therefore, are imperfect measures. Some theorists have called for nonmonetary measures of national wealth, such as the amount of time necessary to purchase a given commodity, per capita energy use, or health statistics, all of which speak to the quality of life rather than simply economic activity. Bhutan, for example, uses a measure called *gross national happiness*.

Barney Warf

See also **Regional Economic Development; Uneven Development**

Further Readings

Bureau of Economic Analysis. (2007). *Measuring the economy: A primer on GDP and the national income and product accounts*. Retrieved January 29, 2010, from www.bea.gov/national/pdf/nipa_primer.pdf



GROUND REFERENCE DATA

Remote sensing (RS) of Earth's environment using airborne and satellite-borne sensors has greatly improved our ability to describe and measure the characteristics of Earth's atmosphere, oceans, land surfaces, and dynamic processes over time and space. Products derived through remote sensing enhance our geographical understanding of the environment and how humans interact with and/or affect the environment. Ground reference data (GRD) are critical to the creation of accurate and useful RS products. GRD provide information about actual conditions of features or phenomena of interest and are used for calibration and validation purposes.

GRD may be in the form of point-based information, plot samples, or maps with areal units (e.g.,

polygons) having thematic or continuous data. Before GRD are collected, the exact type and nature of the GRD needed should be carefully considered. *Thematic data* describe classes such as land use type or vegetation type. *Continuous data* describe attributes that vary continuously over space or time, such as percentages, counts, and sizes. For example, continuous data may describe the percent cover of impervious surface within an urban area, the temperature of a portion of ocean surface, or the biomass within a stand of rain forest. GRD should be collected or processed to be in a form comparable with the RS data they are to support.

Collection of GRD may be accomplished by in situ visits and drive-by mapping. GRD are more accurate than reference data collected using other methods (e.g., aerial reconnaissance, interpretation of relatively high-resolution imagery, or compilation of existing ancillary data). GRD collected during in situ visits are considered the most accurate and are often referred to as *ground truth* data. The collection of in situ GRD can be expensive and time-consuming.

GRD are collected to better understand features or phenomena of interest and to calibrate and validate RS products designed to map these features/phenomena. Calibration is the process of using GRD to train a classification algorithm or biophysical data estimation model. Validation is the process of assessing the accuracy of the final product. GRD samples should be divided so that some are used for calibration and the remainder for validation. This ensures that accuracy assessment results are independent.

GRD contain error and uncertainty and thus should not be considered as "ground truth." These errors are associated with things such as timing differences between GRD and RS data, spatial location errors of GRD and co-location errors relative to RS data, human measurement/interpretation errors, and errors associated with the scale of GRD. Scale errors include the use of minimum mapping units that are different from those associated with the RS data and delineation/digitizing error due to map/image display scale.

Lloyd L. Coulter

See also **Aerial Imagery: Interpretation; Image Processing; Remote Sensing**



Further Readings

- Bossler, J. D. (Ed.). (2002). *Manual of geospatial science and technology*. London: Taylor & Francis.
- Congalton, R. G., & Green, K. (1999). *Assessing the accuracy of remotely sensed data: Principles and practices*. New York: Lewis.



GROUNDWATER

Groundwater refers to the saturated layer of Earth's crust extending beneath the land surface to a depth where solid rock does not permit the movement or storage of water. The widespread geographical distribution of groundwater and its usually high quality for human consumption, agriculture, and other uses make this a resource of global importance; it accounts for a third of the planet's total volume of water outside the oceans, or close to 98% of all freshwater outside ice caps and glaciers. The spatial occurrence and quality of groundwater are not uniform, which is the result of geology, climate, surface water interactions, and, increasingly, human use and contamination. There is a growing recognition that a comprehensive understanding of groundwater must consider its multiple and interconnected physical, hydrogeological, and human use dimensions.

This entry is organized as follows: A brief physical characterization of groundwater in the hydrological cycle is followed by a description of its geographical distribution and importance, which leads to assessment of groundwater use, quality, and sustainability challenges. The entry concludes by outlining human organizational and institutional aspects, along with a synthesis of the human-environment dimensions of groundwater.

Groundwater Hydrology

Active groundwater is conventionally distinguished as the portion that circulates in contact and exchange with Earth's surface hydrological cycle; this accounts for approximately half of the total groundwater. The remaining *deep* groundwater

portion occurs within Earth's crust and is largely inaccessible to surface hydrologic interaction or human use. Geological conditions, specifically geochemical processes and residence times, influence the quality of groundwater. Much deep groundwater is considered to be of a quality that is not suitable for ecological or human purposes; for example, it frequently has high dissolved mineral content as a result of prolonged chemical interaction or deposition from saline ocean water over geological timescales. Shallow groundwater extensively interacts with surface water over timescales that vary from days to millennia.

Aquifers are the spatial units of rock, alluvium, and other subsurface materials where groundwater occurs, and they are separated from other aquifers by nonporous geological formations that impede the subsurface flow of water. Aquifer properties include porosity, rock fractures, conductivity (groundwater movement that a pressure gradient produces), and transmissivity (conductivity over the depth of the water-bearing strata). These properties, coupled with groundwater pressure that results from elevation differences of water levels in the aquifer, determine the rates of groundwater extraction that pumping will produce. *Drawdown* and *cone of depression* refer to localized groundwater-level effects resulting from extraction.

Groundwater is recharged vertically from the surface infiltration of rainfall, other atmospheric precipitation, or water bodies, including lakes, rivers, wetlands, and estuaries. Under certain aquifer conditions, recharge may occur laterally from surface water bodies. Water occurring in the immediate near-surface, weathered soil layer, often coinciding with the depth that plant roots will penetrate, is referred to as *soil moisture*. Below this, water percolates in the unsaturated vadose zone (the area between the surface and the saturated zone) and deeper to saturated layers of the aquifer, commonly referred to as the *water table*. Alluvial deposits often result in unconfined aquifer conditions. In contrast, impervious strata, for example, solid or low-porosity rock or clay layers, can result in confined or semiconfined aquifers and, depending on the groundwater pressure, may cause water to flow freely to the surface in artesian wells.

Depending on the water levels, groundwater may reside indefinitely in aquifer storage, or it



may discharge to the surface or to oceans. An important process of groundwater discharge supplies the base flow (minimum dry-season surface flow) in streams and rivers during periods of low precipitation and runoff. A special class of ocean-aquifer interactions accounts for the salinity of groundwater in near-coastal areas. Islands in the ocean often have a lens of low-salinity fresh groundwater perched above the underlying saltwater. The saline-freshwater interface is subject to disruption, for example, through pumping, which may cause salinity ingress to otherwise freshwater aquifers.

It is important to briefly summarize mathematical modeling approaches to groundwater occurrence and movement and to the fate and transport of contaminants. Early mathematical development proceeded from hydraulics and improved on static water budgets that assumed uniform aquifer mixing. Groundwater flow models require extensive parameterization (definition and quantification of multiple variables) and data sets based on extensive monitoring of groundwater levels and flow processes. Models such as MODFLOW are based on finite-element grids that represent the aquifer in three dimensions. Additionally, these models are capable of simulating the geochemical interactions of specific contaminants. Groundwater models are developed and run for research and operational purposes, for example, by agencies charged with the management of water resources.

Geographical Distribution

The occurrence of groundwater is determined by three principal factors: (1) aquifer characteristics that permit recharge and storage of groundwater, (2) precipitation or surface water availability for recharge (bearing in mind the extended, millennial scales of storage and circulation), and (3) human use that may drive aquifer depletion if extraction is significantly in excess of recharge. Despite its recharge from precipitation, groundwater may be abundant in aquifers in low-precipitation (arid and semiarid) regions. As a result, it is a resource of critical importance in the Middle East, North Africa, South and West Asia, Australia, Western North America, and parts of South America and Europe. Due to its ease of access and temporal

dependability compared with surface waters that are often prone to drought and intermittent depletion, groundwater is also extensively used in higher-precipitation humid regions.

Surveys to quantitatively estimate groundwater storage have been conducted at the national and subnational levels; however, these are based on inconsistent methods and differing assumptions of subsurface aquifer characteristics. Reporting problems similarly plague groundwater use data. It is estimated that globally, India is the largest user of groundwater (150 km³/yr. [cubic kilometers per year]), followed by the United States (100 km³/yr.), China (75 km³/yr.), Pakistan (45 km³/yr.), Iran (45 km³/yr.), and Mexico (28 km³/yr.).

Groundwater Use

As indicated above, groundwater is increasingly used for human purposes, including (in order of estimated volume currently extracted) agriculture and livestock, potable water supply in urban and rural areas, power generation, and industrial uses. Historically, humans devised ingenious means to use and extract groundwater. Desert oases occur where shallow groundwater accumulates at the surface. Lift devices from shallow open wells used human and animal draft power and included the Archimedean screw, Persian wheel, and animal skin bailer. Wind-powered and water flow-powered lift devices became important with advances in mechanics and materials. *Qanats*, sloped horizontal tunnels to intercept groundwater within a hillside and convey it by gravity to the surface, were developed in Persia as early as 2,500 yrs. ago. This technique, with some innovation and under a range of names, spread in Central Asia and farther west, to North Africa, Southern Europe, and the Americas, as well as east to parts of China, Japan, and the Philippines. Functioning qanats can still be found.

The 19th-century advent of mechanized pumps, driven initially by steam power and subsequently by electrical motors or hydrocarbon-fueled engines, resulted in widespread tapping of aquifers for human use. Early examples of groundwater-based regional and economic development, particularly for urban expansion and agricultural irrigation, include the American West, Mexico, Spain, the Middle East, India,



China, and Australia. Groundwater development was intricately linked with population growth in urban centers and rural areas alike, human occupation of regions previously considered uninhabitable for lack of access to reliable water supplies, and increased food production. Rural electrification programs in the early and mid 20th century, coupled with the development and reduction in costs of pumps and related irrigation technology, drove the expansion of groundwater-based agriculture, which by a large margin exerts the greatest demand on groundwater resources. In numerous locations, falling water levels resulted from extraction in excess of renewable groundwater supplies. In other aquifers with exceedingly low or nonexistent recharge, extraction is referred to as *groundwater mining*, or use of *fossil groundwater*.

Numerous regions where population growth as well as economic development and diversification away from agriculture were facilitated by reliance on intensive groundwater use began to show symptoms of aquifer depletion: rising costs of extraction (both for deepening and operating wells), declining water quality, land surface subsidence (where compaction of aquifer layers pumped dry caused non-uniform settling and often large surface cracks or sinkholes), and drying of surface streams previously fed partially or wholly by groundwater discharge, among other impacts. This has resulted in serious risk to groundwater-dependent human populations and ecosystems. Related impacts of intensive groundwater use include (a) the mobilization of geogenic sources of arsenic, resulting in often serious contamination of water supplies in some of the world's most densely populated regions, particularly the lower Ganges-Brahmaputra river basin in Bangladesh and parts of India and Nepal; (b) fluoride contamination of groundwater; and (c) salinity ingress in coastal aquifers as well as salt buildup in intensively irrigated soils in arid regions. It is also now recognized that recharge processes can be exacerbated by climate change-driven precipitation variability coupled with human modification of the land surface, for example, compaction of agricultural soils or sealing over urban spaces through paving and roofing. Drought and flood cycles and the variability of surface water resulting from climate change processes may induce additional human reliance on groundwater as a dependable source of supply to meet a range

of demands. At the same time, groundwater use may exert feedbacks on the climate system via greenhouse gas emissions resulting from the generation of power to pump the groundwater. Human use of water is extremely energy intensive; for example, India uses a third of its electrical power to pump groundwater, and Southern California uses a fifth of its power for the full cycle of water service provision.

In sum, groundwater development has been a primary driver of urban and rural growth and prosperity but has often resulted in unsustainable aquifer depletion. Regions considered emblematic of the groundwater extraction-depletion trajectory include the southwestern United States and the high plains Ogallala aquifer, Central and northwest Mexico, northeast Brazil, the Pacific coast of Northern Chile and Peru, Central Spain, most of North Africa and the Middle East, Iran, Central and northwest India, Central Asia, the North China plains, and Western Australia.

Groundwater Pollution

As indicated above, the quality of groundwater varies naturally as a result of geochemical processes, residence times, and proximity to saline water bodies. Anthropogenic sources of pollution, too, influence groundwater quality, specifically nutrients, salinity, pathogens, and inorganic and organic compounds. Groundwater pollution is exceedingly difficult to reverse or remediate, given the nonuniform mixing, long residence times, and geochemical interactions between pollutants and aquifer materials.

Agricultural fertilizers and human and animal waste are the principal source of nutrients that influence groundwater quality. Nitrogen in its soluble form as nitrate is less reactive with aquifer materials than are other nutrients and is conveyed from surface sources and land uses via percolation to the underlying aquifer. In cases where groundwater is used to supply drinking water for human settlements, high concentrations of nitrate are a particular concern due to the risk to human health. Blue baby syndrome can be fatal for infants who consume water, formula, or other food prepared using water with high nitrate levels.

Pathogenic microorganisms including bacteria, protozoa, and viruses occur in groundwater as a



result of human activity and the transmission of these pathogens to the underlying aquifers. Aerobic conditions above the saturated aquifer layer and anaerobic conditions below, along with the physical properties of the aquifer (pore size and geometry) significantly influence the distribution and fate of pathogens in groundwater. In general, shallow aquifers with periodic aerobic conditions are more prone to pathogen contamination than are deep aquifers with extended groundwater residence times.

Salinity is a major concern for groundwater quality. Primary salinity may result from groundwater deposition from ocean water over geologic timescales. Secondary salinity has human causes chiefly related to irrigation using water with high dissolved mineral content. As irrigation is applied, crops consume (transpire) water, or it is evaporated from the soil surface, leaving minerals in or on the soil. Subsequent irrigation may involve an extra watering simply to flush the salts out of the root zone of the soil, which may pollute the underlying groundwater depending on the depth to the aquifer. Salinity resulting from irrigation can cause waterlogging where groundwater levels rise to the surface, a condition that is widespread and growing. Waterlogging is common where surface irrigation using canals brings water into an area with underlying saline groundwater that is unusable for irrigation or where topographic conditions make it difficult to drain excess irrigation water. A special case of salinity is presented by irrigation using groundwater that is brackish, that is, with low to medium levels of salinity that some crops may tolerate. Salinity buildup from irrigation with brackish water can be rapid, often putting such areas out of agricultural production.

Finally, a range of inorganic and organic compounds from human sources may impair groundwater quality. Persistent inorganic pollutants in groundwater may include heavy metals; however, these are usually chemically bound to particles that may not easily pass through soil or aquifer material to reach the groundwater. As indicated above, geogenic sources of arsenic represent an important groundwater pollution problem. Solvents, fuel additives, manufacturing byproducts, and other organic constituents that leach into underlying aquifers are representative of organic pollutants that are increasingly recognized as a risk to human

health and the environment. The wide range of organic pollutants, some highly site specific, makes it difficult to review their occurrence; however, it should be noted that their traceability and often localized occurrence mean that such contaminants are often targeted for remediation efforts. Given the persistence of groundwater pollutants, remediation may involve physically removing (excavating) contaminated aquifer material. Other approaches, particularly for shallow contaminated layers, include phyto-remediation using plants that selectively take up and bind contaminants in their tissue. Remediation is invariably difficult and expensive, and efforts to prevent groundwater pollution through source control are critical.

Human Organization, Management, and Policy

The use of groundwater for human purposes displays unique organizational characteristics that distinguish it from many other natural resources, including surface water. Because of its geographical distribution, groundwater is accessible to a wide range of users. Technology represents a mediating factor for groundwater use and appropriation and, in cases of aquifer depletion such as those discussed above, forms a mechanism for competition among users. In the early stages of a society's development and reliance on groundwater, access was considered to be unencumbered by formal institutional arrangements or systems of rights that applied to surface water or other natural resources. In the Western United States, for example, prior appropriation rights to surface water were only subsequently modified and applied to groundwater—often, however, in a manner dissociated from surface water, although hydrologically the two remain connected. Here, groundwater capture by users with the most powerful pumps generated strong competition among users or simply deprived others of access. In other instances, private capture was pitted against public regulation. In the absence of effective regulation, groundwater has been a prime example of the tragedy of the commons, that is, the private appropriation of publicly owned resources that leads to overuse and degradation.

In societies that historically innovated with collective action to use and manage resources, for



example, canal irrigation in Asia or the Andes, the advent of groundwater use represented a marked departure from community norms for access and management of water. As a result, Tushaar Shah refers to groundwater use as atomistic, resulting from private investment even by smallholder farmers of limited economic means. In some instances, these changes have undone community institutions, rule making, and enforcement and compliance, as well as the distribution of labor, costs, and benefits. In other cases—for example, share-based group wells or aquifer-using societies—attempts have been made to bring groundwater and its use under the purview of community institutions. The role of the state in providing or withholding public investment and infrastructure and setting legal frameworks for groundwater use and dispute resolution increasingly overlaps with more localized public and private interests around groundwater.

In the context of mature institutional arrangements, groundwater use is subject to regulation based on legal provisions (e.g., limits to use, spacing of wells, and titling rights) and economic instruments (land, production, or value-added taxation). A growing body of research and case evidence holds significant promise for groundwater regulation through the water-energy nexus, or synergistic management of energy and water—for example, dual water and energy savings based on efficiency and conservation or pricing of energy to manage the demand for water.

Groundwater is no longer considered an insular resource, separate from surface water or unfettered by competing claims over its use. Aquifers are acknowledged to encompass a multitude of uses and users. Competition among agriculture, urban water supply, power generation, and ecosystem needs is increasingly evident, often across national boundaries. Transboundary aquifers are the subject of growing interest among decision makers and researchers, reflecting a trend in the increasing globalization of water issues and paradigms for its management. Transboundary aquifers of particular note include the Guarani aquifer in South America, the Ganges-Brahmaputra-Meghna aquifer system in South Asia, and the Imperial Valley–Mexicali aquifer in Western North America.

Aquifer depletion remains a principal management and policy challenge for human use of

groundwater. Various groundwater augmentation and demand management strategies have been attempted at a range of scales. At the very local level, for example, individuals may harvest rainwater runoff from their roofs or fields to recharge individual wells. More concerted efforts have been made at the scale of aquifers in the river basins they underlie. Aquifer conservation plans, conjunctive surface and groundwater use, and integrated river basin management all attempt to influence groundwater use. An important strategy for sustainable aquifer management has been based on importation of surface water, often through transfer from distant river basins. In the United States, Southern California and Southern Arizona aquifers rely on massive pumped delivery of surface water from outside their respective river basins, yet neither region has reached sustainable management targets. Finally, in the sequence of expanding scale, transboundary and global initiatives increasingly address multiple, integrated aspects of groundwater.

Human-Environment Interactions Involving Groundwater

From a coupled human-environment perspective, aquifer physical processes and the attendant water quantity and quality exert mutually causal influences on human groundwater dependence, with critical economic and institutional implications. The rapid development of groundwater over relatively short timeframes of human generations must be considered along with aquifer flow and storage that occur over millennia. Climate change with human and natural drivers that are global in scale adds further complexity to local patterns of human dependence on groundwater.

Christopher Scott

See also **Coupled Human and Natural Systems; Environmental Impacts of Agriculture; Environmental Impacts of Cities; Environmental Impacts of Manufacturing; Environmental Impacts of Roads; Human Dimensions of Global Environmental Change; Hydrology; Open-Pit Mining; Surface Water; Urban Water Supply; Water Needs; Water Pollution; Watershed Yield**



Further Readings

- Llamas, R., & Custodio, E. (Eds.). (2003). *Intensive use of groundwater: Challenges and opportunities*. Lisse, Netherlands: Swets & Zeitlinger.
- Loaiciga, H. A. (2003). Climate change and ground water. *Annals of the Association of American Geographers*, 93(1), 30–41.
- Shah, T. (2008). *Taming the anarchy: Groundwater governance in South Asia*. Washington, DC: Resources for the Future Press.
- Zektser, I. S., & Everett, L. G. (2004). *Groundwater resources of the world and their use*. Paris: United Nations Educational, Scientific and Cultural Organization.



GROWTH MACHINE

Growth machine politics suggests that it is the local business elites who are the primary actors in sustaining an image of a city or a region based on a transformational growth ethic. These elites, along with politicians, local media, and utilities, mobilize both to pursue individual economic goals and advocate a viewpoint that growth (at any cost) benefits everyone in the community. This growth ethic seeps into all aspects of community life, including the political system, the agenda for economic development, and the social relations that contribute to local culture. Any issue that deviates from this growth ethic is automatically seen as a potential threat to rents and capital mobility or its exchange value. The rhetoric of these growth machine elites, therefore, tends to revolve around treatment of communities as instruments of profit. This is a doctrine of value-free development, a libertarian-style ethic that sees free markets as the only way to determine the best and highest values for land as well as provide for the economic growth that brings jobs and expands the tax base.

This growth ethic is embedded in long-standing notions of American exceptionalism, where private ownership of property is preferred over transfers of land that benefit the overall public good. Hence, tremendous authority is given to private real estate developers, as well as significant

political autonomy at the local level. A growth machine ideology sees the role of local government as limited to only those actions that contribute directly to the economic development of a locality (zoning regulations, property tax issues, etc.). Growth machine elites are also fixed on the notion that urban planning represents a “rational science” to be used for providing order to urban systems while at the same time growing the infrastructure. Consequently, the urban planning process itself has traditionally been at the service of the growth machine apparatus, seen purely as a neutral force in directing home rule. But this planning power, while offering localities a sense of political autonomy, also represents a Trojan horse of sorts. Only the most affluent towns are able to create wealth and privilege from such an arrangement while perpetuating inequalities of wealth among places. Urban planning in this sense is a durable feature of growth machine politics in that it manipulates public resources to serve the economic exchange interests of local elites, often at the expense of the taxpayer. Growth machine politics, therefore, favor economic exchange values over other concerns, such as environmental, cultural, or social issues that are important to the livability of communities. These issues are taken up by local governments only when they can be justified as part of the growth strategy.

Conflicts arise, however, when other stakeholders in a community place a different value on land. For example, environmentalists, heritage preservation activists, or poverty activists see land from a different perspective. For the environmentalist, land is to be ecologically protected, for the heritage activists, it could have historical significance, and for the poverty activist, the way land is developed has implications for accomplishing a larger public good, such as affordable housing availability. All these actors can emerge to challenge the growth machine’s use value of lands in their jurisdiction. As such, understanding the politics of place is fundamentally linked to this conflict between the exchange and use values of land.

Thomas Chapman

See also **Governance; Place Promotion; Urban and Regional Development; Urban Geography; Urban Planning and Geography; Urban Policy**



Further Readings

- Ferman, B. (2007). *Challenging the growth machine: Neighborhood politics in Chicago and Pittsburgh*. Lawrence: University Press of Kansas.
- Logan, J., & Molotch, H. (1987). *Urban fortunes: The political economy of place*. Berkeley: University of California Press.
- Molotch, H. (1976). The city as a growth machine: Toward a political economy of place. *American Journal of Sociology*, 82(2), 309–330.



GROWTH POLES

Growth poles are geographically pinpointed centers of economic intra- and intersectional linkages that generate positive externalities and spillovers, thereby leading to economic growth. Growth poles can exhibit two opposed forces. If top talent, capital, and knowledge are attracted by the growth poles, regional disparities will increase. If a growth pole's mobile production factors trickle down to weaker regions, it may lead to regional equilibrium. In aiming to achieve the latter, growth poles have been applied as a regional development concept.

François Perroux considered the combination of different sectors as functional nonbounded economic spaces that result in interindustrial multiplier effects, bringing about innovation and culminating in nonspatial polarization of the economy. In the middle of the 20th century, scientists such as Albert Hirschman and Gunnar Myrdal described the unequal distribution of growth poles in physical space and went on to establish an explanatory model for unequal regional development. The model considers cumulative growth processes in centers where production factors yield higher returns. Subsequently, peripheral regions will lose the mobile production factors, resulting in a downward spiral. However, after a while, the disadvantages of growth poles (e.g., pollution, high property and labor costs) may dominate the advantages, and the growth effects will spread into the hinterland. The likelihood of such a pattern depends on factors such as traffic infrastructure, level of education,

sectoral structures, and cultural or social integration between a growth pole and its periphery.

Growth pole protagonists assume a growth trickle down in hierarchical processes from the metropolitan city to the suburbs and from the suburbs to the periphery. Based on this assumption, many industrial and Third World countries tried to use these effects. Since the 1970s, the main mechanisms were to subsidize production plants and concentrate public infrastructure at specific poles within poorer regions or countries. Difficulties occurred through making the idea operationally tractable and combinable with other regional planning concepts such as the central place theory. For instance, what sectors and infrastructures should be promoted at which location? What is the right size of growth poles, and how decentralized should they be when they are distributed across space?

The diffusion of growth effects into the periphery remains a controversial subject in discussions. To date, no decisive empirical evidence of trickle-down effects has been achieved. However, many regional development and adjustment policies are still based partially on the growth pole idea. The currently favored cluster concept, invented by Michael Porter, focuses on the concentration of interconnected businesses and corresponding institutions in physical space. In contrast to the growth-pole concept, the cluster concept puts the emphasis on existent endogenous regional value chains instead of the exogenous creation of growth poles.

Stefan Gaertner

See also **Diffusion; Externalities; Learning Regions; Regional Economic Development; Regional Science; Technological Change, Geography of; Uneven Development; Urban and Regional Development**

Further Readings

- Hirschman, A. (1958). *The strategy of economic development*. New Haven, CT: Yale University Press.
- Myrdal, G. (1957). *Economic theory and underdeveloped regions*. London: Duckworth.
- Perroux, F. (1950). Economic space: Theory and application. *Quarterly Journal of Economics*, 64, 89–104.



Porter, M. (1999). *The competitive advantage of nations*. New York: Free Press.

Thomas, M. (1975). Growth pole theory, technological change, and regional economic growth. *Papers in Regional Science*, 34(1), 3–25.



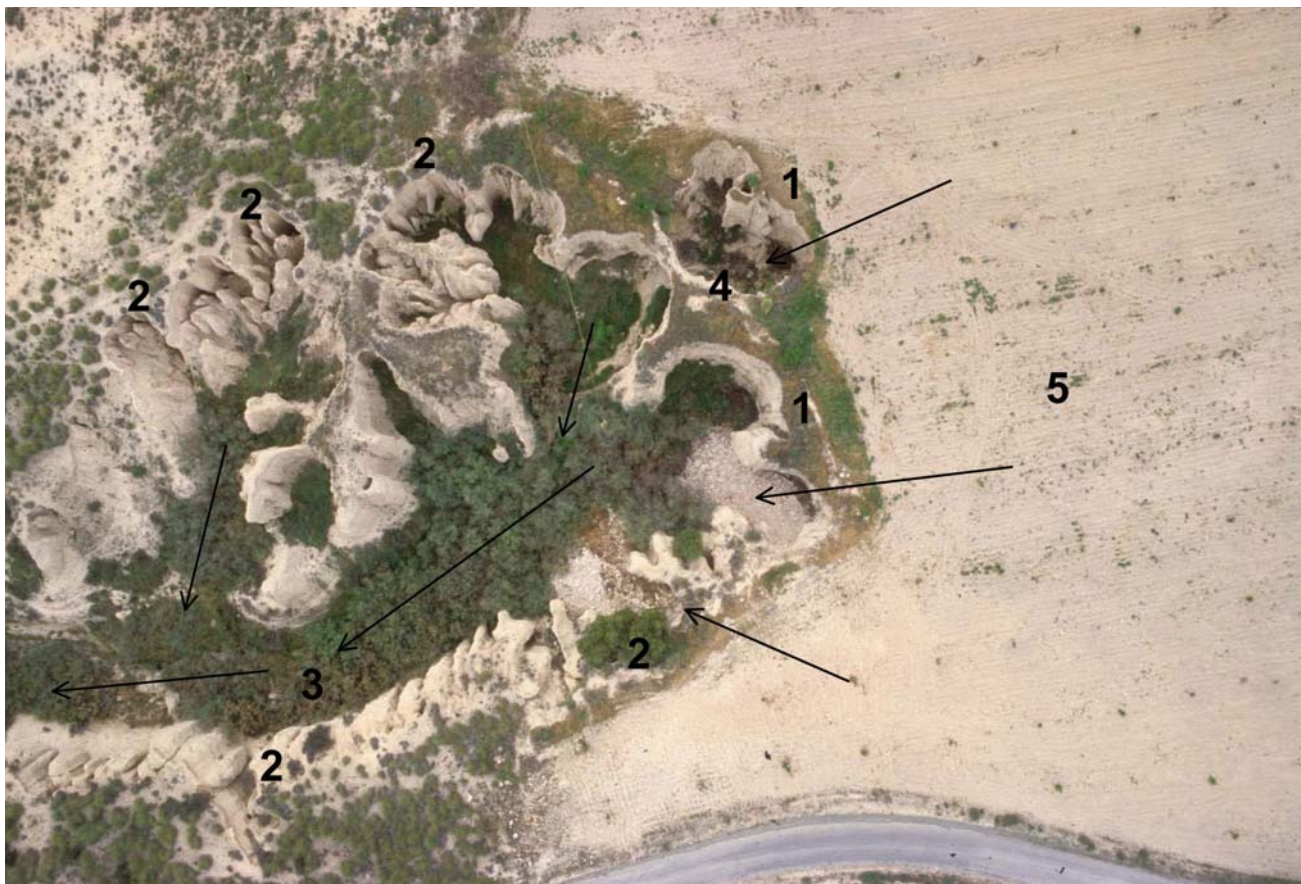
GULLY EROSION

Gully erosion is a phenomenon that can be observed worldwide and is often related to actual or former agricultural land use. *Gullies* are a form of linear (soil) erosion that emerge due to

the erosive power of concentrated overland flow. Soil and unconsolidated rock are removed up to depths of from 0.5 to several meters, and in the worst case, badlands develop.

The process of gully erosion occurs mainly in landscapes with (climate- and/or human-induced) discontinuous vegetation cover and more or less periodic heavy rainfall events when gullies can develop excessive short-time drainage. These precipitous watercourses are also a sign of severe land degradation and are mainly triggered by land use change, inappropriate cultivation and irrigation systems, overgrazing, urbanization, deforestation, and global change.

Gully erosion can be distinguished into ephemeral and permanent gully erosion. The former can be easily erased with ordinary farming equipment,



Gully erosion in southeast Spain derived from aerial photography: (1) very active main headcut(s), (2) side headcuts, (3) densely vegetated main drainage line(s), (4) headcut retreat by piping, and (5) very sparsely vegetated almond grove.

Source: Dr. Irene Marzolf, University of Frankfurt, Germany.

Note: Arrows = flow direction.



but the latter means an irrecoverable loss of land resources.

The process of gully erosion depends on numerous variables—for example, catchment size, vegetation density, land use, substrate characteristics, and slope inclination and length. Furthermore, the velocity and extent of gully erosion depends on the amount of overland flow reaching the top end of the gully (often by convergence of rills), the so-called headcut, which is regressively moving upslope. Thus, gully erosion is conditioned by the properties of the catchment of the gully.

The main processes responsible for headcut retreat are, as mentioned above, headward erosion by overland flow, piping, and undercutting of the headwall by plunge pool development (see images).

The consequences of gully erosion are commonly divided into “on-site” and “off-site” damages. On-site gully erosion destroys and dissects valuable farmland and paths. Off-site, it fills reservoirs or small channels and causes flooding and loss of water quality at the lower reaches. Both damages cause severe socioeconomic problems as loss of arable land or loss of reservoir capacity, which is especially problematic in semiarid to arid regions. Especially in loess areas (Belgium, China, Germany) and regions with a temporary or permanent water deficit (Mediterranean), gully erosion is widely observed and explicitly described. In Belgium and Germany, for example, relicts of former gullying can be found under forests and are believed to be a consequence of former land use changes that can be connected to social problems such as devastating diseases or to climatic change affecting the maintenance of agricultural land and the vegetation cover.

Several techniques have been applied to determine the velocity of gully erosion, such as measuring with benchmark pins, aerial photography (at different spatial scales), GPS (global



Gully erosion in southeast Spain: (1) active gully headcut; (2) undercutting of the headwall; (3) plunge pool directly below the headcut; (4) steep gully sidewall; (5) agricultural road favoring runoff production and concentration; (6) sparsely vegetated catchment.

Source: Dr. Irene Marzolf, University of Frankfurt, Germany.

Note: Arrows = flow direction.

positioning systems), or dendrochronology. For prevention and control of gully erosion, the variables controlling gully erosion have to be taken into account. Possible controls include restoration of vegetation, changes in land management practices, and technical solutions such as check dams.

Christian Geißler

See also [Agricultural Land Use](#); [Basin and Range Topography](#); [Geomorphology](#); [Land Degradation](#); [Land Use](#); [Rill Erosion](#); [Soil Erosion](#)



Further Readings

- Poesen, J., Nachtergaele, J., Verstraeten, G., & Valentin, C. (2003). Gully erosion and environmental change: Importance and research needs. *Catena*, 50, 91–133.
- Poesen, J., Vanwalleghe, T., de Vente, J., Knapen, A., Verstraeten, G., & Martínez-Casasnovas, J. A. (2006). Gully erosion in Europe. In J. Boardman & J. Poesen (Eds.), *Soil erosion in Europe* (pp. 515–536). Chichester, UK: Wiley.
- Valentin, C., Poesen, J., & Li, Y. (2005). Gully erosion: Impacts, factors and control. *Catena*, 63, 132–153.



GUYOT, ARNOLD (1807–1884)

Arnold Guyot, an important 19th-century Swiss and American geographer, is best known for his pathbreaking work in physical geography. He was also a disciple of Carl Ritter, and he introduced and advanced Ritter's vision of geography to the United States. Specifically, he advocated investigating and understanding the causes and consequences of the processes creating Earth's physical and human geography (rather than merely describing them) in terms of Ritter's teleological understanding of these processes.

Born in Switzerland, Guyot earned his doctorate in physical geography in 1835 at the University of Berlin under Ritter's direction. Following the completion of his dissertation, and inspired by his friend Louis Agassiz, Guyot undertook groundbreaking research on alpine glaciation. Guyot taught in Switzerland until 1848, when, due to political instability, he left Europe for the United States. From 1851 to 1855, he served as a lecturer on geography education for the Massachusetts Board of Education. In 1854, Guyot was appointed a professor of geology and physical geography at Princeton University, where he remained until his death, conducting important research in meteorology.

Guyot's influences on American geography began with a series of lectures he gave in Boston shortly after he came to the United States in 1849. The lectures were collected and published as his most famous book, *The Earth and Man: Lectures on Comparative Physical Geography in Its Relation to the History of Mankind*. In this book, Guyot helped introduce Ritter's ideas to an American audience. Rather than presenting geography as a series of facts to be memorized, Guyot argued for studying geography through a comparative framework. In this view, geography should be seen as an interpretive discipline rather than a dry recitation of information.

Guyot's influence on American geography was twofold: first, in helping to overhaul and reform geography education in the United States through teacher training and a series of influential geography textbooks, and second, in introducing and advancing a teleological understanding of Earth and its inhabitants. In this latter influence, Guyot, an evangelical Presbyterian who had studied for the ministry before becoming a geographer, was furthering the ideas of Ritter, arguing that a study of Earth's physical and human geography revealed evidence of a divine plan.

Guyot's teleological views later came under challenge with the rise of Darwinian perspectives. He extended his belief in the all-encompassing role of God in shaping Earth to suggest relationships between climate and human development, a divinely inspired environmental determinism, which, while unremarkable to some during his era, would be later criticized as racist.

Jonathan Leib

See also **Physical Geography, History of; Ritter, Carl**

Further Readings

- Koelsch, W. (2008). Seedbed of reform: Arnold Guyot and school geography in Massachusetts, 1849–1855. *Journal of Geography*, 107, 35–42.
- Livingstone, D. (1992). *The geographical tradition: Episodes in the history of a contested enterprise*. Oxford, UK: Blackwell.

H

HADLEY CELL

The Hadley cell is an atmospheric circulation cell, named after the English scientist George Hadley. In a 1735 paper, Hadley described the global circulation as consisting of one thermally direct cell in each hemisphere. Hadley's conceptual model consisted of rising air at the equator and sinking air at the poles. Surface flow was from the poles toward the equator, while upper-level flow was from the equator toward the poles, completing the cell. Hadley's early contribution did not consider the rotation of Earth, which results in the Coriolis force, an apparent deflection of moving air to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. His description also did not consider seasonal variations due to the annual revolution of Earth around the sun. In the early 20th century, regular meteorological observations became more widespread, and a clearer picture of the global circulation emerged. In a contemporary context, the term *Hadley cell* is used to describe the circulation in the tropics and subtropics, which is thermally direct as Hadley had envisioned. When combined with seasonal variability and deflection of air due to Earth's rotation, the Hadley cell is a useful conceptual tool for understanding tropical circulation.

In the simplest sense, the Hadley cell is still the meridional overturning circulation described by Hadley in 1735 but constrained to the tropics so

that flow near the surface is equatorward and flow near the tropopause (at a height of approximately 15–17 kilometers in the tropics) is poleward. The poleward extent of the Hadley cell is governed by the position of the subtropical high-pressure belt, or, more appropriately, a broken belt of semipermanent high-pressure systems, which are located, on average, near 30° N and 30° S of the equator. Due to the Coriolis force described above, the near-surface air flowing equatorward from the subtropics is deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, resulting in the Northeast and Southeast trade winds, respectively. Similarly, the poleward transport aloft is deflected, and it combines with the converging midlatitude flow, resulting in the formation of a subtropical jet stream at the poleward edge of the Hadley cell. The Hadley cell in each hemisphere is completed by rising motion within the equatorial low-pressure belt that results from intense solar heating and convergence of Northern Hemisphere and Southern Hemisphere trade winds and sinking motion in the subtropics.

The zone of convergence near the thermal equator at the surface is known as the Intertropical Convergence Zone (ITCZ), or equatorial low. It is recognizable on satellite imagery as a bright band of clouds near the equator. The release of latent heat due to the condensation of water vapor within the ITCZ is a major source of energy for the rest of the Hadley cell circulation. Outside the

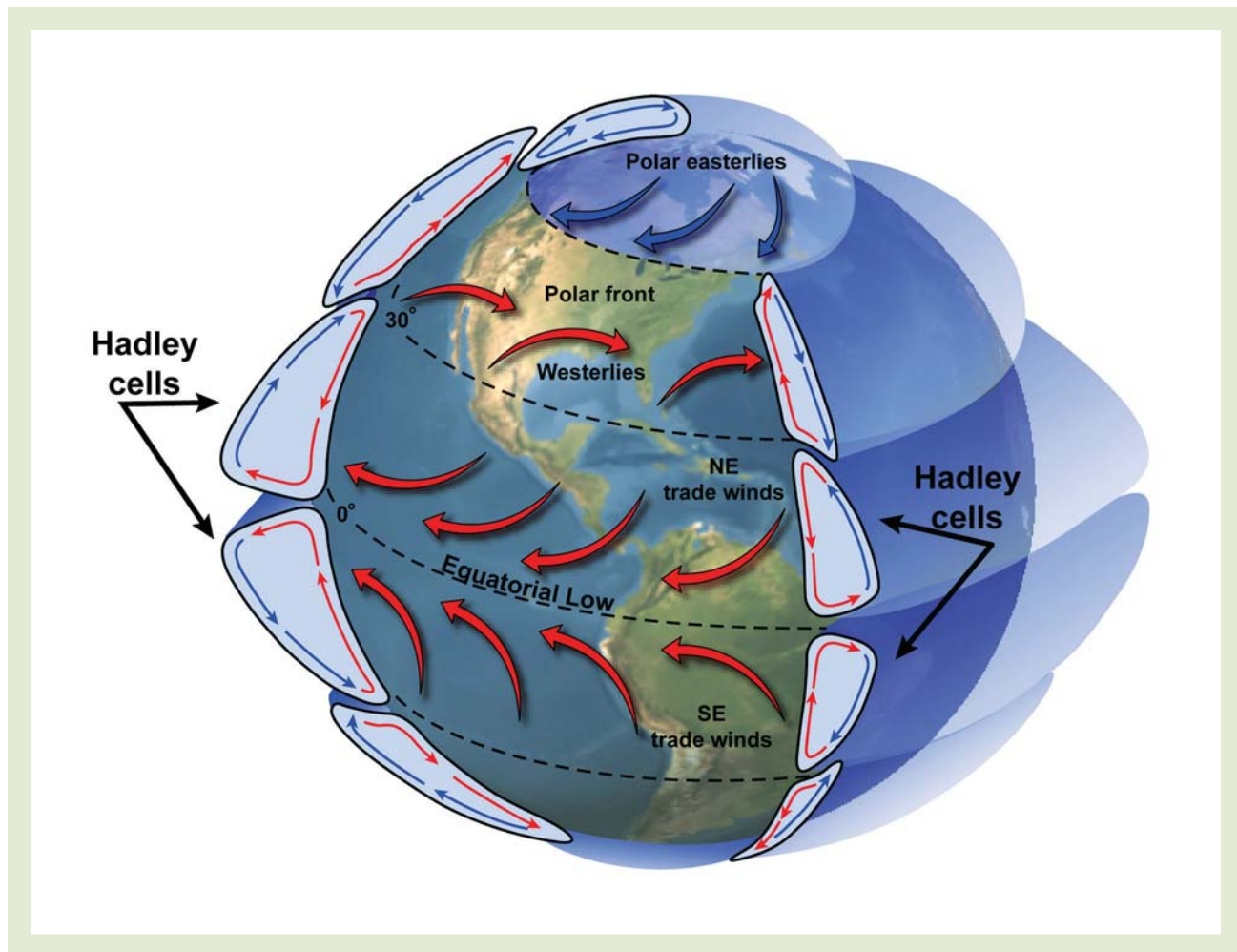


Figure 1 The Hadley cells are composed of rising air in the heart of the tropics and sinking air in the subtropics.

Source: NASA.

ITCZ, there is little cloud development with the Hadley cell. Instead, the region between the ITCZ and subtropical highs is characterized by warm, subsiding air. This phenomenon results in a temperature inversion, where cooler air near the surface lies below the warming, sinking air. This is known as the trade wind inversion since it occurs in the region above the surface trade winds. The result is that many areas of the tropics experience conditions where the atmosphere is very humid but precipitation amounts are low. This also means that precipitation receipt in the tropics and subtropics is largely determined by the position of the ITCZ. Indeed, seasonal movement of the

ITCZ in response to variations in solar energy received produces the strong seasonal variations in precipitation that are experienced within the tropics, and especially within the subtropics. For example, in July the ITCZ's greatest poleward position is over Northern India, where its interaction with the Himalayas plays an integral role in the summer monsoon rains. Such variations in the poleward position of the ITCZ also vary longitudinally due to surface (land/water) variations. Generally, the ITCZ will extend farthest poleward over land in the summer hemisphere. Some of the rain-producing clouds within the ITCZ exhibit strong organization and have the ability



to intensify. These clouds are generally oriented in North-South bands that migrate from east to west, known as easterly waves, and are often precursors to tropical cyclones in the Atlantic Ocean.

The sinking motion on the poleward edge of the Hadley cell is manifest as several semipermanent (i.e., varying in position and intensity but always present) high-pressure systems, including the Bermuda High and the Pacific High. The mean position of the subtropical high-pressure belts is also consistent with the location of subtropical deserts. The sinking motion at the poleward edge of the Hadley cell inhibits the development of clouds and precipitation, keeping these regions dry.

Within the context of the global atmospheric circulation, the Hadley cell is critical for energy transfer from the tropics, where vast amounts of energy are received throughout the year, to the middle and upper latitudes, where the amount of energy received is more variable. Outside the tropics, further transport is governed primarily by transient weather systems, such as midlatitude cyclones and anticyclones. The Hadley cell circulation also influences weather and climate in other parts of the world. For example, the Bermuda High is often an important steering mechanism for Atlantic tropical cyclones entering the extratropics.

Due to the far-reaching influence of the Hadley cell circulation, there has recently been great interest in understanding both historical and possible future changes in the Hadley cell. There has been some observed evidence of a strengthening Hadley cell during winter since 1950, which has been partly attributed to both ocean warming and changes in the frequency and magnitude of El Niño events. Recent studies conducted with both observations and coupled climate models indicate a potential widening of the Hadley cell, resulting in a poleward shift in the subtropical high. Such changes should be closely monitored since variations in the location and intensity of drought are likely to result.

Justin T. Schoof

See also **Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure;**

Atmospheric Variations in Energy; Climate: Tropical Humid; Climate Change; Coriolis Force; Teleconnections

Further Readings

Chen, J., Carlson B., & Del Genio, A. (2002).

Evidence for strengthening of the tropical general circulation in the 1990s. *Science*, 295, 838–841.

Seidel, D., Qiang, F., Randel, W., & Reichler T.

(2008). Widening of the tropical belt in a changing climate. *Nature Geoscience*, 1, 21–24.

HÄGERSTRAND, TORSTEN (1916–2004)

Torsten Hägerstrand was a Swedish geographer who made enormous contributions to human geography. The work that initially established his international reputation and his place as one of the most renowned human geographers of the 20th century concerned the study of population movements over time, the diffusion of innovations, and the behavior of individuals in space and time. Innovation indeed well describes his role in geography, in perhaps four ways: first, the introduction (at least to geography) of the idea of spatial and space-time processes, that geographic development over time could be understood and modeled; second, the particular process of spatial diffusion; third, the technique of Monte Carlo simulation; and fourth, the idea that individual behavior, not just that of large groups, could be modeled temporally and spatially. All were revolutionary. And underlying all these was the conviction that geography could offer integrated perspectives, transcending the boundaries of the humanities and sciences. His early work already insisted on the necessity of construction of theory and the responsibility of testing and evaluating empirical evidence.

Hägerstrand was born in Moheda, Sweden, and was perhaps destined to become a geographer: Even as a child, he explored and mapped his surroundings! He moved to Lund in 1937, where he studied, taught, conducted research on



migration, and completed his licentiate in 1947. In this period, he was profoundly influenced by Edgar Kant (a refugee from the University of Tartu in Estonia) in the role of theory and method in scientific geography. His PhD dissertation was completed in 1953 but was not translated into English until 1966, by Alan Pred as *Innovation Diffusion as a Spatial Process*. This work was unabashedly theoretical and quantitative, when geography in the United States and in the United Kingdom was almost universally idiographic. In 1957, his extended article (based on the licentiate research) "Migration and Area" was published in English, also a pioneering and brilliant contribution to the analysis of migration. But it was not until 1959, at the urging of Bill Garrison, that the University of Washington invited Hägerstrand as a visiting professor. The students, budding exponents of a theoretical and quantitative geography, were excited and inspired by the novelty and brilliance of his ideas, which led to a rapid and enthusiastic dissemination of innovation diffusion theory and methods. The process was furthered by the success of the Lund Symposium in Urban Geography in 1960 and by Hägerstrand's participation in the National Science Foundation Quantitative Methods workshop at Northwestern University in 1961.

Although Hägerstrand's approach was theoretical, quantitative, and devoted to formal modeling, it differed from the dominant early work derived from spatial economics in four basic, indeed revolutionary ways: (1) his goal was to understand spatial processes unfolding over time; (2) the unit of study was the individual or household, not population per se; (3) the processes studied were more social and cultural than economic; and (4) and this required probabilistic rather than deterministic mathematics. The spatial diffusion framework has had enormous subsequent influence within geography and beyond (communications, history, epidemiology, anthropology, even economics). Within geography, perhaps the most influenced was Allan Pred, who translated Hägerstrand's dissertation and did work on urban diffusion and later time-geography. The evaluation of spatial diffusion also required advances in spatial statistics.

Although Hägerstrand was a prominent regional scientist, and indeed president of the

European section of the Regional Science Association in 1968–1969, he critiqued much of regional science work as too mechanistic and uninformed by actual human individual and social experience, as exemplified in his famous article "What About People in Regional Science?" published in 1970. Indeed from this date on, his extended collaboration with Anne Buttner led to the devotion of much time and effort in teaching and writing to the integration and compatibility of the theoretical and quantitative with the social and humanistic.

A major second advance in theory and methodology came in the 1970s with Hägerstrand's work in time-geography, which again influenced many researchers within and outside geography and was viewed by Hägerstrand as his major contribution. Time-geography maps, three dimensionally, the trajectories (of sets) of individuals, considering the opportunities, constraints, and conditions required for meeting. Important subsequent work includes that of Allan Pred and Nigel Thrift. Time-space conceptions are valuable from both theoretical and practical viewpoints, for example, with respect to urban traffic, accessibility, and social networks. In later years, these original interests expanded to reflections on technology and society and a broader concern with urban and regional planning and sustainability.

Hägerstrand was honored by a set of essays dedicated to him in 1981 and by a posthumous appreciation in *Progress in Human Geography*. In the course of his long and fertile career, he received numerous awards, including honorary doctoral degrees from the Universities of Glasgow (1971), Edinburgh (1974), and Bristol (1985); Ohio State University (1985); and the Norwegian School of Economics (1986). He was awarded the Charles P. Daly Medal of the American Geographical Society (1966), the Outstanding Achievement Award of the Association of American Geographers (1968), the Vitus Bering Medal of the Danish Geographical Association (1970), the Anders Retzius Medal of the Swedish Society for Anthropology and Geography (1973), the Victoria Medal of the Royal Geographical Society (1979), and *Lauréat d'Honneur* of the International Geographical Union (1984). He was a member of the Royal Swedish Academy of Sciences; the Royal Academy of History, Letters and Antiquities; and the Royal



Academy of Engineering Sciences. He was an honorary member of the Norwegian Academy, the American Academy of Arts and Sciences, and the Finnish Academy of Science and Corresponding Fellow of the British Academy.

Spatial diffusion, or more broadly space-time processes of landscape evolution, has become part of the conceptual structure of the discipline of geography, with applications across the entire spectrum of geography. Studies of urban development at all scales or of industrial development incorporate the basic ideas of spatial spread or contagion. Statistics for testing and geographic information system technologies for presentation and analysis are widely available. Monte Carlo simulation, a separate thread, remains in wide use across the social sciences. Similarly, time-geographic applications have been widely used and developed from the scale of the daily path to that of the life course.

Spatial diffusion and time-geographic studies, like probably all modeling approaches in geography, have been roundly critiqued as reductionist or for their misuse as a marketing tool. But it is impossible for the honest observer to deny that these processes are the very stuff of landscape change. The revolutionary ideas and methods that Hägerstrand unleashed are not the only ways to analyze such change, and they can be done well or poorly, but they remain a powerful way. The key concept, as Hägerstrand said in 1959, is that the test of geographic understanding lies in the ability of theory and method to reproduce the historical human geography of the landscape, including individual variability. In the words of Alan Pred, Hägerstrand was a man of stupendous originality and unconventional creativity.

Richard Morrill

See also Buttimer, Anne; Diffusion; Pred, Allan; Thrift, Nigel; Time-Geography

Further Readings

Buttimer, A. (2007). Torsten Hägerstrand (1916–2004). *Geographers: Bio-bibliographical Studies*, 26, 119–157.

Hägerstrand, T. (1967). *Innovation diffusion as a spatial process*. Chicago: University of Chicago Press.

Hägerstrand, T. (1970). What about people in regional science? *Regional Science Association Papers*, 24, 7–21.

Pred, A. (1977). The choreography of existence. Comments on Hagerstrand's time-geography and its usefulness. *Economic Geography*, 53, 207–221.

Pred, A. (Ed.). (1981). *Space and time in geography: Essays dedicated to Torsten Hägerstrand*. Lund, Sweden: Gleerup.

Thrift, N. (2005). Torsten Hägerstrand and social theory. *Progress in Human Geography*, 29(3), 337–340.



HAGGETT, PETER (1933–)

Peter Haggett is one of the world's preeminent geographers and professor (now emeritus) of urban and regional geography in the School of Geographic Sciences at the University of Bristol. His fame rests on major contributions in three scientific areas: (1) the nature of geography as a discipline, (2) quantitative methods and location analysis in geography, and (3) the geography of infectious diseases, in particular the analysis of epidemics.

He was born in rural Somerset and took his undergraduate studies at St. Catherine's College, Cambridge, graduating "double first" in 1954. He first taught at University College, London, in 1957, returned to Cambridge from 1957 to 1966, and then went to the University of Bristol, where he taught until his retirement in 1995. He was a visiting professor in many countries, but especially in the United States, Canada, and Australia. He has received many awards and honors, including the ones from the Royal Geographical Society and the American Geographical Society, the Anders Retzius medal (Sweden), Vautrid Lud prize (France), and the *Laureat d'Honneur* of the International Geographical Union. He has received six honorary degrees and also served as the vice chancellor of his university and as the vice president of the British Academy.



Haggett is the author or editor of more than 30 books, emphasizing geographic practice theory and methods in the earlier part of his career and the study of epidemics and the distribution and spatial relations of infectious diseases in the latter half. Along with Richard Chorley, he was a British pioneer of the “quantitative revolution,” and his famous and revolutionary book, *Locational Analysis in Human Geography*, was published in 1965, preceding the earliest American texts. This volume was followed by additional books on models and spatial theory: *Network Analysis in Geography* in 1969, *Elements of Spatial Structure* in 1975, *Locational Analysis* in 1977, and *Locational Methods* in 1977.

In the broader area of geography as a scientific discipline are more influential books, most especially *Geography: A Modern Synthesis* (1972), with three subsequent editions and six translations; *Models in Geography* (1967), with Richard Chorley; *The Geographer's Art* (1990); and *Geography: A Global Synthesis* (2001). With his Cambridge colleagues, he established two pre-eminent journals, *Progress in Physical Geography* and *Progress in Human Geography*.

Haggett generated sustained research since 1977 to understand the geography of infectious diseases, producing monographs on the geography of disease and on the spatial understanding of epidemics. Major works include *Spatial Aspects of Influenza Epidemics* (1986), *Atlas of Disease Distributions* (1988), *World Atlas of Epidemic Diseases* (2004), and *Geographic Structure of Epidemics* (2000).

Richard Morrill

See also **Diffusion; Medical Geography; Quantitative Revolution**

Further Readings

- Haggett, P. (1965). *Locational analysis in human geography*. New York: St. Martin's Press.
 Haggett, P. (1972). *Geography: A modern synthesis*. New York: Harper & Row.
 Haggett, P. (1990). *The geographer's art*. Oxford, UK: Blackwell.

- Haggett, P. (2000). *Geographical structure of epidemics*. Oxford, UK: Oxford University Press.
 Haggett, P. (2001). *Geography: A global synthesis*. Englewood Cliffs, NJ: Prentice Hall.
 Haggett, P., & Chorley, R. (1967). *Models in geography*. Oxford, UK: Oxford University Press.
 Haggett, P., & Chorley, R. (1969). *Network analysis in geography*. London: Edward Arnold.
 Haggett, P., Cliff, A., & Ord, K. (1986). *Spatial aspects of influenza epidemics*. London: Pion.



HANSON, SUSAN (1943–)

Susan Hanson is one of the most accomplished academics in U.S. geography today. During her long and productive career, she became a major researcher of urban labor markets and urban transportation and a founder of American feminist geography. Her accomplishments are also widely recognized. A past Guggenheim Fellow, she is a member of the National Academy of Sciences and the American Academy of Arts and Sciences. Hanson is the first female geographer elected to both academies in 2000.

Hanson's half-century-long career in geography began once she discovered the field as an undergraduate student in Middlebury College (1960–1964), thanks to an outstanding geography professor. After spending several years in Kenya as a Peace Corps volunteer, she earned a PhD in geography from Northwestern University (1967–1973). After earning tenure at the University at Buffalo, where her position was split between the departments of geography and sociology (1972–1980), she moved to Clark University (1981), where she spent the rest of her career. There she currently holds the title of research professor. She chaired Clark's School of Geography for long periods and held prominent national leadership positions, including that of president of the Association of American Geographers.

Susan Hanson has been exceptionally productive. To date, she has authored and edited 7 books, contributed more than 70 articles and commentaries to peer-reviewed journals, and written more than 30 book chapters and more



than a dozen other publications. This prolific work has focused on gender and work, travel activity patterns, feminist approaches to scholarship, and the importance of gender as a category of analysis. It has had a profound impact and has shaped today's geography in fundamental ways.

Hanson's edited volume on the geography of urban transportation is now a classic text in its third edition. Her numerous articles on gendered local labor markets as well as the related book *Gender, Work, and Space* (1995), coauthored with Geraldine Pratt, are central texts in feminist geography. Contrary to traditional geographic approaches to work that assumed the agency of an "economic man" and were gender blind, Hanson's research showed that people make decisions about work not in isolation from but in direct relation to their domestic responsibilities. Since women shoulder most domestic responsibilities, local labor markets also become segmented along gender lines, and women have shorter commuting times and lower-paid jobs.

Hanson's scholarship pioneered not only new research directions but also the ways geographers go about doing their research. Trained as a quantitative geographer, Hanson infused the prevailing quantitative geographic methodologies with feminist sensibility. On many occasions, she called for considering difference that not only includes gender but also extends to class, race, and sexuality. Her research began combining the traditional disciplinary focus on empirical work with the pathbreaking feminist theory of the time. Hanson also opened the door to mixed-methods research by using quantitative and qualitative methods together. And she advocated for bringing feminist reflexivity in all kinds of academic practice, including research, teaching, mentoring, and service.

Yet at the core of her university work is a commitment to her students, whom she views as both a major responsibility and a source of inspiration. Throughout the years, Hanson has advised dozens of undergraduate students and more than 20 PhD students and has served as a mentor to many more.

Despite a successful career, Hanson describes herself as an "accidental academic," a concept in line with feminist rethinking of women's working lives as nonlinear and often improvisational.

This is evident in the context of a career that spans and contributes to the profound shift in academic geography from a male-dominated field to the more diverse discipline today. Hanson's career and life will continue to inspire female college students and those who choose a career in academia.

Marianna Pavlovskaya

See also *Commuting; Feminist Geographies; Feminist Methodologies; Gender and Geography; Transportation Geography*

Further Readings

- Hanson, S. (1992). Geography and feminism: Worlds in collision? *Annals of the Association of American Geographers*, 82, 569–586.
- Hanson, S. (Ed.). (1997). *Ten geographic ideas that changed the world*. New Brunswick, NJ: Rutgers University Press.
- Hanson, S. (1999). Isms and schisms: Healing the rift between the nature-society and the space-society traditions in human geography. *Annals of the Association of American Geographers*, 89(1), 133–143.
- Hanson, S., & Pratt, G. (1991). Job search and the occupational segregation of women. *Annals of the Association of American Geographers*, 81, 229–253.
- Hanson, S., & Pratt, G. (1995). *Gender, work, and space*. New York: Routledge.



HARLEY, BRIAN (1932–1991)

James Brian (J. B.) Harley was a historical geographer and a key figure in the contemporary field of the history of cartography. He helped lay down some of its main theoretical foundations and ideas on how to look at maps and helped structure and expand the discipline as well. Central to his contribution was his conception of the map as a social and not simply a technical construct. As exemplified by his *Maps and the Columbian Encounter*, published in 1990, using notions from



postmodern literary criticism and from the history of art, he especially scrutinized maps for their “hidden agendas” and “silences” and other biases that directly reflect the values of their creators and the times of their creation. He fervently advocated the study of maps within their social and cultural contexts.

Harley was born on July 24, 1932, in Bristol, England. He attended Brewood Grammar School in Staffordshire, and after graduation, he served for 2 years in the British Army in Cyprus, Egypt, and Trieste. Thereafter, he majored in geography and minored in history at the University of Birmingham, receiving his PhD in 1958. In the same year, Harley was appointed to an assistant lectureship in geography at Liverpool University in 1958 and a lectureship at the University of Exeter in 1970, where he became the Montefiore Reader in Geography in 1972. In 1976, he became a professor of geography at the University of Wisconsin, Milwaukee, and director of the Office of Map History at the university's Golda Meir Library, which contains the map collection of the American Geographical Society. For his scholarship, Harley was awarded a Doctor of Letters from Birmingham in 1985 and the silver medal of the British Cartographic Society in 1991. He died of a heart attack on December 20, 1991.

While in Liverpool, Harley turned to the history of cartography. He was influenced early on by Harry Thorpe and R. A. Skelton. His first work in the field was *Christopher Greenwood, County Map-Maker*, published in 1962. It was followed by the valuable *Historian's Guide to Ordnance Survey Maps* in 1964 with C. W. Phillips. In addition to continuing work on the Ordnance Survey, Harley published *Mapping the American Revolutionary War* in 1978 with Barbara Petchenik and numerous articles in *Imago Mundi*, *Cartographica*, and the *Geographical Journal*, among others. In 1977, with David Woodward from the University of Wisconsin, Madison, Harley conceived and collaborated on the monumental six-volume *History of Cartography*, the first three volumes of which were published in five large books in 1987, 1992, and 2007. It is not only becoming the foundational reference work, but it is also profoundly influencing the entire field.

Dennis Reinhardt

See also **Cartography; Cartography, History of; Critical Human Geography; Historical Geography**

Further Readings

- Edney, M. (2005). Brian Harley's career and intellectual legacy. *Cartographica*, 40, 1–17.
- Harley, J. (1990). *Maps and the Columbian encounter*. Chicago: Newberry Library.
- Harley, J. (2001). *The new nature of maps: Essays in the history of cartography*. Baltimore: Johns Hopkins University Press.
- Harley, J., & Woodward, D. (Eds.). (1987). *The history of cartography*. Chicago: University of Chicago Press.



HARTSHORNE, RICHARD (1899–1992)

Richard Hartshorne was an influential early- and mid-20th-century American geographer, best known for his aggressive promotion of chorology as the optimal way of examining landscapes and spatial distributions.

Born and raised in Pennsylvania, he became a math major at Princeton University, completing his degree in 1920 after serving in World War I. Hartshorne then earned a PhD from the University of Chicago in 1924, taking courses from Ellen Semple, J. Paul Goode, and social ecologists such as Harlan Barrows. He was greatly influenced by Alfred Hettner, who led him into neo-Kantian ideas and views of space and, to a lesser extent, environmental determinism. At the University of Minnesota (where he taught from 1924 to 1940) and the University of Wisconsin (where he taught from 1940 to 1970), Hartshorne published early works on the agricultural, urban, and economic landscapes of the Midwest and worked on the political geography of Eastern Europe in the 1930s. He served as president of the Association of American Geographers in 1949.

Greatly influenced by Immanuel Kant and Alfred Hettner, he strongly advocated for chorology as the heart of the discipline. Essentially, his



view was that geography, like history, is a synthetic, not analytic, discipline that seeks to find relations among variables through their proximity in space. Regions thus played a role in Hartshorne's conception analogous to that of periods in the historian's schema. This idea was most fully developed in his famous book, *The Nature of Geography*, published in 1939, a landmark book in the discipline's 20th-century history. Hartshorne's view centered on what he called "areal differentiation," which he saw as unique to the discipline and the basis of its identity within the academic division of labor. Regional geography, therefore, was the heart and soul of the discipline. By combining vast numbers of human and physical elements in unique ways, regions simultaneously overcame the ancient schism between human and physical geography (much like the studies of the land—*pays*—by Paul Vidal de la Blache) and created unique identities that could not be easily understood in a lawlike, scientific manner.

Hartshorne fully acknowledged the complexity of the world and maintained that regions, which are relatively homogeneous units by definition, could be more easily understood individually and, when accreted into larger groups, provided a glimpse into the world's geographies. He raised the important question as to what constitutes a region and what its significance is. Following Kant, he held that regions are not "natural" entities but purely mental constructs, that is, real in their ontological significance only as categories that humans impose on the world to simplify it. Like models, regions are tools that allow people to gain an understanding in the world only by sacrificing some detail. Hartshorne's view has often been oversimplified as crude spatial determinism, in which location is a substitute for explanation and proximity is equated with causality. Indeed, in many preindustrial societies with high degrees of friction of distance and distance decay, this view maintains a certain plausibility.

More radically, Hartshorne maintained that geography should satisfy itself with regions and held that there was little need to pursue explanatory laws, which he wrote off as "science," not geography. "Science," in this reading, was concerned with generalization, while geography, as a

synthetic discipline, was concerned with the unique. Additionally, because landscapes are relatively stable from the perspective of individual life spans (at least, the preindustrial landscapes on which he focused were), he held that there was little need to study their change over time: Geography should be the examination of frozen patterns and should be content with forms and appearances without venturing into the analysis of causal processes. This view reflected Hartshorne's deeply held empiricism: Only by sticking to the data—to the "facts" as given entities—could geographers come to know the real world. Similarly, he had a healthy respect for cartography.

Hartshorne's worldview, like empiricist chorology in general, collapsed in the 1950s as the discipline began its shift into logical positivism. In particular, a famous, stinging rebuke by Fred Schaefer in 1953 criticized his "exceptionalism," the notion that history and geography were only concerned with the unique. Schaefer held that all sciences were concerned with uniqueness to one extent or another. Moreover, simply classifying data on the basis of regions ignored the vital role of processes, a stance that confined geography to an "immature" status. Rather, geographers should seek out explanatory, nomothetic laws. The division between advocates of the idiographic and the nomothetic, between empiricists and those who took theory seriously, became full blown.

Hartshorne never fully recovered from what he perceived to be both a professional and personal attack that he felt oversimplified, distorted, and selectively interpreted his views. In an attempt at a rebuttal, he wrote *Perspectives on the Nature of Geography* in 1959. However, he did back off from his original claim that regions were the penultimate geographic product and claimed that he was never opposed to laws, or, as he called them, "generic concepts," and that geography was always simultaneously nomothetic and idiographic.

Barney Warf

See also Chorology; Empiricism; Hettner, Alfred; Human Geography, History of; Idiographic; Kant, Immanuel; Regional Geography; Regions and Regionalism; Vidal de la Blache, Paul



Further Readings

- Elkins, T., Butzer, K., Lukermann, F., & Martin, G. (1989). *Reflections on Richard Hartshorne's The Nature of Geography*. Washington, DC: Association of American Geographers.
- Hartshorne, R. (1939). *The nature of geography*. Washington, DC: Association of American Geographers. Retrieved January 27, 2010, from www.colorado.edu/geography/giw/hartshorne-r/1939_ng/naturehome.html
- Hartshorne, R. (1958). The concept of geography as a science of space, from Kant and Humboldt to Hettner. *Annals of the Association of American Geographers*, 48, 97–108.
- Hartshorne, R. (1959). *Perspective on The Nature of Geography*. Washington, DC: Association of American Geographers.
- Martin, G. (1994). In memoriam: Richard Hartshorne, 1899–1992. *Annals of the Association of American Geographers*, 84, 480–492.
- Schaefer, F. (1953). Exceptionalism in geography: A methodological examination. *Annals of the Association of American Geographers*, 43, 226–229.



HARVEY, DAVID (1935–)

David Harvey is perhaps the most influential contemporary human geographer in the world. Over several decades, he played a role in the quantitative revolution, but in the early 1970s, he was the seminal figure in the introduction of Marxism into the discipline. In a long series of highly influential books, he has steadfastly advocated on behalf of social justice and offered biting critiques of capitalism, neoliberalism, inequality, and oppression in all its forms.

Born in Gillingham, Kent, England, his initial interest in geography, he has said, came from his early desire to run away from home and see the world. He has certainly done that, both in his academic career and at internationally diverse public speaking engagements. His university training was at Cambridge University, where he

received his PhD in 1961. It was at Cambridge that he became involved in new theoretical debates in the discipline concerning the scientific status of geography. Harvey's dissertation, while seemingly a traditional historical geography of the regionally unique hop cultivation in Kent in the 19th century, reflects this debate as it tries to come to theoretical terms with the causal processes of change leading to the different forms that that cultivation assumed.

After Cambridge, Harvey took a position as Lecturer at the University of Bristol, where he continued his pursuit of scientific geography. Anglo-American geography at the time was dominated by the belief that the object of study of geography was ultimately unique landscapes not conducive to generalization or causal covering laws. In this view, the study of geography was somewhere between the sciences and the humanities. Harvey's cohort of new faculty set out to overturn this conceptualization of the discipline by attempting to render it closer in focus and methodology to the more established sciences.

This quest led to Harvey's first major book, *Explanation in Geography* (1969), which broadly surveys the philosophy and methodology of science as it relates to what he considered to be the main objects of study of geography: time, space, and, most important, space-time, that is, the two dimensions sutured into an indivisible whole. The latter notion was particularly important to the overall argument because it rendered the specific object of study of geography—spatial variation—open to intersubjectively repeatable, and therefore objective, causal analysis. This book thus systematized Harvey's concern with the intersection of process and pattern or spatial form that was embedded in his earlier work on hops cultivation in Kent.

Harvey spent nearly a decade coming to terms with how space and place (pattern, form) could be considered in a more positive, truly scientific manner, and *Explanation in Geography* is indeed considered to be a central manifesto for positivism in geography. Interestingly, however, by the time the book was published, even Harvey himself had moved beyond its main message. This shift was during the late 1960s, and social justice movements literally in the streets rendered the



ultimately ivory tower quest for “scientific rigor” much less important than making a difference in the real world. This was brought home to Harvey dramatically when he moved to the racially and class-polarized city of Baltimore to take a position at Johns Hopkins University in 1969.

His experience on the streets of Baltimore pushed Harvey to seek ways to change an unjust reality, instead of merely questing after a somehow “objective” knowledge of it. This transition in his approach is recorded famously in his second major book, *Social Justice and the City* (1973), which quickly became popular as a legitimizing narrative for those attempting to make the transition from the ivory tower to social activism. In this book, Harvey makes the transition from a liberal advocate of objective scientific planning to a socialist activist increasingly enamored with Karl Marx’s critique of capitalism as a system of exploitation and social oppression.

Harvey spent the entire next decade working out Marx’s critique of capitalism, which was scattered across literally thousands of pages of manuscript, published and unpublished. The resulting book, *The Limits to Capital* (1982), is an attempt to work through Marx with a specific focus on how to theorize capitalist space-time on the basis of Marx’s critique, which largely ignored the theoretical, and ultimately political, importance of spatial variations in social relations. Yet *The Limits to Capital* was published at a time when many on the political left were moving away from Marxism, and as a result, its message was not much studied, much less understood. This change was brought home to Harvey as a result of another personal relocation, this time back to England in 1987 to take up the Halford Mackinder Chair of Geography at Oxford University. In England, particularly, what was considered to be Harvey’s rigorously orthodox Marxism seemed passé to many post-Marxists and others at the time.

Yet Harvey has argued that *The Limits to Capital* is one of the most important of his many works, if not the most important. All the books that follow *The Limits to Capital* are informed by its careful working out of the limits to Marx’s critique of “capital” and to capitalism itself. Harvey fully adopts Marx’s dialectical materialist critique of the processes of capitalism while

extending its critical insights to the production of ever-evolving patterns of capitalist space-time. The latter involves what Harvey calls a “spatial fix,” which Marx largely ignored but which has been absolutely necessary for the survival of capitalism, now increasingly global in scope.

After two books on urbanization, published in the mid 1980s, which provide significant empirical corroboration of the theory worked out in *The Limits to Capital*, Harvey’s next major book, *The Condition of Postmodernity* (1989), became his most popular by far, selling more than 100,000 copies and translated into several languages. *The Condition of Postmodernity* established Harvey as a transdisciplinary scholar, and yet, according to him, it was a book that seemed to literally fly off his pen. It is worth dwelling on this book because it helps characterize all his subsequent works. *The Condition of Postmodernity* was conceived as a written response to his many post-Marxist critics. It successfully theorized, in a systematic Marxist way, the apparently unsystematic (some said “unorganized,” others “postmodern”) empirical nature of capitalist society toward the end of the long postwar boom. Harvey thus fashioned a quite unfashionable Marxist “master narrative” of postmodernity, explaining in very clear prose the systematic processes behind apparently unrelated patterns of events in architecture, social relations, urban politics, social theory, and so on. This perspective allowed for a more holistic grasp of what seemed to be the wholly unrelated movements and events of the oft-celebrated “postmodern.”

Read closely, *The Condition of Postmodernity* can serve as a guide to all the works that Harvey published after *The Limits to Capital*, from the attempt to work out the historical materialist construction of capitalist space/time–place–environment in *Justice, Nature, and the Geography of Difference* (1996), to the investigation of potential anticapitalist movements in *Spaces of Hope* (2000), to the attempt to work out a general theory of uneven geographical development in *Spaces of Global Capital* (2006), to, finally, the popular historical geography, *Paris, Capital of Modernity* (2003) and his latest books on neoliberal globalization and dominance, *The New Imperialism* (2003) and *A Brief History of Neoliberalism* (2005). All these works are thoroughly informed



by the theory worked out so difficultly in *The Limits to Capital* and yet expressed so eloquently in *The Condition of Postmodernity*.

Harvey eventually returned to Johns Hopkins in 1993 and moved on to the City University of New York in 2001, where he holds the title of distinguished professor in the department of anthropology. He continues to write and speak prolifically and now has a small corpus of works written about him.

Kevin Archer

See also **Class, Geography and; Critical Human Geography; Human Geography, History of; Inequality and Geography; Justice, Geography of; Marxism, Geography and; Peet, Richard; Radical Geography; Smith, Neil; Social Justice; Spatial Fix; Uneven Development; Walker, Richard**

Further Readings

- Castree, N., & Gregory, D. (Eds.). (2006). *David Harvey: A critical reader*. London: Blackwell.
- Harvey, D. (1982). *The limits to capital*. Oxford, UK: Blackwell.
- Harvey, D. (1985). *Consciousness and the urban experience*. Oxford, UK: Blackwell.
- Harvey, D. (1985). *The urbanization of capital*. Oxford, UK: Blackwell.
- Harvey, D. (1989). *The condition of postmodernity*. Oxford, UK: Blackwell.
- Harvey, D. (1990). Between space and time: Reflections on the geographical imagination. *Annals of the Association of American Geographers*, 80, 418–434.
- Harvey, D. (1996). *Justice, nature and the geography of difference*. Oxford, UK: Blackwell.
- Harvey, D. (2000). *Spaces of hope*. Berkeley: University of California Press.
- Harvey, D. (2001). *Spaces of capital: Towards a critical geography*. New York: Routledge.
- Harvey, D. (2006). *A brief history of neoliberalism*. Oxford, UK: Oxford University Press.
- Jones, J.-P., III. (2006). *David Harvey: Live theory*. London: Continuum.



HATE, GEOGRAPHIES OF

Postmodern and poststructuralist perspectives continue to strongly influence the humanities and social sciences, revealing unequal power relations between those social groups at “the center” of society and those who traditionally exist at the “margins.” Human geographers are particularly concerned with revealing how notions of place, geographical scale, territorial claims, and social space are implicated in the construction of these “center-margin” identities. Much of this research has focused on the geographies of “race,” gender and sexuality, ethnicity, disability, and other “marginalized” identities that tend to place these groups “outside” long-constructed “norms” of Anglo-American society (usually represented as mostly male, white, Christian, and heterosexual). This leads to various social “border” constructions, thereby “defining” who is “in place” and who is “out of place.” While uncovering the processes by which racial, ethnic, and sexual minorities have been marginalized, human geographers have explored how those “inside” societal norms have constructed these boundaries and how they work to maintain them. At the extreme end are those who passionately believe that North America and Europe represent the last remaining bastions of white, heterosexual, Christian society and actively work to keep it so. This stance has given rise to various “hate groups,” who obsess over their conceptions of what is “normal” within society and what is not.

Through speeches and rallies, publications, social networks, and the extensive use of the Internet, hate groups construct and enforce imaginary social boundaries through threats, intimidation, and at times violence. In the United States, hate groups have included members of the American Patriot and Christian Identity Movements, neo-Nazi groups, and the Ku Klux Klan. The election of an African American president in 2008, combined with a worldwide economic downturn, has also led to an increase in domestic hate group activity. Studying the geographies of hate includes mapping the spatial distribution and extent of hate groups (the Southern Poverty Law Center in Montgomery, Alabama, is the leading tracker of hate groups in the United



States), revealing the geohistorical contexts in which these groups exist and thrive, and examining how hate groups use geographic concepts such as scale, place, borders, and territoriality to further their agendas by excluding certain people from their social spaces.

The neo-Confederate movement provides one example of the geographies of hate. Based on romanticized visions of the Civil War and antebellum southern society, neo-Confederates have constructed and mythologized their vision of the American South as a culturally cohesive white, heterosexual, Christian nation directly descended from immigrants hailing from the Celtic areas of the British Isles and especially Scotland. By definition, such a conceptualization excludes African Americans, gays and lesbians, and non-Christians from the region. Indeed, neo-Confederates support secession from the United States to create (or, in their minds, preserve) the purity of their “nation.”

In addition to hate group activity in the United States, hate groups are proliferating worldwide. Countries such as the United Kingdom, France, and Germany have seen a steady rise in hate group activity, partly because of resentment toward the immigration of foreign-born labor resulting from the processes of global capitalism. The Baltic States and Russia have seen the rise of neo-Nazi skinhead groups who target sexual and ethnic minorities with intimidation and violence. Perhaps the most horrific example of hate group activity exists in places such as Bosnia, Rwanda, and Sudan, where ethnic, nationalist, and religion-based movements have resulted in ethnic cleansing and genocide in recent decades.

Jonathan Leib

See also Emotions, Geography and; Ethnocentrism; Fear, Geographies of; Identity, Geography and; Race and Racism; Whiteness

Further Readings

Flint, C. (Ed.). (2004). *Spaces of hate: Geographies of discrimination and tolerance in the U.S.A.* New York: Routledge.

Flint, C. (Ed.). (2005). *The geography of war and peace: From death camps to diplomats.* Oxford, UK: Oxford University Press.

Gallaher, C. (2003). *On the fault line: Race, class, and the American Patriot Movement.* Lanham, MD: Rowman & Littlefield.

Hague, E., Beirich, H., & Sebesta, E. (Eds.). (2008). *Neo-Confederacy: A critical introduction.* Austin: University of Texas Press.

HAUSHOFER, KARL (1869–1946)

Karl Haushofer was a German army general who, through his *Zeitschrift für Geopolitik* (*Journal of Geopolitics*), was believed by some in the West to be directing Nazi strategy and tactics during World War II. While it was later discovered that such a belief was very greatly exaggerated, the supposed links between Haushofer's geopolitics, political geography, and the Nazis have been given as a partial explanation for geopolitics' (and by extension, political geography's) decline as an academic field of study in the mid 20th century.

Born in Munich, Haushofer served in the German military from 1889 to 1919. Two time periods during his military career were especially important in focusing Haushofer's future direction: his work in Japan from 1908 to 1910, which helped shape his thinking on geopolitics (Haushofer's 1914 doctoral dissertation at the University of Munich focused on Japan), and his service in World War I. Haushofer left the military after the war and took up a teaching position at the University of Munich. He was not alone among Germans in feeling that the Versailles Peace Treaty that ended World War I, reducing the size of German territory and stripping it of its colonies, was unjust punishment for its defeat. Rectifying this situation was the basis for his subsequent geopolitical teaching and writing.

In his work, Haushofer blended previous writings in political geography/geopolitics from Friedrich Ratzel to Halford Mackinder. Haushofer emphasized the Ratzelian concept of *lebensraum* (living space) to suggest that, given its large



population, Germany needed greater amounts of land and resources for its state and people to survive and thrive in international competition with other states, advocating that Germany take over all or parts of adjacent states and other territories. He also proposed a division of global space into three giant blocks or pan-regions: (1) the Americas (centered on the United States), (2) Europe and Africa (centered on Germany), and (3) East/southeast Asia and Australia (centered on Japan). At the same time, borrowing from the Mackinder tradition, Haushofer saw the global geopolitical picture as a competition between land-based and sea-based powers. Early in World War II, Haushofer argued that Germany's lebensraum could best be achieved through the creation of a "heartland" alliance with the Soviet Union and Japan against the maritime-oriented British Empire.

Haushofer's vision of an expansionist Germany fit well with Nazi war aims. Haushofer's connections to the Nazis came through his former student Rudolf Hess, who he first met in the late 1910s and then later taught at the University of Munich. Haushofer visited Hess and Adolph Hitler in prison after the two were arrested for the failed 1923 Munich Beer Hall Putsch. Through these connections, some saw Haushofer's (and, by extension, geopolitics') influence in passages in Hitler's *Mein Kampf*. While more recently geographers have questioned the extent of Haushofer's influence on Hitler and the Nazis (whatever influence he had ended in 1941 following both Hess's flight to Britain and the German invasion of the Soviet Union, in direct contradiction to Haushofer's "geopolitical" advice), the American establishment's need to create a "boogeyman" during World War II to explain Hitler's actions centered on Haushofer and his supposed "Institute of Geopolitics" (which did not exist) masterminding Nazi war strategy (as seen in articles in American magazines such as *Life*, *The New Republic*, and *Reader's Digest* and in a 1943 Academy Award-nominated short documentary, *Plan for Destruction*).

Following the end of the war, Haushofer was interrogated but not charged with war crimes. Instead, he and his wife committed suicide in 1946. Even though geopolitics continued to be practiced by foreign policymakers and analysts in the decades after World War II, the popular

connection between geopolitics and the Nazis led to geopolitics falling out of favor as an academic field of study until the 1980s.

Jonathan Leib

See also **Geopolitics; Human Geography, History of; Political Geography**

Further Readings

- Heske, H. (1987). Karl Haushofer: His role in German geopolitics and Nazi politics. *Political Geography Quarterly*, 6, 135–144.
- Natter, W. (2003). Geopolitics in Germany, 1919–1945. In J. Agnew, K. Mitchell, & G. Toal (Eds.). *A companion to political geography* (pp. 187–203). Oxford, UK: Blackwell.
- Ó Tuathail, G. (1996). *Critical geopolitics*. Minneapolis: University of Minnesota Press.
- Ó Tuathail, G., Dalby, S., & Routledge, P. (1998). *The geopolitics reader*. London: Routledge.



HAYDEN, FERDINAND (1829–1887)

Ferdinand Vandever Hayden, American geologist and paleontologist, was a prominent figure in the scientific exploration of the northern plains and northern Rocky Mountains from the early 1850s to the 1880s. His writings made important contributions to Earth science and also helped familiarize the American public with the scenic wonders of the West.

Born in Westfield, Massachusetts, and raised by relatives in rural upstate New York, Hayden was largely self-made as an Earth scientist. He worked his way through Oberlin College and then studied at Cleveland Medical School and Albany Medical College, which awarded him an MD in 1853. Yet his medical activity was limited to service as a Union Army surgeon during the Civil War. Well before the war, he had become an active field researcher in geology and paleontology, and he returned to them when hostilities ceased.



In Albany, Hayden joined a group of young followers of James Hall, the state geologist of New York. Hall encouraged Hayden to accompany another Hall protégé, Fielding Bradford Meek, to the Dakota badlands in 1853 to collect fossils. After this initial trip, Hayden returned to the northern plains for two more years, working sometimes on his own and sometimes with Meek, who concentrated on the paleontological aspects of their work. Hayden's skill was in rapid geologic reconnaissance—accurately inferring the underlying structure of large areas from widely separated outcrops. Later in the 1850s, Hayden served as a geologist on three more expeditions to the upper Missouri valley. These required considerable enterprise on Hayden's part since there was as yet no sustained and consistently funded program of natural history exploration in the West. Hayden established the stratigraphy of the upper Missouri valley and in the process discovered the remains of extinct megafauna such as camels, horses, and members of the elephant family.

After his wartime medical service, Hayden accepted a professorship at the University of Pennsylvania; yet he continued to spend much of his time in the West. Hayden's survey is now funded by an annual appropriation from the Department of the Interior and has produced a voluminous body of annual reports, bulletins, and miscellaneous publications. This corpus indicates the height of Hayden's national prominence as a public scientist. Along with his solid contributions to geology and paleontology, he was a popularizer and wrote promotional works that helped "sell" the Rocky Mountain West to Easterners as a land of scenic grandeur. He included the prominent landscape photographer William Henry Jackson in his expeditions of the 1870s. Such efforts helped establish the Yellowstone National Park and familiarized the public with the cliff dwellings of Mesa Verde.

Political pressures in Washington forced the coordination of the multiple western surveys under the U.S. Geological Survey (USGS) in 1879. Hayden was a leading contender for the directorship of this new agency but was outmaneuvered by his rivals Clarence King and John Wesley Powell. King became the first head of the USGS and was followed by Powell 2 years later. Hayden

was sidelined, though he continued his fieldwork in the West. Failing health forced him to resign from the USGS in 1886, and he died the following year.

Thomas Frederick Howard

See also **Physical Geography, History of**; **Powell, John Wesley**; **United States Geological Survey (USGS)**

Further Readings

Foster, M. (1994). *Strange genius: The life of Ferdinand Vandeveer Hayden*. Niwot, CO: Roberts Rinehart.

Goetzmann, W. H. (1996). *Exploration and empire: The explorer and the scientist in the winning of the American West* (especially chap. 14, "F. W. Hayden, Gilded Age Explorer," pp. 489–529). New York: Knopf.



HEALTH AND HEALTH CARE, GEOGRAPHY OF

The geography of health and health care explores how and why people's health and access to health care vary from place to place. *Health* is typically defined as a positive quality that encompasses social, physical, and emotional well-being and not merely the absence of disease. *Health care* comprises diverse activities—personal, social, and institutional—for maintaining and promoting health. Formal health care is provided by trained professionals in organized settings such as hospitals and clinics. Informal care is provided by family and community members.

The uneven geographies of health and health care have profound implications for individual and societal well-being. These geographies are of particular interest within the field of medical geography and the broader but closely related field of health geography. This entry discusses several key themes in research on the geography of health and health care.

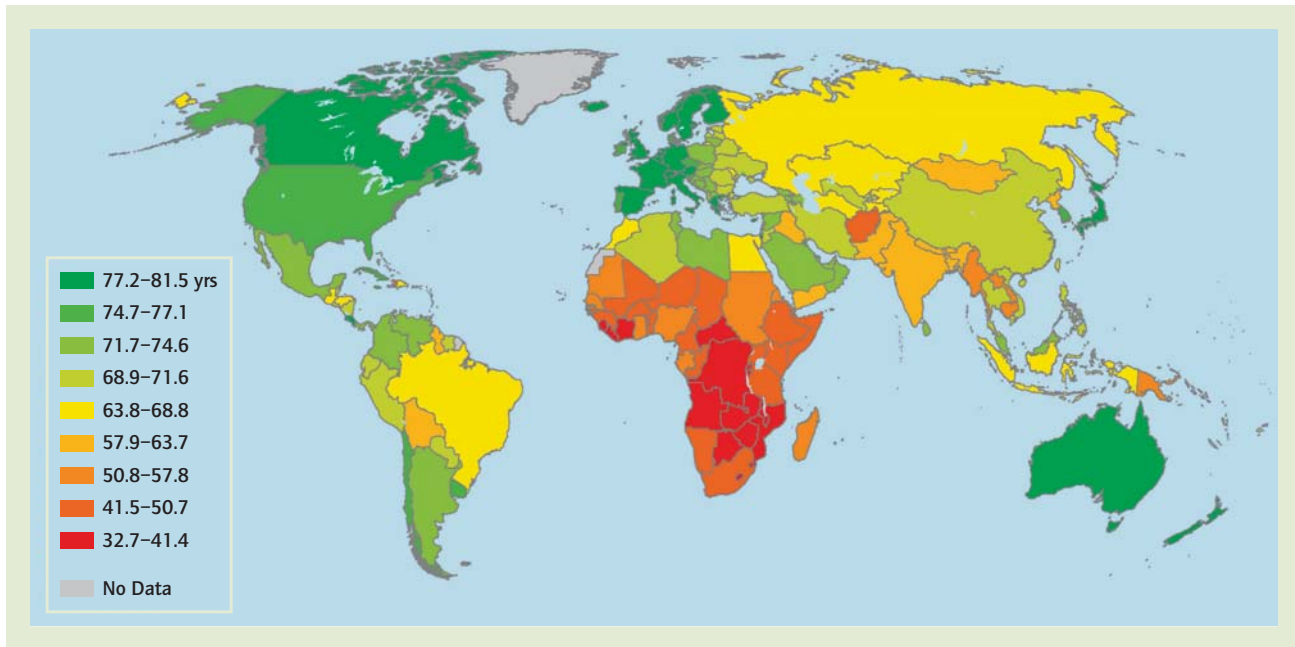


Figure 1 Life expectancy (years) by country, 2008

Source: Copyright © 2009 The Knowers Ark Global Education Project. Retrieved January 20, 2010, from www.theglobaleducationproject.org. Reprinted with permission.

Geographic Health Inequalities: Global

Geographic health inequalities refer to disparities in health from place to place. Such inequalities are apparent at all spatial scales—from the global to the local. At the global scale, indicators such as infant mortality and life expectancy show vast differences in population health between high-income and low-income countries. In 2008, estimates of life expectancy by country ranged from 82 yrs. (years) in Japan to 33 yrs. in Swaziland (Figure 1). Poverty, lack of clean water and sanitation, inadequate food supply, political and cultural unrest, contact with environmental and infectious disease hazards, and lack of medical treatments and facilities create significant barriers to population health in many low-income countries. Some countries in Southern Africa have seen a decrease in life expectancy in recent decades tied to political and economic upheavals and the spread of HIV/AIDS. Declining health and longevity create potent barriers to economic and social development.

The health transition model (epidemiological transition) describes the typical changes in health indicators as places undergo economic development. According to the model, improvements in

economic development are associated with increasing life expectancies and general improvements in health. There is also a shift in the causes of death from communicable diseases and malnutrition to degenerative and humanly created diseases. Degenerative diseases include conditions such as heart disease and cancer, which involve impairment of organs and tissues. Humanly created conditions are related to occupational and environmental exposures and risk behaviors that are by-products of economic development. As industrialization occurs and incomes rise, public health investments, improvements in diet, and access to health care lead to reductions in deaths from infectious diseases. At the same time, longer life spans, exposures to industrial and occupational hazards, and increases in smoking, overnutrition, and other risk behaviors heighten the risk of death from degenerative and humanly created diseases. Although the health transition model holds quite well overall, it does not account for the diversity in health outcomes among countries at similar stages of economic development. Health geographers have shown how social, political, and historical conditions in different places influence their varying health transitions.



<i>Physical Features of the Environment</i>	<i>Climate, Topography, Biota, Air, and Water</i>
Availability of healthy environments at home, work, and play	Quality of housing, employment opportunities and hazards, environmental hazards
Services	Education, health and welfare services, policing, transportation
Sociocultural characteristics	Opportunities for social interaction, religious and cultural organizations, norms and values, crime
Reputation of community	Perception of area by residents, government officials, lending agencies; place attachment

Table 1 Contextual factors that influence health

Source: Adapted from MacIntyre, S., Ellaway, A., & Cummins, S. (2002). Place effects on health: How can we conceptualise, operationalise and measure them? *Social Science & Medicine*, 55, 125–139.

Geographic Health Inequalities: Regional and Local

Health inequalities also exist at the regional scale, often corresponding closely with disparities in class, income, race, and ethnicity. Poor health is strongly associated with economic and social disadvantage: Poverty, lack of education, and social or cultural marginalization increase the risk of ill health. Evidence shows that poor health is tied not only to absolute disadvantage but also to relative disadvantage as reflected in income inequality. Living in a place with a highly unequal income distribution can pose a health risk. Geographic research shows that in places such as the United Kingdom, health inequalities have increased in the past decade, reflecting the widening gap in incomes between the rich and the poor. Strong ties between economic deprivation and health are also evident in large cities in the United States, where we find exceptionally poor health indicators in impoverished inner-city neighborhoods.

The causes of regional and local health inequalities can be grouped into two broad categories: (1) composition and (2) context. “Composition” refers to the socioeconomic and demographic characteristics of populations, such as age, race/ethnicity, and poverty. “Context” describes the characteristics of the places in which people live and interact, including environmental hazards, crime, housing characteristics, and the quality and availability of services, social networks, cultural resources, and employment opportunities (Table 1). Contextual factors affect a wide range of health

concerns from infant mortality to cancer to injury. Obesity, for example, is associated with contextual factors such as the availability of grocery stores and fast-food restaurants, the “walkability” of neighborhood environments, the availability of parks and recreation facilities, and perceptions of crime and safety. To unravel the significance of contextual and compositional factors in affecting particular kinds of health risks, researchers are using multilevel modeling methods that assess the impacts on health outcomes of variables measured at different geographical scales.

There is a growing recognition of the interrelations between composition and context. Not only are the social and economic characteristics of people closely tied to the characteristics of the places in which they live, but also some populations are more vulnerable to health-related environmental exposures. Place characteristics strongly affect the health of the elderly and the poor, who are more dependent than others on the resources in their local communities. The roles of context and composition have been widely debated, and today most health geographers agree that it is the interrelationships between people and places that give rise to health inequalities.

Health and Place

Since the early 1990s, the concept of place has played a central role in our understanding of the geographies of health and health care. Place is a relational concept that describes how people interact with and experience the environments in



which they live. Places are environments infused with meanings. Places vary greatly in size, from the personal space of a room to the vast space of a country or continent. Health geographers study how people's experiences and sense of place affect health and how people and institutions create healthy and unhealthy places.

Therapeutic landscapes, places perceived as beneficial for health, are critically important in current understandings of health and place. These landscapes include culturally defined places of spiritual, emotional, or physical healing, such as Lourdes in France. They also include places with distinctive environmental qualities, such as mineral springs, or topographic features that are thought to promote health and healing. Other places focus on religious structures, such as temples. In visiting these sites, people may experience a "transformation to wellness" through their interactions with the landscape and their social interactions with other visitors. In every case, these therapeutic landscapes reflect the complex layering of historical, social, and cultural relations in a particular place setting. At a more microscale, therapeutic landscapes can also be ordinary spaces, places in everyday life that promote healing and well-being. A prayer room in one's home, a local park, or a gathering place may be a space of relaxation and healing. Places such as spas and resorts, created and operated by business firms, are commercialized therapeutic landscapes. Increasingly important to local economies, these sites represent the uneasy ties between therapeutic and commercial goals.

Unhealthy places—landscapes marred by environmental degradation and contamination—have also attracted interest. Environmental justice describes the uneven distribution of environmental hazards among communities by race, ethnicity, and socioeconomic disadvantage. Racial and ethnic minorities and the poor often bear a disproportionate share of environmental hazards, including air and water contamination and hazardous facilities. People's perceptions of local environmental hazards and their efforts to mobilize against them are key to understanding the impacts of unhealthy place environments. In many disadvantaged communities, people are unaware of local environmental hazards, or if aware, they lack the time and resources needed to

mobilize against them. Community characteristics and sense of place also shape community members' attitudes toward environmental hazards. When people feel a strong attachment to a place, they are likely to resent and oppose environmental threats, whereas those with weaker ties to their residential neighborhoods are less likely to mobilize against such threats.

Geography of Formal Health Care

Formal health care services have distinctive geographies from the global to the local scales. The geography of health care describes spatial variation in the locations, numbers, and types of services. Health services are often divided into three levels: (1) primary-care services that address routine health needs, (2) more specialized secondary services typically offered in hospital settings, and (3) highly specialized tertiary services provided only in the most advanced hospitals. Of the three, primary services are the most numerous and widely distributed over the landscape. Tertiary services are offered at a limited number of highly specialized hospitals, mainly located in large metropolitan areas.

The location of health services is important because people's use of health services is highly localized. Distance strongly affects the choice of service providers: People are less likely to use services located far away from home. This distance decay relationship arises because of the time, cost, and effort involved in traveling long distances and people's lack of familiarity and comfort with faraway services. The negative effect of distance on utilization varies across health services: Primary-care services such as routine medical checkups and dental care exhibit a steeper decline in use with distance than do tertiary services. Population characteristics also affect distance decay. People with low incomes and limited mobility are much more reliant than others on health services located close to home.

The territorial organization of formal health care is significant in several respects. Health care providers typically serve a geographically defined catchment area from which they draw most of their clients. Catchment areas reflect not only distance but also the locations of competing providers and the characteristics of the health



care facility, including quality and cost of services. Some health providers have particular ethnic, religious, or linguistic affiliations, attracting patients from long distances who prefer those affiliations. Publicly funded providers may have a politically defined catchment area. Like other economic and social organizations, health providers often act strategically to shift their catchment areas and patient populations. In the United States, large urban hospitals have established satellite facilities in profitable suburban locations. The ties between health care providers and local communities also have implications for the costs and nature of the services provided. Costs reflect the availability and cost of labor, land, and other inputs; the kinds of services provided reflect local medical cultures and attitudes toward medical intervention. Thus, the geography of formal health care results from the complex interplay among place characteristics, provider decisions, population characteristics, and decision making.

At the global scale, there are marked differences among countries in the availability and quality of services and in how health care is provided. Medical providers, facilities, and treatments are often in short supply in low-income, developing countries. Shortages are especially acute in rural areas, economically marginalized areas, and regions with political and social unrest. Exacerbating these shortages is the migration of doctors and nurses from developing to developed countries, a “brain drain” of medical providers.

The financing and provision of formal health care also differ greatly at the global scale. In some countries, health care is primarily a public service, provided through a network of public hospitals and clinics and financed primarily by tax revenues. Access to care is universal rather than based on ability to pay. Britain’s National Health Service is a good example. In contrast, in countries such as the United States, private provision predominates: Private and nonprofit firms offer services and compete under quasi-market conditions. Although consumers’ ability to choose health providers is high, their choices may be limited by the lack of insurance and other financial barriers. Although public and private represent archetypical forms of health care provision, most countries maintain a mix of the two, with the mix shaped by national politics and historical circumstances.

At the national scale, geographical access to health services varies greatly between urban and rural areas. Health services are less available in rural areas because population numbers and densities are not sufficient to support large numbers of service providers. Rural communities often experience difficulties in attracting and retaining medical professionals. The lack of health care providers means that rural residents face long travel distances in obtaining health services and their choice of providers is limited. Poor geographical access can lead to low rates of service utilization, particularly for routine and preventive services.

An important dimension of the geography of health services is the relationship between service need and geographical accessibility. The inverse-care law describes the situation in which places with the highest need for care have fewer services available. In many American cities, the geographic distribution of primary-care services follows an inverse-care pattern. There are acute shortages of primary-care physicians and dentists in many low-income, inner-city neighborhoods. Although residents might be able to travel outside their neighborhoods for care, economic constraints, lack of knowledge of and familiarity with services in more distant neighborhoods, and sociocultural differences create barriers to travel. Therefore, many low-income urban residents rely on hospital emergency rooms for primary care.

Changes in health policy have profound implications for geographic disparities in health care. Since the 1980s, many industrialized countries (e.g., Canada and Britain) have pursued privatization of health care, with spatially and socially uneven impacts. Privatization is often associated with changes in health care delivery, including the closure of hospital and clinics in some locations. Devolution, the transfer of health care provision and administration from higher to lower levels of government and/or to informal settings, has also been widely adopted. It involves an explicit shift in the geographical scale at which care is provided. In the mental health arena, geographers have documented the geographical and social impacts of deinstitutionalization policies—policies that shifted patients from large, isolated mental hospitals to smaller, community-based facilities. Such policies represent a specific form of devolution that has profoundly affected the lives



of people with mental illness. On the positive side, patients are no longer socially and geographically isolated in large psychiatric institutions; yet many patients were released into community settings with inadequate resources and support, creating new landscapes of despair.

Geography of Informal Care

There is a growing interest in the geographical dimensions of informal health care—care provided in home and community settings. Worldwide, informal care accounts for the vast majority of health care provision. Geographers have studied where informal care is provided, how changing policies affect informal care, how the places in which people live affect the intensity and quality of informal care, and how people actively create caring environments. The home is a critical setting for provision of informal care. Care is interwoven with social relations within and beyond the home, and it depends on relations of trust and mutual effort. People's experiences of home strongly affect the intensity and outcomes of informal care. These experiences differ by gender, age, and so on, according to socially and culturally defined roles and relationships. The geographies of informal care have been studied for vulnerable populations, notably immigrants, who rely on place-based social networks and local cultural resources as important sources of informal care. Everyday rituals related to food preparation, prayer, and social interaction are important in immigrants' efforts to maintain health and well-being in an unfamiliar environment.

In many countries, privatization and devolution policies are shifting the balance between formal and informal care, creating new geographies of informal care. Patients are being released from the hospital earlier and placed in the home and other nonmedical settings. Known as place switching, this process has important implications for both patients and caregivers. For patients, the home is often a therapeutic site that promotes health and healing, so the shift to the home may be beneficial. For caregivers, however, attending to patients' medical needs at home creates emotional, time, and financial challenges for family members. Frequently, the work of informal caregiving falls more heavily on women than on men,

with implications for women's daily activity patterns and social and emotional well-being. The process of caregiving also has a strong geographical component, depending on the availability of resources, services, and social support within the local community.

Conclusion

The uneven geographies of health and health care are continually shaped and reshaped by the interactions between people, places, and institutions. Economic, social, and environmental transformations affect people's health by affecting their vulnerabilities and exposures and their access to resources, services, social networks, and health care. Although worldwide health has improved in the past several decades, we are also seeing new kinds of health concerns, new vulnerabilities, and widening health inequalities in many places. At the same time, health care landscapes are in flux as cost pressures and political imperatives alter the balance between formal and informal care and as patients, caregivers, and providers adjust to the changing health care environment. How these processes unfold is critically important for the changing geographies of health and health care.

Sara McLafferty

See also [Accessibility](#); [Cancer, Geography of](#); [Cholera, Geography of](#); [Disability, Geography of](#); [Disease, Geography of](#); [GIS in Health Research and Health Care](#); [HIV/AIDS, Geography of](#); [Malaria, Geography of](#); [Medical Geography](#); [Mortality Rate](#)

Further Readings

- Boyle, P., Curtis, S., Graham, E., & Moore, E. (2004). *The geography of health inequalities in the developed world: Views from Britain and North America*. Burlington, VT: Ashgate.
- Curtis, S., & Taket, A. (1996). *Health and societies: Changing perspectives*. London: Arnold.
- Gatrell, A. (2002). *Geographies of health: An introduction*. Malden, MA: Blackwell.
- Meade, M., & Earickson, R. (2000). *Medical geography* (2nd ed.). New York: Guilford Press.



HEAVY METALS AS POLLUTANTS

Heavy metal is a poorly defined term that refers to a metallic or metalloid element with a high density and high atomic weight. There is considerable disagreement about whether both or only one of the parameters must be high and about where to set the cutoff values for the parameter(s). Values of 4, 5, and 6 g/cm³ (grams per cubic centimeter) have been used to define high density; 23, 40, and 63 have been used as cutoff values for atomic weight. To remedy these inconsistencies, another parameter, atomic number, has occasionally been used to define heavy metal, but this sometimes resulted in the inclusion of obviously light metals in the list of heavy metals. The absence of a consensus about the definition of the term *heavy metal* has led some to abandon it altogether and use alternatives such as *toxic metals* or *trace metals*. However, these terms also lack a universally accepted definition and do not result in a classification that completely overlaps with the general intent for the meaning of heavy metal. Consequently, heavy metal is still a very widely used term. Metallic elements that are generally considered to be heavy metals include antimony, cadmium, chromium, copper, gold, lead, mercury, nickel, silver, thallium, tin, and zinc. Arsenic and tellurium, both metalloids, and even selenium, a nonmetal, are sometimes included among the heavy metals. Depending on the definition used, the list of heavy metals can have between 40 and 80 elements. Many of these heavy metals are toxic to some degree to humans and other life forms, and therefore, sometimes toxicity is included in the definition of heavy metal. Because of their toxicity, their widespread release into the environment through natural and anthropogenic processes, and their persistence under natural conditions, many heavy metals are of great environmental and human health concern. This entry discusses the sources of heavy metals and their environmental distribution. It then describes their adverse health effects as well as national and international regulatory standards.

Sources of Heavy Metals

Heavy metals have a natural origin and can be released into the environment through weathering

of minerals and their subsequent spread by geological, atmospheric, and biological processes, including erosion, volcanic eruptions, salt spray, wildfires, and uptake by plants. Heavy metal concentrations resulting from these natural processes are generally low beyond the vicinity of ore deposits. Human activities are a much more important source for most of the heavy metals. Anthropogenic release of heavy metals probably began with the onset of the Bronze Age and the mining and smelting of ores and may have affected the atmosphere at a hemispheric scale by 2,500 years BP (before present). Releases reached the first peak in Roman times, when the use of lead, and also copper and zinc, increased markedly. With the advent of the Industrial Revolution and the associated increase in metallurgical activities and burning of fossil fuels, anthropogenic release of heavy metals increased exponentially. Peak releases of various metals occurred at different times during the 20th century as a result of changes in metal usage and fuel type, but they generally occurred in the 1970s. In that period, atmospheric emissions of lead were about 200 times higher than in prehistoric times. Currently, shifts in release volumes and patterns are taking place as a result of shifting patterns in industrial manufacturing.

Common present-day anthropogenic sources of heavy metals include mining, metallurgy and smelting, industrial and domestic wastewater, electroplating and galvanization (cadmium, chromium, nickel, zinc), combustion of fossil fuels (cadmium, lead, nickel), coal-fired power plants and incinerators (arsenic, mercury), and fertilizers (uranium) and pesticides (arsenic, copper). Other human activities such as deforestation, dredging, and construction do not release additional heavy metals to the environment but accelerate their cycling through ecosystems.

Environmental Distribution of Heavy Metals

Because of the numerous sources and environmental persistence, heavy metals occur in virtually all parts of the environment, including air, water, soil, sediments, and plants and animals. In the atmosphere, many types of heavy metal compounds are present, usually in particulate form. Mercury occurs mainly in a gaseous state. Due to



Pipes give off steam at Norilsk Nickel's copper plant, June 14, 2007. The plant is one of three that surround the Arctic town of Norilsk, Russia, contributing to sulfur dioxide and metal-laden dust pollution.

Source: Associated Press Images.

the dynamic nature of the atmosphere, the heavy metals can be transported over great distances and can reach remote areas such as the Arctic. Particles are removed from the atmosphere by wet or dry deposition. The dry deposition rate is determined by the concentration of the heavy metals in the air, particle size, meteorological conditions, and the roughness and filtering quality of the receiving surface. Wet deposition rates are determined by precipitation amount and the concentration of the heavy metal in meteoric water. Atmospheric deposition is a major contributor to heavy metal pools in soils and surface waters. Water bodies in urban and industrial areas can receive up to 50% of their chromium and up to 90% of their cadmium, lead, nickel, and zinc from atmospheric deposition. Airborne heavy metal compounds are also of concern because they can be inhaled and cause health problems in humans.

In water, heavy metals can occur in a dissolved state, but concentrations are generally relatively low. Arsenic, cadmium, and selenium have the highest proportion of dissolved species. For most other heavy metals, higher concentrations are usually present in colloidal hydroxides, oxides, or sulfides and are adsorbed to suspended clay or organic matter. Heavy metal speciation in water depends strongly on the salinity of the water. When fresh riverine water enters an estuary, for example, organic complexes and particulates may flocculate and promote settling of heavy metals.

In aquatic sediments, heavy metals may be bound by organic compounds and may adsorb to the negative exchange sites at the surface of particles of clay minerals. Concentrations are often higher in sediment than in overlaying water. Exchange of heavy metals between the sediment phase and water depends on the chemical



properties of each heavy metal, but desorption from the sediment is favored by low pH, low redox potential, and high salinity. Heavy metals may also flux into the overlying water due to microbial mineralization of organic matter and resuspension of sediments.

In soils, the natural background levels of heavy metals are determined by the composition of the parent material of the soil and the geological and pedological processes that affect it. Anthropogenic heavy metals enter soils mainly via atmospheric deposition, but they can also be added by land application of wastewater sludge and other industrial and dredging spoils and by overapplication of fertilizers and pesticides on farmland. Once in the soil, retention of the heavy metals is greatly affected by the amount and type of organic matter and clay. Heavy metals can also react with anions in the soil and precipitate. In general, soils are efficient in retaining heavy metals under natural conditions, which has led to soils being compared with a filter that cleans the percolating water. Under specific environmental conditions, however (e.g., low redox potential, low pH, very high metal concentrations, the presence of chelating agents), heavy metals can become mobile in the soil environment and leach into groundwater aquifers. Arsenic, mercury, and selenium are subject to volatilization and can transfer from the soil to the atmosphere.

In organisms, heavy metals tend to accumulate faster than they are released, thus leading to bioaccumulation. In water, bioaccumulation is affected by pH, redox potential, availability of complexing agents, salinity, temperature, light, and several biotic factors. In soils, low pH and high clay and organic matter contents raise the availability of heavy metals to plants. Heavy metals, with the exception of mercury, do not biomagnify in the aquatic food chain. The bioavailability of the metals decreases in successive levels of the food chain due to the formation of closed cellular compartments and of insoluble phosphate and sulfur compounds that are not absorbed by the digestive systems of the higher trophic levels.

Adverse Health Effects of Heavy Metals

In small amounts, some heavy metals such as cobalt, copper, iron, manganese, selenium, and

zinc have beneficial effects on human and animal health. However, it has been known since ancient Greek and Roman times that some heavy metals have adverse health effects. It is now well-known that heavy metals such as arsenic, cadmium, chromium, lead, and mercury are toxic to many life forms, even at low levels. They are taken up by humans through dermal contact, inhalation, and ingestion of water, food, and dust. Children are more prone to adverse health effects from exposure to heavy metals than adults because of the greater risk of accidental ingestion and unhygienic habits. A wide range of health problems can result from exposure to heavy metals, including respiratory problems, liver and kidney damage, nerve damage, cancer, and birth defects. Diseases of the brain are the leading cause of human mortality from acute and chronic heavy metal exposure. Some heavy metals are radioactive (cobalt, uranium). In the United States, chronic exposure to lead, commonly present in paint in older housing, is the most significant cause of heavy metal poisoning. Children are especially vulnerable because they absorb more of the ingested lead than adults (50% vs. 10%). Exposure to lead in the uterus or during the early years of life may lead to birth defects, developmental delays, and decreased intelligence. However, morbidity and mortality due to heavy metal exposure are low compared with other illnesses and conditions, except for small-scale exposures to elevated levels.

In plants, both deficiencies and excesses of heavy metals can have negative impacts. Essential elements such as cobalt, copper, manganese, and zinc are required for healthy plant growth. Arsenic, cadmium, chromium, lead, and mercury are toxic to plants to various degrees. The level of toxicity of heavy metals depends on the bioavailable proportion rather than the total concentration. Bioavailability depends on abiotic factors such as pH, the type and amount of clay and organic matter, microbial activity, and moisture content but is also greatly influenced by the plant species and growth stage.

Regulatory Limits

Many nations and international organizations have established environmental standards for heavy metals. The regulations provide acceptable



concentration limits for heavy metals in various media and are intended to safeguard ecosystem and human health. The establishment of the standards has been the subject of considerable debate because of the multiple confounding factors—such as metal speciation, bioavailability, interspecies variability, and interaction with other toxins—that affect the toxic effects of a heavy metal. As a result, a number of standards have been developed for different purposes, with different methods, and for various media. For plant health, few standards have been established, in part because of the large variability in toxicological effects a given metal concentration has on various plant species.

Lead is the only heavy metal classified as a criteria (major) air pollutant in the United States, with a maximum quarterly average standard of $1.5 \mu\text{g}/\text{m}^3$ (micrograms per cubic meter) of air. Standards for water quality in the United States depend on the specific designated use(s) of a water body, such as recreation, support of aquatic and/or wildlife, propagation and harvest of aquatic life, and drinking water source. Some of the current maximum contaminant levels for drinking water sources are 0.01 mg/L (milligrams per liter) for arsenic, 0.005 mg/L for cadmium, 0.1 mg/L for chromium, 1.3 mg/L for copper, 0.015 mg/L for lead, 0.002 mg/L for mercury, 0.1 mg/L for nickel, and 0.05 mg/L for selenium. Standards for aquatic sediments have been established to protect benthic fauna but also because of the influence of sediment pollution on water quality. A wide range of standards exists for sediment quality, most of which are based on a certain probability of some type of adverse biological effect. Safe limits for heavy metal intake by humans are based on the daily or weekly provisional tolerable intake level, which is the upper limit for the amount of a chemical that can be ingested each day or week without appreciable risk to a person's long-term health. The provisional tolerable intake level is calculated based on toxicological tests, epidemiological and accidental exposure information, and a safety factor that takes into account differences between humans and test animals, differences among people, and the nature of the potential health effect. FAO/WHO (Food and Agricultural Organization/World Health Organization) daily provisional tolerable intake values for some heavy metals are $2.1 \mu\text{g}/\text{kg}$ for arsenic,

$1 \mu\text{g}/\text{kg}$ for cadmium, $500 \mu\text{g}/\text{kg}$ for copper, $3.6 \mu\text{g}/\text{kg}$ for lead, $0.7 \mu\text{g}/\text{kg}$ for mercury, and $1,000 \mu\text{g}/\text{kg}$ for zinc.

Johan Liebens

See also **Atmospheric Pollution; Biogeochemical Cycles; Environmental Impacts of Cities; Environmental Impacts of Manufacturing; Environmental Impacts of Roads; Open-Pit Mining; Soil Degradation; Water Pollution**

Further Readings

- Bradl, H. (Ed.). (2005). *Heavy metals in the environment: Origin, interaction and remediation*. Amsterdam, Netherlands: Elsevier/Academic Press.
- Center for Environmental Health Sciences at Dartmouth. (2001). *Dartmouth toxic metals research program*. Retrieved November 20, 2008, from www.dartmouth.edu/~toxmetal
- Dufus, J. H. (2002). "Heavy metals": A meaningless term? (IUPAC Tech. Rep.). *Pure and Applied Chemistry*, 74(5), 793–807.
- Food and Agricultural Organization/World Health Organization. (2007). *Summary of evaluations performed by the joint FAO/WHO expert committee on food additives* (Updated Internet edition). Retrieved November 20, 2008, from <http://jecfa.ilsa.org>
- McLean, J., & Bledsoe, B. (1992). *Behavior of metals in soils* (EPA/540/S-92/018). Washington, DC: USEPA Office of Research and Development.
- Merian, E., Anke, M., Ihnat, M., & Stoeppeler, M. (Eds.). (2004). *Elements and their compounds in the environment: Vol. 1. General aspects*. Weinheim, Germany: Wiley/VCH Verlag.



HEGEMONY

Hegemony refers to the ability of a dominant group to influence and shape others' attitudes, perceptions, and actions. In contradistinction to related phenomena such as imperialism or empire, hegemony does not rely on force or violence and instead requires considerable consent from the



subordinated group. This entry discusses the evolution of the concept of hegemony and its application in geography.

Much of the theorization and application of hegemony is based in Marxist thought. The Italian theorist Antonio Gramsci developed the notion of cultural hegemony around 1930 to explain why the working class had internalized or adopted the capitalist values of the bourgeoisie rather than carrying out the revolution predicted by Marxist theory. Gramsci opposed Marx's economic determinism, positing that the values and norms adopted by the masses were disseminated primarily by civil society groups such as churches, schools, and intellectuals. The state, or political society, applied coercion through its juridical institutions only when people did not consent to the imposed order willingly.

The Frankfurt Institute for Social Research, or the "Frankfurt School," dedicated to neo-Marxist critique of ideology, contributed greatly to the notions of hegemony throughout the mid 20th century. Herbert Marcuse, a key Frankfurt thinker, wrote that in advanced industrial (post-1945) societies, social critique is stemmed by technology and consumerism, which occupy passive subjects with created false needs. Thus, marginalized voices are the only source of true dissent. More recently, Ernesto Laclau and Chantal Mouffe departed from previous views of hegemony (such as those of many Frankfurt thinkers) as a secondary phenomenon of production relations. Instead, they characterized *all* contemporary social relations as hegemonic struggles whose outcomes were discourse and the construction of political identities, as well as new resistances. Thus, in contrast to the totalizing consumerism of which Marcuse spoke, Laclau and Mouffe actually saw the post-1945 climate as more conducive to counterhegemonic movements.

Hegemony has received considerable attention in geography, particularly because it informs the social construction of space and place and the ways in which power and ideology are implicated therein. Edward Soja, building on Henri Lefebvre's notions of the production of space, introduced the term *sociospatial dialectic* to explain the production of space from a Marxist spatial-analytical perspective. Soja (1980) noted that the structure of organized space represents "a

dialectically defined component" of the relations of production, which are "simultaneously social and spatial" and arise from "purposeful social practice" (pp. 208–210). In Soja's account, the social production of space was an integral component of class struggle that reinforced the hegemony of contemporary capitalism, though in a dialectical, rather than mechanistic, way.

A number of cultural geographers have gone beyond this materialist context and examined the production of hegemonic identities and relations beyond class. Tim Cresswell demonstrated how place is constructed around multiple ideological practices and beliefs through hegemonic and counterhegemonic struggles. The construction of place is recursive: Place reproduces the beliefs that have produced it, and these beliefs eventually come to appear self-evident and a matter of commonsense. This issue has been examined in the construction of commemorative places, which aim to "etch" a particular collective memory into the cultural landscape, thereby asserting certain identities as dominant while marginalizing others. For example, African Americans and civil rights activists have protested the creation of memorials to Confederate general and Ku Klux Klan leader Nathan Bedford Forrest. Derek Alderman and Owen Dwyer viewed a memorial to Forrest in an African American neighborhood in Selma, Alabama, as one such example of the operation of collective memory.

In the subfields of political geography and geopolitics, the workings of hegemony at the global scale have been theorized and empirically demonstrated. Some of these understandings are taken from Immanuel Wallerstein, who posited that hegemony occurs in the capitalist world system when a particular state achieves economic, political, and ideological dominance, though it is rooted in that state's supreme efficiency in economic activities. Peter Taylor examined the rise of the three hegemonies in the capitalist world economy (the Netherlands, Britain, and the United States). He noted that their economic supremacy was buttressed by sets of political rules and norms set forth by each and advanced largely by their civil societies, which he termed *prime modernity*. Hence, the hegemon serves as a source of moral and intellectual leadership as well as an example of economic progress for the rest of the world to emulate.



The phenomenon of U.S. hegemony has been viewed by some political geographers as unique from previous examples of hegemony. For example, John Agnew viewed post–World War II globalization and its fragmentation of state territories as a hegemonic project closely linked with U.S. political and economic interests, indicating a break with the exercise of power by previous hegemonies. Similarly, Neil Smith saw the U.S. imposition of relational power, rather than direct, imperial control of territory, as the basis for a U.S.-dominated world order in which legitimacy was predicated on membership in the community of “free” nation-states. There is little consensus over the current state of U.S. hegemony. Some scholars see the United States as a hegemon in decline, while others, such as John Agnew and Stuart Corbridge, broach the idea of a stateless hegemony in which the world order is governed by a hegemonic ideology of transnational liberalism and expansion of global capitalist markets.

While scholars such as Marcuse viewed hegemony as totalizing, Gramsci emphasized that maintaining hegemony does not require constant acquiescence from subordinates; rather, the dominant group carefully defines the acceptable range of resistance to its order. Indeed, Gramsci even acknowledged fluidity in the elite group itself. Thus, hegemony requires continuous effort on the part of those whose interests it serves. This is emphasized by John Agnew, who points out that as the United States has met with resistance from certain parts of the world, it has had to resort to increased unilateral actions and use of force. Importantly, these policies are often questioned even within U.S. society. Laclau and Mouffe noted that while capitalist relations pervade virtually every domain of life, new struggles have fomented in resistance to new forms of subordination, such as the ecological movement, which opposes wasteful and destructive capitalist practices. Paradoxically, the possibilities for success are somewhat limited by dissenters’ reliance on aspects of the capitalist system to support their movements.

Richelle M. Bernazzoli

See also **Colonialism; Cultural Landscape; Geopolitics; Imperialism; Inequality and Geography; Marxism, Geography and; Political Geography; Race and Racism; World-Systems Theory**

Further Readings

- Agnew, J. (2005). *Hegemony: The new shape of global power*. Philadelphia: Temple University Press.
- Agnew, J., & Corbridge, S. (1995). *Mastering space*. London: Routledge.
- Alderman, D., & Dwyer, O. (2004). Putting memory in its place: The politics of commemoration in the American South. In D. Janelle, B. Warf, & K. Hansen (Eds.), *Worldminds: Geographical perspectives on 100 problems* (pp. 55–60). Dordrecht, Netherlands: Kluwer Academic.
- Cresswell, T. (1996). *In place, out of place*. Minneapolis: University of Minnesota Press.
- Hoare, Q., & Smith, G. (1971). *Selections from the prison notebooks of Antonio Gramsci*. New York: International Publishers.
- Laclau, E., & Mouffe, C. (1985). *Hegemony and socialist strategy: Towards a radical democratic politics*. London: Verso Books.
- Lears, T. (1985). The concept of cultural hegemony: Problems and possibilities. *The American Historical Review*, 90(3), 567–593.
- Soja, E. (1980). The socio-spatial dialectic. *Annals of the Association of American Geographers*, 70(2), 207–225.
- Taylor, P. (1999). *Modernities: A geohistorical interpretation*. Cambridge, UK: Polity Press.
- Wallerstein, I. (1974). *The modern world-system*. New York: Academic Press.
- Wiggerhaus, R. (1995). *The Frankfurt School: Its history, theories, and political significance*. Cambridge: MIT Press.



HERBICIDES

Herbicides are a subclass of pesticides that are designed to kill unwanted plants or inhibit their growth. Herbicides contain a wide variety of chemicals, including both inorganic and organic compounds, with different abilities to interrupt specific physiological processes of plants for their survival, growth, and development. The use of herbicides provides a cost-effective method to control the growth of unwanted plants in order



to decrease labor costs and increase crop production. Herbicides are extensively applied in agriculture, forestry, and urban areas for unwanted plant management. In addition, herbicides are often used to control nuisance aquatic plant growths or algae blooms in water bodies.

Initially, most chemical herbicides were inorganic compounds that were usually very toxic to both desirable crops and unwanted plants as well as to mammals. The first synthetic organic herbicide was developed in France in 1932 for use in cereals. The rapid development of synthetic organic herbicides was stimulated by the need for increasing food production and by the Allies' search for potential chemical warfare agents during World War II. Since then, the development and use of herbicides have increased steadily. Indeed, herbicides are the most commonly used pesticides in the world today. Most of the heavy herbicide use takes place in North America, Europe, Japan, and Australia.

There are various herbicide classification schemes based on different herbicidal properties. According to their activity, herbicides can be simply classified as (1) selective herbicides, which are used to kill unwanted plants without harming others, or (2) nonselective herbicides, which kill all plants. According to their movement within the plant, herbicides can also be classified as (1) contact herbicides, which destroy only the plant tissue in contact with the herbicide, or (2) systemic herbicides, which are absorbed either by the roots or the foliar parts of a plant and are then carried throughout the plant to injure it. According to application timing, herbicides are classified as (1) preplanting herbicides, which are applied before a crop is planted; (2) preemergent herbicides, which are applied before the emergence of unwanted plants; or (3) postemergent herbicides, which are applied after crops or unwanted plants have emerged. Herbicides with similar chemical structure often disrupt the same biochemical process in plants. Therefore, herbicides are commonly grouped by their chemical structure and mechanism of action. Understanding a herbicide's mechanism of action is helpful in choosing the appropriate type of herbicide for effective plant management.

Herbicide use plays an important role in modern agriculture by increasing crop production at

low labor cost and decreasing soil erosion through reduced tillage. Although most herbicides are specific plant poisons and have a very low toxicity in animals, some herbicides can be highly toxic to humans and other animals. Herbicides can potentially affect ecosystems by having direct toxicity to nontarget organisms, altering vegetation compositions and habitat structure, or reducing food sources. In addition, some water-soluble herbicides may contaminate surface and groundwater resources, with adverse effects on aquatic fauna. Improper herbicide use can cause negative impacts on the environment and pose a health threat to herbicide applicators and others exposed to herbicides via drinking water or food. Despite their contribution to food production, herbicides must be used appropriately to reduce their risks.

Mei-Hui Li

See also **Agrochemical Pollution; Environmental Impacts of Agriculture; Pesticides; Pest Management**

Further Readings

- Carson, R. (2002). *Silent spring* (Mariner Books ed.). New York: Houghton Mifflin.
- Robbins, P. (2007). *Lawn people: How grasses, weeds, and chemicals make us who we are*. Philadelphia: Temple University Press.



HERODOTUS (CA. 484–CA. 425 BC)

Herodotus (born in Halicarnassus, ca. 484 BC; died in Thurii, ca. 425 BC) was a Greek historian and geographer. His value in the history of geography is related essentially to his focus on ethnicity. His hometown had frequent relations with the so-called barbarian world, and that, together with his extensive travels, especially through the lands of the Black Sea and the Mediterranean Sea, contributed to developing his great curiosity about different countries and allowed him to come in contact with various populations, their traditions, and their customs.



His work *The Histories* provides considerable interesting geographic and cultural information, and for this reason, Herodotus has been described as the father of ethnography as well as the father of history. Among the topics dealt with in his writing are the cultures of Persia, Assyria, India, and Arabia; the customs of various and sometimes legendary populations such as the Hyperboreans, the Androphagi, the Budini, and the Melanchlaeni; and the geography of Scythia and Egypt. The label that he gave to the latter country—"the gift of the Nile"—is still famous and was meant to underline the importance the river's course had in the development of Egyptian civilization.

In some cases, as in his account of the Nile, whose sources he believed to be in the Atlas mountains, Herodotus's geographical knowledge was erroneous; moreover, his words sound imaginative and unreliable on many occasions. However, through collected stories and interviews, he succeeded in describing in a very suggestive way those territories beyond which the world was, at the time, imagined to be uninhabited. Thus, for instance, India became the symbol of distance and mystery both from the physical point of view and from the cultural one. He only reached its boundaries, but he wanted to report about the supposed immense quantities of gold that could be found there and its incredible animals, much bigger than those of any other place. He described ceremonies and traditions that he did not know, supported by the idea that in such far-off countries, everything could be possible.

Herodotus's view of the world was based on a sort of ethnocentrism that expressed itself through the processes of analogy and opposition, keeping Greece as a reference. He postulated that his homeland was at the center of the inhabited area of the world and that the areas distant from it were the most different from Greece, from both the environmental and the cultural points of view. He also considered Greece to have the most favorable location and climate. According to him, at the borders of the known inhabited world, people had to face the hazards of cold weather or unbearable heat, but on the other hand, they could sometimes enjoy extraordinary natural riches.

Susanna Servello

See also **Aristotle; Eratosthenes; Hipparchus; Human Geography, History of; Strabo**

Further Readings

- Hartog, F. (1988). *The mirror of Herodotus: The representation of the Other in the writing of history*. Berkeley: University of California Press.
- Vignolo, R. (2002). *Telling wonders: Ethnographic and political discourse in the work of Herodotus*. Ann Arbor: University of Michigan Press.



HETTNER, ALFRED (1859–1941)

Alfred Hettner was a prominent and highly influential German geographer who powerfully shaped the nature of the discipline in the late 19th and early 20th centuries. Greatly influenced by Immanuel Kant, Alexander von Humboldt, and Carl Ritter, Hettner argued that geography consisted of the art of holistic regional description and synthesis, inductively seeking relations among phenomena that other disciplines ignored, particularly those between humans and the environment.

Son of a museum director in Dresden, Hettner grew up in comfortable circumstances. He started his higher education at the University of Halle in 1877. He moved to Bonn a year later and to Strasbourg a year after that. Much of his training was focused on physical geography. In 1897, he became a professor at Tübingen and later at Heidelberg, where he spent the remainder of his career. He placed great emphasis on the importance of fieldwork and undertook extensive journeys throughout Europe, Russia, and South America, emphasizing climatology and geomorphology and publishing books on all these regions. Health problems gradually forced him to abandon fieldwork and confined him to a wheelchair, although he achieved the status of the leading German theoretician in the discipline. His work became increasingly sophisticated theoretically, leading him to move away from Kant and to advocate more relational views of space.



At times, he engaged in sharp polemical debates with his peers. In 1895, Hettner founded and edited the widely read journal *Geographisches Zeitschrift* (Geographic Periodical).

Rather than embracing all the Earth sciences, as previous generations of German geographers maintained, geography for Hettner was the study of why differences among regions appeared and persisted: The core of the discipline was comparative regional analysis. However, he did not hold to a naive empiricism in which geographic regions and facts were simply given but, like Kant, believed them to be constructed through the mental imposition of conceptual order on Earth's surface. The relations between the abstract and the concrete, the general and the specific, representations and reality, always loomed large, in this view. Thus, for him, geography was defined by its methodology, not its content, and he viewed the growing schism between human and physical geography with alarm. His attempt to focus the discipline around regional synthesis should be seen in light of European colonialism more generally and German nation building and expansionism in particular.

In contrast to the increasingly reactionary geopolitics of Friedrich Ratzel and Karl Haushofer, Hettner represented the progressive face of German geography. In this respect, he shared much with his French counterpart Paul Vidal de la Blache. Both men argued against the racism and xenophobia of geopolitics and environmental determinism, emphasizing instead the constitutive role of culture. By the 1930s, the rise of the Nazis put him in an increasingly precarious professional position.

Hettner was also long active in promoting geography in the schools at all levels and wrote several textbooks. His main disciple was Richard Hartshorne, who carried Hettner's Kantian worldview to the United States (but not unchanged in the process) and played a dominant role in the American version of chorology.

Barney Warf

See also Chorology; Empiricism; Hartshorne, Richard; Human Geography, History of; Humboldt, Alexander von; Kant, Immanuel; Regions and Regionalism; Ritter, Carl; Vidal de la Blache, Paul

Further Readings

- Hartshorne, R. (1958). The concept of geography as a science of space, from Kant and Humboldt to Hettner. *Annals of the Association of American Geographers*, 48, 97–108.
- Harvey, F., & Wardenga, U. (2006). Richard Hartshorne's adaptation of Alfred Hettner's system of geography. *Journal of Historical Geography*, 32, 422–440.
- Leighly, J. (1938). Methodologic controversy in nineteenth century German geography. *Annals of the Association of American Geographers*, 28, 238–258.
- Van Cleef, E. (1930). Review: The geographical work of Alfred Hettner. *Geographical Review*, 20, 354–356.



HEURISTIC METHODS IN SPATIAL ANALYSIS

Many problems in spatial analysis involve the search for optimal solutions. For example, it is important to find locations for public health facilities such that the residents in an area can be best served. There are exact methods that can be used to solve these problems. An exact method exhaustively evaluates each possible solution and identifies the best one. A drawback of this type of approach is its complexity. For a large-sized problem, as measured by the number of inputs, the time used by an exact method may exceed the time frame required to solve the problem. The predicament of solving a problem exactly suggests the use of heuristic methods. Different from exact methods, heuristics generally do not guarantee that the optimal solution will be found.

To understand how a heuristic method works, it is helpful to imagine a graph formed by all the solutions to a problem, where each vertex represents a specific solution and a link exists between two vertices if knowing one will lead to the other (see example that follows). Finding the optimal solution in the network requires starting from any vertex and finding the path to the vertex representing the optimal solution. As the graph can be



of a huge size because of the number of vertices (possible solutions) and their connections, it is impractical to exhaustively traverse each path between vertices. A heuristic method often starts from a randomly chosen vertex and tries to go through a particular path by guessing that there is no need to go through other paths. The chosen path, however, does not necessarily lead to the optimal solution, though the literature generally suggests that near-optimal solutions can be found.

Many heuristic methods are developed using a “greedy” mechanism (one that solves problems by finding locally optimum solutions in the search for a global optimum) to improve the initial solution that is typically determined on a random basis. Though different forms of greedy methods exist, they generally follow the same design logic: If a better solution can be found in the neighborhood of the current solution, then the current solution should be replaced by the new one. The process continues until no such replacement can be made. This idea can be illustrated using a solution approach to the p -median problem, where p nodes must be selected in a network of n nodes such that the total distance from each node to its nearest selected node is minimal. An initial solution to the problem can be p random, unique integers ranging between 1 and n . Substituting a selected node with each of the unselected ones results in a neighborhood of the solution. The current solution can be improved if at least one solution in the neighborhood has a smaller total distance. The replacement continues until no solution is better in all the neighborhoods of the p selected nodes.

Greedy heuristic methods are typically designed for specific problems, which makes it difficult for one method to be used to solve other problems. Also, a greedy method is often myopic, meaning that it can be trapped in a local optimal solution. Metaheuristics have been developed with the hope of addressing these issues.

The diverse family of metaheuristics includes methods such as evolutionary algorithms, simulated annealing, ant colony systems, and tabu search. Different from greedy heuristics, these methods may accept solutions that are worse than the current ones. This feature allows the search algorithm to make “mistakes,” especially at the early stage of the iterations. A second characteristic of metaheuristic methods is that they are often

inspired by a natural process. Evolutionary algorithms, for example, are computer programs that simulate evolution and natural selection in biological systems. A third feature of metaheuristic methods is that they can be used to solve a wide range of search problems.

Evolutionary algorithms have been widely used in spatial analysis. An evolutionary algorithm maintains a set of solutions called a *population* that is often randomly initialized. Each solution in the current population has a chance to be used to create the next generation, though solutions considered to be good have high chances. New solutions are generated using a recombination operation that combines the elements of two solutions selected from the current population. A new solution can be further altered by a mutation operation that introduces unexplored elements into the population. This process continues until a predefined condition, say, the maximum number of iterations, is reached. Using a p -median problem (with $p = 5$ and $n = 10$) as an example, a solution can be represented using a string of five integers, such as (1, 2, 6, 7, 8) and (2, 3, 8, 9, 10). Different approaches can be used to recombine these two hypothetical solutions. For example, the two solutions can be rearranged so that the common elements are listed first and the other elements are listed in an ascending order, namely, (2, 8, 1, 6, 7) and (2, 8, 3, 9, 10). Two new solutions can be generated using a random break point in the unshared elements and exchanging the elements between the two solutions. Using a break point between the third and fourth elements yields (2, 8, 1, 9, 10) and (2, 8, 3, 6, 7). A mutation operation can be used to change an element in the second new solution, so that it becomes, for example, (2, 8, 5, 6, 7).

Heuristic methods have their limitations. They may not be desirable if the goal is to find the optimal solution. Practically, the performance of a heuristic method may be sensitive to its parameters, which often need to be fine-tuned. Searching for parameters that lead to satisfactory performance may itself be a difficult problem.

Ningchuan Xiao

See also **Location-Allocation Modeling; Spatial Analysis; Spatial Decision Support Systems; Spatial Optimization Methods**



Further Readings

- Cooper, L. (1964). Heuristic methods for location-allocation problems. *SIAM Review*, 6, 37–53.
- Russell, S., & Norvig, P. (2003). *Artificial intelligence: A modern approach*. Upper Saddle River, NJ: Pearson Education.
- Xiao, N. (2008). A unified conceptual framework for geographical optimization using evolutionary algorithms. *Annals of the Association of American Geographers*, 98, 795–817.



HIGH-PERFORMANCE COMPUTING

High-performance computing (HPC) is an approach for handling computationally demanding tasks that are beyond the computing capabilities of a single processor. The complexity of geographic problems creates an urgent need for high-performance computing. High-performance geocomputation is a new frontier that combines expertise from geocomputation (the art and science of solving complex spatial problems with computers) and HPC.

A widely acknowledged measure for high performance is floating point operations per second (FLOPS). High-performance computers have the computing capabilities of teraFLOPS (1×10^{12} FLOPS) or even petaFLOPS (1×10^{15} FLOPS). Currently, parallel computing is the mainstream of HPC. Parallel processing aims to improve computational performance by executing the same task with multiple processors simultaneously. A more recent parallel-computing trend is cluster computing, which takes advantage of commercial, off-the-shelf components. Cluster computing is the most popular type of parallel computing for users who cannot afford the high cost of building parallel-computing systems. A famous example is the Beowulf-style cluster, which builds low-cost parallel-processing systems with PC and Ethernet networks. The common software programming models used in clusters are message passing interface and parallel virtual machine. Beyond cluster computing, a much more ambitious idea—one

that is leading the development of grid computing—is to use spare computing resources all over the world by means of a decentralized management strategy.

Early research on high-performance geocomputation involved migrating existing serial algorithms to a parallel-processing framework and experimenting with parallel spatial data analysis including simple map analysis operations, terrain analysis, network analysis, and spatial autocorrelation. Since then, grid technologies have been rapidly developing to better integrate large-scale computational resources and services. The development of grid systems is quickly migrating toward SOA (service-oriented architecture), which promises a suitable platform for implementing geographic information system (GIS) services and improving their performance and integration. However, most grid tools today provide only general-purpose protocols that need to be modified to fit the special needs of geospatial applications.

A number of current GIS grid projects share a similar technical foundation while addressing different problems. These projects include the GEON (the Geosciences Network: Building Cyberinfrastructure for the Geosciences), ESG (Earth System Grid), and GISolve. The Globus Toolkit is currently the de facto grid middleware system that nearly every project uses as the supporting tool for grid-based applications to interact with grid resources.

The advantages of combining HPC technologies with geocomputation include the speed-up of computational time, thus enabling the near-real-time simulation and analysis of large data sets. Despite the advantages, the use of HPC in geocomputation and geographic analysis is still rare. The lack of easy-to-follow examples, the requirement of considerable computer science skills to access and effectively use HPC resources, and the seemingly high cost of transition from traditional- to parallel-programming paradigms discourage geographers from adopting HPC. To promote the use of high-performance geocomputation, more successful demonstrations are needed to provide opportunities for learning. Additionally, the cost of building and accessing HPC resources has to be lowered. The installation and management of HPC tools



need to be simplified to remove geographers' reservations about adopting high-performance geocomputation.

Tong Zhang and Piotr Jankowski

See also **Geocomputation**; **GIScience**

Further Readings

- Armstrong, M. P. (2000). Geography and computational science. *Annals of the Association of American Geographers*, 90, 146–156.
- Openshaw, S., & Turton, I. (2000). *High performance computing and the art of parallel programming*. London: Routledge.
- Saalfeld, A. (2000). Complexity and intractability: Limitations to implementation in analytical cartography. *Cartography and Geographic Information Science*, 27, 239–250.



HIGH TECHNOLOGY

High technology refers to the applied use of sophisticated knowledge and is commonly associated with scientific and engineering innovations. High-technology industries are characterized by the broad application of innovations to a multiplicity of intermediate and end products as well as both process and product innovations.

This broad application has led to the common characterization of high-technology industries as “enabling” industries. They contribute to innovations in traditional industries and form the technical basis for emerging industries. High-technology firms provide devices and processes that are applied to a range of industrial contexts, including new hi-tech consumer end products (e.g., smart phones, digital cameras) and intermediate products for traditional industries (e.g., geographic information systems [GIS] in automobiles). High-technology industries include biotechnology, nanotechnology, information and communication technologies, and a range of material sciences (e.g., advanced polymers).

High technology is often associated with important intermediate products and process innovations, including software and microelectronics. Much of the focus of high-technology industries is on the research and development phase of production, although there are high-technology end producers. Consequently, the central inputs and locational factors for high technology are human and social capital and research and development capacity. Evidence indicates that high-technology firms tend to locate close to pools of skilled labor and close to each other.

A distinctive characteristic of high-technology industries is their extensive potential markets with (relatively) small production footprints. High-technology industries are often measured by significant patent rates and venture capital investment. These metrics are also applied to high-technology industrial districts and innovative regions. However, the measurements are imprecise. For example, the auto industry and agricultural industries have extensive patents and large research and development divisions but are generally considered to be traditional industries. Indeed, a discrete definition of “high-technology” firms, occupations, industries, or regions is complicated by their enabling role across multiple supply chains. Accordingly, high-technology occupations and industries are loosely understood as high skill, high wage, and high value-added.

The geographic distribution of high technology is a significant area of research, theory, and policy practice. Geographers have produced numerous studies of high-technology industrial districts such as Silicon Valley and Boston, as well as studies of the location patterns of industries such as microelectronics, biotechnology, and photonics. Simultaneously, theories about the development of high-technology regions have emerged that include learning regions, regional innovation systems, the “creative class,” the spatial implications of tacit and codified knowledge, and the factors that create an “innovative milieu.”

These theories and the body of empirical work that has grown around them have informed an emerging set of public policies aimed at technology-led economic development strategies. These policies include public investment in



Aerial view of Silicon Valley in Northern California

Source: Xin Zhu/iStockphoto.

targeted science and technology policies, expansion of applied university research, technology transfer programs between universities and industries, and investment in science parks, research centers, and high-technology incubators. The coordination of these policy strategies has become increasingly conscious of the spatial distribution of high-technology activities and is increasingly organized into and around regional innovation systems in both industrialized and industrializing countries.

Jennifer Clark

See also **Agglomeration Economies; Clusters; Electronics Industry, Geography of; Flexible Production; Industrial Districts; Innovation, Geography of; Technological Change, Geography of**

Further Readings

- Christopherson, S., & Clark, J. (2007). *Remaking regional economies: Power, labor, and firm strategies in the knowledge economy*. New York: Routledge.
- Gertler, M., & Wolfe, D. (2002). *Innovation and social learning: Institutional adaptation in an era of technological change*. New York: Palgrave Macmillan.
- Moulaert, F., & Sekia, F. (2003). Territorial innovation models: A critical survey. *Regional Studies*, 37(3), 289–302.
- Saxenian, A. (1994). *Regional advantage: Culture and competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
- Simmie, J. (2005). Innovations and space: A critical review of the literature. *Regional Studies*, 39(6), 789–804.



HIPPARCHUS (CA. 190–CA. 120 BC)

Hipparchus (born in Nicaea) was a Greek geographer and cartographer who was also considered to be one of the greatest astronomers of ancient times. Even though almost all his writings have been lost, his theories have been handed down by Ptolemy and Pliny the Elder.

Hipparchus thought that astronomical observations and methods were fundamental for geographic studies. He was also critical of his predecessor Eratosthenes and argued that the geographer of Cyrene developed his theories without the support of mathematical calculations. His attention also focused on the use of instruments such as the dioptra (which measures the angles of light), which enabled him to estimate the size of the sun and the moon and their distance from Earth. Through the use of a gnomon (part of the sundial that casts the sun's shadow), Hipparchus could also determine the latitude of a place, and he estimated its longitude by observing the beginning and the ending of solar eclipses from different places. He calculated the length of the equator to be 39,960 kilometers. Hipparchus was said to have accurately estimated the inclination of the plane of the ecliptic (the intersection of the celestial sphere with the plane of the mean orbit of Earth), and he discovered the precession of the equinoxes (the fact that they move westward along the ecliptic). Finally, he is remembered for having almost exactly calculated the duration of the solar year.

In the field of cartography, Hipparchus was interested in finding a solution to the representation of a spherical surface on a plane. He dedicated himself to the study of the *stereographic projection*, a particular way of mapping that was probably already known to the Egyptians and that allows the depiction of the curved surface of Earth on a flat map. In cartography, it is used to map the area of the poles, with the result that meridians look like rays originating from a point and parallels look like circles centered at the origin. This type of projection has three essential properties: It is smooth, and conformal, but it does not preserve areas. The fact that it respects angles was extremely useful for navigators in ancient times.

On the basis of sailors' descriptions of the tides along the Gibraltarian, Spanish, and French Atlantic coasts and of those occurring along the Eastern Asian coastline, and taking into account the observations of the Babylonian astronomer Seleucus of Seleucia, Hipparchus deduced the existence of a vast continent that separated the Indian Ocean from the Atlantic.

Susanna Servello

See also [Aristotle](#); [Cartography, History of](#); [Eratosthenes](#); [Herodotus](#); [Human Geography, History of](#); [Knowledge Spillovers](#)

Further Readings

Hipparchus. (1968). *The geographical fragments of Hipparchus* (D. R. Dicks, Ed.). London: Athlone Press.



HISTORICAL GEOGRAPHY

Historical geography is the subfield of the discipline that examines geographies of the past, including their relations with those of the present. In his treatise on historical geography, Andrew Hill Clark argues that the past is at least implied, if not explicit, in all geographic analyses. Clark claims that the concepts and methods of historical geography are applicable to all branches of geography, and therefore, historical geography should not be thought of as a distinct field of geography but more as a methodology, as a way of seeing geographically by focusing on space and time. This entry discusses the development of historical geography from the 1890s to the present, including the emergence of a new critical historical geography, beginning in the 1970s. It then examines the practice of historical geography and its relevance as a subfield today.

Like the field as a whole, the practice and role of historical geography in America were transformed by the four major periods of modern geographic thought. The environmental determinism of the early 20th century used historical geography to



create bigoted, unscientific generalizations about how climate influences society. By the 1920s, historical geography held a central position in American geography, as geography's regional approach repudiated environmental determinism. Historical geography in this period focused on regional narratives that largely examined various aspects of material culture and settlement patterns. The 1950s and 1960s witnessed the quantitative revolution, and historical geography was pushed to the periphery. Finally, influenced by the critical geographies of the 1970s, historical geographies focused on social theory, reflecting the cultural turn in geography, and asked critical questions about culture and identity, economics, politics, scale, and the environment.

Despite these transformations, two things have remained constant throughout each period: (1) the historical geography methodology and its focus on the historical record, primary data sources, and field observations and (2) relevance. As other subfields have increasingly recognized the importance of a historical perspective in answering geographic questions, the need for historical geography as a distinct subfield has been greatly reduced.

Early Historical Geography

From the 1890s to the 1920s, the first major period of modern geographic thought emphasized the role of the physical environment in determining human behavior and shaping settlement patterns. Geographers such as Ellen Churchill Semple and Ellsworth Huntington, adhering to the theory of environmental determinism, used their interpretations of the historical record to show how environmental factors such as climate determined social actions. In doing so, they constructed a social Darwinist narrative that theorized that Northern Europeans possessed a superior intellect and ability due to the temperate climate of the region, while people of color, living in the tropics, were lazy due to the intense heat of the equatorial region. Historical geography, like the field of geography as a whole, began to move away from the theories of environmental determinism in the 1920s, as the regional approach took hold.

Regional geography focused on descriptive, regional-scale narratives concerning the history

of places and regions. These narratives focused on the long-term transformations of a region. Understanding these regional transformations required an understanding of history. Andrew Hill Clark believed that a well-trained historical geographer was simply a well-trained geographer, and a well-trained geographer was a regional specialist who examined changes in the landscape. Carl Sauer and the Berkeley School geographers relied on the historical record to analyze the cultural processes responsible for shaping landscapes. Derwent Whittlesey's theory of sequent occupance influenced American historical geography by examining the historical record and the built environment for changes in the type, form, and density of settlement patterns in an area. To Whittlesey, true historical geography was chronological in arrangement but spatial in treatment. Fundamentally idiographic, regional and historical geography, focusing on areal differentiation and the unique character of regions, was perceived as descriptive, lacking theory, and unscientific. Critics of regional geography emphasized a systematic, nomothetic approach to geography as a spatial science.

The 1950s were a turning point for geography as it transformed into a spatial science. Inspired by the quantitative revolution, geographers took a more abstract and theoretical approach to space that used modeling and statistics to make geography more scientific. While historical geography had been central to American geography, the focus on positivism began to push the historical perspective to the periphery of the field. In 1953, the Hartshorne-Schaefer debate highlighted the difficulty geographers had in determining the future and of geography and its methodology. Detractors of regional geography, and therefore historical geography, claimed that this type of geography was unscientific and of no practical value. The status of historical geography in American geography declined, and it occupied an increasingly peripheralized position, but by the 1970s, the historical perspective experienced a renaissance with the rise of critical geography.

The New Critical Historical Geography

By the 1970s, a more critical geography was burgeoning. Critical historical geography was



more than the collection of historical facts and simple description exemplified by the older regional approach. Instead, critical historical geography examined the pressing issues of spatial scale, the social production of landscapes, the social construction of nature, and social identity, including race, class, gender, and sexual identity. Historical geography began asking critical questions about culture, economics, politics, and past and present spatial practices. This critical historical geography accommodated a variety of methodological and scalar approaches and was influenced by three strains of critical geographic thought—humanism, historical materialism, and postmodernism.

Developed as a reaction to the systematic scientific approaches of the quantitative revolution, humanistic geographers believed that human experiences could not be reduced to positivist abstractions. Humanistic geography rejected the idea of geography as a spatial science. Instead, it focused on a more subjective geography that examined people's experiences in place. By examining the everyday experiences of place, some humanistic geographers wrote historical geographies of ordinary landscapes, since the landscape is an accumulation of past cultural meanings. Other humanistic geographers attempted to bring the use of historiography back. An example is Donald Meinig's ambitious *Shaping of America* series. In this four-volume sequence, Meinig explores 500 years of historical-geographical transformations that helped shape America by examining the spatial processes of urban growth and expansion, the growth of transportation networks, migration and immigration, globalization, and technological innovations.

Continuing to provide critical historical perspectives, historical geographers turned to Marxist geography, which employs the theories and philosophies of Marxism to examine sociospatial relations under capitalism. Under Marxist geography, historical geography used historical materialism to explain the development of the spatial patterns and processes in society. Unlike the older historical geographies, which described the changes in settlement patterns and land use, historical materialist geography examined the sociospatial relations of the production of space, including the roles of class, power, conflict, and

the state. This approach to historical geography examined the social struggles and exploitation that underlie the sociospatial organization of the landscape. In *The Lie of the Land*, Don Mitchell examines the labor relations behind the making of the California agricultural landscape. Unlike the Berkeley School geographers, who described the rural landscapes of rural California, Mitchell used a Marxist approach to show that behind the pastoral images of California lie the social struggles of an exploited invisible army of labor working to produce those idyllic qualities represented in images of the Californian landscape. Inspired by social theory, historical materialist geographies clearly have a moral and political agenda to expose the exploitation and uneven development under capitalism. As part of his historical materialist reworking of geography, David Harvey proposed a historical geography that employs a dual methodological approach that maintains scientific rigor while at the same time being committed to analyze and understand the powerful and conflicting processes of social reproduction. Social theory would continue to influence the development of historical geography as postmodernism and the cultural turn shifted the focus to questions of representation, identity, power relations, and meaning.

By the 1980s, critical historical geography began presenting an eclectic mix of geographies fueled in large part by the cultural turn and postmodernism. Inspired by critical literary theory, this "new" cultural geography relied on textual analysis of the landscape to read visible signs and symbols in an attempt to understand the cultural meanings, ideologies, and values inherent in the landscape. This new phase of historical geography rejected the universal truths of modernity. Instead, it recognized the multiple viewpoints, discourses, and voices that are associated with specific places, times, and contexts. Shaped by the new cultural geography and its focus on representation, this phase of historical geography began to recognize that the gaze of geographers is filtered through the lenses of culture, language, race, gender, class, and sexual identity. Historical geography began to address the historical aspects of power relations associated with forms of social identity by examining the production of space as the result of social struggles. Of particular importance to the growth



of this new phase of historical geography was the connection between feminist geography and the historical record.

Feminist geography examines sociospatial relations and the geographies of difference with reference to uneven gender relations, the social construction of gender, space and place, geographies of sexual identity, and children's geographies. In combining the fields of feminist geography with historical geography, feminist geographers challenge the traditional, antiquarian historical methodology as essentially patriarchal since it erases the role of women and other underrepresented groups from the narrative. The rigorous archival work and field observation of historical geography created the distance necessary to retain the appearance of objectivity. But as feminist geographers point out, no study can be totally objective due to the biases that the researcher brings to each study. In accepting the traditional methods of historical geography as well as the identities and roles of the past, historical geographers reify the notion of difference. In addressing the historical geography of difference, Mona Domosh calls for a reformulation of historical geography methods that are sensitive to the gendered, racial, classed, and sexual constructions of space, place and landscape. This new phase employed a critical historical-geographical way of seeing the past to analyze the cultural contexts of place.

The Practice of Historical Geography

In his assessment of the state of historical geography, Donald Meinig argued that historical geography was essential to the health of the field of geography. He also maintained that as a subfield, historical geography was not simply a body of facts or theories just waiting to be applied. Instead, he claimed, historical geography is a perspective, a way of seeing and thinking. Central to this perspective is the reliance on the historical record and primary data sources, including textual data in archives and visual data gained through field observations. Investigating the archives, historical geographers face a flood of primary documents. While historical geographers may uncover statistical or cartographic documents, the archives are full of written documents

including, but not limited to, letters, diaries, journals, newspapers, reports, city records, company records, planning documents, and meeting minutes. Cole Harris argued that the archival scholarship that is essential to historical geography is an evolving interaction between the researcher and past voices embedded in the documents. The practice of historical geography relies on the triangulation of data and methodologies (e.g., visual data from on-the-ground field observation, data from a variety of archival sources, and ethnographic data from oral histories).

The use of narrative is essential to historical geography. Scholars in a variety of disciplines rely on the use of narrative, but the placing of theory into the narrative is what sets historical geography apart from other disciplines. In comparing historical geography and history, Don Mitchell argues that historical geography, unlike history, uses the historical record to develop a theoretical argument through which to tell a story. Historical geography needs to realize the importance of its theoretical perspectives but not at the expense of empirical analysis and historiography. In *Capital's Utopia*, Anne Mosher blends historiography with a theoretical argument about the industrial restructuring of the American steel industry in the late 19th century. Mosher provides more than a descriptive historical geography of place; she combines historical geography, labor history, and urban design to show how the social production of space in the model industrial town emphasized the social control of the worker. For historical geography to remain a relevant subfield of geography, it needs to continue to emphasize its unique perspective by continuing to present theoretical arguments and narratives based on conscientious examination and critical interpretation of primary documents.

Relevance

As a subfield, historical geography is essential to the field of geography. In describing the relevance of historical geography, Donald Meinig argued that any understanding of place required historical understanding. He maintained that this understanding should not be used merely as a preface to, or simply as background for, a study. Instead, this historical understanding should be seen as a



thoroughly researched study of the cultural, economic, political, or environmental contexts of places. Despite its importance as a subfield of geography, historical geography is once again facing the question of relevance.

Since the 1950s and the quantitative revolution, historical geography has repeatedly had to prove its relevance. As geography became a positivist, nomothetic spatial science, historical geography was pushed from its central role to the periphery due to its connections with a descriptive, idiographic regional geography. The questions of relevance now facing historical geography stem mainly from the general blurring of disciplinary boundaries in the humanities and social sciences and a push by university administrators for more practical, marketable, and relevant skills. The methods of historical geography make it a useful tool in other subfields and disciplines. The results of the overlap with a variety of fields, including cultural geography and environmental history, are geographies with a historical focus. With this blurring of disciplinary boundaries, studies in cultural geography that focus on cultural practices and hegemony may use history in a few paragraphs that provide background or context but may not be theoretically informed historical geographies. These cultural studies, while theoretical, do not fully engage with the historical record to develop the narrative. Environmental history, on the other hand, has the historical record at its core. Adding a geographic dimension to this historical approach to nature produces theoretically informed historical geographies about human-environment relations. The question of relevance may be a reflection of the current state of the academy, which emphasizes the profitability, productivity, and marketability of useful and practical areas of study. But the historical perspective will always be present in geography, and by publishing in journals such as *Historical Geography* and the *Journal of Historical Geography*, historical geographers can continue to raise the profile of historical geography within the field as a whole. As the historical perspective remains central to the study of geography, historical geography will continue to be essential to the intellectual vitality of geography.

Phil Birge-Liberman

See also Berkeley School; Cartography, History of; Clark, Andrew; Cultural Geography; Darby, Henry Clifford; Environmental Determinism; Environmental History; Feminist Geographies; Historicism; Human Geography, History of; Humanistic Geography; Marxism, Geography and; Meinig, Donald; Mitchell, Don; Palimpsest; Quantitative Revolution; Regions and Regionalism; Sauer, Carl; Sequent Occupance; Social Geography; Whittlesey, Derwent

Further Readings

- Clark, A. (1954). Historical geography. In P. James & C. Jones (Eds.), *American geography: Inventory and prospect* (pp. 71–105). Syracuse, NY: Syracuse University Press.
- Domosh, M. (1997). With “stout boots and a stout heart”: Historical methodology and feminist geography. In J. P. Jones III, H. Nast, & S. Roberts (Eds.), *Thresholds in feminist geography: Difference, methodology, and representation* (pp. 225–237). Lanham, MD: Rowman & Littlefield.
- Harris, C. (1978). The historical mind and the practice of geography. In D. Ley & M. Samuels (Eds.), *Humanistic geography: Prospect and problems* (pp. 123–137). Chicago: Maaroufa Press.
- Harris, C. (2001). Archival fieldwork. *Geographical Review*, 91, 328–334.
- Harvey, D. (1984). On the history and present condition of geography: An historical materialist manifesto. *The Professional Geographer*, 36, 1–10.
- Holdsworth, D. (1997). Landscapes and archives as texts. In P. Groth & T. Bressi (Eds.), *Understanding ordinary landscapes* (pp. 44–55). New Haven, CT: Yale University Press.
- Meinig, D. (1979). *The interpretation of ordinary landscape: Geographical essays*. New York: Oxford University Press.
- Meinig, D. (1988, 1995, 2000, 2004). *The shaping of America: A geographical perspective on 500 years of history* (4 vols.). New Haven, CT: Yale University Press.
- Meinig, D. (1989). The historical geography imperative. *Annals of the Association of American Geographers*, 79, 79–87.



- Mitchell, D. (1996). *The lie of the land: Migrant workers and the California landscape*. Minneapolis: University of Minnesota Press.
- Mosher, A. (2004). *Capital's utopia: Vandergrift, Pennsylvania, 1855–1916*. Baltimore: Johns Hopkins University Press.
- Sauer, C. (1941). Foreword to historical geography. *Annals of the Association of American Geographers*, 31, 1–24.
- Whittlesey, D. (1945). The horizon of geography. *Annals of the Association of American Geographers*, 35, 1–36.



HISTORICISM

Historicism is the view that privileges time over space in social analysis. Some aspects of this view may be traced to the Christian eschatology of the medieval era and its linearization of historical time; however, in many respects, this notion—still implicit in much of social theory—had its origins in the 19th century. As the technological triumphs of the steamship and railroad relegated space to the background through massive time-space compression, the social sciences accordingly came to emphasize historicist approaches in which time was synonymous with growth, progress, change, and novelty. Historicism consists of a despatialized consciousness in which geography figures weakly or not at all, or, as Soja (1993) defines it, as “an overdeveloped historical contextualization of social life and social theory that actively submerges and peripheralizes the geographical or spatial imagination” (p. 140). Thus, Michel Foucault held that with the rise of modernity, time became equated discursively with change and fecundity, while space was relegated to the passive and static, a distinction that rests, of course, on an artificial and analytically misleading distinction between the two dimensions.

A central part of this process involved the birth of modern history as an account framed in linear, not cyclical, time (which was the norm in many societies), that is, by portraying time as an inevitable sequence from the past to the present to the future. Typically, historicist thought linearized

time and marginalized space by positing the existence of temporal “stages” of development, anticipating modernization theory by more than a century. Historicism tended to portray the past as a progressive ascent from savagery to civilization, a trend made most explicit in British Whiggish accounts of history. This maneuver robbed the understanding of social change of any sense of contingency, framing the past as a train of events leading inevitably to the present. For the French utopian thinker Condorcet, for example, there were 10 distinct periods ranging from savagery to rule by science. Reading progress into the future, historians such as Herbert Spencer tended to portray history as an inexorable linear movement from simplicity to complexity, from primitiveness to civilization, from darkness to light.

In the same vein, historicists such as Georg Hegel, Karl Marx, and Arnold Toynbee offered sweeping teleological accounts of world history that paid little attention to space, human consciousness, or the contingency of social life. In his formulation, for example, Hegel transformed the ancient doctrine of perpetual change into a doctrine of the development of rational consciousness. Time, in this view, is not simply a measure of change but is synonymous with change, a view that became widely popular in 19th-century historical scholarship. Hegel's work turned attention from eternal Platonic ideals to the concrete specifics of historical circumstances, even if the causal motor he attributed to this, the transcendent world spirit of reason, was itself profoundly Platonic in inspiration. Hegel specified three phases in history: (1) despotisms, in which very few were free (when the world *geist* was centered on the Middle East); (2) oligarchies, in which some were free (when the *geist* centered on Asia); and (3) democracies, in which most were free (when the *geist* had shifted to Europe). His work valorized the nation-state as the embodiment of the world spirit, culminating in the apex of Prussia. Marx, too, engaged in this practice by categorizing the historical record in a series of modes of production (slavery, feudalism, capitalism, socialism) that unfolded in the strict, unyielding course of history. Like other Enlightenment intellectuals, Marx, too, stressed the progressive character of history. This notion deeply influenced many historians, especially German historians, in the late



19th and early 20th centuries and had linkages to related schools of thought such as diffusionism.

Social theory of the 19th century also drew heavily on Darwinian evolution for inspiration and legitimation, biologizing social relations and thus denying their contingency. The original theory of evolution as contingent and open-ended was erroneously usurped as a means of legitimating the notion of “progress” in the history of life, a simplistic, linear view of phyletic gradualism that was challenged in the 20th century. Spencer’s corruption of Darwinian selection—“survival of the fittest” was his phrase, not Darwin’s—drew heavily on modernist notions of progress and dressed historicism in a veil of pseudoscience. In 19th-century social theory, no distinction was made between “evolution” and “progress.” This line of thought persisted until the structuralism of the early 20th century jettisoned the synchronic in pursuit of universally ascribed atemporal structures.

Likewise, Enlightenment geographic thought, Occidentalist and Orientalist to the core, imagined a new, ostensibly universal geography with Europe positioned, naturally, in the middle, a project central to the works of Kant, Toynbee, and others. This task was accomplished by the deployment of linear stages representing universal historical time, in which Europe, naturally, represented the most advanced stage and distance from Europe testified to the nature of earlier, more primitive stages. Nineteenth-century textbook portrayals of the globe framed the Western geographical imagination around a series of continents, typically conflated with simplistic notions of race, that were hierarchically organized in terms of their alleged degree of temporal progress and, thus, their similarity to European and North American white nations. This schema gained respectability through its appeal to various forms of social Darwinism and environmental determinism. In this way did historicism eclipse space in the service of imperial thought. *Beyond Europe was before Europe*, a theme articulated over and over again in modernization theory and its current neoliberal variants.

In the 20th century, critics of historicism, for example, the philosopher Karl Popper, in his famous book *The Poverty of Historicism*, took the doctrine to task for its assumption that sufficient understanding of historical patterns and rhythms

led to the ability to predict future events. This critique reflected the growing emphasis on contingency that increasingly permeated social thought and on the rejection of absolute “laws” of development and teleological views more generally. Nonetheless, elements of historicism continued to haunt doctrines such as modernization theory.

Post-positivist geography, which has aggressively reinserted space into social theory, has gone a great way toward overcoming the legacy of historicism. In this reading, the spatial cannot be reduced to an afterthought of the temporal, for all phenomena are necessarily both in nature. Simultaneously, as in Foucauldian readings that stress the primacy of social praxis, space and time are held to be deeply political, always tied up with existing relations of power. In this light, social changes are always contingent and can pursue a variety of trajectories over space.

Barney Warf

See also Eurocentrism; Geographical Imagination; Human Geography, History of; Orientalism

Further Readings

- Hamilton, P. (2003). *Historicism*. London: Routledge.
- Massey, D. (2005). *For space*. London: Sage.
- Soja, E. (1993). Postmodern geographies and the critique of historicism. In J. Jones, W. Natter, & T. Schatzki (Eds.), *Postmodern contentions* (pp. 113–136). New York: Guilford Press.



HISTORIC PRESERVATION

Historic preservation is the specialized, interdisciplinary study and treatment of historically significant movable and immovable objects, including landscapes. This term is used only in the United States; other countries prefer the word *conservation* to *preservation* and contextualize the meaning, as in such terms as *urban conservation* or *building conservation*. The chief concerns of historic preservation are to establish why certain



Historic row houses line a street on Capitol Hill in Washington, D.C.

Source: Christopher Messer/iStockphoto.

older places have acquired value over time and to identify methods that retain the historical integrity of building and landscape fabric. The overall goal is to ensure that changes to these places are made in a manner that does not impair their historical authenticity.

Within the discipline of geography, historic preservation is primarily associated with cultural landscapes, material culture, and the work of cultural geographers such as Henry Glassie, Fred Kniffen, and J. B. Jackson and secondarily with perception, behavior, place attachment, and the work of humanistic geographers such as David Lowenthal, Yi-Fu Tuan, and David Seamon. Geography's contribution to historic preservation is typically restricted to helping define significance;

it has not yet been a major player in discussions of policy, interventions, and management. Historic preservation therefore remains largely dominated by built environment disciplines such as architecture, landscape architecture, and planning. Since the 1980s, historic preservation has been recognized as a discipline in its own right, with unique theoretical and epistemological foundations, novel research methods, and its own university degree programs and practitioners.

Economics, sustainability, and place making are typical arguments for engaging in historic preservation. Examples include the National Trust for Historic Preservation's highly successful "Main Street" program for downtown revitalization, the addition of pro-preservation measures in



“green” building standards such as LEED 3.0 (Leadership in Energy and Environmental Design) that consider energy used in production and construction, and the connection between preservation, sense of place, and well-being. The traditional approach of treating places and buildings as museums is still evident but increasingly unsustainable in economic as well as cultural terms.

In the United States, the National Park Service’s National Register of Historic Places nomination is the standard used to define historical significance, while the Secretary of the Interior’s Standards for the Treatment of Historic Properties prescribes specific treatments for the “preservation,” “restoration,” “rehabilitation,” and “reconstruction” of buildings and landscapes. Although these guidelines are only required for federal interventions, they have essentially become universal in their application due to their widespread adoption by local and state governments.

In recent years, there has been a shift toward the importance of sociocultural values in defining historical significance, but these ideas are yet to affect the day-to-day practice of historic preservation and are entirely absent from the criteria found in the National Register nomination. Critics charge that historic preservation remains a positivistic endeavor more concerned with the acquisition of “facts” than with fostering a sense of place and human flourishing.

Jeremy Wells

See also **Architecture and Geography; Conservation; Cultural Landscape; Environmental Impact Assessment; Green Building; Jackson, John Brinckerhoff; Landscape Architecture; Landscape Interpretation; Sense of Place; Zoning**

Further Readings

- Riesenweber, J. (2008). Landscape preservation and cultural geography. In R. Longstreth (Ed.), *Cultural landscapes: Balancing nature and heritage in preservation practice* (pp. 23–34). Minneapolis: University of Minnesota Press.
- Tyler, N. (2000). *Historic preservation: An introduction to its history, principles, and practice*. New York: W. W. Norton.



HISTORY OF GEOGRAPHY

See **Cartography, History of; GIS, History of; Human Geography, History of; Physical Geography, History of**



HIV/AIDS, GEOGRAPHY OF

The virus that causes acquired immune deficiency syndrome (AIDS), or acquired immunodeficiency syndrome, was first identified by scientists in 1983. Since then, the geographic origins of the virus have been hotly debated in the scholarly and secular communities. Recent studies by genetic scientists have indicated that HIV-1, the more virulent form of the virus that causes AIDS, can be traced to a closely related strain of virus, called *simian immunodeficiency virus* (SIV), that infects a subspecies of chimpanzees in Central Africa. It also happens that people in this region hunt chimpanzees for bush meat, leading scientists to believe that the virus may have passed from the blood of chimpanzees into humans through superficial wounds. Indeed, many believe that the virus has been prevalent among humans in remote, inaccessible jungle areas since the 1920s. However, in today’s globalized and highly interconnected world, the virus somehow managed to escape from this region into the wider world. There are two forms of this virus, HIV-1 and HIV-2. HIV-2 is restricted to the Guinea Highlands of West Africa, while HIV-1 accounts for the majority of AIDS cases throughout the world.

UNAIDS (Joint United Nations Programme on HIV/AIDS) estimates indicate that the number of persons living with HIV worldwide was 33.2 million in 2007. However as shown in Figure 1, sub-Saharan Africa continues to be the region by far most affected by the AIDS pandemic. In 2007, out of the 33.2 million people infected with HIV, 22.5 million were in sub-Saharan Africa. An additional 1.7 million people were infected with HIV during that year. During the same year, over 1.6 million people were estimated to have died from this syndrome in Africa. It is estimated that more than two out of three (68%) adults and

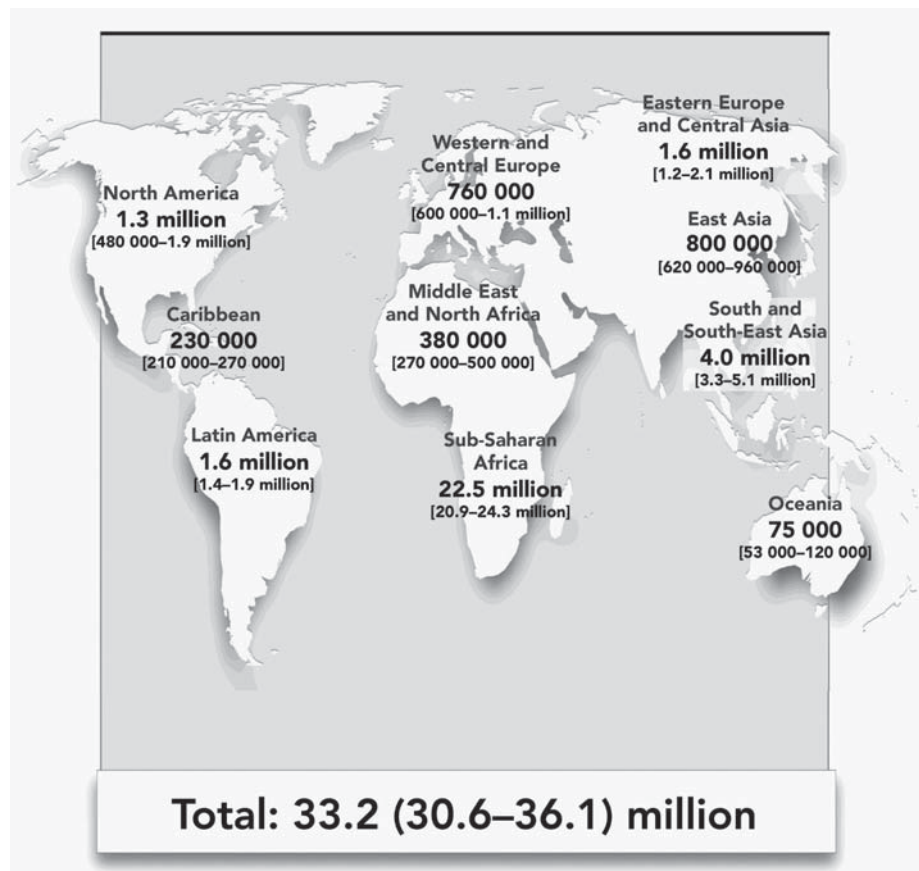


Figure 1 Adults and children estimated to be living with HIV in 2007

Sources: Joint United Nations Programme on HIV/AIDS (UNAIDS) & World Health Organization (WHO). (2007). *2007 AIDS epidemic update* (p. 39). Geneva: UNAIDS. Retrieved January 20, 2010, from the UNAIDS Web site: http://data.unaids.org/pub/EPISlides/2007/2007_epiupdate_en.pdf. Reprinted by permission of UNAIDS.

nearly 90% of children infected with HIV live in this region, and more than three in four (76%) AIDS deaths in 2007 occurred there, illustrating the unmet need for antiretroviral drugs. In the 10 worst-affected countries, all of them in Eastern and Southern Africa, rates of HIV infection range from 16% to over 40%.

With reference to the geographic spread of the epidemic in Africa, John Iliffe, in his 2006 book titled *The African AIDS Epidemic*, masterfully synthesizes the plethora of studies that have been conducted from the 1980s to the present, tracing the geographic beginnings and spread of AIDS throughout the continent. Iliffe weaves together a fascinating story that attempts to explain the

origins, nature, and spread of the virus from its detection in the early 1980s to its current progression throughout the continent. He places the origins of the disease somewhere in present-day Central Africa, from where it spread slowly to East Africa. Several other studies that have examined in greater detail the spatial-temporal trends of AIDS in Africa during the past 25 years show an escalating epidemic in Southern Africa and signs of a stabilizing or declining epidemic in East Africa. At present, Southern Africa remains the worst affected region in the world, with HIV prevalence rates in excess of 25%. Data in these detailed studies lend credence to the saying that “there is not just one epidemic in Africa, but



many.” West Africa and North Africa have consistently experienced lower rates than the other regions, although in some countries in West Africa, the epidemic is creeping up. Even within the other high-risk regions in Central, Eastern, and Southern Africa, some areas have lower rates than others. Thus, it is not just between countries that there are differences in the prevalence of HIV/AIDS, but there are differences between different areas and different groups of people within the same country. In spite of the spatial variations, the epidemic in Africa is largely driven by unsafe sex between men and women.

Outside Africa, rates of infection are generally low, but the numbers of infected people have been recently increasing dramatically in South and southeast Asia, notably in India and China. However, national HIV prevalence rates vary greatly between different countries. While the epidemics in Cambodia, Myanmar, and Thailand all show declines in HIV prevalence, those in Indonesia (especially in the Papua province) and Vietnam are growing. Although the proportion of people living with HIV in India is lower than previously estimated, its epidemic continues to affect large numbers of people (about 2.5 million people). In Asia, the HIV infections have been driven by both injecting drugs with contaminated equipment and unprotected sex. Overall in Asia, an estimated 4.9 million people were living with HIV in 2007, including the 440,000 people who became newly infected during that year. Approximately 300,000 died from AIDS-related illnesses in 2007 in Asia.

When the disease was first identified in North America and Europe, it was first thought to be a disease of homosexual men. In the early years, over 90% of cases were diagnosed in homosexual men. As a result, in the 1980s, HIV/AIDS was often described as “the gay plague.” As such, the early educational campaigns on safe sex targeted gay men. These have largely been successful in reducing the transmission rate among this population in North America and Europe. While the number of new infections of HIV/AIDS among homosexual individuals in North America is on the decline, the disease is now increasingly being spread through unprotected heterosexual sex. Recent UNAIDS estimates indicate that the total number of persons living with HIV is on the increase in North America and Western Europe.

This increase is due mainly to the life-prolonging effects of antiretroviral therapy and an increase in the number of new HIV diagnoses in Western Europe since 2002, combined with a relatively stable number of new HIV infections each year in North America. Overall, approximately 2.1 million people in North America and in Western and Central Europe were living with HIV in 2007, including the 78,000 who acquired HIV during that year. In the context of widespread access to effective antiretroviral treatment, comparatively few people (about 32,000) died of AIDS in these regions in 2007.

With the exception of Eastern Europe and Russia, elsewhere in the world, the HIV epidemics remain generally stable, and HIV transmission continues to occur in people at higher risk of exposure, including sex workers and men who have sex with men. In Latin America, the number of new HIV infections in 2007 was 100,000, which brought the total number of people living with HIV to 1.6 million in 2007. Adult HIV prevalence in the Caribbean was estimated at 1.0% in 2007. Prevalence in this region is highest in the Dominican Republic and Haiti, which together account for nearly three fourths of the 230,000 people living with HIV in the Caribbean. In Eastern Europe and Central Asia, an estimated 150,000 people were newly infected with HIV in 2007, bringing the number of people living with HIV in this region to 1.6 million, compared with 630,000 in 2001, a 150% increase over that time period. Nearly 90% of newly reported HIV diagnoses in this region in 2006 were from two countries: the Russian Federation (66%) and Ukraine (21%). Elsewhere in this region, the annual numbers of newly reported HIV diagnoses are also rising in Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, the Republic of Moldova, Tajikistan, and Uzbekistan (which now has the largest epidemic in Central Asia). The disease in this region is driven by intravenous drug use, which accounts for nearly two thirds of new infections (62%), while more than one third of new infections (37%) are attributed to unprotected heterosexual intercourse.

At the global level, although HIV/AIDS is overwhelmingly concentrated in sub-Saharan Africa, with epicenters in Eastern and Southern Africa, the future epicenter of the pandemic appears to



be the Asian continent, particularly India, China, and Russia, with a combined population of about 2.6 billion people in 2005. Should the epidemic aggressively spread to India, China, and Russia as it has done in Eastern and Southern Africa, the ramifications could be tragic for the region and the whole world. Consequently, examining the geography, the multiple dimensions, and the trajectories of HIV/AIDS vulnerability in sub-Saharan Africa may provide insights for targeting intervention and thus reducing the severity and impact of the disease, not only in Africa but also in other parts of the world where the disease is beginning to take hold.

Ezekiel Kalipeni

See also **Disease, Geography of; Health and Health Care, Geography of; Medical Geography**

Further Readings

- Gould, P. (1993). *The slow plague: A geography of the AIDS pandemic*. Cambridge, MA: Blackwell.
- Iliffe, J. (2006). *The African AIDS epidemic: A history*. Oxford, UK: James Currey.
- Kalipeni, E., & Zulu, L. (2008). Using GIS to model and forecast HIV/AIDS rates in Africa, 1986–2010. *The Professional Geographer*, 60(1), 33–53.
- Shannon, G. W., Pyle, G. W., & Bashshur, R. (1991). *The geography of AIDS: Origins and course of an epidemic*. New York: Guilford Press.

HOME

Home is a concept that refers both to a specific space, such as a dwelling or one's country, and to a sense of belonging—being “at home.” It is an idea that demonstrates the strong relationships between spaces, places, and emotions. Geographers have been interested in a range of aspects of home, including the house as home, material cultures of home, homelessness, home as a site of gendered relations, home and national identity, and the meanings of “home” to different groups.

The most basic meaning of *home* is a place to live. It can refer simultaneously to a current dwelling, a childhood home, or another place where loved ones live. This sense of home brings together ideas about physical space and the relationships that exist within and produce that space. The word *home* can be used to describe any form of dwelling, and in fact, other spaces are also described as home by people who feel a sense of belonging in them. For example, some people who are homeless describe the areas where they regularly spend time as “home” even if these are outdoors. However, in contemporary American society, home has been particularly associated with suburban developments of detached, or single-family, houses. Geographers study this association between particular urban forms, housing design, and familial relationships.

Feminist geographers have argued that this association between the home and particular forms of family life are rooted in the traditional gendered division of labor, in which men engage in paid work outside the home and women are responsible for housework and caring. The home is, therefore, a strongly gendered space, where men, women, and children may have different roles and experiences. This means that, as well as being a place of belonging, a home can be a site of exploitation and exclusion. For many women, the home can be a place of hard physical labor and, too often, the scene of domestic violence. It is also a workplace for many millions of domestic workers.

Meanings of home are not only differentiated along gendered lines. Life-course stages, class, and sexuality affect experiences and understandings of home, as does race/ethnicity. The African American writer bell hooks has argued that for poor women of color in the United States, the home is a site of empowerment, where strength can be gathered to fight the racism of the wider society. Geographers have also shown that *home* can take on a particular meaning for migrants. The house/home can be a site where the “homeland” is invoked and memories kept alive, for example, through interior decoration. This notion illustrates the links between the concept of home as a site of belonging at these very different scales.

Rosie Cox



See also **Gender and Geography; Homelessness; Housing and Housing Markets; Neighborhood; Sense of Place**

Further Readings

- Blunt, A., & Dowling, R. (2006). *Home*. London: Routledge.
- Busch, A. (1999). *Geography of home: Writings on where we live*. Princeton, NJ: Princeton University Press.
- hooks, b. (1991). Homeplace: A site of resistance. In *Yearning: Race, gender and cultural politics* (pp. 41–50). London: Turnaround Books.
- Terkenli, T. (1995). Home as a region. *Geographical Review*, 85(3), 324–334.



HOMELESSNESS

Homelessness denotes an extreme and particular form of poverty characterized by a lack of secure housing. Homelessness is commonly divided into two groups: *absolute* and *relative*. *Absolute homelessness* refers to people who have no shelter at all and are forced to either sleep rough (outside, in stairwells, etc.) or stay in a temporary shelter. *Relative homelessness* includes many people who are able to attain some form of accommodation but for a variety of reasons are precariously or insufficiently housed. This includes those who are doubling up/couch surfing, those who are staying in a rooming house or residential hotel, and/or those who are under constant threat of losing their housing due to eviction. The definition of homelessness is politicized, as different definitions produce wildly varying estimates of the number of homeless as well as different courses of remedial action. The definition of homelessness is often either broadened or restricted, depending on the context and ideological disposition of the analyst, to include panhandlers, itinerant laborers, “squeegee kids” (who approach drivers with offers to clean their windshields), the disaster afflicted, refugees, and others. From a geographical perspective, where homeless people live and what they do there are particularly important to the definition of who is homeless.

Homelessness is not necessarily a permanent condition; people may move in and out of homelessness, often several times in their lives. Homelessness (whether absolute or relative) can be divided into *transitional*, *chronic*, and *episodic* forms. *Transitional homelessness* consists of brief experiences of homelessness, often due to family or economic disruptions, and is the easiest form to treat with preventive or emergency services. *Chronic homelessness* describes an experience of being homeless that lasts for lengthy periods and is interrupted only temporarily by “housed” experiences. *Episodic homelessness* refers to repeated forays in and out of homelessness; it is the most difficult form to address through government policy. Thus, public policy interventions tend to target the chronically homeless while neglecting episodic homelessness.

Early debates often counterposed an individual agency model against a structural understanding of the causes of homelessness. *Individual/agency* explanations of homelessness focus on life-changing events (family breakup, domestic violence, disability) and/or personal failings (mental health, addiction, delinquency, poor job skills) in predicting homelessness. *Structural* explanations, on the other hand, consider capitalist housing and labor markets as systems that produce poverty and homelessness. The foci of research on the structural causes of homelessness include economic restructuring, mass unemployment, rent gouging, gentrification, deindustrialization, deinstitutionalization, housing policies that benefit homeowners at the expense of renters, and the privatization of social housing.

Research has sought to provide more holistic perspectives that integrate the structural and agency models. Economistic work in this area, for instance, finds that while combinations of individual-level variables predict *who* is most susceptible to homelessness in a given place, local housing and labor market conditions determine the *number* and *proportion* of the poor that actually end up homeless. However, this work has been criticized for treating individual-level risk factors as exogenous to housing market conditions, when the evidence suggests that the two are in fact linked. For example, the research suggests that depression and substance abuse are as much an outcome of homelessness as their cause and that



the move out of homelessness is a major factor in reducing both problems. To counter these shortcomings, homelessness research has moved to examine the pathways into and out of homelessness, in which the various risk factors and life situations make certain people who are more susceptible to homelessness interact with the structural processes occurring in labor and housing markets.

A pathways approach contributes to our understanding of the spatiality of homelessness. Geographers have explored how life events intersect with public policies regarding shelter use, time limits, and the level and criteria for accessing welfare state benefits to produce distinct geographies for homeless men and women. Geographers have also examined the importance of context in understanding the myriad homeless and mental health geographies produced through interactions between economic restructuring, deinstitutionalization, policy agendas, and community care networks. There is also now research demonstrating the specific problems and complexities of suburban and rural homelessness. This is of particular importance for policy because of the clustering of shelters and services for the homeless in downtown areas and the relative lack of such services in outlying areas.

The concepts of *visible* and *invisible homelessness* add another dimension to the lived experience of homelessness. Visible homelessness is characterized by engaging in public view in many activities of everyday life, including but not restricted to sleeping rough, panhandling, and washing. The visible homeless are disproportionately male and single. This form attracts the most media and policy attention and is in turn the subject of the most government intervention.



A homeless person rests on a bench in Central Park. According to the Coalition for the Homeless, the number of homeless people in New York City has increased by two thirds over the past decade. More than 36,000 homeless people sleep each night in the New York City municipal shelter system.

Source: Morguefile.

Research has shown how masculinized service provision and public spaces have served to further marginalize those women who are among the visible homeless population. Invisible homelessness, in which women, children, and immigrants disproportionately feature, provokes much less public concern and fewer policy solutions despite its continued growth. The work on invisible homelessness builds on feminist scholarship that demonstrates how homeless women and



Homeless woman with her children at a shelter in St. Petersburg, Russia, on April 7, 2001. Bearing the marks of abuse, the mother comes with her children for a twice-weekly hot meal offered at a Moscow shelter. During Soviet times, homelessness was classified by the government as a crime rather than a human tragedy. Estimates of homelessness in Russia today vary. In St. Petersburg, the government-run City Homeless Registration Center listed 6,500 homeless individuals in November 2009, while Maxim Yegorov, head of the NGO *Nochlezhka* (Night Shelter), estimated that there were at least 54,000 homeless people living in the city.

Source: © Gerd Ludwig/Corbis.

children are doubly marginalized in their exclusion from both public space and essential homelessness services geared toward the visible homeless. Increasingly, the visible homeless are also often subjected to enumeration and “street sweeps,” in which particular individuals are removed from public view. Current policy approaches in the cities of Western nations have been found to be inadequate for dealing with the burgeoning populations of invisible homeless in large cities, both in downtown and in peri-urban areas.

Finally, it must be noted that homelessness is an acute and growing problem in both developed

and developing countries, with implications for emerging geographies of urbanization, uneven development, social attitudes, and political cultures. However, it is even more difficult to define and to determine the extent of homelessness in developing countries, where the problem overlaps with the issue of informal (squatter) settlements and where government policy is mostly hostile and punitive.

Jeff May and Alan Walks

See also **Home; Housing and Housing Markets; Poverty; Social Justice**



Further Readings

- Cloke, P., Milbourne, P., & Widdowfield, R. (2002). *Rural homelessness: Issues, experiences and policy responses*. Bristol, UK: Policy Press.
- Daly, G. (1996). *Homeless: Policies, strategies, and lives on the street*. New York: Routledge.
- Davis, M. (2006). *Planet of slums*. London: Verso.
- Dear, M., & Wolch, J. (1993). *Malign neglect: Homelessness in an American city*. San Francisco: Jossey-Bass.
- Del Casino, V., & Jocoy, C. (2008). Neoliberal subjectivities, the "new" homelessness, and struggles over spaces of/in the city. *Antipode*, 40(2), 192–199.
- DeVerteuil, G. (2003). Homeless mobility, institutional settings, and the new poverty management. *Environment and Planning A*, 35(3), 361–379.
- Klodawsky, F. (2006). Landscapes on the margins: Gender and homelessness. *Gender, Place and Culture*, 13(4), 365–381.
- May, J., Cloke, P., & Johnsen, S. (2007). Alternative cartographies of homelessness: Rendering visible British women's experiences of "invisible" homelessness. *Gender, Place & Culture*, 14(2), 121–140.
- O'Flaherty, B. (2003). Wrong person and wrong place: For homelessness, the conjunction is what matters. *Journal of Housing Economics*, 13(1), 1–15.
- Speak, S., & Tipple, G. (2006). Perceptions, persecution and pity: The limitations of interventions for homelessness in developing countries. *International Journal of Urban and Regional Research*, 30(1), 172–188.
- Timmer, D., Eitzen, D., & Talley, K. (1994). *Paths to homelessness: Extreme poverty and the urban housing crisis*. Boulder, CO: Westview Press.
- Whitzman, C. (2006). At the intersection of invisibilities: Canadian women, homelessness, and health outside the "big city." *Gender, Place and Culture*, 13(4), 383–399.
- Wolch, J., Rahimian, A., & Keogel, P. (1993). Daily and periodic mobility patterns of the urban homeless. *The Professional Geographer*, 45(2), 159–169.

HOU RENZHI (1911–)

Hou Renzhi was singularly influential in shaping the modern study of geography in China, leading its transformation from a tradition of chronicling to a systematic approach. Hou built his reputation by publishing important work on historical Beijing, the historical archaeology of the Huang Ho River basin, and classical Chinese geographical thought. His historically based geographical contribution to the development of the modern city of Beijing included redevelopment of irrigation and water conservation systems and planning for Tiananmen Square.

Hou was born in Hebei Province and holds a BA in history (1936) and an MA in historical geography (1938) from Yenching University, predecessor institution to Peking (now Beijing) University. Hou was an instructor at Yenching and elsewhere during the Japanese occupation of China, before joining H. C. Darby in 1946 to study historical geography at Liverpool University. He completed his doctorate in 1949 and returned to Yenching University just days before the founding of the People's Republic of China.

He was appointed professor and chair of the department of geology and geography with the reorganization of Yenching as Peking University in 1952, and from 1962 to 1966, he served as deputy director of studies at Beijing University (a position akin to vice provost for academic affairs). During the Cultural Revolution in China and the years following it, from 1966 to 1978, regular teaching at the university was suspended. The Red Guards criticized Hou, placed him under house arrest, and beat him, and he spent 1969 through 1971 in a Jiangzi Province labor camp. When Hou was able to resume his research, he undertook pioneering fieldwork on historical archaeology and the historical geography of China's deserts while continuing work on Beijing's historical geography.

Appointed professor and chair in the newly separate department of geography in 1978, Hou led the rejuvenation of the program and the university. From 1983 to 1987, he directed the historical geography research group at Beijing University and then became director of doctoral studies. In 1980, Hou was visiting professor at



the University of British Columbia, the next year a Fulbright Scholar at the University of Illinois, and in 1984 a Luce Fellow in urban planning at Cornell University. Hou was also a member of the International Geographical Union Commission on the History of Geographical Thought (1984–1992). For some 30 years, he served as vice chair of the Chinese Society of Geography. Hou is a long-time member of the Chinese Academy of Sciences, and he was still engaged intellectually with geography as of the writing of this biographical essay.

Among his many honors, Liverpool University granted Hou an Honorary Doctorate of Science in 1984. In 1988, Beijing University honored him for his then six decades of service by publishing a collected volume of his works covering diverse topics such as regional historical geography, historical urban geography, desert history, and the history of geographical thought. The American Geographical Society honored Hou in 1999 with the George Davidson Medal for exceptional research contributions to geography.

Joseph S. Wood

See also **Historical Geography**

Further Readings

- Hou, R. (Ed.). (1985). *Beijing lishi ditu* [Historical atlas of Beijing]. Beijing, People's Republic of China: Beijing Chubanshe.
- Hou, R. (1998). *Hou Renzhi wenji* [Collected works of Hou Renzhi]. Beijing, People's Republic of China: Beijing Chubanshe.



HOUSING AND HOUSING MARKETS

Housing is, in general terms, a tangible structure where people live. It provides protection from the elements and supports basic physical human needs such as a place to eat and sleep. However, the importance of housing is broader than its

physical functions. Housing also provides the space for family interaction—the basic building block from which society is formed. For humankind, housing is as basic a need as is water or food.

Housing, examined from a more complex approach, is a commodity with unique attributes and peculiarities. First, it is produced and consumed in the same location, essentially exhibiting spatial fixity—an attribute uncommon in other commodities. Unlike other consumptive goods, traditional housing is fixed in space and cannot be moved to another location. In other words, the production and consumption of housing depends on road networks that make it accessible to other areas. A housing unit is both a commodity and an investment. Housing as a consumptive good helps define the quality of life or socioeconomic standing of its consumer. Housing is generally the primary investment for many families and can transfer wealth in the form of inheritance to subsequent generations. In urban areas, the housing unit is the primary building block of neighborhoods.

Neighborhoods

Neighborhood can be defined in various ways. A neighborhood can be an area where the housing units are similar in design or type, a geographical area with a distinguishable character or physical feature, or a relatively homogeneous social unit formed by religious, ethnic, or socioeconomic ties. Thus, a neighborhood might share various characteristics throughout a determined geographical area that might delineate a specific type of subdivision of the housing market or submarket. Therefore, housing is strongly influenced by neighborhood characteristics that might influence its value.

Housing Configuration

The housing market consists of available housing units for sale, known as *housing stock*, and families willing to buy those housing units. Housing stock can be distinguished by attributes such as design, type of structure, geographical area, and physical characteristics. These attributes vary across space and can form a specific housing



Real estate sign reflecting the drastic rise in foreclosures in the residential home market industry

Source: Pamela Moore/iStockphoto.

submarket. Families base their decision on acquiring a housing unit according to what is a desirable standard of living and according to its socioeconomic characteristics. Therefore, the final price is the product of the interaction between these two agents: available housing units and families, or sellers and buyers.

Housing is both a consumer good and an investment, and it is subject to the basic economic law of supply and demand. Housing demand has two origins: families and investors. As consumers of housing, families are interested in housing primarily as a commodity. They focus on the internal and external characteristics of the physical housing unit, such as the number of bedrooms and bathrooms, the internal and external dimensions of the structure, the neighborhood characteristics, the geographical location, and public service provision. Families as buyers generate variations across the housing market in which

some neighborhoods might, for example, suit a young urban professional, a double-income couple without kids, or a single parent with children better than others. Speculators and landlords are primarily interested in housing investment opportunities as in any other investment opportunity.

Defining a housing market is not a simple task, although housing units within a specific geographical area are, in general terms, comparable with other units in the same geographical area. Housing markets depend on multiple variables, such as demographics and purchasing power, which are constantly changing. For example, the phenomena of the baby boom generation and the increase in the number of empty nesters are demographic changes that can influence a specific housing market and change its locational preference from a suburb to a southern, sunny location. The rearrangement of the housing stock to satisfy the demand might trigger neighborhood changes or



changes in land use. Thus, as the housing supply is subject to a market economy, it is necessary to recognize the influence of the developer in the process of defining a greater geographical area as a housing market in which the developer can produce and distribute resources.

Housing Markets

As with any other consumer goods, housing markets are the results of the interaction between seller and buyer. The demand for a housing market is based on the same characteristics that influence the demand for other goods—namely, employment, demographics, and income. The national level of employment is an indicator of income; when unemployment increases, housing purchases might decrease. The composition, distribution, and movement of the population are other factors that can influence demand in the housing market. Another important factor influencing the demand for housing is income. For example, high interest rates can slow down home acquisitions, while low interest rates may increase home acquisition, especially during an economic recession. At the same time, unemployment and lower income triggered by a severe recession may lead to a collapse of the housing market, especially when mortgage lenders withdraw from the market.

Besides the buyer, other agents in the housing market include landowners and developers as well as financial institutions and governmental institutions. However, mobility enables people to redefine the geographical limits of housing and labor markets. Thus, employers also play a role in the housing market. Nonetheless, the mortgage credit market is fundamental for both the developer and the buyer. The mortgage credit market is an important force in national and local processes in the demand for housing.

Housing Market Problems

In the United States and other capitalist economies, housing is seen as similar to any other commodity that can be sold and purchased in the market without intervention from the state. It is widely believed that in a market economy, the

pursuit of individual interest promotes collective well-being. Unfortunately, very often, the housing market fails to provide equal access for all socioeconomic groups, especially minorities and buyers with lower economic wealth or limited credit. The scarcity of affordable housing is a factor contributing to overcrowding and retention of lower-quality housing stock. However, low income is just one of the problems for some families trying to access housing. Housing discrimination by sellers and lenders was overt during much of U.S. history and continues to be a problem today.

Sometimes the state intervenes to stimulate the housing market. After World War II, the federal government established the Federal Housing Administration (FHA), making loans affordable for thousands of families to purchase new houses. However, the FHA favored the construction of single-family dwellings in the suburbs over the rehabilitation of old multifamily buildings in the city. Therefore, through a legal framework, the state delineated a public policy that resulted in barriers to affordable housing for minorities, with a negative impact on society.

Jose R. Diaz-Garayua

See also [Chicago School](#); [Commuting](#); [Ethnic Segregation](#); [Filtering](#); [Home](#); [Homelessness](#); [Housing Policy](#); [Hoyt, Homer](#); [Neighborhood](#); [Public Housing](#); [Racial Segregation](#); [Real Estate](#), [Geography](#) and; [Suburbs and Suburbanization](#); [Urban Geography](#); [Urban Spatial Structure](#); [Urban Sprawl](#)

Further Readings

- Boehm, T., & Scholttmann, A. (2004). The dynamic of race, income, and homeownership. *Journal of Urban Economics*, 55(1), 113–130.
- Kaplan, D., Wheeler, J., & Holloway, S. (2009). *Urban geography*. Hoboken, NJ: Wiley.
- Rohe, W., & Stewart, L. (1996). Homeownership and neighborhood stability. *Housing Policy Debate*, 7(1), 37–81.
- Rossi, P., & Weber, E. (1996). The social benefits of homeownership: Empirical evidence from national surveys. *Housing Policy Debate*, 7(1), 1–35.



HOUSING POLICY

Housing policy includes formal laws and regulations that directly affect the construction, maintenance, and use of housing. While housing policies vary by country, they generally aim to meet both physical and social goals. Differences in national policies reflect how much faith a country has in the market to provide housing for its people and under what circumstances the state will intervene. For example, the United States first intervened in the market in response to the Great Depression, introducing new financial instruments and incentives to help jumpstart the economy by making it easier for people to buy homes. In comparison, the United Kingdom and many European countries began investing in resources to support the production of housing for lower-income working families in the late 1800s, in an effort to improve the poor living conditions resulting from rapid industrialization. In most communist states, the market was supplanted by government development programs and redistribution strategies. Poor and developing countries with limited private investment historically are more likely to rely on external agencies for housing assistance. In all cases, an outcome of interest to geographers is the spatial patterns and uneven development that result from housing policy or the absence of it.

Housing goals may be differentiated into physical and social ones. Physical goals may be loosely defined as those concerned with the quantity and quality of housing environments. Social goals, in contrast, focus on housing affordability and equality of access.

Physical Goals

Policy sets standards that public officials use to regulate the development and use of housing. Most common are building codes to ensure sound construction and occupancy standards to prevent overcrowding. Depending on the country, standards may be national or, as in the United States, may be delegated to state and local jurisdictions to develop and enforce. While this arrangement allows for specific standards to be adapted to fit different climates and conditions, it also means that the rules guiding housing production are

uneven. Still, even when standards are uniform, decisions about housing development often are not, since they are subject to human judgment.

The basis for most housing policy is health and safety. During the industrial period, for example, social reformers in the United Kingdom and the United States pushed for standards to ensure sufficient light, air, space, and sanitation in housing built to accommodate the large influx of workers to urban areas. More recently, attention has been paid to eliminating lead-based paint, reducing accidents and falls, and improving air quality inside homes, because these conditions not only contribute to disease and injury but also are expensive for families and government.

Land use restrictions also affect housing. Many countries employ zoning, a formal legal policy that designates how land can be used within a jurisdiction to produce public benefits. A common strategy has been to reduce threats to health and safety by separating the places where people live from the locations of activities that generate noxious odors or noise. Perhaps taken to an extreme, zoning has also been used to exclude some uses from a community by requiring a minimum lot size for homes to be developed, ensuring a low-density and presumably healthier environment. Industrial uses as well as higher-density and/or lower-cost housing are among those that have been excluded through the use of zoning. These practices, often referred to as *exclusionary zoning*, are often linked to uneven development and more recently with urban sprawl in the United States and Europe.

Social Goals

Many developed countries and developing countries promote owning rather than renting as the preferred form of tenure, primarily because it can generate wealth; most agree that a home is a good long-term investment, since housing values usually increase ahead of or at least keep even with inflation. Incentives include tax benefits to owners and even grant programs to help lower-income households buy their first home. However, what is more common is government policy to ensure that sufficient credit is available to keep supply and demand in sync. This can include changing the flow of money via interest rates as well as



finding ways to ensure that purchasers have access to capital, usually in the form of mortgage funds. While such resources make it easy to borrow a significant portion of the home's value and then pay it back by amortizing the loan over a long period of time (e.g., 30 years), mortgages tie up money and put banks at risk. To offset this risk, many countries have made it easier for financial institutions and investors to buy and sell mortgages. These "secondary markets" create opportunities for more investment, which in turn can help increase a country's gross domestic product as well as consumer spending.

In many countries, housing policy also aims to solve perceived social problems. Shortage of housing for socially disadvantaged populations is the problem most frequently addressed; the response may include building publicly owned, low-cost housing for specific populations—for example, people who are aging or with disabilities, low-income families, the homeless—or providing some form of subsidy to help tenants afford privately owned rental housing. Some countries even guarantee a right to housing to ensure that every person has at least some minimal level of shelter. In contrast, policy to transform squatter settlements and shantytowns into formal housing raises questions about what housing rights people have when they do not own land.

Housing policy also has been devised to change uneven development and other spatial patterns that are deemed problematic. For example, a growing concern in the United States, the United Kingdom, Europe, and Australia is the "social exclusion" of poor people, who are often concentrated in substandard social housing in urban areas and isolated from much of the rest of society. To change this situation, housing policies were created to permit governments to demolish these communities and replace them with new, mixed-income developments on the premise that this will help poor people become included in society and improve their situations. Similar assumptions underpin efforts to promote racial and ethnic integration. Still, in most countries, the pattern of housing development continues to be relatively segregated by race and ethnicity as well as by income.

Janet L. Smith

See also **Ethnic Segregation; Filtering; Home; Homelessness; Housing and Housing Markets; Inequality and Geography; Neighborhood; Public Housing; Racial Segregation; Urban Policy; Urban Spatial Structure; Zoning**

Further Readings

Kemeny, J. (1991). *Housing and social theory*.

London: Routledge.

Schwartz, A. (2006). *Housing policy in the United*

States: An introduction. New York: Routledge.

Shlomo, A. (2000). *Housing policy matters: A global analysis*. New York: Oxford University Press.



HOYT, HOMER (1895–1984)

Homer Hoyt pioneered academic and applied real estate market analysis in the mid 20th century. Academics know him primarily for his sector theory of urban land development. Practitioners also know him for advances in procedures that came about from his consulting and appraisal services, including his use of economic base calculations as input measurements to estimate the current and projected demand for commercial and residential real estate. Hoyt innovated procedures for estimation of the highest and best use of a site ("a site looking for a use") and for analyzing location criteria for a real estate activity ("a use looking for a site"). A third legacy is his contributions to the development of institutions important to land economics and real estate, including the Federal Housing Administration, and his endowment of the Homer Hoyt Institute. Hoyt's legacy continues through his \$8 million gift on his death in 1984 to the Homer Hoyt Institute, which today sustains Homer Hoyt's legacy by supporting land economics and real estate research and by providing educational forums for academics and practitioners in the field.

Hoyt was born in St. Joseph, Missouri, in 1895. In his early years, Hoyt lived in a tent near Kansas City with his mother, Elizabeth, who



homeschooled him. She helped him pay the college tuition fee of \$15 per year at the University of Kansas, from which he graduated in 1913 at the age of 17. He won a fellowship from the University of Chicago, where he earned a JD in 1918. In 1917, he accepted a position as an economics instructor at Beloit College in Wisconsin.

At the start of World War I, Hoyt was pulled out of academic life and into public service as an economist for the War Trade Board in Washington, D.C. This pattern of employment would repeat throughout his life. Following the end of the war, he accepted a position as professor of economics at the University of Delaware. In 1920, he declined a professorship in economics at the University of Michigan, working instead as a statistician for the American Telephone and Telegraph Company (AT&T) in New York City. Bored at AT&T, Hoyt returned to academia at the University of North Carolina at Chapel Hill (1921–1923) and then at the University of Missouri at Columbia (1924–1925).

In 1925, Hoyt again left academia for the private sector and public service. Hoyt thrived as an independent scholar. He became a real estate broker and consultant based in Chicago from 1925 to 1934, during which time he completed his PhD in economics at the University of Chicago (1933) and published his influential dissertation *One Hundred Years of Land Values in Chicago: 1830–1933* (reprinted in 1970). Hoyt's dissertation provided the foundation for socioeconomic models of neighborhood change. He documented empirically his hypothesis that real estate values reflected sociodemographic indicators, particularly income and social standing. At the time, race was highly correlated to income and social status and so could substitute for income in thematic map overlays.

Hoyt pioneered procedures known today by geographers as the *map overlay*, an innovation typically credited to the urban planner Ian McHarg. However, McHarg's work was executed nearly 30 years after Hoyt used map overlays in his dissertation and long after Hoyt pioneered map overlays for business decision making and public policy analysis at the Federal Housing Administration (FHA). Hoyt pioneered rigorous economic models to understand and explain the market forces that create the spatial pattern of

urban land use and urban land values. This understanding is a requirement for anticipating changes in land values and land use, which are necessary for business decisions and urban planning. Hoyt was the principal housing economist for the FHA (1934 to 1940), which was established under the National Housing Act. The mandate of the FHA was to revive the collapsed U.S. real estate market and to promote new housing construction. During this period of public service, writing as an independent scholar, Homer Hoyt published two important books: *Principles of Real Estate* (1939; 7th edition published in 1978), coauthored with Arthur Weimer (and later George Bloom), and *Structure and Growth of Residential Neighborhoods in American Cities*, a report for the FHA (1939; reprinted in 1971).

The prevailing urban growth theory of the time was Ernest Burgess's hypothesis of 1927 that cities grew as a series of concentric rings expanding outward from a central core. In the Burgess model, each ring was composed of a specific land use, such as industry or worker housing. Hoyt's sector theory of urban development challenged Burgess's model. His sector theory held that urban spatial patterns are wedge-shaped sectors (not rings) radiating from central nodes, such as the city center, along transportation corridors. Each sector is distinct from the others, and each is fairly homogeneous as regards land use. Sectors, according to Hoyt, were dominated by workers' housing, high-income housing, commercial land use, industrial land use, and so on. Especially important to Hoyt was the social status of the residents of the various sectors as well as the physical geography of the sector. He correlated high-social-status residential areas with higher elevations. Higher-status housing sectors tended to arise among sectors offering unconstrained growth outward toward open, uncongested spaces. In contrast, Hoyt observed that low-income sectors were more likely to have comparatively lower elevations, including flood plains, and to be unable to accommodate future development.

Hoyt was director of research for the Chicago Planning Commission from 1941 to 1943, during which time he published his 1943 *Master Plan of Residential Land Use of Chicago*. He then became director of economic studies for the Regional Plan Association in New York City (1943–1946), for



which he wrote *Economic Status of the New York Metropolitan Region* in 1944. While executing his work for New York, Hoyt agreed to be a visiting professor of land economics at the Massachusetts Institute of Technology and also at Columbia University.

Hoyt's sector theory proved useful in understanding the dynamics of urban growth and was put to use in the post–World War II United States. The mid 20th century was a period of rapid suburban expansion; cities were being shaped by private decisions regarding where to build housing tracts and to which socioeconomic group the housing should be targeted. Private decisions were also being made on where to develop regional shopping centers. Public decisions were being made on where to build public infrastructure such as streets and expressways. Hoyt's map overlays were put to good use in improving these private and public real estate decisions. As a consultant, Homer Hoyt became very wealthy.

Hoyt Associates was founded in Larchmont, New York, at the end of World War II and relocated to Washington, D.C., in 1953. The consulting firm specialized in land economics, demographic studies and real estate appraisals, and location advisory services. Its clients included country and city governments and private investors. Hoyt forecasted the rapid postwar expansion in population and in suburbanization, and he advised local governments to put planning regulations in place ahead of this rapid development. By the early 1970s, Hoyt Associates had performed market analyses for over 200 shopping centers throughout the United States. In 1974, Hoyt shifted his entrepreneurial interests, applying his models to guide his own real estate investments. His endowment to the Homer Hoyt Institute was the acquisition of a barrier island off the coast of St. Lucie County, Florida, which was later sold to the State of Florida to be turned into a turtle sanctuary, and the proceeds were used to sustain the Homer Hoyt Institute (www.hoyt.org).

Grant Thrall

See also **Chicago School; Housing and Housing Markets; Neighborhood; Real Estate, Geography and; Urban Geography; Urban Spatial Structure**

Further Readings

- Hoyt, H. (1923). The inequality in the distribution of wealth and income in the United States. *Journal of the American Statistical Association*, 18(141), 650–651.
- Hoyt, H. (1941). Forces of urban centralization and decentralization. *American Journal of Sociology*, 46(6), 843–852.
- Hoyt, H. (1951). Is city growth controlled by mathematics or physical laws? *Land Economics*, 27(3), 259–262.
- Hoyt, H. (1954). Homer Hoyt on development of economic base concept. *Land Economics*, 30(2), 182–186.
- Hoyt, H. (1960). Changing patterns of land values. *Land Economics*, 36(2), 109–117.
- Hoyt, H. (2000). *One hundred years of land values in Chicago: The relationship of the growth of Chicago to the rise of its land values, 1830–1933*. Frederick, MD: Beard Books. (Original work published 1933; republished 1970 by Arno Press, New York)
- Hoyt, H., & Weimer, A. M. (1939). *Principles of urban real estate*. New York: Ronald Press.



HUMAN DIMENSIONS OF GLOBAL ENVIRONMENTAL CHANGE

Studies of the human dimensions of global environmental change explore the social causes and consequences of large-scale environmental transformations. These include, for example, climate change or global warming, stratospheric ozone depletion, acid rain, land use changes such as wetlands loss and deforestation, biodiversity loss, and changes in the abundance, diversity, and productivity of marine populations. Widespread local-scale changes, such as in water access or water quality, can be considered global environmental problems because of the magnitude of their impacts on society. Human actions are considered to be the central force behind all types of global environmental change, whether it is



through population growth, resource extraction, energy consumption, urbanization, technological change, changes in consumer demands, or shifts in attitudes, lifestyles, and beliefs. Central to all research on the human dimensions of global environmental change is the idea that human activity is changing natural, life-supporting processes and that scientists, policymakers, and the public need to pay attention to what these changes mean for society and its future sustainability.

Human dimensions research encompasses a broad array of issues, discussed in this entry, including (a) the social, economic, political, cultural, and/or demographic drivers of global environmental changes; (b) the impacts of these changes on human systems at scales ranging from the global to the local; (c) the vulnerability of different sectors, regions, and social groups to these changes; and (d) the responses to these changes, including both adaptation to the effects of global environmental change and mitigation of the causes of these changes. Human dimensions researchers are also keenly interested in issues of governance, equity, and social justice and the role of discourse in influencing how global environmental problems are defined and addressed.

The Drivers of Global Environmental Change

Research on the drivers of global environmental change documents how human activities contribute to various types of large-scale environmental changes. This work includes investigations of human activities that affect the entire Earth system. This work also entails study of the role of human activities in contributing to cumulative local changes that influence the global environment through the magnitude and distribution of their effects. Examples of systemic-focused research include the study of present and projected future consumption of fossil fuels on a global scale, with a focus on how this contributes to climate change, or the study of how international regulations of chlorofluorocarbons are implemented and the consequences of this implementation for stratospheric ozone depletion. Research that emphasizes the cumulative effects of local-scale changes draws attention to activities that are occurring on a worldwide basis, such

as the release of untreated sewage into natural waterways, rapid urban spatial expansion, and overfishing of large predatory species, and explores how these activities affect global water systems, global land use patterns, and species survival rates, respectively.

Study of the human drivers sometimes entails modeling the physical processes of environmental change while incorporating social factors such as population growth, energy consumption, or per capita income. This work may also involve the empirical documentation of global-scale changes, based on remote sensing analysis of changing land use patterns or statistical analysis of temperature records in urban areas. The socioeconomic causes of cumulative types of local environmental changes are also emphasized, such as the economic causes of overpumping of groundwater for irrigated agriculture, which, in turn, contributes to salinization and large-scale land degradation.

The Impacts of Global Change

Research on the impacts of global environmental change explores how various types of changes may influence coupled social-ecological systems. Such impacts research often has a sectoral emphasis, focusing on how changes such as higher temperatures, reduced precipitation, or more frequent extreme events associated with climate change may affect specific sectors of an economy, such as agriculture, energy, transportation, health care, or tourism. Sectoral approaches typically document impacts in economic terms, for example, by calculating the effects of environmental change on total crop production, energy costs, infrastructure investment levels, the cost of asthma treatment, or the number of visitors to a tourist destination.

Such research may also document the effects on ecological processes, or what is often referred to as ecosystem or environmental services. Impacts research may sometimes have a regional focus, looking at how a political, economic, or ecological region, such as a nation-state, coastal city, or river delta, may be affected by global environmental changes, again with an emphasis on the prediction and quantification of impacts in economic or ecological terms. In the case of a river delta, for example, an impacts-oriented study



might document the economic consequences of mangrove destruction, due to both upstream water diversions and sea-level rise, on the local shrimp industry, as well as the ecological consequences for biodiversity.

Vulnerability

Vulnerability research examines how and why some groups and individuals are disproportionately exposed to the negative effects of global environmental change and which factors influence their capacity to respond to these changes. Vulnerability research often emphasizes the contextual factors that lead to the negative outcomes of a particular process of change. These contextual factors include economic, social, cultural, political, environmental, and institutional conditions that either constrain or enable effective responses to various types of environmental stresses. Wealth, education level, social capital, access to political power, and cultural worldview are among the many individual attributes that affect these responses. Variations on vulnerability approaches include resilience frameworks, which focus on how society anticipates and plans for future changes, and capabilities, assets, and livelihoods approaches, which emphasize the factors that constrain or enable people to pursue outcomes that they value.

In addition to the emphases on vulnerability and the capacity to respond to single drivers of global environmental change, researchers are increasingly interested in vulnerability to multiple stressors. Multiple-stressor approaches recognize that individuals and communities are often subjected to more than one ongoing process of global change. Recognition of multiple stressors is seen as key to understanding why some regions, individuals, or groups are more able or less able to adapt to global environmental change. These approaches typically combine investigation of vulnerability to changing environmental conditions with an examination of other stressors such as disease, warfare or conflict, and economic disruptions. Research in Southern Africa, for example, shows how climate change, rapid urbanization, the spread of the human immunodeficiency virus/acquired immune deficiency syndrome, and political conflict are all creating stresses on socio-ecological systems.

Expanding the analyses beyond single-stressor approaches has provided greater insights into the social processes that underlie the drivers of global environmental change and that shape vulnerability to these changes.

Adaptation

Research on multiple stressors has also helped identify points of intervention for responding or adapting to multiple global change processes. Adaptation research explores the actions or strategies taken by an individual, household, group, firm, public institution, or governing body either in anticipation of or following exposure to some type of environmental change. Adaptations can take the form of decisions, policies, or behaviors, with the objective of adjusting to new environmental conditions or new types of environmental stresses.

Actions that are taken to reduce the immediate negative outcomes are sometimes referred to as coping strategies. Successful coping strategies are in many cases a prerequisite for successful adaptations that reduce long-term vulnerability to shocks and stressors. However, coping strategies may in some cases undermine adaptive capacity if, for instance, they involve selling productive assets or withdrawing children from school.

Adaptations can also entail actions taken in anticipation of exposure to new conditions. Anticipatory responses may include the purchase of insurance, diversification of crops or investment portfolios, improvements in infrastructure, creation of protected areas, expansion of livelihood options, and so on. They may also include making investments in infrastructure, education, social welfare and job training programs, or livelihood diversification. Such responses are often based on assessments of risk and strategies for social, economic, or environmental planning. Research on adaptation also stresses the significance of actions and interventions made at different scales. External interventions, for example, federal government training and education programs, humanitarian aid from international organizations, suspension of interest payments on debt by international banks, structural adjustment programs, and other actions, may either facilitate or hinder adaptation.



Mitigation

Research on mitigation focuses on policy measures and technological responses that are intended to slow or halt the processes of global environmental change. This notion of mitigation differs from how the term is used in the geographic literature on hazards, where mitigation typically refers to reducing vulnerability and the likelihood of disaster. Within the human dimensions literature, mitigation research focuses on ameliorating the causes of various types of changes, such as reducing greenhouse gas emissions from automobiles or slowing the pace of tropical deforestation (which is also frequently connected to mitigation of carbon emissions).

Topics for mitigation research include emissions trading schemes, carbon taxes, and green development mechanisms. It also includes research on changes in sociotechnical systems, including shifts to alternative energy technologies and the implications of these shifts for social, economic, and environmental sustainability. Mitigation research also explores local political organizations and social movements around environmental issues. Among the most prominent topics are studies of how urban local governments have agreed on carbon emissions reductions. Mitigation research is often tied directly to the issue of sustainability based on the ethical understanding that mitigation is needed to ensure that the activities of the present generation do not undermine the ability of future generations to meet their needs.

Environmental Governance

The issue of governance is an important theme across all facets of research on the human dimensions of global environmental change. Research on governance focuses on questions of how resources are managed, how regulatory frameworks and institutions shape the behavior of individual actors, and how these actors may, in turn, affect institutions. Much attention within this area has been devoted to understanding how neoliberal (i.e., free market) approaches to resource management have contributed to the pace of environmental change. Privatization of common lands under neoliberalism, for example, is connected to

an increased pace of conversion of forest land to agricultural uses, leading to soil degradation, loss of biodiversity, and other effects.

Human dimensions researchers also recognize that efforts to both adapt to and mitigate the causes of global environmental change may require new types of governance structures or new types of cooperative agreements. For example, adaptation to sea-level rise may eventually require relocation of populations from low-lying coastal areas. Yet existing political and economic structures often reinforce migration of new residents into these vulnerable areas, based on the assumption that sea walls and other technological interventions will provide protection. Coastal relocation may ultimately require new types of governance structures that are more regional in scope. The regulation of fisheries on a global basis to ensure species survival represents another situation where new types of cooperative governance may be appropriate.

Equity and Social Justice

Issues of equity and social justice are also becoming increasingly prominent in research on the human dimensions of global environmental change. A growing awareness of the equity issues surrounding global environmental change is not surprising given the widespread recognition that the effects are likely to be highly uneven and are likely to create winners and losers. Some individuals, households, communities, or regions will experience significant negative effects, such as the loss of life and property due to climate extremes, a rise in skin cancer due to stratospheric ozone depletion, the loss of agricultural productivity, increased water stress, and so on, whereas others may experience only minor negative effects, and still others may experience net benefits, such as lower winter-heating costs due to warmer temperatures, a longer agricultural growing season, increased forest productivity, or an expansion of tourism due to land use changes. Equity and justice issues arise in part because these differential effects are not randomly distributed but often systematically harm groups that are already economically or politically marginalized. For example, in many developing world cities, households living in informal housing rely on private water vendors



for their water supply. These households are more likely to experience the negative effects of water supply shortages (e.g., dramatic price increases) than wealthier households, which are more likely to be served by municipal water suppliers.

In addition to inequities regarding environmental impacts or vulnerability to environmental change, geographers studying human dimensions have given much attention to equity in the mitigation of these changes. With regard to climate change, for example, questions of equity in mitigation arise regarding who pays the costs and who bears the burdens associated with emissions reduction policies. These issues are complicated by differential responsibility for historical versus present and future emissions. While most greenhouse gases that are present in the atmosphere today are the result of historical and current activities in industrialized countries, future emissions will increasingly reflect activities in developing countries, especially China (which in 2006 overtook the United States as the world's leading emitter of carbon dioxide), as these countries increase their industrial output and adopt lifestyles that are more energy consumptive. Broader issues of intergenerational equity are also in play with respect to climate change mitigation, including obligations of fairness, maintaining a wide range of options, and ensuring quality of life. The ethical dimensions of environmental change are thus becoming more prominent in human dimensions research.

Environmental Discourse

Finally, human dimensions researchers are increasingly interested in the role of competing discourses in influencing how environmental issues are defined and addressed. Discourses include assumptions, values, judgments, and contentions that provide the basic terms for analyses and debates, influencing both agreements and disagreements. More important, discourses carry political weight and reflect the underlying power structures: Proponents of some discourses have more power, thus exerting a greater influence not only on how specific issues are presented and understood but also on which responses are prioritized and pursued. In relation to global environmental change, questions of discourse arise

not only around definitions of global environmental change—whether the changes are truly global—but also around the approaches used to evaluate and address these changes.

The discourses on global environmental change can be organized into three categories, biophysical discourses, human-environment discourses, and critical discourses, each of which is based on a particular approach to science. Biophysical approaches frame environmental problems as biophysically based concerns that need to be addressed through both technological innovations and international commitments to reduce, limit, or suspend activities that lead to environmental changes.

Human-environment discourses, which are prevalent in much of the literature discussed above, emphasize the integral connections between human and natural systems and the importance of connecting biophysical and social processes to understand drivers, impacts, and vulnerabilities. Proponents of human-environment discourses also emphasize adaptation and social learning as responses to environmental change and stress the formation of partnerships among governments, private sector actors, civil society, and academia.

While the biophysical and human-environment discourses stress the *environmental* aspects of global environmental change, critical voices argue that the focus should be placed on the political, economic, moral, and cultural dimensions. Based on structural and political analyses, including those pertaining to political economy and political ecology, adherents to critical discourses emphasize that the outcomes of environmental change are largely a function of the wider social, economic, and political forces that create and perpetuate inequalities. Recognition of these multiple and competing discourses is vital to understanding the breadth of research on the human dimensions of global environmental change.

Robin M. Leichenko and Karen L. O'Brien

See also [Adaptation to Climate Change](#); [Anthropogenic Climate Change](#); [Climate Change](#); [Climate Policy](#); [Coupled Human and Natural Systems](#); [Cultural Ecology](#); [Differential Vulnerabilities to Hazards](#); [Ecological Footprint](#); [Environmental Discourse](#); [Environmental History](#); [Environmental Impact Assessment](#);



Environmental Impacts of Agriculture; Environmental Impacts of Cities; Environmental Impacts of Manufacturing; Environmental Justice; Environmental Racism; Global Environmental Change; Global Sea-Level Rise; Human Ecology; Human-Induced Invasion of Species; Industrial Ecology; Land Use and Cover Change (LUCC); Political Ecology; Symptoms and Effects of Climate Change; Vulnerability, Risks, and Hazards

Further Readings

- Bulkeley, H., & Betsill, M. (2005). *Cities and climate change: Urban sustainability and global environmental governance*. London: Routledge.
- Leichenko, R., & O'Brien, K. L. (2008). *Environmental change and globalization: Double exposures*. New York: Oxford University Press.
- O'Brien, K. L., & Leichenko, R. (2003). Winners and losers in the context of global change. *Annals of the Association of American Geographers*, 93, 89–103.
- Steffen, W., Sanderson, A. Tyson, P. D., Jäger, J., Matson, P. A., Moore, M., III, et al. (2005). *Global change and the Earth system: A planet under pressure*. Berlin, Germany: Springer.
- Turner, B. L., II, Clark, W. C., Kates, R. W., Richards, J. F., Mathews, J. T., & Meyer, W. B. (Eds.). (1993). *The Earth as transformed by human action: Global and regional changes in the biosphere over the past 300 years*. Cambridge, UK: Cambridge University Press with Clark University.



HUMAN ECOLOGY

The field of human ecology studies and analyzes patterns of interaction between variables of different kinds—physical, chemical, biotic, social, cultural, and economic—affecting people in relation to each other, other organisms, and their surroundings. Defined in this way, human ecology contributes significantly to the understanding of problems relating to the quality of life. It highlights the full range of human experience directly

relating to the quality of life and advances understanding of the interrelationships between the elements of human experiences, including belief systems and cultural traditions, and local and global economic, technical, environmental, and societal conditions. Charles Thornthwaite referred to human ecology as an overall, integrating, and holistic field of study that may be even more all-encompassing than geography. This entry presents interpretations of human ecology from the fields of medicine, family and consumer sciences, anthropology, sociology, demography, urban analysis, geography, and biology.

The intellectual origins of human ecology lie in the emergence of plant and animal ecology in the late 19th and early 20th centuries and in the application of ecological concepts to human populations. Ecology is the scientific study of the distribution and abundance of life and the interactions between organisms and their environment. Ecologists usually either study the relationship between a particular species and the environment (such as the ecology of the rat or the bumblebee) or the characteristics of a particular ecosystem (such as the lowland tropical rain forest ecosystem). Human ecology in this sense is the study of the ecology of human beings, of their interaction with each other and with other organisms and the physical environment. Dieter Steiner and Markus Nauser argued that biology, sociology, anthropology, geography, and psychology form the five intradisciplinary “roots” of human ecology. They argued persuasively not only that human ecology should be centered in the social sciences and the humanities rather than in the natural sciences but also that it inevitably must embrace trans-scientific components of a philosophical and religious nature. Thus, in human ecology, the environment has dimensions beyond the environment of the ecosystems studies in the rest of ecology. These dimensions include culture, human attitudes and behavior, and belief systems and spirituality, as can be found in most anthropological literature concerned with human ecology.

Human ecology often focuses on how individuals and groups adapt to external circumstances, whether they are cultural, social, economic, or biophysical. The ideas and theories of human ecology should therefore be able to help increase our understanding of how groups adjust to public



policy actions. Adaptation in this context is the way in which a population develops or modifies social organization and technology to achieve a working relationship with its environment. Although the biological roots of human ecology would see adaptation as a selective process, analogous to the Darwinian natural selection process, human adaptation is usually discussed in terms of people making *strategic choices* among perceived options. However, the desirability and feasibility of some of those options are likely to be constrained by external conditions.

Interpretations of Human Ecology

Because the study of human life concerns everyone, it is hardly surprising that the analysis of people in relation to their surroundings has been picked up by researchers in many fields. In the 21st century, eight different interpretations of human ecology are current: in medicine, family and consumer sciences, anthropology, sociology, demography, urban analysis, geography, and biology. A ninth interpretation, not yet well formulated, is in the analysis of the human impacts of, and responses and adaptations to, global change. The nature and scale of the ecosystems studied by individual disciplines differ to some degree (Table 1).

Medicine

In medicine, human ecology involves studying how human beings respond in the context of the total environment, other humans, other living organisms, and physical and chemical factors such as heat, dampness, oxygen, and pollutants. This approach sees the human being as an indicator of all aspects of the quality of life. In this sense, human ecology is concerned with the evolution, organization, and interrelationships of the multiplicity of forces that shape continuing human development in a given milieu. Human ecology thus has direct relevance to medicine, for a person's milieu influences her or his state of health, the types of maladies to which he or she is susceptible, her or his attitudes toward and use of medical care, her or his response to treatment, and her or his desire to regain her or his competitive spirit. Since an individual is an active participant in her or his social

order and helps shape her or his way of life, her or his total ecology is reflected in the character of her or his physical and psychological responses.

Family and Consumer Sciences

In family and consumer sciences and related fields, human ecology has come to mean the study of the care and management of, the immediate, mainly indoor, ecosystems in which people live. The label *human ecology* is used in higher education to name many schools and faculties where nutrition, food science, clothing, and even household design are taught.

Anthropology

In anthropology, there is a distinct tradition of studying the close relationship of human societies to their immediate surroundings. In this case, the task of human ecology is to analyze how people are intimately interconnected to their environment in every aspect of their lives and how the people-environment system works and is sustained for future generations.

Sociology

In sociology, human ecology is a macrosociological analytical effort to understand the interconnections between variations in population, organization, environment, and technology in the context of communities and regions. For some sociologists, this is closely related to the urban analysis approach; for others, it is closely related to the anthropological analysis of communities.

Demography

In demography, human ecology has provided a paradigm that, despite a few problems, helps in understanding how populations grow and spread spatially within, and adapt to, both natural and social environments. In this way, modern human ecology has enhanced the theoretical foundations of macrolevel demography. It has also assisted in many ways in the comprehension of specific demographic issues, for example, population growth, migration, urban expansion, and cultural and ethnic differentiation.



<i>Discipline</i>	<i>Scale of Ecosystem Studied</i>	<i>Nature of Questions Asked About the Ecosystem</i>
Medicine, public health	The environment as it affects the individual	Conditions that affect the human body, both its physical and its mental well-being; internal and external environments at home and the workplace; nutrition; pollutants, disease vector habitats, and the possibility of infection and contagion
Family and consumer sciences (domestic science)	Conditions in the household; the environment of the family unit	Nutrition, living conditions, clothing, household cleanliness, exercise, and recreation
Anthropology	Communities in relation to the immediate surroundings on which they are highly dependent	The environment as a provider of the necessities of life; human skill in modifying the environment to sustain that life
Sociology	Groups of people in relation to their living and working environments	How the environment affects life opportunities; the ability to improve quality of life, including recreation and interaction with others
Urban analysis	Study of subdivisions of urban areas, usually at the ward or enumeration district level, in terms of various social indicators, including income, type of employment, and ethnicity	Indicators such as type of housing, number of persons per room, availability of piped water and sanitation, pollution, and access to facilities such as parks, schools, and hospitals
Geography	Usually communities in relation to specific ecosystems, such as wet rice cultivation agro-ecosystems or beachside coastal retirement communities	Environmental constraints on the achievement of human goals; response of the environment to human adaptations to constraints and efforts to overcome them
Biology (ecosystem dynamics)	Analysis of whole cities or agricultural regions	The turnover of energy, water, and materials through both natural and people-driven processes (related to urban and industrial ecology)
Demography	Large numbers of people in whole cities, provinces, or countries in relation to factors that give rise to population movements, including environmental refugees	Impacts of the environmental conditions on human opportunities, including factors that both attract and repel migrants
Global change science	How people, from individuals to whole nations, respond to global-scale changes, particularly climate change and biodiversity loss, by changing policies and behavior, particularly consumption	Establishing the consequences of global change for human life and for biodiversity; demonstrating opportunities for changing behavior and the importance of modifying policies to avoid the adverse consequence of further ecosystem change

Table 1 The scale and nature of the ecosystems studied in human ecology as applied by various disciplines

Source: Author.



Urban Analysis

In urban analysis, human ecology is the analysis of the social character of different areas of cities as a function of the demographic and environmental characteristics of those areas. This approach had its origins in the work of Robert Park and Ernest Burgess, Roderick McKenzie, and other scholars at the University of Chicago in the 1920s and 1930s. It was in part replaced by the body of theory and research that began with the publication of Amos H. Hawley's *Human Ecology*, a landmark volume that led to a major reorientation of the field. Hawley's work dramatically shifted the focus from the description of the physical features of a city and the mapping of social phenomena to the ways in which human populations organize to maintain themselves in given environments, thus relegating spatial analysis to a minor though still valuable position in the field. It is not spatial arrangements themselves but rather the social relations often reflected in spatial patterns and processes that are of interest to human ecologists.

In terms of biological ecosystem analysis, human ecology uses the notion of urban or agro-ecosystems. It not only analyzes the flows of energy, water, and materials affecting the urban population but also considers human behavior and attitudes in the operation of that system. This approach is exemplified by the work of Stephen Boyden and others in Hong Kong.

Geography

Much has been written about geography as human ecology, as the key study of the interrelationships between people and their environment. The roots of this interest go back to the early days of the discipline, when scholars such as Paul Vidal de la Blache and Herbert Fleure used the new concepts of evolution and natural selection in their analyses of the relationship between people and the landscapes in which they lived. At this time, there was a close relationship between geography and anthropology, and almost all geographers acquired at least a year's intensive training in the basics of geology. A sense of both time and culture was necessary for them. These early geographers used the *region* as their ecosystem, writing about life and landscape in the Weald in

England, the Pays de Brie in France, or the Ozarks in the United States. A debate developed about the sizes, scales, and hierarchies of regions and about how human administrative areas might usefully be related to ecological units, bioregions, "natural regions," or river basins. A later development saw the emergence of *landscape ecology*, a term first coined by Carl Troll in Germany in 1939. He brought the human artifacts and the cultural, social, and economic dimensions of mountain landscapes together with the biophysical factors, using highly effective profile and three-dimensional diagrams.

For some geographers, during the 20th century human ecology conjured up images of small-scale, non-Western societies and their local adaptation to the environment—typically largely self-sufficient nonindustrial communities. The work of the Berkeley School under Carl Sauer, particularly in Latin America, and that of Harold Brookfield and his students in New Guinea typified this approach. It implied a holistic view of culture and the environment and the need to be able to analyze both the nuances of culture and society and the constraints imposed on them by all the elements of the landscape. In some ways, this human ecological approach within geography helped overcome some of the disadvantages of the "top-down," "one-size-fits-all" solutions being advocated by agricultural advisers and soil conservationists in their efforts to reduce the land degradation they believed they saw in many tropical areas.

In the 1970s, the human ecological view in geography was seen as a contrast to the spatial analysis approach, which endeavored to seek general laws about causes and effects. This contrast was explained in the United States as two distinct patterns of thought: (1) the spatial analysis, an optimizing view, stemming from research at Northwestern University, and (2) the human ecological view practiced at the University of California under the leadership of Carl Sauer. In much of Europe, the human ecological view held sway, particularly in Denmark and Germany. Later, the total human ecosystem approach was developed for the analysis of cultural landscapes, where human-environment interaction created ecological, socioeconomic, and cultural patterns and feedback mechanisms that changed biological and cultural diversity and affected ecosystem



resilience. Such concerns would be seen by many as a major focus of human ecology.

However, the great expansion of environmental concern since 1970 saw a somewhat belated return to a form of human ecological approach in geography with the appearance of what was, somewhat strangely, called *environmental geography* (strange because geography has always been about people and their environment).

Biology

The environmental movement also prompted the growth of human ecology out of environmental biology as science faculties rushed to set up environmental science programs. In some cases, this led to the establishment of new university programs in human ecology. The landscape architect Ian McHarg argued that human ecology should be part of planning education, since human ecology is the study of the interactions of organisms (including humans) and the environment (including humans among other organisms).

By the later 1980s, science had become worried about global change, especially the impact of climate change on human life and on the ecosystems that support life. William Clark has stressed the importance of human behavior in responding to change, particularly the need to motivate and sustain and maintain collective behavior changes. He said that the time was ripe for international, interdisciplinary commitments to scholarship on the human ecology of global change. Subsequent work by international organizations and consortia has taken a far more holistic and transdisciplinary approach than previous studies. This work has addressed fundamental geographical questions such as the relationship between climate and society or between land use and land cover change. Equally, it can be said that much of it fits comfortably under the large umbrella of human ecology.

Geography as Human Ecology?

The subject matter of human ecology and geography is essentially similar: what happens at the Earth's surface, especially in terms of how people interact with each other and their surroundings. Geography, however, is largely content to divide this field into subdisciplines, not merely the

two areas of physical and human geography but further subdividing these categories into geomorphology, biogeography, cultural geography, historical geography, urban geography, and so on. Human ecology insists on maintaining a holistic approach, although sometimes focusing on particular issues in detail, such as the human ecology of inshore fisheries or of shifting cultivation. If human ecology offers a viewpoint that geography has neglected and also contributes to other disciplines, then its holism and its emphasis on the role of the individual, and of ideas, spirituality, beliefs, and culture, can contribute to both scholarship and human well-being.

Ian Douglas

See also Berkeley School; Chicago School; Cultural Ecology; Darwinism and Geography; Energy and Human Ecology; Feminist Political Ecology; Industrial Ecology; Landscape Ecology; Political Ecology; Regional Geography; Sauer, Carl; Urban Ecology; Urban Metabolism

Further Readings

- Boyden, S., & Millar, S. (1978). Human ecology and the quality of life. *Urban Ecology*, 3, 263–287.
- Brookfield, H. C., & Brown, P. (1963). *Struggle for land: Agriculture and group territories among the Chimbu of the New Guinea Highlands*. Oxford, UK: Oxford University Press.
- Bruhn, J. G. (1970). Human ecology in medicine. *Environmental Research*, 3, 37–53.
- Clark, W. C. (1990). The human ecology of global change: Unresolved questions. *GeoJournal*, 20, 143–150.
- Hawley, A. H. (1950). *Human ecology: A theory of community structure*. New York: Ronald Press.
- McHarg, I. L. (1981). Human ecological planning at Pennsylvania. *Landscape Planning*, 8, 109–120.
- Park, R. (1952). *Human communities: The city and human ecology*. Glencoe, IL: Free Press.
- Porter, P. W. (1978). Geography as human ecology: A decade of progress in a quarter century. *American Behavioral Scientist*, 22, 15–39.
- Sauer, C. O. (1956). The agency of man on the Earth. In W. L. Thomas Jr. (Ed.), *Man's role in changing*



the face of the Earth (pp. 49–69). Chicago: University of Chicago Press.

Steiner, D., & Nauser, M. (Eds.). (1993). *Human ecology: Fragments of anti-fragmentary views of the world*. London: Routledge.

Thornthwaite, C. W. (1940). The relation of geography to human ecology. *Ecological Monographs*, 10, 343–348.

Young, G. L. (1974). Human ecology as an interdisciplinary concept: A critical inquiry. *Advances in Ecological Research*, 8, 1–105.



HUMAN GEOGRAPHY, HISTORY OF

Human geography has a long and complex history stretching into prehistory. At times, the evolution of human geography was closely intertwined with that of cartography and physical and environmental geography, each of which also has its own, distinct history. Every society creates its own geography, both in the sense of an ontology—that is, as material landscapes and spatial distributions—and in the sense of an epistemology—that is, as a world-view of the earth, the meaning of near and far, and how space and place reflect and affect identities. As long as there have been people, there have been human geographies. Australian Aborigines, for example, used so-called song lines to navigate the desert. The Sumerians developed clay maps of their cities, and the Polynesians crossed the Pacific Ocean with maps of currents and winds made from sticks.

Because the history of human geography has been described in detail elsewhere, this entry offers only a brief sketch of several major people, events, and schools of thought from about the 6th century BC to the beginning of the 21st century. The focus here is on Western human geography as it formed in Europe and North America; there is clearly an equally long, complex, and interesting history of geography in Asia and elsewhere waiting to be written. Note that this entry hardly does justice to the complexity of the field and that the encyclopedia includes separate entries on the histories of cartography, physical geography, and geographic information systems.

Premodern Geographies

Generally, premodern geographies were empirical and inductive in nature, often consisting of encyclopedic compilations of place descriptions, a tradition that lasted well into the 19th century. Geography was a practical science intertwined with geodesy, astronomy, surveying, exploration, trade, and military conquest.

The roots of human geography extend at least as far as classical Greece in the 6th century BC, if not before. Classical Greece, from which Western culture ostensibly arose (but with numerous connections to older cultures such as that of the Egyptians), marked the first systematic attempts to describe the shape of the Earth and map the known world, the *ecumene*. For example, Thales (611–547 BC), who lived in Miletus, theorized that the earth floated on water and successfully predicted an eclipse on May 28, 585 BC. Anaximander (610–546 BC) constructed what may be the first map of the world (since lost), invented the gnomon (similar to the sundial), and argued the Earth and all bodies were spherical. Herodotus (485–425 BC) was a historian who coupled history with geography in his famous studies of the Nile River, including its seasonal flooding and soil deposition along its delta. During the Athenian golden age, Aristotle (384–322 BC), a student of Plato and a scientist and philosopher in his own right, theorized a geocentric astronomical system that held sway until the 17th century. He also advocated an early form of climatic determinism based on three belts of temperature and their ability to sustain civilization: that to the south of Greece was too hot, that to the north too cold, leaving Greece alone ideal for civilization. Such a view reflects the close relationship between geography and cosmography that existed until the Enlightenment. At the famous library of Alexandria, center of the classical world's intellectual life but since destroyed, Eratosthenes (276–194 BC) coined the term *geography* and estimated the circumference of the Earth remarkably accurately. Later, Hipparchus (190–120 BC) theorized a grid of the world consisting of latitude and longitude lines.

Within the Roman Empire, prominent geographers included Strabo (64 BC–AD 24), who, like many intellectuals of the age, was actually Greek; he is best known for his 17-volume work *Geography*. Ptolemy (AD 87–150), also working in



Alexandria, concluded that the task of geography is the description of the earth as a whole and presented such a description in his eight-volume *Guide to Geography*. He differentiated geography as the study of universals from topography as the study of localities and chorography as integrating the two. His worldview dominated the Western geographical imagination for a millennium, until the “voyages of discovery” of incipient capitalism dethroned it, influencing explorers such as Columbus.

For a millennium under feudal Europe, geography suffered from the political and ideological dominance of theology; indeed, the rationalist Greek tradition was effectively ended by the hegemony of Christianity. Exploration during this time was relatively rare, largely limited to the Normans, the Vikings, and the famous trips to Asia by Marco Polo, whose views also affected later, Renaissance explorers. A well-known medieval geographic expression consisted of T-in-O maps, *oriented* to the east (i.e., Jerusalem, which was put at the center), which depicted the continents of Europe, Africa, and Asia in crude, highly inaccurate terms that served ideological purposes more than anything else.

In contrast, during the height of the Arab Empire from the 7th to the 12th centuries, geography prospered, in much the same way as did Arabic mathematics (e.g., algebra), astronomy, poetry, and medicine. The Arabs traded extensively with India and discovered the dynamics of the monsoons over the Indian Ocean. Arab cartography was so advanced that Christian kings such as Norman Roger II in Sicily hired Arab mapmakers such as al-Idrisi (1099–1180). In the 9th century, Caliph Harun al-Rashid assembled scholars to translate Greek works to Arabic. Prominent Arab adventurers included Ibn Batuta (1304–1369), who traveled more than 70,000 miles throughout Eurasia over 30 yrs. (years). Abu Al-Raihan al-Biruni (972–1050), a Persian born near the Aral Sea, wrote the *Kitab al-Hind*, which first examined the erosion of the Himalaya mountains. Ibn Khaldun (1332–1406), scholar for the sultan of Egypt, wrote a multivolume world history, the *Muqaddimah*, which explicitly included human-environment interactions (possibly the world’s first).

The Renaissance and the Enlightenment

The gradual expansion of capitalism throughout the 16th to the 19th centuries provided an enormous stimulus to geography, which was highly useful in charting avenues of exploration and conquest, mapping land uses and the distributions of resources across the planet, and helping Europeans understand the worlds they were conquering. Thus, the Portuguese king Henry the Navigator sponsored a series of voyages down the west coast of Africa, including Bartolomeu Dias’s trip around the Cape of Good Hope in 1488 and Vasco da Gama’s trip to India in 1497. Magellan set out to sail around the world but died en route (one of his ships completed the voyage). Columbus, sailing for the Spanish Crown, inadvertently discovered the Americas in 1492, opening a vast new chapter in the rise of the West. Scientific voyagers included Captain James Cook, who undertook three voyages throughout the Pacific in the 18th century. Explorers and scientists brought back vast quantities of data and plant, animal, and mineral samples to Europe, much of it organized, stored, and displayed in universities, museums, zoos, and botanical gardens.

During this era, cartography exploded in scope and sophistication. Many of the first maps produced then were nautical sea charts, including portolan charts of coastal areas. In the 1400s, Martin Behaim in Nuremberg created the first globe. Cadastral maps for surveying and establishing the boundaries of property became common. During the Dutch golden age, when Amsterdam was a major commercial center, the first atlases appeared; these were so important that they were often national secrets. In the 16th century, Martin Waldeemüller (1470–1522) made the first map that showed the Americas, immortalizing the name of the new continent. Gerardus Mercator (1512–1594), a Flemish engraver, created a famous projection in 1569 that allowed the use of straight rhumb lines, or lines of constant compass bearing, which was highly useful for long-distance navigation; the Mercator projection became the world’s most commonly used for centuries to come.

The Enlightenment also saw several prominent geographers make a break with theology. Bernhard Varens (Varenius) was a 17th-century



German who wrote the *Geographia Generalis* in 1650, which served as a major textbook for the next 150 yrs. and was translated into English by Isaac Newton. He distinguished between *specific geography*, which was concerned with the unique character of places, and *general geography*, which was concerned with universal explanatory laws rather than simply collecting empirical data.

Immanuel Kant (1724–1804), better known as a philosopher, was also a professor of geography at the University of Königsberg for 40 yrs. (1756–1797). Kant made numerous contributions to geography, although his factual assertions about other cultures were often empirically erroneous and racist. His philosophical orientation attempted to resolve the debate between British empiricists and Continental rationalists, arguing that the mind is predisposed to the rational organization of sense data. Kant maintained that people never experience things in themselves (*noumena*), only their sense impressions of them (*phenomena*). The world thus has no inherent, preexisting order but is constructed by the mind. Time and space are categories created by the mind to make sense of nature; they are not phenomena themselves but ways to organize phenomena. Kant's contributions to geography included papers in physical geography and his advocacy of a view of absolute space as an abstraction separate from nature. Importantly, he held that space was on a par with time in explanation, a notion that would be smothered by the rise of historicism in the 19th century. Kant held that geography, like history, was concerned with the study of empirical phenomena, and he differentiated between “mathematical geography” (maps and surveying), physical geography, political geography, moral geography (essentially, cultural geography), commercial geography (trade), and theological geography (religious views of landscapes).

European Human Geography in the 19th Century

The Industrial Revolution, urbanization, the growth of literacy, expanding universities, and the growing pragmatic need for geographic information in the face of colonialism gave rise to a steady growth of geographic knowledge and the professionalization of the discipline. A primary

manifestation of this trend was the founding of national geographical societies in Europe, such as the French *Société de Géographie* in 1821; the German *Deutsche Gesellschaft für Geographie* in 1828; the Geographical Society of London (later the British Royal Geographical Society) in 1830, which later became the Institute of British Geographers in 1934; the *Russkoe Geograficheskoe Obshchestvo*, or Russian Geographical Society, in 1845; the *Società Geografica Italiana*, or Italian Geographic Society, in 1867; the Royal Dutch Geographical Society in 1873; and the *Svenska Sällskapet för Antropologi och Geografi*, or Swedish Society for Anthropology and Geography, in 1877. Such societies, along with many other small organizations, led to a proliferation of conferences, sponsored talks, and journals that reflected and contributed to the exponential increases in geographical knowledge throughout the period. Many also served to legitimate the brutal colonial conquests of other parts of the world then under way.

The two leading geographic figures during this period were Alexander von Humboldt, one of the 19th century's most important scientists, and Carl Ritter (1779–1859). von Humboldt is best known for his extensive travels in Latin America (1799–1804) and Siberia (1837–1842). He accumulated vast amounts of empirical data on plants, volcanoes, and climate, among others; he was the first European to see the Orinoco River in Venezuela, and he discovered the Humboldt Current; he was the first to use isolines, such as isobars and isotherms; he theorized the notion of continentality, in which climates far from the ocean behave differently from those nearby; he discovered that air temperatures decrease with altitude and he conducted extensive studies on South American tribes. Many of his observations are contained in his five-volume work *Cosmos* (1830–1859), which offered an agnostic, holistic view of nature, arguing that Earth must be viewed as a unified organic whole. His views influenced, among others, Simon Bolivar and Thomas Jefferson.

In contrast, Carl Ritter (1779–1859) taught geography at Frankfurt and Berlin, traveling some in Europe but not beyond. He is best known for his massive 19-volume work *Erkunde*, which emphasized the comparison and synthesis of regions as an expression of a religious teleology.



Humboldt and Ritter are often considered the founders of modern geography; however, whereas Humboldt was secular, Ritter was religious; Humboldt focused on the physical environment, Ritter on human geographies; Humboldt worked at a fine level of areal differentiation, Ritter worked at the scale of continents.

The 19th century is also known for two famous anarchist geographers. Élisée Reclus (1830–1905) participated in the Paris Commune in 1871 and was subsequently imprisoned and banished. In his 19-volume *Nouvelle Géographie Universelle* and 6-volume *L'Homme et la Terre*, he exhibited a concern with social inequality, preservation of the environment, and town planning. Peter Kropotkin (1842–1921) was a Russian aristocrat who became an anarchist after serving as a military officer in Siberia; in 1885 he wrote the essay “What Geography Ought to Be” in prison, arguing that spatial hierarchies mirror and reinforce social ones. His philosophy emphasized “mutual aid” among decentralized self-governing communities.

The Development of North American Geography

From its inception, the United States developed its own tradition of geographical thought and practice. In addition to his many other accomplishments, President Thomas Jefferson was greatly interested in geography. He negotiated the Louisiana Purchase, sponsored the Lewis and Clark expedition, and initiated the township and range system of land ordnance in 1785, which helped bring the territories of the expanding Western United States into a rationalized, Enlightenment frame of consciousness. The late 18th century also witnessed vast numbers of atlases, textbooks, gazetteers, and travel guides. Jedediah Morse (1761–1826), a Connecticut Calvinist preacher, often called the father of American geography, wrote several bestsellers to assist Americans in understanding their own territory, including the Native Americans; his efforts formed a vital part of the construction of American identity in the early phases of its nationhood.

Human geography in the United States was slow to develop, in part due to the domination of the field by physical geographers such as William Morris Davis (1850–1934). American human geography

also exhibited several characteristics that differentiated it from its European counterpart. There were strong links between American geography and the ongoing colonization of the West: Geographers were active in the so-called opening up of the West through their surveys, charts, maps, and photographs throughout the 19th century, transforming what was for Europeans and Euro-Americans a blank space into a mappable, knowable, and hence controllable one. Human geographers in the United States placed great emphasis on induction (in contrast to European theorizing), fieldwork, and applied, pragmatic applications, and they suffered from suffocating empiricism long after their French, German, and British counterparts had begun to move into more theoretically sophisticated perspectives.

In the latter part of the 19th century, geography became progressively institutionalized as a discipline in professional societies and universities. The American Geographical Society, formed in New York in 1851, sponsored expeditions and the nation's oldest geography journal, the *Geographical Review*. In 1888, the National Geographic Society began in Washington, D.C., to serve scientists working for the federal government. Under its energetic editor Gilbert Grovesner, the society's official journal, *National Geographic*, grew rapidly in popularity and subscriptions, helping to bring the geographical imagination of American foreign conquests home to the expanding middle class. In the process, it became the unofficial voice of American foreign policy. By the 1920s, with more than 1 million subscribers to its journal, the National Geographic Society was the largest educational society in the world, and its photos and texts exercised considerable influence over popular conceptions of geography.

Geographical studies were prevalent throughout the Ivy League in the early 20th century. The first department, however, was at the University of California, Berkeley, which began in 1897. The first PhD program was located at the University of Chicago; founded in 1903, it produced a long stream of famous graduates, including J. Paul Goode, Harlan Barrows, Gilbert White, Homer Hoyt, Derwent Whittlesey, Carl Sauer, and Richard Hartshorne. In 1904, the founding of the Association of American Geographers in Philadelphia, with William Morris Davis as its



first president, marked the growing professionalization of the field; the largest national geographic organization in the world today (with more than 10,000 members), it publishes the *Annals of the Association of American Geographers* and *The Professional Geographer*. Somewhat later, in 1951, the Canadian Association of Geographers held its first meeting.

Geopolitics and Environmental Determinism

As opposed to encyclopedic empiricism, in the late 19th century, classical geopolitics and environmental determinism arose as geography's first true paradigm, marking a shift in the discipline from a collection of facts to a body of theory. This move was closely associated with the aftermath of the Darwinian revolution and the secular challenge to Christian dogma, although it also drew on the earlier (and erroneous) ideas of the French biologist Jean Baptiste Lamarck (1744–1829). The incorporation of the Lamarckian variant of Darwinism centered on the notion that culture is carried biologically, which removed the random chance central to Darwinian theory and posited evolution in much more rapid terms than did natural selection. Social Darwinism came to privilege the biological over the social in the explanation of history and geographies, often legitimating inequality as natural and necessary, as in the works of the historian Herbert Spencer. Not coincidentally, this view of competition and hierarchy occurred amid the waves of European colonialism.

Classical geopolitics, a term coined by the Swedish political scientist Rudolf Kjellen, was formalized in the works of Friedrich Ratzel (1844–1904), who gave formal expression to German fears of encirclement at the hands of Russia, France, and Britain. Sometimes called the father of human geography, Ratzel maintained in his *Anthropogeographie* that nation-states could be viewed as organic, biological organisms. If they were not growing, then they were dying. In their search for living space, or *lebensraum*, states would inevitably come into conflict, or *kulturkampf*. Ratzel's views thus biologized international relations, making them appear as natural rather than social creations, and were read eagerly by later German leaders, including Adolf Hitler.

The Nazi geographer Karl Haushofer (1869–1946) was instrumental in this regard.

The paragon of classical geopolitics was Sir Halford Mackinder (1861–1947), who taught at Oxford University and served as a member of Parliament. In *The Geographical Pivot of History*, written in 1904, he was one of the first theorists to conceive of the globe as an integrated political system. His argument centered on the notion that the age of sea power was over and that railroads, in opening up the interiors of continents, were generating new geographies of centrality and peripherality. The heartland, in this reading, consisted of Eastern Europe and Western Russia, a pivot area relatively inaccessible to marine powers.

As the first ostensibly scientific paradigm in geography, environmental determinism framed the world in terms of a hierarchy of competing races in which climate, continents, and ethnic groups were flattened to dichotomies such as civilized versus uncivilized. Geography textbooks often described dark-skinned peoples as indolent and lazy, in need of Western intervention. Ellen Churchill Semple (1863–1932), a student of Ratzel's, was a prime proponent of this view, arguing in books such as *The Influences of Geographical Environment*, published in 1911, that climate and topography exerted essentially uncontrollable influences over people. Ellsworth Huntington (1876–1947) and Griffith Taylor (1880–1963) wrote in much the same vein, a line of thought that culminated in the racist program of eugenics.

By World War I, environmental determinism was increasingly falling into disfavor under the withering attacks of cultural geographers such as Paul Vidal de la Blache in France and Carl Sauer in the United States. Its principal errors included its omission of countervailing facts and its selective use of evidence, its inability to account for social relations and culture and thus the variable responses to environmental constraints, its ridiculous and unscientific racism, and its simplistic understanding of nature, which itself has been heavily modified by people. The alternative doctrine of environmental possibilism, which gave much more weight to the capacity of people to shape their own worlds, began to gain legitimacy. The legacy of environmental determinism, however, included a widespread retreat from



theory in general, which greatly hampered human geography's subsequent intellectual maturity, and a bifurcation between human and physical geography that put nature off-limits to social analysis until this schism began to heal in the 1990s.

Isaiah Bowman (1878–1950) was a geographer mostly known for his prodigious administrative and political accomplishments. He studied under Davis at Harvard, taught for a decade at Yale, and participated in the American Geographical Society–sponsored expedition to Peru that revealed Machu Picchu in 1911. Later, he served as director of the American Geographical Society (1915–1935), taking time in 1919 to work with the American delegate to the Paris Peace Conference in 1919, where he played a key role in drawing the boundaries of the new post-World War I Europe. A founding member of the Council of Foreign Relations, which publishes *Foreign Affairs*, he also became well acquainted with Presidents Wilson and Franklin Roosevelt. From 1935 to 1948, he was president of Johns Hopkins University, during which time he was a delegate to the conference that led to the founding of the United Nations.

World War II also deeply affected geography, particularly in the United States. Hungry for geographic information about distant conflicts, the public turned to maps in record numbers. Numerous planners and tacticians gained experience in cartography and air photo interpretation, and the quantitative skills learned by others became important in shaping the subsequent changes in academic geography.

Cultural Geography and Chorology

As part of its rejection of environmental determinism in the 1920s, the discipline of geography embraced the long-standing tradition of chorology, also known as areal differentiation. In Europe, the Annales School was important in this regard; a central figure was Paul Vidal de la Blache (1845–1918), the father of French geography, well-known for his studies of small rural areas called *pays* and their associated styles of life, or *genres de vie*. Like many observers, he viewed culture and the soil as deeply shaping one another; however, unlike the environmental determinists, he refused to collapse the social into the physical. By observing how

widely lifestyles varied in what was essentially a homogeneous climate, he initiated a viable alternative to environmental determinism. He also played a central role in the introduction of possibilism to the discipline, a notion first advanced by the historian Lucien Febvre. His German counterpart was Alfred Hettner (1859–1941), who argued in the Kantian tradition that geography consisted of the art of regional synthesis, seeking relations among phenomena that other disciplines ignored.

Carl Sauer (1889–1975) looms large as the father of American cultural geography. Teaching at the University of California, Berkeley for three decades (1923–1954), and giving rise to the Berkeley School, which differed greatly from the discipline's Midwestern roots, he offered a view of culture that avoided the ugly racism pervasive in environmental determinism, advocating instead a relativist reconception that uncoupled moral superiority from military or economic might. Sauer's accomplishments include the introduction of the concept of *landschaft* or landscape into American geography as both a cultural and a natural product; the study of cultural hearths, where innovations such as agriculture began; his advocacy of fieldwork (he was an expert on Mexico); and his insistence that cultural geography take historical context seriously. Sauer's department generated a large number of influential cultural geographers such as John Leighly, Fred Kniffen, Joseph Spencer, Andrew Clark, James Parsons, Carville Earle, Wilbur Zelinsky, and Marvin Mikesell. At Harvard, Derwent Whittlesey (1890–1956) introduced the notion of sequent occupance, a technique for analyzing landscapes as the product of successive groups over time, each of which leaves an imprint, forming a palimpsest.

The most famous advocate of chorology was undoubtedly Richard Hartshorne (1899–1992), who studied under Alfred Hettner, before graduating from the University of Chicago in 1924. The chorologists maintained that the essence of the discipline was the description of regions in all their glorious uniqueness and complexity, including cultural and physical phenomena. Hartshorne argued that the most productive analyses focused on small, relative homogeneous regions, noting that any deployment of the regional concept was inherently a subjective tool to find meaning in the unwieldy complex of data found in the world.



Regions, thus, were mental tools to impose order on chaos. By eschewing theory, chorology found itself mired in empiricism, and the discipline's theoretical progress was halted.

Chorology, and the empiricist cultural geography that it sustained, drew to a close in the 1950s, beginning with the famous attack on Hartshorne's worldview by Frederick Schaefer in 1953. Essentially, Schaefer claimed that the view of geography as an integrative science concerned only with the unique was naive and arrogant, for uniqueness was a problem common to many sciences. By refusing to search for explanatory laws, geography condemned itself to what he called an "immature science." Rather than idiographic regions, geographers should seek nomothetic regularities across regions. This critique helped open the door to the rise of positivism and the quantitative revolution.

Positivism and the Quantitative Revolution

Starting in the 1950s, human geographers embraced a new theoretical paradigm, logical positivism. Epistemologically, this view drew from the Vienna Circle to embrace the scientific method, quantitative methods, hypothesis testing, reproducible results, prediction, and the correspondence theory of truth, setting out to refashion human geography as a science. Drawing on older traditions such as applied geometry, physics, classical German location theory (e.g., the von Thünen model, Weberian location theory, and Christaller's central place theory), and neoclassical economics, this school advocated a Cartesian view of space, that is, geography as geometry, in which landscapes are reduced to isotropic planes. Central to this paradigm were the surfaces, nodes, and hierarchies found in models, including central place approaches to urban systems, gravity models, diffusion models of the spread of diseases and innovations, entropy-maximizing models, location-allocation models to optimize distributions, multivariate statistics, and input-output models to simulate economic systems. Appropriate models were held to distill the essence of the world, revealing its causal properties through the act of simplification.

The originators of the quantitative revolution in geography included the faculty at the Universities of Iowa and Wisconsin, but it was the University of Washington that famously became its epicenter.

There, under the guidance of William Garrison, a cohort of "space cadets" came to play an enormous role in furthering the new paradigm. Brian Berry became a giant within urban and economic geography; William Bunge's *Theoretical Geography* sought to inject rigorous geometry into the field, although he later became radicalized. Richard Morrill wrote extensively on spatial demographics and political redistricting. Others included Duane Marble, John Nystuen, Waldo Tobler, and Michael Dacey, all of whom became leading figures in their day. In Britain, Peter Haggett and Richard Chorley played a similar role.

Although it was highly successful within its own frame of reference, the positivist school also found itself facing increasingly heavy criticism in the 1970s. Humanists objected that such an approach might work well in the natural sciences but not in the social sciences. Critics held that positivism denied the existence of an observer, offering a false sense of objectivity; even the attempt to be scientific and objective is, after all, a value. Rather, critics alleged, all data are value laden and filtered through theory, so that the fact-value distinction is untenable. Positivism's celebration of quantitative techniques was criticized as sterile and overly restrictive; math is but one way to understand reality and not always the optimal one for the analysis of phenomena that often can only be studied through interpretive forms of understanding. Finally, Marxists argued that positivism's ahistorical approach lacked any account of social relations, including class, power, and culture, and thus focused on empirical forms rather than deep social processes. In this reading, positivism deprived itself of any means to comprehend social change.

Marxist Geographies

Drawing on the extensive tradition that began with Karl Marx (1818–1883), geographers in the 1960s and 1970s constructed a view of space and landscape centered on political economy. While there are many varieties of Marxism, they share in common a concern for the centrality of class, the production process, the importance of labor, a deeply historical understanding of how societies are constructed, and the power and politics that pervade all societies, including capitalism. Marxist geographers viewed space in explicitly



social terms, that is, as a construction of historically contingent social structures and relations. The introduction of Marxism into geography was thus simultaneously the spatialization of Marxism as an analytic tradition; historical materialism became historical-geographical materialism. In the process, geography became truly social in outlook, and the understanding of how landscapes and spatial distributions were created and changed became inseparable from the analysis of how societies are structured and transformed.

David Harvey (1935–) played the major role in this process through a long series of influential books that introduced geographers to historical materialism and reworked it along geographic lines. Harvey injected into geography famous notions such as the cycle that linked commodity production to money to commodities, which lay at the heart of capitalist production. Starting with *Social Justice and the City* in 1973, Harvey's works electrified the discipline, reorienting its social analysis, in which landscapes were seen as filled with power relations that perpetuated inequalities. Every social formation under capitalism, he argued, constructs what he termed a *spatial fix*, an optimal landscape that reflects the prerequisites of production yet simultaneously inhibits future rounds of production. Geographies are thus poised between the need for capital to generate spatialities that facilitate capital accumulation and the ever-present need to change those geographies in the perpetual search for growth and expansion. In so doing, Harvey showed that time and space are not absolutes that lie outside society but products of those societies, a move that marked a gradual transition from absolute to relative and relational space.

The contributions of other Marxist geographers such as Neil Smith, Richard Walker, and Michael Storper included shedding light on questions of uneven development and spatial divisions of labor; revealing the central role of the state in the formation and maintenance of capitalist relations (in contrast to the mythology of the free market); reworking urban theory around the issues of production, class, and social reproduction, including topics such as suburbanization, inner-city poverty, and gentrification; and adding great depth to international political economy, primarily through intersections with schools of thought such as dependency theory and world

systems theory. Other Marxists initiated a tradition concerned with the social construction of nature and environmental politics, while yet others ventured into the domain of cultural geography, portraying culture and cultural landscapes not just as sets of ideas but as power relations.

Critics of the Marxist tradition often pointed to its tendency to economic determinism, that is, the reduction of all social issues to labor and production. Others argued that Marxism suffered from an inadequate theorization of human agency and human consciousness. In the late 20th century, Marxism, which had thoroughly reworked human geography, was complemented and at times contested by several other perspectives on how space and society were fused.

Humanistic Geography

In the 1970s, some geographers turned toward the philosophical traditions of phenomenology and existentialism. Originating in hermeneutics, the study of textual meanings that had medieval roots, this school drew on the works of philosophers such as Edmund Husserl (1859–1939) and Martin Heidegger (1889–1976) to explore the implications of human experience in a world without fixed meanings. Humanistic geographers such as Edward Relph were concerned to put people back at the center of social analysis, intersecting with psychology, humanistic philosophy, literary analysis, and linguistics to offer a rich portrait of what it means to be human, that is, to construct webs of symbolic meaning. Jettisoning the myth of objectivity, humanist geographers argued that understanding comes from shared interpretations and the clarification of values.

Central to the project of humanistic geographers was the work of Yi-Fu Tuan, who redefined the notion of place from a sterile, tangible object to the intangible meanings that people give to it. *Place*, as an embodied, erotic, and highly personal locale central to everyday life, was contrasted with *space*, a more abstract, Cartesian notion. Humanistic geographers focused on how consciousness constructs places through understanding and interpretation, that is, how landscapes are authored. *Sense of place* became a term that encapsulated this notion of locales as intangible and symbolic, in contrast to conventional cultural geography's focus



on material landscapes. This line of thought led to the exploration of individual life-worlds and the spaces of the body, the most intimate of geographies: Bodies appear natural but are social constructions, inscribed with social meanings. In arguing for the centrality of human consciousness, humanism mounted a serious challenge to both positivism and Marxism, forcing social science to take seriously the implications of culture, ideology, everyday life, and social reproduction (e.g., in recognizing the role of contingency, the capacity of human actors to do otherwise).

Criticisms of humanism maintained that this perspective lacked a systematic account of social relations, class, power, and production. Thus, humanistic thought centered on an asocial, ahistorical, undersocialized view of the individual, without reference to the mechanisms of social reproduction. Attempts to reconcile humanism and Marxism in the 1980s led human geographers to explore lines of thought such as structuration theory.

Geography and Feminism

Geography has long been a male-dominated discipline. As female academics grew in numbers and were inspired by the women's movement of the 1960s and 1970s, feminist geography grew in size, importance, and sophistication. While there are many views within feminism, all of them assumed the common point of departure that focused on gender. Feminists, such as Susan Hanson, Gillian Rose, and Linda McDowell, maintain that social reality is pervasively gendered and that gender relations intersect (and often precede) class, generally as manifested through patriarchy, that is, gender relations that favor men at the expense of women. Feminism as a political project seeks not to eliminate gender but to eliminate the inequality that arises from patriarchy.

Feminist geographers made numerous contributions to the field, focusing on how gender relations are intimately woven into existing allocations of resources and modes of thought in ways that generally perpetuate patriarchy. To ignore gender is to assume that men's lives are "the norm," that there is no fundamental difference in the ways in which men and women experience and are differentially enabled and constrained by social relations. Widely recognized as the first non-class-based

form of social determination to acquire legitimacy, gender has been thoroughly denaturalized: While gender roles may appear to be natural (i.e., outside of society), they are socially constructed as webs of masculinity and femininity. Feminists opened up the family as an object of geographic scrutiny, questioning the schism between production and reproduction, the economic and the social. In urban geography, feminists focused on gender differences in commuting. Methodologically, feminism helped legitimate the use of qualitative methods such as participant observation, standpoint theory, and grounded theory, emphasizing that knowledge always is a view from somewhere and context-bound.

Postmodernism and Poststructuralism

The 1980s and 1990s witnessed rising diversity in how geographers came to view the world, including the recognition that modernity, far from being a universal feature of human life, was one historical project among many. Diverse thinkers coagulated into a school of thought that came to be known as postmodernism and in the 1990s as the more politically assertive poststructuralism.

It is critical to note that there are many variations in this line of thought, but commonalities typically include placing great emphasis on the constitutive role of language and ideology in the formation of social life. Like humanists, postmodernists argue that every discourse interprets the world from a particular vantage point, that every view is a view from somewhere, and that what one sees depends on where one stands. Postmodernists maintain that for every topic, there are inevitably many competing discourses, none of which is inherently more correct than others. There are thus no *a priori* grounds for deciding what is true or not. To the postmodernist, everything is a discourse because there is no way to see the world outside of discourse. Such a view intersected with the literary tradition of deconstruction, in which texts are pulled apart for their diverse, often contradictory meanings. It also borrowed heavily from the works of Michel Foucault (1926–1984), who emphasized that all knowledge is inescapably sutured to power: Discourses were not simply reflective of the world but constitutive of its inhabitants. From this view, all grand sweeping views of



reality (often labeled *metanarratives*) sweep a great deal under the carpet, obscuring as much as they reveal. Indeed, the essence of postmodernism is that reality is more complex than our languages allow us to admit and that every linguistic construction of order is a simplification and distortion. Thus, every representation of reality, every discourse, is inescapably political; there can be no divorce between the ontology and epistemology of viewpoints.

Postmodern geographers are a diverse group. Marxists, such as Edward Soja and David Harvey, argue that postmodernism is the latest cultural expression of advanced capitalism and that so-called postmodern landscapes reflect the emergence of a globalized, hypermobile, post-Keynesian, post-Fordist regime of production. In this view, postmodernism is essentially a response to the enormous wave of time-space compression unleashed by contemporary capitalism. Others employed the postmodern celebration of difference to reassert the significance of localities and local uniqueness, arguing that when and where social events happen is fundamental to how they happen, a move that elevates geography to the level of epistemology.

Postmodernism gradually gave way to a more politically assertive poststructuralism, although the two terms overlap considerably and some authors use them interchangeably. Like feminism, postmodernism welcomed views from subjugated minorities, the suppressed Other, the subaltern in the developing world. Instead, the poststructuralists ask, who is it that gets to decide what constitutes valid, legitimate, correct, or proper discourse? As an emancipatory political project, this view forced a philosophical shift from the social core to its periphery, from the center to the margins; that is, it required intellectuals to recognize the importance of gender and race, not only ontologically (i.e., as parts of social reality) but also epistemologically (i.e., as they pertain to the creation of knowledge).

Critics of postmodernism accuse it of degenerating into intellectual nihilism and endless relativism, in which all positions come to have equal weight. Some Marxists argue that the postmodern focus on culture and discourse has submerged class as a meaningful social category. Moreover, an overemphasis on difference can be politically disempower-

ing, for without a common political project resting on common assumptions and values, it is difficult to forge alliances across a diverse social spectrum.

More recent issues in human geography have forged even more adventurous conceptions. Drawing on the works of Bruno Latour, for example, poststructuralists have pursued actor-network theory to jettison long-standing dichotomies (e.g., individual and society, culture and economy, nature and culture, time and space), even that between human and nonhuman actors, to create novel notions of hybridity. Rather than places, poststructuralist geographers emphasize mobilities, connectivities, flows, rhizomes, and networks in a relational ontology of space, one that views geographies as always coming into being and forever under construction. Like Doreen Massey's power-geometries and work on commodity chains, this line of thought emphasizes geography as a series of interconnected relational places rather than discrete locales, produced by and in turn shaping social relations in a continuously intertwined mixing. Some use this approach to examine the social production of scale, and others even call for eliminating scale as an analytical category.

Conclusion

This brief review has done little more than sketch some of the broad contours of how human geography as a discipline has existed and changed over two millennia. The field has long served society—typically its hegemonic interests—in numerous ways, including exploration and trade, naturalizing colonialism and racism, and urban and regional planning efforts; more recently, given the hegemony of political economy and social theory, human geography has exhibited a sustained interest in exposing and challenging social and spatial inequalities, denaturalizing what appears given and pointing toward more socially just visions of the future. Given the diversity of topics and approaches, it is clear that there is no single way to view human geography but a plethora of contending schools of thought about space that intersect in creative ways. Moreover, human geography's history is unfinished, for new ways of looking at space are always emerging and are ever likely to do so.

Barney Warf



See also al Idrisi; American Geographical Society; Anarchism and Geography; Annales School; Anthropogeography; Aristotle; Association of American Geographers; Barrows, Harlan; Berkeley School; Berry, Brian; Biruni; Bowman, Isaiah; Bunge, William; Cartography, History of; Central Place Theory; Chicago School; Chorology; Colonialism; Columbus, Christopher; Critical Human Geography; Cultural Geography; Darwinism and Geography; Economic Geography; Empiricism; Enlightenment; Eratosthenes; Eurocentrism; Existentialism and Geography; Exploration; Feminist Geographies; Gender and Geography; Geographical Imagination; Geopolitics; GIS, History of; Gregory, Derek; Hägerstrand, Torsten; Hartshorne, Richard; Harvey, David; Hettner, Alfred; Historical Geography; Humanistic Geography; Humboldt, Alexander von; Huntington, Elsworth; Idiographic; Institute of British Geographers; International Geographical Union; Isard, Walter; Jackson, John Brinckerhoff; Kant, Immanuel; Kropotkin, Peter; Lefebvre, Henri; Lewis and Clark Expedition; Location Theory; Logical Positivism; Los Angeles School; Mackinder, Sir Halford; Magellan, Ferdinand; Marsh, George Perkins; Marxism, Geography and; Meinig, Donald; Modernity; Morrill, Richard; Morse, Jedidiah; National Geographic Society; Nomothetic; Olsson, Gunnar; Orientalism; Palimpsest; Phenomenology; Physical Geography, History of; Political Geography; Population Geography; Postcolonialism; Postmodernism; Poststructuralism; Pred, Allan; Quantitative Revolution; Radical Geography; Ratzel, Friedrich; Reclus, Élisée; Regional Geography; Regional Science; Regions and Regionalism; Relph, Edward; Ritter, Carl; Royal Geographical Society; Sauer, Carl; Schaefer, Fred; Semple, Ellen Churchill; Sequent Occupance; Settlement Geography; Smith, Neil; Social Darwinism; Social Geography; Soja, Edward; Spatial Analysis; Structuralism; Structuration Theory; Subaltern Studies; Surveillance; Symbolism and Place; Taylor, Griffith; Taylor, Peter; Thales; Thrift, Nigel; Time-Geography; Time-Space Compression; Tobler, Waldo; Travel Writing, Geography and; Tuan, Yi-Fu; Urban Geography; Urban Spatial Structure; Varenius; Vidal de la Blache, Paul; Weber, Alfred; White, Gilbert; Whittlesey, Derwent; Wittfogel, Karl; Zelinsky, Wilbur

Further Readings

Cloke, P., Philo, C., & Sadler, D. (1991). *Approaching human geography*. New York: Guilford Press.

- Dickinson, R. (1969). *The makers of modern geography*. New York: Praeger.
- Harvey, D. (1984). On the history and present condition of geography: An historical materialist manifesto. *Professional Geographer*, 36, 1–10.
- Holt-Jensen, A. (2003). *Geography: History and concepts* (3rd ed.). London: Sage.
- James, P. (1972). *All possible worlds: A history of geographical ideas*. New York: Bobbs-Merrill.
- Johnston, R., & Sidaway, J. (2004). *Geography and geographers: Anglo-American human geography since 1945*. London: Arnold.
- Livingstone, D. (1992). *The geographical tradition*. Oxford, UK: Blackwell.
- Murdoch, J. (2005). *Post-structuralist geography: A guide to relational space*. London: Sage.
- Peet, R. (1998). *Modern geographical thought*. Oxford, UK: Blackwell.
- Schulten, S. (2001). *The geographical imagination in America, 1880–1950*. Chicago: University of Chicago Press.



HUMAN-INDUCED INVASION OF SPECIES

An invasion of a species is defined as the introduction, establishment, and subsequent spread of that species in a geographic area different from its original or native geographical range. Once a species has been introduced into a new habitat, it can be naturalized; that is, it can adapt to the new environment and expand its population, usually producing negative effects on native species and on the whole ecosystem structure. Not all human-induced introductions of species are successful, and invasive populations can become extinct shortly or even after a long time. There are two aspects to consider in the ecological study of invasions: (1) the susceptibility of a territory to an alien invasion (i.e., the suitability of a territory to the ecological requirements of an invasive species and its proclivity to be invaded) and (2) the invasiveness of the species (i.e., its capacity to become an invader), which depends on its ethological, physiological, and morphological characteristics, as well as on the number and frequency of invasions on the same habitat over time. This entry



Water hyacinth filling a canal in the Mississippi Delta. Water hyacinth stops boat traffic and interferes with the circulation of water.

Source: Dr. Terry McTigue, National Oceanic and Atmospheric Administration/Department of Commerce.

discusses how an invasion occurs, the effects of invasive species on ecosystems, the history of invasions on islands and elsewhere, and future efforts to control invasive species.

The invasive capacity of plant species will be determined primarily by its capacity for dispersal and spread, rapid growth, great height (increasing its access to light), high leaf area, high use efficiency of the available resources, and great tolerance to environmental stress. Invasive animal species tend to have more flexibility in behavior (including partnership with humans), more aggressiveness, higher reproductive rates, and broader ecological niches (more generalist species).

With regard to habitats, disturbed and highly isolated ecosystems are prone to be invaded. They support communities structured in simplified

networks. New invasive species modify the ecological relationships in the networks, even affecting the whole ecosystem when aliens are recruited among top predators or herbivores.

How Does an Invasion Occur?

Humans, due to their unique ability to remove natural barriers, are responsible for many species colonizing geographical areas located far away from their original habitat through different pathways, which in some ways have changed over history. Briefly, introductions may be as follows:

Intentional. When humans move from one place to another, they intentionally introduce a different species for its use in terms of agriculture, livestock, hunting, fishing, or gardening.



Involuntary. Human activities, especially in modern and contemporaneous times, have promoted the introduction and spread of species from very distant regions and between both hemispheres. Unintentional invasions of species have been favored by ballast water exchange, species traveling attached to the hull of ships, escapes from farms and gardens, species traveling along with agricultural products or transport vehicles, species used in biological control of plagues, or artificial connections of different watersheds. Not only are human-introduced species considered potential invasive organisms, but also the parasites of these invasive species can cause extremely negative effects on native species.

Apart from the direct introduction of plant and animal species, humans have an important indirect role in the passive invasion of species related to the putative human-induced climatic change. Despite the arduous discussion about the origins and effects of the global climate change, different species are being induced by the global temperature warming to move to new locations.

Effects of Invasive Species on Ecosystems

Although invasion biology emerged as a discipline devoted to the study of a primordial topic related to the current biodiversity crisis, its most abundant and robust documentation comes from insular vertebrate paleontology. Recent studies on current ecosystems allow an accurate understanding of the invasion mechanisms, but it should be noted that major invasive processes took place in past times. The recorded global loss of biodiversity in birds and mammals that occurred following the human colonization of islands involved ca. 3,000 species of birds and ca. 200 species of mammals. This extinction event occurred mainly in prehistoric times, and it is one of the global effects of invasive species. Many extinction processes occurred also on continents following the human spread. Although there is still debate on their original causes, climate-related hypotheses are being frequently excluded, while human spread of invasive species, and its consequences on ecosystems, appears as a more plausible hypothesis to explain them.

Even currently, the effects of invasive species on native communities/ecosystems can acquire dramatic dimensions for nature, not only ecologically but also economically (when invasion becomes a plague, directly affecting human interests). Mostly, invasive species act as predators and competitors and have a direct impact on native species. In many cases, the autochthonous species have evolved without predators or competitors so that they do not display defense mechanisms against the new settlers. The impact of the new species can lead the native species to extinction, especially at low population densities.

Eventually, the invasion of a species results in the hybridization and genetic contamination of a native species if there is a genetic exchange between the new and the autochthonous species. Other important effects can be produced indirectly by the introduction of parasites and pathogens that can attack native species, which often lack an immune defense against them.

The interferences with the ecological networks and relationships among native species (such as mutualism) by an invasive species have been also accurately studied. The elimination of mutualisms can promote not only the extinction of one species but also the extirpation of a cascade of species involved in an ecological network.

As a result of all these effects, invasive species decrease biodiversity on the global level, although their effects on particular ecosystems, especially on islands, can sometimes increase local biodiversity.

Past Invasions on Islands

The human diaspora colonized the islands of the world through a process that started in the Paleolithic and ended in roughly the 15th century with the settlement of the Pacific Ocean islands. Together with humans, a plethora of invasive species spread on islands' ecosystems, resulting in drastic changes in the island networks, including both the extinction of natives and the remodeling of island ecosystems. Although the main changes usually occurred just after the first colonization event, some major changes have been recorded in later periods.

Everywhere, human arrival involved the spread of domesticants, commensals, and opportunistic invasive species. The invasive species associated



with each colonization depended on the cultural background of the source communities. Thus, as examples, typically the prehistoric colonization of the Mediterranean islands involved goat, sheep, cow, pig, dogs, and the formerly commensal wood mouse and garden dormouse. The later Roman spread, after the Punic wars, involved a new wave of invasions, including those of black rat, house mouse, chicken, horse, donkey, and other species. On the Pacific Islands, the prehistoric Lapita colonization involved the spread of dogs, pigs, chicken, and kiore. On the Canary Islands, the prehistoric colonization involved the arrival of the house mouse, goat, sheep, pig, and probably the dog. In all these examples, each invasion wave was coeval with an extinction event, suggesting a close relation between them. Also, everywhere, the opening of forests for agricultural purposes through the use of fire contributed to the dispersal and spread of opportunistic invasive (and sometimes native) plant species, which colonized the new space free of competitors.

The presence of a reduced number of mammalian species displaying atypical features acquired in the process of their evolution under isolation conditions is a characteristic of the true islands relatively close to the mainland. The introduction of invasive species with their pathogens is related to the extinction of native species of mammals. Not all alien species have had the same effect on the invaded ecosystems, with the introduced opportunistic predators the top modifiers of ecosystems. On most islands, before human arrival, there were no predators, except for some birds. The introduction of carnivore species by humans (e.g., dogs, cats, weasels, mongooses, snakes, etc.) has been responsible for the extinction of native wildlife. A well-known and documented case is the introduction of the weasel (*Mustela nivalis*) by the Romans on the islands of Mallorca and Menorca (Western Mediterranean) to control the population of rabbits. This species contributed to the local disappearance of the endemic Balearic lizard (*Podarcis lilfordi*) and the endemic midwife toad (*Alytes muletensis*). The Balearic lizard currently survives only on some islets surrounding Mallorca and Menorca, while the Balearic midwife toad survives only in the inaccessible mountain torrents of Mallorca.

Recent research identified rats (*Rattus* spp.) as a major invasive key species, whose effects on

natural ecosystems have been frequently underestimated. Three species of rats associated with humans (*R. rattus*, *R. norvegicus*, and *R. exulans*) invaded a wide range of ecosystems, including a large number of islands. Rats have been incorporated onto the islands through transport in human vessels, although—after their landing on remote islands—their active colonization in the surrounding islands or islets (by swimming there) has been also recorded, amplifying their effects on the natural ecosystems. The effects of rats on seabird populations and on some populations of endemic rats have been documented elsewhere. Nevertheless, the impact of rats may have been much greater than initially established. Recent studies of Terry Hunt suggest that the impact of *R. exulans* through consumption of the seeds of the *Jubaea* trees on Rapa Nui (Eastern Island) probably caused the total deforestation and the complete transformation of the ecosystems of the island.

Historically Recent Invasions

The invasions over the past several centuries represent a further step in the globalization of nature. New methods of transportation as well as the modern technologies developed after the Industrial Revolution have created new opportunities for invasive species. As an example, the ballast water of ships has introduced hundreds of new planktonic species in oceans around the world. Also, some benthonic invaders traveled in the hulls of ships (e.g., *Cordylophora caspia*, a hydrozoan that spread throughout the world from the Caspian Sea, acting as a competitor against other benthonic species).

Large engineering projects also resulted in the invasion of species. A clear example is the Suez Canal, built to link the Red Sea to the Mediterranean Sea (1869). To date, more than 300 marine species from the Red Sea have invaded the Mediterranean. Some of them have proved to be totally negative for the native species (e.g., *Siganus rivulatus*, an introduced fish that is producing very harmful impacts on the marine ecosystems of the eastern Mediterranean).

The rise in maritime traffic increases the possibility of transport and transference of species among harbors. A noticeable case is the arrival of the brown tree snake, *Boiga irregularis*, on Guam,



probably as a stowaway in military cargo from the Papua New Guinea area during the post–World War II years. This highly poisonous species is transforming the whole Guam ecosystem, and it is responsible for the extinction of endemic birds.

Introductions of species to be exploited for fishing and hunting have also been common in recent decades (mainly, bovids have been introduced in several parts of the world, with a negative impact on native vegetation). A well-known example is the introduction of rabbits in Australia. The rabbit population increased at an alarming rate, causing a significant impact on the Australian vegetation. Similarly, the release of several species of river crabs and fishes for fishing purposes in several European countries has significantly affected the populations of native species of these vertebrates by predation and competition.

The Future

Although efforts to control invasive species and possible new introductions have been widely implemented by governments, unfortunately only a small proportion of cases of human-induced invasions have been favorably resolved. It has been suggested that, apart from preventing the arrival of more individuals of introduced species, information to the public in general, integration of prevention and control actions, good knowledge of the invasive species, and direct eradication are the best tools to manage invasive species. Specific laws to control importations can also be enacted to stop the invasion of species originated by common market policies. Recently, it has been documented that different snake species invaded the Mediterranean island of Eivissa, which was originally without them. These snakes have been introduced through the import of olive trees from Europe for gardens. Local authorities cannot control the free market existing in the European Community, and consequently, future invasions of aliens may unstoppable.

Pere Bover and Josep Antoni Alcover

See also **Adaptive Radiation; Anthropogenic Climate Change; Biodiversity; Biogeography; Centers of Domestication; Conservation; Coupled Human and**

Animal Systems; Domestication of Animals; Domestication of Plants; Extinctions; Great American Exchange; Invasion and Succession; Island Biogeography

Further Readings

- Elton, C. S. (1958). *The ecology of invasions by animals and plants*. Chicago: University of Chicago Press.
- Ruiz, G. M., & Carlton, J. T. (Eds.). (2003). *Invasive species*. Washington, DC: Island Press.
- Sax, D. F., Stachowicz, J. J., & Gaines, S. D. (Eds.). (2005). *Species invasions*. Sunderland, MA: Sinauer.



HUMANISTIC GEOGRAPHY

Humanism is a term that encompasses a variety of philosophical positions that go back to the Renaissance, during which scholars such as Erasmus and Petrarch offered views of the social world that put people in the center, in contrast to the prevailing religious interpretations. Closely associated with humanism is hermeneutics (from Hermes, the Greek messenger of the gods), which is essentially the study of meanings; originating from medieval attempts to find the one “true” meaning of the Bible, hermeneutics was extended to include the multiplicity of meanings inherent in all literary texts and social actions.

A Very Brief History of Humanistic Thought

Two closely related approaches to humanistic thought have characterized it over time, phenomenology and existentialism. Both are concerned with the shape of human experience, the nature of subjectivity, and there is considerable overlap. Whereas phenomenology tends to emphasize the nature of human experience and meaning, existentialism is more often concerned with the ethical conduct of life.

Several giants in the history of philosophy invoked these lines of thought. The Danish Christian existentialist Søren Kierkegaard (1813–1855) offered a Romantic critique of the Enlightenment,



claiming that objectivity is a myth and that all people faced an agonizing choice between faith and reason, the sacred and the profane, and ethics and pleasure. Edmund Husserl (1859–1939) propounded a transcendental phenomenology, noting that the view of science as an objective map of the outer world reduced the human observer to a passive receptor. Objects do not have meanings in and of themselves, he argued; rather, meanings are constructed by the human mind. Husserl called for a science of phenomenology that would strip away the biases that the mind created in its perceptions of the world to reveal the essence, the reality of things in themselves. Martin Heidegger (1889–1976) asked the apparently simple question “What does it mean to be?” and offered a very complex answer. His view rested on the notion of the hermeneutics of “being” (*Dasein*)—the understanding of which meant an escape from abstract theorizing. Jean-Paul Sartre (1905–1980) attempted a merger of existentialism and Marxism, noting that in contemporary capitalism the human condition is depersonalized and alienated. Essentially, all these views maintain that objectivity is a hurdle to effective understanding and that there is no privileged conceptual vantage point; every view is a view from somewhere and is inescapably laden with biases. We cannot know the world except for the meanings people give to it. Human subjectivity is thus not a barrier to understanding the world but the only route to know it. Meanings are essentially arbitrary phenomena, and logic cannot inform our moral choices. Despite this predicament, as Sartre noted, humans are “condemned to freedom”—that is, they must make choices even if there are no firm grounds for doing so.

Central Tenets of Humanistic Thought

The project of a humanistic social science was thus to put people back in the center of social analysis, to reveal the thing that makes people human—namely, consciousness. Social science has long had a poor conception of the human subject, a flaw humanism attempts to overcome. It is consciousness that makes us subjects rather than objects—that is, allows us to be actors in the world with will and volition. Mapping human consciousness allows us to move past sterile models of human behavior such as *Homo economicus*

and recover the sensuous nature of experience—the ways in which the self, the environment, and others are framed symbolically. This task involves some understanding of intentionality, our deeply human desires and motivations, and our anticipations and expectations.

Uncovering the multiple dimensions of human consciousness, however, is no simple task. It is essential to avoid simplistic and biologically reductionist notions of “human nature.” In the broadest sense, consciousness is what makes us human. In some respects, human consciousness differs qualitatively from that of animals (e.g., in our sense of self, time, humor, death), although with many primates this difference is a matter of degree. Constructing a humanistic understanding of consciousness has also invoked various psychological understandings of sensation, perception, and cognition, leading to intersections with behavioral approaches. Consciousness includes our emotions and memories, pleasures and fears, sense of sexuality, hopes for the future, and more, both rational and irrational. This view sees human beings as active, creative actors and stresses their constructive role in making the world. Social reality does not simply happen to individuals “behind their backs” or “above their heads”; they make the world that makes them. Humanistic social science is thus unapologetically anthropocentric and antinaturalist (it objects to using the same means to understand the natural and social worlds) and antideterminist (noting that people’s actions render social structures ever changing and contingent).

Humanistic thought emphasizes the central role of language, as a set of signs that we use to negotiate the world and share meanings. Language is the means by which we bring the world into consciousness, and thought is always linguistically structured. As linguists and philosophers such as Wittgenstein and others have demonstrated, language is an opaque medium of understanding with a structure of its own. There is no language-free theory, and language limits and constrains the ways in which meanings are constructed, at times letting them escape their authors. The intersections of humanistic thought and literature in the form of textual deconstruction allowed every system of signs (e.g., a text, a landscape) to be pulled apart.



Like positivism and empiricism, the humanistic approach begins with the individual's experience in the construction of knowledge. The task of social science is to enter into another's taken-for-granted world—to see reality through other people's eyes and acknowledge their view as a valid source. Truth is found in the subjective meanings that people assign to their worlds, and explanation is the recovery of their intentions. Humanism thus advocated a self-consciously empathetic social science that did not strive for the holy grail of objectivity but rather confronted its own inevitable assumptions and biases. This approach forces researchers to acknowledge both the subjectivity of the observer and the subjectivity of the observed, to question their own assumptions and biases, rendering the old subject/object dichotomy false and inserting the researcher into the research process. In doing so, humanism confronted social science with the need to clarify the ethics and morals of the observer, making clear his or her positionality in the research process. It also legitimated the use of qualitative research methods that sought to uncover the views of subjects, such as participant observation and case studies.

Humanistic Geography

Humanistic thought has a long history in the discipline of geography. In the early 20th century, French cultural geography owed much to Paul Vidal de la Blache, who studied the unity of culture and landscape in terms of the lifestyles (*genres de vie*) in small rural areas called *pays*, uniting land and life through an understanding of how consciousness and the Earth are deeply intertwined. In the 1960s and 1970s, major contributions to the American literature on humanistic geography were made by several authors. Edward Relph was concerned with the cultural impacts of mass production and consumption, the homogenization of capitalist landscapes, and the resulting alienation. Anne Buttimer introduced the notion of life-worlds, a phenomenological recovery of *genres de vie* that took as its point of departure the multiple ways in which consciousness was preconsciously sutured to the locale in the intimate rhythms of everyday life. David Lowenthal wrote on landscape tastes and perceptions and the relationship between history and cultural

heritage. David Ley offered richly detailed urban ethnographies of the inner city and social geographies of Canadian cities.

Yi-Fu Tuan, who coined the term *humanistic geography*, holds pride of place in this pantheon. Tuan's contributions included the widely popular notion of "sense of place," the highly subjective set of feelings and impressions that individuals attach to specific locales. In this reading, places are intangible webs of meaning, not simply physical points. Sense of place, for example, makes a house into a home or a church into a locale saturated with religious overtones or defines a gang's turf. Tuan applied this set of notions, broadly grouped under the label *topophilia*, to studies of nature versus wilderness, spaces of pain and torture, sacred places, patriotism, pets, and more.

This line of thought offered a useful differentiation between space and place. In part, the difference is a matter of scale. Space generally concerns broader domains than that which individuals experience on a daily basis. However, space in the Western tradition is often used in a highly abstract sense, such as a Cartesian plane or isotropic plains used in mathematical models. In contrast, place refers to smaller, localized, more intimately experienced, intangible depositories of experience. The shift from space to place—one of the major contributions of humanistic geography—saw a transition from abstract, disembodied space to the embodied, erotic, personal, and pungent places of individual worlds. Such a move exhibited a concern with particularity and specificity rather than generality and made little effort to search for "general laws." Humanistic geographers were interested in what makes places unique, how they enter the human consciousness, and how that consciousness in turn constructs places through interpretation. In doing so, they opened to geography linkages to hitherto closed domains, such as landscape architecture, cultural anthropology, the sociology of the self, and the arts and humanities.

Another topic legitimized through humanistic geography was the geography of identity and the body. While classical theories of the human subject portrayed identities as unitary and stable, the phenomenologists argued that identity is a multiplicity of unstable, sometimes contradictory, context-dependent traits that change over time and space. Identities are both space forming and space



formed—that is, they are inextricably intertwined with geographies in complex and contingent ways. Likewise, they explored the multiple ways in which identity, subjectivity, the body, and place are tied together. The interface between body and mind is an ancient topic of philosophical consideration; the fact that we both *have* bodies and *are* bodies confronts us with the nebulous intersections of mind and matter. The body is where the mind resides—the locus of consciousness, tangible and corporeal evidence of its existence, giving existential and phenomenological depth to lived experience. While bodies typically appear as “natural,” they are in fact social constructions deeply inscribed with multiple meanings, “embodiments” of class, gender, ethnic, and other relations. The body is the primary vehicle through which the prevailing economic and political institutions inscribe the self, producing a bundle of signs that encodes, reproduces, and contests hegemonic notions of identity, order and discipline, morality and ethics, and sensuality and sexuality.

In insisting on the primacy of the intentional subject, humanistic scholars were adamant that geographies and landscapes are always *authored*—that is, they are created by people, who give meaning to them. This position was very much at odds with rival perspectives, including the impersonal geometries of positivism. Humanists challenged behavioral geographers to explore not simply the actions of people but also their intentions, avoiding simplistic black box models such as *H. economicus*. Finally, humanist thought mounted a serious challenge to Marxism, pointing out its flawed conception of human subjectivity and questioning its economic determinism and teleological view of history and geography, in which people are represented as finders of a world already made. Instead, humanists argued, the social world is open-ended and contingent, forever in the process of becoming.

Humanistic thought, however, also had its critics. Marxists and others pointed out that it offered no account of social relations, of class, power, and production. Moreover, humanism’s notion of the subject, however rich, was a largely asocial, undersocialized account of individuals in purely personal, not interpersonal, terms. For example, a dwelling is not just a site of caring and memories but also a locus of social reproduction,

family relations, patriarchy, and power. Moreover, by being silent about social relations, humanistic thought lapsed into an uncritical view of the world as simply structured by choice, a mythologized vision of “free will” devoid of social constraints. Humanism’s critics argued that methodologically this approach was deeply flawed, offering, for example, no means of validating, confirming, or disproving its claims. Some even held that humanistic thought was opposed to science. These problems led critics to argue that humanism sufficed as a critique of other positions—a way of unmasking presuppositions—but not as an alternative.

Humanistic thought made great contributions to geography, helping revive cultural geography and forcing researchers to take seriously the complex question of human consciousness. It jettisoned the myth of objective research and made explicit discussion of values and biases an integral part of the research process. In the end, humanistic geography, faced with serious critiques of its own, was largely integrated into other paradigms such as structuration theory and the various post-structuralist perspectives that arose in the 1980s and 1990s.

Barney Warf

See also Body, Geography of; Buttimer, Anne; Ethics, Geography and; Everyday Life, Existentialism and Geography; Human Geography, History of; Identity, Geography and; Ley, David; Participant Observation; Phenomenology; Place; Qualitative Methods; Relph, Edward; Sense of Place; Situated Knowledge; Social Geography; Symbolism and Place; Tuan, Yi-Fu

Further Readings

- Buttimer, A. (1976). Grasping the dynamism of lifeworld. *Annals of the Association of American Geographers*, 66, 277–292.
- Duncan, J., & Ley, D. (1982). Structural Marxism and human geography. *Annals of the Association of American Geographers*, 72, 30–59.
- Entrikin, J. (1976). Contemporary humanism in geography. *Annals of the Association of American Geographers*, 66, 615–632.



- Ley, D., & Samuels, M. (1978). *Humanistic geography: Prospects and problems*. Chicago: Maaroufa Press.
- Relph, E. (1976). *Place and placelessness*. London: Pion.
- Tuan, Y.-F. (1974). *Topophilia*. Englewood Cliffs, NJ: Prentice Hall.



HUMANISTIC GISCIENCE

Humanistic GIScience aims to integrate knowledge derived from the humanistic tradition with key issues related to spatial data representation, analysis, and visualization in the context of GIScience. Rather than attempting to maximize accuracy by minimizing or even eliminating uncertainty, humanistic GIScience incorporates the human subjective and even imaginative dimensions of experience in the process of spatial data handling.

Recent developments in ubiquitous computing have made almost everything computable with explicit geotagging. The goal of humanistic GIScience is to build dialogues with the humanistic tradition to understand human life in the context of social or human-centered computing. Recent works on the integration of indigenous knowledge, feminist perspectives, public participation GIS, collaborative GIS, and GIS-based art practices into the conventional GIS modeling processes are examples of humanistic GIScience in practice.

The search for a new means of analysis and modeling via computers has been increasingly entwined with a persistent search for the deeper meaning of such activities. As the aesthetic and humanistic traditions within GIScience expand, artists' renditions of reality in novels, poems, paintings, movies, music, and songs can be rich sources of inspiration for GIScientists to explore alternative conceptualizations of space, place, time, environment, region, and scale. In addition to representations of space framed by Euclidean geometry, humanistic GIScience attempts to find novel ways to handle the textures of place as articulated in the humanistic tradition. Furthermore,

the development of humanistic GIScience is transforming geospatial technologies into a locative media for affective practices through self-expression and storytelling. For example, practitioners of feminist GIS such as Mei-Po Kwan have developed GIS that incorporate the geography of women's fear into their representations of urban landscapes. Others have attempted to combine GIS with local ethnographies that incorporate indigenous forms of environmental knowledge. Yet others develop neogeographic, Web-based "mash-ups" that rely on volunteered data to map various phenomena, including local place perceptions.

In many ways similar to the development of humanistic geography, humanistic GIScience also aims to put people back at the center of spatial analysis. Along with critical GIScience, humanistic GIScience has significantly broadened and enriched the theoretical foundations of GIScience. The pluralistic theoretical approaches have precipitated diverse GIS practices in the age of Web 2.0, in which we can document and record individual experiences and share them instantaneously with a global audience.

The development of Web 2.0 technologies in general, and especially user-generated content in the form of volunteered geographic information (VGI), has shifted the focus of GIScience from handling geospatial information to handling information geospatially. The Web offers a brave new world of geotagged information unprecedented in human history, in a variety of multimedia forms from text (blogs), to photos, videos, and traditional geospatial data, to social networking sites such as Facebook and microblogs such as Twitter. These developments constitute a very rich data source on human subjectivity and behavior, which may further expand the development of humanistic GIScience and affective geospatial practices.

In addition to the vast multimedia data available, recent breakthroughs in mapping and visualization technologies offer additional resources for the development of humanistic GIScience. The launching of Google Earth and Google Map StreetView, for example, has shifted the predominant orthogonal view to an oblique view, which is more natural and intimate to most people. For most GIS users, the dominant orthogonal view has promoted the kind of geography that is



quantitative, objective, and analytical, whereas the oblique view will retrieve the kind of geography that is more qualitative, subjective, and interpretative. This means that GIScience will need not only the part of geography that is rooted in the tradition of spatial analysis (*means* of analysis) but also the part of geography that is anchored in the tradition of hermeneutic interrogation (*meanings* of analysis). Recent works in emotional mapping best embody the spirit of the emerging humanistic GIScience practices.

The development of humanistic GIScience has ontological as well as epistemological implications as it confronts GIS users with the questions of what exists/can be known and how we know it. Instead of making simplistic, dichotomous assumptions regarding the researcher and the researched, humanistic GIScience has reinserted the user/researcher at the very center of the research enterprise. Consequently, the emergence of humanistic GIScience has also stimulated further discussions on theories of truth in GIScience research. Besides coherence, correspondence, consensus, and contextual theories of truth, practices following the humanistic GIScience will expand the recent discussion and debates on non-representational theory and the performative theory of truth—what is considered true is intimately connected to the practices and performances developed by users employing various technical means.

While the development of GIScience was concomitant with the development of GIS, GIScience is no longer reliant on these tools for its existence and meaning. With the development of a humanistic component, GIScience became more than a computational science in search of new algorithms. In fact, GIScience is also emerging as a humanistic science in search of meanings for its computations and an area for speculating about what lies beyond the limits of computation—GISciencists' new *terrae incognitae*. At the interface of computing technologies with humanistic scholarship, we can expect groundbreaking development in the future.

Daniel Z. Sui

See also Collaborative GIS; Feminist Methodologies; Humanistic Geography; Kwan, Mei-Po; Neogeography;

Ontological Foundations of Geographical Data; Ontology; Public Participation GIS; Situated Knowledge; Sui, Daniel

Further Readings

- Casey, E. S. (2005). *Earth-mapping: Artists reshaping landscape*. Minneapolis: University of Minnesota Press.
- Flake, G. W. (1998). *The computational beauty of nature: Computer explorations of fractals, chaos, complex systems, and adaptation*. Cambridge: MIT Press.
- Gelernter, D. (1997). *Machine beauty: Elegance and the heart of technology*. New York: Basic Books.
- Goodchild, M. F. (2007). Citizens as sensors: The world of volunteered geography. *GeoJournal*, 69(4), 211–221.
- Jaimes, A., Sebe, N., & Gatica-Perez, D. (2006). Human-centered computing: A multimedia perspective. In *Proceedings of the 14th annual ACM international conference on multimedia* (pp. 855–864). Santa Barbara, CA, October 23–27. Retrieved February 26, 2010, from www.idiap.ch/~gatica/publications/JaimesSebeGatica-acmmm06.pdf
- Kwan, M.-P. (2002). Feminist visualization: Re-envisioning GIS as a method in feminist geographic research. *Annals of the Association of American Geographers*, 92(4), 645–661.
- Kwan, M.-P. (2007). Affecting geospatial technologies: Toward a feminist politics of emotion. *The Professional Geographer*, 59(1), 22–34.
- Miller, H. J. (2007). Place-based versus people-based geographic information science. *Geography Compass*, 1, 503–535.
- Sheppard, E. (2005). Knowledge production through critical GIS: Genealogy and prospects. *Cartographica*, 40(4), 5–21.
- Smith, G. (2008). *Tagging: People-powered metadata for the social web*. Berkeley, CA: New Riders.
- Sui, D. Z. (2004). GIS, cartography, and the third culture: Geographical imaginations in the computer age. *The Professional Geographer*, 56(1), 62–72.



HUMAN RIGHTS, GEOGRAPHY AND

Human rights touch almost every aspect of life. Taken as a whole, they suggest a way of living together in peace, dignity, and freedom. A geographical perspective of human rights attempts to answer the question of whether people have the right, literally, to a place in the world. At its core, the concept of human rights involves political, cultural, economic, social, or environmental processes where issues of oppression are central to human struggles that are inextricably tied to particular places. As such, the major themes of locality, movement, and nature-society relations in the discipline of geography play an important role in any scholarship based on human rights. The late 20th and early 21st centuries have seen the emergence of human rights as a formal field of study that focuses mainly on the abuses of the state in oppressing its residents and citizens. In the context of international law, global awareness of the unjust treatment of people by governments or institutions is now commonplace. International entities such as the United Nations, Human Rights Watch, and Amnesty International now play a large role in revealing these abuses and pressuring governments to stop human rights abuses.

The initial concepts of universal human rights reach as far back as the Enlightenment, but it was the Holocaust in the mid 20th century that became the impetus for modern conceptions of human rights on a global scale. Engaging in mass violence, torture, and the mistreatment of human beings was certainly not a new aspect of humanity. But the rise of modern technology took human cruelty to new and frightening levels, giving rise to a systematic genocide that remains unparalleled in human history. As a direct result of the Holocaust, the United Nations adopted the Universal Declaration of Human Rights in 1948. The Declaration sets out a list of universal human rights, depicting them as “a common standard of achievement for all peoples and all nations.” Among these rights are the right to life, the right not to be tortured or enslaved, the right to seek asylum from persecution, and the right not to be subjected to arbitrary arrest, detention, or exile. The Declaration also grants freedom of thought, expression, and

religion. The cultural rights laid out in the document include the right to marriage, education, employment, food, and shelter. Although in a legal sense the Declaration is a nonbinding document, it has grown to become a major factor in international law since its adoption. In fact, many of the rights in the Declaration formed the groundwork for several regional human rights documents, such as the European Convention of Human Rights, the African Charter of Human and Peoples Rights, and the Helsinki Accords. While the Declaration has succeeded in extending human rights to some places (mostly Western democracies), it has not succeeded in extending rights to other places in the world. Indeed, the late 20th and early 21st centuries have seen their share of human rights atrocities in many places, including Guatemala, Cambodia, China, the Soviet Union, Tibet, Bosnia, and the Darfur region of Sudan, as well as the “disappearances” in Argentina and Chile, the death squad killings in El Salvador, and the genocide in Rwanda.

One important aspect involving a geographical examination of human rights is the selection of appropriate spatial scales of analysis. The selection of which level of analysis to use will, to a large extent, help define the degree and extent of the human rights abuses. Exercising one’s human rights in a local context may require access to physical space, an important geographic concern. For example, exercising one’s legal rights requires access to a courtroom, and implementing one’s political rights requires access to a voting booth. The right to education requires access to schools. Connections between human rights and physical access may also play out at larger geographical scales, such as differences in access to health care between urban and rural populations. In the United States, spatial scale plays a role in accessing the right to marriage for same-sex couples, as some states legally allow such arrangements and some do not. Physical access and spatial scale also play a role in reproductive rights for women throughout the world, restricting access to birth control and abortion in some places but not in others.

Situating human rights issues within their local contexts requires a geographical approach to reveal the overlapping networks of politics, economics, and law. For example, the 35-year-old “war on drugs” waged by the U.S. government reveals broad



geographical disparities in the implementation of policies related to drug-related arrests, imprisonment, and law enforcement, disproportionately affecting low-income communities of color. Since 1980, there has been a substantial divergence in racial composition related to drug offenses, as both the numbers and the proportions of African Americans arrested and imprisoned for these crimes have far outpaced those of whites. Nationwide, black men are sent to prison on drug charges at 13 times the rate of white men. Additionally, there are broad geographical variations among the nation's cities related to the degree of drug-related offenses, suggesting that local priorities and politics related to law enforcement may be influential in producing uneven geographies of political, social, cultural, and economic rights related to law enforcement within the United States.

The processes of globalization in the 21st century indicate that the causes of and solutions to human rights problems are more complex and dispersed. One country sells weapons or buys diamonds, which perpetuates conflict elsewhere; trade policies create poverty; closing borders to migration perpetuates a spatial unevenness of economic burdens and human rights abuses; and environmental abuses cause distant disasters. But it is at the scale of the nation or state that people are far more apt to be harmed by their own government than by other actors. These abuses take the form of political or military repression, judicial corruption, economic discrimination against minorities, and so on. Abusive governments and corrupt elites often appeal to "state sovereignty," insisting on noninterference in internal affairs whenever they face international pressure to reform. The United Nations and other international bodies have been roundly criticized for standing by, or even defending, the prerogative of rogue governments to do what they wish by making claims of sovereignty, noninterference, or regional solidarity. Many observers, such as Amnesty International, argue that the United States' recent record on human rights abuses, mostly committed in the name of countering terrorism, has crippled its ability to respond effectively even where it seeks to uphold human rights. Consequently, ongoing human rights abuses and mass atrocities continue in countries such as Afghanistan, Iraq, Iran, North Korea, Cuba, Colombia, the Congo (Zaire),

Georgia, Israel and the occupied Palestinian territories, Somalia, Sri Lanka, and Sudan. Other powerful and influential nations have also been criticized for allowing regional political repression to continue, such as China for its occupation of Tibet and India for its reluctance to address government repression in Myanmar/Burma.

Geography offers a means to help understand and transform the way human rights are defined, interpreted, and implemented. Human rights can never be "guaranteed" but instead represent continuing struggles by making claims on geographical space to build a more just world. Whether one chooses to examine human rights at the local, regional, or global scale, a geographical perspective is necessary to reveal the unjust distribution of society's benefits and burdens.

Thomas Chapman

See also **Citizenship**; **Environmental Justice**; **Genocide**, **Geographies of**; **Justice**, **Geography of**; **Political Geography**; **Social Justice**

Further Readings

- Ball, O., & Gready, P. (2006). *The no-nonsense guide to human rights*. Oxford, UK: New Internationalist.
- Carmalt, J. (2007). Rights and place: Using geography in human rights work. *Human Rights Quarterly*, 29(1), 68–85.
- Honey, R. (2006). Human rights. In G. Gaile & C. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 730–735). Oxford, UK: Oxford University Press.
- International Council on Human Rights Policy. (2003). *Duties sans frontières: Human rights and global social justice*. Geneva: Author. Retrieved February 21, 2009, from www.ichrp.org
- King, R. (2008). *Disparity by geography: The war on drugs in America's cities*. Retrieved February 21, 2009, from The Sentencing Project Web site: www.sentencingproject.org
- Roth, K. (2009). *Human Rights Watch 2008 world report*. Retrieved February 21, 2009, from Human Rights Watch Web site: www.hrw.org



HUMBOLDT, ALEXANDER VON (1769–1859)

Alexander von Humboldt is commonly called a “Renaissance man” because he was so talented in many subjects, notably natural history, geology, mining, engineering, anthropology, cartography, botany, political science, and diplomacy. Humboldt’s inquisitive mind and ability to master many separate subjects dovetailed with the social conditions of the era in which he lived. His times, broadly called the Enlightenment, valued science and empirical observation while challenging older ways of viewing the world. Humboldt was no mere observer of those times; he in fact shaped them through his extensive studies and travels. Although German by birth, he represented a new class of individuals we today call citizens of the world. Although the modern discipline of geography emerged after Humboldt’s death, geographers quickly realized that Humboldt was one of the pioneers of their field.

Friedrich Wilhelm Heinrich Alexander von Humboldt was born on September 14, 1769, in Berlin. As a child, Humboldt was tutored by highly trained scholars, and he later studied at two universities, Frankfurt-an-der-Oder and Gottingen. When he was 22 years old, Humboldt entered the Freiburg School of Mines, where he studied geology and mining. On graduating, he became assessor of mines in Bayreuth. Given Humboldt’s gift for observation and interpretation, as well as the practical application of knowledge, he advanced rapidly. Humboldt’s charismatic personality and intelligence enabled him to interact with learned individuals throughout Europe. The fact that Humboldt was fluent in several languages (his brother Wilhelm was a linguist) also helped him build an international network of colleagues and associates. In 1796, on the death of his mother, Humboldt inherited a fortune. That wealth freed him to engage in his true passions, exploration and science. Given Humboldt’s enthusiasm for unexplored places, he sensed an opportunity to make major scientific discoveries in the Americas. At that time, Europe controlled most of the Americas, with the exception of the recently created United States.

By the late 18th century, Humboldt was poised to become one of the world’s great scientific explorers. Now that he had developed connections in high

places, including Spain, he called on them to open doors for him in the Americas. In 1799, after receiving unprecedented permission from Spain, Humboldt departed for the Caribbean and South America in the company of the noted botanist Aimé Bonpland. Their goal was to observe the environment in order to determine its potential productivity. However, Humboldt also explored these places for the pure joy of making scientific discoveries. On arriving in the New World, the expedition traveled deep into Northern South America, where Humboldt and his colleague collected thousands of geological, botanical, and zoological specimens while also making hundreds of detailed geomagnetic and celestial observations. Humboldt’s expeditions also had a cultural and economic focus. In late 1800 and early 1801, Humboldt visited Cuba to study the slave-based economy of the sugar plantations, which he found repugnant to his liberal philosophy.

Humboldt’s success on these expeditions can be credited to his ability to select, and listen carefully to, the best native guides and local contacts. By 1802, Humboldt had explored Western South America in the vicinity of Ecuador’s Mt. Chimborazo, whose 5,759-meter summit he managed to climb (setting a world record in the process). Humboldt next headed eastward into the upper reaches of the Amazon basin, thence westward into the former Inca strongholds of the Peruvian Andes, where he was intrigued by the diversity of the indigenous cultures. While in Western South America, Humboldt studied the cold ocean current that would later bear his name (though it is now called the Peruvian current). Because Humboldt was also a noted cartographer and illustrator, his reports contained a wealth of maps and observations, which he made available to Spain (and other countries). This was a major accomplishment, but Humboldt was not the first European scientific explorer to study South America. Consider the controversial Alessandro Malaspina, who had conducted explorations about a decade earlier (1789–1794). However, whereas Malaspina wound up in a Spanish prison as an alleged spy, Humboldt’s motives were never seriously questioned.

When his observations concluded in South America, Humboldt headed north to Mexico, where he spent about a year making field observations and studying the maps in the archives.



Simultaneously, Humboldt engaged in a wide-ranging political commentary about conditions pertaining to Mexican society and culture. It should be noted that Humboldt traveled widely with the blessings of Spain at a time when its New World possessions were about to be challenged by both outside powers and internal rebellion. In that sense, Humboldt's reports not only provided a remarkably candid assessment of conditions in New Spain but also a blueprint for those seeking opportunities to seize these possessions from Spain.

Before returning to Europe in 1804, Humboldt visited Philadelphia and Washington, D.C., where he was hosted by President Thomas Jefferson. During this visit, Humboldt provided Jefferson with a copy of his "Map of the Kingdom of New Spain" (Figure 1), which revealed the state of knowledge about the North American West and excited much interest on both sides of the Atlantic. On returning to Europe, Humboldt lived in Paris and then returned to Berlin. He spent much of his time writing his epic *Voyages aux régions équinoxiales du nouveau continent, fait en 1799–1804*—a huge book that paradoxically drained his fortune while resulting in his enduring fame. In that book, Humboldt propounded many scientific concepts pertaining to both botany and geophysics. He was the first person to demonstrate that points of equal temperature could be mapped using a line—the now-familiar isotherm—and he also introduced the concept that vegetation is zoned vertically (i.e., by altitude as well as latitude). Humboldt was a master cartographer and illustrator who invented new ways of portraying phenomena such as vegetation distribution, volcanism, and geomagnetic forces.

In his later years, Humboldt continued to write about the world around him in a way that combined science, philosophy, and spirituality. His *Cosmos* is a classic in the literature, revealing Humboldt's vision of placing science in a philosophical perspective. Given his well-publicized travels, numerous books, and innumerable lectures, Humboldt became a legend in his own time. Throughout the early to mid 19th century, in fact, aspiring scientists tried to link their careers to his. An endorsement by Humboldt was as good as gold; small wonder that his name became synonymous with genius and authority. In 1859,

Humboldt died in his native city of Berlin, leaving a legacy that is both imposing and inimitable.

In retrospect, Humboldt and his work have become something of a Rorschach test. Whereas Humboldt was almost universally, and simply, known as a great "naturalist" and "scientist" in his own lifetime, things began to change by the mid 19th century. As disciplines such as botany, geology, and meteorology became established, the practitioners of those disciplines came to focus on Humboldt's work in those particular areas. Naturally, given their interests, Humboldt was adopted as one of their own. Given the rise of professional geography in the 20th century, with its emphasis on how to explain the distribution of phenomena and how to decipher the interconnections between nature and humankind, it is not surprising that Humboldt was soon adopted as one of the pioneers of modern geography. He could, after all, deduce the character of a place based on its appearance and location, and he could also brilliantly interpret phenomena in spatial terms. Those are the hallmarks of a geographer, but then again the things that Humboldt encountered—rock formations in mountain ranges, individual plants and animals, human inhabitants, even cultural attitudes—fascinated him in their own right. Given the recent negative reinterpretations of European colonialism, it is not surprising that some critics, including postcolonialist geographers, consider Humboldt an imperialist at heart. However, a close reading of Humboldt's reports suggests that he was as subversive as he was complicit. Call him what you will, Humboldt above all serves as a reminder that the reputations of historical figures as well as the disciplines they represent are constantly evolving.

Richard V. Francaviglia

See also **Exploration; Human Geography, History of; Ritter, Carl**

Further Readings

Helferich, G. (2004). *Humboldt's cosmos*. New York: Penguin.



- Humboldt, A. (1811). *Political essay on the Kingdom of New Spain, with physical sections and maps founded on astronomical observations and trigonometrical and barometrical measurements*. London: Longman, Hurst, Rees, Orme, & Brown.
- Humboldt, A. (1846–1858). *Cosmos: A sketch of a physical description of the universe*. London: Longman, Brown, Green, & Longmans.
- Jackson, S. T. (2009). Alexander von Humboldt and the general physics of the Earth. *Science*, 324, 596–597.
- Mathewson, K., & Sluyter, A. (Eds.). (2006). Humboldt in the Americas [Special issue]. *Geographical Review*, 96(3).
- Rupke, N. (2008). *Alexander von Humboldt: A metabiography*. Chicago: University of Chicago Press.

HUMIDITY

Humidity is a parameter representing the amount of water vapor in the air. This is expressed in numerous ways: relative humidity, mixing ratio, specific humidity, and absolute humidity. Relative humidity is the most commonly used term when we refer to humidity in the field of geography and in our daily lives. Relative humidity is the ratio of the water vapor content that is actually present in the air to the water vapor content in the saturated air at a prescribed temperature, and its values are given as a percentage. As a definition, relative humidity is expressed as the ratio of the actual vapor pressure (e , the partial pressure of water vapor) to the equilibrium or saturation vapor pressure (e_s , the vapor pressure of the saturated air) and is given as $RH = e/e_s \times 100$.

Alternatively, we are able to consider the parameter as the ratio of the actual mixing ratio (q ; described later) to the saturation mixing ratio (q_s). A condition in which air is completely saturated has 100% relative humidity. Air with relative humidity higher than 100% is called supersaturated. Relative humidity varies with water vapor content and/or temperature. In other

words, relative humidity varies with temperature even when the total amount of water vapor does not change. This is because the saturation vapor pressure depends on temperature, whereas actual vapor pressure does not.

Relative humidity has an inverse relationship to the diurnal variation of air temperature near the ground surface, and therefore, its value becomes smaller as temperature increases. In urban areas, the surface air temperature is generally higher, and lesser evapotranspiration occurs than in its surrounding areas. As a result, relative humidity has a tendency to be lower in urban areas. Relative humidity can be measured in the field using instruments such as sling hygrometers.

Other parameters that represent humidity—the mixing ratio, specific humidity, and absolute humidity—are defined from a different perspective to relative humidity as these depend on water vapor content but are independent of temperature.

The mixing ratio (q) is the ratio of the mass of water vapor to the mass of dry air, whereas specific humidity (s) is represented by the ratio of the mass of water vapor to the total mass of air. Consequently, specific humidity has almost equivalent values to the mixing ratio. These variables are presented here in kilograms per kilogram but are usually expressed in grams per kilogram. The mixing ratio (q) and specific humidity (s) are both functions of vapor pressure (e) and total pressure (p). Hence, these variables are given as $q = 0.622e/(p - 0.378e)$ and $s = 0.622e/p$. On the other hand, absolute humidity gives the water vapor density in the air and is expressed in kilograms per cubic meter.

Besides these parameters, other variables such as dew-point temperature and dew-point depression (temperature/dew-point spread) also represent the amount of water vapor in the air. These variables are generally used in the fields of weather forecasts and atmospheric sciences rather than in the field of geography.

Hiroyuki Kusaka

See also Atmospheric Moisture; Climate: Tropical Humid; Clouds; Precipitation, Global; Precipitation Formation



Further Readings

- Aguado, E., & Burt, J. (2006). *Understanding weather and climate*. Upper Saddle River, NJ: Prentice Hall.
- Dai, A., Trenberth, K. E., & Karl, T. R. (1999). Effects of clouds, soil moisture, precipitation, and water vapor on diurnal temperature range. *Journal of Climate*, 12, 2451–2473.

HUNGER

More than 60 yrs. (years) after the human right to adequate food was formally declared by the United Nations (UN), hunger remains a characteristic feature of many people in the capitalist world system. Hundreds of millions of people, from Chicago to Mumbai and from Russia to Malawi, are unable to reliably access and consume an adequate diet. This condition exists, strikingly, in a world where food production and trade have easily outpaced population growth for decades. For example, in 2006, agricultural output (not all of it food) was nearly 40% higher than in 1990, a period during which the world's population increased by around 25%. The number of hungry people in the world grew during that same period, and while hunger declined in relative terms in all the world's major regions, the recent price rise in food and the worldwide economic crisis threaten to reverse that encouraging trend. This entry discusses the definition and measurement of hunger, the world geography of undernutrition and malnutrition, the concept of food insecurity, the impact of globalization and urbanization on world hunger, and the shift of responsibility for hunger from government to private individuals and organizations.

Defining and Measuring Hunger

In a very basic sense, hunger is the experience of not being able to consume enough and the right kinds of food. While this seems straightforward enough, the identification, explanation, and alleviation of hunger are fraught with disagreements over conceptual issues related to the socially and

culturally complex and dynamic relationship between human beings and food. An effort to produce a body of scientific knowledge related to that experience emerged with the modern state and its imperative to measure, quantify, and, thereby, manage and regulate the population. For well over a century, intellectual debates over the concept and phenomenon of hunger have concerned questions of objectivity, universality, reliability, validity, and statistical precision. To take one example, in the late decades of the 1800s, British nutritionists, social reformers, government officials, and colonial administrators considered local food practices—whether they reflected “rational” behavior or not—and optimal diets as they argued over the discovery of universal standards by which to determine who in Britain and its colonies was “hungry” and who had died as a result of “starvation.” In the United States, social, political, and policy debates since the 1960s have increasingly revolved around questions about the validity and reliability of hunger data, leading to a broad, state-sponsored effort to develop methods for the scientific measurement of hunger. These examples also serve to illustrate the point that scientific knowledge about hunger, no matter how technically precise, is infused with, and shaped by, politics (power relations), culture (social meanings), and the environment (human relationships with biophysical systems). In short, the task of defining and measuring hunger confronts powerful social, political, economic, and environmental geographies in the relationship of people to food and, therefore, in what constitutes hunger. In the early 2000s, conceptual debates about hunger have settled on three prominent, not uncontested, understandings of hunger.

The World Geography of Undernutrition and Malnutrition

The two most commonly recognized forms of hunger are undernutrition and malnutrition. Very basically, undernutrition occurs when a person is unable to consume enough calories to remain healthy and active on a continuing basis, depending on her or his age, sex, height, age, and daily physical exertion. Malnutrition specifies a person's inability to consume a nutritionally balanced



Civilians rush to retrieve high-nutrition meals donated by Project Handclasp and Kids Against Hunger in Marose, Haiti, September 20, 2008. The supplies were delivered by crewmen embarked aboard the amphibious assault ship *USS Kearsarge*, which had been diverted from its deployment in support of the humanitarian assistance mission Continuing Promise 2008 to conduct hurricane relief operations in Haiti coordinated by the U.S. Agency for International Development.

Source: U.S. Navy photo by Mass Communication Specialist Seaman Apprentice Joshua Adam Nuzzo.

diet. This can involve either deficient or excessive consumption of particular nutrients, such as proteins or carbohydrates. Both of these kinds of hunger result in a range of physical and mental effects on the body, most notably stunting (low height for age), wasting (low weight for height), underweight (low weight for age), impaired cognitive development, greater susceptibility to disease and injury, and, in the case of malnutrition, obesity.

The world maps of undernutrition and malnutrition are typically drawn using estimates of deficient calorie, vitamin, and protein consumption; stunting; underweight children; and infant mortality. Deficient calorie consumption is the most common indicator used to examine the global distribution of

hunger. The UN estimates that more than 900 million people, slightly less than 15% of the world's total population, do not consume enough calories on a daily basis. More than a third of those live in the South Asian countries of India, Bangladesh, and Pakistan, and another 14% of the world's population of undernourished people live in China. In relation to national populations, inadequate calorie consumption is highest in countries in Central, East, and Southern Africa, where more than one third of the people are undernourished. In some countries, notably the Democratic Republic of the Congo, Chad, Burundi, and Eritrea, the rate of undernourishment exceeded 50% a decade ago and has increased during the intervening period. Especially high rates are also found in South Asia, the



Developed countries	15
Near East and North Africa	42
Latin America and the Caribbean	53
Sub-Saharan Africa	265
Asia and the Pacific	642
Total	1.02 billion

Table 1 Undernourishment by region, 2009 (in millions)

Source: Based on data from FAO Economic and Social Development Department. (2009, October). Undernourishment around the world. In *The state of food insecurity in the world 2009* (p. 11). Rome: Food and Agriculture Organization of the United Nations. Retrieved March 1, 2010, from <ftp://ftp.fao.org/docrep/fao/012/i0876e/i0876e02.pdf>.

Caribbean, and Central America. One of the highest rates of hunger outside Africa is in Haiti, where almost two thirds of the people are estimated to be undernourished. Among all the developing countries, the lowest rates of caloric deficiency are in Mexico and in the countries of North Africa. While a significant number of people in the United States, Canada, Europe, and Japan also experience this condition, the rate of undernutrition is extremely low in these countries.

Food Insecurity

Hunger takes a third form, known as food insecurity, which occurs when people are unable to reliably obtain a healthy and *socially acceptable* diet in *socially acceptable* ways. This understanding of hunger rests on the acknowledgment that food is not just a source of energy and nutrients and that the food consumption process involves more than the ingestion of food. It recognizes that food—what kind and how it is produced or acquired, prepared, served, and eaten—is central to cultural identity and social standing. Hunger, therefore, disrupts not only physiological processes and mental development but also “normal” cultural and social functioning. As with food insecurity, hunger represents a lack of control by people over what they eat and on what terms, and it is revealed in feelings of anxiety, frustration, guilt,

and humiliation as well as socially unacceptable behaviors or practices surrounding food consumption, such as “dumpster diving” and trash picking, panhandling or begging, and the use of soup kitchens and food pantries.

Inasmuch as food insecurity is a subjective and distinctly contextual condition—that is, one for which objective and universal indicators do not exist—it is difficult to map at the global scale. The way it is experienced, and the reasons why, differ significantly from place to place. For example, food insecurity exists in the anguish of a mother in India who, without other recourse, feeds her children imported food that was processed without considering her religious conventions; in the fear of a Mexican farmer that by having to grow genetically modified maize he is subjecting his family to adverse health effects and undermining the sustainability of his farm; and in the social alienation of a Canadian or American man who lacks income and must obtain food through an emergency kitchen.

The Globalization, Urbanization, and Depoliticization of Hunger

The geography of hunger exists not only in its spatial patterns of incidence but also in the underlying causal processes. Several broad geographic processes are particularly relevant in the early 21st century. The first involves the tendency toward a liberalized and globalized agro-food system involving corporate concentration in food production, processing, distribution, and retailing and the opening of national food sectors to imports and investment capital from multinational firms. This process is linked to a general decline in subsistence and locally oriented farming (a majority of the world’s population still earns a livelihood by producing food) and the increasing inability of consumers, particularly those with low incomes, to determine what they eat. The latter, paradoxically, is associated with rising obesity among poor people, who often reside in what policymakers and scholars refer to as “food deserts”—that is, rural areas and central-city neighborhoods, where a range of affordable fresh foods is effectively unavailable due in large part to a reduction in the number of local grocery stores as a result of changes in the retail industry.



Globalization also connects with processes of rapid urbanization, especially in Asia and Africa, which are fundamentally reshaping the social, political, and environmental relations through which people access food. Due to significant reductions in various forms of state support, including those stabilizing prices and protecting land tenure, and competition from imports emanating from the capital-intensive and heavily subsidized agricultural sectors of North America and Europe, many small-scale farmers have been dislocated economically, and migration to cities is an increasingly popular survival strategy. This, in turn, has contributed significantly to the rapid growth of urban areas and the urbanization of hunger throughout the developing world. The growing scale of urban food insecurity has drawn the attention of scholars and policymakers, with much of the focus on the ways in which hunger in cities differs from hunger in rural settings. For example, poor urban dwellers generally have fewer sources of nonmarket access to food, and therefore, they need more cash income to buy food, which is usually earned by working outside the home. This, in combination with the lack of adequate housing, places severe limits on the space and time necessary for preparing food and managing household food resources. These temporal and spatial demands are especially severe for women in their everyday lives, as they typically retain their traditional roles as homemakers and caregivers and cannot rely as much on informal safety nets (food sharing, child care, loans, and so on, based on social, often familial, connections), which tend to be weaker in urban areas due to the newness and constant churning of the poor urban populations. All this, furthermore, contributes to profound changes in diets and food practices—most important, a shift to processed and often higher-fat foods—and, thus, increases in the rates of heart disease and obesity among the urban poor.

The third causal process underlying patterns of hunger in the world consists of the shift of responsibility for hunger and famine prevention and alleviation from national-level governments to international relief agencies and humanitarian organizations and to local communities, charities, and social networks. This simultaneous global/local shift represents a “depoliticization” of hunger over the past 35 yrs. because it places responsibility

in the hands of private individuals and organizations, which are ultimately less accountable to those suffering from that condition and less able to provide fundamental solutions. From Africa to North America, central governments have claimed to be addressing hunger by encouraging private sector responses. The changing political status of hunger—from a violation of a person’s rights to a project for charity—does not mean that charities and humanitarian organizations have not contributed in many practical ways to the alleviation of hungry people’s suffering, nor does it suggest that hungry people are docile, passive subjects who do little more than await the next act of kindness. Indeed, the latter impression is soundly contradicted by the recent spate of protests against governments around the world, from Haiti to Egypt to Malaysia, which arose as a response to rising food prices and failed state policies.

Andy Walter

See also **Agrofoods; Famine, Geography of; Food, Geography of; Food and Agriculture Organization (FAO); Poverty**

Further Readings

- De Waal, A. (1998). *Famine crimes: Politics and the disaster relief industry in Africa*. Bloomington: Indiana University Press.
- Patel, R. (2008). *Stuffed and starved: The hidden battle for the world food system*. Brooklyn, NY: Melville House.
- Riches, G. (1997). *First world hunger: Food security and welfare politics*. New York: St. Martin’s Press.
- Vernon, J. (2007). *Hunger: A modern history*. Cambridge, MA: Belknap Press.



HUNTING AND GATHERING

For the vast, overwhelming majority of time in which human beings have existed—97% to 99% of the period since the first hominids



appeared—they lived in a type of society commonly known as hunting and gathering. Many species of the genera *Australopithecus* and *Homo* practiced this form of survival, which also typified the lifestyle, social organization, and culture of *Homo sapiens* until relatively recently—that is, until the emergence of agriculture roughly 10,000 years ago. Thus, hunting and gathering is often equated with the Paleolithic, or “Old Stone Age,” which ended with the Neolithic, or “New Stone Age” (some include a Mesolithic as well), although these terms are not universally accepted. Moreover, the line between agricultural and hunting and gathering societies is not always clear, as many societies relied on both as necessary.

Prior to agriculture, humans obtained sustenance through several modalities, including fishing, the hunting of animals, and the gathering of a wide variety of foodstuffs. Reliant on the sources made possible by their immediate environment, small groups of people, often as few as a dozen and rarely more than 50, wandered nomadically, following the seasonal rhythms of plants and migratory cycles of animals. This constant movement has led some to call hunting and gathering a “permanent camping trip.” Hunting and gathering thus made human beings food collectors, not producers. Stone and bone tools such as knives, adzes, needles, and scraping implements were the norm in cultures that lacked metal. Typically, such small bands and tribes are characterized by a sexual division of labor, in which men and boys hunt—often unsuccessfully—and women gather, often with babies on their backs or small children nearby.

Although Paleolithic hunters could be very skilled, and may have played a critical role in the extinction of numerous Pleistocene megafauna, the actual slaughter of very large animals such as mammoths was typically rather rare; smaller game such as deer and rabbits were much more common food sources. Hunting with spears and arrows was the norm, with slings and knives used when possible. The domestication of the dog, perhaps as early as 50,000 BC, also played a role that enabled hunting. More important as a source of caloric intake was gathering, the work of women, which provided the vast bulk of nutrients in most hunting-and-gathering societies. Because humans are opportunistic, adaptable improvisers, gathering allowed an exceptionally diverse

variety of foods to be collected, including roots, fruits, berries, tubers, insects, carrion, eggs, grubs, frogs, seeds, nuts, and slow animals such as snails or turtles. This form of resource exploitation thus depended on lightly using a wide variety of resources rather than intensively using a few. Because it does not generate large quantities of calories per unit area, population densities remained very low. Numerous variations in hunting and gathering existed in different local climates and ecologies.

Several innovations allowed hunter and gatherers to spread to almost every ecological niche in the world. The controlled use of fire, as well as the needle and thread, enabled people to move into northerly latitudes and withstand the harsh winters of Northern Eurasia, eventually migrating into North America via the Bering Straits. Fire played a key role in the Paleolithic modification of many habitats, especially the midlatitude grasslands and forests. Rather than passively respond to their environment, therefore, hunter-gatherers actively shaped it.

Most people lived in small, self-sufficient bands, although the existence of very early trade networks in obsidian, amber, flint, seashells, feathers, and other goods indicates that some long-distance exchanges did occur. Unlike agricultural societies, in which most people spend the bulk of their time laboring, many hunter-gatherers had ample free time to relax; indeed, many people may have more free time than they do today. Organized warfare existed occasionally but was relatively uncommon, infrequent, and generally small scale and highly ritualistic.

Although they are technologically simple compared with contemporary societies, hunting-and-gathering cultures were not necessarily culturally simple. Without a complex division of labor, most such cultures were relatively egalitarian, with no classes or private property and leadership confined to a chieftain. Simple survival necessitated an intimate knowledge of nature, including the ability to identify countless species of plants and animals, to understand their behavior, to identify and use medicinal plants and herbs, or to find water in arid environments. From observations of contemporary hunters and gatherers, which form much of the basis of knowledge about them, religious beliefs were predominantly animistic or



A pygmy subsistence hunter from the BaAka tribe, an indigenous hunter-gatherer group located throughout Cameroon and the Central African Republic, crouches with his spear beside a duiker which has been captured in his snare.

Source: © Martin Harvey/Corbis; used by permission.

nature worshipping. Without writing, memory formed the basis of historical and institutional consciousness, typically in the form of numerous oral folk songs, legends, and myths as told by griots, shamans, or storytellers and their counterparts. Because it was overwhelmingly verbal and aural in nature, almost all Paleolithic art has disappeared today. Pigments, jewelry, elaborate arrowheads, spearheads, and fishhooks all point to the existence of a sense of aesthetics. The existence of cave paintings in places such as Lascaux and Altamira testify to the use of symbols and abstract thought. Some observers note that the widespread dispersal of stone carvings such as the famous Earth Mother of Willendorf (25,000 BC) may indicate a high regard for women, and even matrilineal lines of descent.

In such societies, both birth rates and death rates are high; most people would begin sexual reproduction in their early teens, and average life expectancy rarely exceeded 30 years. Extended families and kinship ties formed the critical bases of local social organization and support networks. Because both birth and death rates were high, population growth rates were generally very low; some tribes practiced deliberate attempts to minimize growth through prolonged lactation or infanticide.

This form of lifestyle, which was critically important to the prehistory of human beings, was gradually annihilated beginning with the emergence of dense, agricultural societies with complex divisions of labor at the start of the Neolithic revolution around 10,000 BC. The rise of the



nation-state actively discouraged nomadism. Today, hunting and gathering is almost extinct. Small pockets can still be found among some South American tribes in the greater Amazon forest, in parts of Central Africa, among the San or !Kung people in Namibia, in parts of southeast Asia, in New Guinea, and perhaps among a few Australian Aborigines. But everywhere, hunting and gathering is a dying form of subsistence, as its last practitioners are drawn into urbanized regions and commodified labor markets.

Barney Warf

See also **Centers of Domestication; Domestication of Animals; Domestication of Plants; Nomadism**

Further Readings

- Gowdy, J. (Ed.). (1997). *Limited wants, unlimited means: A reader on hunter-gatherer economics and the environment*. Washington, DC: Island Press.
- Ingold, T., & Riches, D. (Eds.). (1997). *Hunters and gatherers: Vol. 1. History, evolution and social change*. London: Berg.
- Ingold, T., & Riches, D. (Eds.). (1997). *Hunters and gatherers: Vol. 2. Property, power and ideology*. London: Berg.
- Jochim, M. (1998). *A hunter-gatherer landscape: Southwest Germany in the late Paleolithic and Mesolithic*. London: Springer.
- Lee, R., & Daly, R. (Eds.). (2004). *The Cambridge encyclopedia of hunters and gatherers*. Cambridge, UK: Cambridge University Press.



HUNTINGTON, ELLSWORTH (1876–1947)

The American geographer Ellsworth Huntington is most remembered for his explorations of Palestine, the Middle East, and Central Asia and the 28 books and more than 240 articles that chronicled these expeditions. The ideas and theories he derived from these researches

can be broadly categorized as “geodeterministic” in that he stressed the impacts of physical, climatic factors on the development of “racial” characteristics, heredity, and civilizations. Perhaps unsurprisingly, Huntington was also president of the American Eugenics Society from 1934 to 1938. His theories have since been discredited as ethnocentric and racist, since they asserted that people from the temperate latitudes (especially the northeastern United States) were better endowed for progress than those living in tropical climates. His impact as an educator and promoter of geography as a discipline, however, should not be understated. In addition, unlike many of his contemporaries, his theories were largely based on personal experience and observation rather than on secondhand accounts.

Born in Galenburg, Illinois, Huntington’s education in geography began at Beloit College under the mentorship of Professor William Morris Davis. His professional career began in 1897 with a 4-year stint as an instructor at Euphrates College in Turkey, during which he published his first paper on the Upper Euphrates in 1902, after spending a year exploring the local canyons. His teaching gradually gave way to exploration thereafter, and during the height of the “Great Game” from 1903 to 1906, he spent much of his time exploring Central Asia on behalf of the Carnegie Institution and the American Association of Geographers. During this period, his observation that vast areas of presently arid land had once been inhabited led to his interest in the role climate change played in human demography and development and his theory that there had been large-scale changes in climate throughout history.

On his return, he took up a teaching position as an instructor at Yale University in 1907, which led to the publication of his first major books, *The Pulse of Asia* and *Explorations in Turkestan*. In these, he outlined his theories regarding the centrality of physical factors in the social and intellectual development of peoples and asserted that migrations by the Manchus and the Mongols were prompted by climatic changes rather than specific, contingent historical developments. Huntington’s teaching was again interrupted by a 1909



expedition, this time to Palestine, and from 1910 to 1913 by a series of expeditions through the United States, Mexico, and Central America as a researcher with the Carnegie Institute. After these travels, Huntington settled into a position as research associate at Yale. He continued his work in cultural geography there and published *The Climatic Factor* in 1914, *Civilization and Climate* in 1915, *The Character of Races* in 1924, *The Human Habitat* in 1927, *The Principles of Human Geography* (with S. Cushing in 1940)—and perhaps his most influential work—*Mainsprings of Civilization* in 1945, the year in which he retired.

Edward Rice

See also **Environmental Determinism; Human Geography, History of; Semple, Ellen Churchill**

Further Readings

- Huntington, E. (1907). *The pulse of Asia*. New York: Houghton Mifflin.
 Huntington, E. (1945). *Mainsprings of civilization*. New York: Wiley.

HURRICANE KATRINA

The 2005 Atlantic hurricane season broke several records, including the most named tropical storms in a single year, totaling 27 (the average is 10), and the most hurricanes, 15 (the average is 5); and 7 of these were rated intense, or greater than Category 3 (the average is 2—i.e., sustained winds above 111 mi./hr. [miles per hour], or 179 km/hr. [kilometers per hour]). The 2005 season was the only time two Category 5 storms were in the Gulf of Mexico (Katrina and Rita) and the first time three Category 3 or more hurricanes made U.S. landfall in subsequent years (2004 and 2005). Hurricane Katrina was the costliest storm in U.S. history, at an estimated \$105 billion. The 2005 season experienced the greatest damage total in

1 yr. (year), estimated at \$150 billion (2008 dollars).

Storm History

Katrina began as a slow-moving easterly wave of low pressure in the trade wind belt near the west coast of Africa. The mass of rain clouds traveled across the Atlantic Ocean, becoming Tropical Depression 12 on August 23, 2005. The system intensified overnight to Tropical Storm Katrina (39 mi./hr., or 63 km/hr.) east of the Bahamas. Rapid strengthening followed as the system passed over 82 °F (28 °C) water. These storms feed on the latent heat of condensation, and warmer water provides more energy for the storm.

Hurricane warnings were posted along the Southern Florida coast. On August 25, Katrina reached 74 mi./hr. (119 km/hr.) and Category 1 status on the Saffir–Simpson Hurricane Damage Potential Scale. At 5 p.m., Katrina made landfall near North Miami Beach with sustained winds of 80 mi./hr. (128 km/hr.), causing flooding and damage and taking 14 human lives. By morning, Katrina had reached the Gulf of Mexico and moved westward over the warm water of the Loop Current. Sea surface temperatures reached 92 °F (33 °C), feeding rapid intensification.

By August 27, the system shifted course to the northwest and then north, provoking warnings for the Gulf Coast from Western Florida to Louisiana. Category 5 status was achieved on August 28, when winds crossed the 155-mi./hr. (250 km/hr.) mark, only to increase to 175 mi./hr. (280 km/hr.), with a central pressure of 902 mb (millibars) (26.61 in./hg [inches per hectogram]) later that day; normal sea-level pressure is 1,013.2 mb.

The governor of Louisiana declared a state of emergency for her state on August 26, followed by President George W. Bush's major disaster declaration on the afternoon of August 28. Evacuation efforts were underway by the morning of August 28. Estimates place the number of people who were evacuated at nearly 1 million, with 374,000 of these listed at shelters in other states. The critical problem was that 120,000 residents of the New Orleans area did not have



personal automobiles and had to rely on public transportation.

A buoy 50 mi. southeast from the mouth of the Mississippi River measured a wave height of 55 feet (16.8 meters) on the morning of August 29—a record for the National Data Buoy Center. Landfall occurred at 6:10 a.m. CDT (central daylight time) in Plaquemines Parish between the Mississippi River mouth and Grand Isle. Katrina slowed to a Category 3 with sustained winds up to 130 mi./hr. (210 km/hr.). By 8:00 a.m., Katrina was 40 mi. southeast of New Orleans, shifting slightly to the east; then, by 10:00 a.m., it made a second landfall along the Louisiana-Mississippi border. The lethal front-right quadrant of the storm was hitting the Mississippi Gulf Coast, while easterly winds north of the eye wall were pushing the waters of Lake Pontchartrain into New Orleans. The storm surge and winds obliterated many towns, with the damage extending east into coastal Alabama. Sixty oil spills, totaling 4 million gallons, occurred as facilities along the coast broke and more than 100 oil-drilling platforms were destroyed.

As happens with these latent heat engines, Katrina started to weaken as it moved inland, though it was still a powerful rainfall event. By 7 p.m., on the day of landfall, it was about 30 mi. north of Meridian, Mississippi, with winds below 74 mi./hr. (119 km/hr.)—it was now Tropical Storm Katrina. By the time it reached Tennessee on August 30, Katrina dropped to a tropical depression. On August 31, it became an extratropical depression as it crossed the Great Lakes into Canada.

In the days following landfall, the nation watched the grim story unfold on television. Twenty-five thousand people were stranded at the Louisiana Superdome and another 20,000 at the convention center in New Orleans with little food, water, or any sanitation facilities—24 people died at the center. Tragically, four hospitals with intensive care patients were likewise stranded without electricity or supplies for days after landfall. Many days passed as the federal government and its Federal Emergency Management Administration (FEMA) delayed their response for as yet unexplained reasons. The head of FEMA was removed from office on September 9, but the slow response continued.

Eventually, 1.2 million people underwent some form of evacuation.

Engineering Failures in New Orleans

Katrina nearly obliterated the sandy barrier islands that lay offshore. Under normal circumstances, these islands serve to protect the Mississippi River delta from wave action. The Chandeleur Islands, 19 to 25 mi. (30–40 km) from the Louisiana-Mississippi Gulf Coast, lost half their sand inventory due to Hurricane Georges (1988). More sand losses followed from Hurricanes Lili (2002), Ivan (2004), and Dennis (2005). However, Katrina basically wiped out the islands, leaving about 10% of the former sand volume.

The city of New Orleans is almost entirely below the elevation of the Mississippi River, with sections of the city below sea level. Severe flooding is a certainty for existing and planned settlements. The events of 2005, following the passage of Hurricane Katrina, will remain for many years as one of the greatest engineering failures by the government and the U.S. Army Corps of Engineers. Fully 80% of New Orleans was under water. Four levee breaks and at least 50 levee breaches (topping) led to the inundation of a major city.

More than 4 yrs. after the disaster, much of the debris of lost neighborhoods still remains. Six investigations by civil engineers, scientists, and political bodies agreed that the design, construction, and maintenance of the “protection” system were flawed. Many structures failed before they reached the design failure limits. After all, Hurricane Katrina was a Category 3 as it moved onshore. Several of the levee floodwalls were weak because they were not anchored to the correct depth, such as along the 17th Street Canal. In 2007, civil engineers inspecting the levee and floodwall repair discovered that the composition of fill materials was too low in clays and too high in sand. At the end of 2009, repair work in New Orleans was still not completed.

Future Forecast

Research has established a “total dissipation index” to rate the potential destructiveness of tropical cyclones over their lifetime. The MIT (Massachusetts Institute of Technology) scientist



Views of inundated areas in New Orleans following the breaking of the levees surrounding the city as a result of Hurricane Katrina

Source: Lieutenant Commander Mark Moran, National Oceanic and Atmospheric Administration (NOAA) Corps, NOAA Marine and Aviation Operations, Air and Space Operations Center.

Kerry Emanuel defined an “index of potential destructiveness” and found that the intensity of tropical storms and hurricanes had increased markedly since the 1970s. Storms have been lasting longer, with increased intensity. Emanuel determined strong correlations between tropical sea surface temperatures and the doubling of power of storms.

Another research team, headed by Carlos Hoyos, Georgia Institute of Technology, completed work in 2006 and found that the increasing numbers of Categories 4 and 5 hurricanes since 1970 were directly linked to increasing sea surface temperatures. These increases in temperature were the only statistically significant variables explaining the intensification of global hurricane strength.

Given the climate change now underway, the forecast is for further intensification.

Researchers suggest that global climate change, when considered alongside increased coastal population settlement and rising sea levels of more than 0.4 in. (1 centimeter) per year along the Gulf Coast, will produce substantial future hurricane-related losses. Warmer seas provide more energy, and warmer air absorbs more water vapor, with all this energy converted into tropical cyclone winds. Researchers identified the key role of higher ocean and air temperatures. The forecast for vulnerable coastal regions is not positive.

Robert W. Christopherson



See also **Coastal Hazards; Hurricanes, Physical Geography of; Hurricanes, Risk and Hazard; Natural Hazards and Risk Analysis; Weather and Climate Controls**

Further Readings

- Editors of Time. (2005). *Hurricane Katrina: The storm that changed America*. New York: Time Books.
- Elsner, J. B., Kossin, J. P., & Jagger, T. H. (2008). The increasing intensity of the strongest tropical cyclones. *Nature*, 455, 92–95.
- Emanuel, K. (2005). Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, 436, 686–688.
- Horne, J. (2008). *Breach of faith: Hurricane Katrina and the near death of a great American city*. New York: Random House.
- Hoyos, C. D., Agudelo, P. A., Webster, P. J., & Curry, J. A. (2006). Deconvolution of factors contributing to the increase in global hurricane intensity. *Science*, 312, 94–97.



HURRICANES, PHYSICAL GEOGRAPHY OF

Labeled a typhoon in the Pacific Ocean west of the International Dateline and a cyclone over the Bay of Bengal and Arabian Sea, a hurricane is powered by the heat and moisture of the tropics rather than temperature differences across latitudes, as is the case for the more common extratropical cyclone. This entry describes the characteristics and classification of hurricanes, the types of damage they can cause, and current research on hurricane activity.

A hurricane begins as an area of low air pressure over warm ocean waters (at least 27 °C down to 50 m [meters] below the sea surface). As a result of atmospheric instability, the area of low pressure features numerous showers and thunderstorms that, over several days, organize the winds into a counterclockwise (clockwise in the Southern Hemisphere) swirl. The swirl in turn helps new thunderstorms develop. The swirl

becomes a tropical storm when the circulating wind speeds, estimated at 10 m above the ocean, exceed 17 m/s (meters per second), averaged over 1 minute.

When the wind speeds reach 33 m/s or more, the tropical storm is called a hurricane. Once formed, the hurricane winds are maintained by the import of heat from the ocean at high temperatures and the export of heat at lower temperatures in the upper troposphere (close to 16 kilometers above sea level at the equator), similar to the way a steam engine converts thermal energy into mechanical motion.

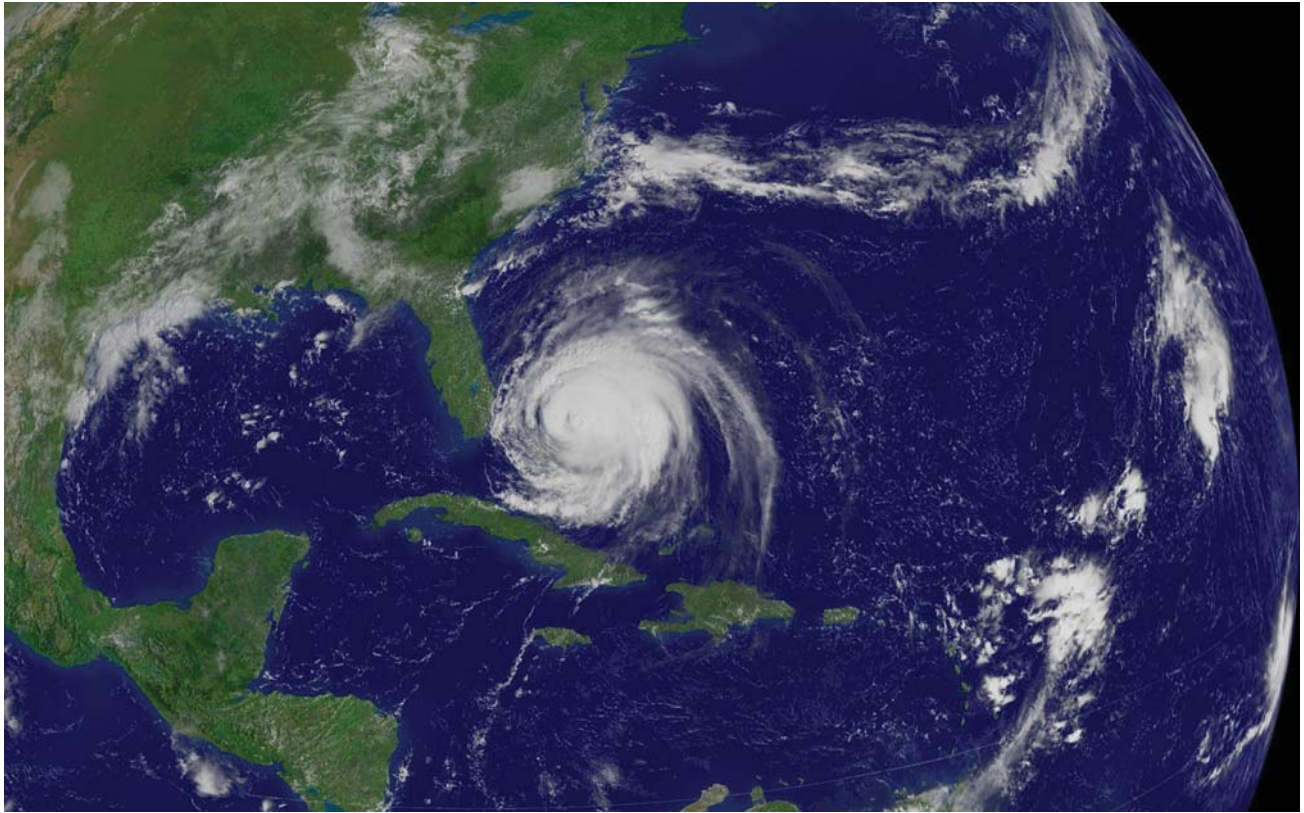
Hurricane Winds

Strong winds are the defining characteristic of a hurricane. Wind is caused by the change in air pressure from one location to another. In the eye of a hurricane, the air pressure, which is the weight of a column of air from the surface of the Earth to the top of the atmosphere, is quite low compared with the air pressure outside the hurricane. This pressure difference causes the air to move inward, toward the center of the hurricane.

By a combination of friction, as the air rubs on the ocean below, and the spin of the Earth, as it rotates on its axis, the air spirals inward in a counterclockwise direction toward the region of lowest pressure. The vertical component of the Earth's spin is too weak to support a spiral within about 5° of latitude from the equator, so hurricanes do not develop close to the equator.

To a first approximation, the pressure difference between the eye and the air outside the hurricane determines the speed of the wind. Since the pressure outside the hurricane is roughly uniform, a hurricane's central pressure is another measure of a hurricane's intensity. The lower the central pressure, the more intense is the hurricane. Pressures inside the most intense hurricanes are among the lowest that occur anywhere on the Earth's surface at sea level.

Hurricanes vary widely in intensity, as measured by their fastest-moving winds. Hurricane intensities are grouped into five categories (Saffir-Simpson scale), with the weakest, Category 1, winds blowing at most 42 m/s and the strongest, Category 5, winds exceeding speeds of 69 m/s.



Pictured from space, Hurricane Frances lashes the Bahamas Islands on September 3, 2004.

Source: National Oceanic and Atmospheric Administration.

Three Category 5 hurricanes hit the United States during the 20th century, including the Florida Keys Hurricane in 1935, Hurricane Camille in 1969, and Hurricane Andrew in 1992.

Hurricanes also vary considerably in size (spatial extent), with the smallest hurricanes measuring only a few hundred kilometers in radius (measured from the eye center to the outermost closed line of constant surface pressure) and the largest exceeding a thousand kilometers or more.

In the largest and most intense hurricanes (e.g., Hurricane Katrina in 2005), the strongest winds are located in the eye wall that surrounds the nearly calm eye. The distance from the center of the hurricane to the location where the winds are blowing the strongest is called the radius of maximum winds. In a well-developed hurricane, the radius of maximum winds is found at the inner edge of the eye wall. This distance varies considerably from hurricane to

hurricane though, and due to cycles of eye wall replacement, even from day to day for a particular hurricane. While the wind just above the ocean surface spirals anticlockwise toward the center, the air at high altitudes blows outward in a clockwise spiral. This outward-flowing air produces thin cirrus (feathery) clouds that extend to great distances (thousands of kilometers) from the center of the hurricane. The presence of these clouds may be the first sign that a hurricane is approaching.

Hurricanes are steered by large-scale wind streams in the atmosphere and by the increasing component of the Earth's spin away from the equator. In the deep tropics, these forces push a hurricane slightly north of due west (in the Northern Hemisphere). Once north of about 23° of latitude, a hurricane tends to take a more northwestward track, moving eventually northeastward at still higher latitudes. This creates the parabola-shaped track often reproduced on



maps of historical hurricanes. Local fluctuations in the magnitude and direction of steering can result in tracks that deviate significantly from this pattern.

Landfall occurs when the hurricane center crosses a coastline. Because the fastest winds are located in the eye wall, it is possible for a hurricane's fastest winds to be over land even if landfall does not occur. Similarly, it is possible for a hurricane to make landfall and have its fastest winds remain out at sea. Fortunately, the ferocious winds slacken quickly after the hurricane moves over land. Hurricanes made landfall in the United States at an average rate of five every 3 years during the 20th century.

Hurricane Damage

Winds blowing overland from a hurricane destroy poorly constructed buildings and mobile homes. Debris such as signs, roofing material, and small items left outside become flying projectiles, adding to the destructive power of the wind.

Besides the destructive power of the winds, hurricane damage results from two other causes: flooding from torrential rains and storm surge. Rainfall is the quantity of water, expressed in millimeters, that falls from the hurricane in a specified area over a given time interval. Hurricanes derive energy from the ocean by evaporating the water into the air, which then gets converted back to liquid water through condensation inside thunderstorm clouds. The water falls from the clouds as rain, and the stronger the hurricane thunderstorms, the greater the amount of rain and thus the greater the potential for flooding.

The amount of rain deposited over land from a hurricane depends on many complex factors, including hurricane intensity, forward speed, and the underlying topography. The rainfall of a hurricane can intensify when the strong winds carry the moisture up a mountainside. The saturation condition of the soil from previous rains also plays a role in whether and to what extent flooding will occur. Freshwater flooding from torrential hurricane rainfall can be a serious danger hundreds of kilometers from the point of landfall.

Bands of showers and thunderstorms that spiral inward toward the hurricane center are the first sensible weather experienced as a hurricane approaches. High-wind gusts and heavy downpours occur in the individual rain bands, with relatively calm weather occurring between the bands. A brief tornado may form in a rain band, especially as the hurricane crosses the coastline.

Storm surge is ocean water that is pushed toward the shore by the force of the winds moving around the storm. Over the open ocean, the water can flow in all directions (including downward) away from the storm. Strong winds blowing across the ocean surface create a stress that forces the water levels to increase downwind and decrease upwind. This wind setup is inversely proportional to ocean depth, so over the deep ocean away from land, the water level rises are minimal. However, when the hurricane approaches shallow water, there is no room for the water to flow underneath, so it rises and gets pushed by the wind as a surge, much like a snowplow pushes the snow from the roadway. The advancing surge can increase the water level 5 m or more above sea level. In addition, wind-driven waves are superimposed on the storm surge. The total water level can cause severe surge impacts in coastal areas, particularly when the storm surge coincides with the normal high tide caused by the sun and the moon.

The slope of the continental shelf also determines the level of surge in a particular area. A shallow slope will allow a greater surge. With a steeper continental shelf, coastal areas will not experience as much surge inundation, although large breaking waves can still present major problems. The low pressure in the middle of the storm causes a smaller part of the storm surge.

The pressure inside the eye is much lower than the surrounding atmosphere, so the water gets lifted. This will cause the sea surface over the open ocean to rise in regions of low pressure and fall in regions of high pressure. In general, for a 1 hectopascal drop in surface pressure, there is a 1 centimeter rise in sea level. In short, the cause of storm surge is the combined effect of low air pressure and persistent winds blowing over the ocean surface.



Hurricane Tracking

Today, hurricanes are tracked with satellites, radar, and specially equipped aircraft on reconnaissance flights. Ocean buoys and ships also provide storm information. Successful experiments with remotely piloted drone aircraft (aerosonde) suggest that they might be used to help forecast the intensity and track of hurricanes in the near future.

Because of their potential for death and destruction, the U.S. National Hurricane Center issues watches and warnings for hurricanes threatening the United States a few days before a potential landfall. A hurricane watch means that hurricane conditions in specific coastal areas are possible within 36 hrs. (hours). A hurricane warning means that hurricane winds associated with a hurricane are expected in a specified coastal area within 24 hrs. A hurricane warning can remain in effect when dangerously high water or a combination of dangerously high water and exceptionally high waves continues, even though the wind may be less than hurricane intensity.

Global Hurricane Activity

On average, 50 hurricanes occur worldwide each year. Hurricanes develop during the time of year when the ocean temperatures are hottest. Over the North Atlantic (including the Gulf of Mexico and the Caribbean Sea), this includes the months of June through November, with a sharp peak from late August through the middle of September. The time difference between the peak in solar radiation receipt in June (Northern Hemisphere) and the peak in hurricane activity is due to the fact that the terrestrial (oceanic) long-wave radiation emission lags solar radiation by a few months. Worldwide, May is the least active month for hurricanes, while September is the most active.

Hurricane activity, on time scales of seasons and longer, responds to variations in climate. To a first order, greater ocean warmth and relatively calm winds enhance the potential for hurricanes. For instance, in the western tropical North Atlantic and Caribbean Sea, deep warm water and low values of upper atmospheric wind shear create

conditions favorable to initiate and sustain hurricanes before they strike the United States. The strength and position of the subtropical high-pressure zone determine the steering currents, which is important for predicting landfall probabilities. Catastrophe models that project future damage losses from hurricanes now include this information.

Increases in ocean temperature will raise a hurricane's potential intensity, other things being equal. However, corresponding increases in atmospheric wind shear—in which winds at different altitudes blow in different directions and tear apart the developing hurricane—could counter this tendency by dispersing the hurricane's heat. A recent study based on a set of homogenized satellite-derived wind speeds indicates that the strongest hurricanes are getting stronger worldwide. Modeling studies indicate that rainfall from hurricanes may get heavier in the future. However, more research is needed to better understand these important issues.

James B. Elsner

See also Air Masses; Atmospheric Energy Transfer; Atmospheric Pressure; Climate Change; Coastal Hazards; Floods; Hurricane Katrina; Hurricanes, Risk and Hazard; Oceans; Thunderstorms; Wind

Further Readings

Emanuel, K. (2005). *Divine wind: The history and science of hurricanes*. New York: Oxford University Press.



HURRICANES, RISK AND HAZARD

Throughout history, hurricanes have been the leading cause of deaths associated with short-term natural hazards. Populations along coastal areas are exposed to a number of hurricane-related hazards, including, but not limited to, storm surge, high-speed winds, heavy rainfall, flooding, and tornadoes. This entry explores the geography



of hurricane risk in the United States and provides an overview of hazards associated with hurricane events.

Geography of Risk

An average of two hurricanes reaches the coast of the United States each year. In the United States, hurricanes most frequently make landfall along the shores of Eastern Florida, Georgia, South Carolina, and North Carolina; however, coastlines along the Gulf of Mexico as well as the Atlantic coast from Virginia to Maine are also at risk. Hurricanes often span hundreds of miles in width and thus are capable of causing widespread damage to inland areas. Most of the substantial damage and loss of life attributed to hurricane hazards transpires within 60 to 100 mi. (miles) of where the storm makes landfall.

Population growth along the coastal areas has increased the number of Americans at risk from hurricane hazards. The U.S. Census Bureau estimated that in 2007, more than 35 million Americans along the coastline from North Carolina to Texas were at high risk from hurricane-related threats. In addition, the locations most vulnerable to hurricane events experienced 247% population growth since the 1950s. Despite the increasing coastal population, hurricane-related deaths have dramatically decreased throughout the past century due in part to better warning systems. However, economic losses resulting from hurricane hazards have greatly increased because of rising property values, new construction, and increased industrialization in coastal areas.

Hurricane Hazards

Hazards attributed to hurricane events vary greatly in magnitude, geographic extent, and the resulting damage. The hazards that result in the most damage to coastal areas during a hurricane include storm surge, high-speed winds, heavy rainfall, flooding, and tornadoes. These hazards are described in further detail below.

Historically, the storm surge has been responsible for the majority of hurricane-related deaths. The storm surge is a hurricane tide that is primarily driven by strong winds. Storm

surges can raise local ocean water levels by more than 20 ft. (feet) and can extend along a coastline for more than 100 mi. Much of the damage caused by a storm surge is limited to locations near the coastline. Debris carried by these waves contributes to their destructive force, causing significant damage to buildings and property located in low-lying areas. The most devastating storm surge in U.S. history occurred during the Galveston Hurricane of 1900, where an estimated 8,000 to 12,000 people on Galveston Island, Texas, were killed when a 15- to 18-ft. storm surge inundated the island.

High-speed winds are another hazard related to hurricanes. Hurricane-force winds exceeding 74 mi./hr. (miles per hour) often suspend large debris into the air, causing widespread damage to homes, buildings, trees, and utility lines. Hurricane-force winds are responsible for some of the highest wind speeds ever recorded. Hurricane Celia generated sustained winds of 161 mi./hr. as it made landfall on the coast of Corpus Christi, Texas, in 1970, and Hurricane Camille, in 1969, struck the Louisiana coastline with sustained winds reported at 172 mi./hr.

Heavy rainfall and flooding pose a threat to both coastal and inland areas. On average, hurricanes produce 6 to 12 inches of rain after landfall; however, the heavy rainfall is not always confined to the coast. Inland areas are at risk of getting substantial rainfall produced by the remnants of a hurricane. Between 1970 and 1999, inland flooding accounted for more than half of all hurricane-related deaths, with most of these fatalities occurring at night while the victims were driving.

Tornadoes are also a hazard associated with hurricanes. The devastating winds produced by hurricane-spawned tornadoes compound to the destruction already caused by other hurricane-related hazards. These tornadoes frequently occur before the eye of the storm moves ashore and usually develop in the front right quadrant of the hurricane's track. Studies conducted on tornadic activity during hurricanes indicate that almost 60% of all hurricanes that hit the United States between 1948 and 1986 generated at least one tornado. However, the number of tornadoes hurricanes produce



Galveston Island, Texas, after Hurricane Ike made landfall, September 13, 2008

Source: U.S. Air Force photo by Staff Sergeant James L. Harper Jr., 1st Combat Camera Squadron.

varies. For example, in 2004, six tropical storms that struck the United States produced more than 300 tornadoes. Tornadoic activity during hurricanes also varies geographically. Areas along the coastlines of Texas and Louisiana and the west coast of Florida are almost twice as likely to experience tornadoes during a hurricane event as areas located along the North Atlantic coastline.

Protective Measures

Substantial progress has been made in reducing the number of fatalities associated with hurricanes. Improved forecasting techniques have assisted in the issuance of more accurate hurricane watches and warnings. The establishment of better warning systems has led to more effective communication of hurricane threats to

communities. In addition, the implementation of evacuation strategies has greatly reduced the number of hurricane-related deaths. However, numerous challenges still exist in mitigating economic and property losses during hurricane events. Failure by local and state governments to evaluate hurricane risks as well as make mitigation efforts a priority in their communities greatly increases the losses associated with hurricanes. As demonstrated during Hurricane Katrina in 2005, lack of preparedness before, during, and after a hurricane event can have devastating consequences on a community. Improved management of hurricane events, as well as the implementation of better mitigation strategies along the coastline, can greatly reduce the losses related to hurricane hazards.

Laura Kathryn Siebeneck



See also **Coastal Hazards; Hurricane Katrina; Hurricanes, Physical Geography of; Vulnerability, Risks, and Hazards**

Further Readings

- Fitzpatrick, P. J. (2006). *Hurricanes: A reference handbook* (2nd ed., pp. 25–35). Santa Barbara, CA: ABC-CLIO.
- Longshore, D. (2008). *Encyclopedia of hurricanes, typhoons, and cyclones*. New York: Facts on File.
- Pielke, R. A., Jr., & Pielke, R. A., Sr. (1997). *Hurricanes: Their nature and impacts on society* (pp. 118–137). West Sussex, UK: Wiley.
- U.S. Census Bureau. (2008, July 23). *U.S. Census Bureau issues facts for features special edition: 2008 Hurricane season begins* [Press release]. Retrieved November 1, 2008, from www.reuters.com/article/pressrelease/idus175000+23-jul-2008+bw20080723



HYBRID GEOGRAPHIES

Geography has long been characterized as an integrative field—a hybrid discipline that combines elements of the natural and social sciences. With contributions from the humanities and social theory, more explicit considerations of hybrid geographies have attracted increasing critical attention. This trend represents both a new set of concepts in response to new technologies and conditions as well as a renewed embrace of one of the oldest ideas in geography—that simultaneous inquiry of social and natural elements can provide important insights.

At their most basic, hybrid geographies are places, organisms, or other entities that cannot or should not be readily characterized by any single category. As the term *hybrid* denotes, these places or things feature elements from multiple origins to the extent that they can only properly be considered as new and often rather fluid kinds. In this respect, the study of hybrid geographies represents an effort to depart from common dualisms found in geography and other fields.

In fact, hybrid geographies signify new kinds of places or entities, new ontologies, as well as new ways of generating knowledge to conceptualize these new kinds. This epistemological turn presents something of a conundrum: In its deepest form, the study of hybrid geographies calls for the obliteration of prior categories such as nature/society, local/global, inside/outside, or natural/artifactual to instead recognize associations, networks, or mixed qualities that resist traditional dualisms. While this effort to find alternative frameworks appeals to geographers who oppose labels such as “physical” or “human” to delimit their field’s principal perspectives, a determined effort to defy categorization can also lead to problems of linguistic or conceptual clarity. Hybrid geographies therefore can seem rather elusive or even provide ironic reminders that categories and dualisms are often created for the very practical purpose of simplifying complex ideas.

Describing places as hybrid geographies is, at least initially, the most obvious and intuitive aspect of a much broader project. Relating to critical studies of landscape, a number of scholars emphasize that cities, farmlands, wildlife refuges, and even wilderness areas are not only natural or social spaces but that these can all be considered sites of synthesis where human and nonhuman agency conspire and coalesce. In this view, landscapes are not merely an array of physical objects but rather dynamic places built through social activities, economies, and values as well as environmental conditions.

This integration across potentially disparate categories may be very apparent or quite subtle, but in either case, such blending can be seen as a form of hybridization. Cities may seem at a glance to consist purely of human elements: asphalt and concrete, glass, steel, and mechanization; but a closer look, inevitably, also reveals nonhuman elements such as terrain, watercourses, plants, wildlife, or weather. Similarly, on careful inspection, “natural” places such as wildlife refuges or wilderness areas reveal complex generative histories of human use, management, regulation, and mapping.

If pursued vigorously, this integrative consideration of landscapes can be extended to virtually any setting to make a case for hybridity. After all, with advances in technology, we can



now detect industrial residues in the most remote icefields on the planet and synthetic chemicals in the cord blood of newborn babies. In the face of retreating glaciers or the early onset of puberty in children, it may be only appropriate to reconsider these and many other disparate contexts as hybrid geographies of inseparable natural and social production.

This idea leads us to rethink how we describe or come to understand the world fundamentally. Rather than thinking in terms of set categories—of nature and society, for example—an epistemological shift toward hybridity recasts the framework to emphasize relationships. Scholars promoting concepts of hybridity label it somewhat differently: Jonathan Murdoch presents it as “associationalism,” Sarah Whatmore calls it “commotion,” and Bruno Latour orients it by means of networks, but in each case, the effect is to blur the distinctions between categories and emphasize connectivity. Such a project effectively diminishes the role of essential or “pure” qualities in a place or entity and instead highlights the dynamic qualities that destabilize traditional ontologies. To return to one of the examples above, a Greenland icefield is no longer the exclusive result of natural climate and precipitation, but instead it is a shifting (and currently diminishing) product of these processes, inseparably conjoined with emissions from coal-fired power plants and automobiles and a global trend toward industrial development.

This type of reformulation understandably makes many people uneasy. Hybrid geographies challenge long-held views of what we think we know about the world. In this respect, the study of hybrid geographies can bring a radical philosophy to geographical inquiry in ways that remain to be fully explored. At the basic level of communicating ideas, how do we describe places or organisms if we are committed to turning away from dualistic categories? Bruno Latour seeks to blur the distinction between set categories with actor-network theory, which highlights the relationships among natural, social, and technological systems. This networked approach informs much of the geographical work on hybridity and has gained considerable popular relevance with the advent of the Internet and social networking Web sites.

Broader changes in technology and land use have, in fact, spurred a good deal of activity in the study of hybrid geographies in recent years. This has occurred across a variety of scales and contexts, from the scientific manipulation of particular organisms to the reclassification of entire landscapes. Two cases, the production of genetically modified organisms (GMOs) and the conversion of closed military bases, provide useful examples to consider the range of conditions and processes hybrid geographies can encompass.

Genetically Modified Organisms

Hybridization attracts public notice most often in the context of cross-fertilizing plants or animals, with the subsequent organism often exhibiting characteristics that blend the features of the originals. While such hybrids initially occurred without human intervention, plant and animal breeders quickly recognized that certain traits in offspring could be emphasized if disparate species or varieties were intentionally selected and combined. What began as the deliberate, relatively simple process of mixing parental stock repeatedly until the desirable qualities emerged has, with technological advances, become in some cases a much more directed process of selecting particular qualities from disparate origins and blending genetic material to create GMOs or transgenic organisms.

This relatively recent ability to infiltrate the genetic stock of organisms has vastly expanded the array and kinds of hybrids now extant. Entire landscapes can be filled with organisms that never could have been formed without active intervention and manipulation by human technicians. Such hybrid geographies have gained the most acclaim and notoriety in the context of agriculture, including products such as “golden” rice and oranges loaded with omega-3 fatty acids. Golden rice was developed by incorporating unrelated genetic material from daffodils and a soil bacterium into the endosperm of rice to boost levels of beta-carotene and vitamin A. Differing markedly in appearance and nutritional content from unmodified rice, golden rice can be grown and consumed much like any other plant, but its high-tech origins nudge it out of the standard categories of “natural” foodstuffs. At a basic level, it



is clearly the blended product of human intervention and long-standing environmental processes.

Oranges with enhanced levels of omega-3 fatty acids were similarly developed with the goal of improving the nutritional capacities of a common food, but in this case, the genetic modification reaches across a more striking gap. Omega-3 oranges rely not just on plant-to-plant transfer but also on the manipulation of genetic material from anchovies into commercially grown citrus fruit. Few consumers of the resulting orange juice are likely even aware that they are ingesting the crossed product of a fruit-fish hybrid, a point that highlights the sometimes invisible qualities of hybrid geographies.

Military Conversions

Moving to a rather different scale and context, we can also find hybrid geographies in a number of sites formerly managed exclusively for military production and now undergoing conversion to a more diverse array of land uses. For example, nearly two dozen former military installations in the United States have recently been converted and reclassified as national wildlife refuges.

Through a mix of natural, social, and technological processes, these conversion sites develop into altogether new geographies that retain qualities from multiple categories. Many of these sites contain unexploded ordnance, chemically contaminated soils and waters, ammunition bunkers, missile storage igloos, airport runways, or other remnants of military production while also exhibiting characteristics associated with the conservation mission of the U.S. National Wildlife Refuge System, such as habitat for imperiled plants and animals. In this way, these military-to-wildlife conversion sites no longer fit neatly into categories of spaces of either/only militarism or wildlife conservation but instead call for a more diffuse notion of multiplicity and coproduction. In other words, they may be much more aptly considered as hybrid spaces or hybrid geographies. What may have once been tempting to consider as an *artificial* array of military bases is, in these cases, blending increasingly with what was once formerly seen as a *natural* system of wildlife refuges.

As highlighted above, the study of hybrid geographies not only focuses on these sorts of places

and organisms that defy easy categorization but also seeks to challenge the earlier assumptions that allowed categories such as natural and artificial to withstand critical scrutiny. In both respects, hybrid geographies represent efforts to enhance geography's critical engagement with the world and to seek meaning in ways that challenge existing disciplinary assumptions.

David Havlick

See also **Actor-Network Theory; Critical Human Geography; Nature-Society Theory; Poststructuralism; Social Construction of Nature**

Further Readings

- Castree, N. (2005). *Nature*. London: Routledge.
- Cronon, W. (1995). The trouble with wilderness; or, getting back to the wrong nature. In W. Cronon (Ed.), *Uncommon ground: Toward reinventing nature* (pp. 69–90). New York: W. W. Norton.
- Latour, B. (1993). *We have never been modern*. Cambridge, MA: Harvard University Press.
- Murdoch, J. (1997). Towards a geography of heterogeneous associations. *Progress in Human Geography*, 21(3), 321–337.
- Review symposium: Sarah Whatmore, *Hybrid geographies*. (2005). *Antipode*, 37(4), 818–845.
- Whatmore, S. (2002). *Hybrid geographies: Natures, cultures, spaces*. London: Sage.



HYBRIDIZATION OF PLANT AND ANIMAL SPECIES

Hybridization is a fundamental evolutionary process that can lead to further differentiation by the creation of unique individuals or new evolutionary significant units that eventually may become new species. However, hybridization can also create significant barriers on the path to diversification by allowing gene flow between two related yet distinct individuals or populations that will decrease the differentiation between them. Charles Darwin devoted Chapter 9 of *The Origin of*



Species to the discussion of hybridization and the outcomes that result from two distinct species or populations reproducing to create unique offspring—whether viable or sterile. The processes of hybridization as well as the offspring that are generated through this method are of great importance to biogeographers and other natural and physical scientists who are investigating speciation or loss of diversity in specific assemblages. Additionally, hybridization is a significant phenomenon when discussing the modern breeding of domestic animals and plants.

Types of Hybrids

Hybrids are those individuals that have been produced through the reproductive crossing of two parents from distinct taxonomic groups. Hybrids that result from the crossing of two separate species are generally referred to as interspecific hybrids. Typically, interspecific hybrids have nonviable or sterile offspring, which is the criterion used to distinguish taxonomic groups as separate or belonging to distinct species. The *biological species concept* is based on this observation that two distinct species cannot produce viable offspring. However, there are always exceptions to this rule, and often, viable offspring are produced through these crosses, whether random or intentional.

When two individuals from the same species group, but from different subspecies, cross, their offspring are referred to as intraspecific hybrids. These intraspecific crosses can also occur between distinct populations, cultivars, and specific breeds within a single species or the primary gene pool for a taxonomic group. This type of hybridization is particularly important in animal and plant breeding efforts that strive to incorporate characteristics from two distinct sets of parental groups that can be consistently found in offspring as a result of reproductive crossing and can confer some benefit to the offspring that is not found individually in either parent population.

On occasion, hybrids result from the crossing of individuals from different genera, referred to as intergeneric hybrids. Even rarer are hybrids above the genus level—at the family level. These offspring are known as interfamilial hybrids and are very uncommon in nature.

Examples of Hybrids

Examples of hybrids include the following:

- Domestic dogs are dogs that are bred using different breeds.
- Mules are the result of the crossing between a female horse and a male donkey.
- The zeedonk/zonkey is the result of a cross between a zebra and a donkey.
- The limequat is a lime and kumquat hybrid.
- The tangelo is a cross between different citrus subspecies.
- The triticale is a hybrid of wheat and rye.

Benefits of Hybridization

The process of hybridization between individuals from distinct evolutionary groups has had a tremendous impact on the diversity of specific ecosystems, particularly agro-ecosystems. Speciation may result from hybridization, thus increasing the amount of biodiversity found within a specific range or region. Reticulate speciation occurs between two distinct species that are part of a monophyletic group when they hybridize and create a new species; thus, having been separated at one point in evolutionary history, they come back in contact to create a new species. Heterosis, or hybrid vigor, is also a beneficial result of hybridization. Farmers for centuries have been consciously and unconsciously taking advantage of the positive outcome of crossing individuals from distinct populations or races. Intraspecific hybrids typically have a higher fitness than either parent population would have through normal reproduction within each parental group, thereby conferring this benefit to the hybrid offspring. Modern plant- and animal-breeding programs have taken advantage of the granted benefits of heterosis by creating advanced cultivars that are extremely fit under certain conditions. For example, conventionally produced corn (or maize) is the product of hybridization to capture hybrid vigor in each generation. Additionally, domestic dogs that are the result of hybridization between more than one distinct breed often outlive and have less health problems than their purebred counterparts.



Limitations of Hybridization

Just as the process of hybridization can bestow benefits to the populations and offspring affected by this evolutionary process, there are also several limitations to the phenomenon. Many of the resulting offspring have serious health and genetic limitations because of the resulting admixture of chromosomes from distinct parental populations. Many of these offspring have deleterious characteristics and do not live for more than a few hours or days after birth. Typically, hybrids between different species and higher taxonomic groups are not reproductively viable because of chromosome problems or dysfunctional reproduction issues. This is more common with animal hybridization, but it can occur in plant hybrids as well.

Of particular concern when dealing with hybrid offspring is the potential for genetic erosion through introgressive hybridization, or introgression. Introgression occurs when a hybrid offspring then backcrosses with one of the parental groups. This backcrossing, or introgression, can cause a loss of allelic diversity within the parental group, thus diluting the genetic diversity of the parental population. This is very significant when investigating the domestication of agricultural plant species. Oftentimes, traditionally and conventionally bred material will hybridize in the areas of origin with the wild ancestor or progenitor of the population, causing a significant loss of diversity in the gene pool of the species. This is referred to as genetic erosion and can occur in both plant and animal populations. This type of introgressive hybridization has occurred in common beans as well as between different species of crocodile. The most devastating consequence of such a cross is that often one of the species is already threatened, and through hybridization and subsequent backcrossing with parental groups, that population suffers severe genetic erosion or pollution of its genome and, in rare cases, extinction.

Laura R. Lewis

See also **Agrobiodiversity; Agroecology; Crop Genetic Diversity; Domestication of Animals; Domestication of Plants; Genetically Modified Organisms (GMOs); Nature-Society Theory**

Further Readings

- Anderson, E., & Stebbins, G. L., Jr. (1954). Hybridization as an evolutionary stimulus. *Evolution*, 8(4), 378–388.
- Arnold, M. L. (1992). Natural hybridization as an evolutionary process. *Annual Review of Ecology and Systematics*, 23, 237–261.
- Darwin, C. (1859). *The origin of species*. Middlesex, UK: Penguin.
- Ellstrand, N. C. (2003). *Dangerous liaisons? When cultivated plants mate with their wild relatives*. Baltimore: Johns Hopkins University Press.



HYDROELECTRIC POWER

Hydroelectricity is a derivative of hydropower, which is energy captured from river systems. Hydroelectricity is a scientific-technological system that resulted from the invention of electricity and the creation of the river water-powered turbine onto which a rotor is mounted to generate electricity. Michael Faraday (1791–1867) is credited with inventing electricity in his London laboratory in 1831. Twenty years passed before the Francis turbine was created in 1851. Hydroelectricity became a physical reality when the turbine and the rotor were effectively assembled to generate electricity at Rothbury, United Kingdom, in December 1880, and the first public electricity-supplying unit was installed at Godalming, United Kingdom, in 1881. In the United States, the earliest hydroelectric installation was placed at Appleton, Wisconsin, in 1882, and by 1889, a textile mill in Juiz de Fora, Minas Gerais, Brazil, built its own electricity source to service the mill. The diffusion of this power source coincided with the accelerating pace of industrialization in Europe and the Americas.

Hydroelectricity enlarged the energy matrix at the time, post-1880s, when the pace of industrialization increased in northwestern Europe and the northeastern United States. The demand for electricity was rooted in the illumination of public spaces such as streets, parks, and public buildings, abolishing the gas lamps. Horse-drawn



streetcars were replaced by electric trolley cars, and factories turned to dynamo-powered machinery and away from belt-driven equipment. The increased demand for electricity fostered the expansion of the installed power park, which was building local thermal electric power stations in the coal-rich states. Coal-poor states such as France, Italy, and Switzerland decided to power their growing manufacturing systems by tapping into rivers to draw on the hydroelectric potential, reducing their dependence on coal and foreign exchange transfers. All three countries developed heavy engineering industries to build the mechanical infrastructure for hydropower dams. Builders of hydroelectric projects discovered an attractive incentive in hydroelectric power stations—namely, that they provided the least costly energy.

Just as there was a notable time lag between the invention of electricity and the introduction and spread of hydroelectric dams, there was also a time lag between the setting up of the transmission system and the effective transmission of electricity to the required distance. The one-time ½-km (kilometer) power line gradually expanded to hundreds of kilometers of transmission lines, and now 3,000 km of lines exist; with the coming of superconductivity, even these limits will fall. Efficiency (measured in kilovolts) is determined by the distance the electricity is transmitted—that is, the higher the number of kilovolts, the greater is the distance that the power can be transmitted. Energy loss occurs at two levels: one in transmission (transport) and the other in stepping up or down the kilovolt value of the electricity sent. Generally, 15% of electricity is lost in the transforming process. This is mechanical, not distance based.

Hydroelectricity has been instrumental in the industrialization process in many countries. From 1920 to 1940, hydroelectricity was widely implanted as a key electricity source in Europe and had strong acceptance in the USSR from 1917 to 1990. In the United States, hydroelectricity acquired landmark status with the Hoover Dam on the Lower Colorado River. In the mid 1930s, the United States created the Tennessee Valley Authority, with a multiple hydroelectric dam system to foster regional economic development and land reclamation. The Columbia River basin became the site for numerous major dams, for example, Bonneville and Grand Coulee, serving

industrialization needs such as aluminum production and uranium processing for the federal government and the electricity needs of the Pacific coast region. Many of these dams would later become a key cause of population declines in several species of salmon, by destroying important spawning and rearing habitats.

The post–World War II years became a time of economic reconstruction in much of Europe, the USSR, and East Asia. South Korea embarked on reconstruction and hydroelectric expansion after 1953. In the 1950s, the expansion of hydroelectric plant construction began in Europe and the United States; this was also a time when significant changes in the global economy and electricity demand enhanced the attractiveness of domestic hydroelectric sources. The planning and building of hydroelectric systems can take years as numerous environmental assessment studies, project cost analyses, market demand inventories, and electricity delivery systems transmission networks have to be assembled and placed in chronological order for effective implantation and service.

Expansion of the hydroelectricity sector is measurable by using the volume of total kilowatts generated. Between 1950 and 2005, the world's total number of installed hydroelectric systems increased by 1,588%. The distribution of installed hydroelectric systems is regionally uneven and reflects the increased availability of other energy sources. It is instructive to consider electricity data from a regional perspective and in proportion (%) to the total number of installed electricity-generating systems (Figures 1 and 2).

Hydroelectricity contributes generally about 20% of the total electricity consumed worldwide. The global distribution of installed hydroelectric systems is uneven in time of construction, size, and service area. Here, technological changes contribute toward updating the equipment and providing improved transmission systems to significantly extend the reach of regions served. Globally, Asia by 2005 had become the dominant hydroelectric region, registering 34.4% of all operating hydroelectric units. Up to 64.4% of South America's electricity needs were met by the hydroelectric sector in 2005. China's hydroelectric sector provided 23% of the country's electricity needs in 2005, illustrating the growing

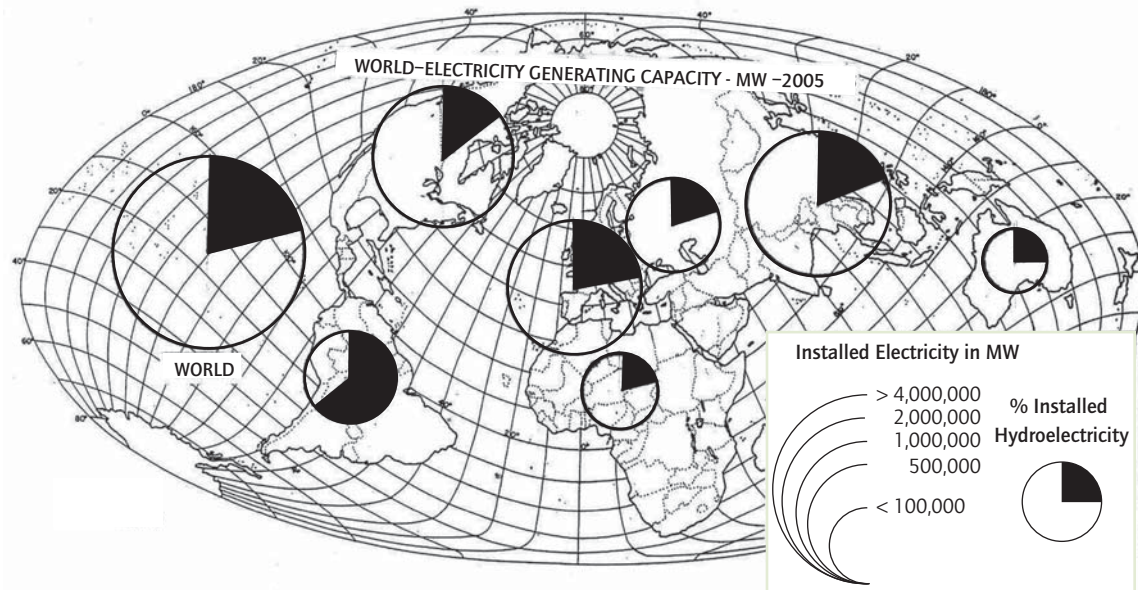


Figure 1 World electricity-generating capacity (in megawatts), 2005

Source: Adapted from United Nations. (2007). *2005 Energy statistics yearbook* (Table 32, pp. 430–461). New York: Author.

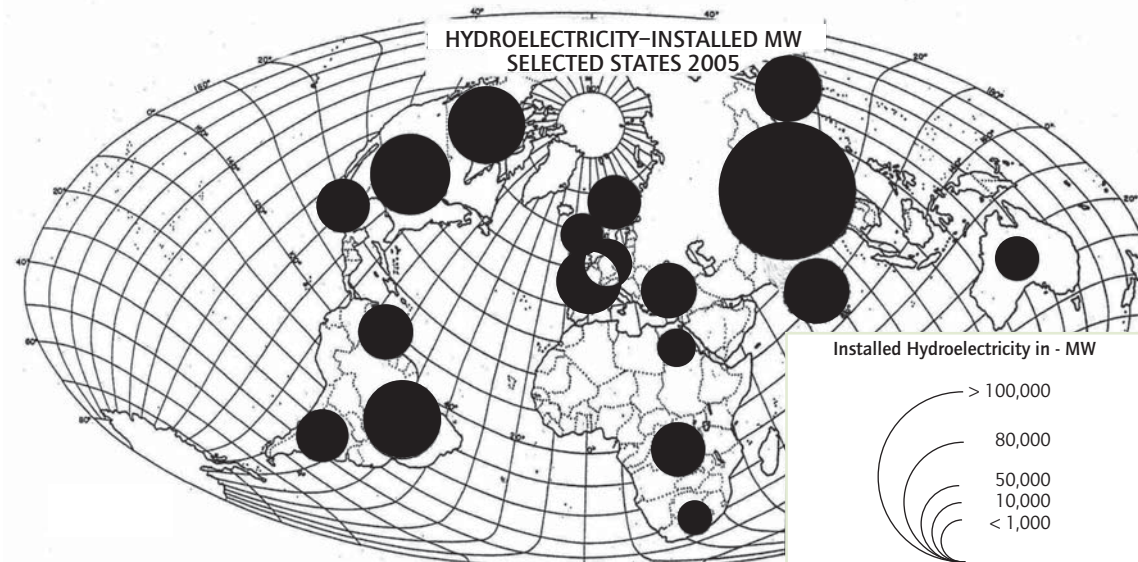


Figure 2 Hydroelectricity installed capacity (in megawatts) in selected states, 2005

Source: Adapted from United Nations. (2007). *2005 Energy statistics yearbook* (Table 32, pp. 430–461). New York: Author.



Turcurui-Tocantins Rivers, Para, Brazil

Source: Rolf Sternberg, 2005.

demand for electricity there, as well as the pressure to enlarge the electricity supply systems everywhere. A prominent hydroelectricity-dependent country is Norway, as it derives up to 98% of its electricity supply from waterpower! In the same category is Paraguay. Brazil is another hydroelectric-dependent state as 76% of its electricity needs are hydro generated. Two projects in Brazil provided 33% of all the electricity consumed in the country in 2008: (1) Turcurui (Turcurui-Tocantins Rivers image), with an installed capacity of 8,340 MW (megawatts), and (2) Itaipu (Itaipu-Binacional image), at 14,000 MW.

The diffusion of hydroelectricity coincided with the expansion of industrialization from the core manufacturing regions, namely, northwestern Europe and the northeastern United States, at the end of the 19th century. In the United States, the 1930s was an era when large mega-hydroelectric

projects revealed their long-range functionality (a megaproject has an installed generating capacity of 1,000-plus MW). The real expansion of the hydroelectric sector dates back to the 1930s and parallels the industrialization of the rest of the world. The more industrialized states succeeded in installing hydropower plants in choice locations; states entering the industrial age were at the beginning of tapping into their hydroelectric potential. Hence, the data reveal significant regional difference in hydroelectricity generation and point to notable shifts in the standard of living once electricity became available to a growing number of users.

In regional evaluation and by select time intervals, the swift acceptance of hydroelectricity in South America and Asia stands out in the total advances in installed capacity (measured in megawatts) as well as in the annual consumption rates



Itaipu-Binacional—installing the rotor system in Engine 5, 1986

Source: Rolf Sternberg, 1986.

(measured in kilowatts per hour). Table 1 provides the installed generating capacity values since 1950. Africa stands out as the world's electricity stepchild, and that condition cannot be disconnected from that continent's difficult history. While Asia recorded the largest absolute hydroelectric installation increases, in relative terms, hydroelectric power's share in total electricity generation declined as electricity demand outpaced hydropower construction schedules. Worldwide, this pattern of absolute installation values made significant gains, though the relative hydroelectric dependence declined.

Future projects for continued expansion of the hydroelectric sector will depend on long-term energy needs and planning. In the industrialized regions, increased expansion of the hydroelectric sector is predicated on the quest for maximum energy independence, minimal environmental

impact (though with notable exceptions for mega-dam projects in countries such as China, India, and Brazil), reduced greenhouse gas emissions, optimal energy conservation, and especially low cost per kilowatt of installed generating capacity and long-term project productivity.

Hydroelectricity is not anchored in the past. Hydroelectricity will register notable changes in the following decades as the potential of seawater will be tapped. The other challenge will be generating hydroelectric power without the construction of dams. These evolving changes are responses to global concerns over environmental conservation, the more intensive use of human skills, and the significantly reduced dependence on the physical resource base. These shifts in efforts and emphasis will significantly increase the energy dependence on hydropower-derived electricity. Emerging changes in the hydroelectric sector may

	1950 Total	Hydro	% Hyd.	1975 Total	Hydro	% Hyd.	1990 Total	Hydro	% Hyd.	2005 Total	Hydro	% Hyd.
World	154,092	51,360	33	1,616,073	371,089	23	2,746,127	628,429	23	4,207,766	866,846	21
Africa	3,521	485	14	31,804	9,545	30	72,742	19,332	27	109,597	23,124	21
N. America	N/A	N/A	N/A	610,267	100,006	16	926,446	160,186	17	1,269,416	184,107	14.5
S. America	5,056	2,164	42.8	44,192	25,508	70	116,809	80,375	69	191,546	123,266	64
Asia	14,912	7,584	51	227,643	58,902	26	572,942	N/A	21	1,448,332	271,435	19
Europe	83,259	27,355	33	447,522	118,447	26	678,338	171,588	25	1,127,459	244,774	22
Russia	19,614	3,218	16	217,484	40,515	17	333,100	64,100	19	233,120	45,835	20
Oceania	2,989	944	32	27,101	9,166	34	45,750	12,256	27	61,617	15,140	25
Congo	240	230	96	1,217	1,159	98	2,831	2,772	98	2,573	12,540	98.7
Egypt	N/A	N/A	N/A	3,955	2,448	62	11,738	2,745	23.4	16,961	2,745	16
South Africa	2,448	8	3	14,298	197	14	25,890	593	2.3	40,426	1,441	3.6
Canada	8,466	7,782	92	61,352	37,282	56	101,273	57,926	57	121,515	71,978	59
Mexico	1,235	607	49	11,328	4,120	36.4	29,274	7,837	26.8	51,101	10,571	20.7
USA	N/A	N/A	N/A	527,346	66,553	12.6	775,396	90,141	12	1,067,008	96,924	9
Argentina	1,680	43	2.6	9,260	1,531	16.5	17,128	6,499	38	28,185	9,852	35
Brazil	1,883	1,536	81.6	19,569	16,184	82.7	52,892	45,558	86	93,157	70,857	76
Venezuela	350	35	10	4,570	1,735	38	18,647	7,914	42	22,135	14,597	66
China	N/A	N/A	N/A	43,000	13,500	31.4	98,600	30,100	30.5	508,000	117,888	23
India	2,346	562	24	22,249	8,467	38	75,995	18,864	24.8	143,772	32,326	22.5
Japan	10,543	6,559	62	112,285	24,853	22	194,763	37,830	19	277,323	47,292	17
Turkey	420	20	5	4,187	1,780	42.5	16,316	6,765	41.5	38,843	12,906	33
France	11,862	5,272	44	46,289	17,273	37	103,410	24,747	24	116,979	25,287	21
Germany	16,555	2,317	14	86,323	6,205	7	123,160	8,944	7	125,031	8,341	6.7
Sweden	4,130	3,230	78	23,135	12,716	55	34,189	16,331	47.8	33,390	16,345	49
UK	19,083	602	3	73,923	2,451	3	73,059	4,171	5.7	81,858	4,301	5
Australia	2,171	284	13	21,111	5,570	26	36,782	7,268	19.8	50,618	9,285	18

Table 1 Installed electricity and hydroelectricity capacity data (in megawatts and percent) for the world, its regions, and selected countries

Sources: United Nations. (1984). *1982 energy statistics yearbook* (Table 36, pp. 630–647). New York: Author; United Nations. (1992). *1990 Energy statistics yearbook* (Table 32, pp. 374–399). New York: Author; United Nations. (2007). *2005 energy statistics yearbook* (Table 32, pp. 430–461). New York: Author.



converge with solving the superconductivity challenge. It is hoped that the world's oceans will provide the low-cost hydroelectricity that a clean world depends on.

Rolf Sternberg

See also **Energy Policy; Energy Resources; Renewable Resources; Rivers; Watershed Management**

Further Readings

- Boyle, G. (Ed.). (2004). *Renewable energy* (2nd ed.). New York: Oxford University Press.
- Boyle, G., Everett, B., & Ramage, J. (Eds.). (2003). *Energy systems and sustainability*. New York: Oxford University Press.
- Patterson, W. (2007). *Keeping the lights on*. London: Earthscan.
- Scheer, H. (2007). *Energy autonomy*. London: Earthscan.



HYDROLOGICAL CONNECTIVITY

Hydrological connectivity defines the spatial and temporal pattern of the links among surface or subsurface water networks flowing across a landscape, and hence, it determines the ease with which water may move across a landscape or through a river system. Hydrological connectivity is a dynamic property of the system, and its long-term integration can be expressed using probabilities whereby a point in the landscape connects with another point or with a receiving water body such as a river or a lake. The strength of the hydrological connectivity is a function of two factors: (1) the surface facilitating or impeding the movement of water and (2) the temporal structure of the rainfall or river flow time series driving the movement.

The degree to which the surface facilitates or impedes the movement of water is determined by the surface properties and their spatial structure. As water moves along a terrestrial flow path, at each point there are four options available for water movement: (1) evaporation, (2) entering depression storage, (3) infiltration, or (4) moving

along the flow path down the slope. The water may move down the slope along the surface, through the subsurface within the soil, or through a groundwater aquifer. The characteristics of the landscape and storm determine the set of probabilities that the water will move in each of these directions. For example, in many semiarid environments, there is a two-phase pattern of infiltration rates controlled by vegetation, with areas under vegetation having far greater infiltration rates. This pattern leads to short overland flow travel distances and hence hydrological disconnection. Under temperate conditions, subtle topographic hollows can cause overland flow to infiltrate and cause disconnection. Flow concentrations, in the form of rills and channels, promote efficient transmission and hence facilitate connection. Points further from the river channel have longer travel times, and hence, there is a greater probability of disconnection along the flow path. Therefore, the catchment has to be in the runoff-generating and -transmitting state for longer for the flow to connect. This relationship with the temporal characteristics of storms led Bracken and Croke to define two types of disconnection: Type 1, where the points along a flow path that are more prone to wetness become dry before the material delivered from upstream has passed through them, and Type 2, where the event is of insufficient magnitude and duration to wet the driest point along a flow path.

Indices

It is possible to describe hydrological connectivity at the landscape scale with the Network Index through the analysis of potential soil wetness and flow paths. The Network Index describes the catchment average wetness required both for a point in the landscape to be generating runoff and for there to be a continuous flow path from that point to the river channel capable of transmitting the water, and hence it describes the propensity for Type 2 disconnections. In 2006, Reckendorfer, Baranyi, Funk, and Schiemer applied a connectivity parameter based on the number of days per year that the main channel was able to flow into the adjacent wetland. In 2007, Lasne, Lek, and Laffaille used a typology based on the type and frequency of connections



between the near-channel water areas and the main channel.

Simulation

A number of hydrological simulation models are capable of tracing the flow paths taken by water through a catchment and hence are able to give insights into the dynamics and patterns of the predicted hydrological connectivity. One approach is the hydroAgent model, which is an agent-based model coupled with the CRUM-2D hydrological model. Another approach is the Lagrangian particle-tracking model, SLIM, which has been coupled with the ParFlow model of Maxwell and colleagues.

Applications

Hydrological connectivity theory is used in two key areas within the environmental sciences: (1) nonpoint source pollution risk modeling and (2) ecohydrology. It is established that for a pollutant to reach a river or lake there must be both a point-scale risk and a connection to the receiving water body to form a critical source area. This philosophy has underpinned many of the nonpoint source pollution risk tools developed. For example, the Phosphorus Index (P-Index) uses a threshold distance to the river channel to determine greater connectivity. The Sullivan County's Interactive Mapping Application (SCI-MAP) risk-modeling framework of Reaney, Lane, Heathwaite, and Dugdale, in a publication in review, uses the Network Index measure to capture a detailed representation of the hydrological connectivity. Hydrological connectivity has been applied in ecohydrology to describe the interactions between the main river channel and the adjacent, but occasionally connected, water bodies. For example, Reckendorfer and his colleagues found that the number of species followed a hump-shaped distribution with a peak at a hydrological connectivity level of 1 month per year.

S. M. Reaney

See also **GIS in Water Management; Hydrology; Network Analysis; Nonpoint Sources of Pollution; Rivers; Surface Water; Water Pollution; Watershed Management**

Further Readings

- Bracken, L. J., & Croke, J. (2007). The concept of hydrological connectivity and its contribution to understanding runoff-dominated geomorphic systems. *Hydrological Processes*, 21, 1749–1763.
- Lane, S. N., Brookes, C. J., Kirkby, M. J., & Holden, J. (2004). A network-index based version of TOPMODEL for use with high-resolution digital topographic data. *Hydrological Processes*, 18, 191–201.
- Lasne, E., Lek, S., & Laffaille, P. (2007). Patterns in fish assemblages in the Loire floodplain: The role of hydrological connectivity and implications for conservation. *Biological Conservation*, 139, 258–268.
- Maxwell, R. M., Welty, C., & Harvey, R. W. (2007). Revisiting the Cape Cod bacteria injection experiment using a stochastic modeling approach. *Environmental Science & Technology*, 41(15), 5548–5558.
- Reaney, S. M. (2008). The use of agent based modelling techniques in hydrology: Determining the spatial and temporal origin of channel flow in semi-arid catchments. *Earth Surface Processes and Landforms*, 33, 317–327.
- Reckendorfer, W., Baranyi, C., Funk, A., & Schiemer, F. (2006). Floodplain restoration by reinforcing hydrological connectivity: Expected effects on aquatic mollusc communities. *Journal of Applied Ecology*, 43, 474–484.



HYDROLOGY

Hydrology is the multidisciplinary science that seeks to understand, describe, and predict the occurrence, circulation, and distribution of water on and under the Earth's land surface, as well as the physical, chemical, and biological interactions of this water with the terrestrial environments of our planet. The science of hydrology uses the study of physical laws to determine the modes and amounts of the movement of water through the hydrologic cycle on Earth, and as such, hydrology incorporates elements of meteorology, climatology, oceanography, glaciology,



hydrogeology, and ecology in its studies. Such integration is not commonly done and requires attention to processes at work deeper in the upper crust of the Earth, including volcanic activity. Understanding the waters of the Earth and assessing the locations, interactions, amounts, and changes in the water masses of the planet require a discussion of the deep tectonic water cycle; the shallow-surface hydrologic cycle, in which water cycles between liquid, vapor, and solid states; and the hydrological accounting systems used to track the volume of water. After reviewing these concepts, this entry considers the threat posed by global water scarcity and the growing importance of hydrology in understanding and responding to it, especially in light of the human impacts on water availability. It concludes with a brief look at the challenges posted by water law in North America.

Tectonic Water Cycle

In terms of a rough calculation of the total water of the Earth, the surface of the planet is considered to have one ocean mass (1 OM). Earth originally had about 4.2 OM locked up inside it when it first accreted from space about 4.5 billion yrs. (years) ago. The 1 OM now on the surface had escaped since accretion to form the modern oceans, leaving about 0.2 OM behind in the upper mantle. The lower mantle still has about 3 OM locked up inside it. The molten core of the Earth beneath has no water at all in it. The tectonic water cycle has water constantly escaping from inside the Earth through volcanic eruptions on land and beneath the sea. In fact, more than 50% of all volcanic gas comes out as steam in new or juvenile water, to be added to the surface supplies. Some water is also returned to the interior of the Earth as it goes down subduction zones or is absorbed directly into the undersea floor.

Yearly fluxes of water through the Earth's upper crust include (1) shallow hydrologic flow on the continents, amounting to about 37,400 km³ (cubic kilometers) per year, and (2) free hydrostatic water movement to depths of possibly as much as 15 km in sedimentary basins on continents, where the sediments compact and

emit water like a sponge under their own weight at compactive water expulsion rates of ~3 km³/yr. Beneath the oceans, in the seafloor plates to depths of ~5 to 7 km, there is total flank convection or free convection of water at rates of >240 km³/yr. Close to the volcanic rift zones in the oceans, forced convection of water in the rocks of the sea bottom amounts to ~40 km³/yr.

Surface Hydrologic Cycle

The hydrologic cycle at the uppermost surface of Earth is a continuous and cyclic process by which water is evaporated from the oceans and blown as vapor and clouds over landmasses, where uplifting and cooling of the air masses causes further condensation and precipitation. The resulting precipitation is stored as snow and ice at high altitudes and high latitudes in snowfields and glaciers, runs off as overland flow in rivers, or goes into underground flow and groundwater storage. Some underground water flows back out through porous and permeable stream banks and into stream channels as base flow. Other stream water and groundwater goes into lakes and then evaporates back into the atmosphere or goes into plant roots and is transpired as vapor into the atmosphere as well. The hydrological cycle is powered by solar energy, the rotation of Earth, and the gravitational attraction of the planet. It is modulated by winds and the latent heat absorbed in evaporation and released in condensation.

The analysis of movements of water in the hydrosphere of Earth is fundamental, so an accounting of all the inputs and outputs in any particular place, or for the whole world, requires various water balance equations. Fundamentally, the water balance equation relates precipitation (P) to the runoff or river discharge (Q), the evapotranspiration (ET), and any changes in storage (S), thus $P = Q + ET \pm S$.

The water balance can also be calculated to incorporate the atmosphere so that the water vapor flux into and out of the system can be included. The surficial or subsurface soil moisture and groundwater storages can also be calculated to enable better predictions for agriculture. Water balance relations in any area exert profound control on human land use possibilities.



The hydrological cycle of a catchment or drainage basin consists of one major input, six kinds of storages, seven transfer processes, and three outputs. Collectively, these inputs, storages, transfers, and outputs constitute a convenient analysis method of the hydrologic system of the world, which enables more precise determinations of a vital resource. The major input in the hydrologic system is, of course, precipitation in the form of rain, snow, sleet, hail, drizzle, and fog. Precipitation intensity and volume, coupled with atmospheric temperatures that affect the solid precipitation by keeping it solid or melting it, control the output from a drainage basin. The storages in a catchment include interception, vegetation, surface basins, and channel locations above the ground surface and soil moisture and groundwater below. Water that is intercepted is held in leaves, branches, and stems or inside the cells of the vegetation, where it was obtained from the soil moisture. The three types of soil moisture are (1) *hygroscopic water*, which is held tightly at the molecular level around soil particles so that it is unavailable to plants; (2) *capillary water*, which moves upward in fine threads in the vadose zone of aeration from the water table; and (3) *gravitational water*, which drains slowly downward to replenish the groundwater in the zone of saturation beneath the water table.

Water transfers through the hydrological cycle include the above-ground throughfall and stemflow, surface runoff, and channel flow; the infiltration movement into the ground; and the below-ground percolation, throughflow, and groundwater flow. *Throughfall* occurs from leaves, and stemflow of water runs down tree trunks after it has been intercepted from atmospheric precipitation. Surface runoff or overland flow produces the rivers of the world. Infiltration of water into the soil is controlled by the nature and properties of the soil, as its grain size, compaction, porosity, and permeability facilitate or impede water transmission. Percolation downward and throughflow laterally, occur through the interconnected pore spaces and small cracks and joints in the soil and rock of the vadose zone or the zone of aeration above the water table. Below the water table, where all openings are saturated with water in the unconfined water zone, or even deeper in the confined or artesian

water zones underground, groundwater flow occurs in all directions as a result of pressure differentials. Catchment outputs are then the evaporation of surface water bodies, transpiration through the stomata pores on leaves, and the runoff of rivers.

Hydrological Accounting Systems

Because of the ever-increasing need to keep track of the amount of water available for use by humans, most developed countries have hydrological accounting systems that make good estimates of water volume and percentages in all its forms and places. This process necessitates the acquiring and public maintenance of things such as the following:

- Streamflow records
- Precipitation records
- Topographic maps
- Groundwater data
- Evaporation and transpiration data
- Data on the quality of the supply

Thus, the many portions of the hydrological cycle of Earth can be measured and simulated on ever-finer spatial and temporal scales. Robust models of each hydrological subprocess have been developed, with the result that the current and future status of the global water system are fairly well understood and predictable. The social aspects of water use are not easily available, however, and are therefore less predictable. Nonetheless, warnings of decreased water availability in the future are likely, in part because of increased population as well as the uncertainties associated with global climate change.

World Hydrological Accounting

In the accounting system that has been developed in the past four decades since the International Hydrological Decade of the late 1960s, we can see that of the total evaporation on Earth, about 85%, or $\sim 428,000 \text{ km}^3/\text{yr.}$, is from the sea and another 15%, or $\sim 67,000 \text{ km}^3/\text{yr.}$, from the land, which also includes transpiration from plants. The total precipitation over the land is about 25%, or $110,500 \text{ km}^3/\text{yr.}$, whereas over the sea, it



is about 75%, or $\sim 384,000 \text{ km}^3/\text{yr}$. The total storage of water in the rivers of the world is only $\sim 2000 \text{ km}^3$, and in lakes it is $\sim 175,000 \text{ km}^3$. About 8% returns to the sea as runoff and groundwater, with perhaps $\sim 40,700 \text{ km}^3/\text{yr}$ going in through rivers, although if the groundwater discharge that goes into the rivers as base flow were included, then the rivers' discharge would be something more like $\sim 45,500 \text{ km}^3/\text{yr}$.

If we consider the total water mass at the surface of the Earth, some $1,338 \times 10^6 \text{ km}^3$, or about 97%, is in the ocean, while 2.5% is freshwater. Now, if we take that 2.5% as 100% of the freshwater potentially available to humans, we find that about 78% is surface water, with the remaining 22% being groundwater ($\sim 23,400 \times 10^3 \text{ km}^3$). This underground water is divided up as 0.18% ($17 \times 10^3 \text{ km}^3$) soil moisture, much of which is available for plants; 11% shallow groundwater; and 11% deep groundwater. That most essential 78% of the water on the surface is then considered as 100%, with the large quantity presently stored in ice and glaciers at 99%, or some $25,500 \times 10^3 \text{ km}^3$, whereas freshwater lakes have only 0.33%, saline lakes 0.28%, and rivers and streams 0.003%, with the total in the atmosphere at any one time at about 0.03%. Clearly, surface water supplies on the continents are extremely limited, and as climate change takes place, some places may have even less supply than they do now. That is why many scientists regard the 21st century as the most likely time of maximum water conflict between nation-states.

In 1993, the United States withdrew a total of an estimated 1,283.3 billion L (liters) (339 billion gal. [gallons]) of so-called blue water per day from lakes, streams, and underground sources. By 2000, this amount was up to 1,554.5 billion L (408 billion gal.) of water a day, but that is not a lot compared with the much higher rate of increase from 1950 to 1980. In fact, after 1980, water conservation methods had improved enough to cause a flattening out of the rate in the United States. Evapotranspiration from nonirrigated cropland in the world is referred to as "green" water, and it is estimated to be $\sim 7,600 \text{ km}^3/\text{yr}$ from cropland and $\sim 14,400 \text{ km}^3/\text{yr}$ from permanent grazing land. This is about one third of the total terrestrial evapotranspiration. At the present time, only about 10% of maximum available blue water and

30% of green water resources are used in the world. This might appear to offer an opportunity for further development of these hydrological resources, but in fact, the high variability of water resource availability in time and space, in spite of artificial storage at $\sim 7200 \text{ km}^3$, precludes additional availability.

The predictions of global water scarcity in this century as populations increase and climate changes have led to the recognition of the need for worldwide monitoring and new methods to monitor international impacts. Thus, to assess global water access, a water scarcity index has been proposed: $R_{ws} = (W - S)/Q$, where W is the annual water withdrawal from all sectors, S is the water availability from desalinated water (miniscule in most cases), and Q is the annual renewable freshwater resources. Any region with an R_{ws} beyond 0.4 is considered highly water stressed. Moderate water stresses range from 0.2 to <0.4 ; low water stress is from 0.1 to <0.2 , and areas with no water stress are <0.1 . Water scarcity thus can be easily designated as severe in the well-populated Midwest and much of the intermontane west of the United States, as well as in the heavily populated basins of the Yellow River, Indus, Ganges, and Amu Darya in Asia. This latter point is significant because although the amount of available water in Asia is large, as it originates from the great "water towers" of the Himalayas, the populations and the agricultural irrigation demands are equally large, so that the water stress ratio is the highest among the continents. Nearly 2.4 billion people are currently living in these highly water-stressed areas.

Because of the huge human impacts on hydrological processes, it does not make sense to study only natural hydrological cycles. Accordingly, the impacts of human interventions on the water cycles are increasingly being studied to simulate more realistic analysis of hydrology on a global scale. To do this, some accounting must be made of domestic water extracted and returned to river flow by humans, as well as irrigation water and that sent to industry and then returned to the rivers. Such use of the water resources by humans results in the addition of a great variety of contaminants far beyond the natural additions of salts or other materials that preclude normal use by humans. Degradation of water



quality is to be expected in the anthropogenically modulated or controlled environments in which most humans live. The increase in contamination of freshwater systems worldwide by thousands of industrial and natural chemical compounds is a key environmental problem facing humanity. With a total global runoff of about 40,700 km³/yr., only about 12,500 km³/yr. is actually accessible, although only about a third of it is used. Total water withdrawals are ~4,430 km³/yr., with ~2,880 km³/yr. going to agriculture, ~975 km³/yr. going to industry, and ~300 km³/yr. going to municipalities. In the course of these withdrawals and returns, the fluxes of macropollutants are truly staggering: Total inorganic nitrogen (~75% anthropogenic) is 21×10^6 tons/yr., total phosphorus is $\sim 5.6 \times 10^6$ tons/yr., and heavy metals (zinc [Zn], chromium [Cr], nickel [Ni], lead [Pb], copper [Cu], cadmium [Cd], and mercury [Hg]) amount to $0.3\text{--}1 \times 10^6$ tons/yr. Examples of ubiquitous water pollutants include solvents, petrochemicals, lubricants, flame retardants, detergents, pharmaceuticals, hormones, pesticides, biocides, cyanotoxins, disinfection by-products, as well as metabolites or reactive products from all these.

Future Water Shortages

The science of hydrology that is practiced in most countries considers surface freshwater supplies first and foremost in terms of location, flow and flood characteristics, and other aspects of water in the immediate human environment. Next comes attention to soil moisture for crops and then deeper forms of groundwater, whether it is the unconfined, or water table, water or the deeper confined or artesian aquifers, where water is commonly under some pressure. Further afield from most human environments, the large storage of snow and ice is certainly worthy of notice, especially because in the world of climate change toward which we are heading, the likely melting of so much ice will perhaps help a little in some places. New lands and resources would be opened up in some areas, while other lands will be inundated by the sea as its levels rise. The prospect of disruption of the hydrological cycle, which was considered to

have been explained both qualitatively and quantitatively in the late 20th century, now seems quite possible. The human race and its historic, prehistoric, archaeological, and evolutionary precursors have always been at the mercy of slow and rapid climate change, even if it went unrecognized due to ignorance or was denied because of the wishful thinking that “it won’t happen to us.”

The increasing importance of hydrology has been obvious for much of the past half-century as increasingly detailed information on the availability and use of surface and underground water supplies became available. In the early days of the settlement of North America by humans from Asia and later from Europe, Africa, and Latin America, there were always plentiful supplies of reasonably clean and potable water. That is no longer true. In the course of development of the continent, tiny and mammoth dams were built willy-nilly, first to produce power, later for irrigation supplies, and still later as flood control devices. The problem with this multiple use was apparent, however, because dams need to be empty for flood control and full for irrigation and power production; careful meteorological and hydrological record keeping was seen as the best means to enable statistically precise predictions of floods and droughts so that dams could be managed most effectively. A problem with this approach occurs when the climate changes, since past hydrological records do not enable very accurate prediction of the future.

In the wetter regions of Eastern North America, the need for agricultural, urban, and commercial lands since the early European settlement had led to the draining and filling of wetlands such as swamps, bogs, and coastal marshes because for centuries they had been regarded as wastelands. Only in the latter half of the 20th century did their environmental value as important pollution-filtering screens and shoreline protection habitats become obvious. Thus, the relationship of water to land in North America has long been one of damming, pumping, draining, and diverting water to reinvent the landscapes. Swamplands and wetlands have become fields and farms, arid lands have bloomed, and cities have thrived far from water supplies. The 100th meridian splits the continent



into two regions: the wet east, with more than 50 cm (centimeters) of precipitation a year, and the arid west, most of which has less than 50 cm of precipitation per year. The results for more than a century and a half have been the development of extensive irrigation networks in the American West. Without irrigation, these lands would not grow crops, but with it, the soils can become waterlogged and saline so that plants will not survive. There is always a small amount of salinity in irrigation water, and because plant roots absorb the water but leave the salts behind, the salts can only increase unless they are flushed out through expensive soil desalinization schemes involving sheet flooding and expensively engineered soil drainage schemes.

Water Law

A major problem with hydrologic analysis and use of water in North America, however, is that water law was developed several centuries ago and has maintained its hold on legal use whether or not it makes sense in the modern world. Certainly, the rights of prior appropriation of surface water supplies, or “first in time, first in right,” or the nonsensical divorcing of surface water appropriation from underground water appropriation has led to litigation between states; both indicate that new legislation has been required for many years. A further problem in the fair sharing of water between states is that the pumping of water near state boundaries has also resulted in cross-border movement of underground water with no real legal resolution to date. Revisions of water

law in North America are likely to be a major issue in future years.

John F. Shroder

See also **GIS in Water Management; Groundwater; Hydroelectric Power; Hydrological Connectivity; International Watershed Management; Oceanic Circulation; Oceans; Precipitation, Global; Precipitation Formation; Rivers; Surface Water; Urban Water Supply; Water Degradation; Water Management and Treatment; Water Needs; Watershed Management; Watershed Yield**

Further Readings

- Davie, T. (2008). *Fundamentals of hydrology*. New York: Routledge.
- Dooge, J. C. I., & O’Kane, P. (2003). *Deterministic methods in systems hydrology*. London: Taylor & Francis.
- Knapp, B. J. (2007). *Elements of geographical hydrology*. London: Taylor & Francis. (Original work published 1979)
- Maidment, D. R. (1993). *Handbook of hydrology*. New York: McGraw-Hill.
- Wilhite, D. A. (2005). *Drought and water crises: Science, technology, and management issues*. London: Routledge.



HYDROTHERMAL ENERGY

See Geothermal Energy



IBN BATTUTA **(AD 1304–1368)**

Ibn Battuta was the greatest medieval traveler and author of an extensive travel account. His full recorded name reflects his North African origin: Shams al-Din Abu 'Abdallah Muhammad ibn 'Abdallah al-Lawati al-Tanji. He was born in Tangier to a family of Islamic jurists and ended his days as a judge (*qadi*) in rural Morocco.

The story of his travels, which took place between 1325 and 1355, was dictated in Fez to the young court writer Ibn Juzayy (1321–1356) on the orders of the Marinid Sultan of Morocco Abu 'Inan. Ibn Battuta traveled routes extending 3 times those of Marco Polo, but he mostly stayed within the countries under Muslim rule. He was not a learned geographer and made no claims to academic learning, but he was a keen observer of people, places, local cultures, and elites, and his narrative provides rich, vivid, and usually reliable information about the places visited, individuals encountered, and stories heard.

His odyssey started in 1325 with a pilgrimage to Mecca; however, he soon developed a passion for travel and sought new destinations and new routes. At the time of his journeys, Islam was undergoing a massive expansion in South Asia, sub-Saharan Africa, and parts of Eurasia. Ibn Battuta's account, usually simply called *The Rihla* (Travels), offers unique glimpses into the process of expansion of the frontiers of the *Dar al-Islam*

(Abode of Islam) in the mid 14th century. The full title of this book, an important and original example of the *rihla* genre of Arabic travel literature, is *Tuhfat al-nuzzar fi ghara'ib al-amsar wa 'aja'ib al-asfar* (A Gift to Those Who Contemplate the Wonders of Cities and the Marvels of Travels).

The chronology of Ibn Battuta's travels is not always clear; after completing his first pilgrimage, he continued to travel, mostly in Asia, spending many years in India and visiting Sri Lanka, Indonesia, and China before deciding in 1349 to return to Morocco. This was about the time of the Black Death epidemic, which carried away his mother and eventually himself. On state missions and on his own initiative, he then traveled again (in 1350 to Spain and in 1351–1355 to West Africa). By contemporary count, Ibn Battuta visited the equivalent of 44 countries. Staying either within the territories governed by the Muslim rulers or among the Muslim communities abroad in non-Islamic states, he pursued the company of religious teachers, pious sheikhs, and legists and gained most of his employment and patronage as a raconteur and an expert in the Maliki school of law, common in North Africa. He had an interest in mysticism and miracles and periodically returned to Mecca for repeat pilgrimages (sometimes to escape court intrigue and persecution).

Travel was fraught with danger, and Ibn Battuta suffered the hardships of weather, discomfort, shipwreck, piracy, and robbery. He was an unusually self-aware traveler, inquiring about



itineraries, transport, seasons, and schedules. Early on, he decided never to travel by the same road twice if he could help it and so observed the terrain, economy, and population from diverse routes. He traveled by camel, horse, mule, litter, wagon, and boat and never failed to describe the mode of transportation for himself, his companions, and his hosts. His encounters with queens and princesses provided occasional patronage and protection; he married and divorced the daughters of his learned friends and colleagues, or female relatives of patrons in the service. Such women often declined to accompany him on his journeys, and he resorted to the company of slave girls, purchased or presented to him. A devout Muslim who benefited from the expansionist jihad against non-Muslims, Ibn Battuta admired the piety and learning of some Muslim women (in Mecca and in India) and openly deplored others' free socialization with men (in Africa) or refusal to cover up (in India and Africa). He was impressed with the high status of women among the Turks and Mongols and distressed by the Hindu custom of widow self-immolation (*suttee* or *sati*).

Ibn Battuta's stories of faraway places and remarkable phenomena were received with some skepticism by his contemporaries, including the great historian and philosopher Ibn Khaldūn (1331–1406), who met him in person. His book had limited circulation, mostly in North Africa in abridged versions, and did not become well-known until the 19th century. In 2004, Ibn Battuta's 700th anniversary was celebrated throughout the Arab world; a large shopping mall in Dubai (UAE) bears his name, plays have been written about him, and multiple Web sites recount his travels on the Internet.

Marina A. Tolmacheva

See also al-Idrisi; Human Geography, History of; Ibn Khaldūn; Travel Writing, Geography and

Further Readings

Dunn, R. (1986). *The adventures of Ibn Battuta: A Muslim traveler of the 14th century*. Berkeley: University of California Press.

Euben, R. (2006). *Journeys to the other shore: Muslim and Western travelers in search of knowledge*. Princeton, NJ: Princeton University Press.

Hamdun, S., & King, N. (1975). *Ibn Battuta in black Africa*. Princeton, NJ: Markus Wiener. (New expanded edition, New York: Markus Wiener, 2004)

Ibn Battuta. (1958–2000). *Travels of Ibn Battuta A.D. 1325–1354* (H. Gibb, Trans.; 5 vols.). Cambridge, UK: Hakluyt Society.

Tolmacheva, M. (1993). Ibn Battuta on women's travel in the Dar al-Islam. In F. Bonnie & S. McLeod (Eds.), *Women and the journey: The female travel experience* (pp. 119–140). Pullman: Washington State University Press.



IBN KHALDŪN (AD 1331–1406)

Ibn Khaldūn al Hadrami was a great Arab historian and philosopher of history and social sciences. Compared in the West to Thucydides and Machiavelli, he developed a theory of world history embedded in sociology, social psychology, demography, and cultural ecology. He was also active in politics and the practice and teaching of law.

We know of his life from contemporary records and from his autobiography *Kitab al-ta'rif bi-Ibn Khaldum wa rihlatuhu gharban was sharqan* (Information About Ibn Khaldūn and His Travels West and East). He was born in Tunis to an upper-class family that fled Andalusia after the fall of Seville to the Reconquista and had served the Hafsid dynasty, but he withdrew from politics into mysticism. Both his parents died in the plague epidemic in 1349. In adult life, Ibn Khaldūn sometimes withdrew from competition for prestigious appointments to pursue contemplative religious or scholarly life. The unstable North African politics is reflected in his political alliances with rulers and courtiers, shifting loyalties, and occasional imprisonments. About 1352, he moved from Tunis to Fez and served the Marinid Sultan Abu Inan Faris. Changes of fortune after the latter's death in 1358 made him seek success in



Granada, but he was driven out by intrigue and returned to North Africa. After moving from the Hafsid court at Bougie to Tlemcen and again to Fez, Ibn Khaldūn sought refuge with the Berbers in Qal'at Ibn Salama (1375–1378). That is where he wrote the *Muqaddima*, or Introduction (often translated “Prolegomena”) to his world history. He then returned to Tunis and continued writing, now in the service of Abu 'l-Abbas, the former ruler of Tlemcen who had conquered Tunis. His loyalty under suspicion, he left in 1382 under the pretext of performing the hajj, or pilgrimage to Mecca.

After reaching Alexandria, he went to Cairo, where the Mamluk sultan Barquq soon appointed him a grand *Qadi* (supreme judge) of the Maliki school of religious law, common in North Africa. This was the start of a new period and a new career for Ibn Khaldūn. He resigned the judgeship or was dismissed five times, received teaching appointments and diplomatic missions, and continued research to amplify his oeuvre, *Kitab al-Ibar*. The full title translates as “The Explanation and Records of the Early History and Political Events Concerning the Arabs, Persians (non-Arabs), and Berbers, and the Supreme Rulers Who Were Contemporary With Them.” The Introduction and First Book became known independently as the *Muqaddima* in Ibn Khaldūn's lifetime. Books 2 through 5 are a history of the Arabs, Persians, Jews, Greeks, Romans, and Berbers. Book 6 deals with the theory of knowledge and the relationship between science and civilization as an outcome of social organization. There is no full translation of the complete work. The *Muqaddima* is available in the three-volume English translation by Franz Rosenthal and in an abridged paperback edition.

In 1401, Ibn Khaldūn was recruited by the new Sultan Faraj to accompany him to Damascus, then besieged by Timur (Tamerlane). From the walls of the city, he was lowered to meet Timur and spent several weeks in his camp, where he was invited to speak of history, the Abbasid caliphs, the Maghrib, and Ibn Khaldūn's personal and family history. He also negotiated release for himself and his escort, but Damascus was surrendered and sacked. Back in Egypt, Ibn Khaldūn twice regained the Maliki judgeship and died in Cairo while in office.

Ibn Khaldūn pioneered the critical study of history with an emphasis on reason and empiricism. He is also often called the founder of sociology, political science, demography, and even economics. Because his theory of civilization (*'umran*) is focused on the urban environment as the cradle of culture, as opposed to the tribal and nomadic lifestyle, he is also viewed as an environmental historian. Ibn Khaldūn's interpretation of human history is centered on the theory of cyclical progress—the rise and fall of dynasties originating from nomadic societies that build empires and settle in cities. The rise of political dynasties depends on the sense of tribal cohesion, or *'asabiya*. The nomads are rough and savage but hardy and frugal; they are freedom loving, upright, and self-reliant and make excellent fighters. Towns are the seats of crafts and culture, and luxury corrupts the people and undermines their solidarity. Rising expenditures require higher taxes, which discourage production and reduce revenue. The rulers are separated from the people who originally brought them to power, and decline sets in within three generations. In their weakened state, they are conquered by another group held together by *'asabiya*, which may be reinforced by religion. The conquerors inevitably wish to emulate the conquered, they are seduced by luxury and the lure of royal power; the state weakens, the population decreases, the group relationship deteriorates, and decay sets in.

Ibn Khaldūn consciously combines an objective and empirical methodology of historiography with the analysis of psychological and environmental factors in the development of social and political organization. He draws extensively on his personal knowledge of the Berber tribes, their habitat, and their history. For a geographical setting of his world history, Ibn Khaldūn draws significantly from the introductory sections of the *Nuzhat al-mushtaq*, an outstanding universal geography by the 12th-century North African geographer al-Idrisi. Some manuscripts of the *Muqaddima* are illustrated with the round world map copied from al-Idrisi's *Geography*.

Marina A. Tolmacheva

See also [al-Idrisi](#); [Ibn-Battuta](#)



Further Readings

- Ahmad, Z. (2003). *The epistemology of Ibn Khaldun*. London: Routledge.
- Azmeh, A. (1981). *Ibn Khaldun in modern scholarship: A study in Orientalism*. London: Third World Centre.
- Baali, F. (1988). *Society, state, and urbanism: Ibn Khaldun's sociological thought*. Albany: State University of New York Press.
- Ibn Khaldūn. (2004). *The Muqaddimah: An introduction to history* (New abridged ed., N. J. Dawood, Trans., with Introductions by B. Lawrence & F. Rosenthal). Princeton, NJ: Princeton University Press.
- Ibn Khaldūn on the Web: http://historymedren.about.com/od/ibnkhaldun/Ibn_Khaldun_on_the_Web.htm
- Lacoste, Y. (1997). *Ibn Khaldun: The birth of history and the past of the Third World* (D. Macy, Trans.). London: Verso.



ICE

In the 50 yrs. (years) between the third (1957–1959) and fourth International Polar Year (2007–2009), our understanding of the ice, as a material substance and geomorphic agent, has been transformed. Considered a robust frigid material in the 1950s, the ice was something to be endured, conquered, and studied. As prolonged scientific inquiry and research programs in ice-based places increased during the 1950s, our understandings of these complex material geographies significantly increased, as did the sciences of glaciology, seismology, and ice sheet dynamics. Poised on a delicate, irreversible climatic threshold, the ice is now a key indicator of environmental change and its consequences for human societies, from the glacial meltwaters of the Himalayas to the inhabited Arctic.

We live on a planet whose landscape surfaces are predominately shaped by the geomorphic action of ice, particularly that of glaciers and ice sheets. Scientists collectively refer to this ice-based environment as the cryosphere (Figure 1). Derived

from the Greek word *kryo* for “cold” or “too cold,” it is the term that describes collectively the portions of the Earth’s surface where water is in a solid form, including ice caps, snow, sea ice, ice shelves, ice sheets, glaciers, and permafrost. The cryosphere takes many forms. Topographically, these range from the high places of mountaintops and glacial cirques to the sea ice of the high Arctic and the quaternary ice sheets of Greenland and Antarctica. The cryosphere is now understood as an integral part of the global climate system, with important linkages and feedbacks to the stability of global climate and responses to anthropogenic-induced climate change. Warming of the major ice regions of the Arctic and Antarctic will cause vast quantities of water to be released and will affect sea-level rise and ocean current circulations.

The cryosphere is also an integral part of the weather imaginaries and a media icon of climate change. As a site of visually dramatic weather events and looming environmental catastrophe, ice-based environments have moved from the peripheries of the Western geographic imagination to the center of debates on climate change; satellite maps of ozone holes over the poles, melting Siberian permafrost, the “opening” of the Northwest Passage, the impact of melting glaciers on water supplies, ice sheet collapse, and future sea-level rise are part of the visual lexicon of climate change. Far from the historical aesthetic of “icy spaces” as sites of vigorously demanding exploration and robust masculinities, the ice is now imaged and imagined as a vulnerable materiality that exhibits the effects of climate change.

Retreating Ice

The rates of temperature change in the Arctic are double the rate of change of the Earth as a whole, and this has had a dramatic effect on icescapes and the lives of indigenous peoples in the circumpolar North. Evidence of this can be found in the rapid decrease in sea ice, shorter winter seasons, decrease in the age of sea ice, thinning of the Greenland ice sheet, melting of Siberian permafrost, and retreat of glaciers in all areas of the Arctic. The most dramatic event in recent years has been the opening of the fabled Northwest Passage in September 2007 to shipping for the first time in 8,900 yrs. Arctic warming and the

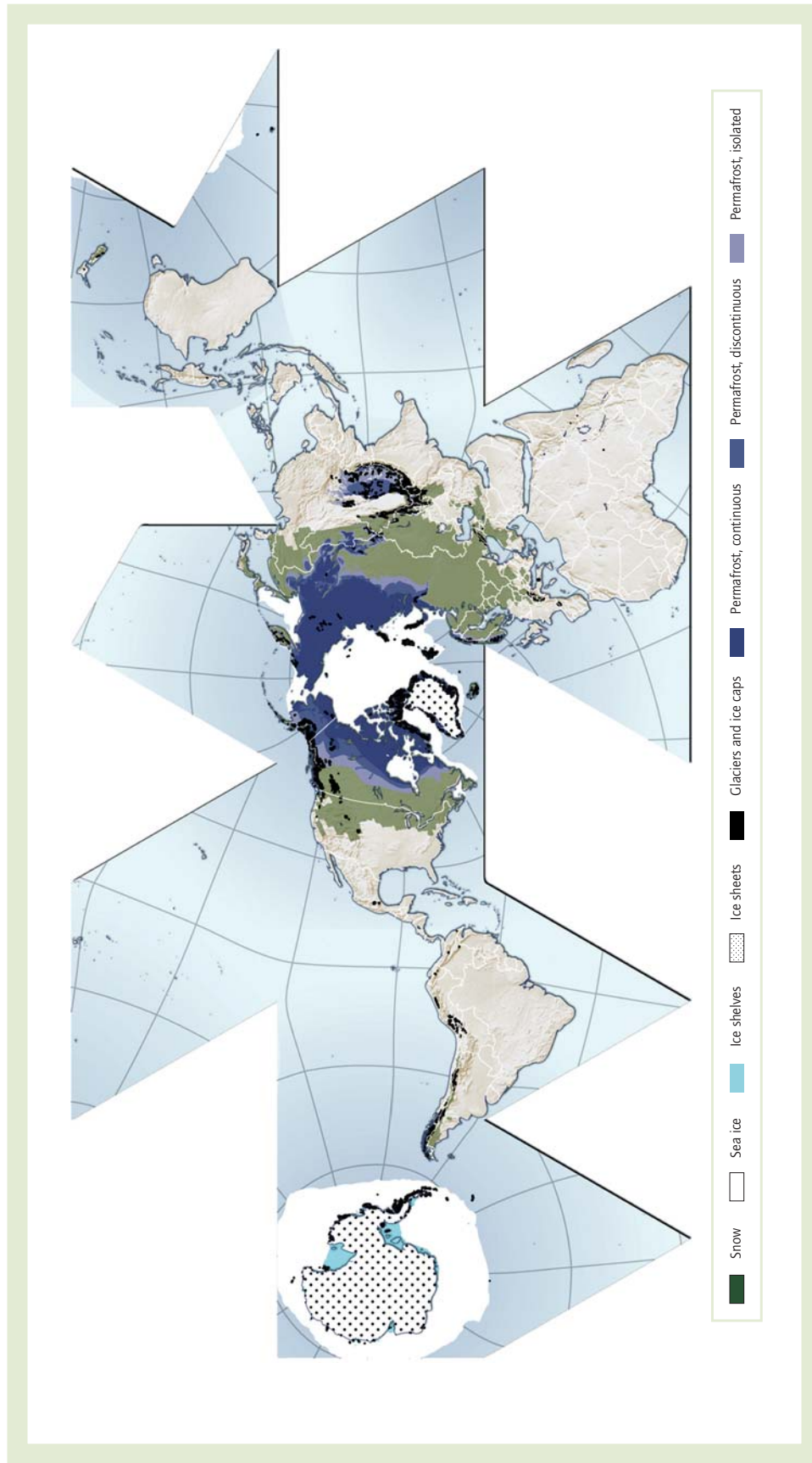
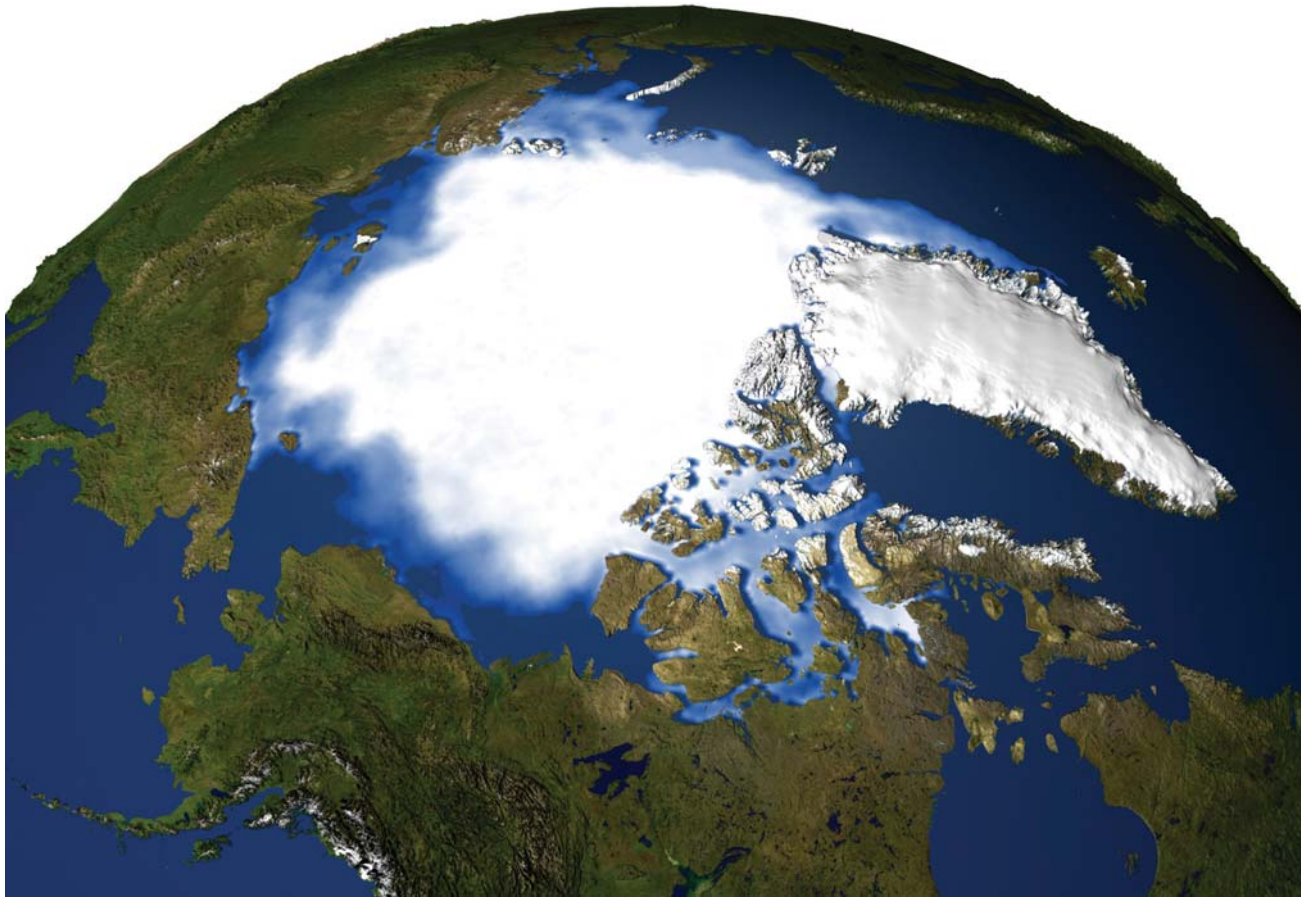


Figure 1 The cryosphere, world map

Source: Hugo Ahlenius, Cartographer & Designer. (2007, June). In *UNEP/GRID-Arendal maps and graphics library*. Retrieved May 25, 2010, from <http://maps.grida.no/go/graphic/the-cryosphere-world-map>.



Sea ice minimum 1979 to 1981. Satellites have made continual observations of Arctic sea ice extent since 1978, recording a general decline throughout that period.

Source: NASA.

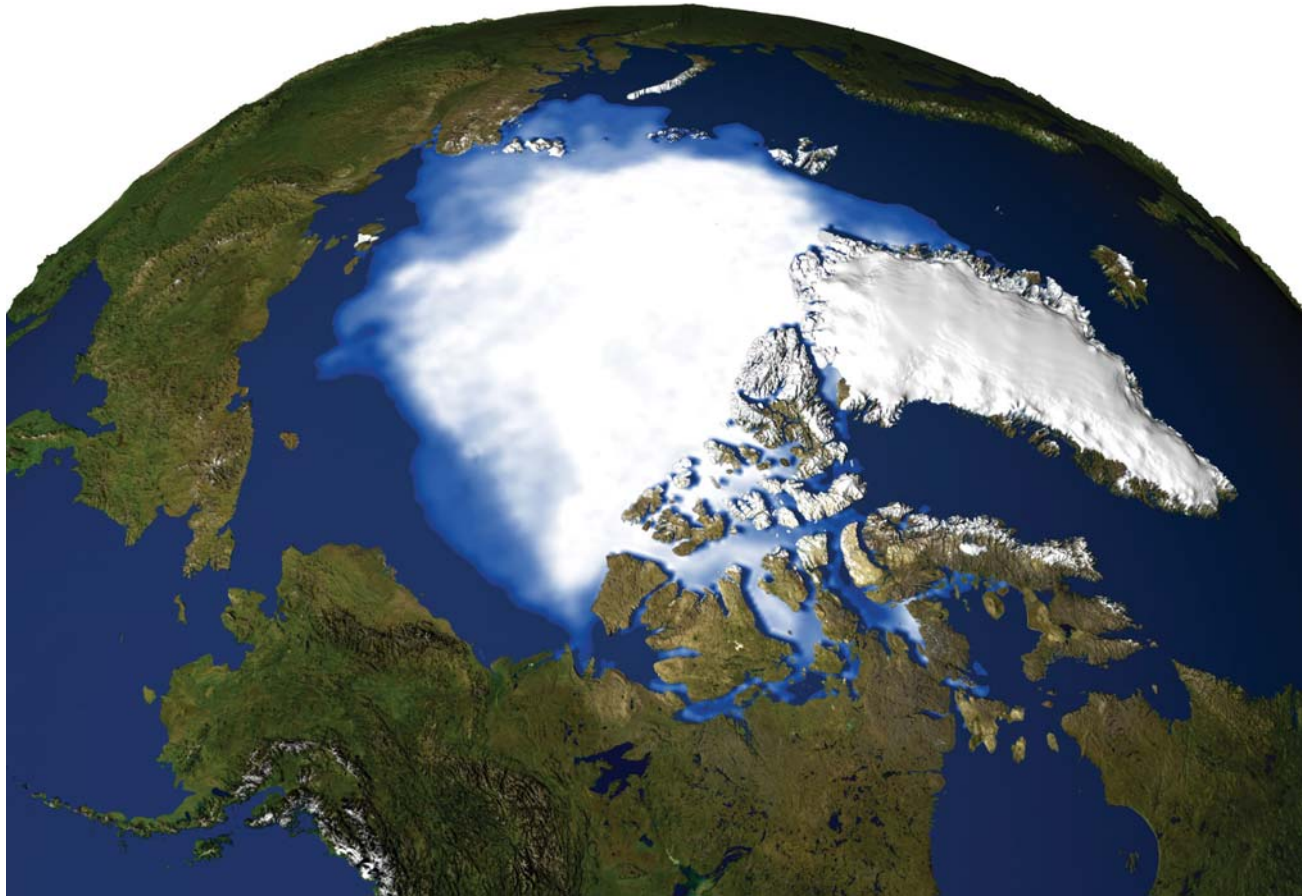
subsequent ice retreat are caused by increased concentrations of greenhouse gases as well as other anthropogenic pollutants such as methane, tropospheric ozone, and black carbon. This rapid change in ice conditions is altering the ecosystems throughout the circumpolar North and causing increased stress on human and nonhuman inhabitants. Worryingly, the retreat of ice in the Arctic increases the likelihood of more development and resource extraction in the Arctic, thus increasing fossil fuel emissions.

Modeling the Ice

While there are many unanswered questions about the effects of warming on the ice, the material archives of the ice have revolutionized our view of the Earth and our understanding of

climate change. Ice cores retrieved from the ice sheets of Greenland and Antarctica have helped scientists correlate important data for future climate prediction based on the past records of atmospheric changes that are recorded in tiny trapped bubbles of air entombed in the ice over the past 800,000 yrs. The most startling discovery has been that climate change is not a process of slow, gradual change but climate is nonlinear—it flickers and spikes: Abrupt events can occur over months and years, not hundreds and thousands of years as scientists previously thought. This knowledge of abrupt climate change has profound implications for the rate of human adaptation and the resilience of communities when facing sudden rapid change.

The other major technology of ice is the Earth-observing satellites that monitor and provide data



Sea ice minimum 2003 to 2005. Since 2002, satellite records have revealed unusually early onsets of springtime melting in the areas north of Alaska and Siberia. In addition, the 2004–2005 winter season showed a smaller recovery of sea ice extent than any previous winter in the satellite record, and the earliest onset of melt throughout the Arctic.

Source: NASA.

on the major ice sheets and sea ice. What these satellite images tell us is that both sea ice and ice sheets are changing much faster than was appreciated by scientists in their computer modeling of the ice. Today ice sheets can be monitored through unprecedented temporal and spatial scales. This has prompted scientists to rethink the ice sheet timescales, and rather than presuming that the large ice sheets of Greenland and West Antarctica would not react as quickly as glaciers to temperature changes, satellite data are indicating large-scale changes in the ice, alongside the rapid retreat of smaller glaciers around the world (Figure 2). These major questions about the rate of change in large-scale ice sheets, as recently highlighted by the Intergovernmental Panel on Climate Change,

highlight uncertainty about sea-level rises and the future stability of the large ice sheets.

While scientists grapple with questions in the laboratory of ice, glacial retreat and the failure of nonpolar glaciers have far-reaching consequences for societies that live in ice regions, or depend on glacial melt for water supplies, and the ecosystems that this glacial melt supports. In recent years, the changing environmental conditions of the Arctic have given rise to several new challenges to governance by circumpolar peoples, most notably the petition by the Nobel Prize nominee Sheila Watt-Cloutier to the U.S. government for the “Right to Be Cold.” As scientists attempt to understand the complex interdependencies between ice, temperature, and fossil fuel consumption in changing

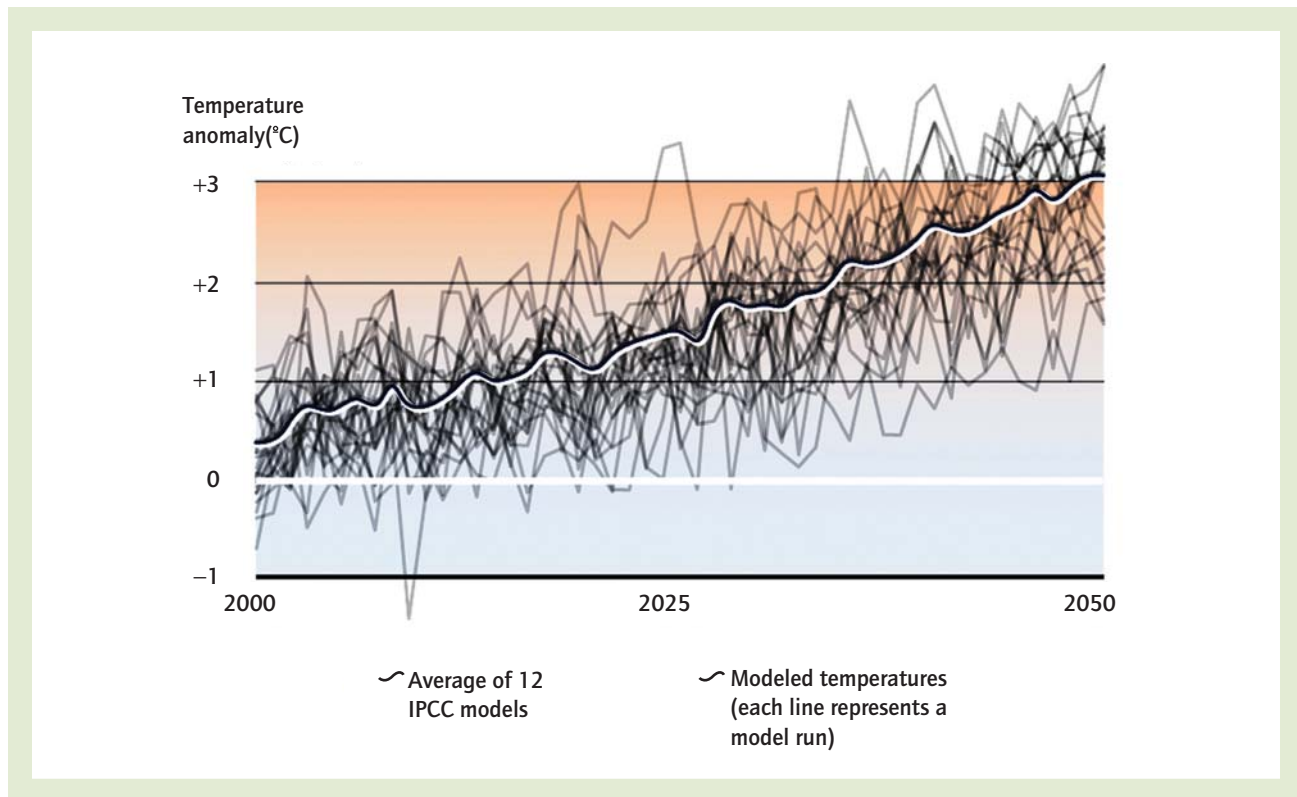


Figure 2 Projected temperatures in the 21st century

Source: Hugo Ahlenius, Cartographer & Designer. (2007, June). In *UNEP/GRID-Arendal maps and graphics library*. Retrieved May 25, 2010, from <http://maps.grida.no/go/graphic/projected-temperatures-in-the-21th-century>.

global climates, geographers and publics attempt to map the responsibilities that connect fossil fuel consumption in Western societies to the changing icescapes of the Arctic, Himalayas, and Andes, and social scientists try to assess the impact on communities and societies. Many questions remain about how the ice will respond to increasing global warming and particularly the effect of polar amplification on the last two remaining ice sheets from the Quaternary period in Greenland and Antarctica. One thing that is certain is that the ice is on the move, changing state, changing mass balance, and changing both the human and the biophysical worlds.

Kathryn Yusoff

See also **Climate: Polar; Glaciers: Continental; Glaciers: Mountain; Periglacial Environments; Poles, North and South**

Further Readings

- Alley, R. (2000). *The two mile time machine: Ice cores, abrupt climate change, and our future*. Princeton, NJ: Princeton University Press.
- Cosgrove, D., & della Dora, V. (Eds.). (2008). *High places: Geographies of mountains and ice*. London: I. B. Tauris.
- Lemke, P., Ren, J., Alley, R. B., Allison, I., Carrasco, J., Flato, G., et al. (2007). Observations: Changes in snow, ice and frozen ground. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, & K. B. Averyt (Eds.), *Climate change 2007: The physical science basis. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change* (pp. 337–384). New York: Oxford University Press.
- Pyne, S. J. (1986). *The ice: Journey to Antarctica*. Seattle: University of Washington.



IDENTITY, GEOGRAPHY AND

Identities help us know who we are and who we are not. Collective or social identities serve to order social and political relations between different groups, while personal or individual identities, sometimes called psychic identities, are crucial in the formation of subjects and allow for identification of individuals with groups. Geographers are interested in identities because they are spatial phenomena in that people identify with particular places, landscapes, and territorial entities. These can be, for example, local, regional, or national identities. With the emergence of the modern nation-state system and modernity, national identity was for a long time considered a more important identity than other identifications. Nations, as Benedict Anderson suggested, are groups of people who invent themselves as “imagined communities” on the basis of a common history, culture, or heritage, thereby defining who is a member of a national group and who is not. These definitions of membership create boundaries between “us” and “them.” In the context of nation-states, such social group boundaries are thought to be reflected in the actual borders of states, but social boundaries also delineate ethnic or racial groups that do not necessarily lay claim to territory.

Recent globalization has shown that privileging the nation-state as the site of primary identification is problematic. Globalization and transnationalism have also served to highlight an important aspect of identities that had long been neglected: that the idea of homogeneous (national) identity needs to be critically examined and corrected toward an understanding of identity as not organic or static but as emerging in specific historical, social, and political contexts.

Identities are neither neatly nested in hierarchical spatial entities nor are they singular, nor are identity and geography easily mapped onto one another as early work in geography and the social sciences assumed. This entry considers identities in their multiplicity and in their relationship to geography, emphasizing the fluid and situational character of both identities and space. Creating group unity on which identity is based does not erase within-group differences or power

imbalances. Gender, religious, class, or generational identifications, and different interests exist simultaneously within groups, and multiple identifications frequently conflict as individuals try to negotiate their identities in different social settings and places. This approach to identity as multiple identifications forms a break from widespread, earlier notions of identity as stable and occupied Western philosophy in much of the 20th century. Earlier ideas common in Western philosophy of an assumed coherent subject have been supplanted by notions that the human subject is constituted out of multiple identifications and of difference that do not necessarily amount to a coherent and consistent whole. Scholars now largely agree that identities are constituted through social relations with others. There are, however, different explanations with regard to how subject formation takes place, with the most prominent approaches deriving from the constitution of the subject in and through discourse, psychoanalytic approaches to the subject, and conceptualizations developing from combinations of these approaches that aim to resolve some of the problems inherent in each.

Conceptual Approaches to Identities

Poststructural and postmodern scholarship have moved the understanding of identities away from fixity of identity and toward understanding identities as constructed in relation to difference. Conceptualizing identities in this fashion posits that identity is not, as assumed earlier, coherent and stable, but rather that identities are multiple and emerge as identifications in social interactions between different people and between individuals and groups. In fact, identities and identifications (and with them, human subjectivity and subject formation) are relational as they rely on others to come into existence. Identities are socially and politically constructed through the everyday life interactions of individuals and groups—that is, through individual identification and group formation, shared experiences, and the narratives that groups tell about themselves. For an individual to develop an identification with someone, there needs to be someone (or group) to identify with.

Another aspect of identifications is that they are also influenced by external ascriptions of



identity. Discourses about and representations of groups are integral to the processes of identity construction. It is therefore necessary to analyze identities in relation to and within the institutions and discourses that enable and constrain them in order to also analyze the power relations that constitute them. Discourses always are supported by underlying power, and they are simultaneously exertions of power. Uneven power relations within a society enable certain segments to assume the authority to label, categorize, and thereby define groups, often as others that differ from a certain norm. Official categorizations in the census are but one example of how labeling and categorization construct identities. As groups internalize such ascribed identities, processes of identity construction become perpetuated and reinforced. Discourse always implies power as it produces meaning and ideas, and identities can only be understood if the configurations of power in which they emerge are taken into consideration.

More broadly, then, the construction of identities can be understood as a dialectical process. This dialectic involves knowing oneself as well as everyone else. In particular, knowledge of others is important in defining one's identity. Stuart Hall (1997) argues that

when you know what everybody else is, then you are what they are not. Identity is always, in that sense, a structured representation which only achieves its positive through the narrow eye of the negative. It has to go through the eye of the needle of the other before it can construct itself. (p. 21)

Identities thus emerge in the articulation of relational and representational identifications with one another rather than in only one of these realms.

These notions of identities are partly influenced by the theories of discourse as constitutive of the human subject as developed by Michel Foucault in *The History of Sexuality*, in which he traces the development of new discourses and categorizations emerging in the 18th century that serve to order and discipline human subjects. These new discourses of, among others, homosexuality and mental illness established human subjectivity as the effect of power relations. Discourses here serve to naturalize certain behaviors and thereby

create the normality that human subjects conform to. Uneven power relations allow the majority of the population to structure categories and representations that, in turn, structure power and consolidate the symbolic dominance or hegemony of the majority.

The work of Frantz Fanon allows for examination of the relationship between external ascription of subject positions and the internalization and struggle of individuals with such identifications. In his work, Fanon draws on his training as a psychiatrist to examine the colonized and racialized subject. In *Black Skin, White Masks*, Fanon describes the moment when a racialized colonial subject becomes fixed into his subject position as a black man just in the instant when a little white girl calls him so. Fanon analyzes how this black man, the racialized colonial subject, becomes aware of and internalizes that ascription of race and otherness in relation, and inferior, to the white colonizers. This psychosocial analysis shows the interplay between discursive ascriptions of identity and psychological and subconscious processes in the process of subject formation.

More recent postcolonial scholarship has drawn on both poststructural and psychoanalytic theories in its conceptions of identities and identifications. Psychoanalytic approaches heavily influenced Homi Bhabha's thinking about identities as identification. He developed his ideas drawing on Jacques Lacan and Fanon, arguing that identifications do not simply confirm an already existing identity. Identification, for Bhabha (1994) is

never a self-fulfilling prophecy—it is always the production of an image of identity and the transformation of the subject in assuming that image. . . . Identification . . . is always the return of an image of identity that bears the mark of splitting in the Other place from which it comes. (p. 45)

Here, the constitutive outside of identification becomes part of the human subject.

Identity Politics

Group identity cannot be reduced to being other than another group or individuals. While identity is not natural or inherent, and requires



differences and a constitutive outside, identity is often able to translate such difference into otherness in order to assert its own continuity and strength. To achieve certain goals, group identity may become defined as opposition to an Other—a group, an individual, or a more abstract threat. Social boundaries then are meaningful in that they symbolize and delimit a perceived unity within from the Other outside. The goal of identity formation, and more so of identity politics, is the construction of boundaries that exclude others to mobilize based on this (perceived) naturalized identity in order to accomplish specific, political goals. Being part of one group, in this line of argument, is diametrically opposed to membership in the other group. Such binary oppositions serve to strategically reduce the complexity and multitude of identities of groups or group members to a dichotomy of “us” versus “them” in order to facilitate political mobilization. Group identity becomes strengthened, while the Other’s complexity becomes locked into a specific identity and reduced to a single characteristic against which one’s own group mobilizes. Identity politics thus reduces the dimensions of difference to create a basis for collective action. Essentializing particular aspects of identity, identity politics may serve progressive as well as reactionary political purposes. In the civil rights struggle in the United States, identity politics served to expand human and civil rights for African Americans, thereby mobilizing for progressive political goals. On the other side of the political spectrum, demonizing Muslim populations as the Other serves an identity politics aimed at achieving particular geopolitical goals or the exclusion of Muslims in the West.

Performativity and Hybridity

Feminist, poststructural, and postcolonial scholarship offer different conceptualizations of political potential when rethinking identity, identifications, and subject formation. Judith Butler’s concept of performativity shows that identity categories need not be fixed, despite attempts at continuous ascription. In conceptualizing identities as performative, that is, in positing human subjectivity as enacted in the practices of subjects, Butler opens up the possibility for change and

counters the fixing of categories of identity and difference. Her conceptualization allows for individuals’ practices to disrupt and change the meaning of identity categories by enacting these ascribed categories differently, and thus to counteract the tendencies of ascribed identities to fix such identities as “natural” or naturalized. Butler argues that the human subject only emerges as it performs its identities in relation to enabling and constraining discourses rather than preexisting discourses or norms that socialize a partially formed subject. There is no previously existing source of identity; rather, identity comes into being in the practices, actions, and gestures of subjects that reference discourses. Conceiving of identification in this manner emphasizes the agency of decentered subjects. That is, by performing them, subjects are able to change identifications, albeit within limits and constraints. Performativity opens up a space for struggles against the ascription and fixing of identities onto subjects, and thus a space for resistance. However, Butler cautions that performativity may not be naively interpreted as liberating the subject from ascribed identity. Rather, subjects’ practices can also contribute to a recurring performance of ascribed identities that may simply reinforce such identities rather than making space for new identifications to emerge.

Another attempt at rethinking notions of identity is the concept of hybridity, which is deemed to disrupt the structures and historical contexts it emerges from, thereby opening up new possibilities for progressive politics and resistance. Hybridity, however, is not simply a mix of previously existing identity and difference. Instead, Homi Bhabha suggests that hybridity emerges out of the traces of other meanings and discourses, combining them to new meanings or representations. It is important to note in this context that these other meanings are not considered original or prior, just temporally earlier. Hybridity, as Bhabha conceives it, does not necessarily resemble other meanings but is a new negotiation of new meanings and representations. Hybridity seeks to resist binary oppositions of culture, of us versus them, or hegemonic culture and the oppressed and thus opens up a space that moves beyond essentialized identities to unravel the margin (however abstract) as the site of resistance.



There are limitations to conceiving of hybridity as abstract space that is “in between” and not located or rooted as necessarily progressive. Geographers have cautioned not to adopt (spatial) metaphors and concepts such as “hybridity” uncritically. While the emancipatory potential of hybrid identities for resistance cannot be denied, hybridity might also become complicit in reifying hegemonic narratives and dominance. Other criticism takes issue with the notion of hybridity as abstract space of resistance because the abstract may be too easily appropriated for reactionary purposes rather than counteracting hegemonic power.

Identities and Changing Geographies

These changing conceptions of identities also influence the ways in which geographers consider relationships between identities and space. Recent geographic work has moved away from earlier studies that assumed identities as homogeneous, coherent, and easily mapped onto space. Such work paid little attention to differentiations within groups and tended to assume identity as stable and spatially fixed. Early works in urban social geography posited that areas in cities were characterized by bounded identities such as race, ethnicity, and immigrant nationality/origin.

Although the conceptualization of identities has changed, the relationship between identity and spatial entities remains a central theme in geography. Parallel to criticism against the problematic notion of “identity” as coherent or singular, numerous criticisms have been levied against earlier studies and conceptions of identity as homogeneous and as easily mapped onto space. Identities, geographers now argue, are enacted in relation to space. Contrary to earlier assumptions of identity being easily mapped onto spatial entities, space and identity are co-constructed. Geographers are specifically interested in the ways in which identities are co-constituted with territory, space, place, and landscape.

Landscapes, an important feature of humanistic geography, for instance, continue to be associated with identification and the ways in which social life plays out and is articulated. Contrary to humanistic geography, however, landscapes, in more recent approaches are considered as both

expressions of identities and central to creating identifications. Both are always in the process of becoming. Similarly, feminist geographers who analyze the relationship between places and identities emphasize that places are central to expressions of identities as well as to exertions of power among and between groups. Sacred spaces, religious places, and communal locations are but some examples that highlight how power and identities are enacted in relation to them. For example, feminist geographers have analyzed how communal places such as churches, temples, and assembly halls help religious groups create and maintain their religious identities while temples also become sites of differentiation according to gender and caste. In these analyses, neither places nor identities are homogeneous or static, and they entail inclusions as well as exclusions. Instead, recent geographic analysis focuses on the ways places and identities are co-constructed and on the ways construction of places and identities involve power relations between different people and groups of people.

The construction of space in relation to identities is both inclusive and exclusive. Discourses that sanction particular identities and behaviors also sanction these behaviors and identities in particular spaces. As certain practices are normalized or naturalized in spaces, these entail exclusions of other practices. The exclusion of women from public space is one example of the ways in which a dominant group, in this case men, asserts its gender identities through producing and sanctioning particular uses of space, which in turn render other types of practices and identities gendered female out of place. These spatial exclusions may intensify polarizations and oppositions. If the Other is deemed dangerous, a fear of or opposition to that Other turns into a fear of or opposition to the space the Other occupies. But such spaces discursively constructed as Other may gain shifting meanings over time as well, as Kay Anderson's research on Vancouver's Chinatown shows. Geographic research on urban space and identity emphasizes that spaces of exclusion need to be understood as shifting grids of multiple identifications and differences, the analysis of which allows for disruption, stabilizing ascriptions of spaces as dangerous. In addition, the new geographies of globalization and transnationalism have allowed



for new connections across space that also enable new multilocal and cosmopolitan identifications.

Patricia Ehrkamp

See also Cosmopolitanism; Difference, Geographies of; Discourse and Geography; Ethnicity; Gays and Lesbians, Geography and/of; Gender and Geography; Globalization; Humanistic Geography; Hybrid Geographies; Nation; Nationalism; Orientalism; Psychoanalysis, Geography and; Postmodernism; Race and Racism; Sexuality, Geography and/of; Structuration Theory; Subaltern Studies; Symbolism and Place; Transnationalism

Further Readings

- Anderson, K. (1991). *Vancouver's Chinatown: Racial discourse in Canada, 1875–1980*. Montreal, Quebec, Canada: McGill-Queen's University Press.
- Bhabha, H. (1990). The third space: Interview with Homi K. Bhabha. In J. Rutherford (Ed.), *Identity: Community, culture, difference* (pp. 207–221). London: Lawrence & Wishart.
- Bhabha, H. (1994). *The location of culture*. London: Routledge.
- Butler, J. (1990). *Gender trouble: Feminism and the subversion of identity*. New York: Routledge.
- Giddens, A. (1991). *Modernity and self-identity: Self and society in the late modern age*. Stanford, CA: Stanford University Press.
- Hall, S. (1996). Introduction: Who needs “identity”? In S. Hall, & P. du Gay (Eds.), *Questions of cultural identity* (pp. 1–17). London: Sage.
- Hall, S. (1997). The local and the global: Globalization and ethnicity. In A. King (Ed.), *Culture, globalization and the world-system: Contemporary conditions for the representation of identity* (pp. 19–39). Minneapolis: University of Minnesota Press.
- Jenkins, R. (1994). *Social identities*. London: Routledge.
- Keith, M., & Pile, S. (Eds.). (1993). *Place and the politics of identity*. London: Routledge.
- Mitchell, K. (1997). Different diasporas and the hype of hybridity. *Environment and Planning D: Society and Space*, 15, 533–553.

- Natter, W., & Jones, J. (1997). Identity, space, and other uncertainties. In G. Benko & U. Strohmayr (Eds.), *Space and social theory: Geographical interpretations of postmodernism* (pp. 141–161). Oxford, UK: Blackwell.
- Pile, S., & Thrift, N. (Eds.). (1995). *Mapping the subject*. London: Routledge.
- Sibley, D. (1995). *Geographies of exclusion*. London: Routledge.



IDIOGRAPHIC

The term *idiographic* refers to the unique aspects of individual areas, that is, those that cannot be understood easily, if at all, on the basis of general rules of inference or deduction. Much of geography has traditionally been concerned with the idiographic in the context of regions and places, long mapping the unusual, colorful, and extraordinary. However, the uniqueness of places has also long been at the center of significant philosophical debates about how to study geography.

The tradition of chorology or areal differentiation, which predominated in the early 20th century, was epitomized by Richard Hartshorne, who maintained that geography is an integrative science concerned exclusively with the unique. In this perspective, regions form the highest form of geographic understanding. Idiographic perspectives hold that each region is a unique combination of physical and human elements embedded in the landscape. Smaller regions are more likely to be more internally homogeneous, and broader ones can be understood through the accretion of small units. Upholding the idiographic in this manner essentially disregards the need for general themes or causal properties that transcend regions—the key point of nomothetic (law seeking) approaches to geography. The idiographic approach has thus long been associated with atheoretical empiricist and inductive forms of thought in geography, that is, generalization without explanation or theorization.

Beginning with Fred Schaefer's famous critique of regional geography in 1953, the idiographic approach began to wane in popularity. The move into a nomothetic science sought to subsume all



the unique details of a place under general laws of understanding that could be applied in all contexts. The attempt to make geography nomothetic and thus “scientific” entailed a shift from regions without theories to theories without regions. This shift corresponded with the decline in popularity of regional geography more broadly.

However, in the 1980s, beginning with Doreen Massey’s well-known work on regions in the changing spatial division of labor, geographers acquired a new respect for the idiographic. The so-called localities school attempted to resurrect the idiographic by approaching it in terms of the historical development of regions over time. Beginning with the observation that no social process unfolds in precisely the same way in different places, this view held that regions acquired unique combinations of imprints of different divisions of labor (i.e., investments, labor market practices, cultural forms). In such a view, general laws of explanation are only observable in unique, idiographic contexts, and the local becomes more than some inexplicable phenomenon—an object of scientific understanding. In an age of globalization, the local is always shot through with the global, requiring a multiscalar approach. Unlike the earlier tradition of chorology, therefore, this approach is theoretically sophisticated and far from the empiricism that plagued earlier attempts.

Barney Warf

See also Chorology; Hartshorne, Richard; Human Geography, History of; Nomothetic; Regional Geography; Regions and Regionalism

Further Readings

- Hart, J. (1982). The highest form of the geographer’s art. *Annals of the Association of American Geographers*, 72, 1–29.
- Hartshorne, R. (1939). *The nature of geography*. Washington, DC: Association of American Geographers.
- Massey, D. (1985). *Spatial divisions of labor*. London: Routledge.
- Schaefer, F. (1953). Exceptionalism in geography: A methodological examination. *Annals of the Association of American Geographers*, 43, 226–229.



IMAGE ENHANCEMENT

Image enhancement is applied to improve the overall visual quality of an image—to smooth or sharpen image features such as edges for better visual interpretation or better subsequent digital image analysis. It is applied to many types of images, such as medical images, digital photography, and remotely sensed imagery.

In geography, Earth’s surface information can be obtained by the interpretation and understanding of images acquired from sensor devices on board satellites and airplanes. Recently, many new remote sensors have been developed that can detect electromagnetic signals in different wavelength ranges with various spatial and spectral resolutions. However, the original images delivered to general users may not display all the surface objects clearly. Human analysts may not be able to distinguish slight brightness differences for different objects on the original images. The objective of image enhancement is to optimize the image appearance and to aid human analysts with particular image interpretation tasks. The evaluation of the quality of the enhancement is usually subjective; it depends on the human eye and on the particular application. Various image enhancement techniques have been developed for remotely sensed imagery. The commonly used methods include contrast enhancement, spatial filtering, and Fourier transform.

In original images, the brightness values rarely cover the entire range of the gray levels (commonly 8 bits or 256 levels). Therefore, the image contrast may be low, or the image appears dark. Contrast enhancement increases the contrast between image objects and between objects and their surroundings by modifying the brightness values of the image pixels. The brightness value frequency distributions or histograms will be changed. The result is an output image with better image contrast for optimal visualization and interpretation. There are several contrast enhancement methods. For example, the linear contrast stretch methods uniformly expand the range of the brightness values to fill the entire range of the gray levels. The histogram equalization method is a nonlinear contrast stretch method, which considers the frequency distribution or histogram of the image brightness values and assigns pixel values based on



equalizing the histogram. As a result, the pixel values are redistributed according to the histogram. Therefore, the contrast is stretched for pixels with brightness values that appear more frequently and reduced for pixels with infrequent brightness values, such as very dark or very bright pixels.

The contrast enhancement assigns a new value to a pixel based on the brightness value of this single pixel. Spatial filtering assigns a new value to a pixel based on the values of a local neighborhood, or a window, of this pixel. Spatial filters include low-pass filters, high-pass filters, and directional filters. Low-pass filters emphasize low-frequency features and have a smoothing effect on the image. High-pass filters emphasize high-frequency features and may be used for edge enhancement and detection. Directional filters can be used to detect edges in specific orientations.

Fourier transform is a mathematical operation to transform the original image from the spatial domain—the (x, y) coordinate space of the image—to the frequency domain. In the transformed Fourier spectrum, the lower frequencies in the original image are plotted at the center of the spectrum, and the high frequencies are plotted away from the center. Various filters can be designed and applied to the Fourier spectrum. For example, a circular low-frequency blocking filter blocks the center of the Fourier spectrum and can be used as a high-pass filter. After filtering in the frequency domain, an inverse Fourier transform is performed to transform the filtered version back to the spatial domain. With the high-pass filter, the result is an edge-enhanced image. With the low-pass filter, the result is a smoothed image.

In summary, image enhancement is a useful digital-image-processing procedure that can improve the visual quality of an image. The selection of image enhancement methods depends on the specific application. For example, when applying low-pass filters, the enhanced image can actually look too smooth and worse than the original image. However, some speckle noises can be reduced or removed. An enhancement method suitable for one application may not be appropriate for another purpose.

Jinfei Wang

See also **Image Fusion; Image Interpretation; Image Processing; Remote Sensing**

Further Readings

- Jensen, J. (2004). *Introductory digital image processing: A remote sensing perspective* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.
- Lillesand, T., Kiefer, R., & Chipman, J. (2007). *Remote sensing and image interpretation* (6th ed.). New York: Wiley.

IMAGE FUSION

Image fusion is a technique to combine multi-source images such as a high-spatial-resolution panchromatic or radar image and a lower-spatial-resolution multispectral image to produce a high-spatial-resolution multispectral image. Ideally, the fused image inherits high-resolution spatial information from the panchromatic or radar image and preserves the original spectral characteristics of the multispectral image. Most Earth observation satellite systems provide two types of image data: a panchromatic image with high spatial resolution and a multispectral image with lower spatial resolution but higher spectral resolution. To effectively use such images, image fusion techniques can be employed to combine the high-resolution panchromatic and low-resolution multispectral images into one color image. Such techniques can extend the application potential of remote-sensing image data.

A variety of methods for fusing panchromatic images of high spatial resolution with multispectral images of lower spatial resolution were developed. Pohl and Van Genderen grouped the existing image fusion techniques into two classes: (1) color-related techniques such as intensity-hue-saturation (IHS) and hue-saturation-value (HSV) fusion methods and (2) statistical/numerical methods such as principal components analysis (PCA), high-pass filtering (HPF), Brovey transform (BT), regression variable substitution (RVS), and wavelet methods. Ranchin and Wald distinguished three groups of fusion methods: (1) the projection and substitution methods, (2) the relative spectral contribution methods, and (3) the methods relevant to the ARSIS (the French acronym for “spatial



resolution enhancement by injection of structures”) concept. There are also some hybrid methods that use combined methods from more than one group. Among the existing fusion methods, the IHS transform and PCA methods are the algorithms most commonly used by the remote-sensing community.

Problems and limitations associated with the available fusion techniques have been reported by many studies. The most significant problem is that the fused image usually has a notable deviation in visual appearance and in spectral values from the original image. These deviations, called color distortions, affect further interpretation, especially when the wavelength range of a panchromatic image does not correspond to that of the employed multispectral image. Another potential problem arises from the fact that panchromatic and multispectral images are often taken in different seasons of the year. In image fusion, it is desirable to minimize the color distortion since this ensures that features separable in the original multispectral image are still separable in the fused image.

Other terms with similar meanings to image fusion that can be found in the literature include *image pan-sharpening*, *image merging*, *image combination*, *image synergy*, and *image integration*. *Data fusion* is another term related to image fusion, but it has a broader meaning than image fusion.

Yangrong Ling

See also **Image Enhancement; Image Processing; Remote Sensing**

Further Readings

- Chavez, P., Sides, S., & Anderson, J. (1991). Comparison of three different methods to merge multiresolution and multispectral data: TM & SPOT pan. *Photogrammetric Engineering and Remote Sensing*, 57(3), 295–303.
- Pohl, C., & Van Genderen, J. (1998). Multisensor image fusion in remote sensing: Concepts, methods and applications. *International Journal of Remote Sensing*, 19(5), 823–854.
- Ranchin, T., & Wald, L. (2000). Fusion of high spatial and spectral resolution images: The ARSIS concept and its implementation. *Photogrammetric Engineering and Remote Sensing*, 66(1), 49–61.



IMAGE INTERPRETATION

Image interpretation is the process used in remote sensing to extract meaningful information from photographic and digital images taken of the Earth’s surface and atmosphere. The goal is to identify, count, measure, and classify geographic objects or features in the landscape as they are represented by single images or to infer physical geographic processes from two or more images. Whether these objects are individual trees, clusters of trees, or a whole forest or whether the objects are buildings, neighborhoods, or a complete town depends on the spatial resolution of the remote sensor. Similarly, whether the tree is deciduous or coniferous or whether the building is a house or a store partly depends on the spectral resolution of the remote sensor. Spatial, spectral (and radiometric, referring to gray levels) resolutions refer to the specific designs of the optical-based or pulse-based sensors used in remote sensing, where variations of these resolutions determine the geographic scale and level of detail and the quality of interpretability. For instance, the widely used U.S.-based Landsat Thematic Mapper series has sensors designed with spatial resolutions of 30 m (meters) and spectral resolutions of six or seven bands or channels (referring to energy wavelengths), which makes them ideal for applications where objects are no smaller than 30 m on the ground, while the more recent Ikonos sensors are capable of much more detailed applications where objects of approximately 4 or 1 m should be recognizable.

On close inspection, raw aerial photographs and digital images are found to be composed of intricate patterns of basic tones and textures. Figure 1 illustrates the image interpretation process where these patterns are converted into meaningful geographic information. Most image interpretation procedures require the interaction of human skill, experience, and knowledge, with support from rigorous, systematic computer calculations.

At this point, the interpretation process can follow one of two directions. First is the traditional visual approach used when handling aerial photographs, which involves the systematic search for clues in how target objects on the ground

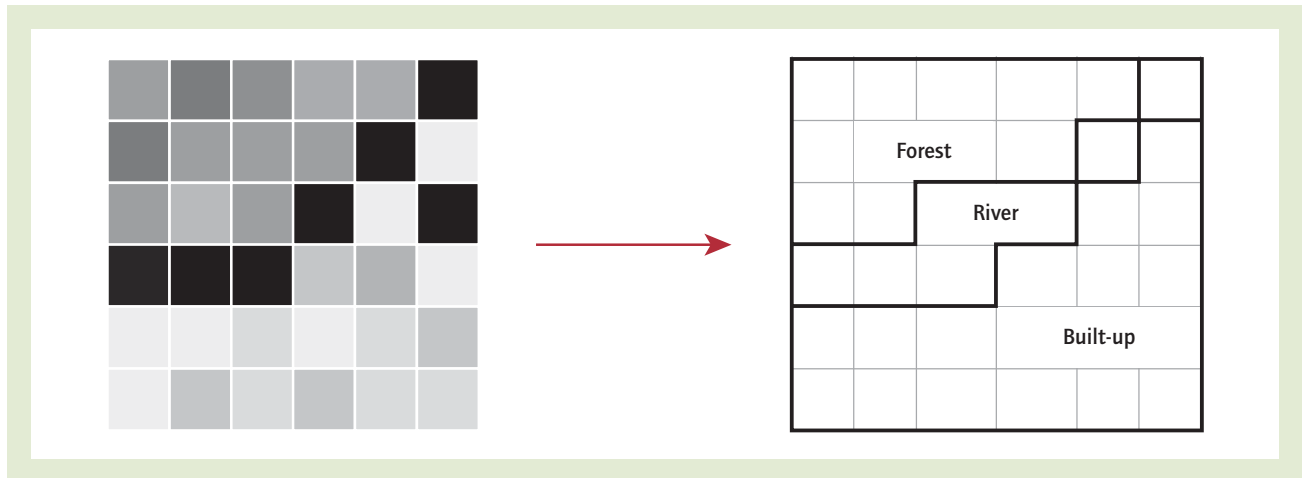


Figure 1 The image interpretation process

Source: Victor Mesev.

appear on the photos by understanding the interplay of tone, texture, shadow, pattern, association, shape, size, and site (refer to basic texts such as Campbell, 2006, for detailed discussions of each). The manual approach is heavily dependent on overlapping photos taken along the flight path, which facilitate a three-dimensional (3D) perspective when viewed with stereoscopes. The 3D view aids in object recognition and further assists with the calculation of scale, horizontal distances, and vertical heights of objects.

The other approach to interpretation is the computer analysis of digital images, where a number of algorithms are designed to enhance, contrast, and classify target objects based on numeric multispectral similarities. One of the simplest techniques to help identify geographic features is to enhance the visual appearance of the digital image by stretching the brightness levels of the data model used to represent the image. Remembering that raw images replicate the typically homogeneous nature of reality in small areas, pixel values are clumped within narrow data ranges, rendering the identification of geographic features difficult. By stretching this narrow range across the full extent of the data model (i.e., 256 brightness levels for 8-bit words), enhancement methods, such as linear contrast or histogram equalization, are able to “illuminate” and reveal much more detail in the landscape. However,

enhancements are for visual purposes only and do not alter pixel values. Alternatively, edge enhancement is a filtering technique that involves a moving window designed to attenuate the values of pixels representing boundaries between geographic objects. This should make the interpretation of objects and features a little easier, although the image remains numeric.

For complete interpretation, digital images are frequently segmented, or classified into thematic groups based on similar pixel values (Figure 1 is an example of the conversion of similar pixels into three thematic land covers). Classification is backed by a growing literature and includes a variety of deterministic and stochastic approaches that focus on clustering individual pixels (or even predicting subpixel proportions), an emphasis on neighborhoods of pixels, commonly divided into textural analysis and object-based discrimination, as well as the use of ancillary data from other sources. In all cases, classification is intended to produce user-friendly maps that determine the geographic extent of land cover types, such as forests, soils, built-up areas, and water bodies, as well as attempting to infer land use types, such as agricultural practices and residential habitation. Of course, visual skills and computer proficiency are interrelated and important in both the traditional manual and the computer approaches, to the point where the blurred



distinction is encapsulated by current digital photogrammetric interpretation.

Remotely sensed images are an important source of geographic information. If the correct resolutions are chosen, image interpretation can extract spatial information on the Earth's surface and atmosphere that is recent, globally comprehensive, and relatively consistent in quality. Such information is frequently the framework data for many mapping applications, the basis for measuring global environmental concerns, and used for a variety of spatial analyses by geographic information systems (examples can be found in Mesev, 2007). They are also the basis for revising topographic maps, such as those produced by the U.S. Geological Survey, which updates its series using aerial photographs and digital images. However, it is important to remember that information extracted from remotely sensed images has many limitations. Image resolutions determine scale and the level of detail, but the interpretation process itself can be highly subjective—depending on the specifications of the application, the skills of the analyst, and the choice of automated classification algorithms. Furthermore, the paradox is that although remote sensing captures the world's surface as it really is, a dynamic gradation of intricate features, the image interpretation process is an exercise in simplifying and insisting on static, sterilized, and compartmentalized maps.

Victor Mesev and Jennifer Miller

See also [Aerial Imagery: Interpretation](#); [Image Enhancement](#); [Image Texture](#); [Land Use and Land Cover Mapping](#); [Multispectral Imagery](#); [Object-Based Image Analysis](#); [Radiometric Resolution](#); [Remote Sensing](#); [Spatial Resolution](#); [Spectral Resolution](#); [Three-Dimensional Data Models](#)

Further Readings

- Campbell, J. (2006). *Introduction to remote sensing*. New York: Guilford Press.
- Mesev, V. (Ed.). (2007). *Integration of GIS and remote sensing*. Chichester, UK: Wiley.



IMAGE PROCESSING

Image processing is the application of software to digital satellite or aerial imagery in an effort to enhance the imagery and/or highlight features with the intent to gather information about the landscape and its spatial patterns. A few examples of how geographers use image-processing techniques include analyzing land cover and land use, detecting changes to the landscape, updating existing maps, analyzing vegetation patterns, performing biophysical analysis, supporting siting analysis, and studying environmental hazards and disaster recovery. The results of image processing are often combined with geographic information system (GIS) software and data to provide enhanced analysis and problem-solving support.

Digital imagery is provided in raster format, as a matrix of numbers representing the amount of light reflectance as collected throughout various portions of the electromagnetic spectrum. Complex image-processing software routines are applied to the image with the ultimate goal of highlighting landscape patterns. Image-processing techniques may be divided into three general categories: image preprocessing, image enhancement, and image classification.

Image Preprocessing

Image preprocessing involves geometric correction, georeferencing and image registration, and radiometric correction. Geometric correction involves applying algorithms to the image that correct for the curvature of Earth and the motion of the sensor. Georeferencing involves establishing a geographic coordinate system or registering images to each other, which is required for precise overlay of ancillary digital data or other imagery. Radiometric correction is the process of ensuring the accuracy of the surface reflectance values as represented by the digital numbers in the image. Most often, this process includes correcting for atmospheric attenuation of light waves because of atmospheric constituents such as water, dust, or pollution. In addition, images may contain system errors such as random missing pixels, missing partial or complete lines, or a



consistent striping. Often these detector errors can be improved on in that values can be assigned to the missing data based on the surrounding pixel values; however, nothing replaces the fact that the data were not collected in the first place.

Image Enhancement

Image enhancement is the largest of the three categories in terms of number of techniques, which range from basic contrast enhancement to more state-of-the-art techniques such as texture analysis. The end results of image enhancement techniques are an increase in the visual interpretability of the image or the creation of a new image data set that will be used in follow-up enhancement or classification processes. Matrix algebra concepts and related algorithms are applied to an image, operating on the individual bands or multiple bands that represent different portions of the electromagnetic spectrum. Example techniques include a ratio of spectral bands to highlight vegetation patterns or health; edge enhancement algorithms that denote large digital value changes indicating an “edge” or change in land cover; and statistical methods such as principal component analysis, which seeks to reduce the redundancy among the different spectral bands by compiling as much unique information from the multiple image bands into fewer new image layers.

Change Detection

Change detection is the process of determining changes in land cover across time. Depending on the subject under investigation, anniversary dates and phenological cycles should be considered. In addition, environmental issues such as atmospheric conditions and soil moisture must also be considered when selecting the imagery. Once the imagery is selected, each image must be preprocessed as noted above and a change detection method selected. Each image is then digitally analyzed in the same manner, which includes image classification, principal component analysis, or vegetation indices. The images are then processed through the change detection algorithm, and an accuracy assessment is performed on the results.

Image Classification

Creating a land use and/or land cover map may be described as the ultimate goal of image processing. Image classification involves clustering pixels with similar digital values into similar land cover categories that eventually portray patterns of land cover on the landscape. There are four general types of image classification: supervised, unsupervised, and fuzzy classifications, and hybrid approaches. Before any classification begins, a classification scheme must be selected; there are several well-established, standardized systems from which to choose.

Supervised classification involves selecting training samples of areas in the image that are representative of the various components that have been outlined in the selected classification system. These training samples can be of water, grass, trees, pavement, buildings, and so on. Or if vegetation is the focus, training samples may be selected that represent deciduous trees, coniferous trees, and various types of grasses based on spectral reflectance curves. These training samples are selected by digitally drawing on the image a point, line, or polygon that contains the land cover. These samples are used to “train” the computer as they are representative digital values of the land cover in question. The software will then cluster the various pixels together based on their similar digital values, making the assumption that numbers of the same value are the same land cover.

Unsupervised classification involves allowing the computer to cluster the digital numbers into groups of similar values, based on the assumption that similar values indicate similar land cover. The analyst only combines the clusters of similar land covers (if necessary).

Both supervised and unsupervised classifications are considered traditional “hard” classifications in that every pixel is placed into a discrete cluster or category. Fuzzy classifications are an attempt to address the heterogeneity of Earth’s landscape and the “fuzzy” boundaries that exists between various landscape phenomena. “Pure” pixels, representing a single land cover, may be rare in an image. Because of the pixel size, a pixel may represent multiple land covers within this spatial resolution represented on the ground. Add to this the continuous



nature of Earth's surface, to include transitions between land covers; this is the mixed-pixel problem. Fuzzy classification operates on fuzzy set theory, in which classes are created that do not have established boundaries; membership in each class is defined by a value that ranges from 0 to 1 indicating degree of membership in the class. Fuzzy classification is similar to supervised classification in that training samples are collected; however, a mixture of pure and mixed training samples may be collected. Each pixel in the image is then placed into one of the categories based on their degree of membership, which may range from full membership at 100% (pure) to partial membership; a pixel may have partial membership in several categories. A membership matrix is computed that includes the grades of category membership for each pixel, which can then be translated into a proportion of land cover components for each pixel.

While no classification method is perfect in all situations, decisions regarding classification method must be determined on a case-by-case basis. Hybrid image classification options are user defined and combine the various classification methods in a way that is most advantageous to the user and the analysis situation. After all classification techniques are applied, clusters are named according to the selected land cover classification scheme and an accuracy assessment is conducted based on in situ data or information collected from a source of equal or higher spatial resolution. The resulting accuracy should have an overall accuracy of 85% or greater and/or a kappa coefficient value greater than .8 (80%).

Among the commercial off-the-shelf image processing software are Leica Geosystems' ERDAS Imagine, PCI's Geomatica, ER Mapper, and ENVI, while GIS packages such as ArcGIS, Idrisi, MapInfo GIS, GRASS GIS, and Intergraph's GeoMedia perform some image-processing functions as well.

Lisa Keys-Mathews

See also [Aerial Imagery: Data](#); [Aerial Imagery: Interpretation](#); [Image Enhancement](#); [Image Fusion](#); [Image Interpretation](#); [Image Texture](#); [Map Algebra](#); [Remote Sensing](#)

Further Readings

- Campbell, J. (2007). *Introduction to remote sensing* (4th ed.). New York: Guilford Press.
- Jensen, J. (2005). *Introductory digital image processing: A remote sensing perspective* (3rd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Lillesand, T., Kiefer, R., & Chipman, J. (2008). *Remote sensing and image interpretation* (6th ed.). Hoboken, NJ: Wiley.



IMAGE REGISTRATION

Image registration is the process of precisely overlaying two (or more) images of the same area through geometrically aligning common features (or control points) identified in the images. The images can be taken at different times, from different viewpoints, and/or by different sensors. The registered images can be used for different purposes, such as change detection if the images are taken at different times, digital elevation model generation or shape reconstruction when the images are collected from different viewpoints, information integration when the images are taken by different sensors, and image mosaicking when the images have overlapping areas.

Figure 1 shows an example of image mosaicking, where the features 1, 2, 3, 4, 5, 6 and 1', 2', 3', 4', 5', 6' are the common control points identified in the overlapping area of the images ① and ②'. The overlapping area can be registered through the alignment (or overlay) of the common points.

Normally, image registration consists of four steps: (1) feature detection and extraction, (2) feature matching, (3) transformation function fitting, and (4) image transformation and image resampling. Each of the steps is explained in the following four sections.

Feature Detection and Extraction

For image registration, a sufficient number of control points (common features) are required to estimate an optimal geometric transformation between two images. The control points can be

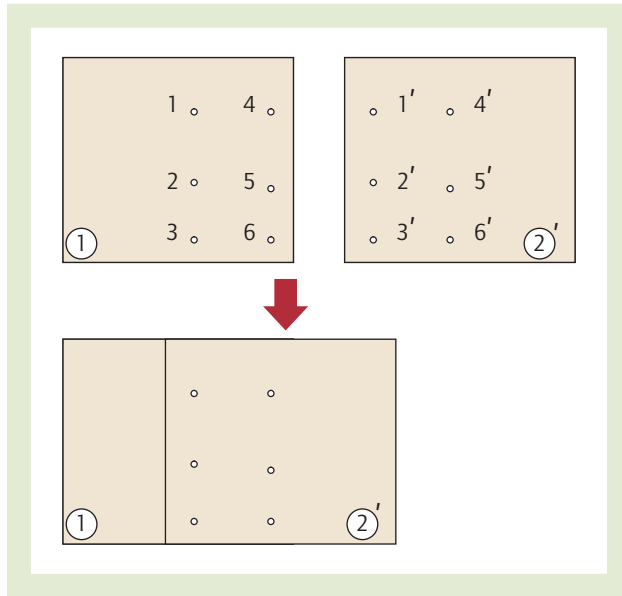


Figure 1 Image registration for mosaicking through overlaying the control points

Source: Authors.

selected manually or extracted automatically. They are, normally, any of the following features:

- Line intersections
- Points of locally maximum curvature (such as building corners)
- Gravity centers of closed boundary regions (such as centers of building roofs or traffic islands)
- Centers of windows having locally maximum variance

The minimum number of control points required depends on the transformation function used. For example, when the conformal transformation function (Equations 1 and 2) is used, at least two control points are required. Because there are four unknowns a , b , c , and d in the transformation function, two control points are the minimum number to solve the equations and find the unknowns. More control points are usually required to achieve accurate solutions by least square approximation.

$$x' = ax + by + c \quad (1)$$

$$y' = -bx + ay + d \quad (2)$$

Feature Matching

After automated feature detection, numerous features can be extracted. However, many feature points may be extracted from one image but not from the other. Therefore, feature matching is necessary to find corresponding points (common features) in both images. The feature matching usually starts from one feature point on one image and then searches for the corresponding point on the other image.

Basically, there are two kinds of feature matching approaches: (1) area-based methods and (2) feature-based methods. In area-based methods, cross-correlation is often used as a similarity measure to find the corresponding point on the other image. In feature-based methods, the sum of squared differences is usually used to identify the corresponding point.

Transformation Function Selection and Fitting

Transformation function is used to model the geometric relationship between two images. A transformation function should take the possible geometric distortion between two images into consideration. There are two categories of possible distortions:

1. Global distortion
2. Local distortion

Different distortions need different transformation functions to overcome the distortion between two images.

- If there is no distortion but only rotation and translation difference between two images, a rigid transformation function can be used, such as conformal transformation function (Equations 1 and 2).
- For global distortion, many transformation functions can be used, such as affine, projective, and polynomial transformations.
- If local distortion is present, a more complicated transformation function is required, such as piecewise affine, piecewise polynomial, elastic, and radial basis functions.

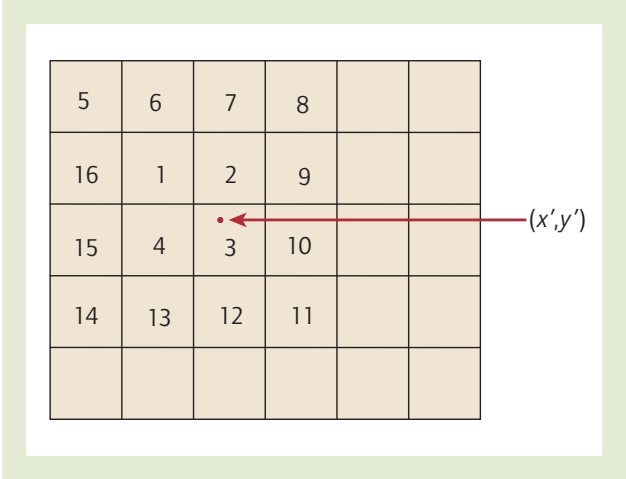


Figure 2 Image resampling, where the grids and numbers represent pixels and their gray values in the image before the transformation, respectively, and the gray value for the position (x', y') , which needs to be interpolated

Source: Authors.

Image Transformation and Image Resampling

After the transformation function has been selected, the unknown coefficients of the function, such as a , b , c , and d in Equations 1 and 2, can be calculated according to the control points. One image can then be transformed to precisely overlay the other image, in which the pixels of the image being transformed need to be resampled.

In the transformation, usually, the pixel position (x, y) in the target image (i.e., the image after the transformation) is transformed into its corresponding position (x', y') in the image before the transformation. The gray value of the pixel (x, y) is then determined by pixel resampling in the image before the transformation according to the pixel gray values around the position (x', y') (Figure 2).

For image resampling, three interpolation methods can be used:

- Nearest-neighbor interpolation
- Bilinear interpolation
- Cubic interpolation

If the nearest-neighbor method is used, the gray value of the point (x', y') will be the value of the nearest pixel—that is, Gray Value 3 in Figure 2. For the bilinear method, the gray value of the point (x', y') will be determined by the four pixels with the values of 1, 2, 3, and 4. For the cubic method, the 16 pixels around the point (x', y') will be used to calculate the gray value for (x', y') .

Yun Zhang and Zhen Xiong

See also **Image Enhancement; Image Fusion; Image Interpretation; Image Processing; Image Texture**

Further Readings

Brown, L. G. (1992). A survey of image registration techniques. *ACM Computing Surveys*, 24(4), 325–376.

Zitova, B., & Flusser, J. (2003). Image registration methods: A survey. *Image and Vision Computing*, 21, 977–1000.

 IMAGE TEXTURE

Image texture refers to the subtle spectral differences present in digital or analog images and is defined as the spatial variation in pixel intensities or brightness values. The two most common ways to compute image texture are through first-order or second-order gray-level statistics. First-order texture statistics of local areas can be computed for means, standard deviation, and variance, among others. When computing these values, a moving window (e.g., a 3×3 pixel window) computes the mean (or one of the other statistics), which is then assigned to the center pixel. For example, a 3×3 moving window can be used to calculate the standard deviation for the center pixel. This process would help determine the pixel areas that have the most standard deviation (e.g., spectral differences) and would amplify edges within the image. This kind of information is usually not readily apparent when simply visually examining the image.



Second-order image texture measures represent a higher-order set of image texture information. These measures are based on spectral value spatial dependency gray level co-occurrence matrices (GLCM), which contain information about pixels and their neighbors at fixed orientations and distances. The GLCM-derived texture measurements have been widely adopted by the remote-sensing community, and typical measures that can be used to extract useful textural information are angular single moment, correlation, entropy, and homogeneity. Jensen and Gatrell (2005) demonstrated that image texture homogeneity was positively correlated with socioeconomic and population variables.

Most remote-sensing/image-processing software packages contain algorithms to measure both first- and second-order image texture. These algorithms usually allow the user to control many parameters. Some of the parameters that the user will probably control when computing image texture are the kind of image texture to measure (standard deviation, homogeneity, and so on; spectral band (e.g., near-infrared band); neighborhood pixel window size (e.g., 3×3 , 5×5 , or 7×7 , although larger windows may be selected); and quantization level of the output texture image (8 bit, 12 bit, etc.). It is often necessary to experiment with these parameters until an optimum solution is found.

Image-processing algorithms, such as most forms of supervised and unsupervised classification, are usually single-pixel operations that do not consider image texture information in the classification process. However, sometimes researchers compute texture images and then incorporate them into the classification process as additional bands or as variance thresholds that define clusters (see Lillesand, Kiefer, & Chipman, 2004). In addition, recently, new image classification algorithms, such as feature extraction and other object-oriented methods, have begun to incorporate texture directly into the image classification process.

Ryan R. Jensen

See also **Aerial Imagery: Data; Aerial Imagery: Interpretation; Image Interpretation**

Further Readings

- Haralick, R. (1979). Statistical and structural approaches to texture. *Proceedings of the IEEE*, 67, 786–804.
- Haralick, R. (1986). Statistical image texture analysis. In T. Young & K. S. Fu (Eds.), *Handbook of pattern recognition in image processing* (pp. 247–280). New York: Academic Press.
- Jensen, J. (2005). *Introductory digital image processing: A remote sensing perspective* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
- Jensen, R., & Gatrell, J. (2005). Image homogeneity and urban demographics: An integrated approach to applied geo-techniques. In R. Jensen, J. Gatrell, & D. McLean (Eds.), *Geo-spatial technologies in urban environments* (pp. 73–80). Berlin, Germany: Springer-Verlag.
- Lillesand, T., Kiefer, R., & Chipman, J. (2004). *Remote sensing and image interpretation* (5th ed.). Hoboken, NJ: Wiley.



IMAGING SPECTROSCOPY

The terms *imaging spectroscopy*, *imaging spectrometry*, *hyperspectral imaging*, and, occasionally, *ultraspectral imaging* are often used interchangeably. Even though semantic differences might exist, a common definition for such terms is as follows: the simultaneous acquisition of spatially coregistered images, in many narrow, spectrally contiguous bands, measured in calibrated radiance units, from a remotely operated platform. A variety of imaging spectrometers exist for imaging spectroscopy applications. Imaging-spectrometer-collected data facilitate quantitative and qualitative characterization of both the surface and the atmosphere, using geometrically coherent spectral measurements. This result can then be used for the unambiguous direct and indirect identification of surface materials and atmospheric trace gases, the measurement of their relative concentrations, and subsequently the assignment of the proportional contribution of mixed pixel signals (e.g., spectral unmixing), the



derivation of their spatial distribution (e.g., mapping), and finally their evolution over time (multi-temporal analysis).

More than 300 yrs. (years) ago, in 1704, Sir Isaac Newton published his *Treatise of Light*, which presented the concept of dispersion of light. He demonstrated that white light could be split up into its component colors by means of a prism and found that each pure color is characterized by a specific refrangibility. Newton's corpuscular theory was gradually succeeded over time by the wave theory. Consequently, the substantial summary of past experiences performed by James Maxwell in 1873 resulted in his equations of electromagnetic waves. But it was not until the 19th century that the quantitative measurement of dispersed light was recognized and standardized.

A major contribution was Joseph von Fraunhofer's discovery of the dark lines in the solar spectrum in the early 1800s and their interpretation as absorption lines on the basis of experiments by Robert Bunsen and Gustav Kirchhoff in the mid 1800s. The term *spectroscopy* was first used in the late 19th century and provides the empirical foundations for atomic and molecular physics. Significant achievements in imaging spectroscopy are attributed to airborne instruments, particularly arising in the early 1980s and 1990s. However, it was not until 1999 that the first imaging spectrometer was launched in space (the National Aeronautics and Space Administration's Moderate-Resolution Imaging Spectroradiometer, or MODIS).

Michael E. Schaepman

See also **National Aeronautics and Space Administration (NASA); Remote Sensing; Spectral Characteristics of Terrestrial Surfaces; Spectral Resolution; Spectral Transformations**

Further Readings

- Born, M., & Wolf, E. (1999). *Principles of optics*. Cambridge, UK: Cambridge University Press.
- Goetz, A., Vane, G., Solomon, J., & Rock, B. (1985). Imaging spectrometry for earth remote sensing. *Science*, 228, 1147–1153.

Maxwell, J. (1873). *A treatise on electricity and magnetism*. Oxford, UK: Clarendon Press.

Schaepman, M. (2009). Imaging spectrometers.

In T. A. Warner, M. D. Nellis, & G. Foody (Eds.), *The SAGE handbook of remote sensing* (pp. 166–178). London: Sage.

Schaepman, M., Ustin, S., Plaza, A., Painter, T., Verrelst, J., & Liang, S. (2009). Earth system science related imaging spectroscopy: An assessment. *Remote Sensing of Environment*, 113, S123–S137.



IMMIGRATION

Immigration or international migration is one of the most significant and contested forms of spatial mobility of population in the 21st century. Its most basic definition is migration of a person or group of persons across a national boundary with the intent to stay. Migrations from culture regions of origin to regions of residence and control by members of other ethnic groups have occurred for millennia, but immigration as it is understood today is a relatively recent spatial phenomenon. Immigration, as defined above, assumes two requisite conditions: first, that political states have internationally recognized boundaries, and second, that political states have the sovereign right to determine who can cross those boundaries, particularly with the intent to stay. From the late 19th through the mid 20th century, for example, most of the African continent went through a spatial transformation from traditional settlement regions to colonization by European powers to independence with political borders approximating the colonial borders, ultimately imposing the status of “immigrant” to migrants who had maintained migration patterns that predated the borders. The same would be true of the former colonial regions of Asia (see Figure 1). In the Western Hemisphere, “colonists” came from a variety of countries, but new migrants were not considered “immigrants” until after each country gained its independence. Similarly, immigration defined the dominant populations and cultures of Australia and New Zealand.

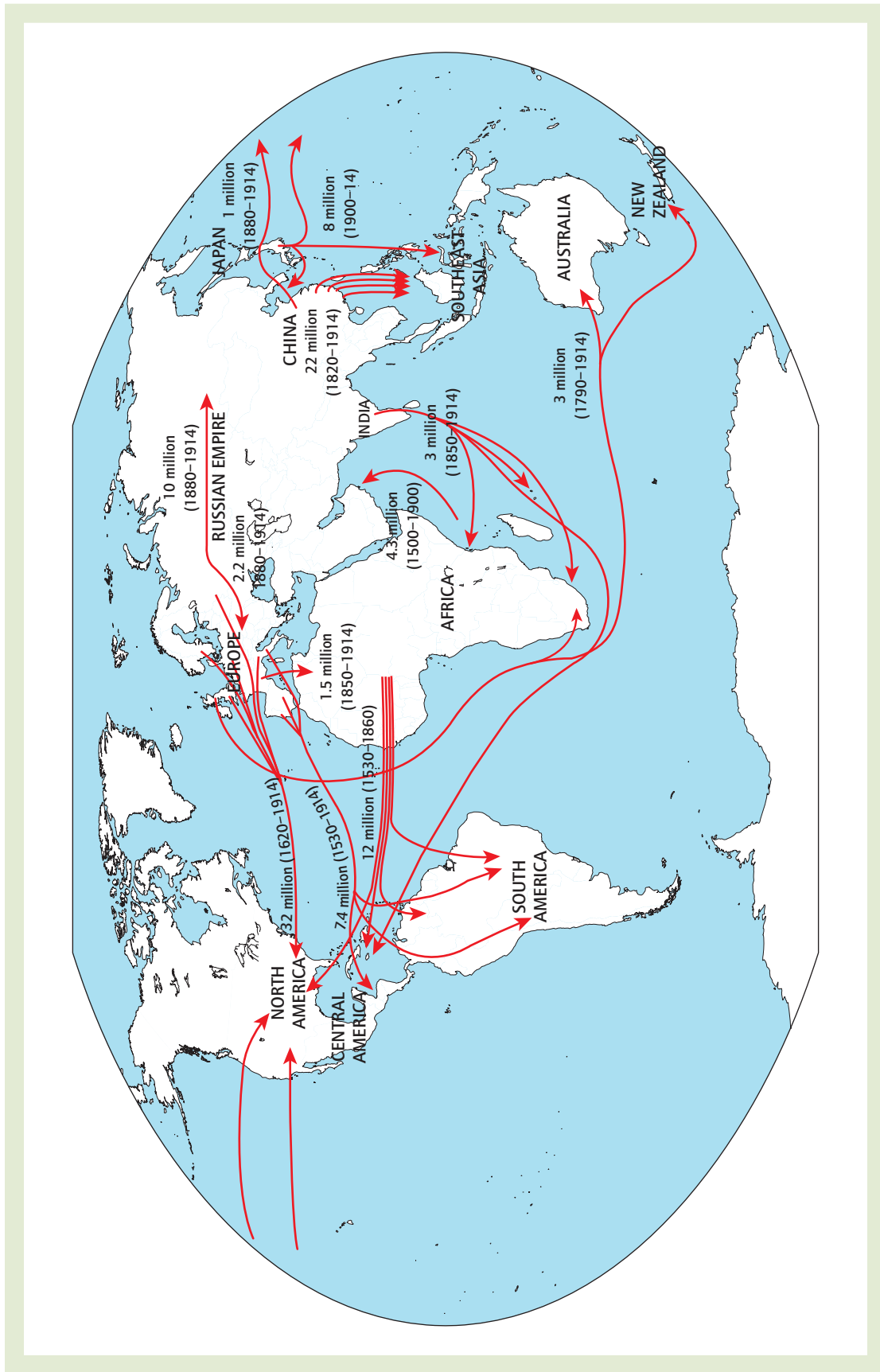


Figure 1 Colonial migrations, 1500–1914, reflect the spatial reconfigurations of populations during centuries of European domination
Source: Based on *Philip's Atlas of World History*, 2005. Map copyright Philip's, a division of Octopus Publishing Group Ltd.



This 1902 photo shows immigrants coming up the boardwalk from the barge, which has taken them off the steamship company's docks and transported them to Ellis Island. The big building in the background is the new hospital just opened. The ferry boat seen in the middle of the picture runs from New York to Ellis Island.

Source: Library of Congress.

A variety of terms are used to refer to immigrants, depending on the context. An *immigrant* enters a country with the intent to stay, whereas the same migrant is an *emigrant* from his or her country of origin. Migrations can be *free*, or *volitional*, whereby the migrants freely make the choice to immigrate to a new country, or they can be *forced*, in that the decision to emigrate is imposed on migrants. This latter situation can encompass a variety of migration contexts. The global slave trade has historically accounted for the largest proportion of forced migrations, but persons displaced by wars and natural disasters account for a growing number of international migrants. In a contemporary context, immigrants are also considered *documented*, having entered *with* the authorization of the host country;

undocumented, having entered *without* such authorization; or *guest workers*, having entered with authorization to work but not to become permanent residents or citizens of the host country. While most countries require some form of authorization or *entry visa* for lawful entry, whether for a shorter period of time as a tourist, a student, or temporary laborer or permanently as an immigrant, some countries also require *exit visas*, or permits for their citizens to leave the country.

As with any migration, immigration involves push and pull factors that fall into three interrelated categories—economic, political, and environmental. The most common reason for immigration is to improve one's economic situation. A migrant goes where he or she hopes to



earn more than what can be earned at home. Such migrants can range from unskilled laborers to educated professionals. Many professionals from developing regions immigrate to developed countries to gain an income commensurate with their education, something that would be less likely in their home countries. Skilled, semi-skilled, and unskilled laborers migrate to fill labor niches created by changes in the economic or demographic structure of the destination country. For example, declining birth rates in European countries have resulted in the recruitment of labor migrants, often categorized as guest workers, to meet labor demands. Historically, Europe was a “migrant-sending” region, but in recent decades, European countries have had to face the need for writing immigration laws and for developing means to incorporate immigrants into their societies.

An economic migrant’s intent to stay may not be permanent. It may be just long enough to achieve an economic goal, such as a better house and economic freedom at home or paying for the education of his or her children. Thus, once the economic goal is achieved, the migrant may choose to return to the community of origin. While this type of “sojourner” international migration is nothing new, contemporary transportation and communication technology have increased the ease with which migrants can remain connected to family members in their community of origin. This allows for the establishment of a *transnational* household, where one or more members of the household lives and works in another country and remits earnings to the home community.

Political migrants leave a situation of war, oppression, persecution, or a well-founded fear of persecution in pursuit of freedom and safety. Since World War II, such migrants are classified either as political refugees or as seeking political asylum. In 1951, the United Nations drafted a definition and protocol for designating such migrants as refugees and for their treatment by countries where they seek asylum. Environmental migrants are displaced by such an extreme environmental disaster that they need to leave their country. An example of this type is the 1995 eruption of the Soufriere Hills volcano in Montserrat, a British overseas territory in the Caribbean,

destroying the capital city of Plymouth and much of the surrounding territory and displacing two thirds of the island’s population.

Countries differ in their laws concerning the incorporation of immigrants as full members of their society. Rights of citizenship can be claimed by *jus sanguinis*, the right of blood, descending from the dominant ethnic group of the country; by *jus soli*, citizenship by birth in that country; or by *naturalization*, the conference of the rights of citizenship to an immigrant who has met the requirements outlined by the host country. As a country built on immigration, the United States passed naturalization laws very early in its history and recognizes *jus soli* for children of immigrants. In recent decades, due to significant increases in immigrants and guest workers, several European countries, including Germany, whose citizenship laws were historically based on *jus sanguinis*, have passed laws allowing immigrants, guest workers, and refugees granted political asylum the right to become citizens. However, there are still many countries worldwide that permit immigrants to enter but have not yet developed a process by which they can become citizens.

Ines M. Miyares

See also **Citizenship; Migration; Population Geography; Refugees; Transnationalism**

Further Readings

- Castles, S., & Miller, M. (2003). *The age of migration* (3rd ed.). New York: Guilford Press.
- Miyares, I., & Airriess, C. (2007). *Contemporary ethnic geographies in America*. Lanham, MD: Rowman & Littlefield.



IMPERIALISM

Imperialism is the process of forcibly expanding state authority over autonomous foreign territory by means of military conquest. More broadly, imperialism is the complex of practices through which one population establishes and maintains



instrumental control over the spaces, resources, and everyday lives of another. Imperialism is also the ideology through which a population is persuaded to support its domination of another and persuades that other to accept such domination.

There is no single and authoritative definition of empire, and it could even be claimed that any attempt to assert such a definition would itself be an imperializing act. Despite this, differing conceptions of imperialism and its root cognate—empire—do converge on certain principal geopolitical characteristics. Most broadly, imperialism entails the usurpation by an alien power of another's territorial autarchy. This usurpation commonly takes the form of conquest by force, albeit to varying degrees depending on the place and time. The specifics of alien rule are highly contingent on the cultural practices and material needs of both the rulers and those they rule, yielding multiple, varied, and complex “imperial regimes of rule.” One very general illustration of this would be the predilection of European empires for acquiring territory, as contrasted with southeast Asian empires' focus on the capture and mass relocation of populations. Furthermore, within the European empires there are significant differences between those beholden to monarchical versus republican models of internal governance or between those established chiefly through state military exercises versus those outsourced to private adventurers and mercantile enterprises.

Variations notwithstanding, imperialism can be understood through the world-systems concept of intertwined core and periphery regions, according to which global wealth is concentrated in core countries, while countries in the periphery (such as most of those in the global South today) do not benefit from this wealth. Core regions, and their metropolitan centers in particular, are greatly enriched through the expropriation of wealth from subjugated peripheries. It may even be argued that this asymmetrical core-periphery relationship is the central dynamic of imperialism through which empires are formed, expanded, and maintained by means of forcible exploitation of ever more distant markets and labor forces. It is also debatable, however, whether this explanation is as readily applicable to empires based outside Western Europe during the latter half of the second millennium.

In its constitution of sharply differentiated and dependent core-periphery relations, imperialism is inextricably conjoined with colonialism. The tightness with which the two are coupled, however, is again highly variable and open to debate. Most narrowly defined, and hearkening back to classical Greek city-states and the agricultural *coloniae* of Imperial Rome, a colony is an imperial possession established on empty (or, more commonly, forcibly emptied) peripheral territory that is occupied by settlers from the core and subject to a more or less direct imperial rule from the core's metropolitan center. This definition, however, tends to underemphasize other, equally significant types of imperial territorial possessions in which preexisting populations are too sizable or well entrenched to be removed prior to resettlement. Such possessions tend instead to be administered by co-opted indigenous intermediaries overseen by functionaries imported from the imperial core, commonly with the intent of gradually absorbing the conquered population into the empire. Furthermore, the diverse spatial manifestations of different empires complicate the definition and identification of colonies. In the case of dispersed empires predicated on a distinct homeland and far-flung conquests, imperial possessions can be more plainly evident as colonies by virtue of their territorial discontinuity. But such recognition can be much more equivocal in the case of peripheral territories held by contiguous empires characterized not by detached possessions but by successive waves of accretive growth just over their own frontiers. Finally, imperialism in practice includes both the resettlement of some core personnel within all its subordinated peripheries and, barring out-and-out genocide, the continued exploitation of expunged populations. Thus, while colonization through dispossession is inherently an on-the-ground practice of imperialism, it is not a necessary one—imperial standing does not depend on possession of colonies in the strictest, narrowly defined sense of the term. Rather, empires deploy in varied combinations a spectrum of colonizing practices that range from the most direct forms of military occupation to more subtle insinuations of hegemonic influence, all inflected by local conditions in targeted peripheries and attenuated by the exercise of foreign rule over increasing distances.



Imperialism thus entails that ever more distant and distinct peoples will be subsumed within the boundaries of any given empire. Over time, this process tacitly encourages migration to the metropolitan cores and across the empire along the same routes initially established to logistically expedite peripheral occupation and extraction. Therefore, over the course of their developmental trajectories, all empires become inherently multicultural. As an ideology, imperialism facilitates social cohesion and continued expansion under such conditions. Working through media such as religious artifacts and their allied rituals, literary and topical communications, popular entertainments, and public commemorations, the ideology of imperialism effects a colonization of the mind whereby empire building is valorized and the conquered are given incentive to embrace, and even try to pass as, their conquerors. Thus, even empires without clearly determinable colonies strive to colonize the most intimate terrain, that is, their subjects' psyches. The inclusivity of imperial multiculturalism, however, is also heavily disciplined by the state's differential and strategically selective extension of suffrage rights. A strong incentive to adopt the cultural practices of, and even identify with, the imperial core is therefore frustrated by the establishment of elaborate social hierarchies that restrict the extent to which different subject peoples may assimilate into imperial society. Some peoples may never be permitted to rise any higher than the rank of the subaltern, whereas others may be regarded as too alien to rise at all no matter how well they mask themselves in the likeness of the conqueror.

The capacity of imperialism to establish and promulgate cultural hegemony, while delimiting who is considered fit to participate and to what degree in that hegemony, operates not just within empires but between them as well. By way of example, the military, economic, legal, infrastructural, architectural, and even sartorial reforms instituted in times and places as far apart as tsarist Russia, Rama V's Siam, the Ottoman Empire, or late-19th-century Japan all reveal a consistent propensity among the then-waning and aspirant empires alike: self-conscious emulation of the practices of Western Europe's rising imperial powers, as much to stave off being conquered by those powers as to pass as one and reap similar

rewards. Imperial triumphs thus work both to absorb populations internal to empires and to entrain external populations far beyond the territory of the empire and its prospective conquests.

In its expansive influence, imperialism produces a global space divided into a ranked order of triumphal cores with peripheral dependencies. Furthermore, it simultaneously projects this mapping onto time. The peripheral is discursively conflated with the traditional and the backward and denigrated in juxtaposition with the core's presumptive forward-looking modernity. The everyday life practices of people in the peripheries thus become holdovers of a mythologized past, and imperialism takes penultimate form as civilization's solemn duty to progressively eradicate primordial savagery for the alleged good of the conqueror and the conquered alike. This is not the case for all times and places—empires founded by nomadic pastoralists like the Mongols or Osmanli Turks, for instance, tended to see empire less as a base for the export of civilization than a crossroad at which civilizations might best be collected and cherry-picked. But as a guiding geopolitical dynamic of the latter half of the second millennium, especially its terminal two centuries, imperialism colonized space itself and, through it, both time and consciousness. Indeed, treatises from the late 19th and early 20th centuries go so far as to assume tacitly "the empire" as a natural increment of geographical scale, situated firmly and irremovably between "the nation" and "the world."

Of course, it has been proven empirically over time that the empire is far less an inevitable and inextricable scalar metric than had been previously assumed. Every empire to date has succumbed to imperial overreach, the invariably fatal penchant for conquering more territory than can be ultimately held. And over the course of two World Wars and a prolonged, lingering third (the "Third World" War, as Mexico's Zapatista insurgents christened the Cold War), the larger global system of *de jure* imperialism itself suffered similar collapse. Extant empires ripped one another apart, all the while attempting to salvage themselves as repackaged commonwealths and coprosperity spheres. Concurrent with this process, subjugated peoples took up the task of liberating themselves as newly minted nations, more often than not following



the prescription to vomit up the colonizer—and by means of violence, if necessary. Ironically, such programs of national liberation were often aided and abetted, or even sown outright, by adjacent empires seeking to deploy nationality as a tool for destabilizing their competition.

It can be argued that in a decolonized and nationally reformulated global arena, blunt projections of imperial power can no longer be legitimized. Rather, a different sort of domination is necessary, one attained through the enactment of “soft power” that persuades others to cooperate willingly with a hegemon’s agenda. Past empires, however, have been no strangers to persuasion, to indirect rule, and to the dissemination of beliefs that domination will serve the best interests of the dominated. Nor does hegemonic soft power remain so soft—current hegemonies have demonstrated a growing propensity to assert “unipolar preponderance” through massive shows of force against uncooperative foreign states. Hegemonic soft power, then, may be less a kinder, gentler new technique for dominance in a more polite postcolonial age than a temporary shift of emphasis within an arsenal of previously well-established imperial practices. This suspicion, in turn, has resulted in a growing body of literature examining the imperialist characteristics of self-declaredly nonimperialist, or even anti-imperialist, state formations such as the Union of Soviet Socialist Republics, the United States of America, the European Union, or the People’s Republic of China. More radically, it has been claimed that empire has taken on a new and largely despatialized form, enacted via globally diffuse networks of electronically linked state functionaries, business elites, and conjoined transnational institutions such as the World Trade Organization and the World Bank. Such claims for aspatiality, however, must contend with the persistent financial, technological, mass-cultural, and military preeminence of core regions and their long-established metropolitan centers in configurations substantially similar to those of a century ago. Empires do indeed rise and fall, but imperialism continues to prove far more durable in its self-servingly opportunistic ordering of space, time, and consciousness.

Imperialism, then, is something that must be defined multiply and flexibly (although not so

open-endedly that, in its pervasiveness, it ends up meaning both everything and nothing). It is the more or less involuntary absorption of populations under expanding alien rule, the continued domination at a distance of the spaces and conditions of other’s everyday lives, the extraction and exportation of material resources from subjugated peripheries to conquering cores, and the means through which these programs are legitimized. Imperialism is all these things in varying and complex articulations, at different times and in different places, the here and now included.

Steven Flusty

See also **Antiglobalization; Colonialism; Decolonization; Geopolitics; Neocolonialism; Neoliberalism; Orientalism; Race and Empire; Resistance, Geographies of; World-Systems Theory**

Further Readings

- Agnew, J. (2005). *Hegemony: The new shape of global power*. Philadelphia: Temple University Press.
- Bell, M., Butlin, R., & Heffernan, M. (Eds.). (1995). *Geography and imperialism 1820–1940*. Manchester, UK: Manchester University Press.
- Fanon, F. (2008). *Black skin white masks*. New York: Grove Press. (Original work published 1952)
- Ferguson, N. (2005). *Colossus: The rise and fall of the American empire*. New York: Penguin.
- Gregory, D. (2004). *The colonial present: Afghanistan, Palestine, Iraq*. Hoboken, NJ: Wiley-Blackwell.
- Hardt, M., & Negri, A. (2000). *Empire*. Cambridge, MA: Harvard University Press.
- Zielonka, J. (2006). *Europe as empire: The nature of the enlarged European Union*. Oxford, UK: Oxford University Press.



IMPERMEABLE SURFACES

Impermeable surfaces come in two types: (1) anthropogenic ones and (2) those produced by natural processes. When most people use this term, they are especially concerned with the



anthropogenic types of impermeable surfaces that inhibit or prevent ready infiltration of water into the substrate, with the result that the volumes and velocities of overland flow of water increase and floods result.

Urbanization of watersheds commonly increases production of impermeable surfaces through the introduction of buildings, roads, paved parking lots, and various asphalt construction layers. Where impermeable surfaces are introduced into a watershed, especially if they are formed in later times after bridges and other structures have already been built downstream, there is then an increased propensity for even larger flash floods downstream, which the older bridges will not handle. This increased “flashiness,” as the result of construction of new impermeable surfaces upstream, often goes unrecognized in flood-control construction because the surfaces are spatially and temporally scattered. A further problem resulting from construction of impermeable surfaces is the increased pollution of nearby rivers, lakes, bays, and estuaries. The newly accelerated or channelized overland flow carries with it much of the animal and human wastes that would normally be spread more slowly into the soil and thereby degraded in the processes of infiltration. In some places, the introduction of concrete paving stones or brick and cobblestone pavers makes it somewhat more permeable and allows greater infiltration because of the common introduction of sand in the joints between the blocks, although they still provide the desired firm surface for bearing traffic.

Natural varieties of impermeable surfaces are certain forms of eroded or bare bedrock that is relatively unfractured, which thereby prevents water infiltration. While many kinds of lava flows are fairly impermeable when they are first extruded, later cooling can result in fractures that do allow some water to infiltrate into them. An unusual group of impermeable surfaces that can be entirely natural but that are commonly exacerbated or accelerated by humans, are the various kinds of duricrusts (hard, thin layers on the surface of the soil) that form in different climatic regimes. In the humid tropics, natural subsoil accumulations of iron and aluminum sesquioxides form in the subsoil from long-term weathering of bedrock into soft, clay-rich saprolites that can be

subsequently exposed by natural or human-caused soil erosion and hardened into rigid ferruginous (iron, silica, aluminum) crusts. Those lateritic duricrusts that become exposed on the surface can be quite impermeable and commonly resemble a thick and even shiny layer of iron (iron shield or cuirasse) on the ground. In more arid regions, the cementation can be rich in calcium carbonate so that impermeable calcrete or caliche crusts and caprocks result. Where precipitated from a lake that has dried up through climate change, as has happened at the Great Salt Lake and Bonneville Salt Flats in Utah or Death Valley in California, the high concentration of salt in the evaporating waters can result in an impermeable layer of rock salt (salcrete) or gypsum (gypcrete) on the surface. In arid parts of Australia, silcretes bearing opal are relatively impermeable concentrations of long-term weathering and siliceous cementation.

John F. Shroder

See also Flash Floods; Floods; Nonpoint Sources of Pollution

Further Readings

- Raphael, M., Feddema, J., Orme, A. J., & Orme, A. R. (1994). The unusual storms of February 1992 in Southern California. *Physical Geography*, 15, 442–464.
- Schick, A., Grodek, T., & Wolman, M. (1999). Hydrologic processes and geomorphic constraints on urbanization of alluvial fan slopes. *Geomorphology*, 31, 325–335.

IMPORT SUBSTITUTION INDUSTRIALIZATION

Import substitution industrialization (ISI) is an approach to national development based on the notion that conditions in the developing world vary markedly from conditions in the developed world. In an attempt to reconcile some of these



differences, ISI relies on strong state intervention to protect developing industries from competition with foreign firms. This protection is most commonly in the form of high tariffs on imported goods. After the initial period of protection, the state then is supposed to remove protections to allow the now established industries to compete with foreign firms. The result of a successful implementation of ISI should be the development of national value-added industries. These industries in turn lead to a reduction in the country's dependence on foreign markets, which is symptomatic of economies based on the export of raw goods. ISI was most popular between the 1930s and the 1980s in Latin America, though some countries in Asia and Africa also adopted it in the 1950s.

Theoretical Roots and Background

ISI is partially based on the idea of the "infant industry" put forth by Friedrich List, a 19th-century German economist. List argued that, contrary to what free-market proponents such as Adam Smith and his followers were saying, state intervention was needed in less developed countries to protect their fledgling industries from competition with much further developed industries from other countries such as Britain. Once the infant firms had caught up with the mature foreign firms, they could then participate in unregulated competition in the world market. List's ideas represented an important departure from the neoclassical model of economic development. They have influenced and continue to influence several popular state-led development models since the 19th century, including ISI. Another important influence for ISI is the Singer-Prebisch thesis, which calls for a move away from exporting raw materials and toward exporting value-added goods to improve a country's position in the global market.

Both the infant industry model (IIM) and ISI, two of the main development models based on the ideas of List, have in common an emphasis on developing human capital and local markets and an initial reliance on capital raised by the state to start an industry. However, they have two important differences. First, the IIM favors selective protection of industries most likely to succeed,

while ISI calls for indiscriminate protection of local industries. Second, IIM favors building export industries, while ISI often relies on industries that will satisfy local demand.

ISI in Practice

Application of ISI in practice began in Latin America in the 1930s, during the Great Depression. The global market for primary goods from Latin America plummeted as a result of the Depression, and later, as a result of the outbreak of World War II. Without a market for their primary goods, Latin American countries were unable to import manufactured goods and realized that they would need to develop their own industries to satisfy local demand. They began to build their industries by focusing on domestic markets and regional trading rather than on the volatile world market. Evidence of increasing state involvement in industry at this time can be seen, for example, in the nationalization of foreign-owned railways and oil companies in Mexico. Further development and support of the ISI approach came from the structuralist ideas underlying the United Nations Economic Commission for Latin America (ECLA). Some of the key proponents and theorists for this approach included ECLA Executive Secretary Raúl Prebisch and the Brazilian economist Celso Furtado.

ISI-based policies enjoyed their greatest popularity in Latin America during the 1960s and 1970s in spite of already obvious problems related to balance of payments deficits from the heavy borrowing involved in ISI policies. Evidence of these policies include the popularity of trading blocs in Latin America to protect and promote regional trade on more favorable terms than trade on the world market. These trading blocs were thought to be necessary for many of the smaller Latin American countries to have access to sufficiently large markets for their goods.

In 1960, Costa Rica, Guatemala, and Nicaragua created the Central American Common Market (CACM) to promote development of industries in Central America. Under this agreement, consumer goods were the most highly taxed because these goods were the focus of ISI policies for promoting domestic production in these countries. All goods entering the CACM zone were taxed at



the same rate on entry under a common tariff barrier, and some goods, including many industrial ones, were traded tariff-free within the CACM zone. The Latin American Free Trade Association, founded in the 1960s and now known as the Latin American Integration Association, is another example of these trading blocs.

Other evidence of ISI at work in Latin America at this time includes massive state-funded infrastructure projects in Brazil, Argentina, and Mexico, meant to catapult these countries into the realm of highly developed countries. Unfortunately, the capital for these projects came from loans, and as oil prices increased and raw material prices decreased, balance of payments deficits in many Latin American countries grew. The global recession in the 1970s and early 1980s caused interest rates to increase and brought to a halt many of these state-funded development projects and ultimately led to abandonment of many ISI development strategies in Latin America.

Notable examples of ISI in practice in countries outside Latin America include South Korea, Taiwan, India, and China. Many countries outside Latin America that adopted ISI deemphasized the inward-looking elements of ISI and instead focused on maintaining high tariff barriers while protecting and promoting export industries such as steel and petrochemicals.

Results of the ISI Approach

The major advantages of ISI approaches include promotion of domestic employment in higher-skilled jobs; shorter travel distances for goods from their place of production to their place of consumption, resulting in reduced fuel consumption and pollution; and the possibility for countries to resist the impact of global economic shocks on national economies by limiting their dependence on global markets. The success of ISI in achieving these advantages differed with each situation, and it is difficult to think of one country that truly achieved success following an ISI approach to development. India and China are often cited as examples of successful ISI implementation, but India's record of growth under ISI was only mediocre and China's rapid economic growth started after it began liberalizing its markets in the late 1970s. In Latin America, ISI has

been declared both a success and a failure. For example, Brazil and Mexico's levels of economic growth were relatively high between 1950 and 1980 when ISI approaches were still in use, but their national production remained much smaller than that of either Britain or the United States.

Lisa Rausch

See also **Dependency Theory; Development Theory; Export-Led Development; Industrialization; Trade; Underdevelopment; World-Systems Theory**

Further Readings

- Rapley, J. (2002). *Understanding development: Theory and practice in the Third World* (2nd ed.). Boulder, CO: Lynne Rienner.
- Ward, J. (1997). *Latin America: Development and conflict since 1945*. London: Routledge.
- Willis, K. (2005). *Theories and practices of development*. London: Routledge.



INCUBATOR ZONES

Incubator zones are designed to encourage entrepreneurship by providing business support services and technical assistance. They primarily cater to start-up businesses or other businesses that are not well established. The exact services that are provided by incubator zones vary, but they generally provide a variety of business support services. Businesses are generally required to apply in order to become part of an incubator program. Acceptance is based on a variety of factors, including the nature of the business and the quality of the potential entrepreneur's business plan.

History of Incubator Zones

According to the National Business Incubation Association, the first incubator zone in the United States was the Batavia Industrial Center. It opened in 1959 in Batavia, New York. By the late 1970s, incubator zones became more common in the



United States, especially in the Northeast, where they were seen as a means to help bring about the revitalization of communities that had been hit hard by deindustrialization. The growth of incubator zones accelerated rapidly in the 1980s as many communities recognized the value of promoting small-business development as a means of promoting economic growth. Incubator zones have spread throughout the world. The National Business Incubation Association estimates that there are currently about 5,000 incubator zones around the world.

The U.S. Small Business Administration promoted the development of incubator zones in the mid 1980s. The Small Business Administration held several conferences and published several handbooks and a newsletter. Another important development in the growth of incubator zones in the United States was the creation, in 1982, by the Pennsylvania Legislature of the Ben Franklin Partnership Program, one of the first comprehensive manufacturing and technology agendas in the United States. Incubator zones were a key component of this program, which serves as a model for other programs around the United States.

Services Provided by Incubator Zones

The length of time that a business spends in an incubator zone varies, depending on a number of factors, including the nature of the business and the entrepreneur's level of business acumen. In industries, such as biotechnology, that have relatively long research and development cycles, companies generally require more time in an incubator zone than service or manufacturing companies that can bring a product or service to market in a relatively short time. On average, companies spend a little less than 3 yrs. (years) in an incubator zone. Most incubator programs set benchmarks, such as staffing levels or revenues, to determine when companies are ready to leave an incubator zone.

Incubator zones provide a variety of services to start-up companies, but some of the most common services that they provide are management guidance, technical assistance, and consulting services. Many incubator zones provide additional resources, including access to suitable rental

space, flexible lease terms, shared services, and assistance in securing the financing necessary to allow a company to grow.

Many incubator zones in the United States are affiliated with the National Business Incubation Association, a nonprofit organization whose primary mission is to provide training and to serve as a source of information on incubator management and tools to assist start-up businesses. In addition, the National Business Incubation Association conducts research, compiles statistical data, produces publications to disseminate best practices, and tracks relevant legislation.

Role of Incubator Zones in Economic Development

Incubator zones are sponsored by a variety of entities, including national or regional government, colleges, and universities, while others are private entities. They cater to a variety of industrial sectors, including technology, professional services, manufacturing, food processing, biotechnology, health care, the media, the arts, and fashion. Incubator zones are often part of a wider economic development strategy. Incubator zones provide a variety of economic and socioeconomic benefits, including creating new jobs and wealth, enhancing the entrepreneurial climate of a community, diversifying the local economy, accelerating the growth of industry, encouraging business ownership by women and minorities, helping to bring about community revitalization, and facilitating the transfer of knowledge from universities and large corporations. Incubator zones are created in a variety of settings, from rural areas to inner cities. Some examples of communities in the United States with incubator zones include Birmingham, Alabama; Columbus, Ohio; Troy, New York; Philadelphia; San Jose, California; and Atlanta. Incubator zones are found in many countries around the world, including Australia, China, Israel, South Korea, and the United Kingdom.

In addition to playing an important role in promoting economic development, incubator zones can play a particularly important role in helping research scientists bring potential new products to market. Most researchers lack significant business knowledge, and unfortunately that lack of



knowledge can prevent potentially significant new products from ever making it to the market. Incubator zones can help bridge this knowledge gap, making it possible to transform innovative ideas into marketable products.

Jared Wouters

See also Agglomeration Economies; Economic Geography; Industrial Districts; Innovation, Geography of; Learning Regions; Regional Economic Development; Technological Change, Geography of

Further Readings

- Falcone, T., & Wilson, T. (2008). A proactive culture of support. *Competitiveness Review*, 18(3), 241–256.
- Kim, H., & Ames, M. (2006). Business incubators as economic development tools: Rethinking models based on the Korea experience. *International Journal of Technology Management*, 33(1), 1–24.
- McGowan, P., van der Sijde, P., & Kirby, D. (2008). The role of universities in the entrepreneurship industry: Promoting the entrepreneurship agenda in HEIs. *Industry & Higher Education*, 22(1), 49–59.
- National Business Incubation Association. (n.d.). *The history of business incubation*. Retrieved October 6, 2009, from www.nbia.org/resource_library/history
- National Business Incubation Association. (n.d.). *What is business incubation?* Retrieved October 6, 2009, from www.nbia.org/resource_library/what_is



INDIGENEITY

Developed over the past two decades, the term *indigeneity* has developed out of the contemporary global indigenous peoples' movement. The term describes this evolving pan-indigenous movement and corresponding identity among peoples who, despite often considerable cultural divergence, share significant symmetries that have evolved from the common experiences of

European colonialism. These similarities are founded in an ancestral birthright in the land, a common core of collective interests, and the shared experience of dispossession precipitated through the colonial projects perpetrated against their communities by colonial and neocolonial state administrations. The term is used not only to support the rights of indigenous peoples but also to recognize indigenous ways of knowing and the ethical codes evolved over thousands of years by indigenous communities.

Origin and Development of the Indigenous Peoples' Movement

The history of the indigenous peoples' movement is traced by many to the 1923 appeal by Deskaheh to the League of Nations on behalf of the Six Nations of the Iroquois Confederacy. Deskaheh, a traditional leader of the Cayuga, sought the support of the League in his claims against the Canadian government, who were imposing a tribal council system of administration on the Six Nations Grand River reserve. Despite his failure to address his petition, "The Redman's Appeal for Justice," before the League, Deskaheh did succeed in presenting his case before several ambassadors with the assistance of the mayor of Geneva and convinced these ambassadors to address these concerns directly with the Canadian government. Unfortunately, while he was in Geneva, the Canadian government succeeded in forcing a "democratically elected" government on the Six Nations reserve, and subsequently, Deskaheh lost his mandate.

Despite Deskaheh's failure to have his nation recognized by and their case heard before the League, the recognition of the unique political status of indigenous peoples has nonetheless slowly developed in the international community for over the past 80 yrs. (years). The first significant recognition of the need for protecting indigenous peoples' rights against the encompassing domination of state governments came in 1957, when the International Labour Organization (ILO) issued its "Indigenous and Tribal Populations Convention," later updated in 1989 by a more strongly worded convention. Through these conventions, the ILO set in motion an evolving international legal framework that not only



recognizes the status of indigenous peoples as a unique category within international law but also recognizes that indigenous peoples require protection from the continuing colonial and neocolonial projects of state governments.

Following in the footsteps of the ILO, the United Nations (UN) began in 1982 to investigate the demands made by indigenous peoples for attention to their unique status within the international state system. While the UN had adamantly affirmed the sovereign rights of peoples colonized by European powers throughout Africa, Asia, and the Pacific to decolonization and self-determination through the “Declaration on the Granting of Independence to Colonial Countries and Peoples of 1960,” the organization had made no move toward addressing the situation of peoples whose lands had been subsumed into settler states, predominately in the Americas and the South Pacific, or those peoples who remained disenfranchised minorities within the newly decolonized states of Africa and Asia. Beginning with the Martinez-Cobo study in 1983, the UN started down a path whose ultimate outcome has been the recognition of indigenous peoples’ self-determining rights within an organizational structure that had previously failed to acknowledge any self-determining authority other than through internationally recognized states. Following the recommendation of the Martinez-Cobo study, the UN created the Working Group on Indigenous People under the Office of the UN High Commissioner on Human Rights. The primary aims of this working group were twofold: first, to create a permanent forum for indigenous peoples within the UN system and, second, to draft a Declaration on Indigenous Peoples Rights with the hope that this instrument would provide the next step in further defining the evolving international legal framework for indigenous peoples’ rights. With the creation of the UN Permanent Forum on Indigenous Issues in 2000 and the approval by the UN General Assembly of the Declaration on Indigenous Peoples’ Rights in 2007, the international indigenous peoples’ movement has entered a new era.

Definition and Goals

The issue of defining which groups of peoples can and cannot be considered indigenous has been

and continues to be a significant challenge for international fora. While the definitions created by a range of organizations and authors have varied, sometimes significantly over the past 50 yrs., recently a broad consensus has formed within the international political community. Four core principles have been agreed on in defining indigenous peoples: First, they generally live within, or maintain attachments to, geographically distinct territories; second, they tend to maintain distinct social, economic, and political institutions within their territories; third, they typically aspire to remain distinct culturally, geographically, and institutionally rather than assimilate fully into national society; and, fourth, they self-identify as indigenous or tribal. Central to the issue of definition is self-identification as an indigenous people.

It is within the political arena that indigenous peoples are voicing their sociopolitical, cultural, and economic aims. These political aims are significantly similar across the breadth of the global indigenous peoples’ movement. They are founded on securing a land base, protecting and controlling the natural resources of that land base, attaining a degree of political and legal authority over those territories, and securing the right to speak and maintain their ancestral languages, with freedom of cultural and religious expression.

While the political community has begun to close the definitional boundaries around specific groups, clearly defining particular groups as indigenous peoples while excluding others, the academic community continues to openly debate indigeneity. In an effort to achieve their political aims, indigenous peoples have, as have other groups struggling for the recognition of human rights, employed strategic essentialism. Unfortunately, the strategic performance of an essentialized cultural identity to secure political ends is a means that leaves the academic community, and many nonacademics, confused and troubled. Since 2003, an extensive debate concerning the indigenous peoples’ movement and the appropriateness of defining any group of people as indigenous has been held within the pages of *Current Anthropology* and other journals. Central to this argument has been the claim by groups of people who self-identify as indigenous to be the “first peoples” or “first nations” of particular territories. Current anthropological and archaeological thought holds



that *Homo sapiens sapiens* first evolved in Eastern Africa and migrated out to populate the planet beginning around 100,000 yrs. ago. Since most peoples are migrants to the landmasses in which they currently live, whether this migration occurred 50,000 or 200 yrs. ago, some argue that no group can claim indigeneity. Others argue that the impact of colonial contact has transformed nearly every human culture to the point that no group can claim an “authentic” indigenous identity. These arguments ignore or gloss over the realities of European colonialism, which created the first global world order and brought the cultural, political, and economic imperatives of Europe to every corner of the world. They also ignore the devastating effect of disease, warfare, and colonial “civilizing” projects on indigenous populations. Dealing with the political, moral, and ethical ramifications this colonization has wrought on the planet has been the work of international fora representing indigenous peoples over the past 80 yrs. The demands brought by indigenous peoples for a just reconciliation of the ongoing impacts of colonization are the central political aim of the international indigenous rights movement.

Jay T. Johnson

See also **Indigenous Agriculture; Indigenous Cartographies; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Forestry; Indigenous Reserves; Indigenous Water Management**

Further Readings

- Cadena, M., & Starn, O. (2007). *Indigenous experience today*. Oxford, UK: Berg.
- Cornthassel, J. (2003). Who is indigenous? “Peoplehood” and ethnonationalist approaches to rearticulating indigenous identity. *Nationalism & Ethnic Politics*, 9(1), 75–100.
- Johnson, J., Cant, G., Howitt, R., & Peters, E. (2007). Creating anti-colonial geographies: Embracing indigenous peoples’ knowledges and rights. *Geographical Research*, 45(2), 117–120.
- Shaw, W., Herman, R., & Dobbs, G. (2006). Encountering indigeneity: Re-imagining and decolonizing geography. *Geografiska Annaler B: Human Geography*, 88(3), 267–276.

INDIGENOUS AGRICULTURE

Indigenous agriculture encompasses agricultural practices and techniques that are unique to a given culture and society and has evolved from place-bound tradition. In practice, it is often more diverse, complex, and risk-prone than both industrialized and green revolution agriculture. The concept may refer to the agricultural practices of groups that claim status as indigenous people, but it is not usually so restricted. While farmers often experiment and innovate, the invention of new agricultural implements and the domestication of new cultivars are not very common occurrences, and successful innovations are often diffused widely. “Indigenous” may thus refer more to local control over knowledge and technology than to origin. The debate on the virtues and relevance of indigenous agriculture focuses on the developing world and is related to a wider debate on indigenous knowledge and its relevance in development. There is also a question of how indigenous agriculture, which has not been the focus of science-based advances in agriculture, can be best assisted. Furthermore, there is considerable interest in indigenous agriculture as a basis for an alternative development that is environmentally sound, less dependent on external input, and locally controlled. While research has documented a range of practices and techniques, differing views on indigenous agriculture persist among scientists and peasant groups.

Under the dominant modernization paradigm, smallholder agricultural practice in the tropics is seen as traditional and static. Today, the objective is to transform or replace the practice of resource-poor “traditional agriculture” with “modern agriculture” through standardized green revolution packages of monoculture, including hybrid seed, agrochemicals, mechanization, and irrigation. In the transformation approach, this dichotomy is emphasized, and tradition in agriculture is seen mainly as a problem to be overcome through technology transfer. Resource poverty, and the lack of capital investment and inputs, leads to poor efficiency in agriculture, and the lack of innovation is seen as a key problem. The Green Revolution from the 1960s onward has led to substantial increases in the output of



Locals water beds as they implement new farming methods near Andranolava, Madagascar, on December 14, 2007. Much of the land on the edge of the rain forests has been ruined through slash-and-burn agriculture techniques.

Source: AP Photo/Joana Coutinho, Mantadia Corridor Restoration and Conservation Project.

rice and wheat, for instance, in India. However, criticisms have focused on environmental sustainability, resilience, increased dependence on inputs, and social impacts. The focus on increasing yield per acre for a few selected crops has resulted in significantly less research being carried out on other crops and on more complex and diverse farming systems.

An alternative outlook emerged in the 1980s, when indigenous agriculture was viewed more as an underused resource and less as an obstacle to rural development. Inspiration was drawn from cultural ecology and from agrarian populism. Paul Richards, drawing on research in West Africa, argued that cultivators' reluctance to

adopt modern scientific advice should not be viewed as a stubborn refusal to change but rather as an unwillingness to accept inappropriate methods. He argued that while technology transfer through dramatic modernization had a poor track record in the region, the most successful innovations in food crop production had indigenous roots. In cases where he found that scientific advice had often failed and peasant farmers were often successful, this was explained through a positive, inquisitive, and experimental approach on the part of the indigenous peasant rather than through an unchanging inherited knowledge base. The peasants were better able to estimate the simultaneous effect of several variables and



to adopt and adapt technology selectively. D. Michael Warren, David Brokensha, and other researchers have sought to document and disseminate indigenous knowledge in agriculture as taxonomies, techniques, and farmers' innovations in order to mobilize an underused resource in development. Under the "farmer first" paradigm, Robert Chambers and colleagues called for increased learning from smallholder practice in diverse and risk-prone resource-poor agriculture and a more creative interaction between scientists and farmers in the development of agriculture. This approach would involve a reversal of the learning process inherent in technology transfer to better serve the needs of complex, risk-prone, and diverse farming systems.

Indigenous agricultural practices may be extensive or intensive. An example of extensive cultivation is swidden cultivation, which relies on long fallow periods to regenerate soil nutrients. The practice can be efficient, but shortening cultivation intervals in response to population growth can be destructive. Intercropping or relay cropping with cereal, leguminous, and other crops is used as an alternative to crop rotation in arable cultivation. Examples of intensive methods include rainwater harvesting, which can reduce risk and increase productivity in semiarid environments. Furthermore, indigenous irrigation may include stream diversion, storage, and horizontal wells tapping into aquifers (*quanat*), as well as more flexible strategies of flood cultivation in wetlands and spate irrigation, which relies on ephemeral streams. Another intensive practice is agroforestry; the integration of field crops with livestock and also trees for shade, mulch, and additional produce. Specific intensive field techniques exist, such as the raised field cultivation in wetlands in the area around Lake Titicaca in South America. One research objective relating to "indigenous agricultural knowledge" is to document, develop or rehabilitate, and disseminate such practices.

Anthony Bebbington argues that the emphasis on indigenous agricultural knowledge may be seen as voluntarist, ignoring how the state, the economy, and wider systems of social relationships affect peasant agency. He has described how indigenous farmers and their peasant organizations in Ecuador have sought to abandon organic farming

and instead modernize production through, among other means, the increased use of agrochemical inputs in order to sustain their Indian identity and rural way of life. Thus, resistance to the modernization of indigenous agriculture is not necessarily a preferred strategy of indigenous people and other peasant communities.

Mattias Tagseth

See also Agriculture, Preindustrial; Agroforestry; Bush Fallow Farming; Indigeneity; Indigenous and Community Conserved Areas; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Forestry; Indigenous Reserves; Indigenous Water Management; Nomadism; Peasants, Peasantry; Shifting Cultivation

Further Readings

- Bebbington, A. (1994). Theory and relevance in indigenous agriculture: Knowledge, agency and organization. In D. Booth (Ed.), *Rethinking social development: Theory, research and practice* (pp. 202–225). Essex, UK: Longman Scientific and Technical.
- Chambers, R., Pacey, A., & Thrupp, L. (Eds.). (1989). *Farmer first: Farmer innovation and agricultural research*. London: Intermediate Technology.
- Richards, P. (1985). *Indigenous agricultural revolution: Ecology and food production in West Africa*. London: Hutchinson.

INDIGENOUS AND COMMUNITY CONSERVED AREAS

Indigenous and community conserved areas (ICCAs) are natural and/or modified ecosystems containing significant biodiversity values, ecological services, and cultural values. ICCAs are voluntarily conserved by indigenous peoples and local communities (both sedentary and mobile), through customary laws or other effective means. This term has been used for convenience and



Khonoma Tragopan Sanctuary, declared as a completely inviolate area by the Angami tribe of Nagaland, India

Source: Author.

incorporates a wide range of phrases used to denote such sites, including biocultural heritage sites, indigenous protected areas, and locally managed marine areas, among others. The term is not meant to show disrespect to the legitimate demands of many indigenous populations to be called “peoples” instead of “communities” and to recognize their homelands as “territories” instead of “areas.” ICCAs are relatively new in conservation and environmental circles, having originated from work done on community-initiated conservation in India in the late 1990s (see the Khonoma Tragopan Sanctuary photo). But the sites and initiatives they denote are as old as human civilization itself and are in many ways the world’s oldest protected areas. These include sacred sites protected from all or most human

uses other than once-a-year rituals, watershed forests conserved with only minimal subsistence use, wildlife populations left strictly alone for ethical reasons, and indigenous and mobile peoples’ territories managed to balance ecosystem protection and resource use.

Recognition of the reality and spread of ICCAs is recent—a result of a shift that took place in international conservation forums in the first few years of the new millennium. For over a century before this, it had been assumed that wildlife and biodiversity could best be conserved in designated protected areas managed by government bureaucracies, aided at best by scientists and conservation nongovernmental organizations (NGOs). This has now given way to the realization that there are a variety of other actors who can be



equally if not more capable—in particular, indigenous peoples and other traditional local communities (hereafter called communities).

The Diversity of ICCAs

Community conservation initiatives are extremely diverse and can be classified or analyzed from several points of view:

- Their coverage of different kinds of ecosystems and wildlife species (encompassing the full range found on Earth)
- The objectives and motivations behind their establishment (including ethical, cultural, economic, and political reasons)
- Their origins (autochthonous by communities or triggered by outsiders)
- The institutions governing them (as different as the communities themselves, ranging from entire villages to youth clubs and women's groups and specialized conservation groups)
- The various ecological and social impacts they have
- Their size (ranging from a tiny patch of forest or sea of less than 1 ha (hectare) to several million ha of rain forest, savanna, or mixed land uses).

ICCAs include the following geographies:

- Indigenous peoples' territories managed for sustainable use, cultural values, or explicit conservation objectives (e.g., many indigenous protected areas in the Amazon and Australia)
- Terrestrial or marine territories over which mobile or nomadic communities have traditionally roamed, managing the resources through customary regulations and practices (e.g., the territories of the Qashqai in Iran and the Borana in Ethiopia and Kenya, both containing substantial wetland and wildlife values)
- Sacred spaces, ranging from tiny forest groves and wetlands to entire landscapes and seascapes, often left completely or largely free from human use (e.g., thousands of sacred groves in India and several sacred crocodile ponds in Mali)

- Resource catchment areas, from which communities derive their livelihoods or key ecosystem benefits, managed such that these benefits are sustained over time (e.g., community forests in many African and South Asian countries)
- Nesting or roosting sites, or other critical habitats of wild animals, conserved for ethical or other reasons explicitly oriented toward protecting these animals (e.g., dozens of waterfowl nesting wetlands in Southern India)
- Community forests managed by towns (e.g., several in North America)
- Landscapes with mosaics of natural and agricultural ecosystems, managed by farming communities or mixed rural-urban communities (e.g., the Potato Park in the Andean highlands of Peru, the rice terrace regions of the Philippines, or the protected landscapes of Spain and many other European countries)

Though extremely diverse, ICCAs display three essential characteristics: (1) the community (or communities) is the most important decision maker, even though other actors may play a role; (2) the community has one or more crucial links to the area and its species: cultural, spiritual, ecological, economic, and political; and (3) whatever the objectives of management may be, conservation is being achieved in varying degrees.

The Significance of ICCAs

The international conservation community has started paying much more attention to ICCAs, for several important reasons:

- They conserve or have the potential to conserve an enormous part of the Earth's beleaguered biodiversity (see the Coron Island photo); indeed, though existing documentation is not adequate to judge their extent, they may cover an area as big as government-designated protected areas (which today amount to about 12% of the Earth's terrestrial surface).
- They help or can help in providing connectivity across large landscapes and seascapes, which is crucial for migration of wildlife, livestock, and people and for genetic exchange.



Coron Island, a biodiversity-rich coral island seascape managed under ancestral domain claim by the Tagbanwa indigenous people of the Philippines

Source: Author.

- They provide substantial environmental services, such as water and nutrition flows, soil protection, and others.
- They provide enormous survival and economic benefits and important lessons on how to link nature conservation with livelihood security.
- They are “natural” sites for cultural sustenance, displaying the varying ways in which humans have lived with and within nature; a great many are sites of spiritual significance, and in the case of many indigenous and mobile peoples, the land itself is akin to the temples and churches of mainstream religions.
- They are often seamless landscapes of wild and agricultural or domesticated biodiversity, providing important ecological and cultural links between two crucial parts of human life that have in modern times become artificially compartmentalized and separated.

In many ways, ICCAs can become a crucial component of the human response to global climate change. They are effective ways of avoiding or mitigating climate impacts, by ensuring the continued protection of ecosystems. Equally valuable is their potential for adaptation, by providing corridors for ecosystem and species migration that will inevitably occur due to changing climatic conditions, and because their biological and cultural diversity contains the bases of resilience that communities everywhere will need.

ICCAs are not a panacea for all conservation and livelihood problems, nor should their growing profile imply that communities everywhere are conservation oriented. ICCAs have their own strengths, including locally adapted practices based on sophisticated knowledge, often strong institutions and customary law, and others. They also have their own weaknesses, including



sometimes the neglect of species not considered important or local inequities that undermine the sustainability of the initiative. Increasingly, ICCAs face serious threats from inappropriate “development” and infrastructure activities such as mining, dams, and urbanization; the lack of tenurial security in countries where community rights and territories are not adequately recognized; the changing cultural norms, and other forces. These are greatly compounded by the lack of recognition of most ICCAs by state agencies and NGOs. Over the past few centuries of centralized rule and industrial exploitation of resources in such countries, their role has been seriously eroded.

Do ICCAs Have a Future?

If ICCAs are to remain or become a significant component of conservation and sustainability of human life, they need urgent recognition and support. Having understood this, the International Union for Conservation of Nature and the International Convention on Biological Diversity (through its Programme of Work on Protected Areas) have urged countries to consider ICCAs as crucial components of their conservation policies and practices. Some countries have started providing the legal and policy backing for this (with some, such as Australia and Colombia, having started several years ago), but most have a long way to go. Even where countries are beginning to recognize ICCAs, often it is done in top-down ways, with governments dictating to communities what kind of (rather homogeneous) management institutions should be established—a contradiction in terms!

Considerable innovation is needed in national and regional policies to support ICCAs, in particular to respect that they represent a crucial interface between ecological and cultural diversity and are at their core site specific, constantly evolving responses to the challenges and opportunities that communities find living with nature. Many need technical and financial support and social recognition; conversely, many may thrive under deliberate neglect since the most culturally sensitive communities may find even a bit of public exposure detrimental to their interests.

Ashish Kothari

See also Biodiversity; Biosphere Reserves; Community-Based Conservation; Environmental Services; Indigeneity; Indigenous Agriculture; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Reserves; Parks and Reserves; Patches and Corridors in Wildlife Conservation

Further Readings

- Borrini-Feyerabend, G., & Kothari, A. (2008). *Recognising and supporting indigenous and community conservation: Ideas and experiences from the grassroots*. Retrieved November 28, 2008, from http://cmsdata.iucn.org/downloads/ceesp_briefing_note_9_iccas.pdf
- International Union for Conservation of Nature. (2009). *Indigenous and community conserved areas*. Retrieved November 28, 2008, from www.iccaforum.org
- International Union for Conservation of Nature. (2009). *Indigenous and community conserved areas and national legislation: Support or hindrance?* Retrieved November 28, 2008, from http://cms.iucn.org/about/union/commissions/ceesp/topics/governance/icca/ceesp_icca_legislation/index.cfm
- Kothari, A. (2006). Community conserved areas. In M. Lockwood, G. L. Worboys, & A. Kothari (Eds.), *Managing protected areas* (pp. 549–573). London: Earthscan.
- Special issue on community conserved areas. (2006). *Parks*, 16(1), 1–79.

INDIGENOUS CARTOGRAPHIES

Indigenous cartographies are the mapping practices, past and present, produced or conceptualized by indigenous peoples and informed by the aesthetics and sign systems of the societies from which they derive. They are as diverse as the peoples who practice them. In Mesoamerica, Mixtec *lienzos* depicted the genealogical histories of cities through place name symbols and pathways. In Siberia, Chukchi and Mansi navigational cartography is inscribed on bark or painted directly on trees along a route. Bozo cartography in West



Africa includes depictions of watersheds drawn on the ground as part of an annual ceremony. And in North America, Dine Navajo cartography includes the placement of rocks and cairns in lines in the landscape to mark the stages of stories.

Characteristics of Indigenous Cartographies

From this diversity, common characteristics emerge that reflect the common characteristics of indigenous knowledge systems generally. Indigenous cartographies are characterized by performativity, the inextricability of the spiritual from geographical experience and expression, an emphasis on storied place names, and the incorporation of physical landscape and community memory as a cartographic archive.

When viewed through nonindigenous eyes, it may be difficult to recognize some of those practices as mapping because they stand apart from Western or Euro-American expectations of how maps work and what maps should look like. For decades, this restricted vision limited nonindigenous awareness of such traditions to a few popular examples, such as the bone carvings of coastlines made by Inuit peoples and the tide charts created from sticks and shells by Marshall Island sailors for teaching traditional navigation techniques.

In the 1970s, largely through the works of G. Malcolm Lewis and Louis de Vorsey, building on the early work of Bruno Adler, a cartobibliographic record for American Indian mapmaking began to take shape in map history. This early work analyzed the accuracy of linear, Euclidean measure in Native maps in comparison with European maps. While this analysis qualified less measurably accurate examples as primitive, cognitive, or maplike, the revelation that some indigenous maps do contain such measurability overturned the perception that Native people had no concept or skills of distance measurement. The Columbian Encounter conferences and symposia of 1992, including the first traveling exhibition devoted to indigenous cartography, encouraged further scholarship, shifting attention to Native peoples' contributions to colonial cartographies such as the Hudson's Bay Company maps, the Lewis and Clark expedition, and the *relaciones geograficas* of New Spain. Through both archival

study and visual analysis, scholars examined the unacknowledged processes by which Native cartographies were transformed into printed, European maps as part of the colonial project, driving the European printed map market while simultaneously erasing their own ancient geographies.

Theoretical Perspectives

These symposia coincided with, and were thus influenced and enriched by, the critical theoretical breakthroughs in geography during the late 1980s and early 1990s. Drawing on the work of Michel Foucault and Jacques Derrida, Brian Harley called on geographers and historians to deconstruct the Euro-American map, to uncover the power relations inherent to the positivist epistemology of Western cartography, and to explore the indigenous epistemologies silenced by the colonial cartographic tradition. Barbara Belyea, also through a close reading of Foucault, called for indigenous maps to be evaluated on their own terms rather than through comparison with a European "standard." Robert Rundstrom further widened the theoretical critique by focusing on the transmission of knowledge itself. If nonindigenous culture is inscriptive, emphasizing the storage of information in objects for later use, and indigenous culture is incorporative, emphasizing the process of communicating knowledge itself, then maps as objects could no longer be a useful approach to the study of indigenous cartographies. A processual approach, Rundstrom wrote, would be a more culturally relevant and inclusive framework for Native map histories.

These theoretical contributions literally opened the eyes of Western geographers by redefining the nature of maps and mapmaking and bringing a wider awareness of indigenous map traditions. The landmark publication in 1998 of an indigenous volume for the History of Cartography Project solidified indigenous cartographies in map history, by compiling extensive research for the Americas and the Pacific, delineating the less well-known regions (including all of Africa), and articulating a new definition of the map to include more performative and word-based mapping traditions. Today, through an intersection of efforts from map history, anthropology, media studies, and indigenous social movements, the history of



indigenous cartographies from everywhere on Earth continue to be written into the global canon of indigenous map history.

Although mapping has been fundamental to indigenous self-determination and management of environmental and economic resources, as evidenced in the rise of participatory geographic information system (GIS), community GIS, tribal GIS, and online communities such as the Aboriginal Mapping Network and the Indigenous Mapping Network, these projects remain largely characterized by Western, nonindigenous map techniques and largely practiced by nonindigenous mapmakers. To this situation, the theoretical contributions of the field of indigenous cartography are relevant. In 1995, Rundstrom began to critique the positivist epistemological structure of GIS and the potentially harmful effect of such technology on traditional knowledge, drawing parallels to Native peoples' marginalization by cartography during the colonial era. In 2005, the indigenous geographers Johnson, Louis, and Pramano called attention to the fact that as the inherent power and ubiquity of GIS is only likely to increase, it is imperative that indigenous communities are trained in the epistemologies embedded in their maps to avoid their remarginalization by cartography.

This dialogue about the epistemological underpinnings of geospatial technologies, and the impact of such technologies on indigenous cartographies and communities, is today an unresolved interdisciplinary discussion linking geography, international development, anthropology, and indigenous studies. New theoretical challenges include the incorporation of indigenous methodologies into mapping protocol and process, the spatial and visual encoding of the structures of Native science and Traditional Ecological Knowledge, and the interplay between indigenous and nonindigenous cartographies within each mapping project.

Impact of Technology and Global Media

Meanwhile, geospatial technologies are becoming more flexible in their sensory and design capabilities, indigenous peoples' use of global media has become more intricate, and a multitude of innovative new mapping projects are being shared

online. Many of these projects continue the traditional emphasis on storied place names as the heart of mapping indigenous cultural knowledge; as the representation of these names are evaluated and redesigned, the performative structures of traditional indigenous cartographies are gradually being incorporated. Audio and video technologies and the participatory benefits of blogging are now central to incorporating place-based stories into both tribal online GIS and indigenous cultural education sites, for instance, at the Web site Pepamuteiati Nitassinat (As we walk across our land), where Innu place names and stories are mapped with Google Maps, video clips, and elder recordings, and at the Bdote Memory Map, where Dakota people use blogs to tell stories and discuss the meanings of place names in the Twin Cities.

Margaret Wickens Pearce

See also **Cartography; Cartography, History of; GIScience; Harley, Brian; Imperialism; Indigeneity; Indigenous Environmental Knowledge; Indigenous Environmental Practices**

Further Readings

- Aporta, C., & Higgs, E. (2005). Satellite culture: Global positioning systems, Inuit wayfinding, and the need for a new account of technology. *Current Anthropology*, 36, 729–753.
- Belyea, B. (1996). Inland journeys, Native maps. *Cartographica*, 33(2), 1–16.
- Chapin, M., Lamb, Z., & Threlkeld, B. (2005). Mapping indigenous lands. *Annual Review of Anthropology*, 34, 619–638.
- Johnson, J., Louis, R., & Pramano, A. (2006). Facing future: Encouraging critical cartographic literacies in indigenous communities. *Acme*, 4, 80–98.
- Lewis, G. (1986). Indicators of unacknowledged assimilations from Amerindian maps on Euro-American maps of North America: Some general principles arising from a study of La Verendrye's Composite Map, 1728–29. *Imago Mundi*, 38, 9–34.
- Lewis, G. (Ed.). (1998). *Cartographic encounters: Perspectives on Native American mapmaking and map use*. Chicago: University of Chicago Press.



Rundstrom, R. (1991). Mapping, postmodernism, indigenous people, and the changing direction of North American cartography. *Cartographica*, 28(2), 1–12.

Rundstrom, R. (1995). GIS, Indigenous peoples, and epistemological diversity. *Cartography and Geographic Information Systems*, 22(1), 45–57.

Woodward, D., & Lewis, G. (Eds.). (1998). *The history of cartography: Vol. 2, Book 3. Cartography in the traditional African, American, Arctic, Australian, and Pacific societies*. Chicago: University of Chicago Press.



INDIGENOUS ENVIRONMENTAL KNOWLEDGE

Multiple terms have been used to describe the environmental knowledge and cultural resource practices of indigenous peoples, including *indigenous environmental knowledge*, *traditional ecological knowledge*, *indigenous technical knowledge*, and *ethnoecology*. The Western study of indigenous environmental knowledge is centuries old (e.g., Carl Linnaeus's 1732 publication, *Iter Lapponicus*, included extensive descriptions of Sami indigenous environmental knowledge from Northern Scandinavia). There is a central paradox in the description and analysis of one knowledge and belief system from within the context of another, and the Western study of indigenous knowledge has been critiqued and challenged by numerous indigenous writers, in part because of the common assumption of the superiority of the Western tradition.

The United Nations Permanent Forum on Indigenous Issues states that there are around 370 million indigenous people in 70 countries across the globe. They have different social, cultural, economic, and political characteristics to those of the dominant societies in which they live. They are the descendants of those who inhabited a country or a region subsequently colonized by people of different cultures or ethnic origins. Territory and place are often central to indigenous identities, expressed through concepts such as

land rights, sacred sites, and traditional resource use. These concepts are underpinned by unique indigenous environmental knowledge systems. While individually unique to particular people in specific geographic locations, there are nevertheless common aspects to these knowledge systems.

Characteristics and Interpretation

Some characteristics of indigenous environmental knowledge include a local or regional focus, oral transmission, a basis in practical engagement in everyday life, dynamism of form and content, integrated and holistic perspectives, and a situation within a broader cultural context. Although some of these characteristics are likely to be common to most systems of indigenous environmental knowledge, it is important to remember that terms such as *indigenous* and *Western* risk overgeneralizing what are diverse, complex, and dynamic groups. Similarly, separating indigenous environmental knowledge from its social and institutional context is inappropriate—it is unlikely to function merely as an adjunct to Western science, in isolation from the local social norms in which it was created. Many indigenous systems are based around cultural values such as respect and reciprocity, which are also a core element of the management processes that use the knowledge. Unsatisfactory outcomes are likely if these values are replaced by a simple resource utilitarianism.

While indigenous environmental knowledge is based on extensive empirical observation, its interpretation can be radically different from conventional scientific or Western paradigms. Fikret Berkes stresses that indigenous environmental knowledge centers on *relationships* between living beings, including humans. In contrast, heritage paradigms, among other common influential conventional scientific theories of value, have a focus on objects, entities, and places while the all but invisible background of relationships, behaviors, nonhuman entities, and kinship structures that arguably shape people-environment relations are ignored. Within indigenous environmental knowledge, there is often a strong correspondence between attitudes toward the environment and a belief in the *sacredness* of the living world, reflected in English translations of indigenous terms such as



caring for country, a community of beings, and all my relations. The Native American Tewa scholar Gregory Cajete uses the term *native science* to describe indigenous holistic and inclusive approaches to considering environments and their occupants and stresses the aliveness and connectedness of all things. “Native science” focuses on learning about an intricately interlinked universe rather than objectively explaining it. It also acknowledges mutual reciprocity: The world is not a resource for human use but a family of beings with mutual obligations and needs. This acknowledgment has compounded attempts at integrating indigenous peoples’ social and cultural values into natural resource management (e.g., in relation to water resource management in a thirsty agricultural continent such as Australia).

Indigenous Environmental Knowledge and Resource Management

The increasing recognition of the value of indigenous environmental knowledge in natural resource management during the past few decades is embedded in a historical controversy surrounding the sustainability of indigenous environmental management. This controversy is arguably the result of a general lack of knowledge of, and lack of informed literature on, indigenous actors’ motivations behind environmental management practices in distinct socioeconomic and political contexts.

During the colonial era, indigenous environmental practices were often strange to the mindset of many Europeans. Limited European knowledge of the physical dynamics of tropical environments, for example, led to the dismissal of indigenous burning practices. Indigenous use of fire was instead labeled as an “evil” practice during the early 20th century, perceived to result in forest degradation and loss of colonial property. Such labeling of indigenous environmental management as unsustainable has increasingly been critiqued and refuted with the acknowledgment of nonequilibrium ecology. The recognition of savanna ecosystems as “unstable” has, for example, led to a gradual change toward acknowledging the value of fire in traditional indigenous shifting cultivation systems and bush-fire protection schemes in savanna environments.

The indigenous use of fire in maintaining Northern Australian landscapes and ecosystems has been extensively investigated in collaborations between Western scientists and managers and indigenous experts. These attempts at collaboration provide recognition of the relationship between the importance of biodiversity in indigenous environmental knowledge systems and the acknowledgment that Western social and economic traditions have contributed to extensive global environmental degradation. Thus, in attempting to find solutions to the ongoing environmental decline, researchers have investigated worldviews that value the intrinsic rights of non-human others, suggesting that Westerners can learn from these belief systems.

However, environmental managers’ attempts in particular situations to incorporate effective indigenous practices into contemporary Western land management are often controversial and by no means broadly accepted, even in situations where indigenous people are numerically dominant. Indigenous environmental knowledge is also still often challenged today through a form of “ecological imperialism” that justifies an assumption of the superiority of Western knowledge over indigenous knowledge systems. In her notion of the colonization of discourses, Sandie Suchet proposes that Eurocentric discourses construct indigenous people and indigenous environments as resources to be developed or conserved by undermining or rendering indigenous environmental knowledge silent through a portrayal of indigenous people and their environments as pristine and unspoiled examples of nature.

While being alert to the dangers of essentializing and decontextualizing indigenous knowledge systems, it is also inappropriate to romanticize indigenous lifestyles and uncritically think of indigenous peoples as “ecological angels” or the “original conservationists.” There is a danger of seeing indigenous knowledge as something of an elixir for all the ills befalling communities in modern-day society. There usually is a range of environmental behaviors demonstrated in any group, which may include actions that have negative outcomes. Some reasons for this are that knowledge often is unevenly distributed among individuals, young people may have different views or knowledge, and



detailed local knowledge may be inadequate without knowledge on a broader scale, especially in changing environments. Some researchers have argued that conservation outcomes from indigenous environmental behavior are derived from a focus on optimal harvest efficiency rather than a desire to conserve species or habitats per se. Simply because it is deemed “indigenous knowledge” does not mean that it is necessarily more suitable than the knowledge of perceived “outsiders”; it must be fit for the purpose.

Research on Indigenous Environmental Knowledge

Indigenous environmental knowledge has been investigated by several Western disciplines, including biology, geography, and anthropology. In biology, the congruence between indigenous knowledge and practice has been linked to concepts of adaptive management, and there is extensive work on the similarities between ethnotaxonomies and scientific ones. As examples, there are numerous studies of circumpolar peoples’ environmental knowledge systems that have repeatedly demonstrated the significance and efficacy of this knowledge. In Alaska, biologists conducting whale censuses had significantly more accurate results once they incorporated the knowledge of indigenous whalers. The 2004 Arctic Climate Impact Assessment, commissioned by the Arctic Council, used collaboration with indigenous peoples to access unique, long-term knowledge of weather patterns and flora and fauna distribution in compiling a compelling picture of rapid climate change in the Arctic.

In geography and anthropology, recent discussions about the extent and age of human influence on the environment have been linked with the voices of indigenous writers who are concerned with the place of nonhuman others in overall social and environmental relationships. This point, about the agency and intent of nonhuman actors, is probably most difficult for Western science to accept but has been repeatedly stressed by indigenous academics. The Maori biologist Mere Roberts argues against the removal of the spiritual dimension from scientific enquiry, emphasizing the presence of a moral universe. Indigenous writers have also challenged the

primacy of nonindigenous researchers in these discussions, arguing that it is not valid to interpret one belief system within the structures of another. Western concepts of objectivity undermine the distinctive position of indigenous knowledge systems that adhere to the rightness of their views. Increasingly, indigenous geographers themselves are exploring these issues, along with nonindigenous geographers working on indigenous geographies. These explorations, together with the increasing political voice of indigenous people, have shown that a distinction between indigenous environmental knowledge and perceived “outsider” knowledge does not by itself provide an adequate way to understand or overcome conflicts over land management and rights to land. Environmental knowledge is instead interwoven with, and divided across gaps in, daily resource politics at various scales—local, national, and international.

Christine Eriksen and Michael Adams

See also *Environmental Ethics; Ethnicity and Nature; Ethnocentrism; Eurocentrism; Indigeneity; Indigenous Agriculture; Indigenous Cartographies; Indigenous Environmental Practices; Indigenous Reserves; Indigenous Water Management; Shifting Cultivation*

Further Readings

- Berkes, F. (2008). *Sacred ecology* (2nd ed.). London: Routledge.
- Cajete, G. (1999). *Native science: Natural laws of interdependence*. Santa Fe, NM: Clear Light Books.
- Deloria, V., Jr. (1997). *Red earth, white lies: Native Americans and the myth of scientific fact*. Golden, CO: Fulcrum Books.
- Ellen, R., Parkes, P., & Bicker, A. (Eds.). (2000). *Indigenous environmental knowledge and its transformations: Critical anthropological perspectives*. London: Routledge.
- Head, L. (2007). Evolving nature-culture relationships. In I. Douglas, R. Huggett, & C. Perkins (Eds.). *Companion encyclopaedia of geography: From local to global* (pp. 835–846). London: Routledge.



- Jackson, S. (2006). Compartmentalising culture: The articulation and consideration of indigenous values in water resource management. *Australian Geographer*, 37, 19–31.
- Roberts, M. (1996). Indigenous knowledge and Western science: Perspectives from the Pacific. *Royal Society of New Zealand Miscellaneous Series*, 50, 69–75.
- Sefa Dei, G., Hall, B., & Goldin-Rosenberg, D. (Eds.). (2000). *Indigenous knowledge in global contexts: Multiple readings of our worlds*. Toronto, Ontario, Canada: University of Toronto Press.
- Special issue on traditional ecological knowledge. (2000). *Ecological Applications*, 10(5).
- Suchet, S. (2002). Totally wild? Colonising discourses, indigenous knowledges and managing wildlife. *Australian Geographer*, 33, 141–157.
- UN Permanent Forum on Indigenous Issues: www.un.org/esa/socdev/unpfii



INDIGENOUS ENVIRONMENTAL PRACTICES

Indigenous environmental practices can be thought of as a combination of behaviors, knowledge, and beliefs. In other words, indigenous practices are embedded in a larger sociocultural context that includes both the social institutions that regulate and convey knowledge and larger cosmologies. The concept of indigenous environmental practices is itself a nonindigenous construct, arising out of Western interest in those practices. There have been positive and negative consequences of outside recognition of these practices.

Indigenous environmental practices tend to be highly diverse and adapted to local conditions. Transmission can occur through storytelling, taboos, rituals, and underlying values such as respect, humility, and reciprocity. Elders and healers are often charged with the role of maintaining and conveying knowledge. Examples of such practices include the following:

- Monitoring of species numbers based on observed animal behaviors, life histories, movements and migrations, habitat and dietary preferences

- Controlling hunting or fishing of specific species, for instance, through animal totems and the recognition of taboo species
- Protection of specific habitats during various times of the year. Examples include the protection of headwaters because they function as fish spawning grounds or the protection of groves of trees planted by ancestors that function to attract various monkey species for hunting.
- Protection of species' vulnerable life stages. This may include prohibition of the hunting of pregnant female or young animals.
- Various forms of resource rotation, both with regard to hunting and agricultural cycles. In agriculture, this can take the form of slash-and-burn (i.e., swidden) systems.
- Integrated farming practices such as polyculture. In polycultural approaches, two or more plant (and sometimes animal) species are planted in specific temporal or spatial orders to provide two or more outputs. The species planted together generally exist in mutually enhancing relation (ecologically or economically) to one another.
- The use of fire to shape landscapes. As has been documented in places as diverse as North and South America, Africa, and Australia, indigenous peoples have long used fire to control the movement, prevalence, and spread of wildlife and plant species, thereby creating intricate ecological mosaics, often invisible to outsiders.
- Knowledge and use of medicinal plants, including identification of the respective plants and the knowledge of how to process them. In many cases, indigenous peoples' knowledge of medicinal plant has drawn the attention of outside scientists and bioprospectors, with little, if any, benefit to the indigenous communities. In the case of the neem tree (*Azadirachta indica*) in India or the Ayahuasca vine (*Banisteriopsis caapi*) in the Amazon, indigenous objections to the foreign use and patenting of native plants are both moral and practical. Such action has been termed *biopiracy* by indigenous leaders.

It should be acknowledged that the characterization of certain behaviors as "indigenous environmental practices" is a nonindigenous construct.



The label “environmental” implies a nature-culture dichotomy that is not necessarily shared in the same way by all indigenous peoples. The idea of “practices” implies the separation of knowledge from practice, when in fact the two often form a cohesive yet nonfixed and dynamic whole. Moreover, many “indigenous” environmental practices are complex hybrids of “modern” and “traditional” techniques.

For many years, colonial officials (and after them, scientists and developers) derided indigenous techniques as inert, unproductive, and archaic. Later research, however, revealed the intricacy of local practices, their high degree of dynamism, and the ability of indigenous practitioners to constantly reassess and adapt to changing circumstances. Whereas colonial authorities had blamed local practices for environmentally detrimental outcomes, scholarship in the later 20th century found that in many cases it was precisely the destruction of local knowledge and practices in favor of maladapted Western resource management methods that resulted in ecological deterioration.

More recently, outside interest in indigenous environmental practices intensified with the emergence of international environmental concepts such as “sustainable development” in the 1980s and 1990s. Against the background of the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, indigenous peoples—especially those of the Amazon Basin—and their environmental practices emerged as potential “saviors” of industrialized society. There was recognition that most remaining biodiversity-rich regions of the world are also indigenous homelands. Such cartographical congruency lent credibility to indigenous claims that native peoples had protected and safeguarded the world’s fragile ecosystems. This approach led to a heavy phase of indigenous activism and numerous publications calling for the protection of both biodiversity and cultural diversity. The 1992 Convention on Biological Diversity emphasizes the desirability of protecting indigenous knowledge systems and practices for purposes of biodiversity conservation and sustainable development. In conservation policy circles, the interest in indigenous environmental practices expressed itself in the emergence of a

new paradigm: community-based conservation. In this framework, indigenous environmental knowledge and practices are recruited as ingredients of successful conservation.

As interest in indigenous environmental practices has increased, indigenous histories have experienced greater scrutiny (largely on the part of nonindigenous researchers). For example, while research emerged from the Amazon detailing that indigenous gardening techniques actually increased biodiversity in places, other scholarship in the same area highlighted perceived indigenous overhunting. While indigenous territorial rights were being put forth as a strategy to slow deforestation and biodiversity loss, practices deemed “environmental” became standards of “authenticity” that indigenous peoples now had to meet in order to have political currency.

Sonja K. Pieck

See also [Community-Based Conservation](#); [Indigeneity](#); [Indigenous Agriculture](#); [Indigenous Environmental Knowledge](#); [Indigenous Forestry](#); [Indigenous Reserves](#); [Indigenous Water Management](#); [Sustainable Development](#); [United Nations Conference on Environment and Development](#)

Further Readings

- Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, 10, 1251–1262.
- Brush, S., & Stabinsky, D. (Eds.). (1996). *Valuing local knowledge: Indigenous people and intellectual property rights*. Washington, DC: Island Press.
- Krech, S. (1999). *The ecological Indian: Myth and history*. New York: W. W. Norton.
- Nadasdy, P. (2005). Transcending the debate over the ecologically noble Indian: Indigenous peoples and environmentalism. *Ethnohistory*, 52, 291–331.
- Oldfield, M., & Alcorn, J. (1991). *Biodiversity: Culture, conservation and ecodevelopment*. Boulder, CO: Westview Press.



INDIGENOUS FORESTRY

Indigenous forestry started getting recognition after the failure of state-dominated forestry, which excluded historical forestry management by indigenous and local communities. Indigenous forestry is defined as an approach that sees local indigenous forestry users as taking a central role in how their resources are managed and used. The indigenous forestry approach contrasts with conventional or scientific forestry, which brings in outside knowledge that indigenous people are then forced to use in planning, management, and use of their forests. Globally, there have been moves toward incorporating the interests of indigenous forest communities in Africa's Congo Basin, in the Amazon forest, and in southeast Asia.

The adoption of the Declaration on the Rights of Indigenous Peoples by the United Nations General Assembly in September 2007 has further highlighted the importance of 370 million indigenous peoples globally. Indigenous forestry relies on indigenous or local forestry use and practices that have been acquired over a long period of time. The recognition of the ownership rights of forests for the indigenous peoples goes beyond a moral necessity but is also socially, economically, and politically necessary.

Indigenous knowledge is important in indigenous forestry management. Most governments' policies view indigenous communities as destroying forests. The expert view of foresters has largely continued with knowledge perceived as coming from the forestry experts to the indigenous communities.

There are many reasons for promoting indigenous forestry. First, indigenous forestry is often seen as a way of promoting sustainability. Since indigenous communities have managed and used forestry resources over many years, they have developed time-tested management systems that have ensured that forest resources would be available for future generations. Dependency on forests for various products such as food, medicines, and construction materials that are basic human requirements means that the indigenous communities will look after their resources.

Second, indigenous forestry is in line with the values of modern democratic society. Democracy

values the input of local citizens who must have a say in issues that affect their lives. This is often referred to in terms of the subsidiarity principle. Justification for the subsidiarity principle blames centralized institutional arrangements by stating that local issues have to be addressed locally. Forestry is a local issue, where indigenous knowledge, if it exists in that locality, should be a basis for deciding on its management and use. This results in the crafting of locally specific and locally relevant rules. Indigenous forestry is one way of connecting the local views with higher levels of government.

Third, indigenous forestry is rooted in local culture, norms, and values. By allowing people to manage their forests using local norms and practices, we are more likely to make people follow their rules and regulations rather than if they were imposed by regional or central government. People's beliefs should be central in any power relationship. Such power relationships can only be legitimate if they coincide with the beliefs, values, and expectations of a specific community. In the long run, it is argued that it is cheaper to enforce and monitor rules and regulations that are considered legitimate by local communities.

It is important, however, to avoid romanticizing everything that is labeled indigenous forestry. Those who oppose the use of indigenous forestry knowledge argue that science needs to lead development within the forestry sector. According to many analysts, most indigenous forestry decisions are based on morals that are not scientifically valid. While enforcement of forest management requirements is normally improved through local cooperation, this can also work against effective enforcement. Because of the close social ties among indigenous people, enforcing forestry rules and regulations against relatives might not be socially acceptable. This will result in forest management rules being potentially ignored under the indigenous management system.

Indigenous forestry is also blamed for perpetuating oppressive practices such as unfair treatment of women, which might be part of the broader indigenous customs and practices. Customary practices entrench gender, age, ethnicity, and class differences. This comes in sharp contrast with the goals, if not always the practice, of most modern democratic states. The customary norms and



practices might not be fair to the indigenous communities. Some tribal leaders or men might benefit more from the indigenous forestry practices, and this needs to be assessed critically. Mahmood Mamdani notes that governments, in pursuit of their own power, might selectively choose certain customs that bolster their own power—and not those of the indigenous communities.

The exclusionary forestry policy, based on science, is problematic since it does not take into account the indigenous knowledge systems and livelihood needs of the local people. Forestry policy has downplayed and even actively undermined the indigenous knowledge systems. The replacement of indigenous trees with monocultures of eucalyptus species in parts of India and the developing countries at large illustrates commercial interest in fast-growing species, which have revenue-generating potential, rather than ecological diversity. In the Amazon Forest and southeast Asia, for instance, huge areas of forests are being cleared for large-scale ranching and soy cultivation. Whereas global climate change is encouraging the maintenance of some indigenous forests as absorbers of carbon dioxide on the one hand, climate change has also resulted in the destruction of indigenous forests in a quest to grow biofuels to reduce fossil fuels consumption, such as the palm oil plantations in Malaysia and Indonesia.

Everisto Mapedza

See also **Community Forestry; Indigeneity; Indigenous and Community Conserved Areas; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Reserves; Indigenous Water Management**

Further Readings

- Forsyth, T. (2002). *Critical political ecology*. London: Routledge.
- Mamdani, M. (1996). *Citizen and subject: Contemporary Africa and the legacy of late colonialism*. Princeton, NJ: Princeton University Press.
- Shiva, V. (1993). *Monocultures of the mind*. London: Zed Books.

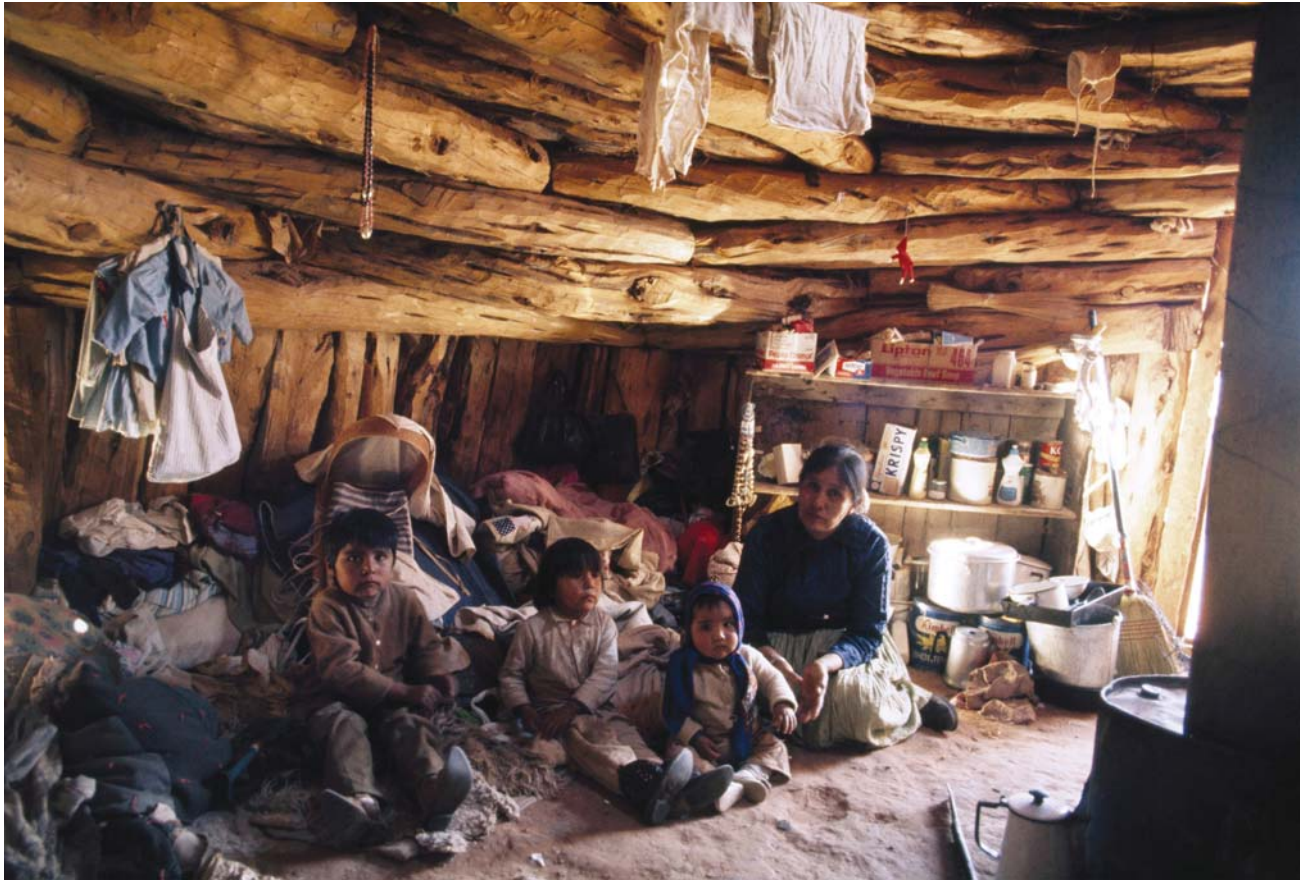
- Sunderlin, W., Hatcher, J., & Liddle, M. (2008). *From exclusion to ownership? Challenges and opportunities in advancing forest tenure reform*. Washington, DC: Rights and Resources Initiative.
- Turton, A., & Warner, J. (2002). *Exploring the population/water resources nexus in the developing world*. Washington, DC: Woodrow Wilson International Center for Scholars.
- Warren, D., Slikkerveer, L., & Brokensha, D. (1995). *The cultural dimension of development: Indigenous knowledge systems*. London: Practical Action.



INDIGENOUS RESERVES

Many countries relocated indigenous peoples to make room for the settlement of newcomers. Canada and the United States created “reserves” and “reservations,” respectively, for this purpose. Because of their unique histories, and legal and political status, reserves and reservations differ from their surrounding territories. They are reminders of First Nations’ and Native Americans’ original ownership of the land in these two countries and the colonial processes that dispossessed them of their lands. Reserves and reservations continue to be culturally important communities for many First Nations and Native American peoples. This entry describes some characteristics and histories of reserves and reservations, pointing out similarities and differences between the two countries.

In Canada, Indian reserves are defined under the Indian Act (1976) as tracts of land set aside for the use of a First Nation band. The term *First Nations reserve* is more commonly used today. According to the U.S. Indian Reorganization Act of 1934, Indian reservations are lands managed by Native American tribes. In total, there are more than 600 occupied reserves in Canada, with an average size of 1,176 ha (hectares) (2,907 acres). Indian reservations in the United States tend to be larger. There are about 310 reservations in the United States, with an average size of about 180,000 acres. Nine U.S. reservations contain more than 1 million acres each.



A Navajo family gathers in its traditional home, called a *hogan*, on the Navajo Indian Reservation, Arizona. While there are exceptions, most reserves and reservations are characterized by low levels of economic development and high levels of poverty.

Source: National Geographic/Getty Images.

While most reserves in Canada were created subsequent to treaty negotiations, some were created through other means, including grants to missionaries, purchases by First Nations, and federal and provincial legislation. Where reserves were created through treaty negotiations, First Nations chiefs attempted to create “homelands,” negotiating farming supplies and instructions. These reserves tend to be larger than reserves in Quebec, the Maritimes, and British Columbia, which were created primarily with the intent of facilitating assimilation. In Canada, most reserves were created through one legal strategy and are located on or near the First Nations’ traditional territory. In the United States, some reservations were created through treaty negotiations, which established reserves on tribal

territories. Subsequent to the 1830 Indian Removal Act, many tribes were moved to reservations outside their traditional territories to clear land for settlement in the Eastern United States. Some reservations were purchased by a tribe or by the federal government, others were created through gifts, and some were created through executive orders or acts of Congress. Currently, most reservations contain lands obtained through different processes with resulting differences in legal status. Many reservations are located outside tribes’ traditional territories.

Subsequent to their establishment, the size of reserves and reservations in both countries was reduced. In Canada, this took place through expropriation, the surrender of land by First Nations communities (some illegally obtained),



and legislation. In the United States, the size of reserve lands was reduced by almost 60% by the 1887 General Allotment Act, which transferred tribal lands to individual private ownership, with subsequent sales. In the 1950s reserve lands were further reduced when the status of 61 tribes was terminated because they were regarded by the Bureau of Indian Affairs as no longer requiring federal assistance. The reduced size of reserves and reservations negatively affects possibilities for economic development.

In Canada and the United States, the title to reserve and reservation lands is held by the federal government. In both countries, they are exempt from taxation. In Canada, most reserves are administered by an elected chief and council type of government defined by the Indian Act (1876), with a level of jurisdiction close to those defined for municipalities, subject to the overriding supervision and control of federal or provincial governments. Some First Nations have negotiated additional powers through self-government agreements. However, Richard Bartlett has characterized the level of federal and provincial control over First Nations' lands as subjugation. The 1934 U.S. Indian Reorganization Act offered tribes the possibility of forming elected tribal governments as well as tribal courts and police systems. Some tribes objected because these structures replaced traditional governments. On some reservations, two forms of government—traditional and new—continue to exist. In both countries, reserves and reservations represent political and administrative units that are unique from the territories that surround them. In both countries, First Nations' and tribal governments' jurisdiction does not extend outside the reserve boundaries, making it difficult to protect rights, for example, to water or to hunting and trapping.

Most reserves and reservations were created in rural and remote areas, far away from access to markets or services, with few natural resources. Because lands and the personal property of individuals, bands, and tribes located on the reserve or reservation are protected from seizure under legal processes, it has been difficult to obtain financing for economic development. The social conditions on many reserves and reservations reflect decades of government neglect. While there are exceptions, most reserves

and reservations are characterized by low levels of economic development and high levels of poverty.

Nevertheless, many First Nations and Native American people value aspects of life in these communities. Resistance to assimilation created reserves and reservations as enclaves where cultures, traditions, and languages could be protected. For many First Nations and Native American people today, the meaning of these communities includes their significance as lands that they “reserved” for themselves in their relationships with newcomers. Despite the poor conditions on reserves and reservations, members of bands and tribes have some rights to housing, social assistance, and access to federal government programs. Recent federal government investments in health, education, and economic development have resulted in modest increases in employment opportunities on reserves. In both countries, tribes and First Nations have invested in gambling operations to increase revenues. Although the proportion of First Nations and Native American people living in cities has grown steadily since the 1950s, the size of reserve and reservation populations continues to grow. Despite earlier assumptions that reserves and reservations would disappear as their inhabitants assimilated or died out, these communities remain as unique elements of geographic landscapes in Canada and the United States.

Evelyn J. Peters

See also Colonialism; Indigeneity; Indigenous and Community Conserved Areas; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Forestry; Indigenous Water Management

Further Readings

- Bartlett, R. (1990). *Indian reserves and aboriginal lands in Canada*. Saskatoon, Canada: University of Saskatchewan Native Law Centre.
- Frantz, K. (1999). *Indian reservations in the United States*. Chicago: University of Chicago Press.



INDIGENOUS WATER MANAGEMENT

Indigenous water management refers to traditional approaches to accessing, collecting, treating, or distributing water that predate globalized industrial and capital- and energy-intensive methods that have spread primarily from Europe and North America. When referred to in the context of development, these methods are portrayed either as a historical accounting of natural resource management or at times as alternative, or techniques to be employed in support of, methods associated with modernity.

Due in part to their origination at a time when populations, markets, and infrastructure needs were radically different from what is commonly found in the modern era, indigenous water management methods are commonly scaled differently than those associated with modernity. While such methods may have supported a subsistence economy, they at times may not be scaled appropriately to suit what is by far the single greatest global use for water—regional commercial agriculture and trade. Indigenous methods can also be difficult to transfer to foreign settings, as they are rooted in specific geographic, social, and cultural contexts.

Culture

Indigenous knowledge derives much of its value from contextualized firsthand life experience, rather than from capital. Therefore, ritual is often intricately woven into indigenous water uses. For example, in Pohnpei, Federated States of Micronesia, the making of the “sakau” drink is a central part of an impassioned ritual that involves the grinding of a root that is a relative to the common pepper plant to produce a muddy-looking drink that has a relaxing effect. Interestingly, the clearing of forests in watersheds to grow the plant for distribution to Europe has created erosion and social problems that grassroots conservationists are now trying to tackle.

Access

In many areas, water has been treated as a “common pool resource,” or “commons,” and use has been typically guided by cultural beliefs and social norms. For example, in some rural areas outside

Cluj, Romania, despite the increasing encroachment of the global market, neighbors do not run water pipes to homes, as it is assumed that water on someone else’s property is available for all to share at no cost.

Sharing water does not mean a lack of organization in its use. Globally, water sources have sometimes been segregated, with different sources reserved for certain levels of society for certain types of purposes (e.g., drinking vs. nondrinking). Water use was often governed or mediated by spiritual and ceremonial leaders in the community. The supernatural penalties expected to follow from violation of expected practices (inappropriate use of certain water, pollution of water, etc.) served to enforce local norms.

Depending on social structures, water can be more or less controlled by families, clans, tribes, and/or ruling elites. In such cases, payment can be required for access to water, especially for commercial purposes (e.g., for livestock), although water for basic household needs may be free. In mobile pastoral cultures, social and familial networks have been very important to negotiating access to water sources. Women are often the traditional collectors and primary users of water, so issues that shape indigenous water uses often affect them disproportionately (see the first photo).

Although what are perceived as indigenous or local methods are often contrasted with what are viewed as Western methods, the distinction is often not that clear-cut. Extant indigenous cultures are not isolated from the surrounding societies, Western and otherwise, and they often incorporate knowledge and technologies of practical benefit. For example, the second photograph shows how on the rural unelectrified island of Fefan, in Chuuk State, Federated States of Micronesia, modern polyvinyl chloride (PVC) pipes have taken the place of tree trunks to bring water by gravity from traditional dug-out springs lined with stone and a modern piece of tin. The hand-dug-out, near-surface groundwater lining with stone and gravity-fed approach is local, but the tin cover and PVC pipe are not.

Techniques for Collecting and Treating Water

There are interesting approaches to water quality management in different parts of the world. The clever complexity of these technologies generally



Woman on the island of Fefan in Chuuk State, Federated States of Micronesia, using untreated water fed by gravity from a stream by PVC (polyvinyl chloride) pipes

Source: Dr. William James Smith Jr.

increases with pressures such as aridity or human population density. Some general methods of indigenous water management are presented below, but these should be considered as only a small sample of the methods actually used, and with many possible variations on each method discussed.

Water Treatment

Technologies for treatment include those used by some Indian women. The process consists of folding of sari material over a jug multiple times and tying it up with vines before dipping it into cholera-laden river water—this has been proven as an effective simple filtration method to mitigate cholera. Such ideas may sometimes hold more promise than

expensive Northern high technologies and perhaps even create useful markets. This is an example of a technology that would be light to ship, simple to use in a decentralized manner, easy to clean by hanging in the sun, and simple to dispose of without hazardous waste. This type of “out-of-the-box” thinking, guided by best global South and island practices can perhaps be combined with Northern science for beneficial results—but only if applications are socially and geographically contextualized and partnerships are sustainable.

Water Collection

Perhaps the most high-profile dimension of indigenous water management has been the

modification of landscapes for the irrigation of croplands. Some major categories include the harvest or channeling of river water, rainwater, and floodwater and, to a lesser extent, of groundwater and springwater. Anil Agarwal and Sunita Narain have discussed the reestablishment of indigenous water management (which was ruined by the land use planning of the English during colonial times), in the form of small check dams to raise the water table.

Bunds

Cultures in many parts of the world have learned to farm on slopes by slowing overland flow with ground-level barriers that run cross-slope. These barriers may be of pegged vegetation or of stones, and they serve to slow water flow, increase soil absorption of water, reduce loss of soil, and increase capture of (fertilizing) runoff. When bunds are made of stone, they may evolve over time, as silt accumulates, to become terraces.

Pits

Pits collect and concentrate rainwater in small fertile plots. Sometimes indigenous areas of water collection are naturally occurring, such as that in the Valley of Fire near Las Vegas, Nevada, in the United States.

Runoff Harvesting

In many arid regions, cultures have relied extensively on agriculture fed by runoff from seasonal storms. Fields are made at the bases of hills or by leveling portions of drainages, such that runoff flows evenly over the fields when it rains. Where there are channels that experience more intense flooding events, canals could be cut into these channels to direct floodwater to fields.

Watershed Delineation and Management

Although many consider watershed management a Western notion, long before there were large watershed-based foundations or agencies performing watershed delineation, the ancient Hawaiian *ahupua'a* tradition flourished, with its delineation of watersheds that well matches present-day U.S. Geological Survey boundaries. Watershed-based management extended from



A blend of indigenous and foreign technologies on the island of Fefan in Chuuk State, Federated States of Micronesia

Source: Dr. William James Smith Jr.

“rim to reef,” in acknowledgment of the social and ecological connectedness of land and fringing reef, and this spatial organization was essential to the daily use of land and water. Today, interest in this tradition is being rekindled in parts of the Hawaiian Islands. Indeed, indigenous water practices reflect much about the evolution of humankind’s relationships with nature.

William James Smith Jr. and Nicholas Grenier

See also **Common Property Resource Management; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Indigenous Forestry; Indigenous Reserves; Islands, Small; Water Management and Treatment; Watershed Management**



Further Readings

- Agarwal, A., & Narain, S. (1997). Dying wisdom: The decline and revival of traditional water harvesting systems in India. *The Ecologist*, 27(3), 112–117.
- Boelens, R., & Hoogendam, P. (Eds.). (2002). *Water rights and empowerment*. Assen, Netherlands: Koninklijke Van Gorcum.
- Critchley, W., Reij, C., & Wilcocks, T. (1994). Indigenous soil and water conservation: A review of the state of knowledge and prospects for building on traditions. *Land Degradation and Rehabilitation*, 5, 293–314.
- Singh, N. (2006). Indigenous water management systems: Interpreting symbolic dimensions in common property resource regimes. *Society and Natural Resources*, 19, 357–366.
- Smith, W., Jr. (2008). The place of rural, remote and least wealthy small islands in international water development: The nexus of geography-technology-sustainability in Chuuk State, Federated States of Micronesia. *Geographical Journal*, 174, 251–268.



INDUSTRIAL DISTRICTS

Industrial districts refer essentially to spatial agglomerations of a specific industry and/or related industries. There is no commonly shared definition of an industrial district and, at times, it has been a source of debate among geographers and economists, but the concept entails concentrations of related firms, suppliers, other support industries, customers, and, of increasingly paramount importance, a high level of human capital.

These industrial regions are generally characterized by numerous small- to medium-sized enterprises (SMEs) rather than one or two large, vertically integrated companies. Within the industrial district, firms specialize in a wide range of functions encompassed by that particular industry. The atmosphere in such areas is notable for an environment that entails both cooperation and competition between companies. Cooperation includes the relationships between firms and suppliers, between suppliers at different levels, and between firms and customers, and even linkages

between competing firms. Competition itself is supposed to be an advantage for an industrial district, as innovation is spurred through interfirm rivalries. Nowadays, many industrial districts are also marked by flexible production systems. Instead of the long production runs that were common to larger (and often Fordist) enterprises, the SMEs within an industrial district are typified by relatively smaller production batches and, most important, the ability to change production runs (by quality and type) quickly. This flexible production environment allows companies to respond swiftly to changing regional and global markets. Most often, lead times are minimized, stemming from reduced times across the research, design, production, and delivery stages. This dynamism is helped by myriad close relationships among different parties, both economic and social, fostered by spatial proximity. Much of the resulting knowledge in such regions is largely tacit—place or industry specific. This network of relationships and knowledge sharing enables the various actors in the industrial districts to react quickly to changing market demands and perhaps, more important, to innovate with regard to both products and processes.

At one time, and following the development of most advanced market economies, industrial districts were seen largely as concentrations of manufacturers and their related suppliers. Much has changed given the large movement of manufacturing activities to locations in emerging economies. The industrial districts of many advanced market economies, instead of production activities, now entail functions including research, development, design, marketing, and management. Given the structural changes in the global economy, moreover, an industrial district can also encompass agglomerations of service industries. Industrial districts can be found within cities or spanning entire regions of a country. By most accounts, the original idea of industrial districts stemmed from the concentrations of small firms in the textile, apparel, and shoe industries located in north-central Italy. Today, however, the term can be applied to locations as varied as Southern California's entertainment industry, the city of London's financial district, and, one of the most commonly referred-to examples, Silicon Valley.

Ronald V. Kalafsky



See also **Agglomeration Economies; Flexible Production; Incubator Zones; Learning Regions**

Further Readings

Porter, M. (1990). *The competitive advantage of nations*. New York: Free Press.

Scott, A. (1988). *New industrial spaces*. London: Pion.

INDUSTRIAL ECOLOGY

Industrial processes alter their surrounding environment through emission of waste products and through the use of natural resources as raw materials to create goods and services. Industrial ecology is the study of the interaction between these two systems (i.e., industrial and environmental), emphasizing the design of manufacturing processes that minimize waste and reduce environmental impacts. Uniquely viewing human industry as part of a dynamic, linked network that includes the environment and the economy, industrial ecology seeks approaches to sustainable use of resources that work well from a holistic perspective. Increasingly, industrial ecologists have broadened their questions and approaches to study and guide material use from “cradle to cradle,” as opposed to just “cradle to grave,” taking into account not just the relations among processes but also the broader infrastructures and social systems that constrain these processes and influence their development.

This young field of research has developed quickly from a foundation in the technical and physical sciences to an interdisciplinary intellectual community that includes academic journals and professional societies. Experts from a range of backgrounds, including the natural and physical sciences, public policy, and law, have joined a discourse that has expanded from questions regarding efficiency of material and energetic flows in industrial processes to include concerns about biodiversity, sustainable development, and public health. Specifically, research topics include determination of material inputs to production, improvements of environmental impacts through

technological change, institutional and managerial responsibility for product design, development of eco-efficient industries and industrial parks, and policy incentives for environmentally friendly practices.

A Systems Perspective

A fundamental component of industrial ecology is the application of a systems perspective to technology and its surrounding environment. This holistic viewpoint of complex interactions maintains that a single part within a network can be best understood not in isolation but rather in the context of its relationship to other parts and its function within the larger whole.

An industrial system is a network of production and consumption built of several steps of varying complexity from raw materials to marketable products, to their use and return to the environment or other parts of the economy. This network exists within, and depends on, the larger ecosystem that provides a stock of natural capital for the creation of products and assimilation of wastes. The ways in which industrial processes are designed and end products are used determine the degree of environmental impact and, in turn, the condition of resources available for production. The socioeconomic environment also factors into decision making regarding the scale of resource use, the design of products and industrial structure, as well as the impact on the biophysical environment.

As with other complex networks, a perturbation in any part of the broad industrial-ecological system can cause rebound effects in other parts of the network. Because of this, implementation of solutions to problems must be done with care to avoid adverse rebound effects. For example, installation of green roofs and vegetation in cities can reduce air temperatures, leading to less energy use for air conditioning and water use for cooling in industrial buildings. However, because these solutions are water intensive, it is unclear whether the net water and energy savings would be positive in a given system. By favoring a comprehensive view over narrow partial analyses, industrial ecologists hope to avoid these rebound effects and exact changes that will have benefits throughout the whole system.



The Ecological Analogy

In its view of human industry as a dynamic component contained within the natural world, industrial ecology highlights the parallels between ecosystem processes and product life cycles. Similar to nutrients traveling through levels of a food web, production consists of a flow of energy and materials through a system (i.e., industrial metabolism), generating usable materials and high-entropy by-products. Because of constant reuse and recycling of waste products by organisms in nature, ecological systems are closed-loop cycles ultimately fueled by solar energy. Industrial ecologists apply knowledge of biological systems to mimic these cycles, with the goal of shifting industrial production from linear processes of unlimited waste to closed-loop cycles where nearly all waste is used as inputs for subsequent steps within the same company or as a resource for others.

Levels of Analysis: Tools and Applications

The view of industrial systems as integrated parts of the natural and social worlds requires analyses that span far beyond the technical and physical aspects of production. Tools used by industrial ecologists to limit the negative impacts of production on the environment thus range from highly specific investigations on particular segments of manufacturing chains to broadscale modeling, some of which include social and cultural considerations.

Evaluation of Existing Systems

Part of the challenge of transitioning from a linear, throughput-oriented production system to a closed-loop system is accounting for energy balances and resource flow from a product, from raw materials to the point at which it is no longer usable. These types of analyses have traditionally been thought of as “cradle to grave,” but industrial ecologists have become increasingly inclined to consider the “cradle-to-cradle” perspective, where a product at the end of its life cycle is reused for another purpose or recycled rather than discarded. Life cycle assessments (LCAs) are production budgeting tools used to inventory all transfers of energy and materials to

the environment, to characterize the impacts of each release, and to identify areas for efficiency improvements to reduce impacts. One such area is the design of products for maximum reuse of its constituent parts. A systems perspective is particularly important in these analyses to ensure that potential improvements aren’t canceled out by the costs of rebound effects in another part of the network.

Because they tend to be oriented on single products or processes, LCAs are often interpreted in tandem with impact assessments of different foci. Environmental impact assessments, for example, evaluate and model waste emissions from entire plants or firms. Cost evaluation techniques (e.g., cost-benefit analysis) can then be used to compare potential methods to reduce impacts. Combining impact assessments from the perspectives of technical, ecological, and socioeconomic systems provides a comprehensive, higher-order picture of the industrial network for technical experts to use when considering efficiency improvements.

Change in Existing Systems

Technological innovation often plays a key role in moving from open- to closed-loop systems by increasing the efficiency of industrial processes or aiding in the recycling of waste products. The existing infrastructure of a given industry to a certain extent “locks in” production methods and efficiency, because upgrades and improvements to industrial capital can be very time-consuming and expensive. There is a burgeoning area of study within industrial ecology dedicated to the economics of such innovation, emphasizing the timing of change and improvements based on the technological inertia in the industry. Systems modeling is typically used to set potential schedules representing the most cost- and energy-efficient timescales for implementing innovative technological change. For example, the energy-intensive pulp and paper industry is a recent target for carbon dioxide emissions reductions. Researchers in Europe and the United States have used dynamic modeling to investigate the impacts of various policy options on emissions given the capital vintage structure (i.e., the lifetime capacity and age structure) of pulp and paper plants.



Industrial ecology emphasizes the design of new products that anticipates environmental impacts from the start, ideally saving manufacturers' costs of cleanup or improvements in the future. The "design for environment," or DFE, approach joins capital vintage approaches and comprehensive environmental assessments toward a forward-thinking view of design. Typically product oriented, this approach focuses on reduction of toxic material use, the potential for recycling, and manufacturer responsibility as a feature of product development rather than an afterthought. The movement toward green cars (e.g., hybrid and electric vehicles) from "end-of-pipe" mechanisms to reduce emissions (e.g., catalytic converters) represents an ongoing application of DFE.

Industrial Systems in a Social Context

Some industrial ecologists emphasize the social sciences as a critical part of the higher-level picture of industrial-ecological interactions and propose complex modeling approaches. Without an understanding of how to generate real changes in the human economy, some argue that many theories in industrial ecology will remain purely academic. To that end, behavioral studies of human consumption and waste patterns, for example, are employed to develop strategies for policies in the industrial world that will be successfully accepted and enacted.

Industrial Ecology in Practice

The archetypal example of industrial ecology in practice is an integrated production network in Kalundborg, Denmark. Borrowing the adaptive strategy of mutualism from nature, this and other eco-industrial parks share materials and energy among participating firms in an effort to achieve greater returns to production than can be achieved when each firm operates independently. These savings costs are incentives for firms to participate in business practices that often result in efficiency improvements and reduced waste emission. Six firms, including an oil refinery, a plasterboard firm, and a pharmaceutical company trade waste for reuse and recycling, recover solvents for manufacturing processes, and share transportation

and security services. Over the past 30 years since the park was founded, evolution of the symbiosis has amounted to substantial annual energy savings; for example, resource exchange between the refinery Statoil and the power station Asnes saves the firms 1.2 million cubic meters of water and 30,000 tons of fossil fuel per year, respectively.

Businesses from around the world are beginning to apply industrial ecological approaches from the eco-industrial park model to smaller-scale partnerships. Texas Industries, for example, enjoyed an increase in cement production and decrease in energy consumption following a 1999 agreement to reuse waste products from neighboring Chaparral Steel. Similar symbiotic developments have emerged throughout the United States and in Japan, Canada, and Puerto Rico, among other places.

The Future of Industrial Ecology

Partly because of its relative youth as a field of research and practice, industrial ecology faces challenges in terms of its scope and direction. Although there has been a distinctive move to include social and cultural questions as previously described, there still is some disagreement about how large a role these concepts should play in the field. There is an active theoretical body of literature focused on moving industrial ecology forward by synthesizing and refining its goals, aims, and breadth.

As the epistemological facet of industrial ecology continues to evolve, there has been difficulty in translating the resulting theories and ideas into application on a larger scale. Although small-scale efficiency improvements can be relatively easy to understand and implement, wider-reaching projects such as the eco-industrial parks have proven more difficult to develop. The current focus on creating sustainable networks of industry will likely remain an active area of research and application in the future as more businesses become interested in how partnerships for the environment can also be potentially profitable.

Similarly, the policy perspective will play a critical role in determining the extent to which novel and innovative ideas are manifested in the industrial world. Use of the market to provide incentives to businesses to implement the ideas and



technologies that are derived from the aforementioned tools and analyses is a critical part of recent discourse. There is an ongoing effort to examine the institutional and organizational barriers to the greening of industry in order to identify practical mechanisms (e.g., ecological tax reform) to create a favorable environment for sustainable development. Similar efforts are encouraging firms to see industrial ecological concepts as opportunities rather than burdens.

Rebecca R. Gasper and Matthias Ruth

See also **Agent-Based Models; Complex Systems Models; Energy Models; Environmental Impacts of Manufacturing; Sustainable Production**

Further Readings

- Ayres, R., & Ayres, L. (Eds.). (2002). *A handbook of industrial ecology*. Cheltenham, UK: Edward Elgar.
- Garner, A. (1995). *Industrial ecology: An introduction*. Ann Arbor, MI: National Pollution Prevention Center for Higher Education.
- Lowe, E., Moran, S., & Holmes, D. (1996). *Fieldbook for the development of eco-industrial parks*. Washington, DC: U.S. Environmental Protection Agency.
- Ruth, M. (2006). A quest for the economics of sustainability and the sustainability of economics. *Ecological Economics*, 56, 332–342.
- van der Bergh, J., & Janssen, M. (Eds.). (2004). *Economics of industrial ecology*. Boston: MIT Press.

heavily involved in the primary economic sector, in agriculture and/or extractive activities. In the case of some countries with few or no natural resource endowments, reliance on the primary sector is untenable, thereby compelling countries into rapid industrialization.

The initial stages of industrialization (basic manufacturing) take advantage of the low-cost advantages that a newly industrialized region or country has, centered on available labor, natural resources, and/or a large market. Next, as levels of human capital and overall capital accumulation rise, production activities move toward advanced manufacturing activities, entailing increased technical sophistication and decreased economic reliance on manufactured goods. The end result is that the overall economic wealth increases and industrial activities become diverse and increasingly complex. This transition also includes the establishment of advanced manufacturing functions such as research, design, logistics, and management as production moves to offshore sites. This transition has been a cause for concern in many advanced market economies, given their large losses of production-related employment. Recent economic history has also suggested that the industrialization process also encompasses a move toward a varied and sophisticated service sector.

Industrialization, as it is generally understood, took place during the Industrial Revolutions of Great Britain, Western Europe, and the United States during the mid 19th century. Japan rapidly developed during the late 19th and early 20th centuries. Notably, Japan again achieved rapid industrialization in the decades following World War II, developing into the world's second largest economy. Similar swift industrialization paths occurred in South Korea and Taiwan, to provide just two examples. Currently, industrialization processes are occurring, at different rates and at various stages, across the world. The most visible examples are found in the recent, rapid economic growth witnessed in China and India.

A noteworthy point is that economic history has demonstrated that no single, clear-cut path to industrialization exists with regard to the methods, types of industries, or even the institutions involved in the process. Geographers and other researchers have been interested in the conditions



INDUSTRIALIZATION

Industrialization refers to the economic growth and processes occurring at any geographical scale, ranging from a metropolitan region to an entire country. Historically, these processes entail the initiation and development of a manufacturing sector that first specializes in basic activities that include the production of commodity-type goods. Before this initial industrialization stage, many regions or countries are



and forces that most often make each industrialization process unique with regard to its pace, methods, institutional involvement, and end results. The paths to industrialization in the United States and Britain were considered to have been largely led by the private sector, but even these economic transitions often involved degrees of policy-led participation. In Western Europe, industrialization entailed a large degree of public sector/private sector interaction, but again, this varied by country. In the above examples, industrialization often started with industries such as textiles, then progressed with heavy industries such as steel and chemical production. A goal was to serve domestic markets and, secondarily, to export to other markets, which sometimes included colonies. For Japan and throughout much of East Asia (with many countries basing growth policies on the Japanese model), the links between government and industry were close. In these instances, government played a strong advisory role, formulating a strong industrial policy. Trade policies such as import substitution and export promotion were also implemented with the aim of achieving rapid economic growth, stability, and higher standards of living. The point to be made with regard to industrialization is that even opinions about government involvement or market structure (e.g., regulation of monopolies) have been viewed quite differently. All the above situations involved industrialization with the end goal of economic development. However, the means to achieve these goals and the paths that were taken have been quite different.

An overwhelming feature of industrialization is its spatial unevenness. This apparent unevenness occurs at a variety of scales, within regions, within countries, and, as has been noted by numerous observers, on a global scale. In many cases, differences in the rates of industrialization have led to core-periphery unevenness in development. Consequently, geographers are interested in the spatial effects of industrialization, including the impacts on labor, firms, markets, governments, and the environment.

Ronald V. Kalafsky

See also **Flexible Production; Industrial Districts; Industrial Revolution; Manufacturing Belt**

Further Readings

Amable, B. (2003). *The diversity of modern capitalism*. Oxford, UK: Oxford University Press.



INDUSTRIAL REVOLUTION

Although capitalism has been a dynamic socioeconomic system since its inception, the pace of technological and social change accelerated exponentially in the 18th and 19th centuries with the Industrial Revolution. It is important not to equate capitalism and industrialization, for they are not synonymous. Historically, the Industrial Revolution occurred long after capitalism began; indeed, for most of capitalism's history, it involved preindustrial forms of production, including artisanal and household types. However, starting in the mid 1800s, an explosive increase in the speed and productivity of capitalist production occurred that transformed the worlds of work, everyday life, and the global economy. Industrialization is a complex process that involves multiple transformations in inputs, outputs, and technologies. Three dimensions are particularly important here: (1) the use of inanimate energy, (2) technological innovation, and (3) increased productivity. This entry first describes these aspects of the Industrial Revolution and then examines its geographical development, cyclical nature, and global impact.

Inanimate Energy

If preindustrial societies relied and continue to rely on animate sources of energy (i.e., human and animal muscle power), industrialization can be defined loosely as the harnessing of inanimate sources of energy. The first of this type was running water in waterwheels, a source used since the late feudal era to grind corn and flour and to saw wood. Running water was a major source of energy in the earliest stages of the Industrial Revolution, but it constrained firms to locating near streams and rivers; moreover, most streams are ephemeral, that is, they do not flow all year long.

A more efficient source of inanimate energy involves the steam engine, originally designed by



Thomas Newcomen in 1712; the first prototype, however, was built by the Scottish engineer James Watt in 1769 as part of an effort to expunge seawater from coal mines that reached under the ocean. The steam engine marked a decisive turning point in the process of industrialization, with widespread applications in several areas of production and transportation. Wood provided the first major source of fuel for this invention, which required heating water into steam to drive the engine's pistons. As producers began to cut down forests in Britain in large numbers, deforesting much of the country, wood supplies began to dwindle, and the rising cost eroded profits. As wood became scarce, producers switched to coal. Thus, as Britain industrialized, several areas became major coal-producing centers, including Southern Wales and Newcastle. As the Industrial Revolution spread across the face of Europe in the 19th century, the large coal deposits of the Northern European lowlands became increasingly important, fueling the growth of manufacturing complexes in Belgium, Northern France, Northern Italy, Germany, Poland, and the Ukraine. In the United States as well, Appalachian coal played a key role in the nation's industrialization, and that industry flourished hand in hand with the rise of the Manufacturing Belt. In the late 19th and 20th centuries, coal was joined by other fossil fuels, particularly petroleum and natural gas. The abundance of cheap energy was the lifeblood of industrialization, and production became increasingly energy intensive as a result.

Technological Innovation

The Industrial Revolution witnessed an explosive jump in the number, diversity, and applications of new technologies. A technology can be defined simply as a means of converting inputs to outputs. These can range from extremely simple to very sophisticated. As industrialization produced an increasingly complex division of labor, as noted by Adam Smith, opportunities for new inventions rose rapidly. These innovations were employed in agriculture, in manufacturing, in transportation and communications, and in services.

In the Industrial Revolution, a major reorganization in the nature of work occurred with the

development of the factory system and a far more detailed division of labor both within and among firms. Prior to this era, industrial work was organized on a small-scale artisanal basis, including home-based work. By the late 18th century, firms in different industries were grouping large numbers of workers together under one roof, a process that effectively created the industrial working class. Inside factories, workers used vast amounts of capital, that is, many types of machines. The introduction of interchangeable parts, invented by the American gun maker Eli Whitney, made the production and operation of machines much cheaper and more reliable. By the early 20th century, Henry Ford introduced the moving assembly line, which further accelerated the tempo of work and the ability of workers to produce.

Productivity Increases

As a consequence of the technological changes of the Industrial Revolution, productivity levels surged. Productivity refers to the level of output generated by a given volume of inputs; productivity increases refer to higher levels of efficiency—that is, greater levels of output per unit of input (e.g., labor hour or unit of land) or, conversely, fewer inputs per unit of output.

Productivity levels rose exponentially in the 19th century throughout the industrializing world. As the cost of producing goods declined, standards of living rose correspondingly. Most workers labored long hours under notoriously exploitative conditions and endured a standard of living quite low compared with those we enjoy today. But nonetheless, over several decades, industrialization saw many kinds of goods become increasingly affordable to the growing middle class. Because wage rates have been linked historically to the marginal productivity of labor, the working class became significantly better off. Most important in this regard concerns the industrialization of agriculture. As food became progressively cheaper, diets improved as more people ate more and better food than ever before, with corresponding improvements in infant mortality rates and life expectancy. With the notorious exception of the Irish Potato Famine of the 1840s, hunger and malnutrition gradually declined throughout Europe.



The Geography of the Industrial Revolution

The Industrial Revolution unfolded very unevenly over time and space. Whereas capitalism had its origins in Northern Italy, industrialization was very much a product of northwestern Europe. Some observers put the first textile factories in Belgium, in cities such as Liège and Flanders, with a tradition that dated to late medieval times. However, it was Britain that became the world's first industrialized nation, a status that likely reflected, among other things, its extensive network of trading ties and prior commercialization of agricultural land through the Enclosures. By the end of the 18th century, Britain stood virtually alone as the world's only industrial economy, a fact that gave it an enormous advantage over its rivals and propelled it to the status of world hegemon. Cities in the Midlands of Britain, such as Leeds and Manchester, were known as the "workhouses of the world" for their high concentrations of workers, capital, and output. Others, such as London, Glasgow, and Liverpool, became shipbuilding centers. In many cities, networks of producers in guns, watches, and light industry formed dense industrial districts.

A half-century after it began in Britain, the Industrial Revolution diffused to the European Continent, North America, and Japan. In France, this process saw the formation of industrial complexes in the lower Seine River, Lille, and Paris. In Italy, Milan and the Po River valley became a major producer of textiles and shoes. In Northern Spain, Barcelona became an important center. In Scandinavia, cities such as Stockholm became major ship producers. In Germany, which was late to industrialize, the Ruhr region became a global center of steel, automobile, and petrochemical firms in the late 19th century, propelling that newly unified nation to global prominence.

By the early 19th century, the revolution leapfrogged across the Atlantic, igniting the industrialization of Southern New England with the growth of the textile industry there. In New York City, a huge complex of light manufacturing arose, centered on garments but including many other small firms. Philadelphia became a large center of ship construction. Stretching across the southern shores of the Great Lakes, the Manufacturing Belt became the second largest industrial

region in the late 19th century, following Britain, largely on the basis of the steel, rubber, tool and die, agricultural implements, and automobile industries. However, industrialization also dramatically affected agriculture and meat packing.

Russia did not become industrialized until the 1920s and 1930s, when the Soviet Union under Stalin leaped to become the world's second largest economy in the span of a decade. Under the Soviet system, heavy manufacturing, particularly steel and armaments, was emphasized over sectors producing consumer goods. Starting in the 1870s, Japan became the first non-Western country to join the industrialized nations, developing a formidable industrial base in steel, railroads, armaments, textiles, and ship building that fueled its expansionary growth and militarism.

In the late 20th century, the process of industrialization diffused to many developing countries, particularly the East Asian Newly Industrialized Countries (NICs) such as South Korea, Hong Kong, Taiwan, and Singapore, many of which borrowed liberally from the Japanese model. More recently, Thailand, Indonesia, and Malaysia have moved down this path. Rapid economic growth in China today represents another stage in the industrialization of Asia, including the production of textiles, toys, and electronics. Similar events occurred in Mexico and Brazil, including the *maquiladores* in the former and an electronics and aerospace industry in the latter. In a sense, the industrialization of the developing world, which is still very partial and incomplete, is a continuation of a long-standing historical process.

Cycles of Industrialization

The nature and form of industrialization varied in successive historical periods. Capitalism is prone to long-term cyclical shifts in its composition, often in waves of roughly 50 to 75 yrs.' (years') duration, often known as Kondratieff waves. This process saw the rise of different industries at different times. Industrialization was thus not one process but a series of them that varied over time and space.

The first wave of the Industrial Revolution (1770s–1820s) centered on the textile industry. In Britain, as in the rest of Europe, North America, Japan, and the developing world today, textiles



have *always* led industrialization. Easy to set up, with few requirements of capital or labor skills, this sector initiated the industrial landscapes of most of the world. Because this early wave of industrialization was centered in Britain, it witnessed that nation become the leading economic power in the world, initiating the period of the Pax Britannica.

The second wave, from the 1820s to the 1880s, was a period dominated by heavy industry. In the 19th century, sectors such as shipbuilding, railroads, and iron and steel plants were critical. Large scale and capital intensive, these types of firms differed markedly from the light industry of textiles. They required massive capital investments, an infrastructure often built by the state, were difficult to enter, and moved toward an oligopoly rather than a competitive market structure. This was the period in which the U.S. Manufacturing Belt began to form, although most of its growth was after the Civil War of the 1860s.

The third wave of industrialization, from the 1880s to the 1930s, saw numerous heavy industries appear, including steel, rubber, glass, and automobiles. This was a period of massive technological change, including capital intensification and automation of work, as well as economic changes. As local markets gave way to national markets, most sectors experienced a steady oligopolization, or concentration of output and ownership in the hands of a few large firms led by robber barons.

In the fourth wave of industrialization, which started during or immediately after the Depression of the 1930s and lasted until the oil shocks of the 1970s, the primary growth sectors were petrochemicals and automobiles. It is often associated with Fordist systems of mass production. With a relatively stable global economy, this era saw the domination of the world system by the United States, which produced a huge share of the planet's industrial output, including, in the 1950s, two thirds of its steel and 60% of its automobiles.

The fifth wave of industrialization, often held to begin after the oil shocks of the 1970s that ended the post-World War II boom, has been led by the electronics industry, which was powered by the microelectronics revolution and by the explosive growth of producer services.

During each era, the major propulsive industry was commonly featured as the “high-tech” sector of its day. Thus, just as electronics is often celebrated at this historical moment for its innovativeness and ability to sustain national competitiveness, so too were the textile industry in the 18th century and the steel industry in the 19th century associated with high levels of productivity and wages.

Consequences of the Industrial Revolution

The Industrial Revolution permanently changed the social and spatial fabric of the world, particularly in the societies that now comprise the economically developed countries. Within a century of its inception, industrialization transformed a series of rural, poverty-stricken societies into relatively prosperous, urbanized ones. It is no exaggeration to credit industrialization with the rise of modernity in all its complex forms.

The Industrial Revolution essentially created the modern working class. For the first time in human history, large numbers of workers labored together using machines. These conditions were markedly different from those facing agricultural or artisanal workers, who were dispersed over large spaces and relied on animate sources of energy. Industrialization gave rise to organized labor markets in which workers were paid by the hour, day, or week. This process was not easy, given how brutally exploitative working conditions were during this time. Workers typically labored for 10, 12, even 14 hours per day, 6 days per week for relatively low wages. Often the work was unsanitary and dangerous, even lethal, as workers were subjected to abusive employers, accidents, poor lighting, and poor air quality. Child labor was also common, subjecting those as young as 4 or 5 yrs. of age to horrendous conditions.

As the result of this process, time—like space and so much else—became a commodity, something bought and sold. The transition from agricultural time to industrial time was important. Prior to the Industrial Revolution, people experienced time seasonally, with different tasks at different times of the year, and rarely felt the need to be conscious of it, for precision was unnecessary. With industrialization, however, time was measured and divided into discrete units, as signaled



Spinners at Cherryville Mfg. Co., North Carolina, 1908. During the Industrial Revolution, child labor was common, subjecting those as young as 4 or 5 yrs. of age to horrendous conditions.

Source: Library of Congress Prints and Photographs Division, LC-USZ62-65667.

by the factory whistle, clock, bell, and stopwatch. This change marked the commodification of time through the labor market.

Industrialization also produced labor unions. The first resistance to employers included the British Luddites in the late 18th and early 19th centuries, who blamed their miserable working conditions on the machines they used and often destroyed them in attempts to halt their exploitation. By the late 19th century, organized labor had created a number of unions, which in the United States included the Knights of Labor, the American Federation of Labor (AFL), and in the 20th century, the Industrial Workers of the World and the Congress of Industrial Organizations (CIO, which later merged with the AFL to form the AFL-CIO). Industrialization was thus often a period of considerable class conflict.

Geographically, the Industrial Revolution was closely associated with the growth of cities. Almost everywhere, industrialization and urbanization have been virtually simultaneous processes. The reasons why firms concentrated in cities are important. Cities were clearly centers of capital as much as they were centers of labor. There are powerful reasons for firms to concentrate, or agglomerate, in cities. Most firms benefit by having close proximity to other firms, including lower transport costs to suppliers of parts and ancillary services, and access to an infrastructure, specialized information, and the labor force. As complexes of firms sprouted in cities, industrialization changed the character of societies from predominantly rural to predominantly urban. In Western Europe, North America, and Japan, for the first time in history, the majority of people



lived in cities. In the United States, for example, the first national census of 1790 showed that 95% of Americans lived in rural areas. This proportion decreased throughout the 19th century, and by 1920, 50% of the nation's population lived in cities. Today, it is roughly 85%, a proportion that is found in most economically developed countries.

Industrialization also shaped the population growth rates and demographic composition. On the eve of the Industrial Revolution, the famous theorist Thomas Malthus predicted that rapid population growth would create widespread famine. Yet Malthus was soon proven to be wrong, at least in the short run. The industrialization of agriculture generated productivity increases greater than the rate of population growth, and the creation of a stable food supply improved most people's diets. As a result, life expectancy rose. Industrialization also lowered death rates, particularly as malnutrition declined and infant mortality rates dropped. Eventually, public health measures and cleaner water helped control the spread of most infectious diseases. As death rates dropped, the populations of industrializing countries increased dramatically. This change was also accompanied by a shift from the extended to the nuclear family. Eventually, industrialization also led to a decline in the birth rate; families had fewer children, and population growth rates declined.

Yet another impact of the Industrial Revolution concerned the global economy. Capitalism had formed a loose network of international trade well before the 18th century. The harnessing of inanimate energy for transportation dramatically accelerated the speed of both land and water transportation, notably through the railroad and steamship, forming a significant round of time-space compression. New, industrialized forms of transportation were not only faster but also cheaper, resulting in cost-space convergence or compression as well. These changes dramatically lowered the barriers to trade, and the volume of imports and exports began to soar. Europe, starting with Britain, could import unprocessed raw materials, including cotton, timber, sugar, wheat, and mineral ores, and export high-value-added finished goods, a process that generated large numbers of jobs in

Europe and contributed to a steady rise in the standard of living.

Finally, the industrial world economy saw an explosion of international finance. British banks, largely concentrated in London, for example, began to extend their activities on an international basis, lending to clients and investing in markets overseas. Much of the capital that financed the American railroad network was from Britain. The globalization of production was thus accompanied by the steady globalization of money and credit.

Barney Warf

See also **Agglomeration Economies; Agriculture, Industrialized; Automobile Industry; Business Cycles and Geography; Demographic Transition; Economic Geography; Fordism; Industrialization; Malthusianism; Manufacturing Belt; Textile Industry; Time-Space Compression; Urbanization**

Further Readings

- Calhoun, C. (1987). Class, space and industrial revolution. In N. Thrift & P. Williams (Eds.), *Class and space: The making of urban society* (pp. 51–72). London: Routledge & Kegan Paul.
- Landes, D. (1969). *The unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the present*. Cambridge, UK: Cambridge University Press.
- Thompson, E. (1967). Time, work-discipline, and industrial capitalism. *Past and Present*, 38, 56–97.



INEQUALITY AND GEOGRAPHY

Human geographers became directly interested in the study of inequality when the focus of the discipline shifted to examining spatial differences using quantitative methods and exploring how different variables varied across space. Typically, such variations occurred across a country or city, although a few scholars were interested in variations across



the globe. At first, the main focus was on how to map, measure, and explain variations, but gradually more normative approaches began to address welfare and justice issues. How did the differences among areas that were being observed affect human life, and insofar as they did, how could the negative aspects be remedied? When Marxism began to influence the discipline in the 1970s, interest in spatial variations was transformed into a stronger, more explicit concern for inequality in all its dimensions. The world was unfair, and something needed to be done to remedy injustices. Of course, for many Marxists the only answer was the demise of the capitalist system.

In recent years, many human geographers have continued to be interested in the broad inequalities in and across societies, but arguably most have concentrated on the problems of specific groups. The unfair treatment of women, black people, ethnic minorities, gays, migrants, those with HIV/AIDS, and others has dominated geographical journals. Only development geographers have really been interested in poverty on a global scale, and only those writing in the more left-wing journals of the discipline, such as *Antipode*, have focused on class. With the shift to postmodernism and poststructuralism, geographers have tended to neglect the normative and policy issues linked to inequality and have focused on how unfairness has developed over time. Postmodern thinkers are typically more interested in discourse analysis and differing interpretations of reality than in remedying past and present wrongs. The idea that progress is possible has diminished in importance by questioning what progress means and whether it is actually desirable. Inequality is integral to postmodern and postcolonial discussions but mainly takes the form of showing how one group or another has been harmed as “progress” or “development” has occurred.

Of course, the field of geography has always attracted a substantial number of those who wanted to get involved in policy issues, but it seems that most geographers are currently less interested in influencing policy than they once were. Those who do get involved in policy work tend to be dismissed as empiricists, insufficiently engaged with theory to take their place at the forefront of the discipline.

Why Is Inequality Important?

That question, of course, is highly political. However, most observers would agree that inequality is undesirable if it means that the wealth of some people and places causes the poverty of others. Such a situation is certainly true in the rural areas of Latin America, where limited numbers of families control most of the cultivable land, a situation that was also once common in Europe. Dependency theorists argue that the wealth of the developed countries has been accumulated at the expense of the “Third World” and that without a redistribution of wealth and resources, billions of people will continue to live in absolute poverty.

Inequality is also important for political reasons. Much of the conflict that has occurred across the globe has been caused by ill feeling over the distribution of resources. This resentment has sometimes taken the disguised form of racial or religious intolerance, but the underlying cause has typically been that one group is much better off than another. Such might be the explanation of the Protestant/Catholic struggles in Northern Ireland, the Palestine/Israel problem, and the genocide that occurred in Bosnia and Croatia, in Rwanda and, currently, in Sudan. It is also a likely cause of the riots that have occurred in some cities in developed countries, such as those in the Watts area of Los Angeles in the 1960s, the interracial hostility in some northern cities of the United Kingdom early in the new millennium, and the French riots of 2005. If class-based revolution is less likely than Marxists once believed, inequality is at the heart of much of the violence, actual and potential, going on in the world today.

Most people would accept that some degree of inequality is inevitable and some even that it is desirable, but how much inequality is acceptable? This question is actually unanswerable because everyone’s view on the matter will be different. Some scholars, particularly economists, argue that inequality is necessary to create the incentives and capital necessary to generate the wealth that will remove poverty, although that view begs the question of how large those incentives need to be. Chief executive officers (CEOs) today earn much larger salaries than they did two or three decades ago. Would they not want to lead their corporations if



their annual pay was in the hundreds of thousands of dollars rather than in the millions? On the other side of the political divide, some still agree with Karl Marx's aphorism, "From each according to his ability, to each according to his needs," even if experience over the years has suggested that this principle has not worked very well in practice. Most people adopt an intermediate position, but what precisely is that?

The only way any such position can be established is through political debate and struggle. If the poor person or the black or the Muslim begins to protest, the question of inequality rises to the fore of the political agenda. If people begin to starve, even though they do not have the strength to protest, then most people would accept that there should be a transfer of resources. Of course, protest is more effective when it occurs on the doorstep of decision makers. Injustice is easier to ignore in Africa than it is in the inner city ghettos of developed countries. For policymakers, and for much of the public, the genocide and starvation occurring in Darfur are a long way away, and thus invisible.

How Do We Measure Inequality?

Equality is relatively easy to measure empirically. In an equally developed society, everyone would earn the same income, every birth would be attended by a health care professional, and every child would start school at the same age and receive the same quality of education. Achieving total equality is, of course, impossible, but we can conceptualize what it means and measure it fairly accurately.

Inequality, by contrast, is more complicated. First, all kinds of measures of inequality are available, and they all produce different results. Measures such as the Gini coefficient, Theil's *T* statistic, the index of dissimilarity, and so on all provide different answers because different statistical assumptions underpin their calculation. Second, trends in inequality also vary according to the time period and the scale over which inequality is measured. If statistics do not lie, they can certainly be manipulated to produce the answers that the analyst wants to find—something particularly likely in the study of inequality.

What Are the Main Features of Inequality?

Differences According to Scale

World Scale

No one can doubt that inequalities among nations are extreme. Today, the total income of the richest 25 million Americans is equal to the total income accruing to almost 2 billion people, 30% of the world's population. Of course, the degree of difference clearly varies according to the indicator we use and how we divide the world, but living conditions for the majority of those living in sub-Saharan Africa and the Indian subcontinent are clearly appalling when compared with the affluence of the majority in developed countries.

Whether those differences are increasing or diminishing is open to debate. One claim is that the ratio of average incomes in the industrialized and developing countries rose from roughly 30:1 at the end of World War II, to 60:1 in the 1970s, to more than 90:1 by the early 2000s. However, other figures show something different; indeed, according to which numbers are used and over which period of time, the data show several different trends.

Equally, there are doubts about the relationship between poverty and inequality. Some scholars argue that poverty has declined in the world over the past decade or so, mainly because living conditions for many East Asians, particularly Chinese people, have improved markedly; others question the level of the poverty line and suggest that it has not. Certainly, while the relative numbers living in abject poverty have declined in recent years, the absolute decline in the numbers of poor people is much less impressive.

National Scale

Since 1980, the distribution of income in virtually every country in the world has become more unequal, particularly given the hegemony of neoliberalism. The rich have seen their share of total earnings and wealth increase rapidly, whether it is in the United States, China, or Brazil. There are many drivers of this inequality, including globalization, regressive taxation, and the growth of unearned income (e.g., dividends). Today, the



world's ultra-rich are not confined to the United States and Western Europe; a few very rich people have emerged in China, India, Mexico, and most oil-rich countries of the Middle East. Equally, large numbers of poor people have moved in search of work into countries with higher incomes, increasing their national levels of inequality.

Regional Scale

Unlike national inequality, regional disparities within countries have sometimes diminished. In Mexico, the past 30 years have seen the north of the country prosper relative to some of the older established industrial centers, although the south continues to struggle. In some places, regional differences have declined because new resources have been exploited, raising the incomes of some poorer regions. Occasionally, government action has managed to reduce inequalities. Sometimes the poor have moved out of poor areas to more prosperous places, even out of the country altogether. But arguably, differences among regions are insignificant because they are effectively determined by more fundamental causes such as income variations by social class and ethnicity. Most poor regions have a much higher proportion of working-class people or ethnic minorities. And when regional incomes rise in a poor area, often it is only the local elite that benefits.

Local Scale

Most urban areas appear to be becoming more unequal. Certainly, global cities are becoming more polarized as the salaries of the highly skilled are determined by global markets while their needs are serviced by a relatively impoverished, often immigrant, "underclass." Fearing crime and violence, the more affluent protect themselves by living in "gated communities" or in apartment buildings heavily protected by security cameras and guards. Whether this tendency is as marked in nonglobalized cities is unclear, but where social inequality is rising, it is likely that residential segregation will follow.

Differences by Social Group

Arguably it is social and political processes that explain most geographical variations.

Gender

On average, throughout the world, men earn more than women, although the difference between the sexes is being reduced in most developed countries. In many poorer countries, however, the divide is still marked. If today Indian widows rarely throw themselves on their dead husbands' funeral pyres, their daughters still live shorter and more brutish lives than their sons. Generally, discrimination between the sexes is more marked at the bottom of the social ladder than at the top. This trend is reflected in the number of female politicians and legislators who have gradually gained power in recent years. However, the conditions in which poor women in Africa, Asia, and Latin America live tend to be distinctly less positive than those of poor men. Women work harder than men, earn less money and respect, and have fewer opportunities for education or higher-paying jobs.

Ethnic and Racial Differences

In most countries, ethnic groups do less well than the majority. White-skinned people in Latin America tend to be more affluent than darker-skinned people, and relatively few live in favelas or squatter settlements. In the United States, African Americans and Hispanics/Latinos are generally much poorer than whites, have less education, are less likely to own homes, and are more likely to be unemployed. Legislation is making a difference in some parts of the world but seldom very quickly. Insofar as race and ethnicity are important motivators of political protest, particularly when allied to religious and language differences, ethnicity must play a key element in any analysis of inequality and its consequences.

Social Class

The June 15, 2006, issue of *The Economist*, in the article "The Rights and Wrongs of the American Model," argued that inequality is acceptable providing that three conditions are met: "First, society as a whole is getting richer; second, there is a safety net for the very poor; and third, everybody, regardless of class, race, creed or sex, has an opportunity to climb up through the system." Unfortunately, the signs are that in recent years



those conditions are not being met in most countries in the world. Insofar as access to work is determined by qualifications, those with a good education tend to get the best jobs. But access to education is a function of social class; richer parents can pay for a better education for their children, whereas poor parents cannot. Rather than equalizing people's opportunities, therefore, too many educational systems are creating new forms of social class division and inequality rather than overcoming such divisions.

A Normative Conclusion

Starting in the late 19th century, and particularly after World War II, many governments across the globe created a form of welfare state. Led by Scandinavia and the United Kingdom, social safety nets were created, social security and minimum wages implemented, the quality of housing and health was improved, and universal education systems were established that would give everyone a chance of improving their lives. Social democracy was premised on the belief that social inequalities should be reduced. Of course, improvements were usually much more modest than anticipated, but social inequality did generally decline.

Arguably, that condition is no longer the case. Recent globalization and the rise of neoliberalism in the 1980s created immense new opportunities for the world's rich, the well educated, and the opportunistic to make very large sums of money. The market regained much of the power that it had lost under social democracy. Governments either reduced their role, including reductions in social services, or found that they could not control the strength of market forces. As a result, inequality has surged after years of decline.

Alan Gilbert

See also **Class, Geography and; Dependency Theory; Digital Divide; Education, Geographies of; Environmental Justice; Ethnic Segregation; Gated Community; Gender and Geography; Globalization; Justice, Geography of; Neoliberalism; Patriarchy, Geography and; Poverty; Race and Racism; Racial Segregation; Segregation and Geography; Social Justice; Spatial Inequality; Uneven Development; World-Systems Theory**

Further Readings

- Blakely, E., & Snyder, M. (1997). *Fortress America: Gated communities in the United States*. Washington, DC: Brookings Institution Press.
- Dollar, D. (2005). Globalization, poverty, and inequality since 1980. *The World Bank Research Observer*, 20, 145–175.
- Firebaugh, G. (2003). *The new geography of global income inequality*. Cambridge, MA: Harvard University Press.
- Gilbert, A. (2007). Inequality and why it matters. *Geography Compass*, 1, 422–447.
- Glasmeier, A. (2006). *An atlas of poverty in America: One nation, pulling apart, 1960–2003*. New York: Routledge.
- The rights and wrongs of the American model. (2006, June 15). Inequality and the American dream [Special issue]. *The Economist*.
- Wade, R. (2004). Is globalization reducing poverty and inequality? *World Development*, 32, 567–589.



INFORMAL ECONOMY

Informal economy—also referred to as the “unorganized,” “unprotected,” or “unregistered” sector—is a process of income generation that is unregulated by the political institutions of a society, in a legal and social environment in which similar activities are regulated.

The absence of institutional regulation in the informal economy affects various elements of the work process. First, it influences the status of labor, which may be undocumented, working below minimum wage, lacking social benefits, or employed under circumstances that legal or societal norms would not otherwise allow. Second, it influences the conditions of work under which labor is employed, which may involve ignoring health, hygiene, and other safety requirements. Third, it refers to a particular form of institutional management. For instance, a company may engage in systematic fiscal fraud or the generalized use of unrecorded cash payments as a means of economic transaction. Scholars of the informal economy emphasize that there is no theoretical



reason to exclude the unrecorded practices of large corporations from the informal economy since they are closely linked with the growth of other informal activities. In a seminal collection of articles titled *The Informal Economy: Studies in Advanced and Less Developed Countries*, Alejandro Portes and Manuel Castells emphasized the existence of an informal economy in all countries by including case studies ranging from New York City and Madrid to Uruguay and Colombia. This perspective reinforces that the informal economy is not a marginal phenomenon but a fundamental politico-economic process at the core of many developing and developed countries. The basic distinction between formal and informal economic activities does not hinge on the character of the final product but on the manner in which it is produced and exchanged. Articles of clothing, restaurant food, meat, fruits, and vegetables, for example, are not illicit commodities, but they may have their origins in legally regulated or unregulated production arrangements.

Characteristics of the Informal Economy

The social and economic characteristics of the informal economy cannot be captured by a strict definition, but existing evidence does lend itself to a limited number of generalizations. First, the informal economy is universal and can be found in countries and regions at very different levels of economic development and industrialization. Indeed, in the current context, the informal sector continues to grow even in the highly institutionalized economies of North America and Western Europe. Research on the topic is more difficult in these contexts because these activities are categorized as clandestine and therefore more actively persecuted. Second, since the forms adopted by unregulated production and distribution vary

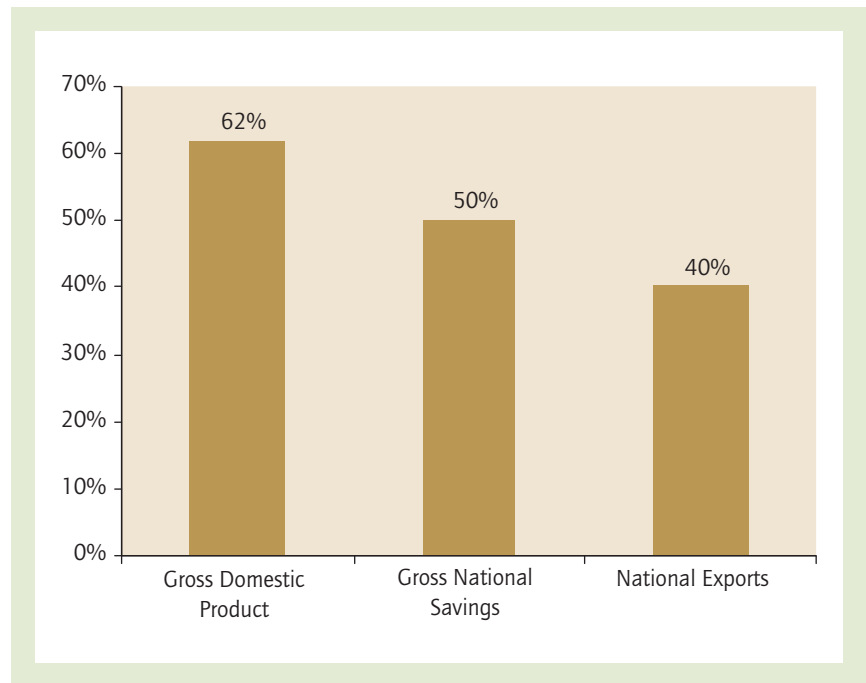


Figure 1 Informal sector's contribution to India's national economy

Source: Created by author, from data in Alta Chen, M., Jhabvala, R., & Lund, F. (2002). *Supporting workers in the informal economy: A policy framework*. Geneva: International Labour Organization.

widely even within single societies, this sector is extremely heterogeneous. Third, there is agreement among researchers working on the informal economy that the sector has grown in size in many different social and economic contexts in the past few decades. Brisk population growth, increasing landlessness, inadequate social support programs, and growing rural-urban migration are presumably some of the factors that have ensured that large enterprises are unable to create enough jobs to absorb the swelling supply of labor. Under such circumstances, increasing numbers of urban and rural people have been forced to, or have chosen to, create alternative sources of employment. All such unregistered, and therefore unrecognized, manufacturing, service, and petty trade activities are also collectively known as the informal sector—the sector of economic activity that is not registered with government agencies and does not comply with regulations governing labor practices, taxes, and licensing. In India, for example, the informal sector is estimated to account for 93% of the total labor force and 64% of the gross domestic product.



Because it is inaccurate and unjust to describe such a large dynamic workforce in terms that relegate it to a peripheral position, many authors and activists prefer to use the term *self-employed*, arguing that these workers are essentially entrepreneurs since they assume all the risks of their businesses. The term *self-employed* seems appropriate to describe people who attempt to generate independent livelihoods under a variety of circumstances, compared with other terms with pejorative connotations, such as *casual* work, or illegal connotations, such as *black economy*, derived from the Italian *lavoro negro*, traditionally used to describe people with connections to the mafia, or *marginal* economy, which utterly fails to capture the significant economic contributions of the sector. The concern some researchers express about the use of the term *self-employed* arises from the possible confusion of the meaning attributed to it by Western capitalism. Self-employment in the context of the industrialized world may imply informed choice to pursue independent livelihoods in the presence of other opportunities. An overwhelming number of people in the developing world as well as some vulnerable groups such as undocumented workers in developed countries are driven to the informal sector not out of a desire to be entrepreneurial but because of lack of options and unmet household subsistence requirements. The absence of a fixed employer, or the difficulty of identifying one due to elaborate chains of subcontracting, is a common characteristic of this sector and one that ensures that workers remain in precarious casual, contractual, migrant, or home-based work environments. While flexibility in working hours and in locations of work is perceived as an attractive option in the formal sector, for socially vulnerable groups it usually translates into undesirable working conditions. Home-based informal-sector workers, for example, frequently work longer and harder hours than formal-sector workers but fail to avail themselves of any legal entitlements for minimum wages or social security benefits, sometimes despite the existence of protective legislation. Hidden but effective structures of dependency make it difficult to supply the evidence needed to prove that the real nature of the relationship between many of the informal-sector workers and those who pay for their work is one of employees and employers.

The informal economy simultaneously encompasses many contradictions within different geographical and cultural contexts: flexibility and exploitation; productivity and abuse; aggressive entrepreneurs and vulnerable workers; survival and greed. However, it shares three commonalities. First, research on the informal economy demonstrates its systemic connection with the formal economy. Home-based workers in Indian slums who sew Gap and Eddie Bauer shirt labels for local contractors and undocumented workers who work in meat-packing plants in the United States demonstrate that the informal sector is an integral component of national and global economies and not a marginal appendix to them. Second, informal-sector workers tend to receive fewer benefits and lower wages and experience worse working conditions than formal-sector workers. This is a prerequisite for their entry into the labor market. Third, although informal workers are frequently harassed, governments tend to tolerate and even stimulate informal economic activities in order to promote political patronage or resolve social conflict. This is as true in governmental attitudes toward “illegals” in North America or Europe as it is in the experiences of squatter settlements in the burgeoning cities of the global South.

Bipasha Baruah

See also **Developing World; Development Theory; Globalization; Labor, Geography of; Remittances; Rural-Urban Migration; Squatter Settlements; Urban and Regional Development; Urban Underclass**

Further Readings

- Chen, M., Sebstad, J., & O'Connell, L. (1999). Counting the invisible workforce: The case of homebased workers. *World Development*, 27, 603–610.
- Guha-Khasnobis, B., Kanbur, R., & Ostrom, E. (Eds.). 2007. *Unlocking human potential: Concepts and policies for linking the informal and formal sectors*. London: Oxford University Press.
- Maloney, W. (2004). Informality revisited. *World Development*, 32(7), 1–20.



INFORMATION SOCIETY

Today, more people are exposed and have access to more information than anytime in the past. This situation results from the information economy. Easy access and ample exposure to information has reshaped modern societies, permeated everyday life, and now influences the decisions people make and the opportunities they seek. There are even world summits that solely address the issues of an information society. Yet not everyone has equal access to information, and geographic patterns of information access have emerged. In effect, areas of higher economic development typically have greater exposure and access to information than lagging areas. This trend is true at the global, national, or regional scale. Some regions and urban places are tied to the information network to a greater extent than others, and such places tend to be sources for information.

The growth of an information society is tied heavily to information and communication technologies. The introduction of the telegraph helped collapse space in the 19th century. Ensuing developments in radio and phone technology furthered the collapse. Television has profoundly affected our ability to access information even to the point of it influencing how we might vote. Today, the Internet is one of the more viable avenues for accessing information. As information technology escalates in ingenuity and capacity, so does the ability of societies to effectively handle information and information flows. The Internet has become a popular way for businesses and institutions to interact with one another, for people to find information pertinent to their needs, or for converting information in hardcopy to a digital format. As such, modern societies have entered the digital age of information.

Not all societies have equal access to digital information. Those that are not fully enveloped within the information network typically have smaller national outputs, or fewer computers, televisions, and phones per person. Still, the ability to access information on the Internet and television or by phone has never been easier anywhere. The economic benefits that can accrue from information flows have for the most part reinforced

existing spatial economic patterns. The Internet has not significantly reshaped spatial economies; if anything it has reinforced their structure. Those regions that are notably tied to a nodal center for economic leadership will continue to be so in the information age. As such, one might view information societies as hierarchically organized, with some people and regions having greater access to tacit information and being further up the hierarchy. Because of this hierarchical structure, it is not practical to view global information patterns as wholly ubiquitous.

Information patterns can be broken into different layers: that which is explicit (or easy to understand and open to public use); that which is tacit (or strategic and difficult to attain); and those layers in between, of which each will produce different geographic patterns. Explicit information patterns or flows will be much more ubiquitous over space than tacit information patterns. It is the concentration of strategic information that has led to truncation in spatial economies. Within information societies, selected cities have subsequently emerged as growth nodes.

Using Internet domains as a proxy for the development of information societies, it becomes clear that some countries and regions dominate. For example, around 45% of domains worldwide recently originated in the United States, and nearly 70% of all domains originate in one of seven countries. While the share of U.S. domains is decreasing, the top seven countries continue to hold around 70%. It is anticipated that as more countries adopt information technology and initiatives, the concentration and control of information patterns could widen. To what extent this happens will unfold in the next few decades.

Though information patterns are becoming somewhat diffuse geographically, it is difficult to parse out quality or tacit information from routine or background information. In the 1930s, Fritz Machlup and Joseph Schumpeter were among the first social scientists to examine patents as a source of knowledge and its distribution. The advantage of using measures of technology as a surrogate for tacit information is that one can isolate highly prized or guarded information. Furthermore, the location of patents can provide an accurate understanding of where key nodes of information exist.



The concept of information society has been compared with the knowledge economy, networked societies, postindustrialism, or the information revolution, to name a few. A commonality in these concepts is that modern societies are becoming increasingly dependent on information, information technologies, and information services. As societies transition from primary to secondary, to postindustrial societies, they inevitably acquiesce to an information society. In fact, the Organisation of Economic Co-operation and Development (OECD) measures the information economy based on the share of a country's GDP (gross domestic product) that is based in this sector. This is done by measuring the amount of regional output that is not based on tangible or manufactured goods. All information societies place a higher premium on codification, infrastructure, and education. Codification enables regions to better manage information in meaningful and competitive ways to create what could be called managed societies. As societies become more information based, they are more apt to become more scientific, technological, and informed. What facilitates this trend, and at the root of an information society, are computers, phones, and other information and communication devices.

Those regions that adapt to being information based will benefit from their early entrance. Whether they can maintain their lead over other regions is contentious. Value-added information that is tradable creates wealth for regions and a new way of working for people. Knowledge and what people do with it is pertinent to the development of an information society. Those regions that foster creativity among their populations are more apt to benefit from an information economy. Added to this is a mobile, educated workforce that desires to live in advantageous locations. The footloose nature of the information economy enables populations to move to desired locations. Still, skilled labor patterns remain concentrated within the so-called footloose nature of the spatial information economy.

Brian Ceb

See also **Castells, Manuel; Communications Geography; Cyberspace; Digital Divide; E-Commerce**

and Geography; Education, Geographies of; Innovation, Geography of; Knowledge, Geography of; Knowledge Spillovers; Learning Regions; Postindustrial Society; Producer Services; Space of Flows; Spatial Data Infrastructures; Telecommunications and Geography

Further Readings

- Castells, M. (2000). *The rise of the network society*. Oxford, UK: Blackwell.
- Webster, F. (2003). *The information society reader*. London: Routledge.
- Webster, F. (2006). *Theories of the information society* (3rd ed.). London: Routledge.
- Zook, M. (2005). *The geography of the Internet industry: Venture capital, dot-coms, and local knowledge*. Boston: Blackwell.



INFRASTRUCTURE

Infrastructures are, and have been historically, the fundamental support network of society. This became apparent as urban populations and their densities rapidly increased during the 19th and 20th centuries. The developing complexity of commodity and information flows evident with globalization has also stressed the critical nature of infrastructure in today's world. Infrastructure is the "hidden hand" behind urban development and nation building, enabling the flow of people and critical resources such as water, energy, waste, information, agricultural produce, and manufactured goods. At the same time, inadequate infrastructure provision, or the failure of infrastructure, generates considerable social disorder. In 2005, this failure was evident in New Orleans in the aftermath of Hurricane Katrina.

The term *infrastructure* was first used to define permanent military facilities, such as dry docks, bases, and airstrips. The meaning of infrastructure was eventually extended to include various other public and private works, including water and sewer networks, treatment plants, transportation systems, health, education, communication and computer networks, power systems,



sport stadiums, and arts centers. There are two distinct infrastructure types, *interurban* and *intra-urban* infrastructures. Interurban infrastructure connects cities into a national network, the national urban system, while *intra-urban* infrastructure connects homes and businesses within an urban center, enabling the functioning of a city as a system.

Despite its importance, infrastructure provision throughout the affluent West has become so normalized that it is generally taken for granted. In part, this status is a reflection of the effectiveness of these complex systems in providing crucial services. As argued by David Perry (1995), when infrastructures “work best, they are noticed least of all” (p. 2). In part, however, the increasing oversight of the importance of infrastructure in sustaining social order and quality of life has been facilitated by an important feature of contemporary infrastructure management, concealing infrastructure.

Maria Kaika and Erik Swyngedouw have argued that while through the early 20th century, infrastructure, and particularly urban infrastructure, maintained an important visual role in the urban landscape, being celebrated as technological advancements of modernization, its role within the urban setting was significantly diminished in the late 20th century. This move toward the invisibility of urban infrastructures has been achieved by closing down infrastructure facilities within cities (such as power plants and pumping stations) and sourcing out power, water, and other services from more distant locations. Greater invisibility of infrastructure has also been achieved by moving infrastructure beneath the city, making the urban underground a rich network of pipes, wires, conduits, and transportation networks. The \$15 billion “Big Dig” in Boston, which took 15 years to construct, provides a recent example. The project involved the construction of 7.8 miles of highway, totaling 161 lane miles, with approximately half of the network built underground.

The Role of Government

In the United States, early links between public infrastructure investment and economic and

political security were recognized by President George Washington and his Treasury Secretary Alexander Hamilton. However, it was not until Thomas Jefferson’s presidency that federal investments in infrastructure first became evident. Much of the early investment was placed on interurban infrastructure, canals, roads, and railways. However, in the mid 19th century, research in Britain by John Snow on water supply and cholera and the work by Edwin Chadwick on sanitation and public health placed a new importance on intra-urban infrastructures. In addition, by the late 19th century, a new emphasis on infrastructures within cities was also facilitated by rapid population growth, and the unprecedented urban densities, which began to be realized in the early industrial centers.

The role of government in the delivery of infrastructure is an important issue in infrastructure provision. Two unique characteristics of public infrastructure are recognized that distinguish these goods from private goods, hence their classification as public goods. Public goods are nonrival in consumption and nonexcludable. Nonrival means that once provided many can use a public good without loss of benefits to others and at minimum extra cost in maintenance. The lighthouse provides a classic example. Once provided, many ships can use the services of a lighthouse, and this use does not reduce the services of the lighthouse to other ships. This condition is very different from that of private goods, where the benefits of consumption are limited to the person consuming (e.g., the benefits of eating an orange are limited to the person consuming the orange, because once it is eaten, there is no orange left). Nonexcludability refers to the difficulty of excluding individuals from using public goods once they are provided. For instance, it is very difficult, or very costly, to exclude ships from using lighthouses. Because of nonrivalness and nonexcludability, private companies have little interest in providing public goods, and unless governments intervene, public goods will be provided at suboptimal levels, generating reductions in quality of life and economic performance.

Government intervention in the provision of infrastructure is also justified because of externalities. One type of externality occurs when the



The I-35 bridge collapse site over the Mississippi River 13 days after the collapse

Source: U.S. Navy photo by Mass Communication Specialist Seaman Joshua Adam Nuzzo.

benefits of providing certain goods to society are greater than those recognized by the individuals consuming these goods. An example is education, which has individual benefits to the person receiving the education, but wider social benefits are evident with a more educated and productive workforce. In selecting investment in schooling, individuals will not account for the external social benefits in their decision making and will tend to select suboptimal levels of education. To encourage more socially optimal choices, government subsidization of education is considered acceptable, lowering education costs to individuals and encouraging more years of schooling.

The recognition of public goods and externalities in the provision of public infrastructure emerged through the early and mid 20th century, largely in response to the disorder and chaos brought on by early capitalism. Improvements in quality of life and social well-being following government intervention in infrastructure delivery—particularly apparent in addressing many of

the stresses experienced by the large and rapidly growing industrial centers—illustrate the effectiveness of public infrastructure provision in simultaneously improving both equity and efficiency within cities.

In the late 20th century, a new philosophy and social movement emerged, neoliberalism, which advocated low taxes and minimal government in social and economic activities as a means of improving economic performance. Becoming politically entrenched in the United States following the election of Ronald Reagan as president in 1980, neoliberalism fundamentally altered the public role in infrastructure provision. Private market values and market incentives in the public realm, along with increased competition, public-private partnerships, and privatization became the new focus of government. The relevance of public goods and externalities in infrastructure provision was increasingly dismissed, with significant scaling back of government in the delivery of infrastructure. However, growing concerns over



infrastructure deterioration within this political environment—most recently evident after the collapse of the I-35W freeway bridge in Minneapolis in August 2007—illustrates the necessity of ongoing funding and maintenance of infrastructures.

In addition, despite the widespread acceptance of neoliberalism, there is no evidence to show that low-taxing, minimal-government cities or regions are the best economic performers. In contrast, business and residential concentrations in cities such as London, Paris, Tokyo, and New York are supported by rich and robust infrastructure networks, such as mass transit systems, road and highway networks, air- and seaports, communication networks, education infrastructure, and arts and cultural facilities. Removing just the subway networks from these cities would significantly limit the capacity of moving large populations, with the resulting congestion making existing residential and business concentrations in these urban centers unmanageable. The extensive public infrastructures within these socially and economically robust cities illustrate the importance of rich and robust infrastructure provision in ensuring quality of life and economic well-being.

Igor Vojnovic

See also **Automobility; Built Environment; Economic Geography; Factors Affecting Location of Firms; Neoliberalism; Public Policy, Geography of; Public-Private Partnerships; Public Space; Public Water Services; Railroads and Geography; Spatial Data Infrastructure; Spatial Fix; Suburban Land Use; Telecommunications and Geography; Transportation Geography; Urban and Regional Development; Urban and Regional Planning; Urban Land Use; Urban Spatial Structure; Urban Water Supply; Wastewater Management; Water Management and Treatment; Zoning**

Further Readings

Graham, S., & Marvin, S. (2001). *Splintering urbanism: Networked infrastructures, technological mobilities, and the urban condition*. London: Routledge.

Kaika, M., & Swyngedouw, E. (2000). Fetishizing the modern city: The phantasmagoria of urban technological networks. *International Journal of Urban and Regional Research*, 24(1), 120–138.

Perry, D. (Ed.). (1995). *Building the public city: The politics, governance, and finance of public infrastructure*. London: Sage.

Vojnovic, I. (2000). Shaping metropolitan Toronto: A study of linear infrastructure subsidies. *Environment and Planning B*, 27, 197–230.

Vojnovic, I. (2006). Urban infrastructures. In T. Bunting & P. Filion (Eds.), *Canadian cities in transition* (pp. 123–137). Toronto, Ontario, Canada: Oxford University Press.



INNOVATION, GEOGRAPHY OF

For more than a century, geographers and economists have developed theories on the spatial agglomeration of economic activity in response to three empirical observations:

1. A large portion of world output is produced in a limited number of highly concentrated core regions.
2. Firms in similar or related industries tend to collocate in particular places.
3. Both of these patterns seem sustainable over time.

While this outcome has most often been attributed to agglomeration economies, some scholars have long pointed out that the economic and institutional fabric of some areas promotes innovative behavior that further reinforces this pattern.

The most lasting contribution among the early analysts is the economist Alfred Marshall's "industrial districts." Besides mentioning the external benefits that single-activity or closely related producers derive from sharing the fixed costs of common resources such as specialized



infrastructure and services, skilled labor pools, and specialized suppliers, Marshall emphasized that through colocation and frequent interaction, producers share a common knowledge base. By the middle of the 20th century, however, technological changes and the enhancement of labor and entrepreneurial mobility had led most regional growth and development scholars to conclude that “such local specialization . . . [had] become increasingly rare,” while, in contrast, “external economies on the broader basis of urban size and diversity [had] remained a powerful locational force” (Hoover & Giarratani, 1970, p. 121). This perspective, according to which innovative activities were seen as less relevant for industrial agglomeration, probably explains why, along with the development and/or refinement of analytical (mathematical) tools unsuited to the study of innovation, increasingly mechanistic and static “resources allocation” or “location-scanning” perspectives became dominant among analysts.

These theoretical approaches, however, proved unable to account for the spontaneous and spectacular rise in the 1970s and 1980s of numerous regions, from the Silicon Valley and Boston’s Route 128 (Boston) in the United States to the so-called Third Italy, Emilia-Romagna, whose main characteristics were the spatial clustering of related and highly innovative firms. Scholars in disciplines ranging from geography and political science to sociology, business management, and economics thus began to (re)discover and further develop more qualitative and dynamic concepts and insights to explain how the industrial and social characteristics of a given place (ranging in scale from streets and industrial districts to cities and regions) provide or fail to provide fertile soil for innovative behavior or, in other words, how some areas act as focal points for innovative activities. These contributions emphasized not only that colocation gives related firms greater flexibility and the opportunity to quickly adapt to sudden shifts in market demand but also that some places are better than others at integrating the formal and informal collective processes essential to the production of continual innovation. Despite early and constant criticism that this “spatial interaction literature” features a number of ill-defined and overlapping concepts or frameworks (from

“industrial districts,” “innovative milieu,” and “clusters” to “learning regions,” “regional innovation systems,” and “techno-regions”), its main message has always been twofold: (1) Where prosperity exists, it is regionally based and (2) the sources of this prosperity are to be found in the regions themselves and not in some exogenous factors.

Questions in the Geography of Innovation

Fundamentally, the geography of innovation literature asks two questions:

1. Why are some regions more innovative than others?
2. How does a specific location matter for the continuous upgrading of firm capabilities?

The perspective in the former question is that of the region, whereas the latter proceeds from the firm perspective. The answers most commonly provided revolve around the importance of geographical proximity between actors, which greatly facilitates formal and informal collaborations between firms (be they potential competitors or in a user-producer relationship) and/or between firms and research institutions; the spin-off of new firms; and the transmission of tacit knowledge (through face-to-face interactions and the interfirm mobility of skilled workers). Each factor is now examined in turn.

Local Linkages and Collaboration

Geographical proximity, because of the frequent interactions and long-term contracts or commitments among people that it allows (whether in working environments or in social activities), is said to often play a crucial role in building the trust bonds that are needed to share sensitive information and to develop a successful customer-supplier relationship.

Spin-Off Formation

Entrepreneurship, especially in terms of employees creating new firms in close proximity



to former employers (so-called spin-offs or start-ups), is said to be greatly facilitated in some regional contexts. On the one hand, an entrepreneurial culture in which individuals continually leave their employers to launch new firms provides ample demonstration effect, which further reinforces this tendency. On the other, localized industries provide easy access to specialized labor, inputs, and knowledgeable investors, which further facilitates the launch of innovative firms. Spin-offs also tend to create a local or regional environment where firms and individuals interact more with each other than would otherwise be the case.

Tacit Knowledge

The more specialized and innovative an activity is, the more it is likely to be geographically concentrated. The more standardized it becomes, the more it tends to migrate toward customers or inputs. This pattern can be attributed in part to the fact that the crucial knowledge in any innovative industry is not standardized information, routine patterns, or the public knowledge of science but rather what is new, what are the latest changes, and the specialized know-how that individuals have acquired through practice and mistakes. Thus, knowledge from which innovations stem is not freely available, which in turn provides firms that locate near its sources a competitive advantage. As such, globalization and improvements in telecommunication technologies have not crowded out the need for proximity but have conversely strengthened it in cases where crucial knowledge is only locally available. In short, geographical proximity between related firms is said to increase the concentration of knowledge spillovers and the speed of information flows. Even though most of the suppliers and customers of a firm might be located outside its regional setting, being located in a specific area typically allows creative and entrepreneurial individuals to absorb thinking processes, along with specialized vocabulary and ways of doing things, while increasing the probability of useful informal encounter. It also makes it easier for entrepreneurs, managers, and technicians to avoid being caught off guard by unanticipated breakthroughs

by allowing them to monitor emerging technologies closely and to find answers to their questions more rapidly.

While the case on behalf of the geographical base of innovation is strong, it should perhaps be handled more cautiously than it often is for reasons ranging from the fuzziness of the main concepts used in this literature, the continued importance of both traditional agglomeration economies and nonregional networks and linkages, and the fact that individuals were born in or like a particular location.

Pierre Desrochers and Samuli Leppälä

See also Agglomeration Economies; Business Cycles and Geography; Economic Geography; Education, Geographies of; Factors Affecting Location of Firms; Incubator Zones; Industrial Districts; Knowledge, Geography of; Knowledge Spillovers; Learning Regions; Technological Change, Geography of

Further Readings

- Clark, G., Feldman, M., & Gertler, M. (2000). *The Oxford handbook of economic geography*. Oxford, UK: Oxford University Press.
- Hoover, E., & Giarratani, F. (1970). *An introduction to regional economics* (3rd ed.). New York: Alfred A. Knopf. Retrieved November 11, 2009, from www.rri.wvu.edu/WebBook/Giarratani/main.htm
- Marshall, A. (1920). *Principles of economics* (8th ed.). London: Macmillan. Retrieved November 11, 2009, from www.econlib.org/library/Marshall/marP.html (Original work published 1890)



INPUT-OUTPUT MODELS

Developed by Wassily Leontief in 1936, input-output models are an alternative to simple economic base and Keynesian approaches to modeling an economic system. Essentially, the models are used to describe and analyze forward and



backward economic linkages between industries. They compile the industrial activity of an economic system into an input-output table that is built around a matrix of monetary transactions. These transactions can be recorded by industry or sector, which are groups of industries involved in similar production processes.

The basic principle of input-output models is that the products sold (outputs) from one industry are purchased (inputs) in the production process by other industries. Therefore, it is plausible that a change in one interindustry linkage can affect the entire system of linkages. For example, the steel industry uses inputs of coal (outputs from the coal industry) to produce goods. These goods are then purchased as inputs in production by other industries, such as the construction industry. What would the impact of a rise in demand for goods produced by the steel industry be on the construction industry, other industries, and the entire economic system? An input-output model could be developed to address these interindustry interdependencies. This type of information provides geographers with a disaggregated view of an economic system in that industries are connected on the basis of buyers and sellers.

Data on the economic linkages between industries are typically collected from surveys of the economic system being modeled and compiled in a table. The table is constructed around a matrix of monetary transactions. The transactions that take place between industries represent a flow of goods and services. They are tabulated based on the value of sales (outputs) and purchases (inputs) of intermediate goods between industries. Like any table, an input-output table consists of a series of columns and rows. The rows of the table reflect the value of sales (outputs) made by each industry. Sales can be further divided to represent sales to final demand. In these categories are included sales of output made to the consumer (households), sales to government (local, state, federal), sales of investment goods (capital equipment), and sales destined to be outside the economic system being modeled (exports). The columns of the input-output table reflect the value of purchases (inputs) that are made by each industry. Purchases can be further divided to represent

<i>Selling Industry</i>	<i>Purchasing Industry</i>	
	X(1)	X(2)
X(1)	x_{11}	x_{12}
X(2)	x_{21}	x_{22}

Table 1 Basic input-output table showing general forward and backward linkages between Industries X and Y

Source: Author.

purchases from value added and purchases of imports. In these categories are included returns to capital (profits and dividends), labor costs (wages and salaries), and purchases of inputs made from outside the economic system being modeled.

Establishing general forward and backward economic linkages between industries is fairly simple with input-output models (see Table 1). In locating the value of sales (outputs) and purchases (inputs) in the table, it is necessary to become familiar with the intersection of rows and columns and what each represents. Consider a linkage between Industries X and Y, with Industry X as the seller. To find the value of sales made from Industry X to industry Y, locate the selling Industry X along the left side of the table and then read across to find the purchasing Industry Y at the top of the table. This would show the value of outputs that are sold from Industry X to Industry Y. Following the previous example, now consider Industry X as the purchaser. To find the value of purchases made by Industry X from Industry Y, locate the buying Industry X along the top of the table and then read down to find the selling Industry Y along the left side of the table. This would show the value of inputs that are purchased by Industry X from Industry Y. Essentially, one-way or multiway economic linkages among industries are possible with input-output analysis. However, analysis of more complicated linkages requires knowledge of matrix algebra.

Input-output models have varying degrees of openness and closure, meaning that there is no



guideline set for determining how many categories of economic activities, final demand, and value are added to include or exclude when developing the model. This largely depends on the analytical purpose of the model. Its use has been extended from the most basic, describing interindustry relations, to include more in-depth and technical analyses of economic systems. Applications of the model include, but are not limited to, forecasting and planning scenarios, economic and policy impact analysis, feasibility studies, and sensitivity analyses. Each of these analyses requires a mathematical manipulation of the transactions table. Commonly, input-output models are used as an alternative to simple economic base and Keynesian models to measure the impacts of multiplier effects within an economic system. With this application, input coefficients that are derived by dividing the purchases in an industry into proportions of total purchases are mathematically altered to represent direct and indirect industry multipliers. The input coefficients can be manipulated to reflect industry-to-industry multipliers in terms of employment, income, and industrial output. For example, in what way does an increase in demand by Industry Y for a good produced by Industry X affect the output of Industry X? However, it should be noted that there are many methods that can be used to calculate economic multipliers from the input-output table.

Regardless of the analytical purpose of input-output models, modeling of an economic system can be undertaken at various scales of geographical inquiry, such as national, regional, state, and metropolitan. In some instances, firm-to-firm interdependencies have been established. Additionally, analyses have compared interindustry relationships across scales so that national, regional, state, and metropolitan economies are compared with other economies at similar geographical scales. To that end, input-output models have been used to help make economic policy decisions.

Todd Sink

See also **Economic Base Analysis; Economic Geography; Location Theory; Models and Modeling; Regional Economic Development**

Further Readings

- Hewings, J. (1985). *Regional input-output analysis*. Beverly Hills, CA: Sage.
- Leontief, W. (1936). Quantitative input-output relations in the economic system of the United States. *Review of Economic Statistics*, 18, 105–125.
- Miernyk, W. (1965). *The elements of input-output analysis*. New York: Random House.
- Miller, R., & Blair, P. (1985). *Input-output analysis: Foundations and extensions*. Englewood Cliffs, NJ: Prentice Hall.

INSTITUTE OF BRITISH GEOGRAPHERS

For some 60 years, the Institute of British Geographers (IBG) has been the United Kingdom's leading learned society for geographers. It was founded in 1933 and merged with the Royal Geographical Society in 1995.

Learned societies play several major roles in the production and diffusion of knowledge. To promote research, they organize conferences, publish journals, and fund projects; to promote their disciplines, they represent them in a range of arenas. Until the establishment of the IBG, academic geographers in the United Kingdom had no such organization. They were able to meet and publish through the Royal Geographical Society (RGS), the Geographical Association (GA), and the British Association for the Advancement of Science (BA), but each of these had a much wider brief than just supporting academic geography. The GA's mission is to promote geographical education at all levels, and most of its attention focuses on the country's school systems, where it has been an extremely successful advocate for and a change agent in geography. The RGS is a well-established London society that did much to promote geography (especially exploration, discovery, and cartography) and geographical education in the 19th century; by the late 1920s, however, academic research (especially in human



geography) was marginal to its concerns. The BA's annual conferences provide a venue where academic geographers can meet in their separate section, but this body's *raison d'être* and membership is also much wider than that of an academic learned society.

Founding and Early Years

Geography was a very small discipline in U.K. universities in the 1930s. Few departments had been established in the 19th century, and the first full honors degree was not launched until 1917. By the end of the 1930s, virtually every university and university college had a small department—more than five permanent staff members was a rarity. Teaching loads were both heavy and broad, and research activity was not put at a premium. Nevertheless, several meetings—organized by a small group based in University of London colleges—determined that university geographers needed a separate society to organize meetings at which research discussions would predominate and to offer a publication outlet, hence the IBG's establishment. It held an annual residential conference (usually just after the New Year) from the start plus occasional field meetings, and in 1935, it launched its publication *Transactions and Papers of the Institute of British Geographers*.

Growth of the Organization

Until after World War II, the organization was small and its operations limited. Officers were elected, but the tradition of an annual presidential address was only instituted in 1948. More important, *Transactions* did not develop as a regular serial publishing refereed academic papers until 1946. Before that, it published only six separate monographs plus reports of the Institute's annual conferences. In 1959, the Institute organized the first of its international seminars—on applied geography—in Poland. These were used to promote international contacts, most of them with geographers in countries behind the Iron Curtain, although there were

also series of Anglo/German and Indo/British seminars; after 1989, the range of countries widened, but the seminars became less necessary as international travel to major conferences became much easier.

Geography student numbers grew rapidly in the United Kingdom after 1945, and university departments expanded accordingly. The annual conference attracted more participants, and *Transactions* became a regular refereed serial, appearing only once per year until 1962. It became a quarterly in 1976 (when it was relaunched as a "New Series"). A second journal—*Area*, which evolved out of a newsletter—was established as a quarterly journal in 1969. The Institute also sponsored a book series, comprising monographs and major edited collections, in conjunction with commercial publishers.

During the 1960s, reflecting the growth in the number of practicing academic geographers, including graduate students, a major change took place in the IBG's organizational framework with the creation of separate study groups, most of which focused on specific areas of the discipline. Until then, the annual conference had comprised the presentation of unrelated papers, and moves to hold symposia on specific topics were among the stimuli for the study groups. The first was the British Geomorphological Research Group (now the British Society for Geomorphology, which is affiliated with the Geological Society of London as well as the RGS), followed soon after by a Population Studies Group (whose initial *raison d'être* was producing an atlas using 1961 census data) and an Urban Geography group. These enrolled members from both among the Institute's membership and beyond obtained subventions from IBG funds. They organized sessions at the annual conference, plus separate 1-day and residential symposia and other meetings; they generated publications (including monographs, conference proceedings, and, in a few cases, new serials); and they promoted research through allocations of small funds. At about the same time, reflecting its expanding membership and activities, the Institute established a permanently staffed office in London (housed in the RGS building).

The number of study groups (renamed research groups after the 1995 merger) grew rapidly.



(Some, such as the Quantitative Methods group, formally associated with the Institute a few years after its foundation, although others, such as the Association of British Climatologists, remained outside, although occasionally organizing sessions at the IBG's conference.) There are now 22 groups, with provision for the creation of fixed-term working groups to explore particular issues; there is also a separate postgraduate research forum. As well as their annual subventions derived from subscription income (which some groups extend by charging their own subscription), grants and loans can be obtained to fund conferences, research and other projects, travel to meetings (especially for postgraduates), and other activities. The research groups are at the heart of the Institute's activities, being responsible for many of the separate sessions, including plenary lectures as well as paper presentations, at the 3-day annual conference (now held in London in late August and attracting a growing number of international attendees), set within a general conference theme.

Merger of the IBG and RGS

In the early 1990s, moves commenced to merge the IBG with the RGS, and this change was approved by substantial majorities in both organizations despite some concerns expressed by IBG members, a number of whom declined to join the new body. This organization is called the Royal Geographical Society (with the Institute of British Geographers)—RGS (with IBG)—and the IBG's former activities largely occur within the ambit of its Research and Higher Education Division. The IBG's two journals (*Transactions of the IBG*—renamed in 1992; it currently has the highest impact factor of all geography journals included in the ISI/Web of Knowledge database—and *Area*, which caters in particular to postgraduate and early-career authors) have been retained, alongside the RGS's house journal (*The Geographical Journal*, which now specializes in papers having an environmental theme).

Ron Johnston

See also **Human Geography, History of; Royal Geographical Society**

Further Readings

- Buchanan, R. (1954). The I.B.G.: Retrospect and prospect. *Transactions and Papers, Institute of British Geographers*, 20, 1–14.
- Johnston, R. J. (1983). The institutionalisation of geography as an academic discipline. In R. J. Johnston & M. Williams (Eds.), *A century of British geography* (pp. 26–39). Oxford, UK: Oxford University Press for the British Academy.
- Steel, R. (1983). *The Institute of British Geographers: The first fifty years*. London: Institute of British Geographers.
- Stoddart, D. (Ed.). (1983). The Institute of British Geographers 1933–1983: A special issue of *Transactions* to mark the fiftieth anniversary of the Institute. *Transactions, Institute of British Geographers*, NS8(1).



INTERACTIVE MAPPING

See Map Animation



INTERGOVERNMENTAL ENVIRONMENTAL ORGANIZATIONS AND INITIATIVES

The environmental issue area is notable for its multiplicity of intergovernmental organizations, numbering nearly 200, with new ones regularly created. Although the United Nations (UN) is a central player in organizing and overseeing many international environmental regulations and initiatives, international environmental governance is conducted largely through organizations created to address specific environmental problems.

The Role of the United Nations

Various organizations within the UN play roles in global environmental governance. The most



central of these is the United Nations Environment Programme (UNEP), a specialized agency of the UN, founded in 1972. UNEP's mission is to play a catalytic role in environmental governance, coordinating environmental efforts by other UN agencies. It has played active roles in environmental monitoring and scientific research on environmental issues and has coordinated and supported the negotiation of international environmental agreements or conventions (treaties). It has also undertaken specific programs to address international environmental issues. Notable among these is its regional seas program, which has negotiated agreements involving 140 states to protect 13 regional seas.

The UN has also held major international conferences on issues relating to environmental issues. The two most influential of these conferences were the United Nations Conference on the Human Environment (UNCHE), held in 1972 in Stockholm, and the United Nations Conference on Environment and Development (UNCED), held in 1992 in Rio de Janeiro. UNCHE involved representatives from 113 states and numerous nongovernmental organizations (NGOs). It produced a Declaration, an Action Plan, and several resolutions, including one that advocated the creation of UNEP.

UNCED focused on the relationship between environment and development. It was attended by representatives of 178 states and featured a parallel "Global Forum" where representatives of 1,500 NGOs met. The conference reiterated the right of states to development and to sovereignty over their natural resources and prioritized the generation of additional financial resources to assist countries with environment and development needs.

Other UN environmental initiatives are worth noting. The World Commission on Environment and Development was established in 1983 at UNEP's recommendation. It produced the report *Our Common Future* in 1987 to give an overview of the difficulties facing the intersecting desires for economic development and environmental protection. The Commission on Sustainable Development was created in 1992 following a recommendation from the Rio Conference. The Millennium Development Goals attempt to improve the lives of people in developing

countries in specific ways by 2015. One goal specifies the need to "ensure environmental sustainability."

International Environmental Organizations

Most intergovernmental environmental cooperation takes place within issue-specific institutions created to address individual environmental problems through specific measures. Each organization has, for the most part, been created through its own negotiation process (usually in the context of a specific treaty). That process results in an anarchic pattern of institutions, where multiple institutions may address different aspects of a given problem or different types of solutions and each organization has a different set of member states.

The earliest intergovernmental institutions focused on what we would now call the sustainable use of species, such as seals, birds, whales, and fish. Different organizations were created to restrict hunting of a given species to a level that would allow reproduction and the indefinite continuation of human use of these resources. These organizations tend to be fairly narrowly focused on a given one or more closely related species, often in a specific region. Examples of existing organizations with this function include the International Whaling Commission and a large number of Regional Fishery Management organizations, which restrict fishing behavior in multiple organizations that focus on species, region, or both.

A different set of organizations addresses the protection of endangered species in a slightly different way, with a focus on preventing extinction and less concern about ensuring continued human use of the species. The two most important organizations of this type are the organization that oversees the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the one for the Convention on Migratory Species. In addition, a UNEP-run secretariat oversees the Convention on Biological Diversity, a process that involves protecting the overall diversity of species and ecosystems.

The International Maritime Organization (IMO) oversees most of the international regulation of



ocean pollution and safety. The IMO issues codes and recommendations to its members and also sponsors intergovernmental conferences leading to the negotiation of binding multilateral conventions on maritime matters, the implementation of which it then oversees.

Other organizations address atmospheric issues. The United Nations Economic Commission for Europe negotiated and implemented multiple agreements to decrease acid rain in Europe. The Ozone Secretariat oversees implementation of the international agreements relating to the protection of the ozone layer. More contentious and less successful so far are international efforts, under the Kyoto Protocol, to decrease emissions of the greenhouse gases that contribute to climate change.

Other intergovernmental environmental institutions are those that address collective action on regional issues, including the Antarctic and the Arctic, and institutions addressing wetlands, desertification, and transboundary movement of hazards, among other issues.

What these intergovernmental institutions have in common is that each is created to address a specific environmental problem. There are similarities across organizations. Many include scientific bodies that are separate from decision-making bodies; most either require unanimous decisions for major policy changes or allow states to opt out of decisions with which they do not agree, and almost all make their primary decisions through regular meetings of the parties. There are linkages between them, sometimes negotiated by necessity, as overlapping mandates can otherwise create conflict or confusion. But, overall, most intergovernmental environmental governance is still done through fairly separate organizations, concerned collectively with natural resources or pollution but addressing these issues through distinct institutional structures.

Elizabeth R. DeSombre

See also **Climate Policy; European Green Movements; International Environmental Movements; United Nations; United Nations Environmental Summits; United Nations Environment Programme (UNEP)**

Further Readings

- Chambers, W., & Green, J. (Eds.). (2005). *Reforming international environmental governance*. Tokyo: UN University Press.
- Chasek, P. (2001). *Earth negotiation*. Tokyo: UN University Press.
- DeSombre, E. (2006). *Global environmental institutions*. New York: Routledge.



INTERNATIONAL CRIMINAL COURT

The International Criminal Court (ICC) is the world's first permanent body established to prosecute genocide, crimes against humanity, war crimes, and aggression. The creation of the ICC was the result of decades of advocacy and campaigning by human rights activists, compromises between nation-states, and transformations in the international political order. The hope attached to the ICC is that a permanent court, capable of prosecuting the most powerful perpetrators on the planet, will prevent future atrocities. The ICC's jurisdiction theoretically extends to the entire globe but in practice is subject to intense geopolitical power. The ICC must also navigate complex relationships with nation-states and the local communities most directly affected by extreme violence. The ICC is an intensely interesting phenomenon from a geographical perspective. It is both a product and a producer of globalization—an agent of geographical transformation as well as a result of such processes.

The international community has been imagined to be a superior space for holding perpetrators accountable, as local and national politics repeatedly protected the powerful—a condition referred to as impunity. The observation that “a person stands a greater chance of being tried and judged for killing one human being than for killing 100,000” highlights the dilemmas of accountability in the wake of mass atrocities. Although it is the powerful who are in a position



to commit genocide, and other massive forms of violence, that same power often protects them against prosecution. Proponents of the ICC have argued that conducting trials “elsewhere” provides a “spatial fix” in that international courts may circumvent and therefore overcome local impunity. While courts distant from the location of the atrocities (and outside the national jurisdiction) might prove capable of holding the most powerful perpetrators accountable, critics of doing justice from “afar” argue that the proceedings may have less relevance for the local communities and present troublesome issues concerning national sovereignty.

Historical Background

Interest in a permanent international body devoted to prosecuting war crimes has been expressed at various points in history. During the political polarization of the Cold War period, the superpowers blocked the establishment of an independent international institution devoted to prosecuting war crimes. As the Cold War moved toward its closure (1989–1991), interest returned in the form of a proposal to prosecute drug trafficking in the Caribbean as an international crime. Although the proposal drifted, the idea of an international court remained in the air. Violence during the breakup of the former Yugoslavia spurred the establishment of a war crimes tribunal in 1993 (the International Criminal Tribunal for the former Yugoslavia [ICTY]), and a second tribunal was established following the genocide in Rwanda in 1994 (the International Criminal Tribunal for Rwanda [ICTR]). Subsequent courts were established in Sierra Leone and Cambodia.

While there is a relative consensus concerning the establishment of these ad hoc tribunals, certain powerful sectors remained averse to a permanent international court that would have jurisdiction over every potential perpetrator on the planet. Among those objecting were the likely subjects—the notoriously violent dictators and despots who had every reason to resist judicial accountability. Objections also came from the U.S. government, which expressed fears that submission to the jurisdiction of an international

court would undermine U.S. sovereignty and its potential for global military activity. While the United States had supported “international justice” for the peoples of Rwanda, the former Yugoslavia, Sierra Leone, and Cambodia, it was far less willing to consider such courts for its own nationals.

Formation of the ICC

The situation came to a head during the conference held in Rome in 1998 to draft and approve a statute for an international criminal court. For 5 weeks, the U.S. delegation to the United Nations (UN) conference wrestled with the rest of the world over the ICC treaty. Washington strenuously objected to elements in the treaty that gave the ICC its powers and, in the minds of the vast majority of the other participants, made the court viable. The United States insisted on conditions that would essentially make it impossible to try an American. Frustrated delegates worried that the resultant ICC would be either weakened by “American exceptionalism” or weakened by the lack of involvement of the United States.

Certain accommodations and compromises were made in an attempt to bring the United States on board. The principle of “complementarity” was among the most significant. Complementarity assures that national jurisdictions have the first obligation to prosecute. It is only when a nation-state proves “unable or unwilling” to prosecute its suspected criminals that the ICC can assume jurisdiction. In a world with less impunity, Colombian national courts would prosecute Colombians, Burmese courts would prosecute Burmese, and so on. But if national courts fail, the ICC is there to act.

A further restriction on the ICC’s powers is the restricted ways in which a case can be brought to the ICC. There are three “trigger” mechanisms that allow the ICC to take up a case. A case can be heard pursuant to

1. a state party referral (a party to the Rome Statute requests the ICC’s intervention);
2. a Security Council referral; or



3. *proprio motu*, in which the prosecutor may initiate investigations on the basis of information on crimes within the jurisdiction of the court.

In particular, allowing the Security Council a veto over the court, as the Security Council can effectively shut down an investigation/prosecution by ordering the ICC to abstain from such action for a year (renewed on a yearly basis), effectively provided the United States with the ability to shut down any case. Despite these appeasements, the United States became increasingly isolated, watching as its allies coalesced into the group of “like-minded nations.”

A notable aspect of the formation of the ICC was the role of international nongovernmental organizations (NGOs). International social movements were essential to the creation and promotion of the ICC. A group of more than 800 NGOs established the Coalition for the International Criminal Court and participated at unprecedented levels in the drafting of the Rome Statute, the lobbying of state parties, and the hard, grassroots work of bringing diverse national constitutions in line with international aspirations regarding human rights norms. Additionally, victims were to have a greater role both in the prosecution and in terms of the possibility of receiving reparations, provisions supported by the NGOs.

When the Rome Statute was drafted and approved in 1998, most observers close to the process believed that it would actually take many years (decades) for the ICC to materialize. In fact, the process moved quite quickly to fruition. By 2002, the Rome Statute had garnered the requisite 60 signatories and came into effect. The Dutch government agreed to host the offices of the ICC in The Hague, a city with an established community of international institutions. The Dutch government also provided substantial financing for the ICC’s infrastructure and passed national legislation associated with the presence on its territory of suspected war criminals and others who would be participating in such trials. In its gestation, the ICC also benefited from its location in The Hague in that many of the staff had significant expertise and experience from working in the ICTY.

When the ICC started in 2002–2003, its staff was extremely conscious of the vulnerability of the institution. At the ICC’s first major press conference in July 2003, the chief prosecutor sought to explain how the fledgling court was going to proceed among a universe of possible crimes. Extreme violence was found everywhere, but what to count as legitimate warfare and what to declare a crime against humanity? The ICC in its initial statements stuck to careful ground, narrowly interpreting its jurisdiction and stressing the limits of its resources. Temporally, the ICC’s jurisdiction covered crimes committed after it came into effect, which meant that any crimes committed before July 2002 were off limits. But by far the question of how the ICC would act *spatially*—how it would interpret its territorial jurisdiction—was the most provocative. In theory, the ICC is distinct in that it can exert jurisdiction (with justification) anywhere on Earth. This is its promise as well as its problem. Its very strength—its universal reach—is also the source of the enmity it has attracted.

Impacts of the ICC

In its first 5 yrs. (years) of operation, the ICC can be analyzed through the lens of its actions and its omissions—cases taken and others ignored or rejected. The most obvious issue is that the four cases taken in the first 5 yrs. have all been in Africa: Uganda, the Democratic Republic of the Congo (DRC), Sudan, and the Central African Republic. That all 12 indictees are African men has raised charges of neocolonialism. There are concerns that the ICC is yet another version of “victor’s justice” in which the powerful (in this case the wealthy “Western” nations, which dominate the institutions of the international community, including the permanent members of the UN Security Council) use institutions such as the police and judiciary to criminalize the actions of the weak while simultaneously legitimizing their own violence. Of its omissions, the ICC controversially rejected requests to investigate alleged crimes in Iraq.

The ICC has been lauded as the culmination of millennial aspirations for justice and the future protection of human rights. Yet, to date, the



“international” court has indicted only African men. Granted, these suspects are accused of heinous violence—rape, child abduction, forcing family members to kill each other—documented in detail by reputable human rights watchdog organizations. Yet their violence and alleged crimes exist alongside those of the state, which happens to be the same authorities that cooperate with the ICC. In the case of Uganda, the prosecutor has investigated and indicted the bizarre, reclusive, and quite possibly insane Joseph Kony of the Lord’s Resistance Army but has (to date) ignored the violations committed by the Ugandan State. With the exception of an investigation into the actions of Sudan’s president, the ICC failed to challenge state-power.

As of 2009, 139 states had signed, representing all regions of the world, including 11 in Asia, 41 in Africa, 26 in Latin America and the Caribbean, 44 in Europe, and 22 in the Middle East and North Africa, as well as Canada, Australia, New Zealand, and several Pacific Ocean states. Future issues associated with prosecuting and preventing atrocities will likely exhibit complex, overlapping, and intertwined geographies. International institutions are proliferating, but local and national politics and social movements remain intense; rather than “overshadowed” by the international, local and regional practices seem fully engaged and inflamed. The ICC’s activities (and its absences) during its gestation and infancy illustrate complicated social, political, and legal geographies.

Amy Ross

See also **Crime, Geography of; Genocide, Geographies of; Justice, Geography of; Law, Geography of; Social Justice; Transnationalism**

Further Readings

- Bass, G. (2001). *Stay the hand of vengeance: The politics of war crimes tribunals*. Princeton, NJ: Princeton University Press.
- Politi, M., & Nesi, G. (Eds.). (2004). *The International Criminal Court and the crime of aggression*. London: Ashgate.



INTERNATIONAL ENVIRONMENTAL MOVEMENTS

International environmental movements are social movements that contest, at an international and sometimes global scale, different kinds of global environmental degradation. They try to show that this degradation is largely the result of current patterns of production, consumption, transportation, and energy use and, more generally, the prevailing organization of social life and the present international economic and political order. In arguing that global environmental degradation is one of the “routine consequences of modernity,” many international environmental movements challenge the very basis of modern society. International environmental movements are important because they define problems, propose solution strategies, and raise social consciousness with respect to global environmental problems such as climate change, biodiversity loss, deforestation, and desertification.

This entry describes the origin and development of international environmental movements, presents several examples of international environmental movement action campaigns and actors, and briefly sketches the context in which international environmental movements operate and the structure of international political opportunities.

Origins and Development

Environmental movements originally constituted one specific part of the “new social movements” that emerged in Western Europe and the United States from the late 1960s onward. Other examples of new social movements include the women’s, peace, and human rights movements, as well as the anti-Vietnam War and civil rights movements in the United States. New social movements distinguished themselves from “old” movements such as the labor movement by their emphasis on “postmaterialist” rather than materialist values; by their predominantly “new middle class” constituency; by their decentralized rather than hierarchical organizational structure; by their distrust in traditional, established ways



of doing politics; by their unconventional action forms; and, finally, by their orientation at the development of new individual and collective identities. New social movements pointed to the “dark sides” of progress, environmental degradation being the most important case in point.

From the 1960s onward, environmental problems have been defined on an ever larger geographical scale: local, national, regional, and global. In the 1960s, local environmental movements typically struggled against polluting factories, new motorways, and the illegal dumping of waste. In the 1970s, movements struggled against the plans of national governments to build new nuclear energy plants and in favor of strong national legislation to halt the pollution of air, water, and soil. From the 1980s onward, environmental movements discovered the transboundary character of environmental pollution, for instance, acid rain, and started to plead for stronger regional (e.g., European) solutions. Finally, from the 1992 United Nations Conference on Environment and Development (UNCED) onward, the global character of many environmental problems was acknowledged: climate change, biodiversity loss, deforestation. UNCED brought together thousands of environmental groups from all over the world: It enabled the growth of contacts between these groups, which was reinforced by the facilities offered by the developments in telecommunication (e-mail, Internet).

Action Campaigns and Actors

Antinuclear Movement

One of the first international environmental movement campaigns was the Western European movement against nuclear energy in the 1970s and early 1980s. Around 1970, many Western European governments had decided to build substantial numbers of (new) nuclear power plants in order to decrease their dependency on oil for electricity generation, and in all those countries antinuclear movements arose. These movements showed striking similarities to the ideal type of a new social movement as described above. The reasons for resistance, for instance, could be labeled as “postmaterialist,” although they

widely differed from one country to another. In some cases, a nuclear plant was considered to threaten the character of the local community and thus to decrease local autonomy. In other cases, nuclear energy and nuclear weapons were seen as different sides of the very same coin. Additional reasons for resistance included the fear of militarization of society due to the ever stronger measures to protect nuclear plants, the unsolved problem of nuclear waste, the resistance to capitalism, and so on. Antinuclear movement activists disproportionately emerged from the “new middle class”; they organized themselves through autonomous local networks, distrusted institutional politics, and fought their case through road blockades, tent camps, and (sometimes) violent confrontations with the police. Activists from different countries struggled shoulder to shoulder, resulting in the development of new, international, and “countercultural” individual and collective identities.

Movement Against Genetically Modified Organisms

The first truly European, or European Union (EU)-wide, international environmental movement was the movement against genetically modified organisms (GMOs). From the mid 1990s onward, seed companies such as Monsanto had tried to introduce genetically modified soy and maize in the European market. Although biotechnology companies and parts of the food sector claimed that consuming GMOs would become inevitable, international environmental NGOs such as Greenpeace and Friends of the Earth organized a massive resistance movement against them. The result was an EU-wide moratorium that lasted until 2004, and public opinion surveys reveal that time and again a vast majority of the European public rejects genetically modified food and feed.

The movement against GMOs consisted of three sectors from society: environmental groups, consumer groups, and farmers. Due to this broad constituency, the movement was able to tap not only into numerous specialized issue publics and their social networks (e.g., organic farmers’ associations) but also into more diffuse constituencies (e.g., supporters of Greenpeace). The success of



the campaign, however, widely differed from one country to another. In France, for instance, the two most important mobilizing groups were Greenpeace France and the farmer's organization Confédération Paysanne (CP), and this cooperation turned out to be very successful. CP's fame reached its peak following the August 1999 destruction of a McDonald's franchise in Millau and the mediagenic performance of its charismatic leader José Bové.

The success of the campaign in France, and also in countries such as Italy and Spain, can be explained by the fact that GMOs were discursively linked with the expansion of neoliberalism, the increase in scale, and the accompanying loss of autonomy, values, and culture for small farmers. GMOs were brought on the market by multinational corporations such as Monsanto in a period when this kind of company was considered among the largest and most greedy beneficiaries of neoliberalism.

Another impact of the European movement against GMOs was the establishment of the "Network of GMO Free Regions" on November 4, 2003. On that day, the ministers of agriculture from 10 European regions, including Upper Austria and Tuscany, signed a document asserting the right of regions to forbid GMOs within their territories. The network has since grown to include 39 major regions from six different countries: Austria, France, Greece, Italy, Spain, and the United Kingdom.

The Greenbelt Movement

An example of a Southern international environmental movement is the Greenbelt movement. The Greenbelt movement provides income and sustenance to millions of people in Kenya through the planting of trees. It also conducts educational campaigns to raise awareness about women's rights, civic empowerment, and the environment throughout Kenya and Africa. The movement was founded by Wangari Maathai, winner of the 2004 Nobel Peace Prize.

Global Environmental Justice

Other present-day international environmental movements include those against the international

trade in toxic waste, the destruction of tropical rain forests, and climate change. The campaigns of these movements are increasingly framed through the perspective of "global environmental justice." Although most actions take place at the local, regional, or national level, these actions are typically coordinated by international or global networks: the Basel Action Network (BAN), the Rainforest Action Network (RAN) and, most important, the Climate Action Network (CAN).

The Climate Action Network

The CAN consists of more than 365 environmental groups working to promote government and individual action to limit human-induced climate change to ecologically sustainable levels. Member groups include national branches of international environmental NGOs such as Greenpeace, World Wide Fund for Nature (WWF), and Friends of the Earth International (FoEI) and also local and regional organizations. CAN members work to achieve their goals through the coordination of information exchange and NGO strategies on international, regional, and national climate issues. Strategies vary from building a dike consisting of sandbags around the conference center where the 2000 UN Climate Summit was held, to lobbying government in favor of national-level climate laws, to solar energy demonstration projects. CAN has 7 regional offices that coordinate these efforts in Africa, Central and Eastern Europe, Europe, Latin America, North America, South Asia, and southeast Asia.

International Environmental Movements and Political Opportunities

International environmental movements try to reach their goals through all kinds of interactions with business, the general public, and, most of all, political authorities. Political opportunities refer to the specific features of a political system that help explain the different action repertoires, organizational forms, and impacts of these movements. For instance, political authorities that repress social movements provoke the application of confrontational movement strategies (demonstrations, blockades, site occupations), whereas



political elites that try to integrate challengers into the political system discourage these radical strategies in favor of a more moderate action repertoire (negotiations, participation in advisory boards, etc.). Similarly, centralized states with limited decision-making competencies for local authorities encourage the foundation of social movements and social movement organizations at the national level (e.g., France, the Netherlands), whereas decentralized states with substantial decision-making competencies at the local or regional level foster the foundation of movements at those levels (e.g., Germany, Switzerland).

The concept of “political opportunity structure” (POS) has been applied mainly to the national level to explain the differences in action repertoires, organizational forms, and impacts of social movements between different countries. International environmental movements, however, operate at the international level, interact with international political authorities, and, consequently, are confronted with international political opportunity structures. Examples of international institutions that are relevant for international environmental movements include the United Nations (the “producer” of international environmental regimes), European Union (EU-wide environmental “directives”), World Trade Organization (WTO; trade regulations with major environmental impacts), and World Bank (loans for the construction of large dams in developing countries). These institutions widely differ with respect to their formal points of access for international environmental movements and NGOs, the responsiveness of the political elites to movement demands, the homogeneity of the institution’s political elite, and, finally, the institution’s policy implementation capacity. These four dimensions of international POS can be summarized as follows:

- A formal institutional structure (open/closed)
- Informal elite strategies (integrative/exclusive)
- Configuration of power (divided elite/united elite)
- A political output structure (weak/strong)

Whereas, for instance, the formal institutional structure of the United Nations (UN) and the EU can be qualified as relatively open to social

movements and social movement organizations, the World Bank and the WTO are much more closed. As predicted by POS theory, international environmental movements generally try to influence UN and EU decisions by lobbying and participating in decision-making procedures, whereas they use more radical strategies against World Bank and WTO policies. The large-scale resistance against World Bank–sponsored large dams in India and Brazil and against WTO-induced free-trade rules that are damaging for the environment are cases in point.

On the other hand, the political output structure of the World Bank and the WTO is very strong. Decisions taken by the World Bank and the WTO are almost always effectuated, a feature missing for many UN and EU decisions. For international environmental movements, it is very difficult to successfully influence World Bank and WTO policies, but, if successful, major policy changes may be the result.

Hein-Anton van der Heijden

See also **Antiglobalization; Environmental Justice; Environmental Law; European Green Movements; Intergovernmental Environmental Organizations and Initiatives; International Environmental NGOs; Nongovernmental Organizations (NGOs); Sustainable Development Alternatives; United Nations Conference on Environment and Development**

Further Readings

- Eckersley, R. (2004). *The green state. Rethinking democracy and sovereignty*. Cambridge: MIT Press.
- Flam, H. (Ed.). (1994). *States and anti-nuclear movements*. Edinburgh, UK: Edinburgh University Press.
- Khagram, S. (2004). *Dams and development: Transnational struggles for water and power*. Ithaca, NY: Cornell University Press.
- Pellow, D. (2007). *Resisting global toxics: Transnational movements for environmental justice*. Cambridge: MIT Press.
- Pickerill, J. (2003). *Cyberprotest. Environmental activism online*. Manchester, UK: Manchester University Press.



Schlosberg, D. (2007). *Defining environmental justice: Theories, movements and nature*. Oxford, UK: Oxford University Press.

van der Heijden, H. A. (2006). Globalization, environmental movements, and international political opportunity structures. *Organization & Environment*, 1, 28–45.



INTERNATIONAL ENVIRONMENTAL NGOS

International environmental NGOs are nongovernmental organizations that, on an international and sometimes global scale, try to influence decision making by governments, corporations, and other social and political organizations, as well as by individual citizens, in order to stop or diminish environmental degradation.

International environmental NGOs can take four different forms, each with their own specific features: (1) international mass membership organizations, (2) national mass membership organizations operating at an international level, (3) international environmental think tanks, and (4) international environmental umbrella organizations. In the following sections, these four categories will be addressed one by one.

International Environmental Mass Membership Organizations

The three most important international mass membership organizations are Greenpeace, World Wide Fund for Nature (WWF), and Friends of the Earth International (FoEI).

Greenpeace

Greenpeace, founded in 1971, is a global campaigning organization with branches in 42 countries and a total constituency of more than 2.5 million. The Dutch and German branches are among its largest, each with 500,000-plus supporters, as are the British and the North American branches, each with about 250,000 supporters.

The origin of Greenpeace is in the peace rather than the environmental movement. Its very first target was the United States testing nuclear devices in Amchitka, Alaska, and nuclear weapons have been a topic of contention ever since. In 1995, Greenpeace's ship *Rainbow Warrior* was bombed by the French army after it entered the waters of the Moruroa atoll in the South Pacific to prevent French nuclear testing.

Greenpeace has played a pivotal role in the adoption of a ban on toxic waste exports to less developed countries, a moratorium on commercial whaling, and bans on the dumping at sea of radioactive and industrial waste. Present priorities include climate change, preservation of the oceans, tropical rain forests, sustainable agriculture, and toxic chemicals. Greenpeace tries to reach its goals by lobbying, by scientific research, and, most of all, by its unconventional action repertoire. Due to its sophisticated communication strategy, Greenpeace has been very successful in raising environmental consciousness.

World Wide Fund for Nature

The WWF, founded in 1961, is the world's largest conservation organization with a joint constituency of more than 5 million. Its largest national branches include the North American and the Dutch ones, each with about 1 million supporters. WWF started as a conservation organization with hundreds of conservation projects, mainly in southern countries, such as the restoration of orangutan habitats and the establishment of panda reserves. In the past couple of decades, it has gradually broadened its mission to stopping the degradation of the planet's natural environment, resulting in coverage of topics such as pollution and climate change. However, contrary to Greenpeace, WWF never applies confrontational action strategies.

Friends of the Earth International

FoEI is the world's largest grassroots environmental network, uniting 69 national member groups and some 5,000 local activist groups on almost every continent. FoEI has more than 2 million members and supporters worldwide; among its largest branches are the German, the British, and the Dutch ones. FoEI's ideological base



Members of the World Wide Fund for Nature set up 1,600 papier-mâché pandas on October 18, 2008, to symbolize the 1,600 pandas left on Earth and to call on people to help reverse the deterioration of our natural environment. The installation was on the Parvis des Libertés et des Droits d'Homme at the Trocadéro esplanade in Paris.

Source: François Guillot/AFP/Getty Images.

could be summarized as “political ecology”: FoEI challenges the current model of economic and corporate globalization. To protect the Earth against further environmental degradation, FoEI aims to increase public participation and democratic decision making and to stimulate grassroots activism.

National Mass Membership Organizations Operating at an International Level

The second form that international environmental NGOs can take is the national, largely U.S.-based, mass membership organizations that have developed international programs. Groups belonging to this category include the National Wildlife Federation (5 million members and supporters), National Resources Defense Council

(NRDC; 1.2 million), Sierra Club (730,000), National Audubon Society (550,000), and Environmental Defense Fund (EDF; 500,000). In sum, these five groups have a staff of well over 1,000 and a joint budget of around \$200 million.

The distinctive feature of this category is its prominent role in influencing negotiations on multilateral environmental agreements. Sierra Club, Audubon Society, and Wildlife Federation are highly involved in international conservation issues such as the protection of tropical rain forests and the United Nations Biodiversity Convention. EDF and NRDC have played an effective role in the negotiations on climate change and ozone layer depletion and have also helped reshape the policies of the multilateral development banks.



Another organization belonging to this category is The Nature Conservancy, a U.S.-based conservation group with more than 1 million members and annual revenues of more than US\$1 billion. The Nature Conservancy has protected more than 69,000 km² (square kilometers) in the United States and more than 473,000 km² internationally.

International Environmental Think Tanks

International environmental think tanks are research institutes that are loosely tied to the problem definitions and solution strategies of international environmental movements. Examples include the German Öko-Institute, the American World Watch Institute and the World Resources Institute, and the London-based International Institute for Environment and Development (IIED). IIED, founded 1971, works globally through a wide range of relationships with partners across the developing world. These partners diverge from smallholder farmers and national governments to regional NGOs and global institutions. At all these levels, IIED provides expertise in achieving sustainable development. Current priorities include the strengthening of local rights to land and natural resources, strengthening corporate responsibility for social and environmental gains, and monitoring the impact of Northern government policy.

International Environmental Umbrella Organizations

International umbrella organizations are “organizations of organizations,” founded to represent the interests of their member groups at a regional or global level. Examples include the European Federation for Transport and Environment and the European Environmental Bureau (EEB). The EEB, founded in 1974, is a confederation of more than 140 environmental NGOs from 31 European countries, with a combined membership of about 14 million. It is the lobbying branch of the European environmental movement at the EU level with direct access to the European Commission.

Hein-Anton van der Heijden

See also European Green Movements; Intergovernmental Environmental Organizations and Initiatives; International Environmental Movements; Sustainable Development; United Nations Environmental Summits

Further Readings

- Arts, B. (1998). *The political influence of global NGOs. Case studies on the climate and biodiversity conventions*. Utrecht, Netherlands: International Books.
- Betsill, M., & Corell, E. (Eds.). (2008). *NGO diplomacy: The influence of nongovernmental organizations in international environmental negotiations*. Cambridge: MIT Press.
- Chasek, P., Downie, D., & Welsh Brown, J. (2006). *Global environmental politics*. Boulder, CO: Westview Press.
- Doherty, B. (2006). Friends of the Earth International: Negotiating a transnational identity. *Environmental Politics*, 5, 860–880.



INTERNATIONAL GEOGRAPHICAL UNION

The International Geographical Union (IGU) is the international organization of academic geographers, established in 1922 in Brussels following a series of international geographical meetings, the first of which was held at Antwerp in 1871. The objectives of the IGU are to promote the study of geographical problems; to initiate and coordinate geographical research requiring international cooperation and to promote its scientific discussion and publication; to provide for the participation of geographers in the work of relevant international organizations; to facilitate the collection and diffusion of geographical data and documentation in and between all member countries; to promote meetings of the IGU, regional conferences between the international geographical congresses, and other meetings in furtherance of the objectives of the Union; to participate in any other appropriate form of international cooperation with the object of advancing the study and application of geography; and to promote



international standardization or compatibility of methods, nomenclature, and symbols employed in geography.

The IGU belongs to the International Council on Science and to the International Social Sciences Council and recognizes them as providing coordinating and representative bodies for the international organization of science and the social sciences, respectively.

IGU membership is normally by country, currently 98, rather than by individuals, national professional organizations, or national societies. Member countries are expected to establish committees for the IGU, frequently functioning through national academies of science. They promote the objectives of the Union in their respective countries, notably the international aspects. They also diffuse information from the executive committee to geographers in their country. Associate country membership applies to small or emerging geographical communities. A third membership class is of corresponding members who may be either individuals or institutions.

The IGU functions through its general assembly, consisting of all member countries and meeting every congress. The assembly elects the executive committee, which consists of the president, the immediate past president, seven other vice presidents, and a secretary-general. The president, the secretary-general, and the executive committee manage the Union's activities, assisted by a secretariat located close to the office of the secretary-general, who serves also as the treasurer.

The working languages of the IGU are English and French. The Union holds a congress every 4 yrs. (years) and a regional conference every 2 yrs. between congresses. Locations for these meetings are competitive. The IGU maintains the Home of Geography, located within the premises of the Italian Geographical Society in Rome, which publishes a newsletter and specialized monographs. The main organ for continuous scientific work is the commissions, currently numbering 36, in addition to task forces (currently four) and special committees (currently two). The commissions reflect both veteran and novel specialties in geography. Commissions are approved by the general assembly, and they constitute a steering committee of 10 to 12 geographers from different countries and the commission itself, to which any

geographers may join. Commissions hold meetings, workshops, and field trips; develop joint research projects; and publish newsletters and journals and exchange information through mailing lists.

Aharon Kellerman

See also **Association of American Geographers; Institute of British Geographers**

Further Readings

International Geographical Union: www.igu-net.org/uk/igu.html



INTERNATIONAL MONETARY FUND

The International Monetary Fund (IMF) is a treaty-based, voluntary association of countries based on their real or potential impacts on the world's economy. It currently controls assets amounting to US\$215 billion and has 182 member countries. Unlike the World Bank, the other "pillar" of the world economy, the IMF has no subsidiaries or affiliates. Its highest authority resides with the Board of Governors (which meets annually), each of whom is appointed by a member country.

IMF membership has varied over time, as has its role and responsibilities in world affairs. The evolution of the IMF can roughly be divided into phases based on the degree of functionality, relevance, and shifting purpose. Initially, the IMF was established at the Bretton Woods Conference (along with the World Bank) in New Hampshire with the signing of the Articles of Agreement in July 1944 and declaration of exchange values by the 44 member countries at the first meeting in 1946. However, most economists and historians disregard the impacts of the early IMF since the most important signatories (Western industrial democracies) refused to establish rules regarding the conversion of each other's currencies into their specific reserves until December 27, 1958.



From that point until the decision by the American President Richard Nixon on August 15, 1971, to refuse conversion of U.S. notes of exchange into gold from the Federal Reserve, the IMF operated to stabilize exchange rates by setting “pegs” that regulated exchange values. This policy constrained the degree to which individual countries could pursue deflationary valuations to stimulate exports or foreign direct investment (FDI) but ensured that variations in exchange rates would also be constrained. In addition, it was believed that the pegs would alleviate uncertainty regarding the risks of FDI and thus help spur reconstruction following World War II. This peg arrangement reflected the desire of the Bretton-Woods signatories to incorporate both the advantages of the prewar gold standard and the flexibility of floating exchange rates that were popular during the interwar years. In addition, it was believed that the disadvantages of submission to the vagaries of the business cycle under the gold standard and the dangers of under- or overvaluation and trade imbalances under the floating exchange rate system could be avoided.

However, the IMF proved difficult to get going. It was generally acknowledged at Bretton-Woods that although the United States had emerged from World War II as the preeminent economic power, it nonetheless suffered from a shortage of currency in relation to its productive output. The U.S. contingent was accordingly wary of arrangements that would help other countries peg their currencies at values that would hurt U.S. exports. Thus, this early version of the IMF lacked effective enforcement mechanisms. This very point was hotly debated during Bretton-Woods, with the noted economist John Maynard Keynes arguing for a stronger, more credit-oriented institution that would have its own currency and accounts (essentially, a bank), while others (led by Harry Dexter White, Chief International Economist at the U.S. Treasury) pushed for IMF management of a pool of member currencies. In the end, a compromise was reached that resulted in a relatively weak version of the IMF in comparison with the current incarnation. With convertibility of member currencies established in 1959, however, the IMF managed to oversee a generally sustained, long period of expanded world trade, economic growth,

and stability within the industrialized democracies until 1970. With the adoption of floating exchange rates in 1973, the IMF began a 5-yr. (year) period of restructuring and adjustment that led to amendment of the constitution in 1978. The most notable adjustment was the replacement of the mechanism of pegged exchange rates with frequent consultation (usually once a year), technical advice, policy support, and loan conditions to ensure that member countries follow policies designed to support economic stability.

The IMF Today

In its current incarnation, the core mission of the IMF broadly remains the same as its founders’ intention: to ensure a smooth, orderly world economy by helping member countries find the most accurate price for their currencies. However, following the debt crises of the 1990s in Brazil, Russia, and five Asian countries (to which the IMF had extended more than US\$100 billion in credit), the IMF’s expanded role of structural adjustment of economies has exacerbated or done little to forestall economic or political instability. A lack of expertise in the area of structural adjustment is unsurprising, as it was a relatively minor function of the IMF at its original inception. The enforcement mechanism was intended to prevent countries from pursuing policies detrimental to their trading partners, not to restructure economies to facilitate smooth participation in the global economy. Similar to the World Bank, the IMF can now use its power as a lender over countries struggling to honor their currency exchange values through the imposition of “conditionalities” that the debtor country must follow to receive a loan. These conditionalities can range from fiscal policy (curtailing domestic spending) to trade policy (increased liberalization) to monetary policy (tightly controlling reserves to discourage inflation). The logic of the conditionalities is that they are designed to ensure that the borrowing country will be able to repay the loan by stimulating exports and increasing the government’s money supply without leading to inflation. However, there are significant political costs attached to radical economic restructuring, which the IMF has been criticized for not recognizing.



Ironically, this restructuring role for the IMF would have been difficult for the architects of the system to recognize. Their focus was simply on ensuring stability within the international monetary system. Over time, the enforcement mechanism designed to ensure resolution of balance-of-payments crises (balance of payments refers to all outstanding payments and debts the residents of a country owe to other countries) and beggar-thy-neighbor monetary policies (using currency devaluation to reduce foreign debt or stimulate exports) has evolved into a restructuring tool for emerging economies. The most obvious turning point in funds development was the closure of the “gold window” by the United States; this unilateral move highlighted a fundamental limitation in the fund’s power to regulate financial matters. This power was largely ineffectual for industrialized countries that maintained large payment surpluses and was certainly impotent where the interests of the largest member of the fund, the United States, were diametrically opposed to IMF’s goals.

The current structure still reflects this imbalance in its allocation of voting power—the United States has 18% of the existing voting rights, more than double of any other country. However, calls for more democratic participation by emerging economies in the IMF have been met with some reforms. Currently, there are more than 180 member countries that receive voting rights in accordance with their level of international trade, national income, and international reserve holdings. In terms of upper-level management, however, the fund continues to reflect dominance by the founding countries. The managing director and deputy managing director rotate between a European and an American (the current director is from France, the first deputy from the United States), the IMF is headquartered in Washington, D.C., and the 24 executive directors in charge of day-to-day operations are dominated by the original signatories.

China, Russia, and Saudi Arabia also have the right to appoint one executive director each, while as a whole, the remaining member countries are allowed to nominate one director to represent all of them. Voting rights are also a function of Special Drawing Rights (SDR), which are based on national income, reserves, and trade balance. The formula applied equates one vote for every 100,000 SDR, the quotas for which are reviewed

every 5 yrs. at a minimum. These quotas have increased steadily as subscription (membership) has increased over time, and if a member country does not pay its subscription, it does not receive its quota of SDR and, hence, has no voting rights. However, since the fund relies on subscriptions to finance loans and operate, countries that contribute a large share of subscriptions relative to the rest of the countries maintain a disproportionate amount of influence. This imbalance can lead to a compromise of the IMF’s core mission to maintain long-term stability in exchange rate relations as certain countries may benefit from less regulation of capital markets.

Subscriptions are not the only source of funding for the IMF, however. In addition, the IMF may borrow funds from the G-10 countries (Canada, Belgium, France, Germany, Italy, the Netherlands, Japan, Sweden, the United Kingdom, and the United States) plus Switzerland under the General Arrangements to Borrow (GAB). The GAB was used in 1998 to settle Russia’s balance-of-payments crisis. The GAB was expanded by the fund shortly afterward and currently has 17,000 million in SDR set aside for balance-of-payment crises.

The enhanced role of restructuring and policy reform during the 1980s and the resulting criticisms from that period and the notable failures during the 1990s have led to some reform. Shortly after the first round of crises, the fund reorganized the Enhanced Structural Adjustment Facility as the Poverty Reduction and Growth Facility. The new version of the facility was charged with identifying poorer countries that were able to achieve the twin goals of poverty reduction and sustainable growth. A total of 77 countries were identified as eligible for a loan in the amount of 140% of their quota payable at 0.5% interest over 10 yrs. This initiative to assist poorer countries was mirrored by the World Bank the same year with a program to aid Heavily Indebted Poor Countries (HIPC), 33 of which were in Africa, with debt relief. The condition for debt relief was that applicants must present and follow through on a yearlong strategy for reducing poverty and encouraging sustainable economic growth. Shortly after the option was developed, Uganda became the first country to apply for and receive debt relief under the Poverty Reduction and Growth Facility mechanism.



In April 2001, the IMF further expanded its surveillance functions, shifting greater emphasis toward identifying money-laundering organizations with terrorist links and pushing developing countries to exercise greater oversight of the offshore financial centers (OFC) that commonly provide money-laundering services. In 2002, a director for special operations was appointed to handle crisis response. By 2003, the fund responded to calls for more voluntary debt-restructuring methods by pushing for greater use of collective action clauses in international bond contracts. In 2006, the Monetary and Capital Markets Department was formed to strengthen fund surveillance of international finance. By 2007, roughly 90% of the fund members had agreed to increased oversight of payments, transfers, and currency arrangements.

The final arena in which the IMF has attempted reform has been its capacity to provide technical assistance. In 1993, the IMF opened regional centers in the developing and developed world to provide continuous advice from Special Missions and Resident Advisors to their respective governments on all aspects of macroeconomic issues. In addition, the IMF has maintained the IMF Institute as a training center for government officials from member nations. Postcrises, the IMF revamped the curricula of the IMF Institute to include the political impacts of the standard IMF conditionalities.

The crises of the 1990s demonstrated that the growth of international capital markets and overall connectedness of world economies by globalization eroded the extent to which floating rates insulate countries from external shocks. Nevertheless, the role of the IMF as a forum for exchange rate management continues. As of 2008, the IMF has acknowledged the need for greater focus on financial crisis prevention rather than response and has added an additional purpose of providing economic and statistical analysis on behalf of their other missions, developing financial sector Reports on the Observance and Codes (ROSC), which detail standards in the areas of transparency (for fiscal, monetary, and financial policy) at the behest of member countries wishing to improve oversight of their financial sector.

Edward Rice

See also [Debt and Debt Crisis](#); [Finance](#); [Geography of Globalization](#); [Neoliberalism](#); [Structural Adjustment](#); [World Bank](#)

Further Readings

- Danaher, K. (1999). *Fifty years is enough: The case against the World Bank and the International Monetary Fund*. Cambridge, MA: South End Press.
- Gould, E. (2006). *Money talks: The International Monetary Fund, conditionality and supplementary financiers*. Stanford, CA: Stanford University Press.
- MacQuillan, L., & Montgomery, P. (Eds.). (1999). *The International Monetary Fund*. Stanford, CA: Hoover Institute.
- Peet, R. (2003). *Unholy Trinity: The IMF, World Bank and WTO*. London: Zed Books.
- Vreeland, J. (2007). *The International Monetary Fund: Politics of conditional lending*. London: Routledge.



INTERNATIONAL WATERSHED MANAGEMENT

International watershed management refers to the multistakeholder process of creation, implementation, and monitoring of plans, projects, and programs aimed at the sustenance and enhancement of watershed functions across national boundaries. The complexity of the term reflects the complexity of approaching watershed management at an international or transboundary scale. At national levels, most countries have environmental laws that dictate the planning approaches and actions that agencies need to take to manage their watersheds, while at an international level there is no legislature that regulates how transboundary watersheds are managed. As a result, international watershed management can become a contentious issue and is generally based on bilateral or multilateral agreements between and among stakeholders. Increasingly, forecasts of climate change and economic shifts single out water resources management as a critical focal point for natural resources management and planning and a potential conflictual arena in sensitive



regions. The complexity of this issue and the varying types of expertise required for problem solving and decision making make it relevant to various subfields of geography, for example, physical, social, economic, and political.

An international or transboundary watershed is defined as all the territory that contributes to a stream, with at least one tributary crossing a political boundary. Sixty percent of the Earth's freshwater bodies fall within transboundary basins. Creating effective transboundary watershed management requires the establishment of working relations and sound communication between stakeholders. Especially in regions with a history of water resources management conflicts—for example, the Colorado, Nile, Tiger-Euphrates, Indus, Mekong, and Incomati Basins or those in the Middle East—the lack of explicit collaborations, communication between the responsible riparian parties, and implementation of professional conflict resolution strategies has contributed to prolonging a crisis state.

Conventions and Treaties

The Convention on the Protection and Use of Transboundary Watercourses and International Lakes encourages riparian parties to enter into bilateral or multilateral agreements based on, for example, water quality and quantity—monitoring data exchanges. This convention is based on *The Helsinki Rules on the Uses of the Waters of International Rivers*, published by the International Law Association in 1966, which embraces the theory of equitable utilization and by which each riparian state in an international basin is entitled to a “reasonable and equitable share” of the watercourse and commits to not cause “substantial injury” to coriparian states. The United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses, adopted in 1997, added to the equitable and reasonable utilization of waters clauses, such as protection of the aquatic environment and promotion of cooperative management mechanisms, and made further provisions on data and information exchange and mechanisms for conflict resolution. However, the treaty most invoked internationally for watershed protection and management is the Ramsar Convention on Wetlands (officially called

The Convention on Wetlands of International Importance), which took effect on December 21, 1975, with presently 158 signatories, and addresses the protection of wetland habitats.

Establishing Effective International Watershed Management

Effective international watershed management requires comprehensive and multidisciplinary approaches and a flexible and integrative framework for addressing the biophysical, socioeconomic, and governance issues affecting water resources and their equitable distribution and use. There are several stages in the planning and management process for watersheds. Throughout the process, care must be taken that basic hydro-diplomacy principles are considered and that continued stakeholder consultation and public participation are ensured. The first step in the management process is establishing plan parameters and objectives, followed by identification of watershed components and processes (also known as a watershed physical inventory), which can be more or less detailed depending on the context. Once the basic basin characteristics and management objectives are set, the stakeholder consultation process to develop practical management options and alternatives can begin. Crucial steps in the development of a management strategy include determination of the legal and policy implications that pertain to all nations participating in the consultation process and a detailed assessment of the environmental, socioeconomic, and political impacts of the plan. While theoretically the steps leading to the top-down implementation of a viable watershed management plan are straightforward, in practice there are several limitations. These include lack of data; reduced accessibility in parts of the basin; inadequate funding; bureaucratic and administrative hurdles dictated by the different political situations of stakeholders; low levels of public awareness, information, and involvement; competing interests; and the relative lack of an international regulatory body or set of water laws pertaining to transboundary watershed management.

Alternative approaches to the top-down integrated water resources management (IWRM) strategy described above include the creation of



bottom-up institutions, through the decentralization of multigovernment services and governance to local and regional authorities, private enterprises, and communities. This approach, known as community-based water resources management (CBWRM), grew from the need to fill the gap in policy making at the regional, interstate level and implementation at the local level, since policies and management plans devised through formal interstate consultations rely on implementation at local levels. Apart from the IWRM or CBWRM strategies, other successful approaches include an adaptive watershed management approach practiced in the Columbia River Basin of the United States and an ecosystem-based river basin management approach practiced in the Ili-Balkhash Basin in Central Asia. These approaches are not mutually exclusive and, to be functional, need to sustainably integrate biophysical, socioeconomic, and political and varying levels of institutional elements in river basins. The bottom line is that transboundary management approaches must be selected on a case-by-case basis and ensure that they meet the needs of all riparian countries and, moreover, that water continues to be regarded as a nonmarketable human right and an international public good to be equitably allocated among stakeholders.

Narcisa Gabriela Pricope

See also **Community-Based Natural Resource Management; Environmental Rights; Indigenous Water Management; Intergovernmental Environmental Organizations and Initiatives; Rivers; Surface Water; Watershed Management**

Further Readings

- DeBarry, P. (2004). *Watersheds*. New York: Wiley.
- Ganoulis, J., Duckstein, L., Literathy, P., & Bogardi, I. (1996). *Transboundary water resources management*. New York: Springer.
- Gregersen, H., Ffolliott, P., & Brooks, K. (2008). *Integrated watershed management*. Wallingford, UK: CABI Press.
- Sabatier, P., Focht, W., Lubell, M., & Trachtenberg, Z. (Eds.). (2005). *Swimming upstream: Collaborative approaches to watershed management*. Cambridge: MIT Press.



INTERNET

See Communications, Geography of; Cyberspace; Google Earth; Digital Divide; Telecommunications and Geography



INTERNET GIS

Internet GIS refers to the use of the Internet as a means to exchange geospatial data, perform geographic information system (GIS) analysis, and visualize maps. Like many other new research fields, there is no general agreement on the term *Internet GIS*. Several alternative names have been adopted in the GIS community to represent similar concepts, such as online GIS, distributed geographic information (DGI), and Web-based GIS (or Web GIS). These different terms are similar, but they are not synonymous. For example, Web-based GIS refers to the use of Web browsers as the primary viewers/containers to conduct GIS tasks. However, some popular GIS applications, such as Google Earth, use their own browsers instead of relying on the default Web browsers. Therefore, Google Earth is an Internet GIS application, but it is not a Web-based GIS application. The term *Internet GIS* has a broader and more enduring meaning than *Web-based GIS*. It has the capacity to include other and new applications of GIS and the Internet.

The Internet is a modern information relay system that connects hundreds of thousands of telecommunication networks and creates an "internetworking" framework. The Internet framework includes local area networks (LAN), wide area networks (WAN), Internet Service Provider (ISP) networks, wireless communication networks, and intranets. Intranets are a subset of the Internet that use the same Internet Protocol and communication technologies within a closed environment, such as a company network, but with limited access and security enhancement.

Early Internet GIS prototypes appeared in the mid 1990s. Xerox Map Viewers, the Alexandria Digital Library project, and GRASSLinks are a few representative Internet GIS prototypes from

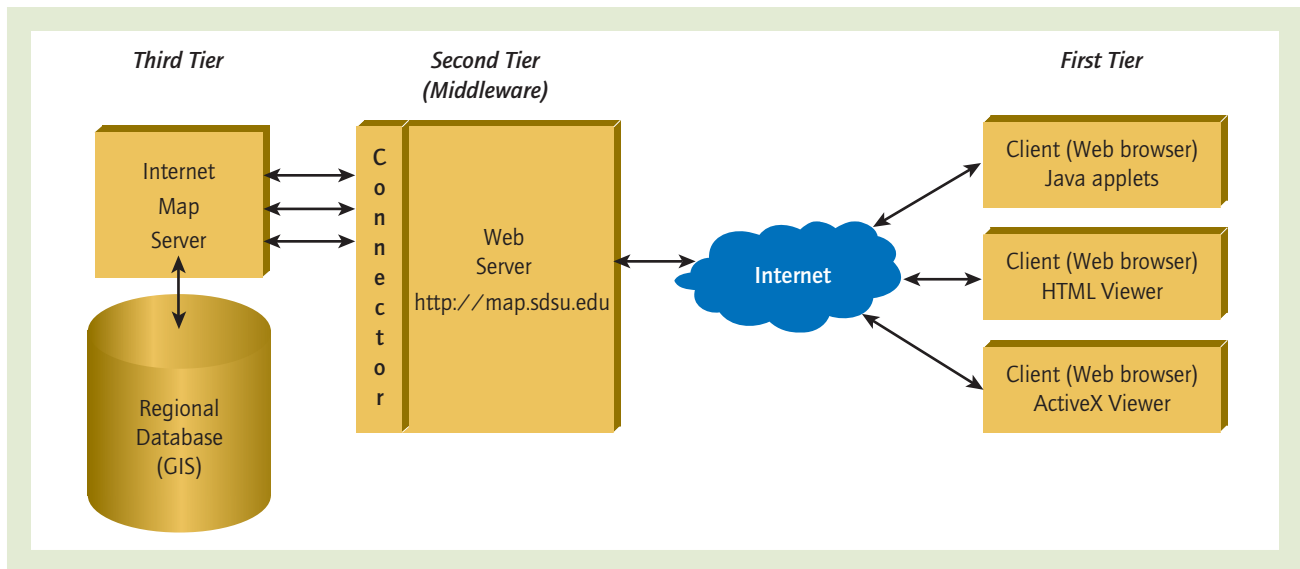


Figure 1 The three-tier architecture of the Internet GIS

Source: Author.

the early period. More recently, we have witnessed an explosion of interest in transforming GIS into the ubiquitous, distributed Internet GIS. These services are of value not only to various professionals using geospatial data in their daily work but also to the general public, to use spatial information for navigational and other purposes involving location-based data. There are Web sites powered by Internet GIS that allow people to check city zoning and parcel information, see where and what types of crimes are occurring in their neighborhoods, and learn when is the trash pickup day on their street.

GIS on the Internet presents a compelling and effective way of disseminating spatial information when compared with traditional paper maps or digital maps stored in centralized GIS or on CDs. Though the melding of GIS and the Internet seems a commonplace now, the idea was revolutionary in 1993. One of the earliest Internet GIS prototypes, called Xerox PARC Map Viewer, appeared on the World Wide Web that year. Developed at Xerox Corporation's Palo Alto Research Center, the Map Viewer allowed users to zoom in on a location on a picture-based map rendering of a globe and retrieve a map of the selected area from a geographic database. In 1994, two important organizations promoting

standardization in Internet GIS were established: the Open Geospatial Consortium (OGC) and the International Organization for Standardization (ISO) Technical Committee 211 (TC211). Specifications developed by OGC and ISO/TC211 for spatial data formats, data exchange, and data communication have become the basis for software interoperability and the ongoing development of Internet GIS. Along with the rapid development of Internet GIS, a new term, *geospatial cyberinfrastructure*, is used to represent the combination of distributed high-performance geospatial computing resources, georeferenced information, geoprocessing Web services, and geographic knowledge.

The Architecture of Internet GIS

Most Internet GIS today adopt a three-tier architecture for system implementation (Figure 1). The first tier, called the *client tier*, includes the user-side Web browser and user-resident Java applets/HTML documents. The user of Internet GIS interacts with the client tier via a graphical user interface (GUI) composed usually of a map and map navigation, spatial and attribute data query, and spatial analysis tools. The primary function of the client tier is to accept users' data requests and to

Type	Applications
Data sharing (exchanging)	• Online data warehouses (data archive) • Online data clearinghouse (metadata)
Information sharing (map sharing)	• Web-based map display • Navigation services
Knowledge sharing (spatial analysis and GIS modeling)	• Online GIS models • Web-based spatial analysis tools

Table 1 The three types of Internet GIS
Source: Author.

display the results of these requests. The second tier is the *middleware tier* and includes the Web server and the server connector (such as Servlet connectors or Active Server Pages [ASP] connectors) to bridge the communication between clients and the map servers. The third tier is the *data storage tier*, which includes the map server and the spatial database server. The three-tier software architecture of Web-based GIS provides customizable functions for different mapping applications and scalable implementations for different volumes of use and, correspondingly, different hardware configurations.

Three Types of Internet GIS

There are many different Internet GIS applications, ranging from data clearinghouses, Web mapping, data portals, Web-based decision support systems, and GPS tracking to digital Earth viewers and virtual globes. In general, we can categorize the various Internet GIS services into three types: (1) data sharing, (2) information sharing, and (3) knowledge sharing (Table 1).

Data sharing combines the functions of online data archive and data search services. Two typical applications are online data warehouses (or data archive centers) and online data clearinghouses. An online data warehouse is used for archiving, accessing, and downloading both GIS databases and/or remotely sensed imagery. A Web-based data clearinghouse can help users search and index the contents of metadata and then access the actual data through the descriptions of metadata.

The second type of Internet GIS services involves information sharing and map sharing. Multiple interactive map servers and mobile navigation services are the typical applications. Web-based mapping functions include the display, zooming in or out, and query of spatial information. The major requirement of information-sharing services is to provide effective Web-based display mechanisms and client-server communication protocol.

The third type of Internet GIS focuses on the sharing of knowledge and GIS models. This is the most challenging task for the development of Internet GIS, and only a few applications are available today. The goal is to provide online GIS modeling and spatial analysis functions without running GIS engines or software packages locally. Some Internet GIS applications use Java or other distributed component technologies (such as .NET or Web services) to develop online GIS model functions. The implementation of these Web-based software components can provide ubiquitous access for all different types of GIS applications.

New Directions of Internet GIS

There are many Internet GIS applications using Web services and application development interfaces (APIs) for Web mapping or geocoding functions. Web services are interoperable and self-describing applications that can communicate with each other. Many software companies, such as ESRI, Google, Yahoo, and Microsoft, have developed several Web service applications and



Web Map APIs. Web application developers can use and combine these APIs and Web services into Web-based GIS applications for providing basic mapping and GIS functions. It is likely that some of today's users of desktop GIS software packages will use in the future exclusively Web-based GIS services and that the user base of desktop GIS will shrink. The advantages of Web services include easy integration with other Web GIS applications and the low cost of software and hardware compared with the cost of software and hardware required by traditional GIS systems.

Another exciting new direction of Internet GIS is the development of three-dimensional (3D) virtual globes such as Google Earth, Microsoft Virtual Earth, and ESRI's ArcGIS Explorer. They represent an evolution in technology, but to people outside the GIS community, it's a revolution in the way people understand geography and the world around them. The virtual globes provide an appealing way to convey to people spatial concepts and geographic information.

Ming-Hsiang Tsou

See also **Distributed Computing; GIScience; GIS Implementation; GIS Web Services; Google Earth; Neogeography**

Further Readings

- Jankowski, P., Tsou, M.-H., & Wright, R. (2007). Applying Internet geographic information system for water quality monitoring. *Geography Compass*, 1, 1315–1337.
- Peng, Z.-R., & Tsou, M.-H. (2003). *Internet GIS: Distributed geographic information services for the Internet and wireless network*. New York: Wiley.
- Plewe, B. (1997). *GIS online: Information retrieval, mapping, and the Internet*. Santa Fe, NM: OnWord Press.
- Tsou, M.-H. (2004). Integrated mobile GIS and wireless Internet map servers for environmental monitoring and management [Special issue on mobile mapping and geographic information systems]. *Cartography and Geographic Information Science*, 31(3), 153–165.



INTEROPERABILITY AND SPATIAL DATA STANDARDS

The International Organization for Standardization (ISO, 1993) defines interoperability as “the capacity to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.” In the context of geographic information, the functional units are geographic information systems (GIS) or Web services. The communication between these units comprises transfer of spatial data as well as querying and execution of remote services. In this respect, two types of interoperability can be distinguished: (1) *syntactic* interoperability refers to format of the transferred data, that is, compliance with spatial data standards, and (2) *semantic* interoperability builds on syntactic interoperability and refers to the accurate preservation and interpretation of the *meaning* of the transferred information. The focus of this entry is on syntactic interoperability and the standards enabling heterogeneous GIS and services to interoperate. Note that the kind of interoperability discussed here relies on lower-level *technical* interoperability, where established standards guarantee that a CD can be read in every CD drive, computers can communicate through telephone wires, electric devices can be operated on every power outlet, and so forth.

Interoperability is a key requirement for the seamless exchange of spatial data between users and organizations employing different GIS and Web services. On a broader scale, the standards enabling interoperability are the cornerstones of spatial data infrastructure (SDI). Without agreements on the formats of the transferred spatial data and the interfaces for accessing the corresponding Web services, mutual data exchange between different GIS would at least require manual transformation of the data or even be impossible altogether. The most important organizations that develop such standards for the geospatial domain are the Open Geospatial Consortium (OGC) and the ISO Technical Committee 211 (ISO/TC211), responsible for geographic information/geomatics. Both organizations have a working agreement, resulting in a frequent mutual adaptation of standards.



Data Interoperability

Before the Web became a common platform for the exchange of geodata, interoperability mainly concerned the exchange of spatial data between different desktop GIS workstations on different kinds of media. Early exchange formats for spatial information such as ESRI's shape file format were de facto standards stemming from the widespread use of their ArcGIS and ArcView software. To enter the market, other software vendors had to support these proprietary formats, which are still common today. Besides specialized GIS formats, vector data were often exchanged in file formats originally developed for computer-aided design (CAD) software. Raster data were (and still are) mostly exchanged in standard graphics file formats such as JPEG, PNG, or (georeferenced) TIFF.

In a more contemporary sense, interoperability is usually reached by standards that are established by industrial consortia or independent standardization organizations. One such vendor-neutral standard for geographic features that is commonly used today is the Geography Markup Language (GML) introduced by the OGC. GML is an eXtensible Markup Language (XML) encoding for the transport and storage of geodata that can be tailored to specific applications via application schemas. Application schemas define the specific feature types and property types that are relevant for a given domain based on the GML meta schema. Due to the complexity of GML caused by this multipurpose design, numerous developers favored the simpler Keyhole Markup Language (KML), especially for nonprofessional or Web 2.0 mash-ups. KML was originally a proprietary format used in Google Earth and has been put under control of the OGC in 2007. It became an open OGC standard in 2008.

Besides the actual data, their descriptions in metadata must also be standardized to allow interoperable data discovery in catalog services. This standardization refers to the metadata encoding as well as the minimum set of mandatory properties, allowing for metadata profiles for different applications. The ISO 19115 specification (part of the ISO 191xx set of standards for geographic information) provides such a standard specifically developed for metadata on geodata.

It comprises more than 400 different elements, of which a small subset is compulsory. Besides ISO 19115, the Dublin core metadata standard is also commonly used for spatial information, although it is a general-purpose standard and has not been developed specifically for geodata.

Web Service Interoperability

Web services enable loosely coupled service-oriented architectures that provide Internet-based access to spatial data stored in remote databases. They allow for the execution of distributed geoprocessing functionality such as the online computation of standard GIS operations. In addition to standards for the formatting of the transferred data, Web services require standardized interfaces for communication with these services. The OGC has developed a number of standards for geospatial Web services, with the most widely adapted being the Web Map Service (WMS) and Web Feature Service (WFS) specifications for the retrieval of raster and vector data, respectively. Further specifications cover advanced functionality such as geodata processing (WPS), sensor observation (SOS), or location services (OpenLS; see Percivall, 2003, for a complete overview). OGC specifications define Web service interfaces by specifying the formats for requests and responses. This implementation-independent approach allows existing proprietary Web services to be subsequently equipped with an additional OGC compliant interface. Such a mapping is especially important for the integration of existing services into SDIs and follows an approach that has proven useful on the technical level: For a user, it is sufficient to know the interface, such as a power outlet or a WMS interface, and the corresponding interactions. It is then irrelevant how the electric power is generated or how a map tile is composed to make use of the interface. At the same time, this approach allows developers great latitude in the actual implementation of the services.

Carsten Keßler

See also **GIS Web Services; Metadata; Open Geodata Standards; Open Geospatial Consortium (OGC); Semantic Interoperability; Spatial Data Infrastructures**



Further Readings

- Bishr, Y. (1998). Overcoming the semantic and other barriers to GIS interoperability. *International Journal of Geographical Information Science*, 12, 299–314.
- International Organization for Standardization. (1993). *ISO/IEC 2382-1:1993 information technology—vocabulary—part 1: Fundamental terms*. Geneva: Author.
- ISO/TC 211 Geographical Information/Geomatics: www.isotc211.org
- Percivall, G. (Ed.). (2003). *OGC reference model Version 0.1.3*. Wayland, MA: Open Geospatial Consortium. Retrieved October 28, 2009, from portal.opengeospatial.org/files/?artifact_id=3836



INTERVIEWING

Interviewing is one of the most common social science research methods; it is used by a wide array of human geographers to gather information about people and particularly their views about their world and how they feel they and others fit within it. Interview “data” are typically obtained through verbal communication between the researcher and participant: face-to-face, over the telephone, and, occasionally yet increasingly, over the Internet as textual chat or Voice Over Internet Protocol (VoIP). The term *interview* is used to describe a wide range of techniques in both popular culture and academia. Though it is sometimes used to describe face-to-face, closed-ended, survey questionnaires that are filled out by the researcher, *interview* more commonly describes the far less structured qualitative technique.

The interview as a modern-day qualitative social science method developed alongside participant observation and other so-called field methods, particularly within the Chicago School of Sociology and their now-famous urban ethnographies of the 1920s, 1930s, and beyond. Among the prominent influences at this time were the work of George Herbert Mead and the philosophy of pragmatism. Both were later interpreted by Herbert Blumer, who coined the term *symbolic interactionism* in an attempt to simplify

the philosophical underpinnings of the interview method. The emphasis of symbolic interactionism is that it is mainly through interaction between humans that social meaning and action can be fully understood. This approach is consistent with the works of several German philosophers and the philosophy of phenomenology, which predates the Chicago School. Phenomenology in particular was opposed to the strict requirements of objectivity in highly structured positivist social science. Yet phenomenology also forms the philosophical basis for reflection, or reflexivity, as a central aspect of qualitative interviewing. The interviewer is expected not only to reflect on the conscious intentions of the research participants but also on his or her own intentions as well as the influence of his or her social position within the interview process.

In terms of practical advantage over more structured methods, qualitative interviews are used in three interrelated types of research: (1) topics that have not yet been studied extensively; (2) exploratory research with groups of people who are hard to reach, such as the homeless; and (3) studies that seek to understand personal or sensitive topics or that require participant reflection. In the case of new topics, and by virtue of the flexible nature of interviews, they provide the opportunity to develop new theoretical concepts rather than simply test existing ones. In relation to the latter two types of research, because the interview is more personable than questionnaires, interviews ideally allow the researcher and the participant to develop a positive rapport or social trust. This helps get at the deeper meanings that such research requires.

Qualitative interviewing is meant to be more conversational than questionnaire-based survey interviewing. Qualitative interviewing involves the concept of the *researcher as instrument*, whereby the researcher, as a social-interpretive being, is considered very central to the interview and interpretive processes. Thus, the researcher's ability to react to the social situations within the interview is not nearly as constricted in the name of objectivity as it would be in the case of survey questionnaires. That said, the researcher often withholds at least some of his or her own personal views—a source of some debate among interview practitioners.



It is the subjective meanings of the participants that are the focus of the qualitative interview, and somewhat paradoxically, these meanings themselves are at least partially socially constructed by the interview process itself. That is, interviews do not entirely tap into preexisting understandings; the interview conversation helps articulate some meanings that might otherwise be left veiled by the participant's need to get on with daily life. By responding to participants in ways that more closely approximate everyday social life, the qualitative interviewer can be more empathetic, which ideally contributes to a positive rapport. Furthermore, the researcher as instrument can simultaneously interview and observe such that the interview process is conducted holistically. Thus, the presentation of self is important in the interview since interview participants do indeed act in response to how the researcher presents himself or herself—for example, as an academic, student, activist, feminist, Muslim, wealthy, or politically left of center. In the case of face-to-face interviews, the researcher as instrument also entails attention to the physical presentation of self in terms of dress, mannerisms, and even the setup of the interview location since these all can both enable and constrain what may be learned through interviewing.

All types of qualitative interviews are meant to be conversational but vary along a continuum from structured to unstructured. Interviews typically involve a list of topics to be covered—an interview guide or interview schedule. For example, semistructured interviews may involve a detailed list of topics and probes in the guide; yet the researcher may nevertheless retain the flexibility to cover the topics out of order or pursue topics raised by the participant. Not only does this allow the interview to be more conversational, it surrenders some control over the path of the conversation to the participant.

Interview “data” are commonly interpreted as text, though the interview itself is often audio recorded and subsequently transcribed into text. Otherwise, field notes taken during the interview are the substance of interpretation. The choice or recording strategy may thus involve trade-offs between the intrusiveness of the recording method, accuracy, and the comfort level of the participant. In all cases of data recording, reflections on the

interview situation (e.g., reasons for guarded responses) are recorded during or soon after the actual conversation. Thus, interpretation occurs throughout the interview process from topic inception through write-up.

Despite the researcher's desire to share power over the form and content of the conversation, interviews, like other qualitative methods, involve some serious ethical challenges. This goes beyond the more straightforward issue of obtaining informed consent, which allows participants to withdraw from the research without negative impacts. However, since much interview work is conducted with disadvantaged groups in society, there are more subtle ethical considerations over issues of power, control, and the uses to which data are put. In most instances, the researcher has the most control over the content and ultimate trajectory of interviews and particularly what is interpreted from them. This can create tensions between interpretations that are intended for more academic audiences and those that serve to more directly address the problems of the group(s) being studied. Such issues are most keenly debated among feminist and participatory action researchers and between them and other types of less action-oriented interview practitioners.

Jamie Baxter

See also **Chicago School; Fieldwork in Human Geography; Feminist Methodologies; Participant Observation; Phenomenology; Positionality; Qualitative Methods; Situated Knowledge**

Further Readings

- Blumer, H. (1962). Society as symbolic interaction. In A. Rose (Ed.), *Human behavior and social process: An interactionist approach* (pp. 20–40). Boston: Houghton-Mifflin.
- Dunn, K. (2005). Interviewing. In I. Hay (Ed.), *Qualitative research methods in human geography*. Oxford, UK: Oxford University Press.
- England, K. (1994). Getting personal: Reflexivity, positionality, and feminist research. *The Professional Geographer*, 46(1), 80–89.



Limb, M., & Dwyer, C. (2001). *Qualitative methodologies for geographers: Issues and debates*. London: Edward Arnold.

Miller, W., & Crabtree, B. (2004). Depth interviewing. In S. Nagy Hess-Biber & P. Leavy (Eds.), *Approaches to qualitative research: A reader on theory and practice*. New York: Oxford University Press.

INVASION AND SUCCESSION

Invasion and succession are the establishment of one or more species in an area previously uninhabited by those species and the subsequent progression of the ecological community's species composition in that area through time. As ecological terms, *invasion* and *succession* are usually discussed independently from each other. Invasion, in an ecological sense, occurs when a species, usually an exotic or nonindigenous species, is introduced to an area and is able to persist in that area, often at the expense of native species. Ecological succession refers to the changes in species composition in an area over time. Succession is typically conceptualized as a progression of species compositions in an area that eventually achieves a climax stage, which remains dominant in an area until a disturbance in that area (e.g., a fire or a strong storm) resets the species composition to an earlier stage of succession. This is an example of secondary succession. Primary succession occurs when ecological communities form in an area that had no previous communities or abiotic habitat development. Ecological community development on land just formed by a volcano or newly uncovered by a landslide is an example of primary succession.

The invasion of an ecological community by an exotic species is typically viewed as a negative process. The invading species can potentially disrupt the interspecies ecological dynamics of the native community. This can result in the loss of native species in an area. The lack of natural predators of the invading species can result in their unchecked population growth. If the invading species are pathogenic to the native species, the natural defenses of the native species may not be able to resist the invading species. These

factors can result in catastrophic ecological disruptions to native communities.

Combining the ecological processes of invasion and succession provides an integrative view of the changes that ecological communities experience through time. This has become more important as modern economic globalization continues to expand linkages between different places in the world. These links are often in the form of major physical transportation agents, such as boats, airplanes, and trains, which have transported many species to areas beyond their native ranges. The introduction of these species to new areas provides them with invasion opportunities. Once these invasive species become established in an area, they will compete with native species for niche space within the stages of succession that the area experiences. Successful invasive species eventually find a stable niche within a native community and in time are described as nonnative elements of the community.

Matthew Miller

See also **Biogeography; Biota and Climate; Biota and Soils; Biota and Topography; Biota Migration and Dispersal; Ecological Zones; Ecosystems; Ecotone; Exotic Species; Human-Induced Invasion of Species; Species-Area Relationship**

Further Readings

Lomolino, M., Riddle, B., & Brown, J. (2005). *Biogeography* (3rd ed.). Sunderland, MA: Sinauer Associates.

Odum, E., & Barrett, G. (2004). *Fundamentals of ecology* (5th ed.). Belmont, CA: Brooks/Cole.

ISARD, WALTER (1919–)

Walter Isard is the father of the discipline of Regional science. Often characterized as an “economic geographer,” his work is much broader, also encompassing urban and regional planning, operations research, transportation, applied engineering, political science, sociology, and ecology.



The focus of regional science is on space and location, and it treats a region (any subnational entity not necessarily defined by political boundaries) as an organic whole.

Walter Isard was born in Philadelphia in 1919. He graduated from Temple University with honors in 1939 and then studied at Harvard and the University of Chicago. While working for the National Resource Planning Board during World War II, he completed his dissertation on building cycles and transportation development and received his PhD from Harvard in 1945. Isard returned to Harvard that year as a research associate and an instructor, and he designed the first course in location theory there. By the late 1940s, he helped form a small group of economists, which eventually expanded in number and breadth to include people from related disciplines, culminating in the founding of the Regional Science Association in 1954. Isard moved to the department of city and regional planning at Massachusetts Institute of Technology in 1953. In 1956, he was invited to join the economics department at the University of Pennsylvania but insisted on forming his own department of regional science, which he served as chair until 1975. He initiated the *Journal of Regional Science* in 1958 and later founded the journals *Regional Science and Urban Economics* and *The International Regional Science Review* in the early 1970s.

The second discipline founded by Isard was Peace Science, a rigorous, interdisciplinary inquiry into the topic. In 1963, he helped form what is now the Peace Science Society, and in 2006, he established the journal *Peace Economics, Peace Science and Public Policy*.

Isard's key initial contribution was the reformulation of the work of European location theorists, such as von Thünen, Alfred Weber, Walter Christaller, and August Lösch, into neoclassical microeconomics. Although there were several scholars who worked on this topic in the United States previously, Isard's *Location and Space Economy* provided a comprehensive, unified framework. Prior to this, economics lacked a formal spatial dimension and treated the economy as if it operated on the head of a pin. Interestingly, the neoclassical core of regional science has caused a distancing between this discipline and human geography, as the latter places an increased emphasis on social theory and political economy.

Isard published several other influential books over the next 20 years, including *Industrial Complex Analysis and Regional Development* in 1959 (an early foray into agglomeration economies); *Methods of Regional Analysis* in 1960 (instruction on a broad spectrum of analytical and practical tools, including input-output analysis and various types of mathematical programming); *General Theory: Social, Political, Economic and Regional* in 1963 (to further unify various aspects of spatial analysis, economics, and related disciplines); *Ecological Economic Analysis for Regional Development* in 1972 (a precursor of modern ecological economics); and the textbook *Introduction to Regional Science* in 1972.

In 1977, Isard moved to Cornell University, where he was given appointments in the department of economics and city and regional planning, as well as the regional science program and peace science program, which he established (he had held a visiting appointment at Cornell since 1971). Isard is now professor emeritus at Cornell and remains active in several fields at the time of this writing.

Isard was the mentor of many notable scholars at the University of Pennsylvania, including William Alonso, Eugene Solensky, and David Boyce. His students in economics at Cornell included Luc Anselin and this author. He has been listed among the ranks of leading economists, and his contributions to other disciplines, especially geography, are well acknowledged.

Adam Rose

See also **Input-Output Models; Location Theory; Models and Modeling; Regional Science; Regional Science Association International (RSAI)**

Further Readings

- Isard, W. (1956). *Location and space economy: A general theory relating to industrial location, market areas, land use, trade and urban structures*. Boston: MIT Press.
- Isard, W. (1960). *Methods of regional analysis: An introduction to regional science*. Boston: MIT Press.
- Isard, W. (1970). *Introduction to regional science*. New York: Prentice Hall.



ISLAND BIOGEOGRAPHY

Islands have always had a great influence on the natural sciences, far out of proportion to the tiny fraction of Earth's surface that they cover. The reason for this is straightforward: Islands and other insular habitats, such as lakes, caves, springs, and mountaintops replicate natural experiments. Island biogeography is a field within biogeography that attempts to describe and understand the innumerable patterns in the distribution of species arising from these natural experiments.

Island Types

Islands can be divided into two broad types: (1) *true islands*, land wholly surrounded by water, and (2) *habitat islands*, other forms of insular habitat, that is, discrete patches of habitat surrounded by strongly contrasting (hostile) habitats.

In terms of geology, geography, and biology, true islands can be subdivided into two types:

Oceanic Islands. These are islands formed over oceanic plates; they are of volcanic origin (although sometimes their subaerial parts are in part or wholly composed of sedimentary, and especially coral, formation as the volcanic core has sunk) and have never been connected to continental landmasses, from which they are separated by deep sea (e.g., Azores, Canaries, Hawaii, Iceland, Tristan da Cunha). They generally lack indigenous land mammals and amphibians but typically have a fair number of bird species and insects and usually some reptiles.

Continental Islands. These islands are located on the continental shelf. Typically, many of these islands have been connected to the mainland during the Quaternary ice ages (e.g., Britain, New Guinea, Sri Lanka, Sumatra, Trinidad). They are rarely remote and always contain some land mammals and amphibians, as well as representatives of the other classes and orders in considerable variety.

Continental Fragments. These are islands that formed on ancient fragments of continental rock stranded out in the oceans by plate tectonic processes, although by their location they might otherwise pass for oceanic islands (e.g., Crete, Cuba, Madagascar, New Zealand, Seychelles). Typically, they exhibit high endemism and relictualism.

The Significance of Islands

The biotas of islands, especially of oceanic islands, characteristically differ from continental biotas in four main ways: They are relatively impoverished, unsaturated, and disharmonic, and they harbor a disproportionately high number of endemic species. Considering New Guinea as the largest island, islands constitute only 3% of the total landmass of the Earth, while more than 15% of plant, land snail, and bird species are restricted to islands. In the case of higher plants, more than 13% of the world's species are endemic to just 13 islands/archipelagoes. The high endemism of islands means that island species are crucially important to global biodiversity. The first three traits mentioned above are often considered as being largely responsible for island species and communities being particularly fragile when exposed to external pressures.

The ecosystems of islands (coastal, marine, and inland) provide valuable services to more than 500 million people—namely, food, tools, industry, medicine, transport, and waste disposal. With increasing human population pressures through high migration and reproductive rates, island systems face several serious issues both in the immediate and in the near future. The natural land cover of island systems has changed drastically under the pressure of growing human populations and the consequent exploitation of the landmass (e.g., the Azores have lost more than 90% of their original native forest during the five centuries of human occupation). On some islands, the impact has exceeded critical thresholds, particularly along the coastal periphery. Anthropogenic changes range from deforestation for cropland to urbanization and the abandonment of degraded land. All these have immediate repercussions in destruction of the remaining habitat and loss of biodiversity.

In the current age of mass anthropogenic extinctions, islands qualify as “hot spots,” combining the attributes of high levels of unique biodiversity, recent species extinctions, and likely future species losses (i.e., they have a high unpaid extinction debt). A disproportionate fraction of all endangered and recently extinct species are island species. The majority of recorded species extinctions since circa AD 1600 have occurred on islands

Group	Islands	Continents	Oceans	Total	% Insular
Mammals	51	30	4	85	60
Birds	92	21	0	113	81
Reptiles	20	1	0	21	95
Molluscs	151	40	0	191	79
Insects	51	10	0	61	84
Plants	139	245	0	384	36
Total	504	347	4	855	59

Table 1 Summaries of known extinctions from islands, continents, and oceans since circa AD 1600

Source: Whittaker, R., & Fernández-Palacios, J. (2007). *Island biogeography: Ecology, evolution, and conservation* (2nd ed., Table 11.2). Oxford, UK: Oxford University Press. Reprinted with permission.

(Table 1). Approximately 70% of recorded extinctions in five animal groups (mammals, birds, amphibians, reptiles, and land snails) have been island species. Avian extinctions are overwhelmingly concentrated on oceanic islands, especially on Hawaii and New Zealand, with very few elsewhere. With few exceptions, oceanic island avi-faunas have lost a significant proportion of their endemic species over the past 1,000 years.

Island Theories

Islands provide replicated series of more or less self-contained systems that can serve as nature’s “laboratories.” They have thus featured predominantly in the development and testing of theories. The equilibrium theory of island biogeography (ETIB) is arguably the single most influential theory in the study of geographic patterns of diversity. Its influence is marked not just by the research it has motivated but also by the theories and applications it has spawned/influenced (e.g., species-energy theory, metapopulation theory, island assembly theory, neutral theory, and stochastic niche theory).

The dynamic, equilibrium model of ETIB postulates that the number of species of a given taxon found on an island will be the product of opposing forces leading consecutively to the gain and loss of species and resulting in a continual turnover of the species present on each island through time. This is captured in graphical mode in Figure 1: The immigration rate declines exponentially and the extinction rate rises exponentially as an initially empty island fills up toward

its equilibrium richness value (shown by the intersection). The immigration rate curve flattens with increasing isolation, and the extinction rate with increasing area, thereby generating a family of curves providing unique combinations of richness and turnover for each combination of area and isolation.

Although ETIB has proved more difficult to test than first hoped, as a heuristic device it has been and continues to be extremely important in organizing thought on patterns of species diversity and in providing a framework against which to consider other models of diversity. Modifications and improvements on the basic ETIB model can help provide a more robust framework for evaluating and predicting patterns of species diversity, although some contend that sharper departures from this theoretical framework are needed.

One key element in any general model is to more explicitly recognize the important role that adaptive radiation plays in increasing species diversity on islands. This is mentioned but not fully developed in the ETIB. Recently, it has been proposed that for oceanic islands, it is important to consider island “ontogeny,” that is, the life history of an island itself, for describing the interplay of immigration, extinction, and speciation in establishing species richness. A volcanic island’s size, topographic complexity, ability to support life, and potentially its likelihood of promoting speciation change over geological time as the island forms out of the ocean, grows larger and higher, and then begins to shrink, lose elevation, and eventually become eroded below the surface

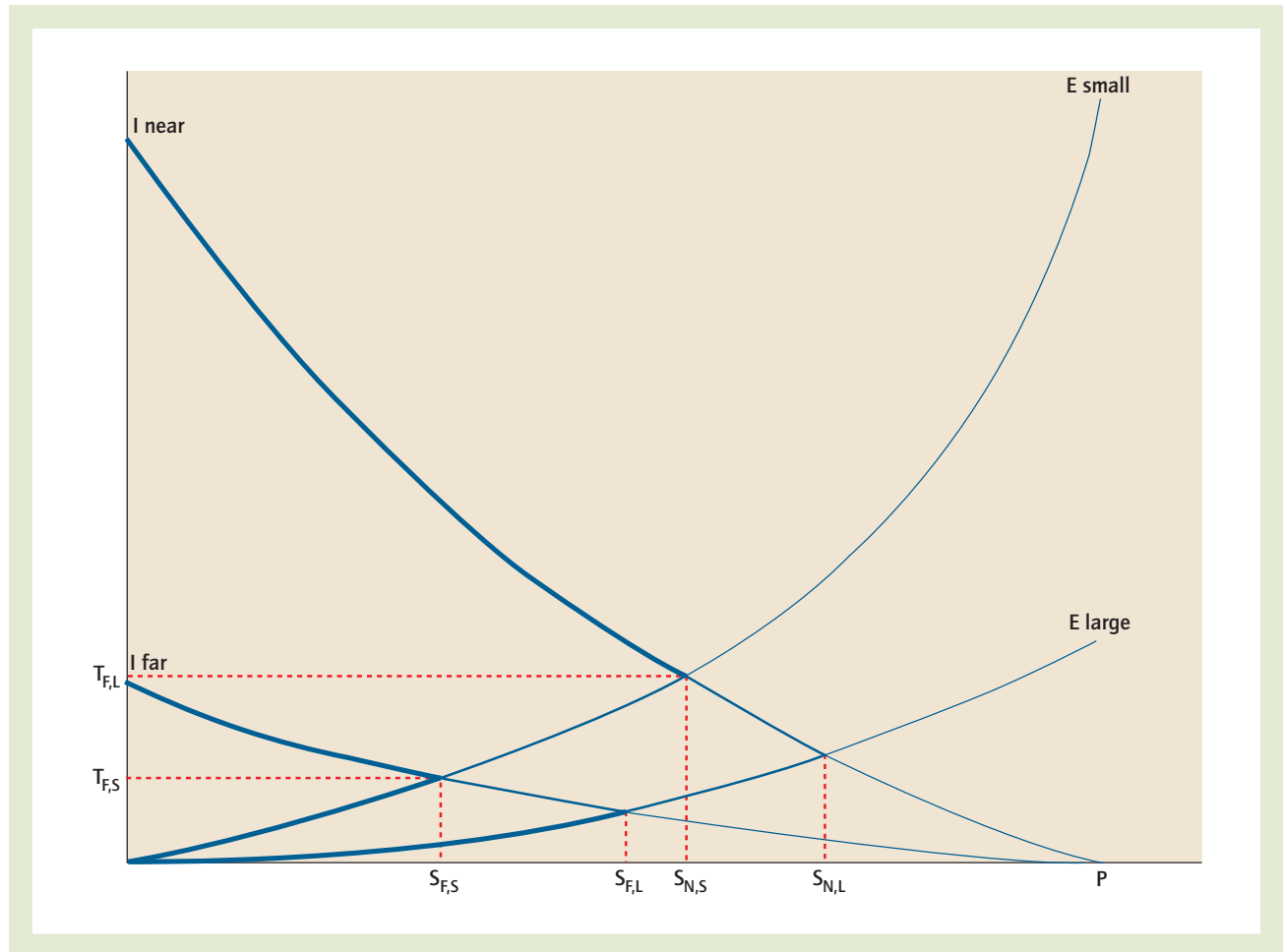


Figure 1 The equilibrium model of island biogeography

Source: Adapted from MacArthur, R., & Wilson, E. (1967). *The theory of island biogeography* (Figure 8, p. 22). Princeton, NJ: Princeton University Press.

Notes: An equilibrium number of species (S) is set by two opposing processes: immigration (I) and extinction (E). The rate of immigration decreases and the rate of extinction increases with increasing richness; the rate of immigration reaches zero when the entire pool (P) of potentially immigrating species have arrived. Immigration rates on islands far (I far) from the source pool are expected to be lower than those on near (I near) islands. Extinction rates are expected to be higher on small (E small) islands than on large (E large) islands. Hence, different equilibrium numbers of species are established based on the area and the isolation of the islands ($S_{F,S}$; $S_{F,L}$; $S_{N,S}$; $S_{N,L}$). Differences in rates of species turnover (T) are expected to vary with the combination of immigration and extinction rates that characterize any given island ($T_{F,L}$; $T_{F,S}$).

of the sea (Figure 2). This and other contributions can offer the foundation for an expanded theory of island biogeography, unifying ecological and evolutionary biogeography.

Island Theory and Conservation Biogeography

Within a few years of the publication of the ETIB, its application to the field of conservation biology

was being vigorously debated. This was based on the realization that reserves and national parks formed islands, that is, habitat islands, inside human-altered landscapes (habitat fragmentation), and that these reserves could lose species as they “relaxed toward equilibrium,” achieving a new lower equilibrium number.

Based mainly on island biogeography theory, a theoretical framework for fragmentation research has been established, seeking to derive

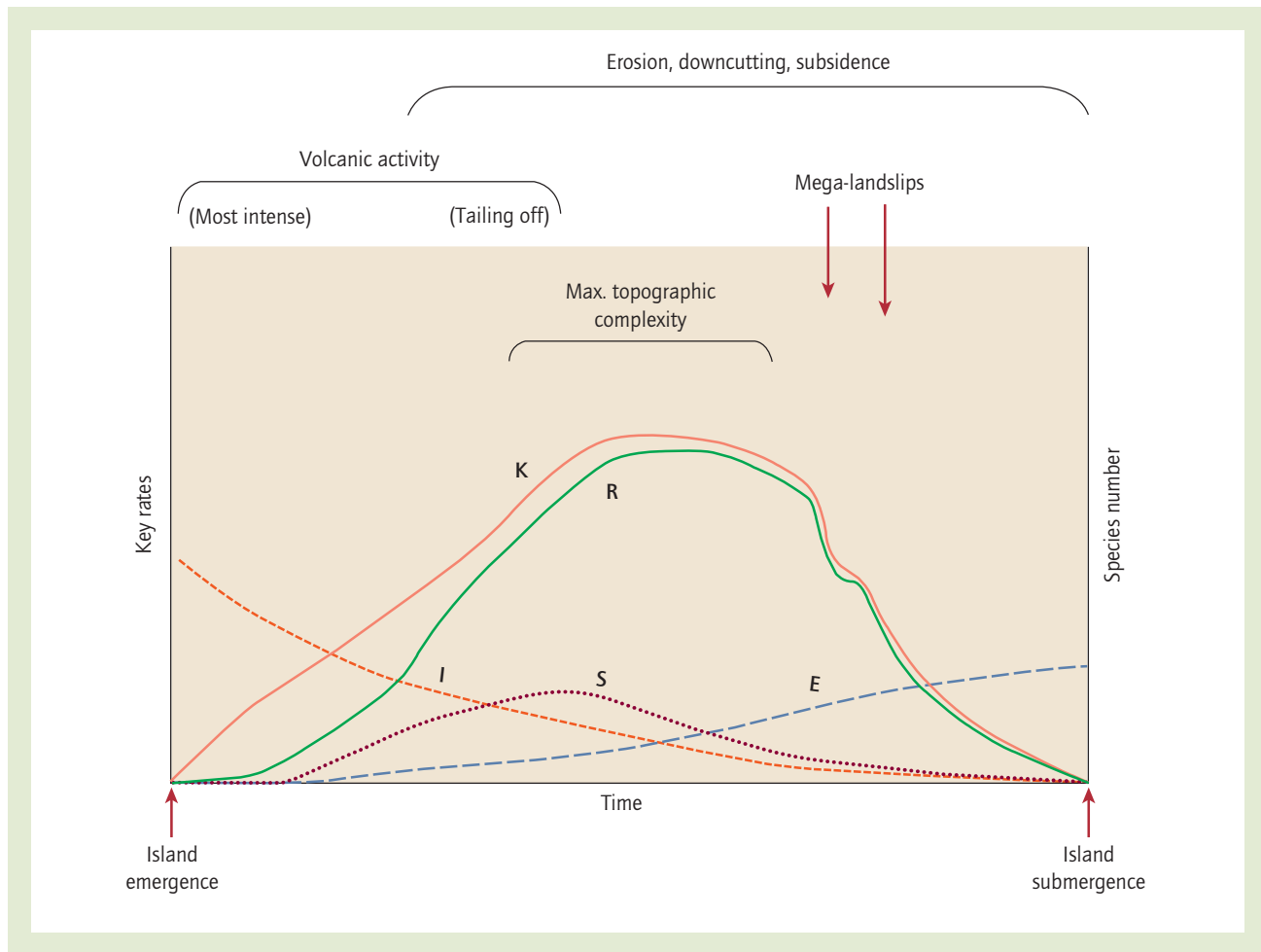


Figure 2 Graphical representation of the key rates and properties of the general dynamic model (GDM) of oceanic island biogeography

Source: Whittaker, R., Triantis, K., & Ladle, R. (2008). A general dynamic theory of oceanic island biogeography. *Journal of Biogeography*, 35, 977–994 (Figure 4, p. 981).

Note: The postulated relationships between the biological characteristics and the ontogeny of a single island, where for Key rates, I is the immigration rate, S is the speciation rate, and E is the extinction rate (each rate referring to the number of species per unit time) and for Species number, K is the potential carrying capacity and R is the realized species richness. For islands showing sudden extensive loss of territory due to landslips (as suggested by the kinks in the K and R curves), the extinction rate curve would require modification. Island building being typically much more rapid than decline, time should be considered as some form of log.

key reserve network design principles (Figure 3). One of the most prominent contributions was the so-called SLOSS debate, which posed the question “Given the opportunity to put a fixed percentage of land into conservation use, is it better to opt for a single large or several small reserves?” Unfortunately, the ETIB does not tell us with any precision how species should be distributed across a system of fragments, and this is crucial to the issue of whether it is better to

advocate one very large reserve or several smaller ones of the same total area.

In general, island theory provides a basic conceptual model for understanding habitat fragmentation. However, apart from a number of broad generalizations, the relevance of island theory for understanding fragmented ecosystems has proved to be limited, so far. Recently, a new subdiscipline has emerged, conservation biogeography, which is the “application of biogeographical principles,



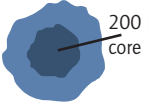
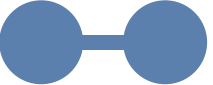
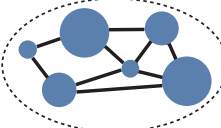
Worse		Better	
a)	Small reserve 	 Large reserve	
b)	Fragmented reserve 	 Unfragmental reserve	
c)	Higher edge effects  500 ha reserve	500 ha reserve  200 ha core Lower edge effects	
d)	Isolated reserves 	 Increased connectivity (corridors)	
e)	Isolated reserves 	 Increased connectivity (stepping stones)	
f)	Partial protection 	 Complete protection	
g)	Uniform habitat 	 Increased habitat diversity	
h)	Local perspective 	 Regional perspective	
i)	Humans excluded 	 Human integration (buffer zones)	

Figure 3 Design guidelines for reserves as suggested by the theory of island biogeography

Sources: Adapted from Shafer, C. (1997). Terrestrial nature reserve design at the urban/rural interface. In M. Schwartz (Ed.), *Conservation in highly fragmented landscapes* (pp. 345–378). New York: Chapman & Hall; adapted and redrawn from Huggett, R. (2004). *Fundamentals of biogeography* (2nd ed., Figure 18.3, p. 362, Routledge Fundamentals of Physical Geography Series). London: Routledge.



theories, and analyses, being those concerned with the distributional dynamics of taxa individually and collectively, to problems concerning the conservation of biodiversity.” Within the context of conservation biogeography, we can reevaluate the theoretical frameworks provided by island theory, their relevance to particular systems, and their wider and important role in helping us understand the sorts of effects that might be operative in real-world contexts.

Kostas A. Triantis and Robert J. Whittaker

See also Atoll; Barrier Islands; Biodiversity; Biogeography; Bioregionalism; Biosphere Reserves; Biota Migration and Dispersal; Coral Reef; Diamond, Jared; Extinctions; Human-Induced Invasion of Species; Islands, Small; Single Large or Several Small (SLOSS) Debate

Further Readings

- Laurance, W., & Bierregaard, R. (Eds.). (1997). *Tropical forest remnants: Ecology, management, and conservation of fragmented communities*. Chicago: University of Chicago Press.
- MacArthur, R., & Wilson, E. (1967). *The theory of island biogeography*. Princeton, NJ: Princeton University Press.
- Stuessy, T., & Ono, M. (Eds.). (1998). *Evolution and speciation of island plants*. Cambridge, UK: Cambridge University Press.
- Wagner, W., & Funk, V. (Eds.). (2005). *Hawaiian biogeography: Evolution on a hot spot archipelago*. Washington, DC: Smithsonian Institution Press.
- Whittaker, R., Araújo, M., Jepson, P., Ladle, R., Watson, J. & Willis, K. (2005). Conservation biogeography: Assessment and prospect. *Diversity and Distributions*, 11, 3–23.
- Whittaker, R., & Fernández-Palacios, J. (2007). *Island biogeography: Ecology, evolution, and conservation* (2nd ed.). Oxford, UK: Oxford University Press.
- Whittaker, R., Triantis, K., & Ladle, R. (2008). A general dynamic theory of oceanic island biogeography. *Journal of Biogeography*, 35, 977–994.



ISLANDS, SMALL

While one can envision at a global scale that all land is an island between the Earth's vast oceans and seas, relatively small islands dot much of the globe, many of which can easily be traversed by foot in only a few hours. An accurate count of small islands is difficult, as the number changes with tidal conditions and minimum-size requirements. Most are so tiny as to be uninhabited, and a high percentage of them have been termed internationally by organizations such as the United Nations as small-island developing states (SIDS) since 1994. However, there is no formally recognized definition of “small islands.” Approximately, 50 SIDS are located across the Pacific, Atlantic, and Indian Oceans. Small islands tend to be more environmentally fragile, insular, and remote than large islands (e.g., Madagascar, Borneo, New Guinea, or even Greenland) and thus deserve their own entry.

Small islands may be divided into high islands and low islands, and are important to geography for many reasons. For example, there are unique physical processes that form high and low islands: Biodiversity, and endemism in particular, is remarkably high on them. Small islands are likely to be early victims of climate change as reefs bleach, sea-level rises, and storms intensify, which, given their tiny carbon footprint, makes their condition an environmental justice issue. Of course, their relative remoteness results in great social and marine and terrestrial biophysical data gaps, and this too should interest geographers.

High Islands

One approach to classifying small islands is based on their formation. High islands such as the Hawaiian Islands, Bora Bora, and Pohnpei are created by volcanic action, often through tectonic plates moving over fixed hot spots of pressurized magma in the upper mantle. This often results in a dominant conical form with basaltic geology and high relief (see high island photo).

High-island topography causes orographic lifting of moisture-laden clouds fed by the surrounding ocean, producing remarkable amounts



The high island of Tonowas in Chuuk Lagoon, Chuuk State, Federated States of Micronesia

Source: Dr. William James Smith Jr.

of rainfall. Some of the wettest places on Earth are found on small high islands (e.g., approximately 1,200 millimeters per year on Kauai in Hawaii). This high-island relief, together with being spread about large spaces and in great isolation, also results in a tremendous degree of habitat diversity. In the tropical small islands, streams, terrestrial forests, mangrove forests, grasslands, and fringing coral reefs produce habitat for a large number of endangered or endemic species. Charles Darwin's theory of evolution and E. O. Wilson's theory of island biogeography are two scientific cornerstones relating to understanding island biodiversity.

Taking the Micronesia region of the Pacific Ocean as an example, which includes the Republic of the Marshall Islands, Territory of Guam, Commonwealth of the Northern Mariana Islands, Republic of Palau, and Federated States of Micronesia (FSM), all the nations have taken the "Micronesia Challenge" (MC), a commitment to biodiversity conservation, launched in Curitiba, Brazil, in 2006, during the eighth meeting of the Conference of the Parties to the Convention on Biological Diversity. The jurisdictions involved in the MC have committed at least 30% of their marine areas and 20% of their terrestrial areas to be under effective management by 2020. It is estimated that 30% of the world's

coral reefs are significantly damaged and the extent of the damage will double by the year 2030 if no conservation measures are undertaken. Notably, approximately half of the world's plant and animal species that have become extinct are island species. The jurisdictional area associated with the MC represents 10% of the Pacific Ocean, and when implemented, the MC will protect 10% of the world's reef area and 462 coral species, which represent 58% of all known corals. The then-FSM vice-president, Killion, described the initiative as a regional framework that is aimed at poising the Micronesian island governments toward achieving the targets and objectives set forth in the Convention on Biological Diversity and the Millennium Development Goals. Micronesia is a biodiversity "hot spot."

Low Islands and Atoll Structures

In contrast to high islands, low islands are created by deposition of coral rubble and sand on shallow reefs. These shallow reefs form when volcanic islands sink, either through subsidence of the tectonic plate as it moves toward subduction or through compaction as the underlying rocks cool and shrink. As the volcanic cores sink below

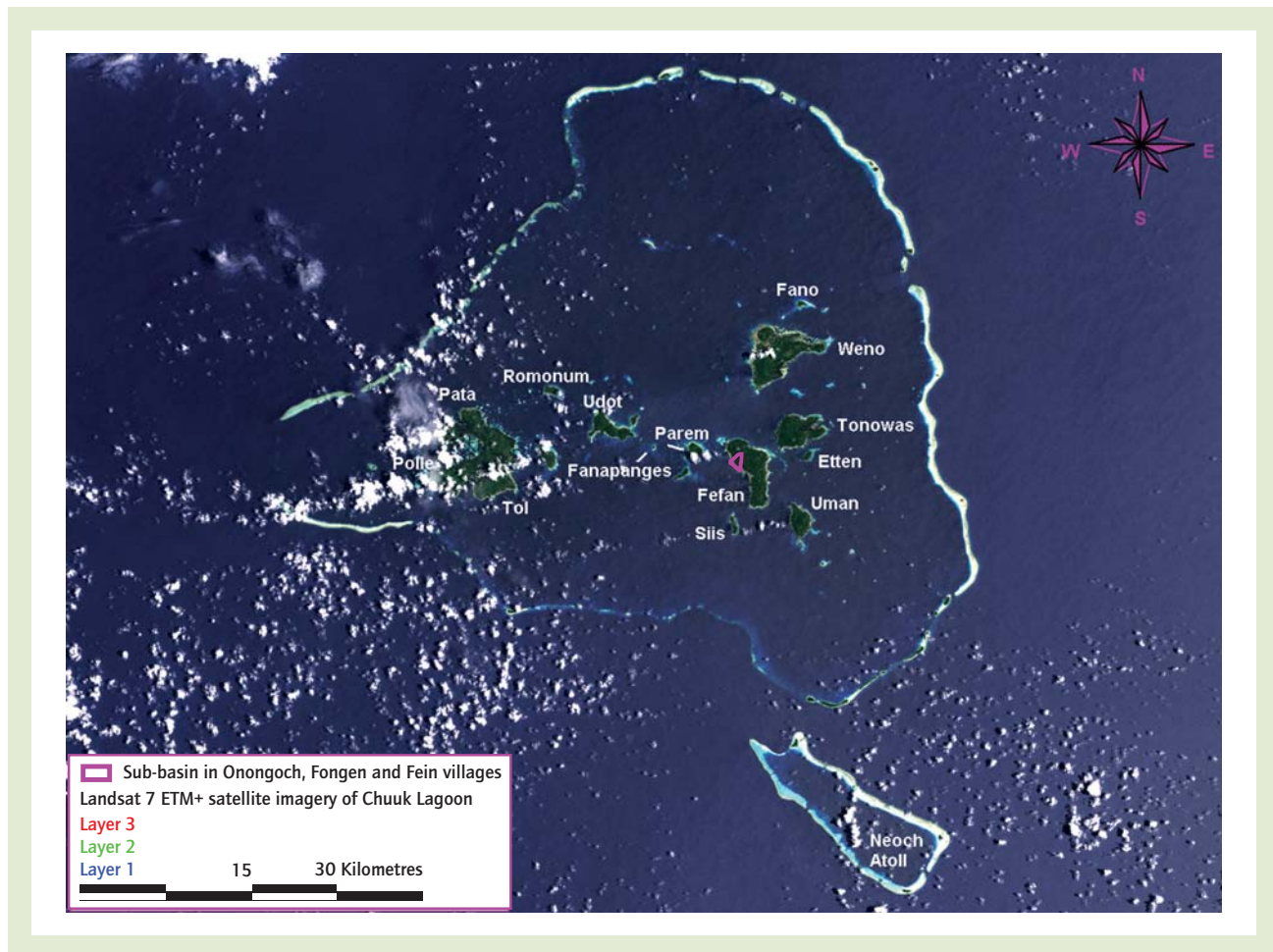


Figure 1 Chuuk Lagoon from satellite imagery, Chuuk State, Federated States of Micronesia

Source: Created by Dr. William James Smith Jr. from LSat.

Note: Coral appears in light blue.

the ocean surface, coral reefs grow upward, maintaining a relatively constant position relative to the surface. Eventually, the volcanic core is completely buried in coral growth, and an atoll, a roughly circular collection of islets around a shallow lagoon, forms. The size of each islet is typically less than 5 square kilometers, with maximum elevation less than 5 meters. Soils are nearly entirely composed of coral sand, with a very shallow freshwater lens. Figure 1 shows Chuuk Lagoon, the world's largest "almost atoll"—note the high islands in the middle and the remaining low islands. Note in the low islands photograph the development of major islands in corners and

the protection from wave action the reef provides for the interior of the lagoon, making fishing and other activities safer. Freshwater lenses tend to be thicker on the inside of the structure.

Saltwater intrusion poses challenges for both vegetation and human settlement on low islands. Low islands produce limited habitat and species diversity. There are few perennial (or even ephemeral) streams; vegetation is predominately herbaceous strand or strand forest; and though mangroves are possible, they are not nearly as developed as on high islands. Climatic diversity is assumed to be nonexistent on atolls because of the relative lack of topographic variation on low islands. Low islands



A string of low islands in the Marshall Islands

Source: Dr. William James Smith Jr.

also typically have smaller populations. Given the projections for climate change, low islands may serve as the “canary in the coalmine” for global climate change. Islands need not be covered permanently with water to be uninhabitable, as unsafe or saline conditions from washover and sea-level rise may make inhabiting such islands impossible. This will create a loss of cultural as well as biophysical diversity, which is unfortunate given that small-island populations are not industrialized and produce negligible greenhouse gases, while their vegetation and large national marine areas serve as significant global carbon sinks.

William James Smith Jr. and Reed Perkins

See also **Archipelago; Atoll; Barrier Islands; Biodiversity; Climate Change; Coral Reef; Coral Reef Geomorphology; Island Biogeography**

Further Readings

- Falkland, A. (1990). *Hydrology and water resources of small islands: A practical guide* (IHP-III, Project 4.6). Paris: United Nations Educational, Scientific and Cultural Organization, International Hydrological Programme.
- Smith, W., Jr. (2008). A geographic analysis of the impact of scale and isolation on coping with hazards on small islands. *IEEE Technology and Society*, 27, 39–47.
- Smith, W., Jr. (2008). The place of rural, remote and least wealthy small islands in international water development: The nexus of geography-technology-sustainability in Chuuk State, Federated States of Micronesia. *Geographical Journal*, 174, 251–268.



ISOPLETH MAPS

Isopleth maps are a type of thematic map used to display and model observations of phenomena with a continuous distribution by representing the values as a third-dimensional surface draped over the area. This common mapping technique is appropriate for diverse topics. Similar terms, mapping techniques, value interpretation, and specific isopleths, especially contours, are discussed.

Broadly called isoline maps, a distinction is sometimes made between isometric and isoplethic mapping, wherein isometric maps display real values such as rainfall amounts and isoplethic maps display calculated values such as population density. The terms *isarithm* and *isogram* are generally synonymous. *Iso* means “equal,” and *pleth* refers to “quantity.”

If something can be measured or generalized at any location, such as air temperature, then potentially, isopleth mapping can be used to show the spatial patterns. Observations cannot be made everywhere, so isopleth maps are constructed by interpolation from measurements at specified locations or associated calculations.

Isopleth maps use lines of equal value to portray patterns. These isopleths or isolines are plotted by assuming an even rate of change between the locations of known values. An isopleth interval identifies the difference in value between adjacent isopleths. The lines drawn are multiples of this isopleth interval. Smaller intervals mean more lines will be shown and more detail will be interpolated. This does not enhance accuracy. Isopleths enclose areas of either higher or lower values. They can neither cross nor split apart, because the line can have only one value. More closely spaced isopleths indicate more rapidly changing values.

Isopleth maps are read by identifying the value of the line through the point or the value of the adjacent higher and lower lines. For a point not on a line, a range is indicated. A value can be interpolated from the relative location between the lines, but the reader should remember the original generalization process used to produce the maps and not infer excessive detail.

The most difficult aspect of reading isopleths involves identifying the continuity between the

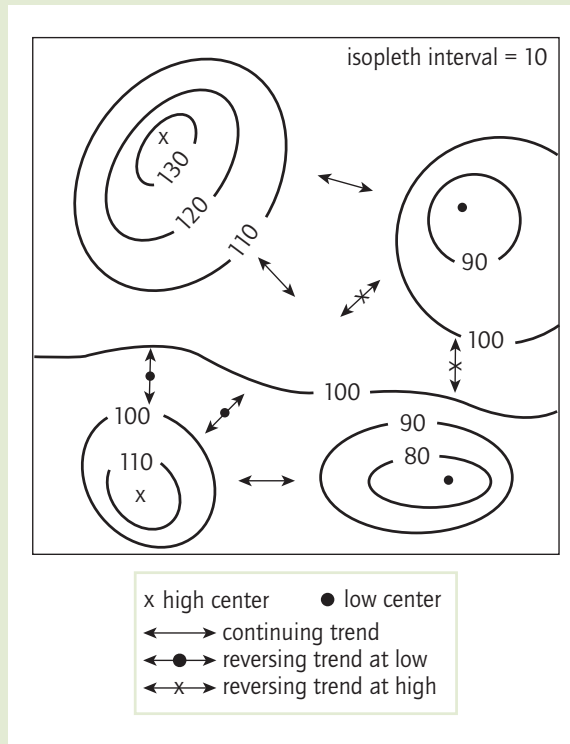


Figure 1 Continuity of values on isopleth maps

Source: Author.

high and low centers. A low center or a depression is an area completely surrounded by higher values. The primary skill involves maintaining the value trend. Any reverse in the trend is indicated by a repeated line value. If the value of the lines is increasing in the direction of a high center and a low center is encountered, the line value most recently passed will be repeated, indicating the change in the trend. However, if the trend is going down from a high center into a depression, the values do not repeat (Figure 1). Shaded isoline maps color the areas between the lines for clarification.

A contour map shows elevation of the land surface and is a specialized isopleth map. These differ by the inclusion of hachures, small tic marks pointing downslope, added to the lines in the low centers. The same interpretation skills are applied to read the values. The first hachured contour line has the same value as the lower adjacent unhachured line.



<i>Name for Isoline</i>	<i>Connects Equal</i>
Geoisotherm	Underground temperatures
Isallobars	Changes in air pressure through time
Isobar	Barometric or atmospheric pressures
Isobaths	Water depths
Isobathytherm	Water depths with equal temperatures
Isobrunr	Occurrences of thunderstorms
Isoceraunic	Numbers of thunderstorms
Isochalaz	Frequencies of hail storms
Isochasm	Aurora recurrences
Isochein	Mean winter temperatures
Isochrones	Elapsed times, such as for travel
Isocost	Production costs
Isodapane	Costs of travel
Isodemic	Population densities
Isodose	Intensities of radiation
Isodrosotherm	Dew point temperatures
Isogonal	Magnetic declinations
Isohaline	Ocean salinities
Isohel	Amounts of solar radiation
Isohume	Humidities
Isohyets	Precipitation
Isohypse	Elevations
Isoneph	Cloud cover
Isopach	Thicknesses of stratigraphic unit or group
Isophene	Times of flowering plants
Isophote	Brightness or illumination
Isoplankt	Plankton or plankton species
Isoquant	Production quantities
Isoseismal	Earthquake intensities
Isoshear	Vertical wind shear strength
Isotac	Dates of thawing each spring
Isotach	Wind speeds
Isothere	Mean summer temperatures
Isotherm	Temperatures
Isotim	Transportation costs from raw material source

Table 1 Names of selected isolines

Source: Author.

Specialized names are applied for different data. Lines that connect points of equal temperature are isotherms, and isobars are lines that show equal atmospheric or barometric pressure (Table 1). The diversity of line types demonstrates the versatility and usefulness of isopleth mapping.

Miriam Helen Hill

See also **Cartography; Choropleth Maps; Dasymeric Maps; Map Generalization; Map Visualization**

Further Readings

- Campbell, J. (2001). *Map use and analysis* (4th ed.). Boston: McGraw-Hill.
- Dent, B., Torguson, J., & Hodler, T. (2009). *Cartography: Thematic map design*. Boston: McGraw-Hill.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2009). *Thematic cartography and geo-visualization* (3rd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

ENCYCLOPEDIA OF
Geography

EDITORIAL BOARD

Editor

Barney Warf
University of Kansas

Associate Editors

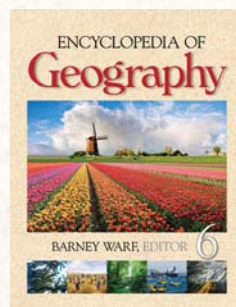
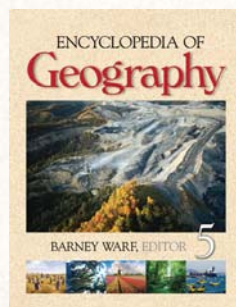
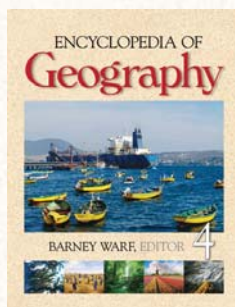
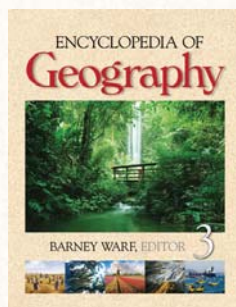
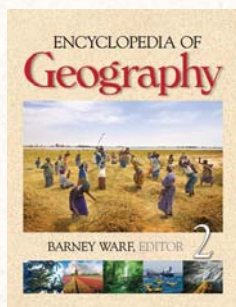
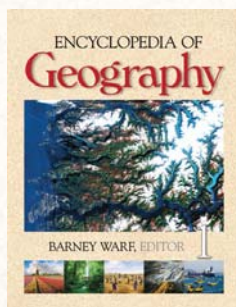
Piotr Jankowski
San Diego State University

Barry D. Solomon
Michigan Technological University

Mark Welford
Georgia Southern University

Managing Editor

Jonathan Leib
Old Dominion University



ENCYCLOPEDIA OF Geography

BARNEY WARF, EDITOR

University of Kansas

4



Los Angeles | London | New Delhi
Singapore | Washington DC

Copyright © 2010 by SAGE Publications, Inc.

All rights reserved. No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

For information:



SAGE Publications, Inc.
2455 Teller Road
Thousand Oaks, California 91320
E-mail: order@sagepub.com

SAGE Publications Ltd.
1 Oliver's Yard
55 City Road
London, EC1Y 1SP
United Kingdom

SAGE Publications India Pvt. Ltd.
B 1/I 1 Mohan Cooperative Industrial Area
Mathura Road, New Delhi 110 044
India

SAGE Publications Asia-Pacific Pte. Ltd.
33 Pekin Street #02-01
Far East Square
Singapore 048763

Printed in Singapore.

Library of Congress Cataloging-in-Publication Data

Encyclopedia of geography, volume I - VI / edited by Barney Warf.

6 v., p. cm.

Includes bibliographical references and index.

ISBN 978-1-4129-5697-0 (cloth)

1. Geography—Encyclopedias. I. Warf, Barney, 1956-

G63.E554 2010

910.3—dc22

2010009453

This book is printed on acid-free paper.

10 11 12 13 14 10 9 8 7 6 5 4 3 2 1

<i>Publisher:</i>	Rolf A. Janke
<i>Assistant to the Publisher:</i>	Michele Thompson
<i>Acquisitions Editor:</i>	Robert Rojek
<i>Developmental Editor:</i>	Diana E. Axelsen
<i>Reference Systems Manager:</i>	Leticia Gutierrez
<i>Reference Systems Coordinator:</i>	Laura Notton
<i>Production Editor:</i>	Tracy Buyan
<i>Copy Editors:</i>	QuADS Prepress (P) Ltd.
<i>Typesetter:</i>	C&M Digitals (P) Ltd.
<i>Proofreaders:</i>	Penelope Sippel, Rae-Ann Goodwin, Annette Van Deusen
<i>Indexer:</i>	Julie Sherman Grayson
<i>Cover Designer:</i>	Ravi Balasuriya
<i>Marketing Manager:</i>	Amberlyn McKay

Volume 4 cover photo: Fishing boats and cargo ship in Guayacan Harbor, Chile. © iStockphoto.com/TimAbbot.

CONTENTS

4

List of Entries

vii

Entries

J 1641

K 1647

L 1675

M 1811

N 1971

O 2057

P 2111

LIST OF ENTRIES

- | | | |
|---|---|--|
| <p> Abler, Ronald
 Absolute Space
 Accessibility
 Acid Rain
 Actor-Network Theory
 Adaptation to Climate Change
 Adaptive Harvest Management
 Adaptive Radiation
 Adiabatic Temperature
 Changes
 Aerial Imagery: Data
 Aerial Imagery: Interpretation
 African Union
 Agamben, Giorgio
 Agent-Based Models
 Agglomeration Economies
 Aging and the Aged,
 Geography of. <i>See</i> Elderly,
 Geography and the
 Agnew, John
 Agricultural Biotechnology
 Agricultural Intensification
 Agricultural Land Use
 Agriculture, Industrialized
 Agriculture, Preindustrial
 Agrobiodiversity
 Agrochemical Pollution
 Agroecology
 Agrofoods
 Agroforestry
 AIDS, Geography of. <i>See</i>
 Disease, Geography of;
 HIV/AIDS, Geography of
 Air Masses </p> | <p> Air Pollution. <i>See</i> Atmospheric
 Pollution
 Albedo
 al-Idrisi
 Altitude
 Ambient Air Quality
 American Geographical Society
 Analytical Operations in GIS
 Anarchism and Geography
 Anaximander
 Animal Geographies
 Annales School
 Anselin, Luc
 Antevs, Ernst
 Anthropogenic Atmospheric
 Change. <i>See</i> Anthropogenic
 Climate Change;
 Stratospheric Ozone
 Depletion
 Anthropogenic Climate Change
 Anthropogeography
 Antiglobalization
 Antipodes
 Antisystemic Movements
 Applied Geography
 Appropriate Technology. <i>See</i>
 Sustainable Development;
 Sustainable Development
 Alternatives; Sustainable
 Production
 Aquaculture
 Archipelago
 Architecture and Geography
 Argumentation Maps </p> | <p> Arid Topography
 Aristotle
 Armstrong, Marc
 Art and Geography
 Asia-Pacific Economic
 Cooperation
 Association of American
 Geographers
 Association of Geographic
 Information Laboratories
 for Europe
 Association of Southeast Asian
 Nations
 Atmospheric Circulation
 Atmospheric Composition and
 Structure
 Atmospheric Energy Transfer
 Atmospheric Moisture
 Atmospheric Particulates
 Across Scales
 Atmospheric Pollution
 Atmospheric Pressure
 Atmospheric Remote Sensing
 Atmospheric Variations
 in Energy
 Atoll
 Automobile Industry
 Automobility
 Avalanches
 Aviation and Geography

 Barrier Islands
 Barrows, Harlan
 Basin and Range Topography </p> |
|---|---|--|

- | | | |
|---|--|---|
| Batty, Michael | Business Models for Geographic Information Systems | Class, Geography and Class, Nature and Client-Server Architecture |
| Bayesian Statistics in Spatial Analysis | Buttimer, Anne | Climate: Dry |
| Behavioral Geography | | Climate: Midlatitude, Mild |
| Berkeley School | | Climate: Midlatitude, Severe |
| Berry, Brian | Cadastral Systems | Climate: Mountain |
| Bhopal, India, Chemical Disaster | CAD Systems | Climate: Polar |
| Biblical Mapping | Câmara, Gilberto | Climate: Tropical Humid |
| Biodiversity | Canadian Association of Geographers | Climate Change |
| Biofuels | Cancer, Geography of | Climate Policy |
| Biogeochemical Cycles | Carbonation | Climate Types |
| Biogeography | Carbon Cycle | Climatic Relict |
| Biome: Boreal Forest | Carbon Trading and Carbon Offsets | Climatology |
| Biome: Desert | Carcinogens | Clouds |
| Biome: Midlatitude Deciduous Forest | Carrying Capacity | Clusters |
| Biome: Midlatitude Grassland | Cartograms | Coal |
| Biome: Tropical Deciduous Forest | Cartography | Coastal Dead Zones |
| Biome: Tropical Rain Forest | Cartography, History of | Coastal Erosion and Deposition |
| Biome: Tropical Savanna | Castells, Manuel | Coastal Hazards |
| Biome: Tropical Scrub | Caverns | Coastal Zone and Marine Pollution |
| Biome: Tundra | Cellular Automata | Cold War, Geography of |
| Biophysical Remote Sensing | Census | Collaborative GIS |
| Bioregionalism | Census Tracts | Colonialism |
| Biosphere Reserves | Centers of Domestication | Color in Map Design |
| Biota and Climate | Central Business District | Columbus, Christopher |
| Biota and Soils | Central Place Theory | Commodity Chains |
| Biota and Topography | Chemical Spills, Environment, and Society | Common Pool Resources |
| Biota Migration and Dispersal | Chernobyl Nuclear Accident | Common Property Resource Management |
| Biotechnology and Ecological Risk | Chicago School | Commons, Tragedy of the Commonwealth of Independent States |
| Biotechnology Industry | Childhood Spatial and Environmental Learning | Communications Geography |
| Biruni | Children, Geography of | Communism and Geography |
| Blaikie, Piers | Chinooks/Foehns | Community-Based Conservation |
| Blaut, James | Chipko Movement | Community-Based Environmental Planning |
| Blindness and Geography | Chlorinated Hydrocarbons | Community-Based Natural Resource Management |
| Body, Geography of | Chlorofluorocarbons | Community Forestry |
| Borderlands | Cholera, Geography of | Commuting |
| Borders and Boundaries | Chorley, Richard | Comparative Advantage |
| Bourghassi, Carmina | Chorology | Competitive Advantage |
| Bowman, Isaiah | Choropleth Maps | Complexity Theory |
| Brownfields | Chrisman, Nicholas | Complex Systems Models |
| Built Environment | Christaller, Walter | Conference of Latin Americanist Geographers |
| Bunge, William | Circuits of Capital | |
| Bush Fallow Farming | Citizenship | |
| Business Cycles and Geography | Civil Society | |
| Business Geography | Clark, Andrew | |
| | Clark, William | |

- Conflation
 Conservation
 Conservation Zoning
 Consumption, Geographies of
 Continental Drift. *See* Plate Tectonics
 Cook, Captain James
 Coordinate Geometry
 Coordinate Systems
 Coordinate Transformations
 Coral Reef
 Coral Reef Geomorphology
 Coriolis Force
 Corporate Voluntary Environmental Initiatives and Self-Regulation
 Cosgrove, Denis
 Cosmopolitanism
 Cost-Benefit Analysis
 Council for Mutual Economic Assistance (COMECON)
 Countermapping
 Counterurbanization
 Coupled Human and Animal Systems
 Coupled Human and Natural Systems
 Creep
 Crime, Geography of
 Crisis
 Critical Geopolitics
 Critical GIS
 Critical Human Geography
 Critical Studies of Nature
 Crop Genetic Diversity
 Crop Rotation
 Cross-Border Cooperation
 Cultural Ecology
 Cultural Geography
 Cultural Landscape
 Cultural Turn
 Cyberspace
 Cyborg Ecologies
 Cyclones: Extratropical
 Cyclones: Occluded

 Dangermond, Jack
 Darby, Henry Clifford
 Darwinism and Geography
 Dasymetric Maps

 Database Management Systems
 Database Versioning
 Data Classification Schemes
 Data Compression Methods
 Data Editing
 Data Format Conversion
 Data Indexing
 Data Querying in GIS
 Datums
 Davis, William Morris
 Dear, Michael
 Debt and Debt Crisis
 Decolonization
 Deep Ecology Movements
 Deforestation
 Deindustrialization
 Delta
 Democracy
 Demographic Transition
 Dendrochronology
 Dependency Theory
 Derechos
 Desertification
 Desert Varnish
 Deterritorialization and Reterritorialization
 Developing World
 Development Theory
 Diamond, Jared
 Diaspora
 Diastrophism
 Difference, Geographies of
 Differential Heating
 Differential Vulnerabilities to Hazards
 Diffusion
 Digital Divide
 Digital Terrain Model
 Digitizing
 Disability, Geography of
 Disaster Prediction and Warning
 Disaster Preparedness
 Discourse and Geography
 Disease, Geography of
 Distance Decay
 Distributed Computing
 Distribution of Resource Access
 Division of Labor

 Domestication Centers. *See* Centers of Domestication
 Domestication of Animals
 Domestication of Plants
 Domino Theory
 Dot Density Maps
 Drought Risk and Hazard
 Drugs, Geography of
 Dunes
 Dynamic and Interactive Displays

 Earle, Carville
 Earthquakes
 Earth's Coordinate Grid
 Eastman, Ronald
 Ecofeminism
 Ecological Economics
 Ecological Fallacy
 Ecological Footprint
 Ecological Imaginaries
 Ecological Justice
 Ecological Mapping
 Ecological Modernization
 Ecological Regimes
 Ecological Risk Analysis
 Ecological Services. *See* Environmental Services
 Ecological Zones
 E-Commerce and Geography
 Economic Base Analysis
 Economic Geography
 Economies of Scale
 Economies of Scope
 Ecoregions
 Ecoshed
 Ecosystem Decay
 Ecosystems
 Ecotone
 Ecotourism
 Education, Geographies of
 Egenhofer, Max
 Elderly, Geography and the
 Electoral Geography
 Electronic Atlases
 Electronics Industry, Geography of
 El Niño
 Emerging Markets

- | | | |
|------------------------------------|-------------------------------------|---------------------------------|
| Emotions, Geography and Empiricism | Environmental Protection | Feminist Environmentalism |
| Endogenous Growth Theory. | Environmental Racism | Feminist Geographies |
| <i>See</i> Knowledge Spillovers; | Environmental Refugees | Feminist Methodologies |
| Learning Regions | Environmental Restoration | Feminist Political Ecology |
| Energy and Human Ecology | Environmental Rights | Fertility Rate |
| Energy Models | Environmental Security | Fieldwork in Human |
| Energy Policy | Environmental Services | Geography |
| Energy Resources | Environmental Social | Fieldwork in Physical |
| Enlightenment | Movements. <i>See</i> International | Geography |
| Enterprise GIS | Environmental Movements | Film and Geography |
| Environmental Certification | Environment and Development | Filtering |
| Environmental Determinism | Epistemology | Filtration |
| Environmental Discourse | Equator | Finance, Geography of |
| Environmental Entitlements | Equinox | Fisher, Peter |
| Environmental Ethics | Eratosthenes | Fish Farming |
| Environmental Footprint. | Error Propagation | Fjords |
| <i>See</i> Ecological Footprint | Ethics, Geography and | Flash Floods |
| Environmental History | Ethnicity | Flexible Production |
| Environmental Imaginaries | Ethnicity and Nature | Flocculation |
| Environmental Impact | Ethnic Segregation | Floodplain |
| Assessment | Ethnocentrism | Floods |
| Environmental Impacts of | Eurocentrism | Flow |
| Agriculture | Euromarket | Flow Maps |
| Environmental Impacts of | European Green Movements | Folding |
| Cities | European Union | Folk Culture and |
| Environmental Impacts of | Everglades Restoration | Geography |
| Manufacturing | Everyday Life, Geography and | Food, Geography of |
| Environmental Impacts of | Existentialism and Geography | Food and Agriculture |
| Mining. <i>See</i> Open-Pit | Exotic Species | Organization (FAO) |
| Mining | Exploration | Footprint Analysis. |
| Environmental Impacts of | Exploratory Spatial Data | <i>See</i> Ecological Footprint |
| Oil Fields | Analysis | Fordism |
| Environmental Impacts of | Export-Led Development | Fordism |
| Pipelines | Export Processing Zones | Foreign Aid |
| Environmental Impacts of | Externalities | Foreign Direct Investment |
| Roads | Extinctions | Forest Degradation |
| Environmental Impacts of | Extractive Reserves | Forest Fragmentation |
| Tourism | Extreme Geography | Forest Land Use |
| Environmental Impacts of War | Exurbs | Forest Restoration |
| Environmental Impact | Factors Affecting Location | Fotheringham, A. Stewart |
| Statement | of Firms | Frank, Andrew |
| Environmental Justice | Fair Trade and Environmental | Frontiers |
| Environmental Law | Certification | Fronts |
| Environmental Management | Famine, Geography of | Gaia Theory |
| Environmental Management: | Faulting | Gama, Vasco da |
| Drylands | Fear, Geographies of | Game Ranching |
| Environmental Mapping | Febvre, Lucien | Gated Community |
| Environmental Perception | Feminist Environmental | Gays and Lesbians, |
| Environmental Planning | Geographies | Geography and/of |
| | | Gazetteers |

- Gender and Environmental Hazards
 Gender and Geography
 Gender and Nature
 General Circulation Model (GCM). *See* Anthropogenic Climate Change; Atmospheric Energy Transfer; Climate Change
 Genetically Modified Organisms (GMOs)
 Genocide, Geographies of
 Gentrification
 Geocoding
 Geocollaboration
 Geocomputation
 Geodemographics
 Geodesy
 Geographical Ignorance
 Geographical Imagination
 Geographically Weighted Regression
 Geographic Information Systems
 Geography Education
 Geolibraries
 Geologic Timescale
 Geomancy
 Geometric Correction
 Geometric Measures
 Geomorphic Cycle
 Geomorphology
 Geophagy
 Geopolitics
 Geosensor Networks
 Geoslavery
 Geospatial Industry
 Geospatial Semantic Web
 Geostatistics
 Geothermal Energy
 Geothermal Features
 Geovisualization. *See* Cartography; Dynamic and Interactive Displays; Three-Dimensional Models
 Getis, Arthur
 Ghetto
 Giddens, Anthony
 Gilbert, Grove Karl
 GIS, Environmental Model Integration and
 GIS, History of
 GIScience
 GIS Design
 GIS Implementation
 GIS in Archaeology
 GIS in Disaster Response
 GIS in Environmental Management
 GIS in Health Research and Health Care
 GIS in Land Use Management
 GIS in Local Government
 GIS in Public Policy
 GIS in Transportation
 GIS in Urban Planning
 GIS in Utilities
 GIS in Water Management
 GIS Software
 GIS Web Services
 Glaciers: Continental
 Glaciers: Mountain
 Global Climate Change. *See* Anthropogenic Climate Change
 Global Environmental Change
 Globalization
 Global Positioning System
 Global Sea-Level Rise
 Global Warming. *See* Anthropogenic Climate Change
 Globes. *See* Cartography; Map Projections
 Glocalization
 Golledge, Reginald
 Goodchild, Michael
 Goode, J. Paul
 Google Earth
 Gottmann, Jean
 Gould, Peter
 Governance
 Governmentality and Conservation
 Gravity Model
 Great American Exchange
 Greenbelts
 Green Building
 Green Design and Development
 Greenhouse Gases
 Green Revolution. *See* Environmental Impacts of Agriculture
 Gregory, Derek
 Gross Domestic Product/Gross National Product
 Ground Reference Data
 Groundwater
 Growth Machine
 Growth Poles
 Gully Erosion
 Guyot, Arnold
 Hadley Cell
 Hägerstrand, Torsten
 Haggett, Peter
 Hanson, Susan
 Harley, Brian
 Hartshorne, Richard
 Harvey, David
 Hate, Geographies of
 Haushofer, Karl
 Hayden, Ferdinand
 Health and Health Care, Geography of
 Heavy Metals as Pollutants
 Hegemony
 Herbicides
 Herodotus
 Hettner, Alfred
 Heuristic Methods in Spatial Analysis
 High-Performance Computing
 High Technology
 Hipparchus
 Historical Geography
 Historicism
 Historic Preservation
 History of Geography. *See* Cartography, History of; GIS, History of; Human Geography, History of; Physical Geography, History of
 HIV/AIDS, Geography of
 Home
 Homelessness
 Hou Renzhi

- Housing and Housing Markets
 Housing Policy
 Hoyt, Homer
 Human Dimensions of Global
 Environmental Change
 Human Ecology
 Human Geography, History of
 Human-Induced Invasion of
 Species
 Humanistic Geography
 Humanistic GIScience
 Human Rights, Geography and
 Humboldt, Alexander von
 Humidity
 Hunger
 Hunting and Gathering
 Huntington, Ellsworth
 Hurricane Katrina
 Hurricanes, Physical
 Geography of
 Hurricanes, Risk and Hazard
 Hybrid Geographies
 Hybridization of Plant and
 Animal Species
 Hydroelectric Power
 Hydrological Connectivity
 Hydrology
 Hydrothermal Energy. *See*
 Geothermal Energy
- Ibn Battuta
 Ibn Khaldūn
 Ice
 Identity, Geography and
 Idiographic
 Image Enhancement
 Image Fusion
 Image Interpretation
 Image Processing
 Image Registration
 Image Texture
 Imaging Spectroscopy
 Immigration
 Imperialism
 Impermeable Surfaces
 Import Substitution
 Industrialization
 Incubator Zones
 Indigeneity
 Indigenous Agriculture
- Indigenous and Community
 Conserved Areas
 Indigenous Cartographies
 Indigenous Environmental
 Knowledge
 Indigenous Environmental
 Practices
 Indigenous Forestry
 Indigenous Reserves
 Indigenous Water Management
 Industrial Districts
 Industrial Ecology
 Industrialization
 Industrial Revolution
 Inequality and Geography
 Informal Economy
 Information Society
 Infrastructure
 Innovation, Geography of
 Input-Output Models
 Institute of British Geographers
 Interactive Mapping. *See* Map
 Animation
 Intergovernmental
 Environmental
 Organizations and Initiatives
 International Criminal Court
 International Environmental
 Movements
 International Environmental
 NGOs
 International Geographical
 Union
 International Monetary Fund
 International Watershed
 Management
 Internet. *See* Communications,
 Geography of; Cyberspace;
 Digital Divide;
 Telecommunications and
 Geography
 Internet GIS
 Interoperability and Spatial
 Data Standards
 Interviewing
 Invasion and Succession
 Isard, Walter
 Island Biogeography
 Islands, Small
 Isopleth Maps
- Jackson, John Brinckerhoff
 Jefferson, Thomas
 Johnston, R. J.
 Journey-to-Work. *See*
 Commuting
 Justice, Geography of
- Kant, Immanuel
 Karst Topography
 Kates, Robert
 Keystone Species
 Knowledge, Geography of
 Knowledge Spillovers
 Köppen, Wladimir
 Köppen-Geiger Climate
 Classification
 Kropotkin, Peter
 Krummholtz
 Kuhn, Werner
 Kwan, Mei-Po
 Kyoto Protocol. *See* Climate
 Policy
- Labor, Geography of
 Lahar. *See* Volcanoes
 Land Degradation
 Landfills
 Landforms
 Land Reform
 Landscape and Wildlife
 Conservation
 Landscape Architecture
 Landscape Biodiversity
 Landscape Design
 Landscape Ecology
 Landscape Interpretation
 Landscape Quality
 Assessment
 Landscape Restoration
 Landslide
 Land Tenure
 Land Tenure Reform
 Land Use
 Land Use Analysis
 Land Use and Cover Change
 (LUCC)
 Land Use and Land Cover
 Mapping
 Land Use History
 Land Use Planning

-
- Land-Water Breeze
 Languages, Geography of
 La Niña
 Lapse Rate
 Latent Heat
 Latitude
 Law, Geography of
 Learning Regions
 Lefebvre, Henri
 Legal Aspects of Geospatial Information
 Lewis, Peirce
 Lewis and Clark Expedition
 Ley, David
 LiDAR and Airborne Laser Scanning
 Lightning
 Lillesand, Thomas
 Linear Referencing and Dynamic Segmentation
 Literature, Geography and
 Livingstone, David
 Locality
 Locally Unwanted Land Uses (LULUs)
 Location-Allocation Modeling
 Location-Based Services
 Location Quotients
 Location Theory
 Logical Positivism
 Longitude
 Los Angeles School
 Lösch, August
 Love Canal
 Lynch, William
- MacEachren, Alan
 Mackinder, Sir Halford
 Magellan, Ferdinand
 Mahan, Alfred Thayer
 Malaria, Geography of
 Malthusianism
 Manufacturing Belt
 Map Algebra
 Map Animation
 Map Design
 Map Evaluation and Testing
 Map Generalization
 Map Projections
 Map Visualization
- Marcus, Melvin G.
 Marginal Regions
 Marine Aquaculture
 Maritime Spaces. *See* Oceans
 Mark, David M.
 Market-Based Environmental Regulation
 Marsh, George Perkins
 Marxism, Geography and
 Masculinities and Geography
 Massey, Doreen
 Mass Wasting
 Mather, John Russell
 Maury, Matthew Fontaine
 McKnight, Tom L.
 Media and Geography
 Medical Geography
 Meinig, Donald
 Mental Maps
 Mercator, Gerardus
 Metadata
 Metropolitan Area
 Microwave/RADAR Data
 Migration
 Military Geography
 Military Spending
 Miller, Harvey J.
 Minerals
 Mining and Geography
 Mitchell, Don
 Mixed Farming
 Mobile GIS
 Mobility
 Models and Modeling
 Modernity
 Modernization Theory
 Modifiable Areal Unit Problem
 Money, Geographies of
 Monmonier, Mark
 Monsoons
 Morrill, Richard
 Morse, Jedediah
 Mortality Rate
 Most Favored Nation Status
 Movimento Sem Terra
 Multimedia Mapping
 Multispectral Imagery
 Multistakeholder Participation
 Multitemporal Imaging
 Multivariate Analysis Methods
- Multivariate Mapping
 Music and Sound, Geography and
 Nation
 National Aeronautics and Space Administration (NASA)
 National Center for Geographic Information and Analysis
 National Council for Geographic Education
 National Geographic Society
 Nationalism
 Natural Growth Rate
 Natural Hazards and Risk Analysis
 Nature
 Nature-Society Theory
 Neighborhood
 Neocolonialism
 Neogeography
 Neoliberal Environmental Policy
 Neoliberalism
 Neo-Malthusianism
 Network Analysis
 Network Data Model
 New International Division of Labor
 Newly Industrializing Countries
 New Urbanism
 Nitrogen Cycle
 Nomadic Herding
 Nomadism
 Nomothetic
 Nongovernmental Organizations (NGOs)
 Nonpoint Sources of Pollution
 Nonrenewable Resources
 Nonrepresentational Theory
 Nonvisual Geographies
 North American Free Trade Agreement (NAFTA)
 North Atlantic Treaty Organization (NATO)
 Not in My Backyard (NIMBY)
 Nuclear Energy

- | | | |
|---|--|--|
| Nutrient Cycles | Patches and Corridors in Wildlife Conservation | Positionality |
| Nyerges, Timothy | Path Dependence | Positivism. <i>See</i> Logical Positivism |
| Object-Based Image Analysis | Patriarchy, Geography and Peasants and Peasantry | Postcolonialism |
| Oceanic Circulation | Peat | Post-Fordism. <i>See</i> Flexible Production |
| Oceans | Pedology. <i>See</i> Soils | Postindustrial Society |
| Offshore Finance | Peet, Richard | Postmodernism |
| Oil Spills | Penck, Walther | Poststructuralism |
| Okabe, Atsuyuki | Periglacial Environments | Poverty |
| Olsson, Gunnar | Permaculture | Powell, John Wesley |
| Ontological Foundations of Geographical Data | Permafrost | Prairie Restoration |
| Ontology | Pesticides | Prairies |
| Open Geodata Standards | Pest Management | Precipitation, Global |
| Open Geospatial Consortium (OGC) | Petroleum | Precipitation Formation |
| Open-Pit Mining | Peuquet, Donna | Pred, Allan |
| Open Source Geospatial Foundation | Phenomenology | Primate Cities |
| Open Source GIS | Phosphorus Cycle | Prime Meridian. <i>See</i> Longitude |
| Open Space | Photochemical Smog | Privacy and Security of Geospatial Information |
| Organic Agriculture | Photogrammetric Methods | Producer Services |
| Organisation for Economic Co-operation and Development (OECD) | Photography, Geography and Physical Geography, History of | Product Cycle |
| Organization of the Petroleum Exporting Countries (OPEC) | Pickles, John | Production of Space |
| Organophosphates | Pilgrimage | Psychoanalysis, Geography and |
| Orientalism | Place | Ptolemy |
| Ortelius | Place Names | Public Housing |
| Other/Otherness | Place Promotion | Public Participation GIS |
| Outsourcing | Plantations | Public Policy, Geography of |
| Overpopulation. <i>See</i> Malthusianism; Neo-Malthusianism | Plate Tectonics | Public-Private Partnerships |
| | Playas | Public Space |
| | Point Pattern Analysis | Public Water Services |
| | Point Sources of Pollution | Pyrogeography |
| | Poles, North and South | |
| | Political Ecology | Qualitative Methods |
| | Political Economy | Quantitative Methods |
| | Political Economy of Resources | Quantitative Revolution |
| | Political Geography | Queer Theory |
| | Polychlorinated Biphenyls (PCBs) | |
| | Popular Culture, Geography and Population and Land Degradation | Race and Empire |
| | Population and Land Use | Race and Nature |
| | Population Density | Race and Racism |
| | Population, Environment, and Development | Racial Segregation |
| | Population Geography | Radiation: Solar and Terrestrial |
| | Population Pyramid | Radical Geography |
| | Portolan Charts | Radiometric Correction |
| | Ports and Maritime Trade | Radiometric Normalization |
| | | Radiometric Resolution |
| | | Railroads and Geography |
| | | Raisz, Erwin |

- Rank-Size Rule
 Ratzel, Friedrich
 Real Estate, Geography and
 Realism
 Reclus, Élisée
 Recycling of Municipal Solid
 Waste
 Redistricting
 Refugees
 Regional Economic
 Development
 Regional Environmental
 Planning
 Regional Geography
 Regional Governance
 Regional Science
 Regional Science Association
 International (RSAI)
 Regions and Regionalism
 Regulation Theory
 Relational Space. *See* Relative/
 Relational Space
 Relative/Relational Space
 Religion, Geography and
 Relph, Edward
 Remittances
 Remote Sensing
 Remote Sensing: Platforms and
 Sensors
 Remote Sensing in Disaster
 Response
 Renewable Resources
 Rent-Gap
 Representations of Space
 Research and Development,
 Geographies of
 Resilience
 Resistance, Geographies of
 Resource Economics
 Resource Geography
 Resource Management. *See*
 Environmental Management
 Resource Management,
 Decision Models in
 Resource Mapping
 Resource Tenure
 Restoration Ecology. *See*
 Environmental Restoration
 Restructuring
 Retail Trade, Geography of
 Rill Erosion
 Risk Analysis and Assessment
 Ritter, Carl
 Rivers
 Rock Weathering
 Rose, Gillian
 Royal Geographical Society
 Rural Development
 Rural Geography
 Rural-Urban Migration
 Russian Geographical Society
 Satellites and Geography
 Sauer, Carl
 Scale, Social Production of
 Scale in GIS
 Schaefer, Fred
 Science, Technology, and
 Environment
 Science and Technology Studies
 Scott, Allen
 Sedimentary Rock
 Sedimentation
 Segregation and Geography
 Self-Organizing Maps
 Semantic Interoperability
 Semantic Reference Systems
 Semple, Ellen Churchill
 Sense of Place
 Sequent Occupance
 Services. *See* Producer Services
 Settlement Geography
 Sexuality, Geography and/of
 Shifting Cultivation
 Shortest-Path Problem
 Single Large or Several Small
 (SLOSS) Debate
 Situated Knowledge
 Smart Growth
 Smith, Neil
 Smog. *See* Photochemical Smog
 Social and Economic Impacts
 of Climate Change
 Social Construction of Nature
 Social Darwinism
 Social Forestry
 Social Geography
 Socialism and Geography
 Social Justice
 Social Movements
 Soil Conservation
 Soil Degradation
 Soil Depletion
 Soil Erosion
 Soils
 Soja, Edward
 Solar Energy
 Solstices
 Sovereignty
 Space, Production of. *See*
 Production of Space
 Space of Flows
 Spaces of Representation/
 Representational Spaces
 Spatial Analysis
 Spatial Autocorrelation
 Spatial Cognition
 Spatial Cognitive Engineering
 Spatial Data Infrastructures
 Spatial Data Integration
 Spatial Data Mining
 Spatial Data Models
 Spatial Data Structures
 Spatial Decision Support
 Systems
 Spatial Econometrics
 Spatial Fix
 Spatial Inequality
 Spatial Interaction Models
 Spatial Interpolation
 Spatialization
 Spatially Integrated Social
 Science
 Spatial Multicriteria Evaluation
 Spatial Optimization Methods
 Spatial Resolution
 Spatial Statistics
 Spatial Strategies of
 Conservation
 Spatial Turn
 Species-Area Relationship
 Spectral Characteristics of
 Terrestrial Surfaces
 Spectral Resolution
 Spectral Transformations
 Spit. *See* Coastal Erosion and
 Deposition
 Sports, Geography of
 Squatter Settlements
 State

- | | | |
|-------------------------------|-----------------------------------|------------------------------|
| Steel Industry, Geography of | Textile Industry | United Nations Conference on |
| Stereoscopy and Orthoimagery | Thales | Environment and |
| Storper, Michael | Thermal Imagery | Development |
| Strabo | Thornthwaite, C. Warren | United Nations Environmental |
| Strahler, Arthur | Three-Dimensional Data | Summits |
| Stratospheric Ozone Depletion | Models | United Nations Environment |
| Strip Mining | Three Mile Island Nuclear | Programme (UNEP) |
| Structural Adjustment | Accident | United States Census Bureau |
| Structuralism | Thrift, Nigel | United States Geological |
| Structuration Theory | Thunderstorms | Survey (USGS) |
| Subaltern Studies | Thünen Model | University Consortium for |
| Suburban Land Use | Timber Plantations | Geographic Information |
| Suburbs and Suburbanization | Time, Geographies of | Science |
| Sui, Daniel | Time-Geography | Unsupervised Classification |
| Suitability Analysis | Time-Space Compression | Unwin, David |
| Sunbelt | T-in-O Maps | Urban and Regional |
| Supervised Classification | Tobler, Waldo | Development |
| Supranational Integration | Tomlinson, Roger | Urban and Regional Planning |
| Surface Water | Topological Relationships | Urban Ecology |
| Surveillance | Toponymy | Urban Environmental Studies |
| Surveying | Topophilia | Urban Gardens |
| Sustainability Science | Tornadoes | Urban Geography |
| Sustainable Agriculture | Tourism | Urban Green Space |
| Sustainable Cities | Township and Range System | Urban Heat Island |
| Sustainable Development | Trade | Urban Hierarchy |
| Sustainable Development | Transhumance. <i>See</i> Nomadism | Urbanization |
| Alternatives | Transnational Corporation | Urban Land Use |
| Sustainable Fisheries | Transnationalism | Urban Metabolism |
| Sustainable Forestry | Transportation Geography | Urban Planning and |
| Sustainable Production | Trap Streets | Geography |
| Symbolism and Place | Travel Writing, Geography and | Urban Policy |
| Symptoms and Effects of | Tree Farming | Urban Solid Waste |
| Climate Change | Trewartha, Glenn | Management |
| | Triangulated Irregular | Urban Spatial Structure |
| | Network (TIN) Data Model | Urban Sprawl |
| Taphonomy | Troll, Carl | Urban Storm Water |
| Taylor, Griffith | Tropical Rain Forests. <i>See</i> | Management |
| Taylor, Peter | Biome: Tropical Rain Forest | Urban Sustainability |
| Technological Change, | Tsunami | Urban Underclass |
| Geography of | Tsunami of 2004, Indian | Urban Water Supply |
| Telecommunications and | Ocean | Usability of Geospatial |
| Geography | Tuan, Yi-Fu | Information |
| Teleconnections | Turner, Billie Lee, II | |
| Television and Geography | Typhoons. <i>See</i> Hurricanes, | Vagueness in Spatial Data |
| Temperature Patterns | Physical Geography of | Vance, James |
| Temporal GIS | Typography in Map Design | Varenius |
| Temporal Resolution | | Vectorization |
| Terrain Analysis | Underdevelopment | Vernacular Landscapes |
| Territory | Uneven Development | as Expressions of |
| Terrorism, Geography of | United Nations | Environmental Ideas |
| Text/Textuality | | |

-
- | | | |
|---|------------------------------------|---|
| Via Campesina (International Farmers' Movement) | Water Needs | Wine Terroir |
| Vidal de la Blache, Paul | Water Pollution | Wise Use Movement |
| Video Games, Geography and | Watershed Management | Wittfogel, Karl |
| Viewshed Analysis | Watershed Yield | Wood, Denis |
| Virilio, Paul | Water Supply Siting and Management | Woodfuel |
| Virtual and Immersive Environments | Watts, Michael | Woodlots. <i>See</i> Forest Fragmentation |
| Virtual Geographies | Wayfinding | World Bank |
| Virtual Globes | Weather and Climate Controls | World Cities |
| Vision and Geography | Weber, Alfred | World Court |
| Volcanic Eruptions as Risk and Hazard | Web Geoprocessing Workflows | World Health Organization (WHO) |
| Volcanoes | Web Service Architectures for GIS | World Summit on Sustainable Development |
| Voronoi Diagrams | Wetlands | World-Systems Theory |
| Vulnerability, Risks, and Hazards | White, Gilbert | World Trade Organization (WTO) |
| | Whiteness | Wright, Dawn |
| Waldseemüller, Martin | Whittlesey, Derwent | Wright, John Kirtland |
| Walker, Richard | Wilderness | Writing |
| War, Geography of | Wildfires: Risk and Hazard | |
| Waste Incineration | Wilson, John | Xeriscaping |
| Wastewater Management | Wind | |
| Water Degradation | Wind Energy | Zelinsky, Wilbur |
| Water Management and Treatment | Wind Erosion | Zoning |
| | Wine, Geography of | |



**JACKSON, JOHN
BRINCKERHOFF
(1909–1996)**

Although not officially a geographer, J. B. Jackson was widely revered as an insightful and prolific analyst of cultural landscapes. Dominating mid-20th-century scholarship on this topic, he was claimed by several disciplines, including landscape architecture, geography, history, literature, and American studies.

Born in France, Jackson spent much of his early life in Europe, including school in Switzerland, as well as the Washington, D.C., area. Later, he went for 1 year to the Experimental College of the University of Wisconsin and then to Harvard, where he completed his BA in 1932. In the military as an intelligence officer during World War II, he acquired cartographic skills and a mastery of aerial photo interpretation, which likely fueled his interest in landscape formation and meaning. Jackson's understanding of cultural landscapes was derived from several sources, such as the influential French geographer Paul Vidal de la Blache and the American Carl Sauer, whom he met in Berkeley. He taught numerous courses at Harvard and at the University of California at Berkeley and was widely influential pedagogically. His later life was largely spent in New Mexico.

In 1951, Jackson launched the magazine *Landscape: The Human Geography of the Southwest*,

which he edited until 1968. Its influence was far greater than its narrow label might suggest. Numerous well-known geographers contributed to it, as did Jackson himself, sometimes using pseudonyms. Although its subscription base was small, it played a significant role in popularizing views of vernacular landscapes, particularly illustrating the human role in imposing meaning on places that might otherwise escape attention. When most academics disdained the vernacular, he celebrated the ordinary and everyday. He focused on American popular landscapes, drawing on his extensive travels across the United States, including mundane phenomena such as parking lots, bus stations, front lawns, roadside restaurants, and strip malls, adapting cultural geography to the age of the automobile. Roads and highways merited special focus as linkages among places and communities. His works blended diverse elements of landscape architecture, historical preservation, and urban planning. Through architecture, he held, people organized space and materialized the aesthetic. His insights were peppered with a disdain for modernism and a love of the baroque, although his work concentrated on the ordinary rather than the unusual or spectacular. He emphasized landscapes as largely unplanned, contingent, often ambiguous, and usually improvised entities. His writings helped move the study of cultural landscapes from its previous focus on relic rural places to contemporary urban ones, and they formed the foundation for the notion that landscapes could be read or interpreted like texts.



Jackson's efforts earned widespread acclaim, including conferences held in his honor. In recognition of his contributions, the Association of American Geographers established the J. B. Jackson Prize, awarded to those who disseminate geographical ideas to a popular, nonprofessional audience.

Barney Warf

See also **Cultural Geography; Cultural Landscape; Meinig, Donald; Sauer, Carl; Vernacular Landscapes as Expressions of Environmental Ideas**

Further Readings

- Jackson, J. (1972). Metamorphosis. *Annals of the Association of American Geographers*, 62, 155–158.
- Jackson, J. (1984). *Discovering the vernacular landscape*. New Haven, CT: Yale University Press.
- Jackson, J. (1996). *A sense of place, a sense of time*. New Haven, CT: Yale University Press.
- Jackson, J. (1999). *Landscape in sight: Looking at America* (H. Horowitz, Ed.). New Haven, CT: Yale University Press.
- J. B. Jackson and geography [Special issue]. (1998). *Geographical Review*, 88(4), 465–622.
- Zube, E. (Ed.). (1970). *Landscapes: Selected writings of J. B. Jackson*. Amherst: University of Massachusetts Press.



JEFFERSON, THOMAS (1743–1826)

President of the United States from 1801 to 1808 and author of the Declaration of Independence, Thomas Jefferson was also a passionate intellectual, accomplished scholar, philosopher, scientist, agronomist, musician, polymath, man of letters, and geographer. In addition to his accomplishments as president, ambassador to France, and founder of the University of Virginia, Jefferson maintained an active interest in the geography of North America, particularly as it pertained to its exploration and potential settlement. Along with Jedediah Morse, he is sometimes called one of the founders of American geography.

Jefferson's interests were both intellectual and pragmatic. He was fascinated by many things geographical, including maps and the accurate measurement of Earth's surface, mountains and geomorphology, climate and weather, and agricultural land use. As president, he directed his corps of engineers to record the nature of plants, birds, snowfalls, and forest clearance. Jefferson's volume *Notes on the State of Virginia*, a study of the climatology of his native state and its relations to humans, published in 1787, was one of 6,000 books in his possession (including 300 on geography), all of which were donated to the newly formed Library of Congress in 1815.

Jefferson and Hugh Williamson wrote the Land Ordinance of 1784, which established a rectilinear survey format in part designed to allocate land to Revolutionary War veterans. Later, the Ordinance became the U.S. Public Lands Survey System, the mechanism for the imposition of the Township and Range method of land surveys widely used west of the Appalachian mountains. Enormously influential as a cadastral scheme used in demarcating private property as well as state and county boundaries, the Township and Range system exemplified the values of the European Enlightenment, the imposition of an orderly, systematic frame of meaning that rationalized the largely unknown wilderness to the west.

Jefferson met Alexander von Humboldt several times in 1804, exchanged maps with him, and corresponded with him (in French) over several years, resulting in the two becoming close friends. He negotiated the Louisiana Purchase in 1804, doubling the size of the United States, and sponsored the Lewis and Clark Expedition through the American West during 1804 to 1806.

Finally, as one who viewed education as essential to a democracy, Jefferson was also an avid supporter of geography in schools. When he was governor of Virginia, he proposed that the discipline be taught in all school academies. In 1817, long retired, he drafted a curriculum for public education that included geography in all primary and secondary schools. Jefferson also insisted that it be included in the courses taught at the University of Virginia, which he founded.

Barney Warf



See also **Human Geography, History of; Lewis and Clark Expedition; Township and Range System**

Further Readings

- Koelsch, W. (2008). Thomas Jefferson, American geographers, and the uses of geography. *Geographical Review*, 98, 260–279.
- Surface, G. (1909). Thomas Jefferson: A pioneer student of American geography. *Bulletin of the American Geographical Society*, 41, 743–750.



JOHNSTON, R. J. (1941–)

One of the most prolific human geographers of the past half-century, Ronald J. Johnston is best known for his research in the areas of political and electoral geography, the history of human geography, and urban social geography. He is highly regarded for his work in political geography; he was one of the geographers who led the resurgence and revitalization of the field starting in the 1970s. Within political geography, Johnston's work has focused primarily on electoral geography, with an emphasis on the British electoral system. Along with Peter Taylor, he authored the main foundational text in electoral geography, *Geography of Elections*, in 1979.

Johnston was born in England. He received his BA and MA from the University of Manchester and his PhD from Monash University in 1967. He is currently a professor in the School of Geographical Sciences at the University of Bristol. He has previously served as vice chancellor of the University of Essex, professor and chair of the department of geography at the University of Sheffield, and a faculty member in the department of geography at the University of Canterbury in New Zealand.

Johnston is a leading writer on the history of human geography since World War II. He is the author of the leading book on the topic, *Geography and Geographers: Anglo-American Human Geography Since 1945*. In terms of his work in urban social geography, Johnston is best known for his work on (a) segregation and residential

differentiation and (b) the role of place in geography and the social sciences (the latter being the subject of his acclaimed 1991 book, *A Question of Place*).

Over all, Johnston is the author or coauthor of 50 books, editor or coeditor of an additional 40 books, and author or coauthor of over 800 journal articles and book chapters. He has received numerous honors for his research, including awards from the Royal Geographical Society and the Association of American Geographers, as well as being awarded honorary doctoral degrees from the University of Essex, Monash University, and the University of Sheffield.

Jonathan Leib

See also **Electoral Geography; Political Geography**

Further Readings

- Johnston, R. (1991). *A question of place: Exploring the practice of human geography*. Oxford, UK: Blackwell.
- Johnston, R., & Pattie, C. (2006). *Putting voters in their place: Geography and elections in Great Britain*. Oxford, UK: Oxford University Press.
- Johnston, R., & Sidaway, J. (2004). *Geography and geographers: Anglo-American human geography since 1945* (6th ed.). London: Hodder Arnold.
- Taylor, P., & Johnston, R. (1979). *Geography of elections*. London: Croom Helm.



JOURNEY-TO-WORK

See **Commuting**



JUSTICE, GEOGRAPHY OF

Scholars in many different fields have dealt with the topic of justice. For some disciplines, such as philosophy, political theory, and law, justice is one of the central concerns. Some of the most widely read contemporary authors from those



fields are theorists of justice, such as Iris Young, John Rawls, Charles Taylor, and Will Kymlicka. Goals in work on justice in the social sciences and humanities have included the following: defining justice, attaining justice, and denouncing and correcting injustices. More than a field in and of itself, justice has been an ethic applied in many disciplines, approaches, and methodologies.

How to think about justice has been, in and of itself, a focus of much work. Whether justice should be conceived individually or collectively, whether it is something to be decided through institutional legal means or beyond, and who decides when a situation is just or unjust are some of the questions addressed by those who engage the theme of justice. Quite often, perceptions of new injustices or new formulations of what would constitute a more just society arise not within the so-called ivory tower of academia but outside it, although the academic world is increasingly engaged with its surrounding social context. In fact, the social sciences have often become more attuned to the diverse questions surrounding justice due to the actions of social groups in the public sphere (e.g., the civil rights movement pushed many researchers to deeper engagement on the question of racial justice).

The geography of justice focuses on the spatialities of the question of justice—how phenomena such as international development, peace and war, racism, sexism, class inequality, environmental destruction, and more have specific spatialities to them. Particular spaces or spatial configurations can produce or maintain a situation of injustice. Additionally, a spatial approach can help correct an unjust situation. Thus, identifying these spatialities is one of the primary focuses of geographers working on questions of justice.

There is no clear starting point at which geographers began to work on this theme, and justice has been a concern of different geographers in many different specialties. Nonetheless, much of the recent work that focuses on questions of space and justice inherits from those subfields of geography that developed as a response to the different sociopolitical upheavals of the 1960s and 1970s, in particular (a) geographies of development, (b) feminist geographies, (c) geographies of race, (d) radical geography, and (e) Marxist geography. For many of these subfields, the highlighting and

analysis of an injustice and its spatialities is the central theme.

Through this work, geographers have been able to contribute new thinking to how questions of justice are approached. For example, even given formal legal equality and the legal end of segregation, geographic work has demonstrated how race continues to be a significant issue in countries such as the United States, through demonstrating inequalities in housing markets that create pools of poverty and electoral gerrymandering that hinders voters from choosing elected representatives responsive to their needs. Even what appears as the “straightforward” work of mapping socioeconomic data from the census or other sources has helped show how poverty and social exclusion do not work in the same ways across the board but are spatially concentrated in certain regions or types of spaces. Geographic work by feminists has demonstrated how spaces of social reproduction and care work (domestic work, child rearing, etc.) have been rendered invisible socially as well as legally and how these have historically been highly feminized spaces. Urban geography has demonstrated how the architecture and urban planning of a city, in and of itself, contributes to the inequalities between groups therein. Work in these fields concerning the geographies of justice focuses on many different scales, from the body to the neighborhood, to the nation and the globe, to producing or redefining scales as such.

Geographies of justice do not only refer to how injustice plays out in space or is created through the production of certain spaces, nor do they focus only on potential policy shifts that could address a particular injustice. Rather they also include struggles for justice, or battles against injustice, that take place through space. These struggles include attention to the spatial strategies of resistance practices, social movements, and other such actors. Some of these spatial strategies are (a) battles over access to space (e.g., antisegregation sit-ins); (b) claiming free or autonomous spaces (e.g., youth squatters’ movements); and (c) the creation of temporary spaces and scales through mega protests (e.g., the countersummits of the global justice movements).

Despite the concentration on the theme of justice in the subfields mentioned above, it should be



noted that geographies of justice have spanned, for the most part, the full gamut of methods and theoretical tendencies that have formed part of modern Anglo-American geography. This topic includes both quantitative and qualitative methods, users and practitioners of GIScience, and a wide variety of theoretical frameworks in human geography (especially from critical theoretical schools), be they Marxist, feminist, postcolonial, postmodern, poststructuralist, various combinations of these, and more. Geographers' concerns with justice have used both more traditional positivist methods for their work as well as post-positivist methods and critiques. Geographic work with justice has thus also had to challenge some older notions of "academic objectivity," at times redefining or questioning neutral objectivity altogether, in order to maintain the ethical goal of pursuing social justice as a guide for research.

It should be noted that geographies of justice are being worked on not only by geographers in many of the subfields of geography but far beyond the disciplinary boundaries. Many other fields of the social sciences and humanities have begun to discuss similar issues and have used geographical concepts as key tools in addressing situations of injustice. This could be seen as the result of the "spatial turn" currently afoot in many academic fields. In addition to other disciplines though, much work on the geographies of justice has taken and is taking place outside the university spaces proper. Much of this can be seen in the growing field of countermapping, which includes participatory projects between academic geographers and community geographers, such as the geographical expeditions of William Bunge and many experiments in indigenous cartography. There is also the increased use of maps by artists to denounce certain situations or to create alternative spaces, such as antiwar maps, maps of access to public spaces, and more. Activist or militant cartography is yet another example of this trend, where social movement networks explicitly

engage in a cartographic project to further their struggles around a particular issue. This trend is the case for the growing number of activist maps dealing with the creation of a new Pan-European Union border and its negative effects for migrant rights.

From this vast diversity, at least one thing is clear. Geographers of all sorts (both within and outside departments) are using the gamut of geographical tools to address situations of injustice or to create social justice. Given the "spatial turn" in Anglo-American social sciences and humanities, as well as the explosion of spatial, and especially cartographic, tools to the general public, the use of geography in the pursuit of social justice seems to be only spreading. While geography is not a panacea, from the already existing examples, it proves to be a useful tool for creating spaces of justice.

Sebastian Cobarrubias

See also **Class, Geography and; Countermapping; Critical Human Geography; Feminist Geographies; Law, Geography of; Race and Racism; Radical Geography; Resistance, Geographies of; Social Justice; Social Movements**

Further Readings

- Blaut, J. (1979). The dissenting tradition. *Annals of the Association of American Geographers*, 69, 157–164.
- Castree, N. (1999). "Out there"? "In here"? Domesticating critical geography. *Area*, 31(1), 81–86.
- Harvey, D. (2001). *Spaces of capital: Towards a critical geography*. New York: Routledge.
- Peet, R. (Ed.). (1977). *Radical geography*. Chicago: Marroufa Press.
- Smith, D. (1994). *Geography and social justice*. Cambridge, MA: Blackwell.

K

KANT, IMMANUEL **(1724–1804)**

Best known as a philosopher primarily concerned with ethics and epistemology, Immanuel Kant was also an important figure in the history of geography, although this aspect of his career is often overlooked. Indeed, he lectured on geography and numerous other topics at the University of Königsberg for 40 years (from 1756 to 1797), a century before it became a university discipline.

Kant's Philosophy of Time and Space

Essentially, Kant tried to resolve the debate between British empiricists and Continental rationalists. He was deeply affected by the works of David Hume, which he read for 11 years, and he accepted that true knowledge began with the senses, a position held by the empiricists; however, he departed from Hume in arguing that the mind is predisposed to a rational organization of sense data. Thus, he maintained that humans never experience things in and of themselves (noumena) but only perceive sense impressions of them (phenomena); we can know nothing about noumena and lots about phenomena. Since we only know a small part of the world at large, the domain of noumena must always greatly exceed that of phenomena.

In a sense, Kant was one of the first philosophers to problematize the matter of perception.

He held the view that the world has no preexisting given order (thus breaking from Aristotle) but is instead constructed by the rational mind—a position that aligned him with rationalists such as Descartes. Thus, instead of the mind revolving around the world, Kant viewed the world as revolving around the mind. Most important for geographers, he asserted that both time and space are categories created by the mind to make sense of nature: Time and space are not phenomena themselves but only ways to organize observable phenomena and impose order, logic, and meaning on the senses. In his most famous work *The Critique of Pure Reason*, published in 1781, Kant argued that reason and rationality are functions of a detached, disembodied observer, akin to Descartes's cogito. In this reading, nature is an external reality, mind is an internal reality, and knowledge is the means of overcoming this dichotomy.

Kant's epistemology differentiated between metaphysics on the one hand and the theoretical and empirical sciences on the other. He defined metaphysics as the analysis of a priori knowledge, including ethics and theology. Although Kant was personally religious, his emphasis on rationality was an important step in the secularization of science. The theoretical (or what he called "exact") sciences included disciplines such as physics and chemistry, which deploy deductive logic to decipher the universal laws of nature independent of time and space. The empirical (or what he called



“rough”) sciences, in contrast, were concerned with finding patterns and order in the welter of observable phenomena embedded in time and space; whereas deductive sciences were concerned with similarities among observations, the empirical ones were focused on finding the differences among them. The empirical sciences were essentially those concerned with time and place—that is, history and geography, respectively, which Kant put on a par in terms of their significance (i.e., the geographic location is as important as the historical context). The widespread privileging of time over space occurred much later, during the rise of 19th-century neo-Kantian historicism. Essentially, Kant argued that history and geography were concerned with understanding unique events. He further asserted that all causality was inherently a function of phenomena being located close in time and proximate in space, a primitive sort of Tobler’s First Law, which asserts that everything is related to everything else but near things are more related than distant things.

Kant argued that time and space formed necessary conditions for the perception of reality and thus for imposing a conceptual order on the world but they could not, by themselves, measure anything else. In some respects, he essentially upheld a Euclidean and Cartesian view of absolute space. Yet Kant’s view was more complex than this notion: While he enshrined Euclidean geometry as the architecture of the mind—a structure, like time, that made experience possible—he also disavowed the Newtonian notion of absolute time and space because it did not allow room for how they are experienced by people, thus introducing the issue of human perception. He did not simply dismiss time and space as subjective illusions but maintained that time and space are “real” only inasmuch as the mind perceives them and makes order of them. Although space existed *a priori*—that is, prior to experience—it could not be understood independent of experience. This argument shifted the focus from the world as it is in itself (noumena) to the world as known by human beings (phenomena) and elevated the question of sensory experience and its relations to reality to an epistemologically critical level. Experience is the continual synthesis of perception, and time and space are thus products of the mind—the tools it uses to render reality legible and meaningful. Such a view can

be seen as an intermediary between the view of space as absolute (i.e., as a container) and relative space (i.e., as relations among objects). This argument not only helped secularize time and space but also lodged their genesis within the individual mind, thus constituting a critical moment in the ascendancy of bourgeois individualism.

Kant’s Contributions to Geography

Kant made a number of important contributions to the emerging Enlightenment era’s understanding of space. He held that geography consisted of the study of people and their relations to the material world—that is, the exterior world outside the self, not the interior world of the mind, which he saw as anthropology. He differentiated between “mathematical geography” (essentially geodesy and map projections), physical geography, political geography, moral geography (spatial differences in customs), commercial geography (essentially trade), and theological geography (i.e., religious views of landscapes).

Most of Kant’s lectures were primarily concerned with physical geography: He wrote papers on earthquakes, rivers, the atmosphere, volcanoes, and the oceans, and 35 sets of student notes were collected in a textbook called *Physical Geography* (although there is some debate as to their accuracy and they have yet to appear in English). Geography included the study of races as part of physical geography, and Kant’s geographical works often exhibited an embarrassing lack of accuracy as well as overt racism and environmental determinism.

Kant also addressed the possibility of an international confederation of nations in his essay “Towards Perpetual Peace” (1795/1991), in which he argued that war could be made obsolete through a rigorous system of global laws and international commerce. Thus, he argued that “the peoples of the earth have entered in varying degrees into a universal community, and it is developed to the point where a violation of laws in one part of the world is felt everywhere” (p. 107). In this respect, he was a foundational thinker of the doctrine of cosmopolitanism and marked a turning point where morality could be formulated beyond the state form, and he thus



signifies the single most important source for normative theories of transnational relations. However, Kant wrote on the eve of the hegemony of the nation-state, and his views anticipated the rise of international organizations in the 20th century, such as the United Nations.

Finally, Kant publicly asserted that geography was critical to a general education; his enormous stature helped make the discipline respectable. His works were particularly influential with later neo-Kantian geographers such as Alfred Hettner and Richard Hartshorne.

Barney Warf

See also **Absolute Space; Cosmopolitanism; Enlightenment; Hartshorne, Richard; Historicism; Human Geography, History of; Relative/Relational Space**

Further Readings

- Elden, S. (2009). Reassessing Kant's geography. *Journal of Historical Geography*, 35, 3–25.
- Hatfield, G. (1991). *The natural and the normative: Theories of spatial perception from Kant to Helmholtz*. Cambridge: MIT Press.
- Kant, I. (1991). Towards perpetual peace: A philosophical project. In H. Reiss (Ed.), *Kant: Political writings* (pp. 93–130). Cambridge, UK: Cambridge University Press. (Original work published 1795)
- Livingstone, D., & Harrison, R. (1981). Immanuel Kant, subjectivism and human geography: A preliminary investigation. *Transactions of the Institute of British Geographers*, 6, 359–374.
- May, J. (1971). *Kant's concept of geography and its relation to recent geographical thought*. Toronto, Ontario, Canada: University of Toronto Press.
- Melnick, A. (1989). *Space, time, and thought in Kant*. Dordrecht, Netherlands: Kluwer.
- Tang, C. (2008). *The geographic imagination of modernity: Geography, literature, and philosophy in German Romanticism*. Stanford, CA: Stanford University Press.
- Withers, C. (2007). *Placing the Enlightenment: Thinking geographically about the Age of Reason*. Chicago: University of Chicago Press.



KARST TOPOGRAPHY

Karst (in German) topography is the name for the many landforms that developed on the surface and within soluble rocks as caves and other forms characteristic of a part of the Kras region of Slovenia, where the landforms developed on and in some 400 square kilometers of limestone (calcium carbonate) and were first studied many years ago. All rocks can be slightly soluble in water, with the result that various karstic landforms can also develop more slowly in the somewhat less soluble magnesium carbonate of dolomite or dolostone, as well as quite quickly in evaporate rocks such as rock salt or gypsum. In fact, some solubility can even occur slowly in silicate rocks such as sandstone, especially where it is cemented with carbonate minerals, or quartzite, basalt, and granite under favorable conditions and over long time periods. The processes of karstification of a region involve dissolution of the bedrock as various minerals are dissolved in the water. Limestone bedrock, the most common host rock of karst topography, is composed of the mineral calcite, which is subjected to the carbonation reaction in the presence of water with a small amount of dissolved carbon dioxide that makes a weak carbonic acid. As this slightly acidic water comes in contact with the limestone bedrock, it has the capability of dissolving and carrying away molecules in solution to make the karst topography. For karst topography to develop best, however, the carbonate must be thick, mechanically strong, and well jointed to allow concentrated percolation locations for the infiltrating water to carry away the solute loads. Chalk rock, for example, is quite a pure form of limestone, but it does not form caves or karst well because it is neither mechanically strong nor well jointed; instead it is soft and crumbly, therefore cave systems cannot become established.

Karst topography is terrain formed in soluble rocks that bears distinctive characteristic of drainage and relief unlike most other landscapes. Instead, it tends to have a rough surface with many enclosed depressions; the soil above the bedrock tends to be thin and patchy, with exposed bare rock that is etched into a great variety of irregular shapes, and much of its drainage is



Karst topography, viewed from a boat on the Li River south of Guilin, China, October 28, 1983

Source: U.S. Geological Survey.

subterranean where it flows through caves and grottos. *True karst* occurs where solutional processes dominate; in some parts of the world where karst processes create almost all the landforms of the region, it may be appropriate to refer to it as “holokarst.” On the other hand, *fluviokarst* occurs where the processes of rivers and solution are approximately equal in their activities. Large parts of the Midwestern United States, for example, are dissected by rivers running over and through carbonate rocks so that the intervening interfluvies can have karst topography developed on and in them. *Glaciokarst* is formed in some areas of higher altitude and latitude where soluble carbonates occur beneath partial covers of ice so that as the glaciers wax and wane, their meltwaters can assist in the excavation of the subterranean topography. *Psuedokarst* landforms are

developed by the very wide variety of nonsolutional processes that mimic some of those of true karst. Thus, granular disintegration of silicate rocks, hydraulic plucking and wave erosion of sea caves, lava flows that have internal lava tubes or caves where the molten rock flowed out, and mass movements that open out chambers underground and produce hummocky topography on the surface can all produce psuedokarstic landforms. *Thermokarst* is rather a misnomer in that it is not a karst at all, has no solutional component whatsoever, and instead is entirely due to the melting of permafrost and ground ice, although its surficial appearance of enclosed depressions may superficially resemble a true karst.

Bare karst occurs where the soluble bedrock is exposed directly to the atmosphere, and *covered karst* has the bedrock beneath mantles of regolith



sediments and soil. *Free karst* has drainages that go unimpeded directly to the ocean, whereas *impounded karst* is surrounded by other less permeable lithologies so that the drainages have to exit in the karst area with a different sort of hydrological system.

From the standpoint of hydrology and depth in the Earth, karst is divided into the surface and near-surface zones of the *epikarst* and the deeper subsurface zones of the *endokarst*. Epikarst is the karstic region in the vadose zone above the water table where there are air-filled openings as well as some water in the openings. Epikarst occurs from the surface and soil of the cutaneous zone, as well as the regolith and enlarged fissures of the subcutaneous zone. In these zones, close to the surface, precipitation is the chief input and evapotranspiration an output. At the base of the epikarst, there is a continuum of percolation involving seepage, trickles, and flows, up to full cave streams. Endokarst, below the epikarst, has the vadose zone of unsaturated percolation and water flow at its very top down into the phreatic zone of saturated water flow below the water table wherein water-filled fissures and pores occur, as well as fully water-filled caves. Outflow springs from the endokarst and epikarst areas occur at many different levels on the surface around higher topography with caves inside it.

Linear caverns in karst areas are *vadose caves*, which are above the water table; *shallow phreatic*, *epiphreatic*, or *water table caves*, which occur right at the water table; or *phreatic caves*, which are entirely below the water table. These basic cave types also have variants in which irregular cave passage loops occur, either entirely up and down beneath the water table as deep phreatic with loops or phreatic with loops that project a little way above the water table so that they become air filled for short distances. In addition, there are mixed loop and epiphreatic caves that have substantial parts both above and below the water table.

Because karst landforms are unusual in appearance and are distributed all over the world, so that a huge and confusing lexicon of descriptive and attempted genetic terms has arisen in many languages to describe them. Multilingual synonyms abound. The following is a brief exposition of some of the better-understood forms,

although it should be realized that fine divisions between some landforms may reflect continua of form and process such that absolute differentiation between types may be somewhat ambiguous at times.

Karst landforms are many and highly varied. Perhaps the best way to consider these landforms is by their size scale, as well as whether or not they are on the surface or underground as subterranean landforms. In addition, karst landforms can be classified based on whether they are positive landforms that resulted from rock having been removed from around them or from material that was deposited to make them or negative landforms wherein material has been removed to leave an opening of some kind.

On the surface where the larger landforms occur, which are most commonly observed as being of karst origin, perhaps the most common are the sinkholes, or dolines. Five main kinds of dolines occur, the solution, the suffusion, the collapse, the subsidence and the stream-sink types. *Solution dolines* occur where the dissolving of the bedrock is concentrated at some intersection of joints or some other favorable circumstance where solution was concentrated. Insoluble residues can eventually clog the drainage so that a *pond doline* results. *Suffosion dolines* are those formed by the processes of a through wash where sediments are carried away both in solution as well as by suspension so that a depression results that is generally fairly well choked with debris. *Collapse dolines*, such as the famous vertically sided *cenotes* in the Yucatan in Mexico, are those where the roof of a cave collapses. Over time, with no further collapse, the vertical walls will degrade and become less steep so that bowl- or cone-shaped dolines can result. *Subsidence dolines* result where a quite soluble rock such as rock salt dissolves and allows the settling or subsidence of overlying sediment or rock without any obvious fracturing or breaking of it. *Stream-sink dolines* or *ponors* form where streams flow down into swallow holes in carbonate rocks and then pass underground.

Uvalas are compound sinkholes that have developed a larger depression complex. As the size increases, a *polje* (plural *polja*)—a large, flat-floored, and closed depression—is formed. Both uvalas and *polja* commonly have permanent or



ephemeral streams in them that disappear into dolines. Polja can be subdivided into a number of different types depending on their relationships to the surrounding geology and hydrological systems. For example, *border polja* have rivers coming into them from outside nonkarst areas that are controlled by the external water tables so that lateral planation and alluvial deposition occur in the polje. *Structural polja* have downfaulted zones of permeable soluble rocks juxtaposed against insoluble rocks. *Baselevel polja* have regional water tables that intersect the ground surface inside them so that they flood periodically.

An *eggbox topography* forms where the limestone is thick and the water table deep so that deep solutional sinkholes form close together. A *cone karst* develops where the sinkholes coalesce together, and the region is dominated by projecting residual relief rather than by closed depressions. The result is a polygonal pattern of ridges around separate dolines. *Cockpit karst* has lower ridges and residual *pepino* hills, whereas tower karst has huge residual hill towers or *mogotes* (haystack hills) that can be steep enough or with vertical and overhanging sides to form a *pinnacle karst*.

Fluvial aspects of karst topography beyond those mentioned above include blind and half-blind valleys, steepheads or pocket valleys, dry valleys, meander caves, natural bridges, and tufa and travertine deposits. *Half-blind valleys* are those where a stream develops a swallow hole and downcuts a small amount upstream from the sink to leave the downstream portion only occasionally still hosting flood waters. A *blind valley*, on the other hand, is one that is closed off at its lower end by a cliff or steep slope facing upstream, below which the stream disappears into the sinkhole of a cave opening. Dry valleys have no surface stream in them, although they once did until the original stream that formed them found and exploited some subterranean exit point to abandon them. *Steepheads* and *pocket valleys* are those where a river emerges from a cave at the head of a valley. *Meander caves* are those where the outer bend of a meander in a karst area undercuts a limestone valley side so that a large overhanging cliff and cave system develops beneath. Karst *natural bridges* form where cave roofs collapse upstream and downstream from the bridge,

where subterranean stream piracy has diverted water beneath them, or where rivers dissolve their way through narrow bands of limestone that cross their paths. Tufa and travertine deposits can be produced by rivers in karst areas because water bodies there are commonly supersaturated with dissolved carbonate. Any disturbance to the water in rapids, waterfalls, or agitated flow through aqueous vegetation or the like on the surface may allow a small amount of carbon dioxide to escape from the water or a bit of water to evaporate, which then can cause some calcium carbonate to precipitate from the water. This carbonate buildup occurs in two main forms: (1) the porous and low-density *tufa*, which commonly has many root and stem casts inside it where the carbonate came out of the solution and precipitated around water plants, and (2) *travertine*, which is compact, of higher density, crystalline, and commonly banded and layered where variations in the water have changed the crystallization character or composition somewhat over time. Together, tufa and travertine can accumulate in masses large enough to constitute dams, mounds, sheets masses, and many other forms.

An additional discussion of karst includes a discussion moving down in scale to the smaller forms. A general term for many types of these smaller forms includes *karren*, which are a highly diverse group of small-scale features and sculpted forms of the bedrock that are exposed on the surface of the ground or that appear inside caves. Bare karst forms can be produced by wetting caused by rain or snowmelt hitting and flowing over the surface or dripping onto and seeping into it to carry away dissolved load. The small landforms that these processes produce are quite common in soluble carbonates but may also be produced on silicate rocks where certain mafic minerals (e.g., amphibole, pyroxene, and some micas) can weather more quickly to produce some solution and granular disintegration from differential decomposition that allows development of similar appearing landforms. The smaller karst landforms produced by solution can be subdivided into (a) bare karst forms produced by surface wetting, (b) bare karst forms produced by concentrated surface runoff, (c) partly covered karst forms, (d) covered karst forms, and (e) polygenetic forms or assemblages of karren. In many



cases, it may be quite difficult to determine whether or not a form was produced while it was covered with moist regolith or saprolite above it and later exhumed or whether it was generated entirely while partially or fully exposed to the atmosphere, or some odd combinations of both these possibilities.

The bare karst forms produced by wetting are scale dependent and include the following, in more or less increasing size: (a) *micropits* and *etched surfaces* are produced by precipitation falling on gently sloping or flat bare rocks to form small pits and rills less than 1 millimeter deep and not larger than a few centimeters; (b) *solution ripples* and *fluted scallops* are shallow, ripple-like flutes that form on steep to vertical surfaces perpendicular to the direction of the water flow over them; (c) *solution flutes* or *rillenkarren* are longitudinal hollows that start at the top of a rock crest and run down the steep rock surface with either rounded (silicate) or sharp (carbonate) ribs between them; (d) *solution bevels* are smooth and flatish tiny risers and treads in stair-step forms; (e) *solution runnels* or *rinnenkarren* are the larger solution hollows that result from larger volumes of overland flow; (f) *decantation runnels* are related to solution runnels that result from the dripping of acidified water from point sources upslope that are either in direct contact with the surface or not, or still exist as a present-day source or not, so that the resulting runnels in the rock can meander and/or reduce in size downslope; and (g) decantation flutings are similar to decantation runnels but have water sources at their heads that are diffuse sheet flows from upslope.

On the other hand, the bare karst forms that are instead produced by concentrated surface runoff also include, in order of more or less increasing size, the following: (a) *microfissures* follow thin small joints up to several centimeters in length but less than 1 centimeter in depth; (b) *splitkarren* or *solution fissures* occur along joints, veins, or stylolite solution features formed between bedding plains that are several centimeters to several meters long and some centimeters deep; (c) *solution slots* or *grikes* and *kluftkarren* are fairly large solution features developed along structural discontinuities such as large and connected joints or faults and can ultimately result in quite accessible and spacious *bogas* openings in the karst, as well

as karst *corridors* and karst *streets*; (d) *clints* are the tabular blocks left between grikes (solution slots); and (e) *solution spikes* or *spitzkarren* are the steep projections between grikes.

The partly covered karst forms that occur include (a) *solution pits*, which are round-bottomed or tapered forms, and (b) *solution pans*, which are dish- or basinal-shaped depressions formed on flat rock surfaces resulting from bedding planes or joints, which may have sides that overhang or carry solution flutes above bottoms covered with organic remains, clay, silt, sand, and pebbles. These two forms of solution pits and pans together are the most common of all karren forms. In addition, other partly covered karst forms are (a) *undercut solution runnels* (*hohlkarren*), which are similar to runnels but become larger with depth as a result of the damper conditions at their bases due to accumulations of soil and/or humus, and (b) *solution notches* (*korrosionkehlen*), which are inwardly curved lateral depressions or recesses produced by chemical etching from damp soil directly abutting the bedrock.

The fully covered karst forms have acidic sediment and soil above them in which the moisture is retained, and this helps them develop as (a) *rounded solution runnels* or *rundkarren*, which are smoothed out by their contact with the cover materials; (b) *cutters*, which are soil-covered solution slots (grikes) that are wider at the top and taper at depth; and (c) *solution pipes, shafts, or wells*, which are conical or cylindrical holes that can develop along joints or in an isolated fashion in unjointed carbonates such as chalk.

Polygenetic karst forms are commonly assemblages of different karren types. They include the following: (a) *karren fields*, exposed tracts of karren that may be as large as several square kilometers; (b) limestone pavements, where numerous soil-covered or bare solution slots (grikes) separate exposed rock surfaces (clints) that can be covered with karren forms, which either developed in the subterranean environment or subaerially, or both but in sequence; (c) *pinnacle karsts* and *stone forests*, a spectacular karst landscape with thin and pointed rock remnants that can be 45 m (meters) tall and 20 m wide at the base, although some tropical forms are known to stand as high as 120 m, with near-vertical sides and sharp, saw-tooth tops; (d) *ruiniform karsts*, a type of karst



wherein the upstanding tabular clints in between the well-developed, wide-solution slots are so well developed that after extensive soil erosion only a few upstanding blocks protrude upward like ancient ruined buildings scattered out in a former cityscape; (e) *corridor karsts*, which develop where large solution slots grow bigger and form aligned or crisscrossing steep-sided valleys that may develop into *labyrinth karsts* or *giant grikelands*; and (f) *coastal karrens*, which develop in the common carbonates along shorelines so that *solution notches* or *nips* develop in the rock exposed above shoe platforms, as well as a dense and pervasive variety of pits, pans, and spikes that may have been partly aided by boring and grazing organisms that can assist in producing *biokarsts* and partly by wave action, wetting and drying, salt weathering, or some plant activity to produce *phytokarst*.

John F. Shroder

See also **Carbonation; Caverns; Geomorphology; Groundwater**

Further Readings

Ford, D., & Williams, P. (2007). *Karst hydrogeology and geomorphology*. New York: Wiley.

KATES, ROBERT (1929–)

Robert (Bob) W. Kates is one of the world's leading geographers of the past half-century. He has said that from the beginning, his grand query was "What is and ought to be the human use of the Earth?" Since 1958, Kates has focused on three main issues: (1) living with hazard, (2) ending hunger, and (3) sustaining life on Earth. He has played a major role in the development of sustainability as a transdiscipline.

Kates was born in New York City in 1929. In his late 20s, he was supporting a young family by working in industry in the Chicago area, having left college without a degree to get married, when he signed up for a night course at a local university that was taught by one of Gilbert White's graduate students at the University of

Chicago. A year later, he was admitted to graduate school in geography at Chicago. Kates began his graduate study in 1958 in an interdisciplinary effort to understand floodplain management. He became geography's most vivid example of the value of second chances. Not since Gilbert White, who became his mentor, has there been a geographer who has so notably shaped research on nature-society relationships. Most of his career was spent as a geography professor at Clark University in Worcester, Massachusetts.

In considering how societies and individuals assess and respond to environmental and other hazards, Kates has led the way in introducing risk assessment perspectives and paying attention to how local rationalities may differ from those of external analysts, both in the United States and in developing countries. His insights about ending hunger have been developed from his experience with hazard modeling, looking into what factors lead to inadequate food supplies and the ways in which that knowledge can be combined with action to reduce hunger.

Since he published a classic paper on sustaining life on Earth in *Scientific American* in 1994, Kates has been a driving force behind the emergence of sustainability science as a new transdiscipline. He coled the preparation of a U.S. National Research Council report (1999) that broke new ground in identifying the challenges both to science and to converting science into action, as did a 2001 paper in *Science* that established a new quasi discipline of sustainability science for research and practice.

Kates's work has earned him major recognition, unmatched by any other geographer in his generation. In 1975, he was elected to the National Academy of Sciences; in 1981, he was awarded a MacArthur Prize Fellowship; and in 1991, he was awarded the President's National Medal of Science in a ceremony at the White House in Washington, D.C. Even so, Kates has, in many cases, taken a path different from that of conventional geographical scholarship. From the beginning, he showed an interest in questions that mattered as much to society as to science. Perhaps influenced by his early immersion in group research, he has actively sought challenges that are too large for any one individual.

Since receiving his PhD in 1962, he has thrown himself into not only contributing to science but



also making his local area better, as he now does in Maine. He shows every day how much he cares about a host of colleagues, collaborators, and former students; and he has no priority higher than his family—his wife, three children, and six grandchildren. It is no accident that he formulated what might be called “the Kates discount rate”—the discount rate applied by grandparents to future benefits for their grandchildren, for whom those future benefits have a higher value than the current costs.

Thomas J. Wilbanks

See also **Hunger; Natural Hazards and Risk Analysis; Sustainability Science; Sustainable Development; White, Gilbert**

Further Readings

- Burton, I., Kates, R., & White, G. (1978). *The environment as hazard*. New York: Oxford University Press.
- Kates, R. (2001). Queries on the human use of the Earth. *Annual Review of Energy and the Environment*, 26, 1–36.
- National Research Council. (1999). *Our common journey: A transition toward sustainability*. Washington, DC: The National Academies Press.

KEYSTONE SPECIES

Keystone species are plants or animals that have important effects on a particular ecosystem’s biodiversity and function, despite having a relatively low abundance. The term *keystone* originated in the field of architecture to describe a centrally located wedge-shaped stone that supports an entire arch. Robert Paine, an American ecologist, first introduced the keystone species concept to ecology in 1966. The meaning of the term in ecology is analogous to its meaning in architecture; similar to the support function of a keystone within an arch, a keystone species is considered a main supporting component of an ecosystem, without which the system would fail. The loss of a keystone species could result in the

loss of several dependent species and critical ecosystem functions.

Paine’s original usage of the term *keystone species* referred specifically to the high trophic position and unique function of a particular predatory starfish species found in a rocky marine intertidal zone. He found that the starfish’s activities clearly modified the species composition and physical appearance of the ecosystem, more than the activities of other predators. The actions of the starfish clearly served to regulate biodiversity in the ecosystem.

In the years since the introduction of the concept, the definition of the term has broadened to include any species with uniquely strong, positive effects on biodiversity regardless of its trophic level; however, the term still has different meanings to different people. A general, current definition of a keystone species encompasses plants, primary consumers, or even species that make important physical modifications to an ecosystem through its daily activities. Thresholds are particularly relevant to keystone species because when the density of a keystone falls below a given level, the biodiversity of the ecosystem is likely to decrease, affecting the balance and stability of the entire ecosystem.

Keystone species differ from *foundation species*. While foundation species serve essential ecosystem functions and affect biodiversity, their impact is primarily the result of their abundance. Keystone species, however, are generally not recognized as being abundant in the ecosystems in which they have a critical role sustaining a biologically diverse environment. Regardless of its classification, the loss of either foundation or keystone species can be detrimental to ecosystem functionality.

Importance of Keystone Species to Biogeographic Distributions

Understanding geographic distributions of plants and animals requires knowledge of both the physical environmental variables (such as light, temperature, and moisture) and the interactions among plant and animal species (such as predation and competition) that limit species’ distributions. In biogeography, the strong biological effects of keystone species provide a compelling example of biotic interactions that can influence



species' geographic ranges. Because keystone species affect competition regimes, ecosystem stability, biodiversity, species density, predation, and resource availability, their presence also indirectly influences where some species are found and where they are absent. Decreases in abundance or removal of the keystone species may result in changes in the distribution not only of the keystone species but of other plants and animals as well. Such distribution changes could affect the flow of energy and nutrients throughout the ecosystem. To geographers and others who study the effects of environmental change and human-environment interactions on biogeographic distributions, the keystone species concept should be considered.

Classification and Examples of Keystone Species

The keystone species concept has been used increasingly by ecologists, biogeographers, and conservation biologists to describe the diversity of important interactions of relatively rare species whose actions influence a diversity of ecosystem functions. One outcome of this broadened recognition is the development of specialized classifications and terminology that describe the multifaceted functions of keystone species. L. Scott Mills and colleagues comprehensively reviewed several categories of keystone species found in the ecological literature. The most common classifications include keystone predators, keystone plants, and keystone modifiers.

Keystone Predators

A keystone predator is a predator that is found at high levels in the food web. A predator may be a keystone species when it controls the densities of certain competitive dominants or key prey species. In the absence of a keystone predator, other competitors may drive out species or decimate populations, resulting in a decrease in overall biodiversity.

Paine's work on marine life in intertidal zones provides the classic case of a keystone predator. He discovered the important interactions of the predatory starfish *Pisaster* in a rocky intertidal zone through experimental removal of the species.

He found that the removal of *Pisaster* led to population explosion of certain mussels and sea urchins, resulting in ecosystem diversity lower than conditions prior to the experiment. Paine's classic work showed that without keystone predators in this particular marine ecosystem, the overall balance of the ecosystem was upset and unpredictable results followed. Though Paine conducted his work in a marine environment, his findings had important implications for many different ecosystems.

Several scholars (e.g., J. Estes and others) consider the sea otter (*Enhydra lutris*) to be a keystone predator because of its important role in limiting the density of sea urchins, a primary consumer of kelp and micro algae in some marine environments. In the absence of sea otters, the sea urchin population explodes, and the kelp population decreases, resulting in the loss of microorganisms that rely on the kelp for habitat and survival. Because of their important role in communities, changes in the population size of a keystone species is likely to have broad impacts on the way the ecosystem functions.

Keystone Plants

Keystone plants are those plants whose removal could result in the elimination of a series of animals and other plants that are collectively dependent on the keystone plant. Often, such dependents include pollinators and seed dispersers. Whitebark pine (*Pinus albicaulis*) is considered a foundation and keystone species of both the upper subalpine forest communities and the alpine treeline ecotone (ATE) of the North American West. Whitebark pine facilitates the development of tree islands in the ATE and thus serves an important role in the distribution of trees at the treeline. Additionally, as recorded by the wildlife biologist Katherine Kendall, its hard, nutritious seeds serve as an important food source for animals such as grizzly bears and squirrels. Whitebark pine also shares a mutualistic relationship with Clark's nutcracker (*Nucifraga columbiana*)—the sole disperser of its seeds, as investigated by the American ecologist Diana Tomback. The removal or loss of whitebark pine from alpine and subalpine ecosystems is likely to substantially affect these species, plus leading to cascading effects on other plant and animal species in downslope ecosystems.



The largest land mammal in North America, the bison's grazing patterns, movements, and behavior influenced the composition of grassland ecosystems 200 years ago. But in the 1800s, human settlement in the region led to the large-scale slaughter of bison and conversion of much of the grass prairie to agriculture. By 1900, this keystone species was nearly extinct. Today approximately 450,000 bison exist due to reintroduction efforts, but more than 95% are in managed private production herds, and the bison's ecological functions have not been restored.

Source: Morguefile.

Keystone Modifiers

Keystone species do not always affect other species through competitive or predatory activities. Keystone modifiers or *ecosystem engineers*, a term designated by Clive Jones, may indirectly affect the species of a particular ecosystem through habitat modification. Modifiers, by changing the physical state of an ecosystem, improve the resources available to certain species, increasing their survival rates. The North American beaver (*Castor canadensis*) may be considered a keystone modifier because of the effects of its damming on hydrology and the resultant

energy and nutrient flow through the ecosystem that results in increased habitat heterogeneity.

Allen K. Knapp and other ecologists have identified the North American bison (*Bison bison*) as a keystone species of the tallgrass prairie. Their grazing reduces the abundance of certain grasses that are competitive dominants, along with woody vegetation from the prairies. Without the removal of the woody grass species, the tallgrass prairie would eventually become a forested environment. Through their preferential grazing and wallowing activities, bison increase habitat heterogeneity and species diversity. Year-round grazing from bison and ungulates, along with natural fire regimes, are



thought to be key factors in the conservation of the remaining tallgrass prairie of North America.

Debates Surrounding the Keystone Species Concept and Ecosystem Conservation

The keystone species concept is one currently surrounded by debate. Keystone species are often at the forefront of discussions on the prioritization of ecosystem and habitat conservation. Within the realm of conservation, an inherent controversy associated with the keystone species is the implication that some species are more important to ecosystems than others. In light of the limited resources available for conservation efforts, proponents of this viewpoint argue that keystone species should be given priority in conservation efforts.

Many scholars, however, question whether the qualities of a single species can be so essential to an ecosystem as to warrant special status. Single-species approaches to conservation, such as preferential targeting of keystone species, may underappreciate the complexity of ecosystem function. Therefore, conservation approaches that emphasize one species may not be successful for long-term biological conservation. Some ecologists (e.g., L. Scott Mills and his colleagues) even call for the abandonment of the keystone species concept altogether because of its vagueness.

John Bruno, John Stachowicz, and Mark Bertness highlighted two primary problems associated with placing keystone species at the forefront of conservation efforts. First, is the difficulty associated with positive identification of keystone species and the strength of their interactions, which must be tested through experimental removal of species. Associated with this difficulty is that the strength of keystone species interactions with other plants and animals may vary from one environment to the next. Second, the ramifications of focusing conservation efforts on single species, possibly at the expense of other species (especially foundation species) that may also be important for ecosystem function and biodiversity, is problematic. Such narrowly focused conservation efforts could result in ecosystem collapse or instability, even with its keystone species population protected. Adaptation of a systems-based perspective to the problem of conservation requires

the recognition that ecosystems are inherently complex. Many ecologists argue that understanding interactions among species (and physical environment) is critical for proper ecosystem functioning and biodiversity protection and that consideration of the abundance of a single species achieves only partial resolutions to problems associated with ecosystem management, at best.

Lynn M. Resler

See also Biodiversity; Biogeography; Conservation; Ecosystems; Extinctions

Further Readings

- Bruno, J., Stachowicz, J., & Bertness, M. (2003). Inclusion of facilitation into ecological theory. *Trends in Ecology and Evolution*, 18, 119–125.
- Estes, J., & Palmisiano, J. (1974). Sea otters: Their role in structuring nearshore communities. *Science*, 185, 1058–1060.
- Jones, C., Lawton, J., & Shachak, M. (1994). Organisms as ecosystem engineers. *Oikos*, 69, 373–386.
- Knapp, A., Blair, J., Briggs, J., Collins, S., Hartnett, D., Johnson, L., et al. (1999). The keystone role of bison in the North American tallgrass prairie. *BioScience*, 49, 39–50.
- Meffe, G., & Carroll, C. (Eds.). (2005). *Principals of conservation biology* (2nd ed.). Sunderland, MA: Sinauer Associates.
- Mills, L., Soulé, M., & Doak, D. (1993). The keystone-species concept in ecology and conservation. *BioScience*, 43, 219–224.
- Paine, R. (1966). Food web complexity and species diversity. *American Naturalist*, 100, 65–75.
- Paine, R. (1969). A note on trophic complexity and community stability. *American Naturalist*, 103, 91–93.
- Paine, R. (1995). A conversation on refining the concept of keystone species. *Conservation Biology*, 9, 962–964.
- Tomback, D., & Kendall, K. (2001). Biodiversity losses: The downward spiral. In D. Tomback, S. Arno, & R. Keane (Eds.), *Whitebark pine communities: Ecology and restoration* (pp. 234–262). Washington, DC: Island Press.



KNOWLEDGE, GEOGRAPHY OF

The geography of knowledge deals with spatial disparities in the generation, diffusion, and application of various categories of knowledge and skills. Spatial disparities in literacy, educational attainment, professional skills, creativity, and technology can be traced back to early human history. Some of their primary causes are spatial concentrations of power and knowledge created by the spatial division of labor, the hierarchical structure and complexity of organizations, the asymmetry and spatial range of power relations, and the ways in which social systems and networks are coordinated and governed in space. Communication technologies—from the creation of the first scripts to the invention of paper and from the construction of the first printing machine to the introduction of digital information systems—changed spatial disparities pertaining to the production, dissemination, and uses of knowledge but never abolished the disparities between the centers and peripheries of national or global urban systems with regard to the distribution of workplaces for highly and marginally skilled persons.

Knowledge can be defined as the capacity for social action; it influences perceptions and evaluations of information and the decision making and actions of persons. Knowledge and power build multifaceted coalitions that reproduce social and spatial inequalities. A head start in knowledge, expertise, and technology is an important prerequisite for competitiveness. All fields of human geography can be enriched by exploring the consequences of spatial differences in knowledge, expertise, professional skills, technology, or educational achievement and how these disparities can be explained. In addition, most political, economic, and social changes (e.g., colonialism, nation building, globalization, neoliberalization, privatization) have impacts on the educational system. This eminent role of knowledge and education in modern societies leads to numerous possible research topics within geography and entails necessary specialization and a large variety of theoretical concepts.

The Geography of Education

Political and scientific interest in spatial disparities of education harks back to the first decades of the 19th century. It was the time when social reformers in France and the United Kingdom believed that poverty, crime, and alcoholism were caused by ignorance and a lack of moral education and when relations between the degree of a nation's literacy and economic performance were discovered. In the 19th century, scholars in the social survey movement studied social and spatial disparities of illiteracy, the availability and quality of schools, the skills and salaries of teachers, and the educational attainment of children with regard to their family environment (e.g., the availability of books). Apart from occasional studies of the locations of schools and universities, of school transport, and of drop-out rates and truancy, human geography neglected spatial disparities in the provision and consumption of schooling until the mid 1960s. With the expansion and restructuring of school systems in the 1960s, spatial and social disparities of educational achievement and education as a means of social stratification, social exclusion, and regional development became a significant topic in geography. The first professor specializing in the geography of education was Robert Geipel. He started his research on spatial disparities of education in the early 1960s at the University of Frankfurt and inspired, in more than 30 years, many scholars to focus on this new field, especially when he was holding a chair at the University of Munich (1969–1994).

The newly emerging geography of education began first to study the location criteria, catchment areas and structural changes of the school and university system, the effects of school closures for community development in sparsely inhabited areas, the extracurricular activities of teachers as an interface between school and community, the spatial consequences of school reforms, and the cultural and economic effects of universities. Later topics included the movement of pupils through the school system; educational attainment and exam scores of students with respect to their place of residence, social origins, and ethnicity; spatial disparities of the educational achievement of the resident adult population and



An aerial view of the University of California, Berkeley. One of the preeminent universities in the world, it ranks at or near the top in fields ranging from engineering and the hard sciences to the social sciences, arts, and humanities.

Source: Sean Goebel/iStockphoto.



their consequences; the spatial distribution of jobs for the highly and lowly educated labor force; the spatial mobility or circulation of talent; and the role of the educational system in the assimilation or seclusion of minorities. Transition rates of various age groups to the different types of secondary schools and colleges and universities; the median number of school years completed; the drop-out rates; the truancy rates; and other indicators of schooling are used to describe the spatial dimension of social structures and processes and to define inner-urban problem areas.

From the 1980s onward, work on the geography of education extended its research to spatial disparities of the sociodemographic structure of teachers and university scholars (e.g., age, skills, gender, ethnic origin, career, and spatial mobility); to relations between educational achievement, labor markets, and spatial mobility; and to spatial disparities of vertical social mobility between generations. At the same time, economic geographers attached increasing importance to the role of professional skills; the diffusion of technical innovations; the spatial distribution of patents, inventions, research input, and output; and the impact of clusters and networks on knowledge generation. From the 1990s onward, the geography of education turned increasingly to theoretical issues of knowledge generation and dissemination and to the nexus between knowledge and space.

The Geography of Science

The geography of science, which developed since the early 1980s mainly in the United Kingdom and the United States, is interested in all steps of the generation, dissemination, and application of scientific knowledge. Locally produced knowledge becomes widely disseminated knowledge only if it is shared with others, recognized by epistemic authorities of the relevant domain, and proved useful. A spatial context or setting in which scientific experiments and studies are carried out does not only influence the generation of knowledge, it also strongly affects the justification, legitimization, and dissemination of scientific results. Places of discovery can have an impact on scientific results. They present distinct opportunities of learning. They induce different

questions and discourses; foster different experiments, practices, and engagements; and have different scientific reputations. The acceptance and reputation of scientific results depend, to a large degree, on where they were generated, shown, and verified. The platform on which scientific results are first presented is often of more importance for their rapid diffusion than is the quality or originality of the findings. Science and the humanities are replete with examples illustrating the extremely long time it took for highly creative ideas, new research questions, and theoretical concepts to be perceived and accepted by the epistemological centers of the relevant disciplines.

David Livingstone described distinctive geographies of writing and reception, showing that the generation of knowledge requires a spatial context other than the showing of experiments and that the legitimization of scientific results, in turn, calls for other locations. A spatial diffusion of scientific knowledge does not guarantee that readers will interpret that knowledge as intended by the writer. Darwin's theory of evolution, for instance, was interpreted very differently depending on the country in question.

Geographies of Creativity

Since the late 1980s, it has become widely accepted that creative ideas emerge and develop in complex, dynamic interactions between the creator and his or her environments. Creative individuals are embedded in particular environments capable of either fostering or hindering their creativity. Cognitive processes are guided not only by personal capabilities or intrinsic motivation but also by interactions with the environment. A creative milieu is not produced solely by the copresence of particular constituents. Much more decisive are their interrelations and mutual modifications. A creative milieu or environment represents a certain possibility or potentiality that must be activated through human communication and interaction. The potential to communicate with other highly creative persons attracts other creative artists and scientists from elsewhere and thus enhances the attractiveness of a place. One cannot predict whether and how often this potential for integrating diverse viewpoints and knowledge bases is activated. This is one of the



reasons why many scholars hesitate to use the terms *creative industry* or *creative class*.

Knowledge and Power

The close dialectical relationship between knowledge and power, and the attraction of power centers for intellectuals and experts, may be regarded as the main reason for the long persistence and continuous reproduction of spatial disparities of socioeconomic structures. Work places of important decision makers, highly skilled specialists, and high-technology industries show a strong tendency toward spatial concentration, whereas low-skilled, routine activities in production and administration show a trend toward dispersion and decentralization. The main characteristic of peripheries is that they constantly lose the largest part of their highly educated people to the centers.

The importance of power to the production and dissemination of various types of knowledge (including orientation knowledge) can hardly be overestimated. Orientation knowledge provides values and a point of reference, declares what is good or evil, bestows identity, and forms the glue that keeps a social system together. Since early history, it has been in the interest of those in power to control or influence institutions of knowledge production and to manipulate and censor the diffusion of information. Since the 19th century, the school system is considered as one of the most important instruments in the socialization of the young. In most countries, the mission of the schools includes consolidating the nation-state by creating and transmitting national identities, ideologies, collective memories, and narratives and by assimilating ethnic minorities and immigrants. Throughout the 19th and 20th centuries, state authorities used the school system to control and discipline their ethnic minorities, to interfere in their cultural development, and to separate the elites from other strata of society.

Schools can also function as sites of ethnic resistance where historical experience and cultural practices of ethnic groups are cultivated. To preserve their culture, most ethnic minorities are eager to organize the education of their children in a certain way, at least in the first years of compulsory schooling. Schools represent a legal

means by which the minorities can protect their culture from intervention by the dominant political apparatus, which is normally the state. It makes a big difference whether an ethnic minority group may use its mother tongue as language of instruction and whether it has a chance to influence the way in which its history and culture are presented to its children. Therefore, the educational system and the language of instruction in schools emerged, during the 19th century, as a focal point of conflict between state building and the national emancipation process in multiethnic states. The language of instruction to be used in schools was of paramount instrumental value in both state nationalism and nation building. The unequal treatment, opportunities, and achievements of minorities in the school system are a fine seismograph for the degree of their vulnerability, their collective social status, and their discrimination and chances in the labor market.

As educational systems are highly context sensitive, generalizations about the impacts of educational policies or school reforms should be checked very carefully. The ideology and practice of decentralized governance (local control) may re(produce) racial segregation and interdistrict funding inequities in the United States but bring great benefits to disadvantaged ethnic groups in European countries. Depending on the context, high per capita income of a community may increase or decrease the transit rates to universities.

Peter Meusbarger

See also **Clusters; Education, Geographies of; Geography Education; Information Society; Innovation, Geography of; Knowledge Spillovers; Learning Regions; Science and Technology Studies; Technological Change, Geography of**

Further Readings

- Bathelt, H., Malmberg, A., & Maskell, P. (2004). Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation. *Progress in Human Geography*, 28, 31–56.
- Hamnett, C., Ramsden, M., & Butler, T. (2007). Social background, ethnicity, school composition and educational attainment in East London. *Urban Studies*, 44, 1255–1280.



Livingstone, D. (2003). *Putting science in its place: Geographies of scientific knowledge*. Chicago: University of Chicago Press.

Malecki, E. (2000). Knowledge and regional competitiveness. *Erdkunde*, 54, 334–351.

Meusburger, P. (2008). The nexus between knowledge and space. In P. Meusburger, M. Welker, & E. Wunder (Eds.), *Clashes of knowledge* (pp. 35–90). Dordrecht, Netherlands: Springer.



KNOWLEDGE SPILLOVERS

By knowledge spillovers, economic geographers usually refer to technical, scientific, or organizational knowledge that, once discovered, easily comes to the attention of other individuals due to its nonrival and (partially) nonexcludable nature. Nonrivalness implies that additional users bear no extra cost and do not prevent others from possessing and using the knowledge. Nonexcludability indicates that it is also impossible, or at least very difficult, to prevent others from gaining the knowledge, whether they have contributed to its production or not. The term *spillover* is intended to highlight the difficulty of controlling knowledge and preventing its unintentional dissemination in the economy. Now regarded as the central factor for economic growth, knowledge spillovers and their underlying circumstances have received increased scholarly attention.

A common assumption in the geography of innovation literature is that knowledge often takes the form of know-how or tacit knowledge, which is hard to convey by means other than repeated face-to-face interaction. When spillovers are thus locally bounded, firms tend to locate near their sources, such as universities, research and development (R&D) intensive firms, or skilled labor. Many empirical studies have therefore examined the impact of universities or labor mobility on regional growth, using various indicators. Patents and patent citations are now most commonly used in this respect, and in the case of scientific knowledge, various bibliometric methods are generating increased interest.

The most influential analytical framework to study the impacts of knowledge spillovers on urban growth was developed in 1992 by Glaeser, Kallal, Scheinkman, and Shleifer, who distinguished among three different perspectives:

1. MAR spillovers, referring to the original insights of the economists Alfred Marshall, Kenneth Arrow, and Paul Romer
2. Porter spillovers, named for the famed management scholar Michael Porter
3. Jacobs spillovers, named after the urban theorist Jane Jacobs

The first two approaches stress spillovers within a sector (intraindustrial spillovers) and the importance of geographical economic specialization, whereas Jacobs spillovers occur between sectors (interindustrial spillovers) and are therefore more abundant in a more diversified local economy. In addition, the MAR perspective favors local monopolies, whereas the other two see strong local competition as a better incubator of innovative behavior. Although much debate surrounds the issue, Jacobs's perspective has gathered most support from researchers.

While the empirical literature on geographically localized knowledge spillovers is extensive, many central questions remain unsettled. The main criticisms revolve around the issues of tacitness—spillovers as externalities—and the actual nature of spillover processes. For example, tacit knowledge was originally viewed as implying that individuals know more than they can tell. It was therefore not merely difficult but impossible to convey this through formal communication. In the more recent literature, a case is now sometimes made that the main difficulty in transmitting much expert knowledge has often more to do with other factors, such as cognitive rather than geographical distance.

Another problematic issue is that knowledge spillovers usually imply that the diffusion is unintended and that the innovator does not receive full compensation. Some scholars therefore use the term *knowledge externalities* interchangeably. In many cases, however, the characteristics of positive externalities are not satisfied, or this proves difficult to verify. Finally, the numerous



empirical studies based on knowledge spillover proxies do not document or even prove their existence, and other explanations or factors might be more significant.

While the importance of knowledge spillovers for the geography of innovation is not likely to falter, improved theories and detailed empirical studies are increasingly called for.

Samuli Leppälä and Pierre Desrochers

See also **Agglomeration Economies; Economic Geography; Externalities; Innovation, Geography of; Knowledge, Geography of; Learning Regions**

Further Readings

- Breschi, S., & Lissoni, F. (2001). Knowledge spillovers and local innovation systems: A critical survey. *Industrial and Corporate Change*, 10, 975–1005.
- Glaeser, E., Kallal, H., Scheinkman, J., & Shleifer, A. (1992). Growth in cities. *Journal of Political Economy*, 100, 1126–1152.
- Jaffe, A., Trajtenberg, M., & Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *Quarterly Journal of Economics*, 108, 577–598.



KÖPPEN, WLADIMIR (1846–1940)

Wladimir Peter Köppen was born on September 25, 1846, in St. Petersburg, Russia. Although best known for his climate classification system, he was originally trained as a botanist. His scientific work, which includes 526 published research articles and numerous books written between 1868 and 1940, is recognized in the fields of geography, meteorology, climatology, and botany. He died on June 22, 1940, in Graz, Austria.

Köppen lived in Russia until he was 20 years old. He had an early curiosity about the environment due to his mother's interest in botany and the family's travels. He started his studies at the University of St. Petersburg in 1864. He later

went to the University of Heidelberg for graduate studies. In 1869, Köppen transferred to the University of Leipzig, where he studied climate impacts on plant growth. He earned his doctoral degree in 1870.

Köppen worked for the Central Physical Observatory at St. Petersburg from 1872 to 1874, where he published 12 research articles. He moved on to the North German Sea Watch, a naval observatory in Hamburg, in 1875, where he developed a forecasting service for northwestern Germany and nearby waters, described the motion of cold fronts, and studied the upper atmosphere. Along with Matthew Maury, he produced wind charts that were valuable to ocean traders and the military. The maps were later used by Tor Bergeron during his research on air masses. While at the naval observatory, Köppen returned to research in climatology and botany.

In the mid 1880s Köppen published a map showing the relationships between temperature regions and vegetation growth. This research resulted in his first attempt at climate classification in 1900, but his early system did not receive much recognition. Subsequent work led to the development of his widely known classification scheme in 1918. The system attempted to explain vegetation distribution using temperature and precipitation data. Köppen revised the system multiple times and published his final version in 1936, although he kept editing it until his death. Despite later modification by others, the basic structure has remained intact. It continues to be one of the most commonly taught climate classification systems.

Among Köppen's other contributions are several books. *The Climate of Geological Prehistory*, which he published with Alfred Wegener in 1924, added to the Milankovitch theory, which explains Earth's glacial and interglacial periods. It was one of the first books in the field of paleoclimatology. Köppen also worked with Rudolph Geiger to publish a five-volume set called *Handbook of Climatology* between 1926 and 1940.

Richard R. Brandt

See also **Climate: Dry; Climate: Midlatitude, Mild; Climate: Midlatitude, Severe; Climate: Mountain; Climate: Polar; Climate: Tropical Humid; Climate Types; Climatology; Köppen-Geiger Climate Classification**



Further Readings

- Daintith, J. (Ed.). (2008). *Biographical encyclopedia of scientists* (3rd ed.). New York: Taylor & Francis.
- Lewis, J. (1996). Winds over the world sea: Maury and Köppen. *Bulletin of the American Meteorological Society*, 77, 935–952.
- Oliver, J., & Hidore, J. (2002). *Climatology: An atmospheric science*. Upper Saddle River, NJ: Prentice Hall.



KÖPPEN-GEIGER CLIMATE CLASSIFICATION

The Köppen-Geiger is a system of global climate classification created by Wladimir Peter Köppen and subsequently updated and revised by Köppen in collaboration with Rudolf Geiger. It is the best-known and most widely used global climate classification available.

Köppen was born in St. Petersburg, Russia, in 1846, and died 94 years later in Austria after making a prolific contribution to science. His early training in botany appears to have exerted considerable influence on the work for which he is best remembered—a global classification of climate. In an interesting twist of fate, his daughter married Alfred Wegener, the pioneer of continental drift, with whom Köppen collaborated on global paleoclimate reconstruction; this project presumably emphasized to him the importance of a global system of climate classification. In the 1930s, Köppen collaborated with Rudolf Geiger, his junior by 48 years, in writing the *Handbuch der Klimatologie* and in updating and revising his climate classification system, which Geiger continued to work on after Köppen's death in 1940. The classification is now widely referred to as the Köppen-Geiger classification in recognition of Geiger's contributions.

In this classification, climates are divided into five major categories, designated by the first five letters of the alphabet and always capitalized (see Table 1). Subsidiary properties of the classification are also denoted by letters of the alphabet,

always in lowercase. The first major division in Köppen's system is the distinction between humid climates and dry climates. The climate zones A, C, D, and E are humid, and the arid B climates are divided into two groups using an uppercase letter—steppe (BS) or desert (BW). Within the humid climate group, distinction is made on the basis of temperature, progressing sequentially from tropical (A, mean temperature of the coldest month $\geq 18^\circ\text{C}$), to temperate (C, mean temperature of the hottest month $>10^\circ\text{C}$ and mean temperature of the coldest month between 0°C and 18°C), to cold (D, mean temperature of the hottest month $>10^\circ\text{C}$ and mean temperature of the coldest month $\leq 0^\circ\text{C}$), to polar (E, mean temperature of the warmest month $<10^\circ\text{C}$), with the E type climates also divided into two groups using an uppercase letter—ET indicating tundra and EF indicating frost climates.

The climate zones A, C, and D are further divided internally on the basis of the seasonality of rainfall using lowercase letters. No further subdivision is made in the case of the ET and EF climates. The tropical A climates are divided into f, rain forest climates, with high temperatures and rainfall all year; m, monsoon, with a dry season; and w, savanna, with the distinction between monsoon and savanna being based on the relative dryness of the dry season.

The arid (B) climates are separated from the humid climates using a dryness threshold and are then divided into steppe (BS) and desert (BW), also using the dryness threshold, which depends on the mean annual temperature and the seasonal distribution of rainfall. As in the subdivision of other climate types, an important principle is whether the most precipitation occurs during the warmer months of the year, when it will be more effective for plant growth. The dryness threshold varies depending on the seasonal distribution of rainfall. If 70% of the precipitation occurs in winter, then the dryness threshold is calculated as twice the mean annual temperature (in $^\circ\text{C}$). Where 70% of the precipitation occurs in summer, the dryness threshold is calculated as 28 plus twice the mean annual temperature. Where the seasonal concentration of precipitation is below 70% in both seasons, the dryness threshold is calculated as 14 plus twice the mean annual temperature. Summer and winter are



1st	2nd	3rd	Description	Criteria
A			Tropical	$T_{\text{cold}} \geq 18$
	f		Rain forest	$P_{\text{dry}} \geq 60$
	m		Monsoon	Not (Af) and $P_{\text{dry}} \geq 100 - \text{MAP}/25$
	w		Savanna	Not (Af) and $P_{\text{dry}} < 100 - \text{MAP}/25$
B			Arid	$\text{MAP} < 10 \times P_{\text{threshold}}$
	W		Desert	$\text{MAP} < 5 \times P_{\text{threshold}}$
	S		Steppe	$\text{MAP} \geq 5 \times P_{\text{threshold}}$
		h	– Hot	$\text{MAT} \geq 18$
		k	– Cold	$\text{MAT} < 18$
C			Temperate	$T_{\text{hot}} > 10$ and $0 < T_{\text{cold}} < 18$
	s		Dry summer	$P_{\text{sdry}} < 40$ and $P_{\text{sdry}} < P_{\text{wwet}}/3$
	w		Dry winter	$P_{\text{wdry}} < P_{\text{swet}}/10$
	f		Without dry season	Not (Cs) or (Cw)
		a	– Hot summer	$T_{\text{hot}} \geq 22$
		b	– Warm summer	Not (a) and $T_{\text{mon10}} \geq 4$
		c	– Cold summer	Not (a or b) and $1 \leq T_{\text{mon10}} < 4$
D			Cold	$T_{\text{hot}} > 10$ and $T_{\text{cold}} \leq 0$
	s		Dry summer	$P_{\text{sdry}} < 40$ and $P_{\text{sdry}} < P_{\text{wwet}}/3$
	w		Dry winter	$P_{\text{wdry}} < P_{\text{swet}}/10$
	f		Without dry season	Not (Ds) or (Dw)
		a	– Hot summer	$T_{\text{hot}} \geq 22$
		b	– Warm summer	Not (a) and $T_{\text{mon10}} \geq 4$
		c	– Cold summer	Not (a, b, or d)
		d	– Very cold winter	Not (a or b) and $T_{\text{cold}} < -38$
E			Polar	$T_{\text{hot}} < 10$
	T		Tundra	$T_{\text{hot}} > 0$
	F		Frost	$T_{\text{hot}} \leq 0$

Table 1 Description of Köppen-Geiger climate symbols and defining criteria

Source: Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11, 1633–1644. Reprinted with permission.

Notes: MAP = mean annual precipitation; MAT = mean annual temperature; T_{hot} = temperature of the hottest month; T_{cold} = temperature of the coldest month; T_{mon10} = number of months when the temperature is above 10; P_{dry} = precipitation of the driest month; P_{sdry} = precipitation of the driest month in summer; P_{wdry} = precipitation of the driest month in winter; P_{swet} = precipitation of the wettest month in summer; P_{wwet} = precipitation of the wettest month in winter; $P_{\text{threshold}}$ = variations according to the following rules (if 70% of MAP occurs in winter, then $P_{\text{threshold}} = 2 \times \text{MAT}$; if 70% of MAP occurs in summer, then $P_{\text{threshold}} = 2 \times \text{MAT} + 28$, otherwise $P_{\text{threshold}} = 2 \times \text{MAT} + 14$). Summer (winter) is defined as the warmer (cooler) 6-month period of ONDJFM or AMJJAS.

defined as 6-month periods where summer (winter) is ONDJFM or AMJJAS.

The arid B climates are further subdivided where the letter k is used to denote that the mean annual temperature is $< 18^\circ\text{C}$ and h where the mean annual temperature is $\geq 18^\circ\text{C}$. In the C and D climates, a third letter is used to distinguish on the basis of seasonal temperature distribution. In each case, the letters a, b, and c are used to indicate hot summer, warm summer, and cold summer, respectively, and

in the case of the D climates, the letter d is used to indicate areas with very cold winters.

The most recent world map based on Köppen's classification, shown in Figure 1, was compiled using the rules set out in Table 1. The percentage of the world's land surface occupied by each main climate type is shown in Table 2. In theory, there are 30 climate types possible using this system; however, the Csc climate does not occur anywhere, and the Cwc type occupies only 0.002% of the land area.

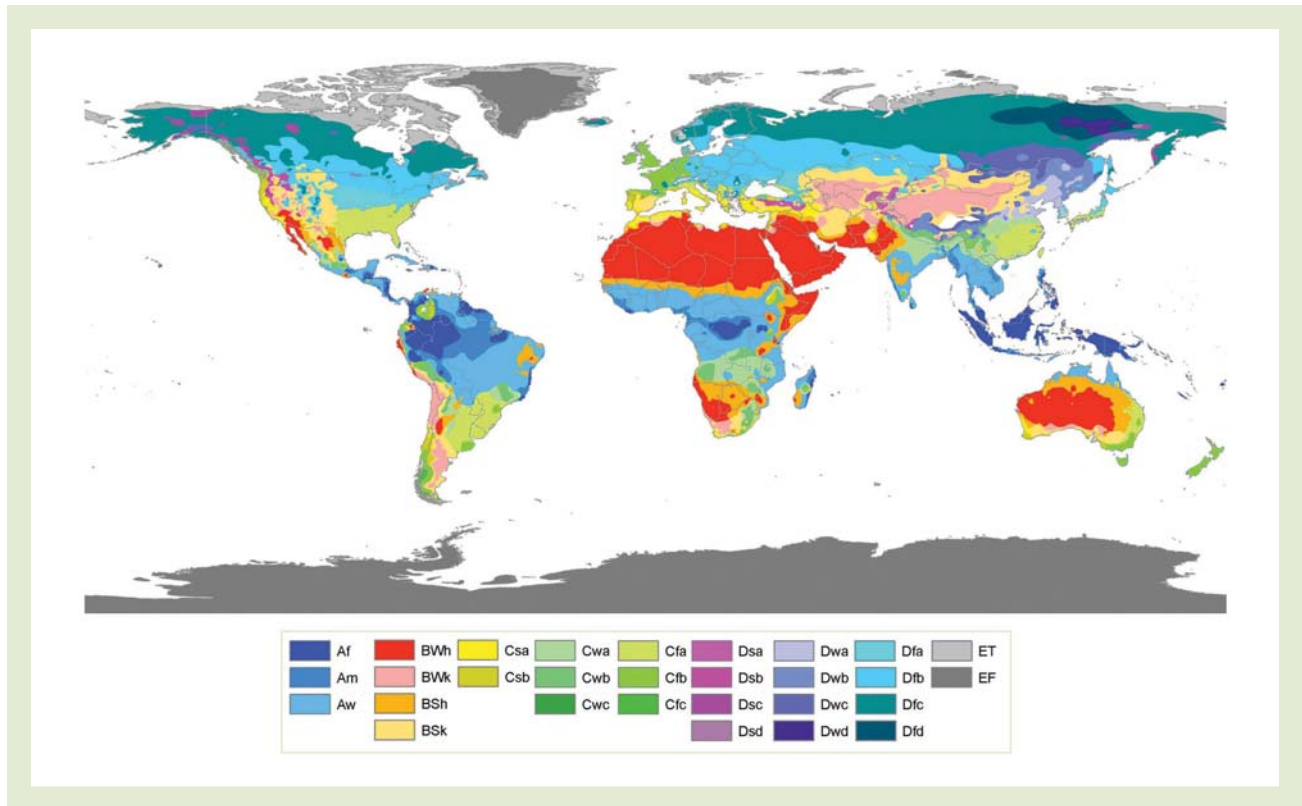


Figure 1 World climate map based on the Köppen-Geiger climate classification

Source: Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11, 1633–1644. Reprinted with permission.

Climate type	A	B	C	D	E
Land area (%)	19	30.2	13.4	24.6	12.8

Table 2 Percentage of the world's land area occupied by each of the main climate types

Source: Based on Peel, M. C., Finlayson, B. L., & McMahon, T. A. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11, 1633–1644.

Following the publication of Köppen's classification in 1918, there was a long and vigorous debate in the literature over the details of the various categories and also about the basic principles. Köppen developed his classification at a time when there were relatively few data available with which to map the world and no electronic tools to assist in analysis and mapping. It is therefore somewhat surprising that new global climate classifications produced using modern databases and computer resources

have not appeared to replace the Köppen-Geiger classification.

Both research scientists and teachers continue to use the Köppen system almost exclusively, and there have recently been two new world maps of climate using the Köppen-Geiger classification, drawn using large computer databases and sophisticated analytical methods (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006; Peel, Finlayson, & McMahon, 2007). Arthur Wilcock seems to have been correct when he said in his 1968 paper,



If, on the other hand, one is convinced that there are in principle strict limits to what can be achieved by any simple classification, one may consider it profitless to seek minor improvements at the cost of confusion. (p. 13)

Brian L. Finlayson

See also **Air Masses; Atmospheric Circulation; Biota and Climate; Climate Types; Climatology; Köppen, Wladimir**

Further Readings

- Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen-Geiger climate classification updated. *Meteorol. Zeitschr*, 15(3), 259–263.
- Peel, M., Finlayson, B., & McMahon, T. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences*, 11, 1633–1644.
- Sanderson, M. (1999). The classification of climates from Pythagoras to Koeppen. *Bulletin of the American Meteorological Society*, 80, 669–673.
- Wilcock, A. (1968). Köppen after fifty years. *Annals of the Association of American Geographers*, 58(1), 12–28.



KROPOTKIN, PETER (1842–1921)

Peter (Pyotr) Alexeyevich Kropotkin was a leading Russian anarchist, social philosopher, explorer, and geographer. He was born and died in the Moscow region, but he traveled very widely and spent half his life in exile. As a prince in a noble family, Kropotkin was selected by Tsar Nicholas I to study in the elite Corps of Pages, a military academy for courtiers. On graduation from the Corps, bored with military science and increasingly disillusioned with the extravagance and pettiness of the Court, he volunteered to serve as an army officer in Siberia and spent 9 years exploring the region, initially as a soldier and later as a civil servant working with the Russian Geographical Society. Subsequently, he wrote extensively about

the physiography of Asia, the desiccation of extensive regions, and postglacial climatic change.

Despite his noble birth, from the age of 12 onward Kropotkin avoided using his title of prince and showed great admiration for the hard work, skills, and moral values of the common people. In European Russia, he observed the suffering of the peasants and the continuing exploitation of workers, even after the abolition of serfdom in 1861. He documented the brutal conditions endured by prisoners, peasants, and miners in Siberia; developed a passionate interest in anarchism, socialism, and communism; and read avidly about the triumphs and eventual annihilation of the Paris Commune. In 1872, he made a 3-month trip to visit the International Workingmen's Association in Switzerland and learn more about Western European experiences of revolution and social transformation. Returning to Russia, he helped build the fledgling anarchist communist movement until he was arrested and imprisoned. He escaped in 1876 and fled to England, where he spent most of the next 40 years, intermingled with shorter periods in France and Switzerland and an 1897 visit to North America. In May 1917, he returned to Russia, but he was soon marginalized by the October Revolution and Lenin's emphasis on tightly controlling political power.

Kropotkin's primary contribution to geography is his vision of an alternative future—decentralized, dispersed, integrated, and powered by renewable sources of electrical energy—and a new geography to counter the capitalist vision of globalized markets based on free trade and comparative advantage. He rejected the exploitation and alienation of labor associated with capitalist mass production, the environmental destruction associated with large-scale urbanization and the heavy use of fossil fuels and artificial fertilizers, and the enormous waste of energy associated with globalized commodity trading. Instead, he advocated the integration of manual and intellectual labor in villages and small towns, with a mixture of agriculture, handicrafts, and small industries. Local territories would be self-governing, cooperatively organized and moderately self-reliant, and loosely federated with neighboring communities and engaging in interregional trade. As well as contributing to the anarchist cause and critiques of capitalist globalization and Soviet authoritarianism,



his work strengthened the Arts and Crafts Movement and helped inspire the movements advocating garden cities, organic farming, community food security, appropriate technology, and bioregionalism. Kropotkin's close intellectual contacts included Élisée Reclus, Patrick Geddes, Ebenezer Howard, and William Morris.

Ray Bromley

See also **Anarchism and Geography**; Reclus, Élisée; Russian Geographical Society

Further Readings

Kropotkin, P. (1899). *Fields, factories and workshops*. London: Hutchinson.

Kropotkin, P. (1902). *Mutual aid*. London: Heinemann.

Woodcock, G., & Avakumović, I. (1950). *The anarchist prince*. London: Boardman.

KRUMMHOLZ

Krummholz, the crooked trees that are battered and stunted by harsh microclimates, exist at the upper edge of tree growth in mountains. Their name is derived from the German term for crooked or twisted wood. These krummholz, or elfin wood, suffer strong winds, low temperatures, intense radiation, and short growing seasons, and thus they become deformed. The geography of krummholz provides clues about microclimates, species' distributions, water supplies, and climate change.

Most krummholz are evergreen trees, such as the Engelmann spruce (*Picea engelmannii*); however, occasionally, deciduous trees, such as the quaking aspen (*Populus tremuloides*), will have a stunted form. In some areas (e.g., the European Alps), the dwarfed and crooked krummholz forms are genetically induced. In other areas (e.g., North America), the krummholz forms are considered



An ecotone of krummholz

Source: Author.



The windward growth of the flag krummbol becomes battered.

Source: Author.

to be caused by microclimatic factors that have acted on the tree during its lifetime.

Krummbol extend from the upper edge of a noncrooked, dense forest, through a transitional zone or ecotone of increasingly crooked trees, to the treeless tundra (see first photo). Often, the ecotone appears as a belt of krummbol, paralleling the contours of a slope. The belt might be quite wide on a leeward slope, where strong, downslope winds, moving first across the tundra and carrying ice and rock particles, blast into the trees. In contrast, winds moving upslope through a forest will cause little deformation because they tend to move slower and be less abrasive.

A variety of factors affect the type and degree of stunting that occur in krummbol. Short and cool growing seasons may prevent maturation and acclimatization of tree tissues to be prepared for winter extremes. Immature tissues may not limit water loss to the dry atmosphere

through the waxy coverings or cuticles of their needles. If krummbol are not protected by snow cover during winter, they are exposed to wind-driven ice and rock crystals that can pit the tissues and accelerate evaporation. Without insulating snow cover, soil water can freeze, preventing roots from uptaking water. Intense ultraviolet radiation, especially at high elevations, can damage exposed tissues. In all these cases, the growth tissues can be killed and may fall off the tree, leaving it weakened and in a crooked and stunted form.

Forms of Krummbol

Although the forms of krummbol can be quite varied (they are as diverse as the diversity of their harsh microclimates), three forms can typically be found. The first form, the flag krummbol, is found just upslope from the symmetrical,



noncrooked trees of the dense forest. This tree is shorter in height than the forest trees, and its upper trunk has a flag form, with growth primarily on the leeward side (see second photo). During winter, ice crystals and rock particles can be bounced along the snowpack by winds and driven into the krummholz, damaging the trees' windward, exposed tissues.

The second form, the flag mat krummholz, exists upslope from the flag. Here, the winds have increased. The trunk is dwarfed, crooked, and flagged with only leeward growth (see third photo). The form includes a prostrate mat that survives beneath the winter snow. The flag mat krummholz are often widely spaced, and winds erode snow from between the trees and deposit it onto the downwind trees. This snow deposit protects parts of the krummholz from damaging winds, provides a layer of insulation against extreme air temperatures, insulates the soil, and provides protection from intense radiation.

The third krummholz form is only a prostrate mat, with no flagged, upright trunk (see fourth photo). This krummholz survives close to the ground surface, where it is most protected from the winds of the nearby tundra. These mats are often asymmetrical, with an apex-oriented upwind. Strong winds erode snow from the mat's apex, exposing it to a battering by rock and ice crystals, to low temperatures, and to intense radiation. This upwind part of the mat is also a snow fence, causing winds to deposit entrained snow on the downwind portion of the mat, insulating and protecting it. The mat survives in a larger and wider form, downwind, in response to this protection. Most mat tissues exposed above the winter snow pack are killed.

The Importance of Krummholz

Krummholz provide a great deal of information about their environment. They indicate the presence of low air temperatures, intense shortwave



The flag mat krummholz has a deformed trunk and a mat that survives when buried by snow.

Source: Author.

radiation, strong winds, frozen soils, and a short growing season. Their various forms indicate varying wind speeds, snowpack depths, growing season lengths, and both summer and winter temperatures. Snowdrifts, collecting within and downwind of krummholz, contribute meltwater to streams and lakes, long after snow packs in the forest have melted. Krummholz offer thermal cover and visual protection for animals. They provide perches for birds. Winds in the krummholz ecotone help keep mammals more insect-free during the summer months. The krummholz ecotone, with both forest and tundra plants and animals, can be seasonally biologically diverse. From tree rings, summer air temperatures can be reconstructed for the krummholz. Often, krummholz will be quite long-lived, yielding a long record.



The mat krummholz is prostrate and protected by winter snow.

Source: Author.

Finally, krummholz offer a never-ending number of unique forms that are both pleasing and perplexing to the human eye and psyche, as krummholz exist on the edge.

Kathy Hansen Crawford

See also **Biogeography**; **Biome: Boreal Forest**; **Biome: Tundra**; **Biota and Climate**; **Climate: Mountain**; **Ecotone**

Further Readings

- Hansen-Bristow, K. J. (1981). *Environmental controls influencing the altitude and form of the forest-tundra ecotone: Colorado Front Range*. Doctoral dissertation, Geography Department, University of Colorado, Boulder.
- Hansen-Bristow, K. J., & Ives, J. (1984). Changes in the forest-tundra ecotone: Colorado Front Range. *Physical Geography*, 5(2), 186–197.

MacDonald, G. (2003). *Biogeography: Space, time, and life*. New York: Wiley.

Price, L. (1981). *Mountains and man: A study of process and environment*. Berkeley: University of California Press.



KUHN, WERNER (1957–)

Werner Kuhn is Professor of Geoinformatics at the University of Münster (Germany) and has been among the most active researchers in geographic information science (GIScience) for many years. Until recently, his main research interest was the semantics of spatial information, which he studies in the context of usability of geospatial data and services. He has developed several ideas and methods, including the algebraic description of semantic properties and their mappings, the derivation of ontologies from texts, and the notion of semantic



reference systems. Apart from this core subject, Werner Kuhn has carried out research in various other fields, such as visualization, engineering of geosoftware, and especially issues related to spatial cognition. Kuhn has produced a long list of internationally respected publications in scientifically leading journals, books, and proceedings.

Kuhn studied geodesy at ETH Zurich and received a diploma in surveying engineering in 1982. At ETH's Institute of Geodesy and Photogrammetry he received his PhD in 1989, with a thesis on human interaction with geographic information systems (GIS). In 1989, he was a postdoctoral research assistant at the National Center for Geographic Information and Analysis (NCGIA), department of surveying engineering, University of Maine. From 1991 to 1996, he held a position as research associate in the department of geoinformation at Vienna University of Technology, Austria. In 1995, he finished his dissertation on the semantics of geospatial information and received the *venia docendi* in GIScience from the Vienna University of Technology.

Based on his broad experience in an international context, Kuhn became a professor of geoinformatics at the Institute for Geoinformatics, University of Muenster, Germany, in 1996. Since 2003, he has held a full professorship at this institute, which was the first of its kind in Germany and introduced the first curriculum in geoinformatics as an independent subject in Europe in 1999.

Although Kuhn's early work was primarily on topological data structures and user interfaces, he turned increasingly to problems of usability of geoinformation, mainly in relationship with theories of spatial behavior, before refocusing his research group at Münster on the challenge of semantic interoperability. For this purpose, he founded MUSIL (the Muenster Semantic Interoperability Lab) in 2002. Broader areas of interest and scientific contributions are computer languages, thematic mapping, human-computer interaction, metaphors, blendings, and semantic translation.

Kuhn is an initiator of the Conference of Spatial Information Theory (COSIT) meetings, which deal with the theoretical foundations of spatial sciences and geoinformation technology. He works with colleagues who create basic theories and methods to deal with the geometric, topological, and semantic aspects of spatial information—for

example, Max Egenhofer, Barry Smith, David Mark, Andrew Frank, and others. Through these collaborations, Kuhn has become one of the main contributors to the theoretical and methodological foundations of geographical information science. Apart from the basic scientific work, he is involved in important developments that concern practical issues of geoinformation. For example, he contributed to different working groups in the Open Geospatial Consortium, served as Technical Director Europe for this organization, and has worked closely with various institutions in public administration and industry. He was also one of the founders of the Association of Geographic Information Laboratories in Europe (AGILE) and has chaired and co-organized important international conferences such as COSIT, GIScience, and AGILE.

Hardy Pundt

See also **GIScience; GIS Design; Map Visualization; Ontological Foundations of Geographic Data; Semantic Interoperability; Semantic Reference Systems; Topological Relationships**

Further Readings

- Brox, C., Bishr, Y., Senkler, K., Zens, K., & Kuhn, W. (2002). Toward a geospatial data infrastructure for North Rhine-Westfalia. *Computers, Environment and Urban Systems*, 26(1), 19–37.
- Harvey, F., Kuhn, W., Pundt, H., Bishr, Y., & Riedemann, C. (1999). Semantic interoperability: A central issue for sharing geographic information. *Annals of Regional Science*, 33(2), 213–232.
- Kuhn, W. (1997). Approaching the issue of information loss in geographic data transfers. *Geographical Systems*, 4(3), 261–276.
- Kuhn, W. (2001). Ontologies in support of activities in geographical space. *International Journal of Geographical Information Science*, 15(7), 613–631.
- Kuhn, W. (2003). Semantic reference systems. *International Journal of Geographical Information Science*, 17(5), 405–409.
- Kuhn, W. (2005). Geospatial semantics: Why, of what, and how? *Journal on Data Semantics*, 3534, 1–24.



KWAN, MEI-PO (1962–)

Mei-Po Kwan is distinguished professor of social and behavioral sciences in the department of geography at Ohio State University. She is primarily associated with the fields of geographic information systems (GIS) and urban, economic, transport, and health geography.

Kwan received a PhD in geography from the University of California at Santa Barbara in 1994. She is editor of the Methods, Models and GIS section of the *Annals of the Association of American Geographers* and has received numerous honors and awards, including the prestigious UCGIS Research Award from the University Consortium for Geographic Information Science and the Edward L. Ullman Award from the Transportation Geography Specialty Group of the Association of American Geographers.

She is an internationally recognized leader in developing and implementing GIS-based methods in research involving individual-level data (both quantitative and qualitative), three-dimensional (3D) geovisualization, geocomputation, and feminist perspectives. Her varied research programs have addressed fundamental questions about geographic methods and have influenced the development of several areas in geographic information science (GIScience) in important ways. Her work has made substantial and broad contributions to the development of innovative geographic methods, including geocomputational algorithms for implementing space-time accessibility measures that are sensitive to individual differences, 3D interactive geovisualization of complex human activity travel data, qualitative GIS and narrative analysis, the use of GIS for articulating people's emotional geographies and as an artistic medium, network-based 3D topological data models, GIS-based intelligent emergency response systems, and protection of geoprivacy through geographic masking.

Her work has focused on individuals' daily lives and the differences that gender, race, and religion can make on their experiences, mobility, and opportunities. She was the first to implement the time-geographic approach with innovative GIS-based methods on large data sets. Using geocomputation and 3D geovisualization, her work has

documented gender differences in individual accessibility that cannot be detected with conventional integral measures of accessibility or statistical approaches. This work has been expanded to take into account the impacts of information and communication technologies on people's daily activity patterns. This work has also led her to a critical engagement with feminist research methods and an ongoing process of reconciling GIS, critical geographies, and qualitative methodologies.

Joe Weber

See also **Accessibility; Critical GIS; Feminist Geographies; GIS Implementation; GIS in Transportation; Humanistic GIScience; Three-Dimensional Data Models; Time-Geography; Transportation Geography**

Further Readings

- Kwan, M.-P. (1998). Space-time and integral measures of individual accessibility: A comparative analysis using a point-based framework. *Geographical Analysis*, 30, 191–216.
- Kwan, M.-P. (2000). Human extensibility and individual hybrid-accessibility in space-time: A multi-scale representation using GIS. In D. Janelle & D. Hodge (Eds.), *Information, place, and cyberspace: Issues in accessibility* (pp. 241–256). Berlin, Germany: Springer-Verlag.
- Kwan, M.-P. (2002). Feminist visualization: Re-envisioning GIS as a method in feminist geographic research. *Annals of the Association of American Geographers*, 92, 645–661.
- Kwan, M.-P. (2008). From oral histories to visual narratives: Re-presenting the post-September 11 experiences of the Muslim women in the United States. *Social and Cultural Geography*, 9, 653–669.
- Kwan, M.-P., & Guoxiang, D. (2008). Geo-narrative: Extending geographic information systems for narrative analysis in qualitative and mixed-method research. *The Professional Geographer*, 60, 443–465.



KYOTO PROTOCOL

See Climate Policy



LABOR, GEOGRAPHY OF

Studying how people reproduce themselves materially in different places has been and remains a major preoccupation of geographical inquiry. What people do to “make a living” varies greatly across noncapitalist and capitalist economies. Economic geographers studying capitalist economies have traditionally privileged the role that capital and its institutions play in shaping the economic landscape. Labor, too simply defined as physical work done for wages, has often been reduced to a factor of production purchased along with equipment and materials to produce new commodities. Although labor quickly became the primary location factor explored by researchers, it was not considered an active agent in the transformation of economic landscapes. In the mid 1990s, however, there were calls to consider labor as an active agent shaping economic space. Most significant was Andrew Herod’s call for a new labor geography, defined as a radical approach that interprets economic space as actively produced by workers as they socially and materially reproduce themselves within systems of capitalist accumulation (although labor geographies also exist in noncapitalist societies). Since then, labor geography has emerged as a significant project within the subdiscipline of economic geography. Still, in its relative infancy, no single analytical framework has come to define or dominate labor geography as the project continues to expand and

engage in broad intellectual debates within geography and with other social sciences.

Historical Roots

There is a long intellectual history leading to the placement of labor at the center of geographical analysis. Early-20th-century geography’s dark flirtation with environmental determinism linked the ability to engage in productive work to climatic conditions. Later, rich descriptions of how people struggle to reproduce themselves by altering and adapting to their environments were central to traditional regional geography. The post–World War II quantitative revolution ushered in a scientific paradigm that attempted to mathematically model location decisions of firms by reducing labor to one of several least-cost variables; in this view, labor was not substantively different from other inputs such as land or capital.

In the 1970s, classical location theory was challenged by a new generation of radical geographers influenced by theoretical Marxism and the political events of the 1960s. These radical scholars were dissatisfied with the theoretical limits of quantitative models based in neoclassical economics. Critiques of traditional location theory challenged the abstraction of firms and workers to mere variables and argued that any discussion of the location of production must consider adversarial relations within broader capitalist processes (e.g., the labor process and



Textile industry strike in Lawrence, Massachusetts (1912)

Source: Library of Congress, LC-USZ62-98168.

industrial restructuring). Throughout the 1980s, the new conceptual position increasingly centered the labor process in analytical frameworks examining local labor market formation and patterns of (dis)investment. Local labor militancy in the face of industrial transformation was traced to the legacies of previous “layers of investment” and past struggles with capital. Discussions of regional economic restructuring at the national scale (e.g., shifts in investment from the Rust Belt to the Sunbelt in the United States) or the global scale (e.g., the rise of export processing zones) were largely in terms of the “capitalist imperative” to locate or create increasingly flexible labor markets as a response to falling rates of profit. While industrial conflict and the emergence of new labor processes became central to economic geography, explanatory accounts still remained very much focused on the power of capital to restructure economies.

Contemporary Labor Geography

The continued marginalization of workers and their institutions (e.g., trade unions) in theories of

capitalist development throughout the 1980s was perhaps to be expected. In many advanced capitalist economies, a prolonged period of neoliberal economic restructuring (in varied Reaganite and Thatcherist versions) forced organized labor into relative retreat. The evidence strongly suggested that unions were unable to improve the economic well-being of workers facing extensive labor market deregulation and deindustrialization. Instead, researchers focused on mapping and debating the primary causes of trade union decline. Yet there were a select number of studies in the late 1980s and early 1990s that began to identify how labor was responding to economic change and how such actions both enabled and challenged capital in specific locations.

In the mid 1990s, Herod was the first geographer to advocate an approach that would interpret economic landscapes from the perspective of working people, a view that noted that capitalist space is actively produced by workers and their institutions as well as by firms. The key geographical difference between capital and labor is that workers reproduce themselves in situ, while more



Congress of Industrial Organizations picketers jeering at workers who were entering a mill in Greensboro, Greene County, Georgia, 1941

Source: Library of Congress, LC-DIG-fsa-8a35773.

mobile capital is able to reproduce itself throughout the space economy. Workers are therefore forced to organize not only within specific places but across space as well. A common example cited by early labor geographers is the existence of “master collective agreements” that remove wages and working conditions from competition over large jurisdictions. Some contracts negotiated at national or even international scales influence investment decisions and regulate capital’s ability to exploit uneven economic development. The challenge, or what others have termed the *geographical dilemma*, facing workers is that there is a constant tension between workers in superior bargaining positions with capital and those with less power who are forced to undermine the “pattern” by lowering wages to attract capital to their communities. As a result, organized labor is most often limited to producing a local scale of action.

The social production of scale continues to preoccupy labor geographers, but there are subtle theoretical differences in its conceptualization and practice. Herod’s initial interest in the “scale appropriateness” of labor strategy reflects the work and influence of Neil Smith. Worker actions against capital take place at numerous scales, ranging from the microlevel (e.g., dissent through the manipulation of personal appearance or dress code), the workplace (e.g., seeking union certification), and the local (e.g., partnerships that cross class lines to attract investment) to the national (e.g., union bargaining with a large employer) and the international (e.g., the formation of union alliances across national boundaries to challenge transnational firms). Workers and their institutions will lean toward workplace, local, national, or international scales of mobilization depending on the time- and place-specific contexts.



Other labor geographers view worker organization as multiscale. Successful campaigns against capital involve simultaneous mobilization at multiple scales where workplace, community, national, and international efforts reinforce one another. For some, adopting the multiscale view still privileges labor internationalism as the most significant scale, despite the “geographical dilemma” limiting international worker solidarity (especially between workers in the global North and the global South). Other labor geographers, however, view different scales of action as nonhierarchical in nature, such as when campaigns require both local and national/international participation and call for frameworks that understand labor action as constituted by complex, interdependent relationships among workers and communities.

Apart from the scalar preoccupations of much of labor geography, there are other contributions to important debates and issues by those interested in excising the agency of workers. Specifically, there is an attempt to highlight how working people engage with social space in ways that shape their lives beyond the immediate workplace. Linda McDowell’s examination of shifting gender and race relations in postindustrial workplaces and labor markets identifies how workers are implicated in reproducing inequality. Community unions—coalitions among labor and non-labor groups for a common struggle—have also been researched by labor geographers as a means of extending the scope of study beyond immediate workplace issues. Extending the inquiry of labor geography beyond the workplace to investigate the entirety of workers’ lives will be an important future consideration for researchers.

The Future of Labor Geography

More than a decade has passed since Herod’s initial call, and although the labor geography project is still relatively new to the confines of economic geography, there has been some recent reflection on its future. Among the concerns raised are the need to extend the project to mainstream industrial relations and labor studies, questions surrounding the theorization of worker agency, and the limited empirical focus of early studies.

There have been calls to extend the conceptual tools used by labor geographers, such as the rich

theoretical understanding of the production of scale, to industrial relations. Labor geographers have engaged in broader labor studies for some time and continue to make theoretical and political contributions to labor union renewal, an extensive body of literature and practices in Anglophonic contexts. The call for multiscale approaches to organizing campaigns is very much part of this project. Discovering how new (largely urban) local initiatives such as the Justice for Janitors campaign organizing cleaners in the United States can be supported and extended to the global scale is one relevant example. Labor geographers can make normative analytical and political contributions by assessing and designing organizing strategy and public policy.

A second concern is the relatively unproblematic conceptualization of “agency” exercised by workers as they shape economic landscapes. Labor geography research is abundantly centered on advanced capitalist labor markets, as less study is focused on the global South. The concentration on established unions in mature industrial relations systems may not accurately capture the growing power asymmetries that exist between capital and workers in unorganized service sectors, immigrant labor markets, and poor economies.

Indeed, to make the labor geography project relevant for the 21st century, several new directions need to be developed. For example, some argue that labor geography may have to revisit the work of feminist geographers and seriously explore how unpaid labor shapes the economic landscape. Presently, researchers do consider the links between paid and unpaid work, but this is largely driven by the need to look more closely at the full lives of wage workers. An “unpaid labor geography” is needed that considers how social reproduction in the home and volunteering in the community shape economic space. In other words, labor geography must more fully engage with broader working-class studies, which see workers as more than “what they do to make a living” and explore the contributions workers make to political and cultural community life. Fortunately, several researchers are already beginning to strengthen labor geography by exploring these gaps in the existing research.

Steven Tufts



See also Class, Geography and; Deindustrialization; Economic Geography; Factors Affecting Location of Firms; Flexible Production; Industrialization; Marxism, Geography and; Massey, Doreen; Mitchell, Don; Radical Geography; Regulation Theory; Scale, Social Production of; Smith, Neil

Further Readings

- Castree, N. (2007). Labour geography: A work in progress. *International Journal of Urban and Regional Research*, 31, 853–862.
- Castree, N., Coe, N., Ward, K., & Samers, M. (2003). *Spaces of work: Global capitalism and the geographies of labour*. London: Sage.
- Herod, A. (1995). The practice of international labor solidarity and the geography of the global economy. *Economic Geography*, 71, 341–363.
- Herod, A. (1997). From a geography of labor to a labor geography: Labor's spatial fix and the geography of capitalism. *Antipode*, 29(1), 1–31.
- Herod, A. (2000). Implications of just-in-time production for union strategy: Lessons from the 1998 General Motors-United Auto Workers dispute. *Annals of the Association of American Geographers*, 90, 521–547.
- Herod, A. (2001). *Labor geographies: Workers and the landscapes of capitalism*. New York: Guilford Press.
- Massey, D. (1984). *Spatial divisions of labour: Social structures and the geography of production*. London: Macmillan.
- McDowell, L. (1997). *Capital culture*. Oxford, UK: Blackwell.
- Mitchell, D. (1996). *The lie of the land*. Minneapolis: University of Minnesota Press.
- Peck, J. (1992). Labor and agglomeration: Control and flexibility in local labor markets. *Economic Geography*, 68, 325–347.
- Storper, M., & Walker, R. (1989). *The capitalist imperative: Territory, technology and industrial growth*. New York: Blackwell.



LAND DEGRADATION

Land degradation is one of the most important global issues because it affects all parts of the world and, more significantly, has severe impacts on agronomic productivity, the environment, food security, and the quality of life. The term *land degradation* is a relatively new scientific description of an ancient environmental problem that has been in existence probably since humans began to use fire to modify landscapes. Essentially, land degradation refers to natural and/or anthropogenic processes that substantially decrease the utility or potential utility of the biophysical environment, sometimes leading to loss or change of features of the environment that cannot be replaced. In the context of utility, land degradation results whenever there is a mismatch between land quality and land use.

This entry first discusses the definition of land degradation and explores the distinction between its proximate and ultimate causes. Though the causes of land degradation are many, the underlying fact is that it is an outcome of the mismanagement of land, which involves two interlocking, complex systems: the natural ecosystem and the human social system. Any efforts aimed at mitigating or managing land degradation or resource management must consider interactions between the two systems that will determine their success or failure. Thus, before describing particular causes, the entry examines the nature of this interaction. The entry then discusses in some detail the impact of poverty and increasing population on land degradation.

Definition and Scope of Land Degradation

Land degradation is only one of many terms that have been used to describe the process of degradation of the biophysical environment; other common references include *degeneration of the soil*, *environmental deterioration*, *exhaustion of land*, and *desertification*. The latter is often used interchangeably with land degradation, although its more appropriate usage is strictly in reference to the process of environmental degeneration





<i>Continent</i>	<i>Total Area</i>	<i>Degraded Area^a</i>	<i>Degraded (%)</i>
Africa	14.326	10.458	73
Asia	18.814	13.417	71
Australia and the Pacific	7.012	3.759	54
Europe	1.456	0.943	65
North America	5.782	4.286	74
South America	4.207	3.058	73
Total	51.597	35.921	70

Table 1 Estimates of all degraded lands (in million square kilometers) in dry areas

Source: Dregne, H. E., & Chou, N. T. (1994). Global desertification dimensions and costs. In H. E. Dregne (Ed.), *Degradation and restoration of arid lands* (pp. 249–281). Lubbock: Texas Technical University Press. Reprinted with permission.

a. Comprises land and vegetation.

<i>Type of Degradation</i>	<i>Light</i>	<i>Moderate</i>	<i>Strong + Extreme</i>	<i>Total</i>
Water erosion	3.43	5.27	2.24	10.94
Wind erosion	2.69	2.54	0.26	5.49
Chemical degradation	0.93	1.03	0.43	2.39
Physical degradation	0.44	0.27	0.12	0.83

Table 2 Estimates of the global extent (in million square kilometers) of land degradation

Source: Oldeman, L. R. (1994). The global extent of land degradation. In D. J. Greenland & I. Szaboles (Eds.), *Land resilience and sustainable land use* (pp. 99–118). Wallingford, UK: CABI. Reprinted with permission.

that occurs particularly (but not exclusively) in the arid, semiarid, and dry subhumid areas, resulting from various climatic variations and human activities. For example, the semiarid to weakly arid areas of Africa are especially vulnerable to land degradation because they are characterized by fragile soils, localized high population densities, and a low-input form of agriculture.

A universally accepted definition of land degradation may not be possible considering the many factors thought to be responsible for it. Land is considered degraded when it suffers a loss of intrinsic qualities as a result of one causative factor, to be discussed in the next section, or a combination of natural and human forces that overrun natural regeneration and/or restorative management. That is,

Net land degradation = (Natural degrading process + Human interference) – (Natural reproduction + Restorative management).

Many scholars of the environment subscribe to the general view that land degradation can occur in any part of the world irrespective of its climate, topography, or environmental characteristics so long as human demands on the natural resource base coupled with natural forces reach certain critical thresholds. Indeed, all world regions suffer from some degree of land degradation (Tables 1 and 2) that not only threatens the local quality of life but in some cases actually threatens the viability of the affected areas. As shown in Table 1, about 70% of the dry land areas worldwide have been affected by land degradation, with Africa,

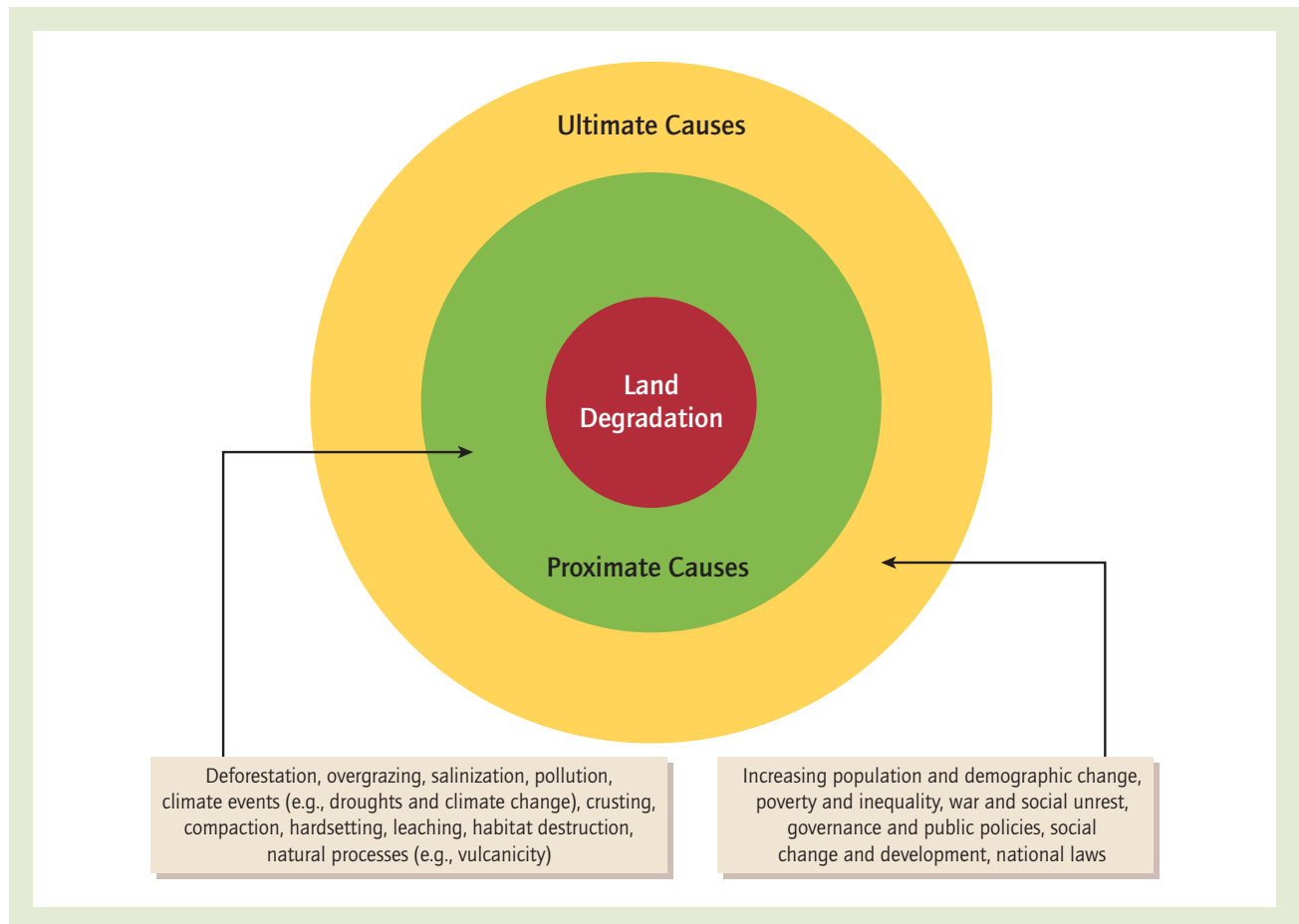


Figure 1 A schematic showing some of the proximate and ultimate causes of land degradation

Source: Author.

Asia, and the Americas having the highest percentages of degraded lands.

Causes and Processes of Land Degradation

Although land degradation has been variously attributed to “acts of God” or “acts of peasantry,” many researchers are in agreement that the problem is most widespread in environments that are exploited by humans; hence, human action takes the most blame. However, the main matrix of stability in most terrestrial environments that safeguards the land against degradation is the delicate set of reciprocal interactions between humans and factors of the biophysical environment, including climate, vegetation, soil, and topography. Any unilateral change in any

one of these components, without making the necessary adjustments for compensation so as to maintain the existing relationship, will undoubtedly result in degradation. Thus, humans alone are not responsible for land degradation. Virtually all environments from time to time suffer some kind of natural catastrophe that degrades land; some environments are especially fragile and highly susceptible to land degradation.

In most cases, it is possible to follow the processes of land degradation, but the cause(s), which could be proximate or ultimate in nature, are more complex. Figure 1 provides a schematic of some of the common causes of land degradation. The causes of land degradation are the agents that determine the rate of degradation. They could be biophysical (e.g., land use and



Picture of a severely degraded landscape due to soil erosion in the semiarid Baringo District of Kenya, East Africa

Source: Author.

land management, including deforestation and tillage methods), socioeconomic (e.g., land tenure), or political (e.g., political stability) forces that influence the effectiveness of the processes of land degradation. Proximate causes are those that are directly linked to the problem at the site of manifestation, while ultimate causes are the driving forces behind the proximate causes. Land degradation is often associated with a chain of causation that stretches away in time and space from the site of manifestation.

Understanding the cause(s) and processes of land degradation is key not only to limiting the consequences of the problem but also to its mitigation and management. Although it has long

been understood that land degradation is an environmental issue, its causes are more diverse and complex, and they cannot be explained solely by examining physical, climatic, chemical, and biological processes and their interaction. Historically, different societies have degraded their lands through one or a combination of the following processes: deforestation and habitat destruction, overgrazing, soil problems (erosion, acidification, salinization, crusting, compaction, hardsetting, leaching, and soil fertility losses), water management problems, overhunting, overfishing, the effects of introduced species, human population growth, increased per capita impact of people, and poverty (see photo).



Poverty

Poverty is an important factor that highlights the intricate complexity of these processes. It is rather obvious in many parts of the world that land degradation and economic growth, or the lack of it (poverty), are intractably linked. People living in the lower cadre of the poverty spiral are in a weak position to provide the stewardship necessary to sustain the land resource base, which in turn moves them further down the poverty spiral—setting a vicious cycle in motion. The extent of the damage inflicted on the land by any of these processes ultimately depends on environmental settings such as geology, topography, and climate, which are also regarded as natural processes of land degradation.

Increasing Population

Throughout the world, there is a diversity of environmental conditions ranging from areas with rugged topography, with dry climates and sparse vegetation cover, to areas of low relief and hot, humid climates with dense plant cover. These different environmental conditions in turn influence the soil types, the intensities of natural processes, and the stability and resilience of different terrains throughout the planet. Terrains with high potential for degradation, such as steep slopes or semiarid areas with sparse vegetation cover, are considered fragile and, therefore, highly susceptible to land degradation. In the fragile lands, energy properties (such as high relief and high rainfall or low relief and low rainfall) and materials interact with human activities to cause land degradation. The interaction is most detrimental to the natural environment where the population is high because of the enormous pressure on the natural resource base. Indeed, a rapidly growing human population is often considered the ultimate cause of land degradation; all the other causes associated with human action are only proximate causes.

Increasing population in different parts of the world is regarded as the ultimate cause of land degradation because people have been forced to adopt intensified means of agricultural production and to expand farming from prime lands onto marginal lands in order to feed their growing numbers. This observation is especially true for

poor, developing countries with fast-growing populations, where the vast majority of people are engaged in agriculture. In such countries, there is enormous pressure to increase agricultural land and to use land resources more intensively. This often results in the expansion of crop production and grazing resources onto erosion-prone landscapes such as steep hillsides, semiarid rangelands where rainfall is often unreliable and hence ill suited for continuous cropping, and semiarid and arid environments where irrigation must be used. People may also be forced to use marginal lands for reasons not directly related to increasing population, such as social unrest, monopolization of the better lands by landlords, or conversion of land into nature preserves and parks.

Exploitation of Marginal Lands

The exploitation of marginal lands results in short-term production gains that are not sustainable in the long term, resulting in severe land degradation and a decline in water supplies. Exploitation of marginal land is not necessarily a recipe for degradation—fluctuations in climate as well as changes in the availability of agricultural inputs and the outbreak of pests and diseases in these fragile landscapes expose them to the risk of degradation. Land degradation reinforces poverty, which in turn induces land degradation because poor people often opt for immediate benefits from the land, often at the expense of long-term sustainability. Although increasing human population often leads to agricultural intensification and land degradation, sometimes there are exceptional cases. For instance, in Machakos, Kenya, Mortimore, Tiffen, and Guchuki have shown that a fivefold increase in population between 1932 and 1990 resulted in better environmental management and increase in agricultural production rather than soil erosion and other forms of land degradation.

Deforestation

Population growth is often accompanied by deforestation, a term that includes processes such as loss of forest cover, woodland, and scrubland cover, which are directly linked to land degradation. Deforestation is one of the proximate causes of land degradation. The term *deforestation* is



often imprecisely used to imply quantitative loss of woody vegetation alone, yet there can also be qualitative degradation, for example, replacement of a species-rich tropical forest with a pine plantation or change to a regrowth (secondary) forest. In the tropical rain forest, the natural vegetation plays an important protective role by minimizing splash erosion, preventing the raindrops from compacting the soil, reducing runoff, and providing shade that maintains high levels of soil moisture. Deforestation in the rain forest removes the soil surface protection, thereby allowing sunlight to reach the soil. This can quickly raise the soil temperature and dry out the soil surface after a few rainless days, creating a thin, hard crust that encourages runoff and raises the potential for soil degradation. Forest degradation can alter local or regional hydrology or initiate changes in the local climate by making the climate drier due to an increase in surface water runoff and a decrease in net evapotranspiration.

Lawrence Morara Kiage

See also **Arid Topography; Climate: Dry; Desertification; Forest Degradation; Population and Land Degradation; Soil Degradation; Soil Erosion**

Further Readings

- Barrow, C. J. (1991). *Land degradation: Development and breakdown of terrestrial environments*. Cambridge, UK: Cambridge University Press.
- Blaikie, P., & Brookfield, H. (1987). *Land degradation and society*. London: Methuen.
- Dregne, H. E. (Ed.). (1994). *Degradation and restoration of arid lands*. Lubbock: Texas Tech University Press.
- Johnson, D. L., & Lewis, L. A. (2007). *Land degradation: Creation and destruction*. Lanham, MD: Rowman & Littlefield.
- Middleton, N., & Thomas, D. (Eds.). (1997). *World atlas of desertification* (2nd ed.). New York: Wiley.
- Tiffen, M., Mortimore, M., & Gichuki, F. (1994). *More people, less erosion: Environmental recovery in Kenya*. Chichester, UK: Wiley.



LANDFILLS

Landfills represent an engineered approach to the land disposal of wastes. In many countries, landfills are the primary means for managing municipal solid wastes and other wastes such as construction and demolition debris. Specially designed landfills are used for the disposal of hazardous and even radioactive wastes. Landfills represent an improvement over the open dumps they replaced and yet create serious problems of their own, including finding suitable sites, controlling leachate and gas emissions, and long-term care and monitoring.

Waste Management History

Humans have always faced waste disposal challenges, and our understanding of past societies owes much to the refuse piles they left behind. Historically, open dumps were the preferred means of refuse disposal and were simple in operation, if inelegant in practice. Dumps fostered problems with insects, rodents, odors, and water pollution. The first sanitary landfill in the United States opened in Fresno, California, in the 1930s and is listed on the National Register of Historic Places. It was innovative because wastes were compacted and covered with soil at the end of each day. After World War II, sanitary landfills became the accepted approach to solid waste disposal. However, sanitary landfills were hardly free of problems. For example, the Fresno Landfill was added to the National Priorities Superfund List by the U.S. Environmental Protection Agency (EPA) and has undergone an extensive cleanup designed to clean up contaminated groundwater and prevent migration of dangerous landfill gases. The Fresno Landfill was not unique—many of the U.S. Superfund sites are former dumps or landfills.

The 1976 Resource Conservation and Recovery Act (RCRA) promulgated stringent waste disposal standards. RCRA Subtitle C addresses hazardous wastes and gave the U.S. EPA primary authority to oversee the permitting of facilities for their treatment, storage, and disposal. Subtitle D provides minimum nationwide standards for the disposal of nonhazardous wastes, with regulatory programs administered by state authorities. RCRA



Hazardous waste and garbage mixture in Lowry Landfill, Colorado, 1978

Source: U.S. Geological Survey.

classifies wastes as hazardous and nonhazardous based on their origin and chemical characteristics. Nonhazardous wastes include both industrial wastes and municipal solid wastes. Municipal solid wastes are generated by households and businesses. Industrial wastes include construction and demolition debris, medical waste, and special wastes, which are large-volume wastes such as mining, crude oil, and natural gas wastes that were exempted from hazardous waste regulations. With its affluent, consumer lifestyles, in 2006, the United States generated 4.6 pounds per person of solid waste each day. While landfill disposal is prioritized below waste reduction, reuse, recycling, and incineration, it remains the most commonly used technique in the United States. Although incineration reduces the volume of wastes, it still produces significant quantities of ash to be landfilled. In many cases, landfilling is the least expensive alternative. In 2006, 41% of municipal solid waste in the United States was recycled or

composted, 13% was combusted for energy recovery, and 55% went directly to landfills.

Environmental Issues at Landfills

The long-term settlement of the landfill's contents and the stability of its slopes remains an ongoing concern after closure. Wastes inside a landfill undergo biological decomposition in a process that can take years or decades. As oxygen is depleted, anaerobic decomposition produces methane and carbon dioxide—both significant greenhouse gases. Landfill gas often contains explosive levels of methane as well as volatile organic compounds, such as the carcinogens benzene and vinyl chloride. Landfill gas is produced for many years after waste disposal has ceased and can migrate off-site. Liquids in the waste and infiltrating precipitation create landfill leachate, a potent pollutant much stronger than sewage and laden with leached organic and inorganic chemicals.



Landfill Design

Under RCRA, landfills are required to prevent groundwater contamination and control gaseous emissions. RCRA forbids the construction of landfills in floodplains, wetlands, and other unsuitable areas. Local and state regulations may further restrict acceptable locations. RCRA Subtitle D (for nonhazardous wastes) specifies that landfills must have a leachate collection system and a single-layer composite liner system. A composite liner consists of a synthetic geomembrane, typically of high-density polyethylene resting on a 2-foot layer of compacted clay. Atop the liner, a leachate collection system constructed of filter soil and gravel and perforated pipes collects and conveys the leachate to a treatment system. Daily cover may consist of soil or alternatives such as polymers, spray slurries, or synthetic fabrics. Other requirements for landfill operators include groundwater monitoring, landfill gas controls, final capping, and continued monitoring and care for 30 years after closure. In addition to the requirements for nonhazardous waste landfills, Subtitle C hazardous waste landfills must have a double liner with leak detection between the liners. To control greenhouse gas emissions and recover energy, some landfills generate electricity from recovered gases.

Landfill Siting

With the implementation of more rigorous design standards, the number of landfills has decreased dramatically, and the industry has undergone concentration. The number of landfills in the United States dropped from 7,924 in 1988 to 1,754 in 2006. One of the most significant problems for landfill disposal is that of finding an acceptable site. Suitable locations must meet physiographic criteria and be politically acceptable in the eyes of local or state permitting authorities, which inevitably encounter “not in my backyard” (NIMBY) activists. Given the politicization of locational decisions, landfill sites often reflect historic land use patterns and/or the geography of least political resistance—spatial analysis suggests that low-income or minority residents are overrepresented near solid waste and hazardous waste landfills. However, a landfill for polychlorinated biphenyl

(PCB)–contaminated soil in the poor, mostly African American, Warren County, North Carolina, resulted in a protracted but eventually successful community resistance campaign that was seminal in the environmental justice movement. Suggested solutions to locational conflict include greater use of geographic information systems, more participatory decision-making processes, and shifting responsibility back to industry.

Mark D. Bjelland

See also **Brownfields; Carcinogens; Environmental Impacts of Cities; Environmental Justice; Love Canal; Not in My Backyard (NIMBY); Recycling of Municipal Solid Waste; Urban Solid Waste Management; Waste Incineration**

Further Readings

- League of Women Voters. (1993). *The garbage primer*. New York: Lyons & Burford.
- Tammemagi, H. (1999). *The waste crisis: Landfills, incinerators, and the search for a sustainable future*. New York: Oxford University Press.



LANDFORMS

Landform is a generic term that describes the shape or form of a particular landscape. Landforms vary widely in shape and scale and are largely classified by the processes that lead to the development of each type of landform. In general, landforms are created by a combination of plate tectonics and erosion. Not only is plate tectonics responsible for producing mountains and volcanoes, but the apparent lack of tectonic activity can also lead to the formation of vast plains and low-relief landforms. No matter what the tectonic setting of a particular place may be, all landforms are directly shaped and influenced by erosion. It is the combination of the tectonic setting and the dominant type of erosion that leads to the primary classifications of landforms.

Classification of landforms is largely due to natural erosive processes, but humans have an



Nearly 370 ft. in diameter, Grand Prismatic Spring in Midway Geyser Basin is the largest hot spring in Yellowstone National Park and is considered to be the third largest in the world (New Zealand has the two largest springs). The Hayden Expedition in 1871 named this spring because of its beautiful coloration, and the artist Thomas Moran made water-color sketches depicting its rainbow-like colors. The colors begin with a deep blue center followed by a pale blue. Green algae forms beyond the shallow edge. Outside the scalloped rim, a band of yellow fades into orange. Red then marks the outer border.

Source: Mila Zinkova.

increasingly significant impact on the development and shape of the landscape. The most common natural processes develop landforms in coastal, glacial, fluvial (rivers), periglacial, *eolian* (also spelled *aeolian*), and karst areas. Landforms in all these settings are also greatly influenced by mass wasting processes such as rockfalls and landslides. Commonly, there is also a combination of processes, such as both physical and chemical weathering, that helps shape each type of landform. Also, the type of bedrock or surface material leads to the degree of resistance to erosion that each area displays. Examples of each major category of landforms are described as follows.

Volcanoes

An example of the complexity of landforms can be found in the processes that develop volcanoes and volcanic landforms. The tectonic setting determines the chemistry of the lavas and largely the shape of the ensuing volcano. Along colliding ocean plates or ocean and continental plate subduction zones, composite volcanoes are formed, which are often cone shaped and produced by a combination of variably explosive and flowing types of eruption. The classic example of the type of tectonic setting containing composite volcanoes can be found in the Cascade Range in the United States, with Mount St. Helens perhaps

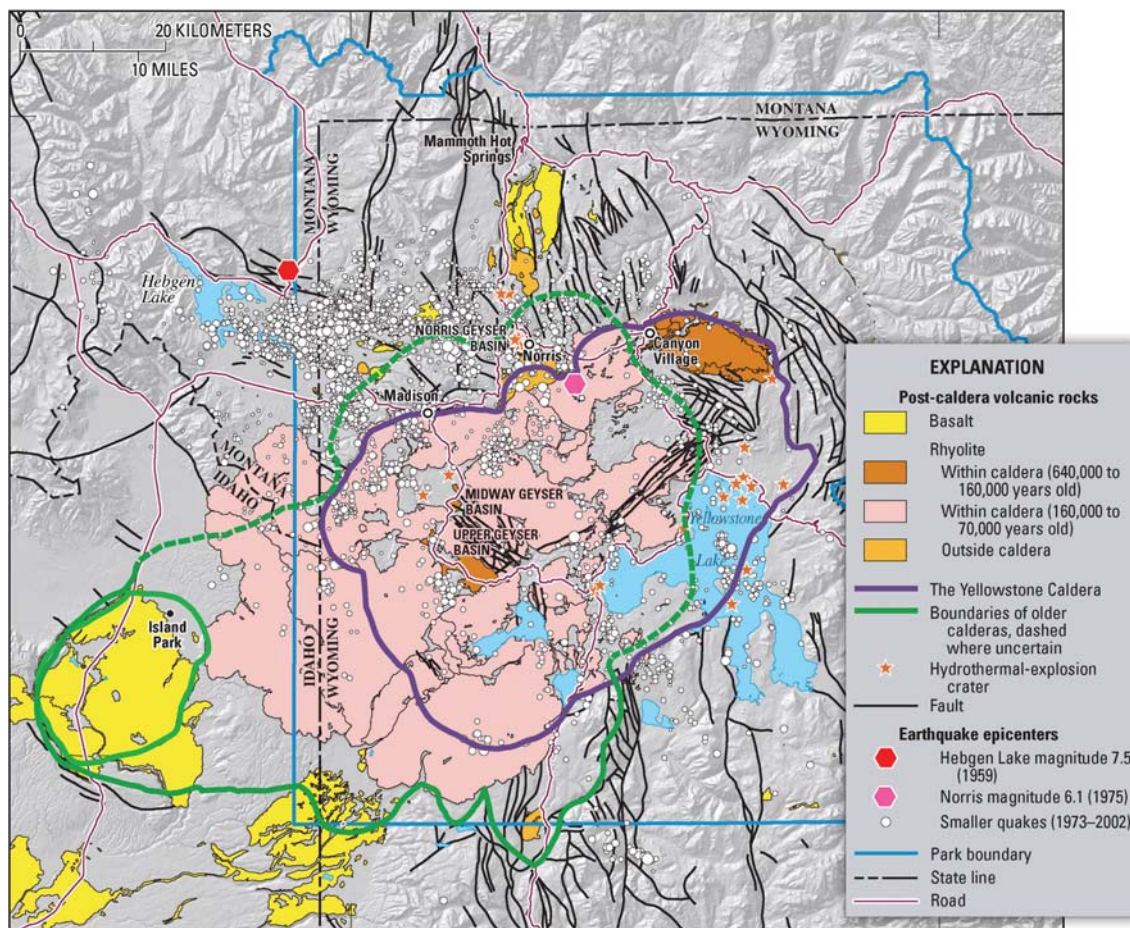


Figure 1 Map of the Yellowstone caldera

Source: U.S. Geological Survey.

being the most famous volcano. The chemistry of hot spot volcanoes, such as those found on the Big Island of Hawaii, is very different from that of composite volcanoes, and the flowing eruptions most often produce large, low-angled, shield-type volcanoes when the hot spot occurs within ocean plates. Hot spots that develop within continental plates can produce subtle volcanoes such as the Yellowstone (Figure 1) or the Long Valley Caldera in California. These landforms do not look like the classic volcano but are capable of producing tremendous climate-changing eruptions and large-scale landforms such as calderas and pyroclastic deposits that can cover large

areas. The chemistry of rift zone volcanism produces flowing eruptions, which often flow over and cover large swaths of land. An example of rift zone volcanics in the United States can be found within the large basalt flows of the Columbia River Basalt Province.

Once a landform is created, its location and size largely determine what types of erosive processes will continue to shape that landform. The Hawaiian island volcanic chain is largely shaped by a complex interaction of processes, including coastal, fluvial, and mass wasting activity. The Cascades are influenced by glacial, fluvial, and mass wasting processes, and the Columbia Basalts



are more heavily carved by fluvial erosion. The coastlines of the Hawaiian Islands are greatly influenced by wave action, which produces landforms similar to other emergent coastal locations. The slopes of the volcanoes are shaped by excessive amounts of rain water that concentrates in streams and through time carves the deep valleys that help make the islands famous. These fluvial processes are much more complex than elucidated here. For example, the porous nature of the volcanic bedrock allows water to flow subsurface from one drainage area to another. Through time, these preferential drainages are eroded into large, U-shaped valleys. These valleys are particularly prominent in the wetter areas of the older islands, such as Kauai, Oahu, and Molokai.

Mass wasting processes on the Hawaiian Islands also are complex and vary widely in spatial and temporal scales. For example, small-scale landslides are common in the steeper parts of the islands and are often induced by heavy rain. However, on occasion, very large landslides will slough off the sides of the islands with devastating results. These failures contain many cubic kilometers of material and are transported miles offshore. These landslides greatly reshape the islands, from the broad gentle slopes of the shield volcanoes to the steep, impressive coastlines that are present today. Fortunately, none of these large-scale mass wasting events has occurred in historic times.

Landform Formation and Sculpting Processes

Landforms can also be defined and described based on the formation processes (primarily tectonics) and sculpting processes (primarily erosion) that shape Earth's surface. The truly intricate interactions between these processes are too complex for this entry and in many cases are still poorly understood. Again, examples primarily from the United States will be used.

The landforms found along the Atlantic and Pacific coastlines of the United States are dramatically different. This is largely due to the differences in the tectonic setting. The tectonically active West Coast has a coastline that is emerging from the Pacific Ocean, and the landforms reflect the generally steep nature of the Pacific Coast. In contrast, the Atlantic Coast is tectonically passive, and the landforms along that coast reflect a

coastline that is slowly subsiding through time. Emergent coasts have characteristically steep cliffs that are shaped by wave action. Waves that strike the Pacific Coast are often larger due to the westerly wind direction and the great expanse of the Pacific. These waves carve the coast into landforms such as marine cliffs, sea arches, sea stacks, and wave cut platforms. Beaches along the Pacific Coast are often small (if they can be found at all) and are bounded by steep cliffs, making public access difficult. If tectonic uplift continues along the Pacific Coast, the wave cut platforms are often uplifted to become marine terraces. In California, these terraces can often be seen in series.

The Atlantic Coast of the United States is dominated by a low-angle coastline with characteristic broad sandy beaches, large estuaries, offshore barrier islands, and brackish-water sounds that separate the islands from the mainland. The beaches of the Atlantic coast characteristically have distinct features shaped by waves, currents, and wind. Beginning offshore and traveling inland, the beach features include longshore bars, longshore troughs, the beach, a wave cut berm, and backshore beach dunes deposited by waves and wind.

Landforms created by glaciers can largely be separated into those caused through erosion by glacial ice and those created by deposition of the eroded material. Again, the tectonic setting greatly influences the type of glacier and the landforms that develop. In tectonically active areas, primarily mountains, alpine or valley glaciers dominate, while in tectonically inactive areas, primarily plains, continental glaciers have the greatest influence. Landforms created by erosion vary greatly between alpine and continental glaciers. Alpine glaciers are responsible for creating much of the high mountain landscapes that people find so breathtaking and beautiful. Alpine glacial landforms are numerous and include arêtes, cols, cirques, horns, hanging valleys, truncated spurs, glacial troughs (the classic U-shaped glacial valleys—fjords if inundated by seawater), tarns, paternoster lakes, and roches moutonnées. Depositional landforms include terminal, lateral, recessional, and ground moraines; glacial erratic; and the features found within the outwash plain of the glaciers.

Continental glacial landforms are often more subdued because of the lower relief of the



landscape but also much larger in scale because of the continental size of the glaciers. Continental glaciers scoured the basins that now hold the Great Lakes of North America, with Lake Superior having the greatest surface area of any freshwater lake in the world. Other features, including kettle lakes and prairie potholes, are formed by a complex process of stagnant ice deposits, which create depressions in glacial debris that later fill with water as the ice melts. Depositional landforms created by continental ice include eskers, kames, drumlins, and a variety of moraine landforms: terminal, lateral, medial, recessional, and ground moraines. Some of these depositional features, such as the drumlin “Bunker Hill” in Boston, Massachusetts, have a very important influence on the history of the United States.

Landforms created by rivers are quite numerous and complex. Again, they can be related to tectonics in that high-relief fluvial landforms are distinctly different from those that develop on low-slope topography. High-relief landforms tend to be erosional, while low-relief landforms tend to be a combination of depositional and erosional landforms. Erosional processes remove material, while depositional processes produce landforms by depositing the material eroded upstream. As with most other landforms, fluvial landforms are dynamic. They often change rapidly, primarily during floods, thus possibly making them the most important landforms in terms of hazards to humans and their infrastructure. Streams and rivers produce distinct patterns on the land. The most common drainage pattern is the dendritic, with trellis, radial, and glacial also being fairly common. High- to moderate-relief fluvial landforms include ravines and canyons, which differ due to age and the volume of water creating the landform. These also often contain rapids and waterfalls created by the differing resistance of the underlying bedrock. Low-slope-angle landforms include the river channel or thalweg, levees, and floodplains. Low-slope rivers also will often meander, which creates point bar deposits, cut banks, and oxbow lakes. The tectonic setting and wave action will determine the type of landform that develops when the river enters the ocean. In oceans with mild wave action, deltas will develop, while in subsiding or sinking coasts, estuaries are a common feature.

Karst, Periglacial, and Eolian Landforms

Karst landforms are named for a region in Slovenia and involve landforms that develop in limestone. These landforms are numerous and often have duplicate names in a variety of languages. Caves are the most common karst features, with their attendant landforms stalactites, stalagmites, columns, draperies, and other dripstone formations. Other landforms include sinkholes, dolines, and tower karsts. The latter can be spectacular and are often the subject of artistic paintings and the background for movies.

Periglacial landforms are climatically driven. These develop in cold, dry climates and are primarily the result of freezing and thawing activity. In Arctic conditions, ice or sand wedges can develop, as well as pingos, solifluction lobes, and thermokarst if the permafrost melts and produces a basin filled with water. Other common landforms include sorted and unsorted patterned ground. These patterns can develop into circles, polygons, nets, and stripes depending on the increasing slope angle. Other landforms include felsenmeer (sea of rocks), and some authors include nivation hollows among the periglacial landforms.

Eolian landforms are landforms produced by wind. These landforms are largely depositional, with the exception of blowouts and yardangs, which involve the removal of material, and ventifacts, which are rocks and boulders that are scoured and shaped by blowing sand. Sand dunes are the most common type of eolian landform and include a variety of different types, including Barchan, parabolic, star, seif, and longitudinal dunes. Some of the most spectacular landscapes in North America, such as the Zion and Canyonlands National Parks, were produced when ancient sand dunes were buried, lithified, and subsequently reexposed by fluvial erosion.

The Role of Scale

The importance of scale was mentioned earlier in this entry. A thorough discussion of variations in scale (such as micro, meso, macro, mega) among all landforms is beyond the scope of this entry; however, a brief discussion of the complexities of scale and the concept of polygenetic processes will



Some of the most spectacular landscapes in North America, such as Canyonlands National Park, Utah, were produced when ancient sand dunes were buried, lithified, and subsequently reexposed by fluvial erosion.

Source: U.S. Geological Survey.

be instructive. Polygenetic processes involve different processes, for example, freeze-thaw versus wetting and drying, which produce similar looking landforms. Similarly, a single process, for example, freeze-thaw, can lead to completely different landforms. A good example of the combination of scale and polygenetic processes can be found within sorted periglacial patterned ground in midlatitude high-mountain environments such as the White Mountains of California. Above 3,900 m (meters), large-scale (macroscale) sorted polygons are relatively common. These polygons average around 5 m in width and are bordered by boulders weighing around 50 to 100 kg (kilograms). These landforms most likely developed in a permafrost environment and are no longer active in the present climate. However, contained within the central area of fines within the large-scale sorted borders are numerous active small-scale (mesoscale) sorted polygons. These 1- to 2-m

landforms are bordered by stones weighing 2 to 5 kg and are produced by yearly freeze-thaw cycles. Contained within the mesoscale polygons and expressed on the surface of the central area of fines are microscale polygons that develop sorted borders composed of gravel and pebbles. The production of microscale landforms is through a combination of diurnal needle ice processes and the wetting and drying of the soil. The drying process opens desiccation cracks and actively sorts the gravels. Each scale of these sorted polygons involves sorted patterns, but each is created by a combination of different (polygenetic) processes.

Anthropogenic Influences

Humans have become the dominant geomorphic agent on Earth, and human activity now moves more material than all the rivers, glaciers, wind, and oceans combined. Human landforms can be



subtle or quite visible from space. Subtle landscapes include enhanced levees, floodwalls, breakwaters, groins, jetties, and even the leveling of land for construction or, more important, agriculture. Flying over almost any landscape other than the oceans reveals a distinct and obvious human imprint on the land. Other human landforms are not as subtle. These include but are not limited to open pit mines, excavation pits for construction projects, and quarries. Human activity primarily affects our coasts, plains, and rivers, but it also affects glacial, periglacial, eolian, and karst landforms. For example, the development and placement of a road will affect numerous landforms and in many cases disrupt the natural landform-creating processes. Human activity will continue to shape the Earth, and human landforms will continue to be a dominant feature of Earth's landscapes, particularly in the lower to moderate latitudes.

Forrest D. Wilkerson

See also [Arid Topography](#); [Basin and Range Topography](#); [Biota and Topography](#); [Carbonation](#); [Caverns](#); [Coastal Erosion and Deposition](#); [Coral Reef Geomorphology](#); [Delta](#); [Diastrophism](#); [Faulting](#); [Folding](#); [Geomorphic Cycle](#); [Geomorphology](#); [Geothermal Features](#); [Glaciers: Continental](#); [Glaciers: Mountain](#); [Gully Erosion](#); [Hydrology](#); [Karst Topography](#); [Landslide](#); [Mass Wasting](#); [Periglacial Environments](#); [Permafrost](#); [Plate Tectonics](#); [Playas](#); [Rill Erosion](#); [Rivers](#); [Rock Weathering](#); [Soil Erosion](#); [Soils](#); [Volcanoes](#); [Wind Erosion](#)

Further Readings

- Brunsdon, D., & Thornes, J. S. (1979). Landscape sensitivity and change. *Transaction of the Institute of British Geographers*, 4, 463–484.
- Leopold, L., Wolman, M., & Miller, J. (1995). *Fluvial processes in geomorphology*. Mineola, NY: Dover.
- Schumm, S. A. (1998). *To interpret the Earth: Ten ways to be wrong*. Cambridge, UK: Cambridge University Press.
- Thorn, C. (1988). *Introduction to theoretical geomorphology*. New York: Springer.



LAND REFORM

Land reform entails the redistribution of private or public lands. Though it is often broadly associated with struggles for social justice, land reform is a somewhat amorphous term, embracing a huge range of practices and historical experiences in how land is identified and transferred (by force, legislation, or markets), the accompanying institutional and legal changes, and the ensuing property relations. Though many industrialized countries have highly unequal distributions of land, land reform is typically discussed in the context of the developing world.

Colonial Antecedents

The challenges and struggles associated with land reform have extensive historical roots in the colonial period. For the rural poor in developing countries, two of the most debilitating legacies of European colonialism were the establishment of uneven landscapes and commodity export-dependent economies, which went, and continue to go, hand in hand. In a broad sense, colonialism both magnified and hardened the inequalities where they already existed (in tributary or feudal societies) or established highly unequal distributions of land, for instance, as extensive export-oriented plantations took over the best agricultural land and as more successful small- and medium-scale farmers expanded within the increasingly competitive economic systems.

Most of the wealth generated by export commodities such as sugar, coffee, tea, palm oil, cocoa, cotton, and tobacco flowed back to Europe or was concentrated in the hands of a relatively small number of large farmers and merchants. At the same time, import dependence on a diverse range of manufactured goods and services became deeply entrenched. This position within international trading networks has proven to be extremely durable for the world's poorest nations, whose export structures are still predominantly based on a small number of mostly low-value commodities with often highly volatile prices in world markets.



Land Inequality

Land inequality is closely associated with poverty and hunger in many places. Land inequality also has a marked gendered character. On a global scale, according to the Food and Agriculture Organization (FAO) of the United Nations, women make up 51% of the total agricultural labor force, with especially high levels in the world's poorest countries, but almost everywhere, women's rates of land ownership pale in comparison with their contribution to agricultural production. Geographically, land inequalities are especially marked throughout most of Latin America, the Caribbean, and Southern Africa, as well as large parts of South Asia and East Africa. In Latin America and the Caribbean, the world's most inequitable region according to a recent United Nations report, 75% of the total agricultural population has access to only 10% of all arable land. At the extreme end of the spectrum, in nations such as Brazil, Guatemala, and Jamaica, a very small percentage of all landholders control more than half of all arable land—an inequality that is magnified by differences in land quality.

In short, the widespread persistence of land inequalities is one starting point for contextualizing challenges and debates associated with land reform. Another key starting point, related somewhat conversely, is the explosiveness of land inequalities in igniting social struggle. In the first half of the 20th century, land inequalities played a central role in inciting major revolutionary struggles in Mexico, Russia, and China, with different processes of land reform ensuing in each case. The land reform following the Chinese Revolution has been described as the largest appropriation and redistribution of property in world history, taking land away from a powerful nobility and transforming it into village collectives.

The Post–World War II Period

The powerful ideological and material implications of land reform were in plain view in the rapid process of decolonization that followed World War II. On the one hand, strong international laws were established to protect the private property relations wrought by colonialism. On the other hand, nearly half of humanity lived in countries

undertaking land reform in the late 1940s. In the subsequent decades, land reform was greatly influenced by escalating Cold War tensions.

While the idea of appropriating large holdings may have resonated strongly with many small farmers and landless workers, collectivization was often viewed with suspicion (if not outright fear) by small farmers. Small farmers were thus frequently seen as a potential bulwark against revolution. In some instances, this brought them little more than anticommunist propaganda, but in other instances, significant private property-based land reforms accompanied attempts to diffuse or keep revolutionary pressures out of the countryside.

For the West, land reform had special importance in East Asia after World War II, with fears of the peasant-led Chinese Revolution both most recent and most proximate. The United States had an important role in encouraging significant redistributive land reforms in Japan, South Korea, and Taiwan, with the hope of creating modest-sized capitalist farmers and mitigating more radical social pressures for transformation. These reforms, which were based on producing for domestic rather than export markets and were supported by things such as extension services, subsidized credit, and protective trade barriers, became widely cited as examples of how state-supported capitalist land reforms can generate significant gains in agricultural output, income distribution, and the diversification of rural economies.

The quick and notable successes of the East Asian land reforms emboldened the case for developmental states to facilitate some degree of redistributive land reform to the rural poor. In the eyes of Keynesian economists and planners, this held the prospect of multiple benefits: enhanced food access and employment and income generation for the poorest segments of rural society; more broadly distributed income, savings, and capital available for investment; and increased demand for farm inputs and nonfarm goods and services.

The 1970s

Prominent development economists began drawing attention to evidence of an inverse relationship between farm size and output per unit area



in the 1970s. That is, while yields might be greater on high-input monocultures, small- and medium-sized farms were found to be more productive per unit of land than large estates, even though large farms generally controlled the best-quality land and had greater access to inputs, irrigation, and credit. A key explanation was that small farms have more diverse and intensive cropping patterns than do large farms, made possible by greater labor intensity, as labor inputs generally drop off quickly as farm size expands.

Unfortunately, gender relations were a severely underappreciated dimension of land reform, and insufficient attention was given to how male-centered land titling processes regularly eroded the customary rights held by women, exacerbated the uneven household divisions of labor and decision-making power, and excluded the female heads of households. A detailed FAO report in 1995 described the dismal gender record in blunt terms, noting that they have rarely worked to women's benefit.

Barriers to Reform Emerge

While Keynesian development theorizing legitimized a private property-based and patriarchal form of land reform "from above," land reform also carried more radical connotations wherever land struggles were welling up "from below" against powerful landowning elites and the interests of foreign companies. This was especially true in Latin America. There, the U.S.-backed land reforms under the "Alliance for Progress" barely dented the region's famous "latifundia-minifundia" (large holder/small holder) divide, while land struggles from below became conflated with Cold War tensions, and the activists routinely found themselves pitted against not only large landholders but also authoritarian governments backed by external political and military support.

Another powerful barrier to land reform was the rise of the input-intensive techniques associated with the Green Revolution. The Green Revolution brought celebrated gains in yield and aggregate production, but it also became notorious for acting as a land reform in reverse, as many poor farmers took on unsustainable debt loads and ended up losing their land to an emerging

class of successful commercial farmers. The dynamics of dislocation and consolidation in countries such as India were also highly gendered.

Land reform was further debilitated by the onset of balance-of-payments crises and heavy levels of state indebtedness across much of the global South in the 1980s, which precipitated the policy prescriptions of the International Monetary Fund and World Bank, known as structural adjustment programs. According to the neoliberal economic logic of structural adjustment, export growth according to a nation's comparative advantage is necessary to resolve balance-of-payments problems, with distributional equity peripheral to macroeconomic growth. In agriculture, this meant that commodity production was encouraged either in the ruts carved by colonialism or in the new, "nontraditional" sectors, which tended to invigorate large-scale farms. At the same time, both ideological and fiscal pressures called for drastically reduced state support for small farmers, in realms such as extension, research, and marketing, while land reform was largely pushed off the policy agenda altogether amid the widening social inequalities associated with adjustment.

Rekindling of Land Struggles in the 1990s

Following the repression waged against land struggles, the land reform in reverse of the Green Revolution, and the policy dictates of structural adjustment, action on land reform reached a low point in the 1980s. However, since then there has been a resurgence of land struggles and rural social movements. The most prominent example of this resurgence is the Landless Workers' Movement (Movimento Sem Terra [MST]) in Brazil, which has taken land reform into its own hands within one of the world's most unequal agrarian landscapes, coordinating the occupation and cultivation of millions of hectares of unused or underused large holdings. Founded in 1985, MST is the largest social movement in Latin America, with an estimated 1.5 landless members. In addition to land reform, MST has established cooperative farms; constructed houses, schools for children and adults, and clinics; and promoted indigenous cultures, a healthy and sustainable environment, and gender equality. In Brazil, fewer



than 2% of landowners control 46.8% of the arable land.

There has also been increasing awareness by rural social movements about the need not only to work at local or national scales but also to build coalitions across borders to better confront the powerful multilateral institutions and corporate actors that dominate the global food economy. The great manifestation of this is La Via Campesina, which describes itself as the international movement of peasants, small- and medium-sized producers, the landless, rural women, indigenous people, rural youth, and agricultural workers. For La Via Campesina, land reform remains at the crux of building more equitable and sustainable rural economies.

The rekindling of latent land struggles helped push land reform back into mainstream development policy debates in the 1990s. One of the most notable sites for the renewal of these debates has been the World Bank, where some development economists—largely ignored through the adjustment era—had been advocating land reform since the 1970s based on empirical evidence of the inverse farm size/productivity relationship. In practice, the World Bank has supported nonconfrontational, market-based reforms, which are principally a set of policies and institutional changes to make land markets more effective with respect to things such as land taxation, the costs of land transactions, and access to capital. Evidence from countries such as Brazil, Colombia, Cambodia, the Philippines, South Africa, and Thailand suggests that market-based land reform has not encouraged land transfers from large holders to smallholders, or



Members of Brazil's Landless Workers Movement (MST) march alongside the financial center of Paulista Avenue in São Paulo, Brazil, on August 12, 2009, as part of national daily demonstrations held until August 21 asking for more efforts on agrarian reform by the federal government.

Source: Mauricio Lima/AFP/Getty Images.

significantly reduced levels of land inequality. Rather, it has at best tended to benefit a middle stratum of commercialized farmers, and at worst, it has had badly regressive outcomes, leaving out smallholders and landless people entirely.



Conclusion

Land reform policies pursued “from above” remain very different from the sort of land reform demanded—and sometimes claimed—by movements pushing “from below.” For land reform to improve the circumstances of landless people and small farmers, the strength of the latter is crucial. But even effective land reform is no panacea. Rather, it is a crucial step toward building more equitable and sustainable rural landscapes, reducing rural poverty, and enhancing food security in many parts of the world. To transform and invigorate rural economies, land reform must be accompanied by institutional supports for small farmers in areas such as appropriate inputs and technology, infrastructure, credit, extension, marketing, and gender equity legislation, with the term *agrarian reform* distinguishing these more comprehensive changes.

Tony Weis

See also **Colonialism; Developing World; Food and Agriculture Organization (FAO); Justice, Geography of; Land Tenure Reform; Movimento Sem Terra; Neoliberalism; Peasants and Peasantry; Population and Land Degradation; Population and Land Use; Structural Adjustment; Via Campesina (International Farmers' Movement); World Bank**

Further Readings

- Borras, S. M., Jr., Kay, C., & Lahiff, E. (Eds.). (2008). *Market-led agrarian reform*. London: Routledge.
- Ghimire, K. B. (Ed.). (2001). *Land reform and peasant livelihoods: The social dynamics of rural poverty and agrarian reform in developing countries*. London: ITDG.
- Weis, T. (2007). *The global food economy: The battle for the future of farming*. London: Zed Books.
- World Bank, Food and Agriculture Organization, and International Fund for Agricultural Development. (2009). *Gender in agriculture sourcebook*. Washington, DC: World Bank. Available from <http://siteresources.worldbank.org/INTGENAGRLIVSOUBOOK/Resources/CompleteBook.pdf>



LANDSCAPE AND WILDLIFE CONSERVATION

Many geographers study the relationships between patterns of habitat variation and the processes through which wildlife species occupy landscapes. An animal's capacity to move across landscapes is a function of both intrinsic factors related to its behavior and physiology and extrinsic factors arising from the distribution of suitable habitat in space and time. Understanding how animals move between habitats across landscapes is important in applied contexts, especially wildlife management and conservation, and theoretical contexts, including evolutionary ecology.

Research on Wildlife-Landscape Interactions

Ecologists have studied wildlife ecology and habitat use for decades. Before the 1970s, most studies of wildlife ecology were not spatially explicit but simply categorized wildlife observations by habitat type, not location. This approach reflected the traditional emphasis in biological ecology on evolutionary processes rather than on spatiotemporal patterns. However, beginning in the late 1960s, theoretical and technological developments helped increase attention to the relationships between process and pattern. First, the theory of island biogeography, published in 1967 by the biologists Robert MacArthur and E. O. Wilson, proposed that an island's size and proximity to other landmasses was a robust predictor of the number of species in, and other characteristics of, the island's biota. Subsequently, other researchers showed that habitats that are not islands but occur in scattered, discrete patches—such as areas of alpine tundra surrounded by montane forest—are analogous to islands in how their size and spatial arrangement affect the distribution of species across landscapes. Second, in the 1980s, the field of landscape ecology flourished with the development of *patch mosaic theory*, which posits that landscapes consist of a variegated pattern (or *mosaic*) of areas (or *habitat patches*) having distinct environmental conditions. Landscapes change because conditions in



the habitat patches fluctuate through time, a process called *patch dynamics*. Finally, during the 1990s, the development and increased availability of geographic information system (GIS) software and the global positioning system (GPS) decreased the cost and increased the feasibility of spatially explicit wildlife research.

Also, since the 1970s, studies of wildlife-landscape interaction have become more prominent due to a growing concern with human-caused environmental change. Organisms respond to environmental change—whether cyclic, long term, or rapid—by migrating from habitat patches where conditions have become unsuitable to those where conditions remain, or have become, suitable. Researchers can develop conservation strategies by analyzing habitat spatiality and patch dynamics, including human disturbance, with regard to the behavior and physiology of particular species.

Wildlife species vary enormously in terms of behavior and physiology, but five factors are important in determining how patch dynamics affect a particular species. First, an animal's size is a basic determinant of habitat requirements; larger animals need larger habitat patches. Second, animals vary in the specificity of their habitat requirements, between *specialists* that can tolerate only the range of environmental conditions in a specific habitat type and *generalists* that can tolerate environmental conditions in a broad range of habitats. Habitat specificity greatly influences a species' ability to move between patches. For instance, deforestation in the Amazon often isolates birds in remnant forest patches because they are unable to cross even narrow clearings. Third, animals vary in mobility between sedentary and vagile (ability to move long distances). Fourth, animals vary in territoriality, between those that aggressively defend a particular area from other individuals of the same species and those that do not. If the habitat patch occupied by an individual in a highly territorial species becomes unsuitable, the animal may perish if nearby, suitable patches are already occupied. Finally, every species is unique ecologically, so that specific patch dynamics in a particular time and place may differently affect similar species. For example, gorillas and chimpanzees in Gabon's rain forests respond differently to human

disturbance because human activities produce patches of plants that gorillas eat but decrease the abundance of chimpanzee food plants. While these behavioral and physiological factors may be correlated—for instance, many generalists are highly vagile—they are distinct and must be considered individually.

Applications to Resource Management and Conservation

Most studies in the geography of wildlife-landscape interaction have intended to inform resource management and conservation efforts. Three main themes have emerged. First, biogeographers have sought to identify spatial configurations of habitat that are optimal for protecting particular species or conserving the largest possible range of biodiversity. Key concepts in this research relate to the size, connectivity, and shape of protected areas. In 1975, the biogeographer Jared Diamond proposed that a single large protected area would protect a greater number of species rather than several small protected areas, based on island biogeographic theory. While this idea remains debated, it has influenced many conservation efforts. Island biogeographic theory also led to the idea of *habitat corridors*, or strips of land that allow animals to move between disconnected habitat patches. Corridor effectiveness depends heavily on a species' behavior and physiology. More broadly, a protected area's shape determines its effectiveness in protecting particular species. For instance, sedentary or territorial animals may be unable to move far enough to locate sufficient habitat in long, narrow protected areas.

Second, biogeographers have sought to identify optimal approaches to protecting particular species through the analysis of species ecology and habitat spatiality. Conservation efforts may include site-specific approaches that protect particular habitat patches and species-specific approaches that provide protection to a species regardless of location. Usually, site-specific approaches are more effective for sedentary species or habitat specialists, while species-specific approaches are better for vagile species and habitat generalists. Computer-based modeling has become increasingly important in evaluating the potential effectiveness of different conservation



approaches in the context of global and local environmental changes.

Finally, nature-society geographers have shown that human-wildlife conflict often results from variation in habitat distribution in space and time. Human-wildlife conflict frequently occurs if both people and animals seek to use a habitat patch. Interspecific competition increases as the number of available habitat patches decreases. Notably, in many landscapes, humans unintentionally create habitat patches in locations where, or at times when, few other patches are available for wildlife. Thus, human-wildlife conflict may occur frequently in human-created habitats, such as fields or gardens. For example, chimpanzees in Uganda raid crops most commonly during periods when food is scarce in adjacent forest patches.

Chris S. Duvall

See also **Biogeography; Conservation; Coupled Human and Animal Systems; Diamond, Jared; Extinctions; Game Ranching; Island Biogeography; Landscape Ecology; Patches and Corridors in Wildlife Conservation; Single Large or Several Small (SLOSS) Debate; Spatial Strategies of Conservation; Species-Area Relationship; Wilderness**

Further Readings

- Bennett, A. F. (1999). *Linkages in the landscape: The role of corridors and connectivity in wildlife conservation*. Gland, Switzerland: International Union for Conservation of Nature.
- Diamond, J. M. (1975). Assembly of species communities. In M. L. Cody & J. M. Diamond (Eds.), *Ecology and evolution of communities* (pp. 342–444). Cambridge, MA: Belknap Press.
- Malanson, G. P. (2002). Extinction-debt trajectories and spatial patterns of habitat destruction. *Annals of the Association of American Geographers*, 92, 177–188.
- Millsaugh, J., & Thompson, F. (2008). *Models for planning wildlife conservation in large landscapes*. New York: Academic Press.
- Naughton-Treves, L. (1998). Predicting patterns of crop damage by wildlife around Kibale National Park. *Conservation Biology*, 12, 156–168.



LANDSCAPE ARCHITECTURE

Landscape architecture is an academic discipline and an area of professional practice that seemingly defies definition. Demarcating the field is a difficult endeavor since the breadth of the field is quite wide, dynamic, and far ranging. This piece focuses on landscape architecture in the United States and Canada (although landscape architecture is alive and well in the rest of the world). However, in the United States, the education of a landscape architect focuses primarily on North American and European studies. This persistence is unfortunate, as few students learn much more than a brief history of landscape architecture in a history survey course akin to the European Grand Tour of the 18th and 19th centuries. A broader, transdisciplinary approach is gaining a foothold, however, producing some promising results in terms of producing more collaborative and multidisciplinary savvy landscape architects. The purpose here is to provide a means by which one can begin to see the wealth of research and practice in which landscape architects have been engaged since landscape architecture gained its professional standing in the late 1800s.

There are numerous similarities between landscape architecture and geography. Geography is generally divided into two areas, physical and human; unfortunately, these two domains are often considered oppositional. The same problem occurs in landscape architecture, which is similarly organized into two broad arenas, the physical and the human; now—as is also the case in geography—a third arena has emerged, geographic information systems (GIS) and other technologies. The field of landscape architecture is also divided in other ways, between academicians and practitioners, designers and nondesigners, and technicians and artists. Such divisions are not always constructive, though they do help differentiate the multiple focuses of the everyday work of a landscape architect. This entry provides a broad sense of landscape architecture: how it is defined; its history and theory, education and professional practice; and the current state of the field.



Definitions

The American Society of Landscape Architects (ASLA), the United States' professional association, defines landscape architecture as a

profession which applies artistic and scientific principles to the research, planning, design and management of both natural and built environments. Practitioners of this profession apply creative and technical skills and scientific, cultural and political knowledge in the planned arrangement of natural and constructed elements on the land with a concern for the stewardship and conservation of natural, constructed and human resources. The resulting environments shall serve useful, aesthetic, safe and enjoyable purposes. (www.kansas.net/~tjhittle/ladef.htm)

The Canadian Society of Landscape Architects offers the following: "Landscape architecture is (the profession) committed to the creation of meaningful and vital outdoor places and to the sustainable management of our environment." Most important, "Landscape architects strive to establish a balance between our use and enjoyment of the land with the conservation and health of the environment." And, finally, "Landscape architects are committed to improving our quality of life by applying creative, technical, and scientific skills to manage and create environments that are attractive, functional, innovative and appropriate." Landscape architects are thus involved in the design, planning, and management of a wide range of spaces, including parks and open space, academic campuses, and residential estates; they are also involved in developing civic infrastructure, in historic preservation and restoration, and in the reclamation of degraded landscapes (e.g., brownfields, extractive industry sites).

History and Theory

"What, then, should the term landscape architecture be taken to mean? It will be understood here to mean the art—or the science, if preferred—of arranging land, together with the spaces and objects upon it, for safe, efficient, healthful, pleasant human use" (Newton, 1971, p. xxi).

One of the first and foremost contemporary comprehensive histories of landscape architecture was produced by Norman Newton in his book *Design on the Land: The Development of Landscape Architecture*, published in 1971. Newton clearly articulated the transformation of a profession from garden design, a largely private endeavor, to landscape architecture as a public service. Another classic book, by Geoffrey and Susan Jellicoe, *The Landscape of Man: Shaping the Environment From Prehistory to the Present Day* (published in 1975; third edition published in 1995), covers landscape to the early 1990s. These volumes offer an inclusive and legible history of the built environment and provide concise descriptions and abundant plans, illustrations, and photographs of gardens and built landscapes from early civilization to the evolution of the modern landscape.

Landscape architecture is firmly rooted in garden design and landscape gardening, despite the fact that this association is still uncomfortable for many in the profession today—a denial of the profession's roots in the garden and a fear of the feminine in the profession, which is still primarily white, male, and upper middle class. Garden design was not, though, given the same historical and theoretical attention as architecture, even though Vitruvius mentions gardens and design in *The Ten Books on Architecture*. Yet it was not until the 18th century that in-depth attention was given to the history of gardens/gardening. The term *landscape gardener* came into usage in the late 1700s, when Humphrey Repton used the term as a professional title. Lancelot Brown is probably the most well-known of the "landscape gardeners," and it was during the 19th century that the term came to be used for those who designed and built gardens (and other landscapes). John Loudon, an English garden designer, published his *Encyclopedia of Gardening* in 1822; this was one of the first illustrated histories of gardens and paved the way for the late-19th- and early-20th-century fascination with the history of the garden.

The term *landscape architect* was first adopted by Frederick Law Olmsted, in 1863, as a professional title. Olmsted learned of this term from his mentor Andrew Jackson Downing (who, in turn, had borrowed the term from Loudon) and shifted its emphasis to the relationship between landscape and the built environment. New York City's



Central Park epitomized this new direction, as it focused on a landscape as both scenery and setting in an urban environment. The term *landscape architect* is often attributed to Patrick Geddes (1854–1932), a Scottish botanist who made unique connections between garden design, public park design, and town and regional planning. Geddes is known as one of the founders of modern town and regional planning, influencing Lewis Mumford, Christopher Tunnard, and others who had a profound impact on 20th-century urban planning. The term *landscape architect* became established as a professional title by the founding, in 1899, of the ASLA. More widespread use and knowledge of the term came with the founding, in 1948, of the International Federation of Landscape Architects. *Landscape Architecture Magazine*, ASLA's flagship journal, was first published in 1910. A brief review reveals the particular practices that predominated in certain eras.

Public parks (as well as residential estate design and planning) have long been a mainstay of the profession. Galen Cranz's *The Politics of Park Design. A History of Urban Parks in America*, published in 1982, provides a means by which to understand the changing physical design and social purpose of parks from the late 18th century through the mid 20th century. Cranz describes four eras of park design and planning: (1) the pleasure ground (1850–1900), (2) the reform park (1900–1930), (3) the recreation facility (1930–1965), and (4) the open space system (1965 and beyond). The profession grappled with the question of the 21st-century park in the late 1980s via the competition for Parc de La Villette (Paris).

During the second and third decades of the 1900s, landscape architecture began to have a profound influence on the American landscape, from national parks to larger-scale public works projects (e.g., parkways and dams). The 1930s and 1940s were the halcyon years of modern landscape architecture. It was during this time that the profession grew in its focus to include new towns, the further investigation of housing (residential estates and suburban development), campus design, and the design and planning of state, regional, and transregional roads and highways. The publication of Ian McHarg's book *Design With Nature* in 1969 marked the height of a new era of ecological design. McHarg introduced what

is now considered a classic form of landscape analysis. His book provided step-by-step instructions for the planning of human settlements that would reverse the existing pattern of destructive development practices. Ann Spirn, one of McHarg's students, produced what has become another classic in landscape architecture and planning, *The Granite Garden*, in 1984, which called attention to the importance of the profession in making and maintaining the urban landscape.

In the 1990s, the profession turned its attention to the radical changes in urban, suburban, and rural landscapes. Greenways and brownfields were the sites of experimentation for this new interest in the repair and restoration of damaged sites and toward more productive use of marginal landscapes. The 1990s and 2000s saw a renewed interest in housing, representation, and the relationship between art and landscape. New technologies (e.g., AutoCAD, Photoshop, Maya) presented new opportunities for visualizing and presenting design ideas. Residential work in the late 1980s and 1990s fluctuated between the new "estate era" and work in new urbanist ventures. Also, the 1980s ushered in an era of urban park renovation as people returned to city centers. Since the 1960s, a large part of this profession has been devoted to international work, with large-resort development continuing to account for a majority of this type of work.

According to the U.S. Department of Labor, Bureau of Labor Statistics, landscape architects held about 26,700 jobs in 2008. About 51% of landscape architects were employed in architectural, engineering, and related services. State and local governments employed approximately 6%. About 21% of landscape architects were self-employed. The job outlook for the profession is healthy, given that employment is expected to increase; this expected growth is attributed to a growing need for the profession's expertise in urban areas because of the growing population and the public's desire for more attractive public spaces. Also, the profession has increasing value particularly in an American landscape where there is an increased need for sustainable design and planning (e.g., storm water management, water conservation, wetland restoration and management) and a demand for national security for government buildings, landmarks, and monuments.



The Current State of Landscape Architecture

Landscape architecture is faced with the task of design and planning in an increasingly urban world. Two formidable concerns for the future of the discipline are ensuring environmental sustainability from the local to global scales and developing viable, dynamic, and responsive strategies to cope with the changing urban landscape. Also, a promising new movement, landscape urbanism, argues that landscape is the most appropriate organizing principle for the city, one that emerges from the bottom up. It is a hybrid strategy that is inspired by landscape ecology and is thus attentive to the fluid movements of plants, animals, and people, as well as ideas, materials, and time.

Joni M. Palmer

See also **Architecture and Geography; Built Environment; Cultural Landscape; Folk Culture and Geography; Jackson, John Brinckerhoff; Landscape Design; Landscape Interpretation; Urban and Regional Planning; Vernacular Landscapes as Expressions of Environmental Ideas; Zoning**

Further Readings

- Bureau of Labor Statistics, U.S. Department of Labor. (2009). Landscape architects. In *Occupational outlook handbook, 2010-11 edition*. Retrieved February 9, 2010, from www.bls.gov/oco/ocos039.htm
- Canadian Society of Landscape Architects. (n.d.). *Landscape architecture in Canada*. Retrieved February 19, 2010, from www.csla.ca/en/landscape-architecture-in-canada
- Corner, J. (1999). *Recovering landscape: Essays in contemporary landscape architecture*. Princeton, NJ: Princeton Architectural Press.
- Cranz, G. (1982). *The politics of park design. A history of urban parks in America*. Cambridge: MIT Press.
- Jellicoe, G., & Jellicoe, S. (1975). *The landscape of man: Shaping the environment from prehistory to the present day*. London: Thames & Hudson.
- McHarg, I. (1969). *Design with nature*. Garden City, NY: Doubleday.

- Newton, N. (1971). *Design on the land: The development of landscape architecture*. Cambridge, MA: Belknap Press.
- Swaffield, S. (Ed.). (2002). *Theory in landscape architecture: A reader*. Philadelphia: University of Pennsylvania Press.
- Treib, M. (Ed.). (1993). *Modern landscape architecture: A critical review*. Cambridge: MIT Press.



LANDSCAPE BIODIVERSITY

Biodiversity, the variety of biological life, is hierarchically organized at different scales, from the molecular and genetic levels to populations, ecosystems, and landscapes. Research on landscape biodiversity studies how the interaction between the distribution of biotic factors and human land use shapes the distribution of biodiversity at landscape scales. Landscape ecology emphasizes the connection between spatial pattern and ecological process. Thus, landscapes are viewed as heterogeneous compositions of many smaller units, typically ecosystems. The type, quality, relative proportion, and spatial distribution of these ecosystems determine the flows of energy, material, and species through the landscape and thus affect the spatial distribution of biodiversity. Abiotic factors such as soils, topography, and climate further interact with and constrain the biological interactions between organisms, resulting in complex spatial patterns of species distribution in a landscape. These spatial patterns in turn influence the distribution of abiotic and biotic resources within the landscape. Thus, landscape biodiversity studies tend to focus on the relationships between pattern (spatial patterns of species distribution) and process (processes of species survival, persistence, growth, and dispersal).

A landscape perspective becomes especially critical for biodiversity management as human impacts on biodiversity increase, since the consequences of human modifications in land use and land cover (such as habitat fragmentation) manifest themselves most severely at the landscape scale yet are often ignored by local ecological



studies. Landscape biodiversity research therefore typically focuses on spatial and temporal scales that are much larger and longer than those addressed in traditional studies of ecology, providing an organizing framework that is useful for land managers and conservation science. For instance, a landscape framework is often used while planning the location of protected areas and parks, such that a park is not created in isolation but is often surrounded by a buffer area of limited human use to improve spatial connectivity and reduce the impacts of habitat fragmentation. Theories of island biogeography, vegetation gradient analysis, and metapopulation dynamics have been influential in landscape biodiversity planning, with conservation biologists striving to protect and restore large, connected landscapes for the survival of rare and endangered species.

Indices of species diversity can be computed at a range of scales, from the local to the landscape level. *Alpha diversity* refers to the diversity of species at a particular location, while *beta diversity* describes the turnover in species between two locations. *Gamma diversity* integrates information from alpha and beta diversity studies to describe the levels of species diversity at larger, landscape scales. The composition and structure of landscapes critically influences gamma diversity, and in-depth understanding of this relationship is critical for biodiversity planning at the landscape scale. The composition of a landscape refers to the number, variety, and relative proportion of the components of a landscape—ecosystems, habitats, and ecological communities. The structure of a landscape is described by the geometry of these components—their size, shape, connectivity, and context—which affects the distribution of specific species to different extents. For instance, area-sensitive species such as large carnivores have requirements for large, unfragmented habitats; edge-sensitive species tend to avoid edges where there are sharp atmospheric gradients and increases in human presence; while dispersal-sensitive species are affected when connectivity between habitats is affected. Thus, other things being equal, patches of greater area constitute better habitat for area-sensitive species. Habitat shape is also critical, as patches of the same size that are more indented or linear have a greater edge, consequently harboring a greater

proportion of edge-generalist species while being avoided by edge-sensitive species. Connectivity between patches affects metapopulation dynamics and determines the overall probability that a species will persist on a landscape. Context is also critical; for instance, an orchard in the midst of a forest is more likely to harbor edge-sensitive forest birds than if it were located in the center of a city.

With the advent of remote sensing and the development of spatial tools for mapping landscapes, hundreds of landscape metrics have been developed that quantify different aspects of landscape spatial structure. Many, if not most, of these metrics are correlated, however, and it is not clear how their increasingly sophisticated computation contributes to biodiversity management. Indices of landscape structure and composition are often treated as substitutes for species diversity assessment. Yet, while simple theoretical models have been developed that relate landscape spatial structure to biodiversity distributions in an intuitively appealing manner, it has been challenging in practice to relate the indices of landscape structure to biodiversity distributions. Thus, the relevance of these metrics for biodiversity planning is unclear.

Several important organizing principles for biodiversity conservation have emerged as a result of using a landscape perspective. Perhaps the best known of these is the often discussed issue of habitat fragmentation, which can pose a serious threat to the movement, growth, reproduction, dispersal, and persistence of species. For example, when old-growth forests are fragmented by the creation of road corridors that cut through them and make it difficult for organisms to move among isolated patches, the survival and persistence of some species become particularly challenging. Awareness of scaling issues is also critical for landscape management, as the lessons learned at one spatial or temporal scale cannot be automatically transferred to another scale. The scale of a landscape is often defined based on human perceptions, and landscapes typically range in size from tens to hundreds of square kilometers. Yet, while this may be the scale most suitable for conservation planning or management, it is also critical to recognize that a landscape can range widely in size when viewed from the perspective of different species—for example,



a tree fungus, for whom a single tree or a clump of trees may provide a landscape, or a large carnivore, which may traverse thousands of kilometers in its lifetime.

Harini Nagendra

See also **Biodiversity; Island Biogeography; Landscape and Wildlife Conservation; Landscape Ecology; Land Use and Land Cover Mapping; Parks and Reserves; Patches and Corridors in Wildlife Conservation; Single Large or Several Small (SLOSS) Debate; Spatial Strategies of Conservation; Species-Area Relationship**

Further Readings

- Gutzwiller, K. J. (Ed.). (2002). *Applying landscape ecology in biological conservation*. New York: Springer-Verlag.
- Noss, R. F. (1990). Indicators for monitoring biodiversity: A hierarchical approach. *Conservation Biology*, 4, 355–364.
- Turner, M. G., Gardner, R. H., & O'Neill, R. V. (2001). *Landscape ecology in theory and practice*. New York: Springer-Verlag.

LANDSCAPE DESIGN

Landscape design and landscape architecture are in their basic forms a manifestation of humans' passionate care for nature. The two concepts are similar, with landscape design focusing more on the artistic merits of design. This entry briefly reviews the history of landscape architecture and then considers the role that it can play in the future. In an era when we acknowledge the ecological damage and the imbalanced growth that humanity has inflicted on the Earth, landscape design has a significant role to play in the procurement of resources and materials and in the interaction with natural form and elements toward creating livable communities. It also offers solutions for global climate change and warming and peak oil (i.e., the maximum global output that occurred recently and the subsequent gradual decline).

History of Landscape Design

Throughout human history, landscape works such as the Greek and Roman gardens shared a commonality of an incessant love for greenery and plants. Other than these, the “elements” of nature (fire, water, air, and earth in the ancient Occident and metal, water, wood, fire, and earth in the ancient Orient) have influenced the design of ancient gardens. Japanese gardens are designed to provide a natural setting, sometimes referred to as a mindscape, which draws the mind toward meditation. It often reflects the influence of Zen Buddhism and takes a minimal form, sometimes using raked pebbles rather than water.

In the West, the history of landscape architecture can be traced back to Gilbert Laing Meason (1820–1900), a Scot, who was the first to refer to buildings found in the paintings of landscapes as landscape architecture. In the 19th century, J. C. Loudon, A. J. Downing, and others expounded on the development of landscape gardening and contributed to the distinctive style of landscape architecture. Other pioneers included Frederick Law Olmsted (1822–1903), whose works included Central Park in New York and the Emerald Necklace Park system in Boston; Dan Kiley (1912–2004), whose works included Miller Garden in Columbus, Indiana, and the Chicago Botanic Garden; Roberto B. Marx (1909–1994) of Brazil (the Ibirapuera Park and the Flamengo Park); and other landscape masters such as Lawrence Halprin (1916– ; Yerba Buena Gardens Master Plan), Ian McHarg (1920–2001), and Martha Schwartz (1950– ; Dublin Docklands), all of whom were great promoters of landscape architecture in the 20th century.

Twenty-First-Century Challenges

The dawn of the 21st century is marked by four new challenges for the practice of landscape architecture. These challenges arise out of the growing emphasis on sustainability and from the desire to use landscape architecture to enhance the urban experience of life, to explore the therapeutic possibilities of landscape architecture, and to enrich our understanding of cultural landscapes.

First, landscape architects are called on to extend the practice of landscape design to embody



A portion of the rock garden at Kongobuji Temple, located in Koyasan (Mount Koya), Japan

Source: Aliza Schlabach/iStockphoto.

the ecological, social, and economic concerns of sustainability in the planning and design of both indoor and urban spaces. As an example of environmental applications, sustainable landscaping considers a green roof or a roof garden as a rain-water reservoir, a heat sink, and an activity venue, as well as an event for visual enjoyment. Another example is the keen interest that has gone into the research and development of sustainable landscape design strategies and practices, such as artificial wetlands and plant and species selection for enhancing ecological and biodiversity balance in both urban and building settings.

Second, landscape urbanism has appeared, as early as in the past decade, as an extended belief and practice of a contemporary urban theory that holds that landscape, rather than architecture, is an effective tool to enhance urban experience in pursuit of a better quality of life. As a new discipline, landscape urbanism perceives cities as natural processes that are constantly changing and

evolving and therefore demand flexible and adaptable mechanisms in the practice of urban landscape design. This belief is driven by an analysis of the existing and potential conditions of selected sites, which provide a set of parameters for understanding their design as dynamic material organizations shaped by a combination of the temporal and dynamic forces that shape modern cities, from the social and political realms to environmental infrastructure. In this manner, landscape design is integrated with urbanism from a theoretical to a practical sense. This new focus is significant, as it expands the scope for landscape architecture to incorporate urban design. Because of this changing role, many landscape architectural practices have entered the realm of urban design.

Third, human health and performance have emerged as a major stream of “therapeutic” landscape design, often referred to as the Healing Garden School. Roger S. Ulrich in particular has put the spotlight on the ability to deploy designed



natural environments for human health benefits in physical, mental, and spiritual recovery. A successful application of this concept has been the use of “healing gardens” for patient recovery in medical wards; patients have recovered and have been discharged at a faster rate when they were accorded a healing garden. *Therapeutic landscape design* thus refers to a specific aspect of a healing process for the body and the mind. Deeper study of the therapeutic landscape philosophy has led to a growing interest in the extension of the healing concept to the relief of the mind and spiritual relief for identified workers or user groups such as university students working under stressful conditions, inviting a new term, *sustainable campus landscape design*.

Fourth and finally, *cultural landscape* is a new concern initiated by world heritage authorities to promote an awareness of how human activities are intertwined with natural elements. The United Nations Educational, Scientific and Cultural Organization’s (UNESCO) World Heritage Committee (1992) has defined the cultural landscape as encompassing (a) an artificial landscape designed and created intentionally by man or as a result of man working with nature; (b) an organically evolved landscape, including relict landscapes and ones in which the evolutionary process is still in progress; and (c) an associative cultural landscape, because of its association with religious, artistic, or cultural considerations. By this definition, the cultural landscape provides a way to preserve works of landscape, natural or human-made, in order to understand human evolving relationships with nature. An example of a cultural landscape often cited is the Bodie State Historic Park, northeast of Yosemite National Park in California, also known as a gold-mining ghost town, where the terrain landscape preserves the history of the mining activities. In essence, cultural landscape is a collection of places; artifacts that serve as a trigger of memories of social relevance and that are being managed and maintained as a living or a fossil exhibition, such as Pompeii.

Stephen S. Y. Lau

See also **Architecture and Geography; Cultural Landscape; Green Design and Development; Landscape Architecture; Landscape Interpretation; Parks and Reserves; Urban Gardens; Urban Green Space**

Further Readings

McHarg, I. L. (1995). *Design with nature*. New York: Wiley.



LANDSCAPE ECOLOGY

Landscape ecology is a relatively young, interdisciplinary (or transdisciplinary) field drawn from the subjects of ecology, geography, and landscape architecture (see Figure 1). It focuses on the relationships between landscape patterns and ecological processes across a broad range of spatial and temporal scales. Human interactions are strongly emphasized, given the often dominant influence of humanity on landscape composition, structure, and functionality. In the past 20 to 30 years, a variety of pattern indices and modeling techniques have been developed to study the heterogeneous, dynamic, human-modified ecosystems across the globe. Research has cast light on ecological conservation, natural resource management, landscape and urban planning, and sustainable land use in many European, North American, Oceanic, and Asian countries.

Development of Landscape Ecology

The term *landscape ecology* was introduced by Carl Troll in 1939. It was defined as the study of causal relationships between ecological communities and their heterogeneous, patchy environments. The recognition of and emphasis on spatial heterogeneity separated landscape ecology from other classical ecological fields and inspired tremendous research interest in this “spatial ecology.” Other basic concepts of landscape ecology were also formed during this early stage, including scale, hierarchy, and landscape dynamics.

In 1982, the International Association of Landscape Ecology was founded. Landscape ecology, as an emerging academic discipline, began to draw increasing attention from scholars in the fields of ecology, geography, and sociology as well as from designers in landscape architecture and urban planning across the world. The

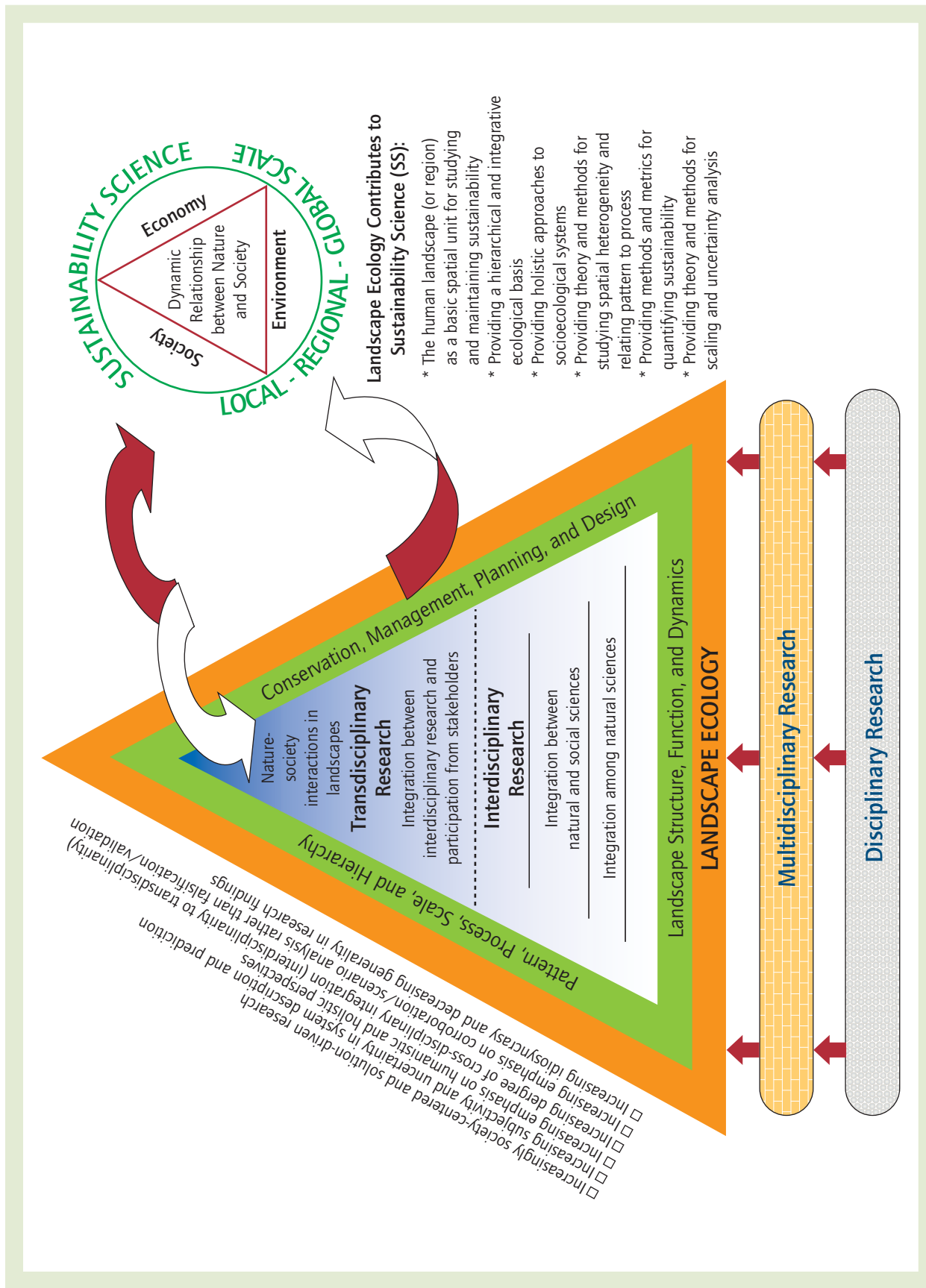


Figure 1 Landscape ecology

Source: Wu, J. (2006). Landscape ecology, cross-disciplinary, and sustainability science (Figure 1). *Landscape Ecology*, 21, 1–4. Reprinted with kind permission of Springer Science and Business Media.



theoretical concepts of landscape ecology evolved rapidly beginning in the 1980s, especially in the exploration of scale and its consequences for pattern and process recognition. Different sets of landscape metrics were created and widely implemented to quantify landscape spatial heterogeneity. Modeling techniques flourished, including neutral models and process-based models. Disturbance and ecosystem succession were extensively investigated and modeled with advanced remote sensing and spatial analysis techniques. Humans and their activities have been increasingly viewed as a landscape component rather than simply an external factor.

Theoretical Approaches

Two landscape ecology approaches are well known; one is the society-centered, holistic view of the European tradition, and the other is the ecology-centered, spatial view of the North American tradition. The former concerns mainly cultural landscapes and focuses on landscape planning that increases the beauty and productivity of urbanized societies, while the latter pays particular attention to natural or human-modified ecosystems and concentrates on the deduction, synthesis, and simulation of landscape pattern-process interactions. Several scholars have advocated that the two distinctive approaches are complementary and, therefore, may be integrated. Others favor the diversity of research methodology and have suggested that while landscape ecology is a transdisciplinary field, individual studies may not have to be cross-disciplinary.

Fundamental Concepts

Despite the differences in the European and North American traditions, the academic disciplines associated with landscape ecology have much in common. Both include the following assumptions:

Spatial heterogeneity is fundamental for the perception of landscape.

The interactions of landscape patterns and ecological processes are the basic subjects of investigation.

Hierarchical views and scaling influence the recognition of landscape patterns and the identification of ecological processes.

Humans are an important landscape component as they modify the landscape and adapt to changes.

Landscape patterns, ecological processes, and human activities are dynamic and intertwining phenomena.

Spatial Heterogeneity

Spatial heterogeneity is the foundation of landscape ecology. It sets the latter apart from traditional ecology, which tends to focus on populations or communities in small and relatively homogeneous areas. *Landscape* is typically viewed as the mosaic of discrete spatial entities at scales ranging from a few hectares to many square kilometers. The patchy appearance of landscape is a reflection of spatial autocorrelation, which is a geographic phenomenon of increasing similarity (or dissimilarity) between locations that are close to one another.

The arrangement (or configuration) of heterogeneous landscape entities is referred to as *pattern*. Patterns may be generated by dissimilar environmental settings, ecological processes, and natural or human disturbances. The perceived pattern of a predefined landscape may vary depending on changes in the criteria for patch segmentation or in the scale of analysis. Tremendous effort has been devoted to the quantification and simulation of landscape spatial patterns since the 1980s.

Pattern-Process Interactions

Understanding the causal relationships between landscape patterns and ecological processes has been a top priority since the establishment of the discipline of landscape ecology. Patterns for landscape are affected by ecological processes, for example, through trophic relationships such as grazing effects on landscape composition and configuration. On the other hand, spatial patterns may influence ecological processes, such as seed dispersal, exotic invasion, and the spread of disturbances. Knowledge of pattern-process interactions has wide implications for ecological



conservation and restoration. However, caution must be taken when investigating and implementing the pattern-process relationships, which might be missing due to the mismatch of sampling scales and the absence of replicate landscapes.

Hierarchy and Scale

The recognition of hierarchy and scale in landscape ecology dates back to the 1950s, and the importance of these concepts has been widely accepted since the 1980s. *Hierarchy* refers to the level of organization, which manifests itself as the nested systems of varying spatial and temporal domains in sequence. For example, a forest landscape may be viewed as a hierarchy of tree gaps, stands, and watersheds from lower to higher levels. Systems at different levels interact with one another, with the lower level generating higher-level patterns and the higher level constraining lower-level processes.

Scale refers to the dimension of space or time for the landscape pattern or process under investigation. From the spatial perspective, scale is viewed as grain (or spatial resolution, i.e., the smallest unit of sampling or observation) and extent (i.e., the size of the study area). From the temporal perspective, scale is regarded as time step (or temporal resolution) and time span, varying from seconds to geological time. Scale is central to landscape ecology, because most landscape patterns and ecological processes are scale dependent, which means that changes in the scale of investigation generate different results for interpreting landscape characteristics.

Hybrid Human-Natural Systems

Today's landscapes are the combined results of historical natural and cultural processes. People's role in shaping landscape patterns and modifying ecosystem functions has become increasingly important, given the advance of society, knowledge, and technology. The impacts of human activities on landscape may be direct or indirect. The former involve modifying the landscape component or configuration directly, as in clearing grasslands for agriculture. The latter occur through manipulation of factors that control the landscape processes, as in the implementation of

fire suppression technology. Both direct and indirect human influences may be regulated and planned to achieve landscape sustainability.

Landscape Dynamics

Patterns of landscape are temporally dynamic and vary with the redistribution of materials, energy, and organisms by natural or human causes. The natural cause of changes in ecological processes may be relatively regular, as in diurnal changes in light availability for plant photosynthesis, or less predictable, as in disturbance events such as forest fires, insect breakouts, and droughts or floods. After a disturbance occurs, ecosystems may restore themselves to their original status through succession without further disturbances. However, because disturbances are often repeated and human modification (such as grazing, logging, and urbanization) is continuous, changes in landscape patterns and processes are often ongoing, never approaching equilibrium, and difficult to predict.

Methodology

Landscape ecology investigates large-extent spatial patterns and ecological processes. One of the most difficult challenges is the lack of replication of landscapes for sampling and experimental design. In contrast with traditional ecology, which is based primarily on experiments, landscape ecology focuses on spatial pattern metrics and simulation models. It also makes use of advanced geographic technologies such as remote sensing and geographic information systems (GIS) for broadscale ecosystem monitoring and spatial data analysis.

Pattern Metrics

Landscape pattern metrics are spatial indices that quantify the landscape composition and spatial configuration of a predefined study area. To apply pattern metrics, the landscape has to be viewed as the integration of discrete spatial units. Each unit is referred to as a *patch*. Patches with similar attributes are assigned to a single class; for example, patches of forested land would belong to the forest class instead of the agriculture or the

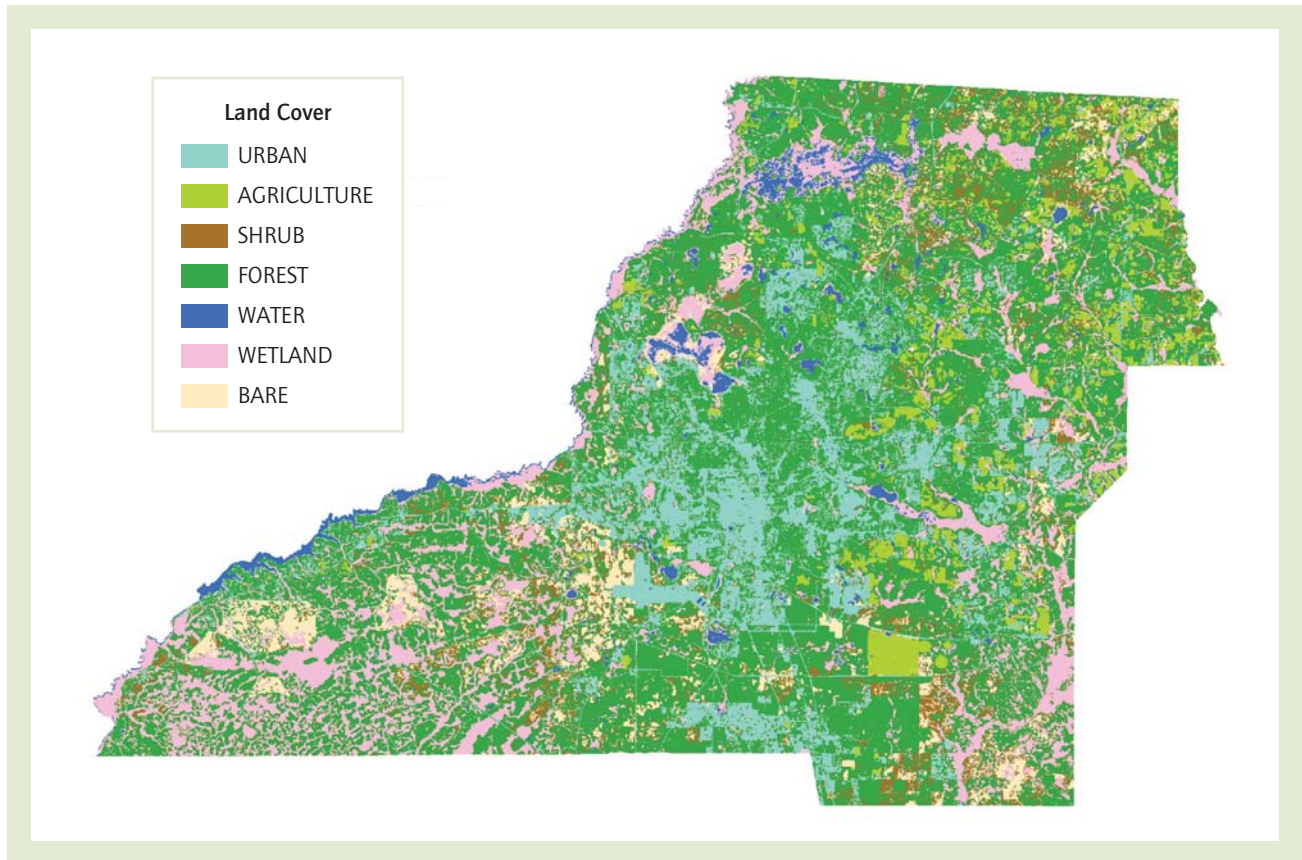


Figure 2 Land cover in Leon County, Florida

Source: Data from Florida Fish and Wildlife Conservation Commission. (2003). *Florida vegetation and landcover*. Tallahassee, FL: Author.

residential class. All patches together make up the landscape.

A variety of size, edge, shape, diversity, and contagion metrics have been developed to measure patch-, class-, and landscape-level patterns. *Size* is related to the area of patches. *Edge* describes the characteristics of the patch perimeter versus the patch core area. *Shape* indicates the complexity of a patch compared with a circle or square. All three metrics can be measured at the patch, class, and landscape levels. *Diversity* measures the richness (i.e., the number of patches of a given class) and evenness (i.e., the distribution of area among different classes) of patch classes at the landscape level. *Contagion* refers to the continuity of patches and may be measured at the class and landscape levels.

Landscape pattern metrics are now incorporated in GIS software packages, for example,

Patch Analyst 4 extension for ArcGIS Desktop. It facilitates the analysis of spatial patterns for the landscape where geographic data are readily available through GIS and remote sensing databases. In the following illustration, several commonly used class- and landscape-level pattern metrics were calculated to explore the spatial characteristics of land cover/use in Leon County, Florida. In 2003, seven land cover classes existed in this area (Figure 2), including Urban, Agriculture, Shrub, Forest, Water, Wetland, and Bare, which were aggregated from the original habitat classification of the Florida Fish and Wildlife Conservation Commission. Patches with areas smaller than 1 acre were extracted and merged to the largest surrounding neighbors before deriving the pattern statistics.

Using Patch Analyst for ArcGIS, mean patch size (MPS), edge density (ED), and area-weighted



<i>Level of Analysis</i>	<i>Area (acres)</i>	<i>NumP</i>	<i>MPS (acres)</i>	<i>ED</i>	<i>AWMSI</i>	<i>Diversity</i>	<i>Evenness</i>
Class	Urban	25,427.43	2,359	10.78	34.92	33.37	—
	Agriculture	9,038.34	1,145	7.89	10.53	2.58	—
	Shrub	10,394.10	6,820	1.52	34.32	3.60	—
	Forest	88,977.42	3,541	25.13	96.38	34.18	—
	Water	4,573.53	938	4.88	6.56	3.93	—
	Wetland	31,528.44	3,204	9.84	39.39	10.63	—
	Bare	11,817.72	3,585	3.30	22.45	5.20	—
Landscape	181,756.98	21,592	8.42	123.07	24.01	1.51	0.78

Table 1 Landscape pattern metrics of land cover in Leon County, Florida

Source: Author.

Notes: Area = class area or total landscape area at the landscape level; NumP = number of patches; MPS = mean patch size; ED = edge density; AWMSI = area-weighted mean shape index; Diversity = Shannon's diversity index; Evenness = Shannon's evenness index.

mean shape index (MSI) were calculated and reported for Leon County at both class and landscape levels, while Shannon's diversity and evenness indices were derived at the landscape level only (Table 1). Results showed that (a) Leon County was dominated by Forest by area; (b) Shrub was the most fragmented land cover type with the lowest MPS, resulting from the highest number of patches and a relatively low number in class area; (c) Forest had the highest MPS among all land cover types, indicating that it was more continuous compared with the rest of the land covers; (d) the shape indices of Forest, Urban, and Wetland were high, indicating the irregular shapes of the three land cover types; and (e) the complicated shape of Forest, Urban, and Wetland contributed to the highest edge density of the three among all the land cover classes. The landscape-level metrics would provide more useful information when comparing two or multiple landscapes or when detecting the temporal changes of a given landscape.

Pattern metrics have been applied widely to the evaluation of landscape heterogeneity as well as to the exploration of relationships between spatial patterns and ecological processes. The results of pattern analysis have practical implementations, for example, wildlife habitat restoration through increasing patch connectivity. However, it is also advised that care be taken when using pattern metrics, which may vary due to inconsistent

criteria for patch segmentation, different solutions in handling edges and borders, shifts in the scale of analysis, and mismatches between landscape patterns and processes. Another limitation of pattern metrics is that they can be applied to discrete data only. For continuous data, geostatistics and graphic approaches provide alternative solutions.

Neutral Model and Process-Based Models

A neutral model is a computer-based simulation technology that produces a two-dimensional (2D) "neutral" map using probability and randomization processes. The term *neutral* is opposite to patterns generated through natural or culture processes. To evaluate whether an observed natural or culture landscape is significantly different from random patterns, neutral models simulate the landscape configuration multiple times (usually 100 to 1,000 realizations) in the absence of certain ecological and/or human factors and compare the overall pattern of simulation results with the observed landscape. Neutral models facilitate the simulation of artificial landscapes, which to some extent compensates for the lack of replication associated with real landscapes.

There are three types of neutral models: (1) complete randomization, (2) randomization with the hierarchical approach, and (3) randomization with the fractal approach (Figure 3).

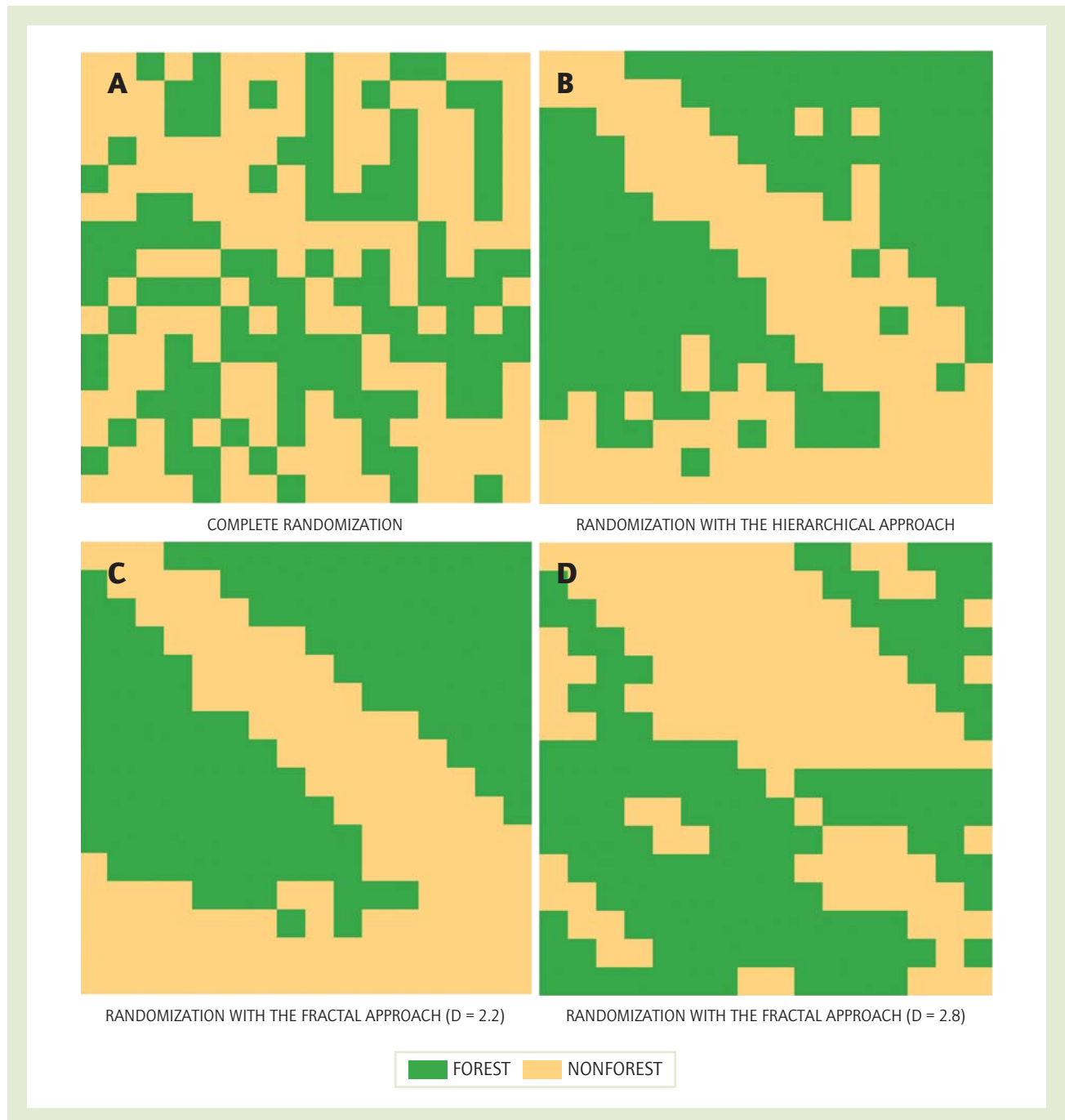


Figure 3 Simulated forest landscapes based on three neutral models. Simulations were performed with the software RULE. Probability of presence of Forest was 0.5 for all simulations. The level of hierarchy was 4 for randomization with the hierarchical approach and randomization with the fractal approach.

Source: Author.

Complete randomization does not consider spatial autocorrelation and determines the presence/absence of a land cover based on probability alone. For example, in a grid of 16 columns $\times$ 16

rows, a random number generator produced a number between 0 and 1 for each of the grid cells. With the assumption that the probability of presence of Forest is equal to 0.5, cells with the



random number ≥ 0.5 were assigned to the Forest land cover type. This resulted in a binary map of Forest versus Nonforest, relatively random in spatial distribution (Figure 3A).

Randomization with the hierarchical approach is simple randomization nested in several aggregation levels. For example, the 16×16 grid may be treated as a hierarchy of four levels, with each quadrature of the higher level divided into four quadrates at the lower level. Assuming that the probability of presence of Forest is equal to 0.75, 1, 0.667, and 1 at each descending level, the total probability of Forest occupancy is approximately 0.5 at the landscape scale (i.e., the product of the four subscale presence probabilities). Simple randomization, the same approach as complete randomization, was performed at each level of hierarchy given the corresponding subscale Forest presence probability. Due to the incorporation of spatial clustering through the nested system, randomization with the hierarchical approach resulted in higher self-organized patterns (Figure 3B) than those produced by complete randomization.

Randomization with the fractal approach is a nested randomization that combines hierarchy and fractal dimension (D). In the 2D space, D measures the resemblance of patches before and after assigning the locations of new pixels with Gaussian randomization. The generated patterns are not correlated when D is 2.5, clustered for lower values (e.g., $D = 2.2$; Figure 3C) and scattered for higher values (e.g., $D = 2.8$; Figure 3D).

In the illustration shown in Figure 3, all four simulated landscapes were produced with RULE, a Microsoft Windows-based software package that generates and analyzes landscape patterns. Probability of the presence of Forest is fixed ($p = 0.5$) for all simulations. The different approaches of neutral models are responsible for the distinctive landscape patterns. The simulated landscape tends to be highly self-organized, with increasing numbers of hierarchy or polarized fractal dimensions.

Process-based models differ from the pattern-based neutral model as they focus more on simulating the mechanisms that drive the changes in landscape patterns and processes. A variety of models have been developed to simulate dispersal, succession, and human behavior. Most of these models are spatially explicit and require the

input of multisource data obtained through ground surveys, remote sensing, and GIS analysis. The process-based models are used to illustrate as well as predict changes in natural and human-dominated landscapes.

Future of Landscape Ecology

Landscape ecology has grown steadily into a well-recognized interdisciplinary field over the past 25 years. Despite the diversity of research topics, landscape ecology developed its own concepts and methods to address the mysteries of the relationships between spatial patterns and ecosystem functions as well as the questions about human-environmental interactions. Understanding the mechanisms of the changing landscape and making reliable predictions of landscape dynamics should be the emphasis of future research. In addition, the rapidly changing global environment and human institutions present new challenges for landscape ecology. Holistic approaches are required to understand the complexity of landscapes. Effective landscape design and sustainable land use are also required to achieve landscape sustainability in practice.

Tingting Zhao

See also **Agroecology; Cultural Ecology; Cultural Landscape; Ecosystems; Ecotone; Energy and Human Ecology; Human Dimensions of Global Environmental Change; Human Ecology; Industrial Ecology; Invasion and Succession; Landscape and Wildlife Conservation; Landscape Biodiversity; Landscape Restoration; Political Ecology; Remote Sensing; Restoration Ecology; Sustainability Science; Urban Ecology; Wilderness; Wildfires: Risk and Hazard**

Further Readings

- Gardner, R. H. (1999). RULE: Map generation and a spatial analysis program. In J. M. Klopatek & R. H. Gardner (Eds.), *Landscape ecological analysis: Issues and applications* (pp. 280–303). New York: Springer.
- Gustafson, E. J. (1998). Quantifying landscape spatial pattern: What is the state of the art? *Ecosystems*, 1, 143–156.



- McGarigal, K., & Marks, B. J. (1995). *FRAGSTATS: Spatial analysis program for quantifying landscape structure* (General Technical Report PNW-GTR-351). Portland, OR: USDA Forest Service, Pacific Northwest Research Station.
- Nassauer, J. I., & Opdam, P. (2008). Design in science: Extending the landscape ecology paradigm. *Landscape Ecology*, 23, 633–644.
- Patch Analyst 4: <http://flash.lakeheadu.ca/~rrempe/p/patch/index.html>
- Turner, M. G., Gardner, R. H., & O'Neill, R. V. (2001). *Landscape ecology in theory and practice: Pattern and process*. New York: Springer.
- Urban, D. L., & Keitt, T. (2001). Landscape connectivity: A graph-theoretic perspective. *Ecology*, 82(5), 1205–1218.
- Wiens, J. A. (2005). Toward a unified landscape ecology. In: J. A. Wiens & M. R. Moss (Eds.), *Issues and perspectives in landscape ecology* (pp. 365–373). Cambridge, UK: Cambridge University Press.
- Wu, J. (2006). Landscape ecology, cross-disciplinarity, and sustainability science. *Landscape Ecology*, 21, 1–4.



LANDSCAPE INTERPRETATION

Landscape is part of the vernacular of architects, artists, earth scientists, geographers, historians, and planners, although the term has a slightly different use and meaning in each discipline. Geographers, landscape pioneers, initiated the exploration and examination of physical geography, land, and environment to organize knowledge about the world. An early definition of landscape was provided by Alexander von Humboldt, the famous German geographer who viewed landscape 200 years ago as the sum of characteristics that make up a region. The roots of landscape interpretation lie in traditional geomorphology and plant ecology.

The concept of landscape held an important place in the geography lexicon during the two world wars and continues to do so today, although it is now less emphasized. Making meaning to better understand the external environment—whether

on a large scale, such as one's backyard, or a small scale, such as a country or the entire world—is known as *landscape interpretation*. The process includes identifying patterns or structures that change over time and space.

The application of landscape interpretation is far-reaching, having its roots in geography and spanning social and vegetation science, conservation, planning, management, restoration, and landscape appraisal and ecology.

Reading the Landscape

The foundation of landscape interpretation is the skill of simply reading a landscape. Two skills are developed in reading the landscape—seeing with the eyes and thinking about what is seen. Few disciplines, however, encourage students to study the world in this informal fashion. Geography's chorological approach values a holistic examination of particular regions and is a fertile ground for landscape reading.

The process of landscape interpretation examines three general ideas, namely, structure, function, and change. Structure refers to the spatial relationships among distinctive components of the environment, such as energy or resources. Function is the interactions among spatial elements, such as the flows of energy within an ecosystem. Change is the temporal alterations of structure and function.

The American geographer Peirce Lewis developed more specific principles (which he called *axioms* and *corollaries*) for reading the landscape in a systematic way. Among these principles is the observation that landscape is an indication of culture, history, geography, and environmental controls. Human-created structures such as roads and places of worship are evidence that document the imprint of culture, providing explanations of who we were, who we are, and who we will become. For example, in Toronto, Canada, it is not uncommon to see a church juxtaposed with a temple and a synagogue. Such a landscape suggests not only that religion is an important part of the culture but moreover that religious diversity is accepted, with all three religious landmarks equally important in the lives of Torontonians. Peirce also argues that the reading of landscapes, whether contemporary or not, must take into



consideration the historical context in which they were created. For example, a barn that stands in isolation in a field tells the story of a farming community that has since disintegrated in an urban settlement. Another of Peirce's principles is that reading landscapes is tightly tied up with the geography context, as culture and history are location and place specific. For example, shopping malls are not located randomly or throughout a city; rather, they are located in specific parts of the city with transportation and access to a residential catchment area. Peirce also insisted that understanding a landscape is closely related to knowing its physical environment; thus, some basic knowledge of physical landscape is needed. For example, terraces rather than flat farmland are built in some parts of the world where landscapes are too steep for traditional agriculture. Finally, although landscapes convey messages, they do so in a subtle way. As a reader of the surroundings, one should learn to ask questions regarding the appearance and form of the landscape, for example, who designed it, why it was designed, how the structure adds to the story of the location and to the surrounding landscapes, and how the society functions. These questions will unearth information that brings to light the less obvious meanings of landscapes.

Interpretation of the Urban Landscape

Landscape interpretation can occur in several ways, from making personal meaning and developing a sense of place to a systematic, more scientific approach. For most of geography's history, the discipline focused on collecting and organizing facts about physical space. Geographers explored the landscape, measured it, and conducted experiments to study the terrain, by means of geomorphological techniques, surveying, or using topographic maps to examine contours.

The classic work of Kevin Lynch provides a systematic way to understand the mental maps of urban landscapes. Lynch identified five landscape features perceived in all urban spaces: paths, boundaries/edges, districts, nodes, and landmarks. Lynch suggested that the interrelatedness of these elements is important to the formation of place legibility, or the fashion in which people interpret elements and combine them to create

understandable layouts of space. For navigation purposes, the interpretation of a landscape primarily uses paths and landmarks. In people's reproduction of a place, in the form of a mental map or a sketch map, paths are used to frame the boundary and create direction, whereas landmarks are added to give more personal meaning to a location, for example, one's favorite coffee shop or the most frequented gasoline station. Gender differences are often noted in landscape interpretation. In particular, sketch maps by males are frequently dominated by paths (e.g., roads, highways, trails) that are used to indicate direction and the main travel arteries, with relatively few landmarks. Females generally focus on landmarks in their drawings of landscape, often using them to identify neighboring paths.

A major change occurred in the late 20th century, with a shift to understanding the "why," "how," "what," and "where" of landscape. During this time, geography was influenced by different schools of thought, including behavioralism, humanism, Marxism, feminism, postmodernism, the social construction of nature, and postcolonialism. As the field changed, geographers shifted their focus from fieldwork in natural landscapes to the qualitative examination of social relations and land uses, understanding landscapes as complex mixtures of social activities and the natural world.

Interpreting Landscapes With Technology

The quantitative approach to landscape interpretation aims to examine the distribution and abundance of phenomena and processes at a range of spatial and temporal scales. Known as landscape metrics, these quantitative measures distinguish patterns on maps or remotely sensed images. This science is related to landscape interpretation and was termed *landscape ecology* in 1939 by the German geographer Carl Troll, with roots in regional geography and vegetation science. Troll primarily used aerial photographs in his research.

Increasingly sophisticated quantitative measures of landscape patterns have been applied since the late 1980s, whose aim is to correlate the processes occurring in the environment or the ecosystem with the patterns manifested in the landscape, especially those not easily identified by the human



eye. This approach groups measurable variables, namely, shape, size of shapes, and textures, to distinguish patterns in the landscape. These research strategies are of interest to geographers as well as ecologists in examining the patterns of movement of sensitive species to predict whether they may migrate due to fragmentation or increased edges in their current space or whether their habitat size is sufficient for population growth.

Two computerized tools have played a pivotal role in recent landscape interpretation research, namely, remote sensing and geographic information systems (GIS). Remote sensing provides large quantities of environmental data in the form of satellite images of Earth's surface. Such data sets are beneficial for quantitative research for several reasons. First, sensors collect data from a distance, reducing the amount of human bias introduced. Second, data can be collected at different spatial scales, ranging from the local and regional to the national and global, and repeated across temporal scales, such as seasons or years. Third, numerous sensors and spectral ranges are available that specialize and distinguish data collection from specific surfaces such as water, farmland, and urban settlements.

A GIS is a computerized system that stores, manages, displays, and analyzes spatial data. Remotely sensed data in conjunction with related digital information (e.g., the locations of landmarks) can be added to further the analysis. A GIS has several functions. First, landscape features can be visualized or represented in a GIS. The second function of GIS is to predict the consequences of potential changes at different spatial and temporal scales. The third function is to evaluate the impact of the actions taken and to compare the results of alternative solutions.

The quality and effectiveness of landscape interpretation using the outputs of remote sensing and GIS depend on the scale, origin, and reliability (or accuracy) of the input data (e.g., GIS data may be incomplete, remote sensing images may be affected by cloud cover).

Niem Tu Huynh

See also **Chicago School; Cultural Landscape; Environmental Perception; Landscape Architecture; Landscape Design; Landscape Ecology; Landscape**

Quality Assessment; Land Use Analysis; Meinig, Donald; Mental Maps; Palimpsest; Remote Sensing; Sauer, Carl; Spatial Cognition; Vernacular Landscapes as Expressions of Environmental Ideas

Further Readings

- Frohn, R. C. (1998). *Remote sensing for landscape ecology*. Boston: Lewis.
- Lynch, K. (1960). *The image of the city*. Cambridge: MIT Press.
- MacIlwraith, T. F. (1997). *Looking for old Ontario*. Toronto, Ontario, Canada: University of Toronto Press.
- Meinig, D. W. (Ed.). (1979). *The interpretation of ordinary landscapes*. New York: Oxford University Press.
- Turner, M. G., & Gardner, R. H. (Eds.). (1990). *Quantitative methods in landscape ecology: The analysis and interpretation of landscape heterogeneity*. New York: Springer-Verlag.



LANDSCAPE QUALITY ASSESSMENT

Landscape quality assessment means aesthetic evaluation of an area of Earth's surface. The word *landscape* originates from the 16th-century Dutch word *landschap*, which described paintings of inland natural or rural scenery. Originally translated into English as *landskip*, the term was gradually replaced by *landscape*. Landscape refers to the surface of land and water bodies that may be viewed and includes physical landforms, land cover, and land uses. The adjective *quality* denotes an aesthetic dimension that derives from the human perception of the landscape. The terms *landscape quality* and *scenic quality* are equivalent, *scenery* deriving from stage backdrops but now applied also to the physical environment. *Scenic quality* is the more common terminology in the United States. *Assessment* means some form of evaluation or discrimination of landscape quality. The terms *values*, *preferences*, *amenity*, and *resources* are sometimes substituted for *quality*.



Significance

Combining both their physical origins and the cultural overlay of human presence, and often created over millennia, landscapes reflect the living synthesis of people and place vital to local and national identity. The characteristics and quality of landscapes help define the self-image of a region—its sense of place—differentiating it from other regions. It is the dynamic backdrop to people's lives. Viewing natural landscapes may provide tangible health benefits. Many landscapes attract visitors, thereby supporting tourism and recreational industries and supporting regional economies. Landscape degradation diminishes quality of life. The iconic value of distinctive landscapes is commonly used in advertising. Many World Heritage Areas (as defined under the Convention concerning the Protection of the World Cultural and Natural Heritage, adopted by the United Nations Educational, Scientific and Cultural Organization [UNESCO] in 1972) and national parks are established to safeguard landscapes of outstanding quality. The results of landscape quality assessment may influence relevant policies.

Theoretical Basis

An evolutionary perspective underlies current theories of landscape quality: Preferences for high-quality landscapes are survival enhancing. Far from being casual or trivial, Stephen Kaplan believes, aesthetics are a guide to human behavior and have far-reaching consequences.

Jay Appleton's prospect-refuge theory postulates that, originally, landscapes were preferred that enabled one to see without being seen, that provided places (prospects) where one could spy out game or the enemy while also providing places (refuges) in which to hide. Empirical studies provide some support to this theory while identifying other contributing factors; for example, mountains and trees (prospects) are preferred, but caves (refuges) are not.

Roger Ulrich's affective theory postulates that natural settings and landscapes produce emotional states of well-being in their viewers. When landscape aesthetics are measured on a like-dislike dichotomy, these states correlate closely

with scales such as beautiful-ugly or scenic quality scales. A study of hospital patients found that those with a view of trees recovered more quickly and required fewer analgesics than those without this view.

Gordon Orians's habitat theory postulates a biological imperative for humans to prefer environments likely to afford the necessities of life. He has found strong preference for the African savanna, containing scattered acacia trees amid extensive grassland, believed to be the environment in which humans evolved. The popularity of pastoral landscapes of trees and grass, as found in parks, reinforces his case.

Stephen and Rachel Kaplan apply information-processing theory to landscape aesthetics, arguing that in extracting information from the environment, humans seek to make sense of the environment and be involved in it. They identified four predictor variables: *coherence* and *legibility*, which help one understand the environment, and *complexity* and *mystery*, which encourage its exploration.

A robust theory that provides an all-encompassing framework with which to understand and predict landscape preferences from microlevel to macrolevel, covering all types of landscapes, does not yet exist. A range of theoretical models is available; these offer explanations of aspects of landscape preferences but fall well short of a comprehensive and definitive explanation.

Development of the Science of Measurement

Stimulated in part by legislative mandates, such as the U.S. National Environmental Policy Act of 1970, which required consideration of unquantified environmental amenities by recognition of scenic quality as an environmental resource, scenic quality has been measured by many studies.

These studies lie along a continuum: from physical studies, which measure characteristics directly from the landscape, through preference studies, which measure the human perception of these characteristics in aesthetic terms, to experimental studies, which identify the feelings and experiences of landscape interactions.



Cape Bauer, South Australia

Source: Author.

Physical studies involve the description, analysis, and sometimes quantification of the physical characteristics of the landscape without reference to human perceptions. Forest managers use Visual Resource Management systems (VMS) and, latterly, the Scenery Management System to measure scenic quality from the forest's formal aesthetic features—that is, its form, line, color, texture, and variety. VMS is used to predict and minimize the visual impact of forestry operations.

Preference studies involve people assessing scenes and rating their scenic quality on a scale from low to high (e.g., 1 to 10). Typically, they use photographs of the region being considered and ask people to rate them. Many studies have established the efficacy of photographs as an alternative to field assessment, provided that they are standardized (e.g., color, 50 mm, landscape format, cloud-free conditions, avoiding composition). Separate measures of the components

of the landforms, trees, water, and so on, in the landscape allow, using multiple regression analysis, the development of predictive models of scenic quality based on their features.

Experiential studies examine the aesthetic experiences gained by the community through its interaction with the landscape; these are broader than solely visual and include abstract qualities, evocative responses, and sense of place and meanings. Obtaining consistent results can be a challenge.

Applications

The very act of identifying and measuring scenic quality opens up possibilities not previously available. These include mapping and incorporation into planning policies; defining objectives to manage, protect, and even enhance scenic quality; delineating areas for designation as World



Heritage Areas and national parks or for use in tourism and recreational promotion; selecting routes for roads and power lines; minimizing developmental impacts; and managing forest harvests and forest and fire management.

Andrew Lothian

See also **Cultural Ecology; Cultural Landscape; Environmental Imaginaries; Environmental Impact Assessment; Environmental Perception; Environmental Restoration; Landscape and Wildlife Conservation; Landscape Biodiversity; Landscape Design; Landscape Ecology; Landscape Interpretation; Landscape Restoration; Political Ecology; Sense of Place**

Further Readings

- Appleton, J. (1975). *The experience of landscape*. London: Wiley.
- Daniel, T. C. (2001). Whither scenic beauty? Visual landscape assessment in the 21st century. *Landscape and Urban Planning*, 54, 267–281.
- Daniel, T. C., & Vining, J. (1983). Methodological issues in the assessment of landscape quality. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the natural environment* (chap. 2, pp. 39–83). New York: Plenum Press.
- Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge, UK: Cambridge University Press.
- Lothian, A. (1999). Landscape and the philosophy of aesthetics: Is landscape quality inherent in the landscape or in the eye of the beholder? *Landscape and Urban Planning*, 44, 177–198.
- Orians, G. H., & J. H. Heerwagen. (1992). Evolved responses to landscapes. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind, evolutionary psychology and the generation of culture* (pp. 555–580). Oxford, UK: Oxford University Press.
- Ulrich, R. S. (1993). Biophilia, biophobia, and natural landscapes. In S. R. Kellert & E. O. Wilson (Eds.), *The biophilia hypothesis* (pp. 73–137). Washington, DC: Island Press.
- Zube, E. H., Sell, J. L., & Taylor, J. G. (1982). Landscape perception: Research, application and theory. *Landscape Planning*, 9, 1–33.



LANDSCAPE RESTORATION

In the past two decades, landscape restoration has increasingly become a field of research and applied science addressing the multifaceted nature of environmental problems, and it has developed an integrated theoretical framework. Whereas maintenance denotes some regular and relatively slight work directed at conserving a humanized environment, restoration consists of a set of actions designed to improve a degraded or simplified environment. Etymologically, “to restore” derives from the Latin word *restaurare* and from the Old French word *restorer*, which means “to repair,” “to rebuild,” or “to renew.” For environmental purposes, this term implies the memory or knowledge of previous conditions, the negative evaluation of recent alterations and the present context, and the will and means to reestablish an ancient equilibrium.

Many restoration models and practices have been applied to ecosystems. More recently, landscape restoration has broadened its scope, with prospects for the sustainable use and management of natural resources. More than the ecosystem concept, the landscape definition pays particular attention to the human dimension and integrates the actions of and interactions between natural and cultural factors. The landscape perspective does not neglect the negative impacts resulting from the exploitation of natural resources. In addition, it places emphasis on emotional, socio-economic, and cultural elements. It is almost a revolution, insofar as it requires an effort to live today with one eye toward yesterday and the other toward tomorrow, to repair the environment, to recognize the dynamic steady state characterizing the structure and functioning of ecosystems, and to substitute an objective-oriented strategy for a reference-oriented approach.

The meaning of landscape restoration varies according to the scientific community, the type of environment to be restored, and the content of the restoration program. For instance, in Switzerland, the simple repairing of biotopes in a disturbed watercourse is called *revalorization* and attends to biodiversity, spawning areas, or anadromous fish. With *revitalization work*, such as dike shifting or dam removal, the aim is to reestablish the dynamic



processes of water and sedimentation and to widen river corridors for flooding or for prevention of bank erosion. More generally, this distinction underlines the coexistence of structural and dynamical restoration models and highlights the frequent temptation to restore and congeal some idealized forms rather than the processes necessary for their formation and maintenance. It raises the question as to whether such labors may actually effect a restoration. After the restoration of a floodplain lake, how long will it remain connected to the main channel, the water flow, and the bed-load transport, which are disrupted by facilities in the humanized floodplain? Clearly, the continuous stability of a biotope is artificial. The progressive sedimentation of this lake will need some "restoration" work again.

Revalorization is a partial process that aims to make an area more natural, with the objective of "renaturation" being to give an anthropogenic environment its natural features back and to restore its ecological functioning, structure, and equilibrium. In ecological restoration, the original or predisturbance condition is called the "reference state." It is usually characterized through historical investigations. Some restoration actions try to reestablish landscapes. However, in societies that have a long tradition of agricultural and grazing activities, it is not easy to identify and choose a reference landscape. This ethical question opens the debate on different visions of nature in expert or vernacular knowledge. Wild nature often appears as a vanished quest for a "paradise lost." The idea of reversibility, which is inherent in restoration or renaturation work, raises several conceptual, scientific, and technical problems. Moreover, the wilderness often does not respond to social demands. Arcadian nature supplies many valuable landscapes, characterized by attractiveness and aesthetic quality, but tends to achieve and fix an ideal/dream state. Functional nature is densely occupied and is developed to the detriment of naturalness.

Environmental, socioeconomic, and cultural problems are deeply intertwined. Landscape restoration recognizes that nature provides socioeconomic and cultural benefits in the form of goods and services. Public participation is useful to define society's needs and wants, to set priorities in restoration motives, and to select restoration actions.

Rather than a reference-oriented strategy, landscape restoration resorts to an objective-oriented strategy that integrates anthropogenic features and processes. For example, the restoration of hedgerows targets at least three objectives. Ecological studies have shown the value of planted, spontaneous, and remnant hedgerows. More than 500 vascular plant species grow and numerous fauna communities are observed in English hedgerows, which provide them with habitats, prevent them from being attacked by predators, and provide access to food and a corridor for movement of some species. Furthermore, the narrow bands of wooden vegetation modify the microclimate, reduce soil erosion, protect nutrients, and prevent floods in adjacent cultivated fields. Hedgerows also appear as a significant component of traditional rural landscapes, which residents give meaning to through filters of cultural heritage, sense of place, and attractive living space.

Many stakeholders have led landscape restoration programs at different levels, particularly non-governmental organizations (e.g., the World Wildlife Fund and the International Union for Conservation of Nature), federal and national agencies (e.g., the U.S. Environmental Protection Agency and the French Mountain Land Restoration service), and the managers of natural resources. Projects are designed for many environments, such as rivers, wetlands, riparian corridors, woodlands, meadows, hedgerows, and so on. Thus, several partners have selected the landscape level to restore a flooded forest in the north of Mali. While forest restoration considers change a menace—because it causes a loss of diversity, coherence, and identity—and attempts to restore the pristine composition, structure, and functions of the past, forest landscape restoration recognizes the multifunctionality of forested areas and aims at finding an optimal balance of ecological, socioeconomic, cultural, and spiritual interests for trees and forests.

The benefits of landscape restoration derive from a multistakeholders approach, including better governance over natural resources, accommodation of competing land uses, participation of local communities, and collaboration with environmental educators. Therefore, rather than following a preestablished, vain, and rigid model, landscape restoration initiatives integrate the specificities of local territories to elaborate



sustainable and durable projects for environments and societies.

Yves-François Le Lay

See also **Applied Geography; Cultural Landscape; Environmental Ethics; Environmental Impact Assessment; Environmental Restoration; Everglades Restoration; Forest Restoration; Landscape and Wildlife Conservation; Landscape Biodiversity; Landscape Design; Landscape Ecology; Landscape Interpretation; Landscape Quality Assessment; Nature; Participatory Planning; Population and Land Degradation; Prairie Restoration; Sustainable Development**

Further Readings

- Antrop, M. (2005). Why landscapes of the past are important for the future. *Landscape and Urban Planning*, 70, 21–34.
- Holl, K. D., Crone, E. E., & Schultz, C. B. (2003). Landscape restoration: Moving from generalities to methodologies. *Bioscience*, 53, 491–502.
- Lamb, D., & Gilmour, D. (2003). *Rehabilitation and restoration of degraded forests*. Gland, Switzerland: International Union for Conservation of Nature.
- Moreira, F., Queiroz, A. I., & Aronson, J. (2006). Restoration principles applied to cultural landscapes. *Journal for Nature Conservation*, 14, 217–224.



LANDSLIDE

A landslide is defined as the rapid downslope movement of slope-forming materials—rock, soil, debris, or combinations of these materials. In regions of the world where steep slopes combine with heavy-moisture episodes, mass movement and landslides are a risk. Landslides are difficult to predict and prepare for because a wide variety of factors influence the likelihood of a landslide occurring. Landslides are an important geomorphic process in mountainous regions, fundamentally shaping the hydrology, geology, and ecology of a place. This natural phenomenon presents a

significant challenge to people who place property and community in the path of potential landslides, challenging planners, government personnel, and citizens to better understand the complexities of landslide occurrence in their region in order to protect infrastructure, resources, property, and people.

Landslide Classification and Causes

Many systems for classifying mass movements have been created in the past century. The most widely used and accepted classification system in the United States was presented in 1958 by David Varnes in *Landslides and Engineering Practice: Special Report 29*, with revisions in *Landslides: Analysis and Control, Special Report 176* in 1978. Six types of movements are defined in this system, and each type is further divided based on the type of material in which the movement occurs. Slides (landslides) are one of the six types of movements defined (Table 1).

The likelihood of a landslide occurring depends on the relationship between shear stress (forces driving materials downslope, namely, gravity forces) and shear strength (forces resisting the movement of material). More specifically, a slope remains stable if the shear stress exerted on the slope is less than or equal to the shear strength of the slope material (a function of normal stress-resisting movement, cohesion, and the internal angle of friction). When shear stress on a slope is greater than shear strength, mass movement occurs. Factors that either increase shear stress or decrease shear strength, therefore, increase the likelihood of a landslide occurring.

Factors that can increase shear stress include the removal of slope material or the oversteepening of slopes, as can occur with stream erosion or road building; heavy precipitation or snowmelt events that increase pore fluid pressure and reduce resistance to movement; overloading of slopes; and earthquakes. Compositional, textural, and structural properties of rocks and soils and the influence of weathering on these properties are the dominant factors determining the shear strength of a slope. Slope material properties strongly influence cohesion and the normal forces acting on slope material. Cohesion-less slope material, soils with high clay content, and soils



Type of Movement		Type of Material		
		Bedrock	Soil	
			Predominantly Coarse Material	Predominantly Fine Material
Falls		Rock fall	Debris fall	Earth fall
Topples		Rock topple	Debris topple	Earth topple
Slides	Rotational (few units)	Rock slump	Debris slump	Earth slump
	Translational (many units)	Rock block slide	Debris block slide	Earth block slide
		Rock slide	Debris slide	Earth slide
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow	Debris flow	Earth flow
		Deep creep	Soil creep	
Complex	Combination of two or more principal types of movement			

Table 1 Classification of mass movements

Source: Varnes, D. J. (1978). Slope movement types and processes. In R. L. Schuster & R. J. Krizek (Eds.), *Landslides: Analysis and control, transportation research board special report 176* (p. 11). Washington, DC: National Academy of Sciences.



Gros Ventre Slide, Grand Teton National Park, Wyoming

Source: U.S. Geological Survey.



The Loma Prieta, California, earthquake on October 17, 1989, near the San Francisco and San Mateo County coast produced this landslide north of Fort Funston. The slide mass is approximately 2,830 m³ of material and is 30 m high.

Source: U.S. Geological Survey.

and rocks composed of inherently weak materials or that become weak with change in water content and jointed rock formations can all decrease the shear strength of slope material, increasing the likelihood of landslide occurrence.

Environmental Consequences of Landslide Occurrence

Landslides are a dominant geomorphic process in mountainous terrains, leaving an unmistakable imprint on the physical geography of mountainous regions at various scales. Deep-seated mega landslides determine the orientation of slopes in some mountainous environments and fundamentally change the organization of fluvial systems. These mega landslides are often closely connected to tectonic events. Common landscape features resulting from surface-based landslides include exposed bare ground at landslide scarps, rounded toe slopes, hummocky topography composed of bumpy mounds and depressions, and abrupt differences in

vegetation on the landslide compared with adjacent stable slopes. Damming of major streams and creation of lakes near the toe of slopes is common with large-scale landslides, such as the Slumgullion earth flow (e.g., Lake San Cristobal) in the San Juan Mountains of Colorado and the 1911 landslide in Tajikistan, which dammed the Murghab River, forming Sarez Lake. Some landslide dams fail soon after formation, while others become long-lasting landscape features. These dams dramatically change sediment/water transport and complementary depositional/erosional cycles in a watershed. Landslides also alter vegetative communities, stripping soil and existing vegetation from slopes to reveal bedrock.

Social Consequences of Landslide Occurrence

According to the U.S. Geological Survey, landslides cause approximately \$1 billion to \$2 billion in damages and more than 25 fatalities on average



annually in the United States. The potential for landslide occurrence must be considered when humans move into mountainous regions, and the danger that people face living in these regions is well documented. On June 23, 1925, a 1-mile-wide section of earth northeast of Jackson, Wyoming, collapsed, damming the Gros Ventre River and creating Lower Slide Lake (see Grand Teton photo). Known as the Gros Ventre Slide, the dam on Lower Slide Lake failed 2 years later, flooding the town of Kelly, Wyoming, and killing six people and hundreds of head of livestock.

Landslide Research in Geography

Research on landslides is extensive. Fields where landslide research abounds include environmental geology, physical geography, geotechnical and civil engineering, hazard management and mitigation, hydrology, and ecology. Primary geographic research themes include landslide recognition and mapping, landslide case studies, analysis of the economic and social impacts of landslides, and predictive model generation for landslide susceptibility using geographic information system (GIS) technology. With rapid development occurring in mountainous regions around the world and numerous examples of human-induced landslides in recent years, the challenge to predict landslide occurrence is immense.

Ashley B. Zung

See also Avalanches; Creep; Disaster Prediction and Warning; GIS in Disaster Response; GIS in Land Use Management; Mass Wasting; Natural Hazards and Risk Analysis; Vulnerability, Risks, and Hazards

Further Readings

- Landslide Hazards Program. (2008, June). *Landslide hazards program*. Retrieved October 15, 2008, from <http://landslides.usgs.gov>
- Schuster, R. L., & Krizek, R. J. (Eds.). (1978). *Landslides: Analysis and control* (Special Report 176). Washington, DC: National Academy of Sciences.
- Sharpe, C. F. S. (1938). *Landslides and related phenomena*. New York: Columbia University Press.

LAND TENURE

Land tenure, or rural property rights, can be defined in several ways. The terms generally concern the ways in which “social relations relate to land use and ownership.” One popular way to view land tenure is as a bundle of rights within a society or community. In such a bundle, rights can be added, removed, or divided to create a very wide variety of rights to land and land-based resources. While land rights are often thought to be produced by titles, deeds, registries, and leases, in reality these are artifacts of a system that involves enforcement, dispute resolution, evidence, identity, forms of logic, institutional formation and operation, and derivation and maintenance of authority and legitimacy. The relevance of land tenure to geography lies in its explicit spatial relevance to Earth’s surface, along with how human elements (based on rights) are arrayed within space. This entry describes the fundamental aspect of tenure security, the types of land tenure, and the more accepted land tenure paradigms.

Tenure Security

Tenure security plays a primary role in the functioning of land tenure. Essentially, it is a “feeling” regarding how secure one is with regard to continued access to and use of one’s land. Such security influences decision making involving investment in and use of lands. Thus, such decisions, along with transactions (buying, selling, renting, loaning, and inheriting), are made based on how secure one’s rights to land are. The logic is that secure tenure leads to making investments (involving time, effort, and money) that are viable over the long term. Thus, there is a connection between tenure security and the rational use and management of resources. Although the concept of land tenure is seemingly straightforward, much research has been undertaken on the nature of tenure security and how it functions, particularly in the developing world, due to the issue’s connections to agricultural productivity and the use of land as collateral for loans. However, tenure security can be difficult to understand, measure, and enhance in a consistent and predictable



way. This is because tenure security is not very tangible, and a wide variety of variables, processes, and contexts are believed to influence it. Generally, secure tenure implies that claims to land are secure because they are defensible against other claims.

A fundamental aspect of tenure security is the means to prove rights to claims by way of evidence. All claims to land are part of a construction of an evidence-based “argument for claim.” Even formal title is only an argument based on evidence that can be, and often is, contested—as are claims based on tribal, ethnic, religious, and other identities. The legitimacy of evidence depends not only on the interpretation or translation of reality into evidence but also on acceptance by others (a community) that the inferences, interpretations, and conclusions are logical and legitimate.

The problem of such proving is at the heart of several popular approaches to land tenure, including the rights recognition approach (recognition of customary or indigenous rights to land), the capital/poverty/property rights approach (described by de Soto and adopted by numerous governments and development agencies), and attachments or claims to land based on identity (with the Palestine-Israel example being perhaps the most extreme).

The “community” aspect of tenure security intersects with how evidence is treated. In many cases, the community is a local village, which has specific internal evidence for a claim that is recognized as legitimate by the community. Evidence at this scale can include community membership, lineage, ethnicity, testimony, land use history, current occupation, and physical signs of occupation. However, such a community can exist within a wider national community in which different evidence is legitimate under formal law. This evidence can value deeds and titles as well as procedures to obtain and defend them. This difference can be problematic because a local community can be unable to defend a claim (using community evidence) against others in a national community (using documentary evidence).

Types of Land Tenure

The primary categories of land tenure types are formal (or statutory) and informal (or

customary). While informal or customary tenure can also be labeled *traditional* or *indigenous*, there are distinctions. Indigenous tenure has to do with particular aboriginal groups and may or may not be customary or traditional. Traditional tenure is largely historical and can have little to do with present-day customary tenure. Thus, customary tenure is a way of approaching tenure that is largely unofficial and comprises the many ways in which people have responded to procedures for institutionalizing land tenure. Customary tenure can be anything from ad hoc to hybridized with statutory tenure and can include traditional or indigenous elements, but it is dynamic and responsive to present-day concerns.

Land Tenure Paradigms

The failure of many past attempts at replacing customary tenure with formal tenure has led many analysts to conclude that there needs to be movement away from the replacement paradigm toward an adaptation paradigm. Such an adaptation approach involves not only the recognition of customary ways by formal law but also the evolutionary transformation of customary law in reaction to exposure to formal law.

While the adaptation paradigm highlights the evolutionary nature of change in both customary and formal tenure systems as these adapt to each other, this approach is different from the evolutionary theory of land rights. This theory holds that population increase results in land scarcity, change in land values, increased uncertainty, and conflict; as a result, a population demands and the state delivers more secure property rights via title. By using population increase and land scarcity as its primary drivers, the theory assumes that the evolution of customary property rights occurs in isolation from interaction with formal tenure systems, which is the central theme of the adaptation paradigm.

Jon Unruh

See also **Agrofoods; Environmental Entitlements; Environmental Justice; Environmental Rights; Environmental Security; Land Reform; Land Tenure**



Reform; Land Use; Land Use History; Law, Geography of; Movimento Sem Terra; Peasants and Peasantry; Rural Development; Via Campesina (International Farmers' Movement)

Further Readings

- Bruce, J. W., & Migot-Adholla, S. E. (1994). *Searching for land tenure security in Africa*. Dubuque, IA: World Bank and Kendall/Hunt.
- de Soto, H. (2000). *The mystery of capital: Why capitalism triumphs in the West and fails everywhere else*. New York: Basic Books.
- Unruh, J. (2006). Land tenure and the "evidence landscape" in developing countries. *Annals of the Association of American Geographers*, 96, 754–772.

LAND TENURE REFORM

Land tenure reform is broadly understood to be a reworking or reorientation of policies, laws, and approaches for managing land tenure—in other words, a restructuring of legal and social relations concerning land. This can include replacing or consolidating laws or making additions to laws to accommodate a new approach to land tenure. Land tenure reform is distinct from land reform in that land is ordinarily not confiscated from some people and redistributed to others as a part of land reform. Thus, land tenure reform is closer to land policy reform. However, land tenure reform can be used to achieve forms of land reform through community-driven land acquisition, market-assisted acquisition, resettlement, or delivery of forms of equity and justice through markets or other incentive mechanisms. The topic is relevant to geography because of the spatial nature of land rights and the ways in which space can be remade or reconstituted with land tenure reform.

Approaches to land tenure reform usually mirror the ideological, social, political, and economic perspectives of those engaged in reform, which may or may not be at odds with those of other sectors of society. Generally, two

approaches to relations about land influence tenure reform. One approach understands land to be a part of the social relations between people, society, and land. More traditional or customary societies favor this approach to land. The other approach pursues the idea that land is a part of the economic relations between people, with land viewed largely as a commodity to be bought and sold—with many types of reform focused on making such transfer easier. Modern industrialized societies favor this second approach. Significant efforts in land tenure reform have sought to move societies from the former to the latter approach. However, the social relations approach cannot easily be legislated out of existence and replaced by market approaches to land. This is because customarily held land also provides important forms of livelihood security and insurance, which are not replaced when land is transformed into a commodity.

Land tenure reform is a priority in many international development agendas, due to its strong relevance in reducing rural poverty and food insecurity. Even so, there is considerable disagreement as to how, when, and for whom such reform should occur. While some advocate the granting of titles to lands, others favor providing greater rights and security of rights to customary forms of tenure. Reform of tenure rules generally assumes that the prevailing approach does not facilitate certain goals, such as poverty reduction, food security, peace, capital mobilization, credit, and so on, and that therefore an improvement is needed. This need for improvement can emerge through change in population pressure, the need for efficiency in landholdings (e.g., family farmers use land more efficiently than large commercial holdings), change in economics, growing land scarcity, land market operation, armed conflict or looming conflict, formalization of customary tenure, and perceived inequity in holdings or the rules under which land is held. While most attempts at land tenure reform are intended to facilitate improvement in peoples' lives, this is not always the case. Some instances of land tenure reform are purposefully political or ethnic, such as the "ethnic cleansing" and the laws that supported this in the Balkans wars in the 1990s.

Many forms of land tenure reform that attempt to improve lives seek to enhance tenure security.



The improvement of such security is thought to facilitate several problems associated with rural property (e.g., food production, credit, land investment), all of which are seen as productive use of land resources. But because the starting point of such reform varies between societies, the reform process and outcomes can vary as well. Reforms that take place with regard to private property, common property, group-held property, property held by particular ethnic groups, scarce land, abundant land, and so on can all take different approaches given the type of improvement needed.

In many cases, land tenure reform is brought to the fore by severe inequity with respect to a number of variables connected to landholdings: location, amount, value, rule-of-law issues, and the viability and legitimacy of dispute resolution mechanisms. This reality is accompanied by the related notion that prevailing, in-place land markets, laws, and enforcement are not able to distribute or redistribute land from the rich to the poor, or vice versa; from unproductive to productive holdings and holders; or from specific groups that are thought to deserve the return or removal of their lands. Because land tenure reform is political, opposition or resistance from some segments of society is normal. Most often, the source of such opposition is those who benefit from the current arrangement and will most likely lose land, wealth, or power as a result of attempts at reform. The obstacles to tenure reform can be strong and take various forms, since the opposition is generally wealthy and connected to or part of the current government structure. However, because the need for such reform can be significant, along with the cost of not reforming, significant political will (often with assistance or pressure from international actors) must often be brought to bear for successful reform to take place.

How to proceed with land tenure reform is a significant concern. While it is easiest to simply import models of land tenure from elsewhere in order to pursue reform, often what works in one society does not work or work as well in another. This is because land tenure is significantly based on history, ideology, and social relations and is not simply a matter of importing law or policy.

Jon Unruh

See also **Environmental Entitlements; Environmental Justice; Environmental Rights; Environmental Security; Land Reform; Land Tenure; Land Use; Law, Geography of; Movimento Sem Terra; Peasants and Peasantry; Rural Development; Via Campesina (International Farmers' Movement)**

Further Readings

- Brinkerhoff, J. W., & Crosby, B. L. (2002). *Managing policy reform: Concepts and tools for decision-makers in developing and transitioning countries*. Bloomfield, CT: Kumarian Press.
- Ghimire, K. B. (Ed.). (2001). *Land reform and peasant livelihoods: The social dynamics of rural poverty and agrarian reforms in developing countries*. London: ITDG.
- McAuslan, P. (2003). *Bringing the law back in: Essays in land, law, and development*. Burlington, VT: Ashgate.



LAND USE

Land use is a difficult term to define, as it lacks a standard interdisciplinary definition and is frequently used interchangeably with the term *land cover*. However, these terms have distinct meanings. Land cover refers to the physical and biological cover over the surface of Earth, including water, vegetation, bare soil or rock, and ice. Land use refers to the ways in which Earth's surface has been transformed by human activities such as farming, industry, transport, and urbanization. A close connection obviously exists between land cover and land use, and they are often treated jointly as land use/land cover. The topic of land use is fundamental to the existence of urban planning, is a basic component of many geographical models of urban and transport phenomena, is central to many human-environment interactions, and is an important component of sustainability.

Land Use Regulation

The concept of land use assumes that all land can be surveyed and classified according to its



economic use. Social activities or cultural meanings are generally ignored. The concept is based on applying classifications to land areas and can be used at different scales, such as individually owned parcels of land or larger administrative overlays. It is an inherently spatial concept as it is a statement about what is happening at different locations. This concept provides a basic set of statistics about the allocation of urban and rural space to different activities, which can be measured for jurisdictions at any spatial scale. As there is generally a finite supply of land available in a jurisdiction, an increase in one land use will require a decrease in other land uses. Evaluating changes in land use over time therefore provides a means of measuring economic change in an area.

Land use cannot be discussed separately from the regulation of land uses. In most jurisdictions, land uses are controlled by zoning laws, which govern what activities may be carried out on properties and where different activities may take place. This is based on the notion that certain land uses are incompatible with others, may reduce property values, cause health and safety problems for humans, or result in environmental damage. Land use regulation is therefore aimed at the legal exclusion of particular land uses (such as industry) from certain areas (such as residential areas) to prevent conflicts or for the preservation of environments such as endangered wetlands. This process, in turn, requires classifications based on knowledge of the potential value of different land uses, the effects of land uses on adjacent land uses, and even the effects of the relative abundance of different land uses within a city on land values (or future land values). Implicit in this is the valuation of land uses, whether for increased land value and taxation or for social desirability. However, land use zones do not necessarily specify which land uses actually exist in an area but only what future uses are planned. Land uses existing before a zoning law is created may be allowed to continue. In that sense, zoning represents a preferred or idealized land use classification and map.

Land use policy and regulation in the United States occur primarily at the local level, and they express a community's economic, cultural, and political interests. As a result, land use classifications vary in their details from one place to another. Regulation tends to be greatest in urban

areas. Many rural areas of the United States have very little land use regulation, and sometimes those regulations are designed to protect what in other communities would be considered LULUs (locally unwanted land uses), such as mining and other extraction activities, solid waste landfills, factory farming, and other livestock operations. Since these decisions are made at the local level, neighborhood-based groups sometimes advocate "not in my backyard" (NIMBY) and are often effective at promoting or blocking a land use policy.

Urban land use regulations tend to be use or activity specific, meaning that a number of specific uses are codified and regulated, whereas in rural areas, uses tend to be embedded within a larger conceptualization of use. Many rural land use regulations allow by right (without requiring regulatory approval) uses that support a main use, such as agricultural districts, which typically allow a number of uses that would need special permission in urban areas. Activities that support farming, such as fueling pumps, grain and chemical storage, farmworker housing, and livestock housing would typically be heavy industrial or commercial uses in urban areas, but in rural areas these are ancillary uses to the farm.

Land Use and Geographic Models

Land use is fundamental to several geographic concepts, such as the idea of functional or areal specialization of agriculture, manufacturing, or other economic activities, whether at the metropolitan, regional, or national level. Several models exist to show how land uses may be ordered by distance from one or more points or the conditions under which land uses may be converted to a new use. For example, models of spatial interaction and trade are based on complementarities between places based on their areal specialization in different products and desire to trade these goods. Without areal specialization, there would be no interaction or trade. Land uses are therefore both absolute and relative in location, in that they depend in part on their proximity to other land uses. The phenomenon of space-time convergence has greatly changed the relative location of land uses in developed countries by decreasing travel costs and times and can be expected to trigger transitions to new land uses (as when



farmland is developed for residential land following construction of a new highway) and alter areal specializations. At larger spatial scales, international trade and globalization can affect land uses on the other side of the world. All land uses involved in the global economy are connected, though they continue to be governed at the local level.

Interest in urban land use emerged at a time when different activities or functions began to be conducted outside the home and eventually in different locations within the city. Residential areas became differentiated from industrial workshops and stores, and similar activities began to be found in particular districts or neighborhoods. These spatially distinct homogeneous land uses became fundamental to constructing models of urban space as well as zoning regulations.

The concentric zone model viewed cities as series of concentric zones or rings, with the center zone containing the central business district (CBD) and the social, transportation, and cultural hubs of the city. The model is conceptually a descendant of Johann Heinrich von Thünen's concentric farmland use model based on 19th-century Germany. Both are models in which land use is based on distance from a commercial center. In the Burgess model, various land uses are in competition for space based on their ability to pay for higher valued locations near the center of the city, with the CBD functions having the highest value and therefore occupying the most valuable position. Outside the CBD, the secondary ring was envisioned as a transitional land use area with mixed uses, including manufacturing and low-income or slum housing. Residential density continues to fall as the rings move outward, with residential categories (based on density) and income having an inverse relationship. The poorest residents of the city live nearest the CBD, and the wealthiest reside at the furthest edge of the city. Burgess envisioned an expanding CBD, exerting land use conversion pressure on the surrounding district; this in turn pushed outward on the other districts. In this and later monocentric formulations (and Von Thünen), changes in transport costs determine changes in the relative value, and therefore use, of land at specific distances. More recent polycentric urban models operate much the same but with land use determined by distance from multiple centers.

Land use is also a fundamental component of transportation planning, as standard approaches assume that travel is a derived demand, or a response to a need to carry out an activity at a different location. Certain land uses (such as retail) will attract many trips relative to others (such as landfills). The abundance and location of different land uses is therefore a strong influence on the direction and frequency of travel. Future transport needs of a city cannot be assessed without first forecasting future land uses, and planning the type and location of land uses to minimize the required travel has emerged as a recent objective of many urban planners.

Land Use Classifications

Land use classification in the United States is based on hierarchical and segregated uses. This implies that land uses exist as (or can be divided into) discrete, nonoverlapping categories and that there exist a few basic types of land use that can be subdivided to provide more detail. These types can then be quantified and mapped. There are several different approaches to land use classification, but the most commonly used are the Anderson land use classification scheme and the Land-Based Classification Standard (LBCS) system.

Anderson Land Use Classification Scheme

For many years, U.S. government agencies collected data about land use, but there was a lack of coordination and uniformity in their classification schemes. As a result, it was impossible to aggregate existing data to make a comparison between land use changes from time to time or place to place. In 1971, James Anderson (with others) worked with the U.S. Geological Survey, National Aeronautics and Space Administration, U.S. Department of Agriculture, Association of American Geographers, and International Geographical Union to develop a national classification system for land usage similar to the economic classification codes applied to commercial and industrial activities. Anderson's classification scheme drew heavily on a system developed for the state of New York but gave special attention



First Level Code (1–9)	Level II	First Level Code (1–9)	Level II
1 Urban or built-up land	11 Residential 12 Commercial and services 13 Industrial 14 Transportation, communications, and utilities 15 Industrial and commercial complexes 16 Mixed urban or built-up land 17 Other urban or built-up land	5 Water	51 Streams and canals 52 Lakes 53 Reservoirs 54 Bays and estuaries
2 Agricultural land	21 Cropland and pasture 22 Orchards, groves, vineyards, nurseries, and ornamental horticultural areas 23 Confined feeding operations 24 Other agricultural land	6 Wetland	61 Forested wetland 62 Nonforested wetland
3 Rangeland	31 Herbaceous rangeland 32 Shrub and brush rangeland 33 Mixed rangeland	7 Barren land	71 Dry salt flats 72 Beaches 73 Sandy areas other than beaches 74 Bare exposed rock 75 Strip mines, quarries, and gravel pits 76 Transitional areas 77 Mixed barren land
4 Forest land	41 Deciduous forest land 42 Evergreen forest land 43 Mixed forest land	8 Tundra	81 Shrub and brush tundra 82 Herbaceous tundra 83 Bare-ground tundra 84 Wet tundra 85 Mixed tundra
		9 Perennial snow or ice	91 Perennial snowfields 92 Glaciers

Table 1 Anderson's land use classification scheme

Source: Anderson, J. R., Hardy, E. E., Road, J. T., & Witmer, R. E. (1976). *A land use and land cover classification system for use with remote sensing data* (Geological Survey Professional Paper 964). Retrieved December 12, 2008, from <http://landcover.usgs.gov/pdf/anderson.pdf>.

to the definition of land use categories used by other federal agencies so that homogeneity and compatibility could be preserved from the past. The system was specifically designed for use with remote sensing applications, which were becoming increasingly common at the time.

Anderson's land use classification scheme is a hierarchical system with coding by digits, in which the first digit designates the broadest descriptor and ensuing numbers provide a sharper focus (Table 1). For instance, first digits show the major category (e.g., 1 = urban or built-up land, 2 = agricultural), while the second digit shows sub-division (e.g., 11 = residential, 12 = commercial

and services). The system was designed so that land uses could also have a third digit if necessary for a land use inventory at more detailed levels (e.g., 111 is for single-family home units, 112 is for multifamily units).

In Anderson's classification, *urban and built-up land* refers to areas of intense human use with a high density of built structures such as cities, towns, villages, and strip developments along highways. This land can be further subdivided into categories such as commercial, residential, industrial, transportation, communication, and utilities and also mixed land (in situations where no single dominant land use can be distinguished).



Agricultural lands uses are those areas that are used primarily for the production of food and fiber, including wetlands when they are drained for agriculture purposes. *Rangeland* is those areas where vegetation such as grasses and shrubs used for grazing animals are found. *Forest land* consists of areas where a closed tree canopy makes up at least 10% or more of the area or areas that are stocked with trees capable of producing timber or other wood products. *Water* includes all those areas within the landmass that are persistently covered with water; these must be at least one eighth of a mile wide if linear or at least 40 acres if extended. *Wetland* includes areas dominated by woody vegetation such as mangrove swamps, shrub swamps, and so on, as well as nonforested wetlands. *Barren land* is land that has limited ability to support life, where less than one third of the area has vegetation cover (e.g., areas of thin soil, sand, or rocks). *Tundra* areas are characterized by extremely cold climate, a variety of vegetation, but low biotic diversity. Finally, the *perennial snow* or *ice* category comprises those areas where this feature is permanent.

Land-Based Classification Standard System

A new LBCS was developed by the American Planning Association in 1994. The purpose of the LBCS system is to support planning applications at different geographical scales. It is an attempt to synthesize land use according to five parameters: human activities, functions, building types, site development character, and land ownership. These multiple dimensions allow users to have precise control over land use classifications, and each dimension can be defined at different levels of detail. The *human activities* dimension of classification directly describes human use of land and is shown in Table 2. These classifications are subdividable into secondary and tertiary categories, such as shopping (2100) and goods-oriented shopping (2110).

An economic function of land or types of establishments on land makes up the functional dimension and is shown in Table 3. Function classifications have a fourth subcategory of ownership, which provides an added layer of detail to the classification. The structure parameter delineates the type of building or structure on the land,

Code	Description
1000	Residential
2000	Shopping, business or trade
2100	Shopping
2110	Goods-oriented shopping
2120	Service-oriented shopping
3000	Industrial, manufacturing, and waste-related
4000	Social, institutional, or infrastructure-related
5000	Travel or movement
6000	Mass assembly of people
7000	Leisure
8000	Natural resources-related
9000	No human activity or unclassifiable activity

Table 2 LBCS—human activities parameter

Source: Land-based classification standards. Reprinted by permission of the American Planning Association.

Code	Description
1000	Residence or accommodations
2000	General sales or services
3000	Manufacturing and wholesale trade
4000	Transportation, communication, information and utilities
4100	Transportation services
4200	Communications and information
4210	Publishing
4220	Motion pictures and sound recording
4230	Telecommunications and broadcasting
4240	Information services and data processing
4241	Online information services
4242	Libraries and archives
4243	News syndicate
4300	Utility and utility services
5000	Arts, entertainment and recreation
6000	Education, public administration, health care, institutions
7000	Construction-related businesses
8000	Mining and extraction establishments
9000	Agriculture, forestry, fishing and hunting

Table 3 LBCS—function parameter

Source: Land-based classification standards. Reprinted by permission of the American Planning Association.



as shown in Table 4. The site-based parameter indicates the current physical state of the land (Is it developed? Developing? etc.), as shown in Table 5. The final LBCS parameter is ownership of the land, which is shown in Table 6.

Despite their detail, these land use classifications have some limitations. For instance, they do not allow for vertical zonation of land uses (such as below- and aboveground or on different floors of a building) or changing land uses at different times of the day, week, or year. In some cases, vegetation is used as a surrogate for human activities. However, even rural land may be used for a specific purpose without any change to the vegetation or the presence of human artifacts, for example, wilderness or parklands. While the LBCS resolves many land use nuances that the Anderson scheme cannot identify, no single scheme can be expected to work for all applications or in all areas.

Code	Description
1000	Residential buildings
1100	Single family building
1110	Detached units
1120	Attached units
1121	Duplex structures
1122	Zero lot line, row houses, etc.
1130	Accessory units
1140	Townhouses
1150	Manufactured housing
1200	Multifamily structures
1300	Other specialized residential structures
2000	Commercial buildings and other specialized structures
3000	Public assembly structures
4000	Institutional or community facilities
5000	Transportation-related facilities
6000	Utility and other non-building structures
7000	Specialized military structures
8000	Sheds, farm buildings, or agricultural facilities
9000	No structure

Table 4 LBCS—structure parameter

Source: Land-based classification standards. Reprinted by permission of the American Planning Association.

Code	Description
1000	Site in natural state
2000	Developing site
3000	Developed site—crops, grazing, forestry, etc.
4000	Developed site—no buildings and no structures
5000	Developed site—non-building structures
5100	Developed site with landscaped or ornamental features
5200	Developed site with billboards, signs, etc.
5300	Developed site with roads, train tracks, and other linear structures
6000	Developed site—with buildings
7000	Developed site—with parks
8000	Not applicable to this dimension
9000	Unclassifiable site development character

Table 5 LBCS—site development parameter

Source: Land-based classification standards. Reprinted by permission of the American Planning Association.

Code	Description
1000	No constraints—private ownership
2000	Some constraints—easements or other use restrictions
3000	Limited restrictions—leased and other tenancy restrictions
4000	Public restrictions—local, state, and federal ownership
4100	Local government
4110	City, village, township, etc.
4120	County, parish, province, etc.
4200	State government
4300	Federal government
5000	Other public use restrictions—regional, special districts, etc.
6000	Nonprofit ownership restrictions
7000	Joint ownership character—public entities
8000	Joint ownership character—public, private, nonprofit, etc.
9000	Not applicable to this parameter

Table 6 LBCS—land ownership

Source: Land-based classification standards. Reprinted by permission of the American Planning Association.



Land Use and GIS

The innovation of geographic information systems (GIS) technology allows the integration of various sources of land use data such as original land (field) surveys, aerial photographs, satellite imagery data, land use and land cover maps, forest inventories, and property records (to reconstruct ownership history). In this way, GIS technology has become an important means of advancing the understanding of the spatial, temporal, and decision-making apparatus of land use and land use changes over the past two decades.

There are a wide variety of GIS data sets for land use. In the United States, at the local level, there are parcel and zoning data sets created by individual cities and counties. Land parcel data (also known as *cadastral* data) represent the smallest geographic level, which describes the rights, interests, ownership, value, and use of land. Because these data are created by individual county assessors, their cost and availability vary from one county to the next. Most local governments create digital versions of their local zoning/land use regulation maps at a scale of 1:4,800. Similarly, zoning data, which reflect legislative regulations through which a city or county government seeks to control the use of buildings and land within its jurisdiction, may be available through local planning organizations.

In addition, two national land use data sets are available for the United States: Land Use and Land Cover (LULC) and National Land Cover Database (NLCD). Manual interpretation of aerial photography (land use maps and surveys) over two decades resulted in the vector LULC database in the 1980s. Areas of discrete land use are mapped using individual polygons, with 37 land use/cover categories. Most of the country is covered at a scale of 1:250,000. However, there are some gaps: For example, only the area around Valdez is available for Alaska. At a scale of 1:100,000, the coverage is even more limited.

NLCD is a raster data set based on LANDSAT satellite images developed in the 1990s by a consortium of federal government agencies. Several versions have been released: The first one was in 1992 (NLCD92), with 21 classes, and covers the coterminous United States, while NLCD01 has 2001 data and covers the entire United States;

and a 2006 version is under preparation. Land uses are mapped at 30 meters' resolution. Both LULC and NLCD data sets use a similar, although not identical, land use classification scheme based on Anderson. Because of their different classification and formats, LULC and NLCD are not directly compatible.

Selima Sultana and William Todd Powell

See also **Agricultural Intensification; Agricultural Land Use; Brownfields; Built Environment; Cadastral Systems; Central Business District; Chicago School; Community-Based Conservation; Conservation Zoning; Cultural Landscape; Deforestation; Environmental Ethics; Environmental Impact Assessment; Environmental Management; Environmental Protection; Environment and Development; Forest Land Use; GIS in Land Use Management; Landfills; Land Use Analysis; Land Use and Cover Change (LUCC); Land Use and Land Cover Mapping; Land Use History; Land Use Planning; Locally Unwanted Land Uses (LULUs); Parks and Reserves; Political Ecology; Population and Land Degradation; Population and Land Use; Population, Environment, and Development; Rural Development; Rural Geography; Soil Conservation; Suburban Land Use; Sustainable Development; Thünen Model; Township and Range System; Urban Gardens; Urban Land Use; Urban Sprawl; Watershed Management; Wetlands; Wilderness; Wise Use Movement; Zoning**

Further Readings

- Anderson, J. R., Hardy, E. E., Roach, J. T., & Witmer, R. E. (1976). *A land use and land cover classification system for use with remote sensor data* (Geological Survey Professional Paper No. 964). Washington, DC: U.S. Government Printing Office.
- Hamman, Y., Moore, A., Whigham, P., & Freeman, C. (2004). *A vector-agent paradigm for dynamic urban modeling*. Retrieved December 10, 2008, from http://eprints.otago.ac.nz/109/1/18_Hammam.pdf
- Hanak, E., & Chen, A. (2007). Wet growth: Effects of water policies on land use in the American West. *Journal of Regional Science*, 47, 85–108.
- Wang, X., & Hofe, R. V. (2007). *Research methods in urban and regional planning*. New York: Springer.



LAND USE ANALYSIS

Land use analysis is the quantitative and qualitative assessment of how humans use land. It addresses three types of questions concerning the what, why, and how of land use.

What Is Land Use?

The first step in land use analysis is to map the land covers and land uses of a study area. There is an important distinction between land cover and land use.

Land cover is the physical cover of the land. For example, two common types of land cover are *built* and *forest*. Land cover can be observed and documented via remote sensing using sensors that are mounted on satellites, airplanes, or ground-based platforms. Cartographic methods are necessary to convert the information from the sensors into maps of land cover categories. Maps of land cover indicate what is on the landscape physically.

Land use is the purpose for which humans use the land. For example, common land uses are *residential* and *recreational*. Remote sensing techniques usually do not reveal land use because they give information about only the physical state of the land. A single land cover type may have many uses. For example, humans can use the forest land cover simultaneously for tourism, biodiversity conservation, and water quality protection. It is usually necessary to collect social data to determine land use, because land use is a social phenomenon.

Scientists are constantly developing more sophisticated methods to generate maps of land cover and to record the various land uses for each land cover. When maps of land use are available from more than one point in time, investigators usually want to characterize land use and land cover change. If the land uses are categories, then a transition matrix is commonly used to summarize the land transitions among the categories over time.

Why Do Humans Use the Land the Way They Do?

The second step in land use analysis is to understand why humans choose some land uses over

other possible uses. The philosophical orientation of the investigator can influence the approach taken to attain this understanding. For example, an economist is likely to examine land prices and financial subsidies in an attempt to understand why developers prefer some locations over others for suburbanization. Sociologists may consider family dynamics and customs to understand how settlers decide to colonize a forest in a manner that maximizes land for future generations. Geologists might examine the soil fertility to explain the spatial distribution of farms. Regardless of the orientation of the investigator, analysts usually find it helpful to use both quantitative and qualitative techniques. Quantitative techniques include statistical methods to examine the association between the patterns in the land use maps and other variables such as prices, family structure, and soil fertility. Qualitative techniques include interviews with stakeholders and historical research concerning the policies that have guided land use decisions.

Land use analysis faces daunting methodological and conceptual challenges. Statistical analysis is complicated by the fact that the results can be sensitive to many characteristics of scale. These characteristics include the spatial, temporal, and categorical scales of the data in terms of both extent and resolution. Furthermore, the data are usually observational, that is, the data are not obtained from controlled experiments, and so large statistical associations do not necessarily guarantee cause-and-effect relationships. Qualitative analysis faces the same challenges. Some of these challenges derive from the fact that the land use system is a complex web of many interacting decision makers who are constantly responding to a variety of types of dynamic information. A major challenge for land use analysts is to be able to state clearly the evidence for a particular hypothesis for a particular domain at a particular scale and not get lost in the complexity. Some scientists use modeling to help gain an understanding of the land system. A land-change model is a computerized algorithm that shows the implications of the many assumptions that it synthesizes. It usually includes a calibration procedure during which it examines the past dynamics of the land use system. Then it can project future land uses based on either an extrapolation of past trends or alternative assumptions.



How Should Humans Manage Land?

The third step in land use analysis is to apply the understanding gained in the previous two steps to offer guidance on how humans should use land in the future, given particular objectives. Typically, this is done through participatory exercises that involve a variety of stakeholders at the level of the village, town, state, nation, or globe. Land use analysts can facilitate discussions among stakeholders by offering scenarios of future land uses. A land use scenario is a story told in words, numbers, and maps concerning the manner in which humans could manage land, including the consequences of those management decisions. Scenario analysis can examine the implications of a scenario that assumes a continuation of present land management practices and can contrast the results with alternative scenarios that might lead to a more desirable future. Such scenarios can help stakeholders envision possible futures and relate those futures to management decisions.

Robert Gilmore Pontius Jr.

See also **Agricultural Land Use; Built Environment; Conservation Zoning; Environmental Management; Environmental Protection; Environment and Development; Forest Land Use; GIS in Land Use Management; Land Use; Land Use and Cover Change (LUCC); Land Use and Land Cover Mapping; Land Use History; Land Use Planning; Locally Unwanted Land Uses (LULUs); Population and Land Use; Soil Conservation; Suburban Land Use; Urban Land Use; Zoning**

Further Readings

- Liverman, D., Moran, E., Rindfuss, R., & Stern, P. (Eds.). (1998). *People and pixels: Linking remote sensing and social science*. Washington, DC: National Academies Press.
- Pontius, R. G., Jr., Boersma, W., Castella, J.-C., Clarke, K., de Nijs, T., Dietzel, C., et al. (2008). Comparing the input, output, and validation maps for several models of land change. *Annals of Regional Science*, 42(1), 11–47.



LAND USE AND COVER CHANGE (LUCC)

Land use and cover change (LUCC) refers to the alteration of Earth's terrestrial surface. The terms *land use* and *land cover* may seem to be interchangeable, but they are not equivalent. Land cover denotes the observed biological and physical attributes of Earth's terrestrial surface, such as vegetation, water, earth materials, and human-made features. Land use signifies the purposes to which the varied resources offered by the biophysical attributes of land cover are exploited by human activities, such as cropping, logging, and building construction. Forest, for example, is a land cover type that may be exploited for land uses as diverse as cultivation, recreation, and settlement.

Studies of land cover and land use were historically separate; the former was largely studied by natural scientists, the latter mainly by social scientists. Connecting the two components are proximate sources of change in human activities that directly modify the physical environment. A change in either land use or land cover is not essentially the product of the other. Changes in land cover may not directly cause land use change, but with further environmental consequences, they may ultimately affect land use. Conversely, changes in land use are likely to result in some land cover change, but other forces such as climatic fluctuations and ecosystem dynamics can also drive land cover change. This entry reviews the history of research on LUCC and describes some of the most important consequences of LUCC, including its impact on biogeochemical cycles, the hydrologic cycle, biodiversity, and human health. It then examines issues related to monitoring, measuring, and modeling LUCC.

Development of LUCC Research

Concerns over the effects of human activities on the environment may be traced back to when George Perkins Marsh published his book *Man and Nature* in 1864. The consequences of LUCC, such as deforestation leading to soil erosion and

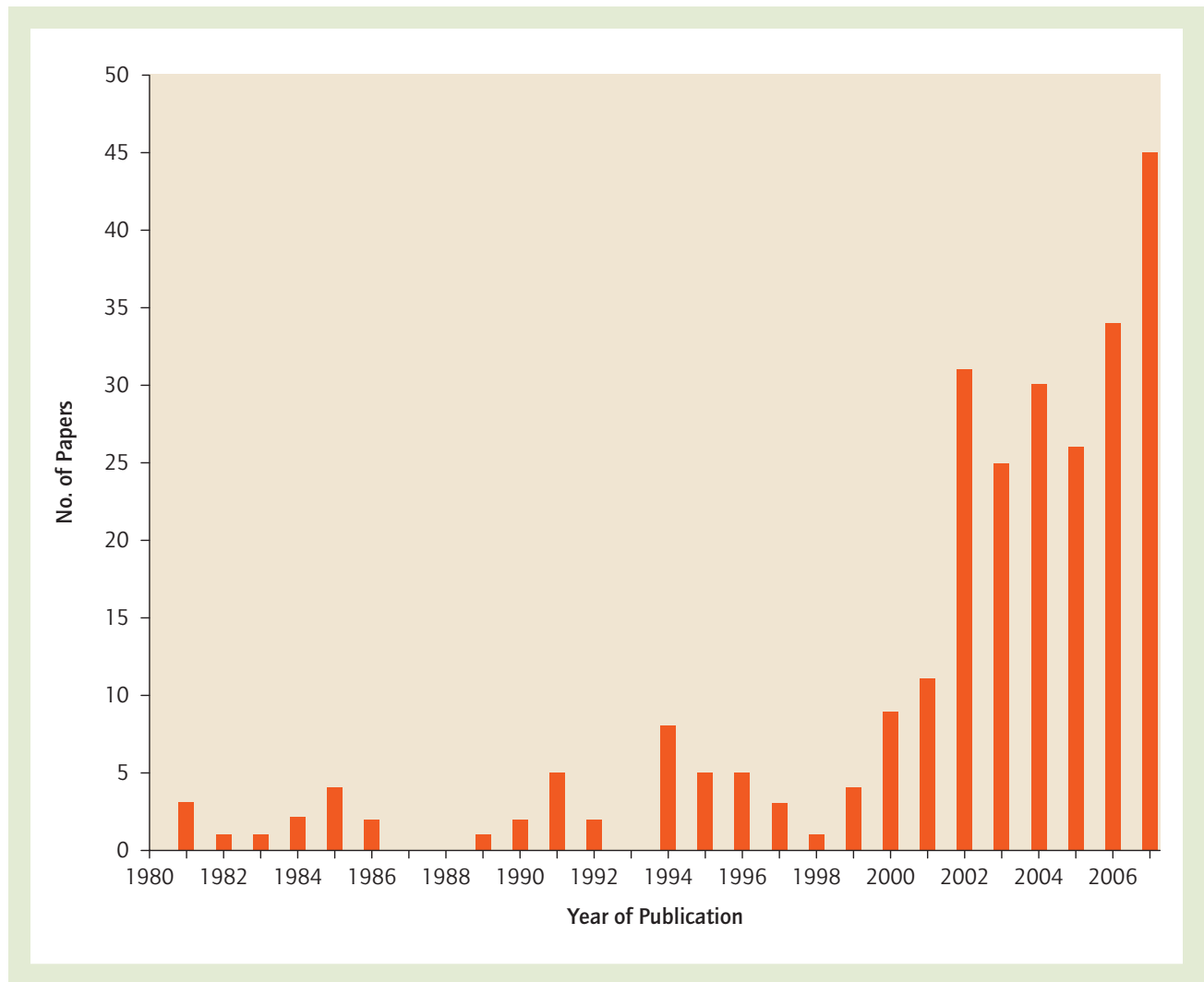


Figure 1 The number of published papers between 1980 and 2007 with land use and/or land cover as their subject

Source: Created by author using data from ISI Web of Science.

subsequently decreased soil productivity, were debated on. LUCC has in the past several decades emerged in the global environmental change research agenda. In the 1970s, it was recognized that land cover change modifies surface albedo and, thus, surface-atmosphere energy exchanges, influencing regional climate. In the early 1980s, terrestrial ecosystems as sources and sinks of carbon were highlighted, underscoring LUCC as a major element of the global carbon cycle. Studies focused on LUCC came into the limelight in the mid 1990s. This can be seen in the growing

number of publications on this topic in the past decade (Figure 1). The need to have a framework for LUCC studies at a global scale, to integrate the social and natural sciences, and to provide greater data availability and standardization also spurred the development of various national and international research programs. In 1994, a core project on LUCC was initiated and jointly run by the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP) on Global Environmental Change. The International Geographical Union



(IGU) established a study group on land use and land cover in 1996 to promote LUCC studies in the world geographical community. In the United States, the National Aeronautics and Space Administration developed a Land Cover and Land Use Change research program, synthesizing the results from different regions where important LUCC processes are taking place, such as the Brazilian Amazon, China, and southeast Asia. These programs and many others worldwide have made considerable progress and demonstrated the importance of cross-disciplinary efforts in addressing the LUCC issues. Because of its stand-alone significance and its critical role in other aspects of global change, LUCC research continues to gain programmatic support.

Consequences

Most of the current LUCC is caused by anthropogenic processes such as urban expansion, a direct cause of land use change, and alteration of fire regimes, an indirect cause leading to land cover change. Anthropogenically induced LUCC affects Earth's systems with many interrelated consequences.

Biogeochemical Cycles

LUCC has significantly influenced the cycling of essential nutrient elements, such as carbon, nitrogen, sulfur, and phosphorus. Extensive clearing and burning of natural vegetation and conversion of forests to agriculture have released carbon into the atmosphere, which may contribute to global warming. In past centuries, modifications generally took place in the temperate grasslands and forests; in the past several decades, forests in the tropics have encountered greater transformation. The high biomass levels of tropical forests comprise a substantial portion of carbon storage; the impact of tropical deforestation on global carbon cycling will thus likely be significant. Intensification of agricultural land use has also profoundly influenced nitrogen and phosphorus cycles. For example, high use of nitrogen fertilizers results in the leakage of soluble nitrate from agricultural systems, causing soil acidification, groundwater pollution, and eutrophication of streams and lakes.

Hydrologic Cycle

Changes in land cover, particularly the removal of forests and the growth of impervious surfaces during urbanization, significantly influence hydrological processes, causing increases in runoff, flooding, soil erosion, and sedimentation (see photo). The hydrologic cycle is the matrix in which all other biogeochemical cycles function. The interactions among LUCC, hydrologic cycling, and biogeochemical cycling may consequently increase the frequency and magnitude of extreme weather events, with the potential to drastically affect ecosystems through changes in temperature and precipitation. The combination of LUCC and climate change may have profound effects on Earth's systems in more significant ways than either acting alone.

Biodiversity

Habitat loss is probably the greatest threat of LUCC to biodiversity. It occurs through habitat fragmentation, such as road construction and deforestation, or habitat conversion from, for example, undisturbed forest or grassland to (eventually) urbanized land. Besides, LUCC often accompanies species introduction, decreasing the diversity of native species. Because biodiversity provides ecosystem goods for basic human needs, from food and fiber to medicines, and ecosystem services such as water purification, crop pollination, climate regulation, and aesthetic beauty, a major loss of biodiversity affects ecosystem functioning, threatening the capacity of Earth to support human societies.

Human Health

LUCC in conjunction with climate change has the potential to facilitate the spread of pathogens and parasites, rendering human societies vulnerable to disease. Vector-borne infectious diseases, such as malaria in Africa and India, liver fluke in southeast Asia, and Lyme disease in the United States, are particularly sensitive to LUCC because LUCC influences the availability of suitable habitats and hence the abundance of the vector and may facilitate the migration of vectors capable of transmitting diseases into previously uninhabitable areas. For example, the spread of irrigation



Sabah, Malaysia, February 2007. LUCC such as deforestation influences hydrologic cycling, causing high sedimentation in rivers.

Source: Author.

systems associated with agricultural intensification alters the temperature and moisture of an area, which in turn can trigger dramatic increases in vector populations and transmission rates for malaria. It is important to understand that socioeconomic factors influencing land use patterns also play a role in disease transmission. The changing location of human settlements in relation to vector habitats modifies the exposure of people to contacts with the vector. As a result, investigation of the consequences of LUCC requires an interdisciplinary approach integrating both natural and social scientific methods.

Monitoring, Measuring, and Modeling of LUCC

Studying LUCC and its causes and consequences frequently requires monitoring LUCC, measuring how much change has occurred, and modeling

the dynamic processes of LUCC under different scenarios.

Monitoring

Remote sensing data offer an important source of information for spatially explicit monitoring of LUCC. Aerial photography is one of the most common and economical forms. It came into widespread use in the late 1930s and has been used to prepare land use maps in many countries. Aerial photography allows long-term and detailed monitoring of LUCC because of its routine acquisition over multiple decades by many government agencies.

Alternatively, satellite imagery has the advantage that a single image covers an extensive area. The deployment of satellites for monitoring Earth's surface resources since 1972 has provided continuous land use/cover data layers for global



land cover inventories. In some regions, satellite imagery is the only practical way to provide timely and reliable assessment of land cover and identification of rapid LUCC. The extensive spatial coverage and frequent temporal intervals that satellite imagery provides would be difficult to obtain from in situ field surveys. However, since satellite imagery relies on spectral reflectance, incorporating ground-based data into analysis of satellite imagery is essential to improve the quality of land use/cover data.

Satellite images are now available at high, medium, and low spatial resolutions for monitoring LUCC at various scales. The Moderate Resolution Imaging Spectroradiometer (MODIS) provides daily global observations of land cover at 250-m (meters) spatial resolution and is often used to characterize land cover and its changes at the global and regional scales. Hyperspatial data with 1- to 4-m resolution from sensors such as IKONOS and Quickbird are available for detailed monitoring of LUCC at the local scale.

Measuring

The conventional way to detect and measure LUCC is to visually compare a series of land use/cover maps of different snapshots derived from remote sensing data or other sources of information of the same area, but such a comparison may disallow the quantification of subtle changes. Change detection is another common approach for measuring LUCC. Unlike statistical summaries that provide data on land use/cover types of different years in areas or percentages, change detection compares land use/cover databases from two different time periods to determine the location, spatial extent, and nature of changes over time. Transition matrices are used to show changes in land use/cover types from one time period to another; the changes in land use/cover from one category to another can then be illustrated in maps. This approach offers more quantitative insights into LUCC. Care must, however, be taken to ensure that the differences between dates are not due to artifacts of the source data.

The development and diversity, in recent decades, of new technologies and methods used to create land use/cover databases suggest that there may be great disparities in the quality and

organization of data. Additionally, data may not be collected according to categories and definitions consistently enough to make different sets comparable. Measuring and quantifying LUCC thus require more standardized classification systems that can be applied uniformly over the time series of analysis.

Modeling

LUCC modeling, such as predicting future LUCC and simulating possible LUCC consequences on human and natural systems, provides insights that can be used to assist policymakers and land managers in sustainable resource management. Models are required because they help enhance our understanding of the dynamic patterns and processes of LUCC that result from the complex interactions among physical, biological, and socioeconomic forces. Advances in geospatial techniques and computational methodologies have improved the capacity needed to model LUCC at different spatial and temporal scales in relation to various human activities. Although land use/cover patterns may be obtained from remote sensing data, modeling the dynamic processes of LUCC requires incorporation of the historical and contemporary causes of the changes. A combination of various biophysical and social data in modeling, such as interviews with land managers, population data, household surveys, land use/cover history, soil maps, and ecological measurements, is thus needed.

Various land use/cover models are available for explanatory or predictive purposes. The combination of agent-based models, used to describe human decision making, with cellular automata models, used to represent biophysical landscape change, offers a promising approach for future model development in LUCC.

Yi-Chen Wang

See also **Agent-Based Models; Agricultural Land Use; Biogeochemical Cycles; Biophysical Remote Sensing; Climate Change; Environment and Development; Forest Land Use; GIS in Land Use Management; Global Environmental Change; Impermeable Surfaces; Land Use; Land Use Analysis; Land Use and Land Cover Mapping; Land Use History; Locally Unwanted Land**



Uses (LULUs); Political Ecology; Population and Land Degradation; Population and Land Use; Population, Environment, and Development; Spectral Characteristics of Terrestrial Surfaces; Suburban Land Use; Urbanization

Further Readings

- Gutman, G., Janetos, A. C., Justice, C. O., Moran, E. F., Mustard, J. F., Rindfuss, R. R., et al. (2004). *Land change science: Observing, monitoring and understanding trajectories of change on the Earth's surface*. Dordrecht, Netherlands: Kluwer Academic.
- Lambin, E. F., & Geist, H. J. (2006). *Land-use and land-cover change: Local processes and global impacts* (IGBP Series). Berlin, Germany: Springer.
- Meyer, W. B., & Turner, B. L., II. (1994). *Changes in land use and land cover: A global perspective*. Cambridge, UK: Cambridge University Press.
- Rogan, J., & Chen, D. M. (2004). Remote sensing technology for mapping and monitoring land-cover and land-use change. *Progress in Planning*, 61, 301–325.



LAND USE AND LAND COVER MAPPING

Land cover refers to the observed physical layer of Earth's surface. It includes vegetation and anthropogenic features as well as bare rock, bare soil, and inland water surfaces. Reliable land cover mapping is of crucial importance for (a) understanding and mitigating climate change and its impacts, (b) sustainable development, (c) natural resource management, (d) biodiversity conservation, and (e) understanding of ecosystems and biogeochemical cycling. For example, land cover characteristics reveal ongoing processes of deforestation, desertification, urbanization, land degradation, loss of biodiversity and ecosystem functions, and water and energy management. In situ and satellite-based land observation efforts as well as different disciplines (e.g., geography, ecology, geology, forestry, land policy, and planning)

use and refer to land cover as one of the most obvious and detectable indicators of land surface characteristics and the associated human-induced or naturally occurring processes.

The Process of Land Use and Land Cover Mapping

The primary units for characterizing land cover are categories (e.g., forest or open water) or continuous variables classifiers (e.g., fraction of tree canopy cover). Secondary outputs of land cover characterization include the surface area of land cover types (in hectares), land cover change (area and change trajectories), and observation byproducts such as field survey data or processed satellite imagery. In applications using land cover maps, the original land cover categories are often associated with specific attributes (e.g., average carbon stocks, degree of artificiality, or function in the hydrological system). In current practice, many national and regional observation programs and research institutes still do not distinguish between land cover and land use. Land use characterizes the arrangements, activities, and inputs people have undertaken on a certain land cover type to produce, change, or maintain it. Observation strategies and methods vary for observing land cover, land use, and associated changes. Common and operational procedures exist for observation of land cover; observing land cover change, land use, and land use change is more challenging and still a subject of research.

Land cover and land use mapping activities can be understood as a process of information extraction governed by the rules of generalization. The degree of generalization, and thus the efficiency of representing reality in a two-dimensional form, is linked to three major factors: (1) the “thematic” component refers to the land classification system and the adopted land cover legend; (2) “cartographic” standards include the spatial reference system, the minimum mapping unit (MMU), and the mapping scale; and (3) the “interpretation” process reflects the characteristics of the source data, the interpretation procedures, and the skill of their use. These factors affect the map products—their content, quality, flexibility, and efficiency for specific applications.



Applications of Land Use and Land Cover Mapping

Land cover and land use in different regions have been mapped and characterized at various times, and many countries have implemented some kind of land monitoring system (e.g., forest, agriculture, and cartographic information systems and inventories). In addition, there are many continental and global land cover map products and activities. There is, for example, a quasi-operational global land cover monitoring system, which integrates information from three common observational scales: (1) moderate-resolution satellite data (e.g., MODIS- or MERIS-type satellite sensor), (2) fine-resolution satellite data (from Landsat- and SPOT-type satellite sensors), and (3) in situ observations (or very high-resolution remote sensing data). Continuity of observations and consistency of land cover characterization is required for all these scales.

Extensive information on land cover has been produced in many regions of the world. The varying purposes, data sources, accuracies, spatial resolutions, and thematic legends of these efforts have resulted in a suite of more or less

incompatible land cover data sets. Many of the available global, regional, and national mapping products exist as independent data sets. For example, multiple definitions and thresholds for a particular land cover type, such as forests, result in different representations of forest class in the different land cover maps. The lack of consistency has triggered the need for harmonization and standardized land cover monitoring. Land categories and classifiers must be defined consistently to identify land cover changes over time. The United Nations (UN) Land Cover Classification System (LCCS) classifiers and the related Land Cover Macro Language provide a comprehensive and flexible framework for thematic land cover characterization. LCCS classifiers enable compatibility to be achieved between existing data sets and for future monitoring of data. An independent accuracy assessment using a sample of ground or other reference data is an integral part of any land cover and land use monitoring effort.

There is a need for both maps (static and updated) and dynamic land monitoring products at different spatial and temporal scales as part of an integrated global land monitoring system (Table 1). These outputs require different sets of

<i>Name</i>	<i>Spatial Resolution</i>	<i>Frequency of Product Update</i>	<i>Maturity</i>
Mapping of land cover			
Land cover maps	250 m–1 km	Annual	Preoperational
Fine-scale land cover and land use maps	10–30 m	3–5 yrs.	Preoperational (for land cover)
Global land cover reference sample database	In situ/1 m	1–5 yrs.	Preoperational (CEOS, GOFC-GOLD)
Monitoring of dynamics and change			
Global land cover dynamics and disturbances	250 m–1 km	Intra-annual/long-time series	Preoperational (for several processes)
Fine-scale land cover and land use change	10–30 m	1–5 yrs.	Preoperational (for land cover)
Monitoring areas of “rapid change”	1–30 m	1–2 yrs. or less	Preoperational (for some change processes)

Table 1 Characteristics of land cover and land use mapping and monitoring products that are useful for observing land cover as an essential climate variable

Source: Townshend, J. R., Latham, J., Arino, O., Balstad, R., Belward, A., Conant, R., et al. (2008). *Integrated global observations of the land: An IGOS-P theme* (IGOL Report No. 8, GTO 54). Rome: Food and Agriculture Organization of the United Nations. Retrieved February 8, 2010, from the FAO Web site at www.fao.org/gtos/igol/docs/IGOS-theme-report-final-draft.pdf.



observations and monitoring approaches. There is also a need to ensure synergy with other observation products (e.g., fire, biophysical parameters, snow cover) that are directly related to land cover and land use characteristics.

Ongoing global mapping efforts (i.e., MERIS-based GLOBCOVER and those using MODIS data) provide consistent and validated land cover data and land cover change indicators worldwide at moderate spatial resolution (250-meter to 1-kilometer spatial resolutions). Land cover and land use change estimates require multitemporal fine-resolution satellite observations. Archived image data (e.g., global Landsat data) and methods are available to implement a global land cover change monitoring system. Global assessments of historical forest change processes based on multiple data sources are available from regional and national programs (e.g., the European CORINE, Brazilian PRODES) and international initiatives, such as the Forest Resources Assessment of the Food and Agriculture Organization of the United Nations.

Martin Herold

See also **Aerial Imagery: Interpretation; Biophysical Remote Sensing; GIS in Land Use Management; Landscape Interpretation; Land Use; Land Use Analysis; Land Use and Cover Change (LUCC); Spectral Characteristics of Terrestrial Surfaces**

Further Readings

Di Gregorio, A. (2005). *UN land cover classification system (LCCS): Classification concepts and user manual for software Version 2*. Retrieved August 20, 2009, from www.glcn.org

Franklin, S. E., & Wulder, M. A. (2002). Remote sensing methods in medium spatial resolution satellite data land cover classification of large areas. *Progress in Physical Geography*, 26, 173–205.

Herold, M., Latham, J. S., Di Gregorio, A., & Schmullius, C. (2006). Evolving standards in land cover characterization. *Journal of Land Use Science*, 1, 157–168.

Herold, M., Woodcock, C. E., Loveland, T. R., Townshend, J., Brady, M., Steenmans, C., et al. (2008). Land cover observations as part of a

global Earth observation system of systems (GEOSS): Progress, activities, and prospects. *IEEE Systems Journal*, 2, 414–423.

Strahler, A., Boschetti, L., Foody, G. M., Fiedl, M. A., Hansen, M. C., Herold, M., et al. (2006). *Global land cover validation: Recommendations for evaluation and accuracy assessment of global land cover maps* (Report of the Committee on Earth Observation Satellites [CEOS], Working Group on Calibration and Validation [WGCV]). Luxembourg: Office for Official Publications of the European Communities.

Townshend, J. R., Latham, J., Arino, O., Balstad, R., Belward, A., Conant, R., et al. (2008). *Integrated global observations of the land: An IGOS-P theme* (IGOL Report No. 8, GTOS 54). Rome: Food and Agriculture Organization of the United Nations.



LAND USE HISTORY

Land use history—the story of human use of Earth's surface and its resources—reflects the record of anthropogenic manipulation of the natural environment. In preagricultural times, this impact was largely confined to fires. The first major land use changes took place with the transition from hunting and gathering communities to agricultural societies. Further changes can be associated with the adoption of new farming techniques and crops as well as with social and historical developments. Starting with the Industrial Revolution in the 19th century, however, land use has become one of the dominating forcing factors of environmental change, gradually affecting natural ecosystems on a global scale. Land use interferes with the climate system as well as with biogeochemical and hydrological cycles and has become a major topic in the context of global change. It has been related to many environmental problems, such as climate change, desertification and soil erosion, biodiversity loss, and emission of greenhouse gases. Thus, knowledge of land use history is crucial to evaluate the impact and consequences of past land use practices on the environment and to use this information to project future developments.



Research Topics and Methods

Land use practices are essential to sustain human life and are determined by environmental settings of the landscape (e.g., climate, soil type), social and cultural conditions, and human needs and skills (e.g., farming techniques). Land use history therefore reflects both environmental and human development and their interactions through time. Studies of historical land use changes are helpful to identify past human-environment interactions, to investigate the resilience of ecosystems, and to predict and assess impacts for future scenarios, especially in terms of sustainability. Major research questions include the coevolution of natural environments and human societies, the sustainability of former land use practices, and how past land use may have significantly altered present-day environments by irreversible changes.

Research in land use history covers several scientific disciplines, ranging from historical and agricultural geography to archaeology and paleoecology, and involves both natural and social sciences. Land use history can be investigated using several approaches. Recent changes can be documented by remote sensing techniques such as satellite images or aerial photographs. Further back in time, information is provided by written sources, location names, historical maps, and early land surveys. Beyond these historical sources, natural archives such as peat deposits, colluvial soils, and lake sediments can be used to reconstruct past environmental conditions and, thus, land use history. Pollen, charcoal, and macrofossil analyses of such sediments provide valuable information about the past composition of vegetation. Decreasing tree pollen and the appearance of weed and cereals in the pollen spectra indicate human cultivation. Minerogenic layers in such sediment sequences can point to periods of greater soil erosion. Additional indications of former land use practices include specific geomorphologic and pedologic features such as terraces, irrigation ditches, and plough horizons.

Examples of Land Use History

The magnitude of land use varies depending on the time period and the geographical area under consideration. Thus, land use history is

intrinsically complex, and there are few global-scale estimates of long-term changes in land use. The following three examples illustrate the position of land use history in the intersection of climate and human society and its importance for present and future environments.

Early Agriculture

Approximately 10,000 yrs. (years) ago, sedentary farming independently evolved in Central America, China, and the Middle East. From the latter, it gradually spread into Europe, Northern Africa, and Western Asia. Shifting cultivation developed as an alternative cultivation method in regions with conditions unsuitable for permanent agriculture, especially the tropics. It is debatable whether this early human land use could have interfered with the climate system by the release of greenhouse gases, which may have prevented a natural cooling trend that would have otherwise started 8,000 yrs. ago. Some of the critical aspects necessary to verify this hypothesis in models are related to land use history—for example, reliable estimates of the area of deforestation, the amount of livestock grazing, or the loss of soil carbon caused by long-term land degradation.

Medieval Europe

Around AD 700, increasing population in Central Europe caused a continuous decline in forest cover as woodlands were cleared for agriculture (Figure 1). During an extreme rainfall event in the 14th century, increased runoff from the deforested land caused devastating floods and soil erosion. The cascading effects (e.g., famines caused by reduced agricultural production) and additional catastrophes such as the bubonic plague and warfare resulted in a significant decrease in population and thus land use. This lasted for more than a century before the situation stabilized in the 16th century, partly due to an increase in agricultural productivity through the adoption of new techniques, for example, elimination of the fallow period in a three-field crop rotation, selective manuring, and introduction of new crops.

European Settlement in North America

Starting in the 18th century, much of Eastern North America was cleared for agriculture and

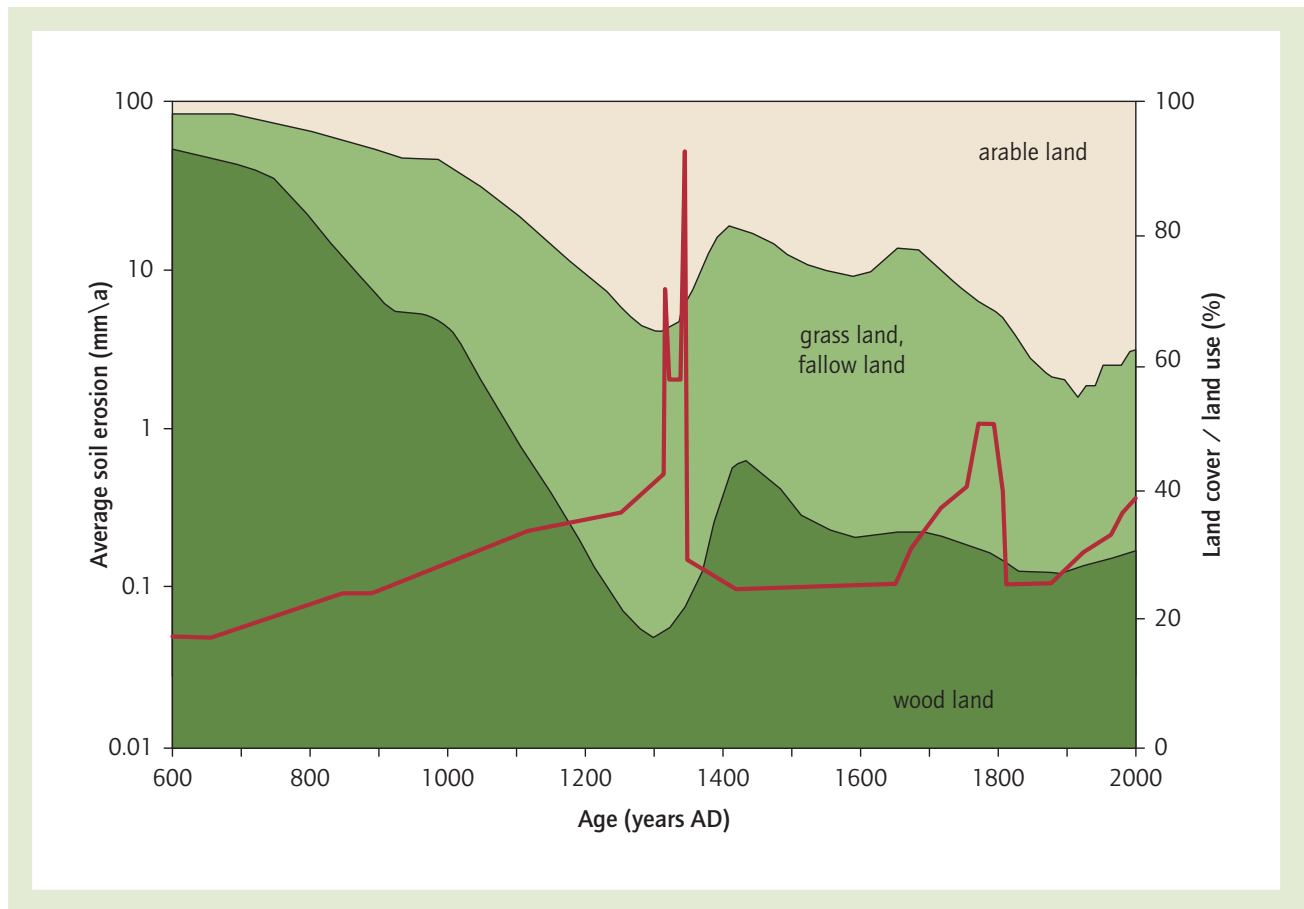


Figure 1 Land use change (shaded areas) and soil erosion (red line) in Central Europe (excluding the Alps)

Source: Bork, H., & Lang, A. (2003). Quantification of past soil erosion and land use/land cover changes in Germany. In A. Lang, K. Hennrich, & R. Dikau (Eds.), *Lecture notes in Earth sciences: Vol. 101. Long term hillslope and fluvial system modeling: Concepts and case studies from the Rhine River catchment* (pp. 232–239). New York: Springer. Reprinted with kind permission of Springer Science and Business Media.

grasslands by the European settlers. In Massachusetts, 60% to 80% of the land was under cultivation around the mid 19th century. Natural reforestation due to the abandonment of farms began around AD 1850 and continued into the 20th century, owing to the relocation of agriculture to the Midwestern states and rural populations moving into cities. Whereas the forest cover was closely linked to agriculture during the previous centuries, the situation changed in the 1950s, when woodlands partially decreased again as a result of residential and industrial developments. These landscape changes represent broad-scale disturbances of presettlement ecosystems; the effects of land use on soil erosion rates and eutrophication of aquatic systems as well as the

persistent impact on modern vegetation, soils, and climate have been demonstrated in several studies.

Dirk Enters

See also [Agricultural Land Use](#); [Centers of Domestication](#); [Deforestation](#); [Domestication of Animals](#); [Domestication of Plants](#); [Environmental History](#); [Environmental Impact Assessment](#); [Environment and Development](#); [Global Environmental Change](#); [Historical Geography](#); [Land Use](#); [Land Use Analysis](#); [Political Ecology](#); [Population and Land Degradation](#); [Population and Land Use](#); [Population, Environment, and Development](#); [Urban Land Use](#); [Wilderness](#)



Further Readings

- Dearing, J. A., Battarbee, R. W., Dikau, R., Larocque, I., & Oldfield, F. (2006). Human-environment interactions. *Regional Environmental Change*, 6, 1–16.
- Foster, D. R., Motzkin, G., & Slater, B. (1998). Land-use history as long-term broad-scale disturbance. *Ecosystems*, 1, 96–119.
- Ruddiman, W. F. (2007). The early anthropogenic hypothesis. *Reviews of Geophysics*, 45, RG4001.



LAND USE PLANNING

Land use planning is a process by which land uses are allocated through legal and political decision making; it is a process by which space is made, and it reflects and distributes power over land and people. Land use planning in the United States takes place within a legal framework that reflects the nation's founding as a republic that stood against feudal traditions, instituting the free holding of land by individuals, regardless of background and/or status. There are several nested and tiered layers of law and regulatory delegation of powers over land use by government, which structure how land use can be planned. This entry focuses on land use planning in the United States, which is illustrative of land use planning processes in many other societies.

Constitutional Requirements

The Bill of Rights of the U.S. Constitution contains two important amendments that shape that country's land use planning: the Fifth and the Fourteenth. The Fifth Amendment includes a clause that prohibits the taking of private property for public use without just compensation. The Fourteenth Amendment requires states to provide equal protection and due processes to protect life, liberty, and property for all citizens under law. These requirements mean that the state cannot condemn land for public purpose

without compensating the landowner at fair market value and it cannot act arbitrarily to favor one landowner or entity over another.

Article 6 of the U.S. Constitution can also affect land use planning. It declares that federal law prevails over state laws unless federal law violates the U.S. Constitution. The federal government can invoke Article 6 for land use planning issues that affect land across states or promote the public interest, such as power transmission line easements, placement of toxic waste dumps, and other facilities that are deemed in the national interest and for which the federal government can override state and local decision making. A prime example of this power is the siting of the high-level nuclear waste repository in Yucca Mountain, Nevada, by the federal government despite strong opposition in Nevada. After years of controversy, the Obama administration announced in March 2010 that the U.S. Department of Energy was withdrawing its pending license for the Yucca Mountain repository.

State and Local Authority

The U.S. Constitution delegates all powers not necessary to the functioning of the federal government to the states. Authority is then delegated from states to cities and counties, which are granted authority over land use by the states. The U.S. Constitution does not mention local governments; local governments are the legal creations of states, which then delegate authority to them. Over time, cities gradually developed independent status from state legislatures, though the extent and type of municipal land use authority depends on whether the city is a general-law city or a home rule (charter) city. Many states have both types of cities. General-law cities are bound by the state's general law, regardless of whether the subject concerns a municipal matter. In this case, state law describes the city's form of government, management structure, personnel matters, election rules, taxation, contracting, and so forth. State statutes prescribe the powers and duties of general-law cities. If something is not allowed by state law, a city cannot do it.



Home rule (charter) cities look to the state's constitution and statutes to determine what they may not do. Such cities have the inherent authority to do just about anything that qualifies as a public purpose and is not contrary to the constitution or laws of the state. They have inherent powers, that is, powers possessed by a city without having been specifically granted by the state. They are free to choose their form of government; for example, they can choose whether the city has a strong mayor who appoints agency directors, whether there is a large or small city council, whether elections are held by district or at large, and what the terms of office are, among other powers. These rules are codified in a charter that is approved by vote of the local citizens. Amendments must also be approved through election.

Each state has its own tax system, but local taxes typically include property taxes, sales taxes, and taxes and/or fees for services such as police, fire, and schools, among others. States and localities also receive intergovernmental transfers from the federal government. The U.S. Constitution and the relationship of cities to their state provide the foundation for land use planning in the country. Outside cities, counties also engage in land use planning, which is also constrained by the U.S. Constitution and state mandates.

Planning, Zoning, and Local Economic Development

The Industrial Revolution of the 19th century caused unprecedented and unorganized urban growth. Housing was located in or adjacent to industrial facilities, building heights and densities were unregulated, and the urban environment was frequently insalubrious. As a result, between 1900 and 1916, land use planning tools began to be developed, including zoning that segregated uses to protect human health and to create orderly economic development patterns. Zoning, as an allocation of space, determines what uses go where and what adjacencies are created. Zoning is also therefore a tool that local governments can use to define the character of a community and its development path. Communities that zone much of their land for industrial

uses will have a very different character from those that harbor single-family neighborhoods. How land is zoned also directly affects local revenues, in the form of a range of taxes. Zoning and land use are thus the key components of a city's powers of exclusion and inclusion, of its wealth and social composition.

As such, the power over land use creates a very strong relationship between local decision makers and economic interests. This relationship, dubbed by Logan and Molotch as the "urban growth machine," is one in which, for local government, land is the principle asset through which elected officials shape the character and revenue stream of the locality. It relies on coordination and planning with local business interests whose activities on the land create not only local wealth, through taxes and fees, but also jobs and prosperity. Local institutions are therefore characterized by a close relationship between politicians and businessmen to enhance the commercial public and private interests of localities. Cities—and increasingly counties—to remain prosperous, compete for revenue-generating land uses and plan their land for the uses they consider will yield the highest revenues. Thus, planning becomes increasingly a function of economic development policy.

Counties face many of the same pressures and also plan land use in unincorporated areas. Counties also have additional responsibilities, as they are the state's designated representatives at the local level, providing health and welfare services in addition to planning services. They, too, compete for revenue-generating development through their land use designations and become an additional competitor in the race for economic development.

Environmental Issues

Over the course of the 20th century, with the rise of the environmental movement, the question of land use has at times been seen as intrinsic to environmental preservation and quality. Tensions about how much authority the federal government should exert in land use planning for environmental protection and orderly land development versus state and local authority have



characterized the relationships among these levels of government since the federal government reserved the public domain. Rather than planning rules, the federal government has created incentives to encourage thoughtful planning of critical resources. For example, the federal Coastal Zone Protection Act in 1972, reauthorized in 1996, provides annual grants to states to develop coastal zone management programs.

At the state level, such tensions have also been prevalent. California's 1972 Coastal Protection Act went further and created a new agency in charge of land use planning along the coastal zone, up to 1 mile inland, with regional agencies throughout the state. The authority of this agency has been contested ever since. Environmental concerns also led to the creation of the landmark 1973 Oregon statewide land use planning law: Oregon Land Use Act (Senate Bill 100). Under that program, all cities and counties adopted 19 comprehensive plans that met mandatory state standards. They address land use, development, housing, transportation, and conservation of natural resources. The law was contested in 2004, when Measure 37 was approved, requiring compensation for property owners whose property value was reduced by local zoning for agricultural land protection or one of the other 19 planning goals. Measure 37 was passed, based on the claim that Senate Bill 100 infringed on private property rights, and more than 7,000 claims for compliance payments or land use waivers were filed, totaling more than \$250 million. It became clear that if local governments' land use authority were curtailed, there would never be enough revenues to pay for the alleged takings. In 2007, voters overturned Measure 37, realizing that it would severely restrict the state and local governments' ability to zone land and that haphazard economic growth would result.

Another result of the 1970s environmental movement was the passage of the Endangered Species Act (ESA) in 1973. Originally intended by Congress to protect charismatic animals such as golden eagles and grizzly bears, with rapid population growth and urbanization in places such as Southern California, a biodiversity hotspot, the ESA has affected local land use planning. The ESA's purposes include providing a

means whereby the ecosystems on which endangered or threatened species depend may be conserved. The ESA has evolved into a land use law, though indirectly, by providing environmental groups with a powerful tool to challenge projects that might endanger the existence of species and their habitats. This has led to the development of plans to ensure the survival of species. In California, this process is reinforced by the California Environmental Quality Act (CEQA), which requires environmental impacts statements for all new developments.

The ESA has, in some places, become a forcing mechanism for large-scale land use planning, determining which lands will remain in permanent open space and which lands can be developed. These are often complex, lengthy, and expensive negotiation processes whose ultimate success depends on many factors, including the constellation of local economic interests, elected officials, and the permit process, which involves layers of government agencies and officials. Nevertheless, short of Oregon-style statewide planning, habitat conservation planning under the ESA has been a step toward regional planning but occurring only where there are endangered species.

In addition to the ESA, there are other emerging considerations that are starting to affect the traditional local purview over land use planning. In places facing possible water shortages, state legislatures have begun to look at the relationship between land development, water availability, and the water intensiveness of land use. Regulations are beginning to emerge to ensure sufficient water supplies for new development by scaling the land use appropriately. Climate change is also a new factor that may encroach on local authority, as agencies begin to better understand the relationship between urban form (land use) and greenhouse gas emissions.

Conclusion

There is an intimate relationship between land use and local economic interests that is longstanding in the United States and that is inscribed in private property protections under the U.S. Constitution. Elkin describes the United States as the



Commercial Republic, reflecting these close ties. However, the unanticipated impacts of human activities, such as the depletion of water resources, impacts on biodiversity, and climate change, are creating new dimensions to land use planning that cannot be readily addressed within the existing framework. In addition, changing revenue sources and structures are also beginning to affect land use decision making, as land use has historically been the foundation for local government-funding streams. At this historical juncture, land use planning rules and conventions are inadequate for changing climatic conditions and the changing demographic profile of the nation. Yet constitutional constraints, entrenched views of private property rights, and the belief in local control over local land use will make future evolutions complex and difficult.

Stephanie Pincetl

See also **Agricultural Land Use; Community-Based Conservation; Community-Based Environmental Planning; Conservation Zoning; Environmental Impact Assessment; Environmental Management; Environmental Planning; Environmental Protection; Land Use Analysis; Land Use and Cover Change (LUCC); Land Use and Land Cover Mapping; Land Use History; Locally Unwanted Land Uses (LULUs); Population, Environment, and Development; Regional Environmental Planning; Rural Development; Rural Geography; Soil Conservation; Urban and Regional Planning; Urban Land Use; Urban Sprawl; Watershed Management; Wetlands; Wilderness; Zoning**

Further Readings

- Andrews, R. N. L. (2006). *Managing the environment, managing ourselves* (2nd ed.). New Haven, CT: Yale University Press.
- Elkin, S. L. (1987). *City and regime in the American republic*. Chicago: University of Chicago Press.
- Logan, J. R., & Molotch, H. L. (2007). *Urban fortunes* (2nd ed.). Berkeley: University of California Press.

LAND-WATER BREEZE

The land-water breeze is a localized land-atmosphere phenomenon that arises due to the differential heating of water and land surfaces. This differential heating creates local atmospheric circulations (i.e., breezes) that can strongly affect weather and climate in coastal regions. The land-water breeze and the differential heating of land and water surfaces are recognized factors in explaining temperature patterns and the differences between coasts and inland locations.

A water breeze, more often called a *sea breeze*, is a cool breeze blowing off an ocean or body of water onto the adjacent land. This breeze is created by the temperature contrast between the cool body of water and the warm land surface. The temperature contrast is usually greatest during warm, sunny afternoons in spring or summer, as the ocean temperature remains cool but the incoming solar radiation heats the land surface. The increased temperature and radiation at the land surface results in the warming of the air (atmosphere) above the land. Because warm air is less dense than cool air, the warm air expands and rises. This upward movement of air creates a local increase in air pressure aloft as the air "piles up" and creates a pressure gradient aloft between the land and ocean locations (Figure 1). Air flows from the local high pressure to the local low pressure. The removal of air above the land surface then creates a local surface low pressure, and the flow of air toward the ocean creates downward-moving air and a high pressure near the surface. Surface air flows from the high pressure over the ocean to the low pressure over the land, carrying the cooler ocean air with it, resulting in the water or sea breeze. This local circulation forms a convection cell or convection loop.

In the land breeze, the situation is reversed. Land breezes occur mainly on cool, clear nights during the fall and winter, when radiational cooling is strongest and water temperatures are fairly warm. At night, the land surface and the atmosphere above it will cool off due to radiational cooling, while the ocean temperature remains relatively constant. As the air above the land surface becomes denser, the atmospheric column contracts, forming

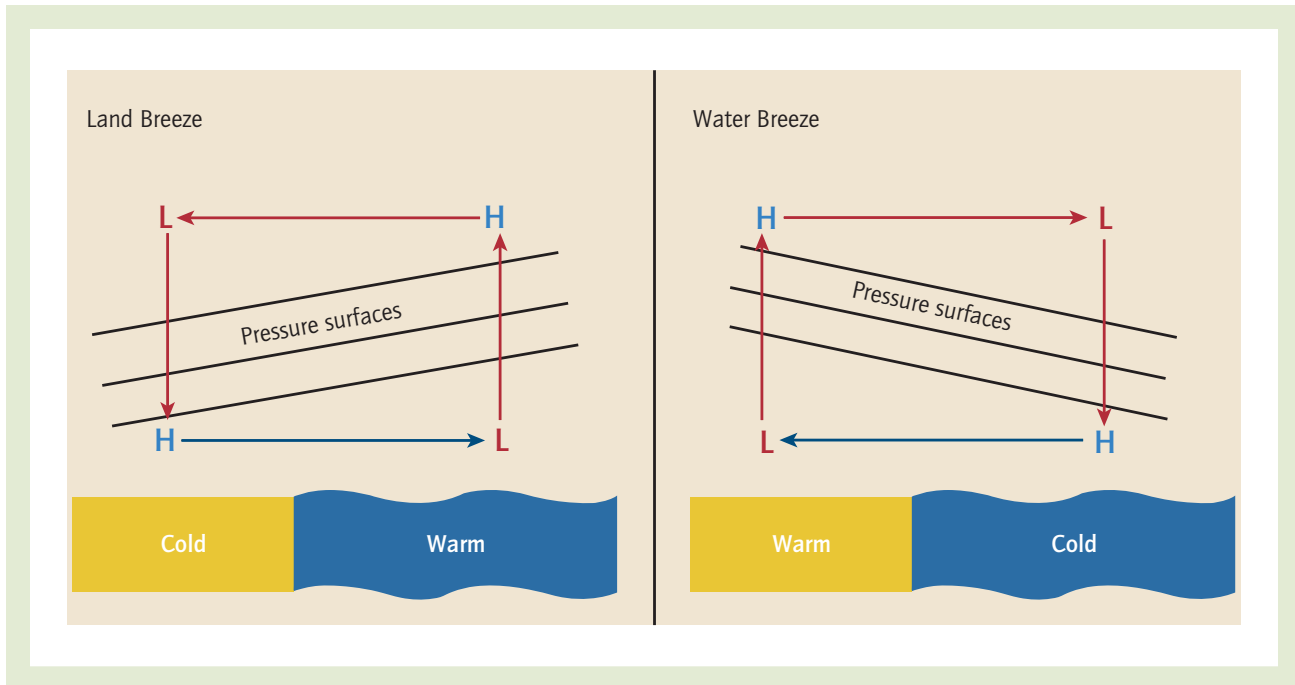


Figure 1 Land-water breeze: surface and aloft circulation

Source: Author.

sinking air and a local area of high pressure. Again, the upper air (aloft) is affected by the heating and cooling of the surface. As the air sinks over the land, a low pressure is created aloft, and a high-pressure center forms over the water. Air aloft flows onshore, which creates further vertical sinking over the land. The onshore flow produces vertical rising over the ocean, creating a local low pressure. The land breeze is produced by offshore flow between the land high and the ocean low pressure.

Jennifer S. Arrigo

See also **Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure; Oceans; Temperature Patterns; Wind**

Further Readings

Simpson, J. E. (1994). *Sea breeze and the local winds*. New York: Cambridge University Press.

LANGUAGES, GEOGRAPHY OF

Language (in contrast to speech) may be understood in several ways: (a) as a means of organizing thought; (b) as a way of communicating, that is, producing and sharing meaning; and (c) as a vehicle for bringing the world into consciousness, that is, of converting sensations into perceptions. Language is a system of symbols through which cognition is structured, and it is intimately wrapped up in individual and collective identity. It is impossible to understand the world without it. Language is thus simultaneously a psychological, social, and cultural phenomenon. In many countries (e.g., Belgium, Canada), languages have deep political significance as well and may be the source of ethnic strife. Because languages are unevenly distributed across space, they are also inherently geographical.

Because languages are semantically and historically related to one another, it is common to group them into families of varying sizes. Linguists and cultural geographers typically maintain that there are roughly eight major language families as well as several others termed *isolates*.



Indo-European Languages

By far the largest and most widespread of the major language families is the Indo-European, a group first identified by the famous linguist William Jones, a British judge stationed in India, in the 18th century. Starting with the migrations of the so-called Aryans around 1500 BC to 2000 BC, perhaps as a result of their domestication of the horse, Indo-Europeans moved in two directions from their homeland near the Caucasus Mountains. (Indeed, names such as *Ireland* and *Iran* are derived from the name of this tribe). One group moved east into Northern India, their languages becoming the basis of the Sanskrit-based Indic languages, such as Hindi, Bengali, Urdu, Gujarati, Bihari, Marathi, Sinhala, and Nepali. Others remained in the Middle East, where their languages eventually became the Indic family, including Farsi (formerly Persian), Kurdish, Armenian, and Pashto in Afghanistan. The other major branch of Indo-Europeans moved into Europe, where they diverged into several groups. The languages of these groups include the Latin-based Romance languages (Italian, Spanish, Portuguese, Catalan, French, Romansch, and Romanian), which arose during the disintegration of the Roman Empire. Greek and Albanian form separate categories in their own right. Farther north, the Germanic languages include German, Dutch, the Scandinavian tongues, and English. Celtic, an early branch once widespread throughout Western Europe, today consists of Scottish and Irish Gaelic, Welsh, Breton in Western France, and extinct tongues such as Cornish; this branch is in danger of disappearing. In Eastern Europe and Russia, the Slavic branch includes Polish, Russian, Ukrainian, Czech, Slovak, Slovenian, Serbo-Croatian, and Bulgarian. The Baltic group of Lithuanian and Latvian is another branch.

With the expansion of Spanish, Portuguese, French, and British colonialism, Indo-European languages were carried throughout much of the world, becoming dominant throughout the New World, Australia, and New Zealand (Figure 1). Today, about half of the world speaks an Indo-European tongue of one sort or another. English, in particular, empowered and diffused by the British and American empires, has become the *lingua franca* of more people than any other tongue (when second-language speakers are included).

English is unquestionably the world's dominant language in commerce, trade, scholarly publications, airlines, international finance, and tourism.

The rise of the nation-state as well as the invention of printing had enormous effects on the social and spatial structure of language. One dialect—typically that of dominant elites, whether in Tuscany, London, Madrid, or Paris—became privileged over others, expanding into national languages, annihilating local differences in vocabulary and pronunciation but integrating diverse groups linguistically into a common group. The newly printed languages were fundamental for the emergence of a national consciousness because they geographically connected speakers of, for example, local varieties of “Englishes,” “Spanishes,” and “Germans” and made known to them the existence of others who shared the same language group. These newly printed languages forged dialects together into national languages. Printing thus constituted a prime dimension in the time-space compression that created modern nation-states.

Afro-Asiatic Languages

A second major language family is Afro-Asiatic, which extends across the Middle East and North Africa (Figure 2). This group includes most of the extinct or nearly extinct languages of the ancient Middle East, such as Canaanite, Phoenician, Assyrian, and Aramaic (of which pockets survive). The dominant branch of the Afro-Asiatic family is Semitic, which includes Arabic (with numerous dialects) and Hebrew, nearly extinct as a spoken language until it was revived by the Zionists at the end of the 19th century. Other branches include Berber, widespread in the Maghreb, and Kushitic, the dominant family of Ethiopia (i.e., Amharic) and Somali.

Ural-Altaic Languages

Ural-Altaic, also sometimes called Finno-Ugric, constitutes a third family. The origins of this group, probably near the Altai mountains of Mongolia, are lost in prehistory. It is likely that speakers of these languages are descendants of several waves of migration that generated populations that continue to speak loosely related tongues stretched across Eurasia (Figure 3). Finnish and Estonian constitute one example; Hungarian, the



Figure 1 Indo-European languages. This group (identified in black shading) is the world's largest and most widespread, encompassing half the world's population.

Source: Author.

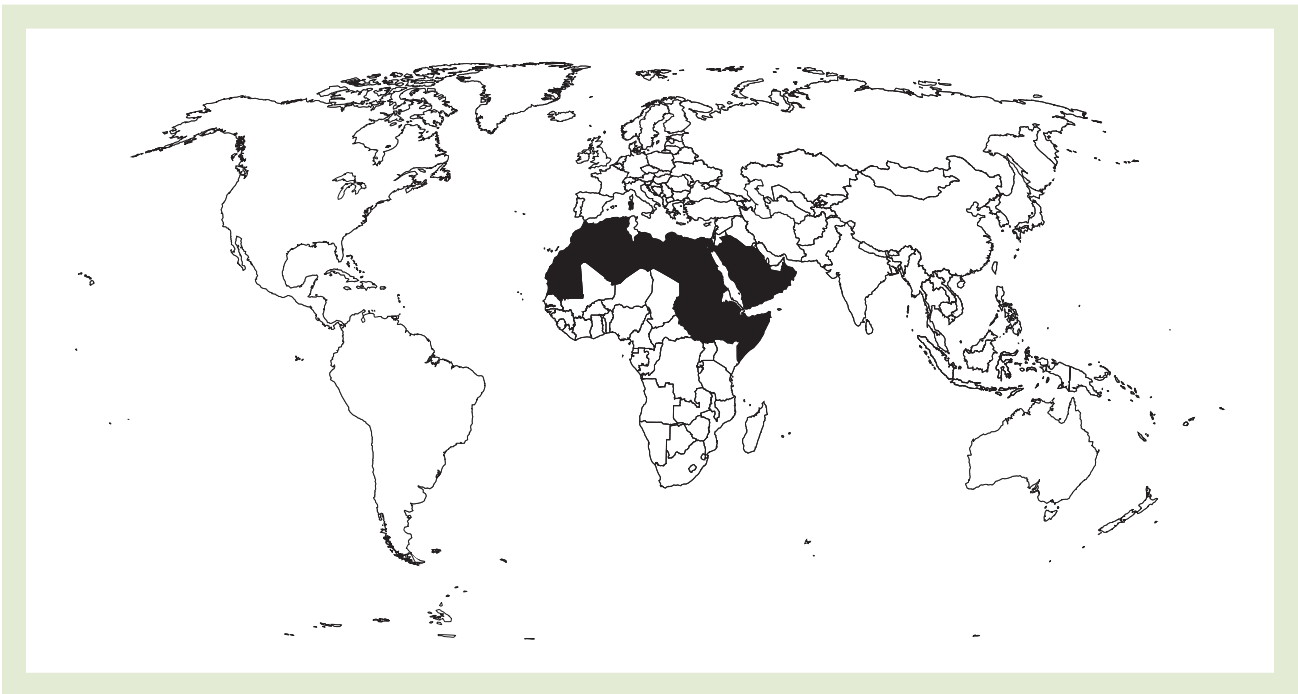


Figure 2 Afro-Asiatic languages. Dominated by Arabic, this group (identified in black shading) includes Hebrew and many extinct or nearly extinct tongues of the Middle East.

Source: Author.

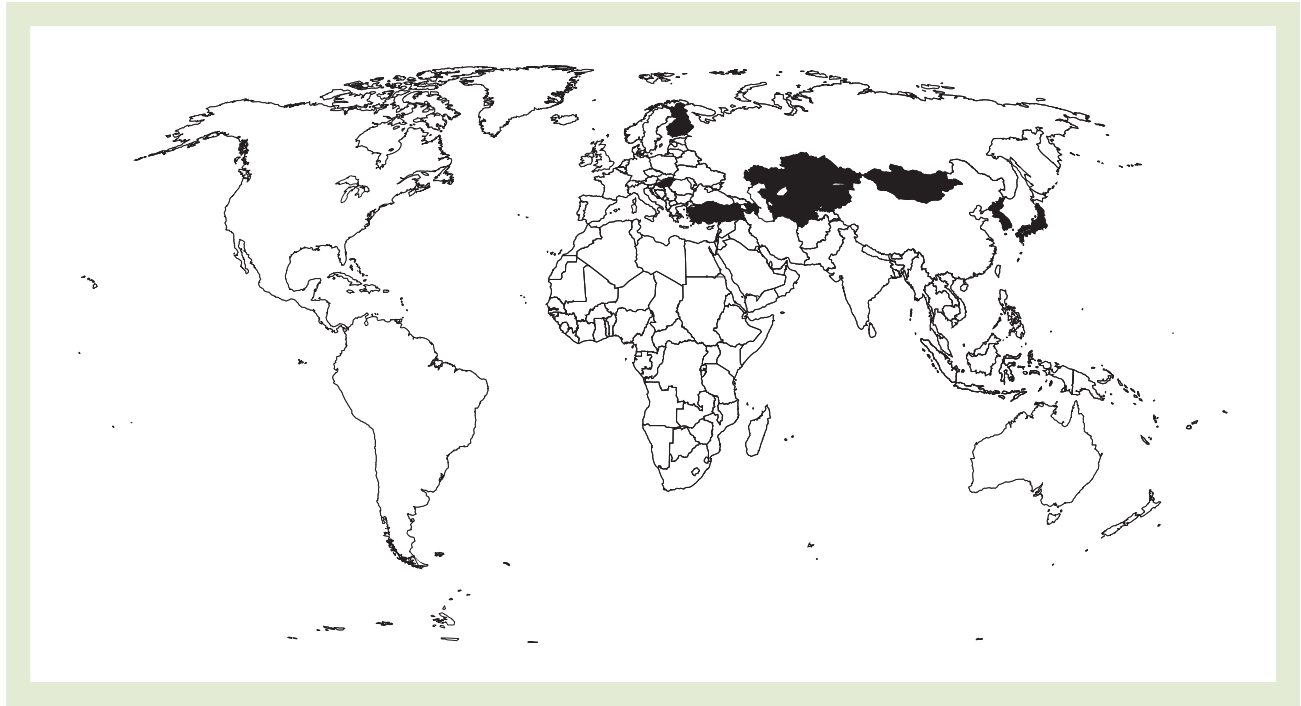


Figure 3 Ural Altaic or Finno-Ugric languages. A diverse group that stretches from Finland to Japan (identified in black shading), there is no consensus about how cohesive it is.

Source: Author.

language of the Magyar who settled in Eastern Europe in the 8th century, is another. A third branch is the Turkic languages, which all emanated from the Turkish migrations into Central Asia and Anatolia in the 9th and 10th centuries; the remaining Turkic languages include Turkish, Azerbaijani, Kazakh, Uzbek, Turkmen, Kyrgyz, and Uighur in Western China. Yet another branch is Mongol and Manchu, formerly spoken in Manchuria but now extinct, as are the indigenous tongues of Siberia, such as Samoyed and Tungic. Finally, although it is controversial, many linguists assign Japanese and Korean to this family as well.

African Languages

Africa south of the Sahara desert is a complex mosaic of tongues from several language families. In addition to the Afro-Asiatic languages in the north (Arabic, Berber) and in the Horn of Africa (Amharic, Somali), it has smaller families such as the Nilo-Saharan and, in Southwest Africa, the famous click languages of the Khoisan family (e.g., !Kung). However, the bulk of the many languages spoken throughout this vast region fall

under the Bantu or Niger-Kordofanian language family, which includes thousands of tongues (Figure 4). Arising from the migrations of agriculturalists from Central Africa around the time of Christ, this family includes languages as diverse as Mande in Western Africa, Kikuyu in Kenya, and Tswana, Nbele, and Zulu in Southern Africa. Along the eastern part of the continent, Swahili has long formed a lingua franca, a trade language that combined words of different languages, including some from Arabic.

Asian Languages

In Eastern Asia, the Sino-Tibetan language family is the most commonly spoken group (Figure 5). Common to this group is the use of tones (although these are found in some African languages, too), in which pitch forms part of the meaning of the word. This family includes Chinese, which embraces a variety of languages that are not mutually intelligible but use a common writing system (a feat only made possible with a pictographic writing system, not an alphabet). Chinese includes Mandarin, the dominant language of Northern China (and the



Figure 4 Bantu or Niger-Kordofanian languages. Dominant in sub-Saharan Africa (identified in black shading), this is a vast collection of loosely related tongues.

Source: Author.

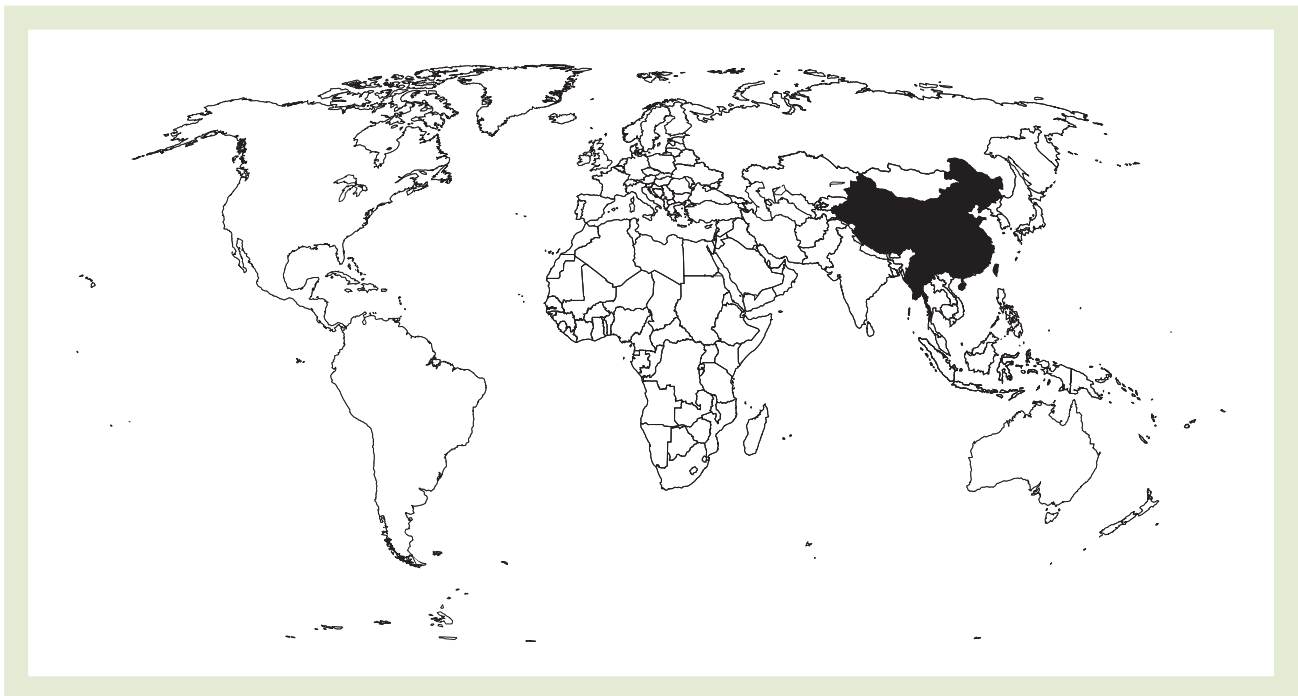


Figure 5 Sino-Tibetan languages. One of the world's largest groups (identified in black shading), it includes multiple forms of Chinese as well as Tibetan and Burmese.

Source: Author.



Figure 6 Malayo-Polynesian languages. In addition to Malay and Tagalog, this group (identified in black shading) includes Malagasy in Madagascar, Maori, and Polynesian tongues such as Hawaiian.

Source: Author.

most commonly spoken language at home in the world) and close to a national tongue (Szechwanese is a dialect), as well as Cantonese and less well-known ones such as Shanghainese, Wu, Hakka, and Fukienese or Taiwanese. This group also includes Tibetan and, because of Tibetan migrations down the Irrawaddy River, Burmese.

A sixth major family is the Malayo-Polynesian, a diverse group that extends across much of south-east Asia into the islands of Polynesia and Micronesia (Figure 6), thus including Hawaiian and New Zealand's Maori. Originating among tribes in Taiwan, this group includes the Malay languages of Malaysia and Indonesia (each with countless dialects) and the numerous tongues of the Philippines, of which Tagalog is the best known. Around AD 500, Indonesian sailors crossed the Indian Ocean and settled in Madagascar, making the language Malagasy part of this family.

Other Language Families

Several other families are worth noting. Southern India is home to a sizable population who do not

speak Indo-European languages but the Dravidian tongues Tamil, Telugu, Kannada, and Malayalam. The Indochinese peninsula is home to two distinct language groups, Austro-Asiatic (Vietnamese, Cambodian) and Thai-Kadai (Thai, Lao). The Aboriginal peoples of Australia and Papua New Guinea, who constitute 1% of the world's population, speak 20% of the world's languages in an enormously diverse group often called Indo-Pacific. The Americas were home to a huge range of indigenous languages prior to the mass demographic and cultural extermination unleashed by the Europeans: More than a dozen families existed in North America (e.g., Iroquoian, Siouan, Salishan, Athabaskan, Mayan) and in South America (Andean, Chibchan, Macro-Carib). Finally, isolate languages such as Basque, with no surviving relatives, and Kartvelian tongues such as Georgian, continue to survive.

Language Death

Today, there are roughly 5,000 to 6,500 languages remaining in the world. Most, however, have very



few speakers, often numbering only in the dozens, and are not written. The total number was much larger in the past and has been steadily declining for centuries. The rise of the nation-state often led to a deliberate homogenization of cultures and dialects, and today, globalization and national school systems have contributed to the decline. In the Americas, disease, genocide, government-run boarding schools in the United States, and cultural assimilation annihilated large numbers of languages. Today, 96% of the planet speaks one of the top 20 languages, and many observers predict that 50% of all languages will disappear within the next century (one every 2 weeks). This decline represents a crisis in cultural diversity that deprives humanity of the rich ways of viewing the world inherent in the multiple different languages.

Language and Geographic Analysis

Finally, in addition to the geography of languages, geographers have long been interested in the role of language in the representation of space. Because language structures and mediates thought, it plays an enormous role in how discourses about the world are organized. Language as a structured symbolic system has figured prominently in philosophy for decades, including varied analyses by authors such as Ludwig Wittgenstein, Benjamin Whorf, Jurgen Habermas, and various poststructuralist authors (e.g., Jacques Derrida), who interpret the world through the lens of discourse. In this light, language is not simply a medium for communicating but an obstacle as well, a force that enters into the making of social and spatial reality. For humanistic geographers, language is a window into the structure of human consciousness and spatial perception, for language shapes how human beings give meaning to space and their sense of place. Language became a central topic in the intersections between geography and literary criticism, including the analysis of landscape as texts. For Gunnar Olsson, the limits of language amounted to the limits of understanding. Feminists have emphasized the gendered nature of language and how it helps to reify or to challenge gender roles and performativity. For followers of Michel Foucault, language is constitutive of ideology and discourse and thus is always intimately associated with power and the social production of subjects. For postmodernists, languages always oversimplify

the world, for reality is more complex than any language can admit. A broad consensus emerging from these various perspectives is that all worldviews are inherently and necessarily partial, contingent, and situated in context. Such lines of thought have enormous implications for the ways in which truth is conceived (e.g., as a mirror of the world or as part of a situated worldview) and how explanation is justified. Language is thus a deeply epistemological phenomenon, for humans do not simply use language, they are in turn shaped by it.

Barney Warf

See also **Cultural Geography; Discourse and Geography; Epistemology; Humanistic Geography; Literature, Geography and; Olsson, Gunnar; Ontology; Postmodernism; Poststructuralism; Text/Textuality; Writing**

Further Readings

- Comrie, B., Matthews, S., & Polinsky, M. (Eds.). (1996). *The atlas of languages*. New York: Quarto.
- Dalby, A. (2003). *Language in danger: The loss of linguistic diversity and the threat to our future*. New York: Columbia University Press.



LA NIÑA

La Niña refers to anomalously cool central to eastern equatorial Pacific surface waters. These climate events occur every 2 to 7 yrs. (years) and last anywhere from about half a year to 3 yrs., with peak strength in the boreal winter season. *La Niña* is also often synonymous with the “high” phase of the Southern Oscillation, with the *El Niño* comprising the “low” phase. During the high phase, sea-level pressure is higher than normal over the Eastern Pacific (e.g., Tahiti) and lower than normal over the Maritime Continent (e.g., Darwin, Australia). *La Niñas* have a large impact on certain regional climates but have not been extensively studied in geography or the atmospheric sciences.

While *El Niño* (“little boy”) has been part of the Peruvian vernacular for centuries, *La Niña* (“little girl”) was coined by George Philander in the mid 1980s, implying its opposite nature. This definition coincided with a *La Niña* event from



October 1984 to September 1985, which followed on the heels of the very strong 1982–1983 El Niño and marked the first cold period since the mid 1970s. Recent La Niña events, as defined by the National Oceanic and Atmospheric Administration, have occurred in 1988–1989, 1995–1996, 1998–2001, and 2007–2008.

La Niñas often follow strong El Niños. According to the delayed-oscillator theory, “warm” eastward-traveling Kelvin ocean waves and “cold” westward-traveling Rossby ocean waves are generated by westerly wind stress from the El Niño, and when these waves reflect at the boundaries of the Pacific and recross the ocean, their damped signal forms the subsequent La Niña. In general, La Niñas tend to be weaker than their climatological brothers, with the largest temperature anomalies reaching about -2.0°C (Oceanic Niño Index). The basic climate system of the equatorial Pacific is warm, deep waters in the west and cool, shallow waters in the east with easterly surface winds. Since La Niña simply amplifies this base state, it is much more difficult to get strong anomalies than when there is a reversal of the system during an El Niño. La Niñas also affect the biogeography of the Pacific. The shoaling of the Eastern Pacific Ocean mixed layer is accompanied by vigorous upwelling. More nutrients are brought to the ocean surface during La Niña, causing widespread primary productivity blooms, which support a diverse marine ecosystem.

La Niñas change the global atmospheric circulation. While El Niños thermodynamically increase the instability of the tropical atmosphere, La Niñas concentrate convection over the Maritime Continent, which receives copious rainfall. Thus, the zonal atmospheric circulations, or Walker Circulation, are dynamically altered, with much of the Pacific dominated by subsidence and dry conditions. These changes in the Pacific are communicated to the rest of the globe through “teleconnections”—a combination of variations in the meridional Hadley Circulation, “atmospheric bridge” mechanisms, and atmospheric Rossby wave trains (Figure 1).

In boreal winter over the United States, the southern states are anomalously dry and warm, the northeast is wet and cool, a band from the Pacific coast of Alaska to the Northern Great Plains is cool, and the Ohio Valley is wet. Also in this season, northeast Brazil tends to experience



Figure 1 Example of an atmospheric Rossby wave train (anomalous high- and low-pressure centers and jet streams) associated with La Niña

Sources: Google Earth and the National Oceanic and Atmospheric Administration.

wetter (cooler) conditions than normal. Japan and West Africa are anomalously cool, and southeast Africa is wet and cool. Conversely, parts of equatorial Africa are drier than normal. In boreal summers, there is no La Niña signal in the extratropical Northern Hemisphere, but West Africa remains cool, the Caribbean becomes cool and wet, and most of South Asia is cooler than normal, with India also becoming wetter than normal. Also in this season, the South Pacific island nations experience warm conditions, the west coast of South America is cool, and Argentina, Uruguay, and Southern Brazil become dry. Just as El Niño and La Niña are near mirror images in the Pacific Ocean, many of the teleconnections are seen as opposites as well. However, some scientists dispute this linearity assumption. Finally, generalities about the impacts of La Niña are problematic because every event is different. Figure 2 shows the evolution of global precipitation and temperature anomalies during the strongest La Niña in the satellite era.

For reasons not yet completely understood, the El Niño-La Niña cycle undergoes decadal-scale variability tied to the Pacific Decadal Oscillation

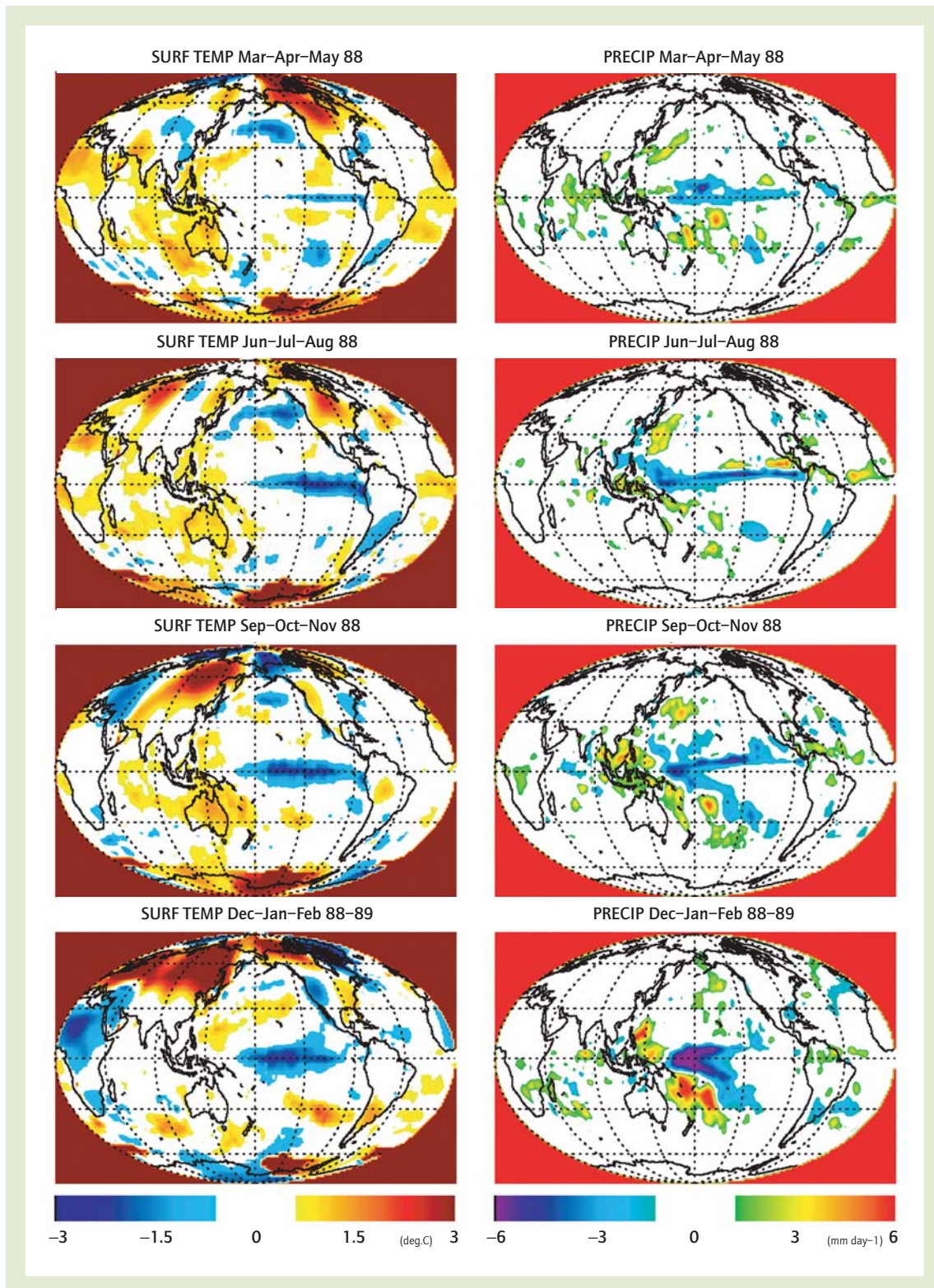


Figure 2 Surface temperature and rainfall anomalies, based on 1951–1980 and 1987–1996 data, respectively, averaged over 3-month seasons during 1988

Sources: Global Precipitation Climatology Project and Goddard Institute for Space Studies, NASA, Surface Temperature Analysis.



(PDO). Recent trends in the PDO suggest that the mid 2000s could mark a regime shift into a 30-yr. period where La Niñas will dominate over El Niños and may explain the lingering 2007–2008 La Niña. The last time the PDO pendulum swung to La Niña was between the 1950s and 1970s (before the term *La Niña* existed). There is also some controversy as to whether global warming may lead to a permanent La Niña-like state. In 1996, Amy Clement and coauthors first postulated that if a uniform heating was imposed on the surface of the ocean, upwelling could regulate the warming. Known as the *ocean dynamical thermostat* mechanism, the Eastern Pacific (where upwelling occurs) should warm less fast than the Western Pacific, and the zonal temperature and pressure gradients should increase. This would lead to stronger easterlies, inhibiting westerly disturbances and the formation of El Niños. This theory has been corroborated by some climate models and observations but not others, so further study is needed.

Even though the global impacts of La Niñas are equal in scope to the impacts of El Niños, La Niñas have not received the same attention in the scientific community. A search for “El Niño” in journal article titles and abstracts from a large publication database uncovered 9,573 records, but “La Niña” could only muster 1,645. This disparity must be rectified with greater research emphasis on La Niña, especially since it may play an important role in Earth’s climate in the near future.

Scott Curtis

See also Climate Change; El Niño; Oceanic Circulation; Oceans; Precipitation, Global; Teleconnections; Temperature Patterns

Further Readings

- Clement, A. C., Richard, S., Cane, M. A., & Zebiak, S. E. (1996). An ocean dynamical thermostat. *Journal of Climate*, 9, 2190–2196.
- Philander, S. (1985). El-Niño and La-Niña. *Journal of the Atmospheric Sciences*, 42, 2652–2662.
- Ropelewski, C. F., & Halpert, M. S. (1989). Precipitation patterns associated with the high phase of the Southern Oscillation Index. *Journal of Climate*, 2, 268–284.



LAPSE RATE

Lapse rates are the average changes in temperature at different levels in the atmosphere. Four different rates are environmental, normal, dry adiabatic, and wet adiabatic. Each is applied in specifically different situations. The changing temperatures affect the humidity and the climatic patterns. Types of lapse rate, their applications, their relationship to cloud formation and atmospheric lifting, and the environmental hazards are discussed here.

The environmental lapse rate is the actual change in air temperature with altitude at a specific place at a specified time. The temperature depends on current micro- and macro-meteorological conditions. In general, temperatures are expected to decrease with altitude through the troposphere, the lowest temperature zone of the atmosphere. However, temperature variations occur, and the actual situation makes the environmental lapse rate. For example, this might be measured with a thermometer as a balloon rises vertically from the surface through the air.

The normal lapse rate is the mean of the environmental lapse rates. Considered to be 6.5 °C/1,000 m (meters) or 3.5 °F/1,000 ft. (feet), this value is used both to estimate the temperature at a higher elevation, such as for an airplane flying overhead, and to compare temperatures between locations at different elevations, for example, San Francisco, California, near the coast, and Denver, Colorado, about a mile higher.

The normal lapse rate is closely related to the greenhouse effect. Because the troposphere is predominantly heated by the absorption of terrestrial radiation, more of this Earth radiation is trapped near the surface than reaches the higher levels. So temperatures near the surface are generally warmer than in layers aloft, and this average temperature differentiation is the normal lapse rate.

The dry adiabatic lapse rate applies to temperature changes in an unsaturated parcel of air that is physically changing elevations. The atmospheric pressure surrounding a parcel of rising air decreases, so it expands and cools. Thus, the rate of temperature change is greater than the normal lapse rate. The dry adiabatic lapse rate is about 10 °C/1,000 m, or 5.5 °F/1,000 ft.

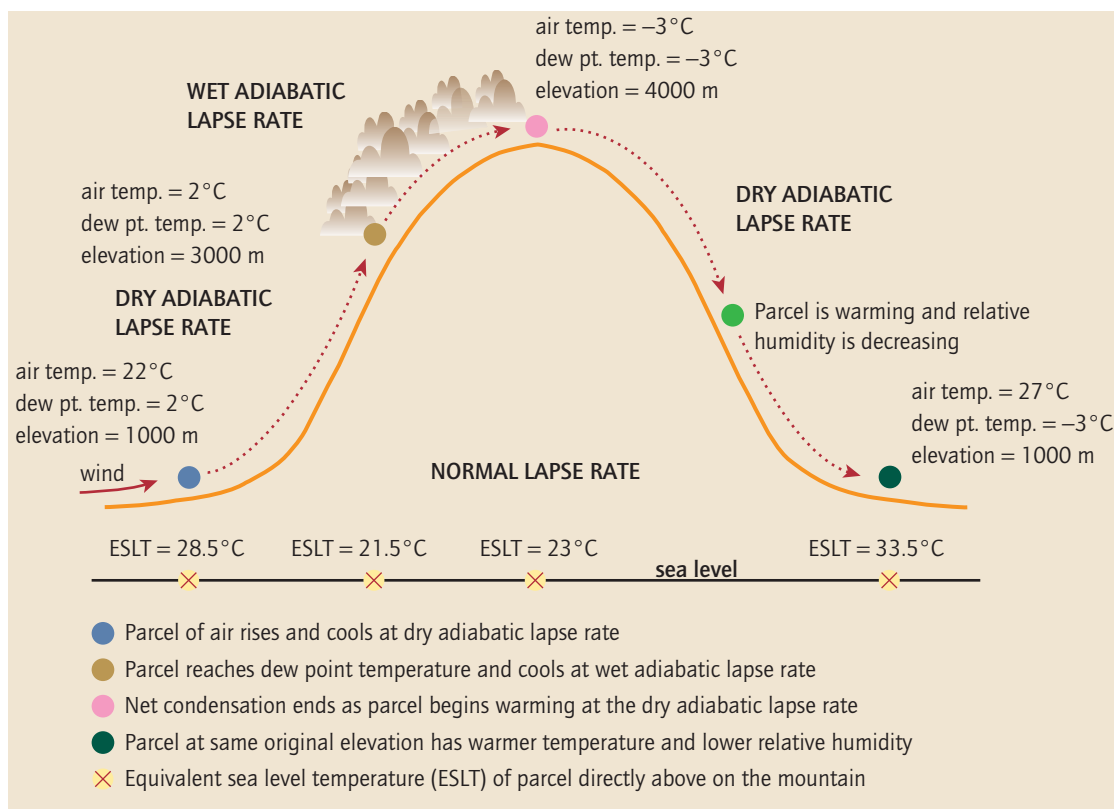


Figure 1 Lapse rates example diagram

Source: Author.

As unsaturated air cools, the relative humidity rises, and the temperature approaches the dew point temperature. Once cooled to the dew point temperature, net condensation exceeds net evaporation, and latent heat stored by the moisture is released to the environment in a warming effect. Thus, a parcel of rising saturated air will not cool as rapidly as rising unsaturated air. The result is the wet adiabatic lapse rate of 5 °C/1,000 m or 3.0 °F/1,000 ft. This rate depends on the amount of condensing moisture.

Application of Lapse Rates

Typically, a mountain example is used to model the temperature changes of the air. The normal lapse rate is used if temperatures are being compared from one location to another or to eliminate the impact of elevation on the temperature. The

equivalent sea-level temperature results from calculations to remove the impact of elevation and convert the temperature to zero elevation units. The dry adiabatic lapse rate applies while the temperature remains above the dew point temperature moving up the mountain. On reaching the dew point temperature, when the air becomes saturated and the net condensation begins building clouds, the temperature drops at the wet adiabatic lapse rate as it continues to rise. Air moving back down the leeward side of the mountain will warm at the dry adiabatic rate (Figure 1).

If condensation has occurred on the windward side of the mountain, the subsiding air on the leeward side will be warmer and drier than the air at the same elevation on the windward side, because of the moisture removed by condensation and the latent heat released to the air. The lower humidities and higher temperatures on the leeward side



of a mountain range produce a rain shadow effect, which accounts for some regions' arid and semi-arid climates.

Lapse Rates, Air Parcel Movement, and Atmospheric Hazards

Lapse rates are very important for understanding cloud formation, because the rate of temperature change in the moving air affects the level at which condensation begins. Four processes cause air to rise: (1) convergence occurs when winds meet, as at the intertropical convergence zone (ITCZ) and the polar front; (2) convection makes air rise because of density differences; (3) air rises at frontal boundaries as the warmer, lighter air overrides the cooler, heavier air; and (4) orographic lifting forces air over a topographic barrier, such as the mountain in the previous illustration. Regardless of the cause, the rising air will cool as the decreased atmospheric pressure results in expansion.

The lapse rates are averages, but in the absence of actual measurements, they are helpful in predicting atmospheric conditions and modeling air

parcel behavior. Atmospheric stability depends on the relationship between the environmental lapse rates and the adiabatic lapse rate. A parcel of air forced to rise for any reason will move through air layers, which changes the temperature at the environmental lapse rate. If this local temporal rate is less than the dry adiabatic lapse rate, the rising air will be warmer than the surrounding air. It will resist vertical movement and thereby will be stable. However, if the environmental lapse rate is greater than the dry adiabatic lapse rate, the rising air will end up warmer and lighter than the surrounding air. This situation yields instability and invokes continued lifting of the air. Extreme instability is associated with strong thunderstorms and tornado development. Intermediate situations may yield conditional instability (Figure 2).

In some situations, the environmental lapse rate may show a temperature increase with height. Such a layer is a temperature inversion, and due to the stability provided by these warmer layers, atmospheric mixing becomes limited. Pollutants may become concentrated below this warm layer

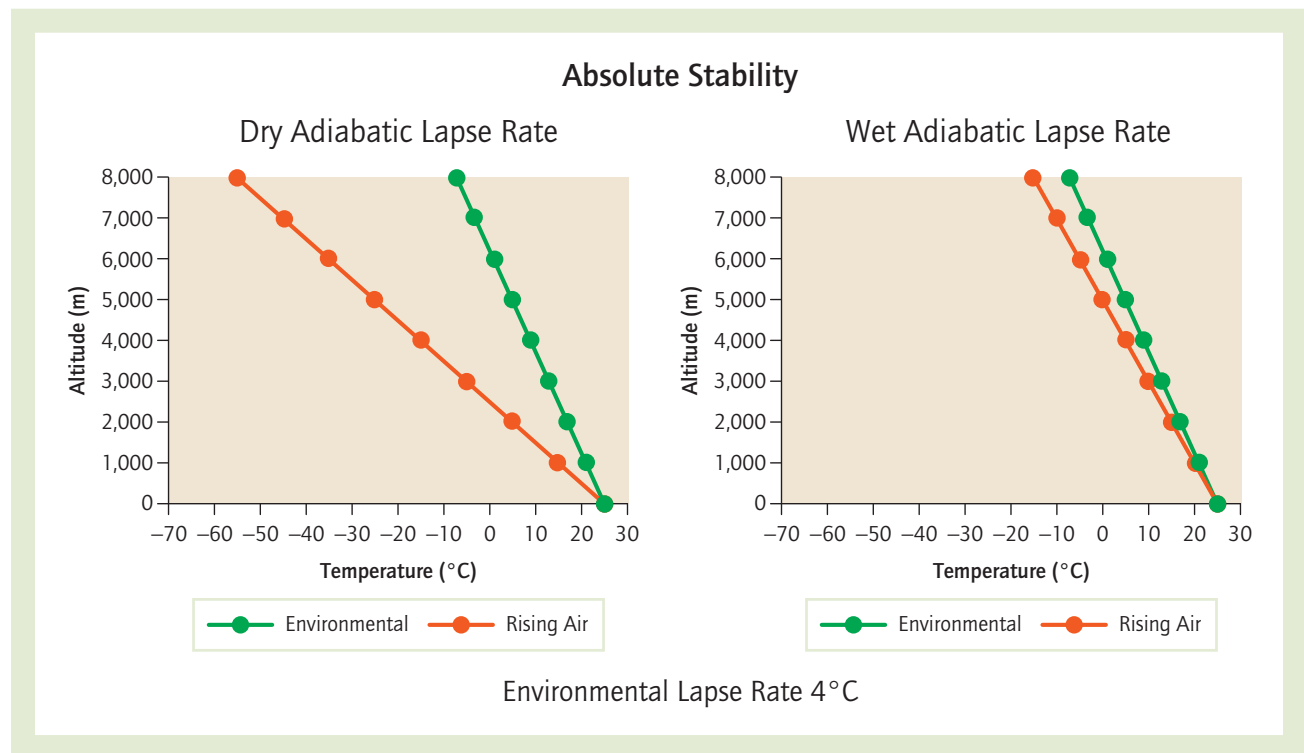


Figure 2 Atmospheric stability and instability

(Continued)

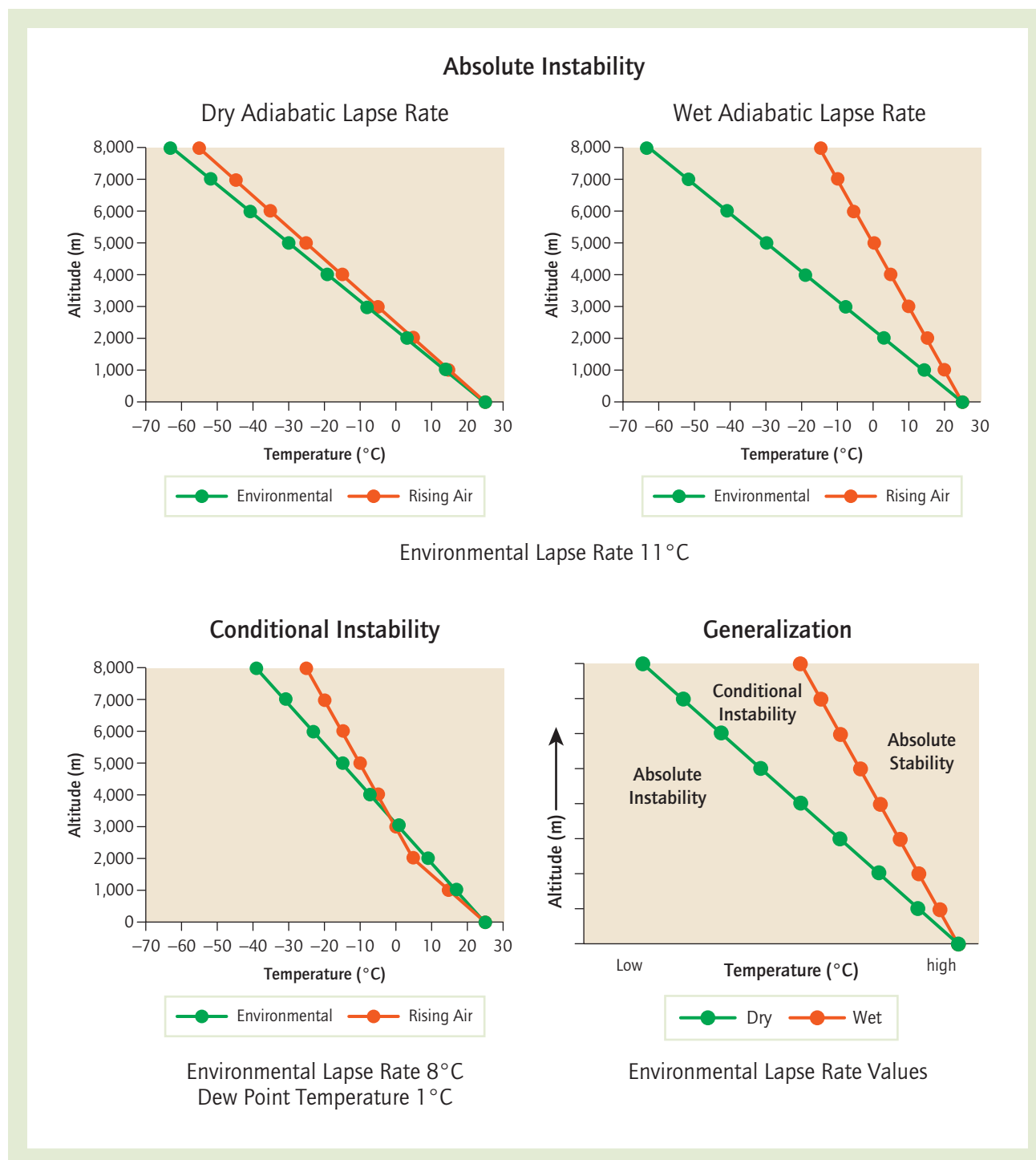


Figure 2 (Continued)

Source: Author.

rather than thoroughly dispersed. Air quality advisories, alerts, and warnings may be issued, directed especially at persons with respiratory problems and other health risks (Figure 3).

Lapse rates control the patterns of condensation, air movement, and air quality. Although lapse rates may be variable, their inclusion in atmospheric models aids prediction and forecasting.

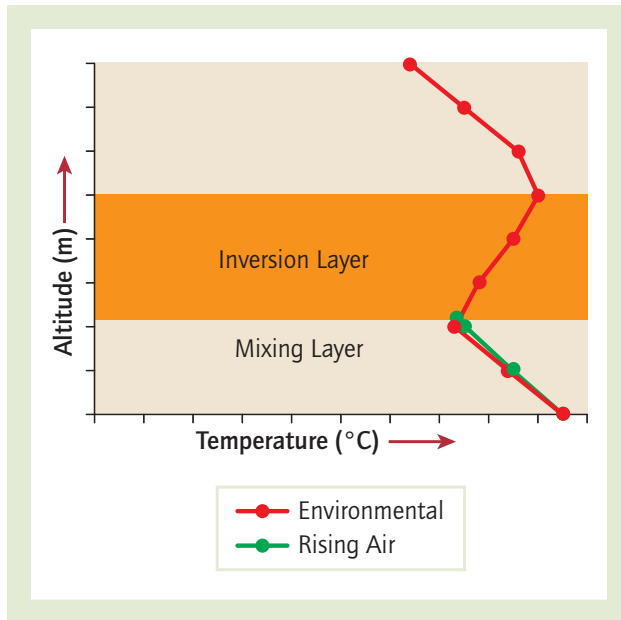


Figure 3 Temperature inversion

Source: Author.

The temperature differences that result between moving air and air at rest contribute to the complexity and variability of local weather conditions.

Miriam Helen Hill

See also **Adiabatic Temperature Changes; Atmospheric Moisture; Atmospheric Pressure; Climate: Mountain; Clouds; Precipitation Formation; Radiation: Solar and Terrestrial; Temperature Patterns**

Further Readings

- Ackerman, S., & Knox, J. A. (2006). *Meteorology: Understanding the atmosphere* (2nd ed.). Belmont, CA: Brooks/Cole.
- Aguado, E., & Burt, J. E. (2009). *Understanding weather and climate* (5th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Ahrens, C. D. (2008). *Meteorology today: An introduction to weather, climate, and the environment* (9th ed.). Belmont, CA: Brooks/Cole.
- Lutgens, F. K., Tarbuck, E. J., & Tasa, D. (2009). *The atmosphere: An introduction to meteorology* (11th ed.). Upper Saddle River, NJ: Prentice Hall.



LATENT HEAT

Latent heat is the energy absorbed or released in the form of heat by a substance when it changes its physical state (i.e., solid, liquid, or gas). The change associated with the solid-liquid transition is called the *latent heat of fusion* (melting), and the change associated with the liquid-gas transition is called the *latent heat of evaporation* (boiling). The International System of Units (SI) for latent heat is joules per kilogram or kilojoules per kilogram (kJ/kg). Because 1 cal/g (calorie per gram) = 4.185 kJ/kg, for pure water, the latent heat of melting of 65 cal/g = 272 kJ/kg and the latent heat of evaporation at 10 °C of 425 cal/g = 1.78×10^3 kJ/kg. It is important to note that the amount of latent heat involved in a process depends on the temperature at which the process is occurring.

Latent Heat in the Ocean Heat Budget

Latent heat in the ocean results from evaporation at the ocean surface. As water changes from liquid in the ocean to vapor in the atmosphere, the ocean loses energy in the form of the latent heat of vaporization, and the atmosphere gains heat when the vapor condenses. Since water vapor pressure depends on temperature, sea surface temperature is an important parameter in determining the latent heat flux. The oceans effectively capture a major portion (about 50%) of the sun's radiated energy and transfer much of it to the atmosphere as latent heat of vaporization and as radiation. The rate of heat flow is expressed in joules per second (J/s) per square meter, or watts per square meter (W/m^2) ($1 \text{ W} = 1 \text{ J/s}$).

The analysis of atmospheric modeled data for the 1958–2001 period in the Mediterranean Sea reveals that the time-mean latent heat is negative for the whole domain, with a mean value of -88 W/m^2 . Its temporal mean ranges from -20 W/m^2 in the Alborán Sea (Western Mediterranean) to -125 W/m^2 in the Levantine basin, Aegean Sea, and Gulf of Lions. Regarding its seasonal cycle, the minimum value (-125 W/m^2) is detected by mid November and the maximum (-51 W/m^2) by mid May. The amplitude of the seasonal cycle is 37 W/m^2 . In terms of total heat

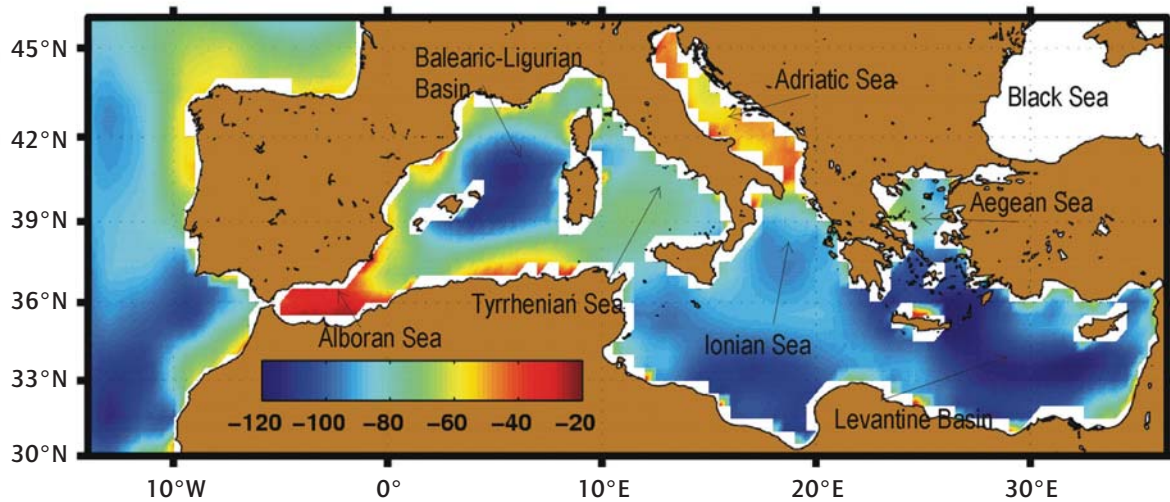


Figure 1 Spatial distribution of the temporal mean of latent heat (in watts per square meter) over the Mediterranean Sea using 44 years (1958–2001) of atmospheric model data. The main regional subbasins are indicated.

Source: Adapted from Ruiz, S., Gomis, D., Sotillo, M. G., & Josey, S. A. (2008). Characterization of surface heat fluxes in the Mediterranean Sea from a 44-year high-resolution atmospheric data set. *Global and Planetary Change*, 63, 258–274.

budget, which takes into account all the components (latent heat, sensible heat, long-wave radiation, and shortwave radiation), there is a practical cancellation (-1 W/m^2) of the heat flux components for the whole period mentioned above (see Figure 1).

In conclusion, *latent heat* is one of the most variable terms in the global heat budget, and it is crucial at short (e.g., heavy precipitation) and longer timescales (e.g., interannual variability). New international long-term experimental programs aim at better quantification and understanding of the hydrological cycle, and particularly of latent heat. Estimates of latent heat will improve with increasing high-resolution in situ and remote data (ship campaigns, buoy stations, and satellite measurements) and will be useful for both numerical weather prediction models and climate models.

Simón Ruiz

See also **Adiabatic Temperature Changes; Atmospheric Energy Transfer; Atmospheric Moisture; Differential Heating; Lapse Rate; Temperature Patterns**

Further Readings

- Gill, A. E. (1982). *Atmosphere-oceans dynamics* (International Geophysics Series, Vol. 30). New York: Academic Press.
- Ruiz, S., Gomis, D., Sotillo, M. G., & Josey, S. A. (2008). Characterization of surface heat fluxes in the Mediterranean Sea from a 44-year high-resolution atmospheric data set. *Global and Planetary Change*, 63, 258–274.
- Zemansky, M. W., & Dittman, R. H. (1981). *Heat and thermodynamics*. New York: McGraw-Hill.



LATITUDE

Latitude is the angular distance of a position from the equator to the nearest pole. However, latitude can acquire different meanings if inappropriately applied to other locations on Earth.

Often expressed in degrees from the equator (positive north and negative south), latitude can



be expressed in a variety of units (radians, grads, semicircles, arc seconds, or mils) and formats (+/– or N/S, to indicate the hemisphere; degrees: minutes and fractional minutes; or degrees: minutes: seconds and fractional seconds). Since one minute of latitude is equal to one nautical mile latitude, tick marks are used on charts as a local graphic scale. Without reference to a specific geodetic datum, latitude values will point to different places on Earth.

If Earth were perfectly spherical, then the general definition for *geographic latitude* might suffice—that is, the angle from the equatorial plane for a line from the center of mass of the spherical Earth to a position. Earth and its gravity field are slightly elliptical in shape. The distance from the center of Earth to the equator is about 21 km (kilometers) longer than the distance from the center to either pole. A consequence of this flattened spherical shape, an ellipsoid of rotation, is that the force of gravity is only exactly toward the center of mass of Earth along the equator or at either pole. Everywhere else, the plumb bob, the bubble level, or the horizon at sea, the references for local level, are affected by the ellipsoidal gravity surface that is perpendicular to a line from a position toward but slightly away from the center of the Earth. The angle between the equatorial plane and a line perpendicular to the ellipsoid surface that passes through a position is the *geodetic latitude*.

There are other latitudes. If one measures position with respect to a sphere that has the same surface area as a reference ellipsoid, the north-south angle is the *authalic latitude*. *Geocentric latitude* is the angle, similar to *geographic latitude* for a sphere, between the equatorial plane and the center of the ellipsoid. There is a *parametric* (or *reduced*) *latitude*, defined as the angle between the equatorial plane and a line from the center of the ellipsoid perpendicular to a surface defined by a sphere tangent to the ellipsoid along the equator or the latitude on a sphere for which the parallel has the same radius as the parallel of geodetic latitude on the ellipsoid through the same point. *Conformal latitude* is a transformation of *geodetic latitude* that allows a conformal mapping using spherical geometry. *Isometric latitude* is proportional to the parallels on an ellipsoidal Mercator projection. *Rectifying latitude* is

the angular distance along a line of longitude from the equator to a point on Earth.

Other latitudes have been defined on Earth, including *astronomic*, *auxiliary equidistant*, *geomagnetic*, *magnetic*, and *transverse*. Surveyors use the word for the y value in a traverse defined in a plane coordinate system.

The importance for geography is that these latitudes are represented by significantly different angles, making their appropriate selection and use critical for positioning and analysis.

Peter H. Dana

See also **Datums; Earth's Coordinate Grid; Equator; Geodesy; Longitude**

Further Readings

American Society of Civil Engineers. (1994). *The glossary of mapping sciences*. Bethesda, MD: Author.

National Geodetic Information Center. (1986). *Geodetic glossary*. Rockville, MD: Author.

Snyder, J. P. (1987). *Map projections: A working manual* (USGS Professional Paper No. 1395).

Washington, DC: Government Printing Office.

Torge, W. (1991). *Geodesy* (2nd ed.). New York: deGruyter.



LAW, GEOGRAPHY OF

Work on the geography of law focuses on the relationships of law and legal questions to the study of spatial phenomena. Initially developed by a community of scholars working across their respective disciplines, it took shape as a subdiscipline in its own right in the 1990s, usually referred to as *legal geography*, with a modest if growing presence in English language geography. In the broadest terms, work in this tradition posits that there exists a serious and substantial link between law (reflected in legislation, court decisions, administrative tribunals, etc.) and the geographical shape of the social, political, and cultural worlds. This is seen in many different ways, from



the legal organization of international relations down to municipal ordinances governing urban zoning and districting, the placement of public parks and monuments, and the organization of labor protests and panhandling. While the research themes taken up are not radically different from those in other areas of geography, it is the emphasis on the long-ignored connection between law and space that sets apart this field.

Origins

The interface of law and geography has been of interest since at least the 19th century, when geographers, legal thinkers, and ethnologists sought to determine the influence that climate, environment, and social organization might have on the laws governing different “primitive” and “advanced” peoples. For the most part, however, law has developed independently of the social sciences, geography included. Modern legal thought, driven by positivist and normative perspectives, has long understood law as an autonomous and internally coherent sphere of human knowledge. In this sense, it is often held at an intellectual distance from the material world in which it is applied, leaving it “uncontaminated” by political, social, or cultural concerns. This is not a view that encourages cross-disciplinary collaboration, and while geographers do often engage with other disciplines, law has not traditionally been one of them.

In the 1960s and 1970s, however, scholars of law began to rethink the discipline’s isolation from the social sphere. This body of work, typically dubbed “critical legal studies,” sought to challenge orthodox understandings of law, which invariably portrayed the latter as somehow “above” society and removed from politics and culture. Critical legal studies sought to show how, despite claims to the contrary, law naturalizes and normalizes particular kinds of social and political relationships and distributions of power. In the U.S. context, this notion is seen in terms of rights: The way in which the law and the courts address rights to abortion, sexual discrimination, privacy, or free speech are underscored by culturally and socially specific ideas about what makes for a “good” society. By analyzing legislative texts, jurisprudence, and legal

scholarship, critical legal studies has both unsettled existing claims about rights and proposed more radically open-ended approaches to understanding rights under the law.

The break with classical understandings of law initiated by this movement was in turn extremely important for the community of legal scholars and geographers, who, from the late 1980s, started to bring the two disciplines into an interdisciplinary dialogue. If legal scholarship was concerned with rights and the law in a fairly abstract sense, legal geographers were more concerned with examining what Nicholas Blomley dubbed the “law-space nexus,” the ways in which geographical space figures in the legal field and the ways in which law, in turn, shapes space. Property law, for example, posits a set of power-laden spatial relationships between owners, who claim a kind of exclusive jurisdiction over a parcel of land, and nonowners, who enjoy a far more limited set of rights to the properties they may lease, rent, or otherwise use. Governing a society in which private property is seen in these terms requires not just the requisite legal texts but also a range of geographical strategies, from land surveys to cadastral maps, zoning laws, antitrespassing ordinances, and so on.

On a broader scale, international legal texts such as the Geneva Convention on refugees establish and reinforce an organization of global space in which citizens are defined as people who belong to a particular nation-state. Those caught outside their state risk being left in a kind of geographical netherworld, as Viktor Navorski, played by Tom Hanks in the 2004 movie *The Terminal*, discovers. Indeed, the legal geographies of refugee flows can be seen in the proliferation of “stateless” and “lawless” spaces around the world, the most prominent being in Guantánamo Bay, Cuba, where several hundred “enemy combatants” were—from 2001 until the U.S. Supreme Court’s ruling (*Boumediene et al. v. Bush*, June 12, 2008)—held in a legally defined state of limbo, neither fully part of nor fully apart from U.S. legal jurisdiction. Seen as disruptive to the settled geographies of nation-states, refugees, enemy combatants, and other displaced persons present a legal-geographic paradox of sorts, exposing the geographical fault lines and limits of the international legal system.



Emphases

Law, then, is an important way in which the world is given spatial shape, from the global to the local, and scholarship on the geography of law is appropriately diverse in its concerns and approaches. Nonetheless, a few common trends are apparent. First, legal geography is deeply concerned with power and with the spatial organization of relations of power and rule. In particular, law is seen not simply as oppression but as a way of producing commonsense arguments about the world that naturalize the operations of power in and across geographical space. In this regard, it connects to a wide range of work in the social sciences where power is a focal point of analysis. As in critical legal studies, a good deal of work here is explicitly critical in nature, often adopting Marxist or poststructuralist interpretative tools. Second, work in legal geography has focused largely on urban and “local” spatial scales of analysis, such as the community, the region, and the city. Other spatial scales, though, often emerge in analyses of the nested and overlapping jurisdictions that typically govern the law’s application, such as in decisions over whether federal, state, or provincial legal authorities have jurisdiction over workplace safety. Third, while the past two decades or so have seen a proliferation of case studies that deal with the geography of law, relatively little work has been done on the subfield’s methodological frameworks. This void contrasts sharply with other areas of human geography, economic and social geography in particular, where the same period has witnessed a relative explosion in debates over these questions. The subfield, in short, is fluid and dynamic, providing little in the way of orthodoxy or canonical texts through which to anchor the reader.

The remainder of this entry proceeds by identifying three broad approaches that have found their place within the geography of law. These are neither exhaustive nor mutually exclusive categorizations, and scholars who do the work described below might not all describe themselves as legal geographers (although some certainly would). Rather, the discussion is meant to offer a preliminary sense of the field and its approaches to the intersections of law, politics, society, and space.

Research Directions

A sizable body of scholarship has been devoted to examining how law frames space, that is, how geography is embedded within legal reasoning and how legislatures and courts make (sometimes unconscious) claims about the relationship between people and place when they draft, examine, and overturn laws. At the international scale, this idea is seen in legal struggles to govern trade and human migration into the European Union or at the United States/Mexico border. In such cases, the law is a key forum through which spatial borders, barriers, and limits are both pulled down and reestablished. At finer scales, too, court rulings and legislative texts provide valuable insights into how ideas about community and identity are inscribed in legalized common sense. In the United States, for instance, courts have been called to evaluate the legality of the electoral districts created after each census, leading to often aesthetic judgments about the “natural” shape of communities and the relationship between geography and identity. Like citizenship, community is a profoundly geographical category, one that is often hard to separate from a territorial unit of space. Here, the law is a powerful medium where some claims about what constitutes a community are deemed legitimate while others are not—the sort of judgment that people might well make on a day-to-day basis but that, when legally enshrined, carries numerous implications for political and social life. Other work has sought to analyze laws and legal reasoning relating to the development and restoration of parks, monuments, and other elements of the built environment, tracing the legal landscape often at work within the geographical landscape of the built environment.

Geographers and anthropologists have also scrutinized the lived geographies of law, the ways in which law, geography, and power are experienced in everyday life. Struggles over community-policing tactics and the spatial spread of legal aid clinics and health care services point to how law, space, and power operate within a sociospatial context. Ethnographic accounts of police work chronicle how law enforcement authorities use a series of geographical strategies to police and control the populations under their purview, while



work on gypsies and refugees has sought to map how these populations negotiate their passage from place to place and contend with law enforcement authorities. Also, scholarship addresses the geographies of privacy, wiretapping, and the legal governance of sidewalk spaces, labor strikes, and the like. Here, courts, legislators, and city councils have sought to govern the kinds of privacy and autonomy that should be accorded to people in public spaces, creating a set of geographical claims about where, exactly, the public and the private are found that affect public life and autonomy in important ways.

Finally, research has focused on *geographies of resistance*. In many instances, the spatial consequences of the law have provoked popular movements (strikes, protests, occupation) designed to disrupt its intended application and to highlight the disruptions and violence that take place when the law is used to disrupt or destroy complex patterns of social relations. Resistance to the gentrification of lower-income neighborhoods, for instance, highlights how law in the form of urban planning policy and policing techniques has prompted the creation of social and political movements designed to challenge the spatial strategies of state control to which these communities are often subjected. In this way, the law has emerged as a repressive and controlling force and, in turn, as a site of resistance.

Conclusion

The geography of law offers a rich and complex way of thinking about the relationship between law and space, providing valuable insights into the shifting juridical-spatial parameters of the social, political, and cultural worlds. Ongoing research, in turn, has sought to draw the field of legal geography out of the Anglo-American context and into other national and institutional contexts. Also, increasing attention is being paid to the connections between law, space, and environment, a departure from the traditional focus on law, space, and society.

Henry Sivak

See also **Citizenship; Crime, Geography of; Geoslavery; Immigration; Justice, Geography of; Legal Aspects of**

Geospatial Information; Political Geography; Privacy and Security of Geospatial Information; Public Space; Refugees; Resistance, Geographies of; Social Geography; Social Justice; Urban Geography; Urban Policy

Further Readings

- Blomley, N. K. (1989). Text and context: Rethinking the law-space nexus. *Progress in Human Geography*, 13, 512–534.
- Blomley, N., Delaney, D., & Ford, R. (Eds.). (2001). *The legal geographies reader: Law, power, and space*. London: Blackwell.
- Boumediene et al. v. Bush, 128 S. Ct. 2229 (2008).
- Curry, M. R. (2000). The power to be silent: Testimony, identity, and the power of place. *Historical Geography*, 28, 5–16.
- Holder, J., & Harrison, C. (2003). *Law and geography*. Oxford, UK: Oxford University Press.
- Mitchell, D. (2003). *The right to the city: Social justice and the fight for public space*. New York: Guilford Press.



LEARNING REGIONS

The concept of *learning regions* reflects the rapid economic development in places such as the “Third Italy” (that country’s high-technology zone centered on Emilia-Romagna), which drew attention to the importance of cooperation between small- and medium-sized establishments (SMEs) in industrial districts and between firms and local authorities at the regional level in achieving international competitiveness. Theoretically, the idea reflects the view of post-Fordist societies as learning economies, where innovation is seen as a socially and territorially embedded, interactive learning process that cannot be understood independently of its institutional and cultural contexts.

Although these contributions share a common emphasis on the important role of innovation as contextualized social processes of interactive learning, they also disclose interesting differences. One such difference can be identified between the American and European approaches. Learning



regions in a North American context are closely associated with the knowledge infrastructure of leading universities and research institutions, which play an essential role in a knowledge-based economy, producing, attracting, and retaining highly skilled workers (e.g., Silicon Valley). In contrast, the focus of learning regions in a European context is more on the role that social capital and trust play in promoting formal and informal interfirm networks and the process of interactive learning (e.g., the industrial districts in the Third Italy). As the differences in these interpretations of learning regions demonstrate, the concept can be fuzzy, and its use both theoretically and practically is rather flexible. To provide an analytically more precise understanding, the next section of this entry identifies three important building blocks of the concept.

Building Blocks of the Concept of Learning Regions

The concept of *learning regions* has been used in at least three different ways. The notion was originally introduced by economic geographers in the mid 1990s, when they used it to emphasize the role played by cooperation and collective learning in regional clusters and networks to promote the innovativeness and competitiveness of firms and regions. The second approach originates from the writings of evolutionary and institutional economics, where innovation is seen as a socially and territorially embedded, interactive learning process, making knowledge the most fundamental resource and learning the most important process. The third approach, which conceptualizes learning regions as regionally based development coalitions, was developed by organizational researchers taking their knowledge of how to form intrafirm and interfirm learning organizations and applying it at the regional level as a bottom-up, horizontally based cooperation among different actors in a local or regional setting.

When learning regions are defined in this way, they resemble a regional innovation system, incorporating the elements of a bottom-up, interactive innovation model. The innovation system concept can be understood in both narrow and broad ways. A narrow definition of the innovation

system primarily incorporates the research and development (R&D) functions of universities, public and private research institutes, and corporations, reflecting a top-down model of innovation. A broader conception of innovation systems includes all aspects of the economic structure and the organizational and institutional context affecting learning and innovation in a region. This type of regional innovation system may be denoted as a “territorially embedded regional innovation system,” in which firms base their innovation activity mainly on localized learning processes stimulated by geographical, social, and cultural proximity, without much direct interaction with knowledge-creating organizations (i.e., R&D institutes and universities).

Learning and Innovation in Regional Economies

According to the perspective on learning regions as regionally based development coalitions, they should be looked on as a way to formulate long-term, partnership-based development strategies initiating learning-based processes of innovation and change. In the promotion of learning regions, the interlinkages of learning organizations ranging from work organizations inside firms to different actors of the community, or “regional development coalitions,” are highlighted. Of strategic importance in this context is the capacity of people, organizations, networks, and regions to learn. The concept of a learning region can thus be used to describe a region characterized by innovative activity based on localized, interactive learning and cooperation promoted by organizational innovations to exploit learning-based competitiveness. This view implies a broad understanding of a regional innovation system with a strong focus on competence building in addition to learning and innovation. Thus, knowledge and innovation should not simply be equated with R&D. Innovative activities have much broader knowledge bases than just science-based R&D, and there are many examples of nations and regions demonstrating rapid economic growth and a high living standard with an industry competing on the bases of non-R&D-based incremental innovations (e.g., Denmark and the Third Italy).



The attractiveness of the concept of learning regions to planners and politicians lies in its promise of economic growth and job generation as well as social cohesion. As such, learning regions may be analyzed as a response and a challenge at the regional level, especially for regions with weak territorial competence bases, to contemporary changes in the global economy, underlining the strategic role played by social capital's emphasis on the social and cultural aspects of regions facilitating collective action for mutual benefit. Thus, it is not accidental that this approach to learning regions was used by the European Union as part of new policies to promote the less developed regional economies within it.

Bjørn Asheim

See also **Agglomeration Economies; Clusters; Competitive Advantage; Flexible Production; High Technology; Industrial Districts; Innovation, Geography of; Knowledge, Geography of; Knowledge Spillovers; Los Angeles School; Regional Economic Development; Research and Development, Geographies of; Technological Change, Geography of; Urban and Regional Development**

Further Readings

- Asheim, B. (1996). Industrial districts as "learning regions": A condition for prosperity? *European Planning Studies*, 4(4), 379–400.
- Asheim, B. (2000). Industrial districts: The contributions of Marshall and beyond. In G. Clark, M. Feldman, & M. Gertler (Eds.), *The Oxford handbook of economic geography* (pp. 413–431). Oxford, UK: Oxford University Press.
- Asheim, B., & Gertler, M. (2005). The geography of innovation: Regional innovation systems. In J. Fagerberg, D. Mowery, & R. Nelson (Eds.), *The Oxford handbook of innovation* (pp. 291–317). Oxford, UK: Oxford University Press.
- Florida, R. (1995). Towards the learning region. *Futures*, 27(5), 527–536.
- Lundvall, B.-Å. (2008). National innovation systems: Analytical concept and development tool. *Industry & Innovation*, 14(1), 95–119.

Morgan, K. (1997). The learning region: Institutions, innovation and regional renewal. *Regional Studies*, 31, 491–504.

Piore, M., & Sabel, C. (1984). *The second industrial divide: Possibilities for prosperity*. New York: Basic Books.

Rutten, R., & Boekema, F. (Eds.). (2007). *The learning region. Foundations, state of the art, future*. Cheltenham, UK: Edward Elgar.

Storper, M. (1993). Regional "worlds" of production. *Regional Studies*, 27, 433–455.

Woolcock, M. (1998). Social capital and economic development: Toward a theoretical synthesis and policy framework. *Theory and Society*, 27, 151–208.



LEFEBVRE, HENRI (1901–1991)

Most well known to geographers today on account of his elaboration of the spatial character of contemporary capitalism, Henri Lefebvre also has an honored place in what is called *cultural studies* due to the interdisciplinary nature of his writings. Born in Hagetmau in the Pyrenees, Lefebvre became a professor of both philosophy and sociology and ultimately a prominent French intellectual whose life spanned almost the entirety of the 20th century (1901–1991). The expansive character of his life parallels his prolific output as the author of more than 60 books, many of which still await translation from French into English. Although the breadth of topics covered in his works is staggering, two of this self-proclaimed Marxist philosopher's most enduring themes center on everyday life and the production of space.

To understand Lefebvre's life—and his life's work—is to understand the key problems of the 20th century as a whole. Moved by the large and violent struggles that coincided with his early life, namely, World War I and the Russian Revolution, Lefebvre came to be regarded as a lifelong committed activist. He shared ideas with proponents of surrealism and existentialism such as André Breton and Jean-Paul Sartre, and during World War II, he became a resistance fighter in



the south of France. After the war, he worked as a taxi driver in Paris, gaining the significant knowledge of city life that is expressed in his theoretical writings. He cultivated an often turbulent relationship with the French Communist Party from 1928 until his expulsion in 1957, soon afterward publishing an autobiography titled *La somme et le reste* [The sum and the rest] in 1959. His friendship with the Situationists, including Guy Debord, ended in a dispute over the ownership of ideas. Still, Lefebvre was regarded as one of the intellectual godfathers of the upheavals of May 1968, and he published *The Explosion* (1968), a depiction of the events of that year. He also came to heavily denounce the structuralism of Louis Althusser, who reciprocated Lefebvre's feelings of contempt.

Although his life's work is located at the intersections of geography, sociology, literary criticism, and urban studies, Lefebvre initially moved to the Sorbonne in Paris during the 1920s as a student of philosophy. There, he soon formed part of a group of rebellious young philosophers whose chief target of attack was Henri Bergson, a noted philosopher of temporality. Whereas both thinkers were intent on reconciling philosophy with lived experience, in contrast to Bergson, Lefebvre underscored the encounter between philosophy and the ideas of Karl Marx. In *The Survival of Capitalism* (1973), Lefebvre remarks that although Marxian thought is not comprehensive enough on its own, it is "indispensable," as is evidenced by the titles of two of his works that have seen English translation: *Dialectical Materialism* (1939) and *The Sociology of Marx* (1966). It was Marx's notion of alienation that first captured Lefebvre's attention, as demonstrated by his early work titled *La conscience mystifiée* (Mystified Consciousness, 1936, cowritten with Norbert Guterman and still untranslated). This early work on a topic that he believed Marx had not sufficiently explored brought Lefebvre to outline his most extensive and most ambitious project: a critique of "everyday life."

No fewer than three volumes of Lefebvre's *Critique of Everyday Life* were published during his lifetime (1947, 1961, and 1981). In all of them, he considers the topic from a characteristically interdisciplinary approach, continuing to flesh out the Marxist concept of alienation as not only

economic but also social, political, ideological, and philosophical. The subject matter of the three volumes of the *Critique* blends literary and cultural analysis with philosophy and the social, economic, and historical changes of the postwar period. This eclectic approach is continued and even taken to its limits in the posthumously published volume titled *Rhythmanalysis* (1992), a term that Lefebvre attributes to the work of Gaston Bachelard in the second volume of the *Critique*. Partly written in collaboration with his wife, Catherine Régulier, this group of essays has been considered a fourth volume of the *Critique*. In the claim made throughout the essays for a less analytical approach to the rhythms of everyday life, Lefebvre anticipates the attention given to mobility by recent scholarship in geography. His *Critique* directly influenced Michel de Certeau's book *The Practice of Everyday Life* and remains a seminal text in the field of cultural studies as a whole.

Concurrently with the *Critique*, Lefebvre also elaborated on the spatial character of capitalism, giving particular attention to cities and the urban. Critics have often taken the heart of his spatial endeavor to be *The Production of Space* (1974), where he outlines a dialectical understanding of space as shaped and reshaped through representational spaces, spaces of representation, and spatial practices. Ultimately, for Lefebvre, space is crucial not only to capitalism but also to the contestation of capital. In taking on the concept of space, he once again returns to a topic that he states was insufficiently explored by Marx. Nevertheless, his ideas on space and the urban were not always well received, as is evidenced by his conflict with Manuel Castells, his former assistant in Nanterre, France, and author of *The Urban Question*. History, however, has looked favorably on this direction of Lefebvre's work, as can be seen in its revival, particularly in Anglophonic criticism, by geographers such as David Harvey and Edward Soja. Among English language readers, one of his most widely read pieces on urban space is "The Right to the City" (1968), which continues to be an important work for geographers, among them Don Mitchell, who published a work with the same title in 2003.

In totality, Lefebvre's work is an explicitly political project that reconciles Marx's critique of capital with the textures of everyday life and the



spatial concerns of the geographer. Although studying his life and work may not be enough to understand 20th-century events and thought, it is indispensable.

Benjamin Fraser

See also **Castells, Manuel; Critical Human Geography; Everyday Life, Geography and; Harvey, David; Marxism, Geography and; Production of Space; Representations of Space; Soja, Edward; Spaces of Representation/Representational Spaces**

Further Readings

- Aronowitz, S. (2007). The ignored philosopher and social theorist. *Situations*, 2(1), 133–156.
- Elden, S. (2004). *Understanding Henri Lefebvre: Theory and the possible*. London: Continuum.
- Fraser, B. (2008). Toward a philosophy of the urban: Henri Lefebvre's uncomfortable application of Bergsonism. *Environment and Planning D: Society and Space*, 26(2), 338–358.
- Lefebvre, H. (1991). *The production of space* (D. Nicholson-Smith, Trans.). New York: Wiley-Blackwell. (Original work published 1974)
- Merrifield, A. (2006). *Henri Lefebvre: A critical introduction*. New York; London: Routledge.
- Shields, R. (1999). *Lefebvre: Love and struggle: Spatial dialectics*. London: Routledge.



LEGAL ASPECTS OF GEOSPATIAL INFORMATION

Legal aspects of geospatial information refers to the legal requirements and restrictions governing the use of geographic information, including information generated through geographic information systems (GIS). There are six key legal issues associated with geospatial information:

1. Liability (contract and tort)
2. Public access to, use, and ownership of geoinformation and geographic data

3. Intellectual property rights
4. Copyright
5. Spatial data privacy
6. Evidentiary admissibility of GIS products

Liability

Liability laws apply to organizations that use, sell, or give geographic information as well as to purveyors of GIS software. U.S. courts have held GIS providers liable and determined that they should bear some financial responsibility for damages if their actions result in mistakes that damage or harm others. Evolving case law deals with GIS such as aeronautical and navigational maps, subjecting them to product liability laws. State and local agencies that sell geographic information at a profit most likely face greater liability than agencies that disseminate the information at cost, release information according to Freedom of Information Act (FOIA) rules, or provide data for free.

Public Access and Data Ownership

Property rights are at the heart of issues related to law as these rights are related to the ownership of geographic information. In the case of geographic information, the owner of the data set also owns the copyright to the information; thus, ownership confers exclusivity of use and control of the information. The U.S. federal government cannot legally copyright the data it collects; furthermore, the FOIA requires that data sell for no more than the cost required to reproduce them. In contrast, U.S. state and local governments can legally own data, and some have used the sale of geographic information as a means to generate revenues. Records whose dissemination may pose a threat to national security may be withheld from use outside their originally intended purposes; however, the legal process permits individuals or organizations to petition for the release of withheld information.

Intellectual Property Rights

Intellectual property rights apply to several different fruits of intellectual labor: (a) original works of authorship, (b) functional inventions,



(c) trademarks, and (d) trade secrets. Among these, it is the first, original works of authorship, that is most applicable to GIS. Traditional criminal law related to intellectual property rights is designed to handle rights associated with tangible objects, such as the physical written word; thus, it is ill prepared to address GIS data and information. Today, the World Intellectual Property Organization (WIPO), under the auspices of the United Nations since 1974, is addressing the unique issue of digital intellectual property under its “Digital Agenda.”

Copyright

Copyright is the legal means to protect intellectual property rights of original works of authorship, including GIS data and products. Copyright protection automatically resides in original works of authorship, with no mark or notice required. While publication is not a prerequisite for copyright protection, copyrighted work must be in a tangible and identifiable physical form. Paper maps were first covered by copyright protection as pieces of literature or art, under the Berne Convention of 1886. Today, digital mapping media and GIS data sets and software also meet this standard. In the United States, a copyright is valid as long as its last author survives and remains valid for an additional 70 years. The copyright on a work “made for hire” lasts for 75 years from its date of publication or for 100 years from the date it was created, whichever comes first.

Privacy and Confidentiality

Data privacy and confidentiality are growing in importance in the GIS communities. The ability of GIS to combine previously unrelated databases with specific locational information provides improved means for tracking the whereabouts of individuals. Concerns about privacy and confidentiality stress the dangers of government-held data, citing Orwellian “big brother” scenarios. The ability to match and integrate separate and disparate digital databases collected by government poses a threat to our privacy, especially when they can be integrated with and augmented by private data sets, such as those owned by insurance companies or credit-reporting bureaus, in a for-profit setting.

Law regarding data privacy appears to be trending toward diminution of privacy rights. Generally, legal decisions regarding Fourth Amendment protections against unreasonable search and seizure have held that there is a difference between what occurs inside our homes (where we may expect protection of our privacy) and what occurs in public space. Codes of ethics represent an extra-legal safeguard for data privacy; however, they do not have the weight of law.

Evidentiary Admissibility of GIS Products

One last issue is how GIS products fare as evidence in courts of law. Evidence is material offered in a court of law to persuade a jury about the truth or falsity of a disputed fact. All federal courts in the United States abide by the rules of evidentiary admissibility published in the *Federal Rules of Evidence*, and states follow similar sets of published rules.

There is a key contradiction in the admissibility of GIS products: On the one hand, if GIS information is considered as purely a representation of facts, then its admissibility is assured; on the other hand, the classification of GIS products as literary or artistic works under copyright laws raises problems. The ease with which digital data may be altered, leaving no evidence of any changes, is another problem.

GIS information easily clears the first evidentiary hurdle—that evidence must be relevant to be deemed admissible; however, because GIS products may be copyrighted as literature or art and thus may be easily altered, GIS evidence is generally treated as “hearsay” and thus is generally not admissible. There are exceptions; for example, when the GIS evidence qualifies as a business record, developed in the course of regular business practice, it may be admissible. GIS evidence may also be treated as an exception to hearsay rules if it is determined to be authentic. To authenticate GIS products, the developer must do the following:

Show the input procedures used to get the data into the computer

Show which tests were used to ensure the accuracy and reliability of both the computer operations and the information that produced the data



Demonstrate that the computer record was generated in the regular course of business and that the business did indeed rely on it

Legal issues in GIS have changed dramatically over the past decade, encompassing a growing number of concerns that are increasing in complexity and interrelatedness. GIS professionals are wise to consult applicable statutes and case law to ensure that their operations comply with all applicable laws.

Nancy J. Obermeyer

See also **Business Models for Geographic Information Systems; Geoslavery; Privacy and Security of Geospatial Information; Law, Geography of; Usability of Geospatial Information**

Further Readings

- Cho, G. (1998). *Geographic information systems and the law: Mapping the legal frontiers*. New York: Wiley.
- Obermeyer, N. J., & Pinto, J. K. (1994). *Managing geographic information systems*. New York: Guilford Press. (See especially Chapter 13, "Legal Issues in GIS")
- Onsrud, H. J. (1992). Evidence generated from GIS. *GIS Law*, 1(3), 1–9.
- Onsrud, H. J. (1999). Liability in the use of geographic information systems and geographic datasets. In P. Longley, D. Maguire, & D. Rhind (Eds.), *Geographical information systems: Vol. 2. Management issues and applications* (pp. 643–652). New York: Wiley.
- Onsrud, H. J., & Lopez, X. (1998). Intellectual property rights in disseminating digital geographic data, products, and services: Conflicts and commonalities among European Union and United States approaches. In I. Masser & F. Salge (Eds.), *European geographic information infrastructures: Opportunities and pitfalls* (pp. 153–167). London: Taylor & Francis.
- World Intellectual Property Organization. (n.d.). *What is WIPO?* Retrieved February 1, 2010, from www.wipo.int/about-wipo/en/gib.htm



LEWIS, PEIRCE (1927–)

Peirce Lewis is a noted cultural geographer who has played a key role in developing ways of understanding landscape. Lewis completed his BA (summa cum laude, 1950) in philosophy and history at Albion College. He subsequently earned both his MA (1953) and PhD (1958) in geography from the University of Michigan. After completing a National Science Foundation fellowship at the University of Washington, he joined the faculty in the geography department at Pennsylvania State University (Penn State) in 1958. Over the next 40 years, not only did his name become synonymous with one of the country's leading geography programs, but the quality of his work also cultivated widespread appeal and international recognition. Lewis's 1985 presidential address to the Association of American Geographers ("Beyond Description") articulates his discontent with mere geographic description. His work has consistently probed great depths, always seeking to better understand space, place, and landscape. As a testament to the high quality of his scholarship, he was honored with numerous awards and fellowships, including a Guggenheim (1986) and a Woodrow Wilson (1987) fellowship. Furthermore, as befits a consummate professor, Lewis's career has shown remarkable balance. He has repeatedly been recognized for teaching excellence, including being the recipient of the highly coveted Lindback Award (1981), Penn State's most distinguished teaching award. In 1995, he retired from academia, yet he has continued to build on his impressive career. Following on the heels of the 2003 J. B. Jackson Award for *New Orleans: The Making of an Urban Landscape*, in 2007, the Association of American Geographers bestowed on the former association president (1983) the Lifetime Achievement Award.

For over five decades, Peirce Lewis published a series of seminal works on topics such as the American landscape, the cultural geography of North America, human-environmental interaction, cartographic analysis, geography and children's literature, and regional geomorphology. Yet the one component that stands out is his relentless pursuit of understanding the forces that



shape the landscape. During the earlier stages of his career, Lewis's attention was focused primarily on the natural environment and the principles of geomorphology. One of his most influential mentors, Pierre Dansereau, helped cultivate Lewis's appreciation of changes in the physical landscape. Later, the writings of Carl Sauer, J. B. Jackson, and Henrie Glassey (an American folklorist) became more central to his career, as his professional gaze shifted toward cultural phenomena. Lewis's work has repeatedly stressed the importance of looking for patterns that signal the meanings the landscape holds. No work exemplifies his uncanny ability to interpret the landscape more than his 1979 signature piece, *Axioms for Reading the Landscape*. This publication not only helps readers understand how to appreciate the built environment, but it gives clues to reveal the messages it is sending us.

Lewis's drive for understanding landscape change (both natural and cultural) has remained steadfast throughout his career. Contrary to his unassuming personality, Peirce Lewis's work has inspired and empowered geographers at all stages in their careers. Fledgling graduate students share an equal admiration with seasoned professors for the quality and insightfulness of his publications. Many of today's leading scholars can trace the evolution of their geographic thought back to Peirce Lewis.

Jeffrey S. Smith

See also **Cultural Geography; Cultural Landscape; Jackson, John Brinckerhoff; Meinig, Donald**

Further Readings

- Lewis, P. (1972). Small town in Pennsylvania. *Annals of the Association of American Geographers*, 62(2), 323–351.
- Lewis, P. (1985). Presidential address: Beyond description. *Annals of the Association of American Geographers*, 75(4), 465–478.
- Lewis, P. (2003). *New Orleans: The making of an urban landscape* (2nd ed.). Richmond: University of Virginia Press.

LEWIS AND CLARK EXPEDITION

Historical convention of long standing has it that the expedition of Meriwether Lewis and William Clark was dispatched by President Thomas Jefferson in 1804 to explore the newly acquired territory of Louisiana. In fact, the exploration of Louisiana was a secondary part of the mission of Lewis and Clark. Their primary objective, made clear by Jefferson in a number of letters and other documents, was to locate a commercially practical water route across the North American continent. In other words, Lewis and Clark were sent to find the fabled Northwest Passage. That their expedition (1804–1806) coincided with America's acquisition of the vast territory of Louisiana—the entire western portion of the Mississippi's drainage basin—was simply fortuitous (see Figure 1).

By the time Jefferson was elected president in 1800, he had already made three aborted attempts to have some kind of water route between the Mississippi and the Pacific explored. His thinking was simple and consistent with geographical theory of the later Enlightenment: All major rivers had a common source area where their headwaters interlocked. Since a short portage linked the headwaters of the primary eastern branch of the Mississippi (the Ohio) and the headwaters of a major river flowing to the Atlantic (e.g., the Potomac), the Jeffersonian concept of symmetrical geography held that a short portage ought also to link the headwaters of the Mississippi's major western tributary (the Missouri) and a stream, such as the Columbia, flowing to the Pacific. Jefferson impressed on Lewis that his mission had a single overriding objective: to locate this hypothetical short portage between the upper Missouri and upper Columbia, thereby ending a centuries-long search for a water route through or around North America. Jefferson well knew that the country that discovered such a water route would possess enormous commercial advantages, including control over the Indian trade of the interior. To Jefferson, controlling commerce was the most important step to controlling territory, so the mission he set for Lewis and Clark was, first, commercial but with an unwritten imperial objective as well.



Figure 1 A map of Lewis and Clark's track across the western portion of North America, from the Mississippi to the Pacific Ocean

Although Lewis, a long-time family friend of Jefferson's, was selected to lead the expedition, he prevailed on the President to add a co-commander, William Clark, Lewis's former commanding officer in the U.S. Army in Ohio and a close friend. Clark agreed, and after acquiring geographical information from Jefferson's library, learning the rudiments

of scientific observation, and acquiring supplies in Pittsburgh, Lewis traveled down the Ohio River in the summer of 1803, picking up Clark near the falls of the Ohio; the two recruited army and other personnel and went into winter encampment across the Mississippi from St. Louis, at that time the jumping-off point for western travel.



Source: Lewis, S. (Copyist), & Harrison, S. (Engraver). (1814). A map of Lewis and Clarks track. In P. Allen, N. Biddle, W. Clark, & L. Meriwether (Eds.), *History of the expedition under the command of Captains Lewis and Clark*. Washington, DC: Library of Congress, Geography and Maps Division.

After a winter spent preparing their command for an arduous journey, the Lewis and Clark expedition started up the Missouri River on May 14, 1804. Clark's estimates indicate that they planned to reach the Pacific and travel back to St. Louis within one traveling season. This highly inaccurate calculation was, of course, predicated

on the Jeffersonian notion of a short connection between the upper Missouri and the upper Columbia Rivers. By late fall of 1804, the expedition had reached only as far as Central North Dakota. They built Fort Mandan near the Knife River villages of the Mandan and Hidatsa Indians. This area had been, for 1,000 years, the central point



of Indian trade on the upper Missouri and was a well-known location for white traders as well, who had been contacted by French traders out of Canada in the 1730s, and a favored destination for St. Louis traders since the 1770s. Through the first leg of their journey, then, Lewis and Clark were traveling through well-known territory. Beyond the Mandans, all was conjecture. During their winter sojourn with the Mandans and Hidatsas, they learned much of the country to the west, and Clark prepared a map based on information from the Indians. This map—accurate in its basic form but wildly out of scale—showed the source of the Missouri River only about 200 mi. (miles) from the Pacific and just across a final dividing ridge from the Great River of the West, the Columbia. During the summer and fall of 1805, the explorers would learn how inadequately they had been able to convert Indian information on distances and direction into a Euro-American frame of reference.

Leaving the Knife River villages, the expedition traveled up the Missouri River, past the mouth of the Yellowstone, past the Missouri's Great Falls, and thence to the Three Forks of the Missouri, where they took the westernmost branch—the Jefferson River—which was believed to lead to the fabled short portage between Atlantic and Pacific waters. Certainly, the greatest disappointment of the entire expedition came in August 2005, when Lewis crested the Continental Divide at Lemhi Pass in southwestern Montana and, instead of seeing open plains with a huge river flowing toward the Pacific, saw only the immense Bitterroot Mountains, their tops covered with snow. A long and tortuous trek—down to the Salmon River, which was deemed impassable, over Lost Trail Pass to the Bitterroot River and then over the Bitterroot Mountains—brought the expedition again to navigable waters. In September 1805, they reached the Clearwater River, a tributary of the Snake that flows to the Columbia and, thence, to the ocean. Jefferson's short portage had turned into an overland trip of 640 mi. through some of the most difficult terrain in North America. The expedition finally reached the Columbia's estuary in November 1805 and, in December, built their winter encampment—Fort Clatsop—near Pacific shores just south of present-day Astoria, Oregon. Here, they spent a

miserable winter in the cold and damp of the Pacific Northwest.

The return trip, beginning in the spring of 1806, was spent in sorting out some of the puzzles in western geography that still remained: Where was the connecting link between the Missouri and Columbia rivers? Where was the common source area of the western streams? The captains split their command in an attempt to solve these riddles and, in early August 1806, rejoined near the confluence of the Yellowstone and Missouri, reaching St. Louis on September 23, 1806. There, they began the work of compiling the journal notes and maps of their 28-month journey. Clark's final map showed their answers to the remaining puzzles of western geography. But the connecting link still involved a long overland journey of more than 140 mi. and included a difficult mountain crossing between Clark's Fork of the Columbia and the Missouri. And the common-source area that Clark postulated was a pure geographical myth that bedeviled Western cartographers for another four decades. On his final map, Clark showed the sources of the Missouri, Yellowstone, Big Horn, Platte, Arkansas, Rio Grande, Multnomah (a fictitious river based on mistaken impressions of the Willamette), and Snake—all within an area of about 70 mi.². The later explorations of the Rocky Mountain fur traders would, by the 1840s, clear up this massive misconception. In the meantime, it colored Americans' views of the West and shaped the first phases of western exploration by the fur trade between 1807 and 1836.

For all the misconceptions that remained in the final reports of Lewis and Clark, they were the first to have traversed the American West and returned with voluminous reports—not just on mountains and rivers but also on vegetation and soil and wildlife and indigenous peoples. On their information, the first wave of American entrepreneurs entered the West—Manuel Lisa's Missouri Fur Company and John Jacob Astor's American Fur Company. To paraphrase Bernard DeVoto, Lewis and Clark gave the West to the American people, a West with which the mind could deal. Their expedition marked the end of a three-century-long search for a Northwest Passage. But it culminated in data that could be used by real people in settling and using a real area,



and in that sense, the expedition—based on the tenets of Enlightenment science—ultimately became successful in the context of American utilitarianism.

John Logan Allen

See also **Exploration; Jefferson, Thomas**

Further Readings

- Allen, J. L. (1991). *Lewis and Clark and the image of the American Northwest*. New York: Dover.
- Jones, L. (2002). *The essential Lewis and Clark*. New York: HarperCollins.
- Moulton, G. M. (Ed.). (1983–2003). *The journals of the Lewis and Clark expedition* (13 vols.; includes Atlas [Vol. 1] and Index [Vol. 13]). Lincoln: University of Nebraska Press. Available from <http://lewisandclarkjournals.unl.edu>
- Moulton, G. M. (Ed.). (2003). *The journals of the Lewis and Clark expedition* (Abridged). Lincoln: University of Nebraska Press.

LEY, DAVID (1947–)

David Ley is a well-known humanistic geographer whose research has dealt with several topics, including symbolic landscapes, critiques of structural Marxism, gentrification, immigration, and urban neighborhoods.

After completing a bachelor's degree at Oxford University, Ley crossed the Atlantic Ocean by ship to begin graduate study in geography at the University of Pennsylvania with Peter Gould. Whereas Gould favored quantitative approaches to geographic analysis, Ley found himself leading others on a divergent path of qualitative research. On the forefront of humanist geography, geography that centers on human experience and interpretation, Ley's doctoral dissertation, *The Black Inner City as Frontier Outpost: Images and Behaviour of a Philadelphia Neighbourhood*, was published in 1974 by the Association of American Geographers (AAG) and became a "classic" in geography, celebrated in recollections published 25 years later. The book explores

the racialized microgeographies of daily life in an African American neighborhood in Philadelphia.

By the time he completed his doctoral studies, Ley was offered a job as an assistant professor in Vancouver, Canada, in the department of geography at the University of British Columbia, where he still works today. In the years that followed, Ley worked collaboratively with other social geographers to build humanistic geography. With Jim Duncan, he explored the relationship between landscape, aestheticization, and interpretive frameworks and authored key texts in social geography. *Neighbourhood Organizations and the Welfare State* (published in 1994 with Shlomo Hasson) examined the struggles among inner-city neighborhood groups.

Ley quickly became an active citizen, student, professor, and researcher in Vancouver and began a program of research on the urban and cultural geographies of the city that evolved throughout his career. The focus of Ley's research changed as he studied the shifting cultural and economic forces in the city and suburbs, from the changes bound up in processes of gentrification to the significant demographic shifts driven by international migration to Vancouver in the late 20th century. His 1996 book on gentrification, *The New Middle Class and the Remaking of the Central City*, straddles the subdisciplines of urban and social geography, tracks the changing demographics in six Canadian cities as greater numbers of women enter the work force, and "follows the hippies" who search for particular urban lifestyles and landscapes. Ley's most recent book, *Millionaire Migrants: Trans-Pacific Life Lines*, examines transnational linkages among wealthy migrants in Vancouver, Toronto, and East Asia.

Ley published many key papers in the fields of urban and social geography and later in the field of migration as he charted population change through immigration and mapped poverty in Canadian cities. An oft-cited paper, "Between Europe and Asia: The Case of the Missing Sequoias," combines his interest in social and urban geography and migration with a close reading of a community struggle over zoning that brings to the forefront the classed, racialized, and cultural dimensions of neighborhood conflict.

Ley was the first codirector of the Vancouver Centre of the Canadian Metropolis Project, one



node in a larger global network designed to fuel research on immigration through collaboration between scholars, policymakers, and immigration service providers. Ley is a fellow of the Royal Society and holds a Canada Research Chair in geography. He became a Pierre Trudeau Fellow in 2003 and was given the Lifetime Achievement Award by the AAG in 2009, to name but a few of the many honors he achieved during the course of his career. Ley trained many geographers who themselves now teach at universities in Canada, the United States, Australia, and Britain.

Alison Mountz

See also **Gentrification; Existentialism and Geography; Humanistic Geography; Phenomenology; Postindustrial Society**

Further Readings

- Bourne, L., & Ley, D. (Eds.). (1993). *The changing social geography of Canadian cities*. Montreal, Quebec, Canada: McGill-Queens Press.
- Clarke, C., Ley, D., & Peach, C. (Eds.). (1984). *Geography and ethnic pluralism*. London: Allen & Unwin.
- Duncan, J., & Ley, D. (Eds.). (1993). *Place/culture/representation*. London: Routledge.
- Hasson, S., & Ley, D. (1994). *Neighbourhood organisations and the welfare state*. Toronto, Ontario, Canada: University of Toronto Press.
- Ley, D. (1974). *The black inner city as frontier outpost: Images and behavior of a Philadelphia neighborhood* (Monograph Series, No. 7). Washington, DC: Association of American Geographers.
- Ley, D. (1983). *A social geography of the city*. New York: Harper & Row.
- Ley, D. (1995). Between Europe and Asia: The case of the missing sequoias. *Ecumene*, 2, 185–210.
- Ley, D. (1996). *The new middle class and the remaking of the central city*. Oxford, UK: Oxford University Press.
- Ley, D. (2010). *Millionaire migrants: Trans-Pacific life lines*. Oxford, UK: Wiley-Blackwell.
- Ley, D., & Samuels, M. (Eds.). (1978). *Humanistic geography*. Chicago: Maaroufa Press.



LiDAR AND AIRBORNE LASER SCANNING

Light detection and ranging (LiDAR), also known as airborne laser scanning, is an active remote sensing technology that measures distances between the sensor and points on the surface and stores the geographic location of those ground points.

Measurement Method

LiDAR systems use pulses of light amplified by stimulated emission of radiation (laser). The time that lapses between emitting a laser pulse, the reflection of the pulse off of a surface, and its subsequent return to the sensor is used to determine the distance to the surface from the sensor in the equation: Distance = (Rate × Time)/2, where Rate is equal to the speed of light and Time is the aforementioned lapse of time for a pulse to return to the sensor. A global positioning system (GPS) and an inertial measurement unit are used to measure the position of the sensor and attitude (angle) of the aircraft. The position and angle of the aircraft are in turn used with the distance measurement to geographically reference the points where laser pulses reflected off of a surface.

Characteristics of LiDAR Sensors

Features of LiDAR sensor systems that may vary include the platform used to carry the sensor, the wavelength of light used for the lasers, whether pulses are discrete or continuous, and scanning characteristics. Most platforms that carry LiDAR systems are either small manned airplanes or helicopters. Some systems are suitable for satellite deployment. Fields such as forestry and surveying use LiDAR technology packaged for in situ, ground-based measurements.

LiDAR sensors often use near-infrared light because it reflects well off of vegetation, in particular, and also strongly off of human-made and other surfaces. Often, LiDAR data are separated into ground and vegetation canopy returns during postprocessing of the data. Applications such as coastal mapping use infrared lasers (which reflect off of the water surface) and green lasers



(which travel through water to an extent) in combination to map shallow areas.

Discrete-return LiDAR uses short laser pulses to collect surface information. One pulse may strike multiple surfaces, and each surface it strikes could reflect back a portion of the emitted energy. A *multiple-return LiDAR* system measures the multiple moments of reflection in the path of one laser, as opposed to recording only the last return. *Continuous LiDAR* measures the full waveform of each laser pulse by continuously recording the intensity of reflection during the laser's travel.

Profiling LiDAR sends a pulse down at nadir to provide a linear trace, or profile, of surface elevation data. *Scanning LiDAR* consists of optics to allow the angle of the pulse exiting the sensor to change, and as the system scans back and forth, the specific angle of the pulse is used in combination with distance, GPS, and inertial measurements to determine the coordinates of the surface reflection point. The frequency of scanning determines the density of LiDAR return points with respect to the footprint of the laser pulse on the surface. Furthermore, high-angle pulses and topography can affect the quality of a given return.

Grant Fraley

See also **Aerial Imagery: Data; Aerial Imagery: Interpretation; Biophysical Remote Sensing; Imaging Spectroscopy; Multispectral Imagery; Panchromatic Imagery; Photogrammetric Methods; Remote Sensing; Remote Sensing: Platforms and Sensors; Stereoscopy and Orthoimagery; Thermal Imagery**

Further Readings

- Anderson, J., Martin, M., Smith, M.-L., Dubayah, R., Hofton, M., Hyde, P., et al. (2006). The use of waveform Lidar to measure northern temperate mixed conifer and deciduous forest structure in New Hampshire. *Remote Sensing of Environment*, 105(3), 248–261.
- Chow, T., & Hodgshon, M. (2009). Effects of lidar post-spacing and DEM resolution to mean slope estimation. *International Journal of Geographical Information Science*, 23(10), 1277–1295.



LIGHTNING

The lightning flash is one of the most visually remarkable, yet scientifically elusive, of all atmospheric phenomena. Though the earliest lightning observations go back thousands of years, perhaps the biggest breakthrough in our understanding of the lightning flash came in the mid 18th century, when Benjamin Franklin suggested—and later proved in his famous kite experiment—that lightning was an electrical phenomenon. Such a discovery set the stage for subsequent research into lightning formation, lightning detection, lightning safety, and even the use of lightning as a source of energy.

To the weather enthusiast, lightning offers incredible visual displays, sometimes referred to as Nature's fireworks. To the scientist, lightning detection provides a wealth of information on atmospheric processes, thunderstorm formation, and interactions between the land surface and the atmosphere, and it can be used to inform forecasters and hazard mitigation specialists. Unfortunately, lightning is also a deadly phenomenon and can cause severe damage to built structures, trees, and airplanes, as well as disrupt power grids and ignite fires.

Lightning Formation

Cloud Electrification

An understanding of lightning formation begins with an understanding of electrical charge in the atmosphere. In the absence of clouds and major weather systems (i.e., “fair-weather” conditions), Earth's atmosphere contains a preponderance of positively charged ions (an ion is simply a charged particle), while Earth's surface contains a preponderance of negatively charged ions. This global-scale distribution of charge is largely the result of thunderstorms, which act to remove negative charge from the atmosphere and deposit it on Earth's surface. Since air is a poor conductor of electricity, an exceptionally large electrical field must be established for lightning to occur. Under fair-weather conditions, Earth's electrical field is relatively weak, but in a thunderstorm environment, the strength of the electrical field increases



Time-lapse photography captures cloud-to-ground lightning during a nighttime thunderstorm in Norman, Oklahoma.

Source: National Oceanic and Atmospheric Administration.

by many orders of magnitude until an electrical current can move freely between the cloud and another conducting surface.

The most popular theory for the development of electrical charge in thunderstorms is the noninductive charging mechanism. Since thunderstorms grow to altitudes where temperatures are below freezing, they become composed of liquid water, ice crystals, and hailstones. Each of these particles has a slightly different arrangement of electrons, meaning that as they collide with each other in the turbulent air currents found within a thunderstorm, electrons will be transferred between them. This transfer of electrons results in an accumulation of positive charge near the upper portions of the thunderstorm (where ice particles are kept aloft) and an accumulation of negative charge in the middle and lower portions of the thunderstorm (where small, but heavier hailstones settle). Secondary charging mechanisms help strengthen the electrical field as electrons are continuously transferred between colliding thunderstorm particles. On the ground, an accumulation of positive charge builds as negative charge near the lower portion of the thunderstorm repels the negative

charge on Earth's surface that existed under fair-weather conditions. When a lightning flash occurs between the cloud and the ground, negative charge is transferred back to the ground.

Lightning Flashes

There are three primary types of lightning flashes: those that occur within the cloud (i.e., intracloud), between clouds (i.e., cloud to cloud), and between the cloud and the ground (i.e., cloud to ground). Approximately 80% of all lightning flashes occur either within the cloud or between clouds. Other types of optical and electromagnetic phenomena, both on the ground (e.g., St. Elmo's Fire) and in the upper atmosphere (e.g., sprites and jets), have been observed in association with lightning flashes.

To the naked eye, a lightning flash appears as a continuous flash of light. However, high-speed photography and laboratory experiments have revealed that a single lightning flash is actually composed of a series of flashes each lasting just a few millionths of a second. In a typical cloud-to-ground flash, negative ions (electrons) begin



moving downward through the cloud toward the ground. To facilitate this process, electrons may branch out and take multiple paths downward—this creates the “forked” appearance of many lightning flashes. As the flow of electrons moves downward, a stepped leader is formed that attempts to establish a conductive channel for electrons to flow through and neutralize the charge difference between the cloud and the ground. As the channel nears the ground, a spark occurs on a conducting surface (e.g., the top of a tree), creating a conduit for electrons to flow through. Once the lightning channel is established, the current flows upward toward the cloud, creating a brilliant flash known as a *return stroke*. Depending on the strength of the electrical field, multiple return strokes may occur in an effort to dispel the negative charge from the cloud.

A less frequent type of cloud-to-ground flash is the positive flash, which transfers positive charge from the cloud to the ground. These flashes often originate in thunderstorms that are horizontally tilted, exposing the positively charged upper regions of the cloud to the ground. Positive flashes may also emanate from the sides of the cloud, striking the ground a considerable distance from the main body of the thunderstorm. This type of flash is often referred to as a “bolt from the blue,” since it occurs away from the thunderstorm under generally clear skies.

Lightning Detection

Prior to the advent of modern lightning detection equipment, the occurrence of lightning was typically inferred by the sound of thunder—the sound wave produced by a lightning flash as it rapidly heats and expands the air around it. Weather observers would mark the presence of thunderstorms in their logbooks if audible thunder was detected. The first attempts to measure the electrical field in the vicinity of thunderstorms took place in the early 1950s and used sferics, or radio waves, to measure electromagnetic radiation produced by the lightning flash.

One of the biggest shortcomings of early lightning detection methods was that they could not pinpoint the true location of the lightning channel. This changed in the 1970s with the development of magnetic direction finders. These ground-based instruments are able to “sense” the

radiation emitted during the first few microseconds when a flash strikes the ground or a ground-based object. The first sensors became operational in 1979 and covered only small portions of the United States. In 1989, these regional networks merged into the present-day National Lightning Detection Network, based in Tucson, Arizona. This network consists of more than 100 sensors that record the time and location of all cloud-to-ground flashes, as well as other characteristics (e.g., magnitude of the electrical current, number of return strokes). Some regional lightning networks in the private sector continue to operate their own direction finders for specialized research and monitoring purposes. Lightning sensors have also been placed aboard satellites to provide global coverage of cloud-to-ground and intra-cloud lightning (a map produced by the National Atmospheric and Space Administration [NASA] showing the global distribution of lightning flashes can be found at <http://virtualskies.arc.nasa.gov/research/tutorial/lightningMap.html>).

Lightning Impacts

Lightning is the leading cause of thunderstorm-related fatalities in the United States, killing an average of 100 people annually from 1959 to 2006. Since the 1930s, lightning fatalities and fatality rates have steadily declined due to a decreasing rural population, improvements in forecasts and warnings, better medical response to victims, and mitigation efforts through public education. Fatality rates are often much higher in less developed countries (6 fatalities per million population) in comparison with more developed nations (from 0.1 to 1 per million). People engaged in outdoor recreational or work-related activities are the most vulnerable to the hazard. Uniquely, males are far more likely to be killed by lightning than females, with males comprising nearly 85% of lightning fatalities in the United States. Victims struck directly or indirectly by lightning often suffer from injuries to the cardiac and neurological systems (cardiac arrest being the most common cause of death) as well as psychological effects that include neurocognitive deficits, memory problems, and even depression. The spatial distribution of lightning fatalities and injuries is commensurate with population and cloud-to-ground lightning densities. Casualties tend to occur most



often during warm-season afternoons, when thunderstorms are at their climatological maximum and people are more likely to be outdoors.

Lightning routinely causes damage to personal, commercial, and public property and is a major source of property, agricultural, and casualty insurance losses. Though lightning losses are often isolated and rarely achieve the tallies reported for other weather hazards such as tornadoes and hurricanes, the cumulative insured losses from lightning are considerable, with an estimated \$5 billion in insured losses annually. Lightning regularly disrupts electricity generation, transmission, and distribution. The hazard is a major cause of local and regional electrical and telecommunication blackouts and inflicts losses of millions of dollars annually on utility infrastructure and sales. Lightning-initiated wildland fires result in annual timber and property losses of millions of dollars, with millions of dollars more spent on fire prevention and suppression in the more developed countries. The National Interagency Fire Center estimates that approximately 12,000 wildland fires are initiated by lightning each year in the United States, affecting an average of 5 million acres annually.

Geographical Studies of Lightning

The spatial and temporal distribution of lightning flashes and the utility of lightning data sets have been explored in a variety of geographical studies. The general goal of these studies is to inform researchers and those with lightning-oriented interests of the patterns of lightning within a range of meteorological and hazard scenarios. Geographers are in a unique position to provide this information using advanced visualization and mapping techniques (i.e., geographic information systems, or GIS) that allow inferences into mechanism, causation, and other process-based inquiries.

The spectrum of geographically based lightning studies is rather broad and contains many overlapping categories and components. Most of these studies employ a descriptive approach, where patterns in lightning frequency are mapped and explained across various space and timescales (i.e., a lightning climatology). Some studies use this information to explore the possible mechanisms for the resulting distributions and the

processes and weather systems that drive them. Still other studies use lightning data to explore various properties of the atmosphere. Improvements in the spatial and temporal resolution of lightning data have allowed for such investigations from the macroscale down to the microscale. Examples include the use of lightning data to understand the role of aerosols and other small particles in thunderstorm composition, rainfall, and cloud electrification as well as the atmospheric processes occurring in severe thunderstorms, tropical cyclones, and winter storms (e.g., “thundersnow”). Lightning data have been used in macroscale studies to examine the relationship between atmospheric circulation patterns and the frequency and intensity of convection in subtropical and midlatitude environments.

Among geographers who use lightning data sets, the role of land use in initiating and altering the frequency and character of lightning flashes has been a popular research topic in recent years. In particular, there has been a significant growth in the number and scope of studies examining the lightning climatology of urban areas, both in the United States and abroad (e.g., South America, Western Europe, Australia). These studies are part of a much larger initiative aimed at examining how the urban environment affects atmospheric processes across multiple scales. Relatively fewer studies have investigated the distribution of lightning over mountainous terrain and the relationships between slope angle, aspect, elevation, and lightning frequency. Continued improvements in lightning detection networks and a longer time series will likely lead to more studies of lightning over complex terrain. Additionally, the continued development of satellite-based lightning sensors will provide a longer time series of lightning coverage over the oceans and higher latitudes. This information will be of value to studies examining the global distribution of lightning and its trends over time, particularly in the context of global and regional climate change. Continued development of GIS technologies will be of tremendous benefit to climatological studies of lightning as well as studies exploring the relationships between lightning and other aspects of the Earth system (e.g., land cover, demographics) across space and time.

*Christopher M. Fuhrmann
and Walker S. Ashley*



See also **Natural Hazards and Risk Analysis; Thunderstorms; Vulnerability, Risks, and Hazards; Wildfires: Risk and Hazard**

Further Readings

- Curran, E. B., Holle, R. L., & López, R. E. (2000). Lightning casualties and damages in the United States from 1959 to 1994. *Journal of Climate*, 13, 3448–3464.
- MacGorman, D. R., & Rust, W. D. (1998). *The electrical nature of storms*. New York: Oxford University Press.
- Orville, R. E. (2008). Development of the National Lightning Detection Network. *Bulletin of the American Meteorological Society*, 89, 180–190.
- Orville, R. E., & Huffines, G. R. (2001). Cloud-to-ground lightning in the United States: NLDN results in the first decade, 1989–98. *Monthly Weather Review*, 129, 1179–1193.
- Stallins, J. A., & Rose, L. S. (2008). Urban lightning: Current research, methods, and the geographical perspective. *Geography Compass*, 2/3, 620–639.

LILLESAND, THOMAS (1946–)

Thomas M. Lillesand has long been a major figure in the development of remote sensing techniques, applications, and policies. He is a professor emeritus of the Nelson Institute for Environmental Studies, the department of forest ecology and management, and the department of civil and environmental engineering at the University of Wisconsin, Madison (UW).

Lillesand grew up in Wisconsin and obtained degrees in civil engineering from the UW (BS, 1969; MS, 1970; PhD, 1973). He began his career as a remote sensing educator in 1973, as a faculty member at the State University of New York (SUNY), Syracuse, College of Environmental Science and Forestry. From 1978 to 1982, he taught at the University of Minnesota and directed that university's Remote Sensing Laboratory. He joined the faculty at UW in 1982 and was the

director of Wisconsin's Environmental Remote Sensing Center (ERSC). For many years he also chaired UW's Environmental Monitoring graduate program.

Lillesand taught numerous courses in photogrammetry, visual image interpretation, photographic and electro-optical remote sensing systems, digital image processing, environmental monitoring, and graduate research methods. He advised a total of 76 MS and PhD students over the course of his academic career. Many of these have become leaders in key positions in academia, government, and the private sector. The scope of Tom's highly interdisciplinary research activity has ranged from statewide and regional land cover classification and change detection to applications of remote sensing in forestry and agriculture, civil engineering, long-term ecosystem science, climate change, and water resources management. Sponsors of his research have included the National Atmospheric and Space Administration (NASA), the National Atmospheric and Oceanic Administration (NOAA), the U.S. Department of Agriculture (USDA), the National Science Foundation (NSF), the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), the Department of Energy (DOE), and the Environmental Protection Agency (EPA), among others. He has also been active in U.S. remote sensing policy issues.

Lillesand has authored or coauthored more than 200 professional publications. He is the senior author, along with Ralph Kiefer and Jonathan Chipman, of *Remote Sensing and Image Interpretation*, published in 1979 and now in its sixth edition. This book has been translated into several languages, making it one of the most used remote sensing texts and references in the world.

Over the years, Lillesand has provided frequent service as a consultant and scientific advisor to numerous governmental agencies, as an expert witness, and as a leader in professional organizations. For example, he served on the Science Advisory Panel for the Earth Observing System (EOS) Land Processes Distributed Active Archive Center. He was appointed by Secretary of Commerce Malcolm Baldrige to represent the American Society for Photogrammetry and Remote Sensing (ASPRS) on the Land Remote Sensing Satellite Advisory Committee and has provided both U.S.



House and Senate subcommittee testimony on four occasions dealing with the policy and management of the U.S. Landsat satellite program and defining the basic research requirements underpinning U.S. commercial opportunities in geospatial science and technology. Lillesand has also chaired and served on numerous key committees for ASPRS. He has served as an officer within three ASPRS Regions and as director of the Remote Sensing Applications Division. He served as the national president of ASPRS from 1998 to 1999. He has received several national awards for his professional accomplishments, including the Alan Gordon Memorial Award for Scientific Achievements in Remote Sensing and Image Interpretation, the Talbert Abrams Award for excellence in Authorship and Recording of Scientific Development in Photogrammetry, the Earle J. Fennell Award for Outstanding Contributions to Education in the Mapping Sciences, and the SAIC/Estes Memorial Teaching Award. He is a fellow in ASPRS, a certified photogrammetrist, and a certified mapping scientist in the area of remote sensing.

Lillesand retired in 2006, after 33 years as a teacher, researcher, and advisor, but continues to serve as president of the Board of Trustees of the ASPRS Foundation. He also consults on a part-time basis, primarily as an expert witness.

Nicole Simons

See also **Remote Sensing**

Further Readings

- Bolstad, P., & Lillesand, T. (1992). Semi-automated training approaches for spectral class definition. *International Journal of Remote Sensing*, 13(6), 3157.
- Chipman, J., & Lillesand, T. (2007). Satellite-based assessment of the dynamics of new lakes in Southern Egypt. *International Journal of Remote Sensing*, 28(19), 4365–4379.
- Lillesand, T., Kiefer, R., & Chipman, J. (2008). *Remote sensing and image interpretation* (6th ed.). Hoboken, NJ: Wiley.



LINEAR REFERENCING AND DYNAMIC SEGMENTATION

Dynamic segmentation is a computer-based database management system using the principles of relational algebra and topological integrity to minimize error and maximize efficiency of map analysis and display. Linear features are stored as nodes and arcs and provide only the minimum of geometric properties for proper display on maps.

When these linear features, such as roads and railways, have multiple attribute tables, dynamic segmentation is used to query and display such attributes. Examples include the number of accidents at different parts of the pavement or speed limits that differ within the same segment. Since geometric nodes and arcs are the foundation of linear features stored in a geographic information system (GIS), dynamic segmentation becomes quite useful to represent attribute data that do not sync perfectly with the geometric range of the linear features.

Utilities and transportation networks often have information without geographic coordinates. Usually, this information is based on a fixed reference point along a route. The data stored are referred to as a *linear referencing system*. For example, highway accidents often are coded based on the nearest intersection and the network distance from the intersection (i.e., the driving distance from the accident location to the nearest intersection). Tables containing such information are known as *milepost tables*. Using a map, one can dynamically calculate the coordinate information and display accident sites. Since dynamic calculations can be done using computer memory, the storage of such information permanently is deemed redundant. In addition, since highway maps and other linear maps are stored and updated independently of the accident tables, there is no need to separately change the accident coordinates whenever a highway map is updated (since, in the milepost table, there are no accident coordinates to begin with). This approach restricts the propagation of error and is important since geometric coordinate error cannot be eliminated. Another benefit is that line segments need not be broken into smaller pieces. Actual breaks are limited to intersections with other lines or change of direction in the line segment.



Logical Data Model

Network data, which are used extensively in the transportation and utility domains, have benefited immensely from graph theory—a branch of mathematics that studies the properties of nodes and arcs. A graph, $G = (V, E)$, consists of a finite set of vertices, V , and edges, E (joining the V s). When the edges are directed and the vertices are weighted, they represent a network. The geometric coordinates of the vertices allow the network to be mapped in relation to Earth's surface. However, the properties of the network are independent of the actual coordinates and are a function of the number of edges the vertices enclose (the mathematical branch of low-dimensional topology deals with the properties of graphs).

Milepost tables use this topological property of the network, allowing storage of complete information without map duplication.

GIS software that incorporates dynamic segmentation includes Environmental Systems Research Institute's ArcGIS software and Caliper Corporation's TransCAD software.

Aniruddha Banerjee

See also Map Algebra; Network Analysis; Spatial Analysis; Topological Relationships; Triangulated Irregular Network (TIN) Data Model

Further Readings

Shekhar, S., & Chawla, S. (2003). *Spatial databases: A tour*. Upper Saddle River, NJ: Prentice Hall.



LITERATURE, GEOGRAPHY AND

The study of literature from a geographical perspective takes as its premise the recognition that questions of space, place, and spatiality are constitutive of, rather than merely supplementary to, the kinds of meaning, significance, and communication that literature produces. This idea exceeds the simple recognition that literary narratives

(poems, novels, myths, etc.) unfold at particular locations. Rather, there are five broad fields of literary geographical concern:

1. Literature as a humanistic and meaningful narrative of place
2. Literature as an object of historical geographical analysis
3. Literature as a site of ideological critique
4. Literature as an exposition of postcolonial geographical imaginations
5. Literature as an expression of particular spatialities and their attendant "structures of feeling"

Within these fields, the relation between text and context is taken seriously, because it is in this site that the historical, social, political, and philosophical significance of literature is most acute—precisely because the geographical and historical contexts of literary production and consumption affect and determine that significance.

As Andrew Thacker has noted, literary texts represent social spaces. For example, from the enclosed, gendered spatialities and formal social marriage circuits of Jane Austen's predominantly rural England to the modernist urban encounters and fragmentary perspectives of James Joyce's Dublin, literature inscribes a whole history of sociospatial relations and images of geographical reality. At the same time, social spaces shape literary forms. Thus, there are particular spatial histories to writing communities and their readerships, in which social, economic, and political contextual relations feed into the production of distinct literary forms. Geography shapes literary history, as literatures are both expressions of particular cultures, nationalities, and languages and at the same time sites of passage, translation, and communication between different cultures, identities, and beliefs.

Geography has also fed into the study of narrative (diegetics) within literary criticism. Since the "spatial turn," literary studies often employ spatial languages and metaphors to better explicate the ways in which narrative functions and has its own "textual space," extending from the materiality and locational specificity of the book to the structured space of the page itself. Spatial metaphors have thus become ubiquitous within literary



criticism. Border, boundary, margin, orientation, mapping, (de)territorialization, and so on have come to be constitutive of literary sense.

Humanistic Geography: Narratives of Place

The first sustained geographical engagement with literature was through humanistic geographers of the 1970s and 1980s such as Yi-Fu Tuan, Douglas Pocock, and Anne Buttimer. They sought to study literature as a way of thinking about the more subjective ways in which people experience particular places and render them meaningful. In reaction to the dominance of quantitative methods of sociospatial analysis, particular novelists and literary representations of places were studied from a nonmathematical horizon of meaning, memory, and identity. Humanistic research on a given author or novel would, on the one hand, seek to communicate how literature carried a sense of “authentic” geographical awareness of the lives, worldviews, and practices associated with a specific milieu or a particular place. On the other hand, and reflecting perhaps a naive acceptance of literature as a taken-for-granted creation of artistic “genius,” it would also claim for literature universal capacities for the illumination of humanity not found in social scientific research. This approach can be traced historically to J. K. Wright’s 1947 presidential address to the Association of American Geographers, “*Terrae Incognitae: The Place of the Imagination in Geography*,” in which he called for greater geographical engagement with literary criticism and the humanities more broadly.

For Marxist geographers, however, humanistic geography, focusing primarily on “the text” and the privileged insight that an authorial voice lends, lacked the requisite level of criticality. Beyond the cultural turn, this criticality in relation to literature can be seen in the three subsequent fields of research, encompassing questions of textuality, the historicity of literary texts, and the politics of representation more broadly.

The Object of Historical-Geographical Literary Analysis

In explicating the geographic work of literature, historical geographers seek to unpack texts in

relation not only to the historically distinctive representations of fictional and “real” space (actual or imagined landscapes, nations, cities, ruralities, etc.) but also to the spatial contexts that condition the production and consumption of an object named *literature*. In this way, geographical literary study does not provide access to “language” in a pure form but to writings in the plural, in their varied geographical and historical specificity. Literature, in the widest possible sense, involves the production, dissemination, and consumption of novels, stories, tales, and myths of whatever genre (picaresque, religious-moralistic, colonial, gothic, crime, avant-garde, romance, etc.). Within this context, literature arises as an aesthetic category, defined through complex social assemblages: authors, editors, publishers, technologies of paper and ink, reviewers, critics, and historians. However, beyond the scope of particular scholarly aesthetic definitions of literature, there is also the more banal, but no less important, everyday production of literature found in the writing of letters, e-mails, Internet blogs, diaries, and so on. Different print cultures can be geographically examined as the contested and evolving locus through which positions such as “author” and “reader” come to be articulated.

Focusing on a particular literary form, critics such as Franco Moretti and Pierre Bourdieu describe the spatial histories of the novel. The novel form developed primarily in the 18th- and 19th-century European contexts, where industrialization, the development of the bourgeoisie, the rise of nation-states, and imperialistic and colonial encounters unfolded within the wide economic and social transformations of urban capitals such as Paris and London. While these cities exerted a hegemonic publication and print culture, conditioning practices of reading and expectations (literary canons and genres, library stocks), literature is not thereby tied in any concrete and definitive way to its sites of origin. Literature travels; texts are translated, styles imitated, and ideas disseminated. Books are thus mobile commodities that trace out important social lives.

Literature as a Site of Ideological Critique

As commodities, the consumption of literature can be analyzed as part of the uneven distribution of



cultural capital more broadly. For Bourdieu, this ideological class stratification is historically and geographically produced. In this way, the aesthetic appreciation of the *form* of literature is scripted along particular class boundaries and types of education. Furthermore, many geographers have turned to the specific *content* of literatures, critiquing particular representations and imaginations that are culturally repressive, ideologically hegemonic, and normalizing. For these geographers, literature figures as a crucial site for the (re)production of particular geographical ideas, consciousnesses, identities, and cultures (nationalities, races, classes, genders, etc.). Literature can thus be framed as a conservative site for the reproduction of particular values. But, for the same reason, it can carry a transgressive function of resistance, critique, and democratic expression.

With critical resources from the “cultural turn” (the widespread acknowledgment of the centrality of culture and ideology in all social systems), geographers study how particular geographical imaginations are disseminated, reproduced, and framed through certain types of language, form, narrative, and style. By unpacking the work of narrative and employing concepts from literary theory, geographers can grasp the structured ways in which meaning is articulated through habitual media forms. Thus, certain forms of textual representation perform particular relations of power, from popular novels to mundane nonfiction texts, including the encyclopedic entry, which replicates a specifically structured narrative space to communicate authoritatively. In this way, it is important to unpack the complex and ambiguous relation between truth and fiction that literature inevitably throws up. Spaces, places, and particular geographic communities (classes, cultures, nationalities, genders, races, historical events, etc.) are framed through literature. Texts often (problematically) reduce social geographical complexity within narratives. These representations inevitably run up against notions of truth: the accuracy of representation, the level of their reality. They also come up against their opposite: where a text is dismissed as “purely fictional,” as that which is merely imagined and desired. In reality, it is incredibly difficult to separate these, and a critical geographic perspective is attentive

to how the separation between truth and fiction is enacted or dissimulated and with what particular ideological effects.

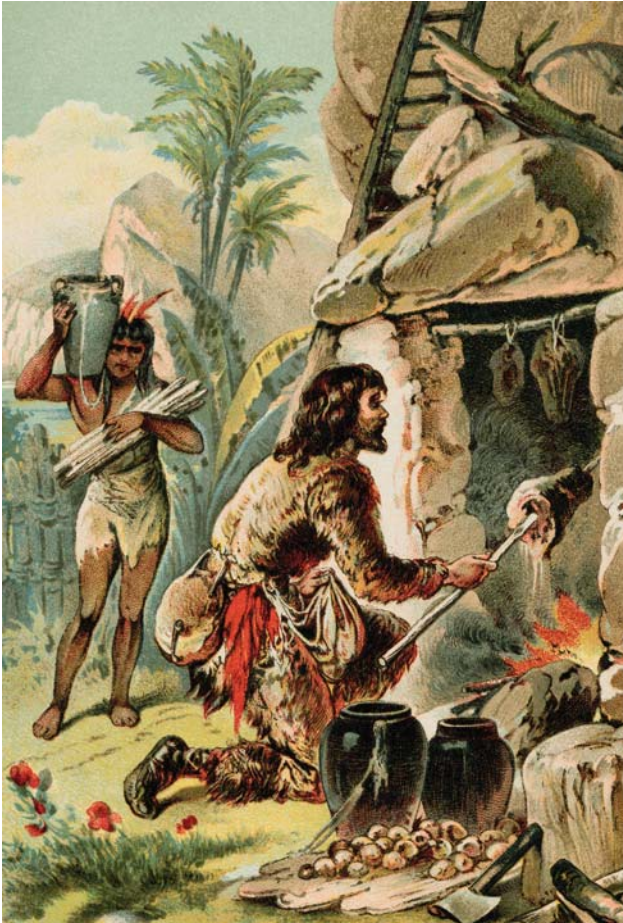
The Exposition of Postcolonial Geographical Imaginations

Perhaps the most important field for ideological critique is circumscribed by the postcolonial critic Edward Said. As Said noted, literature is not a neutral aesthetic phenomenon but a site where politics, language, geography, and culture are inextricable, where different geographical imaginations and ideologies are historically produced, reproduced, and contested. Greek dramas and myths, travel writings, colonial novels of romance and exploration—all have historically shaped the ways in which different cultures and places are rendered visible, encountered and imagined, desired and feared. Said coined the term *Orientalism* to describe Western literary practices of constructing and relating to cultural Others, in particular the imagined space of the Orient. Many geographers, such as Derek Gregory, have taken Said’s key literary-historical texts and work to expose the continuing legacies of Orientalist representations within contemporary media forms.

In relation to the historical-geographical analysis of key texts, Daniel Defoe’s *Robinson Crusoe* (1719) and Joseph Conrad’s *Heart of Darkness* (1899) have proved exceptional resources for geographers interested in the geographical history and desires of nation building, the formation of Empire, and the imperialistic practices, moralities, and racisms that are bound up with particular geographical imaginations. An example is the prevalent geographical binary found in numerous literatures of the “Dark Continent” of Africa, contrasted and constituted in relation to the “light” of European civilization, reason, religion, and industry. More broadly, this field is interested in raising questions on the politics of representing and speaking “for” other cultures through dominant colonial languages and literatures (e.g., English and French).

Expressions of Spatiality

As Raymond Williams noted, it is possible to analyze distinct “structures of feeling” attendant on



Chromolithograph of a cooking scene from *Robinson Crusoe*, showing a man dressed in furs cooking meat over a fire while a native carries supplies

Source: Bettmann/CORBIS.

varying historico-geographical experiences of the city, “nature,” the country, and other spaces. These structures of feeling correspond to different spatialities, shaped and experienced in important ways by different kinds of literary representation (poems, novels, religious texts, etc.). Spatiality here can be thought as the co-constitutive relations between society and space. As both society and space are constantly shifting and rewriting their coordinates, different literatures emerge that register particular historico-geographical spatialities. In this context, David Harvey has produced a particularly clear geographical analysis of the works of Honoré de Balzac—situating his literature within the shifting spatialities of the urban, capitalistic experience in 19th-century

Paris. Literature here acts as an important registration of the everyday practices, beliefs, and identities that accompany the broader shifts of historical-geographical materialism. The cultural critic Walter Benjamin provided further theoretical rigor for geographers seeking to make sense of these relations between literature and the spaces of modernity, particularly Paris. Within this horizon, James Joyce is another author whose texts, particularly *Ulysses*, have proved particularly fruitful in explicating the nature of modernist renderings of urban experience and the significance of geographical imaginations in the construction of narratives. Indeed, it was hoped by Joyce that one could reconstruct the city of Dublin from *Ulysses*. What these works signify is the pedagogic value of literature for grasping geographical configurations, consciousness, and the changing horizons of perception of space and time.

José Luis Romanillos

See also **Cultural Geography; Cultural Landscape; Discourse and Geography; Geographical Imagination; Historical Geography; Humanistic Geography; Modernity; Postcolonialism; Sense of Place; Symbolism and Place; Text/Textuality; Writing**

Further Readings

- Bourdieu, P. (1993). *The field of cultural production: Essays on art and literature* (R. Johnson, Ed.). Oxford, UK: Polity Press.
- Brosseau, M. (1994). Geography's literature. *Progress in Human Geography*, 18(3), 333–353.
- Harvey, D. (2003). *Paris, capital of modernity*. London: Routledge.
- Moretti, F. (1998). *Atlas of the European novel 1800–1900*. London: Verso.
- Phillips, R., & McCracken, S. (Eds.). (2006). The spatial imaginary. *New Formations*, 57.
- Pocock, D. (Ed.). (1981). *Humanistic geography and literature: Essays on the literature of place*. London: Croom Helm.
- Said, E. (1994). *Culture and imperialism*. London: Vintage.
- Williams, R. (1985). *The country and the city*. London: Hogarth Press.



LIVINGSTONE, DAVID (1953–)

The history of geography was in some ways rewritten in David N. Livingstone's influential volume *The Geographical Tradition* (1992), which constituted both an important new disciplinary history and an attempt to write geography's history *differently*. Setting his work apart from textbook accounts and "in-house" disciplinary histories, Livingstone's book related the development of geography more closely to its broader social and intellectual contexts than had previous works, from Enlightenment challenges to classical authority, to the colonially acquisitive age of reconnaissance, to the age of statistics and the modern government and academic institutions of the late 20th century. Drawing on wider debates in the history of science, Livingstone demonstrated that geographical knowledge could be understood as a cultural product of, and political resource for, the times and places in which it was produced. He thus took up key questions raised in the post-modern turn in the history and philosophy of science—revolving around the demythologization of science as the objective, disinterested pursuit of knowledge—and explored their implications for the "messy" and applied contexts associated with the Western geographical tradition.

Built on theoretically informed and rigorous historical scholarship, Livingstone's work helped open geography's history to more reflexive and, at times, critical interpretations, and it did so by adding to, rather than detracting from, the historical richness of the field. Livingstone brought to these questions analytical skills honed in unraveling the complex interrelations of 19th-century science and religion. In works such as *Darwin's Forgotten Defenders* (1987), which focuses on some 19th-century theologians, and *The Preadamite Theory and the Marriage of Science and Religion* (1992), Livingstone challenged the "conflict model" of relations between science and religion, incorporating a broad sense of the intellectual diversity present in strains of Christian and evolutionary thought. In the North American context, Livingstone also contributed a major scientific biography of the Harvard physiographer Nathaniel Southgate Shaler. This work (1987) explores the interplay of regionalism,

race, class, and science that shaped Shaler's late-19th-century career and offers, through Shaler, a vital portrait of the Cambridge scientific community during the 1870s and 1880s, when Darwinism shook the intellectual landscape.

Livingstone's close attention to historical context has been matched by a concern for situating scientific actors in their spatial and geographical settings. In a series of papers during the 1990s, Livingstone pushed geographers and historians to consider how particular geographical arrangements of scientific knowledge and knowledge-making practices were critical to what science is and how it has worked. Whether conceptualized in terms of specialized architectural spaces, the research field, or other local settings for scientific activities, in terms of national scientific cultures and institutions and varied national receptions of scientific ideas, or through the spatial relations and patterns of circulation that make such scientific spaces possible, notions of a *geography of science*, and the *geography of geographical knowledge* in particular, have emerged as cutting-edge fields, at both the subdisciplinary and the interdisciplinary levels. Livingstone elaborated some of these ideas in a slim volume, *Putting Science in Its Place* (2003), an elegant formulation of the geography of scientific knowledge as framed by three spatial categories: (1) *sites* (archetypal sites, venues of science), (2) *regions* (regional differences in scientific culture, uneven development of science), and (3) *circulation* (movement, mapping, scientific travel, spatial relations, diffusion). Bringing together scholarship in the history of science with the history and geography of geographical knowledge, Livingstone has also edited, with Charles Withers, recent collections such as *Geography and Enlightenment* and *Geography and Revolution*.

David Livingstone is a professor of geography and intellectual history at Queen's University Belfast, where he earned his PhD in 1982. His honors include the Order of the British Empire for service in geography and history, membership in the Royal Irish Academy, and a fellowship in the British Academy.

Scott Kirsch

See also **Enlightenment; Human Geography, History of; Modernity**



Further Readings

- Livingstone, D. (1984). The history of science and the history of geography: Interactions and implications. *History of Science*, 22, 271–302.
- Livingstone, D. (1987). *Darwin's forgotten defenders: The encounter between evolutionary theory and evolutionary thought*. Edinburgh, UK: Scottish Academic Press.
- Livingstone, D. (1987). *Nathaniel Southgate Shaler and the culture of American science*. Tuscaloosa: University of Alabama Press.
- Livingstone, D. (1992). *The geographical tradition: Episodes in the history of a contested enterprise*. Oxford, UK: Blackwell.
- Livingstone, D. (1992). *The preadamite theory and the marriage of science and religion*. Philadelphia: American Philosophical Society.
- Livingstone, D. (1994). Science and religion: Foreword to the historical geography of an encounter. *Journal of Historical Geography*, 20, 367–383.
- Livingstone, D. (1995). The spaces of knowledge: Contributions toward a historical geography of science. *Society and Space*, 12, 5–35.
- Livingstone, D. (2003). *Putting science in its place: Geographies of scientific knowledge*. Chicago: University of Chicago Press.
- Livingstone, D. (2008). *Adam's ancestors: Race, religion and the politics of human origins*. Baltimore: Johns Hopkins University Press.
- Livingstone, D., & Withers, C. (Eds.). (1999). *Geography and enlightenment*. Chicago: University of Chicago Press.
- Livingstone, D., & Withers, C. (Eds.). (2005). *Geography and revolution*. Chicago: University of Chicago Press.



LOCALITY

Although human geographers sometimes disagree over the specific meaning of concepts such as place, space, region, and territory, few would question the centrality of such concepts to the discipline. Not so with the concept of locality, which is commonly taken to mean a distinct place or location in which events occur. This concept gained a certain

currency in the 1980s and early 1990s but very quickly became embroiled in a wider debate about theory and methods in human geography. Concerns were expressed by some radical geographers that the study of locality equated with empiricism: It seemed to signal a retreat from geographic theories grounded in Karl Marx's historical materialism. Although proponents of the locality concept vigorously countered such criticisms, they could not fully dispel the view that a fascination with locality amounted to an empiricist obsession with the detailed characteristics of specific places rather than with interrogating wider theoretical propositions about the capitalist space economy.

The appearance of the concept of locality in human geography texts in the mid 1980s can be attributed to an interdisciplinary research program funded by the Economic and Social Research Council in the United Kingdom. The Changing Urban and Regional System (CURS) program was designed with broadly three aims in mind:

1. To conduct detailed empirical research of economic, social, and political change in a variety of localities across the United Kingdom: The localities (seven in all) were selected on the basis of the uniqueness of certain characteristics, such as relative location, labor market, rural/urban mix, size, economy, and politics, as well as the presence of relevant locally based research teams. Although at the outset, there was a clear emphasis on difference and the uniqueness of each locality, the research teams nonetheless shared in common a broader appreciation of the importance of theory and conceptualization.

2. To interrogate wider propositions about the restructuring of the British space economy at a time of rapid economic, social, and political change: The research teams were eager to test certain theories about spatial restructuring that had emerged in the 1960s and 1970s, such as the approach to uneven development set out by Doreen Massey in her analysis of the geography of industrial restructuring. It was argued that locality-specific events and outcomes could not be read directly from global and national processes because “place makes a difference.” This assertion was supported by a definition of locality as those locally emergent properties that result from a putative combination of the particular class and



political relations of a place and wider rounds of investment and economic restructuring.

3. To engage proactively with economic and political change in such a manner as to inform policymakers and activists about the most practical means of contesting and coping with the localized social and economic consequences associated with the transformation of the United Kingdom from a manufacturing to a service economy: A particular target of action here was the neoliberal policies of the Conservative government led by Margaret Thatcher, which were seen by many radical geographers to be blaming the victims of spatial restructuring, that is, workers caught up in the restructuring of industrial localities once heavily dependent on industries such as steel, engineering, automobile manufacture, shipbuilding, and coal. However, the research teams did not confine themselves to male-dominated industrial labor markets; they were also interested in the emergence of new economic forms and the diversity of labor market processes. The teams were especially interested in identifying examples of “proactive localities” or collective action drawing on the resources and civic capacities of the localities in question.

The results of the CURS program were published in a series of journal articles and edited collections, each of which highlighted specific processes such as labor market restructuring, policy and politics, household strategies, and work and everyday life. While some common intellectual themes did emerge, there was little evidence that, collectively, locality studies shared in common praxis and theory; and this was despite the efforts of Doreen Massey and Philip Cooke (the latter was the research program coordinator), both of whom strove to impose some theoretical coherence retrospectively on the locality concept. Indeed, such efforts only intensified criticisms of the project, creating space for some important theoretical contributions from geographers, many of whom were not members of the original locality research teams.

The Significance of Locality Studies

Human geographers eventually moved on from locality studies, with many shunning empirical case

studies to engage in wider epistemological and ontological preoccupations with space and place. Nonetheless, the debate about locality was important for shaping at least two important new developments in the discipline. First, prompted by a memorable analogy from Neil Smith about a hot-air balloon and the “gestalt of scale,” the locality question led to a flurry of theoretical interventions around the production of spatial scale, leading eventually to a “scale debate” in human geography. The question of scale triggered some of the most exciting work to emerge in the discipline in the 1990s and 2000s. Research conducted on scales of labor activism, the rescaling of the state, and the relationship between locality-based growth coalitions and the politics of economic development can be attributed at least in part to the theoretical fallout of the locality debate.

Second, the locality concept engendered some challenging new theoretical work on sociospatial relations. Here, Doreen Massey’s work continues to be influential in its emphasis on the idea that space should not be seen as some sort of residual dimension of social and economic life or as simply a container for other processes that are compositional in structure yet essentially placeless. Rather, space shapes and gives meaning to wider (regional, national, global, etc.) natural and social processes that are, in turn, place shaping.

In hindsight, the appearance of the locality concept marked a tipping point in the transition from territorial to relational views of spatiality, with the latter becoming dominant by the 2000s. However, the debate about locality continues to be relevant, not so much for how it once shed light on local-scale geographies of economic restructuring but rather for what it now reveals about the circumstances under which certain intellectual themes and debates endure in the discipline while others are quickly discarded. Time will tell whether the locality concept will make a return to geography and, if so, in what forms and under what sorts of circumstances. The pendulum of spatial intellectual thought might yet swing back toward locality (as well as to its sister concepts of place, territory, and scale), at the expense of the current interest in globalization (and corresponding ideas of site, relational space, and flat ontology).

Andrew E. G. Jonas



See also **Chorology; Cultural Landscape; Idiographic; Massey, Doreen; Palimpsest; Place; Regional Geography; Regions and Regionalism; Relative/Relational Space; Scale, Social Production of; Smith, Neil; Territory**

Further Readings

- Cooke, P. (1987). Clinical inference and geographic theory. *Antipode*, 19, 69–78.
- Jonas, A. (2006). Pro scale: Further reflections on the scale debate in human geography. *Transactions of the Institute of British Geographers*, 31, 399–406.
- Massey, D. (1991). The political place of locality studies. *Environment and Planning A*, 23, 267–281.
- Smith, N. (1987). Dangers of the empirical turn: The CURS initiative. *Antipode*, 19, 59–68.



LOCALLY UNWANTED LAND USES (LULUs)

The acronym LULU stands for locally unwanted land use—a facility whose siting is resisted by local residents. Typically consisting of hazardous waste repositories, landfills, power plants, highways, and other projects that may pose an environmental or health risk, LULUs may also be prisons, low-income housing, shelters, treatment centers, and other facilities perceived as lowering property values and posing a security risk. A LULU may also be a facility that is resisted due to racial prejudice. LULUs are closely linked to the more common acronym NIMBY (not in my backyard), a term referring to the common position taken by local residents when faced with a LULU.

Geographers and planners take a particular interest in LULUs, because resistance to them illustrates the dynamics of political conflict in urban space. While geographers are more inclined to address the structural conditions giving rise to the LULUs and the NIMBY response, it generally falls to planners to suggest ways to overcome this resistance through measures such as public participation in decision making, risk communication, “fair-share” allocation, mediation, compensation, negotiated settlement, and, when all else fails, outright preemption by higher levels of

government. Justification for public intervention comes through portrayal of local resistance to a public good as parochial and self-serving, typically under the assumption that there is a geographic dichotomy between parochial economic self-interest and regional public goals.

However, beginning in the late 1970s, a critique of this common understanding emerged from environmental and local activists addressing the subset of LULUs involving health threats. They suggested that the term NIMBY presupposed acceptance of the need for the LULU, implying that the facility should be located *somewhere*, just not in “my” backyard, when the facility should be viewed as unacceptable *anywhere*. Such resistance has been particularly noticeable in low-income neighborhoods and communities of color where waste repositories have been proposed. Thus, a more appropriate term for resistance to the LULU in this instance would be NIABY, or not in anybody’s backyard. The latter suggests elimination of the facility up front rather than accommodation of the offending practice and/or its waste by-products.

Recognition of environmental LULUs and the organized resistance to them has increased since the 1950s due to the post–World War II introduction of chlorinated hydrocarbons in the production process, which are linked to health problems (e.g., at Love Canal and other Superfund waste disposal sites). Another issue concerns the spatial separation of the site of production from residential areas, an idea dating from the late 19th century, in which homes are often portrayed as a refuge from the consequences of factories and other sites of work. Such separation is now under attack as the continued expansion of the forces of production, and the ensuing negative externalities of production (e.g., noise, waste, and pollution), has invaded these residential sanctuaries.

Michael K. Heiman

See also **Externalities; Love Canal; Not in My Backyard (NIMBY); Urban Solid Waste Management**

Further Readings

- Heiman, M. (1990). From “not in my backyard!” to “not in anybody’s backyard!” *Journal of the American Planning Association*, 56, 359–362.



Popper, F. (1981, April). Siting LULUs. *Planning*, 47, 12–15.

Schively, C. (2007). Understanding the NIMBY and LULU phenomena: Reassessing our knowledge base and informing future research. *Journal of Planning Literature*, 21, 255–266.



LOCATION-ALLOCATION MODELING

Though often used to refer to more general location-theoretic constructs, location-allocation modeling is a specific class of spatial optimization model where two simultaneous decisions are being made about where a facility should be sited (location) and what entities/areas should be served by the facility (allocation). Geographers have made important and sustained contributions to this area of research, developing and extending mathematical models, devising effective solution techniques, and applying models to public and private sector planning problems. Prominent geographers working in the area include Charles ReVelle, Gerard Rushton, Michael Goodchild, and Richard Church, among others.

A location-allocation model locates a multiple number of facilities and allocates the demand served by these facilities so that access and/or system service is as efficient as possible. This definition recognizes the significance and necessity of optimizing a system on the whole in a coordinated fashion, in contrast to one-at-a-time addition of a facility when multiple facilities are sited.

Many different types of facilities are possible in a location-allocation model. In retail, a facility could be an outlet, store, warehouse, restaurant, and so on. Facilities associated with emergency services could include not only fire and police stations but also ambulances, warning sirens, disaster relief centers, and so on. Potential facilities could be schools, libraries, or even public pools and salt pile storage sites for road maintenance. Depending on the type of facility, examples of demand to be served could be stores receiving merchandise from a warehouse, neighborhoods being serviced by a school, or homes/businesses

being protected by a fire station. Given the facility and demand types, the location-allocation problem involves selecting facility sites (location) and prescribing which demand is served by what facility (allocation). Of interest is accomplishing the location and allocation in such a manner that system service is as good and/or efficient as possible. System service then is characterized in terms of economic efficiency.

A location-allocation model is a mathematical representation of a planning problem consisting of decision variables associated with location and allocation choices, the objective(s) to be optimized, and the constraining conditions that must be satisfied. The model is specified in algebraic terms as a series of linear and/or nonlinear functions. Some prominent location-allocation models include the simple plant location problem, the p -median problem, the capacitated plant location problem, and the transportation p -median problem. Of course, there are many other location-allocation models, some extensions of these basic problems.

There are two primary variants of location-allocation models, distinguishable by their spatial representation of potential facility locations. One variant allows facilities to be located anywhere in continuous space. Facilities are therefore considered to be feasible at any location in space. Travel through space is often assumed to occur in a readily defined manner, such as Euclidean or rectilinear distance. In contrast, the other primary variant assumes that facilities are only allowed at discrete locations. That is, facilities are limited to a finite set of potential sites. As a result, travel through space is assumed to take place through a transportation network consisting of nodes and arcs. Other distinctions of location-allocation models include capacitated versus uncapacitated facilities, stochastic versus static demand, and complete versus partial assignment of demand to a facility.

Depending on the location-allocation model of interest, the problem solution may be accomplished by applying an exact or heuristic approach. An exact solution approach is one where an optimal solution is guaranteed by the method. That is, it is possible to prove that the solution is the best possible and no other solution exists that is better. Examples of exact approaches include enumeration, linear programming, and integer-linear



programming. A heuristic solution approach, on the other hand, is one where feasibility is usually ensured (all constraints satisfied), but there is no guarantee of its quality. More specifically, a heuristic is a strategy-based approach that typically employs rules-of-thumb procedures to obtain a solution, preferably of high quality. Examples of successful heuristics applied to location-allocation models include alternating heuristic, interchange, simulated annealing, tabu search, genetic algorithms, and so on. A general finding is that exact approaches typically require considerable computational effort and can be limited in the size of problems that can be solved, whereas heuristic approaches are often capable of deriving good solutions quickly but with uncertainty about solution quality.

Location-allocation models continue to have practical relevance in planning, policy, and decision making but are also viewed as important because they can be used to represent other location-theoretic constructs, such as coverage models. Nevertheless, location-allocation models have proven to be challenging to solve in practice. Part of this difficulty is attributable to the complexities of dealing with geographic space and spatial relationships, but it is also the result of large problems being associated with better-quality, more detailed spatial information managed using geographic information systems (GIS). The continuing challenges in location-allocation modeling will be its use in new application contexts, the extension of existing models to account for enhanced problem realities, the development of heuristics to solve larger planning problems more quickly and efficiently, and further development of exact approaches for model solution.

Alan T. Murray

See also **Models and Modeling; Quantitative Methods; Spatial Optimization Methods**

Further Readings

Church, R., & Murray, A. (2008). *Business site selection, location analysis and GIS*. New York: Wiley.

Cooper, L. (1963). Location-allocation problems. *Operations Research*, 11, 331–343.

Hakimi, L. (1964). Optimum locations of switching centers and absolute centers and medians of a graph. *Operations Research*, 12, 450–459.

ReVelle, C., & Swain, R. (1970). Central facilities location. *Geographical Analysis*, 2, 30–42.



LOCATION-BASED SERVICES

Location-based services (LBSs) have emerged primarily due to the availability of, and the possibility of coupling, “location,” “mobility,” and “context” information. Of these, location and mobility play central roles, and context describes the environment for the process of decision making in LBSs. LBSs are different from conventional geographic information systems (GIS) in that they feature mobility and the possibility of position determination while mobile. In other words, spatial decision making in LBSs is based on mobility and position, which involves dynamic locations of people and objects. An example of LBS is a navigation system in which a user’s location (“location”) is continuously (“mobility”) computed for the purpose of finding routes (“context”), among other things. LBSs, in general, could provide answers to questions such as the following:

- Where am I located at any given time with respect to another given location?
- Where are the locations of given people/objects with respect to my current location?
- Where is the nearest location of a specific person/object with respect to my current location?
- Is my location within a given proximity to a certain person/object?

As is clear from the above questions, LBSs must be able to provide “location” and “mobility” information and use them in a “context” to reason and make decisions.

Figure 1 highlights the types of features LBSs support and the types of technologies they use. The green circle highlights the features typically supported by LBSs, which include localization,

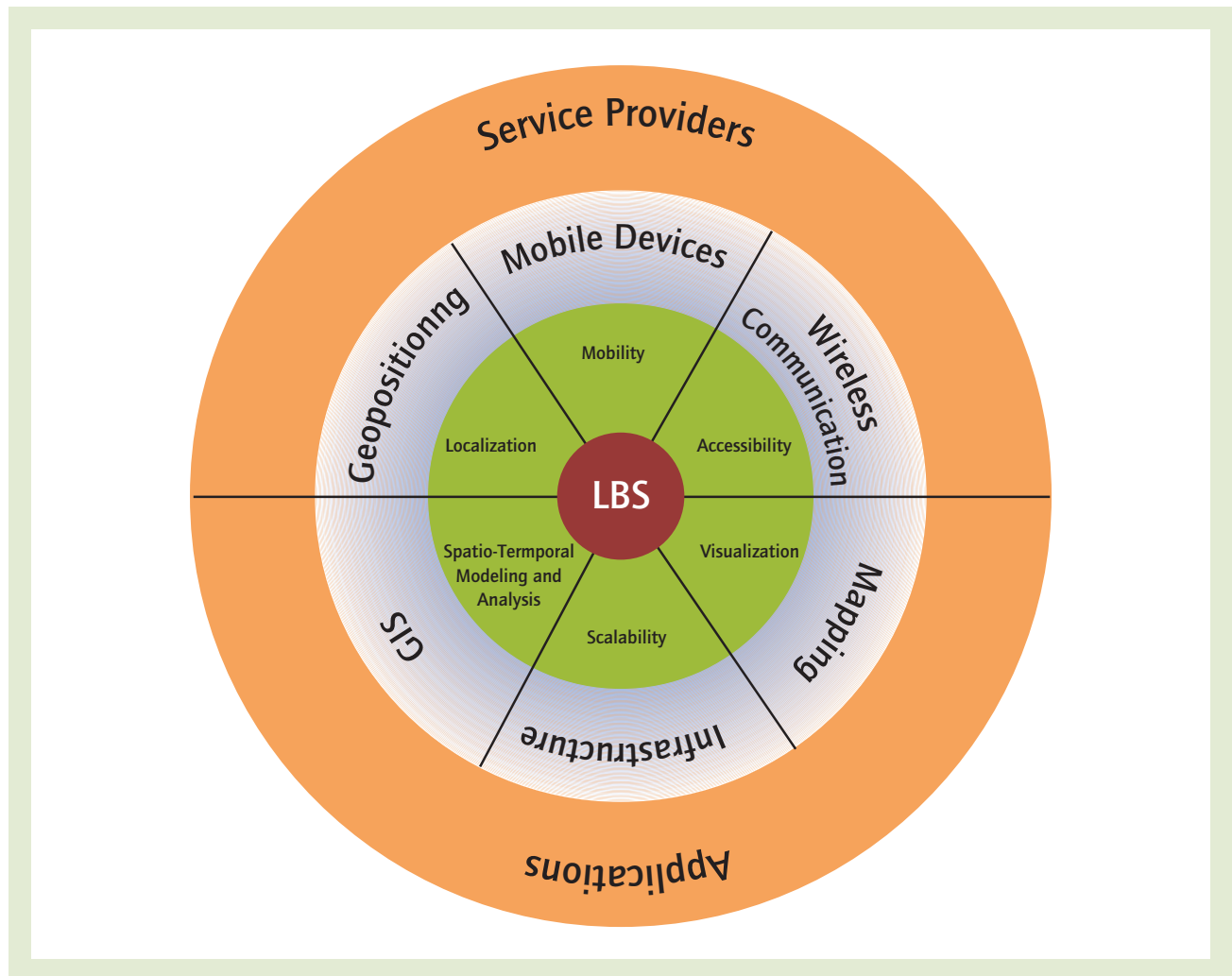


Figure 1 LBS features and technologies

Source: Author.

mobility, accessibility, visualization, scalability, and spatiotemporal modeling and analysis. The localization feature is for finding a user's location, which could be requested at fixed intervals or on the fly. It is worth noting the difference between position and location, as well as their relation to localization in general. By *position*, we refer to coordinates (e.g., latitude and longitude) as computed by a positioning technology. By *location*, we refer to a place to which the position belongs. For example, the coordinates of a car as determined by a navigation system give the position of the car and the road segment constituting the location of the car. The access feature is for accessing information and functionality remotely from the

user's current location. The visualization feature is for presenting location and context in a meaningful way to the user. The scalability feature guarantees solutions with acceptable response times regardless of how much information is being computed for decision making. For example, a task in one location may require a much larger amount of data for computation and visualization than would be needed in another location. The spatiotemporal modeling and analysis support efficient reasoning and decision making at a given location and within a user-specified context.

The blue circle in Figure 1 highlights the common technologies on which LBSs are based. Each category of technologies is for implementing one



of the features in the green circle. Geopositioning technologies are for implementing the localization feature—that is, finding the position and location of people and objects. The types of geopositioning technologies used in LBSs include global positioning system (GPS), radio frequency identification (RFID), and Wi-Fi, among others. Most such technologies provide position information that, depending on the application/service at hand, could be converted to location. Mobile devices are used for implementing the mobility feature and include primarily personal digital assistants (i.e., handheld computers) and cell phones, especially smart phones. Wireless communication allows LBS users to access data and other relevant resources remotely from various sources, such as LBS providers and third-party vendors. Mapping is a predominant form of visualizing information. *Infrastructure* refers to the underlying set of platforms and components required for the LBS. One example of such a LBS platform would be the Android system by Google. GIS, general purpose and specialized, is used for spatiotemporal modeling and analysis and for developing or customizing tools to support LBS decision making.

While LBS applications and services share common features and technologies, the implementation of each LBS application or service may require a unique infrastructure as well as specific sets of spatial and nonspatial data to meet the requirements of the underlying application or service. For example, an LBS used for advertising coupons for customers requires a different infrastructure and different sets of spatial and nonspatial data from an LBS that is used for education.

Since the early developments in LBSs, applications and services based on LBSs have been emerging continually and rapidly. Currently, such applications and services include the health, environment, education, and marketing domains, among others.

A recent trend has been to merge LBSs with social networks (SNs), resulting in a new research thrust called *location-based social networks* (LBSNs). LBSNs are social networks that can provide location-based information without computation but, instead, through the experiences of those who are trusted members in the network and who are willing to share their

location-based experiences. An example in health care is the work by Elizabeth LaRue and her colleagues called COMPANION; members of the network can assist a member suffering from depression. Another example of LBSN is the recent work by Hassan Karimi and his colleagues, where a framework for social navigation network (SoNavNet) can assist members of the network with navigation, points of interest, and route recommendations that are based on members' experiences.

Hassan A. Karimi

See also **Dynamic and Interactive Displays; Global Positioning Systems (GPS); Mobile GIS; Mobility**

Further Readings

- Karimi, H. A., & Hammad, A. (Eds.). (2004). *Telegeoinformatics: Location-based computing and services*. Boca Raton, FL: CRC Press.
- Raper, J., Gartner, G., Karimi, H. A., & Rizos, C. (2007a). Applications of location-based services: A selected review. *Journal of Location Based Services*, 1, 89–111.
- Raper, J., Gartner, G., Karimi, H. A., & Rizos, C. (2007b). A critical evaluation of location based services and their potential. *Journal of Location Based Services*, 1, 5–45.



LOCATION QUOTIENTS

Location quotients are a simple, widely used technique, primarily in economic geography, to measure how specialized the structure of the economy of a given study region is in comparison with a reference region (typically the country). They compare regional structural composition with that of the reference region by assessing an industry's share of a total regional economy relative to its share nationally. Usually, location quotients use employment data, although they can be used with any other kind of relevant information, such as output. Thus, in its simplest terms, a location quotient (LQ) can be defined as



$$LQ = \frac{\frac{\text{Regional industrial employment}}{\text{Total regional employment}}}{\frac{\text{National industrial employment}}{\text{Total national employment}}}$$

In mathematical terms,

$$LQ = \frac{e_{ir}/e_{tr}}{e_{ib}/e_{tb}},$$

where

- e_{ir} = employment in industry i in region r ,
- e_{tr} = total employment in region r ,
- e_{ib} = employment in industry i in reference region b , and
- e_{tb} = total employment in reference region b .

For example, to compare how specialized the economy of New York City is in banking in relation to that of the United States (base region), say that we are given the following hypothetical data:

- $e_{b,ny}$ = Employment in banking in New York City
= 350,000.
- $e_{t,ny}$ = Total employment in New York City
= 3,000,000.
- $e_{b,us}$ = Employment in banking in the United States
= 12,000,000.
- $e_{t,us}$ = Total employment in the United States
= 120,000,000.

Thus, New York's location quotient in banking would be

$$LQ_{b,ny} = 350,000/3,000,000 = 0.1166 = 1.166.$$

And the location quotient in banking for the United States would be

$$LQ_{b,us} = 12,000,000/120,000,000 = 0.10 = 1.00.$$

Thus, New York City's location quotient in banking indicates that it is more specialized (by 16%) in this industry than is the country as a whole.

A location quotient greater than unity indicates that the region is more specialized in a particular industry than is the country and is likely exporting the output of the industry; that is, it reflects a comparative advantage or economic base. Employment in excess of that necessary to yield a location

quotient of 1.0 is assumed to be driven by regional exports; high location quotients are thus associated with economic multiplier effects. A quotient equal to 1.0 indicates that the region and the country are equally specialized; that is, the region is neither importing nor exporting output in that sector. A quotient less than 1.0 indicates a region that is less specialized than is the country; that is, its degree of specialization is unlikely to meet local demand, and it is likely importing output in the industry. Obviously, if regions are more specialized in some sectors ($LQ > 1.0$), they will be less specialized in others ($LQ < 1.0$). The choice of reference region (e.g., a county vs. state or country) is important, for it can affect the outcome significantly. Such an approach assumes that local productivity equals that of the country as a whole; if the region enjoys a comparative advantage in the industry under question, it may be more productive than the country as a whole.

Location quotients can be mapped at a variety of spatial scales and over time to yield a simple portrait of how regional diversity and complexity change geographically and temporally. Maps of comparative advantage, for example, use location quotients. Obviously, such a measure is relatively crude, and more sophisticated measures of regional specialization exist. Nonetheless, location quotients are widely used in many urban planning and economic analysis circles because they yield a convenient and readily understandable portrait of regional specialization.

Barney Warf

See also **Comparative Advantage; Economic Base Analysis**

Further Readings

Economic Modeling Specialists Inc. (n.d.).

Understanding location quotients. Retrieved May 13, 2009, from www.economicmodeling.com/resources/wp-content/uploads/2007/10/emsi_understandinglq.pdf

Leigh, R. (1970). The use of location quotients in urban economic base studies. *Land Economics*, 46(2), 202–205.



LOCATION THEORY

Location theory refers to a conceptual perspective widely used in economic geography during the 1950s and 1960s, primarily during the reign of the philosophy of logical positivism. Location theory exemplified geography as a spatial science, primarily concerned about abstract laws applicable under all circumstances.

Location theories in various forms shared a common focus on the centrality of models as bridges between the empirical world and the theoretical world of prediction and explanation. Models distill the essence of the world, revealing causal properties via simplification. A good model is simple enough to be understood by its users, representative enough to be used in a wide variety of circumstances, and complex enough to capture the essence of the phenomenon under investigation. Typically, models were developed, tested, and applied using quantitative methods. This approach to geography relied on a Cartesian view of absolute space, generally in the form of an isotropic plain in which space is reduced to distance and spatial variations only occur through transport costs. Essentially, location theory reduced geography to a form of geometry, a view in which spatiality is manifested as surfaces, nodes, networks, hierarchies, and diffusion processes. In short, this theory presented a view of space devoid of social relations.

Location theory developed close ties to neo-classical economics, spatializing economic relations through the use of cost-minimization and profit- and utility-maximization models. Often, it began with the assumption, and reached the conclusion, that unfettered markets were Pareto-optimal in nature. In some cases, location theory turned to cognitive psychology and behavioral geography to incorporate probabilistic models of behavior under uncertainty in studies of spatial cognition, decision theory, and suboptimality. This line of thought has been central to the discipline of regional science, a hybrid of economic geography and spatial economics.

Although it arose in popularity in the 1950s and 1960s, location theory drew on an older tradition of German economic geography that extended to the early 19th century. For example, Johann Henrich von Thünen (1783–1850), a

wealthy Prussian landlord, bought a 1,146-acre estate at Mecklenburg in 1810 and compiled data in 1821 for *The Isolated State*, the first model of land markets, which subsequently had important effects on studies of early land use (see Figure 1). In 1909, Alfred Weber (1868–1958), younger brother of the famed sociologist Max Weber, inspired the first industrial location theory. Weberian analysis centered on transportation costs, arguing that firms located where the sum of transporting inputs and outputs was minimized, leading them to be resource or market oriented. Walter Christaller (1893–1969) wrote his enormously influential dissertation *Central Places in Southern Germany*, in 1933, which founded central place theory, the conception of city systems in terms of a hierarchy of market areas distributing goods and services. This view of city systems posits them as retail centers (central places) that distribute goods and services to their surrounding hinterlands. Each good has a threshold, or minimum market size, and a range, or maximum distance consumers will travel to purchase it. A hierarchy of goods and services leads to a hierarchy of central places, with lower-order ones nested within the hinterlands of higher-order ones. Assuming an isotropic plain, a hexagonal network of market areas should emerge. Central place theory became the basis of most urban geography in the late 1950s and 1960s. Finally, August Lösch (1906–1945) contributed to location theory with the publication of *The Economics of Location* in 1939.

Location theorists developed and applied a variety of models to understand economic and demographic phenomena such as urban spatial structure, the location of firms, the influences of transportation costs, technological change, migration, and the optimal location of facilities. One group, gravity models, originated in Newtonian physics and became a highly successful way of modeling spatial interaction and predicting (though not necessarily explaining) patterns of interurban migration. Gravity models are widely used in studies of commuting and shopping, for traffic planning, and for models of transportation and communication. Similarly, network and graph theory became a useful way of mathematically describing the essential properties of networks of any kind, noting the accessibility of different nodes. It became a useful way of approaching transportation problems (e.g.,

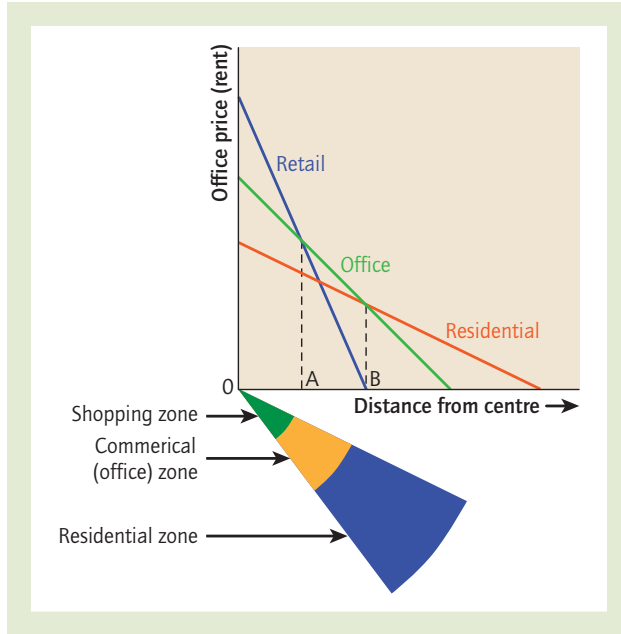


Figure 1 The von Thünen model, developed in the early 19th century, has long played a central role in models of land use and continues to be useful today as a means of explicating how land markets maximize rents (profits). Although originally construed as means of analyzing agricultural land use patterns, it also has broad applicability to urban land markets, as illustrated by the varying uses competing for high-rent land at the urban core and progressively lower-rent land with distance toward the periphery.

Source: Figure 8, p. 50, from *A Dictionary of Geography, Second Edition*, by Susan Mayhew. Copyright © Susan Mayhew 1992, 1997, 2004. Reprinted with permission of Oxford University Press. All rights reserved.

the famous “traveling salesman” problem). Increasingly sophisticated mathematics invoked linear programming algorithms to develop location-allocation models, a convenient way to find optimal locations (e.g., for factories or stores) by minimizing transport costs subject to some constraint (e.g., total travel costs or time). Combined with geographic information systems (GIS), this approach is widely used in engineering and site location studies, such as for public services.

A somewhat different category of location theory concerned the process of spatial diffusion. Introduced by the famous Swedish geographer Torsten Hägerstrand, this approach was concerned with the ways in which innovations (e.g., new technologies,

information, and diseases) moved through time and space. Diffusion was held to be either contagious or hierarchical. The use of so-called Monte Carlo models introduced probability theory into models of the innovation adoption process. Originally designed to maximize the adoption of new techniques for development purposes, the topic is useful for epidemiologists and in marketing, where it is applied to analyses of consumer behavior.

There is no doubt that location theory made great contributions to human geography. It popularized the use of rigorous quantitative techniques such as multiple regression, log-linear modeling, factor analysis, discriminate functions, and entropy maximization and minimized armchair speculation by asserting the importance of testable hypotheses. Its models have found a wide array of applications, including traffic planning and retail trade analysis, and shaped development strategies during the heyday of modernization theory. Location theory uncovered a great deal of structure, pattern, and regularity in human spatial behavior, shedding considerable light on how markets function and allowing alternative scenarios to be envisioned and assessed. Coupled with GIS, this approach raised the analytical sophistication of economic and urban geography significantly.

Ultimately, however, location theory declined in popularity as logical positivism fell from favor. Its central problems included the fetishization of quantitative approaches; its increasingly unrealistic assumption of an objective, value-free observer; and its silence concerning social relations and social structures. The ontology of location theory is essentially atomistic; that is, it reduces the social to the individual through a process often called *methodological individualism* and, in so doing, tears variables from their social context. The focus on models led location theorists to ignore wider issues of class, gender, power, and struggle, positing instead an antiseptic, ahistorical, and sterile world of social order but not social change. Because it did not take subjectivity seriously, it deprived itself of any way to include human consciousness in all its complexity and richness. Location theory thus focused on appearances rather than causes, forms rather than processes, naturalizing the status quo and leaving itself incapable of being critical.

Barney Warf



See also **Applied Geography; Central Place Theory; Diffusion; Economic Geography; Factors Affecting Location of Firms; GIS in Transportation; Gravity Model; Growth Poles; Hägerstrand, Torsten; Innovation, Geography of; Input-Output Models; Logical Positivism; Lösch, August; Models and Modeling; Nomothetic; Quantitative Methods; Quantitative Revolution; Regional Science; Spatial Analysis; Spatial Interaction Models; Thünen Model; Tobler, Waldo; Transportation Geography; Urban Geography; Weber, Alfred**

Further Readings

- Harrington, J., & Warf, B. (1994). *Industrial location: Principles, practice, and policy*. London: Routledge.
- Nickel, S., & Puerto, J. (2005). *Location theory: A unified approach*. Amsterdam: Springer.



LOGICAL POSITIVISM

Logical positivism (often simply called *positivism*) has long been, and still remains, an enormously influential philosophy in geography and many other disciplines. It is commonly associated with the scientific method, which holds that scientific knowledge can be attained only through rigorous logical analysis and empirical evidence. It remains the dominant guiding epistemology of natural and physical scientists, although it has profoundly affected the history and contents of many social sciences as well.

Historical Origins

Although its history can arguably be traced as far back as classical Greece, logical positivism formally originated in the 1920s in Austria and Germany. Among its founding leaders were Rudolf Carnap, Moritz Schlick (founder of the Vienna Circle), Hans Reichenbach (founder of the Berlin Circle), Carl Hempel, Otto Neurath, Victor Kraft, Kurt Grelling, Philipp Frank, and Herbert Feigl. While the early logical positivists combined the logical concepts of Ernst Mach with the ideas of

Friedrich Ludwig Gottlob Frege and the British philosopher and mathematician Bertrand Russell, they were also inspired by Ludwig Wittgenstein's notion that philosophy's role was to provide a logical clarification of thought. As such, metaphysical speculation, that is, knowledge not grounded in logic and empirical evidence (such as religion), is automatically deemed unscientific. The growth of logical positivism in the United States came about during the 1930s. Many of the scholars behind the movement in Europe immigrated to the United States, where their ideas were well received. For example, in the late 1930s, Feigl, Frank, Carnap, and Hempel relocated to the University of Iowa, Harvard University, the University of Chicago, and the City College of New York, respectively.

Tenets of Positivism

Positivism differs from logical positivism in that the former originated from Auguste Comte during the period from 1798 to 1857 and aims to distinguish science from both metaphysics and religion. The two terms, however, are often used interchangeably. Logical positivism distinguishes mathematics and logic, and the analytical statements that can be formed from them, from empiricism. Positivism, more so than logical positivism, can be based on empirically accessible experiences of the world. Logical positivists hold that scientific knowledge does not rise solely from experience (i.e., positivism differs from empiricism). Logical positivists privileged mathematics in scientific decision making as the surest way to analyze data. Logical positivism recognizes only two types of scientific reasoning. The first is based on statements that can be verified empirically (a posteriori). The second is based on analytical statements of logic and mathematics that are deemed to be true or false by their mere definition and deduction (a priori).

Logical positivism encompasses two important concepts dealing with the structure of scientific theories: the differences between observational and theoretical statements (where truth is the correspondence between them) and between synthetic and analytical statements. These differences are used to explain deductive reasoning in scientific theorizing.

Positivists attempt to construct universal laws of explanation based on generalizations of empirical



patterns. For example, if Consumer A lives closer to a mall than Consumer B, then he or she is more likely to shop at that mall than Consumer B. Similarly, people tend to migrate more frequently over shorter distances than over longer ones. Because distance imposes costs on consumers and migrants, they collectively will tend to travel less frequently the farther away they live. From such observations, distance decay becomes an observed “law” of consumer and migrant behavior. All these notions combine to create “a Truth,” as opposed to “one truth” among many.

Advancements in logical positivism were based on two distinctions. First, analytical statements of truth are true *a priori*, that is, by their definition and association with logic, the formal sciences, and mathematics. Logical knowledge from mathematics, for example, is reducible to formal logic. Second, empirical statements of truths are empirically proven through hypothesis testing. Empirical knowledge includes physics, biology, chemistry, and the other natural sciences.

Since the rise of logical positivism, a significant advance was the rise of Karl Popper’s principle of falsification: Popper argued that science proceeds not by verifying hypotheses but by falsifying them. Only statements that can be falsified empirically are held to hold scientific value, and science proceeds not by verifying true statements but by eliminating false ones. Logical positivists are well-known for their emphasis on verification in that ideas or propositions go through a finite procedure to determine if they are true or false. Metaphysics and religion do not follow the same procedures of “truth telling.”

Critics argue that the verifiability criterion adopted in logical positivism is itself nonverifiable. Another criticism of logical positivism was that observations are inevitably couched in theoretical terms. That is, data are always theory laden (but not theory determined); the strict separation of facts and values is thus difficult, if not impossible, to sustain. There is also concern that truth changes as scientific paradigms shift: Positivism’s reliance on the correspondence theory of truth ignores the cultural and historical contexts in which true claims are established. As knowledge has increasingly come to be seen itself as a social construction, positivism’s portrayal of Truth as external to the social world came under mounting criticism.

Positivism in Geography

Logical positivism’s greatest influence in geography is associated with the quantitative revolution of the 1950s and 1960s, which included a heavy emphasis on laws and theories by geographers and a predilection for empirically based models. Traditional geography consisted almost entirely of regional description. The maturation of the logical positivist movement in the 1950s confronted geographers with the task of deciding in which direction to take the discipline, a conundrum exemplified in the adversarial stands of Richard Hartshorne and Fred Schaefer. Hartshorne advocated descriptive (traditional) geography, while Schaefer pushed for a new, scientific geography. Schaefer attacked Hartshorne’s empiricist emphasis on regional distinctions and instead favored nomothetic, lawlike statements to explain and predict spatial patterns. This attack encouraged geographers to rethink the direction of the discipline in a way that made it more theoretical and mathematical. As geography became more quantitatively based during the quantitative revolution of the 1950s and 1960s, it became heavily grounded in scientific rules of knowledge collection (e.g., random sampling) and hypothesis testing. Statistical techniques and abstract scientific models and theories evolved rapidly in number and sophistication.

The positivists were largely responsible for the introduction of numerous models into human geography, particularly the urban and economic parts of the discipline, including various quantitative models of migration (gravity models), diffusion of innovations, central place theory, location-allocation models, network analysis and graph theory, multivariate statistical techniques, and input-output models. However, it is now recognized that quantitative analysis and positivism are not synonymous (e.g., one can be a nonpositivist quantitative analyst, such as a quantitative Marxist).

Positivist thinking is often associated with neo-classical economic modeling in geography. In this regard, techniques have traditionally been borrowed from other disciplines and used to explain spatial processes and relationships. For example, the bid-rent curve, which originated in von Thünen’s famous land use model, is an example of simple, quantitative economic modeling. Waldo Tobler may have been the first to create a law (“Tobler’s First Law”) in geography based on gravity models,



using mathematical procedures to show that all phenomena are interrelated and that nearer things are more closely related than are distant things. Tobler's model has its inspiration in Newton's law of universal gravitation and has helped create statistical procedures unique to geography, known as geostatistics. Positivism was also instrumental in the growth of disciplines such as regional science.

The Decline of Positivism in Geography

Positivism is considerably less popular in geography today than it was several decades ago. Several schools of thought challenged its hegemony, including behavioralism, Marxism, and humanism. The notion that positive spatial science could provide realistic models was attacked because so many oversimplified models ignored historical context, social relations, power and conflict, and the dynamics of individual behavior. Marxists alleged that positivism's emphasis on positive rather than normative standards led it to be overly apolitical, antiseptic, and incapable of critically addressing pressing social problems. Quantitative models were held to be able to describe the world but not explain it, focusing on patterns but not processes. Positivism's emphasis on prediction as the hallmark of science was also criticized; prediction in the social sciences has always been problematic, and even in some physical sciences (e.g., ecology, geology), prediction is of limited value. The growth of humanistic thought led to a further critique of positivist models in geography as inappropriate when applied to the behavior of thinking human beings, with critics noting that the domains of emotion and subjectivity were not captured by quantitative analysis: In short, positivism did not provide an adequate account of the human subject and consciousness. Finally, the positivist assumption of a value-free, objective observer (the myth of "immaculate perception") was severely criticized; postpositivist thought emphasizes the embeddedness of knowledge within its social context. Nonetheless, despite these criticisms, logical positivism still lingers in human and especially physical geography, and it has had enormous impacts on the trajectory of geographic inquiry.

Brian Ceh

See also **Empiricism; Epistemology; Gravity Model; Human Geography, History of; Input-Output Models;**

Location Theory; Models and Modeling; Morrill, Richard; Nomothetic; Quantitative Methods; Quantitative Revolution; Regional Science; Schaefer, Fred; Spatial Interaction Models; Tobler, Waldo

Further Readings

- Friedman, M. (1999). *Reconsidering logical positivism*. Cambridge, UK: Cambridge University Press.
- Harvey, D. (1969). *Explanation in geography*. New York: Edward Arnold.
- Johnston, R., & Sidaway, J. (2004). *Geography and geographers: Anglo-American human geography since 1945*. London: Edward Arnold.
- Mayhall, C. (2002). *On logical positivism*. Florence, KY: Wadsworth.
- Schaeffer, F. (1953). Exceptionalism in geography. *Annals of the Association of American Geographers*, 43, 226–249.



LONGITUDE

Longitude is the angular distance around Earth from a reference plane that defines a prime meridian. A meridian is synonymous with a line of longitude. Some conventions apply to angular expressions of longitude. One is that the angle is expressed counterclockwise with respect to the view from the North Pole to the South Pole. Sometimes, the angle from the zero meridian is stated as a value from 0° to 360°. The other convention is to express the longitude as a negative value from 0° to –180° west from the prime and as a positive value from 0° to +180° east of the prime. Longitude can be expressed in a variety of units (radians, grads, semicircles, arc seconds, or mils) and formats (+/– or E/W, to indicate the hemisphere; degrees: minutes and fractional minutes; or degrees: minutes: seconds and fractional seconds).

The determination of longitude on the surface of Earth is difficult because there is no physical meaning to any prime meridian. The prime meridian has been variously located in Amsterdam, Athens, Beijing, Djakarta, Berlin, Bern, Brussels, Copenhagen, the Canary Islands, Helsinki, Istanbul,



Lisbon, Madrid, Moscow, Oslo, Paris, Rio de Janeiro, Rome, St. Petersburg, Stockholm, Tokyo, Washington, and other places. It was not until the 1884 Meridian Conference that Greenwich, England, was selected as a suitable common prime meridian for the 22 attending countries, a decision based on the dominance of British charts in navigation. The Greenwich prime was defined as the center of the Royal Observatory transit telescope. Since then, most geodetic datums in use place the actual zero line of longitude a few tens of meters east or west of the original transit instrument. Even a datum used within Britain, such as the Ordnance Survey of 1936, places the zero line of longitude several meters away from the original Greenwich meridian. Without reference to a specific geodetic datum, longitude values will point to different places on Earth.

Since the establishment of an implied zero meridian in the 1960s by the *Bureau International de L'Heure*, modern geodetic datums fix the zero line of longitude not with a single point or line but based on a network of observatories around the world with longitudes whose offset from zero is defined. Geodesists may base their zero line of longitude on the International Earth Rotation Service's International Terrestrial Reference Frame (ITRF), which is updated to a new version every few years to account for continental drift. Modern global geodetic datums, such as the World Geodetic System of 1984 (WGS-84), are occasionally reset to ITRF, slightly changing the location of the zero line of longitude.

Peter H. Dana

See also **Datums; Earth's Coordinate Grid; Equator; Latitude**

Further Readings

- Cross, P. A. (1990). Position: Just what does it mean? *Journal of Navigation*, 43(2), 246–262.
- Howse, D. (1980). *Greenwich time and the discovery of the longitude*. Oxford, UK: Oxford University Press.
- Sobel, D. (1998). *Longitude*. London: Fourth Estate.

LOS ANGELES SCHOOL

In the late 20th century, an unusually large and fecund group of loosely affiliated, Marxist-inspired urban and economic geographers began to form in Southern California, particularly at the University of California at Los Angeles (UCLA) and the University of Southern California. This group, including notables such as Michael Dear, Edward Soja, Allen Scott, Michael Storper, and Mike Davis, played a key role in shaping urban political economy and injecting space into debates about the changing structure of capitalism. In particular, it was instrumental in theorizing the urban division of labor under post-Fordism or flexible production and, more broadly, in injecting space into the heart of all social analysis, helping dethrone historicism.

The so-called Los Angeles School upheld the greater conurbation of the region as the prototype of postindustrial, polycentric urbanization under advanced, globalized capitalism. This view was in contrast to the Chicago School of the early 20th century, which was located within, and concentrated on, the epitome of industrialized, unicentric urbanization embedded within a largely national market. In many ways, the school arose as an attempt to make sense of the bewildering changes unfolding across the region as Los Angeles was repeatedly reconfigured by massive social, technological, and spatial changes, which were generating a new urban regime of accumulation. Rather than an exception to long-held norms of urban analysis, Los Angeles became the new template for understanding other cities. Thus, for Soja, in a line used often in his works, “it all comes together in L.A.”; that is, Los Angeles is the exemplar of contemporary capitalism in all its gory complexity. As the ideas of the Los Angeles School became increasingly important in the discipline, other urban areas began to be dissected in similar terms. While it does not constitute a homogeneous whole—some doubt even the existence of such a school—certain commonalities run throughout.

Central to this line of thought was the primacy of production systems as the core of urban analysis, in contrast to the privileged status of individual decision making and residential space in both social ecology and neoclassical economic analyses. Scott's work laid the ground conceptually for the idea of



an urban division of labor organized around the input-output transactions of firms, which range from densely clustered, vertically integrated networks in the inner city to more dispersed, capital-intensive firms on the periphery. The historic shift into flexible production—a phenomenon identified rather early by some in the Los Angeles School—marked a significant transformation of firm organization and associated labor markets, ushering in broad-based changes in residential space, such as gentrification, and mounting social and spatial inequality, including homelessness. Intimately intertwined with this perspective was an account of the state, via various urban planning practices, as it accommodated the shifting imperatives of capital and sought to reign in the anarchy of the market. In this way, the Los Angeles School's view became an important stepping stone in the incorporation of regulation and regime theory, with close ties to subsequent work on world cities.

Moreover, this view noted, urban areas had become increasingly globalized—that is, situated within a worldwide division of labor or, more specifically, as a part of a global “necklace” of city-regions that propelled the international economy forward. Subsequent work elaborated on the role of interpersonal contact, face-to-face communications, and tacit knowledge in the creation of dense pools of firms locked into tightly bound networks. Firms and neighborhoods throughout Los Angeles, from the dream factories of Hollywood to the aerospace complex of Orange County to the immigrant clusters of Koreatown, were thus all simultaneously local and global, positioned between and across two scales that were more complementary than mutually exclusive.

For more culturally inclined scholars such as Michael Dear, Los Angeles exemplified postmodernism as an ideological stance and cultural practice, in contrast to the modernism of Chicago. Los Angeles was a pastiche, a complex text to be deconstructed, often with neologisms. The play of capital over space, and its relations with labor, generated a fragmented quilt of local communities, a leapfrogging checkerboard that defies easy generalization, and called for approaches that embraced the heterogeneity, hybridity, and fractionalized nature of urban space. Stepping aside from the convenient models of urbanism bequeathed by traditional urban analysis implied moving

beyond simple stereotypes about the Los Angeles region as a “set of suburbs looking for a city.” To quote Dear and Dahmann (2008), “In modernist urbanism, the impetus for growth and change proceeds outward from the city’s central core to its hinterlands. But in postmodern urbanism, this logic is precisely reversed” (p. 269). Thus, Los Angeles incorporated a diverse mix of architectural types, immigrant communities (notably including many Latinos and Asians rather than the traditional black-white chasm), political practices, cultural configurations, and lifestyles.

In offering this set of interpretations, the Los Angeles School did much more than simply substitute one model of urbanization for another (i.e., a Sunbelt version rather than a Midwestern one); rather, it redefined the meaning of the urban and recast the nature of urban theory itself.

Barney Warf

See also **Chicago School; Dear, Michael; Flexible Production; Industrial Districts; Scott, Allen; Soja, Edward; Storper, Michael; World Cities**

Further Readings

- Davis, M. (2006). *City of quartz: Excavating the future in Los Angeles*. New York: Verso.
- Dear, M. (Ed.). (2001). *From Chicago to L.A.: Making sense of urban theory*. Thousand Oaks, CA: Sage.
- Dear, M. (2003). The Los Angeles School of urbanism: An intellectual history. *Urban Geography*, 24(6), 493–509.
- Dear, M., & Dahmann, N. (2008). Urban politics and the Los Angeles School of urbanism. *Urban Affairs Review*, 44, 266–279.
- Dear, M., & Flusty, S. (1998). Postmodern urbanism. *Annals of the Association of American Geographers*, 88(1), 50–72.
- Scott, A. (1993). *Technopolis: High-technology industry and regional development in Southern California*. Berkeley: University of California Press.
- Scott, A. (2005). *On Hollywood: The place, the industry*. Princeton, NJ: Princeton University Press.
- Scott, A., & Soja, E. (1996). *The city: Los Angeles and urban theory at the end of the twentieth century*. Berkeley: University of California Press.



- Scott, A., & Storper, M. (1986). *Production, work, territory: The geographical anatomy of industrial capitalism*. Boston: Allen & Unwin.
- Shearmur, R. (2008). Chicago and LA: A clash of epistemologies. *Urban Geography*, 29(2), 167–176.
- Soja, E. (1996). *Thirdspace: Journeys to Los Angeles and other real-and-imagined places*. Oxford, UK: Blackwell.
- Storper, M., & Scott, A. (Eds.). (1992). *Pathways to industrialization and regional development*. Boston: Routledge.

LÖSCH, AUGUST (1906–1945)

The economist August Lösch was a major contributor to the formation of the body of knowledge combining geography and economics. With the geographer Walter Christaller, he made important contributions to the intellectual thread of location theory extending back to J. H. von Thünen and carrying forward to the formation of the multidisciplinary field of regional science.

Lösch's childhood years were spent in Heidenheim, Württemberg, Germany. He studied economics in Freiburg, Baden-Württemberg, Germany, with Walter Eucken (1891–1950) and later studied economics under the mentorship of Joseph Schumpeter (1883–1950) at Harvard University. Among Schumpeter's students were the economists James Tobin, Robert Heilbroner, Shigeto Tsuru, Nicholas Georgescu-Roegen, Abram Bergson, Paul Samuelson, and Robert Solow; the latter two received the Nobel Prize in Economics.

Schumpeter was important in August Lösch's intellectual development. Schumpeter wrote on the interdependence between demographic change, trade, economic development, and cycles of economic growth and on the importance of entrepreneurship in creating technical and financial innovations. Lösch's research dealt with the geospatial patterns of population, trade, and economic development. His most well-known contribution was *The Spatial Organization of the Economy* (1940). He acknowledged the

importance of the prior work of Christaller (1893–1969). Lösch generalized Christaller's work and explained it with formal economic logic. The contributions of both geographers stand in mutual support of each other.

Lösch developed his hypotheses in the logical positivistic style of the location analysis school pioneered by Johann Heinrich von Thünen (1783–1850). Lösch's conjecture was that spatial patterns of settlement can be described, and their interaction and location explained and predicted, based on their productive activities and their trade. He concluded, as had Christaller earlier, that in a spatial equilibrium, there would be a hierarchy of places. Higher-order places would produce goods and services that required greater numbers of people distributed over larger trade areas for their support. Lower-order places offer goods and services that require fewer people to be sustained. Lower-order places, with their smaller trade areas, are embedded among fewer higher-order places and their larger trade areas. Christaller's system of central places begins at the highest order, while Lösch's system begins at the lowest order.

Trade areas would arise in the shape of hexagons if the landscape were isotropic. Hexagons are the most compact of packable shapes. Christaller had shown that nodes of development are expected to arise on the apices, arcs, or interior of the trade area boundaries, depending on the initial assumptions of the model and characteristics of the landscape. Lösch demonstrated that the locations of Christaller's nodes were special cases of a more general geometry. Lösch's generalization predicted that surrounding a centrally located place, wedge-shaped zones of intensive higher development would arise, alternating with zones of comparatively sparse development. Because all places were geospatially connected, trade and people would naturally flow between the zones, but with the development advantage going to the zone that was "place rich."

Grant Thrall

See also **Applied Geography; Central Place Theory; Christaller, Walter; Location Theory; Logical Positivism; Models and Modeling; Thünen Model; Urban Hierarchy**



Further Readings

- Lösch, A. (1937). Population cycles as a cause of business cycles. *Quarterly Journal of Economics*, 51, 649–662.
- Lösch, A. (1954). *The economics of location*. New Haven, CT: Yale University Press. (Original work published in German in 1940)

LOVE CANAL

Love Canal, with its shocking images of toxic chemicals seeping into suburban basements and the emergency evacuation of a neighborhood, played a critical role in raising awareness of the dangers of industrial wastes. Love Canal was an abandoned canal in Niagara Falls, New York, where approximately 22,000 tons of chemical wastes were dumped in the 1940s and 1950s. After the dump's closure, a public elementary school, streets of modest single-family houses, and a public housing complex were built on and around the former canal. Over time, drums of chemical wastes began protruding through the soil, chemicals ponded on the surface, and choking odors filled basements and neighborhoods. When it grabbed national headlines in 1978, Love Canal dramatically increased the public's fear of chemical wastes, sparked the grassroots antitoxics and environmental justice movements, and led to the creation of stringent state and federal laws to address past contamination.

Hazardous Waste Management Before Love Canal

The first half of the 20th century witnessed explosive growth in the chemical industry as new chemicals were developed and production volumes increased dramatically. Unfortunately, some of the new organic chemicals were highly toxic and persistent in the environment. In the absence of federal hazardous waste regulations, the chemical industry often chose inexpensive waste disposal solutions such as open dumping or liquid-waste lagoons. Aware of toxicity issues, companies often attempted to control human

exposure through geographic isolation by fencing the disposal site, posting warning signs, and maintaining long-term trusteeship of the land. When that trusteeship broke down, situations such as Love Canal emerged.

Historical Geography of Love Canal

Love Canal, in the southeastern corner of Niagara Falls, was the site of William T. Love's failed attempt to generate hydroelectricity by connecting the upper and lower Niagara River, bypassing the Niagara Falls. Less than 1 mile of the canal was built before Love's financial backers dropped out, and he lost the site to mortgage foreclosure. In the 1920s, the canal was used as a municipal waste dump, and in the early 1940s, it was leased and eventually purchased by Hooker Chemical and Plastics Corporation (later Occidental Chemical Corporation) for chemical waste disposal. Between 1942 and 1952, Hooker Chemical drained the canal and dumped wastes containing at least 200 different toxic chemicals, including organic solvents classified as known or probable carcinogens, such as benzene, trichloroethylene, and tetrachloroethylene. In 1952, the dump was closed and covered with soil; in 1953, it was sold to the Niagara Falls School Board for \$1, along with a stern warning that chemical wastes were buried at the site.

Discovery of Contamination

Soon after residents moved into the neighborhood, there emerged isolated complaints of chemical odors or residues in basements and yards, along with minor explosions and spontaneous fires. Heavy precipitation in 1976 and 1978 brought rising water tables, spreading the buried chemical wastes. Environmental monitoring conducted by the State of New York and U.S. Environmental Protection Agency (EPA) confirmed the presence of hazardous chemicals in basements. Media attention, the frequent presence of environmental sampling crews, and a paralyzed real estate market led to calls for government intervention. Leading the call for help was neighborhood resident and grassroots activist Lois Gibbs, who circulated a petition, collected anecdotal evidence of serious health effects, and pressured reluctant politicians and government officials into



Evacuated Love Canal neighborhood

Source: Lawrence Potts.

addressing the contamination. In August 1978, the State of New York declared a public health emergency and ordered the permanent relocation of 239 families living along the canal. In 1979, the Love Canal Homeowners Association, led by Lois Gibbs, succeeded in convincing officials to expand the relocation order. President Jimmy Carter declared two federal emergencies, which provided funds for the relocation of more than 550 additional families in a wider 10-block area. By 1989, the residential relocations and the environmental investigation and cleanup had cost the state and federal governments \$140 million. After 16 years of extensive litigation, the Occidental Chemical Corporation agreed to reimburse \$129 million in costs. Contaminants at the site were contained with a synthetic liner and clay cap, and in 2004, the cleanup was declared complete. A follow-up health study conducted by the State of New York and the U.S. Agency for Toxic

Substances and Disease Registry concluded that Love Canal residents were not at higher risk for cancer but were at significantly higher risk for low-birth weight children, birth defects, and other adverse reproductive outcomes.

Influence of Love Canal on Hazardous Waste Policy

The 1970s were a decade of significant progress in regulating hazardous chemicals, including amendment of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1972 and passage of the Resource Conservation and Recovery Act (RCRA) and the Toxic Substances Control Act (TSCA) in 1976. The RCRA established a system of regulations specifying the proper tracking, storage, transportation, treatment, and disposal of hazardous wastes from “the cradle to the grave.” Despite these efforts, a gap remained—past



contamination. Legislation addressing past contamination had foundered on controversies such as victim compensation and assigning liability. Given the recent passage of the RCRA and TSCA, the Love Canal incident was a source of considerable political embarrassment and galvanized public concern over abandoned waste sites. Spurred on by Love Canal and similar sites such as the Stringfellow Acid Pits in California and Valley of the Drums in Kentucky, Congress passed the Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA) in 1980. The two primary features of the original CERCLA were its \$1.6 billion cleanup fund (the Superfund) and its strict, joint, several, and retroactive liability provisions. CERCLA's stringent liability regime, a direct response to Love Canal, created unintended problems of excessive litigation and stigmatization of a whole class of potentially contaminated former industrial sites known as *brownfield* sites. In addition to shaping hazardous waste legislation, Love Canal left its mark on the environmental movement. Lois Gibbs went on to found the Citizen's Clearinghouse for Hazardous Waste (renamed the Center for Health, Environment and Justice), an influential nongovernmental agency that supports communities in their efforts to address toxic hazards and promote environmental justice.

Mark D. Bjelland

See also **Brownfields; Chemical Spills, Environment, and Society; Environmental Justice; Landfills; Point Sources of Pollution**

Further Readings

- Blum, E. D. (2008). *Love Canal revisited: Race, class, and gender in environmental activism*. Lawrence: University Press of Kansas.
- Colten, C., & Skinner, P. (1996). *The road to Love Canal: Managing industrial waste before EPA*. Austin: University of Texas Press.
- Fletcher, T. (2003). *From Love Canal to environmental justice: The politics of hazardous waste on the Canada-U.S. border*. Peterborough, Ontario, Canada: Broadview Press.
- Levine, A. G. (1982). *Love Canal: Science, politics, and people*. Lexington, MA: Lexington Books.



LYNCH, WILLIAM (1806–1865)

William Francis Lynch was an officer of the U.S. Navy who, in 1848, led the first successful expedition to explore and map the Dead Sea and established, for the first time, the depth of its surface below sea level.

Curiosity about the Dead Sea can be traced back to our earliest written sources for the region. Stories to explain the landscape and its bizarre mineral features found their way into the Bible (Genesis 19) in the form of the story of the destruction of the cities of Sodom and Gomorrah, located in the valley that is now the Dead Sea. And while the many visitors to the Holy Land often showed great curiosity about this lake, the legend grew that one could not enter it and live. Indeed, as late as 1816, two British naval officers, Charles Irby and James Mangles, traveled around the lake but were unwilling to set out on it, plumb its depth, or seek explanations for its minerals and salts. It is against this background of uncritically accepted biblical history, growing geological curiosity, but persisting fearful legends that it was a place of death that we have to view the first recorded explorations of the lake. The first was in 1835 by an Irish citizen, Christopher Costigan, who died shortly after rowing round the lake, leaving no notes. The second was in 1837 by the Royal Navy's Thomas Molyneux. He plumbed the lake, made notes, but died only weeks later.

In contrast, both in equipment and labor power, Lynch's was a far more careful affair. He studied the Sea of Galilee, followed the Jordan River south, and then made a careful survey of the Dead Sea, producing the first modern map and the first chart. All the while noting the region's geology, flora and fauna, and agricultural capability, the whole account was interspersed with notes on the customs and activities of all he met. In memory of the two earlier explorers, whose route he consciously followed, he named the northern point of El-Lisan "Point Costigan" and the southern one "Point Molyneux"—the latter has disappeared with the reduction in the lake's area, but the former, renamed Cape Costigan, survives on Survey of Israel maps.



Lynch's orders were to explore and survey the Dead Sea with the object of promoting scientific knowledge of the area and advancing the reputation of the navy. However, while he fulfilled these orders admirably, his hidden agenda was his real driving force, as becomes clear from his publications. In the face of increasing concern over the Bible's historical accuracy and challenges to it from geology and the fossil record, Lynch believed that his work showed that, at least, geology could not undermine the scriptures and that, indeed, further investigation might yield the ruins of the destroyed cities of Genesis 19. His work must, therefore, be located not only within the history of geological exploration but also within the history of Bible versus science debates. On his return home, Lynch published two distinct accounts of his journey: *Narrative of the United States' Expedition to the River Jordan and the Dead Sea*

(1849), which contains much of his theological thought, and the *Official Report of the United States' Expedition to the River Jordan and the Dead Sea* (1852), which has the character of a logbook; they need to be read together to appreciate that remarkable journey.

Thomas John O'Loughlin

See also **Biblical Mapping**

Further Readings

Andrew, C. (2005). *Sailors in the Holy Land: The 1848 American expedition to the Dead Sea and the search for Sodom and Gomorrah*. Annapolis, MD: U.S. Naval Institute Press.

M

MACEachREN, ALAN **(1952–)**

Alan MacEachren is an American cartographer, an author, and a professor of geography at Pennsylvania State University. He is a pioneer in cartography and geographic information science (GIScience) research, known particularly for popularizing the term *geographic visualization* and setting its research agenda and more recently for establishing and directing the GeoVISTA Center at Penn State and launching the research initiative of geovisual analytics.

MacEachren argues that geovisualization (as it has come to be known) is more than the introduction of computing technology in the creation of dynamic maps and visual representations; it also considers the complex cognitive processes of representation users and the development of tools and theories that enable problem solving and knowledge construction. MacEachren presented the process of geovisualization as a complement to cartographic communication, which had long been the dominant paradigm for understanding map use. His landmark (Cartography)³ diagram, first published in 1994, categorized maps by three dimensions: (1) the level of interactivity, (2) the primary purpose/use, and (3) the degree to which the map is designed for individual or multiple users. Maps for geovisualization, for example, are typically highly interactive, reveal

unknown characteristics of the data, and are designed for a single or small number of users. This contrasts in each of these dimensions with the more traditional use of maps for communication. MacEachren is the author of the influential 1995 book *How Maps Work*, which links maps to cognitive linguistics, spatial cognition, and philosophy.

More recently, MacEachren has focused on the theory and practice of geovisual analytics, which extends geovisualization to modeling, reasoning, analyzing, and representing the large-volume heterogeneous databases that are encountered by those working in health, environment, national security, and other fields using georeferenced data. The geovisual-analytic approach, part of a larger interdisciplinary “visual analytics” research initiative, integrates statistical, psychological, and decision-science concepts, with an explicit focus on facilitating time-sensitive analytical reasoning to solve problems related to spatial data. Geovisual analytics is a major research theme at the GeoVISTA Center, which MacEachren and his colleagues in geography and information sciences at Penn State founded in 1998. The center has become an interdisciplinary research hub, focusing on spatial representation, multivariate spatial analysis, collaborative decision making, human factors, and many other GIScience issues. The expansion of geographic information technology to support its use by multiple individuals, groups, and institutions



simultaneously is of particular interest to MacEachren and his colleagues.

Robert Edsall

See also [Cartography](#); [Geovisualization](#); [GIScience](#)

Further Readings

- Dykes, J., MacEachren, A., & Kraak, M. J. (Eds.). (2005). *Exploring geovisualization*. Amsterdam: Elsevier.
- MacEachren, A. (1995). *How maps work: Representation, visualization and design*. New York: Guilford Press.
- MacEachren, A., Gahegan, M., Pike, W., Brewer, I., Cai, G., Lengerich, E., et al. (2004). Geovisualization for knowledge construction and decision-support. *Computer Graphics & Applications*, 24(1), 13–17.
- MacEachren, A., & Kraak, M.-J. (1996). Exploratory cartographic visualization: Advancing the agenda. *Computers & Geosciences*, 4(4), 335–343.



MACKINDER, SIR HALFORD (1861–1947)

Sir Halford Mackinder was a leading political geographer of the early 20th century, best remembered today for his “heartland” model of global geopolitics. Mackinder was a leader in the founding of academic geography in Britain. He was appointed the first geographer at Oxford in 1887 and started its School of Geography in 1899. In addition, he helped the University of Reading in 1892 and served as director of the London School of Economics from 1903 to 1908. Mackinder combined his academic career with political pursuits, serving as a Member of Parliament from 1910 to 1922 and chair of the Imperial Shipping Committee from 1920 to 1939.

Mackinder is remembered primarily for creating political geography’s most famous global geopolitical model, the heartland model. First developed in 1904, and refined over the next

40 years, Mackinder created a map of the world with three main areas: (1) *the Heartland* or *pivot area*, analogous originally to much of the Asian part of Russia but later extended to include most of the Soviet Union; (2) the *inner crescent* or *rimland*, the European and Asian areas surrounding the Heartland; and (3) the *outer crescent*, or everything else. Mackinder argued that the Heartland was the key to world power, that whoever controlled the Heartland could control the world. He based this argument on two factors: first, that over the sweep of history, those who had attacked and tried to conquer Europe had come from the Heartland and, second, because of its physical location on the Earth’s surface, the Heartland was impenetrable from attack on three sides, the east (Gobi Desert), the south (the Himalayas), and the north (Arctic Ocean), thereby making it the greatest defensive position on the planet. He argued that a naval power (i.e., Britain) would not be able to take over the Heartland. He suggested that the only way into the Heartland was through Eastern Europe and that, therefore, controlling Eastern Europe was the key to world domination.

Despite its long-lasting influence within political geography specifically and policy circles generally, there are major criticisms of Mackinder’s model. First, there have been critiques of his model specifically—for example, that a great defensive position in an inhospitable area with few people does not translate into an offensive strategy for world domination; that the growth in importance of airpower, nuclear weapons, and missile systems makes his model obsolete; and that the Heartland model’s Eurocentric-focus making the rest of the world irrelevant is problematic.

Beyond these specific issues, several critiques of Mackinder have been offered in recent years by students of critical geopolitics concerning such grand global geopolitical models that seek to “objectively” and from a “scientific, rational, neutral” perspective explain where power resides in the world and how it operates. First, Mackinder’s model is based in large part on the world’s physical geography—that is, how oceans and continents fit together. Such models ignore the billions of people who populate the world. As well, by placing Europe in the center of his maps, Mackinder made it appear “natural” that Europe



was the center of global power. In addition, Mackinder is purporting to present a global model of power offering a detached “view from above the clouds,” or a “god’s eye view” of the world and how it operates. However, while purporting to provide a dispassionate view of the world, Mackinder’s main interest was in making sure that the Germans did not challenge the British for global supremacy, with his main concern being that Germany would gain control over Eastern Europe. Thus, this supposedly scientific, dispassionate “god’s eye” view of how the world works was in reality a warning to Britain to look out for Germany and a possible alliance between Germany and Russia (thereby equating controlling Europe with controlling the world). Given Mackinder’s own political views championing the British Empire and its continuation as the leading global power, these warnings are not ultimately surprising.

Despite these problems, some Western policymakers in the post–World War II era saw Mackinder as a soothsayer for “predicting” the geographic contours of the Cold War. Mackinder and his ideas still have defenders today, for example, the influential late-20th-century and early-21st-century defense strategist Colin Gray; and Mackinder’s ideas have been extended to the domination and control of outer space, what one writer has referred to as “astropolitik.”

Jonathan Leib

See also **Geopolitics; Human Geography, History of; Political Geography**

Further Readings

- Blouet, B. (Ed.). (2005). *Global geostrategy: Mackinder and the defense of the West*. London: Frank Cass.
- Mackinder, H. (1904). The geographical pivot of history. *Geographical Journal*, 23, 421–437.
- Mackinder, H. (1919). *Democratic ideals and reality*. London: Constable.
- Ó Tuathail, G. (1996). *Critical geopolitics*. Minneapolis: University of Minnesota Press.

MAGELLAN, FERDINAND (1480–1521)

Ferdinand Magellan, or in Portuguese, Fernão de Magalhães, is well known as the first navigator whose ships circumnavigated the globe (Figure 1). Magellan was responsible for planning the journey, seeking financing, and surviving the subarctic winter of the straits in South America that bear his name; he was one of the first Europeans to set foot in the Marianas Islands and the Philippines. With Rui Falero, a scholar on celestial navigation, he convinced the Spanish king Charles I (later Emperor Charles V) and his Flemish advisors that the Spice Islands, also known as the Western Islands, the Moluccas, or *la especiería*, lay west of the line of demarcation of the Treaty of Tordesillas (1494) and thus were a Spanish, not Portuguese, possession. Albuquerque had conquered the Malaysian port of Malacca in 1511, explored the islands to the east, and used the Moluccas to initiate trade with China. In Spain, Americo Vespucci, Díaz de Solis, and members of the Council of Indies agreed with Magellan’s certainty that a strait opened to the South Sea. In the 16th century, these contested territories represented a highly desirable possession because of the abundance of clove, nutmeg, and cinnamon to be obtained there.

The 16th-century Dominican historian Bartolomé de las Casas wrote in his *History of the Indies* one of the most detailed descriptions of Magellan, including an account of his meeting with the Spanish chancellor Xevres while he was present at Valladolid. In this meeting, he came with a globe in his hand to describe with great certainty a new route to the Pacific that would place the Spanish Empire at a great advantage relative to the Portuguese. With the intervention of the Archbishop of Burgos, the one who had negotiated with the Catholic monarchs on behalf of Columbus, Magellan left with four ships, more than 230 men, and four court officials. The journey, as recorded in the several accounts by its participants, was treacherous. Some of the men took part in a mutiny at San Julián Bay, and most of them eventually died because of starvation, thirst, and scurvy.

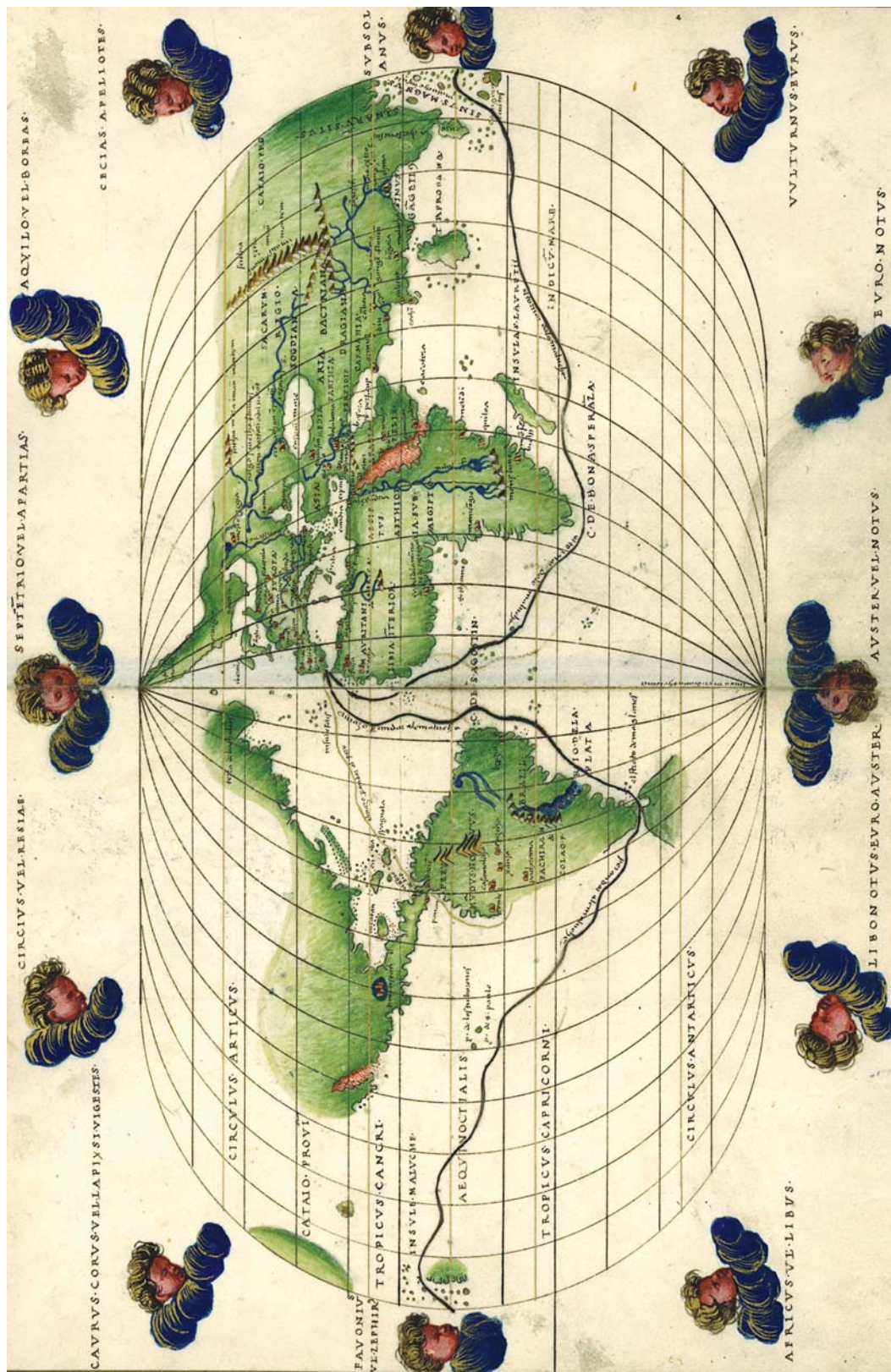


Figure 1 Historical map of Battista Agnese in 1544 from the Portolan Atlas, showing the route Magellan took around the world and the route from Cadiz, Spain, to Peru, with overland portage across the Isthmus of Panama
Source: mapsorama.com.



After securing the first Spanish contact in the Philippines and the first conversion to Christianity, Magellan died on Mactan Island after a failed attack on a local native king. As with Columbus, the glory accounted in his biographies was largely due to the efforts of others; in the case of Magellan, only two vessels returned to Europe, the *Victoria*, under the command of Juan Sebastian Elcano, and the *Trinidad*, with Esteban Gómez in charge.

Magellan's journals, personal records, and letters written during his journey are lost. The most important narrative that has been translated into several languages is Antonio Pigafetta's *Primo viaggio intorno al mondo*, with maps well known for their inaccuracy. In addition, there are other firsthand accounts of the expedition, including Francisco Albo's *Diario ó Derrotero del Viage de Magellanes*. This account is useful for historians and geographers because it identifies the position of the "Unfortunate Islands" and it established that Amsterdam Island in the Indian Ocean was "discovered" by the *Victoria*. Also important are the anonymous Leiden narrative in Portuguese, printed in Coimbra as *Um Derroteiro Inédito*, and the Roteiro of "the Genovese pilot," which is known for the details of Magellan's death. Important in any discussions about Magellan's contributions is the Spanish cosmographer Diego Ribero's 1529 map that shows the extent of the Pacific Ocean, which Magellan named.

Magellan's contributions are key to the history of geography and trade in many ways. For the history of cartography, besides improving map accuracy and demonstrating the great distances between Europe and the Pacific islands, his journey stimulated the production of terrestrial globes that eliminated the edges of the world. With further exploration and conquests, the economies of the empire were strengthened. Magellan's expedition to the Spice Islands initiated the Spanish exploration of the Pacific Ocean, whose islands became a central stopping point in the newly expanded trade of the Indies with the new route from Manila to Acapulco.

Santa Arias

See also **Columbus, Christopher; Exploration; Human Geography, History of**

Further Readings

- Bergreen, L. (2004). *Over the edge of the world: Magellan's terrifying circumnavigation of the globe*. New York: HarperPerennial.
- Martin, T. (1971). Magellan historiography. *Hispanic American Historical Review*, 51, 313–335.
- Pigafetta, A. (1995). *The first voyage around the world (1519–1522)* (T. Cachey, Ed.). Rome, Italy: Marsilio.



MAHAN, ALFRED THAYER (1840–1914)

A late-19th-century American naval strategist and historian, Alfred Thayer Mahan is best known for his geostrategic writings on the geopolitical importance of sea power.

Born in New York in 1840, Mahan graduated from the U.S. Naval Academy and served as a captain in the U.S. Navy. In 1885, Mahan was appointed a lecturer at the Naval War College. Mahan's lectures served as the basis for his most influential work, his 1890 book, *The Influence of Sea Power Upon History*. Mahan argued that global geopolitical success was based on a country's sea power through its control of the oceans. Highlighting the importance of commerce and economic power, Mahan argued that a state needed a large powerful navy to protect and control commercial sea lanes. In Mahan's view, a country's potential sea power was based on a variety of factors, including its coastal physical geography (e.g., the length and nature of its coastline and harbors), the size of its population, and its national and governmental "character."

Mahan's argument about the primacy of sea power was influential in policy circles both in the United States and abroad. His rise to prominence occurred in the late 19th and early 20th centuries during the height of European imperialism and as the United States was itself in the process of becoming an overseas empire.



Mahan's work both influenced and was influenced by American and European actions. As part of his call for American control of the seas, Mahan advocated the U.S. takeover of Hawaii, the Caribbean, the Philippines, as well as Panama to build a canal connecting the Atlantic and the Pacific Oceans. Mahan also promoted the buildup of the American Navy, as epitomized in President Theodore Roosevelt's construction of the "Great White Fleet." His notoriety extended beyond policy circles to the general public through the many articles he wrote for popular American magazines of the time.

Beyond the United States, Mahan's writings also had important policy impact in the early 20th century. Mahan's work and policy prescriptions were important in England, Germany, and Japan, influencing naval buildups in these countries as well. Mahan is also credited with coining the regional designation term *Middle East* in 1902.

Mahan died in 1914 and is best remembered today within the history of early-20th-century geopolitics for his emphasis on the importance of sea power as juxtaposed to Halford Mackinder's land-based geopolitics.

Jonathan Leib

See also **Geopolitics; Human Geography, History of; Military Geography**

Further Readings

- Glassner, M., & Fahrner, C. (2004). *Political geography* (3rd ed.). New York: Wiley.
- Mahan, A. T. (1915). *The influence of sea power upon history, 1660–1783* (25th ed.). Boston: Little, Brown. (Original work published 1890)
- Ó Tuathail, G. (1996). *Critical geopolitics*. Minneapolis: University of Minnesota Press.
- Smith, N., & Nijman, J. (1994). Mahan, Alfred Thayer. In J. O'Loughlin (Ed.), *Dictionary of geopolitics* (pp. 156–158). Westport, CT: Greenwood Press.



MALARIA, GEOGRAPHY OF

Malaria is an infectious, vector-borne disease caused by the plasmodium parasite, which is spread from person to person by the anopheles mosquito. Acute symptoms of the disease include high fever, chills, headache, and fatigue, with common complications such as coma, anemia, and liver damage. Historically, malaria was widespread globally, but today it is confined mainly to the tropics, where it continues to exact a high toll on human health and development, with approximately 1 million deaths annually, countless infections and complications, and associated social and economic burdens. The vast majority of malarial infections and deaths occur in sub-Saharan Africa, as well as in tropical South and Central America, and South and Southeast Asia. The geography of malaria can be understood as the interaction between three interrelated geographies: (1) that of the anopheles mosquito, the vector for the disease; (2) that of the plasmodium parasite, the direct cause of malaria; (3) and that of human resistance to malaria, whether innate, acquired, or developed through culture and technology.

Since anopheles mosquitoes are the only means of transmitting the parasite from one person to another, their distribution has been the key factor shaping the geography of malaria. While there are several hundred species of anopheles mosquitoes, only about 40 are considered efficient vectors for malaria due to their ability to withstand the parasite and its anthropophilic feeding characteristics (i.e., a tendency to favor human over animal blood). Thus, in some locales where climatic conditions would seem to favor the presence of malaria, the absence of an efficient vector has left them malaria free. Nevertheless, malaria vectors are found in a wide array of landscapes, from tropical forests and savannas, to coastal marshes, to agricultural areas and cities. The most dangerous malaria vector, *Anopheles gambiae*, endemic to central Africa, sustains the world's highest rates of malarial infection and mortality.

Malaria parasites spend the sexual phase of their life cycle inside the anopheles mosquito. Insofar as the mosquito is cold-blooded,



the survival and reproduction of the parasite are sensitive to ambient temperature. Different species of the parasite are better equipped to handle low temperatures. *Plasmodium falciparum*, the deadliest form of the parasite, is less resistant to cold and as a result has always been most prevalent in the tropics. Another species, *Plasmodium vivax*, is capable of withstanding cooler and highly seasonal climates, which historically has allowed for a broader geographical reach into temperate zones such as the Southern United States, Southern England, Italy, and northwestern Argentina.

Finally, differences in human resistance to malarial infection help explain the heterogeneous geography of the disease. Genetic factors offer complete or partial resistance to infection for some ethnic groups. Most famously, the sickle-cell trait, found in about 20% of people in sub-Saharan Africa, reduces the severity of malarial symptoms. Many ethnic groups, including most Africans, have genetic immunity to *P. vivax* infection. In addition, partial yet impermanent resistance to malaria can also be acquired through exposure to infection. In areas where the prevalence of malaria is epidemiologically “stable,” such as sub-Saharan Africa, environmental conditions are optimal for year-round transmission of the parasite, but rates of immunity after childhood are very high. As a result, in such “endemic” regions, children suffer the vast majority of deaths from endemic malaria.

Today, there are many places where malaria could exist, or has existed in the past, but does not now. This differential geography can be explained mostly by the success or failure of efforts to control the disease. Prior to the 20th century, when a modern scientific understanding of malaria crystallized, cultural interventions that reduced the severity of malaria were unintentional. In particular, wetland drainage for agriculture—such as in England in the 1700s or the United States in the 1800s—eliminated the breeding areas for malaria vectors. From the early 20th century, malaria control became a public health imperative for colonial powers and developmental states. For several decades, it depended on a combination of strategies that included environmental sanitation (mainly draining wetlands), vector control, improving housing conditions,

and eliminating the parasite in the bloodstream through doses of quinine and other drugs. After 1945, international philanthropies and development institutions shifted to promoting house spraying with DDT, a potent insecticide, as the principal control strategy. Under the auspices of the World Health Organization, the Global Malaria Eradication Program was partially successful, with noteworthy achievements in Latin America and Asia. Over time, however, mosquitoes and parasites developed resistance to DDT and synthetic drugs, respectively, thus undermining the bases of the eradication program. Other financial, political, and logistical obstacles led to the near abandonment of malaria eradication programs.

As a consequence, malaria experienced a marked recrudescence from the 1970s onward. In some areas, such as the Amazon basin, the resurgence of malaria has accompanied agricultural colonization: Migrants, lacking immunity, enter areas where malaria is endemic, while at the same time transforming local land use and land cover (i.e., through deforestation) in ways that favor development of the local malaria vector (*Anopheles darlingi*). A similar dynamic has been observed in Malaysia and Africa. Since both vector and parasite are sensitive to environmental change, many scientists predict that global warming will expand endemic malaria zones, both poleward (i.e., away from the tropics) and to higher elevations. Today, GIS and remote sensing are central to research modeling the potential effects of environmental change on malaria transmission.

Malaria undermines the development prospects of the countries where it is endemic; as Sachs and Malaney (2002) note, “Where malaria prospers most, human societies have prospered least” (p. 680). The disease imposes a high economic and social burden due to the costs of prevention, drug treatment, and medical care; lower labor force productivity; and macroeconomic impacts from lower levels of tourism, trade, and foreign investment. There is also a circular relationship between malaria and underdevelopment, since desperately poor countries are ill equipped to address their public health problems. Recent philanthropic and multilateral aid programs have renewed and refocused efforts to bring malaria under control, employing strategies that take into

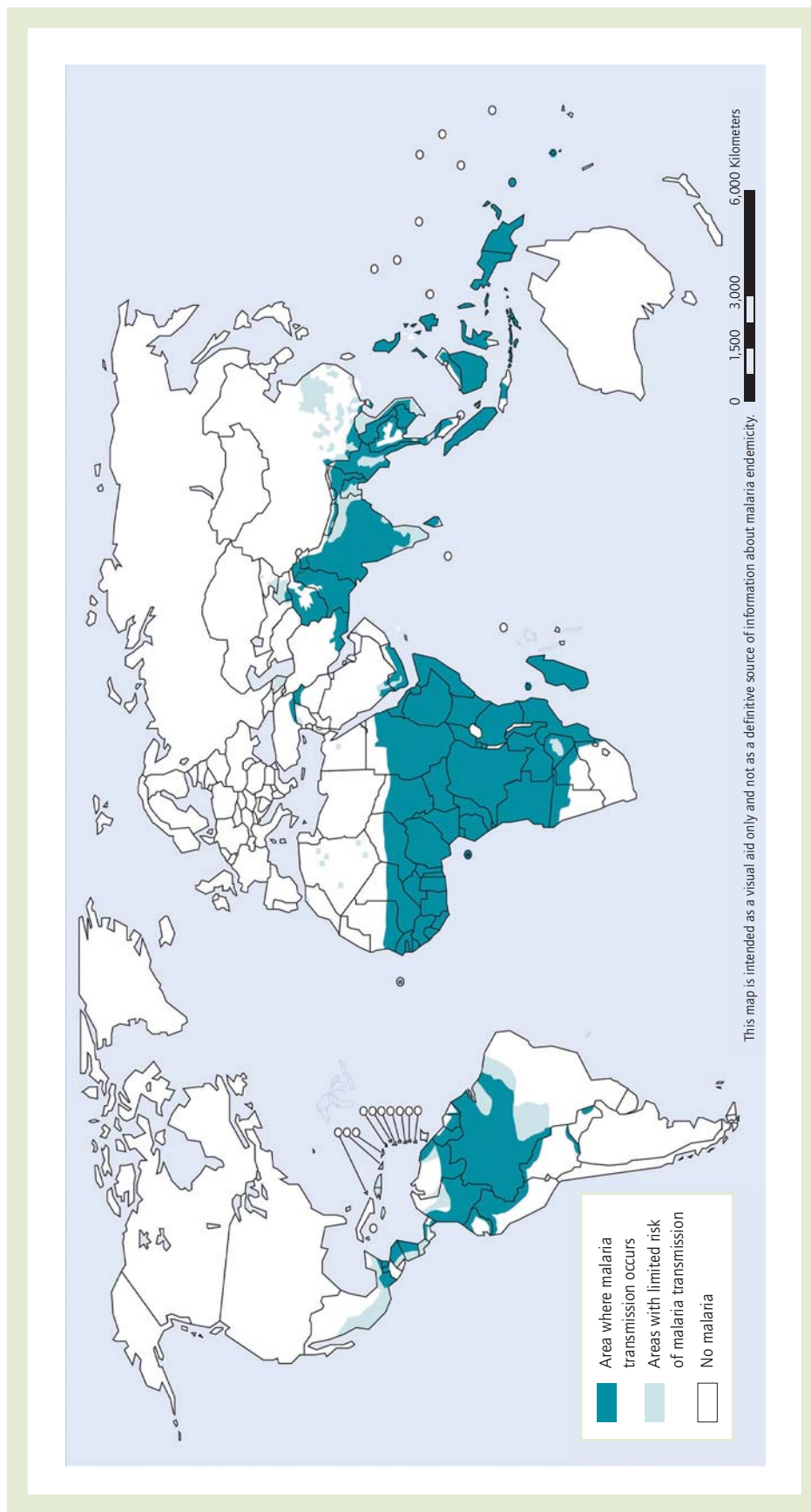


Figure 1 Malaria transmission areas, 2008
Source: World Health Organization, 2008. All rights reserved.



consideration the geographically variable character of the disease.

Eric D. Carter

See also **Anthropogenic Climate Change; Disease, Geography of; Medical Geography**

Further Readings

- Packard, R. (2007). *The making of a tropical disease: A short history of malaria*. Baltimore: Johns Hopkins University Press.
- Sachs, J., & Malaney, P. (2002). The economic and social burden of malaria. *Nature*, 415, 680–685.
- Singer, B., & Caldas de Castro, M. (2001). Agricultural colonization and malaria on the Amazon frontier. *Annals of the New York Academy of Science*, 954, 184–222.
- Warrell, D., & Gilles, H. (Eds.). (2002). *Essential malariology* (4th ed.). London: Arnold.



MALTHUSIANISM

Malthusianism in contemporary usage refers generally to the problems of food and resource scarcity created by and the limits imposed on human population growth. It refers to the work of the English cleric Thomas Robert Malthus, particularly his *Essay on the Principle of Population*, first published in 1798. Although debates about the relative merits and demerits of Malthusian thought are now fairly sterile, they are nonetheless relevant to discussions of international development, population geography, food security, and migration. The following sums up the history, influence, and limitations of Malthusian thought.

Malthus's "principles" of population were, first, that human population grows geometrically (e.g., 1, 2, 4, 16 . . .) and, second, that its ability to feed itself grows only arithmetically (e.g., 1, 2, 3, 4 . . .). Malthus allowed only two ways around this essential contradiction. With "preventive" checks, families, when faced with an inability to support their offspring adequately, should intentionally restrict their own fertility. For Malthus,

however, such a victory of—as he saw it, “reason” over “nature”—was trumped by a “passion between the sexes,” which was particularly indomitable in the lower classes. With “positive” checks, however, the relative fixity of food supplies compared with population itself limited population growth in the form of famine, disease, and human misery. This latter check was regarded by Malthus as an inescapable law of nature leading to population “equilibrium” and is perhaps the essential core of what we call Malthusianism, even as it is used today.

Malthus penned his essay in the midst of the rapid population growth associated with industrialization and capitalization of agriculture in Britain, as well as the violent social upheavals in France and America. He aimed his canons at radical utopians such as William Godwin and the Marquis de Condorcet, who believed that human reason and scientific advancement could transcend so-called natural laws and who consequently helped establish Britain's first welfare legislation. Malthus argued that social intervention in natural laws via social welfare would only temporarily stave off human misery, while encouraging population growth and lead to an even bigger calamity in the future. Consequently, he suggested, it was more humane in the long term to allow the poor to starve, though his critics cynically countered that this was a liberal construction meant to preserve the status quo, and hence his bourgeois lifestyle.

It is also notable that preventive checks for Malthus did not include birth control. Nevertheless, a number of 19th-century social reformers appropriated Malthus's ideas for decriminalizing birth control. These reformers were called neo-Malthusians; adding the prefix *neo* to *Malthusianism* in this early context (it has been used in different ways since) suggested a version of Malthusianism that accepted technological intervention in supposed natural laws, something Malthus himself would have repudiated as a threat to social order. Neo-Malthusianism retained all other basic tenets of Malthusianism. It had a wide range of political purposes depending on its various proponents, not the least of which were popular movements toward eugenics throughout Europe and the United States in the late 19th and early 20th centuries.



Malthus's ideas, in some form or another, experienced something of a revival in the mid 20th century, particularly as they were incorporated into international policy discussions. The preeminent economist John Maynard Keynes, for example, trumpeted Malthus in his critiques of European reconstruction plans after World War I. Malthusian doctrine was also frequently deployed after World War II by certain critics of international food aid and the diffusion of Western agricultural practices. For example, Garrett Hardin's notorious "lifeboat ethics" argument of 1974 was largely an extrapolation of Malthus's argument against helping the poor on an international scale. The biologist Paul Ehrlich also notoriously revived Malthusian thinking and applied it to nonfood environmental resources, including clean air and water, timber, and mineral resources, in his 1968 book *The Population Bomb* (republished extensively afterward). At the end of the Cold War, literatures concerning relationships between population, resources, and violence, variably termed *environmental security*, *resource wars*, or *green-war*, also took a predominantly neo-Malthusian approach.

Malthus remains a contested figure more than 170 years after his death. Neo-Malthusians typically contend that even if Malthus himself underestimated the agricultural potential of the Americans and could not possibly have foreseen 20th-century developments in agrosience, the ultimate finitude of natural resources suggests a theoretical ceiling *somewhere*. They often point to current global food and environmental crises as evidence. They argue that although Malthus may have operated with a crude understanding of equilibrium theory, more advanced ecological understandings of dynamic equilibrium suggest that the Malthusian predictions could still be realized.

Few scholars seriously contest that there exists some theoretical limit to population, but critics argue that this limit is not a presocial, inescapable natural law but rather a social construction born out of human economic, political, and cultural life. Promethean versions of this critique suggest that population growth is a problem inevitably addressed by economic and technological progress. Distributionist versions of this critique point out that adequate food supplies exist for the

global population even as projected into the future but that current local food shortages reflect distributional or pricing inequities resulting from unfair terms of international trade and lending, economic liberalization, and political corruption. Critics also see the global environmental crisis as a consequence of overconsumption in the developed world, not population growth in the developing world. In 1974, the geographer David Harvey suggested that the population-resource theory was an ideological construct, rather than unquestionable science, that works to preserve this unevenness. Furthermore, Malthusian limits to population are derived from theoretical beliefs that such a limit *must exist somewhere* and then mistaken for the empirical reality that they are supposed to model. Consequently, Malthusian limits are a product of human endeavor, not a limit on it.

Kolson Schlosser

See also **Carrying Capacity; Developing World; Hunger; Neo-Malthusianism; Population and Land Degradation; Population, Environment, and Development; Population Geography; Poverty**

Further Readings

- Greene, R. (1999). *Malthusian worlds: U.S. leadership and the governing of the population crisis*. Boulder, CO: Westview Press.
- Harvey, D. (1974). Population, resources, and the ideology of science. *Economic Geography*, 50, 256–277.
- Malthus, T., & Gilbert, G. (1999). *An essay on the principle of population*. New York: Oxford University Press.



MANUFACTURING BELT

The North American Manufacturing Belt emerged between 1830 and 1880, and well into the 1970s, industry located in this zone dominated manufacturing employment in the continent. This made the belt one of four broad industrial regions that



together dominated world industrial production through most of the 20th century. The belt was identified in academic literature in the 1930s and has been the subject of considerable research, mainly focused on its dynamics, geography, and subsequent decline and restructuring in the late 20th century.

Dynamics and Geography

When industrialization first gripped Canada and the United States, manufacturing took the form of many small establishments located in the Atlantic coast states and along the St. Lawrence River. These early enterprises were closely entwined with rural activities and added factory work to an industrializing countryside. Subsequent migration and urbanization, westward frontier expansion, and railroad and telegraph construction fueled industrial development within a westward-expanding industrial belt. In the American South, there was a relative retardation of industrial development because of weaker urbanization, limited investment in transport and communications infrastructure or farm mechanization, and a very different labor market. By 1870, industrial activity already covered the area subsequently known as the Manufacturing Belt, marked by Minneapolis and St. Louis in the west, Toronto and Montreal in the north, and Louisville, Cincinnati, and Baltimore in the south. In the period from 1860 to 1880, however, manufacturers in this region became functionally integrated into a continental geography of labor, market, and resource supply regions. By 1880, specialized establishments supplied products to wide market territories within the continent, factories depended on the skilled workers of well-developed urban labor markets, while their suppliers included not only mines, lumber mills, cotton gins, and grain elevators located outside the belt but also factories located in other industrial cities. Thus, the belt was formed through a process of regional specialization.

A spatially differentiated process of cumulative causation, operating on a continental scale, produced local and regional specializations within the belt on the back of initial advantages. Clear signs of manufacturing specialization are discernible even in 1880. The leading metropolitan centers for manufacturing each had disproportionate

shares of national employment in specific industries: In New York, it was garment production; in Philadelphia, textile production; and in Chicago, slaughterhouses and meat packing. Other local specializations included fruit and vegetable canning in Baltimore; musical instruments in Boston; furniture in Grand Rapids; tobacco in Louisville; glass, iron, and steel in Pittsburgh; and agricultural implements in Springfield, Ohio. A high-tech region emerged in New England associated with the American system of production, featuring interchangeable parts production and focused on the U.S. armories in Springfield, Massachusetts.

The belt developed a distinctive geography: An array of industrial regions comprising outer-ring cities and industrial towns clustered around metropolitan centers. Metropolitan centers provided finance, wholesale, warehouse, and transport services for manufacturers and served as innovation centers and information nodes. As early as 1880, 15 regional metropolises and 50 other industrial cities, all located in the belt, dominated U.S. manufacturing. A similar pattern emerged in Canada, where Toronto and Montreal, along with the many industrial cities, such as Hamilton and London, that constitute the Windsor-Quebec corridor, housed around 70% of national manufacturing employment for most of the 20th century. These industrial cities were distinctive: Their layout and pattern of development contrasts strongly with the newer metropolitan centers of the South and the West, such as Los Angeles, Phoenix, Houston, Denver, or Calgary. Specialized industrial districts emerged within the metropolitan cores. Some were keyed to major assembly operations, as at the Baldwin Locomotive Works in Philadelphia, which subcontracted parts production to adjacent suppliers in a way that enabled large-scale assembly of locomotives. Others featured the rental of machines and factory spaces to numerous enterprises, as in the Philadelphia textile industry. Yet others were the result of regulations concerning polluting industries and water rights, or localized agglomeration economies, such as those related to New York or Toronto garment manufacture. Historical geographers have been reinterpreting the dynamics, patterns, and causes of the suburbanization of manufacturing within metropolitan areas. This is largely because industrial facilities and associated



residential areas tended to be scattered 10 to 40 kilometres around major centers before the residential growth engulfed them. The belt featured diverse industrial and urban locales set in a dominant landscape of farms and forests, including satellite industrial towns, company towns, single-industry resource towns with processing industries, and small-factory villages. Workshops remained important even with the development of factory organization, machinofacture, and wage work. Thus, the belt's internal diversity complicates the metro-centered region model.

Beginning in the 1880s, a second industrial revolution associated with steel, electrical energy, and university-trained engineers altered the spatial dynamics of North American industry. New industries emerged, such as the automobile industry, which relied on the Manufacturing Belt, labor skills, innovation centers, capital, and suppliers. These industries tended to locate production inside the belt. General Electric and Westinghouse developed plants at Lynn, Schenectady, and Pittsburgh, while Ford and GM localized automobile production in southern Michigan. Corporations emerged and restructured their operations, closing older production facilities and deindustrializing some regions. While Canada's Maritime provinces faced deindustrialization at the hands of companies headquartered in Montreal and Toronto, leading U.S. firms established factories in Ontario, thus turning Canada into the first "branch plant economy"—a term coined in Canada in the 1920s. San Francisco emerged as the center of a substantial but distant industrial region. Some industries that supplied processed materials—oil, steel—to manufacturers, and that had developed first within the belt, relocated to take advantage of new resources. Steel production migrated westward and also developed in Birmingham, Alabama. Oil production in Texas and California outstripped the output in Pennsylvania. A new social organization of innovation and production came to characterize the belt. University-trained engineers, backed by specialized research labs, institutes, and universities, supplanted skilled workers as the innovators and controllers of factory production. Accountants, engineers, and lawyers professionalized the management of companies operating many factories from head

offices located in metropolitan centers. High levels of trade union membership marked the industries of the belt. Together, these processes restructured the activities that made up the belt and its relations with peripheral regions, intensifying production relations in some parts of the belt and closing plants in other places in a historical example of creative destruction that nevertheless reconfirmed the belt's locational advantages for many manufacturers.

Decline and Restructuring

In the early 1980s, the decline of manufacturing employment in the belt relative to the U.S. Sunbelt was widely recognized and attributed to a combination of government investments in the Sunbelt states and new realities for U.S. corporations under globalization. Massive government investments in manufacturing capability during World War II augmented the belt's industrial profile but also located new production facilities for military equipment in the U.S. West and South. These facilities became home to some of the growth industries under the next industrial revolution technologies: computing, telecommunications, and aircraft. Subsequently, federal government investments in freeways and housing, new migration patterns, and new amenities such as air conditioners contributed to postwar growth in the Sunbelt states. In a massive restructuring of the U.S. space economy during the 1980s and 1990s, corporations closed older plants, invested in new ones, or subcontracted production, sometimes to factories located in Asia, Mexico, or the Caribbean. U.S. Steel was transformed into USX, whose interests focused on construction and land development as steel mills were closed in the face of growing imports of cheap steel. The North American auto industry was restructured through competition from foreign makes, investments in new assembly plants, and vertical disintegration of the supply chain. As corporations adopted global network production systems, Manufacturing Belt states struggled to retain their former share of North American employment in manufacturing. John Deere, General Electric, IBM, General Motors, and Ford are some of the few major U.S. corporations with headquarters in the



Mittal Steel's Cleveland Works, May 20, 2005. Low-priced foreign steel has crippled an already fragile industry that had been dealing with high labor and materials costs for years. From 1997 to 2004, 45 steel manufacturers (about 40 % of those operating in the United States) went bankrupt. More than 85,000 jobs were lost from Western Pennsylvania through West Virginia, Ohio, Michigan, Indiana, and Illinois, according to the United Steelworkers Union.

Source: AP Photo/Mark Duncan.



Manufacturing Belt surviving from the heady days of innovation in the early 20th century. The results in the belt are diverse. They register as abandoned brownfield sites, pockets of high unemployment, outmigration, and struggles to retain or develop new identities after factory closings. They also figure as investments in a new economy: office towers, shopping malls, suburban housing, and some new factories. Together, these landscapes are witness to the latest rounds of creative destruction that reshape economy and society in North America.

The Manufacturing Belt was perceived as a distinct region, and one that was significant because of both its scale and its density, but the belt as a regional entity is also problematic. The belt is a product of analysis of the geography of manufacturing employment and investment in U.S. census returns. It is defined by the density of mills and plants, manufacturing workers, transport infrastructure, and power sites relative to other parts of the U.S. space economy. It was initially treated as a U.S. entity rather than a continental phenomenon. It was conceived as a system of cities but has been broadened to include industrial towns and an industrial countryside. Much of the research into the belt has focused on industrial districts and dynamics within its metropolitan centers. As the service sector expanded, manufacturing employment lost its cachet as the pivot of economic performance, so this is a historical sector whose fortunes have waned: The region is now better known as the Rust Belt or the Snowbelt. Yet the Manufacturing Belt continues to manifest in the higher population densities, older infrastructure, dense rail network, and other features of the Snowbelt states; in the regular division of the United States into geographic entities that permit rapid identification of the Manufacturing Belt states; and in studies of its “other”: the Sunbelt states and cities. In these ways, the belt remains an important reference point in the political economy of the United States and Canada.

Gordon M. Winder

See also **Deindustrialization; Economic Geography; Industrialization; Industrial Revolution; Uneven Development**

Further Readings

- Bluestone, B., & Harrison, B. (1982). *The deindustrialization of America: Plant closings, community abandonment*. New York: Basic Books.
- Cassetti, E. (1984). Manufacturing productivity and Snowbelt-Sunbelt shifts. *Economic Geography*, 60(4), 313–324.
- Cooke, P. (1997). *The rise of the Rustbelt*. London: UCL Press.
- Essletzbichler, J. (2004). The geography of job creation and destruction in the U.S. manufacturing sector, 1967–1997. *Annals of the Association of American Geographers*, 94(3), 602–619.
- Kerr, D. (1987). The emergence of the industrial heartland, 1750–1950. In L. McCann (Ed.), *Heartland and hinterland: A geography of Canada* (pp. 70–107). Scarborough, Ontario, Canada: Prentice Hall.
- Lewis, R. (2001). A city transformed: Manufacturing districts and suburban growth in Montreal, 1850–1929. *Journal of Historical Geography*, 27(1), 20–35.
- Meyer, D. (1983). Emergence of the American Manufacturing Belt: An interpretation. *Journal of Historical Geography*, 9(2), 145–174.
- Muller, E., & Groves, P. (1979). The emergence of industrial districts in mid-nineteenth-century Baltimore. *Geographical Review*, 69, 159–178.
- Page, B., & Walker, R. (1991). From settlement to Fordism: The agro-industrial revolution in the American Midwest. *Economic Geography*, 67, 281–315.
- Sawers, L., & Tabb, W. (1984). *Sunbelt, Snowbelt: Urban development and regional restructuring*. New York: Oxford University Press.
- Winder, G. (1999). The North American Manufacturing Belt in 1880: A cluster of regional industrial systems or one large industrial district? *Economic Geography*, 75(1), 71–92.



MAP ALGEBRA

Map algebra (also called *cartographic modeling*) is a set of operators, operations, and rules governing the manipulation and analysis of spatial data using the raster data model. The raster data



model represents geographic objects and fields by tessellating space as cells, each of which is associated with a value indicating the identity, rank, or quantity of the phenomenon that occupies it. Map algebra treats raster layers as variables in algebra and calculates new raster layers by applying one or a sequence of operations using expressions.

Map algebra decomposes spatial analytic tasks into elementary operations that can be flexibly recombined. Elementary operations in map algebra are grouped into local, focal, and zonal categories based on the *spatial scope* of the operations. Local operations calculate on the cell-by-cell bases values in the output raster layer using cell values of the input raster layers at the same location. Focal operations calculate output cell values using the input cell values within their respective neighborhoods. A neighborhood is a set of cells that bear certain relationships to the center of the neighborhood. Zonal operations calculate output cell values using the input cell values within the same zones. A zone is a set of cells sharing the same measurement value. A zone may comprise one contiguous grouping of cells or of multiple groupings of cells.

Map algebra operations have been expanded on since their inception in the late 1970s and early 1980s. While the original spatial scope was confined to two-dimensional space, it has been later extended to three-dimensional spaces, in which two-dimensional cells are replaced by three-dimensional voxels. A similar extension was also made for spatio-temporal data sets, where the third dimension is time. Map algebra operations for vector fields, where cell values are vectors (magnitude plus direction) rather than scalar measurements, were also developed. Spatial analysis in the vector data model does not have an algebra counterpart, mainly because the analysis units in the vector data model are not spatially uniform. Recent research, however, has shown that the map algebra approach is also viable for the vector data model.

Although map algebra is a powerful spatial analysis language widely used in spatial analysis with geographic information systems (GIS), its operations do not comprise a set of atomic operations on which all complex raster analyses can be based. Also, the classification of the operations

into local, focal, and zonal groups is rather arbitrary. The search for a generic set of operations for both raster and vector data remains a challenge for researchers in GIS.

Xingong Li

See also **GIScience; Quantitative Methods; Spatial Analysis**

Further Readings

- Berry, J. K. (2007). *Map analysis: Understanding spatial pattern and relationships*. San Francisco: GeoTec Media.
- DeMers, M. N. (2002). *GIS modeling in raster*. New York: Wiley.
- Tomlin, D. (1990). *Geographic information systems and cartographic modeling*. Englewood Cliffs, NJ: Prentice Hall.



MAP ANIMATION

Map animation, in its simplest form, is the display of a series of static thematic maps sequentially to convey changes in a specific phenomenon. Geographers and cartographers use maps to display geographic information in an interesting way to show patterns of change in specific phenomena. This entry first presents a brief history of map animation and then examines the concept of visual variables used for animating maps. Map animation types are reviewed according to categories emphasizing change, location, or an attribute. Given the increasing use of computing technologies and the World Wide Web, online interactive map animations are highlighted.

History of Map Animation

Before computers and their related technologies became commonplace, geographers and cartographers had used techniques such as hand drawings of each map, and a camera recorded each map frame of the animation. Despite these early



technological challenges, geographers advanced the technology for animating maps. Norman Thrower, as early as in the 1950s, promoted the possibility and promise of animating maps for showing the distribution of the conversion of forests to agricultural land, the spread of populations over time, and the change in political boundaries. One of the earliest computer map animations was a three-dimensional portrayal of a population growth model of Detroit, Michigan, by Waldo Tobler in 1970.

Further developments in map animation were inhibited by the high costs of reproducing graphic/color images, the high cost of computer hard disk space, and the lack of animation software development. However, with continuing technological advances, the increase in the number of users, and the decline in the cost of computing equipment such as hard disk storage, computing technology use has blossomed in the past 20 years, and map animation has become much easier to design, use, and distribute. The technological advances in computing power and speed and animation software have allowed geographers to break through the early limitations of cost and time to display a plethora of information on maps.

Animations and Their Visual Variables

David DiBiase and his colleagues in the early 1990s showed how specific visual variables for static maps can aid in the development of map animations. Animating maps requires knowledge and programming of visual variables that involve duration, rates of change, and the order the maps are displayed in. Duration is the length of time a map is displayed. The rate of change is defined by m/d , where m is the magnitude of the change and d is the duration of each frame. By either increasing the magnitude or decreasing the duration, the animation would speed up, or by decreasing the magnitude or increasing the duration, the rate of change would decrease. The order is the sequence in which the map frames are displayed. In Figure 1, A shows the slower and the faster rates of change related to geographic position, and B shows a series of maps with increasing rate of change related to circle size.

Animation Categories

Map animations that emphasize change may display demographic shifts in the U.S. population center after each decennial census count. Animations that emphasize location may display the world map and the global locations of active volcanoes over a certain time period. Animations that emphasize attribute differences in the Earth-Sun Geometry would display the Earth's seasonal relative position to the sun. Many of these animations are helpful didactic tools to teach and visualize the changeability of a dynamic process, especially when the phenomenon is much larger than the human scale.

Technological Advances and Interactive Map Animation

Software tools such as Adobe Flash technology and Microsoft PowerPoint have made it much easier to animate a series of static maps. With the advent of the World Wide Web, the current robustness of broadband Internet connections, and inexpensive hard disk space, animated weather forecast radar maps and online interactive map animations have become commonplace. These online animations allow users to virtually visit interesting places across the world. Mark Harrower provides a good example of an interactive map animation of a Wisconsin Lakeshore Nature Preserve. Users can easily maneuver around the Preserve site and zoom in for detailed views and even see photographs of meadow or forest patches within the preserve.

Map animations have been increasingly integrated with geographic information systems (GIS) and satellite remote sensing so that graphic programs such as ArcGIS, Google Earth, and NASA World Wind can display multiple layers of geographic data and multiple scales of imagery to enhance the visual dynamism of the animations.

With all these technological advances in animating maps, the question is whether the map animation effectively engages the user. Map animations need to follow the proper map design principles and display the visual variable slowly enough for the user to understand the interaction or change. When map animation is effectively

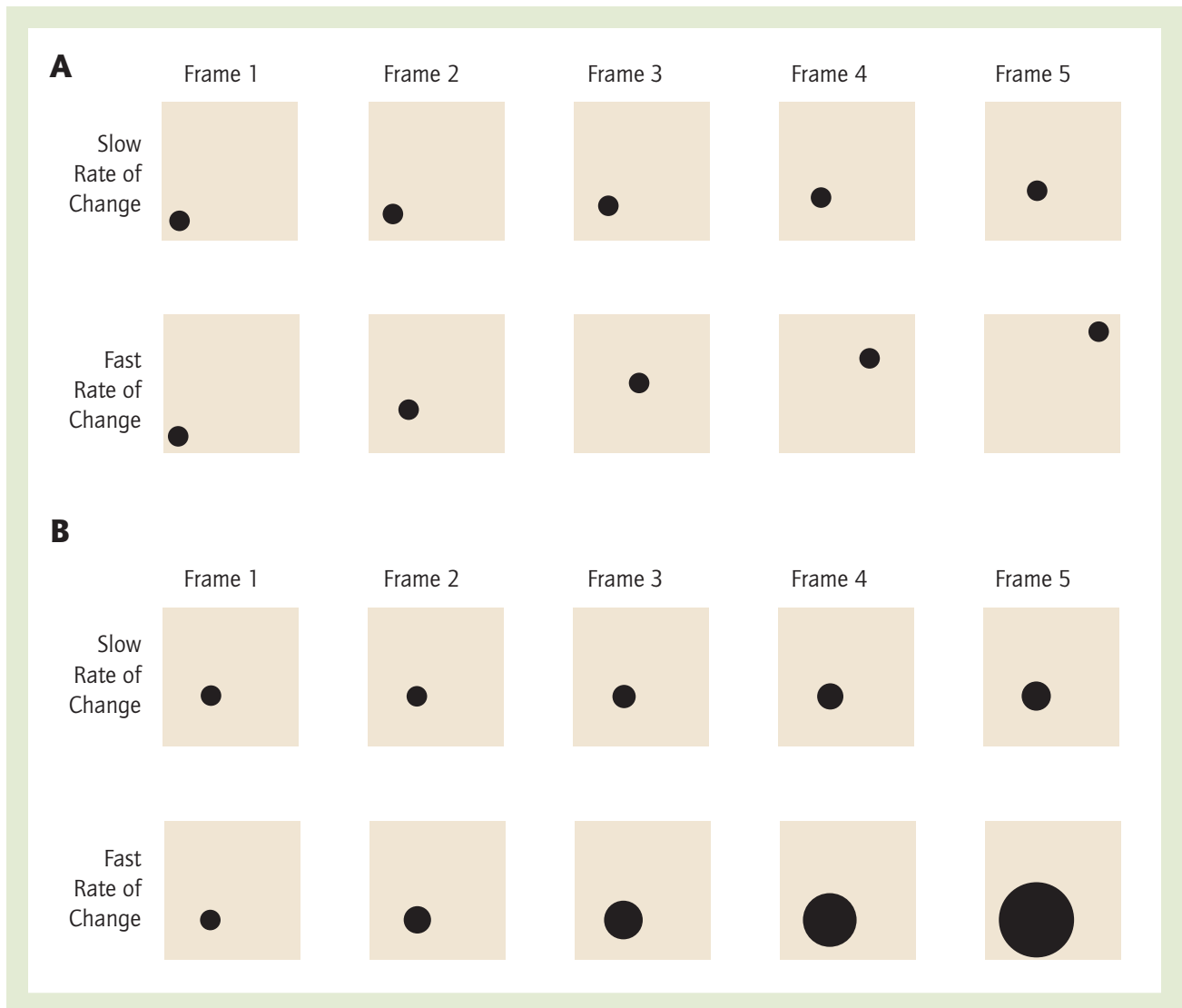


Figure 1 Visual variable rates of change for (A) geographic position and (B) circle size

Sources: Slocum, T., McMaster, R. B., Kessler, F. C., & Howard, H. (2005). *Thematic cartography and geovisualization* (2nd ed., p. 377). Upper Saddle River, NJ: Pearson Education. Copyright © 2005. Reprinted by permission of Pearson Education, Inc.; Adapted from DiBiase, D., MacEachren, A. M., Krygier, J. B., & Reeves, C. (1992). Animation and the role of map design in scientific visualization. *Cartography and Geographic Information Science*, 19(4), 205. Reprinted by permission of the ACSM.

Note: Rate of change is defined as m/d , where m is the magnitude of the change and d is the duration of each frame. For these cases, duration is presumed to be constant in each frame.

used, the advantages of this expanding aspect of geography can impress the user with the dynamism of real-world phenomena and effectively convey its meaning.

Kin M. Ma

See also **Map Design; Map Visualization**

Further Readings

Dent, B. D., Torguson, J. S., & Hodler, T. W. (2006). *Cartography: Thematic map design* (pp. 280–297). Boston: McGraw-Hill.



- DiBiase, D., MacEachren, A. M., Krygier, J. B., & Reeves, C. (1992). Animation and the role of map design in scientific visualization. *Cartography and Geographic Information Science*, 19(4), 201–214.
- Harrower, M. (2003, Winter). Tips for designing effective animated maps. *Cartographic Perspectives*, 44, 63–65.
- Lakeshore Nature Preserve. (2009, July). *Lakeshore nature preserve interactive map* (a detailed interactive map of lakeshore nature preserve on the shore of Lake Mendota in Wisconsin). Retrieved July 17, 2009, from www.lakeshorepreserve.wisc.edu/imap/LakeshoreNaturePreserve.html
- Slocum, T. A., McMaster, R. B., Kessler, F. C., & Howard, H. H. (2009). *Thematic cartography and geovisualization* (3rd ed., pp. 389–407). Upper Saddle River, NJ: Pearson Education.
- Thrower, N. (1959). Animated cartography. *The Professional Geographer*, 11(6), 9–12.



MAP DESIGN

Maps remain the primary means of communicating arguments and exploring information in geography. Clear and compelling map design can propel research in geography, while poor design can hinder it. Good map design results from careful planning and consideration of choices that are made throughout the cartographic process. Some of these choices are informed by cartographic theories of abstraction and representation, while others are informed by psychological theories of vision and perception, and still others are informed by artistic theories of harmony and balance. These choices apply to both the map itself and the map image, defined here as the completed map document: a printed page, a journal illustration, an interactive animated Web application, or a visualization system designed for data analysis and exploration.

Aesthetic Considerations: Lessons From Visual Design

Effective cartographic design remains a subjective and artistic endeavor. Many principles of aesthetics, visual harmony, hierarchy, and balance have

been developed in the visual arts and apply to projects both in cartography and in other visual design fields (including graphic design, painting, and architecture).

Figure-Ground Relationships

First and foremost of the design priorities is the establishment of a visual hierarchy to convey the relative importance of the various elements on the map image. A hierarchy should be planned before the map is constructed, as it will determine scale and symbol choices. Important information on your map should stand out as *figure*, while contextual, less important information should recede (visually) to the background, or *ground*. Figure can be achieved by *closure*, by placing the figure entirely on the map image. Figure by *differentiation* is achieved by setting the figure apart from other elements—say, by a darker color or by richer detail. Figure can also be achieved by *contour*, that is, using drop shadows, stippling, or other techniques to make the figure appear closer to the reader (Figure 1).

Visual Balance

The map image can be thought of as a two-dimensional plane balancing on a fulcrum at the visual center, slightly toward the top of the image from the geometric center of the image. The addition of darkness to the plane adds visual weight that needs to be counterbalanced across the fulcrum by similarly dark, or weighty, elements. Not every square inch of a map image needs to be filled; some blank space is not only acceptable but appreciated. A map image should have such “negative” space distributed evenly.

Internal Consistency

Stylistic similarity of symbols, type, color, size, and other elements provides for cleanliness and organization of the graphic. The level of detail of line work and iconicity of symbols, for example, should be generally similar across the map and across themes. A particular form of internal consistency is *interparallelism*, which holds that straight-line elements on the map (e.g., “leader” lines, which connect labels to symbols; the labels themselves; or schematized representations of linear features) should be parallel to each other whenever possible.

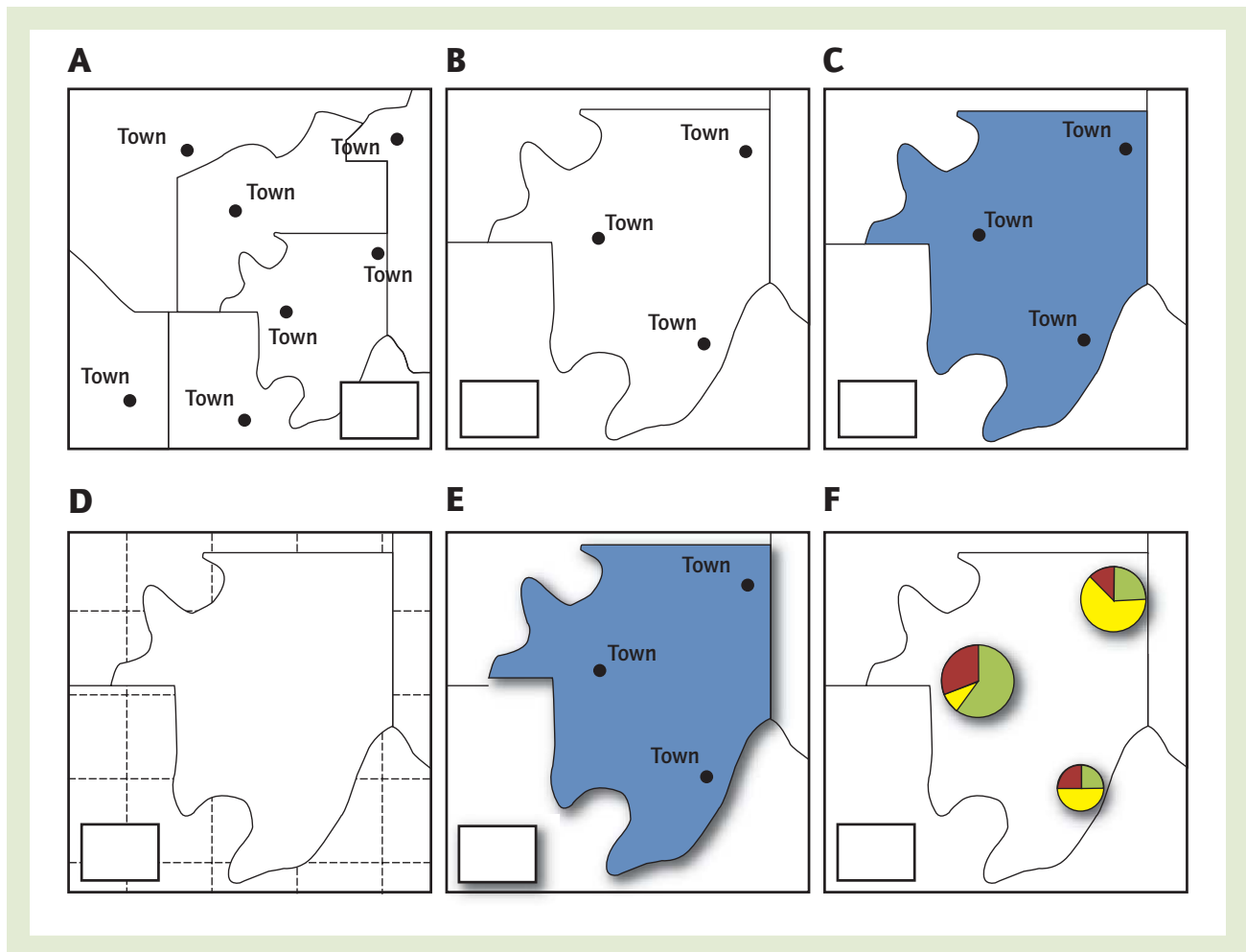


Figure 1 Figure-ground relationships: (A) poor figure-ground contrast; figure created using (B) closure and detail, (C) differentiation, and (D), (E), and (F) contour, with varying emphasis

Source: Author.

Simplicity

A vital and somewhat counterintuitive cartographic guideline is that “what matters is not what you put *on* a map but what you take *off*.” In our age of easy-to-obtain data, maps are often generated with a glut of information that clutters the image, obscures the message, and confuses readers. Simplicity is almost always favored in visual design over complexity, even in information communication and visualization.

Cartographic Abstraction in Design

A large part of the art of cartographic design that occurs before pen is put to paper (or mouse to mouse pad) is finding appropriate ways to *abstract*

information to fit the audience and the purpose of the map. Cartographic abstraction includes strategies for data simplification through selection, aggregation, generalization, and classification and subsequent strategies for data symbolization through cartographic modeling, colors, icons, line work, and labels.

The Base Map

Often overlooked, the design of the base map sends subtle clues about the focus and accuracy of the map as a whole. In the creation of the base map, the cartographer determines the scale, projection, orientation, and extent of the map. The level of detail of the base map depends on its scale and message; features on the base map such as



coastlines, rivers, street networks, and labels should be *generalized* to remove unnecessary information that would mislead or detract from the main purpose of the map.

Selection and Generalization of Themes

For both reference maps and thematic maps, appropriate selection of the information to include on a map focuses the attention of the reader and allows associations to be made. Once the themes have been selected, attribute generalization such as classifying data into categories, aggregating data into spatial units, or eliminating details may also be appropriate to clarify the message. These techniques are often highly subjective and can greatly influence the arguments presented by the map.

Symbolization Strategies

Appropriate symbolization is also subjective, but convention provides most of the necessary design answers. Conventions can be defied on occasion to highlight unusual data or facilitate analytical reasoning, but in general, cartographers and graphic designers use symbolization conventions that are intuitive to most readers. In most scientific uses, simple geometric symbols are favored over complex pictorial symbols, which are more often used for tourism, advertising, or children's maps. Two aspects of symbolization—color and type—are complex and ubiquitous and are considered in particular below.

Color

Graphic designers describe color using (at least) three dimensions: hue, saturation, and value. *Hue* refers to the color's wavelength (red vs. green); *saturation* refers to the intensity of a color (electric blue vs. slate blue); *value* refers to the darkness of a color (pink vs. red vs. maroon). Color schemes can be used to encode kinds of relationships: A *sequential* color scheme, varying only in value, typically represents quantitative or other ordered data, while a *diverging* scheme, which starts with a dark value of one hue and proceeds through a light neutral color to a dark value of a different hue, is used to highlight opposing qualitative extremes. A *spectral* scheme, which appears

as a rainbow of hues, is often used on weather maps but is best reserved for qualitative data such as land use categories, ethnicity, or climate zones.

Perceptual limitations influence color choices: Most humans can differentiate no more than seven or eight different values of the same hue, a color appears darker if it is surrounded by light colors (and vice versa), and color-blind users cannot differentiate certain color pairs. The display device chosen may also influence color choices: Color printers tend to produce different (more saturated) colors from RGB projectors, and a color map likely to be photocopied needs to be designed so that the color encodings remain logical in black-and-white.

Type

Like color, type has several dimensions: font, size, stance, orientation, case, style, color, letter spacing, and several others. Well-established guidelines for the use of these dimensions to encode information on maps are found in cartography texts; only a sampling of these is reviewed here. Fonts on a map give a map style and spirit and should be used judiciously; fancy fonts are hard to read, and standard fonts appear dull. Convention holds that water features or other features representing flow are labeled using italic fonts, while stationary features are labeled with upright fonts. Space can be included between letters on maps to indicate the extent of an areal feature; typically, point and linear features' labels should not be "letter spaced" in this way. Type can be colored to allow the reader to connect the label with the symbol, which may be colored similarly, though some color combinations (black on yellow) are more legible than others (red on green).

Elements of a Map: Are They All Always Necessary?

While the attention of a reader of a map image should be directed toward the map itself, by examining existing effective map images, a reader will note the presence of several elements apart from the map itself, often on the map images. Some of these elements provide explanation and context, while others provide balance, identity, or visual interest.



Title

An economical and careful choice of words in a title provides succinct reference about the message of the map. A title is not always necessary: The title of the legend, for example, often doubles as the title of the map (e.g., “Median Household Income”). The title should be positioned and sized on the map image to draw the eye at first glance and then lead the eye to the focus of the map.

Legend

Careful design of the map legend is both vital and underappreciated. A legend is not always necessary (see Google Earth, USGS topo maps), but it is almost always needed on thematic maps and on reference maps if the symbols on the map are not obvious. Symbols in the legend should match the symbols on the map exactly. Elements within the legend should be spatially organized according to the same visual design principles, described above, that govern the map image as a whole.

Inset Maps

One or more inset maps can also be used to provide context and to fill blank spaces on the map. Inset maps are used for a variety of purposes: They can provide detail, orient the reader, show a complementary theme, relate noncontiguous areas (e.g., Alaska and Hawaii), or diagram nonspatial attributes (e.g., a histogram or population chart). Inset maps are usually set off from the main map with a visual separator, such as a line or a box, and if they are of different scales from the main map, this should be made clear.

Scale Indicator

A bar scale, representative fraction, or verbal scale (“1 centimeter to the kilometer”), like other map elements, is not always necessary, and on small-scale maps, a scale indicator may not hold true across the map. A scale indicator should be present if measurement of distance is important for the use of the map or if the scale would not be obvious to the intended audience. In this case, the scale indicator should be as small as is practical, and the measurements indicated should consist of round numbers with appropriate units (e.g., a tick mark every 100 km [kilometers], rather than

every 79 km, or 1:100,000 rather than 1:99,621, unless precise measurements are vital).

Directional Indicator

The “north arrow” should be used only in circumstances where the convention of north-up is violated or where the area mapped is unfamiliar to the audience. A directional indicator is also sometimes used as a logo for the cartographer or the mapping company and can thus serve as a stylistic means of establishing an artistic identity. Like scales, north arrows are often inaccurate except at specific locations, particularly on small-scale maps. If a north arrow is used, it should be as small as is practical.

The Neat Line

A thin line or linear design (e.g., a pair of lines or a border design) is typically used to frame the map. This provides closure to the map and gives an impression that one is looking through a window onto a scene. This “neat line” is used on print maps and those on computer screens (e.g., GIS and Web maps).

Map Design in the 21st Century

Decades before interactive mapping came into use, cartographers developed guidelines for “optimal” design, depending on the purpose and audience of the map. Today, many of those guidelines have been relaxed as map readers themselves have become cartographers. What was once a costly and time-consuming process—resulting in one printed map that was difficult to change once created—is now more fluid and less labor intensive, often resulting in ephemeral maps meant for use by a single person at one specific time. Of course, thousands of maps are created daily to be printed and displayed to a wide public audience, and in these cases, traditional map design skills are paramount. However, even a map that is rapidly and individually created in GIS or on Web mapping applications is still the result of myriad subjective and artistic choices of its creator, and the success of a map remains heavily dependent on good map design practice.

Robert Edsall



See also **Cartograms; Cartography; Choropleth Maps; Isopleth Maps; Map Evaluation and Testing; Map Generalization; Map Projections; Map Visualization**

Further Readings

- Brewer, C. (2005). *Designing better maps: A guide for GIS users*. Redlands, CA: ESRI Press.
- Dent, B., Torgerson, J., & Hodler, T. (2008). *Cartography: Thematic map design* (6th ed.). Boston: McGraw-Hill.
- Krygier, J., & Wood, D. (2005). *Making maps: A visual guide to map design*. New York: Guilford Press.
- MacEachren, A. (1994). *Some truth with maps*. Washington, DC: AAG.
- Robinson, A., Morrison, J., Muehrcke, P., Kimerling, J., & Guptill, S. (1995). *Elements of cartography* (particularly pts. 5 and 6). New York: Wiley.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2008). *Thematic cartography and geovisualization* (3rd ed., chaps. 9–11). Upper Saddle River, NJ: Pearson/Prentice Hall.
- Tufte, E. (1983). *The visual display of quantitative information*. Cheshire, CT: Graphics Press.



MAP EVALUATION AND TESTING

A map is an abstraction and simplification of geographic reality to scale, created by selecting the most pertinent information, translating it into graphic symbols, and, usually, projecting it on a flat medium (paper or a computer screen). More maps are now made and used than ever before. Technology allows their quick and easy production, even by the map users themselves, who may generate the maps they need, for example, within a GIS or with applications such as Google Maps or Windows Live Maps on the Internet.

The main reason for the abundant use of map displays is that they are a very efficient means for the communication, analysis, synthesis, and *exploration* of geographic information to solve people's geographic problems. There is neither an

alternative nor a better way to provide insight into geographic patterns, relationships, and trends. Electronic databases have taken over the traditional role of maps as a geographic data storehouse, but new map roles emerged in digital environments, for example, as a geographic interface to additional information ("clickable maps").

A potential problem is that today maps are not as effective and efficient as they could be. In the past, the production of maps was cumbersome and time-consuming. Maps were made by specialists (cartographers), who applied a user-centered approach in map design. This approach starts with a careful analysis of the purpose and use of the map, as well as the prospective user (group). Based on that view, decisions are made regarding geographic contents, map scale, map projection, and level of accuracy. Thereafter, cartographic symbols are designed and combined into a map in such a way that geographic information is properly communicated. The cartographic "grammar" applied in those design activities is largely based on knowledge obtained from systematic map-use research, informing about the ways in which map users perceive combinations of cartographic symbols and attach geographic meaning to them. Such a user-centered design approach should still be followed today, when maps are often made for noncartographers, as may be the case with maps in various thematic atlases and maps on TV, on the Web, or in newspapers.

Because of the emergence of new map types (e.g., dynamic and interactive displays) and because maps are often generated by nonspecialists, scientific map evaluation and testing are still very much required, not only to arrive at more efficient and effective maps but also to improve the hardware and software with which maps can be generated.

Two broad categories of map-use research may be distinguished: perceptual/cognitive and functional. The first type of research is mainly done to find out in general *how* maps, or their elements, work in geographic problem solving. Functional-map-use research is more specific and based on the clear assumption that a map is made for a particular purpose and that it is important to find out whether and to what extent a particular map meets that purpose (usability research).



Map evaluation and testing may have both a qualitative and a quantitative character. Qualitative research is particularly required when new products have to be tested and when there is no knowledge available on how people use these products to answer geographic questions. Think, for instance, of small map displays in mobile geo-applications on smart phones and handheld computers. There is also a need for quantitative measures telling us, for instance, how long it takes for a person to execute a particular map use task and how many map users arrive at the “correct” answer.

Several tools are available to collect the required test data. Four main categories of techniques of map evaluation and testing may be distinguished: interview, questionnaire, observation, and product analysis. An interview with map users may take two different forms: structured and unstructured. During an unstructured or in-depth interview (which may also be executed with a focus group representing map users), questions are formulated spontaneously, albeit within an interview framework. The advantage of unstructured interviews is that a lot of in-depth information can be gathered when little is known of the geographic problem-solving process under investigation. But their disadvantage is that it is difficult to compare the answers obtained from different users. Comparability of data is afforded by structured interviews and written questionnaires directed toward the functioning of map displays.

To obtain useful and comparable results through questionnaires and interviews, it is recommended to have the users actually execute one or more tasks with the help of the designed map(s). The outcomes of these tasks, which could be answers to geographic questions, and also maps generated by the users themselves, can be a subject of product analysis. In evaluating existing map displays, cartographic experts use the same cartographic knowledge that is applied in the user-centered map design approach referred to above. Such evaluation, performed by experts, is called heuristic evaluation.

Information about the functioning of map displays cannot only be derived by analyzing the outcomes of task execution. It is also important to investigate the map-use process itself. Interviews and questionnaires may be applied here

again, but there is a potential problem of subjects feeling inclined to interpret and rationalize their problem-solving behavior. Moreover, test subjects may be steered too much into directions predicted by the investigator.

These problems do not occur if information is obtained by participant observation while the map is being used. Verifiable data may be collected with special recording equipment that also makes it possible to carefully analyze the observations at a later stage. Examples of possible recording techniques are video, registration of eye movements and brain activities, and screen logging. One problem with these techniques is that the analysis of the outcomes cannot provide complete in-depth information on the cognitive processes that take place in the minds of the subjects. After all, we want to know not only what the map users are actually doing but also why they are doing it and what they are thinking when things go right or wrong. For this purpose, the think-aloud method, in which map users are asked to verbalize their thoughts when executing particular problem-solving tasks, is appropriate.

Corné P. J. M. van Elzakker

See also **Dynamic and Interactive Displays; Heuristic Methods in Spatial Analysis; Map Animation; Map Design; Map Projections; Participant Observation**

Further Readings

Commission on Use and User Issues of the
International Cartographic Association (ICA),
Bibliography: www.univie.ac.at/icacomuse



MAP GENERALIZATION

The capacity to comprehend the physical world depends on our capacity to model it. Given the complex interplay of multiscale processes (both human and physical), it is critical that we model it at multiple levels of detail and that we have the capacity to understand and model the interaction of these processes *between* scales. In many



respects, a map is a model: Within a set of constraints, it seeks to reveal scale-dependent patterns that arise from the complex interplay of those processes.

Traditionally, it has been the preserve and responsibility of the cartographer to abstract and visualize the world in all its forms, at various levels of detail, both topographic and thematic. Attempts to automate the cartographic design process (the craft and the science of the human hand) have highlighted the complexity and challenges of modeling and visualizing the world. This task has been made even more complex as a result of the introduction of technology that has created a fundamental paradigm shift in how we use, explore, and interact with geographic information. Where once the map reflected all that we knew, now the digital image has become a looking glass to the digital database—one that stores geographies of the world, at multiple levels of detail, and supports functionality far beyond that of the static page. It is this paradigm shift that has spawned new visualization methodologies and exploratory data analysis techniques. But technology has not obviated the need for good design, that is to say, efficient and effective ways of conveying as many ideas as possible, in the shortest time and with the least amount of ink—both beautifully and hideously illustrated in the books of Tufte.

Attempts to mimic the cartographic hand have had mixed success. Various approaches (most recently, agent-based modeling) have tried to deal with the fact that design is a complex decision-making process. We need the “eyes of the cartographer” to evaluate designs, and various cartometric techniques have been developed to measure content, generate candidate designs, and evaluate map output. Ideas concerned with data modeling and database design have gravitated toward the concept that we should store and maintain geographic information at the finest level of detail and, through the process of generalization, create multiple representations at different scales (i.e., multiple levels of detail). This paradigm has replaced ideas that echo past approaches to map series production—in which a set of independent databases were created, each of a predefined and fixed scale, each requiring its own maintenance

and update. The new model is one in which updates are made once, and if the right multi-scale model underpins the data model, any change at the fine scale can automatically “trickle through” the smaller scales, making changes and updates where necessary.

This entry expands on conventional approaches to automated mapping, beginning with a discussion of model and cartographic generalization. Through illustration, the entry highlights the importance of evaluation and analysis techniques to support map generalization.

Model and Cartographic Generalization

Many national mapping agencies (such as Britain’s Ordnance Survey or the U.S. Geological Survey) continue to print paper maps at national coverage, at a variety of fixed scales. Figure 1 shows a part of the city of Portsmouth, England, at three scales: detailed 1:25,000 scale (Figure 1A), 1:50,000 scale (Figure 1B), and 1:250,000 scale (Figure 1C)—all products of Ordnance Survey.

The idea is that in a highly automated environment, we can capture a detailed representation of the real world. This is referred to as the primary digital landscape model (DLM) and is typically mapped at 1:10,000 scale. Then, through the process of map generalization, we create generalized views of the world—maps that enable us to comprehend larger and larger geographical extents but in increasingly less detail (Figures 1B and C). The process of map generalization can be achieved through a combination of two very complementary methodologies—cartographic and model generalization. The process of model generalization involves modeling between fundamentally different phenomena. For example, instead of conveying pavements, trees, individual buildings, and gardens, we convey major roads, forests, and cities. These higher-level concepts comprise the features found in the primary model. The process of model generalization creates what are termed secondary DLMs.

In the process of cartographic generalization, we apply a set of techniques that resolve relatively subtle ambiguities to maximize the quality and clarity of the finished map—something that a

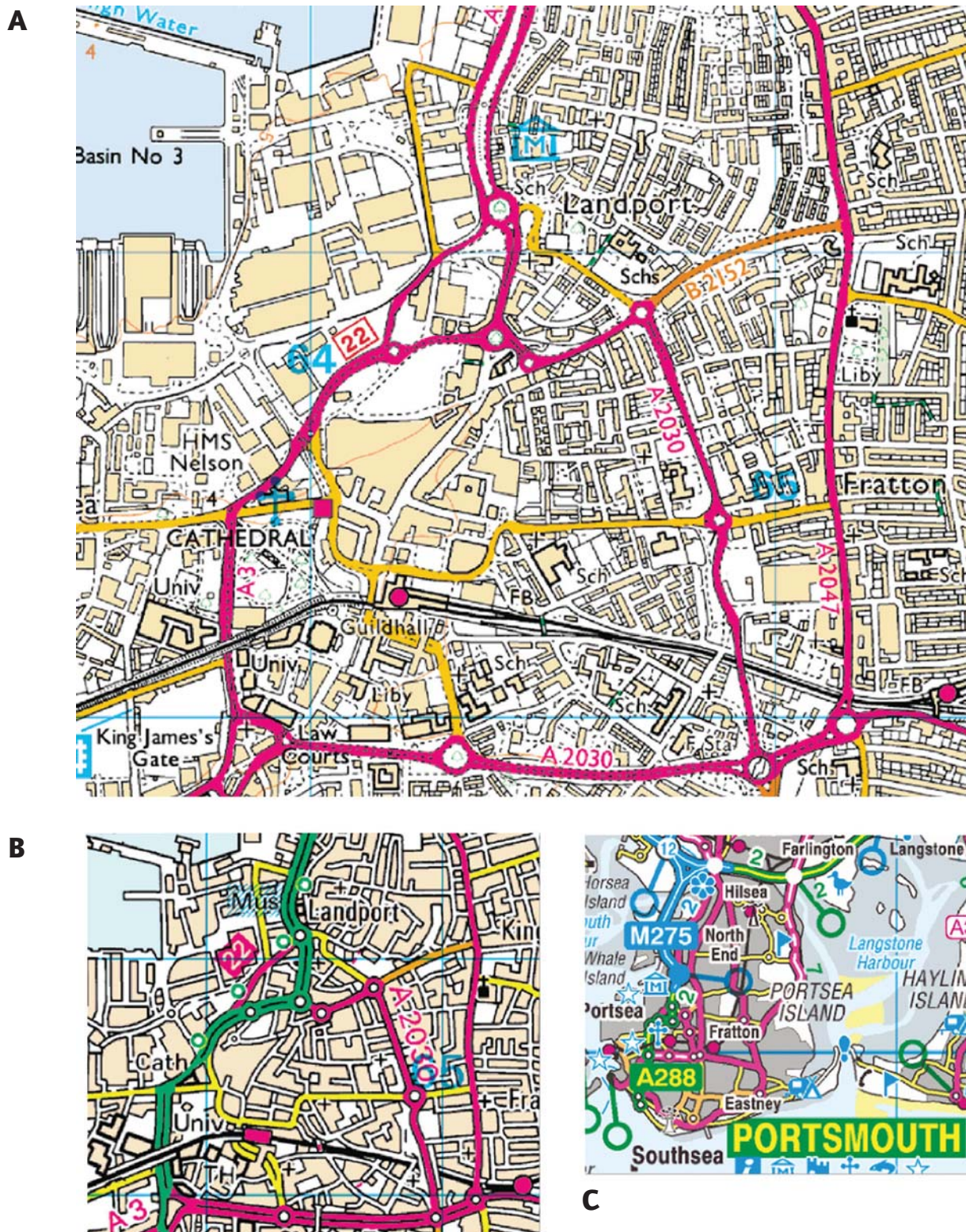


Figure 1 Part of Portsmouth, England, represented at (A) 1:25,000, (B) 1:50,000, and (C) 1:250,000 scales

Sources: Authors. Mapping from Ordnance Survey © Crown Copyright. All rights reserved.

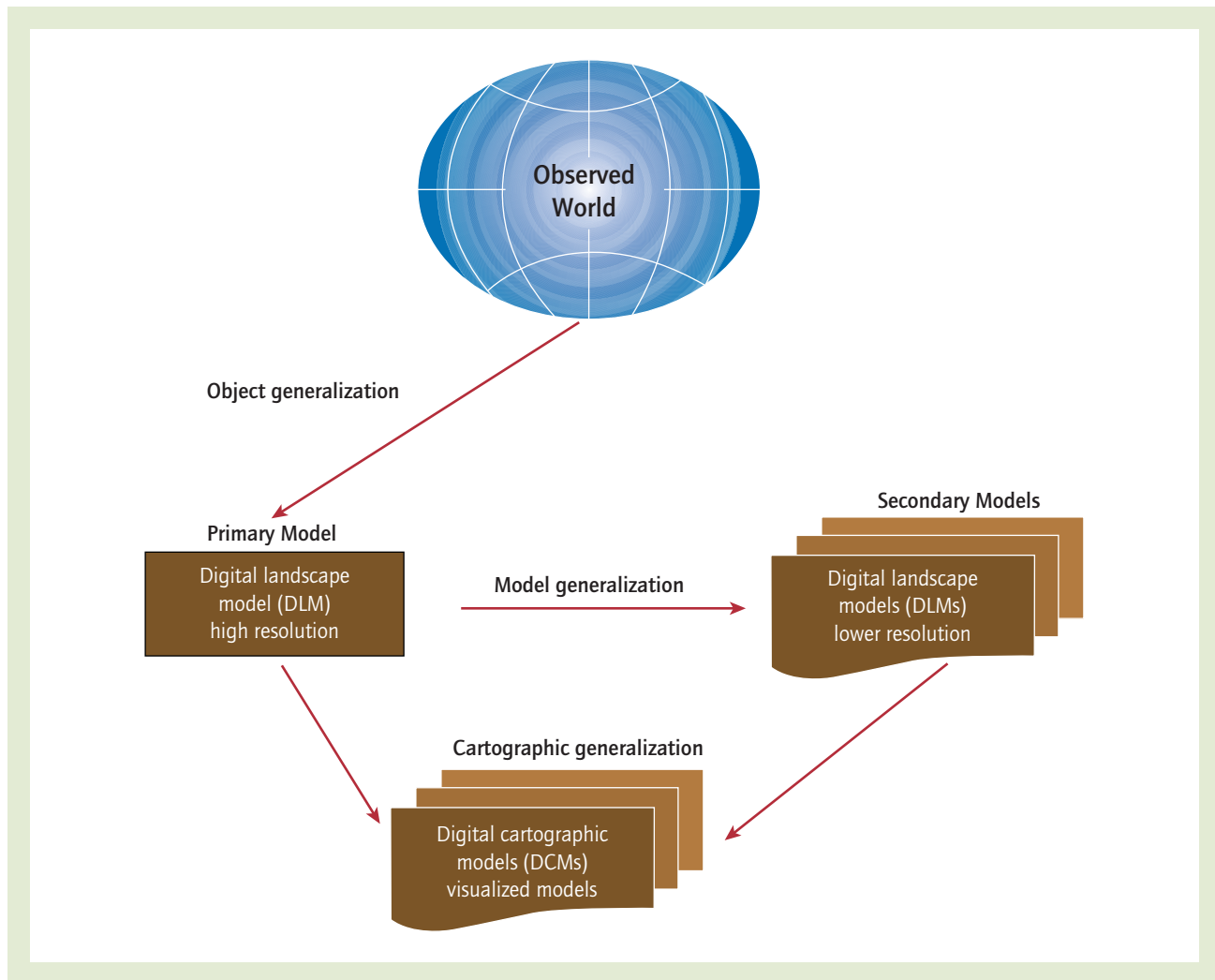


Figure 2 The first abstraction of reality creates the primary DLM, from which digital cartographic models (DCM) can be produced—either directly from the DLM or via the process of model generalization and the creation of secondary landscape models.

Source: Authors.

cartographer would describe as “the application of cartographic licence.” The process of cartographic generalization—applied to either the primary or the secondary model—produces the finished product. These ideas are summarized in Figure 2.

Model Generalization

Automating the process of model generalization has proved challenging and requires us to explicitly model the taxonomic and partonomic

relationships that exist between various geographic phenomena. These ideas tie directly to issues of data modeling and database design. It is common sense to interpret a dense region of buildings as being a town or a city. But in an automated context, we need to make this notion explicit within the model. Furthermore, we need to make explicit the range of scales (or levels of detail) at which it is appropriate to display a particular set of phenomena. In this way, and in combination with knowledge of the user’s task, the system knows when to represent the city as a dot (e.g., with the word “Edinburgh” next to it) and



when to represent the city in all its detail (such as in Figure 1A). It would take a huge amount of effort to create all the conceptual linkages that exist between all these scale-dependent phenomena. Thus, a lot of effort has been invested in trying to automate the process whereby phenomena are automatically grouped together—this is termed *data enrichment*. By illustration, we can say that we are all familiar with the concept and the function of a hospital. At a detailed level, we know it to be made up of wards, outpatient facilities, accident and emergency centers, parking lots, and laboratories. Algorithms have been developed that automatically “gather up” these various features to be able to collectively and generically represent this feature at smaller scales. Figure 3 shows the application of this algorithm in the context of a retail park (shopping mall) in Southampton, England, in which all the individual buildings and shared spaces have been collectively grouped together (Figure 3A) to be able to symbolize the retail park at a smaller scale (Figure 3B).

Cartographic Generalization

The cartographer applies a set of techniques that improve the legibility of the final product. For any map, the symbology has to be of a size discernible to the human eye, and this often means that a feature is represented larger than its geographical extent. For example, on A to Z road maps, the roads are distorted in width to fit the name of the street down their center. This increase in road width is at the expense of showing the blocks of buildings that lie between the roads. Separate from this process of exaggeration is that of displacement. Where a collection of important features are close together, it is necessary to marginally displace the features in order to discern their presence. Sometimes features are enhanced because of their importance (such as tourist features), and sometimes we symbolize features to overcome space constraints. Figure 4 shows seven techniques typically used to improve the legibility of a map; all these techniques come under the heading of cartographic generalization, each is shown with an example before and after application of the method.

Evaluation

The considerable research effort that has gone into developing techniques such as those in Figure 4 reflects the subtle and complex conditions under which these techniques are applied. Research in both model and cartographic generalization has reminded us that cartography has much to do with design and is a complex decision-making process. For example, when is it appropriate to displace a set of features in order to improve their legibility? At what point is it necessary to collapse a set of features (group them together) and represent them in some other form of symbology? At what point is the map so distorted that a particular technique can no longer be applied? What is the optimal order or grouping of these techniques? When is it no longer sufficient to apply cartographic generalization and instead it is necessary to apply model generalization techniques (in which we display a fundamentally different set of phenomena)? These sorts of questions have highlighted the importance of methods of evaluation. Evaluation is required at two key stages. The first is in the analysis of the various phenomena being mapped. This analysis is used to control both model and cartographic generalization processes. The second form of evaluation is assessing the final map's quality. Attempts to automate cartography have identified many qualities of the map that we wish to measure. We might want to measure the density of features in order to assess what space is available for displacement. We might want to preserve specific Gestalt properties among features—such as the orientation pattern of a set of buildings or the twisting nature of a mountain pass. All these qualities need to be measured since preservation of these qualities is often critical to the interpretation of the feature. Thus, the sinuous nature of a river might indicate a flat delta, or a large expanse of densely packed buildings might indicate a city. Techniques have been developed to model continuous regions (modeling the merging of adjoining regions), collections of discrete objects (i.e., using Voronoi diagrams), and the qualities of networks (i.e., using graph theory).

By way of example, Figure 5 shows a space-exhaustive tessellation of space, using a Voronoi

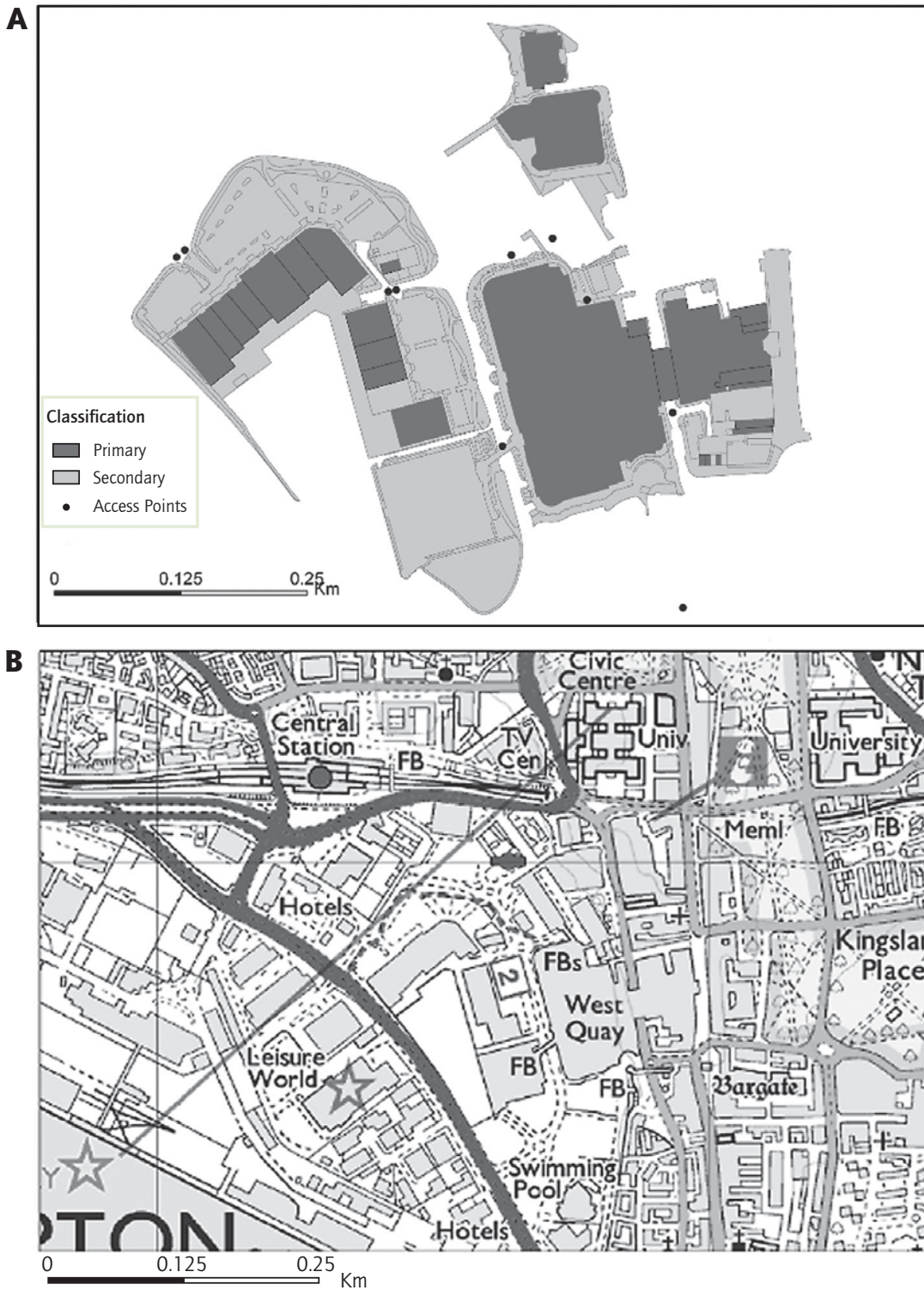


Figure 3 Modeling the function associated with a collection of buildings to derive secondary digital landscape models (example is a retail park in Southampton, England)

Sources: Authors. Mapping from Ordnance Survey © Crown Copyright. All rights reserved.



Operator	Before	After
Smoothing Reduce angularity of the map object		
Collapse Reduce dimensionality of map object (area to point, linear polygon to line)		
Displacement Small movement of map objects in order to minimize overlap		
Enhancement Emphasize characteristics of map feature and meet minimum legibility requirements		
Typification Replacement of a group of map features with a prototypical subset		
Text placement Nonoverlapping unambiguous placement of text		
Symbolization Change of symbology according to theme (pictorial, iconic), or reduce space required for symbol		

Figure 4 Definition of generalization operator, initial data, and result after application of the technique

Source: Authors.

diagram based on the center point of a collection of buildings. In this particular instance, we have grayscale coded the cells according to the amount of space taken up by the building within its respective cell. This information was used to (a) model the extent of the city, (b) identify the characteristic grouping of buildings (pattern analysis),

(c) identify regions where specific cartographic generalization techniques can be applied, and (d) analyze the quality of the overall solution in preserving the varying densities across the region after generalization. In effect, these evaluation techniques mimic the “eyes of the cartographer” and are a critical component of any automated solution.

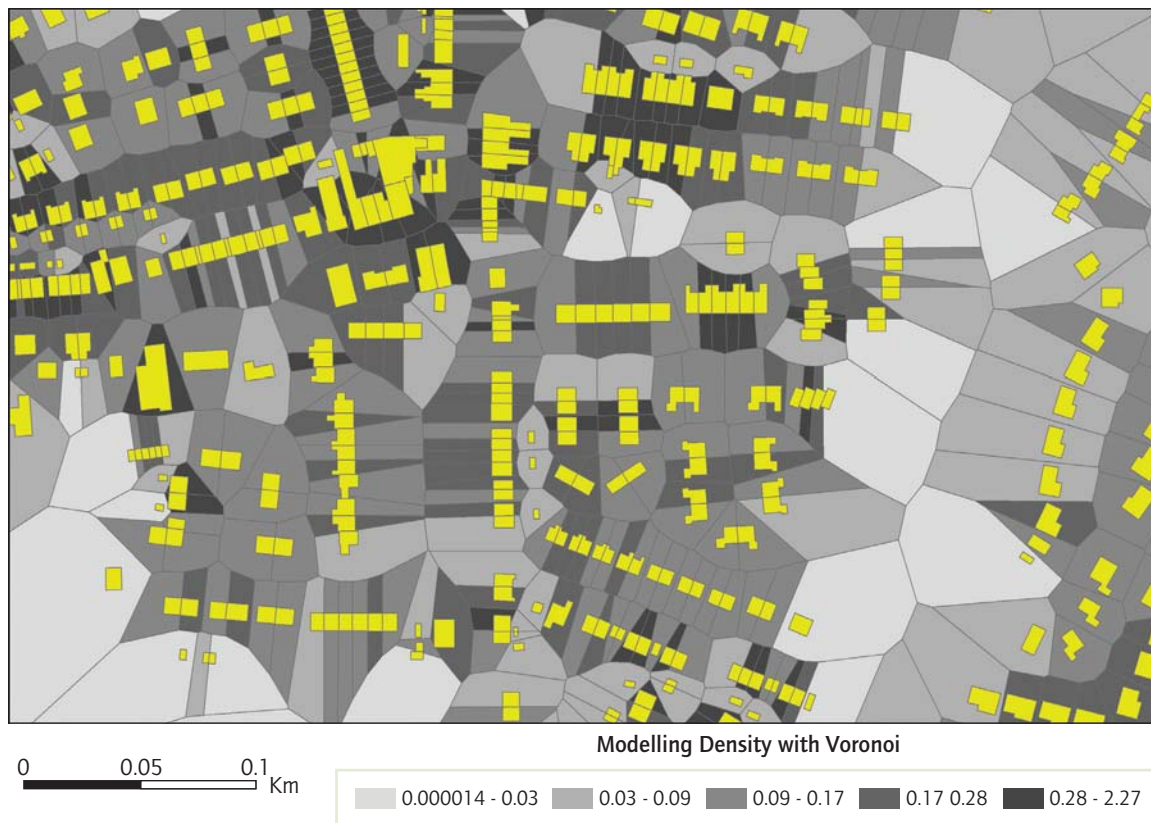


Figure 5 An example of the use of Voronoi modeling as a form of cartometric analysis to both govern the choice of the solution and evaluate the quality of the final product

Sources: Authors. Mapping from Ordnance Survey © Crown Copyright. All rights reserved.

Conclusion

In attempting to automate cartography, early research focused on eliciting the rules that cartographers lived by but found that they live by exemplars, which makes it very difficult to model. Furthermore, it became clear that the human decision-making process was highly context dependent—full of exceptions. This has frustrated developments in automation. Research continues to focus on ideas of a “cartographic syntax,” a framework that makes explicit the linkage between the features of the map, their context, and the emergence of meaning among those features. Research has also produced a set of techniques that in varying degrees mimic the human hand and the human eye. All this research has

revealed just how challenging and creative the art and science of cartography are. While there is value in exploring this subject from a visual and cartographic perspective, it has also proved useful to see the map as a model—an abstraction that visualizes specific concepts and relationships among a set of geographic phenomena. It is this realization that is leading to much greater focus on the data model that underpins the automated creation of maps at multiple levels of detail.

William Mackaness and Omair Chaudhry

See also Cartography; Database Management Systems; Geographic Information Systems; Geovisualization; Map Design; Map Evaluation and Testing; Map Visualization; Representations of Space; Voronoi Diagrams



Further Readings

- Buttenfield, B., & McMaster, R. (1991). *Map generalisation: Making rules for knowledge representation*. New York: Longman.
- Dykes, J., MacEachren, A., & Kraak, M.-J. (2005). *Exploring geovisualisation*. Amsterdam: Elsevier.
- Galanda, M., & Weibel, R. (2003). Using an energy minimization technique for polygon generalization. *Cartography and Geographic Information Science*, 30(3), 259–275.
- Mackaness, W., & Beard, M. (1993). Use of graph theory to support map generalization. *Cartography and Geographic Information Systems*, 20, 210–221.
- Mackaness, W., & Ruas, A. (2007). Evaluation in the map generalisation process. In W. Mackaness, A. Ruas, & L. Sarjakoski (Eds.), *Generalization of geographic information: Cartographic modelling and applications* (pp. 89–112). Amsterdam: Elsevier.
- Mackaness, W. A., Ruas, A., & Sarjakoski, L. (2007). *Generalisation of geographic information: Cartographic modelling and applications*. Amsterdam: Elsevier.
- Muller, J., Lagrange, J., & Weibel, R. (1995). *GIS and generalisation methodology and practice*. London: Taylor & Francis.
- Mustière, S., & van Smaalen, J. (2007). Database requirements for generalization and multiple representation. In W. Mackaness, A. Ruas, & L. Sarjakoski (Eds.), *Generalization of geographic information: Cartographic modelling and applications* (pp. 113–136). Amsterdam: Elsevier.
- Robinson A., & Sale, R. (1995). *Elements of cartography* (6th ed.). New York: Wiley.
- Ruas, A. (1998). A method for building displacement in automated map generalization. *International Journal of Geographical Information Science*, 12(8), 789–803.
- Ruas, A., & Duchene, C. (2007). A prototype generalization system based on the multi agent system paradigm. In W. Mackaness, A. Ruas, & L. Sarjakoski (Eds.), *Generalization of geographic information: Cartographic modelling and applications* (pp. 269–284). Amsterdam: Elsevier.
- Sheppard, E., & McMaster, R. (Eds.). (2004). *Scale and geographic inquiry: Nature, society and method*. Oxford, UK: Blackwell.
- Tufte, E. (1983). *The visual display of quantitative information*. Cheshire, CT: Graphic Press.



MAP PROJECTIONS

Projections are manipulations of Earth's coordinates that are undertaken to represent the spherical Earth's surface as a flat plane. Projections are required to map the Earth on paper; the type of manipulation and the resulting output form a projection. Many diverse projections have been made, and they differ dramatically in appearance and properties. Most significantly, the properties of projections must correctly be matched with the purpose of the map, or else the map message may be distorted or inaccurately presented. Although projections apply mathematical formulas to position coordinates systematically, simple illustrative models are described here to clarify the output of the manipulations and to present classifications of projection types. Also, the resulting properties or characteristics of the projections and some specific projections and their strengths and weaknesses are discussed.

Projections build from a coordinate system and a datum. Most often, the coordinate system used is latitude and longitude, and this system provides a graticule or grid of intersecting lines, parallels and meridians, within which the data coordinates are plotted. In that Earth is neither perfectly smooth nor perfectly spherical, a datum provides a standardized definition of its shape as a model. So the datum describes Earth's shape around which the graticule is constructed, and the projection manipulates this grid to portray the curved Earth's surface on a flat sheet.

Visualization of Projections

The mathematical manipulations of projections are best understood by imagining a clear globe with the graticule printed on its surface, a light bulb used to illuminate the globe, and a large sheet of paper on which to project the lines from the globe using the light bulb. The positioning of the paper and the placement of the bulb in relationship to the globe provide for diverse configurations of the projected grid. This example depicts the categorization of projections.

The first of the variables in these models is the placement of the light bulb, providing different viewpoints. For the gnomonic position, the light



bulb is in the center of the globe. The placement of the bulb against the side of the globe makes the stereographic position. The light bulb can also be placed at infinity for the orthographic projection.

A second variable is the shape formed from the paper. The result provides a developable surface for the projection and drawing of the grid lines. The paper can be left as a flat surface to be planar. It can be wrapped into a cylinder to make the category of the projection cylindrical. A third configuration is to form a cone from the paper. This approach yields the development surface classified as conic.

A third variable is the aspect or the orientation of the paper or the developable surface to the globe. Regular orientations result in the simplest lines and are standardized based on the form made of the paper. For a planar projection, the paper is placed at a pole. For a cylindrical projection, the paper is wrapped around the equator. The conic version places the point of the cone at a pole. Rotating these placements 90° is a transverse orientation. An oblique orientation is any other placement.

Additional variations involve the configuration of the surface of the paper to that of the globe. The paper and the globe are tangent where they touch. This point is especially significant, because only where this occurs will the scale or size relationship of mapped features on the paper and the globe be identical. Tangency may be absent, may occur at one point, or may form a circle or ellipse, or two circles or ellipses. Usually, the regular orientation of the planar projection has tangency at the pole, and the cylindrical projection has tangency along the equator. However, the paper may be formed so that it intersects the globe. This form is described as secant. The advantage of creating a projection based on a secant developable surface is the increase in the area of tangency and the enhanced closeness of all points to being at the same scale as the globe.

Projection Properties

Projections inevitably involve distortion because the curved Earth's surface cannot be made flat. The characteristics maintained by projections are

the properties of the projection. Major properties include equal area or equivalence, and shape or conformality. No projection can be both equivalent and conformal. Minor properties include distance and direction.

An equivalent projection means that the size of small areas is comparable throughout the map. These projections are suitable to show dot distributions and the location of individual features where the distribution or relationship between the features is the central concern. Unfortunately, this capability is not inherent in many map projections.

A conformal map displays the shape of small areas by maintaining the angles within the graticule. These projections are particularly good for thematic maps communicating the characteristics of political units, such as choropleth maps. Sizes are progressively distorted.

The property of distance entails measurement from the central point of the projection rather than the accuracy of measurement between any two points. The property of direction means that the measurement of directions will match those on Earth's surface; however, once again, this quality ranges from correct to limited to absent depending on the projection.

Because of the inherent distortion in converting the curved surface of the Earth into a flat representation, no projection and no map accurately portray these four properties. Many projections are devised that strive to improve one property while sacrificing the others to varying extents. These projections are called compromise projections, because they forgo accuracy of one or more properties for improved qualities on other properties.

Sample Projections

Many projections have been devised. A few of the better-known ones and their strengths and weaknesses are discussed here to help illustrate the concepts that have been described and the importance of matching the use of the projection with the properties that are inherent to it. Cartographic tradition requires identification of the projection used to produce a map to be included in the legend or documentation.

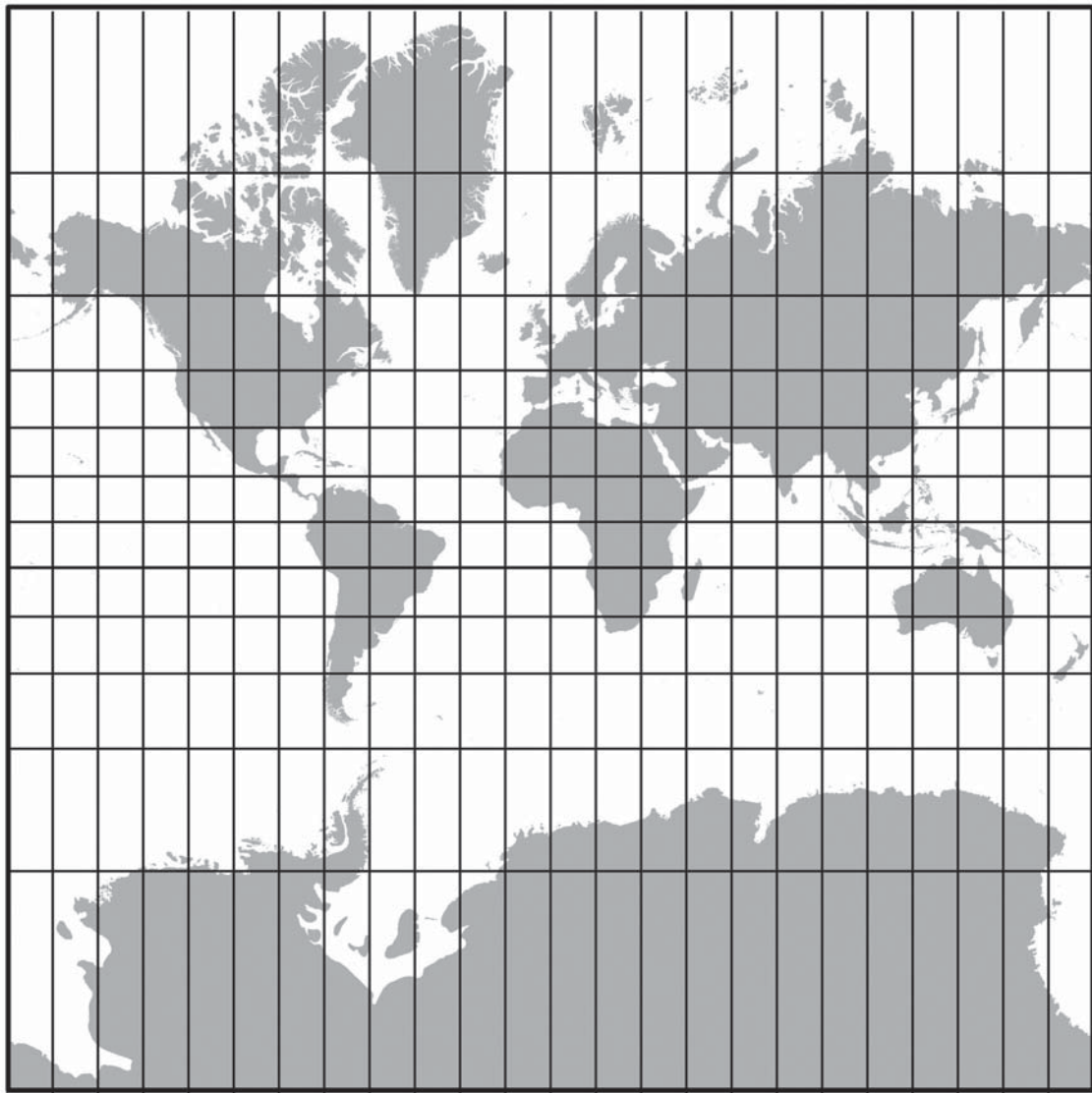


Figure 1 Mercator projection

Source: Author.

The most common projection is the Mercator projection, named after its creator, Gerardus Mercator (Figure 1). It uses a cylindrical developable surface with tangency at the equator. Secant variations are also used. The Mercator projection is conformal and shows true direction, thus it is used for navigation charts. Parallels are straight but become more widely spaced with increased latitudes. The poles cannot be shown with the regular

aspect. Meridians are straight and evenly spaced. The greatest strengths are the rectangular shape, conformality, and ability to show true direction with a straight line drawn on the map. The weakness is misrepresentation of the area at high latitudes, thus exaggerating the size of areas such as Greenland and leading to misperceptions about the spatial relationships of distances between points at different locations across the map.

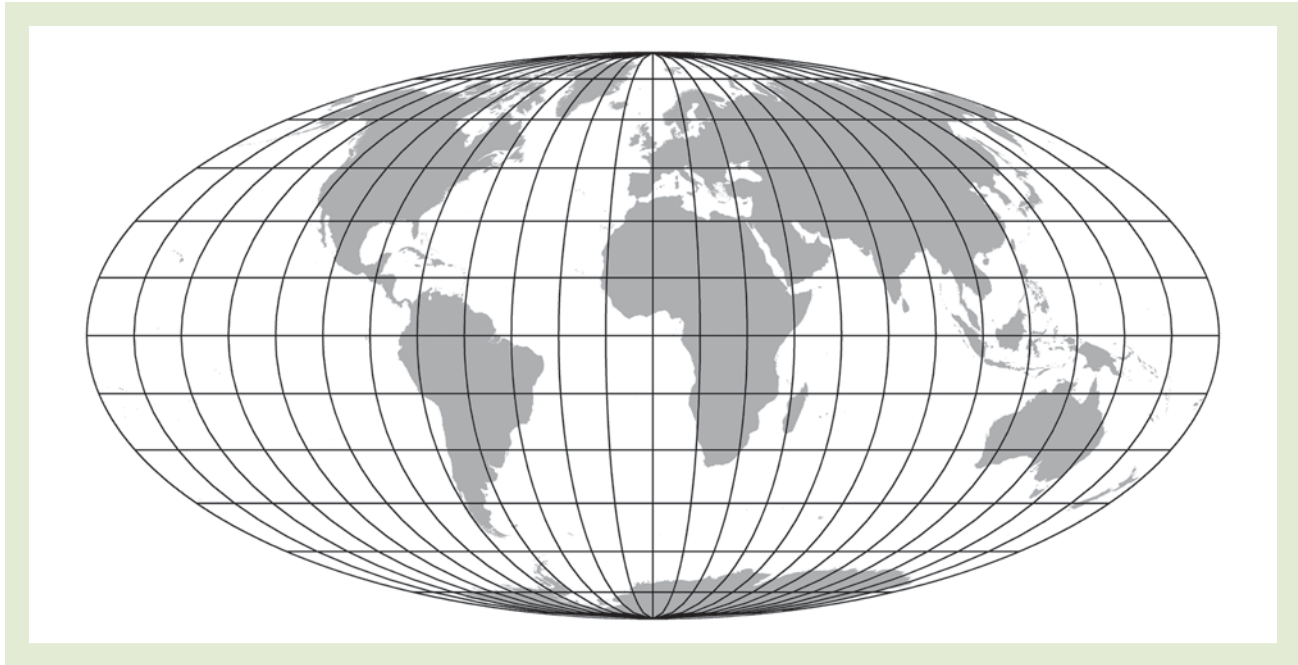


Figure 2 Mollweide projection

Source: Author.

The Mollweide projection, created by Carl Mollweide in 1805, is an equal-area projection (Figure 2). The parallels are both straight and parallel, placed to provide equivalence, and the meridians other than the central meridian are curved. Most shapes, directions, and distances are distorted, especially near the map edges. Strengths include the compact elliptical shape, which enables the polar areas to be represented. Weaknesses include the progressive shape distortion and inaccurate lengths of the parallels.

The Robinson projection is a compromise projection (Figure 3). Developed for Rand McNally by Arthur Robinson, a noted academic cartographer, it was used for about a decade by the National Geographic Society for their world maps. The parallels are straight and parallel, and the meridians, except for the central meridian, are curved. Although no projection properties are maintained, the straight parallels, the curved meridians (except for the central meridian), and the attempt to reduce distortions result in a pleasing and realistic appearance.

The Winkel Tripel projection (Figure 4) is another compromise projection combining two earlier projections and has somewhat less distortion

of the polar areas than the Robinson projection. The central meridian and the equator are straight, but other parallels and meridians are curved. The National Geographic Society substituted this projection for the previously used Robinson projection. Although no projection properties are maintained and the distortion is somewhat less than the Robinson, the overall shape is less pleasing.

The Plate Carrée projection is a compromise projection based on plotting the latitude and longitude coordinates as a simple grid (Figure 5). It is also called a rectangular projection; but in the traditional form, the grids are squares. All parallels and meridians are straight lines. The strength is the ease of use; however, the weakness is the failure to maintain projection properties. Many Web site maps display data in this format, which is inappropriate for density and pattern considerations. This projection is easily and best applied to small areas such as city maps, where the distortions will be sufficiently limited to make them insignificant.

The sinusoidal projection is an equal-area projection (Figure 6). The shape of these projections is variable, and this one is noted for its ornament

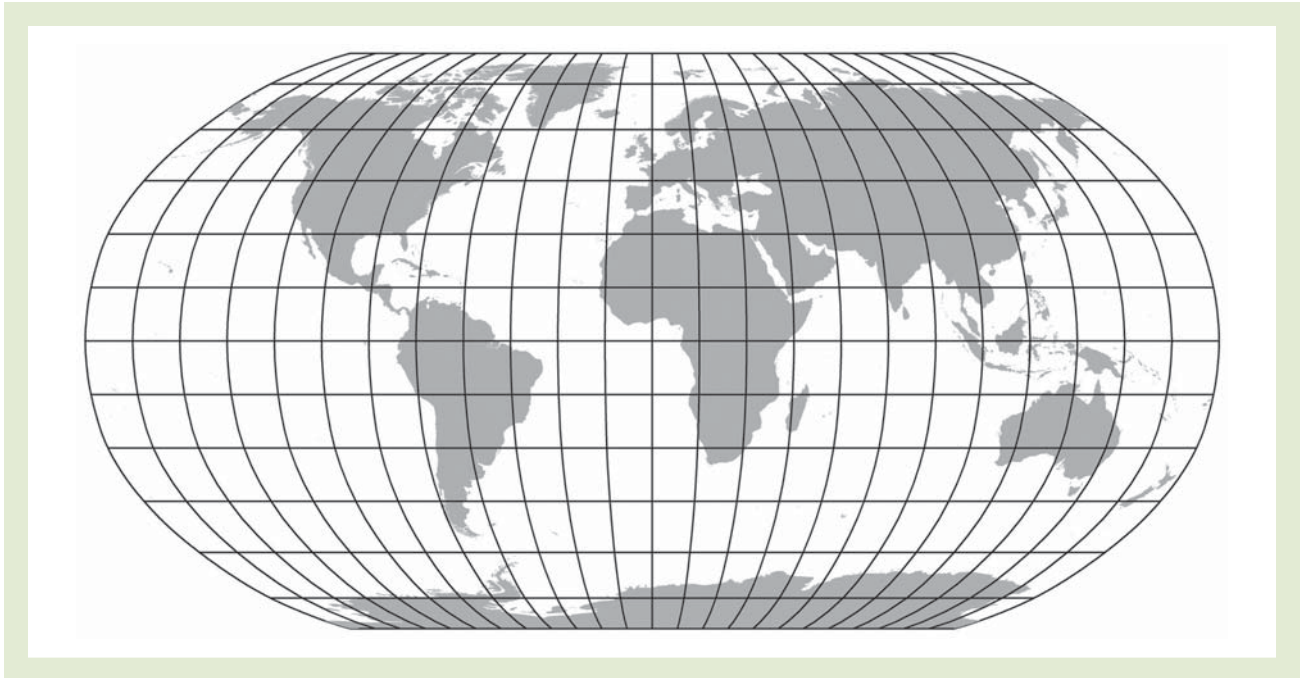


Figure 3 Robinson projection

Source: Author.

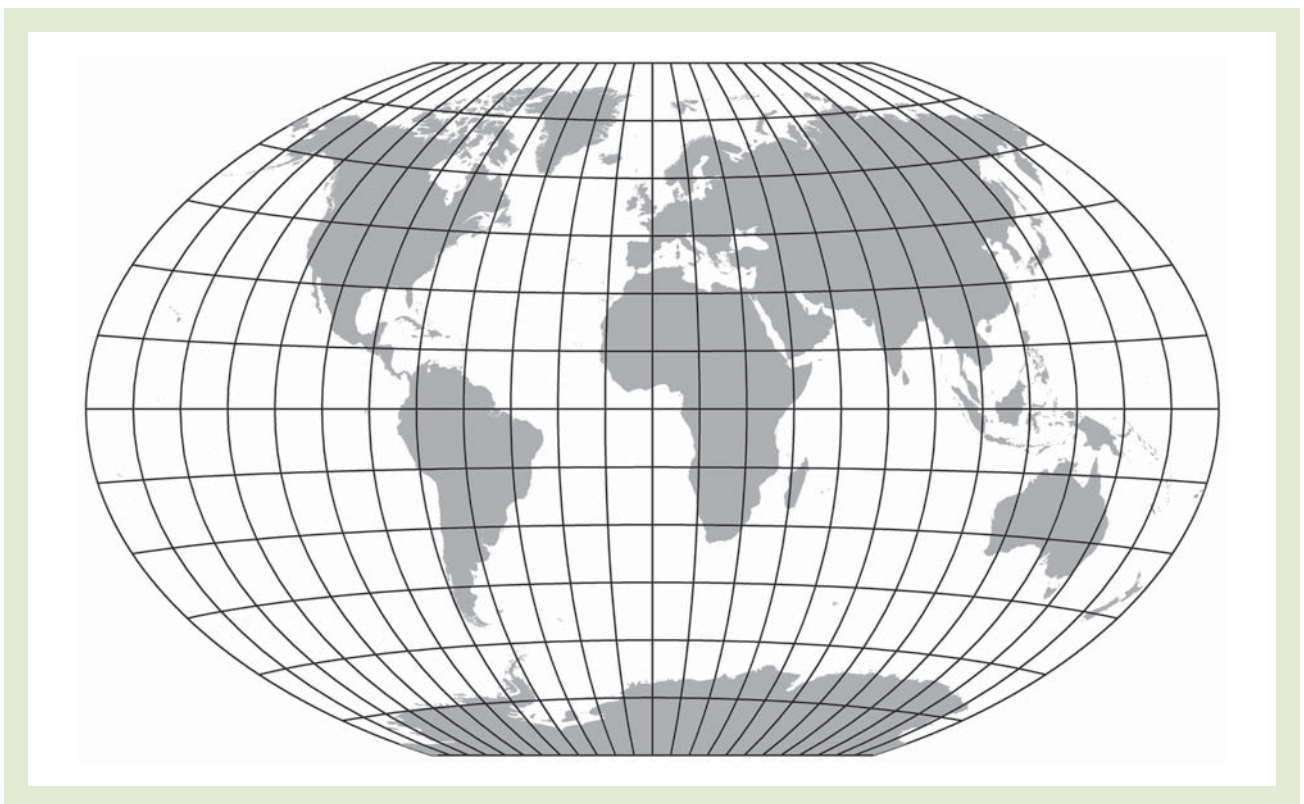


Figure 4 Winkel Tripel projection

Source: Author.

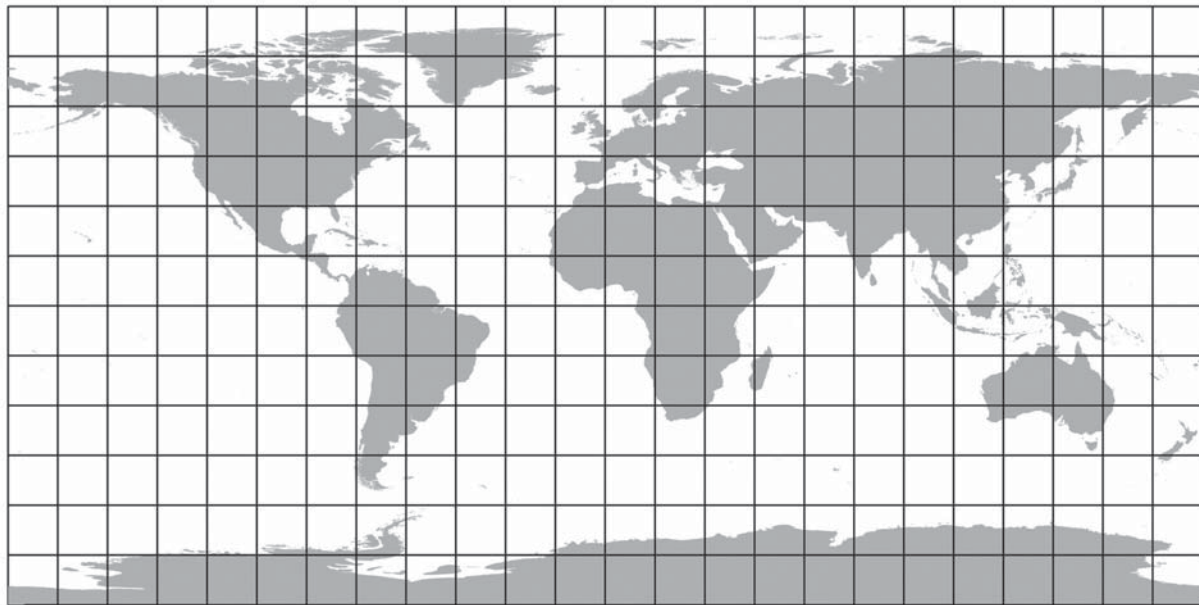


Figure 5 Plate Carrée projection

Source: Author.

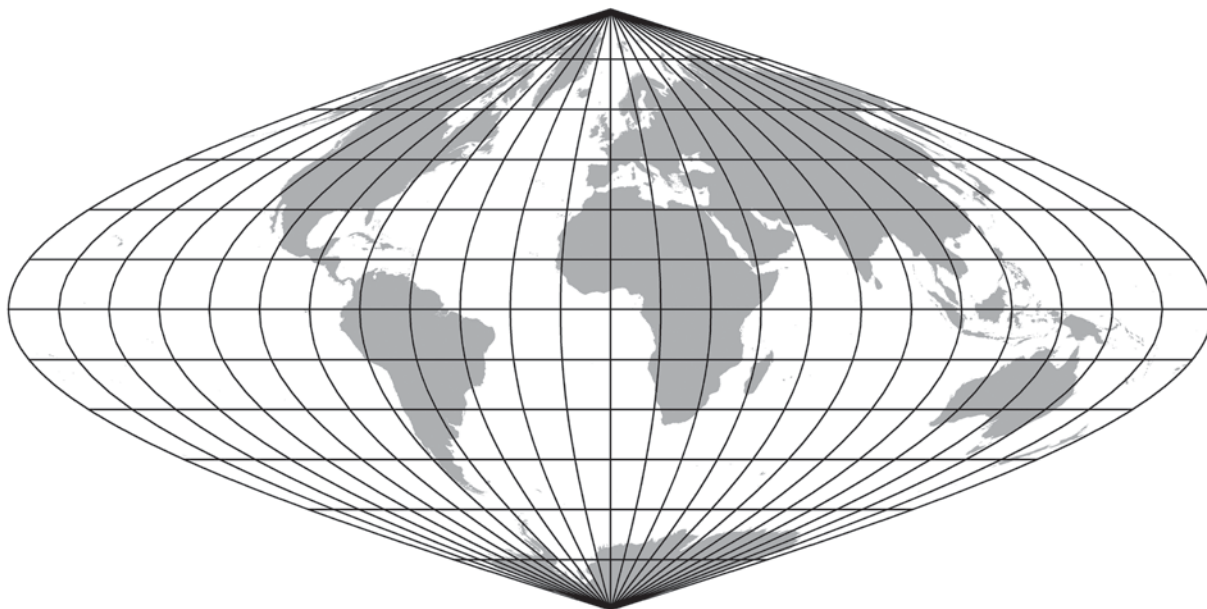


Figure 6 Sinusoidal projection

Source: Author.

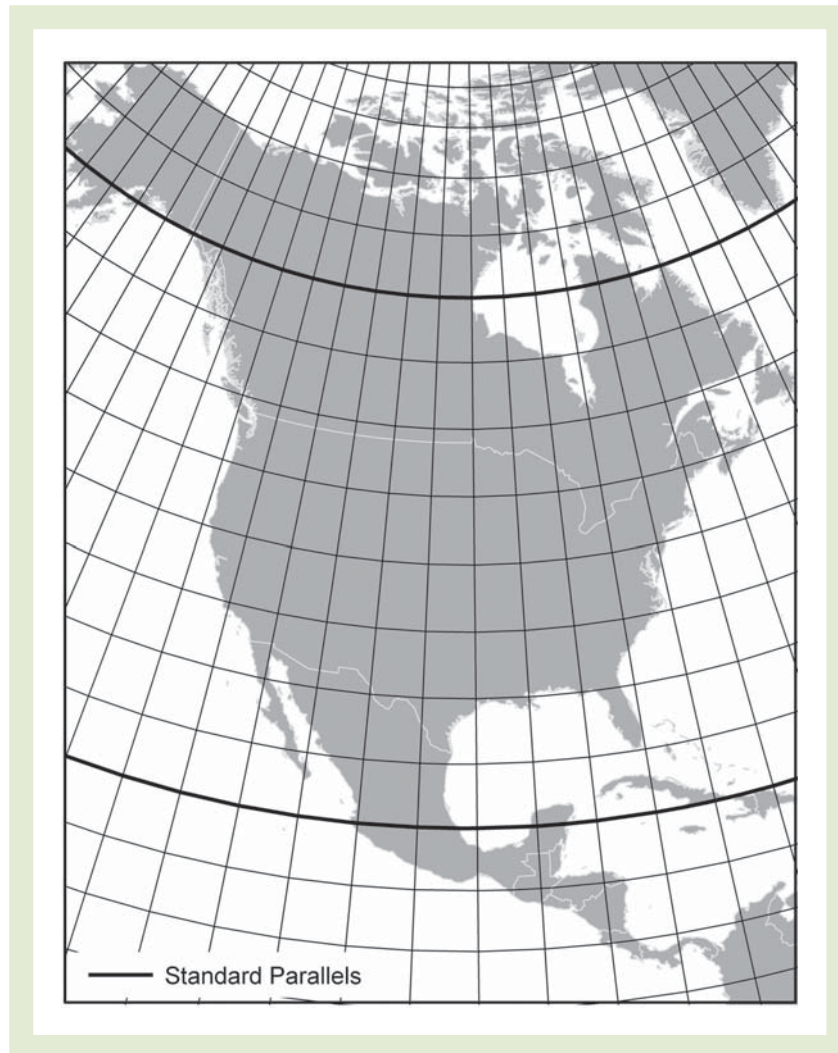


Figure 7 Albers equal-area projection of North America

Source: Author.

shape. The sinusoidal projection is often interrupted to use multiple central meridians to show the continental areas better. Parallels are straight, of appropriate lengths, and evenly spaced. Meridians are sine curves coming to a point at the poles. The right-angle intersection of parallels and meridians is absent, with the angle of intersection increasing toward the map edges. Thus, shapes are distorted away from the central meridian or meridians.

Some map projections are better adapted to mapping regions rather than the entire world. The Albers equal-area projection, for example, is satisfactory for mapping North America and good for showing the size relationships of areas (Figure 7).

It is conic and uses the secant method with two standard parallels. Meridians are straight, converging at the poles, and parallels are curved, forming concentric circles on the full cone. The two parallels make it best adapted to middle-latitude areas with wide east-to-west extent, so it is often used to map the United States, but it is less suitable for showing all of North America.

The Lambert conformal conic projection is used to show the shapes of middle-latitude regions such as North America (Figure 8). The cone-shaped developable surface uses the secant method with two standard parallels. Meridians are straight, converging at the poles, and parallels are curved, forming concentric circles on the full

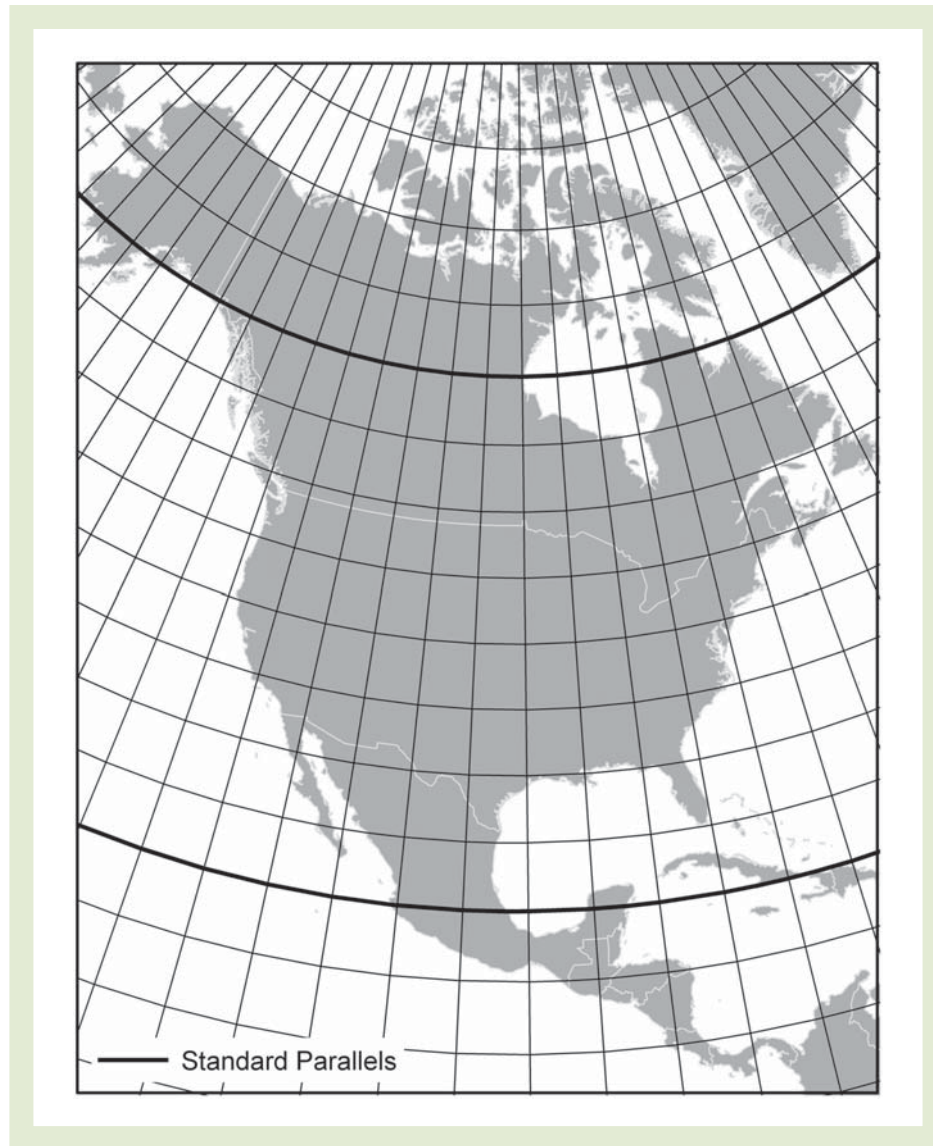


Figure 8 Lambert conformal conic projection of North America

Source: Author.

cone, with progressively closer spacing toward the poles. The suitable mapping areas are similar to those of the previously described projection.

Earth can be depicted as round, elliptical, square, dodecahedral, heart shaped, or double heart shaped, and even as an armadillo, the orthoapsidal projection. As the form is altered, the sizes and shapes of the ocean and land areas depicted are stretched and twisted. Mapmakers must be aware of the accuracy and limitations of the projection as they make their design choices; software programs offer diverse options with data tests for suitability.

Awareness of the type of projection applied aids in map reading and interpretation and may help identify those occasions when the ease of map production leads to inappropriate cartographic design.

Miriam Helen Hill

See also **Cartography; Cartography, History of; Coordinate Geometry; Coordinate Systems; Coordinate Transformations; Datums; Dot Density Maps; Goode, J. Paul; Map Design; Mercator, Gerardus; Waldseemüller, Martin**



Further Readings

- Campbell, J. (2001). *Map use and analysis* (4th ed.). Boston: McGraw-Hill.
- Dent, B., Torguson, J., & Hodler, T. (2009). *Cartography: Thematic map design*. Boston: McGraw-Hill.
- Krygier, J., & Wood, D. (2005). *Making maps: A visual guide to map design for GIS*. New York: Guilford Press.
- Monmonier, M. (1996). *How to lie with maps* (2nd ed.). Chicago: University of Chicago Press.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2009). *Thematic cartography and geovisualization* (3rd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Snyder, J. (1987). *Map projections: A working manual* (U.S. Geological Survey, Professional Paper 1395). Washington, DC: Government Printing Office.



MAP VISUALIZATION

Map visualization is an important component of geovisualization and refers to the dynamic representation of geospatial data and information for exploratory purposes and decision support. Unlike analog maps, which statically portray information to passive viewers, map visualizations today often require interaction with the viewer. The introduction of viewer interaction (e.g., changing map parameters such as scale or adding and removing map layers on demand and on the fly) with a cartographic production represents a fundamental change in mapping practice. Maps are no longer considered simply graphical inventories or informational artifacts; rather, the use of maps in interactive and exploratory fashion can enhance understanding, facilitate and extend scientific inquiry, and support decision making.

Recent advances in information technology, together with the proliferation of geospatial data, contributed greatly to this shift from static, cartographic maps to more dynamic geospatial representations and, more important, from a passive map-viewing audience to active spatial analysts

and mapping participants. In particular, the development, diffusion, and integration of geographic information systems (GIS), remote sensing (RS), cartography, and the Internet have revolutionized maps, mapping, and map visualization. Among the most notable changes to maps and mapping, which in turn spawned the tools, techniques, and field of geovisualization itself, was the shift from analog or hardcopy map production to digital cartography in the late 20th century. In addition to making map production more efficient, the digital tools and platforms on which geovisualization operates (e.g., GIS/design/statistics software, databases, network computers, the Internet) also facilitate the widespread diffusion, sharing, use, and viewing of geovisualization products, processes, and practices, as well as the development of the next generation of geovisualization techniques (e.g., mobile maps, interactive multimedia maps).

As information technology becomes more accessible, and as geographers and other professionals' monopoly on mapmaking disappears, map visualization itself becomes more accessible and more widely applied. Map visualization in the above-described sense is used by geographers and the scientific community, but it is also used across the public and private sectors (e.g., emergency responders, transportation engineers, planners, marketing companies). Furthermore, the emergence of neogeography, which refers to the creation and sharing of maps online for friends and visitors out of personal interest and curiosity, speaks to the continued diffusion of geovisualization tools and technology and to the changing population, behavior, and expectations of 21st-century mapmakers.

As geovisualization tools and techniques become more common, familiarity with geography and expectations from map visualization will also change. For example, the form and content of maps, which at one time were largely limited to the domain of the physical Earth, now extend into the realm of virtual worlds, cyberspaces, spaces of interactions, exchanges, flows, and networks, all of which are not necessarily bound to any particular geographic location. Moreover, this democratization of maps and mapping is not without its own complications or consequences. As data from myriad sources continue to



be collected and distributed, map visualization techniques will continue to highlight numerous questions on transparency and privacy and the broader implications of living in a geospatially enabled world.

Michael Shin

See also **Cartography; Geographic Information Systems; GIScience; Map Design; Map Evaluation and Testing; Neogeography; Remote Sensing; Spatial Analysis**

Further Readings

- Dodge, M., McDerby, M., & Turner, M. (2008). *Geographic visualization: Concepts, tools and applications*. West Sussex, UK: Wiley.
- MacEachren, A. M. (1995). *How maps work: Representation, visualization and design*. New York: Guilford Press.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2005). *Thematic cartography and geographic visualization* (2nd ed.). Upper Saddle River, NJ: Pearson.



MARCUS, MELVIN G. (1929–1997)

Melvin Gerald Marcus was born in Seattle, Washington, an environment that molded him as a geographer, environmental educator, and mountaineer. He claimed 52 first ascents by age 19, becoming the youngest person elected to the American Alpine Club. Recruited to Yale, he majored in geology while playing basketball and reaching the NCAA Final Four. While at Yale, Maynard Miller invited him to explore the Juneau Icefields, leading to a series of expeditions that fueled Marcus's interest in glaciology.

The Korean War interrupted his education in 1951. Volunteering for the Air Force, he piloted B-26 bombers. Postwar military duty in Japan prompted him to switch to a field that encompassed mountains, travel, and people. He left Yale, which had no geography department, and graduated with geography degrees from the University

of Miami (BA, 1956), the University of Colorado (MA, 1957), and the University of Chicago (PhD, 1964), where he studied the mass balance of the Lemon Creek Glacier, Juneau Icefields.

Marcus held teaching positions at Rutgers University (1960–1964), the University of Michigan (1965–1973), and Arizona State University (1974–1997). He was chair of the geography departments at the University of Michigan and Arizona State University. He also taught at Christchurch University and West Point on sabbaticals.

Marcus took students of all backgrounds into challenging field environments. Despite objections, he included women for the first time in the 1960s science expeditions to the St. Elias and Wrangell ranges in the Yukon and Alaska. His passion for environmental education led to two decades as a board member with Yosemite National Institutes, where he developed a geography-based environmental curriculum that eventually reached 40,000 students per year.

Marcus's research initially focused on glaciology and mountain climates, often in unexplored and unstudied settings. In the 1970s, his research expanded to include human-environment interactions, usually with an emphasis on human impacts on micro- and meso-climates, ranging from building effects on heat flux to land use impacts on dust storms. Later writings such as *Geography's Inner Worlds* examined the status of geography and geographic education.

As president of the Association of American Geographers (1977–1978) and in his presidential address, "Coming Full Circle," Marcus advocated for the importance of physical geography and commissioned the strategic plan that generated Specialty Groups, which were critical in keeping physical geographers within geography. He was vice president of the American Geographical Society from 1986 to 1996 and chair of the U.S. National Committee of the International Geographical Union, a position he used to influence the *Rediscovering Geography* report, which advocated for geography's role in the world.

W. Andrew Marcus

See also **American Geographical Society; Association of American Geographers; International Geographical Union**



Further Readings

- Abler, R. F., Marcus, M. G., & Olson, J. M. (Eds.). (1992). *Geography's inner worlds: Pervasive themes in contemporary American geography*. New Brunswick, NJ: Rutgers University Press.
- Graf, W. L., Gober, P., & Brazel, A. J. (2001). Melvin G. Marcus, 1929–1997. *Annals of the Association of American Geographers*, 91, 724–733.
- Marcus, M. G. (1979). Coming full circle: Physical geography in the twentieth century. *Annals of the Association of American Geographers*, 69, 521–532.
- National Research Council. (1997). *Rediscovering geography: New relevance for science and society*. Washington, DC: National Academy Press.

MARGINAL REGIONS

Marginal regions are regions that are situated somewhere at the edge or at the margin of a system and are not part of the traditional center-periphery model. Marginal regions and peripheries are not the same. Marginal regions are also called associated regions, isolated regions, or dead angles. While centers and peripheries exist in more or less intense mutual relationships, these regions (or places) occupy different positions within the system. They can be categorized as follows:

1. **Associated region:** A place can lead a life of its own and yet be associated with a major center, such as the port city of a capital. There are close ties between it and the center but no unilateral dependency.
2. **Isolated region:** A place may have intense internal relations but little contact with the outside world, thus remaining isolated from it and living according to its own rhythm.

3. **Dead angle:** A place (or a region) can be situated off the main communication flow and lead a very introverted life at the edge of a system, lacking a development potential of its own.

Types 2 (isolated region) and 3 (dead angle) resemble most what we would call marginal regions. They may exist inside a polarized region but are not part of it.

Marginality can be encountered in various contexts and at a variety of scales. It has a distinctly spatial component. Socially marginal groups, for example, often congregate in specific locations, as exemplified by the dwelling areas of the Untouchables in India, the Ghetto for the Jews in medieval European cities, certain housing estates, and gated communities.

Ways of Looking at Marginality

Walter Leimgruber's attempt to understand marginal regions identified four different types of marginality: geometrical, ecological, economic, and social. Other possible approaches (political, cultural, risks/hazards, and perception) also exist, thus demonstrating the diversity of the concept and the various disciplines that would be involved in marginality research.

A purely materialistic perspective would define marginality by some threshold value of the gross domestic product (GDP) per capita. This restricted view is static and overlooks other manifestations. Social marginality cannot be reduced to the GDP. Marginality is not the end-stage of a process, but it may be of limited duration. A dynamic approach is therefore required. A suggestion could lie in the comparison of market integration and the level of productive forces. A region where both are low can be classified as marginal, and a change in one or in both parameters would lift the region out of marginality (Figure 1).

Another approach is based on the diversity of human societies, which "are not necessarily unified collectivities" (Giddens, 1984, p. 24). This diversity manifests itself in highly varied human behaviors, which define a social mainstream within which all individuals oscillate (Figure 2). Certain individuals' behavior, however, is located at the

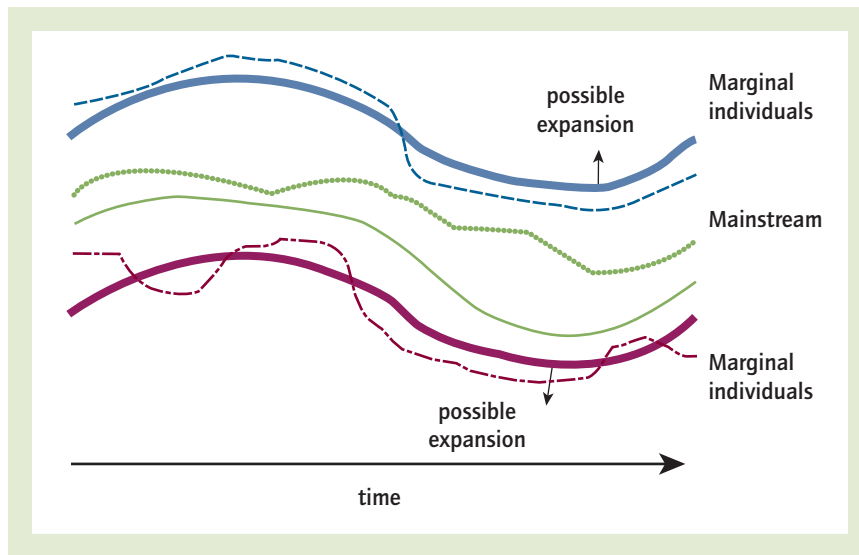


Figure 1 Possible trajectories for marginal individuals over time. The degree to which individuals fluctuate from established social norms is temporally and geographically fluid.

Source: Leimgruber, W. (2004). *Between global and local: Marginality and marginal regions in the context of globalization and deregulation*. London: Ashgate. Copyright © Walter Leimgruber.

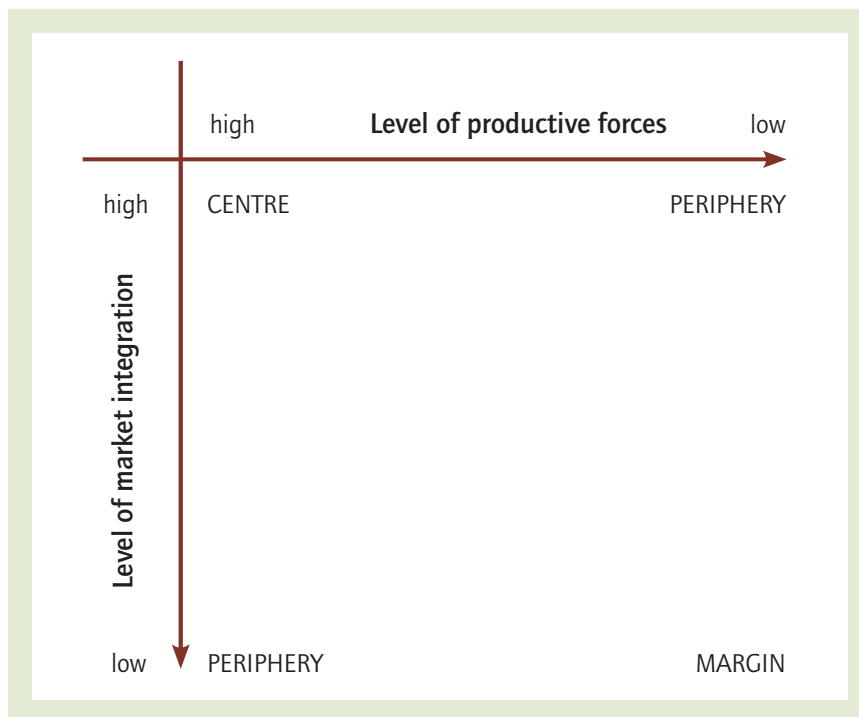


Figure 2 Marginal regions in the context of productive forces and market relations. Marginal regions tend to be peripheralized in terms of both productive capacity and their level of integration into wider divisions of labor.

Source: Leimgruber, W. (2004). *Between global and local: Marginality and marginal regions in the context of globalization and deregulation*. London: Ashgate. Copyright © Walter Leimgruber.

extremes of a society's range and may even reach considerably beyond it. Such persons no longer belong to the society's "mainstream" but are marginal persons. While the mainstream is relatively stable over time, marginal individuals can nevertheless have a long-term impact on the society in that they may bring about transformations; they are in fact essential elements of every society. "While the continued existence of large collectivities or societies evidently does not depend upon the activities of any particular individual, such collectivities or societies manifestly would cease to be if all the agents involved disappeared" (Giddens, 1984, p. 24). The sum of such marginal individuals can be called a marginal group or community.

From a political perspective, marginality can be associated with regions along political boundaries where the application of state authority ends, where the military function of a boundary is prevalent, and where investments are traditionally low. This kind of marginality can also be described as geometrical.

There is also a positive side to marginality that tends to be overlooked. Marginal subjects (individuals, groups) can be agents of social transformation and innovation. Indeed, persons who have brought about substantial changes were often socially marginalized (e.g., St. John the Baptist, Jesus Christ, St. Francis of Assisi). Even Einstein, in his outer appearance, did not conform to standard social expectations.

This variety of meanings is the reason why a wider approach



to marginality and marginal regions is required, an approach that helps revise the dichotomy between cores and marginal areas. One could also include the natural environment, which has become marginalized over the past few centuries due to the emphasis on the material well-being of an affluent society.

Walter Leimgruber

See also **Difference, Geographies of; Orientalism; Uneven Development**

Further Readings

- Douglas, M. (1996). *Natural symbols: Explorations in cosmology*. London: Routledge.
- Giddens, A. (1984). *The constitution of society*. Cambridge, UK: Polity Press.
- Leimgruber, W. (2004). *Between global and local: Marginality and marginal regions in the context of globalization and deregulation*. London: Ashgate.



MARINE AQUACULTURE

Marine aquaculture refers to the farming of aquatic organisms in coastal or off-shore marine environments, involving controlled interventions to increase production by specific groups claiming ownership of the cultivated stock. Marine aquaculture involves the farming of a high diversity of aquatic organisms, including mollusks, crustaceans, fish, and aquatic plants, amounting to 240 reported species in 2004, cultivated in diverse environments (brackish and marine areas), with different technologies (cages, ponds) and a wide spectrum of production systems operated by distinct groups (individuals, cooperatives, corporations) in several regions of the world.

Production and Distribution

Marine aquaculture has been practiced for millennia, especially in Asian cultures, but it has grown exponentially since the 1980s in response to a widespread decline of the world's fisheries and increased consumption of aquatic species by

the developed nations. Aquaculture growth exceeds that of all other animal-food-producing sectors, at a rate of 8.8% per year since 1970 as opposed to 1.2% for capture fisheries and 2.8% for terrestrial meat production systems, but shows signs of leveling off, although high growth rates remain for some regions and species. Although most aquaculture production of fish, crustaceans, and mollusks is derived from freshwater environments representing 56.6% by quantity and 50.1% by value of aquaculture production aggregated, marine aquaculture production is significant and was reported by the Food and Agriculture Organization (FAO) to be 35.07 million metric tons in 2006, with an overall value of US\$44.8 billion, including all aquatic organisms and geographical zones. Of the world total, China accounts for 67.6% of the total quantity and 39.9% of the total value of marine aquaculture, thus dominating the marine aquaculture industry.

Much of the marine production consists of high-end finfish as well as relatively low-priced mussels and oysters, while brackish-water production is dominated by high-value crustaceans and finfish. The high diversity of aquaculture production is illustrated by the variety of species farmed. Aquatic plants and mollusks show the greatest rate of growth since the early 2000s, while mollusks and crustaceans show the greatest increase in value. Diadromous fish also show a stark increase since 2004. While these numbers illustrate the emergent trends in marine aquaculture, they also reflect the efforts by countries to improve their reporting systems. Geographically, marine aquaculture production and value is clearly dominated by Asia, followed by Europe and the Americas, while Africa and Oceania remain marginal.

Balancing Economic Growth With Environmental and Social Sustainability

Proponents of marine aquaculture argue that the industry provides an alternative to declining fisheries, enhancing the food security of local populations while providing employment and attracting economic investments in the host countries, often developing nations. China is the country with the highest number of fish farmers (4.5 million) in 2004. Other countries with a high number of fishers and fish farmers include India, Indonesia,



Figure 1 Top 20 nations most reliant on marine aquaculture, 2006

Sources: Adapted from Food and Agriculture Organization of the United Nations Aquaculture Statistics (2006) and EarthTrends GDP Statistics (2008).

and Vietnam. Employment in fisheries and aquaculture has been growing in low- and middle-income countries and declining or stagnating in the industrialized states. Most of the production of marine aquaculture comes from low- to middle-income nations. Marine aquaculture plays an important role in providing cash income and investments to developing countries and contributes importantly to the national economies of many developing states. Latin American and Asian states are particularly dependent on marine aquaculture, with Chile having more than 9% of its gross domestic product derived solely from marine aquaculture (not counting freshwater aquaculture).

Despite the importance of marine aquaculture to national economies, there are no reliable estimates of the actual returns of the activity to local communities and local producers. Marine aquaculture is heavily criticized for its environmental impacts on coastal wetland ecosystems and its mixed record in terms of social benefits to rural communities. Pond aquaculture in brackish systems has caused considerable loss of wetlands, especially mangroves. In Latin America, between 20% and 50% of mangrove destruction since the 1980s has been attributed to shrimp aquaculture expansion. Issues of water quality degradation, invasive species, and disease spread are also tied to the presence of high densities of aquatic organisms and the addition of feeds and antibiotics. Feed in

particular is controversial as it is often derived from fish and other aquatic organisms caught in the wild, thus adding pressure to the already over-exploited fisheries, instead of providing a solution. Opponents of marine aquaculture have therefore argued that its economic benefits mask considerable environmental and social costs.

Marine-aquaculture-related environmental degradation directly affects coastal communities, which experience declining returns in local fisheries and other wetland-related goods and services. Marine aquaculture also creates social tensions in coastal communities between those who choose to engage in the activity and those who depend on the formerly readily available wetland ecosystems. In that regard, marine aquaculture has facilitated the privatization of wetlands, limiting their use by the coastal poor. Additionally, small-scale producers have been unable to remain competitive when faced with large-scale industrial complexes with economies of scale, thus raising issues of equality within the industry itself. In response to these criticisms, the industry has started to establish best management practices (BMPs) in order to limit environmental and social impacts. These BMPs are seen by some small producers as another barrier limiting their entry into the aquaculture industry. Many small producers have limited access to credit or markets, thus restricting the extent to which they can conform to international standards and regulations. More work needs to be



done therefore to draw small-scale producers into national and international markets, while maintaining the integrity of the natural resource base on which both marine aquaculture operations and human populations depend.

Karina Benessaiah

See also **Aquaculture; Coastal Zone and Marine Pollution; Fish Farming; Food, Geography of; Oceans; Wetlands**

Further Readings

- Barbier, E. B., & Cox, M. (2003). Does economic development lead to mangrove loss? A cross-country analysis. *Contemporary Economic Policy*, 21(4), 418–432.
- Food and Agriculture Organization of the United Nations. (2006). *State of world aquaculture*. Rome, Italy: FAO Fisheries and Aquaculture Department.
- Food and Agriculture Organization of the United Nations. (2007). *The state of world fisheries and aquaculture*. Rome, Italy: FAO Fisheries and Aquaculture Department.
- Lebel, L., Tri, N. H., Saengnoee, A., Pasong, S., Buatama, U., & Thoa, L. K. (2002). Industrial transformation and shrimp aquaculture in Thailand and Vietnam: Pathways to ecological, social and economic sustainability. *Ambio*, 31(4), 311–323.
- Naylor, R. L., Goldburg, R. J., Primavera, J. H., Kautsky, N., Beveridge, M. C. M., Clay, J., et al. (2000). Effect of aquaculture on world fish supplies. *Nature*, 405, 1017–1024.
- Paez-Osuna, F. (2001). The environmental impact of shrimp aquaculture: Causes, effects, and mitigating alternatives. *Environmental Management*, 28(1), 131–140.
- Tobey, J., Clay, J., & Vergne, P. (1998). *Maintaining a balance: The economic, environmental, and social impacts of shrimp farming in Latin America*. Washington, DC: Island Press.
- World Bank. (2007). *Changing the face of the waters: The promise and challenge of sustainable aquaculture* (Agriculture and Rural Development Series). Washington, DC: Author.



MARITIME SPACES

See Oceans



MARK, DAVID M. (1947–)

A pioneer in geographic information science (GIScience) research, David Mark played a formative role in establishing the cognitive and linguistic foundations of the discipline. His early work on topographic data modeling also included seminal contributions to the development of triangulated irregular networks (TINs) and algorithmic flow modeling. He authored or coauthored more than 220 papers and played an instrumental role in establishing several national organizations and conference series to promote GIScience. A professor in the Department of Geography at the University at Buffalo, State University of New York (SUNY) since 1981, Mark received the University Consortium on Geographic Information Science (UCGIS) Researcher of the Year award in 2004 and was appointed SUNY Distinguished Professor in 2007.

Mark received his BA and PhD degrees in geography at Simon Fraser University in 1970 and 1977 and an MA in geography at the University of British Columbia in 1974. As an undergraduate, he proposed a correction for statistical analysis of the orientation of sedimentary strata, which is still widely used in geological studies. While a master's student, Mark began work on the TIN model of topographic representation under the supervision of Thomas Poiker (formerly "Peucker"). His rigorous comparative analysis demonstrated the relative effectiveness of TINs and contributed to their widespread adoption in geographic information systems (GIS). Later work on topographic analysis yielded the well-known D8 flow routing algorithm, which eliminated spurious pits from digital elevation models.

In the 1980s, Mark's research began to focus on the fundamental properties of geographic features and their representation. Papers on the fractal nature of geographic phenomena summarized for geographers the importance of scale dependence in measurement and the utility of recursive partitioning schemes. This period also witnessed



the beginning of a long-lasting collaboration with the philosopher Barry Smith to investigate the ontological constraints of geographic categorization. Questions of how people experience, cognize, and communicate with respect to spatial phenomena led to co-organization of a workshop in 1990 in Las Navas, Spain, which is often considered the birthplace of the cognitive and linguistic threads of GIScience.

Throughout the 1990s, Mark contributed to the emerging field of GIScience a series of reasoned investigations on spatial relations and experiential, cognitive, and formal models of geographic space. A 1995 paper titled “Naïve Geography” added a new dimension to the discipline, demonstrating that the commonsense view of the world could itself be a coherent and fruitful subject of scientific inquiry. Focusing on the particular domain of landforms, Mark pioneered the new field of ethno-physiography and is currently involved in a project to document and compare terms used by the Yindjibarndi and Navajo cultures to describe natural elements of the landscape.

An important aspect of Mark’s career has been his talent for facilitating cross-disciplinary collaboration through the organization of workshops, conferences, centers, and funded projects. In 1988, he was a member of the team that established the National Center for Geographic Information and Analysis (NCGIA), and he became director of the Buffalo NCGIA site in 1995. Mark was instrumental in the founding of the UCGIS in 1991 and served as one of its first presidents. Under his guidance, the Las Navas workshop spawned the highly successful ongoing Conference on Spatial Information Theory (COSIT) series. He was also program cochair of the first two GIScience conferences in 2000 and 2002. Perhaps his biggest success, however, was the establishment in 2000 of the first and only National Science Foundation Integrative Graduate Education and Research Traineeship (NSF IGERT) program in GIScience, which to date has funded 62 PhD students in seven disciplines.

Befitting his academic interest in natural kinds, Mark is also an avid birder, with a lifetime count of more than 2,700 species. In 1980, he broke the single-year Canadian birding record with 417 species.

Barry Kronenfeld

See also Egenhofer, Max; Flow; Frank, Andrew; GIScience; Goodchild, Michael; National Center for Geographic Information and Analysis; Ontology; Triangulated Irregular Network (TIN) Data Model; University Consortium for Geographic Information Science

Further Readings

- Egenhofer, M., & Mark, D. (1995). Modeling conceptual neighborhoods of topological relations. *International Journal of Geographical Information Systems*, 9(5), 555–565.
- Goodchild, M., & Mark, D. (1987). The fractal nature of geographic phenomena. *Annals of the Association of American Geographers*, 77, 265–278.
- Mark, D. (1975). Computer analysis of topography: A comparison of terrain storage methods. *Geografiska Annaler*, 57A, 179–188.
- Mark, D. (1984). Automated detection of drainage networks from digital elevation models. *Cartographica*, 21, 168–178.
- Mark, D., & Aronson, P. (1984). Scale-dependent fractal dimensions of topographic surfaces: An empirical investigation, with applications in geomorphology and computer mapping. *Mathematical Geology*, 16, 671–683.



MARKET-BASED ENVIRONMENTAL REGULATION

Market-based environmental regulation involves the use of one or more economic policy instruments by government agencies to regulate the environment. Such regulation is enacted as a means to an end—usually incentives to cost-effectively control air, water, or land pollution—though similar policies have been enacted for other purposes. These include payments for ecosystem services and controlling overfishing. Sometimes such market-based environmental regulation is considered neoliberal and is strongly promoted by free-market advocates, but in most



cases, these programs are instituted to maximize the cost-effectiveness of government action. This form of regulation has increased in popularity around the world following the success of the U.S. Environmental Protection Agency's Acid Rain Control Program, which began in the early 1990s. The main categories of market-based environmental regulations are environmental charges/taxes, tradable permits, and payments for environmental services. This entry addresses each of these in turn.

Environmental Charge/Tax Systems

Economists call environmental pollution an *externality*, or a social cost external to market transactions. The English economist Arthur Pigou proposed in 1912 that such market "failures" should be internalized by government taxation. Yet environmental charges and pollution taxes have had very limited application to date. One municipal system growing in popularity is to charge households or businesses for solid-waste disposal in proportion to the amount of waste generated, the so-called pay-as-you-throw or unit-pricing policy. A pollution tax was enacted under the Superfund Program created by the U.S. Comprehensive Environmental Response, Compensation & Liability Act of 1980, designed to clean up high-priority hazardous-waste dumps. This program created an excise tax on chemicals and petroleum companies, though it was rescinded in 1996. A few European countries have had experience with modest pollution taxes, including the Netherlands, France, and Denmark, and carbon or climate change taxes exist in Sweden, Finland, Norway, the Netherlands, the United Kingdom, and Quebec.

A more successful environmental charge program in the United States has been deposit refund systems, which have been enacted in 11 states for specified beverage containers and 12 states for automobile batteries. Deposit refund systems for beverage containers also exist in nine European countries, Canada, Israel, Japan, South Korea, Taiwan, India, Kiribati, Micronesia, and South Australia. Germany has a deposit refund system for car batteries, refundable deposits on beverage containers since May 2006 under the Green Dot Program, and broader "take back" packaging

requirements for industry to encourage recycling (funded by a license fee levied on the producer).

Tradable Permits

Emissions trading systems were based on the ideas of the economist Ronald Coase, who won the Nobel Prize in Economics in 1991. They were, however, not operationalized until their application by the U.S. Environmental Protection Agency in the mid 1970s. The idea is to provide flexibility for pollution sources to reduce their emissions by allowing trading among firms with different abatement costs. Two basic program models exist: One approach "offsets" emissions on a case-by-case basis, and the other approach allows trading among a large number of sources, with a cap placed on total systemwide emissions of a specific type.

Several applications of emissions trading have been for air pollution control, often by 50% or more. The focus has typically been on emissions from electric power plants. Most of these programs were developed in the United States, such as the national Acid Rain Program's sulfur dioxide (SO_2) allowance market, nitrogen oxide (NO_x) allowance trading in the Eastern United States, volatile organic compound trading in Chicago, and the Regional Clean Air Incentives Market for NO_x and SO_2 in Southern California. The Acid Rain (control) Program is considered a notable success. Greenhouse gas trading between nations is encouraged by the Kyoto Protocol. The European Union (EU) Emissions Trading System was implemented for this purpose in 2005, which covers nearly half of the region's emissions. Many of these programs allow for emissions "banking," whereby excess emission reductions made in one year can be used to meet future emission targets.

Tradable permit systems have also been applied to water. These include effluent trading in watersheds, wetlands mitigation banking (United States), water markets (Australia, Chile, South Africa, and the western United States), and individual transferable quotas fisheries management (New Zealand, Australia, Iceland, Canada, and the United States). Serious problems have beset these programs, with fisheries management being the most successful.



Payments for Environmental Services

Payments for environmental services (PES) are voluntary transactions for well-defined environmental services between one or more users or buyers, such as government, an international agency, or nongovernmental group, and sellers, usually private landholders. This phenomenon is another case where externalities may, under certain conditions, be overcome through private negotiation between the affected parties à la Coase. While strictly speaking not a form of regulation, PES usually requires government participation or sanction. These programs make the most sense when ecosystems are mismanaged because many of their benefits are externalities from the perspective of ecosystem managers. Examples include hydrological, watershed, and biodiversity services; soil and land conservation; landscape quality maintenance and enhancement; eradication of invasive plants; reforestation and forest conservation; and carbon sequestration. PES programs have been applied in developed countries such as the United States, the United Kingdom, and Australia and developing countries in Central and South America, South Africa, and China.

Criticisms

Several criticisms have been leveled at market-based environmental regulations, especially emissions trading and pollution taxes. One criticism is that these instruments are tools of neoliberal economic policy that serve class interests, sanction the right to pollute, and in the international context are neocolonial. Emissions trading systems have also been accused of promoting environmental injustice, since domestic programs such as SO₂ or NO_x trading can in theory result in greater geographic concentrations of emissions than if there were no trading. Questions have also been raised about the effects of international trading of greenhouse gases on developing countries, which may be enticed to sell opportunities for low-cost emission reductions to richer nations or their industries. These concerns notwithstanding, the popularity of market-based environmental regulations can be expected to increase around the world.

Barry D. Solomon

See also **Environmental Services; Neoliberal Environmental Policy; Neoliberalism**

Further Readings

- Bailey, I. (2007). Market environmentalism, new environmental policy instruments, and climate policy in the United Kingdom and Germany. *Annals of the Association of American Geographers*, 97, 530–550.
- Coase, R. H. (1960). The problem of social cost. *Journal of Law and Economics*, 3, 1–44.
- Engel, S., Pagiola, S., & Wunder, S. (2008). Designing payments for environmental services in theory and practice. *Ecological Economics*, 65, 663–674.
- Solomon, B. D. (1999). New directions in emissions trading: The potential contribution of new institutional economics. *Ecological Economics*, 30, 371–387.
- Stavins, R. N. (2000). Market-based environmental policies. In P. Portney & R. N. Stavins (Eds.), *Public policies for environmental protection* (pp. 31–56). Washington, DC: Resources for the Future.



MARSH, GEORGE PERKINS (1801–1882)

George Perkins Marsh was a polymath, scholar, and diplomat. He was a well-known scholar in North America in the mid 1800s, published several notable works on the origins and history of the English language, and had an extensive knowledge of 20 languages. It is ironic, therefore, that he is best remembered for his seminal work *Man and Nature; or, Physical Geography as Modified by Human Action*, since he had no formal training in physical geography or ecology. Drawing on his keen observations growing up in Vermont and his subsequent travels in the Middle East, Marsh was the first to demonstrate that human activities have extensive, adverse impacts on the physical environment. Thus, Marsh is considered by many to be the first environmentalist.



Marsh was born in Woodstock, Vermont, in 1801. He was the fifth child of Charles Marsh, a district attorney under John Adams. George was a voracious, early reader, but he suffered an eye affliction when he was 8 years old that plagued him for the rest of his life. As a result, he developed a prodigious memory and an abiding love of the outdoors. Marsh pursued a variety of careers with varying degrees of success, including teacher, lawyer, editor, farmer, politician, and diplomat. In 1825, he established a law practice in Burlington, Vermont, which gave him an entrée into the world of politics. He served as a congressman in Washington, D.C. (1843–1849), where he helped establish the Smithsonian Institution. During his time as U.S. Minister to Turkey (1849–1854), he also traveled through Egypt and Palestine collecting specimens for the Smithsonian and noting evidence of human impacts on the environment. From 1861 until his death in 1882, he served as U.S. ambassador to Italy.

Man and Nature was published in 1864, but Marsh identified the underlying themes many years earlier in Vermont. He had observed that after the forests were cleared, springs dried up and excessive runoff after storms caused extensive erosion. Marsh was concerned not merely that humans were disturbing the balance of nature but that the cumulative damages so wrought would eventually harm society. His observations in Europe confirmed his theories but also indicated possible management solutions. Marsh was not a strict conservationist, but he blended a reverence for nature from transcendentalism with a good dose of Vermont practicality. He advocated taming nature for human needs through careful management.

Man and Nature was well received by scientists, policymakers, and the public, and it was instrumental in creating the national forest system in the United States and promoting improved forest management practices in the United States and Europe. *Man and Nature* remains a relevant and enduring classic.

Dominic Golding

See also **Conservation; Environmental Management; Human Geography, History of; Nature; Social Construction of Nature**

Further Readings

- Lowenthal, D. (1958). *George Perkins Marsh: Versatile Vermonter*. New York: Columbia University Press.
- Lowenthal, D. (2000). *George Perkins Marsh: Prophet of conservation*. Seattle: University of Washington Press.
- Marsh, G. P. (1965). *Man and nature; or, physical geography as modified by human action*. Cambridge, MA: Belknap Press of Harvard University. (Original work published 1864)



MARXISM, GEOGRAPHY AND

Marxism—one of the world's most powerful and influential ideologies—has had an enormous social and intellectual impact on vast areas of the world, including the discipline of geography. Marxism is simultaneously a form of political economy, a moral theory of justice, a mode of historical perspective, and a platform for political action. It is clearly impossible to summarize this gigantic, complex, diverse, and occasionally contradictory body of work on Marxism in one essay; rather, following a sketch of Marxist political economy, this essay focuses on the multiple ways in which geographers have selectively appropriated Marxism to understand space. The encounter between Marxism and geography, it must be noted, was mutually transformative: As geography incorporated many central notions of Marxism, such as class, power, struggle, labor, and historical context, so too was Marxism also changed, becoming more explicitly spatial in focus.

Karl Marx and His Worldview

One of the most widely influential figures in world intellectual history, Marx studied Greek philosophy for his PhD at the University of Berlin in Germany, then moved to Paris in 1843, where he met his lifelong friend and coauthor, Friedrich Engels; in 1845 he moved to Brussels, then back to Paris in 1849, and then shifted to London in 1852, where he worked briefly as a journalist for the *New York Tribune*. He was active politically



in the International Workingmen's Association (also known as the First International) and wrote on behalf of workers' movements. Marx's major works include *Das Kapital* (three volumes), *The Communist Manifesto*, and *Grundrisse (Outline of a Critique of Political Economy)*. Marx and his ideas were clearly products of their times, that is, 19th-century Europe (especially Britain) amid the Industrial Revolution.

Marx was heavily influenced by three strains of European social thought, particularly German idealism, British political economy, and French utopian socialism. From Georg Hegel, whose works affected Marx enormously, he acquired a deep appreciation of dialectics, a sense of science as the holistic study of relations among phenomena, and a conception of the important role of human consciousness in structuring and changing social life. From French scholars such as Condorcet, Charles Fourier, and Comte de Saint-Simon, Marx incorporated the view that social relations were open, contingent, and subject to change. Later, however, Marx's early idealism is often held to have given way to a more materialist analysis, in which the forces and relations of production were preeminent. Finally, from British political economy, particularly the works of Adam Smith and David Ricardo, Marx learned the tools with which he dissected capitalism, including the labor theory of value.

There are multiple foundations of Marxist thought. Most centrally, Marxism is often equated with historical materialism, an attempt to make history into a science. Marxism is resolutely historical in focus, emphatically emphasizing that events, people, and ideas must always be situated within their historical context; thus, *when* things happen is critical to *how* they happen, for different societies produce different contexts. Departing radically from Hegel, who was known for his idealistic view of history, Marxism stresses that ideas originate from social and material circumstances, not vice versa; matter has primacy over consciousness. In effect, Marx "turned Hegel upon his head." Notably, historical materialism lacked a real sense of spatiality (i.e., there was, originally, no geographical materialism), and Marx himself said little about geography other than occasional references to the division between towns and the countryside.

Second, Marxism is usually interpreted to be structuralist in its focus, although this point is often debated. Structuralism as a formal philosophy emerged later than Marxism and had different roots (i.e., in linguistics). Nonetheless, Marxism typically (but not always) exhibits a structuralist ontology, that is, an understanding that what is real in the world is not merely what is observable but the relations among phenomena, which may not be immediately detected. In this sense, Marxism differs greatly from much Western social science, which is often empiricist or overly individualistic in focus (e.g., neoclassical economics). The holistic focus of structuralist ontology leads Marxism to view humans as inescapably *social* beings, with social origins and consequences, and they can never be understood simply as isolated individuals outside their historical context.

A third pillar of Marxism concerns the centrality of labor, a common notion among classical political economists. Labor (i.e., work and production) is privileged analytically: All societies must provide for themselves, and to do so, people must engage in organized systems of work. Through labor, people enter into social relations, reproduce society, materialize ideas, and change nature (as well as themselves). By privileging labor over other forms of social activity—as in Marx's distinction between the economic base and the political, legal, and cultural "superstructure"—Marxism made itself vulnerable to charges of economic determinism. The core of this view is the labor theory of value, which Marx acquired by reading Adam Smith: In this perspective, value emanates from the amount of *socially necessary* labor time that goes into the production of goods (not just one person's time but the minimum that a given historical configuration of technology and people can produce). Thus, value is produced at the workplace, not through exchange in the market (as in neoclassical economics), and the prices of goods will tend to gravitate toward the amount of labor embodied in their production.

Marx differentiated between use and exchange values: The former refer to the qualitative, subjective utility derived from goods (e.g., a house shelters a family and keeps them warm and safe), while exchange values refer to their market price



(e.g., a house can be bought and sold for a given amount). Because capitalism is the process of commodifying goods—turning them into objects bought and sold on the market, for a profit—labor too becomes a commodity, organized through labor markets. The key to understanding capitalism, for Marxists, is how the labor theory of value operates within the workplace: Because the use value of the worker to the capitalist exceeds his or her exchange value (i.e., wages and salaries), a surplus is inevitably generated. Workers thus produce all value but receive only the exchange value of their labor in return. Capitalists *must* pay workers less than the value of what they produce, or there would be no profit. The labor contract is, in this view, inherently and inescapably exploitative: There can be no such thing as a “fair wage,” for all profits are, by definition, theft from wages. Thus, Marx viewed labor markets as alienating, that is, separating workers from their capacity to generate value for themselves. Capitalists seek to increase profits by keeping wages low, but they also must increase purchasing power (wages) simultaneously. There is therefore a fundamental contradiction between production and consumption: In minimizing the costs of labor, capitalists also minimize the ability of workers to consume; workers are, in effect, forced to live on too little because they produce too much.

Arising from the organization of production is class, a foundational concept of Marxism. Indeed, Marx arguably was the first theorist to analyze society in class terms. Unlike popular definitions of class, which emphasize consumption and income, Marxist views of class begin with the relations of production, that is, whether one owns the capital, equipment, machinery, and other tools necessary to produce goods or whether one only can offer one's labor. Because the labor theory of value is trans-historical in nature, Marxism posits that all social systems other than “primitive communism” (i.e., hunting and gathering) have classes, including slavery, feudalism, capitalism, and socialism. The relations between classes are complex, contingent, and ever-changing. The primary classes of capitalism are capitalists (the bourgeoisie) and workers (the proletariat), although Marx did allow for other, smaller classes, such as peasants, the petit bourgeoisie (“middle class”), and the lumpen proletariat (the

impoverished, often homeless bottom rungs of society, which form a “reserve army of labor” that capitalists can use to lower wages as necessary). Class, it must be emphasized, is not simply an economic phenomenon but a political and cultural one too: In most societies, almost all members accept the ideas of the ruling class as “natural”; that is, ideology obfuscates the reality of class. Class divides become most visible during periods of crisis, and Marxism posited itself as a science of society, in contrast to bourgeois ideology or false consciousness. The contradictions between classes—class struggle—form the motor that drives history forward, leading to revolutionary changes by which one form of society gives way to another. Thus, Marx viewed history as the progression of various modes of production, giving Marxism a teleological sense of time, including the future as well as the past, which has been criticized for minimizing human agency.

Capitalism differs from other modes of production in that it must grow to survive. Under the relentless pressure of competition, firms must continually innovate; from this basic fact spring both the tremendous vitality of capitalism as well as its greatest weakness. The necessity to extract surplus value inexorably leads to conditions in which more is produced than can be consumed; that is, there is overaccumulation, which is built into the DNA of commodity production. Ultimately, this process leads to an excess supply, falling prices, and thus a tendency for the profit rate to decline. To combat the chronic problem of overproduction, capitalists must seek out markets on which to unload their excess output, leading capitalism to exhibit what Marx called a “wolf hunger” to expand, as with the European “Voyages of Discovery” in the 16th, 17th, and 18th centuries. Ultimately, Marx predicted, the crises of capitalism will intensify, immiserating the proletariat, leading it to realize its common humanity and replace the rule of capital with the rule of labor (socialism) and, eventually, a classless utopia of communism, where “true history” begins.

Marxism is much greater than Marx. In the 20th century, various kinds of Marxism arose in theory and in practice. Most common was the Stalinist version, which became dominant in the Soviet Union and its client states, as well as the Maoist variant in China. For some, Marx's



ideas are inspirational, sketching visions of a new world free of class and injustice; for others, Marxism was a dogmatic worldview that led to the horrors of the gulag and murderous totalitarian regimes. Academic variants of Marxism include the nonstructuralist version ("Western Marxism"), such as the Frankfurt School of the 1930s, led by Theodor Adorno, Max Horkheimer, and Herbert Marcuse, which focused on the role of culture (as well as its descendant, Jurgen Habermas); Antonio Gramsci's work on ideology; Rosa Luxemburg; Georg Lukacs; E. P. Thompson; and Walter Benjamin, who played a key role in analyzing representations and consumption in class-based terms. In the late 20th century, feminist Marxism added to the diversity of this worldview.

Marxism in Geography

The entry of Marxism into the discipline of geography may be held to begin during the turbulent decade of the 1960s, when radical geographers emphasized the need for social relevance. William Bunge, for example, led projects such as the Detroit Geographical Expeditions, and the journal *Antipode* was founded in 1969, followed by the Union of Socialist Geographers in 1974. The works of Henri Lefebvre were also inspirational, although they were not translated into English until the 1990s. With the adoption of Marxist ideas, space was increasingly viewed as a social and historical product for the first time, in contrast to its frozen, given status under both chorology and logical positivism, a shift that helped end the long rule of historicism in the social sciences and greatly elevated issues of spatiality in social thought.

The central figure in this transformation was David Harvey, who, in a series of works such as *Social Justice and City* (1973), *The Limits to Capital* (1982), and *Consciousness and the Urban Experience* (1985), initiated a systematic spatialization of Marx's magnum opus, *Capital*. The Marxification of geography was thus the spatialization of Marxism, in which historical-geographical materialism was transformed into a historical-geographical materialism. Harvey began the arduous task of charting the cycle of production from money to commodities and back to money form in

geographic terms, leading him to generate important notions such as the various circuits of capital, the spatial fix, and time-space compression.

Building on Harvey's contributions, Marxist geographers began to advance on several fronts. Many, such as Edward Soja, initiated a long-standing retheorization of the social and the spatial as simultaneously determinant arenas. A central theme that emerged throughout was uneven spatial development, that is, the inequalities between wealthy and impoverished regions that emerged as part of the changing capitalist division of labor. Contrary to neoclassical promises that spatial inequality would be mitigated by the movements of capital and labor, Marxists maintained that uneven development was a necessary, inescapable part of capitalism. This process was manifested as scales ranging from the urban (e.g., ghettos and suburbs) to the national (e.g., the Rust Belt and the Sunbelt in the United States, or Northern vs. Southern Britain) and the global (i.e., the schism between the developed and underdeveloped worlds).

Marxist international political economy, for example, theorized the possibilities of development in a world economy in which the rules were stacked against developing countries. Students of colonialism, such as James Blaut, offered devastating critiques of how the modern world economy came to be and the continued legacy of bias that privileges Western knowledge over that generated in other parts of the world. Dependency theorists, drawing on the works of Andre Gunder Frank, offered blistering critiques of modernization theory and its current variant, neoliberalism, to reveal that poverty does not simply "happen" but is a historical product, actively created, not simply given. Thus, via the process of underdevelopment, First World countries produced poverty in the Third World over 500 years of colonialism and contemporary neo-colonialism. Thus, underdevelopment is not simply a state but an active process. Wallersteinian world-systems theory extended this view to include a more sophisticated portrait of the dimensions of the global economy, including the political structure of the interstate system through its tripartite division into core, periphery, and semiperiphery. Such views have become the core of much political geography today, concerned as the subdiscipline is with globalization



and critical geopolitics in their various forms, as well as opposition to it.

Marxist geographers also reinvigorated the discipline's concerns with the state, which was, in social terms, not some unbiased, apolitical actor but an institution deeply linked to particular class interests. Moving beyond Marx's original assertion that the state amounted to little more than the "executive committee of the bourgeoisie" as well as neoclassical portrayals of the state as a parasite feeding off the largesse of the market, Marxists argued that it amounts to the instrument by which one class dominates another, or an arena of class conflict: Politics, in short, is class war by another means. In moderating the anarchic, self-destructive tendencies of the market, the state does what no single private entity can do (e.g., protect property rights, provide public goods and services, mitigate negative externalities). To facilitate the needs of capitalists, the state must legitimate itself in the eyes of its citizens, presenting a facade of representing the interests of the ruling class as the "public interest." The Marxist view of the state demolished fantasies of the unfettered free market and played a key role in the revival of political geography and urban political economy more broadly.

Marxist urban geography reveals cities as intertwined systems of production and reproduction, that is, as holistically integrated entities rather than just the summation of individual choices. The changing urban division of labor became a central object of inquiry in the works of scholars such as Allen Scott, Michael Storper, Richard Walker, and others, including the ways in which firms are integrated into networks of relations, and changing urban and global urban hierarchies. A bevy of urban topics fell under the Marxist gaze, such as the politics of urban land use, housing markets, suburbanization, ghettos and inner-city poverty, gentrification and the rent gap, and struggles over public space. Urban governance, ranging from regime and regulation theories to growth coalitions to the neoliberal state, received special attention.

Long sensitive to allegations that Marxism lacked an adequate theory on the subject, Marxist geography engaged in an intense debate, with humanistic geographers such as David Ley, over the relative weights to assign to structure and agency in social analysis. Some geographers

invoked overly determinist French scholars such as Louis Althusser, while others were inspired by nonstructuralist Marxist historians such as E. P. Thompson. The entry of Giddens's structuration theory in the 1980s effectively resolved this dilemma and led to the proliferation of social constructivism throughout the discipline. In essence, this matter forced Marxists to take seriously issues of ideology, culture, consciousness, everyday life, and social reproduction. Marxist cultural geographers such as Don Mitchell reframed culture not simply as a set of ideas but as a power relation tied to class interests. Feminist scholars effectively integrated Marxism with understandings of gender, injecting the first non-class-based forms of analysis into the discipline and opening the doors to identity theory. Others, such as Denis Cosgrove, offered insightful dissections of spatial representations ranging from landscape paintings to critical cartography to the history of the globe, drawing on Michel Foucault to assert that every form of spatial knowledge was also a claim to power. Many geographers influenced by Marxist notions of class, if not Marxists per se, analyzed the history of geography itself as a changing power/knowledge configuration.

Finally, Marxists even began retheorizing nature, and with it, human-nature interactions. Neil Smith famously argued in *Uneven Development* that the production of space was simultaneously the production of nature and that people and nature were always unified through labor, the conversion of material goods into social commodities. In this light, ostensible struggles of "people versus nature" are really struggles among social groups. Political ecology, with its attendant concerns for environmental justice, in many respects was an outgrowth of this line of thought, and it helped dethrone the simplistic, and often racist, Malthusianism, which blames the poor for their poverty. In environmental politics, for example, Michael Watts's work on African famines revealed that hunger is socially constructed through differential access to resources. Similarly, natural hazards are shown to be not "natural" at all but deeply entwined with class, race, and gender relations. In essence, Marxism helped denaturalize nature, revealing that it cannot be understood independently of society. The social construction of the nature perspective refutes



long-standing assumptions that nature is situated “outside” of human affairs, a primordial, unalterable “given.”

Marxism is not without its critics, many of whom continue to allege that it suffers from a debilitating economic determinism, an inadequate account of human agency, and teleological overtones. The end of the Cold War helped free academic Marxism from the horrors of the Soviet Union and inspired a new round of inquiry. Marxism has become so commonplace in human geography today that many practitioners scarcely call themselves Marxist. Marxism forced geographers to take historical context seriously; to understand spatial phenomena as social constructions, not simply as “given”; to appreciate the division of labor and the importance of work and labor; to understand how class figures in all social relations even as the ruling class keeps itself invisible via ideology; to address the ever-changing complexity of capitalism as an economic, political, and ideological system; to acknowledge the profound role of the state; to view ideas as inescapably linked to power interests, never as free floating in some abstract mental vacuum; and to gather around a common moral core grounded in justice, fairness, and opposition to sexism, racism, and other forms of social oppression. Marxism offers a comprehensive means to suture together many of the disparate topics that geographers study, in contrast to the common “test a million hypotheses” approach that tends to lapse into empiricism. As a moral philosophy, therefore, Marxism urges geographers to be critical, to point out how social and spatial relations could be better, and to never be satisfied with the status quo. To appreciate its impacts, one must view the many Marxist ideas that have insinuated themselves in political, economic, urban, cultural, and historical geography and via social constructivism more broadly into political ecology and even into contemporary retheorizations of cartography and geographic information systems. Thus, although the classical, 19th-century Marxism may have proved to be a failed historical project, contemporary Marxism—changing, adapting, modifying, borrowing, and contributing to other lines of thought—remains very much alive.

Barney Warf

See also Class, Geography and; Class, Nature and; Colonialism; Critical Human Geography; Dependency Theory; Environmental Justice; Feminist Geographies; Feminist Political Ecology; Globalization; Governance; Harvey, David; Human Geography, History of; Inequality and Geography; Justice, Geography of; Neoliberalism; Peet, Richard; Political Ecology; Political Economy; Radical Geography; Smith, Neil; Socialism and Geography; Social Justice; Spatial Fix; Spatial Turn; State; Structuration Theory; Time-Space Compression; Underdevelopment; Uneven Development; Walker, Richard; Watts, Michael; World-Systems Theory

Further Readings

- Blaut, J. (1993). *The colonizer's model of the world: Geographical diffusionism and Eurocentric history*. New York: Guilford Press.
- Castree, N., & Braun, B. (Eds.). (2001). *Social nature: Theory, practice, and politics*. London: Blackwell.
- Duncan, J., & Ley, D. (1982). Structural Marxism and human geography. *Annals of the Association of American Geographers*, 72, 30–59.
- Harvey, D. (1973). *Social justice and the city*. London: Edward Arnold.
- Harvey, D. (1976). Labor, capital, and class struggle around the built environment in advanced capitalist societies. *Politics and Society*, 6, 265–295.
- Harvey, D. (1978). The urban process under capitalism: A framework for analysis. *International Journal of Urban and Regional Research*, 2, 101–131.
- Harvey, D. (1982). *The limits to capital*. Oxford, UK: Blackwell.
- Harvey, D. (1985). The geopolitics of capitalism. In D. Gregory & J. Urry (Eds.), *Social relations and spatial structures* (pp. 128–163). New York: St. Martin's Press.
- Hudson, R. (2006). On what's right and keeping left: Or why geography still needs Marxian political economy. *Antipode*, 38, 374–395.
- Massey, D. (1984). *Spatial divisions of labour: Social structures and the geography of production*. London: Macmillan.
- Mitchell, D. (2000). *Cultural geography: A critical introduction*. Malden, MA: Blackwell.
- Peet, R., & Thrift, N. (Eds.). (1990). *New models in geography*. London: Unwin Hyman.



MASCULINITIES AND GEOGRAPHY

Masculinity is a concept that first and foremost implies that how men and women live and practice their lives is dependent on gender relations. Within these relations, masculinities take place and are expressed through practices that, according to Robert Connell, affect experience, personality, and culture. But the concept also has geographical implications as expressions of masculinities vary from place to place and influence place identities and local ongoing negotiations within existing gender relations. Masculinity cannot be understood as a singular or a static concept but will vary through space and time.

By focusing on the processes and relationships that define the variations among different masculinities, it is possible to reveal

- Scott, A., & Storper, M. (1986). *Production, work, territory: The geographical anatomy of industrial capitalism*. Boston: Allen & Unwin.
- Smith, N. (1984). *Uneven development: Nature, capital and the production of space*. Oxford, UK: Blackwell.
- Soja, E. (1980). The socio-spatial dialectic. *Annals of the Association of American Geographers*, 70, 207–225.
- Swyngedouw, E. (2003). The Marxian alternative: Historical-geographical materialism and the political economy of capitalism. In E. Sheppard & T. Barnes (Eds.), *A companion to economic geography* (pp. 41–59). Oxford, UK: Blackwell.
- Walker, R., & Storper, M. (1989). *The capitalist imperative: Territory, technology and industrial growth*. Oxford, UK: Blackwell.
- Wallerstein, I. (1976). *The modern world-system*. New York: Academic Press.



Florida State College football game, 1993. Although rule changes and technological changes have made football safer, it remains a violent and predominantly masculine sport. Success at sports, especially football, is a key signifier of success.

Source: AP Photo/Chris O'Meara.



geographical variations but also difference in status and hegemonic power. Spatial inequalities in the form of dualistic distinctions can, for example, turn into hegemonic versus deviant masculinities. Such a relationship is possible to find, for example, in the relations between urban and rural masculinities; masculinity as hegemonic differs with the geographical and social contexts.

The media are important actors in the construction of the differentiation of masculinities. A recent expression is in the great variety in Western European or Anglo American reality television series. One of the ideas behind shows such as the television reality series *Farmer Wants a Wife* is to essentialize rural identities and practices as well as demarcate the rural from the urban. Such relations are also expressed in people's daily activities, talk, and discourse. In the process of identifying oneself, one commits to certain, often geographically or culturally based, qualities while distancing oneself from others.

Geographers have taken the spatial implications of masculinities seriously and have focused on the importance of a contextual analysis. A trend that has been accentuated and developed recently is the increasing interest in how the relationship between masculinities and other identity-building dimensions such as class, sexuality, and "race" is constituted. In this understanding, places and spaces are merged with social processes. Thus, taking into account the relational character of identity construction and reconstruction helps avoid the common mistake in defining masculinity by using established divisions of behaviors as male or female.

The strengths of geography in defining and applying a concept such as masculinities are that (a) the discipline pays attention to existing geographical variations and (b) it illuminates the power relations inherent in the relationship between space and identity. By illuminating how space is used to build up discourses of differences, the reproductive as well as the transformative aspects of the concept of masculinities are exposed.

Susanne Stenbacka

See also **Feminist Geographies; Gender and Geography; Sexuality, Geography and/of**

Further Readings

- Berg, L., & Longhurst, R. (2003). Placing masculinities and geography. *Gender, Place and Culture*, 4, 351–360.
- Connell, R. (2005). *Masculinities* (2nd ed.). Berkeley: University of California Press.



MASSEY, DOREEN (1944–)

One of contemporary geography's leading theoreticians, Doreen Massey has made numerous pioneering inroads in the analysis of space and place, including gender relations, globalization, and the nature of places. Massey is simultaneously an influential scholar in geographic thought; urban, economic, and political geography; feminism; and Third World development.

Born in Manchester and educated at the University of Pennsylvania and Oxford, Massey began her career at a London think tank, the Centre for Environmental Studies, from 1968 to 1980. In 1982, she became a professor at the Open University. She cofounded and edits *Soundings*, a journal of politics and culture. In 1982, she became a fellow of the British Academy, and in 1998, she was awarded the Prix Vautrin Lud (the "Nobel Prize of geography"). In addition to academic work, she is also a social activist and has also conducted extensive fieldwork in Nicaragua, Venezuela, and South Africa.

Much of her early work concerned the dynamics and implications of industrial restructuring and deindustrialization, particularly in peripheral places that attracted only industrial branch plants. British studies of deindustrialization indicated how it occurred differently in different places, with significant variations in the impacts. More broadly, no social process unfolds in the same way in different places. *Spatial Divisions of Labor*, which Massey published in 1984, was a critical book in the rejuvenation of economic geography. Massey examined changes in the spatial division of labor in Britain, unveiling how different localities experienced different "waves" of investment that powerfully shaped the local landscape, labor markets, gender relations, and



cultures. Over time, each region played different roles in the ever-changing national (and, increasingly, global) market. As successive “waves” were superimposed on one another, each region came to have a unique historical trajectory reflected in how various “rounds of production” were sedimented into the landscape. The resulting palimpsests both revitalized an older idea from cultural geography and allowed geography to accept local uniqueness in analytically rigorous terms by embedding local areas within broader notions of uneven spatial development. This line of thought led Massey’s contributions to play a major role in the revitalization of regional geography in the 1980s and 1990s. In this reading, space and place are not passive recipients of social change but actively contribute to their making.

Massey is also well known for her work on gender and feminist geographies. *Space, Place, and Gender*, published in 1994, broke new ground in pointing out the ways in which gender relations are spatially constructed. Broadly, she demonstrated how the home and social reproduction in general were as critical for capitalist accumulation as the workplace. For example, an influential essay titled “A Woman’s Place?” examined how changes in the British spatial division of labor reconfigured relations at home, leading at times to local patriarchal family structures and at times ones with relatively equalized gender roles.

Massey’s work on place was extended via poststructuralist theory into a notion of power geometries and relational space that called attention to the intertwined scales of the global, national, and local, refusing to see these as a simple hierarchy in which the global determines the local. Massey criticizes notions that maintain place as an island of stability in the constantly shifting oceans of capitalist change. Rather, she promotes a progressive sense of place that links places to other places, a view in which places constantly change, producing and receiving changes through their interactions with one another. A relational politics of place calls into question easy distinctions such as inside/outside, near/far, space/place, and global/local, artificial differentiations that are always embedded in each other and mutually constituted. In *For Space*, published in 2005, she argues passionately that

Cartesian conceptions of space as a passive surface inevitably de-emphasize the temporal flux that is always an inherent part of geographies and simultaneously create a false dichotomy between the local and the global. As an alternative, she suggests three maxims: (1) that space be seen as the product of interrelations, that is, of embedded social practices in which identities and human ties are co-constituted; (2) that space be understood as the sphere of multiple possibilities, that is, as a contingent simultaneity of heterogeneous historical trajectories; and (3) that space must be conceived as always under construction, in the process of forever being made, implying a continual openness to the future. Her latest book, *World City*, which appeared in 2007, undermines the notion that London and New York dominate the world’s financial markets; rather, all places are complicit in this process, and the volume asks readers to consider their role in producing and maintaining global geographies of responsibilities.

Barney Warf

See also **Deindustrialization; Economic Geography; Feminist Geographies; Gender and Geography; Locality; Palimpsest; Relative/Relational Space**

Further Readings

- Callard, F. (2004). Doreen Massey. In P. Hubbard, R. Kitchin, & G. Valentine (Eds.), *Key thinkers on space and place* (pp. 219–225). London: Sage.
- Massey, D. (1979). In what sense a regional problem? *Regional Studies*, 13, 233–243.
- Massey, D. (1984). *Spatial divisions of labor: Social structures and the geography of production*. New York: Methuen.
- Massey, D. (1992). Place and the politics of space-time. *New Left Review*, 196, 65–84.
- Massey, D. (1993). Power-geometry and a progressive sense of place. In J. Bird (Ed.), *Mapping the futures: Local cultures, global change* (pp. 59–69). New York: Routledge.
- Massey, D. (1994). *Space, place and gender*. Oxford, UK: Polity.



- Massey, D. (1999). Imagining globalization: Power-geometries of time-space. In A. Brah, M. Hickman, & M. Mac an Ghail (Eds.), *Global futures: Migration, environment and globalization* (pp. 27–44). Basingstoke, UK: Macmillan.
- Massey, D. (2005). *For space*. London: Sage.
- Massey, D. (2007). *World city*. London: Polity Press.
- Massey, D., & Allen, J. (Eds.). (1984). *Geography matters!* Cambridge, UK: Cambridge University Press.
- Massey, D., & Meegan, R. (1982) *The anatomy of job loss: The how, why, and where of employment decline*. London and New York: Methuen.
- McDowell, L., & Massey, D. (1984) A woman's place? In D. Massey & J. Allen (Eds.), *Geography matters! A reader* (pp. 128–149). Cambridge, UK: University of Cambridge Press.



MASS WASTING

Mass wasting is a term for a wide variety of motions of rock, debris, earth, and organic matter that are moved downhill by gravity with various fluids entrained, such as water and air as well as ice. The concept of mass wasting is commonly supplanted by several other terms, such as *mass movement* or *slope failure*, and it also includes a tremendous diversity of things such as the various forms of creep, talus accumulation, flow of dry loess, burst of wet peat bogs, or block streams and rock glaciers as well. Classification of such diverse phenomena has been refined over the past century and a half, ultimately with emphasis on the types of material and types of movement, with a present-day consensus classification using rates of movement and the amounts and phase of the entrained H₂O system (water, ice, steam). The result is a matrix classification of mass-movement phenomena that enables understanding, although it is recognized that fine gradations of process type can occur in various continua between one form and another.

The types of material subject to mass wasting includes rock, as large masses or many smaller fragments; fine-grained earth, which is sand, silt, and clay; and fine organic matter, such as peat or humus in soil. Debris is a mixture of rock and

earth in various proportions. Types of motion in discrete landslides are falls, topples, slides, flows, and lateral spreads, whereas pervasive nondiscrete movements on slopes can include creep as well as isolated unit rock falls or slides that lead to accumulations of talus. Rates of motion range from the imperceptibly slow, where a few millimeters or centimeters a year occur, to hundreds of kilometers an hour, or even faster than the speed of sound, where lateral blasts from volcanoes impart exceptional velocities in certain cases. All phases of the H₂O system can be involved, from the merely ancillary presence of minor amounts of H₂O up to and including one phase or another of the H₂O as the primary motivating mechanism.

Falls of rock, debris, and earth (rock fall, debris fall, earth fall) from cliffs involve relatively simple accelerations through the air to a point of impact, at which point some further bouncing, rolling, and gliding of particles can occur to a certain extent. Topple failure occurs where a block of rock, debris, or earth rotates forward around a pivot zone at its base until it then tumbles over completely, usually breaking up in the process. Slides, such as the common rock slide, debris slide, or earth slide, can occur where rock debris or earth moves as one large block or breaks up into many separate units. They involve linear or translational slipping movements over inclined bedding planes or planar glide surfaces (as a glide block), or down curvilinear shear surfaces (as a slump block) with backward rotation. Flowing motions can be quite complex because there can be many laminar and turbulent actions in dry or wet media, where the particles move past each other in a variety of irregular motions that constitute distributed shear. For example, whole mountains can collapse internally under the force of gravity as a kind of rock flow or deep creep along many internal small shear planes until a ridge-top graben or ditch results in a sagging (sagging) failure with antislope scarps lower down as the mountain bulges outward. Or as sediment concentrations increase in mixtures of clastic particles of debris with water, forming a slurry that resembles wet concrete, various forms of rapid, wet, debris flow result. If the material is all fine grained, yet full of water, a mudflow occurs. If a dry mass of wind-blown dust or loess is shaken strongly by an earthquake, for example, all of the weak bonds between its particles may be ruptured,



and it can become a fluidized granular flow that is like loose talcum powder, as a loess flow. Or where a peat bog of plant-matter accumulation undergoes a torrential rainstorm, it may become super-saturated and break out as a bog burst. An earthflow results where fine-grained and damp clastic accumulations flow slowly downslope as viscous granular flows. On steep mountains where surficial soil layers, rock fragments, and vegetation are accelerated off the slopes in torrential rainstorms, a debris avalanche results. On the other hand, where a dry mass of rock fragments is detached from a steep mountain slope in what would normally be considered just a rockslide, if the acceleration is rapid enough, it may become a high-speed-flow *sturzstrom* landslide with a long runout zone.

Long-runout-zone slope failures occur where the ratio of fall height to runout length is generally less than about 0.6. This implies that the coefficient of friction between the flowing mass and the substrate is somehow reduced. These unusual *sturzstroms* were first thought to have been energized by trapped or entrained air that might somehow have kept the particles from interacting with the substrate and thereby have reduced friction. It was thought also that perhaps they formed a kind of wing shape or airfoil vacuum kept aloft like an airplane or were fluidized by moving air squeezing between particles, until such features were observed on the airless moon. Other explanations included mechanical dilation caused by strong vibration in motion and grain separation caused by acoustic vibration or sheer noise. Most recently, it has been recognized that rapid motion causes much frictional heat, which in turn converts any water into steam whose pressure will reduce friction. Indeed, a number of large *sturzstroms*, or rockslides, in the Himalayas and the Alps are now known to have melted glass “frictionites” in shear planes at their base. Finally, in some instances where blocks of glacial ice are also caught up in the moving masses, there may be a component of frictional reduction through incorporation of ice water mixtures in some fashion.

Lateral spreads or “quick-clay” failures are a special class of mass movement that incorporate unusual sliding and flowing motions so much that they can be quite dangerous and so are deserving of special attention. These forms of slope failure are caused where past continental glaciers first

depressed the crust isostatically into the sea, where they deposited their finely ground rock flours from abrasion of the bedrock. These small clay particles settled to the shallow sea bottom and collected as an aggregate of particles in a card-house matrix held together by ions of salt, where the positive sodium on one particle was attracted to the negative chlorine on another. Then, in postglacial times, with isostatic rebound of the mass up out of the sea, the fresh groundwater on the land would flush out the salt and leave behind an apparently stable but actually quite weak mass of wet quick-clay capable, when disturbed by constructional vibrations or other similar circumstances, of conversion or remolding from solid ground into a wet, soupy mass.

The role of water as a primary motivating agent in mass wasting or mass movement is well known, and if there is no preexisting slip surface to lubricate or make slippery, then some other aspects of the water must be responsible for the movement. Instead, what we find are a number of other important aspects, especially that water added to a slope has tremendous weight or load that can exceed the shear strength of the slope so that failure results. In addition, water can dissolve internal cements and thereby reduce cohesion, or it can produce hydrostatic pore-water pressure or seepage pressures underground. Similarly, saturation of sediments destroys capillary tension that can hold moist material together, or clays can swell as water is added, and freeze and thaw of slopes can disrupt materials and cause movement.

Talus is a form of one-by-one accumulation of rock fragments at slope bases where isolated rock units are pried off cliffs by the action of freeze and thaw and other minor disruptive processes. The rock particles bounce and roll downhill, sorted in part as a function of size and momentum, until they come to rest at the angle of repose, which is generally between 30° and 40°, depending on the size, with the coarser particles generally forming steeper slopes. Active talus is still in the process of being formed by additional small rock falls and rockslides, whereas inactive talus may have a vegetation cover slowly colonizing it.

Soil creep on slopes is a form of mass wasting that occurs all over the world yet is hardly noticed by most people. Fence posts, gravestones, and electric power line poles are tilted and displaced,



Mount Rainier National Park, Washington. The protalus rampart on the north side of Sunrise Ridge is separated from the partly vegetated talus on the left by a depression 5 to 6 ft. deep and 20 to 30 ft. wide. A thick, wedge-shaped snowbank blanketed the talus and the depression when the arcuate rampart was formed.

Source: U.S. Geological Survey.

retaining walls bowed out, and roads moved, all slowly and imperceptibly until the damage is done. Effectively, what happens is that a number of minor processes combine to move soil particles downhill in a series of uncoordinated but overall, in aggregate, quite pervasive small motions that collectively move enormous amounts of material. For example, expansion and contraction of soil particles on a slope occurs through wetting and drying, heating and cooling, and freeze and thaw. In any expansion part of the cycle, the slope materials move outward perpendicular to the slope, but in the return contraction, they tend to withdraw downward with gravity rather than back the way they came. The result is a ratcheting motion of out and down repeated over and over so that in aggregate everything is pulled downslope over time. Similarly, many other minor little processes move particles downslope; plant roots push a little more easily downslope than upslope against gravity, animals throw dirt from their burrows preferentially

downhill, and when the unused burrows or root cavities collapse, they do so downward. Any animals that walk on a hillslope have weight that pushes the soil downward a bit. Trees commonly have curved trunks on hillslopes that are often cited as evidence of soil creep that has pulled them into that curve, but instead, in a mix-up of cause and effect, it is not actually soil creep that produces the curve but rather creep of snow downhill against the tree that deforms it. In fact, this snow-creep force can also be transmitted into the soil through the roots and help cause the soil creep rather than be the result of it.

Creep of small protalus lobes and large rock glaciers in high-altitude and high-latitude environments is another form of mass wasting or mass movement that takes place where accumulations of rock fragments at the bases of cliffs become mobilized by creep of their internal ice cements or ice cores so that the features move forward as ever-increasing large lobate forms with transverse ridges



and furrows on their gently sloping tops and steep fronts at the angle of repose on their leading edge.

Gelifluction (*solifluction* in the older literature) is the mass-wasting process typical of permafrost environments, where the active summer thaw layer above the permanently frozen ground beneath becomes saturated with water that cannot percolate further downward and instead piles up in the soil to saturate it and cause instability. The combination of water-saturated soil on slopes above the permafrost, coupled with strong freeze and thaw in the soils, results in gelifluction lobes that move slowly downslope.

Other minor forms of mass wasting on slopes include blockstreams, which are thin masses of rock fragments that have been moved downhill, probably as a variation of a gelifluction process. Ploughing blocks on slopes move in a similar fashion, having to do with progressive freeze and thaw, probably because rocks lose their heat more quickly than the surrounding soils, so they freeze earlier to form ice crystals at their bases, which may help in their motion.

All forms of mass wasting or mass movement, whether they are landslides bounded by discrete shear surfaces or the diffuse results of unbounded creep, can result in deposits of unsorted, unstratified mixtures of multiple sizes of rock particles and organic matter. Such masses of sediment are considered to be *colluvium*, which is a nonspecific, generic term that can be applied. Commonly, because of the great diversity of forms of mass wasting, it can be quite difficult for nonspecialists to recognize the different types. Use of the term *colluvium* is, however, a safe way to classify an instance of mass wasting until more analytical studies can be performed.

John F. Shroder

See also **Creep; Landslide; Permafrost; Rock Weathering**

Further Readings

Howard, A. D. (1997). Badland morphology and evolution: Interpretation using a simulation model. *Earth Surface Processes and Landforms*, 22, 211–227.

Kusky, T. (2008). *Landslides: Mass wasting, soil, and mineral hazards*. New York: Facts on File.

Wemple, B. C., Swanson, F. J., & Jones, J. A. (2001). Forest roads and geomorphic process interactions, Cascade Range, Oregon. *Earth Surface Processes and Landforms*, 26, 191–204.

Woo, M. K., Lewkowicz, A. G., & Rouse, W. R. (1992). Response of the Canadian permafrost environment to climatic change. *Physical Geography*, 13, 287–317.



MATHER, JOHN RUSSELL (1923–2003)

John Russell (“Russ”) Mather was an accomplished geographical climatologist whose career spanned the second half of the 20th century. Mather’s work is relevant because it helped establish the climatic water budget and the linkages between climate and water resources as major themes within modern climate science and geography. This entry recalls Mather’s work at the Laboratory of Climatology in New Jersey and at the University of Delaware (UD). His contributions to American geography—especially to the Association of American Geographers (AAG) and the American Geographical Society (AGS)—are summarized as well.

Mather was born in Boston, Massachusetts, on October 9, 1923. He began his career in 1948 at the Laboratory of Climatology—after completing his BS and MS degrees in meteorology at MIT—and worked there full-time until 1961. He simultaneously pursued his PhD in geography at Johns Hopkins University, completing it in 1951. Mather’s efforts at the laboratory were invested primarily in the climatic water budget, especially in its practical applications. Much of modern water-budget climatology was forged by Mather and his colleagues at the laboratory. Following the death of C. W. Thornthwaite in 1963, Mather became president and director of the C. W. Thornthwaite Associates Laboratory of Climatology, a post he retained until 1972.

Mather’s desire to teach—along with his ambivalence toward measurement work—moved



him to leave the Laboratory and join the faculty of UD in 1961. (He retired from UD in 2000.) In 1966, Mather became the first chair of the new UD Geography Department and began laying a foundation for its current programs, especially within climatology; his role in this is among his greatest achievements. Mather was the major advisor for 6 PhD students (5 at UD) and 17 master's students. His first PhD student was Mel Marcus, who, like Mather, was elected president of the AAG. Of Mather's UD PhD students, only Johannes Feddema now leads an academic life—at the University of Kansas.

Mather's enduring interest in the climatic water budget is evident in the overwhelming majority of his publications. He produced more than 25 journal articles and 60 monographs, and he published five important books. The books deal with applied climatology, water-budget analysis, water resources, American and Soviet geographers' contributions to global-change research, and, finally, the many contributions of C. W. Thornthwaite, Mather's mentor.

Mather held prestigious posts and received notable awards. He was elected president of the AAG in the early 1990s, and he received both the AAG and the AAG Climate Specialty Group Lifetime Achievement Awards in the late 1990s. Mather additionally served as secretary of the AGS and was honored with its Charles P. Daly Medal for distinguished service. He also was elected fellow of the American Association for the Advancement of Science in 1989. He died in Avondale, Pennsylvania, on January 3, 2003.

Cort J. Willmott

See also **American Geographical Society; Association of American Geographers; Climatology; Marcus, Melvin G.**

Further Readings

- Legates, D. R. (Ed.). (2005). John "Russ" Mather [Special issue]. *Physical Geography*, 26(6).
 Willmott, C. J. (2006). John Russell Mather, 1923–2003 (Memorial). *Annals of the Association of American Geographers*, 96(3), 660–665.



MAURY, MATTHEW FONTAINE (1806–1873)

Matthew Fontaine Maury is remembered today as the father of oceanography. During his lifetime, however, Maury identified himself with geography. In 1855, 30 years into his U.S. Navy career, the self-taught Maury pulled together the work he (and others) had done on Earth's oceans and atmosphere and published *The Physical Geography of the Sea*, a book that went through eight editions (reprinted into the 1930s) and was translated into six languages. Its title was posited by Alexander von Humboldt, who lauded Maury's scientific research. Oceanography came into vogue only after the HMS *Challenger* expedition (1872–1876), which had the effect of outmoding almost everything Maury had written. The most enduring contribution of *The Physical Geography of the Sea* was Maury's "Diagram of the Winds," which became a standard inclusion (with modification of the polar winds) in geography textbooks thereafter. Maury is also remembered for his pioneering work in the mapping sciences, particularly his charts of ocean surface temperatures, global ocean currents, the distribution of whales, and the "telegraphic plateau" between North America and Europe.

Maury was born on January 14, 1806, not far from Fredericksburg, Virginia, into a devoutly religious family, a fact reflected in the teleological orientation of his scientific writings. He saw divine purpose behind the order of nature and is therefore a transitional figure in the history of modern science. His inability to keep religion and science separate, combined with his over-generalizations and glib explanations of process, led to some stern criticism in the scientific community. Commercial interests, foreign governments, and the educated public, however, heaped kudos on him for applying science to practical problem solving at sea. As the first superintendent of what is today the Naval Observatory, Maury mined a trove of sailing logs and other records deposited in Washington, D.C., by ships' captains since the Revolutionary War. He used these data to prepare his continuously updated Wind and Current Charts, which made their first appearance in 1847 during the "golden age of



sail.” By recommending “tracks in the sea,” Maury’s research effected a revolutionary reduction in sailing time. By 1855, using Maury’s sailing directions, it took a clipper only 133 days to make the journey from New York to San Francisco; a decade earlier, it had taken 180 days. Maury’s charts were made available to foreign fleets; in return, he asked for copies of the captains’ sailing logs—more data for refining his advice to mariners.

Maury resigned his commission in the U.S. Navy in 1861, when Virginia joined the Confederate States of America. At the end of the Civil War, he moved to Mexico, then England, where he began writing a series of geography textbooks for schools. In 1868, he returned to the United States to take a professorship at Virginia Military Institute, where he undertook a physical survey of Virginia, revised his textbook on *Physical Geography*, and advocated for “agricultural meteorology.” He died in Lexington on February 1, 1873. His monument in Richmond proclaims him a “pathfinder of the seas.” An obituary in the *New York Herald* called him a “distinguished physical geographer.”

Donald J. Zeigler

See also **Human Geography, History of; Humboldt, Alexander von; Oceanic Circulation; Oceans**

Further Readings

- Hearn, C. (2002). *Tracks in the sea: Matthew Fontaine Maury and the mapping of the oceans*. New York: International Marine/McGraw-Hill.
- Maury, M. F. (1963). *The physical geography of the sea and its meteorology* (J. Leighly, Ed., 8th ed.). Cambridge, MA: Belknap Press of Harvard University Press. (Original work published 1855)

MCKNIGHT, TOM L. (1928–2004)

Tom Lee McKnight was an influential geographer, educator, and college textbook author. In a professional teaching career that spanned nearly

40 years, he wrote widely adopted textbooks on physical and regional geography and worked with college and K–12 teachers across the United States to expand and improve geography education.

McKnight was born in Dallas, Texas, on October 8, 1928. He was introduced to geography by Edwin J. Foscue at Southern Methodist University, where he graduated with a bachelor’s degree in geology and a minor in geography in 1949. He finished his master’s degree in geography at the University of Colorado in 1951 and his PhD in geography at the University of Wisconsin in 1955. In 1956, McKnight was hired by the Department of Geography at the University of California, Los Angeles (UCLA), where he served as department chair from 1978 to 1983.

Throughout his career, McKnight traveled widely, specializing in the geographies of Australasia and North America. He helped establish the University of California Education Abroad Program in Australia and served as its first director from 1984 to 1985. In addition to teaching at UCLA, he had appointments as a visiting professor at nine American, three Australian, and three Canadian universities.

McKnight was a vigorous advocate for the discipline of geography. He helped develop the Community College/UCLA Geographic Alliance. This organization of educators was a model for the National Geographic Society Geographic Alliances that eventually spread throughout the United States and Canada. McKnight’s textbook-writing career began in 1961, when he was asked to join Edwin Foscue and Langdon White as coauthor for *Regional Geography of Anglo-America*. McKnight became sole author of this textbook by its fifth edition, then retitled *The Regional Geography of the United States and Canada*.

In 1984, the first edition of his popular *Physical Geography: A Landscape Appreciation* was published. Well illustrated and written in an accessible style with strong emphasis on the integration of the four “spheres” of physical geography—atmosphere, hydrosphere, biosphere, and lithosphere—it quickly became one of the most widely used, and most influential, college-level physical geography textbooks. In 2002, this book was given the *McGuffey Award* by the Text and Academic Authors Association in recognition of its enduring excellence.



Among his other textbooks are *World Economic Geography*, with Langdon White and Paul Griffin (1964); *Australia's Corner of the World: A Geographic Summation* (1970); *Essentials of Physical Geography* (1992); *Introduction to Geography*, with Edward Bergman (1993); and *Oceania: The Geography of Australia, New Zealand, and the Pacific Islands* (1995).

His many awards and honors include a Fulbright and an American Philosophical Society grant for research in Australia, the California Geographical Society's Outstanding Educator Award in 1988, and the Australia-International Medal from the Institute of Australian Geographers in 2001.

Tom McKnight died on February 16, 2004, at the age of 75.

Darrel Hess

Further Readings

McKnight, T. (2004). *The regional geography of the United States and Canada*. New York: Prentice Hall.



MEDIA AND GEOGRAPHY

How and why geographers engage with media is inherently tied to questions of what media are and do. The term *media* itself is ambiguous: dictionary.com defines the singular form *medium* as “an intervening agency, means, or instrument,” and the term was first applied to printed newspapers more than two centuries ago. Since the early 20th century, the usage of the term as a singular collective noun began to be popularized and its application expanded. Following this general meaning and expanded usage, an intersection of media with geography can be understood as an intimate and inextricable part of the geographic discipline. From long-standing traditions of cartographic creation and analysis to humanist explorations of art and literature to critical, feminist, and poststructuralist engagements with film and multimedia, different media forms have proved both informative and revealing for

geographers working through different modes of theoretical and methodological encounter.

It is generally agreed that media in their different forms—such as film, music, newspapers, comic books, video games, animation—are produced and consumed in historically specific and carefully constructed ways and that many factors combine to frame how meaning and expression are generated. Thus, media cannot be engaged in isolation but rather must be linked in multiple and complex ways to other forms of material evidence and theoretical engagement. Current streams of media geography largely take a critical approach to different media types, moving beyond understandings of media as visual or naive reflections of the “real” world or as materializations of the preestablished intentionality of their maker to understandings of media as discrete moments in the production and circulation of cultural meaning or expression. Importantly, this point is not to limit media to technologies of meaning (re)construction but also to understand media as objects of information transfer and creation wherein media themselves may be understood as differentiating forces of communication, social contestation, or affective and intellectual transformation. Media geography, then, explores broad questions of material production, cultural meaning, and bodily affects and percepts in relation to the practices and processes by which geographical information is gathered, geographical facts are ordered, and imaginative geographies are created. The differences present in how these questions are engaged with are not so much a matter of different understandings of media themselves as of what different forms and types of media do or can do.

Friedrich Kittler believes that media determine human situations, while Marshall McLuhan's famous phrase “The medium is the message” is also applicable to the study of media geography. Later critical geographers argue that media hold powerful transformative potential because people use cultural representations to create social relationships and to define space. These observations concerning media underscore differing insights into the meaning of information, the material importance of media, and how forces of technical expression may both positively and negatively



influence or affect our lives. What the observations share are their important implications for an understanding of media today, particularly within the context of geography.

Media geography often takes different media forms that are presented as natural, universal, or true and analyzes them to reveal how alternative geographic narratives may be visible. For instance, recent research in media geography has explored and explained the bond between media culture and nationalism or gender relations, providing insights into the motivations of media producers to prioritize time and history over space and geography by enmeshing the media consumer in systems of visibility and normalization. To critically engage media landscapes, then, it is important to understand that their places and spaces are never neutral.

Doreen Massey's early work conceptualized space as created by social relations, full of power and symbolism and containing a complex web of relations. Just how spatial-social power structures are involved in the transformation of these geographies may both reflect and serve as virtual and concrete responses to contested spaces/places. Geographic media studies help uncover the political interests underlying the production of cultural representations by presenting geographies through which to study these issues and their transparencies: As a number of recent works have noted, artistic quality often matters less than the role of the consumers and their attempts to resist and subvert the reinforcement of gender, sexual, and/or racial stereotypes. Media geography thus also promotes the active role of the consumer—understanding the relations of creative production comes first, followed by the different perceptions it may guide. Researchers can thus be exposed to the interconnections between private and public, especially private meanings and their role in sustaining and/or transforming personal and social forces such as memory and remembrance.

In addition to the readily apparent and tangible roles media forms offer to geographic exploration and analysis, it is also important to explicitly “place” media within different geographic discourses both contextually *and* methodologically if their full geographic power is to be realized. John Thornes advocates for media literacy in geography

because of the discipline's great visual legacy and suggests that there is a certain geographic clarity that can be derived from the study of media representation or expression. However, geographers should be open to moving beyond more orthodox notions of the “visual” to include the different sensory forces often present in media, such as sound images. Recent work within the discipline has stressed this point.

In an important article, Daniel Sui explored how visual geographic metaphors are being replaced by more evocative aural metaphors more common to electronic communication media, resulting in a reconfiguration of geographic discourse in the late 20th century. Sui made the connection that sight and sound are interconnected in many ways and should therefore be more fully appreciated for what they can bring to the exploration of geographic phenomena. Because of this, Sui emphasized how geography will become intellectually handicapped if the discipline confines itself to a single set of metaphors. This view led to positivist, realist, postmodern, feminist, and anarchist approaches to visualization that expanded the differing conceptualizations of visibility and defined media as inherently geovisual (in a broad sense of the term), while also understanding that there is an equally inherent geographical specificity to each media event. However, what this specificity is may always be open to contestation and negotiation. Clarity about what media are and do, then, requires an acknowledgement of both affective *and* kinetic aspects of media to account for epistemological and ontological differences in how media are understood, encountered, and engaged.

Media may change meaning as the environment in and through which they are consumed and engaged with transforms. Therefore, the function of their characteristics in relation to social processes can be understood as the purveyor of a specific relationship to the body and the imagination. The inherent characteristics located within media forms can instill emotional comfort or distancing, confinement or intimacy, hope or threat. Recent work has also found that media are a cognitive mode of understanding that can provide a “scientific” method for grasping the complexities of the postmodern world. Furthermore, new relationships within and between



various forms of “mixed media,” as interrelated sets of objects and texts, highlight exciting new forms of geographical analysis and bodily engagements with media and their role as both social network and agent.

There exists an affinity between the generic structures of media and the concerns of postmodernism that perhaps clarifies the necessary attention to the production and consumption of media, specifically how the body has been figured in postmodernism and cultural theory as a site of crisis. It is possible to gain important insights into geographical phenomena such as the city and landscape and into geographic technologies such as GIS (geographic information systems) and even video games and comic books through the use of different geographical theories and concepts working through the body. Such modes of exploration are helpful in understanding the production of media space and the creation of a *spectorial topoanalysis*, Giuliana Bruno’s term for the spaces of a spectator’s engagement with space through the experience of film. Popular media can be placed into a theoretical context bounded by semiotics, theories of ideology and subjectivity, ideas of affective concept and thought creation, and theories of self and identity. There are different semiotic complexities to media texts (including literal and symbolic meanings), leading us to conclude that media and human understandings of the world are inseparable from the bodily imagination and that spectorial subjectivity is entangled within a predisposed and socially influenced embodied gaze.

One can, of course, view media as a text, and the use of the textual metaphor runs deep in media geography theory. Various works discuss the concerns of qualitative methodology related to how the world is viewed, experienced, and constructed by social actors, while also stressing the importance of systems of meaning to any qualitative textual analysis. This methodology provides access to the motives, aspirations, and power relationships that account for how places, people, and events are made and represented. An interpretation of texts, which can include landscapes, archival materials, maps, literature, or visual images—all forms of media—is one of many ways of qualitatively engaging with different media forms or types.

In these explorations of the intersections between geography and media representations, media geographers may focus on a single static photograph—as in Susan Sontag’s claims that photographic images provide most of the knowledge people have about the look of the past and the reach of the present. Edward Said also saw the importance of “fictional” texts to the production of geographical knowledge, particularly how the interpretation of texts can provide insights into the ordering of society and space. Texts may be understood as culturally coded and may contain clues to the political, social, and economic circumstances of the society that produces them. This view, in turn, results in what some geographers see as a larger and a more critical engagement between cartography and social theory that may bring about a better understanding of how media can be best used within the discipline of geography.

If the geographical imagination can be conceived broadly to include those practices and processes by which we both situate and create ourselves and in which our selves are situated and created in space and time, then media participate in at least three fundamental ways: (1) in empirical practices of gathering factual information in visual and aural forms; (2) in cognitive processes of ordering information to produce knowledge of spaces/places, peoples, and events; and (3) in the affective and imaginative processes of visualizing the world beyond conventional experiences.

While media may be engaged from the perspective of agency and causality, narrative detail, circulation, or consumption and affect, media researchers are interested in focusing on the ways in which geographers might use media to allow technologies and critical geographies to intertwine in a useful discourse so that we might more fully understand the spaces, identities, and powers contained within the performances of particular media forms or representations and learn how to harness these powers. Using media to think geographically can illuminate issues far beyond the narrative content of media. The constructions and performances are central elements in ongoing and increasingly visual and aural encounters between diverse cultures, not to mention engagements with our own cultural productions and social relations of the past, present, and future. The spatiality of social



interaction is naturalized, and indeed neutralized, within the realistic appearance of media representations and is inscribed by sociopolitical relations of which media are simultaneously medium and product. Vision, for example, and thus its media manifestations, can be irrevocably tied to domains of knowledge, arrangements of social space, and lines of force and visibility. While this constitutes the cultural formations that make visual media possible, these forms of media cannot simply be reduced to signifiers of social forces and relations premised solely on models of *media theory* or to models of spectacle within politically based culture wars, as the controversies related to both Mel Gibson's *The Passion of the Christ* and *Apocalypse*, Michael Moore's *Fahrenheit 9/11*, and the Al Gore-narrated *An Inconvenient Truth* so aptly illustrate.

James Craine and Giorgio Hadi Curti

See also Film and Geography; Literature, Geography and; Nonrepresentational Theory; Place Promotion; Popular Culture, Geography and; Representations of Space; Spaces of Representation/Representational Spaces; Symbolism and Place; Television and Geography; Video Games, Geography and

Further Readings

- ACME: An International E-Journal for Critical Geographies: www.acme-journal.org
 Aether: The Journal of Media Geography: www.aetherjournal.org
 Aitken, S., & Zonn, L. (Eds.). (1994). *Place, power, situation, and spectacle: A geography of film*. Lanham, MD: Rowman & Littlefield.
 Cresswell, T., & Dixon, D. (2002). Introduction: Engaging film. In T. Cresswell & D. Dixon (Eds.), *Engaging film* (pp. 1–10). Lanham, MD: Rowman & Littlefield.
 Sui, D. (2000). Visuality, aurality, and shifting metaphors of geographical thought in the late twentieth century. *Annals of the Association of American Geographers*, 90, 322–343.
 Thornes, J. (2004). The visual turn in geography. *Antipode*, 36, 787–794.



MEDICAL GEOGRAPHY

Medical geography, also known as health geography, is the application of geographical methods and techniques to the study of health. Research in medical geography has as wide a reach as research in the health sciences to address issues of disability, access to health care, parasitology, the spatial distribution of cancer cases, and the diffusion of diseases.

Although studies of human-environment interactions in relation to health are among the oldest recorded in medical research (e.g., Hippocrates), medical geography has gained particular prominence today as a way to better understand health beyond the confines of the human body, by examining health in local, regional, and global contexts. The way in which this is done ranges from post-modern Foucauldian critiques of the construction of mental health and the physical design of sanatoriums to the mapping of cancer rates across cities and states. While there are many approaches adopted within medical geography, three common theoretical views are described here: (1) human ecology, (2) the structuralist interpretation, and (3) critical approaches. Subsequently, common techniques, involving geographic information systems (GIS), spatial analysis, and remote sensing, are described as they relate to the field of medical geography.

Human Ecology

The human ecology approach to medical geography proposes an understanding of health that is integrative, concerning population, behavioral, and habitat characteristics of the state of individual health. Population factors affecting health include genes, gender, and age. Stages and differences in the life course of individuals are significant determinants of health status. However, of importance to the human ecology approach is the subjugated role of genetics, where behavior and habitat rank equivalently with demographic and genetic measures in understanding health. Behavioral factors integral to understanding health include belief systems, social networks and organization, and access to technology, broadly defined. Habitat components include



characteristics of the natural habitat, the built environment, and the social environment. Also important to the human ecology approach is the recognition that the factors that affect health operate at a variety of scales, microbiotic to global, and are mediated in a number of ways by social and natural environments.

The human ecology approach interweaves geography with numerous disciplines: ecology, population biology, genetics, demography, epidemiology, the social sciences, public administration and policy, urban and regional planning, and architecture and environmental design, as well as medicine and the health sciences. Rarely is it possible for research scientists to span the ecological approach with necessary attention to all its components; however, an appreciation for the larger interactions among individuals, across scales, and spanning time offers a quintessentially geographical grounding to the research.

The Structuralist Interpretation

Types and organizations of power structures have enormous implications for understanding inequities in health, vulnerabilities to disease, and lack of access to health care. A structuralist approach to health examines the ways in which power arrangements play out on individual health. Medical geographers have adapted this approach by helping to articulate and visualize the ways in which disempowerment is shown through inequities in health across space (across countries and within countries). For example, to critique economic indicators such as national income, health metrics, such as infant mortality rates and life expectancy, are increasingly used to understand development differently.

Critical Approaches

Critical approaches have done much to rethink the way in which we understand, or construct, notions of health and illness. Feminist methods have revealed the ways in which Western, biomedical approaches interfere with female conceptualizations of the body, in relation to the social and natural environment. Critical race studies have challenged the dichotomous and limited

view of race and ethnicity commonly used in design frames for medical experimentation and research. Furthermore, postmodern perspectives have also criticized how health care is operationalized, particularly in defining mental behaviors or forms of disability as problematic, in need of correction, observation, and remedy. Medical geographers have adapted critical approaches to study how localities and design manifest as evidence of power constructs.

GIS and Spatial Analysis

Though cartographic techniques have been used in the health sciences for many years, developments in GIS have led to the automated collection, distribution, and analysis of disease and measures of health. Health and behavioral surveillance systems are now also collecting geographic information (address information at a minimum or geographic coordinates—latitude and longitude), as are the agencies that collect vital records and statistics (birth certificates and death certificates) and agencies that conduct large-scale health interview surveys. A few countries, or localities, are now operating with real-time disease surveillance. The digitalization of health information offers many new opportunities to monitor and evaluate the distribution of disease. Simulations of disease outbreaks can be generated, and individual and ecological correlates of disease can be studied, using techniques such as multilevel modeling and hierarchical Bayesian approaches.

A variety of types of cluster analysis have been devised by geographers, many for health applications specifically, such as the Geographic Analysis Machine (GAM), space-time scan statistics, and Local Indicators of Spatial Analysis (LISA). Cluster analysis has been used widely in medicine and public health to identify hot spots, or areas where to target health care funding, in relation to sexually transmitted diseases and other contagious diseases, cancer mortalities, and vector-borne diseases (e.g., malaria, dengue fever, and Lyme disease). GIS and spatial analysis have also been used to study differences in access to health care, how neighborhood and urban design affect access to healthy food options, recreation, and walking as an alternative to automotive transportation, and inequities in exposure to toxic releases.



Health Applications of Remote Sensing

In addition to the mapping and analysis of disease patterns with GIS, medical geographers are using remote sensing, such as satellite imagery and aerial photography, to study the habitats of disease vectors, such as mosquitoes, ticks, or flies. This is done by classifying imagery associated with vegetation and examining vector habitats in proximity to the built environment. There is increasing interest in the health consequences of climate change on human populations that occur through intensification of human migration as well as the spreading of vector populations in response to warmer climate.

Future Directions

Future directions in the arena of medical geography involve the development of databases and analytical tools that better enable geographers and health professionals to study information about individuals that may change over both space and time. This will allow researchers to distinguish between differences in environmental exposures and changes in the social environment, which can affect health differently in different localities over the life course. In particular, the study of migration and health, which was very difficult before, is becoming more manageable. Other space-time survey data sets capture daily travel patterns, using armband GPS devices, which can be used to study urban land use patterns from the individual perspective, and study what those use patterns mean in terms of opportunity for healthy behaviors. Other research directions promise to investigate the impact of climate change on human health and how the impacts differ locally. HIV/AIDS and the social consequences of coping with HIV/AIDS (e.g., orphans and the decline in the productive labor force) continue to be on the forefront of the global public health agenda. Finally, medical geographers are studying how activities in the global political economy manifest locally and affect human health across borders. A few components of such research are sex work, the global drug trade, the global arms trade, and the growth of urban slums and borderlands, all of which are intimately linked with issues of global public health.

Lisa Jordan

See also **Cancer, Geography of; Carcinogens; Cholera, Geography of; Disease, Geography of; GIS in Health Research and Health Care; Health and Health Care, Geography of; HIV/AIDS, Geography of; Malaria, Geography of**

Further Readings

- Gatrell, A. (2002). *Geographies of health: An introduction*. Malden, MA: Blackwell.
- Kearns, R., & Moon, G. (2002). From medical geography to health geography: Novelty, place and theory after a decade of change. *Progress in Human Geography*, 26, 605–625.
- Meade, M., & Earickson, R. (2000). *Medical geography*. New York: Guilford Press.
- Parr, H. (2004). Medical geography: Critical medical and health geography? *Progress in Human Geography*, 28, 246–257.
- Sui, D. (2007). GIS and health geography: Towards a new synergy. *Geography Compass*, 1, 556–582.

MEINIG, DONALD (1924–)

Until his retirement in 2004 as Maxwell Research Professor of Geography at Syracuse University, Donald W. Meinig was one of North America's most accomplished and productive historical geographers. A native of the Palouse region of eastern Washington State, Meinig received his MA (1950) and PhD (1953) from the University of Washington and taught at the University of Utah before joining the faculty of Syracuse University in 1959. During his long and distinguished career, Meinig produced a series of highly praised studies that provided new interpretations of the historical and cultural forces that shaped several distinct American regions, including the Northwest, Mormon country, the Southwest, and Texas.

Meinig devoted the last two decades of his professional career to a monumental four-volume series, *The Shaping of America: A Geographical Perspective on 500 Years of History*. This unprecedented achievement represents the most ambitious attempt ever by a geographer to bring the entire enterprise of discovery, conquest, settlement,



and development of the United States into a coherent conceptual framework.

Meinig's approach in this study is to portray America as a "gigantic geographic growth with a continually changing geographic character, structure, and system" (Volume 1, p. xv), with close attention to the varieties of peoples involved and the larger context of bordering societies. Throughout the series, he emphasizes the imperial dimensions of this enterprise and demonstrates that America was "created from a massive aggression against a long succession of peoples" (p. xviii). Throughout a narrative of more than 2,000 pages, Meinig employs several consistent basic principles that inform his approach: context, coverage, scale, structure, tension, and change (pp. xvi–xvii). He also examines the dynamic and changing nature of the spatial morphology of the United States using the concepts of core, domain, and sphere that he developed for earlier studies.

Unlike most professional geographers, Meinig does not claim to belong to a tradition or school of scholarship, and he feels that this lack of association gave him the freedom to move geography—historical geography in particular—in new directions. He has been particularly interested in elevating regional geography from the practice of merely listing categorized descriptions into something more artful and interesting to other disciplines. His method of doing this is to add history, context, interconnection, and constant flux to regional description, remaking it as interpretation and focusing on space, place, and change. To Meinig, geography has the potential to be art as well as science. To be a geographer is to see the world in a particular way, and to do geography is to express this view with language, diagrams, and maps full of movement and tension. Although few geographers have been as careful as Meinig in their use of language, fewer still have been as masterful in their use of maps and diagrams to enhance their interpretative narratives, to stress the dynamics of change, and to stimulate the geographical imagination.

Few works by geographers have received the attention and praise across disciplines that Meinig's work has inspired. Historians in particular have embraced his grand narrative for the scope of its monumental task and the explication of patterns that resulted from his approach. Nevertheless, he

has been criticized for privileging pattern at the expense of process and political and social forces at the expense of economic and environmental ones. Other critics have found his language to be, on the one hand, too carefully crafted for effect and, on the other, unscientific and imprecise.

Nevertheless, Meinig has brought to the writing of American historical geographies a wealth of fresh ideas and a high standard of literary and cartographic excellence. He stimulates the geographical imagination of readers with lucid prose that is challenging and yet free of jargon and with maps and diagrams that are equally fluid, readable, and vivid.

Scott Anderson

See also **Historical Geography**

Further Readings

- Baker, A. (2005). Writing geography, making history: D.W. Meinig's geographical perspective on the history of America. *Journal of Historical Geography*, 31(4), 634–646.
- Meinig, D. (1968). *The Great Columbia Plain: A historical geography, 1805–1910*. Seattle: University of Washington Press.
- Meinig, D. (1969). *Imperial Texas: An interpretive essay in cultural geography*. Austin: University of Texas Press.
- Meinig, D. (1969). *Southwest: Three peoples in geographical change 1600–1970*. New York: Oxford University Press.
- Meinig, D. (Ed.). (1979). *The interpretation of ordinary landscapes*. New York: Oxford University Press.
- Meinig, D. (1986–2004). *The shaping of America: A geographical perspective on 500 years of history* (Vols. 1–4). New Haven, CT: Yale University Press.
- Wickoff, W., & Colten, C. (Eds.). (2009). Donald Meinig: Shaping American geography [Special issue]. *Geographical Review*, 99(3). Retrieved November 20, 2009, from www.amergeog.org/gr/jul09.html
- Wynn, G. (2005). D. W. Meinig and the shaping of America. *Journal of Historical Geography*, 31(4), 610–633.



MENTAL MAPS

The term *mental map* refers to the cognitive representation of environmental information that a human being acquires through different (direct and indirect) sources. The term was first used by Edward Tolman in 1948 to refer to the mental representation of spatial layouts learned by rats to find food in a labyrinth. The term is synonymous with the terms *cognitive map* and *spatial mental representation*. The latter expression is a more neutral term offered in response to the criticism that the map metaphor is too restrictive and provides the incorrect impression that environmental information is indeed mentally stored in a maplike format. Nonetheless, the term *mental* or *cognitive map* is still widely used. The criticism and discussion of the map metaphor was particularly active in the second half of the 20th century, and alternative terms have been proposed, such as *spatial schemata*, *cognitive collage*, and *world graph*.

Mental maps are the result of a multimodal integration of various information sources. On the side of the cognitive agent, different sensory inputs contribute to the information that is stored about an environment. Visual information is the most prominent sensory channel, leading to abundant information about environments through direct experience. However, research has shown that environments are perceived and understood in diverse ways, not through visual perception alone. Besides other *exteroceptive senses* (i.e., senses that receive or respond to information from outside the body, e.g., smell, hearing, and balance), *proprioceptive information* (information about the internal state of the body) has been shown to contribute to understanding spatial environments. Proprioception and *vestibular* (balance) information, for example, play an important role in establishing an understanding of travelled distances and spatial environments, even in the absence of externally caused body movements such as those that occur when traveling by car or train. The multimodal origin of mental maps is supported further by the fact that they can be created in the complete absence of visual information by both sighted and visually impaired cognitive agents.

Mental maps are also created through the study of secondary sources. These sources can be in map format themselves, either as classic paper maps or digital tools, such as Google Earth (the most common Earth viewer), providing maplike information. Other secondary sources include texts (e.g., travel itineraries, movies) and verbal descriptions of spatial environments (e.g., route directions). In the latter case, the mostly qualitative verbal descriptions provide input for creating an often underspecified, sparse mental representation of a spatial environment that, when interacting with the environment, can guide spatial behavior.

Hence, it is important to bear in mind that mental representations of spatial environments are the result of a multimodal combination of sensory inputs and are not restricted to visual information alone. Furthermore, nonsensory sources such as maps, text, and verbal descriptions also contribute to the kind of information that is stored in a mental map.

Distortions in Mental Maps

One of the defining characteristics of mental maps is that they systematically represent certain aspects of the environment while neglecting others. This phenomenon is often referred to as distortions in mental maps. For example, distance, angle, and areal extent are not veridically represented in a mental map (a property that they indeed share with most cartographic maps). However, the selectiveness of cognitive agents regarding which aspects to represent in a mental map is an evolutionary necessity that should be seen as a positive adaptation to their environments rather than a limitation. To draw an analogy, mapmakers pursue a very similar goal by emphasizing some aspects and deemphasizing others to abstract a large, complex environment to the size of a map or to communicate only a particular characteristic of an environment. The selection criteria that humans employ are often more abstract (schematic) than the mapping rules in cartography. Additionally, the mental representation of environmental information is not constrained by a representational medium such as the two dimensions of paper maps; mental representations are not a map. This means that inconsistencies can be resolved more easily in mental maps and do not pose a representational problem.



The absence of selection strategies would lead to an information overflow in a cognitive agent that would slow down decision making dramatically. While we are seldom in danger from predators these days, the evolutionary roots are important to understand. This evolutionary adaption is what Andy Clark terms the “007 principle”: Evolved creatures will avoid storing information about environment in a costly way. They instead use the environment itself to contribute information and fill in the gaps (or details). Cognitive beings aim to know only as much as they need to know.

Much research has been devoted to revealing the aspects of environments that the human cognitive system is focusing on and that are used to simplify complex spatial relationships. It is important to understand that the inconsistencies in mental representations are often resolved by offloading information to the environment. This means that we do not need to mentally store every aspect of information about the environment, just those aspects that allow us to make the right decision (at least in most situations). An example is the tendency to orthogonalize intersections (see below) rather than mentally representing angle information properly. In almost all navigational situations in street networks, angular information is not relevant for successfully choosing the correct route (branch) to take at an intersection. The following are among the most prominent aspects of organizing spatial knowledge:

Cognitively Salient Elements of Environments. While landmarks are among the most researched elements that humans use to anchor spatial information, other elements are essential for organizing spatial information cognitively. The term *cognitively salient* has to be extended to mean not only visually salient objects but all structures that cognitive beings use to organize spatial knowledge. To this end, in 1960, Kevin Lynch identified the following five categories of structures used by cognitive beings to organize spatial knowledge: (1) landmarks (salient entities in the environment), (2) nodes (strategic places in the environment, such as street intersections), (3) paths (predominant elements in built environments that connect nodes and landmarks), (4) districts (area-like elements), and (5) edges (boundaries between areas).



Figure 1 Physical locations of San Diego and Reno are often different from those in mental maps.

Source: Robert Roth.

The Hierarchical Organization of Spatial Knowledge. In a classic experiment by Albert Stevens and Patty Coupe, participants had to indicate the direction from San Diego, California, to Reno, Nevada (tested against various other pairs of cities). Most participants judged Reno to be east of San Diego, while it actually is located to the west (see Figure 1). Stevens and Coupe were able to demonstrate with this experiment that the information that is represented on states (California is west of Nevada) is inherited by the cities within that state. Thus, because the information is hierarchically organized, an incorrect inference of the relative positions of Reno and San Diego is made (in this example).

Aligning Spatial Information. B. Tversky noted that one way to simplify directional information between entities in space is to align them with each other. A prominent example is the mental representation of North and South America along a primarily north-south axis. However, the actual



latitudes of the two continents are instead diagonally placed to each other. This effect can be observed for many entities located in space. On a smaller scale we find, for example, the following simplifications that are applied to street networks: the orthogonalization of street intersections, the straightening of curved paths, and the alignment of nonparallel streets.

Understanding the mental representation of spatial information (often referred to as a mental map) is a central research topic in and outside geography. The goal is to fundamentally understand how information about our environments is cognitively processed, stored, transformed, and communicated. Research on mental maps has led to several insights into how spatial information is cognitively structured. Revealing the principles that underlie human understanding of environments is important, as it allows for tailoring technical solutions to spatial problems (e.g., wayfinding or spatial decision making) using the strategies naturally used and understood by humans.

Alexander Klippel

See also **Behavioral Geography; Childhood Spatial and Environmental Learning; Representations of Space; Spatial Cognition; Wayfinding**

Further Readings

- Clark, A. (1989). *Microcognition: Philosophy, cognitive science, and parallel distributed processing*. Cambridge: MIT Press.
- Evans, G. (1980). Environmental cognition. *Psychological Bulletin*, 88, 259–287.
- Kitchin, R., & Blades, M. (2002). *The cognition of geographic space*. London: Tauris.
- Lynch, K. (1960). *The image of the city*. Cambridge: MIT Press.
- Stevens, A., & Coupe, P. (1978). Distortions in judged spatial relations. *Cognitive Psychology*, 10(4), 422–437.
- Tolman, E. (1948). Cognitive maps in rats and men. *Psychological Review*, 55(4), 189–208.
- Tversky, B. (1981). Distortion in memory for maps. *Cognitive Psychology*, 13(3), 407–433.

MERCATOR, GERARDUS (1512–1594)

Gerardus Mercator was a Flemish engraver and cartographer who lived during the so-called Age of Exploration, that is, the 16th century, when European capitalism and colonialism began their epochal period of global conquest, and his work both reflected and greatly enabled this expansion.

Born Gerhard Kremer, Mercator changed his name as a university student in Louvain, where he lived from 1530 to 1552. At an early age, he studied to be a priest at a monastic school in Her-togenbosch, where he learned calligraphy and Latin. In Louvain, he was trained in philosophy, surveying, scientific instruments, mathematics, astronomy, and geography, receiving his master's degree in 1532. He married in 1536 and eventually had six children. In 1544, he was jailed briefly under suspicion of heresy but released for lack of evidence. In 1552, he relocated to Duisberg, in what later became Germany, where he taught mathematics at the local gymnasium, or high school, until the cartographic workshop he founded acquired steady work under his long-time patron, the Duke of Cleves.

While his early talent lay in engraving, Mercator steadily moved from detailed maps of Flanders to globes to flat maps of the world, whose projections drew on his mathematical training. Some claim that Mercator coined the term *atlas*. In 1538, he published a double-cordiform (heart shaped) map of the world, the first to show two distinct continents in the Western Hemisphere; this map was lost but was eventually found in New York in 1878. In 1546, he produced a set of observational instruments for use in Charles V's campaigns. Thereafter, he took to producing a series of maps and globes, particularly concerning Europe. In 1578, he published a revised version of Ptolemy's classic, *Geography*, including 27 maps. A comprehensive global atlas begun in 1585 was completed and published by his sons in 1594, after Mercator's death.

Mercator is most famous, however, for his map projection, named after him, which he unveiled in 1569 with his *Nova et Aucta Orbis Terrae Descriptio ad Usum Navigatium Emendate* (New and Augmented Description of the Earth Designed



Figure 1 Mercator's projection of the world famously allowed easy lines of constant compass bearing but distorted areas at a great distance from the equator.

Source: Author.

for Purposes of Navigation). It is a cylindrical projection with no distortion at the equator. Unlike earlier maps, this one employed a graticule of latitude and longitude lines that did not converge at the poles. Simon Winchester calls it “an adroitly contrived confection of secants and cosines; it was neat, tidy and hugely popular; and it was turned into charts that mariners used for generations.” The Mercator projection came to enjoy enormous popularity and fame due to the numerous advantages it offered. In particular, it was widely popular in nautical and seafaring circles because it allowed loxodromes or rhumb lines—lines of constant compass bearing—to be represented as straight lines. While shape and direction are preserved throughout the map, size is increasingly distorted with distance from the equator, greatly exaggerating the areas of regions at high latitudes (most famously, Greenland) and

leaving it unable to represent the poles (Figure 1). Its application, however, was muted by the inability to measure longitude accurately during the 16th century.

Undoubtedly, the Mercator projection revolutionized cartography and greatly facilitated its role in European expansionism. It also had deep ideological effects: In standardizing it with rigorous mathematical rules, Mercator helped overcome the long-lasting influence of Ptolemy. Over time, the Mercator projection became the most widely used map projection in history, familiar to every student who has looked at a world map, leading to widespread misconceptions about the relative areal sizes of landmasses in the economically developed Northern Hemisphere, thus sustaining and amplifying discourses of Orientalism and their attendant geographical imaginations. In the 20th century, it was supplanted, or even



displaced, by equal-area projections, such as the Peters projection.

Barney Warf

See also **Cartography, History of; Human Geography, History of; Map Projections; Ortelius**

Further Readings

- Crane, N. (2003). *Mercator: The man who mapped the planet*. New York: Henry Holt.
- Monmonier, M. (2004). *Rhumb lines and map wars: A social history of the Mercator projection*. Chicago: University of Chicago Press.
- Winchester, S. (2003, January 23). The mapmaker to blame for distorted worldviews. *The New York Times*. Retrieved November 20, 2009, from <http://query.nytimes.com/gst/fullpage.html?res=9903E1DD1130F930A15752C0A9659C8B63>

METADATA

Metadata are data about data. More specifically within geography, they consist of digital background information about the origins of geospatial data. The data metadata describe are not necessarily limited to purely electronic data sets but can involve various formats and media. As standard operating procedure within geographic information systems (GIS), metadata play an essential role in identifying data usability and accessibility. A lack of metadata renders a data set less useful or even useless in analysis, since its legitimacy cannot be ensured. The following describes the content, format, standards, uses, and importance of metadata in geography.

Metadata accompany geospatial data in a separate file that includes pertinent information about the data set. The content is designed to allow for situational evaluation of data usability. This record consists of basic identification, quality, spatial reference, organization, attribute, acquisition, and proper usage information on a data set. Common examples of this content are title, author, contact information, equipment

used, processing history, update plan, purpose, rights of use, and geographic projection. Metadata also include the author and currency of the metadata themselves.

The content of metadata follows international (International Organization for Standardization, ISO) or national (Federal Geographic Data Committee, FGDC) standards. These standards specify the different types of information that should be present but do not dictate organizational or transfer protocol. The format for metadata is Extensible Markup Language (XML) or Standardized Generalized Markup Language (SGML), although it can also be a word-processing document, in Hypertext Markup Language (HTML), in Portable Document Format (PDF), or a text file, so long as it accompanies the data.

Organizations use metadata to maintain internal data management standards, to plan spatial data updates and acquisitions, to keep a data inventory for data clearinghouses, and to facilitate spatial data transfer and proper interpretation. They implement metadata to set priorities and maintain data quality and consistency. Metadata can also optimize communication between organizations through a common platform for discussing and documenting data.

Within geography, the importance of metadata rises above that of simple organization, since spatial data sets are incorporated into analysis and decision making. Considering the exponential growth of GIS data availability, there needs to be a mechanism for sorting and evaluating such data prior to acquisition and usage. Metadata maintenance is essential for spatial data management and documentation. This documentation facilitates data location, acquisition, interpretation, and implementation. It provides a clear indicator of the accuracy and currency of data and the legality of data usage. It also identifies the original purpose and scale of the data so that proper incorporation of metadata into mapmaking and decision making can minimize inaccuracy and bias. Metadata play a vital role in geography by providing a common language for geospatial data set interoperation, thus ensuring timeliness and accuracy.

Sarah M. Wandersee



See also Database Management Systems; Interoperability and Spatial Data Standards; Legal Aspects of Geospatial Information; Ontological Foundations of Geographical Data; Open Geodata Standards; Spatial Data Integration; Usability of Geospatial Information

Further Readings

Federal Geographic Data Committee. (1998). *Content standard for digital geospatial metadata*. Washington, DC: Author.

 METROPOLITAN AREA

Metropolitan areas are large population centers (central cities) together with their adjacent zones of influence, where influence may be measured by levels of commuting to the central city or by commercial ties and media penetration—thus typically encompassing rural areas and physically separate satellite towns that are economically integrated with the core city.

Metropolitan areas were an innovation of the U.S. Census, first called “metropolitan districts” in 1930 and only fully developed as “metropolitan areas” for the 1950 Census. Areas were recognized around independent central cities of 50,000 or more people and, for most of the country, consisted of the county containing the central city plus adjacent counties with “significant” ties to the central county, in particular commuting levels of 15% or more to the central city and thresholds of density and nonagricultural employment. In New England, metropolitan areas were defined on the basis of towns, local government units smaller than the county. As these were not statistically compatible with county-based areas for the rest of the country, New England County Equivalent Metropolitan Areas were also defined. However, just as serious a problem of inconsistency and noncomparability resulted from the inconvenient fact that county size and shape varied tremendously across states.

Nevertheless, the metropolitan area designation proved immensely popular, in part because it gave competing cities some sense of their relative

Category	Population	% Share
Metropolitan	226	80
Central city	85	30
Other urban	115	41
Rural	26	9
Nonmetropolitan	55	20
Urban	23	8
Rural	32	12

Table 1 U.S. metropolitan population, 2000 (in millions). By 2008, the metropolitan population is at least 84 % of the total population of more than 300 million. Note that metropolitan areas do contain a sizable rural population and that the “other urban” category, mainly suburbs, exceeds the central city population.

Source: U.S. Census Bureau. (n.d.). *Number of inhabitants, 1950, 1960, 1970, 1980, 1990, and 2000, urbanized areas*. Washington, DC: Government Printing Office.

importance in the national economy, as well as becoming a useful measure of growth from census to census. More important, metropolitan areas soon became the legal units for implementation of myriad federal programs and for the allocation of federal funds. Indeed, the definition of areas is so politically important and sensitive that they are defined by the Office of Management and Budget in the White House and are the subject of battles for autonomy versus inclusion as part of larger areas.

Definitions and rules for delimitation have changed over the years. For example, by 1970, eligibility was based on actual urban agglomerations over 50,000 (urbanized areas), and “consolidated” metropolitan statistical areas were recognized, consisting of adjoining “primary” metropolitan areas with high levels of commuting and economic integration. As of 1990, only commuting to the core urbanized areas was used as a basis for adding outlying counties, resulting in a substantial increase in metropolitan territory and population. Periodically, taskforces have been formed to consider more basic reforms toward greater consistency and comparability, for example, defining areas based on smaller units such as zip codes or census tracts, but the availability of quality data for intercensal years only by counties

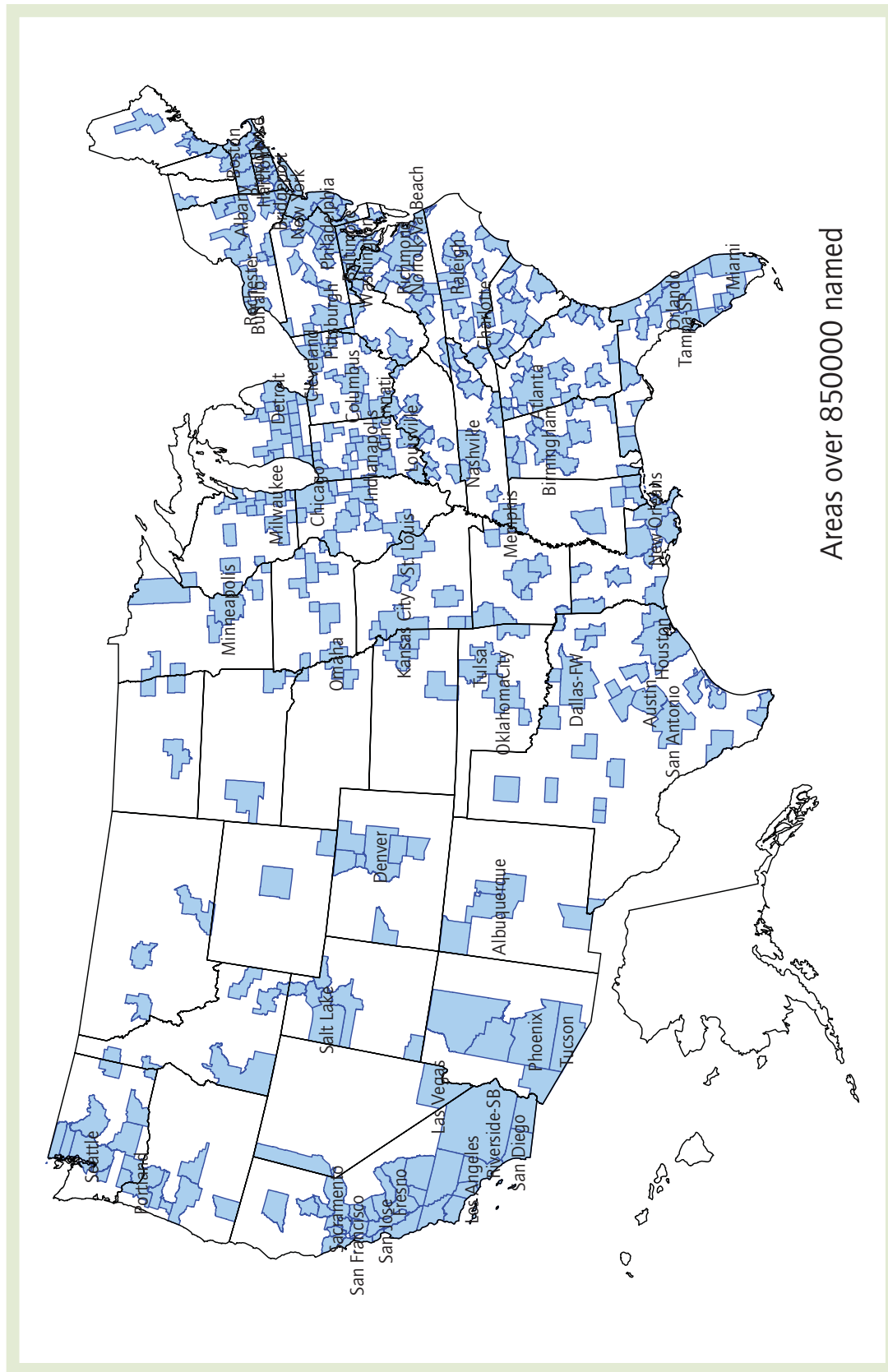


Figure 1 Large U.S. metropolitan areas, 2003

Source: U.S. Census Bureau. (n.d.). *Number of inhabitants, 1950, 1960, 1970, 1980, 1990, and 2000, urbanized areas*. Washington, DC: Government Printing Office.



Rank	Area	Population (in thousands)	
		Metropolitan Area	Consolidated Area
1	New York	18,816	21,962
2	Los Angeles	12,576	17,755
3	Chicago	9,525	9,745
4	Dallas	6,145	6,498
5	Philadelphia	5,828	6,385
6	Houston	5,628	5,729
7	Miami	5,413	5,413
8	Washington, D.C.	5,367	8,242
9	Atlanta	5,279	5,628
10	Boston	4,482	7,477
11	Detroit	4,468	5,405
12	San Francisco	4,204	7,265
13	Phoenix	4,179	4,179
14	Seattle	4,109	4,109

Table 2 Largest U.S. metropolitan areas, 2007

Source: U.S. Census Bureau. (n.d.). *Number of inhabitants, 1950, 1960, 1970, 1980, 1990, and 2000, urbanized areas*. Washington, DC: Government Printing Office.

has thus far stalled such efforts. However, census tracts and zip-code-based areas (RUCAS, or rural-urban commuting areas) have been defined by the U.S. Department of Agriculture for rural-based programming.

Metropolitan areas should be distinguished from related settlement terms, such as (a) an agglomeration or conurbation, which usually connotes the actual densely built up urban settlement and which in the United States is called an (b) “urbanized area” (the core of any metropolitan area) with more than 50,000 in population; (c) the “business economic area” (BEA), which in the United States is the set of territorially exhaustive economic regions, the cores of which are usually metropolitan areas; (d) micropolitan statistical areas, first defined for the 2000 census and analogous to metropolitan areas but defining areas related to census-defined agglomerations of between 10,000 and 50,000 people; and (e) megalopolis, or larger complexes of closely related metropolitan areas, such as the original megalopolis extending from Boston to Washington (now even farther) and comparable megacities across the globe.

Metropolitan areas have been similarly defined for many countries, but of course with widely varying criteria, rendering comparability very problematic. Perhaps the more directly comparable metropolitan areas are those of Canada, Mexico, Taiwan, and much of the European Union. Most countries do try to define urban agglomerations (but definitions of *urban* vary) and economic regions (comparable with the U.S. BEA regions). And some countries define commuter sheds around major cities for transportation planning purposes.

Richard Morrill

See also **Suburbs and Suburbanization; Urban Geography; Urban Hierarchy; Urban Spatial Structure; Urban Sprawl**

Further Readings

U.S. Census Bureau: www.census.gov

 MICROWAVE/RADAR DATA

Remote sensing for Earth surface information increasingly uses varied components of the electromagnetic spectrum, such as microwave energy in wavelengths between 1 mm (millimeter) and 1 m (meter). Microwave can be passive or active. Passive sensors record the energy received. There is limited passive microwave sensing primarily at coarse spatial resolution for atmospheric studies. Active microwave sends and receives energy and is much more widely used.

Active microwave is RADAR, an acronym for Radio Detection and Ranging. RADAR systems emit energy, and the returning waves are recorded in intensity and time of travel. The time of travel can be converted to distance from the sensor to the surface and used to determine with considerable accuracy surface distance and elevations by sensors known as Interferometric RADAR (IFSAR or ISAR). RADAR has extensive use in navigation and meteorology, but the focus here is on imaging radar for feature analysis. RADAR advantages over optical sensors include the ability to collect



imagery at night, to penetrate clouds, and, under some conditions, to penetrate into vegetation and hyperarid soils.

Operational Characteristics

RADAR images to the side of the platform at a variable angle are called Side Looking Airborne Radar (SLAR or SAR). RADAR uses different specific wavelengths, such as X, L, C, P, or K band. RADAR energy can also be sent and received in different polarizations, vertical (V) or horizontal (H), for four possible images from one wavelength; HH, HV, VH, and VV (quad polarization). A historic RADAR limitation was that the quality of the data was limited by the size of the antenna. This problem was ingeniously resolved by incorporation of the Doppler effect in processing, caused by slight frequency shifts (caused by the movement of the sensor) between sending and receiving energy known as Synthetic Aperture Radar (SAR).

Variations in RADAR return result in high or low image values, bright to dark tones called backscatter. The backscatter will vary based on wavelength and polarization but is generally determined by surface aspect or geometry, dielectric constant, and texture or roughness.

Applications

There are multiple applications of RADAR. Foremost among these are information in cloudy areas, humid tropics and high latitudes, and areas of limited sunlight and high latitudes in winter. SLAR provides a shaded-relief appearance excellent for delineation of geologic and geomorphic features (Figure 1).

RADAR successfully maps snow and ice in lake or ocean flows and monitors shipping lanes for icebergs. Because oil dampens waves, RADAR can locate oil spills and natural seeps. Other applications include urban analysis, deforestation, biomass estimations in a variety of vegetation communities, flood mapping, agriculture, and generalized land cover mapping (Figures 2 and 3).

RADAR has been acquired from aircraft for more than 50 years. It has been collected from

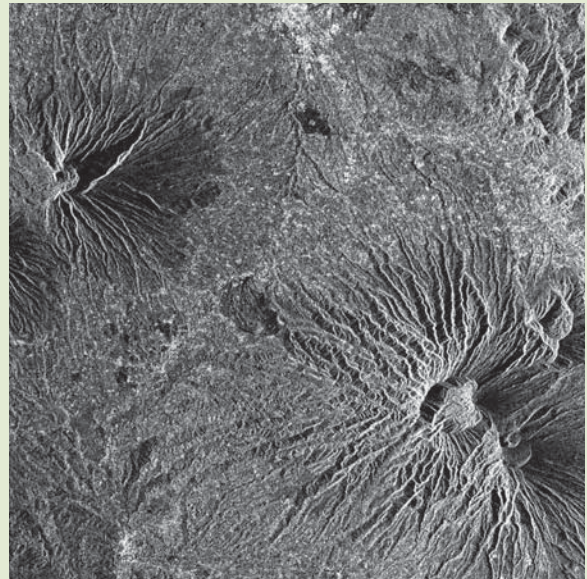


Figure 1 Volcanic structures in Indonesia via RADAR

Source: Canadian Space Agency.



Figure 2 Sandia Labs RADAR image of rice fields in southeast Asia

Source: Sandia National Laboratories.

space since 1978, but systematic space-borne acquisition has only occurred since about 1995. Recently, space-borne RADAR has been obtained by the Canadian, Russian, and European space



Figure 3 Individual RADAR bands can be combined to provide color as in this Shuttle Imaging Radar image of New Orleans.

Sources: U.S. Geological Survey and NASA.

agencies and through German and Japanese platforms, among others.

Barry Haack

See also **Imaging Spectroscopy; Radiometric Resolution; Remote Sensing**

Further Readings

- Elachi, C., & van Zyl, J. (2006). *Introduction to the physics and techniques of remote sensing* (2nd ed.). New York: Wiley.
- Henderson, F., & Lewis, A. (Eds.). (1998). *Principles and applications of imaging radar: Manual of remote sensing* (3rd ed., Vol. 2). New York: Wiley.
- Lillesand, T., Kiefer, R., & Chipman, J. (2008). *Remote sensing and image interpretation*. New York: Wiley.



MIGRATION

Human migration involves the movement of a person (a migrant) between two places for a certain period of time. It is often considered a permanent relocation, as compared with temporary spatial mobility, which includes all kinds of movement by people, such as commuting, circulating, visiting, shopping, and temporarily working away from home.

This entry first details the most significant forms of migration according to their differing patterns and geographical scale. Next, migration decision making and the ever-changing dynamic processes of migrant behavior are examined. Last, the entry reviews some major constructs that migration scholars have presented as theoretical explanations of this constantly changing livelihood strategy of human mobility.

Forms of Migration

Internal migration within national political boundaries has always been the largest kind of population redistribution enumerated since demographic statistics have been collected and compared at global scales. Its character is often differentiated by the source and destination regions of such internal flows. Hence, rural-to-rural migration, rural-to-urban migration, urban-to-rural migration, and urban-to-urban migration can each feature in an internal migration system of population transfers and exchanges between these geographic places.

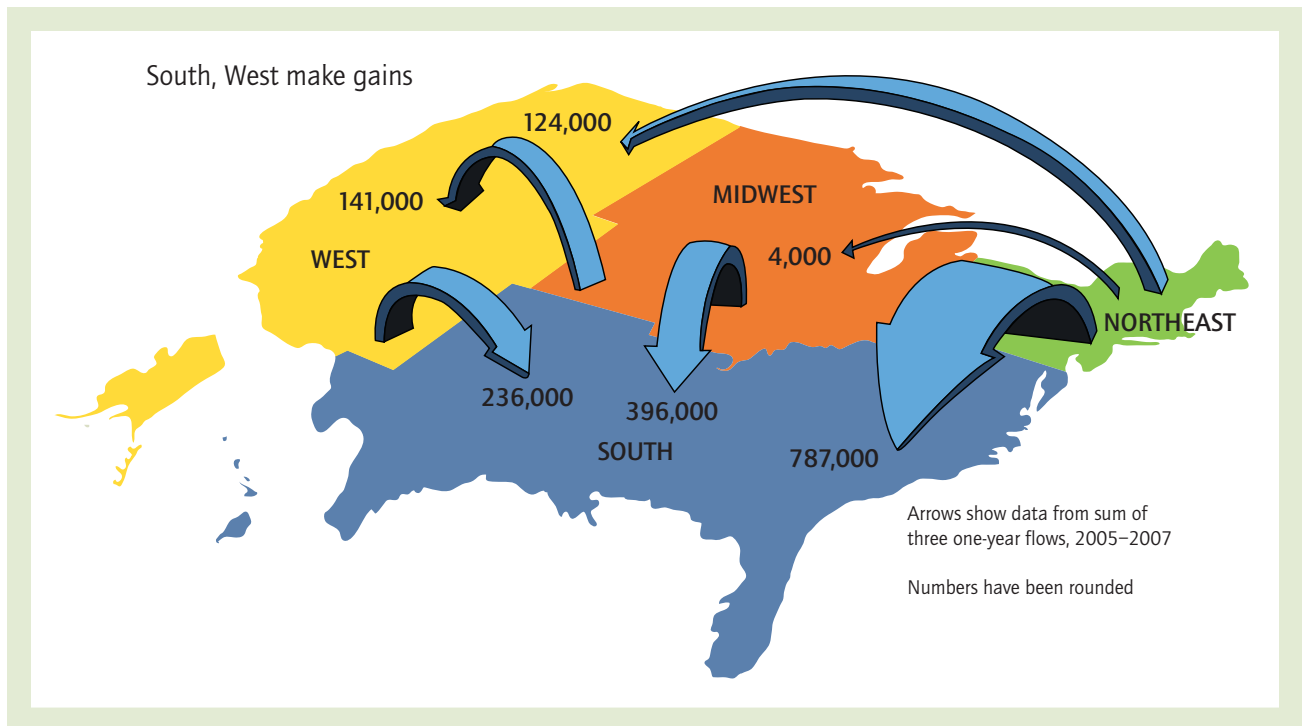


Figure 1 Net regional U.S. migration, 2007

Source: Based on Cohn, D., & Morin, R. (2008, December 17). *American mobility: Who moves? Who stays put? Where's home?* (p. 11). Washington, DC: Pew Research Center.

Shorter-distance changes of residence that do not cross the definable boundary of a place (e.g., a city) are more generally referred to as residential mobility, and within urban realms, it is common to distinguish between interurban migration and intra-urban residential mobility. Further differentiations within this group of internal migration streams and counterstreams might be characterized by the growth of megacities, or global cities, in which rapid urbanization occurs within national urban hierarchies. The accelerated growth of these large conurbations in countries of the global South occurs as a consequence of in-migration from rural and urban sources and the accompanying fertility increases of the immigrant populations. Indeed, the 20th century witnessed the rapid urbanization of the world's population, which in 2009 stands at more than 6.7 billion.

Migrants who cross national borders are said to undertake international migration. Immigration is a relatively permanent move into a different country from the migrant's home, whereas

emigration is the relatively permanent move out of the home country. In contemporary times, such international "cross-border" movements can take on a more complex character, with migrants living "betwixt and between" two "life-worlds," experiencing and practicing transnational migration, undertaking repetitive mobilities, maintaining close social contacts, and building multilocal, transnational networks of kith and kin.

With increasing globalization, rates of international migration have grown in recent years. In 2006, there were 191 million international migrants in the world, with this estimate representing more than a twofold increase from 76 million in 1960. Whereas many countries are now "sending sources" of international migration, relatively few countries are the targeted hosts of immigration streams, and since immigration policies invariably restrict and control entrance to these receiving countries, migrants have long sought irregular means of entry and access to work "across borders." Most, however, pursue legal means of entry, including short- and

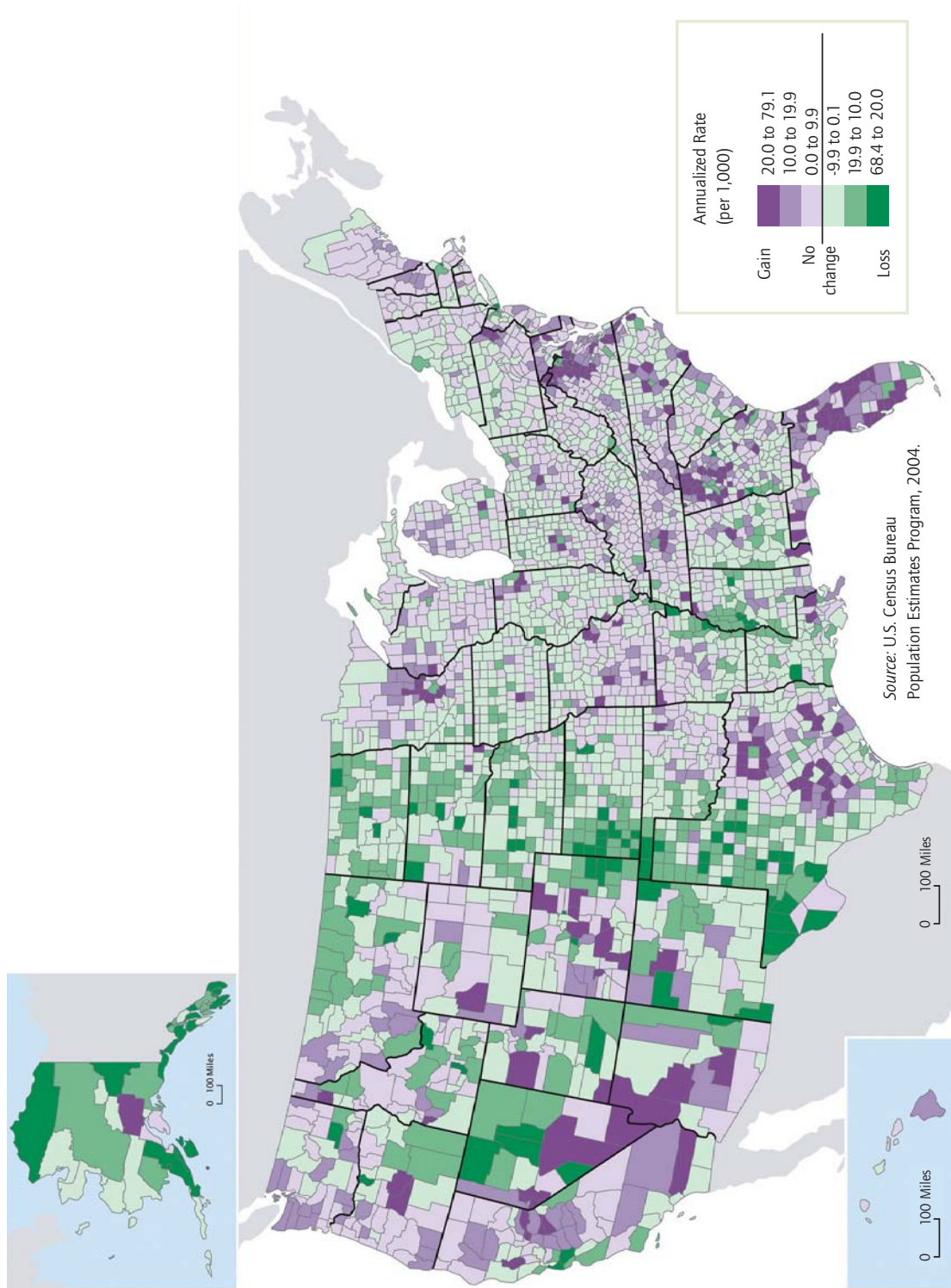


Figure 2 Average annual rate of domestic net migration by county: 2000–2004

Source: Perry, M. J. (2006, April). *Domestic net migration in the United States: 2000 to 2004* (Current Population Reports) (p. 11, figure 4). Washington, DC: U.S. Department of Commerce, U.S. Census Bureau. www.census.gov/prod/2006pubs/p25-1135.pdf.



long-term sojourning, the acquisition of visas for study, educational advancement and work permission, and often lengthy legal immigration and permanent residence petitioning and asylum petitioning. Irregular migration is the currently acceptable label for those undertaking nonlegal means of entry, replacing the plethora of xenophobic labels that have commonly been used in many a contentious anti-immigration debate, such as “illegals,” “illegal aliens,” “undocumented,” “unauthorized,” “overstayers,” “clandestine entrants,” “failed asylum seekers,” and “unwanted foreigners.”

Decision Making: Voluntary Versus Involuntary Migration

Migration can also be differentiated according to the conditions that prompted the decision to move away from the migrant's original place of residence, with a dichotomous categorization distinguishing a move as either voluntary or involuntary, “forced” migration. Voluntary migration is often economically driven, is selective by age and resource endowment, and includes the whole range from unskilled workers to highly skilled workers seeking better opportunities, experiences, and incomes in more distant labor markets than the ones they can access by staying in their original homes (including commuting and temporary work off-farm or in nearby urban centers). Voluntary migration is also a decision made and undertaken collectively by migrants and partners, migrant families, and selected members. On the other hand, the migrant's dependants—infants, young children, female partners—who are “tied movers” can be considered to be migrating involuntarily if not involved in the decision making by the household head or patriarch. In short, the social (and gendered) contexts of family power relationships often intervene in decision making concerned with the migration of families and family members.

Theoretical Explanations

Certain historical and more contemporary explanations of voluntary and involuntary migration amply demonstrate the richness of explanations of human migration as both historical and spatial

contexts vary and change, thereby rendering this mobility option extremely flexible, ever changeable and changing. There is now a growing consensus that multiple theoretical explanations reign, not one all-encompassing single theory, though the pathway to this holistic generalization has been built on many informative constructs, with some of the most exemplary detailed below.

In the late 18th century, Ernest George Ravenstein used mixed methods of analysis to inductively generate a series of “laws of migration” that attempted to explain and predict migration patterns both within (internal migration) and between (international migration) nations. Two concepts, absorption and dispersion, were derived to explain county increases and decreases, respectively, as Britain went through its urban-industrial transformation during the second half of the 19th century. Ravenstein's first paper in 1885 proposed seven “laws of migration” or generalizable regularities in internal patterns of movement: (1) most migrants only proceed a short distance and toward centers of absorption; (2) as migrants move toward absorption centers, they leave “gaps” that are filled up by migrants from more remote districts, creating migration flows that reach to “the most remote corner of the kingdom”; (3) the process of dispersion is inverse to that of absorption; (4) each main current of migration produces a compensating countercurrent; (5) migrants proceeding long distances generally go by preference to one of the great centers of commerce or industry; (6) the natives of towns are less migratory than those of the rural parts of the country; and (7) females are more migratory than males. Several of these original seven laws included assertions that were later considered “additional laws of migration”; (8) most migrants are adults; (9) large towns grow more by migration than by natural increase; (10) migration increases in volume as industry and commerce develop and transportation improves; (11) the largest volume of internal migration is rural-urban migration; and (12) the major determinants of migration are economic forces.

This view should remind us that internal migration became an adaptive strategy for rural people in the past centuries, as their agrarian livelihoods were transformed. Ravenstein's “laws,” however, did not explain why some rural adults would



A migrant family waiting in a bus station in Cuiaba, Brazil, in September 1985. During the 1970s and 1980s, many families such as these immigrated to territories of the Amazon such as Rondonia and Acre in search of a better life.

Source: Stephanie Maze/Corbis.

move while others would not. For this, Guy Standing's conceptual explanation is insightful.

Standing proposed that four conditions needed to exist to make peasants in traditional communities become migrants, the conditions being reflected in the decay in the traditional mode of exploitation (i.e., feudalism): (1) migration must exist as an acceptable response to adversity or frustrated aspirations; (2) peasants come to identify their condition as neither just nor inevitable, because some reciprocal relationship between them and their feudal landlords has been violated; (3) staying and instigating a revolt is seen as having a minimal chance of success, because the peasants are not organized in their objection to oppression, violence, or economic threats and they lack communal strength and unity; and (4) peasants come to reject customary forms of

exploitation because of a growing sense of deprivation and despair that things won't get better and because of increases in their disadvantageous position in contrast to their previous situation.

Changing the scale from internal to international mobility, Douglas Massey, in a commentary on Mexican international migration and development relations, developed an interesting theoretical construct to explain the prevalence of emigration in developing countries. Three structural conditions were said to characterize the development process: (1) the cyclical nature of industrial expansion in urban areas, paired with the more or less constant pressure for out-migration from rural areas, determined by capital formation, enclosure, and market creation, which together destroy the basis of peasant social organization and weaken their ties to rural



communities; (2) discontinuities in economic growth across time and space (i.e., uneven geographic distributions within countries and between countries), producing cyclical constrictions of opportunity in developing urban economies paired with expansions of opportunities in growing (metropolitan/core) economies abroad; and (3) declining real costs of transportation and communication, actualized by increasing access to reliable and affordable systems.

Discussing the dynamic deepening of the Mexico-U.S. migration system, Massey also explained why there is a tendency for international emigration to become progressively independent of the economic conditions that originally caused it, referring to this maturing of the migration system as the result of cumulative causation. Three mutually reinforcing processes appear to be at work in this transformational dynamic: (1) transnational network formation; (2) agrarian transformation, via emigrant earnings, remittances, and returnee “demonstration effects”; and (3) the evolution over time of deprivation and impoverishment in source communities.

Now, finally, returning to forced migration, this label has become a suitable categorization of a range of global movements in which an element of coercion exists, including threats to life and livelihood arising from biophysical or social/anthropogenic crises—environmental disasters, chemical or nuclear disasters, famine, civil war, genocide, or development-induced displacement. Natural disasters, environmental degradation and destruction, warfare, civil strife, banditry, warlord enmity, genocide, and every imaginable horror brought about by military power struggles and the accompanying “collateral damage,” which threatens and kills local civilian populations, are contemporary forces instigating and perpetuating such involuntary, forced migrations. Refugees, asylum seekers, internally displaced persons (IDPs), and development-induced and environmental-disaster-displaced persons are some of the main groups forced to flee their homelands and seek asylum beyond their nation’s borders. A majority of these displaced persons and refugees are the rural poor and powerless in the global South—Africa, Asia, and Latin America—who have consistently suffered from disruption, destruction, and displacement in recent decades.

A growing practice among international criminal groups, syndicates, and organizations is to profit from such forced migration by ushering in a new form of slavery and coercion in which the migrants are treated as disposable commodities. These underground organizations prey on young women and children by offering hope, while tricking, brutalizing, and selling them into prostitution and sex working, sweatshop labor, and similar illicit, dehumanizing and/or dangerous occupations in which they have little autonomy or basic rights and human dignities. The International Labour Office has recently estimated that at least 12 million people work as slaves or in other forms of forced labor and as many as 2.5 million are in forced labor as the result of cross-border trafficking, with approximately half being employed against their wills in sex trafficking.

Dennis Conway

See also **Commuting; Gravity Model; Immigration; Mobility; Rural-Urban Migration**

Further Readings

- Boyle, P., Halfacree, K., & Robinson, V. (1998). *Exploring contemporary migration*. Harlow, UK: Pearson Education.
- Conway, D. (2006). Globalization of labor: Increasing complexity, more unruly. In D. Conway & N. Heynen (Eds.), *Globalization's contradictions: Geographies of discipline, destruction and transformation* (pp. 79–94). London: Routledge.
- International Organization for Migration. (2005). *World migration report 2005: Costs and benefits of international migration*. Geneva: Author.
- Kosiński, L., & Mansell Prothero, R. (1975). *People on the move: Studies on internal migration*. London: Methuen.
- Massey, D. (1988). Economic development and international migration in comparative perspective. *Population and Development Review*, 14(3), 383–414.
- Ravenstein, E. (1885). The laws of migration. *Journal of the Statistical Society*, 48(2), 167–219.
- Stalker, P. (2000). *Workers without frontiers: The impact of globalization on international migration*. Boulder, CO: Lynne Reinner.



Standing, G. (1981). Migration and modes of exploitation. *Journal of Peasant Studies*, 8, 173–211.

Williams, P. (1999). *Illegal immigration and commercial sex: The new slave trade*. London: Frank Cass.



MILITARY GEOGRAPHY

Military geography generally applies the concepts and techniques of geography to the study of military problems, situations, and activities. It examines, among other things, the causal effects of physical geography (e.g., terrain, climate) on military battles, campaigns, and wars. More recent developments in the discipline, however, have broadened the scope of military geography to include the study of military operations other than war (known by the acronym MOOTW), as well as the impacts of militarism on societies and the environment and also the use of environmental resources as components of military-related activities.

Military geography is intimately associated with the development of the discipline, an association that dates far back to early Greece. Thucydides's account of the Peloponnesian War (431–404 BCE), for example, is an early application of geographic perspectives to the study of military activities. From a non-Western perspective, Sun Tzu's *The Art of War* may also be considered an early example of military geography. The birth of "modern" military geography, though, is generally marked by Théophile Lavellée's *Géographie Physique, Historique et Militaire* (1836) and Albrecht von Roon's *Militärische Landerbeschreibung von Europa* (1837). These two publications firmly established the connection between military campaigns, imperialism, and the formation of the nation-state in Europe. In the United States, W. C. Brown is credited with publishing the first text on military geography, although it was the writings of Alfred Thayer Mahan that provided the main American contributions to the emergent field of military geography. A naval historian, Mahan wrote more

than 20 books; the most important of his works were his 1890 *The Influence of Sea Power Upon History, 1660–1783* and its 1892 companion, *The Influence of Sea Power Upon History: The French Revolution and Empire, 1793–1812*. Mahan's writings, coupled with those of the British geographer Halford Mackinder, were also influential in the development of both political geography and geopolitics.

Throughout the 20th century, military geography has been significantly influenced not only by changing technologies (e.g., air photos, remote sensing, geographic information systems) but also by military conflicts. Indeed, it is often impossible to disentangle these two external influences on the development of military geography. During World War I, for example, geographers provided written descriptions of the physical landscapes involved in military campaigns. Other geographers participated in the 1919 Paris Peace Conference, which led to the Treaty of Versailles, and in the subsequent attempts to redraw the political boundaries of postwar Europe. Academically, military geographers produced numerous writings, emphasizing the applied and practical aspects of geography for the study of military-related problems. The works of D. W. Johnson—*Topography and Strategy in the War* (1917) and *Battlefields of the World War, Western and Southern Fronts: A Study in Military Geography* (1921)—epitomize much of the work of military geographers during this period.

After World War II, the wartime experiences of many geographers led to significant changes within and beyond academia. During the war, for example, many governmental agencies sought persons with the diversity of training and education that the study of geography provided. Hundreds of geographers were engaged in the war effort, being employed in the Office of Strategic Services (OSS), the War Department, the Intelligence Division, and the Army Map Service. Women also contributed to the application of geographic perspectives and techniques to military problems, notably in the fields of mapping and surveying. Within academia, geographers applied their research activities to studies that would have a direct bearing on military-related problems. R. A. Bagnold's *Physics of Blown Sand and Desert Dunes* (1941), for example,



was very important for military planning related to the North African campaign—namely, how mechanized vehicles would operate in Aeolian environments.

World War II, and the contributions of military geographers, also provided a catalyst to more far-reaching changes in the structure of academic geography. For example, the efforts of F. Webster McBryde (who was employed in the War Department) led to the formation of the American Society for Professional Geographers (an association that later merged with the long-standing and more research-oriented Association of American Geographers). Equally important were the writings of individuals such as Edward Ackerman and Fred Schaefer, who argued that regional geographers, as a whole, were not well trained as social scientists and that geography, as an applied discipline, required a greater emphasis on, and training in, systematic specialties. Consequently, the military experiences of World War II, and of the geographers who participated in many facets of that conflict, facilitated the growth of a more systematic—and nomothetic—approach to geography and a move away from regional geography. Subsequent and continued advances in quantitative methods and air photo interpretation remained techniques of the subfield.

Just as World War II heralded a blossoming of military geography, the tumultuous events of the 1960s—especially America's involvement in the Vietnam War—led to a decline in military geography as a subfield. Traditional work did continue, but geography as a whole moved away. As Eugene Palka (2003) writes, "Contributing to the war effort in Vietnam came to be regarded as irresponsible by many members of the AAG," and consequently, the "controversy surrounding the Vietnam War cast a persistent shadow on military geography throughout the 1970s" (p. 506).

The end of the Cold War, and the hegemonic rise of the United States as the sole global superpower, contributed to a renewed—and reworked—military geography. "Classical" studies of military geography continued, as exemplified by the writings of Palka, Arnon Soffer, Julian Minghi, and Harold Winters. However, the late 20th and early 21st centuries also have witnessed an enlargement of the

scope of military geography, to include, more explicitly, studies of peace and peacetime operations, nuclear disarmament, and the diffusion of arms and arms manufacture. Especially noteworthy are two edited volumes: David Pepper and Alan Jenkins's *The Geography of Peace and War* (1985) and Colin Flint's *The Geography of War and Peace: From Death Camps to Diplomats* (2005).

The changing terrain of military geography was given impetus by a series of seminal publications in the early 21st century. Among these was Rachel Woodward's 2005 article, "From Military Geography to Militarism's Geographies: Disciplinary Engagements with the Geographies of Militarism and Military Activities" in *Progress in Human Geography*. Woodward makes a distinction between military geography and "militarism's geographies," where the latter refers to

the shaping of civilian space and social relations by military objectives, rationales and structures, either as part of the deliberate extension of military influence into civilian spheres of life and the prioritizing of military institutions, or as a byproduct of those processes. (p. 721)

A revitalized military geography has led many scholars to cast a critical eye inward. The works of Trevor Barnes, Matthew Farish, and Trevor Paglen, for example, critically examined the nexus of geography and the military-industrial complex and highlighted the symbiosis that exists between war, imperialism, and geography. Geographers have also transformed traditional areas of inquiry within the subfield. Military geographers, for example, have long worked at the intersections of human and physical geography. Traditionally, this work emphasized the impact of physical processes, such as terrain and climate, on the conduct of military campaigns and battles. More recent work, though, has examined the political economy of environmental resources (e.g., oil and diamonds) and how these resources contribute to military conflicts.

James Tyner

See also Geopolitics; Mackinder, Sir Halford; Mahan, Alfred Thayer; Military Spending; Political Geography; Terrorism, Geography of; War, Geography of



Further Readings

- Ackerman, E. (1945). Geographic training, wartime research, and immediate professional objectives. *Annals of the Association of American Geographers*, 35, 121–143.
- Flint, C. (Ed.). (2005). *The geography of war and peace: From death camps to diplomats*. Oxford, UK: Oxford University Press.
- Le Billon, P. (2000). The political economy of transition in Cambodia 1989–1999: War, peace and forest exploitation. *Development and Change*, 31(4), 785–805.
- Le Billon, P. (2001). The political ecology of war: Natural resources and armed conflict. *Political Geography*, 20, 561–584.
- Palka, E. (2003). Military geography. In G. Gaile & Cort J. Willmott (Eds.), *Geography in America at the dawn of the 21st century*. Oxford, UK: Oxford University Press.
- Palka, E., & Galgano, F. (Eds.). (2005). *Military geography: From peace to war*. Dubuque, IA: McGraw-Hill.
- Pepper, D., & Jenkins, A. (Eds.). (1985). *The geography of peace and war*. Oxford, UK: Blackwell.
- Soffer, A., & Minghi, J. (1986). Israel's security landscapes: The impact of military considerations on land uses. *The Professional Geographer*, 38, 28–41.
- Winters, H. (1998). *Battling the elements: Weather and terrain in the conduct of war*. Baltimore: Johns Hopkins University Press.
- Woodward, R. (2004). *Military geographies*. New York: Wiley.
- Woodward, R. (2005). From military geography to militarism's geographies: Disciplinary engagements with the geographies of militarism and military activities. *Progress in Human Geography*, 29, 718–740.

Institute's annual *SIPRI Yearbook 2007*, the aggregate military expenditure by all national governments in 2006 was \$1.024 billion in market exchange rate (MER) terms. Adjusted for inflation, this figure marked a 37% growth in military budgets since 1997. This level of increased military spending follows a long trend that dates to World War II and that greatly accelerated during the Cold War. The levels of military spending over the past 60 years have been—and continue to be—a dynamic force that has deeply altered the fabric of social, political, spatial, and economic relationships, from the scale of the local to that of the global.

There are four fundamental aspects of military expenditures. First, high levels of military expenditure are a prerequisite for the geopolitical power of a nation-state, a point exemplified by a global U.S. hegemony, which is founded upon enormous levels of military spending. Second, preparation for war has increasingly integrated private firms, modern production practices, and technological innovation with government spending. This mixture has created a military-industrial complex dedicated to the production of arms. Third, military spending has spatially reorganized local, national, and global economies in a manner quite different from that of the civilian economy. Fourth, high levels of military spending accelerate the international proliferation of advanced weaponry. Finally, there are significant methodological problems inherent in all military expenditures data that must be addressed in geographical research, especially given the polemical debate that often infuses popular discourses on national spending.

Military Spending and the Production of Geopolitical Power

Ranking national military expenditures in MER terms, when combined with similar data from previous years, reveals the close link between military spending and the production of global geopolitical power. The major military spender in 2008 was the United States, with \$6.071 billion. This accounts for 41% of world military spending in the same year. China, with \$84.9 billion, came in second. France and the United Kingdom each spent roughly \$65 billion, putting them in



MILITARY SPENDING

Military expenditures, broadly defined, are the aggregate funds spent by a national government for military-related purposes. According to the Stockholm International Peace Research



Region	Spending, 2008 (\$ b.)	Increase, 1999–2008 (%)
Africa	20.4	+40
North Africa	7.8	+94
Sub-Saharan	12.6	+19
Americas	603	+64
Caribbean	..	..
Central America	4.5	+21
North America	564	+66
South America	34.1	+50
Asia and Oceania	206	+52
Central Asia	..	..
East Asia	157	+56
Oceania	16.6	+36
South Asia	30.9	+41
Europe	320	+14
Eastern	43.6	+174
West and Central	277	+5
Middle East	75.6	+56
World total	1226	+45

Table 1 National military spending

Source: Petter Stålenheim, P., Kelly, N., Perdomo, C., Perlo-Freeman, S., & Sköns, E. (2009). Appendix 5A. Military expenditure data, 1999–2008. In *SIPRI yearbook 2009: Armaments, disarmaments, and international security*. Retrieved February 4, 2010, from www.sipri.org/yearbook/2009/05/05A. Copyright © Stockholm International Peace Research Institute.

Note: To allow comparison over time, the above spending figures are in U.S. dollars at constant (2005) prices.

third and fourth place, respectively. Russia ranked fifth, with \$58.6 billion. Russia's status marks a stark contrast to the position of the former USSR, which typically vied with the United States for the title of the world's biggest military spender during the Cold War.

Although Tables 1 and 2 give estimates of military spending in constant U.S. dollars, estimates of relative expenditure levels can also be given in terms of purchasing parity power (PPP), which reflects national differences in the costs of weapons systems. Expressing military expenditures in PPP terms is necessary because there are vast differences among states in the quantities of capital and labor that a given amount of funds can purchase. For example, \$100 billion

Rank	Country	Spending (\$ b.)	World Share (%)
1	USA	607	41.5
2	China	[84.9]	[5.8]
3	France	65.7	4.5
4	UK	65.3	4.5
5	Russia	[58.6]	[4.0]
6	Germany	46.8	3.2
7	Japan	46.3	3.2
8	Italy	40.6	2.8
9	Saudi Arabia	38.2	2.6
10	India	30	2.1
	World total	1464	

Table 2 The top 10 military spenders, 2008

Source: Petter Stålenheim, P., Kelly, N., Perdomo, C., Perlo-Freeman, S., & Sköns, E. (2009). Appendix 5A. Military expenditure data, 1999–2008. In *SIPRI yearbook 2009: Armaments, disarmaments, and international security*. Retrieved February 4, 2010, from www.sipri.org/yearbook/2009/05/05A. Copyright © Stockholm International Peace Research Institute.

Note: [] = SIPRI estimate. The spending figures are in current U.S. dollars.

spent in China will purchase significantly more armaments or military services than the equivalent amount spent in the United States. Equalizing national differences in costs tends to reduce the relative size of military expenditures in Western Europe and Japan and raise the rankings of poorer countries such as China, India, Russia, and Saudi Arabia. Notwithstanding this caveat, it should be immediately apparent that the current U.S. hegemony in world affairs is due, in large part, to its unparalleled dedication funding its military.

These enormous expenditures, particularly those of the United States, are the root of all modern geopolitical power. They have also created a historically novel military-industrial complex dedicated to the manufacture of the weapons of war, which has extended the social effects of military spending well beyond the battlefield and into the fabric of civil society.

The Military-Industrial Complex

Aggregate military expenditure figures break down into numerous subcategories, including



labor and health care costs for personnel; operations and management costs for logistical management; procurement costs for new weapons, hardware, ammunition, and other supplies; research, design, testing, and engineering (RDT&E) costs of designing new weapon systems; and construction and maintenance costs for bases, supply depots, and housing for personnel. Labor, operations and management, health care, and construction costs are a significant portion of most military spending, particularly within the United States, where military service members receive free housing and health care. This entry concentrates on the effects of procurement and RDT&E expenditures, since it is these two categories that have had the most profound impacts. This phenomenon lies in the heart of what President Dwight Eisenhower called the “military-industrial complex,” and it is radically dissimilar to any other segment of the global economy in form and function.

World War II introduced substantial changes in the material preconditions for battlefield superiority. Militant nationalism and the implementation of Fordist production practices produced a new model of warfare in which military victory was suddenly predicated on industrial capacity. Large-scale industrial production of armaments became a prerequisite to national survival, and mechanized weapons of war began rolling off assembly lines in large volumes. Producing these weapons in prodigious numbers necessitated co-opting civilian resources, production lines, and technological knowledge at a scale achievable only by a national government directly managing the civilian economy. This style of industrial management birthed a novel relationship between the private and the public sectors of the economy: the military-industrial sector, comprised of nominally civilian businesses dedicated to production of complex, mechanized armaments, funded through military procurement budgets.

The detonation of the atomic bombs over Hiroshima and Nagasaki in 1945, and the ensuing Cold War tensions between the United States and USSR, marked another watershed moment in the practices that underlie modern preparations for warfare. Globally, military budgets declined only briefly after World War II, and rose with the Korean War. The massive influx of capital into

scientific research ushered in a new era of innovation led by military innovation that emphasized not the capacity to manufacture arms per se, but rather the extension of weapons capabilities on the battlefield through technological innovation. Moreover, the new commitment to innovation enshrined in rapidly increasing military RDT&E expenditures focused on the creation of “smart weapons” through the use of electronics and computers. The result was a blizzard of technological advancements in weapons capabilities, many of which found their way into the civilian sector, including, for example, microcomputers, an outgrowth of mechanical calculators designed to compute artillery ballistic tables; the Internet, initially a project of the U.S. Defense Advanced Research Projects Agency; satellite surveillance and communications technologies, including global positioning systems and remote sensing technologies; and the vast majority of early aviation advancement, including the jet engine, to name a few. The age of the ICBM and cruise missile had begun.

Tracing the historical trajectory of the global military-industrial economy makes clear the link between procurement and RDT&E spending and the creation of a distinct sector of the economy. Measured in terms of the total value of all domestic and international arms sales, in 2006 U.S. companies represented 40 of the largest 100 armament manufacturers, another 32 firms were based in Western Europe, and yet another 6 were Japanese. These combined to form 78 of the 100 largest arms companies in the world, all found within countries typically viewed as bastions of democratic freedom; an additional nine firms were Russian and three were from India.

The historical and empirical links between military spending and arms manufacturing foreground the single most salient feature of military expenditures: an institutionalized relationship between government and industry that, while mediated by money, is fundamentally political in nature. Much of the economic literature is steeped in neoclassical economic discourse, which has a tendency to misapply market-based economic theory to a structurally unique segment of the economy. This error obfuscates the fundamental differences between the military-industrial sector and the civilian economy, particularly a “market”



characterized by a monopsony (the Defense Department) and oligopolistic arms producers.

This critique is further extended by recognizing the argument that the pricing mechanism commonly utilized by national governments in procurement and RDT&E is significantly different from the operations of the market economy, particularly those inherent to economies of scale. Needless to say, governments are reluctant to purchase multimillion-dollar weapon systems when a significant percentage might be defective; not only is it a wasted expenditure, it also has the potential to be disastrous if a weapon fails at a critical point in battle. Thus, the practice of “cost-plus” contracting arose as a common method to minimize defect rates. Under the cost-plus system, national governments agree to pay all of the costs of design and production, including overruns, in addition to a profit which is determined as a percentage of those costs. The emphasis is not placed on obtaining a weapon at the lowest price, but on buying weapons that work irrespective of cost. The ultimate effect, however, is to expressly subvert the normal operations of supply and demand common in civilian markets.

Typically, military expenditures are expressed as a proportion of gross domestic product (GDP). This approach, however, underestimates military spending. Unlike the bulk of government spending, these expenditures are not transfer payments, nor are they investments in infrastructure that is indirectly productive (e.g., roads and bridges). Yet such expenditures do not belong in any of the “private” categories either, differing in two major ways: the civilian macroeconomy is comprised of many actors making numerous and diverse small investments, whereas military expenditures represent a vast flow of capital directed at significant fewer projects. Moreover, RDT&E spending is immune to the normal constraints common to normal economic markets, which ensures that contractors can maintain unpromising avenues of research well past the point at which they would have been terminated in the civilian market.

The cost of each new generation of weapons is dramatically accelerating over time. Accelerating costs, driven by the increasing emphasis on high-technology aerospace innovations and cost-plus contracting, are a key factor driving the continued expansion of military spending. Expanding

the capability of each successive generation of weaponry is becoming increasingly difficult, and, hence, increasingly expensive.

Concurrent with, and partially as a response to, the escalating unit cost of weapon systems is an increasingly oligopolistic industry structure, coupled with a process of subcontracting the production of dual-use technologies, that is, products with military applications that are manufactured for the civilian market. The roll call of defense mergers from 1990 to 2001 is telling: The total number of U.S. firms capable of producing advanced fighter/bomber aircraft declined from nine to two; the total number of missile manufacturers fell from 14 to 4, with only one company capable of producing air-to-air missiles; firms with the capability of producing space-launch vehicles fell from six to two; and the manufacturers of major avionic subsystems were, in many cases, bought by the dominant aerospace contractors. Consequentially, U.S. defense contracting increasingly resembles a monopoly-monopsony relationship—the very antithesis of the competitive market. This process of consolidation is paradoxically coupled with an expansion in subcontracting, since advanced weapons require an increasing number of intermediate inputs (which themselves require high-tech inputs in turn). The new defense megafirms outsource production in an effort to reduce costs and maximize profit. Unfortunately, good data on subcontracting practices do not exist, but the available data suggest that defense firms, due to the specialized nature of their products, tend to subcontract with each other rather than with other industries. The arms industry in Western Europe, too, has undergone consolidation and intensive subcontracting, with, for example, pan-European defense contractors Alenia Aeronautica, BAE Systems, and EADS forming a consortium to manufacture Europe’s next-generation fighter aircraft, the Eurofighter Typhoon.

Despite the massive structural changes in the industry and increasing unit costs, profits in the defense industry remain high and continue to grow. These expenditures ultimately determine the size and shape of the defense industry, since there is no civilian demand for missiles or tanks. Moreover, it is unclear whether current levels of investment in RDT&E and armament production



can continue unabated, and the implications of this trend for the current military powers are indeterminate at best; the U.S. government, in particular, has begun to struggle under a mountain of debt incurred in funding its advanced weapons programs.

Geographic Patterns of Military Expenditures

Because of their role in the military-industrial sector, military expenditures have produced numerous ancillary effects at a wide variety of spatial scales. At the subnational scale, such spending produces substantial variation in local and regional economic structure and growth. At the global scale, military expenditures have produced a burgeoning international arms trade. Each of these components has its own, distinctive geography.

Impacts in the United States

In *The Rise of the Gunbelt: The Military Remapping of Industrial America*, Ann Markusen documents the creation of a distinctive subregion within the United States, the titular “Gunbelt” of America. In Markusen’s view, the Gunbelt—centered on the “holster” of Texas and stretching down the west coast, through the South, and up the eastern seaboard—accounts for most of the regional economic variations within the United States. In particular, military RDT&E and procurement expenditures, which heavily favor the Gunbelt states, have actively contributed to the decline of traditional manufacturing regions of the north and actively created a new locus of U.S. industrial capacity, particularly in the West. This process has both shifted industrial capacity and motivated U.S. citizens to relocate internally as they follow the numerous employment opportunities created by the defense industry. High levels of defense expenditures also inject money into localities, which can have a positive effect on local economic prosperity. Contrariwise, the decision to cancel the flow of military funds into a region can be disastrous for cities and towns dependent upon them; the loss of contracts for aerospace contracts would, for example, have serious implications for the prosperity of Seattle, many of

whose inhabitants are dependent upon the prosperity of aerospace giant Boeing. Because it is largely divorced from the wider operations of the civilian economy, military spending has the potential to create local prosperity in the midst of a wider economic recession, or local decline during a period of national prosperity—geographic variations that would otherwise be inexplicable.

Markusen notes that there are two general patterns to defense spending in the United States. During the Cold War, military spending tends to focus on the Gunbelt itself, with funds going to high-tech aerospace manufacturers and RDT&E research facilities primarily located on the west coast and in Texas. During times of “hot” war, many more contracts go to traditional manufacturing regions states, where stocks of ammunition and other low-tech ordinance are replenished via low-tech mass production.

Transnational Impacts

Military expenditures also produce transnational variations, in the form of a distinctive pattern in arms trade. National governments, seeking to prevent local job losses and keep their military-industrial base “warm” during times of peace, increasingly use exports as a means to encourage private arms production. Direct transfers among countries are the sale or gift of a complete weapon or weapon system, whereas licensed production involves the underlying sale or transfer of production techniques and associated technologies necessary to actually make a particular weapons system. The United States leads the world in both categories of arms transfers and is the largest distributor of all major weapons systems, and the recipient nations that it favors tend to receive the bulk of the global flow in arms. Small arms, which require much less in the way of technology to manufacture, are a scourge all by themselves; they are, however, easy to make, cheap to buy, and almost impossible to track. Stemming the tide of conventional weaponry flowing from the industrialized world is an almost intractable problem, however, since reductions in national military budgets counterintuitively produce an increasing volume of international transfers, as national militaries sell off stocks of older weapons to make up for budgetary shortfalls.

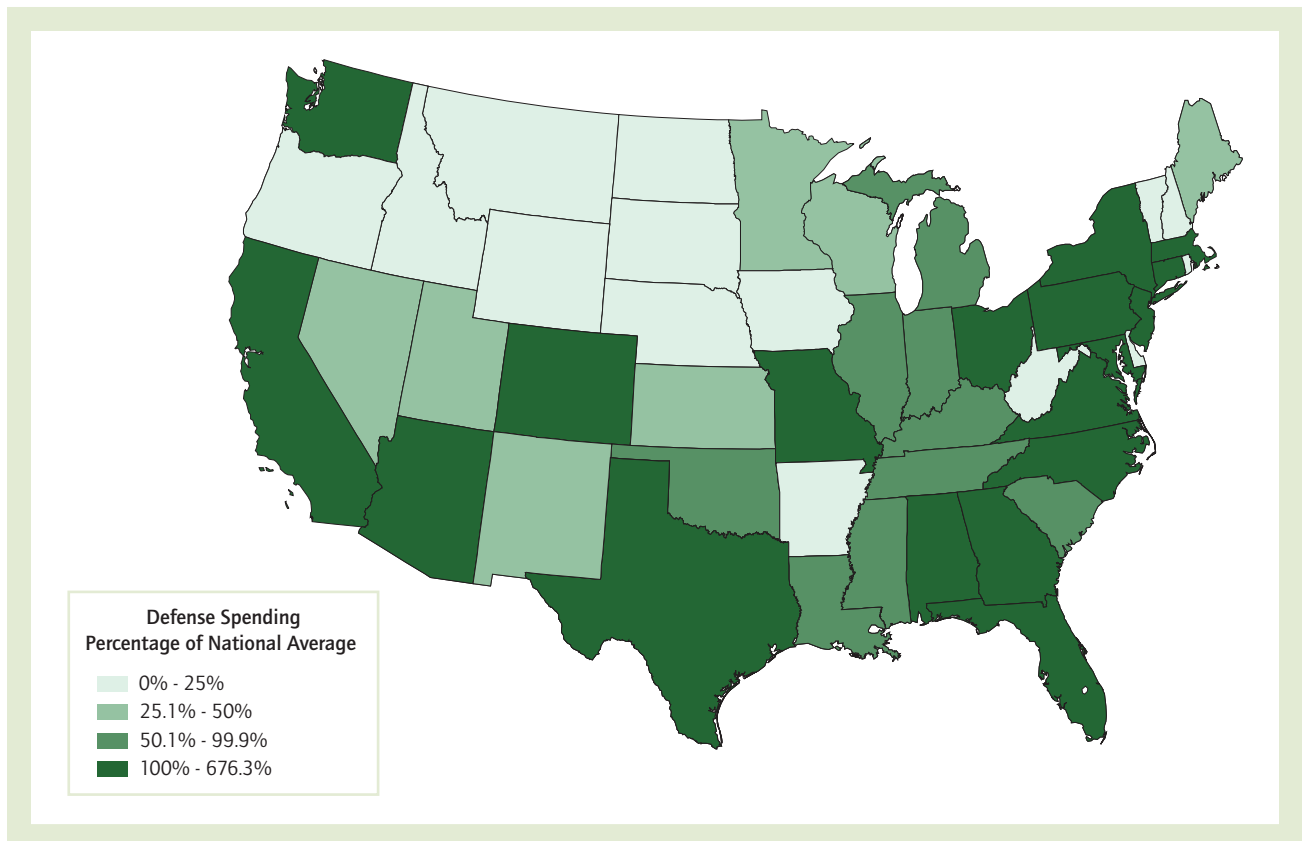


Figure 1 The Gunbelt in 2008. The majority of U.S. military expenditures are concentrated in the South and West.

Source: Adapted from data in U.S. Department of Defense. (2008). *Projected defense purchases: Detail by industry and state, calendar years 2008 through 2013* [Online]. Retrieved March 8, 2009, from www.ra.pae.osd.mil/ra/DEPPS2008.pdf.

The Veracity of Expenditure Data

Great care is necessary to responsibly utilize military expenditure data, particularly given the culture of secrecy and polemical popular discourse surrounding the subject. Even when a dedicated third party devotes significant efforts to itemizing military spending, definitions of what constitute a military expenditure vary widely by source.

There are numerous ways to decrease military spending on paper, especially when relying on totals self-reported by a national government; differing methods of aggregation will produce substantially different aggregate totals. Within the U.S. federal budget, for example, there are numerous items that are reported as civilian expenditures, but are actually earmarked for dedicated military projects. For example, funding for nuclear weapons research is technically

allotted to the Department of Energy, not the Department of Defense, and the donation of military hardware or supply of military loans to foreign governments is often handled by the Department of State. The federal budget for military spending also excludes civil defense costs, paramilitary organizations such as the National Guard, demobilization and disarmament costs, current expenditures for past military activities, and veterans' benefits and health care are separately funded by the Veterans Administration and classified as civilian expenditures. The exclusion of these items produces a substantial undervaluation for the largest military budget in the world, and ignores one of the fastest growing budgets within the U.S. government (the Department of Homeland Security), as well as all expenditures dedicated to servicing debt accrued during military buildups or wars.

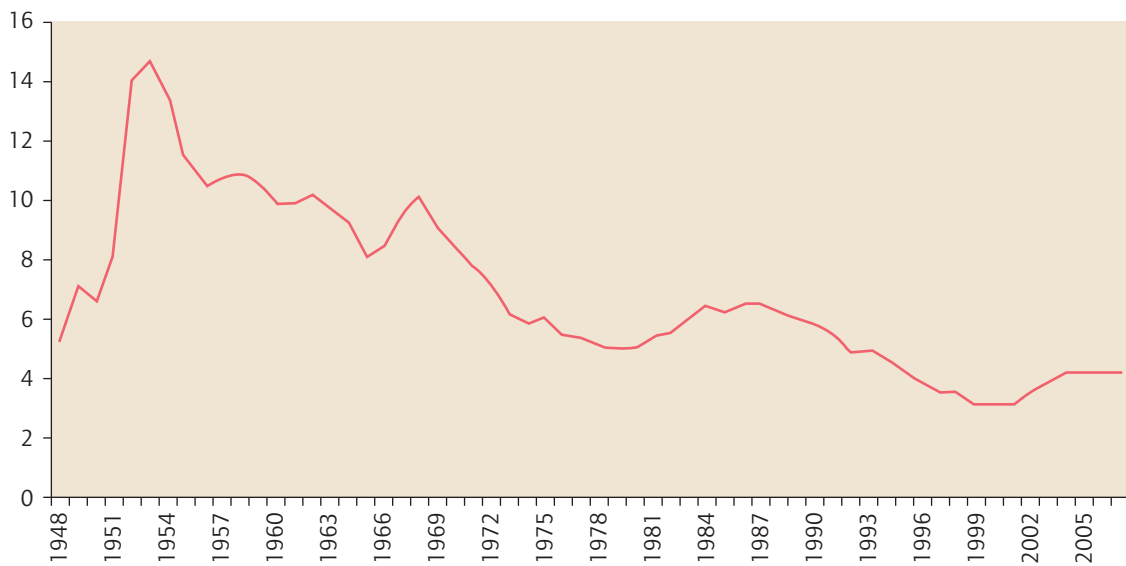


Figure 2 U.S. defense budget as percent of GDP. Although it has declined to roughly 5% of GDP, the official Defense Department budget excludes numerous items such as veterans' benefits, military foreign aid, spy satellites, and research on nuclear weapons.

Source: Author.

This problem expands enormously in complexity as it expands in scale, with each country possessing a different language(s), governmental idiosyncrasies and budgetary conventions. As a rule of thumb, however, aggregate data tend to reflect a substantial undervaluation of military budgets in Western Europe, the United States, and Japan, and overvaluation in the rest of the world.

Conclusion

Despite the continued expansion of global military expenditures, normative political discourse among the nations of the West, most especially within the United States, tends to minimize the financial cost of developing, outfitting and supporting modern militaries.

S. Willis Bassett

See also **Economic Geography; Military Geography; Neoliberalism; War, Geography of**

Further Readings

- Brzoska, M. (2004). The economics of arms imports after the end of the cold war. *Defence and Peace Economics*, 15(2), 111–123.
- Cypher, J. (2007, June). From military Keynesianism to global-neoliberal militarism. *Monthly Review*, pp. 37–55.
- Dowdy, J. (1997). Winners and losers in the arms industry downturn. *Foreign Policy*, 107, 88–101.
- Markusen, A. (1991). *The rise of the gunbelt: The military remapping of industrial America*. New York: Oxford University Press.
- Sandler, T., & Hartley, K. (2007). *Handbook of defense economics. Volume 2, Defense in a globalized world* (Handbooks in Economics, 12). Amsterdam: Elsevier.
- Stockholm International Peace Research Institute (SIPRI). (2007). *SIPRI yearbook 2007: Armaments, disarmaments, and international security*. New York: Oxford University Press.



Warf, B., & Grimes, J. (1997). The distribution of military expenditures in the United States: Spatial, technological, occupational, and sectoral. In J. Brauer & W. Gissy (Eds.), *Economics of conflict and peace* (pp. 83–103). London: Avebury Press.



MILLER, HARVEY J. (1962–)

Harvey J. Miller is well known and respected for his research involving time-geography, transportation, and spatial analysis and modeling. His research in time-geography has built on the work of Torsten Hagerstrand by analyzing space-time accessibility. Miller's research involves exploring both theoretical concepts and methodological approaches to better understand how individuals make decisions in a given environment and the patterns that emerge as a result. He emphasizes the need and the potential for people-based spatial analysis to better represent the dynamics of individual activity patterns in both space and time. One application has been substantive contributions to transportation geography. He has built methods for using space-time accessibility measures to evaluate the flow of traffic to mitigate congestion. His research accomplishments have been recognized with several awards, including the Geoffrey J. D. Hewings Award from the North American Regional Science Council in 1997 and a Superior Research Award from the University of Utah in 2004.

Miller is currently a professor of geography and chair of the Department of Geography at the University of Utah. His education began at Kent State University, where he earned a Bachelor of Arts degree in 1985, followed by a Master's of Arts degree in geography in 1987. In 1991, he earned his PhD in geography from Ohio State University. On completing his doctorate, he became an assistant professor at the University of Utah, where he has continued on as department chair. He has influenced and shaped much of the department's reputation in quantitative analysis and modeling in urban economic geography, population migration, biogeography, and natural hazards.

Miller has served on numerous national and international organizations, reflective of his areas of interest and expertise. Nationally, he serves on the Committee on Geographic Information Science and Applications, Transportation Research Board (2003–2005, board member; 2005–2011, cochair); he has been on the board of the University Consortium for Geographic Information Science (2000–2003) and on a policy committee of the National Research Council to identify data needs for place-based decision making. Internationally, he serves on several editorial boards, including being the North American Editor for the *International Journal of Geographical Information Science* (2000–2004).

Elizabeth A. Wentz

See also **Regional Science; Spatial Interaction Models; Time-Geography; Transportation Geography**

Further Readings

- Miller, H. (1991). Modeling accessibility using space-time prism concepts within geographical information systems. *International Journal of Geographical Information Systems*, 5, 287–301.
- Miller, H. (1999). Potential contributions of spatial analysis to geographic information systems for transportation (GIS-T). *Geographical Analysis*, 31, 373–399.
- Miller, H. (2005). What about people in geographic information science? In P. Fisher & D. Unwin (Eds.), *Re-presenting geographical information systems* (pp. 215–242). New York: Wiley.
- Miller, H., & Wentz, E. (2003). Representation and spatial analysis in geographic information systems. *Annals of the Association of American Geographers*, 93(3), 574–594.



MINERALS

The International Mineralogical Association (IMA) defines a mineral species as an element or chemical compound that is normally crystalline



and that has formed as a result of geological processes. There are currently about 4,100 such species known. But minerals are more than just chemical elements and compounds. They are the building blocks of the rocks that form mountain chains and the sands of deserts and beaches. Minerals, and the rocks they constitute, record the history of the Earth and are the source of the metals and raw materials on which our everyday lives so greatly depend. Minerals are the enablers of civilization. They have been used by humans from the Stone Age through today. Minerals are useful for one of two reasons: They either have a useful property (e.g., talc is soft, inert, and white, rendering it useful as a cosmetic) or contain an important element (e.g., chalcopyrite [CuFeS₂] is an important ore of copper). The first group comprises the *industrial minerals*, whereas the second is often referred to as the *ore minerals*.

Characteristics and Classification

The characteristic criteria of minerals are implicit in their geological definition: Minerals are naturally occurring, are solid, have a definite chemical composition and an orderly crystal structure, and are typically inorganic. Quartz (hexagonal SiO₂), halite (or rock salt, cubic NaCl; see first photo),



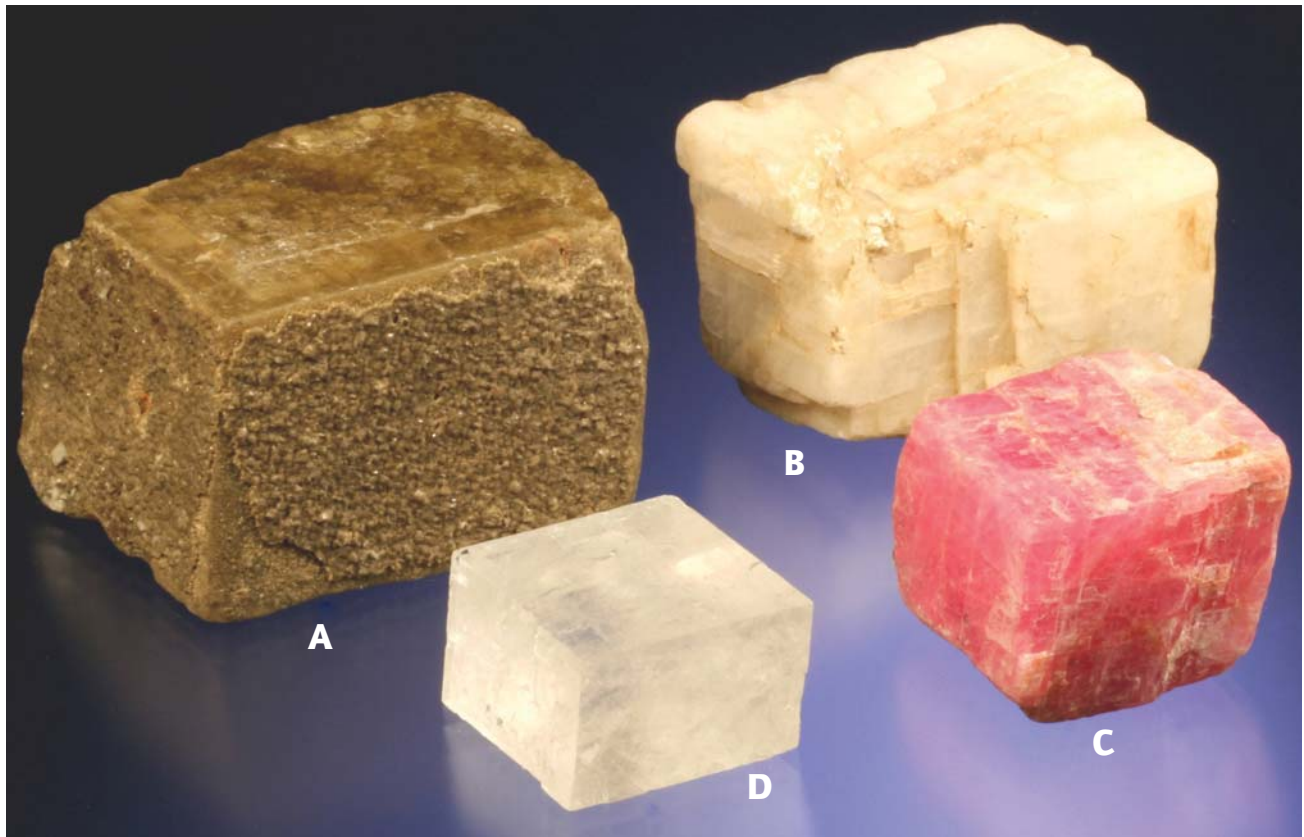
The outward appearance of these halite crystals is a consequence of their internal cubic structure.

Source: Photograph taken by author of specimen at the A. E. Seaman Mineral Museum.

and gold (cubic Au) are familiar examples. There are, however, a few exceptions to the rule. For example, native mercury is considered a mineral even though it is normally liquid at ordinary temperatures, and opal is a mineral, although it is frequently amorphous and contains a variable amount of water. But for the vast majority of minerals, the IMA definition works well. Thus, diamond is a mineral, but coal is not; ice is a mineral, but water is not.

Together, the chemical composition and crystal structure of a mineral define it as a particular species and determine all of its chemical and physical properties. Mineralogists classify minerals according to their chemistry (e.g., sulfides, oxides, carbonates). Within each chemical division are individual groups of minerals based on similarity of their atomic structures. The classification hierarchy is simple, consisting of only three levels: (1) group, (2) species, and (3) variety. A common example is the calcite group, which includes various species such as calcite, siderite, magnesite, and rhodochrosite, among others (see second photo). These minerals all have similar structures and a general formula M²⁺CO₃, where M²⁺ is a divalent metal cation, such as Ca²⁺, Fe²⁺, Mg²⁺, or Mn²⁺. When Ca²⁺ is the dominant cation, the species is calcite; if Fe²⁺ predominates, the species is siderite; and Mg²⁺ and Mn²⁺ result in magnesite and rhodochrosite, respectively. Sometimes a particular color variant or other distinguishing feature earns a species a varietal name. Thus, colorless calcite is known as “Iceland spar,” whereas red corundum is ruby, and purple quartz is amethyst.

Minerals derive their names from several sources, and those proposed for new species being described today must be approved by the IMA before they are generally accepted by the scientific community. There are few hard-and-fast rules dictating how a mineral should be named. Some are named after people (e.g., millerite [see third photo] for W. H. Miller, a famous British mineralogist), while others are named for geographic places (e.g., calumetite for Calumet, Michigan, where it was first found). Minerals such as cavansite (a calcium vanadium silicate) or nahpoite (NaHPO₄) derive their names from their chemical compositions, while others, such as hematite, are named for their physical



Cleavage rhombs of calcite group species (A) siderite, (B) magnesite, (C) rhodochrosite, and (D) calcite

Source: Photograph taken by author of specimen at the A. E. Seaman Mineral Museum.

appearance. Hematite commonly occurs in earthy red masses (in Greek, *haimatitis* means blood red). Magnetite is highly magnetic, and azurite is azure blue. One species, minrecordite, is even named after a popular journal, the *Mineralogical Record*.

Because of their different atomic structures, variable compositions, and different environments of formation, crystals of various minerals can assume myriad shapes and colors. The outward overall appearance of a crystal is known as its “habit” and is governed by both intrinsic and extrinsic factors. Intrinsically, a mineral’s atomic structure plays a significant role in governing its outward appearance. It determines what symmetry is possible and what is not. We don’t see six-sided halite crystals because the underlying atomic structure of that mineral is based on the fourfold symmetry of a cube. Depending on their size and

charge, various elements may be incorporated into its structure as the crystal grows. Some may act as chromophores, absorbing specific wavelengths of light, thereby imparting different colors to the original mineral. While the atomic structure dictates which elements it might accept, it is the composition of the fluids available to the growing crystal that determines whether or not those elements are present. Sometimes, certain dissolved impurities may prevent the growth of one particular crystal face from developing in favor of another, leading to distorted crystals. Additional extrinsic factors such as the presence or absence of fluxing elements, temperature, pH, and time have an influence on the final outcome of what the mineral looks like. The diversity in physical appearance within even a single common species such as quartz or calcite is staggering (see fourth photo).



Millerite in calcite geode from Milwaukee, Wisconsin

Source: Photograph taken by author of specimen at the A. E. Seaman Mineral Museum.

Mineral-Forming Environments

For convenience, the means by which minerals form may be grouped into four basic geological processes: (1) precipitation from aqueous solutions, (2) crystallization from magma, (3) chemical alteration, and (4) recrystallization in the solid state by heat and pressure (metamorphism). These processes may act independently or in combination to form various minerals. Species with limited fields of stability tend to occur in few geological environments, whereas those stable over wide ranges of physical and chemical conditions are found in a greater number of geological environments. Thus, heavily hydrated minerals such as mirabilite ($\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) are found in salt lakes and playas, but they quickly dehydrate into less hydrated species on exposure to air. Quartz, on the other hand, is stable over a broad range of conditions and is a common constituent of igneous,



These colorless crystals (A) and banded agate (B) are both the same species: quartz.

Source: Photograph taken by author of specimen at the A. E. Seaman Mineral Museum.

sedimentary, and metamorphic rocks alike, as well as being the main component of many sands.

One of the simplest ways certain minerals form is by direct precipitation from aqueous solutions.



If a glass of saltwater is left out on the counter-top, the water slowly evaporates, concentrating the dissolved salt to a point where the solution becomes supersaturated, and salt crystals begin to form on the bottom of the glass. This is not unlike the process that forms salt flats in playa lakes or, on a grander scale, beds of rock salt such as that hosted by the great Salina formation, stretching from New York to Michigan and formed by the evaporation of an ancient sea. Halite, gypsum, potash, and other minerals formed in a similar manner are called evaporites and constitute an economically important group of industrial minerals.

In the case of evaporites, the water is of meteoric origin and relatively cool. In the case of hydrothermal deposits, the water is hot and may be meteoric, magmatic, or tectonic in origin. Yellowstone National Park provides a classic example of a meteoric hydrothermal system. There, groundwater is warmed by proximity to a magma chamber that enables it to dissolve silica, calcite, and other minerals that precipitate on cooling to form cones around erupting geysers or extensive travertine flows at Mammoth Hot Springs. Similarly, brines flowing through deeply buried sediments are warmed as a consequence of burial and may dissolve and concentrate various metals as chloride complexes. If these brines later encounter a source of reduced sulfur, lead and zinc sulfides may precipitate to form galena and sphalerite, creating an economically important Mississippi Valley Type deposit, such as in the famous Tri-State Mining District of Kansas, Oklahoma, and Missouri.

As magmas cool, individual minerals begin to crystallize out. Those with the highest melting temperatures are the first to crystallize (e.g., olivine, pyroxene, anorthite). As the process continues, various elements are selectively removed from the melt, and ions of unusual size or charge that don't fit into the structures of the precipitating minerals may accumulate and form a hydrothermal solution rich in metals such as gold, silver, bismuth, tin, tungsten, uranium, and others, resulting in hydrothermal vein deposits such as the famous tin mines of Cornwall, England, or the tin/tungsten deposits of Malaysia. In magmas of granitic composition, the late-stage fluids sometimes crystallize to form rocks known as

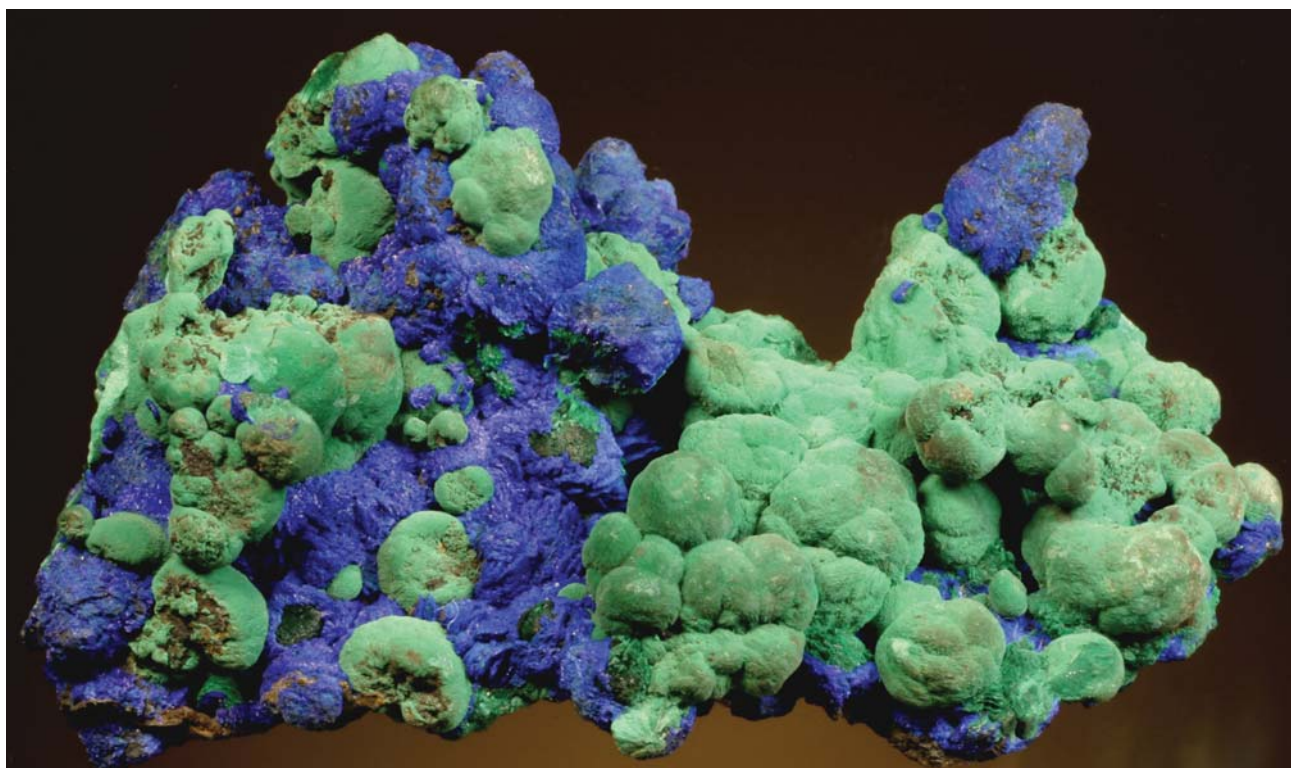


Green tourmaline on quartz from Minas Gerais, Brazil

Source: Photograph taken by author of specimen at the A. E. Seaman Mineral Museum.

granitic pegmatites, famous for gem minerals such as topaz, aquamarine, and tourmaline (see fifth photo), as well as strategic metals such as lithium, beryllium, and tantalum and rare earth elements so important to today's technology. Important pegmatite fields are located in Minas Gerais, Brazil, the Black Hills of South Dakota, Bernic Lake, Manitoba, and the northern areas of Pakistan and adjoining Afghanistan.

Minerals react differently to the different chemical environments provided by nature. In generally arid climates (e.g., southern Arizona and New Mexico), limestone appears resistant to erosion, forming protective caps on buttes and mesas, but in a more humid region (e.g., Guilin, China), a dramatic, karst topography has developed. This is a direct result of the instability of calcite (limestone's principal constituent) in an acidic (low pH) environment. In passing through air, rainwater dissolves carbon dioxide, forming carbonic acid, which promotes dissolution of the calcite. Many other minerals are also affected by changes in pH and/or oxidation potential. A classic example is the development of oxide zones on metal-bearing sulfide deposits. Above the water table, conditions are generally more oxidizing, and more



Azurite (blue) and malachite (green), two common secondary copper minerals from Bisbee, Arizona

Source: Photograph taken by author of specimen at the A. E. Seaman Mineral Museum.

reducing below it. Metals leached from sulfide minerals above the water table may recombine with available anions to form “secondary,” or supergene, minerals (e.g., sulfates, carbonates, phosphates, arsenates, etc.), depending on what anions are available (see sixth photo). Below the water table, the metals may recombine with reduced sulfur to form a zone of secondary enrichment, or high-grade ore. The rusty “iron hat” or gossan that often caps such deposits was an important indicator to early prospectors in the American Southwest that an ore body may lie beneath.

Minerals are also affected by changes in temperature and pressure and may recrystallize in the solid state to form new minerals that are more stable in the prevailing conditions. The same tectonic forces supplying the pressure driving the resulting metamorphism often form folded mountain chains such as the Appalachians, with rocks hosting garnet, kyanite, sillimanite, and other metamorphic minerals.

Minerals affect our everyday lives in more ways than we can imagine. Without them, we

would have no houses, cars, airplanes, or computers. Their supply and demand figures prominently in the global economy and geopolitical decision making, and their geographic distribution has determined the location of railroads, highways, and villages. As you read this final sentence, look around you and imagine what would be left in your surroundings were there no minerals.

George W. Robinson

See also [Biogeochemical Cycles](#); [Karst Topography](#); [Mining and Geography](#); [Rock Weathering](#); [Sedimentary Rock](#)

Further Readings

Back, M., & Mandarino, J. (2008). *Fleischer's glossary of mineral species* (2008). Tucson, AZ: Mineralogical Record.



- Berry, L., & Mason, B. (1959). *Mineralogy: Concepts, descriptions, determinations*. San Francisco: W. H. Freeman.
- Pough, F. (1998). *A field guide to rocks and minerals*. Boston: Houghton Mifflin Harcourt.
- Robinson, G. (1994). *Minerals*. New York: Simon & Schuster.

MINING AND GEOGRAPHY

Mining is defined as the extraction and concentration of metallic and nonmetallic minerals for use in a variety of human activities. As a distinctively human pursuit, the extraction and use of resources from the surface of the Earth is essential for most industrial production and the provision of a wide variety of materials. Geographers have long examined mining activities, primarily by focusing on the distribution of resources, the expansion of mining activities, the development of technologies to extract elements from the Earth, and the environmental and social impacts of mining operations.

The Mining Frontier

According to the U.S. Geological Survey, more than 70 chemical elements and dozens of minerals are currently mined from more than 100 different types of deposits. According to the Raw Materials Group, in 2005, the value of global mining production was approximately \$800 billion, with metals accounting for roughly 27% of the total, industrial minerals and diamonds 7%, coal and uranium 52%, and crushed rock 14%. Of the many metals that are currently being mined around the planet, gold, iron, copper, nickel, zinc, and lead production account for more than 80% of all production. These metals are extracted primarily by large international mining corporations operating in numerous countries. In contrast, coal is extracted primarily within countries for domestic consumption and energy production.

Mining is inherently a geographic dilemma because many elements created by geologic

processes are unevenly distributed across the Earth. Moreover, concentrations of these elements that humanity has deemed important are often located in remote areas, far away from where they can be refined or will be incorporated into manufactured items. This dilemma forms one of the most important focal points for geographers as they have labored to identify the locations of these resources. Consequently, the frontier for mineral exploration has continually expanded over time. In addition, as new mining activities have been established along this frontier, they have led to the creation of many new social, economic, and political relationships among different places and societies.

Since antiquity, miners have explored and exploited hillsides, streambeds, and subterranean depths in pursuit of the rarest and most valuable minerals, such as gold, silver, copper, and diamonds. During the earliest human civilizations in Asia, Africa, Latin America, and Europe, the frontiers for minerals such as gold, silver, and copper were generally located within the economic and political domains of each society and formed the basis of most international trading networks. By the 15th century, the mining frontier rapidly expanded as the European powers conquered the Western Hemisphere, Southeast Asia, and several parts of Africa. Alongside this expansion of the mining frontier, many European powers also established colonial mining settlements and forced local populations to work in their mines. Since then, a series of discoveries of rich mineral deposits in places such as California, Alaska, Peru, and Central Asia have incorporated ever more remote areas into the mining frontier. Along this frontier, new cities and mining settlements have rapidly appeared, often as part of far-flung empires or as part of growing nation-states.

Mining Technologies

The productive capacity of mining operations is a function of the relative concentration and quantity of a particular element that is being exploited and the technologies used to extract it. Researchers have illustrated that for many millennia, human labor (often in the form of brutal slavery) and rudimentary tools constituted most mining



A 20-foot-diameter ball mill rotates at a copper mine's underground processing facility in Chile. This process breaks copper-bearing ore from golf-ball-sized pieces into dust. Chile's economy is buoyed by Chinese demand for its copper, much of it mined by state-owned Chilean companies.

Source: Michael Fuller/iStockphoto.

technologies. Since then, innovations in technologies such as geographic information systems, heavy machinery, and explosives have dramatically increased the productive capacity of large-scale mines and have gradually reduced the role of human labor in extractive activities. These new technologies are critically important because many of the richest and most readily accessible deposits of valuable minerals have been exhausted and because they allow mining companies to extract very small concentrations of elements from very large volumes of earth. As these new types of mining are very expensive, the mining sector has increasingly become dominated by corporations with access to large quantities of capital, the most sophisticated technologies, and global transportation and production systems.

Geographers have increasingly focused their attention on these global mining production systems through the use of new spatial technologies as well as research focused on economic globalization, shifting patterns of employment and production, commodity networks, and the spread of large transnational mining corporations to new regions.

Mining and the Environment

The mining sector has historically been one of the dirtiest industries and is also the subject of contentious debates about the role of mining in fostering sustainable economic development. Abandoned mining installations are the source of



environmental problems such as toxic acid mine drainage. In addition, because large companies now engage in vast, open-pit mining operations that deploy new and untested technologies such as cyanide heap leaching and deep-water tailings disposal, many researchers have increasingly focused their attention on the environmental legacies of mining as well as the potential threats that these activities pose for fragile ecosystems and human health. Furthermore, because many transnational mining operations are now being located at the most remote fringes of the mining frontier, and often where human populations are impoverished, their role in fostering economic and sustainable development has been a topic of debate across many disciplines. This issue, which is often referred to as the “resource curse” hypothesis, has become even more relevant since the mining sector expanded rapidly at the end of the 20th century.

Recent geographic research focusing on the human and environmental dimensions of mining often draws on development studies or cultural and political ecology approaches to understand the multiscale and complex social and environmental transformations that mining activities are initiating. In addition, critical geographic research has begun to address the role of mining in local struggles over natural resources, the formation of social movements, and social change.

Jeffrey Bury

See also **Coal; Distribution of Resource Access; Energy Resources; Minerals; Open-Pit Mining; Petroleum**

Further Readings

- Bebbington, A., Bury, J., Humphreys-Bebbington, D., Langan, J., Munoz, J., & Scurrah, M. (2008). Mining and social movements: Struggles over livelihood and rural territorial development in the Andes. *World Development*, 36, 2888–2905.
- Bury, J. (2007). Mining and migration in the Peruvian Andes. *The Professional Geographer*, 58, 378–389.
- U.S. Geological Survey. (2008). *Mineral resources program*. Retrieved January 20, 2009, from <http://minerals.usgs.gov>



MITCHELL, DON (1961–)

Don Mitchell is well known for his significant contributions to the field of cultural geography. Mitchell received his PhD from Rutgers University in 1992 and is Distinguished Professor of Geography at Syracuse University. He is a recipient of numerous awards, including a MacArthur Award and Fulbright and Guggenheim fellowships. His scholarship revolves around investigating the way people think and live their lives in particular places, and the associated networks of power that those relationships entail. He focuses on issues related to migrant labor and agricultural landscapes, urban public spaces, the homeless and hungry, and other marginal populations in U.S. cities.

Mitchell approaches ideas and theories of culture through a broadly Marxist and radical framework, exposing the various ways “culture” is revealed in the landscape through social struggles and the exercise of power. Mitchell argues that scholarship and political commitment cannot be divorced, emphasizing a decidedly social justice approach to geography. He has authored numerous articles and three books that examine the various meanings of public space, particularly as it relates to controlling marginalized people and public protesters. Much of this work emphasizes the relationship between law, rights, and public space. His volume *The Lie of the Land*, concerning agriculture in California, emphasized the role of labor in the region’s landscapes. His textbook *Cultural Geography: A Critical Introduction* is seen by many as the starting point for university students interested in understanding the transformation of cultural geography that has occurred in the past two decades. He has also written extensively about struggles over the meaning and control of urban public spaces.

Mitchell is also the founder and director of The People’s Geography Project, which brings the insights of critical contemporary geography to lay audiences, activists, and teachers. This effort, combined with his work with advocates addressing hunger in the Syracuse area, has evolved into the Community Geography Initiative. Community geography uses geographic information systems (GIS) and spatial analyses to create maps



that support community advocacy and organizing, and it serves as a resource for nonprofit social service agencies that would like to use GIS to address community concerns but lack the resources or technical capacity.

Thomas Chapman

See also **Cultural Geography; Landscape Interpretation; Marxism, Geography and; Public Space**

Further Readings

- Mitchell, D. (1996). *The lie of the land: Migrant workers and the California landscape*. Minneapolis: University of Minnesota Press.
- Mitchell, D. (2000). *Cultural geography: A critical introduction*. Malden, MA: Blackwell.
- Mitchell, D. (2003). *The right to the city: Social justice and the fight for public space*. New York: Guilford Press.
- People's Geography Project: www.peoplesgeographyproject.org



MIXED FARMING

Mixed farming includes both arable and livestock farming. However, it has many forms depending on different and interrelated factors including the level of technology available, the relative financial rewards for crops and livestock, farmers' perceptions of risk and their attitudes about farming (e.g., organic/nonorganic), political conditions, the national and international policies of governments, climatic and other physical variables, and the availability of labor.

All these factors, and others, may have effects at different scales. For example, individual fields on a farm may be mixed; a farm may have some fields that are arable and some in pasture for livestock; a region may have some farms that specialize in cereals and others that specialize in livestock. These systems are not static but may change over time in response to one or several of the factors affecting farming. The following cases exemplify the effects of scale and the factors affecting farming.

Case Studies

In parts of Mediterranean Europe, fields may be found with a mix of tree crops, with cereals beneath and in some cases livestock turned onto fodder cereals. The first photo shows a field with sheep turned onto cereal beneath fig trees in Eastern Mallorca, Spain. Formerly, this was common, especially with almonds as the tree crop. Although such mixed fields may still be seen, greater rewards from mass tourism over the past 30 years have reduced interest in agriculture, particularly among younger people who have migrated or who commute to coastal communities with their tourist industries and "improved" lifestyles. Care of trees and cultivation of crops beneath have declined, and many fields have been left to grazing of ruderal vegetation (seminatural plants that have colonized) or have been abandoned. Changes in rewards from agriculture relative to other activities and changes in people's perceptions of lifestyles have affected mixed farming in this dry and agriculturally marginal area of Mallorca.

At the farm scale, mixed farming in the United Kingdom referred to a farm with arable fields and pasture fields for livestock—dairy or beef cows or sheep. Enterprises were seen as interrelated; for example, manures were used as fertilizer on arable fields. Rotation of fields could be practiced; after a period in grass, a field could be ploughed for arable use, whereas arable fields could be put down to grass. This rotation helped maintain soil fertility and, in an era when pesticides and herbicides were uncommon, helped reduce disease and pests. Since World War II, in response to government initiatives and those of the European Community and its Common Agricultural Policy (CAP), the number of mixed farms has declined continuously. Subsidies encouraged specialization, so that in much of eastern England not only are farms specializing in cereals but also the region has a landscape dominated by cereals.

A region of Northern Ireland exemplifies the impacts on mixed farming from changes in the interacting factors affecting agriculture. In 1938, the United Kingdom as a whole was in an agricultural depression, and most food was imported, so there was no demand for specialized farming. At this time of low profitability, farmers spread their risk by practicing mixed farming. Farming in



A mixed field: sheep turned onto fodder cereal beneath fig trees, Eastern Mallorca, Spain

Source: Author.

Northern Ireland was mostly of low mechanization with use of horse-drawn implements. There was some need for feedstuffs to be produced on the farm for livestock, including oats for horses. There was little use of inorganic fertilizers, farmyard manure was used, and fields had rotations of arable crops and grass. Labor was plentiful and met the high labor demands of mixed farming; the lifestyle of families working together on their own farm was highly prized, as families had gained the right to own their small farm only at the end of the 19th century. Figure 1 shows the mix of arable and pasture land in 1938 in part of county Armagh.

By 1990, in contrast, almost all these factors had changed. The experience of World War II had encouraged the national government to promote more home production of food, a policy enhanced when in 1973 the United Kingdom joined the European Community and its CAP. In Northern Ireland, with its moist climate, damp soils, and

small fields and farms, specialization was not into cereals, as in Eastern England, but into grass and livestock. Grass production became more intensive with the use of slurry, rather than farmyard manure and artificial fertilizers. There was less use of rotations; instead, grass that became less productive was ploughed up and replaced. Grass species were changed to more productive rye grasses used directly as pasture or to produce two cuttings each year of silage (grass cut green, as opposed to dried hay, and stored for winter feed). Farming became more mechanized, tractors replaced horses, and there was no need for fields of oats. Supplementary feedstuffs for livestock were easily transported onto the farm. Although the family farm remains a prized possession, families are smaller, and young adults have moved to towns and what are perceived as higher-level occupations. The result of these changes is a decline in mixed farming and a landscape in which grass appears to be the only field cover (Figure 1).

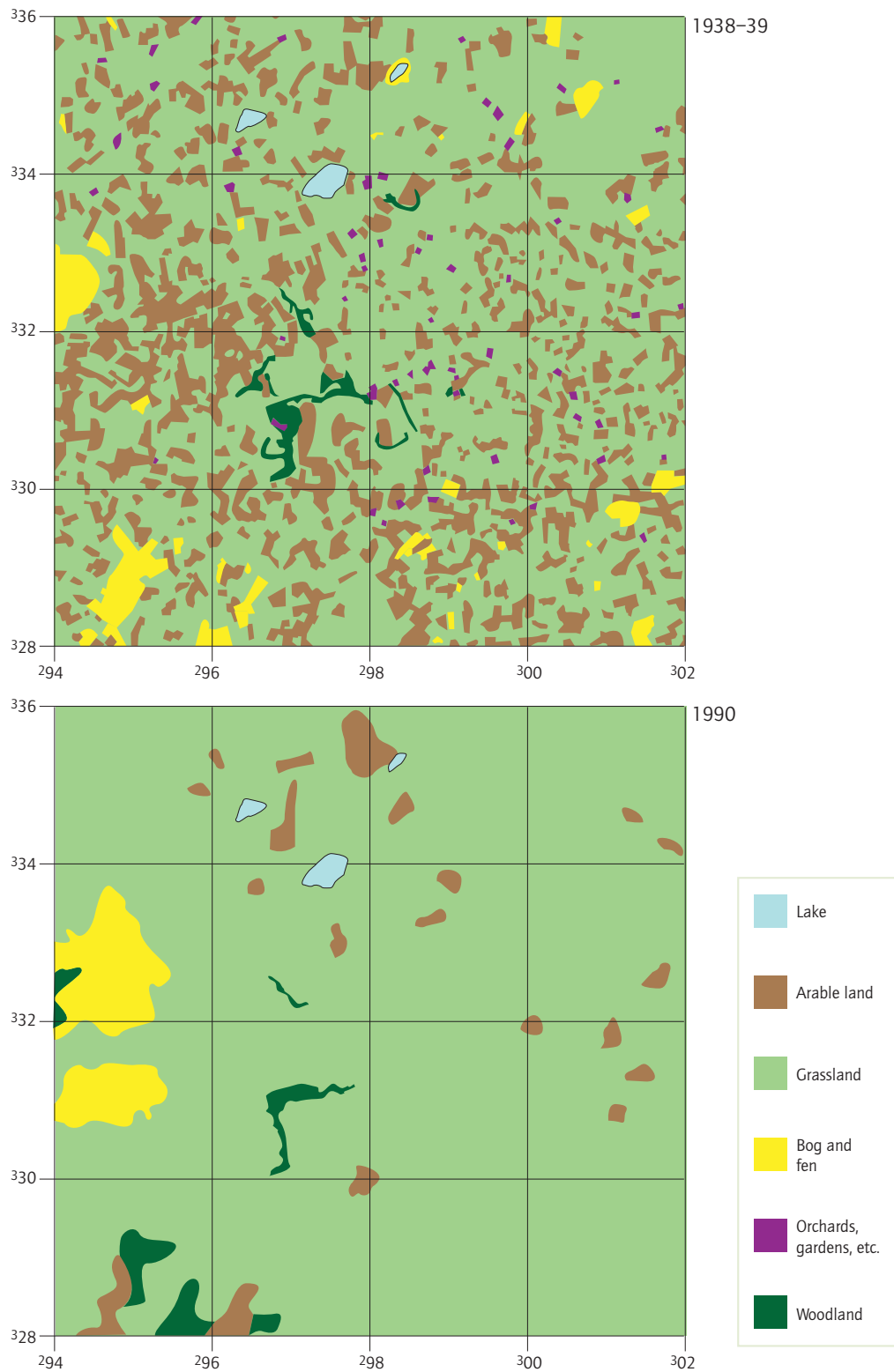


Figure 1 Changed regional pattern of farming, County Armagh, Northern Ireland

Sources: Adapted from *Land Utilization Survey 1938* and *CORINE Land Cover Mapping 1990*.



An example of farming in Southern Africa: Maize or sorghum grown near to and stored in the settlement. Livestock, including goats, are also kept, and the surrounding country is a source of firewood and building materials.

Source: Author.

The examples from Mallorca and Northern Ireland show how changes in the interrelated factors affecting agriculture influence mixed farming. However, mixed farming has not disappeared. In the United Kingdom, there remain small farms where farmers believe that mixed farming can spread risk—if prices of one crop decline, then livestock or other crops may help protect the overall farm income. There are also farms of several thousand hectares that are mixed to make best use of differing land conditions and to achieve maximum profit. There are also new types of mixed farming. For example, some farmers manage areas of their land for environmental purposes, such as rehabilitation of old pastures or planting of new woodlands—encouraged by changes in the CAP. Farmers have also included fields of energy crops; in Northern Ireland, fields of short-rotation coppice willow may be found among pasture fields. Many farmers have diversified their activities to maintain or improve their income. Examples

include development of equine facilities and conversion of redundant farm buildings to small business parks—to produce what might be more properly called mixed enterprises rather than mixed farming.

There are more perspectives on mixed farming in Africa than in Northern Europe. In large parts of Southern Africa, agriculture is characterized by small plots of maize or other cereal and of vegetables, often near the house. Extensive livestock grazing occurs on the surrounding land, which is also used for gathering of firewood. The farming may contain elements of subsistence agriculture and of commercial agriculture. It is mixed farming but not as may be described in many conventional European or North American texts.

R. Tomlinson

See also **Agricultural Land Use; Agriculture, Preindustrial; Agrobiodiversity; Crop Rotation; Organic Agriculture; Shifting Cultivation**



Further Readings

- Food and Agriculture Organization of the United Nations. (2001). *Mixed crop-livestock farming. A review of traditional technologies based on literature and field experience* (FAO Animal Production and Health Papers, No. 152). Rome, Italy: Author.
- Powell, J. M., Pearson, R. A., & Hiernaux, P. H. (2004). Crop-livestock interactions in the West African drylands. *Agronomy Journal*, 96, 469–483.



MOBILE GIS

Mobile GIS (geographic information systems) is an integrated software/hardware framework to allow users access to geospatial data and GIServices through mobile devices (e.g., iPhones, pocket PCs [personal computers], Smart phones, notebook computers, and personal digital assistants [PDAs]) via wired or wireless networks. There are two types of mobile GIS applications: *field-based GIS* and *location-based services* (LBSs). Field-based GIS focuses on GIS data collection, validation, and update in the field, such as adding or editing map features or changing the attribute tables in an existing GIS data set. Location-based services focus on business-oriented location management functions, such as navigation, street routing, finding a specific location, tracking a vehicle, and so on. The major differences between the field-based GIS and LBS are the data-editing capabilities. Most field-based GIS applications need to edit or change the original GIS data or modify feature attributes. LBS rarely changes original GIS data sets but rather uses them as background or reference maps for navigation or tracking purposes. Most field-based GIS software packages are cross-platform and independent of hardware devices, such as ESRI's ArcPAD and Mapinfo's MapXtend. On the other hand, LBS technologies focus on creating commercial value from location-based information, as does Google's mobile map on iPhone applications. Most LBS applications, such as GPS navigation systems and smart phones, are using proprietary operating

systems, which are not interoperable across different platforms.

This entry first describes the components and communication systems of mobile GIS. Next, it examines both LBS and field-based GIS applications and the limitations of mobile GIS. Last, this entry discusses the future directions of mobile GIS.

Components and Communication

The architecture of mobile GIS follows the concepts of client-server architecture as in traditional Internet GIS applications. Client-side mobile GIS components are the end-user hardware devices that display maps or provide analytical results of GIS operations. Server-side components provide comprehensive geospatial data and perform GIS operations based on a request from the client-side components. Between the client and the server, there are various types of communication networks (e.g., hardwired cable connections or wireless communications) to facilitate the exchange of geodata and services. There are six basic components of mobile GIS: (1) positioning systems, (2) mobile GIS receivers, (3) mobile GIS software, (4) a data synchronization and wireless communication component, (5) geospatial data, and (6) GIS content servers (Figure 1).

Mobile GIS can provide geospatial information and GPS coordinates for field-based personnel conducting remote-field (in situ) GIS tasks. To enable comprehensive mobile GIS, wireless communication is essential for connecting mobile GIS devices and GIS content servers. Recent progress in broadband wireless technology is the major momentum for the integration of mobile GIS and Internet GIS. The wireless service coverage (availability) and the bandwidth (speed) are the two key issues for wireless communication. There are many different wireless technologies, ranging from a walkie-talkie to high-speed WiMAX (worldwide interoperability for microwave access) to satellite phone systems. Based on the speed of data transfer, current wireless technologies can be categorized into two groups: narrowband wireless systems and broadband wireless systems. To communicate between mobile GIS and Internet GIS, broadband wireless technologies, such as

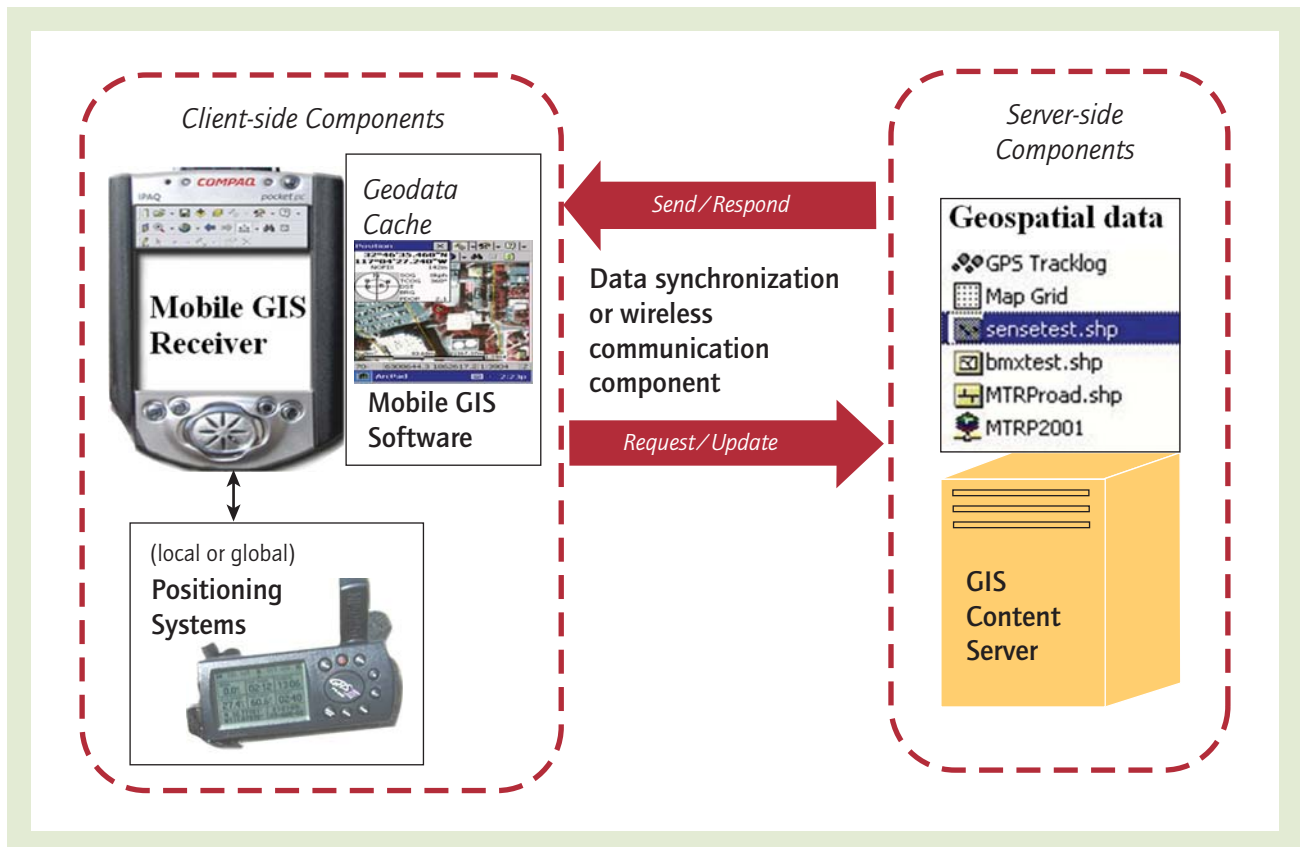


Figure 1 The architecture of mobile GIS

Source: Tsou, M. H. (2004). Integrated mobile GIS and wireless Internet map servers for environmental mapping and management [Special issue]. *Cartography & Geographic Information Science*, 31(3), 153–165.

Wi-Fi or WiMAX, are a better choice because most geospatial information and remote-sensing data are very large and complicated, which requires broadband wireless communication. The size of wireless coverage area is also an important criterion for mobile GIS applications.

Currently, there are three popular wireless communication systems: ad hoc systems, cellular phone systems, and Wi-Fi/WiMAX data network systems. The ad hoc wireless systems are custom designed for specific applications, such as direct satellite phone systems, General Mobile Radio Service (GMRS) for walkie-talkie devices, or ham radio communication. Usually, these systems are narrowband and localized for a small group of special users and require specialized user licenses. 3G and 4G mobile cellular phone communication systems can provide a good coverage area with a decent bandwidth communication. Cellular phone

systems can allow other wireless devices such as PDAs and pocket PCs to receive multimedia services (e.g., streaming audio and video on the devices). Most mobile GIS devices can use 3G or 4G cellular communication systems for collaborative work with Internet or Web-based GIS applications. Wi-Fi and WiMAX are the best communication systems for mobile GIS because they can provide very high-speed and stable Internet connections.

Location-Based Services

One important subdomain of mobile GIS is in LBSs. LBSs refer to a system that offers real-time updates about a location and its surrounding information. This information allows users to select a destination and to create the best route to



get there or to conduct business transactions. LBS systems and mobile devices have emerged as an important means of conducting business in a variety of fields. LBSs focus on business-oriented location management functions, such as navigation, street routing, finding a specific location, tracking a vehicle, and so on. Traditional desktop GIS cannot provide such real-time, portable, location-based information for end users.

Field-Based GIS

Traditionally, field-workers have to take a laptop computer with preloaded data when going into the field. There is no direct connection with office data systems, and field-workers have no way to know whether the data have been updated since they were last downloaded into the laptop. Lack of contact with the office also means that field data updated by the field-workers cannot be made immediately available in the office database. This time delay is not acceptable for time-critical applications such as utility repairs, facility security, and emergency responses. Furthermore, managing and maintaining the synchronization of data and software between the field computer and office computers can be costly and complex. With mobile GIS, coupled with GPS (global positioning systems), there is a direct connection between the field-worker's mobile devices and the database in the server. Any update in the office database will be instantly transmitted to the field-workers, and vice versa. Field-based GIS have been adopted in many application areas, such as facility management, land use management, and emergency and rescue responses.

Limitations

Current mobile GIS lack spatial analysis and GIS modeling functions. Many emergency tasks and disaster management works will need advanced GIS analysis functions that require significant computing power and computer memory. Most mobile GIS devices are tiny and only have very limited computing capability. The preprocessing and postprocessing time for spatial analysis and remote-sensing images might prevent the adoption of mobile GIS for real-time response tasks

due to the hardware limitations. One possible solution is to send the complicated GIS model and spatial functions via the Internet to remote GIS engine services with a comprehensive geospatial cyberinfrastructure. The analysis results will then be sent back to the mobile GIS devices via the network.

Another limitation of mobile GIS is the lack of alternative display methods. Since most mobile GIS devices are small and fragile, emergency responders and managers might be reluctant to use small screens on pocket PC or cellular phones to share their maps with others. One possible alternative is to project maps directly from mobile GIS devices on a white wall or another type of a shared display. It would also be very useful if users could print paper maps directly from their mobile GIS devices via wireless portable printers or from a built-in printer inside a pocket PC or a notebook computer.

Future Directions

Mobile GIS is a very promising field, with a considerable demand for its technology and products from field-based workers, LBS, and GIS vendors. With the development of new mobile GIS technologies and mobile devices (e.g., iPhones, iPod touch, Google's Android platform, Blackberry, and Microsoft Smart Phone systems), many new applications (e.g., homeland security, emergency rescue, real-time environmental monitoring, virtual tour guides, wildfire management, vehicle navigation services) will be possible. Mobile GIS will be more and more ubiquitous and essential in our daily lives and activities.

Ming-Hsiang Tsou

See also **GIScience; Internet GIS; Location-Based Services; Neogeography**

Further Readings

Peng, Z.-R., & Tsou, M.-H. (2003). *Internet GIS: Distributed geographic information services for the Internet and wireless network*. New York: Wiley.



- Tsou, M.-H. (2004). Integrated mobile GIS and wireless Internet map servers for environmental monitoring and management [Special Issue]. *Cartography and Geographic Information Science*, 31(3), 153–165.
- Tsou, M.-H. (2006). Bridging the gap: Connecting Internet-based spatial decision support systems to the field-based personnel with real time wireless mobile GIS applications. In S. Balram & S. Dragičević (Eds.), *Collaborative geographic information systems* (pp. 316–339). Hersey, PA: Idea Group.
- Tsou, M.-H., & Sun, C. H. (2006). Mobile GIServices applied to disaster management. In J. Drummond, R. Billen, D. Forrest, & E. João (Eds.), *Dynamic and mobile GIS: Investigating change in space and time* (Innovations in GIS Book Series; pp. 213–236). London: Taylor & Francis.

MOBILITY

The concept of mobility brings together human characteristics of identity and power with a dynamic understanding of space, place, and change. Different mobilities are shaped by different geographies, by the varying types of spaces people move through (e.g., public or private, urban or rural, real or virtual), and by a range of factors from cultural norms to modern security and immigration controls. Further influences include access to the means of mobility, be they cars, computers, bikes, or pavements, and the varying ability to be mobile, based on age, sex, body type, and other components of identity. Mobility is constructed in relationship to relative immobility, or what are sometimes termed *moorings*, locations where mobility appears temporarily abated. Yet as absolute immobility is all but impossible, the mobility concept proposes that everyone and everything is mobile and that it is matters of scale, difference in speed, and variation in direction that create appearances of relative immobilities. Mobility can also be used to assess the impact of modern telecommunication and computer technologies on sociospatial relations, such as changing labor practices through

which the mobile office makes almost any location a potential workplace, and, in a more metaphorical context, to explore the virtual experiences of moving through spaces via the Internet, videogames, television, and film.

Mobility scholars challenge traditional social science theories that often assume sedentary sociospatial relations and being stationary as the usual condition of life. In contrast, the mobility lens understands motion to be both normal and meaningful, not merely a temporary condition that occurs when moving between fixed locations. The concept thus challenges static understandings of space and spatial relationships, often defined by delimited areas such as nations, regions, cities, and homes. Consequently, where past geographical studies commonly analyzed such places as isolated entities, theories of mobility understand space as interconnected networks through which flows of people, goods, technologies, information, and images move. This constant movement forms the basis for analyses of mobility yet does not deny that there are material aspects to life. Mobility is not ethereal. It is tied to places and exhibited through physical forms. For example, cars allow the function of mobility, but garages, repair shops, streets, and highways are the relatively immobile moorings necessary for mobility to be enacted. Similarly, an airport may seem immobile, but passengers, baggage, workers, inspectors, security guards, capital, goods, vehicles, and so on, continuously move through its spaces. Even the airport buildings and runways, if looked at through a greater temporal lens, are mobile as they are remodeled, extended, damaged, and repaired. Envisioning spatial relations through a lens of mobility thus reformulates ideas of space, scale, and time.

Mobility is relational and differs from person to person. It matters who is doing the moving, where, when, how, and why. Immigrants, diaspora populations, and international tourists experience mobility differently from commuters, nomadic peoples, or prisoners. Men and women experience moving through space differently, as do young and old, people of different social classes, races, ethnicities, and nationalities. For example, if an adult and a child are traveling together, the child, while involved in the same movement, does not experience the same sense of



Family members out for a bike ride. The experience of mobility varies between adult and child and between men and women; thus, even when family members are traveling together on bicycles, their experiences of mobility will differ.

Source: Catherine Yeulet/iStockphoto.

mobility, and thus, the two individuals understand and practice very different mobilities. Similarly, mobility in contemporary European space is very different for an academic with a British passport going to a conference than it is for an Ethiopian economic migrant moving through the illicit spaces of the underground economy. Encountering difference is often an aspect of mobility. Travel writings and accounts of foreign journeys commonly romanticize unfettered movement through the places of otherness, whereas vacations, exile, and emigration are experiences of difference that generate disparate mobilities.

Theories of mobility propose that traveling is in itself meaningful. Travel is not merely the act of getting from one location to another, but how people move and what they do while moving are critical to understanding the networks and relationships of contemporary society. There is significance in the journey between its start and end points. Traveling by car (automobility) produces a different experience from traveling in another manner. The social interactions, duties, habits, and countless aspects of a journey are further changed by who is traveling, where they are traveling, what kind of spaces are being moved through, and why the journey is occurring, among other factors. How a person behaves in a car is usually different from the social interactions experienced in rail, bus, boat, or air travel and different again from walking, cycling, or running. One travels differently with children or pets than when alone; experiences travel differently when with different family members, friends, colleagues, or clients; and is differently mobile due to age, bodily ability, or other factor. Some critics have proposed that analysts favor assessment of certain forms of travel over others, for example, the experiences of global air travel by affluent individuals from Western nations, and thus narrow the definition of mobility to that which is avail-

able and accessible to certain small sections of the population. Others demand that routine activities, such as going to the grocery store, driving to work, or walking to a friend's house are everyday mobilities worth exploring.

Mobility is always socially unequal. The right to movement is variable, and people have different abilities and opportunities to move. The gendering of spaces, for example, women-only carriages on Japanese trains, can be understood as changing the mobility of women in relation to men; fear of crime may reduce the mobility of the elderly and children in relation to young adults;



religious beliefs may limit mobility for some and increase it for others within and between specific locations, such as reserving areas within temples for specific individuals or certain routes for pilgrims. Space can also be understood to be racialized, and in certain contexts racial and ethnic identities may aid or hinder mobility. In the 19th-century United States, African Americans experienced very different mobilities as they traveled through slave and free states, and Native Americans saw their nomadic lifestyles curtailed as they were immobilized on reservations. Synchronously, white Americans were moving west on railroads and in wagon trains, experiencing greater mobility. The meanings of different mobilities are, therefore, produced from different contexts, agencies, experiences, and practices.

Euan Hague and
Michael Christopher Armstrong

See also **Automobility; Aviation and Geography; Immigration; Migration; Space of Flows; Time-Space Compression; Tourism; Transportation Geography**

Further Readings

- Adey, P. (2006). If mobility is everything then it is nothing: Towards a relational politics of (im) mobilities. *Mobilities*, 1, 75–94.
- Cresswell, T. (2006). *On the move: Mobility in the modern Western world*. London: Routledge.
- Featherstone, M., Thrift, N., & Urry, J. (Eds.). (2005). *Automobilities*. London: Sage.
- Frello, B. (2008). Towards a discursive analytics of movement: On the making and unmaking of movement as an object of knowledge. *Mobilities*, 3(1), 25–50.
- Sheller, M., & Urry, J. (2006). The new mobilities paradigm. *Environment and Planning A*, 38, 207–226.
- Urry, J. (2007). *Mobilities*. Cambridge, UK: Polity.
- Uteng, T., & Cresswell, T. (Eds.). (2008). *Gendered mobilities*. Aldershot, UK: Ashgate.
- Verstraete, G., & Cresswell, T. (Eds.). (2002). *Mobilizing place, placing mobility: The politics of representation in a globalized world*. Amsterdam: Rodopi.



MODELS AND MODELING

A model is an idealized, abstract, and structured representation of real phenomena. Models may manifest as verbal descriptions, physical objects, diagrams, maps, mathematical formulas, and computer programs. Representation of complex dynamic systems increasingly involves computer simulation of alternative model outcomes based on specified input parameters, variables, and relationships. These models link a system's structure to behavior for the purpose of changing a structure to improve behavior. The purpose of a model provides the basis on which its utility must be judged, as all models are by definition simplifications of reality. This entry discusses the modeling process, the assessment of model utility, and the differences among several common modeling paradigms.

The Modeling Process

Human beings implicitly model all the time. Routine decisions in everyday life are guided by elaborate and yet incomplete mental models of the tasks at hand. For example, a person driving a car associates a yellow light with the need to slow down (or hurry through the intersection). In making this association, the person's mental model simulates, or translates the perception of a yellow signal into, a decision of whether to slow down or hurry up, depending on rapid evaluation of one's position relative to the intersection. This decision is carried into action by an adjustment of foot pressure on the accelerator and brake pedals. This sequence of information, perceived and acted on by a person's mental model, is one experienced many times over in a given day. In this way, mental models may be largely subconscious but yet represent intricate webs of understanding that guide (and misguide) human behavior.

Formal modeling enables explicit testing of underlying assumptions that humans carry in the form of mental models. One strategy for making models explicit is to slow down one's thought to become aware of the implicit mental models that simulate both immediate and longer-term scenarios of the system of concern. Group modeling experiences benefit from the process of slowing, exposing, and challenging implicit mental models.

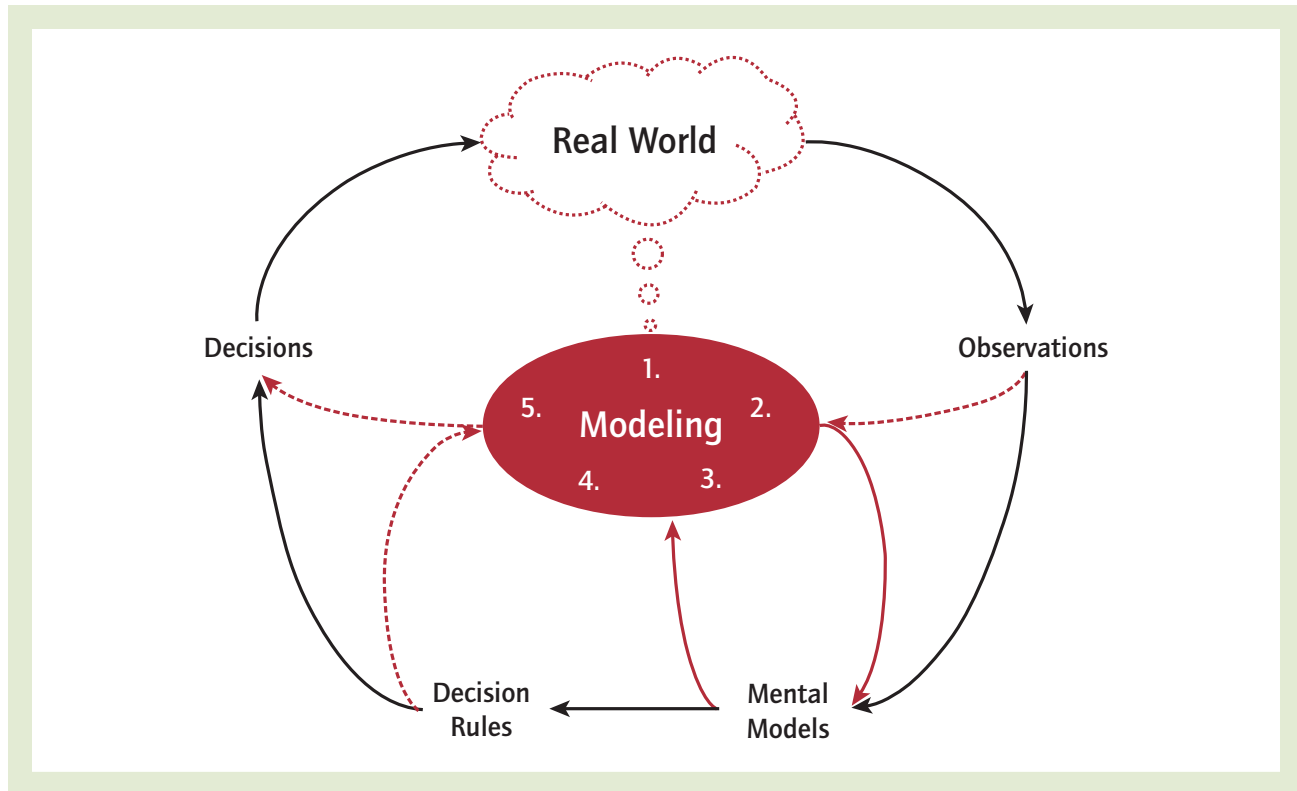


Figure 1 The modeling process in context. The iterative process of modeling creates an experimental learning feedback loop in the context of the real world.

Source: Adapted from Sterman, J. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. New York: McGraw-Hill.

The process of making mental models at least partially explicit—explaining ideas to others in conversation or writing, drawing, or encoding them in computer models—exposes the limitations of their scope, based as they are in an individual’s personal experience. As mental models are formalized, the explicit model becomes an artifact readily shared with others, while the implicit mental models continue to update based on information feedback from both the model and the real worlds.

In a dynamic modeling process (Figure 1), observations and decision rules may be input as data and assumptions into computer models, and simulated output may inform policies for making decisions. As mental models are updated with observations of both the real and the model worlds, they translate into updated decision rules or heuristics that shape the decisions that manifest as actions in the real world. The reflexive relationship between mental models and the

process of modeling reveals it to be at once an art and a science. The art of modeling includes the role of intuition in problem formulation and hypothesis development, as revealed by the selection of relevant variables for the system of interest. The science of modeling centers on a consistent, reproducible methodology for testing theory by comparing simulated output with observed data. Steps of the modeling process generally include the following:

1. Problem formulation and boundary setting
2. Mapping a dynamic hypothesis as a diagram of causal relationships and feedback
3. Computer model formulation as mathematical expressions and/or algorithms
4. Boundary testing and calibration of model to observed data
5. Policy analysis and scenario simulation

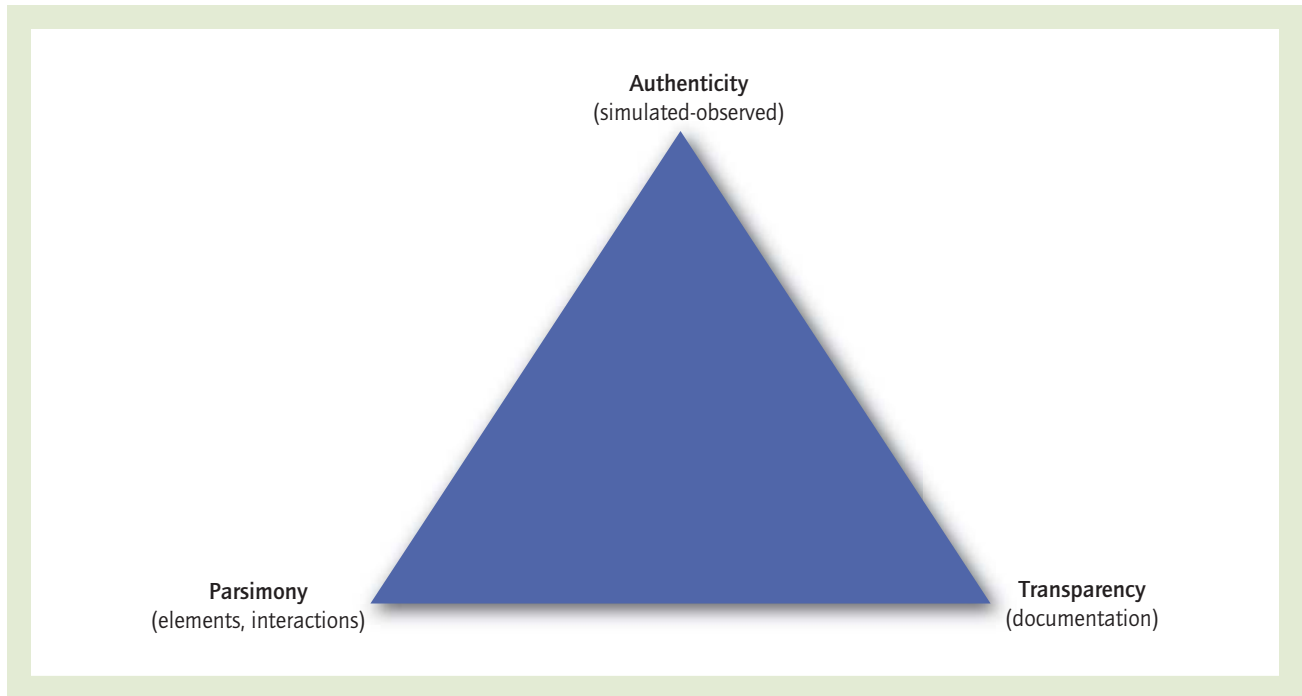


Figure 2 APT dimensions of model utility. Dimensions of authenticity, parsimony, and transparency (APT) help assess the utility of a model relative to its purpose.

Source: Author.

Although the above sequence implies that the modeling process begins with problem formulation, the process may be entered at any stage and is iterative such that the understanding from policy analysis (Step 5) leads back to a reconsideration of the problem as formulated. This “problem of problem formulation” reinforces the value of modeling in moving through new layers of understanding for the system of concern. Because the process of modeling itself is a source of insight, experienced modelers document expectations and results throughout their experiments in these virtual laboratories. This documentation enables utility from the modeling process to be assessed separately from the model *per se*.

Model Utility

The *authenticity* of a model may be assessed in multiple ways—by comparing simulated results with empirical observations and testing whether the model is consistent with the hypothesis articulated *a priori*. While no model will fully represent reality, modelers and decision makers will assess

how plausible the model results seem on the basis of their prior assumptions about the system of concern. Because models are abstractions of reality, regardless of how intricate, much insight may be gleaned from *parsimony*, the art of leaving things out. The principle of parsimony is that models should be as simple as possible but no simpler. One way to assess parsimony is to measure the number of elements and relationships therein. Models with fewer interacting elements have more explanatory power than models that emphasize detail and complexity over dynamic essence. Model utility is also revealed by its relative *transparency*: Can the model be understood by a broad audience? Are the feedback mechanisms driving system behavior clearly documented? Models that lack transparency have a limited utility beyond the experts who interact with them.

The form of a model affects its utility. Physical models range from scaled-down structures such as miniature train sets to scaled-up representations of molecular structures based on connections between core elements. In geomorphology,



scaled-down flumes function as models of water flow through topographically variable sedimentary conditions. Graphical models range from simple diagrams showing elements and relationships (such as those in Figures 1 and 2) to elaborate maps that reveal spatial patterns. Maps of both the cartographic and the cognitive kind may be considered models in the broad sense, models as representations of reality. As for maps, scale matters for models—small-scale systems may be represented with linear models, while nonlinear, large-scale systems remain largely terra incognita.

Modeling Paradigms

Statistical models align with the inductive approach to the scientific method, whereby one draws conclusions based on available evidence. In practice, this is often iterative, such that initial inferences are first drawn with the aid of descriptive statistics, then formal models are formulated to fit part of the data (the training set) and predict another part (the validation set). However, an iterative approach in generating statistical models is problematic in that the identification of variables to include in a statistical model tends to be based largely on the data available, de-emphasizing the role of prior theory, the *a priori*, in shaping model form. Moreover, inference from observation obscures the role processes that are not observable. Reliance on observed data may bias the analysis toward including some things and leaving others out.

In contrast to statistical models, analytical forms of mathematical models are frequently used to develop theory for the system of concern. Newton's $F = ma$ and Einstein's $E = mc^2$ symbolize (in both the literal and the figurative sense) the utility of simple mathematical models for comprehending a wide range of phenomena in the universe. Analytical models tend to describe the average or aggregate behavior of a system, in that they merge individual variations to look for the essence and eliminate the noise. Differential equation models treat processes as continuous in time rather than discrete. This Newtonian worldview is increasingly challenged by suggestions that discrete mathematics is not only more pragmatic from a computational perspective but may more accurately reflect what's going on in the "real world."

The analytical approach using differential equations has advantages in transparency, due to the ability to convey simplified representations of real-world systems through calculus and its approximation on the computer. Simulation software that represents integrals as "stocks" and differentials as "flows" over time has enabled more combinations of ordinary differential equations than may be handled analytically.

Stock-and-flow models based on differential equations emphasize the dynamics of the system more than the spatial patterns created. However, a number of processes warrant explicit spatial representation, such as urban growth and climate change. When adding the spatial dimension to a dynamic model, challenges emerge with respect to the choice of spatial scale and extent. Such choices vary depending on whether raster or vector GIS (geographic information system) data are employed to calibrate the model or whether an abstract representation of space is adequate. Cellular automata are a form of abstract, spatially explicit models that rely on locally induced, memory-less state changes. Automata are discrete units arrayed in space (usually one dimensional or two dimensional) such that each automaton has a fixed number of neighbors with discrete states (e.g., on/off). The state of the individual automaton depends on local rules, conditional on its own state and the state of its neighbors. From a few simple rules, a variety of patterns can emerge. The simplicity of cellular automata provides a benefit of transparency; all one needs is to describe the rule that is in operation, which is especially easy as more students become trained in the Boolean logic that underlies computational systems. The cost of this simplicity is the strictly local behavior and lack of memory, such that cellular automata become more abstract explorations of possible phenomena than any sort of real-world analog.

The advent of object-oriented programming has enabled the development of software for constructing agent- or individual-based dynamic computer models. Object orientation enables individual agents or decision-making units to operate independently and interact with each other. Like cellular automata, agents use rules for decision making. Unlike cellular automata, agents may have memory and may be mobile and interact in non-Euclidean spaces such as social or

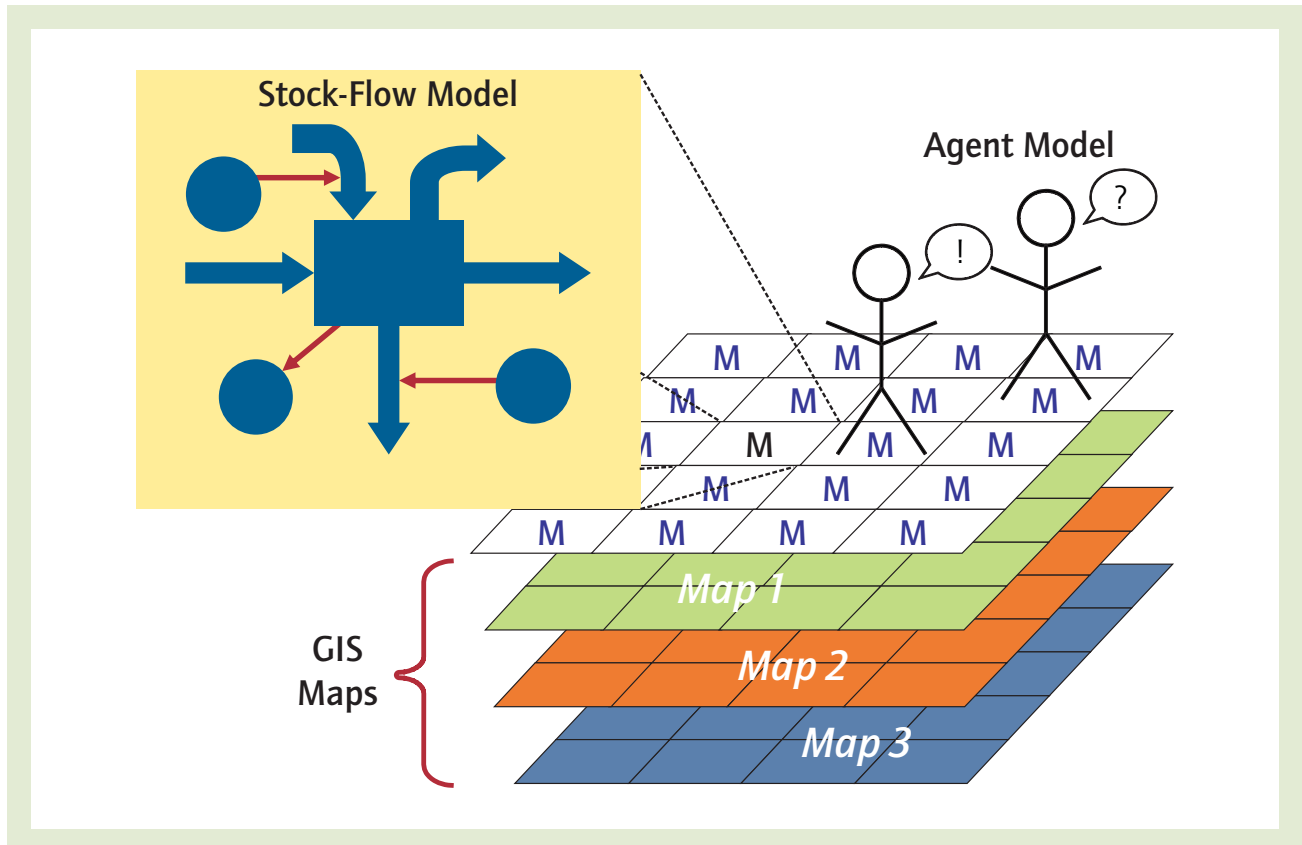


Figure 3 Mixing model paradigms. Distinct model paradigms such as stock-flow models, agent models, and GIS may be integrated with the available software.

Source: Author.

structural networks. The flexibility of the agent-based framework has triggered a broad interest in the social sciences, and individual-based models have been popular in ecology for some time. Agent-based models are able to accommodate a variety of scales and to capture a wide range of heterogeneous individual behavior. Such diversity appeals more broadly to the humanistic side of the social sciences, which has historically been reluctant to embrace highly aggregate and generalized statistical or analytical approaches. Moreover, the flexibility allows for the development of theories that incorporate individual everyday heuristics and examine how such individual behavior produces aggregate patterns. Critics of agent-based modeling emphasize the computational and conceptual challenges of trying to represent too much detail. Opening the door to greater flexibility puts a greater onus on the

modeler to fully think through the problem at hand and abstract accordingly. Because agent-based approaches are still in their infancy, limited guidance is available in the form of established methodologies for model building and verification.

Spatially extended models may couple cellular automata with stock-and-flow models to enable the dynamic model to be replicated for each individual cell of a grid, often corresponding with raster data for input. An abstract notion of space is used in many agent-based models as well, and further efforts are under way to integrate agent-based models with GIS. Figure 3 demonstrates how different modeling paradigms (GIS, stock-flow, and agent) may be combined using the available software packages. Here, a stock-and-flow representation of a continuous process is replicated spatially, embedding dynamic memory into a cellular automata framework where each cell interfaces with



information from the neighboring cells. Computational feasibility has become less of a constraint in choosing which model paradigms to employ, leaving many modelers with their own expertise as the determining constraint, though increased availability of multiparadigm modeling software helps to minimize paradigmatic bias and encourage cross-disciplinary collaboration.

Sara Metcalf

See also **Agent-Based Models; Central Place Theory; Complexity Theory; Complex Systems Models; Digital Terrain Model; Energy Models; GIScience; GIS in Environmental Management; Gravity Model; Input-Output Models; Location-Allocation Modeling; Location Theory; Mental Maps; Regional Science; Spatial Data Models; Spatial Interaction Models; Three-Dimensional Data Models; Thünen Model; Weber, Alfred**

Further Readings

- Forrester, J. (1971). *World dynamics*. Cambridge, MA: Wright-Allen Press.
- Grimm, V., & Railsback, S. (2005). *Individual-based modeling and ecology*. Princeton, NJ: Princeton University Press.
- Harvey, D. (1969). *Explanation in geography*. New York: St. Martin's Press.
- Sterman, J. (2000). *Business dynamics: Systems thinking and modeling for a complex world*. Boston: McGraw-Hill.



MODERNITY

The term *modernity* refers to a set of political, economic, social, and cultural processes usually traced back to forms of knowledge and practice that emerged in Europe around the 16th through the 18th centuries, a period often termed the *Enlightenment*. The philosophies associated with the Enlightenment have been much debated and modified over the centuries, but their central principles of the primacy of reason and the autonomy of the individual continue to underpin dominant forms of social order in today's global context.

Typically implied in the concept of modernity are a sense of rupture with the past and tradition and a sense of progress toward a society governed by greater rationality, justice, and truth. Many scholars challenge these assumptions, highlighting modernity's "dark side," including the projects of colonialism in the 19th century, which were central to the definition of a European identity. They also question the universalism and Eurocentrism of dominant theories of modernity, arguing for a notion of multiple modernities as more productive in understanding the world's diverse forms of social order and development, especially within the Third World. In addition, contemporary debates on modernity address the question of whether recent broad social shifts, associated particularly with processes of globalization and the concomitant proliferation of new forms of knowledge, have in fact ushered in a distinctively new era. This process is central to understanding the geographies of the modern age, including the Enlightenment, technological innovation, colonialism, industrialization, and urbanization.

The Roots of Modernity

As with any historical era, the Enlightenment cannot be bounded definitively by particular years, or even centuries. The ideas that mark the Enlightenment as a distinctively new period could be said to have emerged anywhere between the 16th and 18th centuries, through the work of scholars from Francis Bacon, Thomas Hobbes, and John Locke in the 16th and 17th centuries to Denis Diderot, Voltaire, and David Hume in the 18th century. The paradigm of Enlightenment philosophy that emerged from these and other diversely situated and positioned writers is characterized by an emphasis on the principles of rationality, empiricism, universalism, progress, individualism, freedom, and secularism.

The emphasis on scientific reasoning in Enlightenment philosophies constituted a clear move away from the Church and forms of knowledge established by religious authorities. The world was to be known through experience and critical examination rather than mythical, mystical, or religious explanations. Traditional worldviews thus became associated with oppressive superstition, irrationality, and prejudice. In the narratives



of modernity that spring from Enlightenment ideals, and even those that explore alternative approaches to modernity, this idea of a break with tradition remains central. While the latter is typically associated with the ignorance—or sometimes, more charitably, “innocence”—of the past, the modern worldview is seen to be better, given its future-oriented, progressive state, enlightened by reason.

Central to this positioning of reason as the most superior human attribute is the notion of the independent self. Selfhood continues to occupy a pivotal position in ideas of contemporary modernity, particularly in Western cultures; not just the self as an entity, but specifically the freedom and autonomy of that self, are of primary importance in both Enlightenment thinking and dominant narratives of contemporary modernity. Human agency is central to understanding the modern social order and what it means to be a participant in it. Enlightenment thinkers were by no means the first to emphasize these aspects of the self, much less to develop the notion of an independent self, but the developments of scientific empiricism and analysis during the 17th and 18th centuries, particularly in Britain, lent a distinctly new impetus to these debates. The idea of the individual as an autonomous agent has become arguably the most defining aspect of modernity and has intensified through the democratic and capitalist processes that are globally dominant today.

Newness and Progress

Tradition is by no means synonymous with the past, but the two are often linked together to constitute an “other” against which modernity is defined. The idea of modernity therefore contains within it a strong element of newness and difference from the past. In this sense, each new era may lay claim to a modern identity. The 18th century, however, saw a development of this meaning such that modernity came to describe not just novelty but also improvement. The intellectual endeavor of this period was significant in its orientation to the future and its positioning of human beings as the agents, rather than simply the objects, of history. Human beings were reimagined as autonomous actors, creating a more ordered and equitable world.

The notion of progress thus became a fundamental characteristic of modernity. The liberation of all humans from ignorance, myth and superstition, poverty, and the arbitrary exercise of power was to be gained through turning to reason as the way to know and organize the world. This notion still holds significant sway today, illustrated, for example, by the power invested in science in dominant contemporary discourses. A teleological perspective is built into this understanding of modernity, in the belief that there is one universally right and true way of being, knowing, and doing and that all societies should aspire to the same basic ideals. This perspective and its implications have been manifested in numerous “projects of modernity.” These include Europe’s imperialist and colonial dominations, which reached a peak in the 19th century, and various modernization projects through the mid 20th century aimed at developing Third World countries according to the model of the West.

By constructing the traditional customs and practices of non-Western societies as static, backward, and ignorant, the authors of modernity and modernization projects simultaneously construct themselves as active, progressive, and having superior knowledge. They are thus saviors, fulfilling their moral duty to rescue primitive peoples by showing them the truth. A notion of “self” and “other” can therefore be seen to underpin the notion of modernity, which positions non-Western people in opposition to the ideals of modernity and its attendant principles of the betterment of humanity.

The opposition that has been set up between modernity and tradition in this way has been shown to be problematic. Traditional practices are neither as unchanging nor as oppressive as this binary view assumes, while the structures and practices of modernity have not fulfilled its vision of emancipation and empowerment of all human beings. On the contrary, the global modern age has been realized through numerous large-scale acts of oppression and violence, and influential theorists describe this era as one characterized by increased control and regulation, weakened social ties, and greater risk and uncertainty. The Enlightenment model of modernity as the primary, or sole, means of enabling human flourishing has been challenged, particularly by poststructural



theorists. Scholars working within the framework of poststructuralism and allied more specifically with feminist and postcolonial approaches have been particularly active in highlighting the Eurocentrism and masculinism of modernity. They have thus proffered alternative readings of the projects of modernity, while also identifying and envisioning multiple new ways of being modern in the present and future.

Multiple Modernities

The argument for a recognition of multiple modernities rejects a paradigm of modernity as a necessarily convergent set of processes or the singular end point of those processes. Instead, it advocates an understanding of the world and history as the story of many different cultural programs that are continually being shaped and reshaped. This view refuses a conflation of modernization with Westernization. It emphasizes the fact that although the Western trajectory of development has been globally influential, indeed dominant, it should be understood as one deeply contextual version—a particular set of values, institutions, everyday practices, and discourses—of what it means to be modern. This understanding rejects the universalism of a teleological model and opens up the possibility of appreciating the cultural variety in experiences and productions of modernity.

This approach has implications for many groups who do not fit the dominant model, which has been criticized for its “aculturalism” and gender blindness. Postcolonial scholars point to the importance of power relationships between the West and developing countries, which may have been instigated centuries ago through projects of colonialism but which are no less relevant in understanding today’s globalized economies, cultures, and politics. While the Western model of modernity must be contextualized as one particular evolution, the constantly shifting connections between Western and other countries also require a relational approach to understanding contemporary modernity. This differs from earlier models in that the West can no longer be defined as progressive as opposed to the stagnant cultures of the colonial other. Rather, multiple cultures, including those of the West, can be seen to be

embedded in a range of intersecting and overlapping sociopolitical processes.

In a similar vein, feminist theorists have pointed to the many binary oppositions and power structures implied in discourses based on Enlightenment philosophies, for example, nature/culture, private/public, traditional/modern, past/future, and emotion/reason. The first of each of these is typically, if implicitly, gendered female and devalued in the forward-looking projects of modernity. Revaluing these dimensions of social life is key, such theorists argue, to appreciating the multiple, and often contrasting and contradictory, modes through which modern life is shaped. This work builds on the assertion by feminist and other scholars that all knowledge should be recognized as partial and situated in particular times and places. This is especially true of those forms of knowledge that have become so embedded in the collective unconscious that they are no longer recognized as constructed rather than “natural.”

A New Social Order

A large body of contemporary work addresses the question of whether our times are in fact more usefully understood as a new era than simply as a continuation of a model based on Enlightenment thinking. This notion suggests that there has been a rupture with modernity significant enough to shape a new social order structured through novel values, politics, and ideals and is perhaps most evident in postmodern schools of thought. These take as their central premise the idea that “grand narratives” purporting to explain the world should be dismantled, since in a world characterized more by diversity, multiplicity, and fragmentation than any form of order, there can be no absolute truths.

There is, however, a strong counterargument that despite the plurality of modernities and the newness of our global and technological age, modernity has not truly come to an end or been surpassed. Rather, the social order that is termed *modernity* has been extended and intensified, particularly through the increased reflexivity of institutions and individuals. This reflexivity, or the continual interrogation and revision of all kinds of social phenomena, is itself produced through a proliferation of new forms of knowledge and a concomitant, pervasive sense of uncertainty. This



has been described as living in a “risk society.” We thus live not in an age that has moved away from the forms of knowledge that constitute modernity but rather in a period of heightened or radicalized modernity, termed *late modernity* by theorists including the influential sociologist Anthony Giddens.

Finally, the French theorist Bruno Latour argues that notions of modernity depend on a nature/culture divide that cannot be truly achieved or sustained. The category of modernity therefore must be redefined to take account of the hybrid systems that structure our social worlds. Our age, according to Latour, is neither late modern nor postmodern—we have in fact never been modern.

Shari Daya

See also **Colonialism; Enlightenment; Ethnocentrism; Eurocentrism; Giddens, Anthony; Globalization; Industrial Revolution; Modernization Theory; Postmodernism; Poststructuralism; Situated Knowledge; Urbanization**

Further Readings

- Appadurai, A. (1996). *Modernity at large: Cultural dimensions of globalization*. Minneapolis: University of Minnesota Press.
- Beck, U., Giddens, A., & Lash, S. (1994). *Reflexive modernization: Politics, tradition and aesthetics in the modern social order*. Cambridge, UK: Polity.
- Eisenstadt, S. (2000). Multiple modernities. *Daedalus*, 129(1), 1–29.
- Felski, R. (1995). *The gender of modernity*. Cambridge, MA: Harvard University Press.
- Gaonkar, D. (Ed.). (2001). *Alternative modernities*. Durham, NC: Duke University Press.
- Latour, B. (1993). *We have never been modern*. Cambridge, MA: Harvard University Press.
- Schmidt, J. (Ed.). (1996). *What is Enlightenment? Eighteenth-century questions and twentieth-century answers*. Berkeley: University of California Press.
- Scott, D. (2004). *Conscripts of modernity: The tragedy of colonial Enlightenment*. Durham, NC: Duke University Press.



MODERNIZATION THEORY

Of the various theories that seek to explain patterns of international development, and the lack of it, modernization theory is one of the most famous and certainly the most influential. Modernization theory for decades was the mainstream, orthodox approach to explaining development, and it was enormously important in the foreign policies of the United States and, to a lesser extent, other countries. The essential question that underpins modernization theory is whether or not countries in the developing world follow the historical trajectory set by the West (i.e., Western Europe, North America, and Japan). In this reading, development is likened to a race, with some countries and regions “ahead” and others “falling behind.”

Origins

The origins of modernization theory may be said to lie with the famous sociologist Max Weber, who offered an idealist explanation of the origins of capitalism, particularly in his renowned book *The Protestant Ethic and the Spirit of Capitalism*. For Weber, capitalism could trace its start to the particular values held by Protestants in northern and northwestern Europe. It was no coincidence, he maintained, that Lutheran, Calvinist, Anglican, and Presbyterian countries were the first to industrialize, in contrast to the Catholic nations along the Mediterranean and in Eastern Europe. Protestantism, he held, offered a unique set of values that centered on delayed gratification, frugality, and saving. Material success in this world was held to be an indication (not a guarantee) of God’s grace and entry into heaven. For Protestants, work was an ethical obligation, and profit was a goal, not a sin. Thus, the Protestant ethic was instrumental in producing incipient capitalists.

The core of Weber’s view was that capitalism produced a sustained rationalization of social life. Rationalization is an ambiguous term and has been used in different ways, but essentially, it refers to the process of rendering the world intelligible by the imposition of an orderly, systematic, logical, and scientific worldview, in contrast to metaphysics. Indeed, rationality was at the core of



the Enlightenment project. Weber held that the process of rationalization fomented scientific discoveries and that secularization facilitated the pursuit of profit through an impersonal cost-benefit calculus. Politically, rationalization was manifested in the emergence of bureaucracies, which held to an explicit division of labor, specialized institutions, and lines of authority in which jobs were defined by standardized criteria, not the whims of the people who held them. Bureaucracies were necessary for the growth of laws that applied equally to all as well as to the protection of property rights. Economically, rationalization materialized through the market, in which profit maximization rewarded the innovative and productive and punished the incompetent. Weber asserted that Western rationalization was unique and was not possible in cultures dominated by Catholicism, Islam, Hinduism, or Confucianism.

Weber likened rationalization to an “iron cage” descending over the West, one that emerged from religion but ultimately squeezed religion into the irrational and inexplicable, robbing humanity of its soul. His idealist, pessimistic view thus contrasted sharply with the materialist, optimistic perspective put forth by Karl Marx.

Critics of Weber argued that his reading of the rise of capitalism was naive. Many capitalist institutions were evident in Catholic northern Italy, for example, long before the Industrial Revolution. Others criticize his privileging of religion as the source of social change, asserting that Protestantism was a response to, not a cause of, the new system of class and markets spreading throughout northwestern Europe.

The Parsonian Turn

Talcott Parsons, a professor of sociology at Harvard University, founder of the doctrine of structural functionalism and the first to translate *The Protestant Ethic* into English, played a decisive role in the growth and transformation of modernization theory, adapting it to the historical conditions of the mid 20th century. For Parsons, to be modern meant to be Western in terms of institutions, culture, economy, values, and governance: The terms were synonymous, and it was impossible to have one state without the other. Modernization in this light became an unabashed

celebration of capitalism—and the United States—during the height of the Cold War and a justification of American foreign policy toward states in the developing world.

The Parsonian modification of Weber’s project asserted that Third World countries should deliberately “follow” the path set forth by the United States and its allies, conscientiously adopting their culture, political systems, and markets. Over time, this view held, the developing world would evolve into something resembling the prosperous democracies of the West. What was called for was therefore gradual evolution, not rapid revolution (the latter being the siren call of communist parties everywhere). Thus, whereas Weber held that the rise of capitalism was contingent and specific to northern Europe, Parsonian modernization theory maintained that it was inevitable and universal.

Modernization theory posited that the process of rational economic development occurred simultaneously in the economic, cultural, and political domains. Economically, countries were theorized to move through a linear sequence of stages, such as via the Fischer-Price notion of agricultural, industrial, and postindustrial (service based) economies (although in reality, many countries become postindustrial without ever developing a large manufacturing sector).

The most famous explication of modernization theory was probably Walter Rostow’s exposition in *The Stages of Economic Growth: A Capitalist Manifesto*, published in 1960 with a title that explicitly played on Marx and Engel’s *Communist Manifesto*. Rostow, economic advisor to President John F. Kennedy, held that development was akin to an airplane taking off and proceeded through five distinct stages. The first, *traditional society*, was characterized by low standards of living and preindustrial technologies and life styles and was essentially static. The source of change in this context was necessarily exogenous. Such a stage characterized feudal Europe and characterizes the most economically backward parts of the world today (e.g., New Guinea, parts of sub-Saharan Africa, or Bhutan). The second stage, *preconditions for takeoff*, saw the development of primary-economic-sector activities such as plantations and mining. Countries that fit this description today include Mexico, Brazil, or



Indonesia. As society moved to the third stage, *takeoff*, it witnessed the creation of a physical infrastructure and the rise of social and economic elites open to social and economic change. Take-off itself was manifested through the growth of an export-oriented manufacturing sector as the country became increasingly internationalized, with foreign direct investment fueling much of the growth. As rising incomes generated a growing working class or middle class, domestic demand began to grow, and society became increasingly urbanized. China is perhaps the outstanding example of this stage at this moment in history, as are other rapidly growing Asian newly industrializing countries (NICs). The *drive to maturity*, the fourth stage, witnessed self-sustaining growth, labor unions, and an expanding commercial and industrial base as the division of labor became more refined and specialized. Current examples include South Korea and Taiwan. Finally, Rostow's nirvana, *high mass consumption*, was defined by an enormous middle class, high per capita disposable incomes, low degrees of poverty, and well-developed markets. Obvious examples would be the United States, Canada, Japan, and northwestern Europe.

Closely associated with this version of modernization is the process of spatial diffusion of ideas, technologies, institutions, and change. Modernization theory held that diffusion occurred at two intertwined scales. Internationally, modern characteristics diffused from the First to the Third World (never the other way) via organizations such as the World Bank, the International Monetary Fund, and transnational corporations, as well as through large-scale projects such as the Green Revolution. Within countries, modernity diffused from urban areas to rural ones; cities were viewed as dynamic, propulsive, forward-looking cores, and agrarian regions as inherently hidebound, static, and dominated by antimodern traditions. The implementation of growth pole theory in the 1950s and 1960s was an explicit expression of this ideology. In this light, given the faith that markets only created wealth, poverty was simply the result of the incomplete diffusion of markets, a state that could ultimately be overcome via the adoption of Western norms, technologies, and institutions. Modernization theory thus views uneven development as an incidental,

transient feature of capitalism, not an inevitable result.

Also closely associated with the economic dimensions of modernization theory was the program of population control. Indeed, the gains of rapid economic growth could easily be swallowed up by an expanding population, a view with Malthusian overtones. Modernization theorists, who also implicitly held an affinity for the demographic transition model and its stages, which so closely resembled Rostow's, advocated for birth control policies throughout the developing world. Programs such as the U.S. Agency for International Development (USAID), for example, posited population control and the resulting economic growth it was theorized to bring as a means of enhancing the appeal of the West against the siren call of communism in the wake of the Cuban Revolution of 1959.

In addition to the economic argument, modernization theory also proffered a cultural explanation. Tradition, in this view, was synonymous with economic backwardness and stagnation. Typically dominated by religion, premodern traditions were held to be irrational and detrimental to the process of market expansion and all the fruits it promised. Tradition, therefore, must be sacrificed on the altar of economic transformation. To be modern was to accept change—even rapid, bewildering, alienating change—as inevitable and as inherently good and necessary. That is, change was synonymous with progress. Examples of modernizationist interpretations of culture include David McClelland's analysis of textbooks throughout the developing world in the 1950s, in which he examined the degree to which they promoted entrepreneurial versus traditional values, and Robert Bellah's interpretation of Japan's modernization, which he asserted acquired a "Tokugawa spirit" that mimicked the Protestant ethic and propelled that country's entry into the industrial era. (Later Bellah changed his mind and renounced this view.)

Finally, modernization theory contained an explicitly political theorization, one that not only celebrated the West, and especially American values and institutions, but maintained that capitalism was a necessary precondition for the growth of democratic institutions. This line of thought held that only market-based societies generated



the wealth necessary to sustain a large middle class, which ensured the prevalence of civil liberties, including freedom of speech, assembly, and the press. (However, unlike later neoliberal theorists, modernization theory upheld a proper role for the state.) Unlike traditional societies, in which political power was centralized in the hands of a tiny elite, markets, theorists such as Samuel Huntington held, generated numerous, dispersed centers of power. Later, the famous economist Milton Friedman picked up this view in his assertion that capitalism and democracy always went hand in hand with one another: Economic freedoms and political freedoms were inevitably coupled.

Criticisms of Modernization Theory

Despite its numerous successes, modernization theory came under withering attack in the late 1960s and 1970s. Many pointed to its profoundly ethnocentric reading of culture, which posited the West as the only feasible or desirable model of economic growth, as well as its explicit universalization of American values. Indeed, modernization theorists could be maddeningly arrogant, condescending, and racist, as this quote by K. H. Silvert in 1962 illustrates:

There is something in the quality of the Latin American man and his culture which has made it difficult for him to be truly modern . . . which has made this part of the Western world so prone to excesses of scoundrels, so politically irrational in seeking economic growth, and so ready to reach for gimmicks. (Quoted in Valenzuela & Valenzuela, 1978, p. 542)

Indeed, by focusing only on the internal causes of poverty, specifically on ideas prevalent within a culture, modernization theorists were resolutely silent about the historical context of the societies they examined, ignoring the powerful role of colonialism and its legacy as well as the dynamics of the modern world system, which perpetuate, not reduce, uneven spatial and social development. Such a view ends up blaming the victims of poverty for their status.

As dependency and world-systems theories gained ground in the 1970s, modernization theory suffered a steady decline in popularity and was

quietly relegated to the background of development discourse. Dependency theorists pointed to the ways in which colonialism had left a highly uneven playing field among the world's states, creating a world economy that disadvantaged newly independent countries in the developing world. Interdependence, in this view, amounted to little more than exploitation. Far from eradicating poverty, markets reproduced it through the development of underdevelopment. In this view, developing countries do not simply lag behind the West. However, the rise of neoliberal thought in the 1980s and 1990s in some respects spelled a resurgence of modernization theory, as both schools of thought place enormous emphasis on the market as the primary mechanism driving social change and prosperity. There were differences, however, between modernization theory and neoliberalism, as the former did not universally advocate the privatization and deregulation favored by the latter.

Barney Warf

See also Colonialism; Decolonization; Demographic Transition; Dependency Theory; Developing World; Development Theory; Emerging Markets; Export-Led Development; Foreign Aid; Foreign Direct Investment; Import Substitution Industrialization; Industrialization; Modernity; Neo-Malthusianism; Newly Industrializing Countries; Peasants and Peasantry; Regional Economic Development; Remittances; Rural-Urban Migration; Underdevelopment; Uneven Development; Urbanization; World-Systems Theory

Further Readings

- Bellah, R. (1970). *Tokugawa spirit*. New York: Free Press. (Original work published 1957)
- Gilman, N. (2007). *Mandarins of the future: Modernization theory in Cold War America*. Baltimore: Johns Hopkins University Press.
- Harrison, D. (1988). *The sociology of modernization and development*. London: Routledge.
- Latham, M. (2000). *Modernization as ideology: American social science and "nation building" in the Kennedy era*. Chapel Hill: University of North Carolina Press.
- McClelland, D. (1999). *The achieving society*. New York: Free Press. (Original work published 1961)



- Roberts, T. (2000). *From modernization to globalization: Perspectives on development and social change*. New York: Wiley-Blackwell.
- Rostow, W. (2008). *The stages of economic growth: A capitalist manifesto*. Cambridge, UK: Cambridge University Press. (Original work published 1960)
- So, A. (1990). *Social change and development: Modernization, dependency and world-system theories*. Newbury Park, CA: Sage.
- Valenzuela, J., & Valenzuela, A. (1978). Modernization and dependency: Alternative perspectives in the study of Latin American underdevelopment. *Comparative Politics*, 10, 535–557.
- Weber, M. (1965). *The Protestant ethic and the spirit of capitalism* (T. Parsons, Trans.). New York: Unwin. (Original work published 1905)

MODIFIABLE AREAL UNIT PROBLEM

Often the area (or regional) level rather than the individual level is the target of inference in geographic and environmental science studies. The use of aggregated data sources while performing geographic (or spatially) related inquiries may well lead the researcher into an encounter with the modifiable areal unit problem (MAUP). Geographic analysis requires one to not only consider geographic area—the scale—but also the resolution of the data to be analyzed. The relationships between variables will change as the scale of measurement (resolution) changes. The relative size, scale, level of detail, or depth of penetration that characterizes an object or activity relates to the MAUP. This entry provides a cursory overview of the MAUP as it relates to geographic inquiry.

The outcome of two different geographic (or spatial) aggregations produce different degrees of within-area homogeneity; in geographic terms, the generic name for this is *modifiable areal unit problem*. The MAUP is common to all geographic (spatially) aggregated data. It consists of two interconnected parts. First, there is ambiguity about what constitutes the objects of spatial

study—identified as the scale and aggregation problem. Second, there are the implications this holds for the methods of analysis commonly applied to aggregated data. The MAUP requires the researcher to ask the questions of how to incorporate scale into methods of geographic analysis, how to determine and identify the operational scale of geographic phenomenon, how relationships between variables change as the resolution (scale of measurement) increases or decreases, and to what extent information on geographic relationships at one scale can be used to make inferences about relationships at other scales.

The term *modifiable* is used because neither the choice of the number of geographic units (the scale of the analysis) nor their particular arrangement (how partitioning or zoning is selected given the scale of analysis) is essential and any number of other choices can be made. The MAUP consists of two problems, one statistical and the other geographical, and it is often difficult to isolate one from the other. Statistically, the underlying concern is that the analyst may not be using the appropriate statistic for the problem being addressed. Geographically, the problem is intrinsic to the observation of the effects of different geographic (or spatial) aggregations and the subsequent interpretation of the patterns revealed by the different aggregations.

Hence, it is imperative that the MAUP be analyzed in the context of a well-defined model that identifies the different scale components (from the individual level upward) underlying the behavior of each of the variables.

Emily A. Fogarty

See also **Ecological Fallacy; Scale, Social Production of; Scale in GIS; Spatial Data Integration; Spatial Resolution**

Further Readings

- Haining, R. (2003). *Spatial data analysis: Theory and practice*. Cambridge, UK: Cambridge University Press.
- Openshaw, S. (1983). *The modifiable areal unit problem: Concepts and techniques in modern geography*. Norwich, UK: Geo Books.



MONEY, GEOGRAPHIES OF

Geography and money are no strangers to each other. A sizeable literature has documented the complex, often contradictory ways in which finance and space are shot through with each other. This topic finds its origins in an earlier sociology of money: Writers as diverse as Karl Marx, Max Weber, Émile Durkheim, and Georg Simmel were all concerned with the relations between modernity and commodification. Under industrial capitalism, for example, and the waves of urbanization it generated, cities arose as sites of new forms of social relations centered on money, leading to the widespread objectification of social relations in which everyone becomes a buyer or a seller. The researchers of the Chicago School of sociology, particularly Louis Wirth, were appalled by the predatory relations and culture of calculation that pervaded capitalist societies as ever more people were drawn into a money economy.

In its broadest sense, therefore, money was instrumental in the time-space compression of capitalism, the formation of the nation-state, and the rise of a global economy. Capitalism without complex systems of finance to lubricate investment and trade is unthinkable. Because money is highly mobile, most attention has focused on the international geography of money and the ways in which money supplies are regulated at the global scale.

The Bretton Woods agreements negotiated in New Hampshire following World War II, erected at the behest of the United States, led to the “Bretton Woods system” of international financial management and the General Agreement on Tariffs and Trade (GATT). Between 1947 and 1971, there was very little exchange rate fluctuation; most currencies outside of the Soviet bloc of states were pegged to the U.S. dollar, fluctuating only within 2% in a given year without International Money Fund (IMF) intervention. The dollar, in turn, was pegged to gold, at \$35 an ounce. The fixed exchange rate system required the free international movement of gold as well as minimal government interventions to offset its effects, such as changes in the money supply designed to change real interest rates. The regulations on

exchange rates imposed by Bretton Woods were largely designed to avoid the rounds of depreciations that deepened the Great Depression of the 1930s. Under this system of international regulation, currency appreciations or depreciations reflected government fiscal and monetary policies within a system of relatively nationally contained financial markets in which central bank intervention was effective. Trade balances and foreign exchange markets tended to be strongly connected: Rising imports caused a currency to decline in value as domestic buyers needed more foreign currency to finance purchases.

The system of stable currencies ended abruptly with the collapse of the Bretton Woods agreement in 1971 and the shift to floating exchange rates in 1973. The system’s demise reflected U.S. trade imbalances with its European partners and the overvaluation of the dollar, whose strength was maintained only through a steady outflow of gold. The accumulation of U.S. dollars overseas, which significantly enhanced the growing Euro-market in the 1960s, contributed to an increasingly unviable trade imbalance. Finally, President Richard Nixon announced that the United States would no longer abide by the Bretton Woods rules governing the dollar’s convertibility to gold, forcing a global switch to flexible exchange rates. Hereafter, supply and demand would dictate the value of a nation’s currency, and currency trading became big business.

The global sea change in capitalism that began with the traumatic petrocises of the 1970s, and the massive restructuring of industrialized economies (i.e., widespread deindustrialization), included a fundamental renegotiation of the relations between financial capital and space. Freed from many of the technological and political barriers to movement, capital has become not merely mobile but hypermobile. A key part of this new order was the emergence of what might be called stateless money, which originated in its contemporary form through the Euromarket. Originally, the Euromarket comprised only trade in assets denominated in U.S. dollars but not located in the United States; today it has spread far beyond Europe and includes all trade in financial assets outside the country of issue (e.g., Eurobonds, Eurocurrencies). One of the Euromarket’s prime advantages was its lack of national regulations:

Unfettered by national restrictions, it has been upheld by neo-classical economists as the model of market efficiency.

Capital markets worldwide were profoundly affected by the microelectronics revolution, which eliminated transaction and transmission costs for the movement of capital much in the same way that deregulation and the abolition of capital controls decreased regulatory barriers. Banks, insurance companies, and securities firms, which are generally very information intensive in nature, have been at the forefront of the construction of an extensive network of leased and private telecommunication networks, particularly fiber optics lines. Electronic funds transfer systems form the nervous system of the international financial economy, allowing banks to move capital around at a moment's notice, arbitraging interest-rate differentials, taking advantage of favorable exchange rates, and avoiding political unrest. Such networks give banks the ability to move money—by some estimates, more than \$3 trillion daily—around the globe at stupendous rates (the average currency trade takes less than 25 seconds): Subject to the process of digitization, information and capital become two sides of the same coin.

In the securities markets, global telecommunications systems facilitated the steady integration of national capital markets. Electronic trading frees stock analysts from the need for face-to-face interaction to gain information. The National Association of Securities Dealers Automated Quotation System (NASDAQ), the first fully automated electronic marketplace, is now the world's largest stock market, lacking a trading floor. Online trading allows small investors to trawl the Internet for



A collection of various currencies from countries spanning the globe. Money has been instrumental in the time-space compression of capitalism, the formation of the nation-state, and the rise of a global economy.

Source: Russell Shively/iStockphoto.

information, including real-time prices, eroding the advantage once held by specialists such as Reuters, and execute trades by pushing a few buttons.

The ascendancy of electronic money shifted the function of finance from investing to speculation, institutionalizing volatility in the process. Foreign



investments, for example, have increasingly shifted from foreign direct investment (FDI) to intangible portfolio investments such as stocks and bonds, a process that reflects the securitization of global finance. Unlike FDI, which generates predictable levels of employment, facilitates technology transfer, and alters the material landscape over the long run, financial investments tend to create few jobs and are invisible to all but a few agents, acting in the short run with unpredictable consequences. Furthermore, such funds are provided by nontraditional suppliers: a large and rapidly rising share of private capital flows worldwide is no longer intermediated by banks. Thus, not only has the volume of capital flows increased, but the composition and institutions involved have changed. Globalization and electronic money have had particularly important impacts on currency markets. Since the shift to floating exchange rates in 1971, trading in currencies has become a big business, driven by the need for foreign currency associated with rising levels of international trade, the abolition of exchange controls, and the growth of pension and mutual funds, insurance companies, and institutional investors.

The world of electronic money has changed not only the configuration and behavior of markets but also their relations to the nation-state. Classic interpretations of the nation-state rested heavily on a clear distinction between the domestic and international spheres, a world carved into mutually exclusive geographic jurisdictions. State control in this context implies control over territory. In contrast, the rise of electronic money has generated a fundamental asymmetry between the world's economic and political systems. Because finance has become so inextricably intertwined with electronic transfers of funds worldwide, it presents the global system of nation-states with unprecedented difficulties in attempting to reap the benefits of international finance while simultaneously attempting to avoid its risks.

Barney Warf

See also **E-Commerce and Geography**; **Economic Geography**; **Finance, Geography of**; **Globalization**; **Telecommunications and Geography**

Further Readings

- Cohen, B. (1998). *The geography of money*. Ithaca, NY: Cornell University Press.
- Corbridge, S., Martin, R., & Thrift, N. (1994). *Money, power and space*. Oxford, UK: Blackwell.
- Leyshon, A., & Thrift, N. (1992). Liberalization and consolidation: The single European market and the remaking of European financial capital. *Environment and Planning A*, 24, 49–81.
- Leyshon, A., & Thrift, N. (1997). *Money/space: Geographies of monetary transformation*. London: Routledge.
- Martin, R. (Ed.). (1999). *Money and the space economy*. New York: Wiley.
- Solomon, R. (1999). *Money on the move: The revolution in international finance since 1980*. Princeton, NJ: Princeton University Press.
- Strange, S. (1998). *Mad money: When markets outgrow governments*. Ann Arbor: University of Michigan Press.
- Thrift, N., & Leyshon, A. (1994). A phantom state? The de-traditionalization of money, the international financial system and international financial centres. *Political Geography*, 13, 299–327.



MONMONIER, MARK (1943–)

A professor since 1969 and a prolific author, Mark Monmonier has made invaluable contributions to geography. Specializing in cartography, his work has been internationally acclaimed and is highly influential both inside and outside geography.

After obtaining degrees from Johns Hopkins University (BA, 1964) and the Pennsylvania State University (MS, 1967; PhD, 1969), Mark taught at both the University of Rhode Island and the State University of New York at Albany. In 1973, he accepted a position in the Department of Geography at Syracuse University, and after 25 years, he was awarded the prestigious title of Distinguished Professor.



Funded through institutions such as the National Science Foundation and the John Simon Guggenheim foundation, Monmonier's research has focused on a variety of cartographic topics. Demonstrated through his 200-plus articles and conference papers as well as 16 books, his breadth of knowledge and contribution to geography are extensive. His early interests focused on the use of computer algorithms in statistical mapping. In the late 1980s and through the 1990s, Monmonier became a leader in interactive or digital cartography, a subject matter now generally labeled GIScience. His 1982 book, *Computer-Assisted Cartography: Principles and Prospects*, is considered the first commercial textbook on computer cartography. Though his writings on computer algorithms, map design, and digital cartography were formative in GIScience, Monmonier's interests began to shift toward the social side of cartography, and by the 1990s, his research focused predominantly on 20th-century cartographic technologies and their societal impacts.

Monmonier's publications on social-mapping projects have helped advance understandings of the social, political, and historical contexts in which maps are made and used. More specifically, he has published critically acclaimed books on diverse topics such as journalistic cartography, election mapping, place names, and surveillance mapping. His insights on such topics have been formative in the critique of cartography as a social and political project—rather than a scientific or objective one. Published in 1996, *How to Lie With Maps* is perhaps Monmonier's most widely read and cited book. As useful as maps can be, he reminds his readers that they are generalizations and that they do "lie." Through his accessible writing and often humorous tone, he has taught academics, students, and the general public alike to maintain a cautious and skeptical perspective of maps. Indeed, in 2004, he was awarded a Globe Book Award for Public Understanding of Geography by the Association of American Geographers.

In addition to Monmonier's significant contributions in research and writing, he is an award-winning teacher and graduate advisor and has been an active member of several professional organizations. Some of Monmonier's notable service contributions include being the associate

editor and, later, editor of *The American Cartographer*, the president of the American Cartographic Association, and the editor for the highly regarded (and anticipated) sixth volume of the History of Cartography Project. As of 2009, Monmonier remains an active teacher and is deeply involved with numerous research and writing projects.

Karen Culcasi

See also **Cartography; Cartography, History of**

Further Readings

- Monmonier, M. (1993). *Mapping it out: Expository cartography for the humanities and social sciences*. Chicago: University of Chicago Press.
- Monmonier, M. (1998). *Cartographies of danger: Mapping hazards in America*. Chicago: University of Chicago Press.
- Monmonier, M. (1999). *Maps with the news: The development of American journalistic cartography*. Chicago: University of Chicago Press.
- Monmonier, M. (2000). *Air apparent: How meteorologists learned to map, predict, and dramatize weather*. Chicago: University of Chicago Press.
- Monmonier, M. (2001). *Bushmanders and Bullwinkles: How politicians manipulate electronic maps and census data to win elections*. Chicago: University of Chicago Press.
- Monmonier, M. (2002). *Spying with maps: Surveillance technologies and the future of privacy*. Chicago: University of Chicago Press.
- Monmonier, M. (2004). *Rhumb lines and map wars: A social history of the Mercator projection*. Chicago: University of Chicago Press.
- Monmonier, M. (2007). *From squaw tit to whorehouse meadow: How maps name, claim, and inflame*. Chicago: University of Chicago Press.
- Monmonier, M. (2008). *Coast lines: How mapmakers frame the world and chart environmental change*. Chicago: University of Chicago Press.
- Monmonier, M., & de Blij, H. (1996). *How to lie with maps* (2nd ed.). Chicago: University of Chicago Press.



MONSOONS

The term *monsoon* derives from the Arabic word for season, *mausim*, and refers to the seasonal reversal in atmospheric circulation and the associated precipitation in tropical and subtropical regions. Such reversal of wind direction occurs with the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ) in conjunction with the annual north-south progression of the sun. The movement of the ITCZ induces a temperature difference between the land surface and the ocean. The resultant difference in surface pressure between the ocean and land areas fuels the monsoon winds. This entry presents a brief review of how the monsoonal regions throughout the globe are demarcated and examines in detail the characteristics of the South Asian monsoon.

Monsoonal regions are presently identified by seasonal changes in cross-equatorial flows, changes in wet- and dry-spell transitions, and seasonal changes in divergent circulation in the upper troposphere associated with the large-scale atmospheric overturning taking place in tropical regions. Cross-equatorial flows occur when the mean wind flows across the equator along pressure gradients established due to land-ocean temperature contrasts. Monsoonal climates are characterized by distinct wet and dry spells with wet spells occurring during the monsoon season and dry spells at other times. The large-scale overturning of the atmosphere refers to the three-dimensional circulation associated with the monsoons. When the continental land masses heat up with the ITCZ overhead, large-scale convection or rising motion takes place. Such rising motion in the lower troposphere around 10° latitude is offset by subsidence around 20° . This results in divergent circulation in the upper troposphere. Simultaneously, meridional and zonal circulation cells are set into action with winds blowing in from the cooler surrounding oceans in response to the pressure gradient (see Figure 1).

Current methods emphasize that the monsoon is a global phenomenon where the different regional components interact with each other and the overall general circulation of the atmosphere.

The regional monsoonal components include the tropical and subtropical regions of Asia,

Australia, Africa, South America, and southwestern North America. These regions can be visually identified through the seasonal reversal in mean summer (July) and winter (January) winds at the 850-hPa (hectopascal) geopotential (potential energy of unit mass relative to sea level) height level (Figure 2). In South America, seasonal reversal of the winds is not as distinct as in other regions. The change appears in the direction of the cross-equatorial flow in the Amazon region. In North America, there is no cross-equatorial flow. However, there is a distinct seasonal reversal in mean winds.

Regional Monsoons

Asian Monsoon

The Asian monsoon is the most dominant regional component due to the influence of the Eurasian landmass, the Tibetan Plateau, and the Himalayan mountain range. W. Qian and colleagues demarcate four subcomponents: (1) the South Asian system over the Indian subcontinent and the Arabian Sea; (2) the Southeast Asian system, extending from the Bay of Bengal to Indochina and the southern South China Sea; (3) the East Asian system, extending over the northern South China Sea, eastern China, the Korean Peninsula, and Japan; and (4) the Tibetan Plateau system.

The Asian summer monsoon sets in when a heat low forms over the Eurasian landmass with the advent of the Northern Hemisphere spring. A land-to-sea surface circulation takes place in winter, when the oceans south of the Asian landmass warm with the southward migration of the ITCZ. The wintertime land-to-sea circulation is known as the Asian winter monsoon.

The summer monsoon of the South Asian subcomponent is the most well-defined and annually regular monsoon system due to the influence exerted by the Himalayas on the position of the subtropical jet stream. When the ITCZ lies over the Tibetan Plateau in the Northern Hemisphere spring, a heat low is established in the lower troposphere, while high pressure or divergence is established in the upper atmosphere. As a result, the subtropical jet stream switches north of the Himalayas and directs weather systems that draw

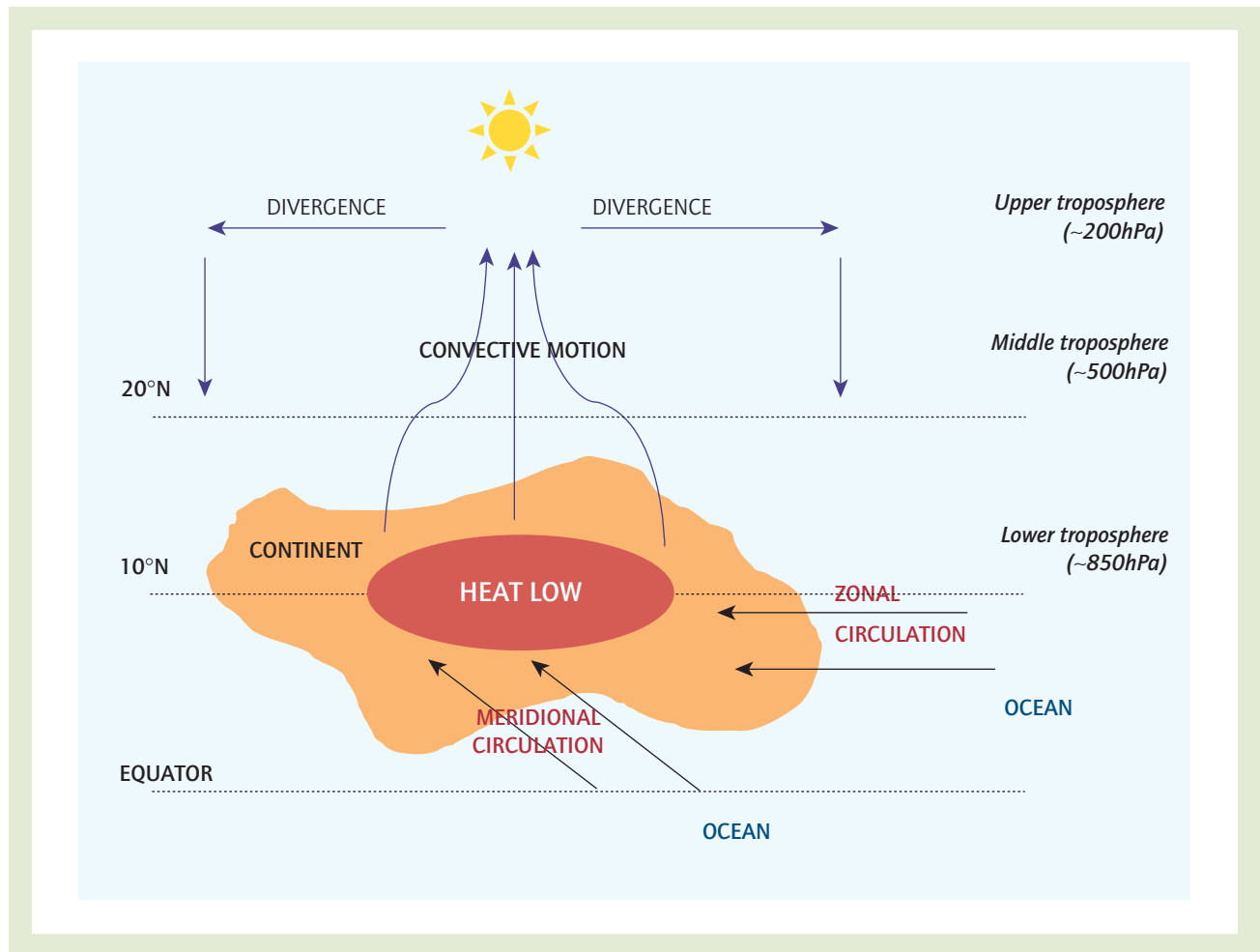


Figure 1 Schematic of the three-dimensional overturning circulation

Source: Author.

moisture in from the surrounding cooler Arabian and Indian oceans toward land.

Australian Monsoon

The Australian summer monsoon sets in when the desert region of north central Australia heats up with the progression of the ITCZ south of the equator in the Southern Hemisphere spring. Northwestern Australia receives rainfall primarily in the form of thunderstorms when the heat low draws in moisture from the warm tropical oceans.

African Monsoon

The African monsoon prevails over the sub-Saharan and Sahelian regions of West Africa.

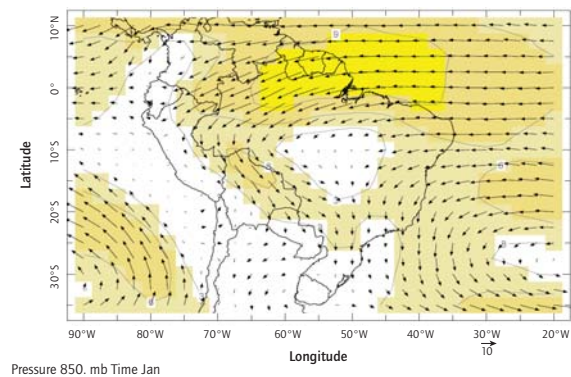
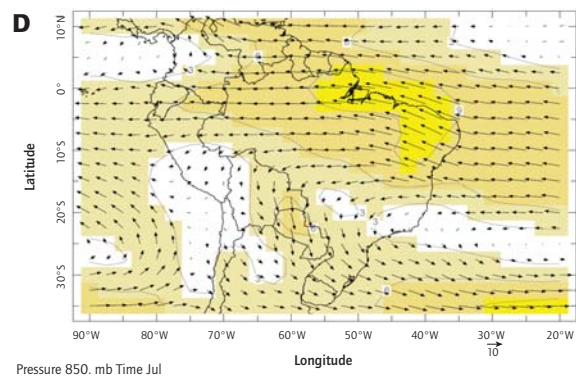
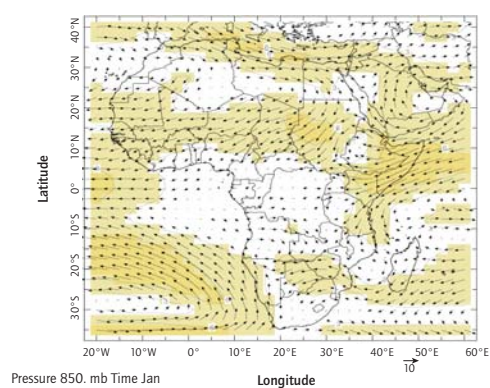
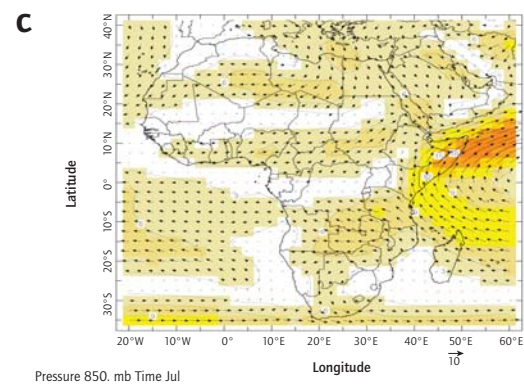
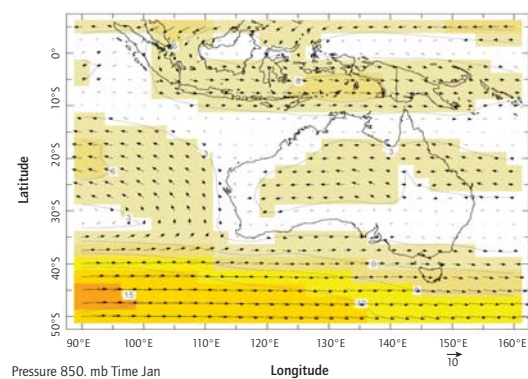
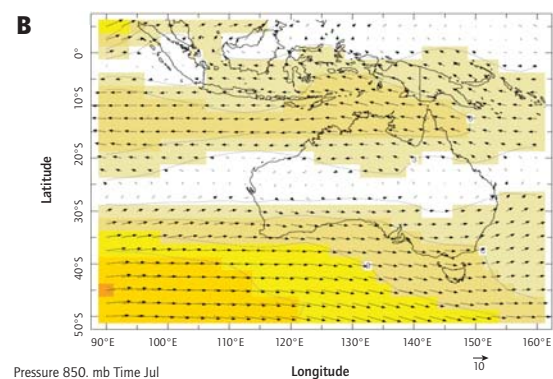
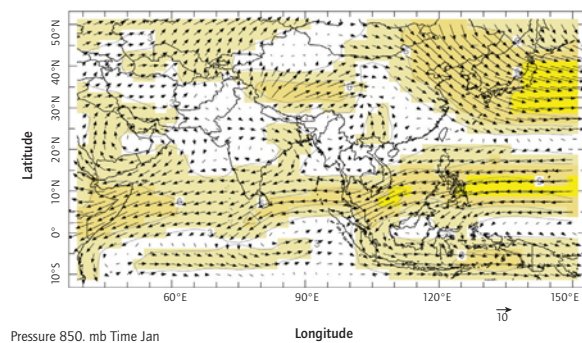
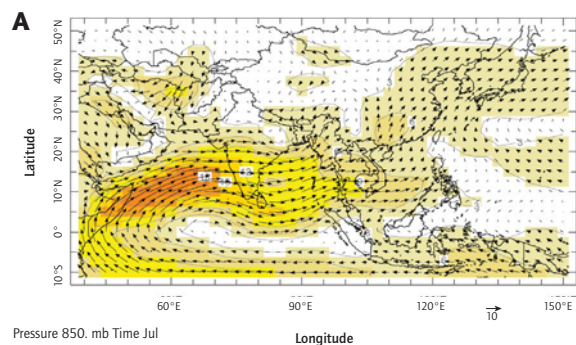
Moisture-laden air is transported from the eastern equatorial Atlantic in response to sensible heating over north central Africa during the Northern Hemisphere summer.

South American

A heat low is established over the Bolivian Andes when the ITCZ is south of the equator in the Southern Hemisphere spring. This draws in moisture-laden cross-equatorial winds from the Atlantic.

North American Monsoon

A heat low is established over the mountainous region in southwestern North America during the



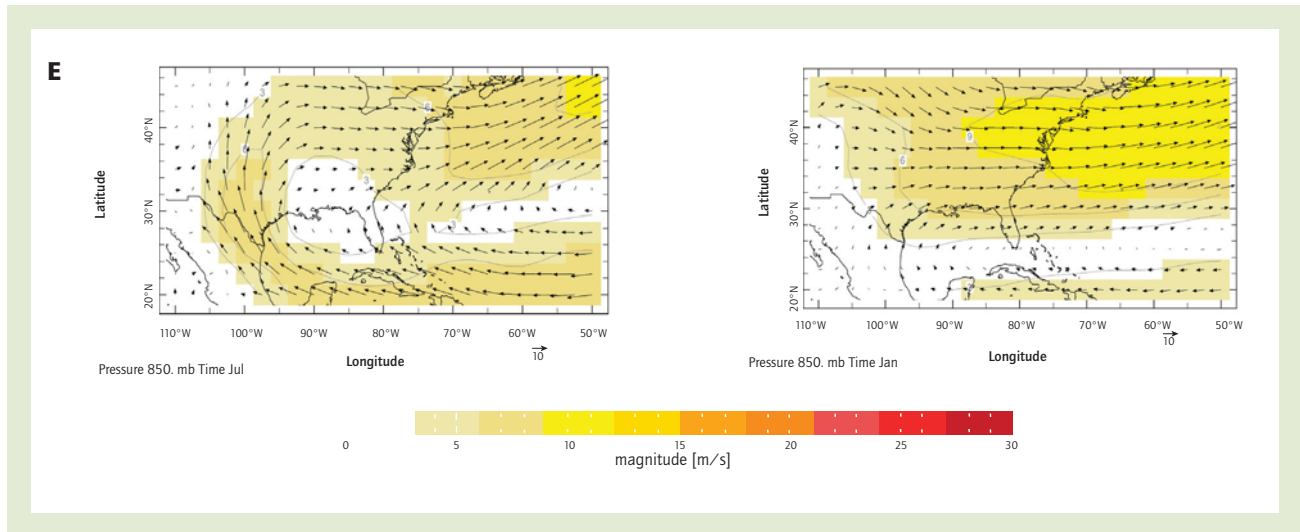


Figure 2 Mean wind vector at 850 hectopascals in July (*left panels*) and January (*right panels*), showing the seasonal reversal in winds and the cross-equatorial flows (where relevant) for (page 1942) (A) Asia, (B) Australia, (C) Africa, (D) South America, and (this page) (E) southwestern North America

Source: Author.

Northern Hemisphere summer. This draws in moisture-laden southwesterly winds over northern Mexico and southwestern North America.

South Asian Monsoon

Impacts on Society

Rainy seasons in South Asia are associated with either the summer or the winter phase of the South Asian subcomponent of the Asian monsoon. The summer monsoon is the key rainy season in the Indian subcontinent. However, the winter monsoon is the major source of rainfall feeding the main agricultural season—the *Rabi*—in southern and southeastern India. It also feeds the main agricultural season—the *Maha*—in Sri Lanka. Rainfall over southern peninsular India and Sri Lanka is diminished during the summer monsoon and enhanced during the winter monsoon.

Extremes in the intensity of the summer and winter monsoons have been associated with devastating droughts and floods in the Indian subcontinental region. The impact of monsoonal extremes on society is profound, as agriculture is the mainstay of the economy in most countries in the region.

Understanding the mechanisms that govern the South Asian monsoon's onset, intensity, duration, and interannual variability is critical to assessing its predictability for purposes of agricultural decision making in the region.

Characteristics and Predictability

There appears to be a negative correlation between South Asian summer monsoon rainfall and the El Niño episodes (El Niño Southern Oscillation—ENSO), and vice versa during La Niña. However, while years of severe drought were associated with the failure of the summer monsoon during El Niño episodes, not all El Niño episodes have caused droughts over India. The exact reason for such fluctuations in the ENSO-monsoon relationship is as yet unclear. Theories have been put forth on the influence of Indian Ocean sea surface temperatures (SSTs) in modulating the ENSO-monsoon relationship.

The ENSO signal appears over the Indian Ocean in preferred interannual and decadal timescales. The signal is apparent in the influence of ENSO on the Indian Ocean dipole (IOD). The exact nature of the relationship between the IOD and the ENSO is as yet unclear. In fact, solar



cycles may modulate the connection between Pacific and Indian Ocean variability such that ENSO-related variability extends into the Indian Ocean during years of low solar activity, when weaker convective activity over the Indian Ocean makes it more susceptible to remote forcing and vice versa.

The South Asian monsoon is also closely related to a phenomenon called the Tropical Biennial Oscillation (TBO). According to the TBO theory, a strong monsoon in 1 year, accompanied by warm SSTs and intense convection, will cool the oceans, and the memory will carry on until the next year. The cooler SSTs will lead to a weaker monsoon and less cooling through latent heating, which will lead to a warmer atmospheric column and warmer SSTs that will in turn prevail until the next year. The amplitude of the TBO could be modulated during years of ENSO-IOD coupling, as the TBO is modulated by an 11-year solar cycle.

Land surface conditions over Eurasia are known to affect the strength of the summer monsoon such that higher than normal snow cover in the Tibetan Plateau and lower than normal snow cover in the Eurasian region precede heavy summer monsoon rainfall.

The South Asian monsoon has “active” and “break” cycles in a given monsoon season. These cycles have periods of 30 to 60 days. These active-break cycles are linked to intraseasonal oscillations (ISOs) associated with the northward propagation of convection. Studies have noted an inverse relationship between ISO activity and South Asian monsoon strength.

Anomalous convective heating over the equatorial Pacific during El Niño episodes results in westward-propagating Rossby waves. These Rossby waves are manifest as positive vorticity anomalies along the North African/Asian Jet. Cold air accompanies such positive vorticity anomalies and reduces the land surface temperature over Asia. This weakens the meridional temperature gradient, reduces the easterly vertical shear (difference of the zonal winds at 200 and 850 hPa over 50°E–90°E and 0°–15°N) of the mean zonal wind, and reduces the northward migration of the tropical convergence zone. This decreases the number of intraseasonal storms reaching land during a monsoon season and reduces the length of the

rainy season. The overall strength of the monsoon results from the interplay between ENSO, the TBO, ISOs, and the annual cycle.

Dynamical predictions of the Asian summer monsoon have not been successful. Current global circulation models cannot capture the ocean-atmosphere coupled variability and do not include land surface processes in an adequate manner. While statistical predictions of the monsoon have had far greater success than dynamical predictions, fluctuations in the quality of the statistical modeling of the monsoon highlight the need to understand the physical basis of the correlations.

Global Change and the South Asian Monsoon

Factors driving long-term trends in boundary conditions drive changes in the strength of the land-ocean temperature gradient and, thus, the strength of the monsoons. Such factors include Earth’s orbital changes, anthropogenic greenhouse gas concentrations, volcanic eruptions, and anthropogenic aerosol loadings. Surface wind speeds associated with the summer and winter phases of the East Asian monsoon declined significantly from 1969 to 2000 due to a weakening of the land-ocean temperature gradient, probably attributable to global warming. There is as yet no evidence on whether wind speeds associated with the South Asian summer and winter monsoons have declined. The Intergovernmental Panel on Climate Change’s Fourth Assessment Report projects an increase in the seasonal mean precipitation rate over South India, Sri Lanka, and the Indian Ocean immediately west of Sri Lanka during summer (June to August) and a decrease in the seasonal mean precipitation rate during winter (December to February) over southern India, the northern Bay of Bengal, and the seas adjoining eastern Sri Lanka in 2090 to 2099. Whether such an increase in summer precipitation and decrease in winter precipitation imply explicit changes in the strength of the South Asian monsoon is yet to be established.

Dinali Nelun Fernando

See also **Atmospheric Circulation; Coastal Hazards; Coriolis Force; Cyclones: Extratropical; Cyclones: Occluded; El Niño; La Niña; Oceans**



Further Readings

- Kodera, K., Coughlin, K., & Arakawa, O. (2007). Possible modulation of the connection between the Pacific and Indian Ocean variability by the solar cycle. *Geophysical Research Letters*, 34, L03710.
- Rajeevan, M. (2001). Prediction of the Indian summer monsoon: Status, problems and prospects. *Current Science*, 81, 1451–1457.
- Ramage, C. S. (1971). *Monsoon meteorology* (International Geophysics Series, Vol. 15). New York: Academic Press.
- Saji, N. H., Goswami, B. N., Vinayachandran, P. N., & Yamagata, T. (1999). A dipole mode in the tropical Indian Ocean. *Nature*, 401, 360–363.
- Shaman, J., & Tziperman, E. (2007). Summertime ENSO–North African–Asian jet teleconnections and implications for the Indian monsoons. *Geophysical Research Letters*, 34, L11702.
- Suppiah, R. (1992). The Australian summer monsoon: A review. *Progress in Physical Geography*, 16, 283–318.
- Trenberth, K. E., Stepaniak, D. P., & Caron, J. M. (2000). The global monsoon as seen through the divergent atmospheric circulation. *Journal of Climate*, 13, 3969–3993.
- Wang, B. (Ed.). (2006). *The Asian monsoon*. New York: Praxis.
- Xu, M., Chang, C., Fu, C., Qi, Y., Robock, A., Robinson, D. A., et al. (2006). Steady decline of East Asian monsoon winds, 1969–2000: Evidence from direct ground measurements of wind speed. *Journal of Geophysical Research*, 111, D24111.

MORRILL, RICHARD (1939–)

Richard Leland Morrill is best known as one of the quantitative revolutionaries who impelled geography toward more scientific epistemologies, theoretical sophistication, and quantitative modes of analysis during the mid 20th century.

He was born in Los Angeles in 1939. He received a BA in geography at Dartmouth College in 1955 and then pursued graduate work at the University of Washington, where he earned his doctorate in 1959. As a graduate student at

Washington, he was one of a small but influential group of students (including William Bunge, Brian Berry, Art Getis, and Duane Marble) under the tutelage of William Garrison, a doyen of the quantitative revolution in geography, who introduced his students to quantitative analysis. Walter Tobler was also a guiding figure for these “Space Cadets” at this time. Morrill taught briefly at Northwestern University in 1959–1960, undertook a postdoctoral research position at the University of Lund in Sweden in 1960–1961, and then returned to the University of Washington in 1961 to take up an assistant professorship. He remained at Washington for the rest of his career. Morrill officially retired in 1997, and he is currently Professor Emeritus.

Morrill’s interests have always been wide ranging and difficult to chart linearly, but his work exemplified two principles: (1) that geography should be a science, as science is the most valid and reliable means of getting at the truth (this stood in contrast with the largely descriptive and parochial aims of geography in the early part of the 20th century), and (2) that geographers should work toward social and spatial justice. (Morrill was a member of CORE [the Congress of Racial Equality] in the 1960s, was involved in the civil rights and other progressive causes, and in 1969 was one of the founding members of *Antipode: A Radical Journal of Geography*.) Systematically, his work has been categorized in terms of political, economic, health, urban, population, and transportation geographies. His research specialties have included social and economic inequality, political representation, redistricting and voting behavior, and modeling spatial behavior. His career has included longtime public service at various scales of government. For example, he has served on the U.S. Census advisory committee, the King County Boundary Review Board, and the Hanford Environmental Dose Reconstruction Project, as well as serving as an expert in various redistricting court cases in Washington, Mississippi, Indiana, and California. He served as president of the Association of American Geographers (AAG) and the Western Regional Science Association. His books include *Migration and the Growth of Urban Settlement* (1965), *Spatial Organization of Society* (1970), *Geography of Poverty in the United States* (1971), *Political*



Redistricting and Geographic Theory (1981), and *Spatial Diffusion* (1988), and he has written more than 200 journal articles. Morrill was also a recipient of a Guggenheim fellowship. To this day, he remains an avid hiker, especially in his beloved Cascade Mountains, east of Seattle.

Michael Brown

See also **Quantitative Revolution; Redistricting**



MORSE, JEDEDIAH (1761–1826)

Father of Samuel Morse, inventor of the telegraph, Jedediah Morse (1761–1826) is sometimes called the father of American geography. After studying divinity at Yale, starting at age 14 and graduating in 1783, Morse became a prominent evangelical Calvinist preacher and man of letters in Charlestown, Massachusetts, near Boston, for 30 years. He was as involved in religious controversies as in geography: A staunch conservative, he wrote extensively in support of orthodox Calvinism and against the rising tide of liberal Unitarianism. In 1798, Morse famously warned of an Illuminati conspiracy, which earned him much ridicule. He was a strong Federalist and became disenchanted with the French Revolution. He was also a founder of the Andover Theological Seminary in 1808 and the American Bible Society in 1816.

As a teacher, he was dissatisfied with geography textbooks, all European in origin, which were inaccurate. During the years 1784 to 1804, Morse wrote numerous, highly popular geography textbooks. His most famous, immensely successful volume was titled *Geography Made Easy: A Short but Comprehensive System*, the first American geography text, first published in 1784 when Morse was just 23, which, with 23 editions, sold more than 400,000 copies by the 1830s. This bestseller about the emerging United States, which described Indians, New England Puritans, “uncultured Baptists,” and decadent slave holders, helped Americans understand their new country and formed an integral part of the project of

constructing nationhood and the new *geographical imaginaries* (i.e., symbolic, rather than physical, places, such as a nation or a diaspora) that it entailed. He followed this volume with *American Geography* in 1789.

Morse also published *The Elements of Geography: Adapted to the Capacities of Children and Youth, and Designed, From Its Cheapness for a Reading Book in Common Schools, as a Useful Winter Evening’s Entertainment for Young People in Private Families*, which first appeared in 1795 and went through four other editions, the last of which appeared in 1804. In 1789 and 1793 he published the two-volume *American Universal Geography*. In 1796, with the assistance of Noah Webster, he finished the first comprehensive geography of North America, titled *The American Gazetteer*, which included seven large foldout maps and 7,000 articles on various places, leaving a large legacy of colonial place names. His works helped greatly to popularize maps and cartographic literacy and made Morse the preeminent American geographer throughout the early 19th century.

His interests in geography included “civilizing” and Christianizing Native Americans. In 1820, he returned to Yale and accepted an appointment from the Secretary of War to do a major study of American Indians. He traveled for 2 years among Indian nations along the Canadian border and gained respect for their cultures; he attempted to rebut common racist stereotypes about them in an 1822 report.

Barney Warf

See also **Human Geography, History of**

Further Readings

- Brown, R. (1941). The American geographies of Jedediah Morse. *Annals of the Association of American Geographers*, 31, 145–217.
- Jackson, L. (1999). Jedediah Morse and the transformation of print culture in New England, 1784–1826. *Early American Literature*, 34, 2–31.
- Martin, G. (1998). The emergence and development of geographic thought in New England. *Economic Geography*, 74(4), 1–13.



Morse, J. (1970). *A report to the Secretary of War of the United States, on Indian affairs*. New York: Augustus M. Kelley. (Original work published 1822)

Moss, R. (1995). *The life of Jedidiah Morse: A station of peculiar exposure*. Knoxville: University of Tennessee Press.



MORTALITY RATE

The crude *mortality rate* refers to the incidence of death per 1,000 people among a given population and is thus essentially the same as the crude death rate; it is therefore closely linked to life expectancy. Mortality should not be confused with *morbidity*, the incidence or prevalence of a given disease. Demographers typically rely on age-specific and sex-specific mortality rates, which measure the number of deaths of a given 5-year age group of males or females. Mortality rates vary considerably across the life cycle, depending on the particular social circumstances in which people live. Typically, mortality rates tend to be relatively high for infants (especially in economically underdeveloped societies) and low during childhood and young adulthood, and then they rise steadily as a person enters middle age, increasing dramatically in old age. However, mortality is a complex phenomenon with multiple demographic, economic, sociological, psychological, cultural, and geographic dimensions.

Like fertility, mortality is a reflection of both biological circumstances (e.g., genetics, diet) and socio-environmental context. The causes of mortality vary greatly among societies (as well as within them). Infant mortality rates (number of deaths of babies less than 1 year old per 1,000 infants) are an important measure of a society's health, as infants are the most vulnerable members of any society. Typically, infant mortality rates are high in preindustrial societies, both historically and in the present; in much of sub-Saharan Africa, infant mortality rates exceed 120 per 1,000 babies. In contrast, economically developed regions such as North America, Japan, and Europe have infant mortality rates of less than 25 per 1,000.

In preindustrial social contexts, the leading causes of mortality are generally infectious bacterial (and to a lesser extent, viral) diseases, including, among others, respiratory infections (e.g., pneumonia), diarrheal diseases (e.g., dysentery), cholera, malaria, tuberculosis, and measles; today, that list also includes AIDS. Many of these diseases are waterborne. Thus, crude mortality rates in much of the developing world (Latin America, Africa, the Middle East, and Asia excluding Japan) tend to exceed 20 deaths per 1,000 people annually. As societies industrialize, the mechanization of agriculture and the correspondingly lower prices of food tend to improve diets and thus lower mortality rates and raise life expectancies. Improved public health measures (particularly, clean drinking water) and access to health care are also important. Thus, crude mortality rates in Europe, Japan, and North America are generally less than 7 deaths per 1,000 people annually. These changes are an integral part of the demographic transition that commonly accompanies industrialization.

Moreover, the decline in mortality rates is accompanied by a shift in the causes of mortality, a phenomenon often called the “epidemiological transition.” Essentially, mortality in economically advanced societies tends to result from environmental and behavioral causes, including obesity, smoking, and alcohol use, which produce proximate causes of death such as heart disease, strokes, and various forms of cancer. Excluding the middle aged and the elderly, other important causes include automobile accidents, homicide, suicide, overuse of prescription medications, illegal drug use, and household accidents.

Barney Warf

See also Demographic Transition; Fertility Rate; Natural Growth Rate; Population Geography

Further Readings

Yaukey, D., & Anderton, D. (2001). *Demography: The study of human population*. Long Grove, IL: Waveland Press.



MOST FAVORED NATION STATUS

The concept of most favored nation (MFN), referred to as normal trade relation (NTR) status since 1998, is a method of establishing reciprocal trading policies between countries. Within geography, the concept of MFN status has not been well applied. Within political and economic geography, leaders of countries have used this concept as a mechanism for enhancing their political position to secure and maintain their status in the global arena. However, historically, the term and the usage of MFN have their origins in the realist school of thought and, more recently, the liberal school.

The concept of MFN is found in two versions: unconditional and conditional. Unconditional MFN status is the highest level that a country can reach. Under this system, a trading partner is guaranteed treatment equal to that given to other favored trading partners without having to make a reciprocal concession. A conditional MFN trading partner gains treatment equal to that offered other favored trading partners, but only if it offers a concession in return. Under the General Agreement on Tariffs and Trade (GATT) and later the World Trade Organization (WTO), most countries today have some form of MFN status.

The earliest moments of the geopolitics of MFN in the United States are illustrated in The Articles of Confederation (1777), the Plan of the Treaties with France (1778), the Treaty of Amity and Commerce Between the United States and France (1778), the Treaty of Alliance Between the United States and France (1778), The Barbary Treaties (1786–1816), *The Federalist* (1787–1788), and the Treaty of Friendship, Limits, and Navigation between Spain and the United States (1795).

However, the 1930s ushered in a new movement within the geopolitics of MFN, which is illustrated in documents such as the speeches of Franklin Delano Roosevelt, the Reciprocal Trade Agreements Act (1934), and the League of Nations Economic Committee's Equality of Treatment in the Present State of International Commercial Relations: The Most-Favoured-Nation Clause (1936). Through these documents, there is a transition in how the United States used MFN status for setting and promoting its agenda

internationally. As of 2005, Cuba and North Korea were the only countries denied MFN status by the United States. However, current issues regarding the future of Iran's MFN status are being debated by members of Congress.

Although little work has been done within geography to analyze the relevance of MFN status, the issue is useful in analyzing countries' behavior regarding trade issues.

R. Rochelle Arrington

See also **Trade**

Further Readings

- Pregelj, V. N. (2005). *Normal trade relations (most-favored-nation) policy of the United States*. Washington, DC: Congressional Research Service, Library of Congress.
- Pregelj, V. N. (2005, March 24). *Country applicability of the U.S. normal trade relations (most-favored-nation) status*. Washington, DC: Congressional Research Service, Library of Congress.



MOVIMENTO SEM TERRA

The Brazilian Movimento dos Trabalhadores Rurais Sem Terra (MST), or Landless Rural Workers Movement, is the most influential landless peasant movement in contemporary Latin America. The MST is a unique, family-based movement committed to the radical transformation of Brazil's unjust agrarian structure. Its current membership numbers more than 1.5 million people spread across 23 Brazilian states. The MST was established in 1984 in the city of Cascavel, in the southern state of Paraná, with the purpose of advancing land reform through the occupation of idle private and public lands. Since its inception, the MST has been led by João Pedro Stédile, a highly charismatic and effective peasant leader from the state of Rio Grande do Sul. Under his leadership, the MST has spearheaded a slow but firm process of land reform in Brazil. Its success



has inspired the creation of similar movements in other Latin American countries. The MST has also played a key role in the global struggle for land reform by actively participating in the Via Campesina, an international peasants' movement that seeks to build solidarity among farmers' movements around the world

The Socioeconomic Context

The history of the MST is intrinsically linked to the history of land dispossession in Brazil since colonial times. The root causes of this dispossession can be traced to the *latifúndia* system (a semifeudal organization of large estates) established by the Portuguese crown during the 16th century to secure both territorial control and economic benefits. Initially, these large estates were granted to selected *donatários* (influential Portuguese noblemen) for their services and loyalty to the crown. The *donatários* developed and administered these large estates on behalf of the Portuguese crown. They also "pacified" indigenous peoples resistant to Portuguese rule by "incorporating" them into the colonial society and economy. Eventually, the crown granted the *donatários*, or their descendants, legal ownership of these large estates. These early *latifundiários*

(large estate landowners) laid the foundation for the establishment of a privileged and powerful landholding class that continues to play a preeminent role in Brazil's social, political, and economic life.

In contrast to the progressive land-granting traditions of the United States, Canada, and Australia, land granting in Brazil was designed to benefit a small minority. Indeed, the establishment, and eventual expansion, of the *latifúndia* system led to an enormous concentration of land in the hands of a few, leading to the uprooting and impoverishment of peasants and the degradation of forest resources, particularly in the Brazilian Amazon. These problems intensified in the 1960s and subsequent decades with the introduction of agricultural modernization. Globalization has further exacerbated this situation. Currently, almost 46% of the country's total registered agricultural land belongs to 1.6% of landowners (Table 1), and more than 20 million rural people live in poverty, including 5 million landless peasants. Notably, most of the agricultural land is presently under corporate control (Table 2).

The unjust agrarian structure has given rise to intermittent peasant rebellions. For example, in the early 1960s, under the leadership of the Peasant Leagues, landless peasants mobilized across Brazil to demand comprehensive land

Rural Property Size (hectares)	Number of Properties	Percentage of Properties	Area (hectares)	Percentage of Area
Less than 10 (<i>Minifúndia</i>)	1,338,711	31.6	7,616,113	1.8
10 to less than 100	2,272,718	53.6	76,757,747	18.0
100 to less than 1,000	557,835	13.2	152,508,203	36.2
More than 1,000 (<i>Latifúndia</i>)	69,123	1.6	183,564,299	44.0
Total	4,238,387	100	420,446,362	100.0

Table 1 Distribution of agricultural landownership in Brazil, 2003

Source: National System of Land Registration (SNCR), INCRA, 2003.

Sector of the Economy	1992 (million hectares)	Percentage of Hectares	2003 (millions hectares)	Percentage of Hectares
Corporate farms	245	74	297	71
Family farms	86	26	123	29
Total	331	100	420	100

Table 2 Distribution of landownership in Brazil by economic groups, 1992–2003

Source: National System of Land Registration (SNCR), INCRA, 2003.



reform from the “leftist” government of João Goulart (1961–1964). In response, frightened *latifundiários* called for military intervention and greeted with relief the military coup of 1964. The military acted swiftly and roughly to reassert control, banning peasant organizations and brutally repressing the peasant leaders. This repression effectively quelled peasant activism until the mid 1970s.

In 1976, the military decreed the expropriation of large tracts of peasant lands to construct the gigantic Itaipú dam along the border with Paraguay. Although the military promised fair compensation, the country’s economic crisis delayed compensation, thus angering the peasants. In response, peasants began to occupy idle public land in the area around Itaipú, with the endorsement of the Catholic and Lutheran churches. The success of these land occupations triggered a wave of similar occupations by landless peasants across southern Brazil in the late 1970s. Over the following years, landless peasants mobilized across Brazil, again with the support of the Catholic Church. In 1984, many of these landless peasant groups came together in Cascavel and established the MST as a national landless peasant organization, with the goal of

pursuing comprehensive land reform. The MST adopted political autonomy and collective leadership as two fundamental organizational principles. It also encouraged the active participation of the whole family in the movement.

The MST’s Praxis

The MST employs both political and economic activism to promote its objectives. This integrated approach teaches the landless to holistically advance sustainable rural livelihoods. Over the past two decades, the MST has achieved remarkable results. First, it has compelled the Brazilian government to redistribute more than 12.5 million hectares of land. Second, the MST has obtained land titles for more than 500,000 landless peasants linked to the movement. Third, it has established hundreds of agricultural settlements, several alternative media outlets, an extensive welfare system, and dozens of agricultural cooperatives and food-processing plants. This is a considerable achievement given the MST’s limited material resources (Table 3).

The MST has encountered serious difficulties in confronting the *latifúndia* system. First, the

<i>Military and Democratic Regimes (Period)</i>	<i>No. of Peasant Families Settled¹</i>	<i>Set Target</i>	<i>Total Area (million hectares, approximate)</i>	<i>Average per Year</i>
Military (1964–1984)	77,465	N/A	13.8	3,873
Sarney (1985–1989)	89,950	1,400,000	4.5	22,487
Collor and Franco (1990–1994)	60,188	N/A	2.3	15,049
Cardoso (1995–2002) ²	540,704	N/A	19	67,588
Lula (2003–2006) ³	381,419	400,000	31	95,354
Total	1,149,726		70.6	

Table 3 Official government numbers of land reform beneficiaries, 1964–2006

Sources: Data collected from Cardozo, F. H. (1997). *Reforma agrária: Compromisso de todos* [Agrarian reform: Commitments to all]. Brasília, Brazil: INCRA. Retrieved November 20, 2009, from www.incra.gov.br/portal/index.php?option=com_docman&task=doc_download&gid=450&Itemid=143; INCRA. (n.d.). *Resumo das atividades do INCRA, 1985–94* [Summary of INCRA activities, 1985–94]. Brasília, Brazil: INCRA. Retrieved November 20, 2009, from www.incra.gov.br/portal/index.php?option=com_docman&task=doc_download&gid=430&Itemid=142; Ministério do Desenvolvimento Agrário. (2006). *Desenvolvimento agrário como estratégia: Balanço MDA 2003/2006* [Agricultural development as strategy: MDA accounts 2003/2006]. Porto Alegre, Brazil: Nead. Retrieved November 20, 2009, from www.mda.gov.br/arquivos/1184712941.pdf.

Notes:

1. Most of these families received land titles via colonization and settlement projects. Although during the 1995–2002 period there was a substantial increase in the granting of land titles, the total number fell short of the 1.4 million target set in 1985.
2. Cardoso’s figures have been hotly contested. In 2006, INCRA revised its figures for 1995–2002. As a result, the total number of beneficiaries decreased from 628,141 to 592,141.
3. During the first term of his mandate, Lula settled peasant families mostly on public land.



pursuit of sustainable rural livelihoods through cooperativism has often been conflict ridden and sometimes divisive. Second, the MST has had limited political support in urban centers. Third, under pressure from the powerful *latifundiários*, the Brazilian government has been unwilling to implement comprehensive land reform and to properly fund postsettlement programs. Finally, the growing interest in biofuel has reenergized the *latifúndia* system. Successive Brazilian governments have encouraged the opening of new agricultural frontiers, such as those in the state of Mato Grosso, by providing financial, technical, and marketing resources. The new prominence of the *latifúndia* has seriously undermined land reform efforts. Newly settled peasants are confronting their lack of access to educational, financial, technological, and marketing resources. The MST has challenged the government to assume its responsibility in providing these resources.

Despite the above constraints, the MST is determined to continue its struggle for land reform and has expanded its grassroots political support in urban centers. It has also reached out to environmentalists, human rights groups, labor unions, and other social actors. It has become a powerful voice for the rural poor and disenfranchised. Embracing political and economic activism to vigorously contest centuries of systemic socioeconomic exclusion, the MST's community-based approach to land reform offers great potential for effectively advancing sustainable rural livelihoods in Brazil.

Wilder Robles

See also Biofuels; Land Reform; Land Tenure Reform; Peasants and Peasantry; Via Campesina (International Farmers' Movement)

Further Readings

- Boron, A. (2008). The class struggles in Brazil: The perspective of the MST. An interview with João Pedro Stédile. In *The socialist register 2008* (pp. 193–216). New York: Merlin Press.
- Fernandes Mançano, B. (1999). *MST: Formação e territorialização* [Formation and territorialization]. São Paulo, Brazil: Editora Hucitech.

- Petras, J., & Veltmeyer, H. (2005). *Social movements and state power: Argentina, Brazil, Bolivia, Ecuador*. Ann Arbor, MI: Pluto Press.
- Robles, W. (2000). Beyond the politics of protest: The landless rural workers movement in Brazil. *Canadian Journal of Development Studies*, 21(3), 657–691.
- Robles, W. (2001). The landless rural workers movement in Brazil. *Journal of Peasant Studies*, 28(2), 146–161.
- Stédile, J. P. (2002). Landless batallions: The Sem Terra Movement of Brazil. *New Left Review*, 77, 77–104.
- Stédile, J. P., & Fernandes Mançano, B. (1999). *Brava gente: A trajetória do MST e a luta pela terra no Brasil* [Brave people: The trajectory of MST in the fight for the land of Brazil]. São Paulo, Brazil: Editora Fundação Perseu Abramo.



MULTIMEDIA MAPPING

Multimedia mapping refers to the integration of computer-assisted mapping systems and multimedia technologies that allow the incorporation of both spatial geographic (i.e., geospatial) information in digital map format and multimedia information. The term *multimedia* implies the use of a personal computer (PC) or the Internet with information presented through the following media: (1) text (descriptive text, narrative, and labels), (2) graphics (drawings, diagrams, charts, snapshots, or photographs), (3) digital video (television-style material in digital format), (4) digital audio sound (music and oral narration), and (5) computer animation (changing maps, objects, and images). Multimedia technology has been extensively used by commercial encyclopedia CD-ROMs, such as Microsoft Encarta Encyclopedia CD-ROM, to provide a multisensory learning environment and the opportunity to improve the understanding of a concept.

Multimedia mapping has gone through several stages. The first stage was the development of interactive maps and electronic atlases during the 1980s. The interactive map is a computer-assisted form of map presentation and is characterized by an intuitive graphical user interface that allows the



user to manipulate the map features through a computer mouse. The link to multimedia information is achieved through superimposing “hotspots” on the cartographic features of the map or on scanned aerial photographs. Interactivity becomes a key feature of the interactive maps, which allow the user to explore more detailed information in the area predefined by the map developer. Examples of early electronic atlases include the BBC’s Domesday Project and Goode’s World Atlas.

The second stage was the development of the hypermap in the early 1990s. Coined by Laurini and Milleret-Raffort (1990), the term *hypermap* describes a multimedia hypertext document with geographical access. In other words, the hypermap is an interactive, digital multimedia map that allows users to zoom and find locations using a hyperlinked gazetteer. The underlying principle of the hypermap is the concept of hypertext. Hypertext represents a single concept or idea. By activating predefined hyperlinks, it is possible for the user to connect a hypertext to other nonlinear text information. If the hypertext is linked to multimedia information, the term *multimedia hypertext* or *hypermedia* is used. Therefore, the hypermap is also called cartographic application of hypertext or hypermedia mapping. The development of hypermaps was made possible with Apple’s Hypercard software, developed for the Macintosh computer and released in 1987. Examples of hypermaps include the Glasgow Online digital atlas and Hypersnige.

The third stage involves the integration of a hypermedia system (which features hypertext, hyperlinks, and multimedia) and a geographic information system (GIS), namely, hypermedia GIS. GIS is a digital mapping and analytical tool that is used to capture, retrieve, manipulate, and display geographic information and features linking of cartographic features with their alphanumeric attributes to perform spatial analysis. Recently, there has been increasing interest in integrating multimedia information in GIS. Shunfu Hu (1999) developed an approach for integrating multimedia data with a GIS database for an area in Everglades National Park. The multimedia database contains descriptive text, ground photographs, digital video clips, and audio segments highlighting the characteristics of Everglades plant communities, individual species, and invasive

exotics, as well as plant-animal interactions, hurricane damage, and postfire vegetation succession. It is linked to a GIS database that includes detailed vegetation maps, satellite imagery, and scanned aerial photographs. The integrated multimedia approach system was implemented in two steps: (1) an interactive multimedia system designed to manipulate multimedia information such as hypertext, hyperlinks, scanned photographs, digital video, and sound was developed in a Microsoft Visual Basic programming environment and (2) a GIS application program to manipulate spatial data was constructed using Visual Basic and Environmental Systems Research Institute (ESRI) MapObjects software. The hypermedia GIS approach provides a unique way to represent geospatial features and associated information on interrelationships between flora, fauna, and human activities in Everglades National Park.

The latest development in multimedia mapping is the convergence of digital mapping, multimedia content, and a global positioning system (GPS). Commercially available hardware such as Red Hen Systems provides photo and video mapping hardware for field data collectors to collect georeferenced digital video imagery with a GPS. Red Hen Systems also provides multimedia mapping software such as MediaMapper and GeoVideo for ESRI ArcGIS to process the video imagery and generate multimedia maps. This type of integrated multimedia mapping system provides an intuitive connection between locations (where) of interest and what they look like.

Multimedia mapping is the direct result of advancement of computer technology, mapping techniques, and GPS, all of which are combined together to allow the collection, exploration, and visualization of geospatial information in digital map format and associated multimedia content (e.g., text, photographs, sound, and video). An obvious advantage of multimedia mapping is the ability to incorporate the multimedia content in a digital map environment that brings vital information to the user.

Shunfu Hu

See also **Electronic Atlases; Geographic Information Systems; Geovisualization; GIScience; Global Positioning System; Map Visualization**



Further Readings

- Cartwright, W. (1999). Development of multimedia. In M. P. Peterson & G. Gartner (Eds.), *Multimedia cartography* (pp. 11–30). New York: Springer.
- Hu, S. (1999). Integrated multimedia approach to the utilization of an Everglades vegetation database. *Photogrammetric Engineering and Remote Sensing*, 65(2), 193–198.
- Hu, S., Gabriel, A. O., & Bodensteiner, L. R. (2003). Inventory and characteristics of wetland habitat on the Winnebago Upper Pool Lakes, Wisconsin, USA: An integrated multimedia-GIS approach. *Wetland*, 23(1), 82–94.
- Laurini, R., & Milleret-Raffort, F. (1990). Principles of geomatic hypermaps. In K. Brassel & H. Kishimoto (Eds.), *Proceedings of the fourth international symposium on spatial data handling* (Vol. 2, pp. 642–655). Zurich, Switzerland: ESRI.
- Openshaw, S., & Mounsey, H. (1987). Geographic information systems and the BBC's Domesday interactive videodisk. *International Journal of Geographical Information Systems*, 1, 2.
- Peterson, M. P. (Ed.). (1995). *Interactive and animated cartography*. Upper Saddle River, NJ: Prentice Hall.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (Eds.). (2005). *Thematic cartography and geographic visualization*. Upper Saddle River, NJ: Pearson Prentice Hall.

to develop true-color photographs, again, in the visible spectral zone, where human eyes perceive reflected sunlight radiation. Multispectral imaging systems simultaneously obtain a series of images recorded at a number of different spectral zones, far beyond the visible light. Multispectral imaging is used in many areas of science and technology but is most widely developed in astronomy, especially in radio astronomy, and in Earth remote sensing, in particular for Land Use and Land Cover Mapping. Images taken at different wavelengths can be combined to make composite images by displaying the image for each wavelength as red, green, or blue in the final image. These composite images result in color patterns that can be used to identify surface features.

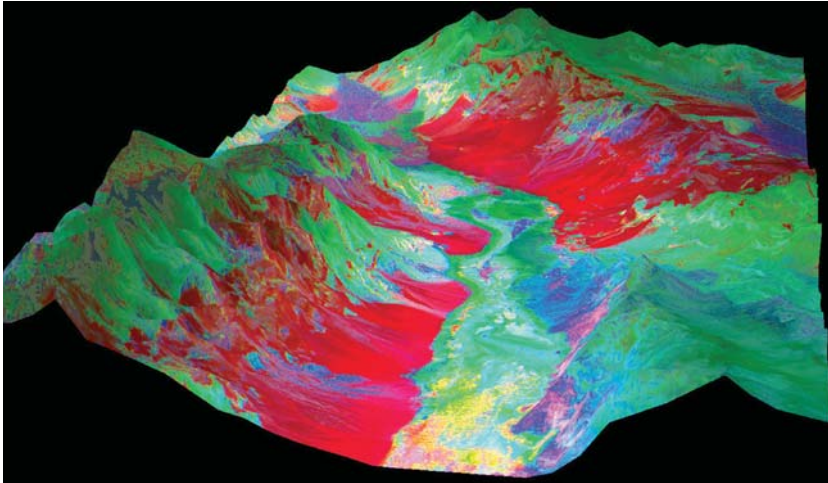
Multispectral imaging is based on principles of spectral radiometry. Radiometry is the measurement of optical radiation, which is electromagnetic radiation within the frequency range between $3 \times 1,011$ Hz (hertz) and $3 \times 1,016$ Hz. This range corresponds to wavelengths between 0.01 and 1,000 μm (micrometers) and includes the regions commonly called the ultraviolet, the visible, and the infrared. A radiometer is a device used to measure the power in electromagnetic radiation. Radiometers can use different types of detectors, for example, thermal detectors or photon detectors (photodiodes). Once the detector absorbs the energy, it quantifies it and converts it into an analog signal or, in modern radiometers, into a digital number. The analog signal can be registered in a film and produce a picture, where the image density corresponds to the amount of energy, registered by a radiometer. Modern multispectral systems use digital imaging technologies, where each multispectral image consists of a two-dimensional array of picture elements (pixels) and the brightness of each pixel corresponds to the amount of registered energy for the corresponding surface element. Such multispectral images can be thought of as a multilayer data set, where each layer corresponds to a particular zone of the electromagnetic spectrum.

Multispectral imagery is widely used in remote sensing for automated image classification, which is based on differences in spectral reflectance of an object in different parts of the electromagnetic spectrum, called a spectral signature (or spectral curve). There are a fair number of different



MULTISPECTRAL IMAGERY

General principles of imaging are based on the registration of electromagnetic energy in particular zones of the electromagnetic spectrum using a particular sensor. In classical photography, reflected sunlight is registered in light-sensitive film. The first photographic films were sensitive in the visible spectral zone and had only one layer to record the integral amount of acquired energy; the films (and produced photographic prints) were black-and-white. The later films were composed of three layers, sensitive to three primary colors—red, green, and blue—which allowed us



Because different materials reflect and emit energy in different ways, the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), with its multispectral infrared channels, can provide detailed information about the composition of Earth's surface. In this three-dimensional perspective view looking north over Death Valley, California, ASTER's bands 13 ($10.6\ \mu\text{m}$), 12 ($9.1\ \mu\text{m}$), and 10 ($8.3\ \mu\text{m}$) are displayed in red, green, and blue, respectively. Salt deposits on the floor of Death Valley appear in shades of yellow, green, purple, and pink, indicating the presence of carbonate, sulfate, and chloride minerals.

Source: NASA/GSFC/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team.

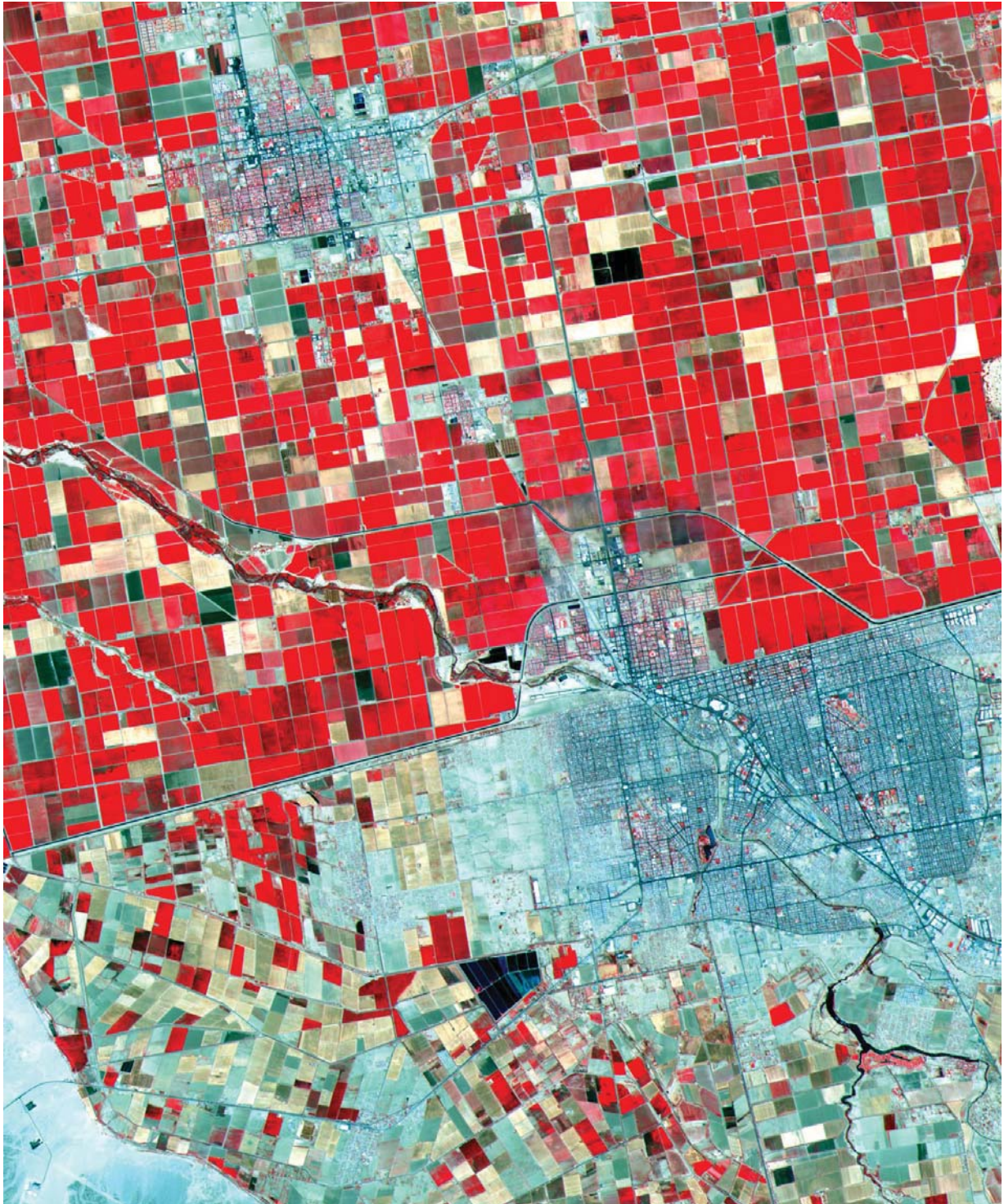
techniques used to extract qualitative and quantitative information about the surface from the recorded images, using analysis of the extracted spectral signatures. Spectral differences in reflectivity at certain wavelengths, identified for the same object in different layers of a multispectral image, can be used to detect and separate objects on Earth's surface. In many cases, the spectral signature of an object can be registered by laboratory or field spectrometry, where a continuous reflectance spectrum of the sample is measured through a defined wavelength region. If such a spectral signature is known for a particular object, similar objects can be delineated, classified, and identified based on matching a discrete spectral pattern, extracted from bands of a multispectral image, against the known spectral curve of the sample object. Laboratory-based measurements of spectral signatures of many materials and objects on Earth are collected by different institutions and are available as spectral databases (spectral libraries, such as ASTER spectral library, maintained by NASA's Jet Propulsion Laboratory, or USGS digital spectral library).

The first film-based multispectral imaging systems comprised four to six synchronized cameras with optical filters transparent to certain wavelengths. The images had classical frame geometry and were composed of optical projectors to produce color composites. Modern digital multispectral systems are usually based on charge coupled device (CCD) arrays and fall into two categories: (1) frame sensors, which use square or rectangular CCD arrays and have geometric characteristics similar to a film camera, and (2) line sensors (scanners), which use linear CCD arrays and therefore have noncentral projection geometries. Multispectral data acquired by such systems range from 0.40 to $2.50\ \mu\text{m}$ and typically consist of 4 to 7 bands of data with single bandwidths 0.07 to $0.20\ \mu\text{m}$ wide. Advanced sensors, acquiring 200 or more bands of data,

are called hyperspectral systems and have a single bandwidth as narrow as $0.01\ \mu\text{m}$.

Multispectral imaging systems can be installed onboard an airborne platform. The first experiments on the use of spectral aerial photography for classification of vegetation were performed in the 1950s. In the 1960s, NASA initiated a large number of studies of different applications of color infrared and multispectral photography.

The first orbital multispectral photograph was acquired by Apollo 9 in 1969 to assess the applicability of such imagery for observation of Earth resources. The first Earth Resources Technology Satellite (ERTS-1), specifically designed for global collection of multispectral images for Earth remote sensing, was launched in 1972. ERTS-1, later renamed in Landsat-1, was followed by the series of Landsat satellites, of which the latest, Landsat-7, is currently in orbit. Landsat 7 was launched in April, 1999, and placed at an altitude of 705 km (kilometers). Landsat 7 employs the Enhanced Thematic Mapper Plus (ETM+) sensor, which continuously collects digital multispectral data in



This May 19, 2000, subscene of the U.S.-Mexico border in California covers an area of 24×30 km. The combination of visible and near-infrared bands displays vegetation in red. The border town of Mexicali-Calexico spans the border in the middle of the image; El Centro, California, is in the upper left. The dramatic difference in land use patterns between the United States and Mexico is highlighted by the lush, regularly gridded agricultural fields of the United States and the more barren fields of Mexico. The Imperial Valley of California is one of the major fruit and vegetable producers for the United States, watered by canals fed from the Colorado River.

Source: NASA/GSFC/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team.



seven spectral bands from 0.45 to 2.35 μm , and one panchromatic image with 0.52- to 0.90- μm wavelengths. The sensor swath width is 185 km, and spatial resolution on Earth's surface is 30 m (meters) for all spectral bands, apart from 60 m for infrared and 15 m for panchromatic bands.

Since the beginning of the era of satellite remote sensing, a large number of visible and infrared imaging sensors have been flown into space to study Earth and other planetary surfaces. These include Landsat (USA), ALI (USA), SPOT (France), IRS (India), JERS (Japan), ASTER (Japan-USA), CBERS (China-Brazil), PRIRODA (Russia), and many others.

Gennady Gienko

See also **Imaging Spectroscopy; Land Use and Land Cover Mapping; Panchromatic Imagery; Remote Sensing; Remote Sensing: Platforms and Sensors; Spectral Characteristics of Terrestrial Surfaces; Spectral Resolution; Thermal Imagery**

Further Readings

Elachi, C., & van Zyl, J. (2006). *Introduction to the physics and techniques of remote sensing* (2nd ed.). Hoboken, NJ: Wiley.

Lillesand, T., & Kiefer, R. (2000). *Remote sensing and image interpretation* (4th ed.). New York: Wiley.



MULTISTAKEHOLDER PARTICIPATION

In contemporary development processes in cities and regions, stakeholder participation among vested-interest groups is often a core activity and seen as more or less mainstream. Such development processes may be of different kinds, for example, addressing spatial planning, neighborhood regeneration, environmental improvements, or behavioral change. The stakeholders involved may also belong to very different categories, for example, the general public, those most affected by these decisions in their daily life, or those with a financial interest in the development. However,

multistakeholder participation in decision analysis tends to become quite complex, and the outcomes can be both positive and negative. To navigate among these pros and cons, it becomes necessary to carefully shape any approach to multistakeholder participation according to the specific conditions of each development process. To successfully facilitate such a customization, it is essential to carefully respond to four guiding questions regarding the participation: Why? Who? When? and How?

Why Participate?

A key entry point, and possibly the most critical question, in each individual participatory process is to clearly resolve the question of *why* extended participation would be required. There are several potential benefits of stakeholder participation, since it may achieve the following:

- To different degrees, delegate influence (and responsibilities) to involved parties
- Ensure the longevity of measures, for example, by developing and securing effective and continuous management of built or social structures
- Resolve differences or placate upset stakeholders when different values and perspectives openly enter into the negotiation
- Build good working relationships among stakeholders
- Get more, and more diversified, knowledge into a planning process, also including diverging values, and thus improve the quality of both the process and its result when issues are assessed from a variety of viewpoints
- Increase stakeholder support, which may include both financial and political backing
- Strengthen trust in involved institutions
- Inform and educate those affected, or the public in general, about the intentions and content of a development project
- Ease implementation of the proposed project

From an ethical perspective, the above list can be seen as ranging between more destructive aims, such as manipulation and therapy in the worst case, up through more positive processes of collaborative knowledge production, social



learning, and negotiation and then toward increased emancipation and shared power among stakeholders.

Moreover, a high degree of caution is needed to evade the wide range of potentially negative outcomes of stakeholder participation. Those with the most power may manipulate the process to favor their own interests and those of actors with no real “stake” in the matter and thus abuse the process for political purposes to the disadvantage of genuine stakeholders. Public officials and/or politicians may refuse to accept results from the process, arguing that they themselves represent the public interest and safeguard the common good. In such processes, there are often delays, since the involvement of diverse stakeholders leads to more feedback loops and thus less streamlined procedures. Costs increase, for example, for the process facilitator, the participating staff, communication materials, and meetings; and new professional skills are needed for facilitating processes, conflict resolution, and communication.

Although it is clear that it may be possible to have many different, and sometimes conflicting, aims when promoting participation, these intentions are seldom clearly stated. Instead, the “why” question is often only implicitly addressed by those initiating such processes. It tends to drown in general and quite unclear assumptions that participation is a “good thing” in itself. This is a problem, since the various approaches and methods to support stakeholder interaction are likely to support very different outputs. If a development process seeks social learning, it will probably need a process design that is distinct from what is required for information purposes, not to mention truly decentralized decision making. Vagueness regarding the purpose of stakeholder participation may thus seriously undermine the foundation of any participative process.

Who Participates?

After the “why” question has been answered, the process initiator—for example, a local or regional government—should have clearly formulated objectives for any extended participation in a particular process. Based on these objectives, it then becomes possible to start exploring *who* should participate, in order to satisfy them.

In a broad sense, a stakeholder is anyone who declares himself or herself to have a stake in an issue—assuming that if someone claims to have a stake he or she probably is affected by the proposed development in one way or another. From such a perspective, most development processes are participatory, insofar as they seldom are the accomplishment of one single person. But what is most important here is the participation of those stakeholders not normally involved. As an example, in the case of spatial planning, this would refer to participation of individuals outside of the municipality’s own planning department and board. Such external stakeholders could be members of the public or local inhabitants, also officials from other municipal departments, external experts, representatives from business, or even researchers.

In some development processes, it may be a good strategy to invite anyone to participate, for example, in the initial phases of larger urban renewal initiatives, where the objective may be to raise general awareness of future activities or to scan public opinion. In other processes, it is probably a good idea to delimit the scope of participation based on particular objectives. In endeavors where specific knowledge is critical, for example, concerning the socioeconomic effects of a certain urban regeneration program, experts of different kinds might be invited to participate. Such experts can be professionals, such as sociologists or economists, and also “local experts” with deep knowledge of the local conditions. When an issue is politically sensitive and the objective is to unlock conflicts and facilitate negotiations and agreement, it becomes essential to ensure that all conflicting views are represented among the participants. If the implementation of a project largely depends on the active participation of local inhabitants, local communities are the primary centers of attention.

To get this right, objectives need to be linked to a mapping of potential stakeholders and their different characteristics. Depending on the nature of the objectives, such a mapping may focus on different qualities, such as the following:

- Those being affected in different ways, distinguishing between those most directly affected and those just having an interest



- Key organizations in different societal sectors, such as citizen groups, communities, nongovernmental organizations, municipalities, business, and local, national, and regional governments
- Key individuals in such organizations, who may “own” a problem or the potential solution to that problem
- Geography, for example, in terms of people living near a certain location or downstream of an intervention
- People who may contribute with different kinds of resources
- The various parties to potential conflicts

Finally, to be able to analyze, understand, and communicate the results of any stakeholder mapping, it is helpful to make use of different graphical representations.

When Should Participation Occur?

On many occasions, wider stakeholder participation is fully justified. The quality of plans and decisions will improve, the long-term sustainability of interventions will be strengthened, and matching between the judgments of officials and experts, on the one hand, and the considerations of different stakeholder groups, on the other, will be better secured. Even so, stakeholder participation often consumes time, effort, and money and also demands trust and endurance among stakeholders. It is easy to wear out both stakeholders in general and those trying to facilitate the participation.

Consequently, it is necessary to be meticulous when determining, first of all, *if* and, then, *when* moments of wider participation should be initiated. There is no place for general calls for participation; instead, quite strategic judgments must be made of “who is good for what and when.” Here, it is extremely helpful to develop some kind of participation timeline, where (a) different objectives are linked to the participation of certain stakeholders, (b) these moments of participation are positioned along the timeline, and (c) estimated costs (in time, effort, money, trust, and endurance) may be added to each moment.

Accordingly, one single development process may consist of several participative subprocesses,

with different sets of stakeholders taking part and pursuing different objectives. From the timeline, it becomes possible to better understand how long each one of these subprocesses should take, how many and which stakeholders need to be involved, and what costs are included. Ultimately, this makes it possible to judge whether participation is critically necessary, just desirable, or at all feasible in relation to the established objectives.

How Should Participation Take Place?

As discussed above, participative processes should be carefully tailored to the intended purpose(s). The next step is to determine how the objectives of participation may be supported by different methods and tools for setting up and facilitating multistakeholder participation—taking the mapping of potential participants, the available timeframe, and the existing resources (once again including time, effort, money, trust, and endurance) into account.

Fortunately, there are a large number of participative methods, each one with its strengths and weaknesses. However, it may become quite difficult to navigate amid this plethora of potential approaches. Some of the approaches are quite extensive and all-inclusive, while others have been developed by consultants or researchers for particular situations or applications. For the individual professional, it is important to develop a framework for assessing the strengths and weaknesses of different approaches. Such a framework would support the understanding of how best to approach participation within a particular development process. Also, since development processes often address complex and composite problems, it is often beneficial to combine different methods to be able to best address a set of objectives, mix of participants, timeframes, and available resources.

Finally, a critical aspect for a successful participative process is how well power relations among participants are handled. Even if there is agreement on overall development objectives, participants will ultimately strive to promote their own (or their group’s) short-term and/or long-term goals. This is not altogether negative but should be expected and confronted. However, an even more critical success factor is the management of



the power relationships that always exist between the group of participants and a variety of external stakeholders. These may be government officials active in mainstream planning or decision making, stakeholders partaking in parallel development processes, or actors in different organizations with some authority over the overall setting of the development process. If these external power relationships are not handled properly, long-term progress is seldom accomplished.

Jaen-Henrik Kain

See also **Built Environment; Civil Society; Community-Based Environmental Planning; Participatory Mapping; Participatory Planning; Public-Private Partnerships**

Further Readings

- Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, 35, 216–224.
- Beierle, T. C., & Cayford, J. (2002). *Democracy in practice: Public participation in environmental decisions*. Washington, DC: RFF Press.
- Friend, J., & Hickling, A. (2005). *Planning under pressure: The strategic choice approach* (3rd ed.). Oxford, UK: Elsevier Architectural Press.
- Healey, P. (2006). *Collaborative planning: Shaping places in fragmented societies* (2nd ed.). Basingstoke, UK: Palgrave Macmillan.
- Piper, J. M. (2005). Partnership and participation in planning and management of river corridors. *Planning, Practice & Research*, 20, 1–22.
- Renn, O., Webler, T., & Wiedermann, P. (Eds.). (1995). *Fairness and competence in citizen participation: Evaluating models for environmental discourse*. Dordrecht, Netherlands: Kluwer Academic.



MULTITEMPORAL IMAGING

Multitemporal imaging is the acquisition of remotely sensed data from more than one time period. Acquiring multiple views of natural or built features through time provides an enhanced

ability to accurately identify these features, significant information about how our world is changing, and unique insight into the relationships between the environment and the impact of human activities. Multitemporal images and analysis techniques provide the tools to monitor land use and land cover change (LUCC) and have been instrumental in providing an understanding of global environmental change. Our understanding of the impacts of global change would not have been possible without multitemporal imaging of diverse phenomena such as snow and ice extent, sea surface temperature, deforestation, drought, water resources, wildfire, desertification, and more.

Imaging Systems for Multitemporal Studies

Multitemporal imaging began with the earliest applications of aerial photography, in which government agencies in the United States regularly acquired aerial photos to monitor agricultural production and soils. These photographs are available from the 1930s onward and are still being used in studies of long-term landscape change. A wide range of Earth-observing satellite systems are now available for multitemporal studies. These systems have varying spatial (size of the smallest resolvable feature), spectral (wavelengths sensed), and temporal (repeat cycle of image acquisition) resolutions. The goal of any multitemporal study will dictate the best combination of spatial, spectral, and temporal resolutions to use.

Moderate-spatial-resolution (~20- to 30-m [meter] pixel size) satellites such as Landsat (first launched in 1972) generally provide repeat coverage of the same spot every 2 to 3 weeks. We therefore have more than 35 years of data from the Landsat satellites for multitemporal studies. Data from Landsat and subsequently launched moderate-spatial-resolution systems such as France's SPOT (Satellite Pour l'Observation de la Terre, first launched in 1986) and the Indian Remote Sensing (IRS) satellite (first launched in 1988) provide multitemporal data across the globe.

Satellite systems that can provide daily coverage of every spot on Earth have a relatively coarse spatial resolution (~1-kilometer pixel size).



Nevertheless, these systems have been ideal for global monitoring of the atmosphere, vegetation, glacial extent, sea surface temperature, and other more ephemeral phenomena. The National Oceanic and Atmospheric Administration's (NOAA) Advanced Very High Resolution Radiometer (AVHRR) began collecting data in 1979, and subsequent AVHRR sensors have provided continuous daily coverage of the Earth. France's SPOT VEGETATION system, first launched in 1998, also provides daily coverage for multitemporal studies of vegetation condition. The United States first launched a more advanced version of the AVHRR system in 2000, called the Moderate Resolution Imaging Spectrometer (MODIS). MODIS was specifically designed to provide long-term multitemporal data to improve our knowledge of global dynamics. Acquiring spectral data in the visible, near-infrared, and thermal-infrared regions of the electromagnetic spectrum, MODIS provides daily data to study the atmosphere, ocean, and land surface at spatial resolutions of 250 to 1,000 m.

More recently, commercial satellite systems have become available that provide very high-spatial-resolution data (0.6–3 m) on an on-demand basis. High-resolution data from these systems can be reacquired in 1- to 5-day time periods, and their high spatial resolution can be an invaluable asset in disaster management and urban planning.

Digital Analysis Techniques for Multitemporal Studies

To make effective use of multitemporal image data requires more rigorous initial digital processing. This preprocessing is required to ensure that images acquired from different sensors through time are (a) radiometrically calibrated to correct for sensor variation, (b) corrected for variation in atmospheric conditions, and (c) geometrically registered to a map base so that pixels from different dates overlay spatially. Without these corrections, it would be impossible to quantitatively compare reflectance values from one image date to another.

Selection of images to use in multitemporal studies also requires consideration based on the specific objectives of the study. It is important for

researchers to take into account naturally occurring changes that may affect their ability to monitor the specific change they are interested in. Time of year, rainfall, temperature, soil moisture, and vegetation growth cycle all must be considered in selecting the images to be used. Studies designed to monitor specific phenomena from one year to the next generally seek to use data from as close as possible to the same day or month.

A wide range of digital processing techniques for multitemporal image analysis have been developed and employed. The most widely used technique involves the classification of each date in the analysis. The classes chosen reflect the nature of the change to be identified; through post-classification comparison, this technique has the advantage of providing specific from-and-to change information. However, this technique is quite sensitive to the accuracy of the individual classifications. Multidate images can also be combined into a single classification whose output reflects both land cover/use classes that have remained the same and classes that have changed. Multitemporal principal components analysis (PCA) can be successfully applied to both multidate and long-time-series data to extract information on change. When multidate image data have been properly preprocessed, it is possible to directly compare values in a single band or a vegetation index from date to date using an algebraic function (e.g., subtracting one date from another). More advanced multitemporal analysis techniques include spectral change vector analysis and the use of artificial neural networks.

Applications

The range and depth of applications using multitemporal imaging spans geography and multiple sciences. These applications encompass both physical and human geography. Physical studies often focus on biophysical, ecological, and environmental change and use multitemporal images to monitor vegetation change, deforestation, agricultural production, rangeland health, soil moisture, snow and ice, flood dynamics, lake and ocean water quality, invasive species, drought, and desertification. Human-geography-related applications include urban planning and growth monitoring, urban hydrology, population



dynamics, fire detection and management, transportation planning, socioeconomic and quality-of-life analyses, disaster emergency response, and monitoring the impacts of human activity on the environment.

Stuart E. Marsh

See also **Global Environmental Change; Land Use and Cover Change (LUCC); Land Use and Land Cover Mapping; Remote Sensing**

Further Readings

- Eastman, J. R., & Fulk, M. (1993). Long sequence time series evaluation using standardized principal components. *Photogrammetric Engineering and Remote Sensing*, 59, 991–996.
- Lu, D., Mausel, P., Brondizio, E., & Moran, E. (2003). Change detection techniques. *International Journal of Remote Sensing*, 25, 2365–2407.
- Lunetta, R. S., & Elvidge, C. (2000). *Remote sensing change detection: Environmental monitoring methods and applications*. New York: Taylor & Francis.
- Rogan, J., Franklin, J., & Roberts, D. A. (2002). A comparison of methods for monitoring multitemporal vegetation change using Thematic Mapper imagery. *Remote Sensing of Environment*, 80, 143–156.

MULTIVARIATE ANALYSIS METHODS

Multivariate analysis methods are defined as statistical procedures that involve the analysis of more than one variable at a time, with an emphasis on modeling the relationships between such variables. The use of these methods in geography became a significant component of the “quantitative revolution” within the discipline during the 1950s and 1960s and has been further stimulated by the widespread use of GIScience and a renewed interest in spatial

statistics from the 1990s. Multivariate analysis methods are broadly classified into two categories: dependence and interdependence techniques. A dependence technique is one where a single variable or a set of variables is identified as the dependent variable to be explained or predicted by other variables known as explanatory or independent variables. An interdependence technique involves the simultaneous analysis of all variables in the data set; variables are not classified as dependent or independent.

Multivariate dependence techniques can be classified as those analyzing a single dependent variable (e.g., multiple regression, discriminant analysis, logistic regression), more than one dependent variable (e.g., analysis of variance), and several dependent-independent relationships (e.g., canonical correlation). *Multiple regression analysis* is used when a single dependent variable is assumed to be statistically associated with at least two independent variables. The goal is to predict changes in the dependent variable in response to changes in values of the independent variables. The statistical rule of least squares is frequently used to achieve this goal. If the dependent variable is qualitative or categorical, *multiple discriminant analysis* is the appropriate multivariate technique. Discriminant analysis is used when a sample can be classified into groups based on a dependent variable that comprises several known categories. The goal is to explain group differences and predict the likelihood that an observation belongs to a particular group, based on a set of quantitative independent variables. *Logistic regression* modeling, or logit analysis, combines multiple regression with discriminant analysis—a set of independent variables are used to predict a categorical and usually dichotomous dependent variable. The key difference between logistic regression and discriminant analysis is that the former includes both qualitative and quantitative independent variables and is not subject to assumptions of normality. *Canonical correlation* analysis is a logical extension of multiple regression with several quantitative dependent variables. The objective is to develop a linear combination of both sets of variables (dependent and independent) such that the correlation between the two sets is minimized. *Multivariate analysis of variance* (MANOVA) is an



extension of the more common univariate analysis of variance (ANOVA), which is used to simultaneously investigate the relationship between several qualitative independent variables (treatments) and at least two quantitative dependent variables. MANOVA is frequently applied in experimental design situations that involve the manipulation of several treatment variables to test hypotheses regarding variation in group responses across multiple dependent variables. *Multivariate analysis of covariance* (MANCOVA) is sometimes combined with MANOVA to remove the effect of uncontrolled quantitative independent variables on the dependent variables, after the experiment.

In multivariate interdependence techniques, all variables are analyzed simultaneously to find an underlying structure that is applicable to the entire set of variables. The choice of the specific technique to be used depends on whether (a) the structure of variables is to be analyzed (factor analysis), (b) observations are to be classified to represent structure (cluster analysis), or (c) our interest is in understanding the structure of observations (multidimensional scaling). *Factor analysis* is essentially a data reduction technique used to investigate interrelationships among a large number of variables and to explain these variables in terms of their common underlying dimensions (factors). The goal is to find a way to reduce the information contained in the large set of original variables into a smaller subset with minimal loss of information. Factor analysis provides empirical estimates of the structure of variables considered and thus serves as an important basis for creating summated scales. *Cluster analysis* is a technique for classifying individuals or objectives into a smaller number of mutually exclusive and relatively homogeneous subgroups. This technique typically involves at least three steps: (1) measurement of the association among observations to determine the number of groups, (2) formation of clusters to classify observations into groups, and (3) comparison of clusters to understand how they differ. *Multidimensional scaling*, also known as perceptual mapping, is often used in conjunction with cluster analysis to transform respondent judgments of preference into distances represented in multidimensional space. If two particular entities are judged by

consumers, for example, to be the most similar compared with all other possible pairs of objects, this technique will position these two entities in a way that the distance between them in multidimensional space is shorter than the distances between any other pair of entities.

Geographers use multivariate analysis methods in both aspatial and spatial contexts. In an aspatial context, the variables being analyzed may, or may not, be linked by spatial location. In the former case, however, the analysis methods consider neither the locations themselves as explicit variables nor the effects of spatial correlation and spatial autocorrelation between the variable observations that arise from their relative locations. Conversely, in a spatial context, geographers use multivariate analysis methods to explicitly model the spatial relationships, possibly including hierarchical relationships, between location-based variables. These may comprise, or include, the locations themselves as variables. Marked and multivariate point pattern analysis, spatial regression models, geostatistics, geographically weighted regression models, and hierarchical linear models for spatial data are examples of such spatially explicit approaches involving multivariate analysis. Where the location-based observations represent area or lattice data, multivariate analysis methods may contend with issues such as the modifiable area unit problem, measuring spatial proximities between observations, and defining spatial hierarchies.

Jayajit Chakraborty and Steven Reader

See also Geographically Weighted Regression; Geostatistics; GIScience; Modifiable Areal Unit Problem; Quantitative Methods; Quantitative Revolution; Spatial Autocorrelation; Spatial Statistics

Further Readings

- Griffith, D., & Amrhein, C. (1997). *Multivariate statistical analysis for geographers*. Englewood Cliffs, NJ: Prentice Hall.
- Wrigley, N. (2002). *Categorical data analysis for geographers and environmental scientists*. Caldwell, NJ: Blackburn Press.



MULTIVARIATE MAPPING

Multivariate mapping is the visual exploration of multiple attributes using a map or data reduction technique. More than one attribute can be visually explored and symbolized using numerous statistical classification systems or data reduction techniques. Complex data relationships can be visually displayed using graphical symbols. Color encodings are used to represent spatial relationships in a given data set in a logical sequence and interpretable format. To successfully communicate these complex spatial relationships, serious attention must be paid to human cognitive factors and perception. In practice, most small-scale data sets are usually displayed using graduated colors, graduated symbols, proportional symbols, dot density, bar charts, and stacked charts, among others. More recently, large-scale data sets have been represented using more complex data reduction techniques.

A set of visual variables (e.g., texture, orientation, color, size, shape, arrangement, and pattern) is available to facilitate the display and cartographic representation (symbol encoding) of multiple attributes. However, thoughtfulness in terms of map design, organization, and presentation of final results is required; symbols must be logically organized in a sequence that provides visual clarity so that the information can be easily decoded; and more important, the information must be successfully displayed and effectively communicated to the intended audience. Choosing colors can be quite challenging, but recent work by Cynthia Brewer has resulted in a very helpful guide to choosing a color scheme.

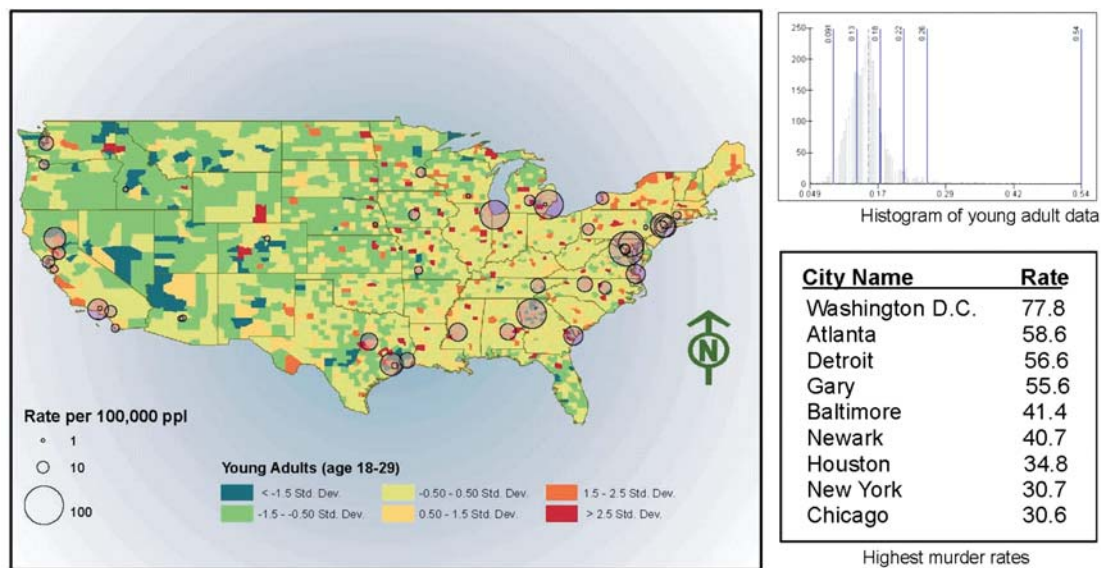
Examples from a geovisualization course are provided to illustrate the concept of multivariate mapping. In this course, students explored two data sets: (1) the first set depicted the relationship between murder rates and families in poverty in selected cities of the United States and (2) the second set depicted housing ownership covering a period from 1900 to 2000. The examples demonstrate the analysis of the covariation among variables within and between the two data sets with the intent of simplifying and visually displaying selected variables.

The use of multivariate mapping allows uncovering of the underlying relationships in data,

developing study hypotheses, and the description of complex spatial relationships. From the analyses of the two data sets, three study hypotheses were defined:

1. There is a spatial association between increased murder rates and the percentage of families living in poverty in selected cities in the United States.
2. Murder rates are higher in cities located in the East Coast than in cities located elsewhere in the United States.
3. Housing ownership is closely associated with economic expansion and prosperity.

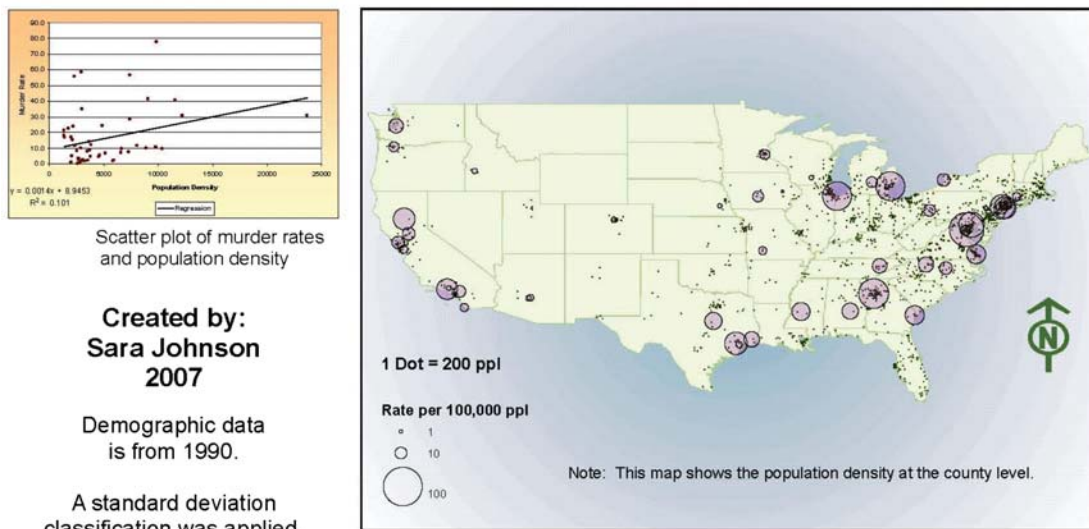
In Figure 1, several plots are presented to illustrate a few variables that may influence murder rates in the United States. The upper panel in Figure 1 has a map, a histogram, and a table. The histogram is used to represent and explore the distribution of the young adult population at a county level. The table summarizes high murder rates, while the choropleth map is overlaid with a proportional symbol map to evaluate whether there is a visual association between murder rates and potentially related variables. A subset of young adults (ages 18–29) is explored together with the murder rates. The six divergent classes are symbolized using a ColorBrewer color scheme, with areas shown in red having the highest numbers and areas in blue having the lowest. In this multivariate map, graduated colors and proportional symbols have been used to represent murder in relation to young adults. From this map, we can infer that the West and Midwest have a lower number of young adults. The red area appears to be more concentrated in the central/eastern side of the United States. There is no apparent visual association between cities with the highest murder rates and cities with large populations of young adults. The lower panel in Figure 1 has a scatter plot, and a dot density map is linked, with proportional symbols representing different murder rates. This plot shows only a very small relation of young adults and population density to increased murder rates, and the highest murder rates appear in areas of high population density. The plot uncovers the fact that in some cities, such as those located in



A multiple attribute map of murder rates and young adult populations

MURDER RATES

Exploring Possible Factors



A multiple attribute map of population density and murder rates

Figure 1 Exploration of the relationship between murder rates and two factors (young adults and population density) in selected cities of the United States

Sources: Courtesy of Sara Johnson, Geovisualization Class of 2007, Southern Illinois University, Carbondale. Sample data pertaining to murder and drug arrests were obtained from Slocum, McMaster, Kessler, and Howard (2008, Table 3.1); housing data were obtained from the U.S. Census Web site, www.census.gov.

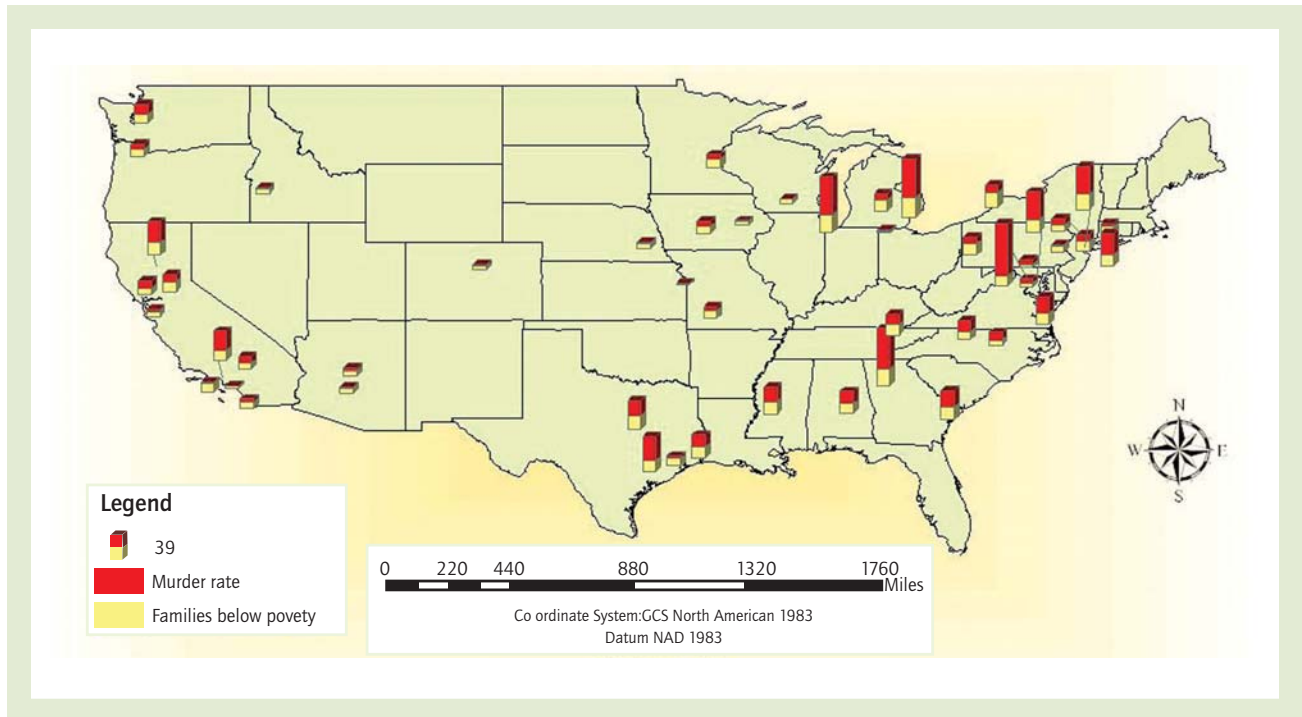


Figure 2 Relationship between murder rates and families in poverty in the United States

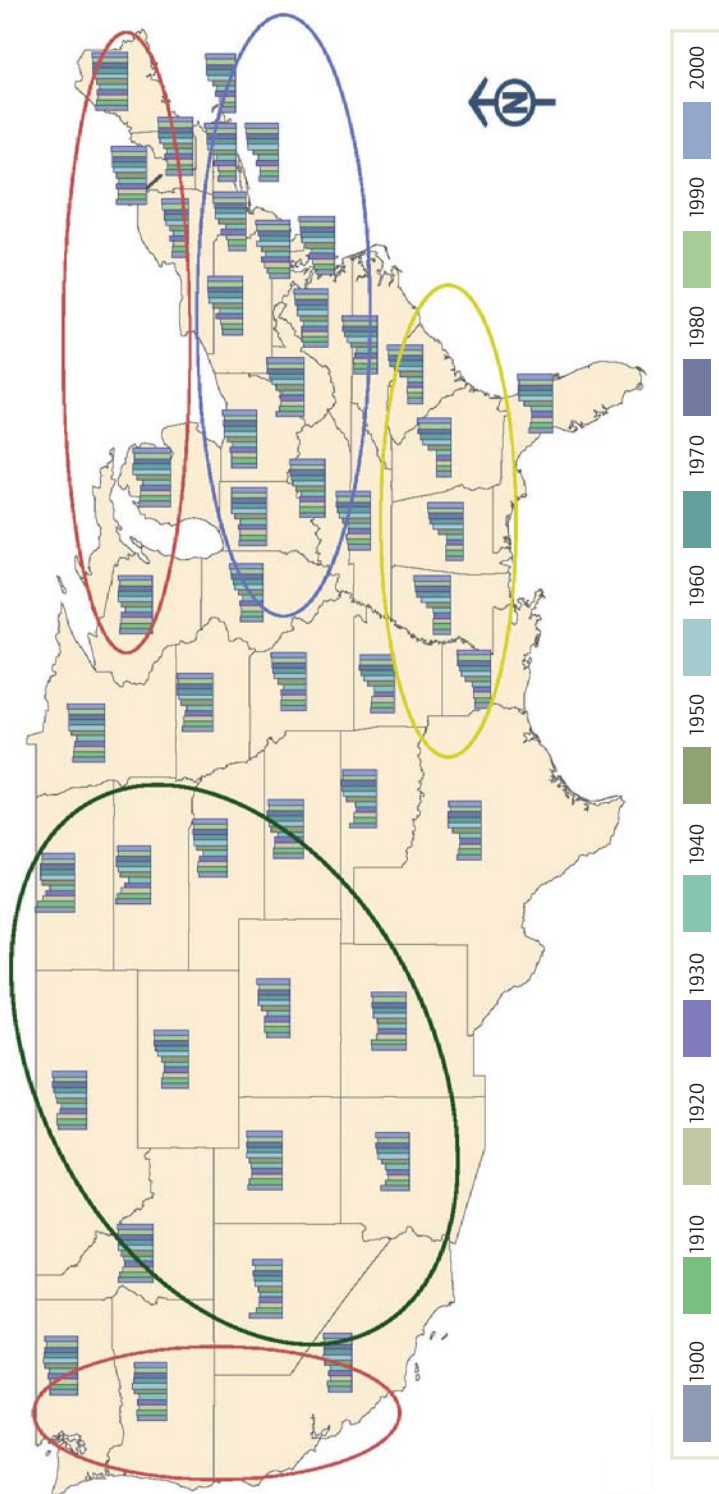
Sources: Courtesy of Olga Guajardo, Geovisualization Class of 2007, Southern Illinois University, Carbondale. Sample data pertaining to murder and drug arrests were obtained from Slocum et al. (2008, Table 3.1); housing data were obtained from the U.S. Census Web site, www.census.gov.

Mississippi and Alabama, high murder rates are not necessarily associated with high population density. This demonstrates that association does not imply causality.

Figure 2 shows a choropleth map linked with stacked charts exploring the relationship between murder rates and families in poverty in selected cities of the United States. Combining a choropleth map together with charts allows the reader to better understand and interpret the data and their spatial patterns, which may provide fundamental clues about the data. Also, new spatial relationships between different attributes can be recognized and further explored.

Figure 3 shows the spatial distribution of the housing ownership rates over the past 100 years for the contiguous 48 states. Each state in the chart map has a bar graph that shows the corresponding rates of housing ownership over 100 years. By placing 10 stacked bar graphs on the states, we can spatially compare and contrast decreases and increases over time. Four

potential trends were identified and are displayed in this figure. Possible spatial variations in housing ownership can be explained by the Great Depression, World War II, and the resulting “baby boom,” all of which made a big impact on the housing ownership rates of all the states. Housing ownership rates are the highest in the midwestern, southeastern, and northeastern regions of the United States in the year 2000. Because of the economic depression and World War II, housing ownership rates decreased from 1930 to 1940 and climbed drastically from 1940 to 1950 due to economic expansion and prosperity in the post–World War II period. It would be interesting to see what will have happened in the decade following the 9/11 attacks and the subsequent war on terrorism. Based on past trends associated with World War II, we can hypothesize that U.S. housing ownership rates will decrease between the years 2000 and 2010, in part due to a shrinking economy and increased national debt.



The Red Ovals

These states which are located along the west coast and the Northeast exhibit the most stable housing ownership rates. There was a slight decrease in 1920 and 1940. But over the past decade, these states showed only a slight increase in ownership.

The Blue Oval

The general trend of these states has been a steady increase in housing ownership over the past 100 years. In contrast to many of the other states, these states showed a small increase in ownership during the 1930s.

The Green Oval

In the Midwest, there was a decline in the rate of housing ownership from 1900 to 1940. Specifically, the Dakotas of the north showed a strong rate of decrease. These states have shown a general increase over the past 60 years, but many have not risen past their 1900 levels.

The Yellow Oval

These states had a very slight decrease around 1930–1940. Then, the ownership rates increased from 1950 to 1980. The 2000 rates are nearly double that of 1900.

Figure 3 Housing ownership in the United States covering the period between 1900 and 2000

Source: Courtesy of Sara Johnson, Geovisualization Class of 2007, Southern Illinois University, Carbondale.



In summary, these examples demonstrate how to effectively combine different types of symbols and successfully communicate the complex patterns depicted in multivariate mapping.

Tonny J. Oyana

See also **Cartography; Choropleth Maps; Map Visualization**

Further Readings

- Brewer, C. (2005). *Designing better maps: A guide for GIS users*. Redlands, CA: ESRI Press.
- Oyana T. J., Achenie, L. E. K., Cuadros-Vargas, E., Rivers, P. A., & Scott, K. E. (2006). A mathematical improvement of the self-organizing map algorithm. Chapter 8: ICT and mathematical modeling. In J. Mwakali & G. Taban-Wani (Eds.), *Advances in engineering and technology* (pp. 522–531). London: Elsevier.
- Oyana, T. J., & Scott, K. E. (2008). A geospatial implementation of a novel delineation clustering algorithm employing the *k*-means. In B. Lars, F. Anders, & P. Hardy (Eds.), *The European Information Society, taking geoinformation science one step further series: Lecture notes in geoinformation and cartography* (pp. 135–157). Heidelberg, Germany: Springer.
- Slocum, T., McMaster, R., Kessler, F., & Howard, H. (2008). *Thematic cartography and geovisualization* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.



MUSIC AND SOUND, GEOGRAPHY OF

The first systematic scholarly studies of music in geography were conducted by cultural geographers in the late 1960s and 1970s. These efforts were largely limited to examining music lyrics for their geographic content. Location and the evocation of attachment to these places is, indeed, one important aspect of the geography of music, but the subfield of music geography has become more

sophisticated in the intervening decades. The current focus is not only on the geographic significance of lyrics but also on the origin and diffusion of disparate musical styles, the geographic variations in consumer demand for various genres and artists, and the enormously important music industry, which produces, markets, and distributes these artistic endeavors.

Prior to the invention of the phonograph in the 1870s and the radio broadcasting of music in the 1920s, music was a purely oral (and aural) tradition that was ephemeral. Recording technology allowed music to become an important material artifact of a particular culture. Recording equipment made it possible for “song catchers” such as John and Alan Lomax to scour the hills and hollows of Appalachia in the 1920s and 1930s in search of and to record folk songs and ballads in the Celtic tradition and to establish the linkages between the new world and the old one left behind. Because of the dominance of the Berkeley School of cultural geography, folk music traditions dominated these geographic studies, and popular modern music was slower to gain a foothold in geography vis-à-vis other disciplines interested in music.

In the 1960s and 1970s, cultural geographers also became interested in the origin and diffusion of popular culture and its associated music. Larry Ford, for example, suggested that the various genres that made up contemporary music (e.g., rock-and-roll, bluegrass, country and western, gospel, blues) could be used pedagogically to illustrate and enliven discussion of geographic concepts such as culture hearths and diffusion mechanisms. Musicologists with an interest in geography examined the place names mentioned in popular country music lyrics, noting that the two states mentioned the most frequently (i.e., Tennessee and Texas) were also the states of origin of the greatest number of members of the Country Music Association. Geographic variations in the melodic elements of the music that would be of interest to musicologists were, however, largely ignored, perhaps because few geographers studying the subject were themselves well versed in the field of musicology.

Coincident with the “cultural turn” in economic geography in the late 1980s, there arose an interest in music geography among a different set



Four musicians performing at the Mountain Music Festival, Asheville, North Carolina, 1930s. This image is one of 400 photographs made in the course of sound-recording expeditions carried out between 1934 and ca. 1950 by John Avery Lomax, Alan Lomax, and Ruby Terrill Lomax, for the Archive of American Folk Song. The photographs depict African American, Mexican American, and white musicians, singers, and dancers, primarily in the Southern United States and the Bahamas. In addition to posed portraits, the images show musicians performing in various settings: at home, in a concert, and during prison labor outdoors.

Source: Library of Congress, Prints & Photographs Division, Lomax Collection (LC-DIG-ppmsc-00442).

of geographic scholars. Economic geographers such as Andrew Leyshon and Allen Scott mainly focused on the corporate aspects of the music market (e.g., the geographic consequences of corporate mergers and acquisitions in the recording industry). Music was a multibillion-dollar culture industry that was driving our consumerist culture. Those economic forces were of more interest to this new set of scholars than the more descriptive aspects that interested cultural geographers two decades earlier. The music industry displayed a tendency toward overproduction (e.g., too many musical acts signed to recording labels, too many records released that did not allow the labels to recoup their costs) as a result of uncertainty in the marketplace. Today, researchers such as Andrew Leyshon struggle to come to grips with the geographic consequences of changes in the demand side of the music industry, such as the downturn

in compact disk (CD) sales, after an initial surge in sales caused by the switch in recording medium from vinyl and cassette tape to CDs, and the increase in mp3 downloads—both legal and illegal. On the production side, geographers have also begun to focus on the geographic implications of home studios (i.e., less expensive and more ubiquitous digital technologies that are replacing older and more expensive analog versions). Still to be thoroughly researched is the seeming rise of independent labels and nontraditional outlets for bringing new musical acts to the attention of the public (e.g., MySpace pages, YouTube videos).

The “new cultural geography” also has had an impact on what aspects of music geographers are examining. Lily Kong, for example, examined the impact of music on national identity in Singapore. Sara Beth Keough examined the spatial impact of



a political decision by Canada to decrease the stranglehold (i.e., cultural hegemony) of the United States by requiring radio stations playing music to devote a considerable percentage of their airtime to playing Canadian music. In an ironic twist, Keough noted that playing the traditional Celtic music on the island of Newfoundland meets the Canadian content rules but reinforces the separatist nationalistic pride of Newfoundlanders, who voluntarily gave up their independence to become part of the Confederation in 1949.

Both cultural and economic geographers have been interested in musical scenes, the places where “the next big thing” in modern music might arise. John Connell and Chris Gibson explore the development of these scenes in places that were previously not known as musical hotbeds (e.g., the Dunedin sound in New Zealand, the grunge music scene in Seattle) but that leaped to the fore because of modern technologies. They examined as well the infrastructure necessary to create a musical scene, including recording studios, clubs and live venues, and often a university-based arty crowd that tolerates and even demands musical experimentation and innovation. Ola Johansson and Thomas L. Bell researched what constitutes a successful tour or circuit for different genres of modern rock music in North America.

Connell and Gibson have not confined their studies to music per se but have extended the aural aspects to include ambient sounds that are representational of particular cultures, such as the CDs of the exotic sounds of kookaburras and didgeridoos sold in tourist shops rather than record stores in Australia. Ambient sounds are used to evoke moods, to relieve stress, and to induce restful states. Even sounds associated with the city (e.g., blaring horns, high-pitched sirens, noisy jackhammers) may evoke pleasant memories for former city dwellers in the same manner that familiar odors and aromas stimulate memories through the olfactory sense.

Another important aspect of the geography of music and sound concerns a more problematic aspect of the aural landscape—soundscapes that are not particularly harmonious, melodic, or pleasant—that is, sounds that are not music but rather noise. A cacophony of discordant sounds can damage the eardrums if they are too loud, and they just as surely diminish the quality of life, as

does visual blight. Likewise, obnoxious soundscapes affect our feeling about places. Because geography is an inherently visual discipline, more research has been conducted on the visual aspect of the human experience than on images of the phenomenal world formed through our other senses. Future research should examine these non-musical soundscapes to a greater extent than has been done in the past. A great deal of research on tactile mapping has been conducted to enable the sight impaired to negotiate their environment, but more research is needed to sensitize those with normal hearing to the life-worlds of those with severe hearing loss. Perhaps the most ironic aspect of the soundscape is the manner in which many attempt to drown it out by listening to their private world of music and sound through the earbuds of their iPods and similar devices, all the while ignoring the sounds of nature or even traffic all around them. Is this privatized aural insularity a good thing for reinforcing a sense of community? Surely it is an important topic to research.

Thomas L. Bell

See also Cultural Geography; Folk Culture and Geography; Nonrepresentational Theory; Popular Culture, Geography and

Further Readings

- Bell, T., & Gripshover, M. (2005). Pop goes the geographer: Synergies between geography and popular culture. In R. Browne (Ed.), *Popular culture studies across the curriculum* (pp. 89–103). Jefferson, NC: McFarland.
- Connell, J., & Gibson, C. (2003). *Sound tracks: Popular music, identity and place*. London: Routledge.
- Connell, J., & Gibson, C. (2008). Ambient Australia: Music, meditation and tourist places. In O. Johansson & T. Bell (Eds.), *Turn up the volume: New essays in music geography*. Aldershot, UK: Ashgate.
- Ford, L. (1971). Geographic factors in the origin, evolution, and diffusion of rock and roll music. *Journal of Geography*, 70, 455–464.



- Keough, S. B. (2008). Internet radio and cultural connections: A case study of the St. John's, Newfoundland radio market. In O. Johansson & T. Bell (Eds.), *Turn up the volume: New essays in music geography*. London: Ashgate.
- Kong, L. (1995). Music and cultural politics: Ideology and resistance in Singapore. *Transactions of the Institute of British Geographers*, 20, 447–459.
- Leyshon, A. (2001). Time-space (and digital) compression: Software formats, musical networks and the reorganization of the music industry. *Environment and Planning A*, 33, 203–220.
- Leyshon, A. (2003). Scary monsters? Software forms, peer-to-peer networks and the specter of the gift. *Environment and Planning D: Society and Space*, 21, 533–558.
- Leyshon, A., Webb, P., French, S., Thrift, N., & Crewe, L. (2005). On the reproduction of the musical economy after the Internet. *Media, Culture and Society*, 27, 177–209.
- Peterson, R., & Davis, R. (1975). The Fertile Crescent of country music. *Journal of Country Music*, 6(1), 19–27.

N

NATION

The term *nation* has multiple meanings. It is frequently employed to refer to a country, as in sentences such as “France is a nation” and “Snow is falling across the nation’s midsection.” It also is used as a synonym for large social groups such as the French, Arabs, or Cherokees. The term *nation* generally refers to large social groups; however, it is also used interchangeably with terms for other large social formations such as ethnic groups, nationalities, races, and tribes. These concepts also overlap as many nations are multiethnic, multiracial, and multitribal. Despite similarities in meanings, nation has its own distinct meanings and origins. It derives from the Latin *nationem*, meaning “breed or race,” which itself stems from *nasci*, “to be born.” When the word *nation* entered the English language in the 13th century, it reflected this original meaning by referring to a “blood-related group.” However, by the 17th century, nation was applied to inhabitants of a country. The use of the word *nation* today echoes one or both of these meanings.

The meaning of nation was expanded and shaped by the Enlightenment and then the Romantic period. The Enlightenment *figures* such as John Locke and John Milton emphasized the rights of individuals with governance dependent on the free consent of the governed. Jean-Jacques Rousseau accepted that individuals’ rights were

essential, but he believed that individual rights could best be protected through group membership because collective groups best provided security to individuals. Therefore, nations were viewed as individuals bound together for collective security rather than by common cultural characteristics. Because states existed to provide security, it was crucial for individuals within states to develop an “ardent love for the fatherland/motherland” so that states could perform their mission of providing security. These ideas fit well with the emerging modern state, whose inhabitants (i.e., citizens) were then seen as a nation bound together by the state.

Rousseau’s preoccupation with security meant that he believed that national membership was best determined by the need to maximize states’ abilities to ensure the security of their citizens. Accordingly, Rousseau believed that the size of nations should be no larger than that which could be sustained by the available natural resources in a territory. Similarly, security also was achieved by the location of states’ boundaries along physiographic features such as mountain ridges and rivers because they were seen as the most easily defensible. Therefore, rather than grouping people together by common cultural characteristics, Rousseau believed that national membership was defined by groups’ optimal sizes relative to the available resources and the location of the individuals within these easily defended boundaries. Today, it is accepted that nations require resources



and need to defend themselves; however, few believe that natural resources determine the existence and the size of nations and who belong to them. However, Rousseau so thoroughly intertwined national identity with the natural world that he and those who built on his ideas believed that nature determined the number, sizes, and appropriate territories of nations.

Later romantics such as Johann Gottfried Herder deemphasized the role of individuals and focused instead on the collective group, *das Volk* (the people), bound together by shared culture, most notably language, religion, and history. Romantics believed that each language was “a currency of thought.” Therefore, to bond together into a nation, individuals had to speak the same language. Vernacular languages were essential because each one embodied a nation’s culture, beliefs, and values, molding its members’ thinking and behavior in a way not completely translatable into other languages. Nature also was seen as a determinant of national identity because it was believed to be a force that shaped culture, including language. This notion was reinforced by environmental determinism as it grew in the 19th century. Thus, language and physiographic regions were seen to go hand in hand and were viewed as mutually reinforcing. For example, Irish nationalists frequently asserted that nature (which often includes God) created an island called Ireland and, therefore, nature intends for one people (i.e., the Irish) to live there under the governance of a single Irish state. This belief is expressed in Article 2 of the Constitution of the Republic of Ireland, written in 1937: “The national territory consists of the whole island of Ireland, its islands and the territorial seas.” Similarly, French nationalists developed the belief that France was naturally bounded by the Atlantic, the Pyrenees, the Alps, and the Rhine River. For example, Buache de la Neuville wrote in 1791 that France’s boundaries should be fixed according to “the natural division of the Globe formed at its origin by the Creator.” By the middle of the 19th century, the concept of natural boundaries provided the French public with “a lesson of sacred union” and a sense of historical continuity.

In the late 19th and early 20th centuries, the idea of race became entangled with these

romantic conceptions of nation, essentially making the two synonymous for a time. Maps too reinforced the unification of these concepts by depicting the spatial distributions of “races,” though they were basically the same as maps of nations defined by languages. An example is seen in a *National Geographic* map titled “The Races of Europe.” It appeared as a supplement in the organization’s December 1918 issue of its magazine, which was devoted to the topic of race. The union of race and nation reached its culmination with the Nazis and likewise was discredited, but their association still lingers as some see nations as somehow genetically based.

In the latter half of the 20th century, scholars recognized that nations cannot be easily defined by objective criteria such as language and religion. A one-to-one correlation between languages and/or religions does not exist. Also, many nations formed before their members spoke a common language. For example, the historian Eric Hobsbawm points out that only about 50% of the French spoke French in 1789 and only 12% to 13% spoke it correctly by the language standards of the time; only 2.5% of Italy’s population spoke Italian regularly in 1860. Hobsbawm also notes that many nations also predate their traditions. These traditions may strengthen the bonds of unity, but they clearly were not the medium for the initial bonding. Hobsbawm coined the phrase *invented traditions* to highlight the true role of traditions to nationhood. Because many nations consciously and deliberately cultivate cultural characteristics to distinguish themselves from those they consider to be “others,” he believed that it is not objective criteria but subjective ones that define nations. Along these lines, Benedict Anderson coined the term *imagined communities* to refer to nations because their distinctiveness is based on their members’ imaginations of themselves and others.

Academics offer differing opinions concerning the true age of nations. Anthony Smith divides these opinions into four paradigms: primordialism, perennialism, ethnosymbolism, and modernism. Primordialism insists that nations are as old as humanity and are natural, organic, and biological entities. Perennialism accepts that nationalism is a modern political force but argues that



most nations are old while conceding that some formed more recently. Ethnosymbolism believes that old identities influenced the development of modern nations while admitting that many memories and cultural practices are subjective and some are fabricated. Finally, modernism argues that nations formed only since the French Revolution. Modernism has five subtypes based on the differing causes of social formation: socio-economic, sociocultural, political, ideological, and constructionist.

Despite differing perspectives on the age of nations, the concepts of nation, ethnic group, race, and tribe clearly draw on many of the same cultural characteristics, which explains their blurred boundaries and also why they are interused as terms. However, their differences stem in part from their varying emphasis on these characteristics. In particular, nations stand apart by a strong sense of self-awareness and the desire for self-governance. Some ethnic groups and races exist because they are classified as such, often by academics or governments, though those grouped in such categories may not be aware of or subscribe to these identity classifications. In contrast, nations have a strong sense of solidarity and a belief that they need their own governments so that they can protect and cultivate their identities. Nations believe that only they know what is best for themselves. In many ways, nations are politicized ethnic, racial, and tribal groups. However, it also means that the desire for self-governance can be shared by individuals of different ethnic, racial, and tribal backgrounds, in turn explaining why some nations are multiethnic, multiracial, and multiracial.

The expectation of self-governance requires territory because policies and laws are tied to territory, though they are ultimately directed at people. The links between nations, their governments, and the territories in which their laws apply are manifested in the nation-state ideal: the belief that every nation must have its own state and within every state a single nation. This ideal is best reflected in a minority of countries, notably in European ones where the ideal was conceived. It poorly describes countries that were most recently European colonies. Overall, the nation-state ideal drives nationalist projects and much conflict around the world.

Some academics argue that not all nations have self-government and point to examples such as Palestinians, Kurds, Basques, and Scots. However, these groups are by no means content with their lack of independence and seek it as a primary goal. At the same time, these examples show that not all members of a social group develop a national identity at the same time. Those who do call for self-governance often identify themselves as nationalists.

In summary, Symmons-Symonolewicz (1985) provides a nuanced definition of nation:

A territorially-based community of human beings sharing a distinct variant of modern culture, bound together by a strong sentiment of unity and solidarity, marked by a clear historically-rooted consciousness of national identity, and possessing, or striving to possess, a genuine political self-government. (p. 221)

George W. White

See also [Borders and Boundaries](#); [Citizenship](#); [Darwinism and Geography](#); [Enlightenment](#); [Ethnicity](#); [Geopolitics](#); [Identity, Geography and](#); [Nationalism](#); [Political Geography](#); [Race and Racism](#); [Territory](#); [Transnationalism](#)

Further Readings

- Anderson, B. (1991). *Imagined communities: Reflections on the origin and spread of nationalism* (Rev. ed.). London: Verso Books.
- Connor, W. (1978). A nation is a nation, is a state, is an ethnic group is a . . . *Ethnic and Racial Studies*, 1(4), 377–400.
- Gellner, E. (1983). *Nations and nationalism*. Ithaca, NY: Cornell University Press.
- Hobsbawm, E. (Ed.). (1983). *The invention of tradition*. New York: Cambridge University Press.
- Hobsbawm, E. (1990). *Nations and nationalism since 1780: Programme, myth, reality* (2nd ed.). Cambridge, UK: Cambridge University Press.
- Pringle, D. (1985). *One island, two nations? A political geographic analysis of the national conflict in Ireland*. New York: Wiley.



- Sahlins, P. (1990). Natural frontiers revisited: France's boundaries since the seventeenth century. *American Historical Review*, 95, 1423–1451.
- Silber, L., & Allan, L. (1997). *The death of Yugoslavia*. London: Penguin.
- Smith, A. (1994). The problem of national identity: Ancient, medieval and modern? *Ethnic and Racial Studies*, 17(3), 375–399.
- Smith, A. (2001). *Nationalism: Theory, ideology, history*. Cambridge, UK: Polity Press.
- Symmons-Symonolewicz, K. (1985). The concept of nationhood: Towards a theoretical clarification. *Canadian Review of Studies in Nationalism*, 12(2), 215–222.
- White, G. (2004). *Nation, state, and territory: Origins, evolutions, and relationships*. Lanham, MD: Rowman & Littlefield.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

In 1958, the National Aeronautics and Space Administration (NASA) was established by President Dwight Eisenhower partially as an extension of the National Advisory Committee on Aeronautics (NACA) and also in response to the Soviet Union's first satellite launch. Under the National Aeronautics and Space Act, NASA is a federally funded public agency with four primary mission directorates:

1. Direct the development and validation of exploration systems
2. Improve modern aeronautics
3. Create and maintain space operations
4. Explore the Earth, solar system, and universe

In accordance with these mission directorates, NASA is responsible for funding projects that advance each of these goals. Two of the first successful projects were the Mercury and Gemini missions, which enabled NASA to become the

first agency to place a human on the moon. NASA also funded programs that led to the development of the first communication and weather satellites. While NASA has greatly expanded knowledge about space with projects such as the Hubble Space Telescope and exploration missions to Mars and other planets, it has also made significant contributions to the exploration about Earth and its systems.

NASA has launched and developed several Earth observation satellites and instruments that record data specifically related to Earth's systems and geography. One of NASA's first successful Earth-orbiting missions is *Terra*. This satellite has five onboard sensors that record data that a multitude of scientists are using to study interactions between Earth's systems. Another successful mission is *Aqua*, a satellite with several onboard sensors that record data about Earth's surface that can enable scientists to observe and understand how Earth's water cycle has changed and is changing over time.

All NASA satellites have components developed by NASA, but some also have instruments and components that were developed with the cooperation of other space and government agencies throughout the world. Some of these missions are Jason-1, Landsat, and Tropical Rainfall Measuring Mission. There are also NASA-developed instruments and flight technology on board other agencies satellites, such as the QuikScat instrument that records wind speed and direction over Earth's land masses and oceans but resides onboard of Japan's Midori mission. Landsat is another mission that uses several satellites to create digital images of Earth by instruments developed through the collaboration between NASA and the U.S. Geological Survey.

The images and data produced from NASA missions have advanced the remote sensing discipline by producing high- and low-resolution imagery and data of Earth and its systems that has also contributed dramatically to the advancement of science in understanding, observing, and predicting Earth's processes and characteristics.

Nicole Simons

See also **Remote Sensing: Platforms and Sensors**



Kennedy Space Center, Florida, 1999. An aerial view of the Launch Complex 39 area shows the Vehicle Assembly Building (VAB, *center*), with the Launch Control Center on its right. On the west side (*lower end*) are (*left to right*) the Orbiter Processing Facility, the Process Control Center, and the Operations Support Building. Looking east (*upper end*) are Launch Pads 39A (*right*) and 39B (*just above the VAB*).

Source: NASA.

Further Readings

- Apt, J., Helfert, M., & Wilkinson, J. (2003). *Orbit: NASA astronauts photograph the Earth*. Washington, DC: National Geographic Society.
- Dick, S., Jacobs, R., Moore, C., Ulrich, B., & Armstrong, N. (2007). *America in space: NASA's first fifty years*. New York: Abrams Books.
- Gorn, M., & Aldrin, B. (2008). *NASA: The complete illustrated history*. New York: Merrell.
- Hoagland, R., & Bara, M. (2007). *Dark mission: The secret history of NASA*. Port Townsend, WA: Feral House.



NATIONAL CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS

The U.S. National Center for Geographic Information and Analysis (NCGIA) was established in 1988 at the University of California, Santa

Barbara; the State University of New York at Buffalo (the University at Buffalo); and the University of Maine. Funded from 1988 through 1996 by the National Science Foundation (NSF) following an open competition, the center continues under a collaborative agreement between the three institutions. The center's mission is to conduct research in geographic information science and to undertake associated educational and outreach programs.

By 1986, it had become clear that geographic information systems (GIS) were a growing computer application with abundant uses in a range of human activities, including science. At NSF, the officer newly responsible for the Geography and Regional Science program, Ronald Abler, saw an opportunity to promote the establishment of a research center that would act as a focus for research and education in this new field. A solicitation was developed that suggested five themes for research: (1) spatial analysis and spatial statistics, (2) spatial relationships and database structures, (3) artificial intelligence and expert systems, (4) visualization, and (5) social, economic, and



institutional issues. Eight teams responded to the solicitation issued by NSF in early 1987, and the project was awarded to the three-site consortium led by University of California, Santa Barbara.

Two key activities immediately served to characterize the new center and its proposal. First, research was to be conducted as a series of initiatives, each one lasting between 2 to 3 years and focusing on a specific topic within the five major themes. Each initiative would begin with a specialist meeting that would bring 20 to 40 scholars together to review the state of the art and develop and prioritize a research agenda. The initiative would proceed through activities both inside the center and in the broader community and would end with presentations on research results at a major conference and a final report. The first specialist meeting was held in December 1988 on the subject of the accuracy of spatial databases, and to date, more than 40 topics have been investigated.

The second activity was developed in response to a perceived lack of textbooks and other teaching materials in the growing field of GIS education. A core curriculum was designed as a collection of 75 sets of prototype lecture notes, and authors were recruited to prepare drafts. During the 1989–1990 academic year, roughly 100 instructors agreed to teach part, or all, of the curriculum, and their experiences were used to prepare a final draft that was published in 1990. More than 1,500 copies of the curriculum, assembled in three large binders, were distributed in the following years and became a foundation for the rapid expansion of worldwide education in GIS.

Michael F. Goodchild

See also Egenhofer, Max; Frank, Andrew; Geographic Information Systems; GIS, History of; GIScience; Goodchild, Michael; Mark, David M.

Further Readings

Abler, R. F. (1987). The National Science Foundation Center for Geographic Information and Analysis. *International Journal of Geographical Information Systems*, 1, 303–326.

DiBiase, D., DeMers, M., Johnson, A., Kemp, K., Luck, A. T., Plewe, B., et al. (Eds.). (2006). *Geographic information science & technology body of knowledge*. Washington, DC: Association of American Geographers.



NATIONAL COUNCIL FOR GEOGRAPHIC EDUCATION

The National Council for Geographic Education (NCGE) is a professional organization whose mission is to enhance the status and quality of geography teaching and learning. The NCGE has played an active role in advancing the place of geography in the American curriculum through workshops, publications, and grant-supported projects targeting underserved groups, research in geographic learning, use of technology, and in the preparation of teachers to introduce the subject of advanced-placement human geography.

The NCGE was established in 1915 by George J. Miller, a professor of geography at the State Teachers College of Mankato, Minnesota. Originally known as the National Council of Geography Teachers, the organization adopted its present name in 1956. The NCGE maintains an open membership policy, welcoming members from all levels of geography education, including students, K–12 teachers, college and university faculty, corporations and libraries, and individuals in the public and private sectors who are interested in geography education. The membership is mainly from the United States, representing every state and the District of Columbia, as well as the territories. The organization also has international members, especially from Canada.

Member services include a bimonthly newsletter, *Perspective*; a peer-reviewed journal, the *Journal of Geography*, published six times per year; and a second journal oriented toward K–12 members, *The Geography Teacher*, published four times each year. The NCGE's Pathways publications series, initiated in 1991, includes more than 30 volumes that address topics of



interest to geography educators relating to research, regional and thematic content, and instructional strategies.

The NCGE sponsors an annual conference at locations across the United States. Meetings have occasionally also been held outside the United States, most recently in Canada and the Dominican Republic. Annual conferences afford members an opportunity to exchange ideas, practice new techniques, and share lessons in a collegial forum. Field trips and plenary sessions in which noted geographers speak are also an important part of the annual conferences, as are the NCGE-sponsored special interest groups, such as the Supplemental Instruction e-mail discussion group, that allow educators with common interests to share ideas and seek solutions to classroom challenges.

The NCGE recognizes excellence in geography education through a multifaceted awards program. The organization's highest honor, the George J. Miller Award, is named after the organization's founder and presented to one geographer each year for distinguished contributions and service to geography. In addition, outstanding teachers, at both the K–12 and the college level, are recognized, and publications and other media, both within and beyond the discipline of geography, are highlighted.

The NCGE is led by officers and an executive planning board elected by the membership. In 2007, the organization's central office, headed by an executive director, was relocated to Washington, D.C.

Martha B. Sharma

See also **Geography Education**

Further Readings

National Council for Geographic Education:
www.ncge.org

Vining, J. (1990). *The National Council for Geographic Education: The first seventy-five years and beyond*. Indiana, PA: NCGE.

NATIONAL GEOGRAPHIC SOCIETY

The National Geographic Society has a wide-ranging impact on how Americans—and the world—understand geography, tying its mission of diffusing geographic knowledge to human fascination with exploration, travel, and adventure. The society both represents and shapes cultural understandings of geography in the United States.

The Washington, D.C.-based National Geographic Society was founded in 1888, in an era of “explorers’ clubs,” with 33 original members that included geologists, bankers, explorers, and meteorologists. Gilbert Grosvenor, the magazine’s first editor, is credited with transforming the magazine from a jargon-ridden technical review to the colorful publication it is today. Under Grosvenor’s reign, *National Geographic* found its footing in eyewitness, photograph-heavy accounts of faraway places. Society projects have included research by Louis and Mary Leakey on the origins of humans in Africa, Jane Goodall on chimpanzees in Tanzania, and Robert Ballard on the sunken *Titanic*. Today *National Geographic* magazine has a circulation of 8.5 million and is published in more than 30 languages.

National Geographic is an internationally known magazine that has long served to educate its readers about distant places. At times, however, the magazine has been as reflective of Western culture as it has been educative. In its early years, *National Geographic* stories carried an imperialist tone common to explorers’ clubs of the day. In hindsight, the bare-breasted photos of women in “exotic” locales are seen as voyeuristic, and the magazine’s mid-20th-century photography is criticized for being more aesthetic than enlightening. In the 1960s and 1970s, the magazine moved in a more realistic and politically charged direction. While this angle created internal dissent about the society’s mission, features such as those illustrating urban conditions in the United States or the impact of apartheid in South Africa ultimately became an important part of *National Geographic* as it is known today.

A key turning point in the National Geographic Society’s history was its December 1970



magazine titled *Our Ecological Crisis*, in which authors took a stand against pollution. In the following years, the society has focused on conservation and increasing environmental awareness while continuing to showcase beautiful locales around the world.

While the magazine is the cornerstone of the National Geographic Society, its educational mission has expanded over the past century to include many other forms of media. Its membership, together with its other enterprises, has funded more than 8,000 field research projects. These and other geographic findings have been profiled in society lectures, books, television specials, and on the Internet, where the National Geographic Web site gets 12 million visitors per month. In recent years, the society has focused on improving geographic literacy through educational alliances, grants to schools, and the nationally televised National Geographic Bee.

Jennifer Mapes

See also **Geography Education; Human Geography, History of; Media and Geography; Photography, Geography and**

Further Readings

- Bryan, C. (1987). *The National Geographic Society: 100 years of adventure and discovery*. New York: H. N. Abrams.
- Lutz, C., & Collins, J. (1993). *Reading National Geographic*. Chicago: University of Chicago Press.



NATIONALISM

Nationalism is a term generally used to describe either the attachment of a person to a particular nation or a political action by a group of persons to achieve statehood (or national self-determination). While there is debate about the origin and antiquity of the idea of a nation, the political manifestation of national identity as nationalism is widely accepted as a relatively modern concept. As the state became the primary

locus of sovereignty in the 18th and 19th centuries, it became increasingly important for ruling elites to construct a narrative that provided the often culturally heterogeneous populations that inhabited the state territory with a single identity. Depending on the circumstances of state formation, this identity could be voluntary and founded on adherence to ideology and institutions, or it could be constructed as involuntary—a function of genetic inheritance with the individual unable to leave the collective or to join except through birth. Nationalism became an increasingly important political ideology in the 20th century as the existence of a distinct national identity became a necessary and—eventually at the end of World War I—a sufficient condition for the creation of a sovereign state. The rise of superpowers and intergovernmental bodies such as the European Union modified concepts of state sovereignty in the latter part of the 20th century, yet nationalism has remained a potent political force, as seen in the breakup of the Soviet Union, Yugoslavia, and Czechoslovakia, as well as in the substate nationalisms of Spain, Britain, and Belgium.

Types of Nationalism

There are many typologies of nationalism; one of the most useful being Hans Kohn's two-part distinction between Western and Eastern or civic and ethnic nationalism. This typology was expanded by Liah Greenfeld to include a third category, collective nationalism, which can take either ethnic or civic forms.

Civic nationalism was the first to develop and is represented by the English model of national identity as a rational choice for those desiring self-determination and individual liberty. The nation is composed of individuals who occupy a common territory and willingly form bonds based on ideology and on shared political institutions. This model is flexible and inclusive, permitting membership to anyone who voluntarily resides in the territory and recognizes the institutions, iconography, and ideology of the group. The goal of civic nationalism is generally statehood, as it is only at that level of sovereignty that ideology can be translated into fully independent institutions. Civic nationalism embodies the



concept of sovereignty of the people; the nation cannot exist without the collective will of the people who support it. This model began in Tudor England but is best represented in the formation of the United States, where the desire for self-determination was largely based on the ideological drive toward greater individual liberty and the need to create new institutions to enshrine popular sovereignty. After two centuries of absorbing immigrants, who identified with countless different language, religious, ethnic, and racial groups, the very strong nationalist ethos of the United States remains almost entirely based on attachment to iconography and institutions.

Collective nationalism is an extension of civic nationalism that grants the nation itself an identity. The nation is created by the will of the people, and once created, it acquires a will and identity of its own that takes priority over the will of individuals. When applied in the context of civic nationalism, as in the case of France, this creates a great deal of political ambiguity, acknowledging the freedom of the individual while simultaneously submerging that freedom in the greater will of the “nation.” Such nationalism generally emerges as an elite caste attempts to preserve its status while transmitting its version of national identity to the masses by indoctrination, as in the case of France, where the bureaucratic elite came into being in the wake of the French Revolution.

Collective nationalism, however, works best when paired with ethnic nationalism. The contradictions of collectivism versus self-determination disappear when there is no choice. Ethnic nationalism assumes that national identity is inherent, and it emerged as a political philosophy with the rise of cultural nationalism in the 19th century. The principal philosophical underpinnings of ethnic nationalism come from German writings on national identity in the late 18th and early 19th centuries, particularly the works of Herder and Fichte. They equated the German language with the new concept of *das Volk* (the people), which in turn created the German nation. Membership in this group was not voluntary; anyone who spoke German was part of *das Volk* and therefore part of the nation. By extension, anyone who did not speak German, was not part of *das Volk* or the nation and could be excluded. By its

very nature, ethnic nationalism is involuntary and exclusionary—it compels all those who fit the objective criteria of the nation to be members and excludes all those who cannot meet those criteria. Ethnic nationalism spread rapidly from Germany to Russia and much of Central and Eastern Europe and became the most common model of nationalism in the 20th century. The involuntary nature of ethnic nationalism combines easily with collectivist nationalism, and the combination can often result in totalitarianism or majoritarianism with fatal consequences for those excluded from the nation. From the Holocaust to Stalin’s ethnic deportation programs, to ethnic cleansing in Serbia, millions have died as a result of this marriage of ethnic nationalism with political will.

A History of Nationalism

Although advocates of the primordialist theory of nationalism would disagree, it is widely contended that nationalism is a modern construct dating back to the 18th century at the earliest, although Liah Greenfeld convincingly dates the first appearance of modern nationalism to the construction of the English identity in Tudor England during the 16th century. That identity was strengthened in the 17th century during the English Civil War and the subsequent Calvinist period that equated Puritan England with ancient Israel and upheld the idea of the English as God’s chosen people. Later in the century, the rise of new intellectual philosophies of John Locke and Thomas Hobbes and the literature of authors such as John Milton focused English national identity on ideas of liberty, individualism, and the importance of popular sovereignty. In the 18th century, those ideas were to lead to the first true political expressions of popular sovereignty in the American and French revolutions, both of which tied together national identity, individual liberty, and the creation of the sovereign state as the ideal container for that identity.

In the early 19th century, however, partly as a response to the rational, humanist nature of French nationalism, a new form of national identity emerged, that of cultural nationalism. This movement emphasized the bonds of language, perceived ethnicity, race, and bloodline and was profoundly emotional in nature. Rejecting the



ideological and voluntary basis of the French and English national models, this form of national identity was entirely determined by genetics and birth. One can neither voluntarily join this national group nor leave it; national identity is held to be imprinted through bloodline, race, and ethnicity and is expressed through language and religion. Thus, the Alsace-Lorraine region of France was French by choice (the inhabitants having taken an active part in the French Revolution) until the newly formed German Empire demanded that the territory be ceded as part of the settlement of the Franco-Prussian War. The basis for the claim was genetic, the people of Alsace-Lorraine spoke German, and therefore, they were part of the German nation and should be part of the new German state. Throughout the 19th century, the Imperial powers of Europe found themselves confronted by increased national self-awareness in their subject peoples. From Ireland to Serbia and from Norway to Greece, literature, music, mythology, art, and language were used to define culturally distinctive national groups that could then press for self-determination.

The 19th century also brought technological changes that greatly aided the formation and maintenance of these new national identities, especially among the ordinary population. The advent of compulsory public education provided the stage for states to promote their vision of the nation while simultaneously becoming a battleground for substate nationalities attempting to preserve and promote their language and culture in the face of the drive toward homogeneity that characterized the emergence of state nationalism. At the same time, the development of mass production and the mass media, at first in the form of newspapers and then in magazines, posters, and radio, permitted the widespread dissemination of these new ideas about national identity.

At the end of World War I, the disintegration of the Ottoman, Austro-Hungarian, and German Empires marked the apogee of state nationalism as virtually the entire postwar territorial settlement was based on Woodrow Wilson's 14 points, which explicitly set out national identity as the basis for state formation. Unfortunately, it was virtually impossible to construct states that precisely matched the territorial boundaries of

nations that had been created in the preceding century. As a result, multinational states were created where majority national identities were able to impose their vision of the nation on the entire population. It is this drive toward a single homogeneous national identity that is known as state nationalism, and it is virtually universal among modern states. Even in the United States, where national identity is based on voluntary attachment to ideology, 19th- and early-20th-century attempts to eliminate Native American languages by educating indigenous children in state boarding schools demonstrate a desire to impose cultural conditions on the American national identity. Likewise, in the Soviet Union, a multination, multiethnic, multilingual, and multireligious collection of territories founded in 1922, commitment to the ideal of communism was the professed litmus test of national belonging, but in practice, the imposition of the Russian language and culture was the ongoing program of state nationalism.

As decolonization of Asia, Africa, and the Middle East proceeded in the interwar and post-World War II periods, state nationalism again dominated. New states, their borders drawn by colonial powers and again rarely able to conform to the stated ideal of containing individual nations in their own states, readily embraced state nationalism where the iconography and identity of the majority nation was imposed on the often unwilling minorities.

In the long term, however, it appears that state nationalism is not universally successful. Spurred by the discrimination and marginalization inherent in state nationalism, those unwilling minorities have increasingly engaged in peripheral nationalism, or the desire for the creation of substate nations to achieve self-determination and statehood. Released from totalitarian control or simply provoked by the perceived ongoing discrimination substate nations across Europe, Africa, and the Middle East in particular have reasserted their claims to self-determination in the wake of the Cold War.

In 1990, Eric Hobsbawm wrote of being able to envision the end of nationalism as a viable political creed. Over the past 20 years, however, political nationalism with the goal of creating new nation-states has flourished as the small nations of



Europe and the Soviet Union have enjoyed new political freedoms associated with the end of the Cold War and the rise of the European Union, which has begun to erode the state as the sole seat of sovereignty. Some of these nationalisms are civic—the Catalans and the Scots in particular base their claims for self-determination on the existence of distinct institutions. Many others are more inclined toward ethnic nationalism—a trajectory that has been headed off in some cases by membership in the European Union. However, in many countries, notably Russia, Serbia, Belarus, and others, indications of both collectivist and ethnic tendencies are evident in the manner in which the elites continue to manipulate history, culture, language, and propaganda to court the masses and marginalize any group that is not part of the constructed “nation.”

Fiona M. Davidson

See also **Borders and Boundaries; Citizenship; Civil Society; Ethnicity; Ethnocentrism; Nation; Orientalism; Political Geography; Race and Racism; State; Supranational Integration**

Further Readings

- Anderson, B. (1983). *Imagined communities*. London: Verso Press.
- Gellner, E. (1997). *Nationalism*. London: Weidenfeld & Nicholson.
- Greenfeld, L. (1992). *Nationalism: Five roads to modernity*. Cambridge, MA: Harvard University Press.
- Hobsbawm, E. (1990). *Nations and nationalism since 1780: Programme, myth and reality*. Cambridge, MA: Cambridge University Press.



NATURAL GROWTH RATE

In demography and population geography, the natural growth rate (NGR) is the difference between birth rates (BR) and death rates (DR), that is, $NGR = BR - DR$. Along with net migration, natural growth rates are one of the two

fundamental components of demographic change. For the world as a whole, natural growth rates are the only measure of population change, although for any unit less than that both natural growth and net migration must be taken into account.

Historically, natural growth rates have been very low, often zero, and at times, when mortality exceeded fertility (such as during famines or plagues), even negative. Only with the Industrial Revolution and the concomitant reductions in death rates (not a rise in birth rates) did natural growth rates rise, leading to an exponential increase in the world's population level (Figure 1). Thus, rapidly growing societies are essentially a product of modernity. Thomas Malthus, the founder of the notion of overpopulation, observed the rise in natural growth in late-18th-century England to sound the alarm that such increases would offset any economic gains, although his conclusions were rendered incorrect by the exponential increases in productivity that industrialization generated.

Natural growth rates vary widely around the world (Figure 2) and reflect the multitude of social, economic, and political factors that shape the geography of birth and death rates, particularly wealth and poverty. Because mortality rates have been to a considerable extent equalized worldwide, the major variations in natural growth rates are mostly attributable to differences in birth rates. Such patterns are largely explainable by appeal to the demographic transition. Generally, the poorest countries have the highest birth rates, and thus the highest natural growth rates, as in parts of Africa and the Arab world. Frequently, rising incomes lead to lower birth rates and smaller families, as in Europe, North America, Japan, Australia, and New Zealand. In many economically developed countries, where death rates exceed birth rates, natural growth may be essentially stagnant (i.e., zero population growth) or even negative, as in much of Eastern Europe and the Soviet Union as well as parts of Southern Africa afflicted by the AIDS crisis, indicating that whatever population increase occurs is due entirely to immigration.

Overall, as global fertility rates have declined, so too has the average worldwide natural growth rate, which is widely expected to continue dropping

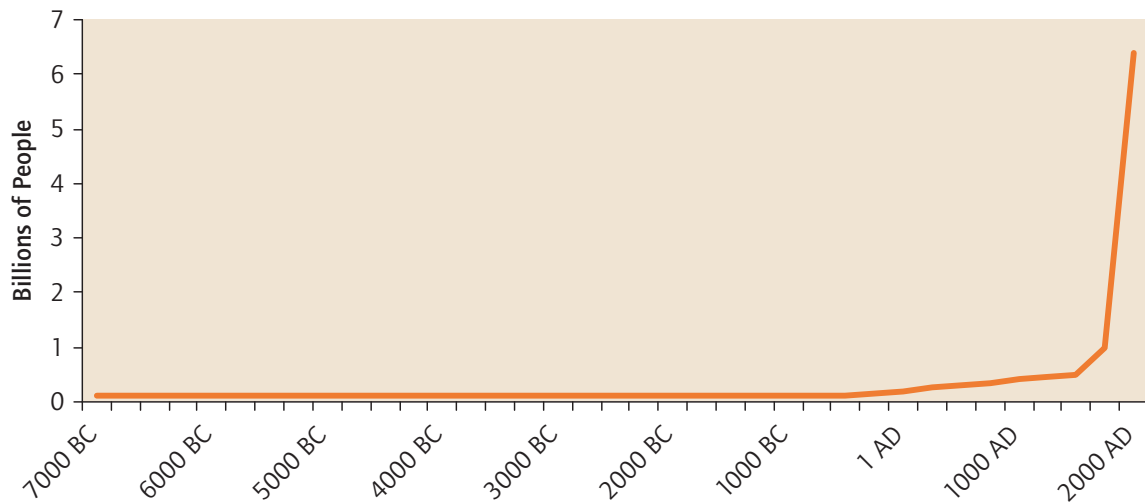


Figure 1 World population level, 7000 BC to AD 2000. The dramatic explosion in the world's population since the Industrial Revolution reflects the decline in mortality rates that it fostered.

Source: Author.

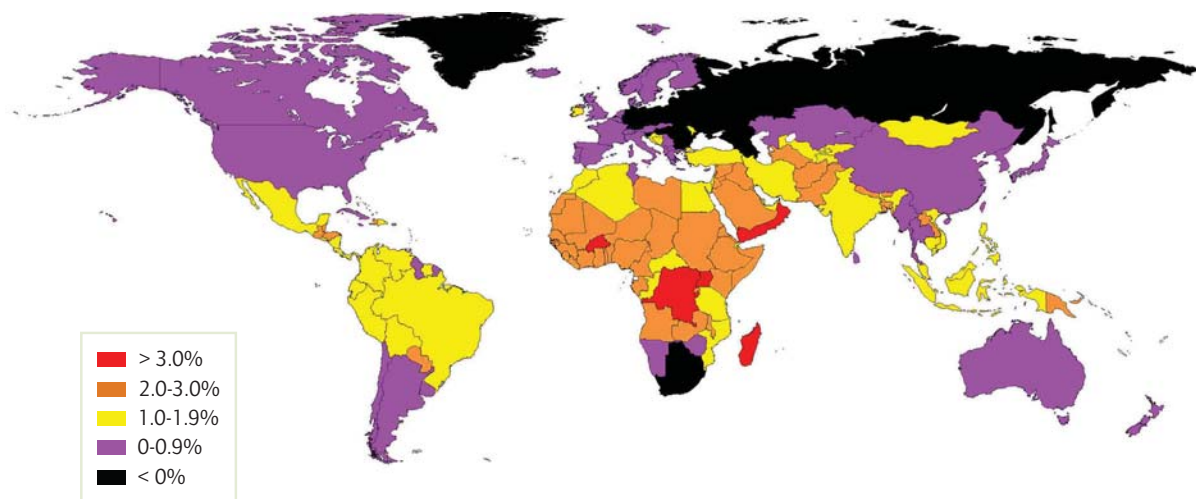


Figure 2 Natural growth rates, 2007. Variations in natural growth around the world primarily reflect differences in mortality rates; some countries experience negative natural growth.

Source: Author.

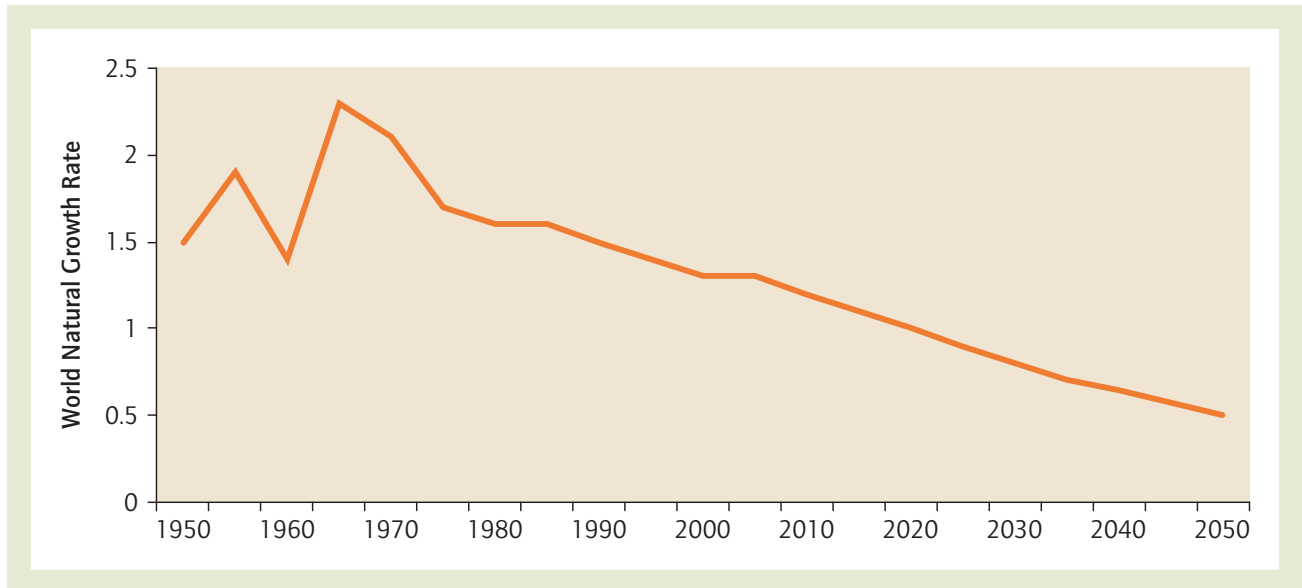


Figure 3 World natural growth rates since 1950 and projected to 2050. Gradual declines in fertility worldwide have led, and are expected to continue to lead, to declines in the world's population increases.

Source: Author.

in the foreseeable future (Figure 3). Thus, whereas the world's natural growth peaked in the mid 1960s (around 2.3% annually) and dropped to 1.3% in 2007, it is projected to fall as low as 0.5% by the year 2050.

Barney Warf

See also **Demographic Transition; Fertility Rate; Malthusianism; Mortality Rate; Neo-Malthusianism; Population Geography; Population Pyramid**



NATURAL HAZARDS AND RISK ANALYSIS

Human beings live on a restless, dynamic planet. Our settlements and livelihoods depend on Earth's variations and variability, past and present, in the form of geology, topography, climate, and the distribution of vegetation and freshwater. At the same time, these variations and variability pose potential threats, which are called natural hazards. Extreme movements in Earth's crust release

energy experienced as earthquakes, volcanoes, and tsunamis on Earth. Climate extremes such as hurricanes release gigantic amounts of energy. Heat waves, blizzards, and ice storms are other climate extremes. Floods and mass movements such as landslides, rock fall, and snow avalanches are more localized but can be very destructive and deadly, as are tornadoes and lightning strikes. Drought is a slow-onset hazard but nevertheless associated at times with great economic cost and displacement of people.

Hazards, however, are not in themselves a problem for humanity. Every day, many thunderstorms flash and rumble around the world in uninhabited areas and over the large surface of the planet covered by oceans. Ice, rock, and debris slides are a normal part of the erosion and deposition cycle, and many take place in uninhabited regions of Earth's mountains. To mention an extreme case, a sizable object (perhaps a meteor or comet) entered the atmosphere and exploded over Tunguska, Siberia, in 1908, flattening 80 million trees over an area of 2,000 square kilometers. But there were no human settlements. Had the event occurred over London or Paris, the outcome for humanity would have been quite different.



At the other end of a continuum of magnitude, even normal (statistically mean) values for some natural processes may endanger the health, livelihoods, and lives of people so poor or so marginalized by society as to live with little protection in highly exposed locations such as very steep slopes, in gullies, on temporary silt islands, or very near a river flood plain. In such cases, “normal” or “small” landslides, seasonal flooding, or the occasional “expected” rock fall may have catastrophic consequences for one or a few households while never being registered as a “disaster” for society.

Disaster Magnitude and Trends

The *Global Assessment of Disaster Risk Reduction 2009* of the United Nations (UN) reveals large human and economic losses to disasters triggered by natural hazards. Excluding deaths due to epidemics, some 8,866 events accounted for 2.3 million deaths in the period 1975 to 2008; economic losses in that period totaled US\$1,528 billion. Deaths were concentrated in low-income countries; while absolute economic losses (especially insured losses) were heavy in high-income countries, although low-income countries bore the brunt of economic damage when compared with their limited gross domestic product. In addition, losses are increasing.

Five of the disasters with the highest death tolls since 1975 have occurred during the recent period 2003 to 2008. These more recent events include 4 of the 10 disasters with the highest economic losses since 1975. Since 2004, the United States has lost US\$200 billion in six hurricanes. In that same period Japan lost US\$40 billion in two earthquakes, and China lost US\$30 billion in the 2008 earthquake in Sichuan.

Risk Analysis

Risk from such natural hazards is a function not only of the magnitude, frequency, and spatial extent of the event but also of specific people's susceptibility to loss, injury, or death. Susceptibility to harm is usually referred to as vulnerability (V) when its determinates are included. Vulnerability may be counteracted by individual and local capacity (C) for protective action and coping in

times of crisis and by protective actions carried out by larger entities such as the nation-state or subnational governmental actors, generally called mitigation (M). One can bring all these together in a useful mnemonic:

$$R = H \times [(V/C) - M],$$

where R is risk and H is hazard, V stands for vulnerability, C represents capacity for personal protection, and M symbolizes larger scale mitigation of risk by preventive action and social protection.

Vulnerability and capacity need to be seen in the context of the processes of marginalization and prejudice in society. All societies have within them groups of people who are stigmatized, marginalized, and excluded to one degree or another because of their perceived characteristics—health status and physical/mental abilities, gender or sexual orientation, age, ethnicity, caste, language, or religious affiliation. Exclusion may lead to situations in which residential location, occupation, income, access to information, and political representation might contribute to increased vulnerability to the impacts of natural hazards. However, such people should not simply be seen as victims. They are also frustrated potential participants in the process of risk reduction. They have knowledge and skills, yet few are included in planning and projects. In the United States, for example, according to a 2009 report by the U.S. National Disability Council, very few people living with disabilities have been asked what they need or want or how they can contribute to risk reduction. In many countries, women's and children's knowledge and capabilities are not recognized by professional emergency managers and planners despite the well-documented achievements by children and women. Social movements make the situation of the marginalized more visible, and some positive policies and practices have begun to find traction as expressed during the 2009 UN Global Platform for Disaster Reduction.

Ambiguity of the Term *Natural Hazard*

What should be obvious by now is that the term *natural hazard* is ambiguous. A possibly better term would simply be *potentially damaging natural events and processes*. More than 200 years



ago, Samuel Johnson refuted idealism by kicking a stone. Johnson's cry, "Thus, I refute it," must resonate with those whose fieldwork puts them in direct contact with natural hazards and their human consequences. The introduction of vulnerability in risk analysis never denies the reality of hurricane force wind. No one who writes about herders who have lost all their animals disputes the power of the sun baking the cracked soil. What natural sciences know about potentially damaging natural events and processes is vital and should be made available to those exposed to such threats. However, departing again somewhat from more conventional views, local knowledge of these processes is also important when it comes to understanding how people cope with natural hazards. People's experience of natural hazards is also a form of knowledge that has been given many names: *ethnoscience*, *folk ecology*, and *indigenous technical knowledge*.

Root Causes of Disaster Risk

What accounts for the degree of social vulnerability, capacity for personal protection, and level of state investment in social protection and preventive action? While detailed answers vary from situation to situation, there are always root causes that can be traced back through the history of control over resources in a particular society and how political power was divided and used. These root causes take particular forms as policy decisions and institutions react to economic, political, and demographic pressures. Focused in this way, historically established power relations (e.g., relations governing land tenure, access to capital and markets, and location decisions)—that is, the "root causes"—are translated by dynamic pressures into specific unsafe conditions: my building or my home under an unstable slope or you living in a zone of seismic activity and sending your child to a school that will likely collapse in an earthquake.

Power—its use and misuse—shapes how disaster risk is distributed socially and spatially. National scale politics defines winners and losers, and this despite substantial international encouragement for development of laws and institutions for reduction and management of disaster risk. There is a large gap between rhetoric and reality,

and this becomes even clearer when one explores the human rights implications and dimensions of disaster risk. So, too, violent conflict has very complex relations with natural hazards and disasters. People displaced by conflict may be forced to settle in locations prone to natural hazards. People caught up in a conflict are often less accessible to humanitarian agencies wanting to respond to the human impact of a natural hazard. Moreover, hazard events may exacerbate an existing conflict, as in Sri Lanka, or afford the occasion for belligerents to seek peace, as in Indonesia—both cases following the impact of the great Asian tsunami in 2004.

Links With Sustainable Development and Climate Change

Root causes of disaster vulnerability are also evident in the ways in which people exploit the natural environment. Possibly damaging natural processes may also take the form of "resources." For this reason, people have settled and farmed on the fertile slopes of volcanoes and in the alluvium deposited by floods for millennia. While this dialectic of resource and resistance has been known for many years, other connections are not as widely appreciated. For example, the Intergovernmental Panel on Climate Change (IPCC) and other authorities warn that climate change is very likely to bring with it more intense storms as well as more variability in rainfall. Thus, not only is misuse of power a source of disaster risk for some but "development" (defined as economic growth) may be implicated too.

Case Studies

Adopting the method of inquiring into root causes, dynamic pressures, and unsafe conditions, the previous points will be made concrete by examining urban and rural disasters in both the industrial West and one of the least developed countries of Africa.

Hurricane Katrina and Monsoon in Mumbai

Between August and September 2005, Hurricane Katrina triggered massive flooding in New Orleans, and more than 1,000 people died.



A month earlier, heavy monsoon rain had triggered widespread flooding in Mumbai, India's commercial capital, and in other parts of Maharashtra State, also killing more than 1,000 state-wide and 447 in Greater Mumbai. While the hazard events were both of high magnitude, many deaths could have been avoided, economic loss lessened, and the suffering caused during evacuation and sheltering could have been avoided were it not for a cascade of other processes.

Root Causes

There was long-standing social marginalization along race/caste lines, respectively, in New Orleans and Mumbai and also long-standing environmental degradation in the coastal wetlands (Katrina) and in the wetlands north of Mumbai and along the Mithi River.

Dynamic Pressures

These included rapid urbanization, urban budget pressure, and poor urban governance (leading especially to poor maintenance of levies and drainage in both cities).

Unsafe Conditions

These included the fact that low-lying residences were not raised on mounds or pillars in either urban region. Evacuation was difficult or impossible, especially since the most vulnerable population in New Orleans had no access to vehicles or public transportation. In Mumbai, the public transportation system was immobilized, there was little warning, and the sanitary conditions in shelters were poor.

Niger Famine

Niger is a large, landlocked country in the Sahel savanna zone of West Africa. Drought and a locust invasion were the natural hazard triggers of the 2005 food emergency in Niger that saw 12 million people in danger of starvation. However, this trigger alone would not have produced a disaster were it not for the following chain of events.

Root Causes

As in much of sub-Saharan Africa, there had been a long-standing marginalization of small

farmers because of urban bias in infrastructure and service provision and more recently a neoliberal policy making health care and education available only to those who can pay.

Dynamic Pressures

An economic policy promoted by international experts led to delays in food aid despite data produced by CARE and Doctors Without Borders documenting widespread malnutrition. Decision makers held to the belief that markets would respond. Other market-oriented policies included the selling off of the country's strategic grain reserve and allowing a small number of traders to corner the remaining supplies. The result was spiraling food prices. Irrigation systems were privatized also in accordance with International Monetary Fund recommendations. The small-scale farmers could not afford irrigation water, which could have provided a buffer during the drought.

Unsafe Conditions

Destitute farmers and pastoralists had no further assets to sell in order to feed their families. They were forced to reduce consumption, skip meals, and resort to wild foods ("famine foods").

Reducing Risks From Natural Hazards

Just as the past two decades have seen a move from a "hazard" to a "vulnerability" paradigm in the theoretical framing of disasters, so also the balance has shifted from reactive efforts in the face of natural hazards to proactive, preventive policies. Short-term warning and response, relief, and recovery activities remain vital to the protection of lives and assets. Warning, damage assessment, and settlement reconstruction are well established, but they are not without controversy. Evaluations of the experiences of Hurricane Mitch (1998), the Gujarat earthquake (2001), the Asian tsunami (2004), Hurricane Katrina (2005), drought and flooding in much of sub-Saharan Africa during the first decade of the 21st century, and the wildfires in Southern Europe and Australia (2008–2009) all show failure to learn lessons from failure. In addition, one can point to the following commonly recurring themes:



- Warning systems are still not people centered and culturally appropriate.
- Power relations and politics are often obscured and unacknowledged in what pass for “merely technical” exercises such as damage and needs assessment.
- Local economies still suffer, and dependency relations are still created by ill-conceived food aid assistance.
- Local knowledge and skill are often overlooked in the rush to “deliver” in postdisaster situations.
- Culturally inappropriate shelter and settlements are still built.
- Culturally inappropriate methods of psychosocial counseling are still practiced.

International Framework for Disaster Risk Reduction

The UN system with many other partners has attempted to learn these hard lessons and guide disaster reduction. Its vision is codified in the Hyogo Framework of Action (HFA), which calls for a global system of institutions working for disaster risk reduction from a local to an international scale. In this ideal schema, there is universal access to knowledge at all levels—clear lines of authority and decentralization that make funds and technology available at the optimal locations and scales. Awareness of hazards and vulnerability as well as recognition and use of capacities and skills are omnipresent at all scales. It is a beautiful vision, but like Plato’s *Republic*, the gulf between dream and reality is large. In fact, ample knowledge and effective tools exist. Funding, coordination, devolution, and decentralization are lacking and flawed. The pieces do not line up. A survey in 2009 by a network of 600 nongovernmental organizations working on disaster issues interviewed 7,000 local respondents in 48 countries—local government officials, civil society leaders, community representatives—and found that few national efforts documented by the UN over 4 years of investment in its HFA, had had an impact at the local level.

The British planner Peter Hall defined planning as the production of an ordered sequence of actions that lead to the realization of a goal. Attempts to integrate natural hazards and disaster

risk into planning complicate that simple-seeming definition. At the international scale, there is no guarantee that UN agencies and other international institutions do, in fact, share the same goal; despite efforts by the UN International Strategy for Disaster Reduction (UNISDR) to bring about diplomatic and rhetorical commitment to its HFA, implementation is uncertain. One may also question the “orderliness” of the sequence of actions given the voluntary and loose coordination among these international and national bodies. At the national scale, there are also divergent goals, and sequencing of actions is influenced by politics and privilege. For example, adoption of insurance instruments and use of financial planning tools such as insurance are not necessarily the result of a purely rational, technocratic exercise but one strongly influenced by political decisions and economic constraints.

Place, Locality, and Communication

It is often said that all disasters are local. This notion will be familiar to geographers as students of place and people-in-places. Although local government and local civil society organizations may be destroyed or at least put temporarily in a state of limited function when a disaster occurs, these forms of governance and self-help remain the core around which relief and recovery build. Also, the importance of such local institutions for prevention and preparedness is very clearly established. Yet many local jurisdictions are underfunded and poorly staffed. Civil society organizations may not have the confidence of local government, and mistrust may be mutual. This standoff is regrettable. While communities can and should do much to prepare and cope with situations themselves, social protection and protection of infrastructure are tasks that fall outside the ability of communities or even groups of communities united by civil society. The two sides—local government and civil society—need each other to achieve sustainable risk reduction.

Communication is a complex subject that features in much geographical research. As the blogosphere expands, and many new media develop and spread rapidly, communication is seldom unidirectional and only top down. During the 2004 hurricane season in the Caribbean, people



in the Dominican Republic received warnings of approaching storms by mobile phone from relatives living in Miami who had seen the television weather channel coverage. There is much horizontal and bottom-up news, analysis, and opinion expressed. These developments have complex consequences—transparency and accountability of authorities may be increased (and one recalls Nobel Laureate Amartya Sen’s aphorism that a famine had never occurred in a country with a free press). Yet this same technology can perpetuate myths and spread misinformation, potentially leading to repeats of the 1938 “War of the Worlds” scenario. Official warnings of tsunamis decades ago in the United States and New Zealand led people to go down to the shoreline to watch them. Informal tornado warnings sent by mobile phone text message to friends in 2009 led people to try to get a glimpse of the funnel cloud (the United States) while mobile phone cameras provided an incentive to wait in order to take photos (Canada).

Conclusion

Several main themes are central to an emerging consensus concerning natural hazards and the analysis of disaster risk:

- A complex systems framework is required to fully understand disaster risk and adequately inform policy and practice.
- This systems framework must include consideration of many subsystems, including politics, culture, economics, and social relations, as well as the dynamics of natural planetary and cislunar subsystems.
- Research and action (and reflection on action) is required at many scales from the 1:1 scale of local and daily life to that of the planet and its immediate surroundings over the long term.
- Crisis, emergency, disaster, and catastrophe (in an ascending scale of severity and social disruption) must be seen as continuous with “normal” and “routine” processes and practices, especially when marginal and deprived groups of people are exposed to potentially harmful natural processes and events.

Ben Wisner, Ilan Kelman, and J. C. Gaillard

See also **Anthropogenic Climate Change; Class, Nature and; Disaster Prediction and Warning; Disaster Preparedness; Drought Risk and Hazard; Earthquakes; Famine, Geography of; Floods; Hurricane Katrina; Risk Analysis and Assessment; Sustainable Development; Tsunami; Tsunami of 2004, Indian Ocean; Vulnerability, Risks, and Hazards**

Further Readings

- Bankoff, G., Frerks, G., & Hilhorst, T. (Eds.). (2004). *Mapping vulnerability: Disasters, development and people*. London: Earthscan.
- Enarson, E., & Morrow, B. (1998). *The gendered terrain of disaster*. New York: Praeger.
- Handmer, J., & Dovers, S. (2007). *Handbook of disasters and emergency policies and institutions*. London: Earthscan.
- Hewitt, K. (1997). *Regions at risk*. Harlow, UK: Addison-Wesley Longman.
- Pelling, M. (2003). *Vulnerability of cities*. London: Earthscan.
- Pelling, M., & Wisner, B. (Eds.). (2009). *Disaster risk reduction: Cases from urban Africa*. London: Earthscan.
- Quarantelli, E. (Ed.). (1998). *What is a disaster?* London: Routledge.
- Smith, K., & Petley, D. (2009). *Environmental hazards* (5th ed.). London: Routledge.
- Steinberg, T. (2000). *Acts of God: The unnatural history of natural disaster in America*. New York: Oxford University Press.
- Twigg, J. (2004). *Disaster risk reduction, mitigation and preparedness in development and emergency programming* (Good Practice Review 9). London: Overseas Development Institute/Humanitarian Practice Network.
- United Nations International Strategy for Disaster Reduction. (2009). *Global assessment report on disaster risk reduction 2009*. Retrieved July 28, 2009, from www.preventionweb.net/english/hyogo/gar/report/index.php?id=9413
- Wisner, B. (2006). Hurricane Katrina: Winds of change. In E. Ramsamy & G. Tate (Eds.), *The black experience in America* (pp. 434–441). Dubuque, IA: Kendall Hunt.



Wisner, B. (2009). Interactions between conflict and natural hazards: Swords, ploughshares, earthquakes, floods and storms. In H. Brauch (Ed.), *Facing global environmental change* (pp. 247–258). Berlin, Germany: Springer Verlag.

Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: Natural hazards, people's vulnerability and disasters* (2nd ed.). London: Routledge.

NATURE

Geography is one of several academic subjects whose *raison d'être* is bound up with the topic of nature. Indeed, to explore the various ways in which geographers have approached this topic is, in effect, to examine the history and present constitution of geography as such. What is nature? Consult any dictionary and one quickly discovers that there is no straightforward answer. *Nature* refers to a wide range of things in a plurality of different ways. This is why it is an unusually complicated word; some say the most complex in the English language. The term has four principal meanings: first, the nonhuman world, especially those parts untouched or barely affected by humans; second, the entire physical world, including humans as biological entities and products of evolution; third, the power or force governing some or all living things; and fourth, the essential quality or property of something. Since the mid 19th century—the period when geography first became established as a teaching and research subject in the West—geographers have regarded nature (in one or more of its four meanings) as a central topic of inquiry. The question is why and how? In exploring the answer to this question, this entry provides major insight into why geography has changed so much over the past 150 years, and what its intellectual contributions have been relative to other subjects.

Beginnings: Geography and the Nature-Society Interface

Nature became central to geography's academic identity in two ways. First, scholars such as Halford Mackinder, Paul Vidal de la Blache, and Friedrich Ratzel, and William Morris Davis saw

the need to study nature as a whole rather than merely a set of discrete parts. Whereas subjects such as chemistry, physics, and botany focused on the investigation of select elements of the natural world, geography would study all these elements in combination (as Alexander von Humboldt had famously sought to do early in the 19th century). This view is what “physical geography” was, according to its 19th-century proponents such as Mary Somerville. In her 1849 book, *Physical Geography*, she defined it as a description of the Earth, the sea, and the air, the distribution of human beings, and the causes of their distribution. Second, this commitment to studying nature as an integrated, multifaceted system was accompanied by a desire to explore its two-way relationships with human societies. For Mackinder and the other early geographers, it was important that nature be studied in context, as something that forms the basis of and is affected by economic, cultural, and political practices. This investigation of “human-environment” relations could be conducted at a range of geographical scales, from the local to the global.

Clearly, geography had high ambitions in its fledgling years as a university subject; it was, in terms of subject matter and scope, very much a “world discipline.” Given this fact, all four meanings of the word *nature* were—unsurprisingly—bound up in geography's late-19th-century identity. The first meaning (the nonhuman world) was the domain of physical geography; the second meaning (the entire physical world, including humans) featured in attempts to explain why some societies seemed to be “closer to nature” than others; the third meaning (a supervening force or power) appeared in attempts to discover what one commentator, referring to physical geography, described as comprehensive principles rather than isolated facts; and the fourth meaning (the essence of something) was apparent in the widespread belief that geography could be a science like any other, its practitioners seekers after a singular truth possessed by all animate and inanimate entities.

Ideals and Actualities: A Growing Early-20th-Century Gap

Within a few decades, it became clear that geography's lofty ambitions were proving to be a burden for the early university geographers. By



identifying geography with a study of nature in all four of its meanings and in the two ways mentioned, geographers had arguably bitten off more than they could chew. The major problem was a practical one. Geography's perspective on the world was so comprehensive, and its subject matter so compendious, that it proved very difficult to demonstrate causal connections between the component parts of the nonhuman world, let alone all these parts and various societies worldwide. Some, like Mackinder, had hoped that a geographical equivalent of Charles Darwin's magisterial theory of evolution might be developed. But this hope was in vain. It was time-consuming enough to provide mere *descriptions* of these societies and their physical environs, never mind plausible explanations. As a result, most early research publications by geographers were beset by what—with hindsight—were serious intellectual weaknesses. For instance, monographs that focused on specific places or regions were often impressionistic and filled with unverified speculations about how and why nature and human society were as they were in given situations. At worst, this shaded into what we would now regard as racism. For instance, the U.S. geographers such as Ellen Semple and Ellsworth Huntington were apt to argue that certain physical environments produced human “races” less intellectually or physically capable than Europeans. Such beliefs were consistent with certain interpretations of Darwin's momentous discovery that all species are ultimately products of “natural selection”—even though Darwin himself was insistent that humanity was a single, indivisible species.

As a result, by the 1920s, gaps began to appear between the stated ideals of geography's founding figures and geography as practiced by their successors. On one side, physical geography began to fragment into subfields, which in turn focused more and more on biophysical phenomena as such (rather than their two-way relationships with human societies). For instance, the regional-scale study of landforms (geomorphology) was fairly well developed by the 1920s, and climatic geography was also becoming more sophisticated. On the other side, “human geography” began to take shape, with its emerging sub-branches usually lacking any deep grounding in physical geography. For instance, the economic geography

of George Chisholm in Britain and the political geography expounded by Isaiah Bowman in the United States were “systematic” rather than “synthetic” in nature. That is, they abstracted specific features of human practice (economics and politics, respectively) and focused on their spatial variation across Earth's surface. The biophysical basis of human activity was not ignored by either of the two geographers, but there was no pretense of offering a scientific and in-depth account of physical geography or of demonstrating its causal influence on human activity in a robust way.

These developments presaged a widespread turn to specialization and a fragmentation of academic geography that set in after World War II. The weakening of geography's holistic ambitions was no doubt aided by the increasing sophistication, precision, and rigor of other university subjects such as physics and economics, both of which produced notable theoretical breakthroughs by the 1930s, underpinned by mathematics and logic. Even so, geographers' commitment to study human-environment relationships at a range of scales did not entirely disappear. Instead, it was finessed and narrowed somewhat so that it could be delivered more readily. For instance, the American geographer Carl Sauer's influential 1925 publication *The Morphology of Landscape* argued that many ostensibly natural environments were the products of cultural practices, such that culture is the agent, the natural area is the medium, and the cultural landscape the result. This research agenda focused many geographers' attention on different cultures and the physical landscapes they created over time, licensing careful fieldwork and archival study. Sauerian cultural geographers needed to know some physical geography germane to their chosen cultural landscape, but the emphasis was on people's practices rather than biophysical processes or events.

Post-1945 Changes

World War II was a turning point for geography and its approach to the topic of nature. Many who subsequently gained positions in university geography departments served in the military between 1939 and 1945. The experience was formative for most, instilling a belief that precision, measurement, and rationality were virtues to which one



should aspire. At the same time, three other developments were significant. First, academic geography had failed to produce major books or intellectual innovations comparable with, say, John Maynard Keynes's (1936) *General Theory of Employment, Interest and Money*. This void became a cause for concern. Second, many outside geography had successfully argued that the physical sciences and the social sciences (with the humanities) had to be different by virtue of their subject matter. There could be no overarching theory or analysis of people and nature, it was argued, because the latter possessed ontological properties quite different from rocks, rivers, or ravines. For instance, humans are self-reflexive, linguistic, tool-making beings who can make their own history and geography. This argument drove a wedge between the two spheres—society and nature—that the original geographers had sought to bring together in a single intellectual frame. Finally, the embarrassment of “environmental determinism”—the prewar argument made by Semple, Huntington, and others that some human “races” were mere reflexes of climate and resources—made some geographers determined to “raise their game” intellectually.

After 1945, geography progressively splintered into two major halves (human and physical), with each fragmenting into relatively discrete “systematic” subdisciplines. The turn to specialization was undertaken in the hope that human and physical geography could become “spatial sciences.” They would discover—through careful measurement, hypothesis testing, and use of statistics—laws explaining spatial patterns (such as the common tendency of rivers to meander or migration flows to be inversely proportional to the size of destination cities). This necessitated a shift in the ways in which geographers tackled nature as a topic. First, interest in nature in the second sense of the term declined, and nature in the first, third, and last senses became the preserve of an increasingly subdivided physical geography. Second, human geography increasingly abstracted the study of political, economic, and cultural practices from their biophysical integument. The prewar fondness of some geographers for discussing “human nature” (in the biological sense) was also quickly abandoned. Third, physical geographers produced increasingly “scientific” descriptions, explanations, and even predictions of Earth

surface phenomena. Specialization, new databases, new remote sensing capabilities, and new computer technologies made this possible, but the price paid was intellectual disunity. Physical geographers divided nature into the five areas that constitute the field to this day (geomorphology, biogeography, climatology, hydrology, and quaternary environmental change). There was also a move toward small-scale, short-term studies because hypothesis testing was very difficult for macroscale analyses of (say) whole ecosystems or river basins. Finally, all the above meant that the study of human-environment relations became a minority pursuit, with “spatial analysis” and the search for general laws and theories becoming geography's new *modus operandi*.

These changes together bolstered the geographers' intellectual self-esteem and improved their external image within the world of higher learning. Ironically, though, geography was effectively abandoning the study of human-environment relations at the very moment when the title of William Thomas's (1956) famous book, *Man's Role in Changing the Face of the Earth*, was becoming as obvious as it was serious. C. P. Snow's famous complaint about the estrangement of “the two cultures”—one literary-humanistic and the other scientific-rational—was (ironically) applicable to postwar geography, the one subject that had made intellectual unity its *raison d'être*. Some efforts to maintain the “unity of geography” were made, with “systems theory” and “models” two of the suggested ways in which human and physical geographers might make common cause. But these efforts could not prevent a growing schism between human and physical geography, with nature effectively erased from the former's intellectual preoccupations. At the same time, physical geography's major branches extended into cognate subjects—such as ecology as in the case of biogeography. This made them increasingly interdisciplinary and reflected their inability to police their own turf once the idea of a unified physical geography was abandoned after 1945.

Recent Developments: The Rediscovery of Nature

Through the 1960s and 1970s, the situation as described above prevailed. However, from the



early 1980s, human-environment geography enjoyed a revival, but in a modern rather than traditional form. The revival was two-pronged. So-called political ecology grew into a major subfield, especially in American geography. Typically focused on rural localities and farming communities in the developing world, political ecology sought to describe and explain patterns of land use. It was, in part, a reaction to a minority tradition of “cultural ecology” in geography that had existed from the early 1950s. Cultural ecology investigated how preindustrial rural cultures were adapted to the possibilities and constraints of the immediate local environment—be it dryland or wetland, inland or maritime. Political ecologists pointed out that many late-20th-century rural communities in the developing world were being influenced by outside forces—notably, international trade and political decision making at the national level. This meant that local land use decisions were, increasingly, to be explained through a “chain of causality” extending up to the global level and often involving unequal relations of power and control. As a result, political ecologists downgraded the causal role of local ecology in explaining land use patterns in developing world settings. Today, political ecology—which now has both a “third world” and a “first world” strand—is a vibrant and large part of geography. In the United States, it has done much to add luster to geography’s reputation within the university system.

Coincident with political ecology’s rise to prominence, the geography of hazards and disasters also burgeoned as a subfield from the early 1980s. As the 20th century drew to a close, famines, floods, hurricanes, and other extreme natural events were claiming ever more lives. Why was this? A new generation of researchers set out to provide answers. Like political ecologists, many were influenced by new critical theories of society, and they argued that disasters may have natural triggers but their root causes lie in patterns of social inequality that make the poor vulnerable to hazard events. Again, this meant that hazards geographers typically did not inquire too deeply into the mechanics of volcanoes, landslides, or tsunamis.

For all their virtues, political ecology and hazards geography did not address the really big

environmental issues that came to people’s attention at the turn of the millennium. What is more, like Sauerian landscape geography, they proved far more adept at elucidating the human dimensions of the human-environment dialectic rather than the physical ones. Anthropogenic environmental change—or what is sometimes simply called “global warming”—calls for something very close to the holistic approach advocated by Mackinder and other like-minded geographers over a century ago. Looking ahead, the scale and complexity of global climate change demand connected multiscalar and multifactoral analysis and policy making. Having split into two subdivided halves (leaving only a modest “center”), geography is not well placed to rise to the challenge. However, some physical geographers are participating in new, transdisciplinary initiatives to understand the relations and feedbacks between the cryosphere, pedosphere, hydrosphere, and atmosphere. So-called Earth systems science and sustainability science have arisen in response to the intellectual challenge and practical threat posed by global environmental change. This is not leading to the reunification of physical geography, nor are physical geographers necessarily in the vanguard of either field. But the latter’s skills as field scientists, accustomed to dealing with open systems, complexity, and uncertainty, have proven valuable assets.

Meanwhile, what of human geography and the topic of nature? Since the early 1990s, human geographers have rediscovered nature after pretty much ignoring it for 30 years. This was not—as might be assumed—a response to global environmental change or a concern to understand and ameliorate “the human impact.” Instead, human geographers rediscovered nature in different ways and for different reasons. First, some radical economic geographers began to talk about the “production of nature” in late capitalist societies. This counterintuitive idea (“nature” seems precisely that which cannot be produced by humans) was intended to have two intellectual consequences. On one side, it called into question arguments about the supposed “end of nature,” voiced by environmentalists such as Bill McKibben (who, in 1989, published a well-known book of this name). Geographers such as Neil Smith argued that what we call “nature” has not been natural for a long



time and questioned the motives of those who would have us alter our way of life in the name of a supposedly vanishing nature in need of protection. On the other side, the production of nature argument directed geographers' attention to the actors and institutions that were consciously altering nature. Smith, a Marxist, suggested that capitalist firms—in their endless search for profits—were producing nature in ways that might not serve the public interest. This argument anticipated by many years the recent furor over genetically modified organisms cultivated for medicinal and nutritional purposes and developed by global agrofoods and pharmaceutical companies.

If Smith's work accented the profound biophysical effects of economic processes, other human geographers updated Sauer's arguments about the power of cultural beliefs. "New" cultural and rural geographers became deeply interested in the ways in which people's ideas, beliefs, and representations of reality become indistinguishable from the material world to which they refer. In a reversal of the epistemic realism that says that most human symbolic representations (words, images, music, etc.) are "mirrors" held up to the physical world, these geographers suggested that representations *become real* for those who hold them dear. For instance, in his 2002 book, *The Intemperate Rainforest*, Bruce Braun showed that Canadians descended from European settlers tended to see "nature" as a pristine space, a refuge devoid of any human presence. This contrasted with a native North American (First Nations) worldview in which what Westerners call "nature" is regarded as a living landscape inclusive of people. "Nature," Braun demonstrated, was a socially constructed idea, not simply an indisputable fact existing regardless of human beliefs about it. The question then becomes whose representation of "nature" comes to count the most in any given situation, why, and with what effects.

By the turn of the new millennium, human geographers such as Smith and Braun had succeeded in "denaturalizing nature." They weren't denying that what we call "nature" exists. Instead, they argued that the supposed "naturalness" of natural things was not all that it seemed to be. Their research revealed that if we want to understand "nature," we often need to look at who is talking about it or altering it, what their agendas

are, and why they use references to nature to communicate their own wishes and desires. However, arguments about the "production" and "construction" of nature attracted criticism from some human geographers. It was felt that these arguments rested on a conceptual dualism in which "society" called the shots over the domain of "nature." The material properties and agency of those things conventionally called "natural" seemed to recede from view. Sarah Whatmore, in her 2002 book *Hybrid Geographies*, argued that the dualism was unrealistic and diverted attention away from how entangled and messy the world actually is. She also argued that even in a world where humanity seemed to be "dominating" nature, nature possessed an enduring liveliness and a capacity to make a difference to the quality of human existence.

Whatmore's book is one example of a new "more than human" geography. Her project has found echoes in so-called nonrepresentational geography, which is especially prominent in Britain. The ambition has been to challenge the idea that the world is divided into two distinct ontological domains of "natural" and "nonnatural" (humanly made) things. Unlike those environmentalists and bioethicists who refer to nature's "special qualities" as part of a campaign to limit human "meddling," geographers such as Whatmore argue that the world comprises endless "hybrids." That is to say, they argue that life is a rich tapestry made up of entirely codependent, co-conditioning entities: rocks, machines, trees, textiles, animals, bacteria, and airplanes. There is, according to Whatmore, no such thing as either "society" or "nature." This amounts to a distinctive intellectual and moral argument: "Nature" is not disappearing or in need of "saving," nor will it exact a Gaia-like "revenge" on humanity, for the simple reason that nature—as such—does not exist!

Conclusion

More than a century after geography became a university discipline, we see that nature is still central to its identity and focus—but in ways that geography's founding figures could scarcely have anticipated. The holistic ambition to elucidate human-environment relationships long ago gave way to more limited attempts to investigate



biophysical processes, events, and entities. While physical geographers still regard nature as something existing “out there” amenable to “objective” understanding, we have seen that many contemporary human geographers have seen fit to question nature’s naturalness in a range of ways. Meanwhile, political ecologists and fellow travelers offer a contemporary and relatively contained version of what Mackinder had in mind in the late 19th century. If one adds all this up, a complex picture emerges: Contemporary geography’s contribution to understanding nature is diverse, even internally contradictory, but undeniably rich by virtue of this heterodoxy.

This fact notwithstanding, academic geography’s public image remains surprisingly close to that promoted by its founders. Unaware of the developments recounted above, many people believe that geography’s strength and distinctiveness lies in its ability to be both an environmental and a social science without problems or contradictions arising. Geographers themselves have done much to sustain this (partial) illusion. Many degree programs still emphasize “human-environment” interactions as a key theme—this is unsurprising, given that candid discussion of geographer’s far from unified approaches to the topic of nature would hardly make for good public relations! Continued calls for the “reunification of geography” made by a minority of academic geographers are unlikely to exert a centripetal force on such a centrifugal field.

Noel Castree

See also **Animal Geographies; Biogeography; Class, Nature and; Critical Studies of Nature; Cultural Ecology; Ecological Economics; Environmental Determinism; Ethnicity and Nature; Gaia Theory; Gender and Nature; Human Geography, History of; Hybrid Geographies; Nature-Society Theory; Physical Geography, History of; Political Ecology; Social Construction of Nature**

Further Readings

- Braun, B. (2002). *The intemperate rainforest*. Minneapolis: University of Minnesota Press.
 Castree, N. (2005). *Nature*. London: Routledge.

- Fitzsimmons, M. (1989). The matter of nature. *Antipode*, 21, 106–120.
 Gold, M. (1984). A history of nature. In D. Massey & J. Allen (Eds.), *Geography matters!* (pp. 24–43). Cambridge, UK: Cambridge University Press.
 Proctor, J. (1998). The social construction of nature. *Annals of the Association of American Geographers*, 88, 352–376.
 Whatmore, S. (2002). *Hybrid geographies*. London: Sage.



NATURE-SOCIETY THEORY

Nature, it has been said many times, is a complex term that is both very familiar and extremely elusive. From “natural yogurt” to “human nature,” from “nature parks” to “natural boundaries,” the term has a range of uses so wide that a loss of grip on what it is we have in mind seems almost inevitable. Since geography framed itself as the discipline entrusted to study the relationship between humans and nature, the changes in our understanding of what nature is have profoundly affected what geographers study and how they study it. The prevalent Western geographical practices traditionally followed the modern dichotomy—presented as the commonsense understanding of the world—that separates nature from culture, or nature from society. In our everyday language, if something is social, then almost by definition it cannot be natural. And if something is described as natural, then it is unlikely to have much to do with society. Thus, despite a rich history of engaging with nature and the environment, geography started to interrogate nature in itself only in recent decades, having previously treated it reductively. Environmental determinism, possibilism, human ecology, and cultural ecology—as well as, to a certain extent, ecological anthropology—have thus been challenged or outright replaced by a multitude of intellectual newcomers. This entry explores many of these challenges, mentioning what new ways of thinking about nature and society have emerged, and how these have changed geographical practices. These include the social production of nature, the social construction of



nature or “social nature,” political ecology, as well as innovative approaches to materialities, heavily influenced by science studies.

None of these challenges emerged or exists in isolation, however much their proponents attempt to police the boundaries around them; instead, responses to these challenges have drawn productively and opportunistically from sources as wide as Marxist, feminist, poststructuralist, postmodernist, and postcolonial thought. Presenting these challenges as a succession of different schools or coherent approaches would be both artificial and stunted; instead, ideas have traveled, been challenged, rejected, and adopted by a variety of authors coming from different backgrounds. While some authors are easier to place within this spectrum, others resist fixity and draw creatively from a variety of more or less compatible new paradigms. Changes in the way nature and society are considered have not come from the social sciences alone; as many “new” ecologists and some political ecologists have highlighted, the understanding developed by ecologists and biologists that nature is not stagnant nor in equilibrium has also had a profound impact, changing how nature-society theories are made.

Nature as the Opposite of Society?

As noted at the outset, in everyday life in the Western world there remains a so-called commonsense understanding that the natural world and the social and political worlds are fundamentally different. Trees are trees, and politics—or society—is something quite different altogether. One challenge to this understanding has come from ecologists and, in particular, “deep” ecologists who attempted to collapse the binary by claiming that nature was all-embracing, making humans an (usually destructive) equal part of it. Paradoxically, this approach has done little more than reify the binary further: Nature, rather than being “everything,” ends up being considered only truly “out there,” surviving in the (few) remaining “real wild” places free from human impacts. This return to a romantic view of nature sees it as something pure and ideally untouched by humans that should be left alone to thrive through its own pristine devices. As the real remaining “true nature” is often physically located in the global South, these

approaches have frequently implied expelling the people who have inhabited these places for generations and directly took part in shaping them. This racism buttressed by naturalism ignores that places are peopled, have histories and geographies, and are social as well as natural places. In response to this, William Cronon first suggested that what might look natural to a Western eye is already mixed up with human worlds and that ignoring this directly threatens not only human livelihoods but the places themselves that proponents of such ideas seek to protect.

Such critiques drew heavily from social constructivism that emerged within the social sciences in the 1980s, and increasing attention was explicitly given to the social dimensions of nature. This change led geographers to explore how the construction of the spatial and the natural at the level of the social imaginary changed over time, for instance, when writing about protected areas and national parks. In such studies, discourses challenging the location and the (im)pertinence of the boundary between nature and culture were variously seen to question who and what were considered legitimate insiders and illegitimate outsiders. Nature, in this line of thinking, could no longer be simply “natural” or wild but rather was taken to be intrinsically social and political. Taking nature in itself, as nonsocial and unchanging, was seen to lead to the perpetuation of power and inequality in the wider world. In a series of works by geographers, drawing creatively from social constructivism, poststructuralism, and Marxism, an agenda emerged that studied the politicized construction of social natures. Binaries such as nature/culture, as well as wild/domestic and nature/artifice, were revisited in this light, all taken in a sense to be equally made and potentially equally political.

In other linguistic contexts, such debates about the construction of nature have taken place within other disciplines such as sociology, albeit with a slightly less political slant. Conceptions of nature and space have been seen to have wider and direct implications for the study of specialized difference as the (human) other is metaphorically and discursively constructed simultaneously to the (nonhuman or “natural”) other. Studies often focused on protected areas, since these particular spatial entities are directly designed for nature conservation, a topic frequently discussed and



appropriated by natural scientists. In this context, the temptations are manifold for those involved in the management of such areas for grounding what are in effect political decisions in “reason” or “objective science.” Grounded in natural arguments purporting to be value-free, linked to a conception of nature as wholly removed from society, such environmental discourses have a perverse tendency of taking on a life of their own, instrumentalized within reactionary politics that have a very real effect on people’s lives. Geographers have therefore put their finger on how political such discourses actually are, and how potentially disempowering they can become to less powerful actors and alternate forms of knowledge, including indigenous ways of knowing.

Putting the Political Back Into Ecology

This attention to livelihoods and social justice is particularly pronounced in what is often presented as the neighboring field of political ecology that has drawn additionally from cultural ecology and the political economy of development. Pertinent questions have included exploring how the relationship between society and nature has been defined and conceptualized, how access to land and resources is controlled in a variety of contexts, and how environmental costs and benefits are distributed. Understanding the interplay between power and space at multiple scales, symbolically and materially, has been a central concern of these approaches, drawing further from feminist and Marxist thinking.

Cindi Katz, for instance, while noting the common threads between the exploitation of people and the exploitation of nature, and referring to feminist and ecofeminist writing, has picked apart the notion of nature as an accumulation strategy, taken to be an investment for the future controlled by powerful capitalist interests. The environmentalist literature, she notes, is so full of the metaphors of investment, saving, and future gain that it often reads like boardroom script. All this, she argues, begs the question of who has rights to determine the appropriate use of preserved land, and how the altered temporalities and spatialities affect future access to the land. In parallel, geographers such as Jessica Budds, Michael Watts, or Paul Robbins have worked within similar

political ecology perspectives to explore examples as varied as the socio-environmental outcomes of water management in Chile, issues of drought and food security in West Africa, or the expansion of turfgrass in the United States. In the Chilean case, such an approach has illustrated how large-scale farmers have exerted greater control over water, while peasant farmers have been granted increasingly less access. Examination of social equity and the environmental aspects of resources management have highlighted new causes for concern in terms of social and spatial justice.

Rethinking the Divide Between Nature and Society

Literature from science studies and in particular from Bruno Latour and Donna Haraway provided a different and equally innovative impetus and theoretical grounding for rescripting the divide between nature and culture (or society), partly through a vigorous engagement with the process of scientific knowledge production. Scientific discourses, rather than being purely rational or objective, are taken to be vulnerable to critical scrutiny only by getting up close and tracing how it is made within the laborious assemblages of expert communities, particular words and phrases, documents, and professional protocols. For authors such as Sarah Whatmore and Steve Hinchliffe, these are seen to be performative achievements that are always partial, contestable, and incomplete. Knowledge producers are taken to be active participants who are situated, embodied, passionate, political, social, temporal, and spatial. They are spatialized, connected, and disconnected in varying ways to others and a lot of elsewheres. Their critique has focused on the silencing effect of approaches to the social construction of nature, noting how these have perversely assumed that that nonhuman world is mute and malleable, endlessly susceptible to being constructed following human ingenuity.

Diverse appeals to relations, actors, materiality, and material encounters have therefore led geographers to explore and spatialize concepts such as hybridity, exploring the physicality and co-presence of the nonhuman, both animate and inanimate. This exploration has led to approaches where nature, rather than being of interest only in



how it is imagined, represented, thought of, or conceived, is also explored through other concrete practices such as growing, gardening, infecting, digging, or counting. The dualism of nature and society is rejected as strongly as in other approaches mentioned earlier, but here this rejection is based on a detailed exploration of the networks—or assemblies or assemblages—that link together humans, organic nonhumans, technological objects, and quasi objects (or hybrid objects) that are combinations of technology and living organisms. Nature is not considered a malleable mass, passive and aspatial, susceptible to human will or to cultural, political, or economic forces and contestations, but instead, it is taken to be something that resists dynamically, takes part in its construction, and makes and shapes its multiple complex present.

Identifying what kinds of spaces remain for nature is crucial to this approach, assuming that it is neither dead nor neatly bounded in a self-sealed shell. This is a more directly political position than might at first appear, since it is driven by the idea that existing conceptions of nature lead to unjust politics that consign people, plants, and animals to unsatisfactory ends and limited spaces. By exploring the specifically messy assemblages as well as the physicality of bodies, plants, and animals that are mobilized to enshrine and construct particular spaces, more just policies are seen to be ultimately made possible. Rather than seeing nature fixed in particular places, figures of transgression—bodies transgressing accepting bounds—are used to foreground the mapping of ideology onto space. The overtly political claims of such approaches have been challenged by authors of a more Marxist bend, pointing out that such claims of politicizing practices that naturalize rarely address the thorny problem of power explicitly, leaving open the question of whether it is possible to weave this approach with practices of a nuanced, historically informed approach to power.

From Universal Nature to Global Nature

Nevertheless, this fusing of innovative ways of rethinking nature has led to a variety of material engagements with nature as something emerging globally. These approaches to the vitality of nature in part address the charge that the

nature-society theory has not contained enough ecology, or else has understood ecology poorly. In the most overt engagements with the dynamic relations and materiality of nature, it is taken to be always already unpredictable, vital, and always shot through with multiple, transversal, and non-linear relations. Interest extends to things as diverse as species, bacteria, viruses, and other runaway mobile hazards. Nature, on this global scale, is taken to be only the provisional outcome of local processes, the current state attained by a world of systems whose ultimate states can never be predicted. Having abandoned the certainties of the physical sciences, a material world remains, which is more deeply imbued with creative and self-generative properties than at any other stage of modernity. In arguing that such “global natures” are always specific assemblages whose intricate geographies form complex webs of different length, density, and duration, with varied consequences in different places, all experienced differently, Bruce Braun has dismissed all temptation of returning to the notion of nature as both singular—and thus culturally situated—or universal.

Juliet J. Fall

See also **Class, Nature and; Critical Studies of Nature; Cultural Ecology; Ecological Economics; Environmental Discourse; Ethnicity and Nature; Gaia Theory; Gender and Nature; Nature; Political Ecology; Race and Nature; Science and Technology Studies; Social Construction of Nature**

Further Readings

- Bakker, K., & Bridge, G. (2006). Material worlds? Resource geographies and the “matter of nature.” *Progress in Human Geography*, 30, 5–27.
- Braun, B. (2002). *The intemperate rainforest: Nature, culture and power on Canada's west coast*. Minneapolis: University of Minnesota Press.
- Braun, B., & Castree, N. (Eds.). (1998). *Remaking reality: Nature at the millennium*. New York: Routledge.
- Budds, J. (2004). Power, nature and neoliberalism: The political ecology of water in Chile. *Singapore Journal of Tropical Geography*, 25, 322–342.



- Castree, N. (2005). *Nature (key ideas in geography)*. London: Routledge.
- Castree, N., & Braun, B. (Eds.). (2001). *Social nature: Theory, practice, and politics*. Malden, MA: Blackwell.
- Cronon, W. (1995). *Uncommon ground: Rethinking the human place in nature*. New York: W. W. Norton.
- Demeritt, D. (2002). What is the “social construction of nature”? A typology and sympathetic critique. *Progress in Human Geography*, 26, 767–790.
- Fall, J. (2002). Divide and rule: Constructing human boundaries in “boundless nature.” *GeoJournal*, 58, 243–251.
- Gregory, D. (2001). (Post)colonialism and the production of nature. In N. Castree & B. Braun (Eds.), *Social nature: Theory, practice, and politics* (pp. 84–111). Malden, MA: Blackwell.
- Haraway, D. J. (1991). *Simians, cyborgs and women: The reinvention of nature*. London: Free Books.
- Hinchliffe, S. (2007). *Geographies of nature: Societies, environments, ecologies*. London: Sage.
- Katz, C. (1998). Whose nature? Whose culture? Private productions of space and the “preservation” of nature. In N. Castree & B. Braun (Eds.), *Remaking reality: Nature at the millenium* (pp. 46–63). London: Routledge.
- Latour, B. (1999). *Pandora’s hope: Essays on the reality of science studies*. Cambridge, MA: Harvard University Press.
- Neumann, R. P. (2005). *Making political ecology (human geography in the making)*. London: Hodder Arnold.
- Robbins, P. (2004). *Political ecology: A critical introduction*. Malden, MA: Blackwell.
- Soper, K. (1995). *What is nature? Culture, politics and the non-human*. Oxford, UK: Blackwell.
- Walker, P. (2005). Political ecology: Where is the ecology? *Progress in Human Geography*, 29, 73–82.
- Whatmore, S. (2002). *Hybrid geographies: Nature cultures spaces*. London: Sage.
- Zimmerer, K. S. (2007). Cultural ecology (and political ecology) in the “environmental borderlands”: Exploring the expanded connectivities within geography. *Progress in Human Geography*, 31, 227–244.



NEIGHBORHOOD

A neighborhood is a geographical entity located within a county, city, town, borough, or other local government political unit. Neighborhoods are not official political constructions, yet many have widely used popular names. For example, in Philadelphia, there is the “Northside,” “Southside,” and “Triangle” neighborhoods. The U.S. Bureau of the Census has tried to capture the neighborhood concept by creating census tracts, which are submunicipal areas of 1,500 to 8,000 people (typically about 4,000) that are considered relatively homogeneous with regard to demographic, housing, and economic characteristics. Census tracts have been created for almost every metropolitan area and for some nonmetropolitan areas. Local elected officials recognize the importance of neighborhoods, and hence many municipal governments have submetropolitan political districts called *wards*. Each ward has a neighborhood representative participating as part of the local governing body.

Governments cannot ignore neighborhoods because many people identify more closely with their neighborhood than with their local political jurisdiction. Homeowners typically have made their major financial investment in their home. Research shows a strong correlation between the rating of home quality and neighborhood quality. This association makes sense because the value of a home can be enhanced by an attractive, noise- and crime-free neighborhood, whereas a poor-quality neighborhood can depress home value. This entry reviews the qualities that residents perceive as determining the quality of their neighborhoods. It then discusses efforts—by government, by the residents themselves, and by nonprofit organizations—to maintain or improve neighborhood quality.

Neighborhood Quality

Most of what we know about U.S. neighborhood quality comes from the American Housing Survey (AHS), which collects approximately 50,000 samples from Americans about housing and neighborhood quality on average every other year from a sample of counties. The AHS shows that the vast



Mott Street in New York City, the traditional center of Chinatown, where the Chinatown Community Center is located

Source: Derek Jensen.

majority of Americans like their neighborhoods. Specifically, the author has combined early AHS surveys. (Neighborhood quality was measured as “excellent,” “good,” “fair,” and “poor” with later ones, which measured neighborhood quality on a 1 to 10 scale from “worst” to “best.”) Over the past 25 years, these surveys show that 30% to 35% of Americans rate their neighborhood quality as “excellent.” Another 46% to 52% rate their neighborhood as “good” quality. Neighborhood is a haven for nearly all these residents. The Pulitzer Prize-winning columnist Murray Kempton underscored that haven concept when he defined a neighborhood as a place where “when you go out of it, you get beat up.”

The remaining 15% to 18% rate their neighborhood as “fair” or “poor” quality. Yet averages are misleading. There are striking differences

among neighborhoods. In one neighborhood in Chester (Pennsylvania), 36% rated their neighborhood as fair quality and another 44% rated it as poor quality. The author identified more than half a dozen other U.S. neighborhoods where more than 70% of the respondents rated their neighborhoods as fair or poor quality.

There is nothing subtle about the causes of the different ratings. When residents do not identify even a single problem that bothers them, neighborhood quality will be rated excellent or good. When residents believe that a problem is so distressing that they want to leave, then their neighborhood is likely to be rated as fair or of poor quality. More specifically, perceptions of unsafe neighborhoods because of behavioral hazards (drug dealing, burglary, rape, and other criminal activities) and deteriorated physical



A Croatian neighborhood festival around the St. Jerome Croatian Roman Catholic Church in the Bridgeport neighborhood of Chicago. In the past, many Chicago neighborhoods were defined by the local parish. Although this is less true today, around some parishes there remains a strong sense of neighborhood and community that becomes very apparent during the summer festivals such as the one featured in these pictures. The tricolor red, white, and blue flag with the central crest is the Croatian flag.

Source: Eric Mathiasen.

conditions (blighted buildings, properties, infrastructure, and litter) lead to a poor-quality neighborhood rating. Based on thousands of samples in many neighborhoods, the author found that if both crime and blight were distressing problems, then more than two thirds of the respondents rated their neighborhood as poor quality. Also, crime and blight are typically found with other stressors, such as odors or

smoke from factories, incinerators, and other smokestack facilities; refineries and petroleum tank farms; airplane noise; and waste management facilities. In the most distressed neighborhoods, more than half of the population was bothered by more than 10 behavioral hazards and physical conditions.

The characteristics of a “better” or “worse” neighborhood are another important dimension of public reaction to neighborhoods. Nationally, about 43% of Americans rate their present neighborhood “about the same” as their prior neighborhood (this includes people who have never moved). Forty percent rate their current neighborhood as “better” and about 17% rate it as “worse.” In general, better versus worse is strongly predicted by the number of distressing problems. However, there are exceptions. For example, one woman in her late 30s rated her current neighborhood as better than her previous one, despite the fact that she lived across the street from a smelly and noisy petrochemical facility about which her neighbors bitterly complained. This woman, in contrast, indicated that this neighborhood was better than her previous neighborhood because it had no street gangs, and therefore, she believed that her teenage son would not become part of a gang and potentially get drawn into gang-related violence. In short, perceptions of neighborhood quality and neighborhood improvement ultimately are individual to each of us, although there are general patterns.

Findings about gender-related differences in neighborhood quality are intriguing. In general, women are more sensitive to hazards and neighborhood conditions than their male counterparts. There are good reasons for this observation, including women’s traditional roles as nurturers, women’s greater feeling of vulnerability, and that until quite recently women’s labor force participation rates were much lower than that of the men. Hence, it is not surprising that women are about twice as likely as men to rate their neighborhood poor quality. However, this difference is not found in the most distressed neighborhoods, places where on average six or more characteristics were labeled as distressing to residents. In these neighborhoods, the behavioral hazards and physical conditions are very apparent, and hence, men and women are equally concerned about them.



A final point about neighborhood quality is that neighborhood attractions such as good schools, convenience to public transportation, leisure activities, access to friends/relatives and to work, and neighborhood appearance have not been strong predictors of neighborhood quality rating. Those who rated their neighborhood as excellent rather than as good quality were more likely to point to attractive appearance and good schools. However, the relationship was not strongly predictive. In short, the major predictors of neighborhood quality are distressing behaviors and physical conditions.

Controlling Neighborhood Quality

The economic, social, and psychological importance that the vast majority of people attach to the quality of their neighborhoods cannot be understated. Accordingly, managing neighborhood quality has been the subject of considerable effort and public debate.

During the 1960s, when many inner-city neighborhoods were vandalized, burned, and partly abandoned, a neighborhood life cycle theory was born, which argued that neighborhoods pass through stages of life (birth, maturation, decline, death, and sometimes rebirth). Decline, it was asserted, is predictable and difficult, if not infeasible, to halt and reverse. For example, landlords will no longer continue to maintain aging properties, which then decline further. Lenders become unwilling to provide loans to people living in declining neighborhoods because they cannot realize an acceptable economic return. So-called redlining was a condition in which banks, insurers, and other financial institutions would not provide financial support to property owners in a neighborhood or part of a neighborhood. Continuing the cycle, middle-class people would leave, and the city government would withdraw police, fire, and sanitation resources, which exacerbated the deterioration. Some argued that the only option was slum clearance. The urban renewal programs of the 1950s and 1960s are testimony to the belief that some neighborhoods could not be salvaged and drastic action had to be taken. That redlining and other detrimental actions disproportionately have coincided with neighborhoods occupied by poor African Americans has

underscored the belief that racial transition means devastating neighborhood decline. Many retorted that this relationship is a self-fulfilling prophecy grounded in racism.

The fear of neighborhood decline has led to government, private, and individual efforts to maintain neighborhood quality. With regard to government, the federal, state, and local governments have tried dozens of financial and political tools. The federal government has provided funds for the police and for schools, pilot programs to stimulate the redevelopment of abandoned and underused brownfield sites, loans to neighborhood groups, and a host of other grant, rebate, and tax programs to try to halt decline and promote redevelopment. Each federal administration has tried to put its own brand on these programs, typically mirroring its political philosophy. For example, one of the major ideological clashes has been about place- and people-based programs. Some administrations (e.g., that of President Ronald Reagan) disproportionately focused on programs to assist people, including incentives to relocate, rather than on rebuilding neighborhoods. Others (e.g., that of President Lyndon Johnson) focused more attention on neighborhood programs. Many states have mirrored federal programs; some have developed their own ideas that have diffused up to the federal government and thence back to states and local governments.

Much of the power for maintaining and enhancing neighborhood quality rests with local governments. They can use zoning, building inspections, school construction and rehabilitation dollars, infrastructure improvements, financial incentives, tree plantings, and many other policy devices to improve declining and devastated neighborhoods. They can employ powerful eminent domain legal tools to take “blighted” property and build luxury housing (gentrification), commercial and community facilities, garages, and enlarged roads. The record of local government and their allies in state government, business, and labor organizations with regard to neighborhoods is mixed—ranging from major reinvestment to maintain the existing population and land uses to near-total destruction and building a new neighborhood for new people.



Because government and private business actions with regard to neighborhoods have been so controversial, groups have often created homeowner and neighborhood associations to protect their investments. Nelson estimates that the number of Americans living in neighborhoods with community associations rose from less than 1% in 1965 to 18% by 2004. These associations are expressions of collective self-regulation. Associations can mandate housing type, requirements on lawns and outdoor care, pets, and they can restrict who can live in a neighborhood and how they live in it; they can lay down a minimum age and minimum financial resources to acquire and maintain residents. Homeowners and neighborhood associations, cooperatives, and other private forms of governance have become a powerful tool to manage individual dwelling units and neighborhood quality. At the extreme, communities have literally been surrounded by the gates and fences; so-called gated communities have appeared in Sunbelt areas of Arizona, California, Florida, and Texas and other new suburban developments across the United States. One estimate is that there are more than 250,000 neighborhood associations in the United States. The typical one has about 200 housing units, but Sun City (Arizona) and Reston (Virginia) each have more than 10,000 units.

These neighborhood groups, in essence, are privatizing neighborhoods. With some exceptions, the local government is relieved of some expenses, such as security, fire, housing inspection, lawn maintenance, and trash collection. Politically, these associations demonstrate the power of homeownership and associated financial investors to manage neighborhood quality. Critics contend that they are antiprogressive mechanisms to control the access of poor people.

The third option for a neighborhood is to hope for one or a handful of strong-willed and talented residents or a not-for-profit organization, typically faith based, to organize and protect the neighborhood against crime, blight, developers, and sometimes even the government. The author has written about a number of these individuals: a woman who fought a losing battle against construction of an incinerator in her neighborhood; a resident who successfully sued the federal government, received funds, and then used those to turn her dilapidated public housing project into a

modest affordable housing facility; a city planner who insisted on high-quality housing standards; and a not-for-profit employee who fought for environmental justice in a rural community. These committed and talented people are rare, and relying on one or more of such persons to come along is a long shot.

Michael R. Greenberg

See also **Census Tracts; Chicago School; Ethnic Segregation; Gated Community; Gentrification; Ghetto; Home; Housing and Housing Markets; Housing Policy; Racial Segregation; Real Estate, Geography and; Segregation and Geography; Social Geography; Urban Geography; Urban Planning and Geography; Urban Spatial Structure; Urban Underclass**

Further Readings

- Greenberg, M. (1999). *Restoring America's neighborhoods: How local people make a difference*. New Brunswick, NJ: Rutgers University Press.
- Greenberg, M., & Schneider, D. (1996). *Environmentally devastated neighborhoods: Perceptions, realities, and policies*. New Brunswick, NJ: Rutgers University Press.
- Keating, W., & Krumholz, N. (Eds.). (1999). *Rebuilding urban neighborhoods*. Thousand Oaks, CA: Sage.
- Nelson, R. (2005). *Private neighborhoods and the transformation of local government*. Washington, DC: Urban Institute Press.
- Putnam, R. (2000). *Bowling alone: The collapse and revival of American community*. New York: Simon & Schuster.



NEOCOLONIALISM

Neocolonialism refers to the continuation of a colonial system in spite of formal recognition of independence of the formerly colonized nation. After World War II, when the European colonial system collapsed, the international community recognized the right to self-determination of peoples living under colonial rule. This right was



used to justify and promote the transition of former colonies to sovereign states, causing a rapid emergence of newly independent countries through the transfer of power from empire to nation-state. As a result, the total number of independent countries increased considerably from the late 1940s to the mid 1970s.

Despite their newly recognized sovereignty, however, these decolonized countries became subject to *de facto* control by Western powers, mostly by the same former empires that had once formally colonized them. Under this arrangement, the emerging countries were subjugated by indirect and subtle forms of domination by political, economic, social, military, and technological forces. In this context, neocolonialism differs from colonialism in the sense that colonialism is a formal and openly exercised system of domination of one country by another. Although neocolonialism is not a formal system, it continues as a practice in which Western powers retain economic but not formal control over the former colonies. Therefore, under neocolonial rule, the relations of power between the former colony and the former colonizer remained virtually intact.

Economically, the newly independent countries continued to be dependent on the Western powers. Facing development problems (i.e., unequal land distribution, inadequate infrastructure, insufficient capital investment, urbanization without industrialization, insufficient housing, and unskilled labor), many former colonies had to confront independence in detrimental conditions. In addition, the territorial integrity of many of those emerging countries was challenged by secessionist ethnic groups and the internal wars that resulted from the artificial boundaries inherited from their colonial times. All these conditions located most former colonies in a very disadvantageous position in the global economy. This disadvantageous position essentially relegated them to the status of producers and exporters of cheap raw materials as well as sources of cheap unskilled labor, while manufactured consumer goods were imported from the Western powers. This internationally imposed division of labor created the necessary conditions for the perpetuation of economic control and domination of the former colonies by Western powers even in the absence of

direct and formal political authority. As these conditions defined the economic situation of these emerging countries, unequal trade became another constitutive element of neocolonialism.

The *de facto* domination of the former colonies by Western powers did not rest solely on their economic muscle. Neocolonialism also restructured class relations by embracing, and sometimes creating, local elites who in return worked hand in hand with the Western powers. These alliances with local groups made the consolidation of neocolonial rule possible in these countries. As was the case under colonial rule, during neocolonialism the cooperation of small local elites with the Western powers had facilitated the West's ability to maintain a dominant position over the local population without any apparent direct involvement. In this way, foreign rule was disguised with a local face that legitimized the national independence and the sovereignty of the newly emerging countries.

To ensure their domination, neocolonial powers also resorted to other less apparent practices. These included aid and investment agreements offered to the newly emerging countries. These assistance packages, founded on promises of modernization meant to lead to social and economic development, have been used to secure the West's sphere of influence. Western foreign aid, therefore, often buys countries off to ensure their cooperation. Recipients of Western aid may be seen as collaborators when they fail to block or interfere with these neocolonial practices.

Likewise, debt became instrumental for neocolonial powers as it generated a new pattern for the extraction of economic surplus of the former colonies by the former colonizers. Debt peonage was characterized by capital outflows from the emerging countries to the Western powers exceeding the total of capital inflow into them. This placed the fragile economies of the former colonies at the mercy of their Western creditors and aid providers. Critics of these Western lending practices view the Bretton Woods institutions (i.e., the World Bank and International Monetary Fund, and, later, the World Trade Organization) as instrumental in creating this debt. These institutions enforce forms of capitalist discipline that most of the time have proved to be detrimental for the least developed countries. Consequently,



these emerging countries with fragile economies are forced to turn to the World Bank, the International Monetary Fund, and the World Trade Organization for help. This help comes through policies, loans, and grants that impose strict economic reforms that favor debt payment and neoliberalism (e.g., reductions in governmental spending in education, health care, and infrastructure; reduction of public assistance to low-income people; currency devaluations; and privatization of public goods). These structural adjustments imposed by the Bretton Woods institutions impose premature capital market liberalization in the former colonies, forcing these economies to succumb to the mighty economies of the West. This practice of forcing developing countries to eliminate trade barriers and compete with the industrialized West only leaves them with more debt—in a situation of interdependence (surplus value is extracted from poor countries to rich ones).

Along with the Bretton Woods institutions, multinational or transnational corporations (TNCs) are major agents underlying neocolonialism. These TNCs are rooted in the expansion of the colonial trading companies, and the vast majority of them have Western bases (three-fourths of all TNCs are based in North America, Western Europe, and Japan). However, the global rise of TNCs flourished during the post-World War II economy and in the context of the new international division of labor (the internationalization of production and the spread of industrialization) that was widely imposed during the 1960s. Currently, through direct ownership of the different parts of the production processes and also through subcontracting and other indirect influences, TNCs account for an increasing proportion of the world's flow of trade, investment, knowledge, skills, and technology transfers. Several have higher turnover than the majority of the world's countries, and they employ millions of people worldwide. TNCs largely operate in the developing world, where they have virtually unlimited access to cheap labor and cheap raw materials, and because of their vast capital and influences over trade, investments, technology transfers, and employment, they have the ability to stabilize and/or destabilize entire national economies. Therefore, their presence in

the developing world has mixed outcomes. On the one hand, TNCs can create jobs, promote technology transfers, bring foreign exchange, increase the median income, and invest in education and health care. On the other hand, TNCs can also cause the displacement of local suppliers, the lowering of national tax regimes, and the softening of labor markets and environmental laws in the developing world. In addition, the profits and the surplus capital generated by these enterprises are repatriated to their countries of origin (mostly in the West), doing very little to ease the debt situation and solve the financial problems of developing countries. This economic power that TNCs have over developing countries represents another form of neocolonial domination. Moreover, TNCs have a long history of political involvement and interference in the developing world. Their interventions range from demands for better incentives (e.g., tax relief and soft environmental laws) to support for military incursions and covert or indirect operations. States in the developing world that confronted multinational corporations often have faced military coups d'état and/or covert operations carried out by the military and intelligence agencies of the Western powers (e.g., Iran in 1953, Guatemala in 1954, Indonesia in 1965, Chile in 1973, Ecuador in 1981, Panamá in 1981, and Venezuela in 2002).

The United States, along with Western European countries, have played a central role in the development of neocolonialism. Following the Spanish-American War of 1898, the United States joined the Western European countries as a colonial power. First through colonies and later through unincorporated territories (e.g., American Samoa, Guam, Northern Mariana Islands, U.S. Virgin Islands, Puerto Rico), the United States expanded its dominions over foreign lands. From the perspective of neocolonial theory, the enormous size of the U.S. economy and military and the influence of American culture and politics worldwide has made the United States a paradigm of neocolonialism. After World War II, the United States emerged as the absolute military and economic superpower. This position was reflected worldwide through its political and economic influences, as well as through its military muscle. Likewise, the superpower position of the United States was reinforced through the



influences of the American popular culture and media. In other words, the superpower condition of the United States explains why, regardless of the fact that the United States represents less than 5% of the world's population, it consumes more than 25% of the world's resources and its influences reach virtually the entire surface of the earth. Such colossal accomplishments were made possible through the neocolonial rule imposed over the developing world.

In the current period, the structures of power operate less through military or direct political control than through economic influences. Shaping the global economic conditions has become increasingly crucial to the assertion of global domination. Now, it is trade rather than conquest that determines international control. Thus, neocolonialism can be seen as a new form of colonialism in which de facto economic domination fails to respect the independence and sovereignty of many countries and thus perpetuates the inequality between developed and undeveloped countries.

Neocolonial theory holds that the West's de facto domination over much of the developing world has obstructed the economic growth and development of these emerging countries. The former colonies are virtually powerless; thus, there is little they can do to escape this system of neocolonial control. The world economy is dominated by Western powers and, therefore, is fixed to their interests. Consequently, the rules of neocolonialism work against the undeveloped countries, which have relatively little experience in industrialization, have to face an imposed international division of labor, and are forced to compete in a system of unequal exchange. These conditions only favor the Western powers, perpetuating neocolonialism.

Luis Sánchez

See also **Antiglobalization; Colonialism; Debt and Debt Crisis; Decolonization; Dependency Theory; Development Theory; Foreign Aid; Foreign Direct Investment; Globalization; Imperialism; International Monetary Fund; Modernization Theory; Neoliberalism; Postcolonialism; Structural Adjustment; Transnational Corporation; World Bank; World-Systems Theory; World Trade Organization (WTO)**

Further Readings

- Chomsky, N. (2003). *Hegemony or survival: America's quest for global dominance*. New York: Metropolitan Books.
- Hoogvelt, A. (2001). *Globalization and the postcolonial world: The new political economy of development*. Baltimore: Johns Hopkins University Press.
- Perkins, J. (2007). *The secret history of the American empire*. New York: Dutton.
- Stiglitz, J. (2002). *Globalization and its discontents*. New York: W. W. Norton.



NEOGEOGRAPHY

The term *neogeography* relates to technical developments in Web-mapping technology and spatial data infrastructures that have significantly changed how users collect, share, and interact with geographic information online. These changes can usefully be considered as a component of broader changes in the nongeographic Internet referred to as Web 2.0. Goodchild maintains that

the early Web was primarily one-directional, allowing a large number of users to view the contents of a comparatively small number of sites, [whereas] the new Web 2.0 is a bi-directional collaboration in which users are able to interact with and provide information to central sites, and to see that information collated and made available to others. (2007b, p. 27)

Neogeography can be considered as the geographic implementation of this principle and is about both technological innovations and the new modes of interaction that these changes enable.

The two main technologies that have driven both neogeography and the Web 2.0 paradigms are Asynchronous Javascript And XML (AJAX) and Application Programming Interfaces (API). AJAX enables the development of Web sites that have a look and feel more akin to a desktop application and have improved the usability of



Web mapping significantly by enabling direct manipulation of map data where user interactions (e.g., click and drag) are visualized instantaneously. This new type of Web site application compares favorably with traditional Web Geographical Information Systems (GIS), where users typically click a pan or zoom control and then wait for the page to reload before visualizing the result of the interaction. The XML component of AJAX refers to eXtensible Markup Language, which is a set of data standards that enable information to be formatted in such a way that it is usable across a variety of different software. For example, using GeoRSS (an emerging XML-type standard), location can be coded into online content, such as news feeds or blog posts. This information could then be used in multiple Web applications; for example, simple display on top of a base map in a Web browser or the listing of content, which is attributed to locations “near” a user of a GPS- and Internet-equipped mobile handset. In both applications, the source information would remain the same; however, the application would differ. API are available from a variety of Web sites, both spatial (e.g., Google Maps, Yahoo! Maps, or Microsoft Live Maps) and aspatial (e.g., Flickr, Facebook, Nestoria) and provide a series of functionality to third-party applications. For example, the API of Google Maps provides basic GIS operations, such as the ability to draw shapes, place points, geocode locations, and display these on top of high-resolution base map or satellite data. An example of the Google Maps API would be the Web site www.londonprofiler.org, which displays a variety of high-resolution sociodemographic data about London on top of the Google-supplied base map and satellite data. Although it is still a technical task to create Web sites using API, the construction of these applications is far simpler than the learning curve required to install, manage, and configure more traditional Web GIS platforms.

The technologies of Web 2.0 have created new ways in which users can create, share, and use information. Often referred to as “crowd sourcing,” this concept relates to how large groups of people can work together toward some common goal by performing functions that are either difficult to automate or expensive to implement in a nondistributed environment.

Within a neogeography context, Daniel Sui calls these changes the “wikification of GIS,” borrowing the terminology from Wikipedia, the user-generated online encyclopedia. A successful project using a collaborative paradigm (wiki) is OpenStreetMap (www.openstreetmap.org), which aims to create a set of free-to-use global map data through assimilation of volunteered geographic information in the form of user-collected GPS tracks and digitized satellite photographs.

Although the use of the term *neogeography* may lose popularity in a similar way to other online neologisms such as “cyberspace” or the “information super highway,” the underlying principles of collaboration and openness are unlikely to lose momentum, and fit into a broader movement toward pervasive GIS. Neogeography has made basic GIS operations and data increasingly accessible to the masses, enabling users with no previous geographic training to create, search, and share their own geographically referenced information. However, the implications of this increased visibility and availability of GIS have ethical implications that need to be considered. These tensions are illustrated between the public interest in high-resolution geographic data and the converse right to privacy. A recent example of these tensions was illustrated by the release of the Google Street View service that supplies horizontal and vertical panoramic photographs of numerous metropolitan areas around the world. Privacy concerns were raised over the incidental capture of individuals and cars within these images, and Google has now responded by automatically blurring faces and car number plates. This type of corporate responsibility should be perceived positively and illustrates how technology can be used to limit potential ethical concerns of innovative new data sources. A major contribution of neogeography has been to break GIS away from the realm of the isolated desktop user and in doing so has created a broader and enthusiastic new audience who may traditionally have only engaged with geographic information in simple map-reading tasks.

Alex David Singleton

See also **Global Positioning System; Goodchild, Michael; Google Earth; Location-Based Services; Mobile GIS**



Further Readings

- Goodchild, M. (2007a). Citizens as sensors: The world of volunteered geography. *GeoJournal*, 69(4), 211–221.
- Goodchild, M. (2007b). Citizens as voluntary sensors: Spatial data infrastructure in the world of Web 2.0. *International Journal of Spatial Data Infrastructures Research*, 2, 24–32.
- Hudson-Smith, A., Crooks, A., Gibin, M., Milton, R., & Batty, M. (2009). NeoGeography and Web 2.0: Concepts, tools, and applications. *Journal of Location-Based Services*, 3(2), 118–145.
- Leadbeater, C. (2008). *We think*. London: Profile Books.
- Sui, D. (2008). The wikification of GIS and its consequences: Or Angelina Jolie's new tattoo and the future of GIS. *Computers, Environment and Urban Systems*, 32(1), 1–5.



NEOLIBERAL ENVIRONMENTAL POLICY

Neoliberal environmental policy comprises a critical component of contemporary nature-society interactions. Neoliberalism is most simply defined as a political philosophy that promotes a greater reliance on markets and less reliance on government for the provision of nearly all goods and services, including environmental services. Invoked by powerful multinational institutions and many national governments to justify their approaches to trade and investment, it has fundamentally shaped the evolution of international governance, development, and environmental regulation over the past 25 years or so. Environmental aspects of neoliberalism include not only explicit, direct policies, such as those creating new environmental markets through privatization schemes of various kinds, but also the indirect environmental effects of market liberalization.

Goals and Tools of Neoliberal Environmental Policy

For its proponents, neoliberal environmental policy reflects commonsense economic science that

produces growing, market-oriented, profit-driven economies that will soon generate sufficient jobs and taxes to rectify any social or environmental problems that might occur. Neoliberal environmental policies contrast with those of previous import-substitution and Keynesian periods, when “command-and-control” approaches sought to solve environmental degradation problems through regulations, standards, fines, and lawsuits that force producers to reduce their environmental impacts. Neoliberal economists criticize that approach as inefficient, unnecessarily expensive, inflexible, and stifling of innovation. A better approach, they argue, comes from private property arrangements and markets that internalize the costs of environmental degradation, and so they promote privatization of agricultural land, fisheries, pollution sinks, biodiversity, and public enterprises ranging from mining companies to water provisioning systems.

Many other neoliberal policies, such as free trade, also affect the environment. Although the environment gets little explicit consideration in the theory promoting, for example, an end to import quotas and tariffs, the general idea is that increased trade increases wealth, which eventually leads to environmental improvement. Similarly, neoliberalism promotes decreased state expenditures, decentralization, and the participation of civil society in governance. Reconfiguring environmental governance to include streamlined states, civil society actors, and local, presumably more representative, levels of government is thought to bring greater efficiencies to environmental regulation.

Criticisms of Neoliberal Environmental Policy

Opponents contend that free trade and investment rules create a global “race to the bottom” as companies look for the regions with the lowest effective environmental regulations. Under neoliberalism, debt payments and foreign exchange earnings become key goals of governments. Natural-resource-dependent sectors such as agriculture, forestry, mining, and fishing often provide the required exports, almost always with high environmental impacts. Meanwhile, other neoliberal policies increase income disparity



and poverty, which drive cycles of environmental degradation as the poor erode soils and clear forests in their desperate attempts to make a living.

Critics of environmental privatization point out the extreme difficulty in constructing resource-conserving markets, especially because markets almost always give too low a value to environmental attributes. They also raise several human rights concerns: First, all people have the right to clean water and air; second, forests, fisheries, and biodiversity have many users and possessors who are harmed when property rights are taken away from them; and third, many environmental attributes and livelihood resources have values that have no price and cannot be justly exchanged for money in markets.

Critics on the left see neoliberalism as a false justification for the plunder and despoiling of natural resources at the hands of transnational corporations, aided and abetted by institutions such as the International Monetary Fund (IMF), the World Bank, and the World Trade Organization (WTO), in collusion with the local political networks. Justifying their actions with selective and hypocritical applications of neoliberal ideas, these U.S.-dominated organizations impose weak environmental and labor regulations and preferential tax and investment regimes. Such conditions allow companies to use destructive inputs and processes banned or severely restricted in developed countries. Similarly, critics on the left argue that privatization is a form of enclosure, essentially transferring wealth away from large numbers of mostly poor people to a small number of powerful actors. *Biopiracy*, for example, is the term they would apply to private companies' search for and patenting of potentially profitable genetic resources originally found in environments owned by specific groups or by humanity in common.

Market Liberalization

Neoliberal policymakers promote market liberalization—the freeing of markets from government intervention—mainly through structural adjustment programs and free trade agreements. Both have controversial environmental impacts.

Structural adjustment programs (SAPs) were imposed on indebted countries by the IMF as a condition for debt renegotiation. They typically

involve currency devaluations, the reduction of public spending, price reforms, subsidy reductions, privatization of public enterprises, and decreased or eliminated export taxes. Such policies make natural resource exports cheaper on world markets and attract foreign investment, while diminishing the ability of the state to regulate environmental impacts. Free trade agreements also have the goal of increasing international trade through decreased tariffs, export taxes, and import quotas while providing protections to investors and owners of intellectual property. Following market liberalization, mining, fisheries, logging, and the area devoted to export crops typically increase.

Critics argue that these instruments of market liberalization create unchecked growth and pollution. They promote a so-called race to the bottom, making it too easy for companies to avoid responsibility for their environmental degradation and harming people who depend on natural resources, such as small farmers, fishers, forest people, and those living downstream from mines. Furthermore, they increase poverty and inequality, which also has negative environmental implications.

Trade negotiations often represent business interests only, but social movements increasingly resist them or call for renegotiation. Such movements criticize the role of trade agreements in undermining national environmental regulations. WTO rules, for example, require that tuna fish caught in nets that also capture dolphins must be treated the same way as tuna caught by dolphin-safe methods; countries cannot simply ban the import of tuna captured by methods that harm dolphin. (They may, however, allow dolphin-safe labeling programs leaving it up to consumers to choose.) Provisions in some free trade agreements give investors the right to sue for compensation if environmental regulations reduce the value of their investments. For example, a U.S. company used North American Free Trade Agreement (NAFTA) provisions to successfully sue a Mexican local government for refusing to permit a hazardous waste landfill.

On the other hand, free traders would argue that trade creates efficiencies that have environmental benefits and provide incentives to conserve productive resources. Furthermore, they claim



that many environmental regulations distort trade and protect domestic producers who don't deserve it. In addition, increased foreign investment is associated with cleaner production processes than local industries due to compliance with international standards, corporate requirements, fear of lawsuits, and the use of more modern and efficient technologies. Finally, any increased poverty is a short-term impact. In the long term, market liberalization raises incomes and permits increased investment in environmental conservation.

The agricultural implications of market liberalization are particularly important for the environment. Market liberalization promotes export agriculture where it is viable but inhibits trade protections for struggling agricultural sectors and regions. Despite many years of negotiations, international trade agreements have been unable to significantly decrease the agricultural subsidies and import protections that the United States, Europe, and Japan lavish on their domestic producers, but they have been successful in getting developing countries to open their economies to agricultural imports. This creates rural crisis in many regions of the world where small local producers are unable to compete with modern, heavily subsidized producers. In marginal agricultural areas, immigration increases, brush and trees revegetate abandoned agricultural fields in a kind of forest transition, rural landscapes are transformed, and traditional crop varieties risk becoming extinct.

New Environmental Markets

Neoliberal ideas hold that the environment is best managed when resource rights are well-defined, defensible, and exchangeable. This can be attained through the privatization of water provisioning systems, public enterprises, and state-owned or common property lands. Even hard-to-divide resources can be privatized and brought into markets through the allocation of tradable sulfur dioxide and nitrogen oxide pollution allowances, carbon credits, transferable fishing quotas, and payments for environmental services. Even something as amorphous as biodiversity should be brought into markets through payments for its conservation and patents on genes and genetically modified organisms with profit potential.

The privatization and decentralization of water management has sparked virulent antiglobalization protest in some cases, such as in Cochabamba, Bolivia, but privatization operates with little public concern in many other places, including parts of the United States, Europe, Australia, Chile, and South Africa. Market purists believe that even water should be privately owned and tradable on a free market with all users paying for provision and treatment. They promote the participation of large international profit-seeking water companies to invest in and manage water systems all over the world. Opponents of the idea assert that water is a basic need that all people deserve, regardless of ability to pay. Case studies of neoliberal reforms in water indicate extreme difficulty in assigning rights transparently and unequivocally, setting effective transfer and use rules that provide market incentives for conservation and efficiency, and frequent conflict with previous approaches to the use and distribution of water. Critics raise serious concerns that market approaches fail to recognize the value of water in the environment, such as for wetlands and other habitat, a failing also shared by public provisioning systems.

Privatization and marketization are also promoted to protect the environmental services provided by forests and watersheds, including water capture and filtration, biodiversity conservation, and carbon mitigation. An international global warming treaty, payments for hydrological service programs, and similar projects create possibilities for some of those services to generate income streams for rural land managers, unleashing market incentives for land use practices that enhance the targeted environmental service. Critics of the idea identify substantial problems monitoring and placing values on such services. They identify the challenges of protection in areas where no one is willing to pay for services, such as water provision and carbon mitigation, and question the economic sustainability of many existing schemes once the initial subsidies from taxes, international development, and the government disappear. Furthermore, like many other market-based approaches, they question the equity implications of such instruments because they favor large producers with economies of scale and buyers with the greatest purchasing power.



Nongovernmental environmental certification systems, of which organic certification is the most familiar, constitute another form of environmental market congruent with neoliberal environmental policy. These programs rely on a set of standards according to which production processes in specific places are evaluated by third-party auditors so that the environmental qualities of products can be identified with a label. Since these programs are voluntary and nongovernmental, they don't violate free trade treaties. Thus, they constitute important new forms of neoliberal environmental governance that generate transnational scales of interactions between social movements, nongovernmental organizations, and private sector stakeholders.

Varied Outcomes and Social Responses

Under neoliberalism, environmental governance is reorganized, often scaled upward to transnational institutions of various kinds. This also restructures environmental politics. Social movements that previously might have made demands on governments to impose regulations on markets now shift their attention to other actors. Some might dress up as turtles to protest WTO rulings limiting national ability to call for turtle-protecting devices on international shrimping fleets. Similarly, ethical trading companies, activists, certification systems, and consultants displace the politics of environmental regulation to distant sites of production, to multistakeholder organizations, to media outlets, and to consumers' shopping carts.

Specific outcomes of neoliberal environmental policy vary greatly, depending on local conditions, histories, and social responses. Neoliberal forestry policies, for example, generally promote privatization and exports, especially through plantations. The emphasis on secure property rights as the foundation of markets, however, can support the formalization of common property rights to indigenous territories, and thus, community forestry can be compatible with neoliberal ideas and policies. Researchers warn against invoking neoliberalism as a monolithic construct with the same outcomes everywhere.

Dan Klooster

See also Agrofoods; Carbon Trading and Carbon Offsets; Fair Trade and Environmental Certification; International Environmental Movements; International Monetary Fund; Market-Based Environmental Regulation; Neoliberalism; Structural Adjustment; Transnational Corporation; World Bank; World Trade Organization (WTO)

Further Readings

- Bumpus, A. G., & Liverman, D. M. (2008). Accumulation by decarbonization and the governance of carbon offsets. *Economic Geography*, 84, 127–155.
- Harvey, D. (2006). Neo-liberalism as creative destruction. *Geografiska Annaler B: Human Geography*, 88, 145–158.
- Liverman, D. M., & Vilas, S. (2006). Neoliberalism and the environment in Latin America. *Annual Review of Environment and Resources*, 31, 327–363.



NEOLIBERALISM

A set of philosophies and discourses emphasizing the importance of free markets to development and prosperity, neoliberalism emerged as the guiding rationale for a wide range of responses to declining levels of economic growth in the 1980s and 1990s. A term used largely by its critics, *neoliberal philosophies* combine elements of classical liberalism with those of social conservatism. This entry reviews the central concepts of neoliberalism and its evolution in the global North and South; examines the neoliberal perspective on relationships between the state, markets, and civil society more generally; and describes criticisms that have been directed at neoliberalism, particularly with respect to its impact on the poor.

The Development of Neoliberalism

Greatly influenced by the writings of the neo-classical economist Friedrich Hayek and, later, Milton Friedman, proponents of neoliberalism view the minimally regulated market as the



institution best able to maximize economic growth and the creation of wealth. For many neoliberals, economies where the forces of demand and supply determine how and where goods and services are produced and exchanged are not only more efficient in generating and allocating resources than the state but also morally superior, because they give individuals freedom to choose the goods and services they want to consume. Although the central importance of free markets to the efficient and equitable allocation of resources is a shared feature of all neoliberal discourses, geographers agree that there is no pure definition of neoliberalism. This is because there are not only significant differences in the range of practices that scholars associate with neoliberalism but also different degrees of market engagement that countries have employed in different geographical contexts.

Friedrich Hayek

Hayek saw free markets as vital to individual liberty because free markets ensured that individuals could not manipulate the resources of a given environment for their own advantage. By communicating information in environments of uncertainty, markets, Hayek argued, facilitate a harmonious order where no individual is able to amass all the complex information required to manipulate the world to his or her own advantage. Writing in 1944 on the relationship between collective forms of social and economic organization and tyranny, Hayek viewed economies that relied on markets to allocate resources as more democratic than those where the distribution of resources was determined by states. In his famous book *The Road to Serfdom*, Hayek argued that centrally planned economies, such as the Soviet Union and Nazi Germany, were more likely to resort to coercive restrictions on individual freedom than capitalist economies because they relied on states rather than markets to determine how resources were allocated. He believed that the impossibility of amassing all the information needed to efficiently and fairly distribute resources inevitably led states to use coercive means to achieve economic control. For Hayek, state intervention in the allocation of resources in an economy was deeply problematic. Hayek argued,

“Economic control is not merely control of a sector of human life which can be separated from the rest . . . it is the control of the means for all our ends” (1944, pp. 91–92).

Milton Friedman

Hayek’s ideas on the relationship between economic and individual freedom were further developed during the 1950s and 1960s by Milton Friedman, who challenged the macroeconomic demand management approach to economic stability advocated by John Maynard Keynes, which was influential in the responses of Britain and the United States to the 1930s Great Depression. A member of Hayek’s Mont Pèlerin Society, founded in 1947 to preserve the fundamental economic principles of classical liberalism, Friedman argued that economies were best stabilized through controls over the supply of money rather than through state fiscal intervention, which he argued tended to produce inflation. Like Hayek, Friedman viewed economic interventions by states as impediments to economic growth and individual liberty. In his 1962 book *Capitalism and Freedom*, he advocated a range of policies to curb forms of state regulation such as military conscription, the levying of income tax, and the fixing of exchange rates. While the ideas of Hayek, Friedman, and other supporters of laissez-faire capitalism gained little popular support during the 1950s and 1960s, they were revived during the 1970s and 1980s when the stable and continuous patterns of economic growth associated with the Keynesian demand management approach ceased to be successful. It is during this period that the philosophies underlying neoliberalism evolved into a loosely coherent set of economic strategies, adopted by regions in both the global North and the global South.

Neoliberalism in the Global North

In the global North, neoliberal philosophies became increasingly popular as the Fordist system of production and consumption, which had developed in tandem with the Keynesian welfare-oriented approach, ceased to produce stable rates of economic growth. Fordism emerged across North America and Europe as a successful regime



of accumulation because it balanced the mass production of standardized industrial goods with high levels of state-supported mass consumption. Between the 1940s and 1960s, Fordist industries became engines of economic growth because they achieved high levels of productivity through the use of technologies that allowed firms to maintain strict control over the production process. As a result, Fordist mass-produced goods were low in cost and affordable to large segments of most population. Fordist mass consumption, on the other hand, was facilitated by states through policies that supported the family wage, job security, and welfare-oriented investments in areas such as health and education. The stable economic growth produced under Fordism began to break down as early as the late 1960s, as industries in a number of sectors became increasingly less profitable. By the mid 1970s, rising levels of unemployment and inflation signaled the end of Fordism and the Keynesian social contract. The crisis of the 1970s created the context for the revival of the ideas of Hayek and the policy prescriptions of Friedman, which heretofore had been largely ignored.

Neoliberalism in the Global South

In the global South, neoliberal discourses emerged in the wake of the 1974 oil price crisis and the rising levels of debt that followed increases in interest rates in the United States. Particularly, among Latin American and Caribbean countries that had borrowed international capital to finance state-led import substitution strategies, the oil price shocks, spiraling debt, and the ensuing recession in the global North challenged the role that states would play in the process of development in the future. In Chile, for example, the 1973 coup d'état that overthrew the democratically elected socialist government of President Salvador Allende marked the beginning of a new relationship between states, markets, and civil society. Under the leadership of General Augusto Pinochet, Chile became the first country where neoliberal policy prescriptions were systematically implemented. Closely influenced by the views of Milton Friedman, whose former students became key architects in the neoliberal restructuring of Chile, these policies included the reduction of public welfare spending, the dismantling of

regulations over entry and competition in markets, and the privatization of formerly nationally owned industries. Described by Friedman as shock treatment, the sudden removal of price and currency controls, the withdrawal of state subsidies, and the liberalization of trade were designed to deliver a quick jolt to the economy that would restore market fundamentals and stimulate growth.

Shock therapy in Chile laid the foundations for a more systematic set of neoliberal strategies that became known as *structural adjustment programs* (SAPs). Administered by the International Monetary Fund (IMF) and the World Bank, and influenced by the U.S. Treasury Department, SAPs aimed to reduce government fiscal imbalances and debt by opening up economies to the market through privatizations, devaluations, reductions in public social spending, and the lifting of trade restrictions and state controls over prices. States seeking financial assistance from either of these institutions were obliged to implement these policies as a condition of gaining access to loans. By the 1990s, nearly every country in the global South had entered an SAP and had begun to implement the relatively standard package of stabilization, privatization, and liberalization policies. Collectively, these policies also became known as the *Washington Consensus* in recognition of the degree of influence that the political and technocratic institutions of the U.S. government had over their formulation.

Changing Relationships Among States, Markets, and Civil Society

The importance of the United States in shaping the nature of neoliberalism in the global South during the 1980s is a reflection of the changing relationship between states, markets, and civil society that had begun to be put into practice by Margaret Thatcher, the then prime minister of the United Kingdom, and Ronald Reagan, the then president of the United States. Both leaders were social conservatives who supported the ideologies associated with classical liberalism that stressed the importance of individual private property, free markets, limited government, and the rule of law. Deeply influenced by the work of Hayek, Thatcher felt that the solution to the



economic crisis of the 1970s lay in the restoration of the market as the key institution responsible for the allocation of resources. But to make the free market play a more central role in everyday life, policies needed to be put in place to reduce the role played by the state in the provision of welfare and increase opportunities for the private accumulation of wealth. The early policies introduced by Thatcher and Reagan revolved around the relaxation, and in many cases, removal of market regulations, such as fixed exchange rates; the reestablishment of private property rights, largely through the privatization of previously nationally owned industries; and the retreat of state from the provision of social welfare. Important to both leaders was the need to make labor more responsive to the changing dynamics of capital, and this was achieved by breaking the old Keynesian social contract by weakening the power of the labor unions and reducing the state's obligation to provide welfare support for all its citizens. In the United States, for example, many of the rights-based income support programs that formed part of the New Deal were restructured in ways that increasingly required beneficiaries to participate in work or educational programs as a condition of receiving aid. As geographers such as Jamie Peck observed, the shift from welfare to workfare has been part of a new system of labor regulation that ensured that workers continued to work even in environments where real wages were declining and employment was becoming more casualized, that is, stripped of many of its benefits, including job security. Throughout the 1980s and 1990s, other governments in the global North implemented similar neoliberal strategies, each with its particular institutionally mediated market-enabling foci.

More than a narrow set of philosophies aimed at economic reform, neoliberalism has also redefined the social relationship between states and civil society. Feminist scholars argue that many of the social policies that have accompanied neoliberalism have sought to create a new type of citizen, one who is self-sufficient, entrepreneurial, and able to compete in markets, without minimal reliance on collective resources. Often drawing on social conservative discourses that valorize individual responsibility and traditional values, neoliberalizing states in both the global North

and the global South have tended to reward and punish particular groups according to the degree to which they meet the neoliberal citizenship ideal. For example, many neoliberalizing states encourage individuals to become more entrepreneurial by promoting microcredit programs that offer small loans at commercial interest rates to those with no incomes. Conversely, to discourage individuals from relying on collective forms of welfare, many have instituted programs such as workfare, which take away the right of individuals to determine the conditions under which they will provide their labor.

Criticisms of Neoliberalism

Critics of neoliberalism view the policies and practices that have been used to reorient and more closely integrate economies within increasingly global markets as deeply unequal and unjust. David Harvey argues that the policies associated with neoliberalism heighten patterns of uneven development because they promote forms of capital accumulation that enable the richest class groupings to accumulate surpluses by appropriating the assets and rights of others. He defines the type of capitalist growth associated with neoliberalism as "accumulation by dispossession" to highlight the extent to which these policies have redistributed wealth from the poorest to the wealthiest of people and places. Many grassroots civil society groups oppose neoliberal policies because of the adverse effects they are argued to have on the lives and livelihoods of poor households, women, and children.

The widening income inequalities and heightened levels of poverty that accompanied early neoliberal reforms have forced many proponents to reconsider the benefits of approaches that emphasize market fundamentals with minimal state intervention. In the global South, this recognition led to the replacement in 1999 of SAPs with poverty reduction approaches that rely on governance structures that encourage greater consultative partnerships between international lenders, borrowing governments, and civil society groups. Critics, however, remain skeptical of the extent to which the philosophies that guide the new Poverty Reduction Strategy Papers differ from those that shaped SAPs. As a number of



A worker in Panama City marches and holds a sign that reads, “Down with neoliberal politics,” May 30, 2002. Thousands of workers, teachers, and students marched to the presidency building to protest against a project to privatize the Social Security Service.

Source: AP Photo/Tomas Munita.

scholars state, these programs still rely on the approval of the World Bank and the IMF before they can be instituted, and approval has remained tied to a vision of development that privileges free market economic growth over poverty reduction. Similar observations have been made by the geographers Adam Tickell and Jamie Peck, who argue that while neoliberalism is no longer crudely focused on rolling back the state, it is increasingly evolving into a set of technocratic policies aimed at rolling out and consolidating the logic of the market in a wide variety of social and economic institutions through state intervention and regulation. In keeping with this observation, geographers also argue that contemporary neoliberalism is evolving into a type of governmentality that naturalizes and embeds market mechanisms into every aspect of everyday life and simultaneously

produces individuals who regulate themselves to conform to this logic.

From the ongoing debates, it is clear that rather than monolithic and static, the neoliberal discourses and practices have been dynamic, adapting to shifting economic conditions, as well as the critiques of civil society groups. Yet to argue that neoliberalism has lost its relevance as a meaningful term would be to ignore the priority that these policies continued to give to free markets and to those best able to compete in them.

Beverley Mullings

See also [Globalization](#); [Governance](#); [Inequality and Geography](#); [International Monetary Fund](#); [Market-Based Environmental Regulation](#); [Neocolonialism](#); [Neoliberal Environmental Policy](#); [Structural Adjustment](#); [World Bank](#); [World Trade Organization \(WTO\)](#)



Further Readings

- Friedman, M. (1962). *Capitalism and freedom*. Chicago: University of Chicago Press.
- Harvey, D. (2005). *A brief history of neoliberalism*. Oxford, UK: Oxford University Press.
- Harvey, D. (2006). Neoliberalism as creative destruction. *Geografiska Annaler*, 88B, 145–158.
- Hayek, F. (1944). *The road to serfdom*. Chicago: University of Chicago Press.
- Klein, N. (2007). *The shock doctrine: The rise of disaster capitalism*. Toronto, Ontario, Canada: Knopf.
- Larner, W. (2000). Neoliberalism: Policy, ideology and governmentality. *Studies in Political Economy*, 63, 5–25.
- Peck, J. (2001). *Workfare states*. New York: Guilford Press.
- Tickell, A., & Peck, J. (2003). Making global rules: Globalisation or neoliberalisation? In J. Peck & H. Yeung (Eds.), *Remaking the global economy: Economic-geographical perspectives* (pp. 163–181). London: Sage.

NEO-MALTHUSIANISM

Thomas Malthus was an English clergyman who popularized a set of ideas on population and agricultural growth in the early 19th century. *Neo-Malthusianism* refers to the variant forms of these ideas that have appeared in scholarly and scientific publications, shaped various kinds of policy making, and often exerted considerable influence on popular discourse over the years.

Malthus's *An Essay on the Principle of Population* was published anonymously in London in 1798. It challenged the optimistic writing of Enlightenment giants Godwin and Condorcet, who believed that scientific progress and refinement of social institutions would ensure enough food for all. Malthus instead pointed to “fixed laws of our nature,” specifically that “population, when unchecked, increases in a geometrical ratio . . . subsistence increases only in an arithmetical ratio.” Since this imbalance was intrinsic to human ecology, food shortage would be a permanent force shaping society and limiting population. Therefore,

he argued, aid to the poor and hungry would only succeed in forestalling the population-limiting effects of food shortage, ultimately making for more people who would inevitably suffer from conflict, sickness, and potential starvation.

Developments since Malthus's time have not fit Malthus's postulates well. Various social institutions, government policies, education, and economic development are now known to effectively curb population growth, and total fertility rates have plummeted worldwide (including throughout most of the developing world since the 1960s). Agricultural output has outpaced human food needs, due largely to the use of external inputs that were largely unknown in Malthus's day: nitrogen fertilizer, mechanization, breeding, pesticides, and information technology. The Food and Agriculture Organization predicts agriculture to continue to outpace food needs for decades; yet hunger continues to stalk areas of the developing world, and food insecurity affects significant numbers in industrialized countries. In 1996, the economist Amartya Sen was awarded the Nobel Peace Prize for showing how little overall food supply had to do with famine. Malthus—as Cohen (1995) bluntly put it in *How Many People Can the Earth Support?*—“has been wrong for nearly two centuries” (p. 429).

Yet Malthus's basic view of population growth as a persistent driver of food shortage has continued to exert widespread and persistent influence on a long and varied history of theories, schools of thought, movements, and policies. Much of this persistent power is due to its malleability and the fact that its basic tenets and implications can be adjusted to changing agendas.

For instance, in the early 20th century, neo-Malthusians took Malthus's stress on the overabundance of poor people to support anti-immigrant organizations and policies in the United States. Academic books stressed the dangers posed by the reproductive urges of “inferior races,” including Jews and the Irish. In the 1960s, neo-Malthusians, such as the Club of Rome, sounded the alarm over the world's high population growth rate and its impacts on resources and the earth's capacity to sustain rising numbers of people. Neo-Malthusianism shaped Cold War thinking in the United States, attributing the spread of communism to high population densities in Asia. These fears were particularly focused on India, where



post–World War II peasant movements were taken as warnings that India might go the way of China. Through the PL-480 program, large amounts of American grain were exported to India well into the 1960s to check the spread of communism while absorbing U.S. grain surpluses.

Beginning in the mid 1990s, neo-Malthusianism helped fill the void in post–Cold War thinking, with academic writers and journalists stressing environmental security as the new driver of Third World conflict. This surge of neo-Malthusianism went beyond food and depicted local shortages of various resources as the principal driver in local conflicts. Robert Kaplan’s lurid essay “The Coming Anarchy” popularized this perspective in public and policy circles, although detailed case studies by geographers and anthropologists showed that such conflicts tended to be driven by other, non-demographic and nonlocal factors.

Most recently, neo-Malthusianism has played a key role in debates over genetically modified crops. In the late 1990s, following Europeans’ rejection of genetically modified foods, writing by both corporate and academic biotechnologists began to raise alarms about population growth and impending food shortages in developing countries, FAO (Food and Agriculture Organization) projections notwithstanding, touting genetic modification as a solution. As with other phases of neo-Malthusianism, this invokes the alarm of population outstripping food supply but adds new elements suited to the times.

Glenn Davis Stone

See also **Famine, Geography of; Food, Geography of; Hunger; Malthusianism; Population and Land Degradation; Population, Environment, and Development; Poverty**

Further Readings

- Cohen, J. (1995). *How many people can the earth support?* New York: W. W. Norton.
- Kaplan, R. (1994, February). The coming anarchy. *The Atlantic Monthly*, pp. 44–76.
- Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to growth: The 30-year update*. London: Chelsea.

Peluso, N., & Watts, M. (2001). Violent environments. In N. Peluso & M. Watts (Eds.), *Violent environments* (pp. 3–38). Ithaca, NY: Cornell University Press.

Ross, E. (1998). *The Malthus factor: Population, poverty, and politics in capitalist development*. London: Zed Books.

Sen, A. (1981). *Poverty and famines: An essay on entitlement and deprivation*. Oxford, UK: Oxford University Press.



NETWORK ANALYSIS

Network analysis refers to the spatial analysis of transport (roads, railroads, airlines) or utility (pipeline, Internet) networks, and it has also been used for examining and optimizing hierarchical relationships within a set of places linked by flows. Network analysis abstracts the fundamental components of a network to depict the connections between places. A network is made up of nodes (locations, or origins and destinations of flows) and links (physical connections or flows between nodes). Loops may be present and allow multiple paths between a pair of nodes. A network may be planar, with nodes at the junctions of all links, or nonplanar, in which links may cross one another without an intersection. Depicting a network at the interurban level is generally straightforward, using cities, ports, or airports as nodes, while representations at the intraurban scale require more care. Street intersections may be used as nodes, though some uses may be more abstract, with nodes representing zones and links approximating flows between them. The link-node structure of a network can be shown as a matrix, and it is common for networks to be specified as a connectivity, impedance, or origin-destination (flow) matrix. These matrices in turn allow for the calculation of shortest-path algorithms and related methodologies, such as aggregate or topological accessibility.

Early Applications in Geography

Network analysis is derived from the mathematical field of graph theory, a branch of topology. Graph theory focuses on the connectivity of a network, not on its visual appearance. Both were introduced



into geography in 1960 by William Garrison, who examined the structure of the Interstate Highway System in the southeastern United States. Analysis of transport networks became common in the 1960s. The centrality of cities was evaluated using a connectivity matrix, and several network measures, such as alpha (the ratio of the number of loops to the maximum possible), beta (the ratio of links to nodes), and gamma (the ratio of actual links to the maximum possible in a planar network), were also developed. They measure the connectivity of the network in different ways, though their usefulness and uniqueness has been debated.

The arrival of network analysis in geography was closely related to the quantitative revolution and its search for regularities that would allow for spatial laws. Studies using network analysis attempted to relate socioeconomic indicators of various countries to their road or rail network structure in the search for universal regularities about development. Other studies attempted to create predictive models of network growth based on observed patterns in their structural change over time. While many early studies were rigorously mathematical and theoretical, later network analyses rarely used the terminology or notation of graph theory.

Network analysis became essential to the new field of transport geography and was compatible with other new quantitative methods in the field, such as spatial interaction modeling. Peter Haggett and Richard Chorley's (1969) book *Network Analysis in Geography* marks the high point of the early network analysis approach in geography. It examined topics such as topological structures, network shape, location, flows, and growth and transformation of networks. These were applied to a wide variety of human and physical geography topics, such as rivers, roads, airlines, and economic linkages between cities or regions. All were treated as instances of network development and amenable to similar kinds of theories and methodologies. Network analysis declined in importance during the 1970s, though it has remained in transport geography textbooks.

Later Developments

In the 1980s, network analysis reemerged as a significant topic due to recognition of the importance

of hierarchy in networks. This trend was stimulated by the phenomenon of airline deregulation and the rise of hub-and-spoke networks with many indirect connections between nodes. The location of a node within these networks and the design of optimal network structures to maximize flows or minimize the costs of flows have become an important part of network analysis and have been extended to many transport modes and types of spatial interactions. Recent work often includes a focus on the vulnerability of a network to disruption, such as the loss of a critical node or link following a disaster.

In the 1990s, small-region (also called *small-world*) networks have continued to be explored in modeling hierarchies and in optimization. In these types of networks, a few nodes have a far greater level of connectivity than would be expected and so allow for shorter routes between average nodes within a network. Transportation networks are only a small part of these studies, as a wide range of biological, engineering, and social phenomena have been investigated for small-world network traits. The mathematical properties of such networks are generally considered to be universal for all such instances, much as in the early network analysis work.

Network Analysis in GIS

While theoretically simple, calculating network measures and shortest routes for all but small networks is extremely labor intensive. These applications were reliant on computers from the very beginning, and the widespread use of GIS has led to an enormous increase in the ease of use of these methodologies. Digital data for street and other networks are readily available, and the network or arc-node data model for GIS allows network analysis. Shortest-path algorithms are easily calculated, and new features such as multimodal and multiscale networks have been developed. Network versions of market area models, spatial interaction, location-allocation, aggregate accessibility, space-time accessibility, and other standard geographic applications have been created. These procedures use road distance or driving time to represent distance instead of Euclidean or straight-line distance. Due to GIS, network analysis has moved away from its original mathematical and



theoretical basis toward a geocomputational perspective using non-Euclidean space.

Joe Weber

See also **Accessibility; GIS in Transportation; Network Data Model; Quantitative Revolution; Spatial Interaction Models; Transportation Geography**

Further Readings

- Garrison, W. L. (1960). Connectivity of the interstate highway system. *Papers and Proceedings of the Regional Science Association*, 6, 121–137.
- Haggett, P., & Chorley, R. J. (1969). *Network analysis in geography*. London: Edward Arnold.
- O'Kelly, M. E., & Miller, H. (1994). The hub network design problem. *Journal of Transport Geography*, 2, 31–40.



NETWORK DATA MODEL

Route planning is a common task. A route plan used to be marked on a paper map, but now it can be easily done on a digital road network using an automotive navigation system or a geographic information system (GIS). A network is a system of linear features that has the appropriate attributes for the flow of objects. A road system is a familiar network; other networks include railways, public transit lines, bicycle paths, utility lines, and streams.

A network data model consists of geometries and attributes. The basic geometric features are edges (links) and junctions (nodes). An edge refers to a line segment defined by two end points. A junction refers to a point, where lines meet or intersect. To be used for route planning, a network must be topology based. Network topology is explicitly expressed through graph theory (a branch of mathematics): edges are directional; edges meet or intersect perfectly at junctions; and if an edge joins two junctions, the junctions are said to be adjacent and incident with the edge. Moreover, the adjacency and incidence relationships are built into matrices. Stored as tables in a GIS, these matrices form the core of a logical

network, which works along with the network geometries for applications such as route planning.

Network attributes include cost impedances, turns, one-way or vehicular restrictions, hierarchy, and elevation fields. Cost impedances relate to edges and turns. Link impedance is the cost of traversing an edge. A simple measure of the cost is the edge's physical length. But the length may not be a reliable measure of cost, especially in cities where speed limits and traffic conditions vary significantly along different streets. A better measure of link impedance is the travel time estimated from the length and speed limit of an edge. For example, it takes 20 minutes to travel 10 mi. (miles) on a road with a speed limit of 30 mi. per hour. A turn is a transition from one edge to another at a junction. Turn impedance is the time it takes to complete a turn. Turn impedance is directional. For example, it may take 5 s (seconds) to go straight or make a right turn and 30 s to make a left turn at a stoplight. A negative turn impedance value usually means a prohibited turn, such as turning the wrong way onto a one-way street. Cost impedances are entered in designated fields. For example, a field called *Minutes* can assign link impedance in travel time.

One-way streets or vehicular restrictions (e.g., “no left turn”) can also be denoted in special fields. For example, “T” in a field called *one-way* means that a street segment is one-way, and “F” means that it is not. The direction of a one-way street is determined by the beginning point and the end point of the edge. Hierarchy refers to a classification of roads, such as interstate, state, and county highways. Given a multiple-level hierarchy, the logical network can use it to optimize route solving on large transportation networks. Overpasses, underpasses, bridges, and tunnels are typically represented as planar features with elevations. Elevations, in this case, are not altitudes but the logical levels of roadways. For example, to show First Avenue crossing Oak Street with an overpass, the elevation value of 1 can be assigned to First Avenue at the crossing, indicating that the overpass is on First Avenue.

Both edges and junctions are vector data represented by points and their *x*-, *y*-coordinates. Vector data in a GIS can be either georelational or object oriented. As examples, shapefile is georelational, and geodatabase is object oriented.



Compared with a shapefile-based network, a geodatabase network has a more flexible data structure, which allows network topology to be embedded in object-oriented representations. Unlike a shapefile-based network, which can only have one edge source, a geodatabase network can have multiple edge sources (e.g., roads, rails, bus routes, and subways) and can connect different groups of edges at specified junctions (e.g., a subway station junction connects a subway route and a bus route).

Networks with topology are useful for a number of applications of which the best known is shortest-path analysis. Shortest-path analysis finds the path with the minimum cumulative impedance between junctions on a network. The path may connect just two junctions—an origin and a destination—or have specific stops between the junctions. Shortest-path analysis can help a driver plan routine trips between home and workplace, a van driver set up a schedule for dozens of deliveries, and an emergency service connect a dispatch station, accident location, and hospital.

Closest facility and allocation are extensions of shortest-path analysis. To find the closest hospital, fire station, or ATM, an algorithm first computes the shortest paths from the select location to all candidate facilities and then chooses the closest facility among the candidates. Allocation is a study of the spatial distribution of public facilities such as fire stations, schools, or even open spaces (in case of an earthquake) on a network. Because the distribution of public facilities defines the extent of their service area, spatial allocation analysis can measure the efficiency of these facilities.

Address matching, also known as geocoding, requires the use of a street network and attributes such as the street name, address range, and ZIP code for each street segment. It compares a street address with the network data, interpolates the address location on the network, and plots the address as a point feature. Address matching is a service offered by Web browsers as well as many public and commercial Web sites.

Shortest path, closest facility, spatial allocation, and address matching are some of the applications using a network. With GIS being increasingly integrated with the Internet, GPS (global positioning system), wireless technology, and Web service, we

can expect to see more interesting and dynamic network applications in the future.

Kang-Tsung (Karl) Chang

See also **Accessibility; GIS in Transportation; Network Analysis; Spatial Interaction Models; Transportation Geography**

Further Readings

Chang, K. (2006). *Introduction to geographic information systems* (4th ed.). New York: McGraw-Hill.

Miller, H., & Shaw, S. (2001). *Geographic information systems for transportation: Principles and applications*. New York: Oxford University Press.



NEW INTERNATIONAL DIVISION OF LABOR

Capitalist development has always occurred unevenly—spatially, sectorally, and temporally—producing differential degrees of industrialization and varying modes and levels of integration into the world economy. Since the 1970s, however, there has been a widespread recognition that a fundamental transformation (now commonly understood as globalization) is taking place in the conditions of capitalist accumulation and expansion of capital on a world-historical scale. The term *new international division of labor* (NIDL) was coined by theorists seeking to explain the spatial shift of manufacturing industries from advanced capitalist countries to developing countries—an ongoing geographic reorganization of production, which finds its origins in the formation of the “world market for labor” and “world market for industrial sites” famously analyzed by the German political economists Folker Fröbel, Jürgen Heinrichs, and Otto Kreye. Under the “old” international division of labor, underdeveloped areas were incorporated into the world economy principally as suppliers of minerals and agricultural commodities. A growing emphasis on factors such as the internationalization of production, the greater



sway of transnational corporations (TNCs), and the enhanced mobility of capital facilitated by modern communications technology and liberalization has generated a transition toward an NIDL in which low-wage developing countries increasingly provide sites for labor-intensive industries that manufacture goods for sale in the world economy.

Theories of the NIDL assign a major role to TNCs as the orchestrator of a global reallocation of manufacturing away from advanced countries toward the developing countries. Varying in emphasis from a “neo-Smithian” focus on changes in the world market to a “neo-Ricardian” one on capital exports, theories of the NIDL have sought to explain a dual pattern of “industrialization” in the developing countries and “deindustrialization” in the advanced countries. In seeking to explain this pattern, the concept of an NIDL focuses on the determining roles played by (a) the development of a worldwide reservoir of potential labor power; (b) the development of the labor process in manufacturing, which has led to the decomposition of production processes into elementary units and the deskilling of the labor force; and (c) the development of the forces of production in the fields of transport and communication, which has made industry less tied to specific locations. These preconditions, together with the desire of TNCs to maximize profits, result in industrial relocation to employ what Fröbel, Heinrichs, and Kreye described as readily available, inexpensive, and “well-disciplined” labor. One key argument of NIDL theorists is that with new technologies, especially space-shrinking systems of transport and communications, sites for manufacturing are increasingly independent of geographical distance. Capital now not only searches for fresh markets but also seeks to incorporate new groups into the labor force.

Thus, it was initially through the export processing zones of the globalizing electronics and textile industries that many women from the developing world have become part of the international working class. Through the exploitation of their labor power within world market factories situated in developing, low-wage countries, specific regions within what was formerly known as the *Third World* became manufacturing sites for consumer markets in the advanced countries

through transnational production arrangements involving foreign direct investment or international subcontracting. In that the term *global factory* refers specifically to the sites of production in transnational production arrangements, it is not limited to “factories” per se but also includes petty commodity producers, often toiling in “informal” establishment such as sweatshops and home industry. Despite this diversity in possible employment forms, the key argument of NIDL theorists is that working conditions in the global factories situated in developing countries tend to be poor on account of their *raison d’être*—to enable TNCs from the core advanced countries to redeploy their capital for goods production to low-cost labor sites in the periphery, where TNCs and their subcontractors extract surplus value from Third World workers.

The signal contributions of theories of the NIDL have been to highlight the growing power of TNCs (in particular, their capacity to optimize differing opportunities for profit by decentralizing production across the globe) and to demonstrate that industrialization and deindustrialization are in fact related phenomena. Indeed, the concern over deindustrialization, unemployment, and the proliferation of low-wage service sector jobs in the advanced countries partly reflects the success of newly industrializing countries in relatively labor-intensive manufacturing markets and the export of semiskilled industries jobs to lower-wage countries under the aegis of TNCs. Critics of the NIDL thesis, however, argue that it overstates the significance of “cheap labor” as the propellant for capital movements across the globe, particularly geographical shifts of manufacturing production. There is no gainsaying the spurt of industrialization that has taken place over the past half-century in the developing (Third World) countries, and in particular in the four “Asian dragons” (Hong Kong, Singapore, Taiwan, and the Republic of Korea), the three “Asian tigers” (Malaysia, Thailand, and China), and what has come to be known as the BRIC (Brazil, Russia, India, and China). Still, the point is that although the contribution of such countries to global manufacturing output has increased, focus on an NIDL may exaggerate the extent of change that has taken place in the world economy, in which the large majority of developing-country workers are still overwhelmingly producers of raw



materials whose relationship to the world economy continues to be defined by the old rather than the new international division of labor.

Étienne Cantin

See also Comparative Advantage; Deindustrialization; Developing World; Division of Labor; Export-Led Development; Export Processing Zones; Globalization; Industrialization; Neocolonialism; Neoliberalism; Newly Industrializing Countries; Outsourcing; Transnational Corporation; Underdevelopment; Uneven Development; World Bank

Further Readings

Fröbel, F., Heinrichs, H., & Kreye, O. (1980). *The new international division of labour: Structural unemployment in industrialised countries and industrialisation in developing countries*.

Cambridge, UK: Cambridge University Press.

Lipietz, A. (1997). Economic restructuring: The new global hierarchy. In J. Veit & W. Wright (Eds.), *Work of the future: Global perspectives* (pp. 45–65). London: Allen & Unwin.

Mittelman, J. (1995). Rethinking the international division of labour in the context of globalisation. *Third World Quarterly*, 16, 273–296.

NEWLY INDUSTRIALIZING COUNTRIES

Newly industrializing countries (NICs), sometimes also called *newly industrializing economies*, are a group of states in the developing world that developed substantial manufacturing bases in the late 20th century. Definitions of this group vary, but they are generally taken to be states that exhibited rapid and sustained increases in GDP, incomes, and industrial employment. Most are located in Asia, although several are found in Latin America as well (Figure 1). Other definitions of NICs include South Africa and Turkey.

The emergence of the NICs has significant implications for development theory as well as the lives of billions of people in the world.

Modernization theorists trumpet their success as proof of the wonders of the market. Whereas dependency theorists maintained that the diffusion of manufacturing from the First World to the Third was unlikely or impossible, the rise of the NICs in the 1970s indicated that the status of the developing world was hardly fixed or static. In terms of world-systems theory, the NICs pointed to states that moved from the global periphery to its semiperiphery.

Common to many NICs was a shift from import substitution to export-led industrialization, in which tariffs and quotas on imports were reduced, foreign direct investment (FDI) was encouraged, and exports aggressively promoted, including through the use of export processing zones. Such moves were often justified by an appeal to neoclassical economic notions, such as comparative advantage. Many states such as South Korea and Taiwan began to develop a capacity in footwear and textiles by the 1960s, moving into more capital-intensive, higher-value-added sectors, such as automobiles, ships, steel, precision machinery, and electronics over the next several decades.

The East Asian NICs are perhaps the most representative members of this group. Following the example set by Japan, which industrialized early, several generations of Asian NICs began to imitate the Japanese model in the famous “flying geese” formation of development. The original “Four Tigers” or “Minidragons” included South Korea, Taiwan, Hong Kong, and Singapore (the latter two former British city-state colonies), all of which developed high-quality educational systems, infrastructures, and government policies conducive to capital accumulation. Some observers point to the legacy of Japanese occupation in this regard, while others note the importance of Confucianism in producing a compliant labor force, as well as a high domestic savings rate. Yet others argue that the NICs’ growth had little to do with a “free market” and much to do with oppressive and authoritarian government strategies that repressed labor. South Korea and Taiwan, for example, were run by military dictatorships for much of the early period of their growth. Yet another factor was the active intervention of the United States in the region during the Cold War (including defense subsidies and

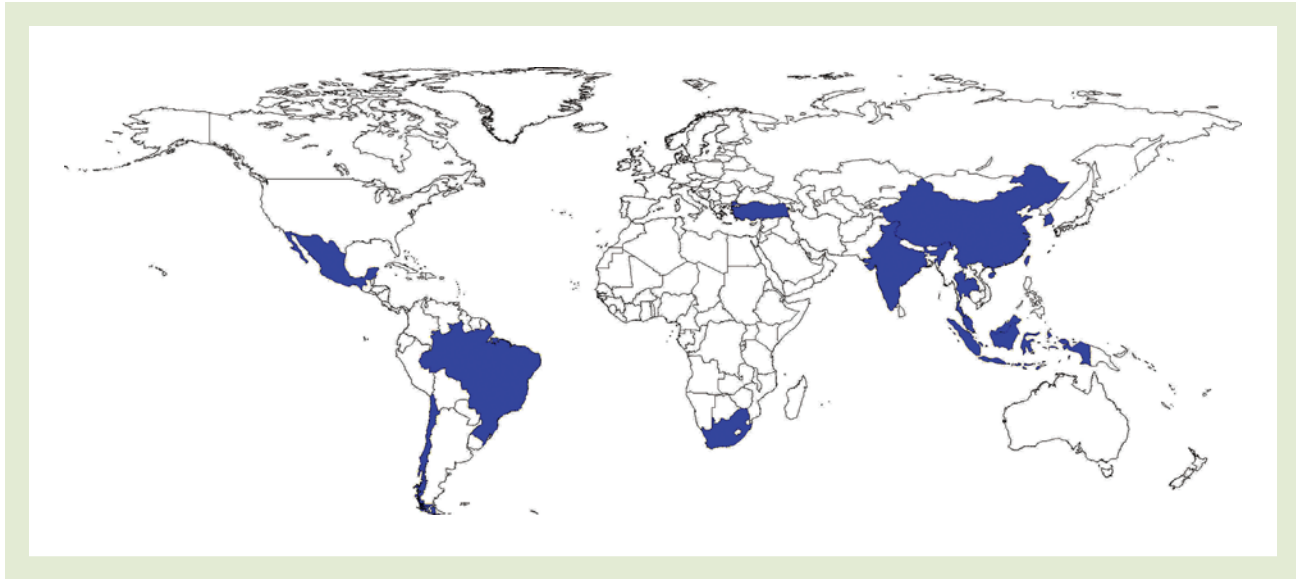


Figure 1 Newly industrializing countries in 2008. Definitions of the NICs vary, but all exhibit rapidly growing economies and exports.

preferential trade agreements), an advantage not afforded to other regions, such as Latin America. Singapore, in particular, developed not only as a center of light manufacturing but also thrived with a very large port and a growing capacity in financial services and telecommunications to become the second wealthiest country in Asia.

The second generation of East Asian “dragons” included Thailand, Malaysia, and Indonesia, all of which pursued the model set by the first generation. To varying degrees, with considerable inequalities within them, these countries developed manufacturing capacities in textiles, automobiles, electronics, and other sectors, often using docile young female workers in foreign-owned assembly plants that resembled Mexico’s *maquiladoras*. Malaysia’s Vision 2020, in which it sought to become a fully industrialized state by that year, included making it the world’s leading producer of semiconductors and small motors for appliances. In all, tens of millions of people were pulled out of poverty to create a growing middle class with higher incomes and purchasing power, although the Asian financial crisis of 1997–1998 revealed that such growth was not inevitable. In all, rising automobile ownership led to increasingly congested cities. All three of these states, to different degrees, have also had autocratic

governments that often take a dim view of civil liberties and dissent.

Of course, looming over all the NICs is China, whose rapid growth since the mid 1970s has transformed the world’s most populous country and made it an enormous economic power. The economic reforms initiated by Deng Xiaoping proved to be quite successful at reintegrating the country back into the world economy, and China has enjoyed growth rates often exceeding 10% annually to become the world’s second largest economy today. Most of China’s growth has been concentrated along its eastern seaboard, where Deng established the famous Special Economic Zones. The most rapidly growing part of China has been the southern province of Guangdong, which has benefited from close ties to Hong Kong entrepreneurs and financiers. China also attracted enormous quantities of foreign direct investment and as the world’s largest exporter, enjoyed sizable trade surpluses, particularly with the United States. Today, China is the world’s leading producer of electronics, apparel, toys, steel, cement, and cotton. As in Taiwan, Korea, and Singapore, the Chinese economy has also steadily moved into higher-value sectors, such as finance. At current rates of economic growth, China may surpass the GDP of the United States by 2050. However, such



growth has simultaneously created huge disparities between the rich and the poor, tens of millions of desperate migrants who have evacuated the interior for the opportunities along the coasts, and an oppressive government much given to censorship, suppression of dissidents, and violations of human rights.

India, too, shows signs of becoming an NIC. The world's second most populous country, with huge reservoirs of poverty, nonetheless exhibited consistent economic growth rates when it abandoned its earlier isolationism and welcomed foreign investment. The prominence of Bengaluru, the heart of the Indian electronics and software industry; the growth of call centers; the financial and cinema complex in Mumbai; and India's growing middle class all point to what will be an increasingly formidable economic power in the future.

Latin American NICs include Brazil, Mexico, and Chile. Brazil's growth, centered on heavy manufacturing such as aerospace in the 1970s, was crippled by the oil shocks and resulting explosion of foreign debt. Likewise, Mexico, which staked its fortunes on petroleum, suffered with the price declines in the late 20th century. The rise of the maquiladoras, now Mexico's largest source of foreign revenues, led to growing capacity in the assembly of textiles, electronics, and automobiles, primarily in the north of the country and often at the cost of great human suffering. The impacts of the North American Free Trade Agreement in this context are complex and contradictory. Chile, since the vicious coup d'état that ousted Allende in 1973, became something of a model of neoliberal experimentation under the brutal reign of Pinochet; nonetheless, Chile has enjoyed the most rapid economic growth in Latin America for several decades, and it exports textiles and wine, among other goods.

The growth of the NICs has not been unproblematic. In all of them, rapid growth has been accompanied by mounting social and spatial inequality, sometimes severe, as well as social and cultural problems associated with rapid transformation. As some states adopted neoliberal policies, safety nets for the poor were often left in disarray.

In addition to trade policy (i.e., export-led industrialization), the growth of the NICs reflects several other factors. Most enjoyed land reform to

one extent or another (e.g., via the Japanese occupation or the Korean war), which broke up feudal rural elites, improved agrarian opportunities, and helped minimize rural-to-urban migration. All had governments that encouraged development, not regulation, with clear long-term priorities and consistent, centralized, growth-oriented policies. All minimized their reliance on foreign funding and encouraged domestic savings, although all NICs encouraged FDI. All sought to move as quickly as possible from low-wage, low-skilled, low-value-added exports to progressively higher wage, higher-value-added ones.

To what degree is the success of the NICs replicable elsewhere? The answer to such a question, which has enormous implications for Third World development possibilities, in no small part depends on the theoretical perspective one adopts to explain the NICs' successes. For advocates of modernization theory, and its neoliberal reincarnation, the NICs represent the success of unfettered capitalism, which, with proper attention to trade policy and finance structures, can be ultimately reproduced virtually anywhere. To advocates of dependency theory, the NICs represent a unique, historically specific set of conditions that cannot be replicated easily. In this reading, the NICs' growth was led by the state, not the market, and such growth did not materialize in many other countries (e.g., the Philippines). And finally, to world-systems theorists, the NICs represent but one moment in the long historical process by which various states slide up and down the hierarchy of countries that defines the global division of labor at different moments in times; that is, their success is possible elsewhere, but not likely. Such concerns notwithstanding, many other countries have attempted to imitate the NICs, with varying degrees of success.

Barney Warf

See also **Dependency Theory; Development Theory; Emerging Markets; Export-Led Development; Export Processing Zones; Foreign Direct Investment; Globalization; Gross Domestic Product/Gross National Product; Import Substitution Industrialization; Modernization Theory; Neoliberalism; New International Division of Labor; Trade; World-Systems Theory**



Further Readings

- Brohman, J. (1996). Postwar development in the Asian NICs: Does the neoliberal model fit reality? *Economic Geography*, 72, 107–130.
- Cumings, B. (1984). The origins and development of the northeast Asian political economy: Industrial sectors, product cycles, and political consequences. *International Organization*, 38, 1–40.
- Jenkins, R. (1991). The political economy of industrialization: A comparison of Latin American and East Asian newly industrializing countries. *Development and Change*, 22, 197–231.
- Milner, C. (Ed.). (1998). *Developing and newly industrializing countries*. Cheltenham, UK: Edward Elgar.
- Noland, M. (1987). Newly industrializing countries' comparative advantage in manufactured goods. *Review of World Economics*, 123(4), 679–696.
- Singer, H., & Hatti, N. (2007). *Newly industrializing countries after the Asian crisis*. New Delhi, India: B. R. Publishing.
- Stubbs, R. (1999). War and economic development: Export-oriented industrialization in East and southeast Asia. *Comparative Politics*, 31(3), 337–355.



NEW URBANISM

New urbanism is a postmodern American urban design and planning movement that began in the 1980s as a challenge to modern urban form and automobile-centered suburban development. The new urbanism movement seeks to redefine the American dream through the creation of walkable neighborhoods modeled after traditional American small towns. Placing the pedestrian at the core of neighborhood design, the movement proclaims a rebirth of sociability, civility, and improvement in public health through walkability and physical activity long thwarted by the design of conventional suburbia.

The roots of new urbanism converged in 1993 in the Congress for the New Urbanism and can be traced to two distinct urban design perspectives: traditional-neighborhood development (TND)

and transit-oriented development (TOD). Both perspectives criticize conventional land use zoning for segregating urban activities and making car travel indispensable resulting in high-energy consumptive lifestyles. In opposition to the proliferation of single-family-home subdivisions devoid of a public realm, sidewalks, and civic amenities, both TOD and TND prescribe the creation of small, walkable neighborhoods with a diverse mix of residences, shops, workplaces, and public facilities reachable within a 5- to 10-minute walk. The two design approaches differ in the way they internally organize development and in the way they articulate the neighborhood with the rest of the urban fabric. TND, which originated on the east coast, is focused on an identifiable town center and laid out on a dense grid of boulevards, narrow streets, alleyways, and plazas. In contrast, TOD, which originated on the west coast, is focused on a transit station to which all major streets converge. In its prototypical formulation, TND commercial and residential blocks are small with small building footprints, where houses with front porches face the street while garages are tucked on alleyways behind houses. TOD is similarly compact in design; however, while TND relies on existing freeways and arterials for metropolitan travel, TOD, organized around transit stations, depends on high-quality transit service for effective substitution of car trips for transit trips—a hallmark of the sustainability claims of the movement.

Roots of the Movement

TND is associated with the 1980s European critique of modern urbanism and functionalist urban planning (e.g., segregation of land uses). This critique was spearheaded by Léon Krier and subsequently endorsed by Prince Charles's urban village movement in the United Kingdom. Krier denounced metropolitan growth and the automobile as destroyers of city life, a sense of community, and the civic realm and advocated the reconstruction of cities into a federation of semi-autonomous pedestrian-scaled urban quarters, where foot travel would substitute for motorized travel, residents would be integrated by occupation, age, and socioeconomic class, a rebirth of



cottage industries would supersede commercial strips, and true civic culture would replace the boredom and alienation of the suburb. Krier's indictments were preceded in the United States by Jane Jacobs's 1960s manifestos against suburbia, urban renewal, and zoning, and by Allan Jacobs and Donald Appleyard's livable-places manifesto in the 1970s. However, Miami architects Andrés Duany and Elizabeth Plater-Zyberk were the first to heed Krier's call for traditional urbanism in the design of Seaside, in Florida's Panhandle. Duany and Plater-Zyberk's efforts to architecturally and urbanistically code in Seaside the character of traditional small towns paid handsomely. This iconic 80-acre resort town became the prototypical TND, widely showcased in architecture, real estate, and news media, including the Hollywood movie *The Truman Show*. The town's incredible real estate success—in 20 years property appreciated more than a hundredfold its original value—rather than its designers' loftier objectives of socioeconomic integration and reduced car use, propelled TND into a new paradigm of planning and community building primarily on greenfields. The Kentlands, a 352-acre community in Maryland designed by Andres Duany and Elizabeth Plater-Zyberk in 1988, and later in 1994, Disney's 5,000-acre town of Celebration, Florida, designed by Robert A. M. Stern and Jaquelin Robertson, became exemplars of traditional neighborhood development on a grand scale.

The west coast approach emerged in the 1970s from



Resort town of Seaside, Walton County, Florida (80 ac., 360 units, retail)

Source: Google Earth.



The town of Celebration, Osceola County, Florida (5,000 ac., 5,000 units, downtown, office park), exemplifies TND exemplar on a grand scale.

Source: Google Earth.



Laguna West, Sacramento County, California (1,033 ac., 3,353 units, 180,000 ft.² retail, 2.7 million ft.² employment)

Source: Google Earth.



Orenco Station, Portland, Oregon (190 ac., 1,850 units, 68,000 ft.² retail)

Source: Google Earth.

among several strands of the ecological critique of the modern metropolis, conventional suburban development, and postindustrial society. One

form of freestanding TOD satellite towns. Laguna West, an 800-acre pedestrian-friendly community built around a lake, town center, and future

strand was the sustainable-communities design movement pioneered in the 1970s by Michael and Judy Corbett with the building of Village Homes in Davis, California—one of the first communities to feature edible gardens, affordable housing, and solar energy and natural drainage design. In the 1980s, the movement's regional scope and design synthesis took shape in San Francisco with Sym Van der Ryn and Peter Calthorpe's work on ecologically minded urban design. However, mass transit, rather than green design, inspired Peter Calthorpe and Douglas Kelbaugh to formulate the "pedestrian pocket," a residential neighborhood placed within walking distance of transit, jobs, schools, shops, parks, and civic amenities. Pedestrian pockets, the forerunners of TOD, were conceived as a regional design strategy for reducing driving, preserving open space, increasing the supply of affordable housing, and reining in urban sprawl. By the 1990s, Peter Calthorpe expanded the pedestrian pocket into TOD, which like earlier streetcar suburbs would be located on a trunk line or on a feeder bus line. As nodes of a transit network and components of a regional planning strategy, TODs can be designed for urban infill or redevelopment, new greenfield in suburban areas, or beyond the city's edge in the



Orenco Station, Portland, Oregon

Source: Author.



transit station in Sacramento, California, was the first “on-ground” test of the TOD idea. However, Laguna West’s still infrequent bus service makes it incomplete as a TOD and still highly dependent on the automobile. Orenco Station, a 190-acre greenfield community built on Portland’s Westside light-rail line, features a retail-and-office town center and a variety of housing types and is considered one of several successful TODs built to date.

As evidence of the movement’s widespread influence, the 2008 *Directory of New Urbanism* boasts 520 places, 3,000 firms, and 4,450 contacts—a burgeoning national-community-building industry, which in 2003 already counted 230 places built or under construction and 309 in some planning stage. However, despite its rapid growth and acceptance, less than 12% of these places were TOD or Hope IV public housing projects, lending support to the view that new urbanism’s larger transportation sustainability and social justice goals have remained somewhat limited. TND communities are typically affordable to the high-end consumer; although walkable, they are still highly automobile dependent, and the majority are located in greenfield sites. Consequently, some critics charge the new urbanist industry with promoting a new type of sprawl, quaint, walkable, and

more compact but expensive, still car dependent, and predominantly located at the urban edge. Despite these criticisms, new urbanism offers a welcome alternative to the ubiquitous commercial strip and generic residential subdivision.

Ivonne Audirac

See also **Architecture and Geography; Housing and Housing Markets; Urban Geography; Urbanization; Urban Planning and Geography; Zoning**

Further Readings

- Calthorpe, P. (1995). *The next American metropolis: Ecology, community, and the American dream*. New York: Princeton Architectural Press.
- Congress for the New Urbanism. (1999). *Charter of the new urbanism*. New York: McGraw-Hill.
- Duany, A., Platter-Zyberk, E., & Speck, J. (2000). *Suburban nation: The rise of sprawl and the decline of the American dream*. New York: North Point Press.
- Krier, L. (1984). Houses, palaces, cities. *Architectural Design*, 54, 7–8.



NITROGEN CYCLE

The nitrogen cycle refers to the geophysical, chemical, and biological processes involved in converting atmospheric nitrogen into a form that plants can use, recycling those nitrogen compounds within ecosystems, and returning them to the atmosphere. Of all the fundamental biogeochemical cycles, the nitrogen cycle is the most complex as it depends on the balanced activity of several different kinds of organisms, ecosystems, and atmospheric processes. It is also the cycle most affected by human activity. Indeed, the manipulation and transportation of nitrogen compounds by humans is now a major component of this fundamental Earth system, transforming what was once a predominantly local cycle into more of a regional and even global flow of material.

Flows of nitrogen through the biosphere are important because the availability of nitrogen plays a regulatory role in the production of biomass. In regions with sufficient water and sunlight, the production of biomass is generally limited by the quantity of chemically active nitrogen available. Although Earth is encapsulated by a nitrogen-rich atmosphere, that nitrogen is locked away in strongly bonded molecules of N_2 . For atmospheric nitrogen to be made available to plants, those bonds must first be broken so that the nitrogen can become part of another chemical compound. In nature, nitrogen-fixing bacteria—and to a much lesser extent, lightning—perform that role. (The word *fixing* can be traced back to the alchemists, who used the word *fixed* to describe what happened when a gas was converted into a liquid or solid.)

In a mature ecological system free of agriculture, the activity of nitrogen-fixing bacteria is more than sufficient. Existing nitrogenous compounds continually get recycled as leaves, grasses, fruits, and seeds fall to the ground and decompose into ammonia (NH_3) and other compounds. Then, in the soil, nitrifying bacteria (as opposed to nitrogen-fixing bacteria) convert the ammonia into nitrite (NO_2^-) and nitrate (NO_3^-), the latter being a highly soluble form of nitrogen that plants can take in through their roots. Nitrogen-fixing bacteria are only needed to make up for the small

losses that occur when nitrogen-containing compounds vaporize, leach away, or get carried away by streams to wetlands, floodplains, and the sea. In soils saturated with water, other types of bacteria, known as denitrifiers, convert nitrogenous compounds back to gases, balancing the activity of nitrogen-fixers.

The emergence of stationary agriculture altered local flows of nitrogen. Transporting nitrogen-rich protein away from the same agricultural fields year after year meant that large quantities of scarce nitrogenous compounds were also being carried away. This nitrogen had to be replenished if stationary farming were to be a long-term endeavor, and much of agricultural history revolves around societies learning, by trial and error, how to accomplish this feat. In many agricultural societies, the cultivation of legumes—which work symbiotically with nitrogen-fixing bacteria—emerged as an important way to replace that nitrogen. Even then, however, the availability of nitrogen remained a limiting factor. Nitrogen-fixing bacteria could replace losses of nitrogen only so quickly, and in the long term, farmers could not produce more crops than bacterial activity allowed. Until the 19th century, societies had no choice but to live within that limit.

Starting in the 19th century, agricultural chemists in Europe became aware of the role that soil nutrients played in plant growth, and farmers began experimenting with a variety of manures and soil additives. By mid century, merchants in Europe and the United States were importing large amounts of nitrogen-rich guano from South America and securing significant quantities of ammonium sulfate, a by-product of coal, from industrial firms. Farmers applied both as a fertilizer. This movement of material represented new pathways for flows of nitrogen. In the case of guano, nitrogen fixed by bacteria in a distant continent began flowing into the soils of Europe and North America. And when farmers applied coal-based ammonium sulfate to their land, their soils began to receive nitrogen fixed by bacteria millions of years ago.

Eventually, in the early 20th century, European engineers and scientists figured out how to bypass nitrogen-fixing bacteria altogether, eliminating previous limits on the production of protein. In particular, the German Haber-Bosch process for



fixing nitrogen industrially—accomplished by converting N_2 and H_2 into ammonia at high temperatures and pressures in the presence of a catalyst—is credited with making inexpensive sources of fixed nitrogen widely available. Today, the world could not produce the quantities of grain and beef that people now consume without industrially manufactured nitrogenous fertilizers, at least not without a radical restructuring of how societies are organized. In addition, when that protein is consumed, nitrogenous compounds are discharged in urine and feces. After passing through feedlot drains, sewage treatment plants, and septic systems, much of this nitrogen is released into waterways. Complicating matters further are additional flows of nitrogenous material from heavily fertilized agricultural soils, flows of nitrogen oxides out of power plants and tailpipes, and the loss of wetlands that host denitrifying bacteria.

For all these reasons, the nitrogen cycle that exists today is quite different from that which existed before stationary agriculture, both in magnitude and spatial complexity. In addition, in the nitrogen cycle of the 21st century, denitrification does not appear to be keeping up with the amount of nitrogen being placed into circulation by industrial processes. As a result, more nitrogenous compounds are reaching the ocean and seeping into groundwater than a century ago. One outcome is the creation of hypoxic dead zones near the mouths of major rivers, which occurs due to excessive quantities of nutrients giving rise to blooms of algae. The eventual decomposition of this organic material consumes the dissolved oxygen that fish need to live. Nitrates carried by water into the ground can also be a problem: High nitrate levels often prevent aquifers from being used as safe sources of water. Increased denitrification is not necessarily desirable either, as the gases emitted include a greenhouse gas (nitrous oxide, N_2O) and a gas (nitric oxide, NO) that reacts with ozone in complex ways.

Today, therefore, we interact with the nitrogen cycle every time we eat protein, flush a toilet, turn on a light, drive a car, apply fertilizer, and, in general, participate in the basic activity of an industrial society. Our activities have resulted not only in larger quantities of chemically active

nitrogen being placed into circulation but also in nitrogenous compounds following new pathways and accumulating in a variety of biogeochemical reservoirs. Many flows of nitrogen are now influenced by policy tools, such as discharge permits, emissions trading programs, watershed management plans, best-management practices for farms, wetland restoration efforts, rules governing the reuse of biosolids, and the creation of wellhead management zones. This management of human-created flows of nitrogen is another way in which human activity has become an important component of the nitrogen cycle.

Hugh S. Gorman

See also Agriculture, Preindustrial; Biogeochemical Cycles; Carbon Cycle; Coastal Dead Zones; Environmental History; Nutrient Cycles

Further Readings

- Galloway, J. N., Dentener, F. J., Capone, D. G., Boyer, E. W., Howarth, R. W., Seitzinger, S. P., et al. (2004). Nitrogen cycles: Past, present, and future. *Biogeochemistry*, 70, 153–226.
- Leigh, G. J. (2004). *The world's greatest fix: A history of nitrogen and agriculture*. New York: Oxford University Press.
- Smil, V. (2001). *Enriching the Earth*. Cambridge: MIT Press.



NOMADIC HERDING

Derived from the Latin word for shepherd (*pastor*) and the Greek word for a wanderer seeking pasture (*nomas*), pastoral nomadism describes a specialized form of mobile animal husbandry. This production system is extensive, and animals are often moved over a large area in an annual cycle. These nomadic herders exploit areas that are too extreme (too dry, steep, cold) to sustain settled agriculture. Since the middle of the 20th century, changes in pastoral zones have discouraged nomadic herding and resulted in degradation of those areas where significant nomadic pastoral communities continue to exist. This entry



first describes the nature of nomadic herding, the structure of herding groups, and the nature of their use of resources. It then describes the impact of modernization on nomadic herding.

Nomadic herding uses animals as intermediate converters of vegetation to produce meat, dairy products, fiber, hides, and other commodities. Modern intensive grazing systems bring food to the animals, limit animal movement, and promote quick growth to slaughter weight. In contrast, traditional pastoral nomads move their animals to food and water. Animals herded nomadically expend large amounts of energy reaching distant fodder. This produces a tougher, leaner, healthier, and tastier meat but lengthens the time required to achieve market weight and requires the herding family to accompany the animals to distant pastures. Nomadic herders achieve mobility by reducing material possessions to essential equipment, living in tents, engaging in annual migrations, and moving base location many times during the year.

Vertical and Horizontal Movements

Movement takes place within a regional spatial framework rooted in local ecology. To support their flocks, all pastoral nomads must control access to seasonally available resources, which are seldom available in one small area for an entire year. Herders must migrate to find necessary resources in different places at various times of the year. The location of water and forage is well-known to pastoralists, and movement to use these resources is regular, not random. Pastoral nomads do not wander aimlessly seeking sustenance, a classic “outside” perception of their movements, but rather regularly revisit specific areas following well-known routes or trajectories.

Some nomadic herders exploit vertical ecological differences in pasture availability by grazing their animals in cooler and moister uplands during the summer months when grass and water are plentiful. By changing altitude from lowland to highland, nomadic herders avoid drought-prone lowland areas. In winter, nomadic herders migrate back to the lowlands to avoid the cold temperatures and snowfalls characteristic of the

highlands, and to find grass and water resources in familiar districts where their seasonal rights to resources are traditionally respected.

In lowland areas where large uplands are absent, nomadic herders spend their dry season grazing close to secure water resources, for example, a permanent stream or group-owned, hand-dug wells. A balance must be maintained between the water and grass available locally and the number of animals that the herders keep in a particular area. To prevent local overgrazing, lowland herders move away from their dry-season water sites during the wetter part of the year. This pulsating, horizontal movement takes lowland pastoralists far from their permanent base along a well-known trajectory to reach the areas that they know by experience are likely to have received rain or collected runoff. Nomadic lowland herders remain at these sites until grass and water are exhausted, and if additional resources are not located in the vicinity or the dry season is fast approaching, the herds are moved back to their dry-season water site.

Resource Rights

All nomadic herders claim the right to use grass and water to support their animals, but they assert absolute ownership rights over local resources only in critical areas. Usually, these exclusive claims are made by horizontal nomads to the grass and water needed to survive in the dry season and by vertical nomads to upland pastures with abundant grass and water. Often in these areas, the nomadic herders have dug the wells or have small agricultural plots to which they claim exclusive ownership. Along the routes they follow to seasonal pasture, nomadic herders claim the right to use unimproved, natural grazing as well as to draw water from local water sources. If the water comes from a well, or the pasture is a managed one, nomadic herders expect to pay a fee to the owner or government agency in control. If the area is wooded or controlled by a local tribal council, herders would expect to comply with local use regulations. Traditionally, nomadic pastoralists claimed the right to graze on the stubble that remained after crops were harvested. Farmers benefited from this grazing use,



Young Masai nomads with cattle in Southern Kenya

Source: Britta Kasholm-Tengve/iStockphoto.

since the animals deposited manure and urea on the fields. These organic fertilizers were free, the farmer typically did not own enough animals to consume much of the postharvest residue, and poorer nomadic families often appeared soon enough in the harvest season to contribute useful temporary labor. Once beneficial to both farmers and herders, this dung-stubble connection has faded as a result of the modernization and mechanization of agriculture and the use of chemical fertilizers.

Herding Groups

Labor is a valuable commodity in pastoral communities, as is the political power needed to enforce pastoral rights. The need for labor is great because many nomadic herders keep several types of animals, each of which has a preference for specific fodder species. Camel herders,

such as the Kababish of Central Sudan and the Somali, may also keep sheep and goats. Because goat milk is an important part of the family diet, the goats are usually grazed near the family residence. Sheep are kept for their wool and their eventual sale in market centers. Sheep need high-quality grazing and daily water availability, so they often are herded separately in distant areas. Camels need far less water, can range far from the herder's domestic base, and can eat thorny, shrubby forage that most livestock reject. At different times of the year, each animal may be foraging far from other herd components, thus requiring separate herders for each species. To ensure enough labor to herd the animals of individual families, small herding groups are formed. These herding groups may contain up to a dozen families, depending on the time of year, and often have a core group of related males. If one family lacks young males to herd its animals, labor can be provided by others; if an unrelated elderly



couple lacks children, they can potentially remain in the group by herding for others. The composition of these groups is always somewhat dynamic; individuals enter and leave as their particular circumstances and comparative advantage permits and as disputes over the timing and direction of movements arise.

The camp group that herds and travels together is the basic building block of nomadic societies. Several herding groups compose a clan, several clans constitute a tribe, and several tribes can under charismatic leadership be grouped into a confederation. Through this hierarchical organization, the community's leaders exercise influence in pursuit of their personal aims and their tribesmen's goals. The ability to generate armed troops has made nomadic herders a formidable political force in many places such as Iran, Turkey, Saudi Arabia, and Mongolia. Herders have used their latent military potential to protect their resource use rights and the zones they deem critical from encroachment by rivals. The same force could be (and was) used to extract resources from farmers, merchants, and, on occasion, governments.

Pasture is owned by an entire community of nomadic herders, and every tribal member has the right to graze animals on the communal pastures controlled by the group. The group, represented by its leaders meeting in a tribal council, determines who can graze in an area and how many animals can exploit the area. People and groups not part of the community can maintain animals on communal pasture only if they have married into the tribe or if they have special political relations (often solidified by marriage) with tribal members. Maintaining such ties is primarily the responsibility of the leaders and is very important. Whenever a drought or a dispute with an enemy occurs, political connections are activated to provide alternative grazing opportunities or allies. Since many nomadic herders live in highly variable, low-productivity environments, these connections constitute an important safety net that offsets environmental and political hazards.

Environmental Management

Although herders use common pastures, herds are privately owned. This has led to claims that private exploitation of communal pasture always results in

overgrazing and, if allowed to proceed unchecked, to land degradation and desertification. This "tragedy of the commons" seldom arose under premodern nomadic herding conditions because herders were able to limit dry-season stocking ratios to the carrying capacity of an area. What human-imposed limits failed to achieve, nature ensured; rapid expansion of herds in a succession of good years was invariably offset by abrupt declines in herd numbers under prolonged drought conditions. This "boom and bust" rhythm was reflected in traditional nomadic pastoral systems. These herding regimes accepted the difficult, disequilibrium environments in which they had to operate and did not expect to produce a steady annual off-take from the range to sell in urban markets.

Modern governments, which depend on the political support of growing urban populations, favor a secure food supply that discourages urban riots and have promoted technological innovations that improve food security. Many of these development initiatives remove environmental constraints from nomadic herding. Wells that tap deep aquifers provide water in drought periods but concentrate so many animals that overgrazing occurs. Veterinary services improve the health of herds but keep too many animals on the range. Motor vehicles make access to pasture and market quicker but allow herds to reach distant grazing before regeneration from earlier use is complete. Herders are encouraged to settle (sedentarization) in order to access health and educational facilities, but pasture decline near settlements is common. Governments favor agriculture over herding by encouraging the conversion of prime grazing land into crop-producing areas and by converting dry-season grazing areas into irrigated agricultural zones. All these modern developments have the urban food consumer more in mind than the well-being of the nomadic animal herder. Only by modernized, mobile nomadic herding can many marginal zones remain contributors to human sustenance.

Douglas L. Johnson

See also **Agriculture, Preindustrial; Desertification; Drought Risk and Hazard; Environmental Management; Indigenous Environmental Practices; Land Degradation; Nomadism**



Further Readings

- Agrawal, A. (1999). *Greener pastures*. Durham, NC: Duke University Press.
- Behnke, R. H., Scoones, I., & Kerven, C. (1993). *Range ecology at disequilibrium*. London: Overseas Development Institute.
- Chatty, D. (2006). *Nomadic societies in the Middle East and North Africa*. Boston: Brill.
- Fratkin, E., & Roth, E. A. (Eds.). (2005). *As pastoralists settle*. New York: Kluwer.



NOMADISM

Nomadism describes a pattern of human behavior for which mobility is essential. Nomadism is defined as continuous wandering, usually in search of food or sustenance. The popular image of the hobo, a homeless male of the late 19th and early 20th centuries, who jumped on and off freight trains while traveling the country looking for work probably comes as close to the basic definition as possible. A completely nomadic existence is almost never attained in reality. Nomadism seems more random in its spatial movement and organization to the outside observer than it is in reality to its practitioner. Most often, the term *nomad* is applied to animal herders, either as individuals or as groups, who move frequently and seasonally in search of support for the animals that form the basis of their livelihood.

Central to the classical concept of the nomad as an aimless wanderer is the belief that the nomad has no fixed home but rather moves where the spirit leads. The nomad is viewed as opportunistic in character, seizing opportunity whenever and wherever advantage exists. As soon as local conditions deteriorate or better opportunities are recognized or hoped for elsewhere, the nomad moves on to a new setting. In practice, mobile nomadic herders (pastoral nomads) are falsely regarded as aimless wanderers, lacking a permanent base, because they carry their home (a tent) with them and erect that dwelling whenever they stop. In practice, nomadic animal herders engage in regular movements between pasture zones that are only available at certain times of the year.

Movement enables these nomadic pastoralists to optimize pasture quality for their animals by shifting from poorer to better seasonally available pasture. Nomadic pastoralism is rotational grazing on a grand scale, substituting seasonal movements over hundreds of miles for the sedentary farmers' rotational shifts of livestock from paddock to paddock.

Nomadism is not migration, which is the process of shifting location from one place to another for a lengthy period. Many migrants have no intention of returning to their original home but rather plan (or hope) to remain permanently in the new location. The movement of European settlers to North America may have involved some returnees to their ancestral homeland, but the vast majority stayed at their destination. Nomadic peoples, for whom mobility is a dominant characteristic, intend to return to a base, usually a part of their total, exploitable habitat that is essential to their livelihood and sense of identity.

Many groups engage in livelihoods for which mobility is essential but are not nomads in the classic rootless sense. Duck herders in India traditionally traveled a regular, limited circuit from their bases in Tamil Nadu. Improved roads, expanded paddy rice areas that provide more postharvest grazing, and access to trucks now permits the movement of thousands of ducks over hundreds of kilometers following the rice harvest. Farmers in the foothills of the Alps and other mountain ranges habitually have moved their cattle to upland meadows for the summer, a seasonal oscillation called *transhumance*. Hunters and gatherers moved in synchronization with seasonal salmon spawning runs in the Pacific Northwest, as did wild rice harvesters in the Great Lakes. Nomadic herders, such as the Saami (Lapps) in Northern Scandinavia, continue to move their reindeer herds to mountain pastures each year. In reality, the idealized, aimless nomad is an idealized construct, viewed from the perspective of the permanently settled community and almost never realized in the real world, against which any more mobile group short of the ideal seems seminomadic.

Douglas L. Johnson

See also **Hunting and Gathering; Nomadic Herding**



Nomadic Tuareg herders and camels in the Sahara Desert, 60 miles north of Timbuktu, Mali, West Africa

Source: Alan Tobey/iStockphoto.

Further Readings

- Humphrey, C., & Sneath, D. (1999). *The end of nomadism? Society, state and the environment in Inner Asia*. Durham, NC: Duke University Press.
- Nambi, V. (2001). Modern technology and new forms of nomadism: Duck herders in Southern India. *Nomadic Peoples*, 5(1), 155–167.



NOMOTHETIC

Beginning with Schaeffer's (1953) famous attack on what he called *exceptionalism*, the claim central of the idiographic approach that history and geography are only concerned with the unique aspects of individual places, the discipline began a transition into a nomothetic body of knowledge,

one that sought general laws of explanation independent of time and space. Whereas idiographic understanding sought to uncover all the aspects of one place, nomothetic understanding sought to reveal how one phenomenon varied among many places.

The idiographic-nomothetic debate, also known as the *systematic versus regional geography* debate, raged throughout the 1950s and early 1960s. This clash of views essentially involved the question whether geography should be involved in general laws of understanding, that is, the relative emphasis on regional differences versus regional similarities, the factors that differentiated places or the commonalities that ran through them. Thus, the shift from an idiographic to nomothetic geography was closely (but not exclusively) associated with the broader decline in the regional approach. This move involved the triumph of the abstract over the concrete, the general over the particular,



and the universal over the specific. Nomothetic approaches valued abstraction and empirical regularities and held that the empirical world existed solely for the purpose of testing theory.

Rejecting the empiricism of the idiographic approach, nomothetic forms of geography are long associated with the attempt to make the discipline more “scientific” in the same sense as the physical sciences. Advocates of the nomothetic approach thus exhibited a disdain for induction and a sustained concern for the role of theory and explanation. This view centered on a sharp fact-value distinction, rigorous methods of data collection and sampling, deductive (also called *nomological*) logic, hypothesis testing, quantitative methods, reproducible results, and predictive ability. These tools are held to uncover the logical structures that underpin the play of empirical surface appearances. All these were hallmarks of the philosophy of logical positivism. In this account, the process of explanation involves embedding the unique within the general, that is, showing an individual set of observations to be the outcome of wider principles at work in a variety of places. A law is held to be a hypothesis that is repeatedly confirmed under controlled conditions. Choosing among competing laws involves invoking the principle of Occam’s razor, that is, choosing the simplest approach whenever possible. Methodologically, nomothetic approaches were closely associated with the rise of statistics and mathematical models, which were central to the rise of spatial analysis and location theory. Epistemologically, nomothetic views relied on a Kantian view of absolute space rather than later relativist notions of space as socially constructed.

Critics argued that this approach effectively reduced geography to geometry, ignoring historical context, social relations, or the role of human consciousness. Moreover, not all regional details could be so easily swept under the carpet of general theory, as the revived localities school maintained.

Barney Warf

See also Berry, Brian; Idiographic; Logical Positivism; Models and Modeling; Quantitative Revolution; Schaefer, Fred

Further Readings

- Berry, B. (1964). Approaches to regional analysis: A synthesis. *Annals of the Association of American Geographers*, 54, 2–11.
- Harvey, D. (1969). *Explanation in geography*. London: Edward Arnold.
- Schaefer, F. (1953). Exceptionalism in geography: A methodological examination. *Annals of the Association of American Geographers*, 43, 226–229.



NONGOVERNMENTAL ORGANIZATIONS (NGOs)

Nongovernmental organizations (NGOs) are nonprofit associations that function independently of institutionalized government structures. NGOs are major players on the global stage because of their numbers and the extensive reach of their activities, often in remote areas with populations overlooked by the state and other organizations. For these reasons, it is important to understand the breadth of NGO activities, explore their history, and be familiar with the praise and criticism directed at these powerful organizations. Although they are grouped under a single, broad description, individual NGOs vary greatly with respect to their objectives, approach, culture, and scale at which they work. NGOs are influenced by the context where they work; their approach and capability vary greatly from place to place.

NGOs have a wide variety of objectives. They usually embrace political (e.g., democracy building), environmental (e.g., forest conservation, animal rights), or social (e.g., women’s empowerment) goals. They also often provide services to communities (e.g., drought relief). NGOs are active in the arenas of national and international politics, humanitarian assistance, and economic development. Some NGOs are staffed by volunteers, but NGO work has also gained prestige as a legitimate, and occasionally well-paid, career.

NGOs engage in a wide range of activities, including human rights advocacy, peacemaking, education and information dissemination,



democracy training and political participation of citizens, sustainable development, environmental conservation, capacity building and community organizing, social movements, law and advocacy, citizens' rights, research, training, provision of basic needs and services, community service, lobbying, and civil disobedience.

NGOs work at local, national, and international scales. They range in size from very small in terms of funding, geographic focus, and constituency to very large, with extensive funding, having geographically dispersed activities, and serving thousands of people. Regardless of the scale of their work, almost all NGOs are motivated by political or charitable ideals. Those NGOs motivated by charitable ideals seek to assist the neediest sections of society. NGOs motivated by political ideals strive to change society and remedy existing inequality. Most NGOs claim to act on behalf of the disenfranchised in today's globalized world. By siding with marginalized groups (e.g., women, slum residents, untouchables), they claim to speak for those who would not otherwise be heard.

Recent History of NGOs

In the 1980s, as development aid began to expand, NGOs were increasingly seen as groups that could facilitate flows of financial aid and services to the poor at a local scale. Because these organizations were already on the ground, locally connected, and in touch with the needs of their constituents, they were considered the ideal way to transfer development aid, technology, and services. International donors found NGOs ready and willing partners, engaged with the local communities that foreign aid was meant to reach. NGOs, for their part, often spent a lot of time looking for financial support, so the opportunity of capturing larger projects and a steadier source of funding from international donors was always welcome. Both a steady income stream and greater amounts of funding from abroad have enabled the growth of the NGO sector as a career in many developing countries.

Current estimates of the number of NGOs stand between 40,000 and the 100,000s—depending on how broadly the term *NGO* is defined. Only

100 years ago, the number of NGOs was estimated to be less than 200. The number, scope, and size of NGOs have proliferated in recent decades. The term *NGO* has become synonymous with any organization implementing economic or social development projects, especially those funded by foreign financial aid. The high-profile delivery of development aid and humanitarian services after a major natural disaster usually arrives through the efforts of NGOs.

The sheer variety of NGOs has led to attempts to categorize them based on the kind of work that an organization does, who it serves, at what scale it works, or from where it receives its funding. This has led to a proliferation of acronyms trying to capture all the different types of NGOs, but very few of these have come into common usage. There are simply too many types of NGOs, so the catchall term *NGO* continues to be favored. However, two useful distinctions have emerged that help separate large, global NGOs from small, local ones: international NGOs (INGOs) and community-based organizations (CBOs), respectively. INGOs are NGOs who have national offices in multiple countries, for example, CARE International. INGOs are distinctive for their global connectedness and large budgets. CBOs are locally based and usually locally funded groups with very strong links and responsibilities to their constituency; their membership comprises the community they serve. They are sometimes called *grassroots organizations*, because the group arose spontaneously from the “roots” of the community, usually in response to an intolerable political situation or environmental threat. CBOs are observed to have a different character from other NGOs because they are started and funded by communities seeking organized social and/or environmental change on a small scale or in a localized area.

In recent decades, NGOs have begun to form transnational networks, in which the resources and information of many different organizations, working at different scales and in geographically dispersed locations, are shared globally for the good of all. These networks have played important roles in disrupting global economic conferences (e.g., protesting meetings of the World Trade Organization) and supporting others (e.g., creating solidarity among women's groups at the United Nations conferences for women). They



also distribute research materials and other vital information from resource-rich areas of the world to resource-poor areas, and vice versa. NGOs are firmly embedded in a globalizing world, and they use their transnational networks like any other multinational organization would—to the greatest possible advantage of their goals.

Praise and Criticism

NGOs are now the preferred choice of donor organizations (sometimes themselves NGOs) for the delivery and provision of development aid and services. NGOs are ideally positioned to reach needy communities because of their history of working closely with such populations. Donors want to tap their local knowledge and field experience in out-of-the-way places. However, as aid from foreign sources to NGOs operating in poor countries has increased, donors have discovered the need to train NGO staff to carry out reporting and accounting procedures, as well as to increase their outreach skills, education, and strategies in the field or in the communities where they work. Donors have realized that NGO staff do not have the necessary skills to carry out the terms of their contracts.

A frequent concern for those watching NGOs is the question of NGO accountability. If NGOs are responsible for their constituencies, then the following question arises: “How are these communities to verify the funding and activities, mandates and reporting, of the NGOs that claim to serve them?” When the members of NGO constituencies come from poor and disenfranchised sections of society, it appears unlikely that they will have the political power to demand that NGOs remain accountable to them. On the other hand, as funding increases, donors financing NGOs want to track their money and report that the aid money is achieving results and improving the capacity of NGOs to deliver in the future.

Critics fear that the professionalizing activities demanded by donor agencies have shifted the focus of NGOs away from the people they serve toward meeting the demands and their responsibilities to donors. Increased reporting and monitoring, demands for efficiency and high-quality communication skills, and hierarchical salary

structures inside organizations have led to a shift in NGOs’ accountability away from their clients and toward their donors. Time and energy previously spent with clients becomes refocused on submitting the required documentation that will sustain funding. Instead of finding motivation in client-driven concerns, NGOs find their objectives driven by donor concerns to maintain funding flows. As donors place greater burdens of accountability on NGOs, NGOs may find themselves shying away from their political and social justice goals of facilitating greater access to economic and democratic opportunities for marginalized peoples.

It has been suggested that NGOs form a “third sector,” that is, neither a state enterprise nor a for-profit corporation. This position gives NGOs a perspective the other two sectors cannot provide. NGOs are not driven by profit, so social, political, and environmental goals can come first. NGOs provide a balance to the state, including the possibility of a challenge to state practices that may not be meeting the needs of citizens. Often, NGOs cast themselves in roles oppositional to a state that is ineffective, unresponsive to citizen needs, or not democratically elected. NGOs have played a significant role in creating and sustaining social movements.

But as NGOs have grown in size, scope, and number, concerns have been raised about whether or not NGOs can continue the work that led to their tremendous popularity, and what new roles they should or should not take on. The growing power of NGOs has led to fears that NGOs may come to replace the state and the services it provides. For example, instead of forcing the state to provide essential services (garbage collection, education, welfare), NGOs begin providing these services. The state withdraws from the social sector, passing on its responsibilities to NGOs and the donors that fund them. The problems with NGOs assuming these responsibilities say NGO critics is that NGOs are not accountable to citizens in the same way that the state is, nor is it appropriate for NGOs to assume service-providing roles over activist roles. Critics charge that NGOs have become apolitical service providers and encourage their constituency to take up responsibilities that enable the state to abnegate its role in providing for citizens.



NGOs have been criticized for moving away from their original, politically charged goals toward more politically neutral positions. They have been accused of seeking closer relationships with governments, instead of keeping watch on those in power and their policies. Some activists fear that without the leadership of NGOs, grass-roots political activism will disappear and voices against the status quo will be silenced.

Questions have been asked about the growing power and role of NGOs in governance at national and international scales. Some question the legitimacy of NGOs in international negotiations, such as their places at the table in venues such as the World Water Forum or the United Nations conferences on women. It is not clear what role NGOs should have in such meetings. NGOs are invited to the table in international discussions because they claim to speak for their constituencies at that local scale, but NGOs operating globally may find themselves cut off from their community-based constituencies. NGOs are not geographically sovereign, have little enforcement power, and no clear mandate to act as representatives. Those who would like to see NGOs representing civil society in international discussions fear that formalizing their participation might serve to limit the contributions NGOs make to global decision making.

Kathleen O'Reilly

See also **Antisystemic Movements; Civil Society; Development Theory; International Environmental Movements; Social Movements; Sustainable Development; Sustainable Development Alternatives; United Nations Conference on Environment and Development**

Further Readings

- Bebbington, A., Hickey, S., & Mitlin, D. (Eds.). (2008). *Can NGOs make a difference? The challenge of development alternatives*. New York: Zed Books.
- Edwards, M., & Fowler, A. (Eds.). (2002). *The Earthscan reader on NGO management*. London: Earthscan.
- Hawken, P. (2007). *Blessed unrest: How the largest social movement in history is restoring grace, justice and beauty to the world*. New York: Penguin Books.

Hulme, D., & Edwards, M. (Eds.). (1997). *NGOs, states and donors: Too close for comfort*. New York: Palgrave Macmillan.

Jordan, L., & van Tuijl, P. (Eds.). (2007). *NGO accountability: Politics, principles, and innovations*. London: Earthscan.

Kamat, S. (2004). The privatization of public interest: Theorizing NGO discourse in a neoliberal era. *Review of International Political Economy*, 11, 155–176.

Tvedt, T. (1998). *Angels of mercy or development diplomats? NGOs and foreign aid*. Trenton, NJ: Africa World Press.



NONPOINT SOURCES OF POLLUTION

A nonpoint source (NPS) of pollution is defined as any water pollution coming from a diffused source. Whereas point pollution sources such as wastewater from sewage or industries are discharged on a single location, NPSs can spread over a very large area where rain, irrigation, or snowmelt can carry pollutants and discharge them in streams, lakes, reservoirs, or coastal waters. These pollutants can be carried either over the ground through surface runoff or below the ground surface through seepage. Depending on their type, these pollutants can be carried over large distances and have a drastic effect on water quality.

Common NPSs

There can be many different kinds of NPSs, but the most significant are crop and grazing agriculture practices that use large amounts of insecticides and fertilizers. Fertilizers are chemicals usually containing nitrogen and phosphorus that are good plant nutrients. Although their presence in the water is not in itself a threat to human health, they encourage algae blooms and eutrophication of the water causing the death of fish and other life forms of the aquatic ecosystem. Both intensive and extensive domestic livestock produce huge amounts of feces that, when improperly managed, can pollute water and create a health



hazard for humans and other animals. Pathogenic diseases such as cholera, dysentery, and hepatitis A are known to be associated with the presence of feces in the water. Fecal coliform bacteria is a good indicator of the presence of fecal material in the water but should not entirely be attributed to feces. Storm runoff water from urban areas can escape the sewage system and carry toxic oils and chemicals to nearby streams. Bad soil conservation practices in agricultural areas can also promote soil erosion and increase the amount of sediment load carried by runoff to water bodies.

Controlling NPSs

Because many human activities are potential contributors, NPSs are inherently difficult to control. Although some of these activities such as burying toxic waste are illegal, others, such as spraying fertilizers and insecticides, are not only legal but are often encouraged and even subsidized by the government. This makes NPS pollution extremely hard to reduce on a large scale, and local policies seldom show sensibility or awareness of the problem. It is considered in many parts of the world as the leading source of water-quality problems. While many actions to reduce NPS pollution necessitate state action, such as the creation and enforcement of more restrictive laws of land management, other measures require local initiatives, such as the implementation of better soil conservation practices or the restoration of riparian vegetation, that can have a strong filtering effect on runoff water.

Philippe Maillard

See also **Agrochemical Pollution; Atmospheric Pollution; Coastal Zone and Marine Pollution; Point Sources of Pollution; Water Pollution**

Further Readings

Hranova, R. (Ed.). (2005). *Diffuse pollution of water resources: Principles and case studies in the Southern African Region*. London: Taylor & Francis.

Novotny, V. (2003). *Water quality: Diffuse pollution and watershed management*. New York: Wiley.

Olsson, L., & Pilesjö, P. (2002). Approaches to spatially distributed hydrological modelling in a GIS environment. In A. Skidmore (Ed.), *Environmental modelling with GIS and remote sensing* (1st ed., pp. 167–199). London: Taylor & Francis.

Yuan, D., Lin, B., Falconer, R., & Tao, J. (2007). Development of an integrated model for assessing the impact of diffuse and point source pollution on coastal waters. *Environmental Modelling and Software*, 22(6), 871–879.



NONRENEWABLE RESOURCES

Humans use a variety of resources whose regeneration rates are too slow to show sufficient increases in stock sizes to be relevant to decision making. Examples include many of the energy sources on which modern economies depend, such as crude oil, natural gas, coal, and uranium, as well as many of the minerals and metals stocks that enter the economy—from iron and copper ores to gravel and sands, to trace minerals important in agriculture and many industrial processes. Other resources could, in principle, be considered renewable—such as tropical forests or fish populations—but current harvest rates are too high to allow for significant regeneration.

Optimal Extraction of Nonrenewable Resources

Given their finiteness, how much of a nonrenewable resource should be used at any given point in time? The 20th-century economists Lewis Gray and Harold Hotelling were the first to recognize that the conditions for optimal resource depletion are different from the optimality conditions for the production of ordinary goods. A basic assumption is that a nonrenewable resource can be extracted just once. Therefore, optimal prices of a unit of a resource must not only reflect its cost of extraction but also account for the opportunity costs associated with depleting the resource endowment by that unit. Traditional



economic models employ positive discount rates to reflect the possibility that technological improvement can give rise to increasing economic wealth and that even though future generations will inherit smaller *physical* resource endowments, an enlarged stock of human-made resources may compensate for the reduction in the physical resource base.

Challenges for Optimal Resource Extraction Models

Three major issues surround the formulation and application of models of optimal resource extraction: (1) discounting, (2) empirical applicability, and (3) the nature of partial equilibrium analysis of resource use.

Discounting

The choice of the discount rate is vital to the evaluation of economic activities since the discount rate determines whether an action has positive present value of profits or utility, whether it is better than others (has higher present value of profits or utility in the set of possible actions), and whether its timing is optimal (e.g., whether waiting would resolve uncertainty and thus increase present value of profits or utility).

Positive discount rates imply that consumption and production of future periods are valued less than present consumption and production. Once a discount rate has been chosen for evaluating alternative consumption and production plans, the question is whether this rate should remain constant over time. A constant discount rate is appropriate if economic agents assume that the probability of factors affecting the choice among actions remains constant over time. Since the determination of a social discount rate is controversial among economists, assumptions on the rate of change in the discount rate are unlikely to be accepted with consensus.

Empirical Relevance

Although traditional models of optimal extraction of nonrenewable resources are widely accepted among resource economists, empirical

evidence for them on the basis of firms' behaviors is rare and usually disappointing. Despite unreliable data, the lack of empirical support is partly because most models do not explicitly account for a firm's production capacities, capital requirements, capital utilization, and time adjustments in production technologies.

Traditional models of optimal nonrenewable resource extraction are also simplistic with respect to the behavioral assumptions on which they are built. For instance, short- and long-term decisions are typically not distinguished. Decision makers may not attempt to identify optimal extraction paths over potentially many decades to centuries but rather choose two or more sets of time periods over which decisions are made. As a consequence, one discount rate may be applied over decisions in the immediate future, while different discount rates may be chosen for the medium- to long-term periods.

Grey and Hotelling-style models on a macroeconomic level are more abundant than their microeconomic counterparts. With these models, time paths of various scarcity measures are investigated on an economy-wide basis. Potential candidates for economic measures of scarcity include resource prices, marginal extraction cost, or scarcity rent rates.

Partial Equilibrium Approach

By its nature, economic theory is anthropocentric and, thus, selective in the consideration of effects of economic actions on the environment and the role of environmental goods and services for economic activities. Many important environmental constraints are typically not captured fully in the economic decision process. Rather, these constraints are captured only as far as they impose apparent, immediate restriction on the deployment of the economically valued factors of production. A variety of constraints that are associated with unpriced material and energy flows that may lead to fundamental changes in the physical or biotic environment are frequently not, but in principle can be, considered. An example that has received considerable attention is climate change, which is being induced in part by the emissions of greenhouse gases from combustion of fossil fuels, methane



and carbon emissions resulting from land use changes, and reduced carbon sequestration from biomass harvesting.

History and Potential Future of Models of Optimal Resource Extraction

The debate about sustainability forces decision makers to broaden their view of the roles of nonrenewable resources and to compare alternative actions with respect to their long-term and systemwide costs and benefits. Use of nonrenewable resources may be considered optimal not only with respect to the narrowly defined partial-equilibrium criteria of traditional economic models of resource use but also with respect to issues concerning the long-term and large-scale performance of an economy that is an integral part of a changing ecosystem. To arrive at that systems view requires enriching traditional economic analysis with insights from physics (most notable the laws of thermodynamics) and ecology (e.g., the notion of material cycles, homeostasis, and evolution) to capture the long-term effects of nonrenewable resource extraction and use on economic and ecosystem performance, since many of the deciding attributes and impacts are not priced and thus not an explicit part of typical economic decision making. Conversely, disregarding these systemwide performance criteria may result in nonrenewable resource extraction at rates that leave the economy less sustainable, even though they may be “optimal” in the narrow sense of traditional resource economics. Reconciling the two perspectives is an active area of research and topic of continued consternation in public policy.

Matthias Ruth

See also **Coal; Cost-Benefit Analysis; Energy Resources; Minerals; Petroleum; Renewable Resources**

Further Readings

Conrad, J. M., & Clark, C. W. (1987). *Natural resource economics*. Cambridge, UK: Cambridge University Press.

- Norgaard, R. B. (1990). Economic indicators of resource scarcity: A critical essay. *Journal of Environmental Economics and Management*, 19, 19–25.
- Ruth, M. (1993). *Integrating economics, ecology and thermodynamics*. Dordrecht, Netherlands: Kluwer Academic.
- Ruth, M. (2006). The economics of sustainability and the sustainability of economics. *Ecological Economics*, 56, 332–342.
- Solow, R. M. (1974). The economics of resources or the resources of economics. *American Economic Review*, 64, 1–14.

NONREPRESENTATIONAL THEORY

Nonrepresentational theory (NRT) is a reaction against the stranglehold of representation in cultural geographies. Although by no means unified, NRT in human geography has two broad positions. Epistemologically, it seeks to challenge the notion that representation is “all there really is” by emphasizing the unruly forces of life that elude cognitions and conceptualizations. It is in this sense that NRT does not herald the overturning of representation—perhaps, as Hayden Lorimer suggests, a better name for nonrepresentational theory would be “more-than-representational theory.” Ontologically, NRT breaks with a Cartesian division between “subject” and “object.” Replacing this philosophical dualism is a flat ontology based on the interplay of affect, practice, and performance. The work of Gilles Deleuze, a 20th-century poststructuralist philosopher, greatly influenced the general contours of NRT. Playing down the hegemony of “images of thought” and structural thinking in philosophy, Deleuze was keen to affirm a world where differences could roam free without being subsumed to representation. The *virtual* is the name Deleuze gives to the domain of differences, relationalities, and potentialities always latent within the world of actualized phenomena. The Deleuzian legacy is clear in NRT—cartographies of the virtual are already always “interfering” with our clearly



cut mappings of the world. NRT champions difference, immanence, and relationality over a geography based on repetition, transcendence, and division.

As the pioneer of NRT, the British geographer Nigel Thrift argues that NRT is at its core a “non-cognitive methodology” for being in the world. Similarly, Dewsbury believes that NRT is a way of presenting the world in all its immanence rather than *representing* it. That is, Dewsbury believes in a kind of “witnessing” of the world before it becomes discursively constituted through representation. In other words, witnessing is an experiential engagement with the radical relationality of perspective. Similarly, John Wylie’s work on landscape calls the reader into a postphenomenological reading of “being.” That is, his account of landscape does not denote a “gazed-upon” space by an intentional subject—landscape is rather the processual forces of being that disclose both subject and object. As a constant producing, landscape is none other than a Deleuzian *folding*. The subject is a folding of landscape itself, or rather, the subject is what comes to occupy the position of the fold—with difference created and assembled through the “variations” and “inflections” of folding. Landscape is thus the materialities and sensibilities *with* which we see. The Cartesian subject dissolves into endless foldings and texturings.

In summary, a nonrepresentational geography seeks to uncover the processual forces of our world that *produce* social and spatial relationships. This is achieved by a noncognitive methodology that pays attention to practice and performance. In a very Heideggerian sense then, NRT pivots around the central ontological condition of “being-in-the-world.” How do we relate with the world, with other humans, and with the nonhuman? NRT answers these questions from a variety of perspectives of philosophers from Maurice Merleau-Ponty and Martin Heidegger to Judith Butler and Bruno Latour. Interested readers should consult the works of geographers such as Nigel Thrift, J. D. Dewsbury, Derek McCormack, and John Wylie.

Ian Graham Ronald Shaw

See also **Epistemology; Ontology; Poststructuralism; Representations of Space; Thrift, Nigel**

Further Readings

- Dewsbury, J. D. (2003). Witnessing space: “Knowledge without contemplation.” *Environment and Planning A*, 35(11), 1907–1932.
- Lorimer, H. (2005). Cultural geography: The busyness of being “more-than-representational.” *Progress in Human Geography*, 29(1), 83–94.
- McCormack, D. P. (2003). An event of geographical ethics in spaces of affect. *Transactions of the Institute of British Geographers*, 28(4), 488–507.
- Thrift, N. (2008). *Non-representational theory: Space, politics, affect*. London: Routledge.
- Wylie, J. (2006). Depths and folds: On landscape and the gazing subject. *Environment and Planning D: Society & Space*, 24(4), 519–535.



NONVISUAL GEOGRAPHIES

The interpretation of nonvisual landscapes explores the role of sensory and perceptual modes other than vision in the construction of geographic space. This topic positions itself at the boundary between social theory and behavioral geography by examining the ways in which nonvisual modes of information acquisition and processing reflect geographic environments and in turn shape those same places by structuring the subjective understanding and behavior of people and their symbolic understanding of space. This understanding and representation of geographic space emanates from several diverse conceptual perspectives, including behavioral geography and poststructuralism. At the individual level, we gather information in an environment from all our senses other than vision alone—hearing, smell, taste, and touch, which includes kinesthesia (muscle memory). Our spatial behavior is informed by these other sense modalities facilitating an understanding of space and place.

A vast array of information informs, guides, and shapes our understanding or misunderstanding about a place. The social construction of vision is dominant and is a historically contextualized way of knowing, also known as *ocularcentrism*. By delving into what vision is not, this line of



thought sheds new light on the role of vision in the making of place and spatial behavior.

Geography has long been emphatically ocular-centric, privileging the visual as a means to acquiring and representing spatial knowledge. Behavioral geographers note the fundamental role of vision in the acquisition of environmental information. A large body of work concerned with representations of space, ranging from cartography to GIS, has illustrated the complex ways in which graphical knowledge is related to visual perception. Many authors have noted the dominance of vision in human understanding, both at an individual behavioral level and at a social-cultural one. Vision is a metaphor for the ways in which we symbolically appropriate the world; for example, we often say “I see” for “I understand.” From Kant onward, the *cogito* of Western knowledge obtained objectivity (even if only mythically) by seeing everything.

The hegemony of vision—the unquestioned naturalness of sight—has come recently under mounting attack from diverse quarters. The changing role of vision in the late 19th century, as the experience of space and time was subjected to massive compression through photography, the telephone, and the automobile. More recently, geography has witnessed a remarkable convergence in social theory and cognitive-behavioral studies around this topic; increasingly, researchers in both of these domains have delved into the social construction of perception.

As a result, the “natural” dominance of vision has been undermined, and its hegemony has been shown to be a historical product. The linkages between ocularcentrism and modernity have been explored and have uncovered the masculinism of the “gaze” that sees all—and thus knows all. Building on Habermas’s theory of communicative interaction, Rorty argued that it holds that the proper model of knowledge is not the mimetic mirror but the conversation. The shift from visual to aural metaphors reflects the hegemony of post-positivist modes of understanding and the corresponding emphasis on knowledge as a multivocal dialogue. Critical social theorists like Lefebvre have argued that visual knowledge is grounded in its historical and political context and that every way of knowing is simultaneously a way of interacting, reproducing, or challenging social structures that are

intimately embedded in individual ways of comprehending the world. Academics teaching geography have reflexively questioned activities that require vision, such as field trips, computer-based spatial learning, and viewing PowerPoint slides. The analysis of geographic representation has been extended to the world scale, where visibility is a consistent theme. Vision, in short, is a political phenomenon as much as a behavioral one.

However, debates about the role of vision have also raised questions about the complex ways in which nonvisual information is key to the acquisition of spatial information and its representation. Much, if not most, interpersonal interaction is nonvisual, such as speech compared with body language; try having a conversation with your eyes closed and note the difference. As the body has become an inspirational topic of inquiry, the role of both visual and nonvisual perception in the construction of body space has received more attention. The spatial behavior of vision-impaired populations offers another means to appreciate the role of nonvisual systems of geographic information acquisition and processing. Although landscapes are primarily apprehended through sight, they inevitably are also known through other modalities. Nonvisual geographies (both tangible and symbolic) are largely unexplored and are apt to be unique in their own right. Phenomenologically inclined geographers such as Tuan and Porteous have been the most receptive to this idea, writing of “smellscape” and “soundscapes.” There is also a growing literature concerned with music, oral traditions, and audible text to describe landscapes in a different manner. Technology is emerging to embed listeners within virtual soundscapes, and for more than 15 years, conferences have run on the auditory display of spatial information. Even food and taste have become subject to geographic scrutiny. In short, to appreciate the importance of vision both literally and figuratively, it is essential to appreciate the significance of nonvisual ways of understanding. This is becoming ever more important with the acceleration of digital telecommunications facilitating nonvisual communication within cyberspace and to provide universal access to these technologies independent of vision, location, or technology platform.

R. Daniel Jacobson



See also **Behavioral Geography; Blindness and Geography; Body, Geography of; Disability, Geography of; Golledge, Reginald; Humanistic Geography; Phenomenology; Representations of Space; Vision and Geography**

Further Readings

- Golledge, R. (1993). Geography and the disabled: A survey with special reference to vision impaired and blind populations. *Transactions of the Institute of British Geographers*, 18, 63–85.
- Heywood, I., & Sandywell, B. (1999). *Interpreting visual culture: Explorations in the hermeneutics of the visual*. London: Routledge.
- Hillis, K. (1996). A geography of the eye: The technologies of virtual reality. In R. Shields (Ed.), *Cultures of Internet: Virtual spaces, real histories, living bodies* (pp. 70–98). London: Sage.
- Kichin, R., Blades, M., & Golledge, R. (1997). Understanding spatial concepts at the geographical scale without the use of vision. *Progress in Human Geography*, 21, 225–242.
- Pocock, D. (1981). Sight and knowledge. *Transactions of the Institute of British Geographers*, 6, 385–393.
- Pocock, D. (1989). Sound and the geographer. *Geography*, 74, 193–200.
- Porteous, D. (1985). Smellscape. *Progress in Human Geography*, 9, 356–378.
- Rodaway, P. (1994). *Sensuous geographies: Body, sense and place*. London: Routledge.
- Sui, D. (2000). Visuality, aurality, and shifting metaphors of geographical thought in the late twentieth century. *Annals of the Association of American Geographers*, 90, 322–343.
- Tuan, Y. (1977). *Space and place: The perspective of experience*. London: Edward Arnold.

procedures for defining rules of origin, expedited customs clearance for cross-border trade, and provided for a wide variety of institutional reforms to safeguard environmental interests and the rights of workers (sidebar agreements). The accord also included provisions to maintain stable flows of energy products, easier business travel, and reduced restrictions on foreign direct investment (FDI) across major sectors outside the energy domain (a concession to Mexico's oil industry). Despite many side agreements covering spheres such as labor conditions and environmental protection, a central goal of the accord was to achieve a phased elimination of import duties for most products and services by 2004. This goal has been achieved, though many nontariff trade barriers are still in place. A further goal was to dilute long-standing restrictions on capital mobility (FDI) and pave the way for new investment across the trilateral region. The net result over the past 15 years has been a dramatic expansion of intra-industry trade (IIT) between the three nations, with much of this IIT being conducted on an intracorporate basis.

Merchandise trade within the NAFTA area is now more than 70% IIT in nature. For example, Ford USA can import components or final assemblies on a duty-free basis from its subsidiaries located in Canada or Mexico—provided that such inputs qualify as 50% North American (i.e., “local content”). Automotive companies from outside NAFTA can also compete on the same basis, provided that 50% NAFTA content can be demonstrated. Since 1994, IIT within the trilateral partnership has witnessed explosive growth. Transnational corporations headquartered outside the NAFTA zone have played an important role too, especially in sectors such as automotive products, aerospace, and electronics.

From the perspective of classical or traditional trade theory, the NAFTA concept made good sense in 1994. With respect to relative factor proportions (comparative advantage), Mexico was cast as labor abundant (low skills), Canada had lots of natural resources, while the United States was capital rich (with high labor skills). Linking the three economies together via free trade would theoretically allow for factor specialization, expanded output, and an aggregate

NORTH AMERICAN FREE TRADE AGREEMENT (NAFTA)

The North American Free Trade Agreement (NAFTA) was ratified in 1994, linking Canada, Mexico, and the United States under a regime of liberalized trilateral commerce that harmonized



About 200 teamsters raise their signs while protesting new NAFTA trucking regulations outside the Holiday Inn in San Diego, June 18, 1996. The teamsters protested a meeting on the North American Free Trade Agreement against lifting a ban on Mexican trucks being allowed on U.S. roads and highways.

Source: AP Photo/Denis Poroy.

rise in consumer welfare. Specialization would also promote economies of scale (increasing returns), a core tenet of new trade theory. Critics of the accord, in contrast, argued that a free trade agreement between two advanced industrial economies and a developing nation within a geographically contiguous region would spur a mass exodus of capital from north to south, as well as downward pressure on northern wages. Neither perspective appears to be entirely correct.

The World Trade Organization (WTO) does not view bilateral or multilateral free trade agreements in a favorable light because such agreements violate core principles such as nondiscrimination and/or most-favored-nation status—principles that were developed and negotiated under several

decades of painful deliberations among hundreds of nations under the General Agreement on Trade and Tariffs. The WTO was proposed as a model for free trade at the global level but tolerates regional agreements provided that they do not cause trade diversion. Thus far, there is no evidence that NAFTA has caused trade diversion to any significant degree. Trade diversion takes place when a regional free trade agreement artificially displaces a lower-cost producer from outside the club as a result of policy-driven cost advantages that accrue to in-club producers. NAFTA does not seem to be a factor in this regard, as witnessed by the massive imports from China, India, and other low-cost producers located in the newly industrializing countries of Asia and South America.



Thus far, econometric modeling has failed to uncover significant evidence of trade diversion (most models are suggestive of trade expansion). Recent econometric work also points to either a zero or negligible impact of NAFTA on U.S. industrial employment. Some studies, in fact, suggest that NAFTA's tariff reductions have decelerated the pre-NAFTA trend toward employment decay in the manufacturing sectors of both Canada and the United States. Between 1994 and 2000, for example, total employment in the U.S. manufacturing sector actually increased (albeit by a modest 1%). On a less optimistic note, there is at least some evidence that trade liberalization has contributed to rising income inequality between regions for all three NAFTA members.

This said, most economists and economic geographers would agree that it is hard to disentangle the trade, income, or employment effects of free trade agreements from broader factors such as capital intensification (process automation), exchange rate movements, import competition from outside the bloc, and declining industrial competitiveness (e.g., lack of investment in new technology). For example, some studies have found a negative relationship between NAFTA-assisted export growth and local employment levels. Capital intensification appears to be the key driver in this rather odd relationship.

Although NAFTA has been a topic of considerable debate over the past 15 years, the accord is here to stay. Looking to the future, at least five areas of contention are likely to persist and/or emerge. These areas of contention include the following:

1. The increasingly adversarial relationship between the United States and Mexico regarding illegal immigration
2. The persistence of nontariff trade barriers based on technical or environmental standards
3. The hardening of U.S. ports of entry in light of post-9/11 security threats
4. The management of NAFTA expansion (Free Trade Area of the Americas)
5. The development of more efficient border management systems

Some of these concerns might be addressed by moving toward a secure external perimeter, where the boundaries of all three nations are monitored and controlled by common standards to facilitate security compliance. This will probably not happen soon, as such a scenario would push NAFTA closer toward a customs union (which is not a politically popular option). Other concerns might be addressed by further policy harmonization, notably with regard to border management (e.g., fast-track entry for people and merchandise). Still other concerns might be dealt with by broadening the mandate of NAFTA's dispute resolution system to include issues such as illegal immigration, antiterrorism measures, and environmental compliance.

Alan D. MacPherson

See also **Globalization; Trade; World Trade Organization (WTO)**

Further Readings

- Britton, J. (2002). Regional implications of North American integration: A Canadian perspective on high technology manufacturing. *Regional Studies*, 36, 359–374.
- Faber, B. (2007). Towards the spatial patterns of sectoral adjustments to trade liberalization: The case of NAFTA in Mexico. *Growth and Change*, 38, 567–594.
- Logan, J. (2008). Belted by NAFTA? A look at trade's effect on the US manufacturing belt. *Regional Studies*, 42, 1–13.



NORTH ATLANTIC TREATY ORGANIZATION (NATO)

The North Atlantic Treaty Organization, commonly known as NATO, is a mutual defense alliance founded on April 4, 1949. NATO's most basic principle is that its 26 member countries pledge to regard an attack on any one of the members as an attack on all members and respond



accordingly. In addition to responding after an attack, NATO also provides an organizational framework for joint military training, planning, and command and control during peacetime. By fostering a high degree of military cooperation and preparedness, NATO aims to deter external threats and advance the collective security of its members.

NATO was one of a number of supranational organizations established in Europe following World War II. Although varied in form and function, these international organizations helped facilitate Europe's postwar recovery by promoting economic and political cooperation. While the European Union and its predecessors focused mainly on economics, NATO emerged as the foremost organization related to military and security issues. As the Soviet Union tightened its control over much of Eastern Europe after 1945, the United States and its European allies began discussing ways to fend off possible Soviet advances into Western Europe. Comparatively small and still recovering from World War II, it appeared unlikely that these Western European countries, even if they joined together, could repulse an attack launched by the much larger Soviet Union.

As a result, NATO was established with the implicit purpose of deterring a Soviet attack by promising a direct American military response, including the possibility of nuclear retaliation. Although not specified in the actual text of the treaty, NATO was largely conceived as an American security guarantee to protect its European allies from the Soviet Union. The Soviet Union responded by arranging a similar military coalition, the Warsaw Pact, with the communist-controlled governments in Eastern Europe. These competing alliances, both backed by nuclear weapons, created a rough balance of power between the NATO military alliance in the west and the Warsaw Pact countries in the east. Given the high probability that any confrontation would escalate to nuclear war, neither side had much room to maneuver. Because of this stalemate, the situation is often referred to as the Cold War, marked by heightened geopolitical rivalry but lacking direct military engagements.

NATO's original roster consisted of 12 members: the United States, Canada, and 10 European

countries (Belgium, Denmark, France, Iceland, Italy, Luxembourg, the Netherlands, Norway, Portugal, and the United Kingdom) mostly along the Atlantic coast, hence the organization's name. By 1990, membership had expanded to include Germany (West Germany in 1955, which included East Germany in 1990), Greece, Spain, and Turkey. Although there were periodic disagreements among NATO members regarding military policy and relations among themselves and with the Soviet Union, the alliance is generally regarded as successful in deterring communist expansion and contributing to economic and political stability in Europe during the Cold War.

The collapse of the Soviet Union and its Warsaw Pact coalition in 1991 opened a period of uncertainty regarding NATO's future. Its rationale for existence, countering a Soviet offensive into Western Europe, was gone. Despite this, NATO has in many ways become more active in the post-Cold War period. First, NATO membership has increased dramatically to reach 28 members with the additions of Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia in 2004 and the joining of Croatia and Albania in April 2009. The current governments of Macedonia, Ukraine, and Georgia have also expressed a desire to become members. These new and potential members, all communist countries during the Cold War, have been eager to join NATO and the European Union in the belief that membership will help counter any attempt by Russia to regain its former influence in Eastern Europe.

Second, although NATO originated as a limited defensive pact, it has become increasingly active in a mix of humanitarian and combat operations beyond the borders of its member countries. During the 1990s, NATO forces were active in parts of the former Yugoslavia. NATO's bombing campaigns against Serbian forces helped end the Bosnia civil war in 1995 and the ethnic cleansing in Kosovo in 1999. NATO-led peacekeeping forces were subsequently deployed in both areas.

The September 11, 2001, attacks against the United States marked an additional turning point for the alliance. Although originally conceived as a mechanism for the United States to assist its allies if they were attacked, the September 11 attacks prompted NATO to declare the attacks

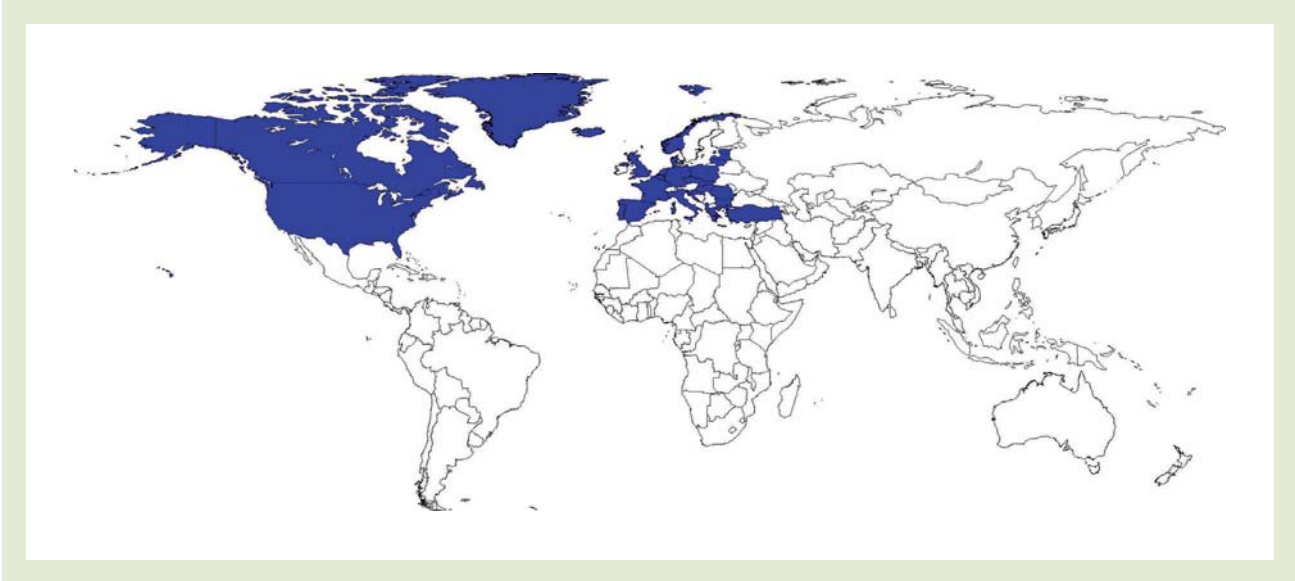


Figure 1 NATO's 28 members in 2009 include the United States, Canada, most of Europe, and Turkey.

Source: Barney Warf.

by the al Qaeda/Taliban regime on the United States as an attack on all NATO members. As a result, NATO-led forces, exceeding 40,000 by 2008, have been active in counterinsurgency, humanitarian, and reconstruction efforts across Afghanistan.

Despite expanding in size and scope since the end of the Cold War, NATO's future remains uncertain. The alliance's contributions in Afghanistan have been criticized for inadequate manpower and resources. While all members have deployed some troops, several countries have specified that their troops not take part in combat operations. It remains unclear if NATO will truly be able to sustain an alliance-wide deployment or if a small group of NATO countries will effectively assume responsibility for all combat operations while most members restrict their troops to relatively peaceful parts of Afghanistan. A second source of concern for NATO is its relations with Russia. Given its origin as an anti-Soviet alliance, Russia's desire to halt NATO's continued expansion into Eastern Europe and former Soviet territories is understandable. Partly in response to heightened tensions over NATO's eastern expansion, Russian leaders have periodically warned that a new Cold War may develop. Indeed, despite

assurances from the United States and other countries that NATO is no longer directed against Russia, it is clear that some Eastern European countries regard NATO as a check against Russian influence. Although it has outlived its original purpose, it is unclear if NATO will assume a more global profile or largely confine itself to the North Atlantic area.

Joshua Hagen

See also Cold War, Geography of; European Union; Geopolitics; Military Geography; Supranational Integration

Further Readings

- Kaplan, L. (2007). *NATO 1948: The birth of the transatlantic alliance*. Lanham, MD: Rowman & Littlefield.
- Moore, R. (2007). *NATO's new mission: Projecting stability in a post-Cold War world*. Westport, CT: Praeger Security International.
- Schmidt, G. (2001). *A history of NATO: The first fifty years*. New York: Palgrave.



NOT IN MY BACKYARD (NIMBY)

“Not in My Backyard” is a common, if stereotyped, slogan of neighborhood and community groups opposed to locally unwanted land uses. Typically, NIMBY movements arise in opposition to perceived environmental threats such as toxic waste dumps, trash incinerators, recycling centers, or landfills; at the state level, they may oppose nuclear power plants or potential transportation routes for trucks or trains carrying dangerous chemicals. In the 19th century, urban locational conflicts erupted over the siting of slaughterhouses, rendering plants, and saloons. NIMBY alliances may arise against social (as opposed to environmental) categories of land uses they deem as undesirable, such as shopping malls, prisons, bridges or tunnels, low-income housing projects, transit systems, homeless shelters, drug rehabilitation centers, or halfway homes for mildly retarded people.

NIMBY movements reflect the spatial distribution of undesirable effects on people’s welfare, such as impingements on their health, noise, or fears of crime or visual and aesthetic blight (typical concerns of low-income NIMBY movements), or negative effects on their property values (a frequent motivator of middle-class ones). Other NIMBY arguments are that the unwanted land use will destroy a small town or neighborhood environment or strain local public resources. NIMBY tactics may include lawsuits, working the legislative and judicial machinery, protests and demonstrations, public relations campaigns in the media (e.g., letters to newspapers), and behind-the-scenes pressure on elected officials.

The strength of NIMBY movements varies in accordance with the socioeconomic status, educational level, and financial resources of its members. Low-income minorities generally have less access to political power in most municipalities, whereas white, middle-class communities are more likely to have the ear of city government officials and be better positioned to oppose unwanted land uses through the courts or bureaucracies. Because decision makers siting noxious land uses, that is, large real estate developers, are more likely to attempt to locate them in predominantly minority

and low-income areas, such communities are more likely to give rise to NIMBY movements, often under the banner of environmental justice. Because local issues affect people’s everyday lives, often in profound ways that speak to their deepest hopes and fears for their future quality of life, NIMBY movements can attract members who are otherwise usually disengaged from formal politics, such as housewives.

Critics of NIMBY movements maintain that they are elitist or parochial and that they hamper necessary development, exhibit a so-called draw-bridge mentality, or are covertly attempting to maintain neighborhood racial homogeneity under the banner of opposition to other unwanted aspects such as noise or pollution. Some argue that NIMBY movements are ethically inconsistent, simply attempting to displace unwanted land uses to less politically powerful areas—that is, they displace the problem rather than solving it. On this reading, NIMBY movements are irrational, selfish, misguided, and obstructionist, and by privileging local interests over social needs, they prevent the attainment of societal goals. After all, facilities such as waste incinerators must go *some-where*. Critics of NIMBYs thus maintain that they elevate local benefits over broader social ones.

A structuralist interpretation of NIMBYs points to the inequalities inherent between the production and consumption of urban space, particularly the spatial distribution of negative externalities in the forms of locally concentrated costs and dispersed social benefits. Rather than irrational opposition to land developers, local resistance is viewed by some as an inevitable outcome of the urban development process. NIMBYs represent consumers of land who are invested in a particular landscape under the threat of change, and their opposition to new facilities is a means of constraining the behavior of capitalists, who often enjoy the backing of the state. Thus, they can no more be annihilated than can private capital investments in the landscape, and they provide a necessary countervailing measure to land developers who would otherwise proceed unchecked.

Barney Warf

See also Home; Locally Unwanted Land Uses (LULUs); Love Canal; Resistance, Geographies of; Urban and Regional Planning; Urban Geography; Zoning



Further Readings

- Heiman, M. (1990). From “Not in My Backyard!” to “Not in Anybody’s Backyard!” *Journal of the American Planning Association*, 56, 359–362.
- Lake, R. (Ed.). (1987). *Resolving locational conflict*. New Brunswick, NJ: Center for Urban Policy Research.
- Lake, R. (1993). Rethinking NIMBY. *Journal of the American Planning Association*, 59, 87–93.
- Ley, D., & Mercer, J. (1980). Locational conflict and the politics of consumption. *Economic Geography*, 56, 89–109.
- Meyer, W., & Brown, M. (1989). Locational conflict in a nineteenth century city. *Political Geography Quarterly*, 8, 107–122.



NUCLEAR ENERGY

Images of the electric grid, cooling towers, atomic bombs, and Hollywood productions serve as examples of what may come to mind when “nuclear energy” is mentioned. It has a complex narrative, occupying a noteworthy place in society.

What nuclear energy represents to current debates on solutions to increasing energy demand, reduction in carbon emissions, energy independence, and national security is juxtaposed with arguments of nuclear proliferation, radioactive contamination, nuclear accidents, and “not in my backyard” sentiments. With a growing presence around the globe with 440-plus commercial reactors in operation or being built, an argument is being made that there is a 21st-century nuclear resurgence in the making. Nuclear energy engages the subatomic realm, natural landscapes, and geopolitical space in particular ways—an engineered solution to some and a problem to others.

The Subatomic

Nuclear energy, also known as atomic energy, occurs with the splitting of a specific atom. The sustained process is known as nuclear fission; heat released from the substance is harnessed to produce steam in commercial nuclear reactors.

Through a series of progressions, the work of the steam becomes electricity. The atom used in commercial nuclear power plants is uranium. This ore is crushed and leached with acid to obtain a concentrated amount of uranium oxide known as yellowcake. In nature, this isotope of uranium exists at low concentrations, typically 0.7%. So that it can be used in commercial reactors, it goes through an enrichment process, increasing its concentration to 4.0% to 5.0%. Pellets that include the enriched uranium are placed in fuel rods that, in turn, are configured into fuel assemblies to make up the reactor core. There are several reactor designs throughout the world; the two predominant designs in the United States are known as boiling water reactors and pressurized water reactors. The electricity produced in these and other commercial reactors is known as nuclear power. Nuclear energy and nuclear power are used interchangeably for the simplified representation of the splitting of atoms.

Nuclear energy can also be derived from joining the light nuclei of atoms with the heavier ones. Two isotopes of hydrogen are combined into helium; the energy released will be harnessed for eventual fusion reactor applications. At present, the mechanics of a fusion reactor is not complete for commercial applications; it is in the research realm—more energy is currently used for the reaction to occur than is released. National and international initiatives continue, the latest being a joint international research and development project, ITER, in Southern France.

Nuclear Politics

Scientists who played a key role in research that led to fission power production included the British nuclear pioneer Ernest Rutherford. He brought attention to the heat produced by the atom radium. French scientists Marie and Pierre Curie, along with Henri Becquerel, discovered radioactivity; the German American scientist J. Robert Oppenheimer is considered the father of the atomic bomb; and the Italian scientist Enrico Fermi discovered fission. From the work of these scientists on the atom has come the work of the atom on and for society.

Currently, research is under way to usher in the next generation of reactors; they are being



Nuclear power plant in Lower Saxony, Germany

Source: Hans F. Meier/iStockphoto.

designed to be modular in construction, to possess shorter building times, to have fewer pumps and valves, and to use less uranium to produce the desired level of energy. Idaho National Laboratory was named the lead laboratory by former President George W. Bush to shepherd the United States into the next stage of nuclear power production. Through the U.S. Energy Policy Act of 2005, initiatives for a nuclear renaissance are being constructed. Internationally, the resurgence is showing more traction; for instance, in 2004, Finland started construction on a next-generation Areva-designed nuclear reactor. Companies such as Areva, Westinghouse, and General Electric-Hitachi, in association with the governments of various countries, are building in Japan, China, and India. Discussions are under way in countries such as Mexico, Canada, and South Africa. The United States hasn't built a new commercial

nuclear reactor in decades, but there are several consortia (vendors such as companies named earlier along with state utility companies) that wish to take advantage of the tax credit incentives and liability insurance. They are submitting applications to the U.S. Nuclear Regulatory Commission for combined construction and operating licenses. The review process takes several years; however, there have been possible construction locations announced by utilities. For example, the North Carolina-based Progress Energy has named Florida and then North Carolina as build locations.

Geography of Fear, Geography of Necessity

Nuclear energy was ushered in as an offshoot of scientists' work on behalf of military defense. During World War II, the atomic bomb was used on Hiroshima and Nagasaki, Japan, as a response to



the Pearl Harbor bombings. An enrichment level closer to 90%, as opposed to the 4% to 5% range seen in commercial nuclear power plants, was used. This technological use solidified the nuclear arms race, and nations such as Britain, China, and the Soviet Union developed a military arsenal in the postwar, Cold War era. Other nations subsequently joined the nuclear race with more of a power production perspective. Japan, France, and South Africa were among these nations.

In 1953, the then U.S. President Dwight Eisenhower pledged before the United Nations the pursuit of nuclear science and technology for peaceful purposes. The U.S. Department of Energy and the U.S. Nuclear Regulatory Commission continue to work with industrial and public stakeholders to answer concerns and move forward on nuclear energy production. As of 2008, there were more than 443 nuclear reactors worldwide (representing 19.4% of the global nuclear power) and 104 nuclear reactors in the United States (19.9%); France represents 80% and Canada 12%. Nuclear power is used as base load—reactors run year-round, except when down for refueling and maintenance—contributing to guaranteed electricity for households and industry. According to the Department of Energy, U.S. electricity demand is expected to increase by 40% to 50% by 2025. And as industrialization occurs around the world, there will be an increased demand for fossil fuels, driving some of the discussions around energy independence and global warming reduction measures to include renewable and nuclear energies as possible solutions.

Similarly, in a post-9/11 world there has been concern expressed about nuclear terrorism—a hijacked plane crashing into a nuclear power plant or the use of stolen radioactive material to make a dirty bomb—not to mention the lingering historical references and/or concerns around another Chernobyl accident or Three Mile Island incident. What affects would a leakage have on communities near nuclear power plants? What evacuation plans are in place? What measures exist for the safe operation of nuclear power plants? Where should nuclear waste be stored? Military and industrial nuclear waste, slated to eventually reside at the Yucca Mountain National Repository in Nevada, is under litigation. The nuclear industry has launched public outreach initiatives to answer these and other questions. At

the same time, antinuclear organizations are engaging communities around issues of environmental justice, land rights, and safety practices. The geographical space of nuclear energy has been reenergized. The politics of engineered landscapes and their necessity plays out on several levels as demand places pressure on natural resources and a geography of necessity is amplified.

Lisa Marshall

See also **Chernobyl Nuclear Accident; Energy and Human Ecology; Energy Policy; Energy Resources; Not in My Backyard (NIMBY); Three Mile Island Nuclear Accident**

Further Readings

- Bird, K., & Sherwin, M. J. (2005). *American Prometheus: The triumph and tragedy of J. Robert Oppenheimer*. New York: Vintage.
- Bodansky, D. (2008). *Nuclear energy* (2nd ed.). New York: Springer-Verlag.
- Miller, B. A. (2000). *Geography and social movements: Comparing antinuclear activism in the Boston area*. Minneapolis: University of Minnesota Press.
- Pasqualetti, M. J. (1983). Nuclear-power impacts: A convergence-divergence schema. *The Professional Geographer*, 35, 427–436.



NUTRIENT CYCLES

Nutrient cycles describe the cycling in terrestrial, limnic, or marine ecosystems and in compartments of these ecosystems of those elements and chemical compounds that are essential for maintaining life. The essential elements include the macronutrients (nitrogen [N], potassium [K], calcium [Ca], magnesium [Mg], phosphorus [P], and sulfur [S])—ordered in the sequence of the mass contributions of these elements to dry shoot matter of higher plants according to Marschner, 1995) and the micronutrients (chlorine [Cl], boron [B], iron [Fe], manganese [Mn], zinc [Zn], copper [Cu], nickel [Ni], and molybdenum [Mo]). Some microorganisms, animals, and humans additionally require other elements such as chromium (Cr), selenium (Se), and



vanadium (V). Carbon and water, which are also needed by all living organisms, are usually not considered as nutrients. This entry focuses on nutrient cycles in terrestrial ecosystems.

Nutrient Cycles in Ecosystems

The cycling of nutrients can be studied at different scales from a few millimeters to the global scale. The most common scale at which nutrient cycling is studied is that of a small plot of 100 to 1,000 square meters or of a small catchment of a few hectares to square kilometers, which are considered as representative for a well-defined ecosystem or landscape. Ecosystem functioning is described by input fluxes, output fluxes, state, and transfer functions translating input into change of state and input and change of state into output. Methodologically, nutrient cycling in ecosystems is frequently assessed by budgeting nutrient stocks and fluxes.

Nutrient stocks are usually determined for different ecosystem compartments such as soil (various depth layers) and below- and aboveground biomass (sometimes further subdivided, e.g., into fine and coarse roots or stems, branches, and leaves) in terrestrial ecosystems.

Nutrient fluxes can be gaseous, water bound, or solid-phase associated. Gaseous fluxes include N_2 fixation from the atmosphere; deposition of nutrient-containing substances, such as ammonia (NH_3), oxides of nitrogen (NO_x), sulfur dioxide (SO_2), nitric acid (HNO_3), sulfuric acid (H_2SO_4), and hydrochloric acid (HCl); and volatilization of NO , N_2O , and N_2 via nitrification and denitrification. Water-bound fluxes include incident precipitation, throughfall (i.e., the part of incident precipitation that falls through the canopy and reaches the soil), stemflow (i.e., the part of incident precipitation that flows via branches and stems to the soil), surface flow (on top of soil), internal soil fluxes (vertical and lateral), stream, and groundwater flow. While water itself can evaporate (via interception, i.e., direct evaporation from the vegetation surface, transpiration through plants, or direct evaporation from soil and water bodies), the nutrients contained in water cannot. Solid-phase-associated fluxes include dry particulate deposition from the atmosphere, litter fall (including fine litter, coarse

litter, and root litter), soil erosion, and bedload and suspended matter in streams.

Nutrient Turnover

After biomass dies and returns as dead organic matter to soil, all contained nutrients are released via leaching and mineralization after mechanical degradation of the fresh litter by soil animals. Mineralization is particularly important for the nitrogen cycle (but to a lesser degree also for all other nutrients). Nitrogen mineralization consists of the release of ammonium (NH_4^+) from organic compounds ("ammonification") and the subsequent oxidation of ammonium to nitrate (NO_3^- , "nitrification") in several steps. Mineralization is a microbiologically mediated process. Mineralization rates depend on climatic conditions (temperature and water availability), chemical milieu (acidity and oxygen availability), and properties of the mineralized organic matter. Mineralization is fastest if the mineralizing microbial community experiences optimum conditions.

Nutrient Cycles in Forest Ecosystems

Perhaps the most studied ecosystems with respect to nutrient cycling are the forest ecosystems. Figure 1 summarizes the results of a study of the potassium cycling in the Brazilian Cerrado, where the native savanna vegetation was compared with nonnative *Pinus caribaea* Morelet plantations on similar soils in the Cerrado region. It becomes evident that nutrient fluxes are small compared with nutrient stocks, which is a general feature of forest ecosystems. The Cerrado case study, however, shows particularly small element fluxes—such as many tropical ecosystems—because the deeply weathered tropical soils are extremely nutrient poor. The native Cerrado vegetation and the pine plantation currently accumulate nutrients from the atmosphere, on balance. This is usually not the case in temperate forest ecosystems on less weathered soils from which nutrients may be net released and leached.

Methods for Assessing Nutrient Cycles

To assess nutrient stocks in the different ecosystem compartments, inventories of biomass and

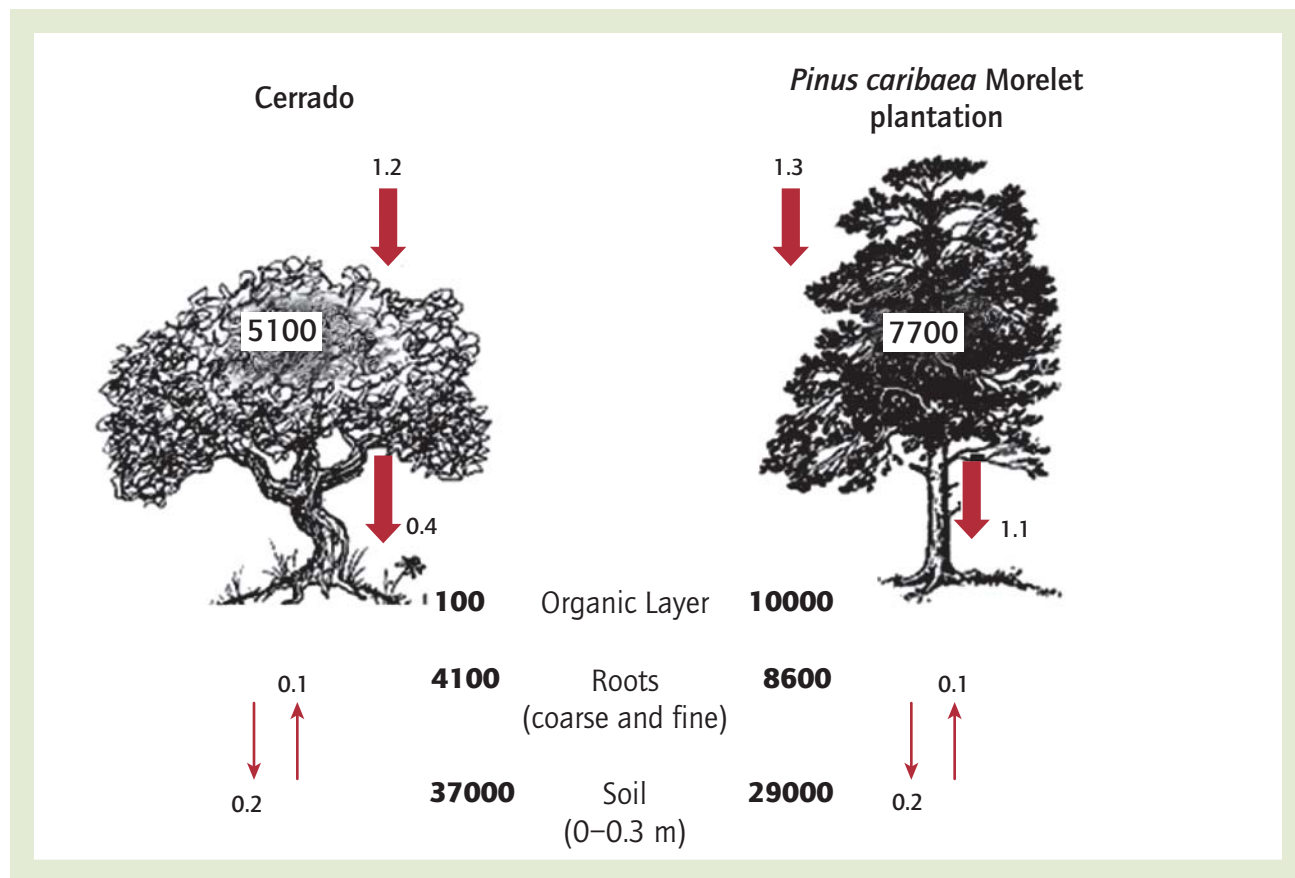


Figure 1 Nutrient cycles. Potassium stocks (g/m², bold numbers) and fluxes (g/m², a-1) in a native Cerrado and a *Pinus caribaea* plantation in Brazil

Sources: Adapted by the author from Lilienfein, J., & Wilcke, W. (2004). Water and element input into native, agri- and silvicultural ecosystems of the Brazilian savanna. *Biogeochemistry*, 67, 183–212; Wilcke, W., & Lilienfein, J. (2002). Biogeochemical consequences of the transformation of native Cerrado into *Pinus caribaea* plantations in Brazil. *Plant Soil*, 238, 175–189; Wilcke, W., & Lilienfein, J. (2005). Nutrient leaching in Oxisols under native and managed vegetation in Brazil. *Soil Science Society America Journal*, 69, 1152–1161.

soil mass and nutrient concentrations in the various compartments need to be undertaken. Usually, aliquots of the compartments are sampled and destructively analyzed. The aboveground water-bound fluxes can be directly measured with special containers collecting incident rainfall (usually measured in clearings or above the forest canopy), throughfall (for which many samplers are needed because throughfall is heterogeneous), and stemflow (the water running down the trunks that is collected with the help of a collar around the stem). In soil, either special lysimeters, which quantitatively collect the percolating water, are used (with high technical efforts and at the disadvantage of some unavoidable disturbances of soil and vegetation) or nonquantitative lysimeters (e.g., the suction cups or plates) are used to determine

nutrient concentrations in soil solution. Then, nutrient fluxes are calculated with the help of a soil water model providing the water fluxes. Furthermore, fine litter fall can be easily collected with litter traps, while the determination of coarse litter fall is more laborious requiring inventories of large pieces of dead organic matter on top of the soil, including standing dead trees. Dry deposition (fine particles and gases) from the atmosphere cannot be measured directly but usually is modeled with complex micrometeorological models or budget approaches of the vegetation canopy. Organic matter turnover can be measured in the field by various approaches (e.g., litter bags that are left on the soil for a certain time to allow for degradation) or in the laboratory by incubating at controlled temperature, moisture, and nutrient



conditions (usually yielding an optimum turnover rate above that in the field). A full nutrient-cycling model combines algorithms describing all fluxes and turnover processes in an ecosystem.

Wolfgang Wilcke

See also **Biogeochemical Cycles; Biota and Soils; Carbon Cycle; Ecosystems; Nitrogen Cycle**

Further Readings

- Likens, G. E., & Bormann, F. H. (1995). *Biogeochemistry of a forested ecosystem*. New York: Springer-Verlag.
- Lilienfein, J., & Wilcke, W. (2004). Water and element input into native, agri- and silvicultural ecosystems of the Brazilian savanna. *Biogeochemistry*, 67, 183–212.
- Marschner, H. (1995). *Mineral nutrition of higher plants* (2nd ed.). London: Academic Press.
- Matzner, E. (Ed.). (2004). *Ecological studies: Vol. 172. Biogeochemistry of forested catchments in a changing environment: A German case study*. Berlin, Germany: Springer-Verlag.
- Schulze, E. D. (Ed.). (2000). *Ecological studies: Vol. 172. Carbon and nitrogen cycling in European forest ecosystems*. Berlin, Germany: Springer-Verlag.
- Wilcke, W., & Lilienfein, J. (2002). Biogeochemical consequences of the transformation of native Cerrado into *Pinus caribaea* plantations in Brazil. *Plant Soil*, 238, 175–189.
- Wilcke, W., & Lilienfein, J. (2005). Nutrient leaching in Oxisols under native and managed vegetation in Brazil. *Soil Science Society America Journal*, 69, 1152–1161.



NYERGES, TIMOTHY (1951–)

Timothy L. Nyerges, professor of geography at the University of Washington, has published numerous influential works on schema integration for spatial databases, information structuring in the analytical use of maps, typologies of geographic information abstractions, the uses of

GIS in transportation planning, the prospect for public participation in GIS use, data-gathering strategies in the study of participatory GIS use, and the design of a Web-based PPGIS (Public Participation GIS).

Nyerges received his PhD from Ohio State University in 1980 under the supervision of Harold Moellering (known for research about animated, analytical cartography, and digital cartographic data standards) and Reginald Golledge (University of California, Santa Barbara, known for research in cognitive and behavioral geography). His dissertation, titled *Modeling the Structure of Cartographic Information for Query Processing*, represented innovative research in the structure of spatial data just as the GIS industry was taking off.

On finishing his PhD, Nyerges worked for 5 years as a computer-cartographer and GIS consultant, eventually moving to the Seattle area in 1983. While a consultant, he served as chair of the Technical Working Group on Data Organization, part of the National Committee for Digital Cartographic Data Standards, a position he held until 1987. He has remained an active advisor at the national level in the area of spatial data standards.

Since 1985, Nyerges has been a member of the faculty in the department of geography at the University of Washington in Seattle, where he has completed research in collaborative spatial decision support systems funded by the National Science Foundation, Environmental Protection Agency, and the Department of Energy. He has also shepherded the undergraduate and graduate GIScience curriculum and served on nearly 50 master's student committees and nearly 30 PhD student committees. He has also served as the director of the governing board for the university's Center for Social Science Computation and Research (1991–1996) and as a board member for the Program on Environment (2000–2003).

Nyerges is an affiliate faculty member at the Center for Water and Watershed Studies in the College of Forest Resources, in Civil and Environmental Engineering, and in the Interdisciplinary PhD Program in Urban Planning and Design. Nationally, he has served as the research chair and program organizer (2005–2008) for the



University Consortium of Geographic Information Science summer meetings and the 2005 Urban and Regional Information Systems Association's Public Participation GIS conference, and he is the 2009–2011 president of the University Consortium for Geographic Information Science.

Participating in the GIS and Society debates of the mid 1990s, with his involvement in the Friday Harbor, Washington, meetings, Nyerges has continued to advance a research agenda on the study of GIS use. His work with Piotr Jankowski (a former student of Nyerges) has led to the development of thorough research designs in the study of GIS use in group decision-making situations, what Nyerges and Jankowski termed *enhanced adaptive structuration theory*. Jankowski and Nyerges ground their thinking about social-behavioral research on spatial decision making, which framed later studies of GIS use for transportation, land use, and water resource decision making.

His recent research has included a 4-year NSF (National Science Foundation) project concerning participatory GIS for transportation, which funded more than 15 graduate students from 2003 to 2007 at the University of Washington, San Diego State University, and the University of Wyoming. The research team, with Nyerges as principal investigator, designed and implemented an Internet platform to support and study public participation in transportation decision making. Nyerges continues to extend this research in the development and study of Internet-based GIS in the area of community vulnerability to regional climate change and variability and coastal zone management.

Matthew W. Wilson

See also **GIScience**; **GIS in Transportation**

Further Readings

- Jankowski, P., & Nyerges, T. (2001). *Geographic information systems for group decision making: Towards a participatory, geographic information science*. London: Taylor & Francis.
- Nyerges, T. (1989). Schema integration analysis for the development of GIS databases. *International Journal of Geographic Information Systems*, 3(2), 153–183.
- Nyerges, T. (1991). Analytical map use. *Cartography and Geographic Information Science*, 18(1), 11–22.
- Nyerges, T. (1995). Geographical information system support for urban/regional transportation analysis. In S. Hanson (Ed.), *The geography of urban transportation* (pp. 163–198). New York: Guilford Press.
- Nyerges, T., & Jankowski, P. (1997). Enhanced adaptive structuration theory: A theory of GIS-supported collaborative decision making. *Geographical Systems*, 4(3), 225–259.
- Nyerges, T., Jankowski, P., & Drew, C. (2002). Data-gathering strategies for social-behavioural research about participatory geographical information system use. *International Journal of Geographical Information Science*, 16(1), 1–22.
- Nyerges, T., Jankowski, P., Tuthill, D., & Ramsey, K. (2006). Collaborative water resource decision support: Results of a field experiment. *Annals of the American Academy of Political and Social Science*, 96(4), 699–725.
- Nyerges, T. L., Ramsey, K., & Wilson, M. W. (2006). Design considerations for an Internet portal to support public participation in transportation improvement decision making. In S. Dragicevic & S. Balram (Eds.), *Collaborative geographic information systems* (pp. 208–236). Hershey, PA: Idea Group.



OBJECT-BASED IMAGE ANALYSIS

Object-based image analysis (OBIA) is a new approach to the analysis of remote-sensing (RS) images in which the basic units, instead of being individual pixels, are image-objects. An image-object is a relatively uniform region of a digital image somewhat different from its surroundings. Typically, image-objects are initially delineated by a segmentation algorithm and then further aggregated using a semiautomated classification that takes into account both their internal features and their mutual relationships. OBIA aims to replicate visual interpretation through semiautomated means, providing greater integration with vector geographic information systems (GIS) with increased consistency and efficiency.

OBIA is an increasingly popular alternative to the traditional pixel-based approach to semiautomated thematic mapping using RS imagery. Pixel-based methods assume that different thematic classes behave like distinct surface materials susceptible of being analyzed with a spectrometric approach. That is, each pixel is treated as a sample introduced in a desktop spectrometer, where its spectral signature (represented by the different values the pixel takes in each band of the image) is compared with the ones of selected samples (training pixels) of each material that can be found in the to-be-mapped

territory. After comparison (i.e., classification), the material having the most similar signature(s) to the one under analysis is selected as the class to which that pixel belongs. The main drawback of this approach is that it cannot exploit the fact that pixels are knitted into an image full of spatial patterns.

In contrast, in OBIA, the spatial structure of the image is explicitly captured by the initial segmentation step, which creates a set of jointly exhaustive, mutually disjoint regions (image-objects) that are more uniform within themselves than when compared with adjacent regions according to a set of predefined similarity criteria. After segmentation, the values of a wide assortment of attributes (radiometric, textural, morphological, and relational) are computed for each image-object, which form the basis for classification. The latter typically consists of an iterative process, where the membership of particular image-objects to a given class may change according to the status of neighboring objects. During this process, image-objects may also be hierarchically nested to allow for the introduction of powerful contextual rules. For example, a group of nearby but not adjacent image-objects labeled “tree,” if surrounded by larger image-objects identified as “soil,” could be merged into an “orchard” superobject. If the latter happens to be in turn embedded in a “city” superobject, it could further change its membership to the “urban park” class.



It is important to note that OBIA encompasses techniques used in many disciplines other than geographic information science. To distinguish RS/GIS OBIA from other domains such as biomedical imaging, the acronym GEOBIA (Geographic Object-Based Image Analysis) has been recently proposed, although it is still unclear whether this acronym will become widely used.

Guillermo Castilla

See also [GIS, History of](#); [Ontological Foundations of Geographical Data](#); [Ontology](#); [Remote Sensing](#)

Further Readings

Blaschke, T. S., Lang, S., & Hay, G. J. (Eds.). (2008). *Object-based image analysis: Spatial concepts for knowledge-driven remote sensing applications* (Series: XVII Lecture Notes in Geoinformation and Cartography). Berlin, Germany: Springer-Verlag.



OCEANIC CIRCULATION

Oceanic circulation is responsible for the majority of heat transfer within the Earth system and, hence, determines weather and climate for the majority of humankind (Figure 1). Circulation within the ocean is patterned by numerous forces but mostly reflects spatial differences in density and heat that are in turn minimized by a complex system of currents within the major ocean basins. The forces affecting ocean circulation are thermohaline differences (horizontal and vertical variations in salt concentrations and temperature), surface-wind-generated stress, the Coriolis force (the deflection of moving bodies across the Earth surface due to its rotation), and underwater topography. This entry will discuss the resulting circulation pattern below, which demonstrates the spatial relations between centers of high and low pressure, the gyres these systems create, as well as the warm (*red*) and cool (*blue*) surface currents that result from interactions between these rotating systems and the larger scale thermohaline circulation.

The major forces driving oceanic circulation are best illustrated by the various gyres (rotating systems of low- or high-pressure-generating wind and water currents) of the ocean basins and the large-scale oscillations associated with El Niño and the monsoonal cycle of the Indian Ocean. Each example highlights the complex interaction of atmospheric pressure systems with the ocean surface and the role of the various forces mentioned above that interact to produce the patterns of oceanic circulation. The most fundamental of these forces, however, is thermohaline circulation.

Thermohaline Circulation

Compared with the circulation patterns generated by atmosphere-ocean coupling and the Coriolis force, thermohaline circulation is extremely slow, on the order of millimeters per second (mm/s), compared with wind-driven current systems (centimeters per second [cm/s]). Despite its slow pace, thermohaline circulation results in a horizontal range of temperature nearly matching the vertical gradient (30 to -1 °C). For the vertical gradient, this results in two distinct zones: (1) the mixed layer (generally the upper 50–200 m [meters] depending on latitude) in which temperatures approximate the surface, and (2) the thermocline (200–800 m in tropics, 50–100 m in summer midlatitudes, nonexistent in polar latitudes and winter midlatitudes). The horizontal gradient is best examined by looking at the gyres, since in this form of heat circulation, they exert the most influence.

Gyres

Subtropical circulation in the Atlantic is dominated by the Atlantic gyre. This is a large, asymmetrical, clockwise-rotating current system. This system is overlain by a large, high-pressure atmospheric system. This high-pressure atmospheric system sets up a wind-stress field that generates outward-flowing surface currents. In addition to wind-stress-generated rotational momentum (the winds are being deflected clockwise by the Coriolis force), these currents become deflected themselves by Ekman transport (the 45° deflection of a wind-generated surface current to the right of wind direction in the Northern Hemisphere by the

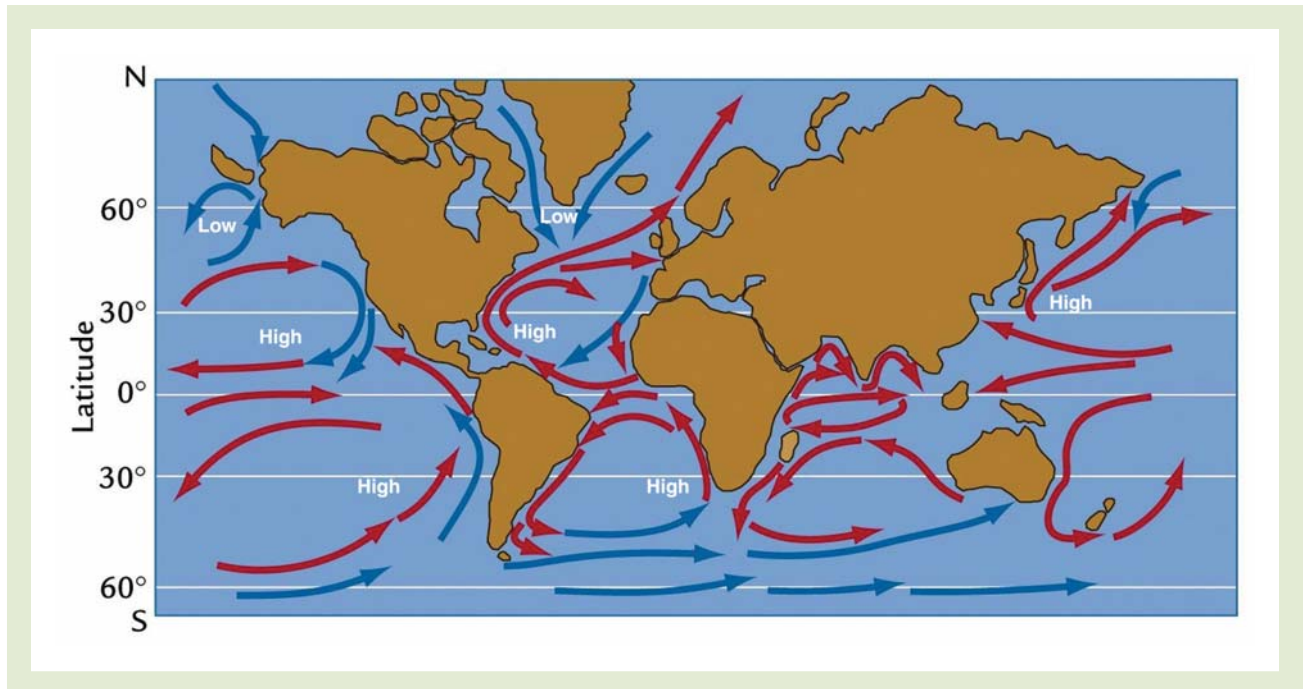


Figure 1 Major currents that drive oceanic circulation

Source: Author.

Coriolis force). The current shear generated by wind stress, frictional forces, and Ekman transport enables the system to acquire relative vorticity, an expression of the tendency of a system to rotate. This is different from the absolute vorticity, which takes into account the vorticity relative to a fixed point and hence includes planetary vorticity—vorticity due to the fact that the Earth rotates. In addition, there is potential vorticity, which factors in the thickness of the rotating body of water and causes the system to shallow (and widen) as it approaches the equator and become narrow and deep as it swings back toward the pole. This is the main way in which topography affects large rotating systems such as the oceanic gyres (seafloor depth controls how deep and hence narrow the current can become). Like all forms of momentum, vorticity is conserved, and its conservation is the mechanism maintaining the gyre.

Boundary Currents

The conservation of vorticity is crucial to understanding the superficial asymmetry of the boundary currents and how they persist within the gyre.

The eastern boundary current (the Florida current) typically has a velocity of ~2 m/s and is usually ~100 km (kilometers) wide. This can be contrasted with the Canary current (the western boundary current), which has an average velocity of .25 m/s and is 1,000-plus km wide. This difference in speed and dimension of the currents reflects difference in the relative vorticity with latitude. As the current moves northward on the western boundary, it gains more negative relative vorticity. In other words, it gains more tendency to rotate clockwise. This is because the Coriolis force increases with latitude, which increases the deflection to the right for northward-moving objects. In the eastern boundary current, the decreasing latitude leads to a loss of negative relative vorticity (or a gain in positive), which acts to slow down rotation. To have an equal volume of water moving northward and southward, the faster western boundary current has to narrow, while the slower eastern boundary current has to widen. Alone, this doesn't ultimately conserve relative vorticity, since wind stress acts throughout the system and is constantly supplying negative relative vorticity. The net result would appear

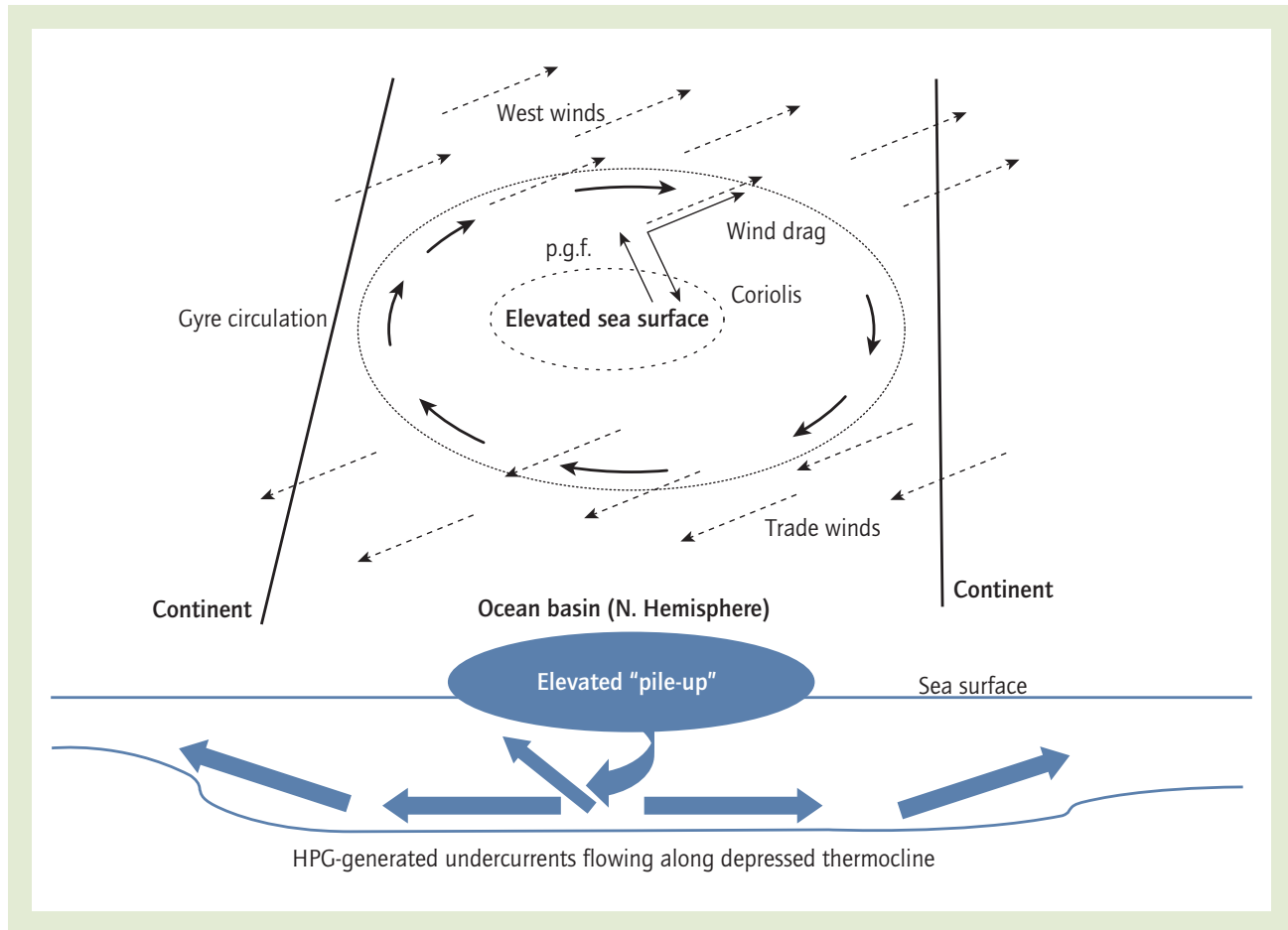


Figure 2 A Northern Hemisphere high-pressure gyre

Source: Author.

to be a constant speeding up of the gyre's rotation. To balance these forces, friction with coastal boundaries and eddy viscosity (internal friction between moving water parcels) in both horizontal and vertical directions increase substantially as the western boundary current speeds up and acts to slow down rotation. As the western boundary current deepens while it moves northward and the eastern boundary current shallows while it moves southward, potential and absolute vorticity are also conserved, and the gyre is maintained in the form it appears.

Pressure Gradients and Geostrophic Currents

The result in the vertical dimension is that water effectively "piles up" in the center of the gyre creating a horizontal pressure gradient and a

pressure gradient force, deepening the thermocline, and creating downwelling (Figure 2). This results in undercurrents underneath the center of the gyre that flow along the thermocline outward.

The forces that maintain the gyre circulation in the Atlantic are similar in the Pacific; however, in the tropical Pacific, there is tighter coupling between atmospheric and oceanic circulation systems relative to the Atlantic. This coupling is most evident in the system of equatorial currents (Figure 3). These currents are geostrophic in that they represent a balance of horizontal pressure gradient forces and the Coriolis force. Since the subtropics have low average wind velocities, there is no significant Ekman transport there, and the southeast (SE) trade winds actually transport water masses across the equator. The eastward blowing northeast (NE) and SE trade winds also

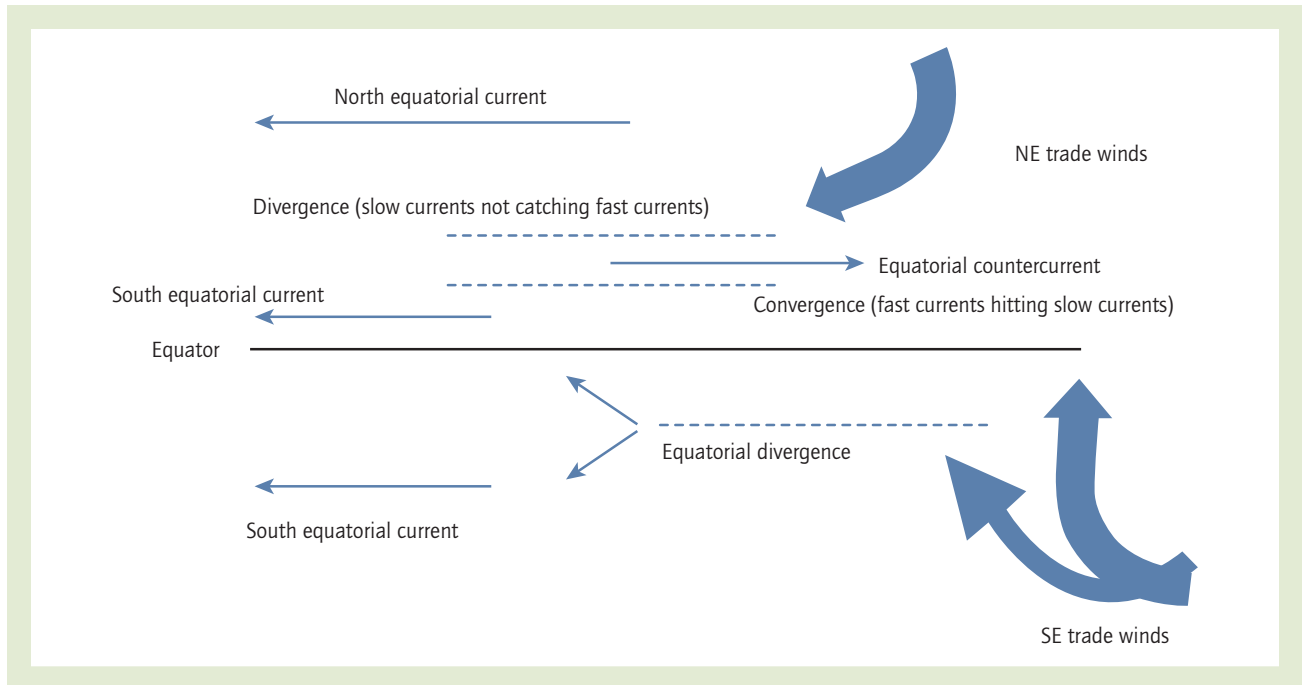


Figure 3 Equatorial current system

Source: Author.

set up a horizontal pressure gradient in the west as surface currents are deflected 45° to the right and left, respectively, of the NE and SE trade winds and pile up water blocked by landmasses. Below the wind-driven (Ekman) layer, this pressure gradient drives a fast moving equatorial undercurrent within the thermocline. In the doldrums (where the winds slacken), the pressure gradient allows the surface water to flow eastward as the equatorial countercurrent. Since the countercurrent is flowing east, even though it is close to the equator, Coriolis forces are strong enough to deflect enough flow southward that a convergence zone forms between the countercurrent and the south equatorial current. This gives rise to another pileup and a northward downsloping horizontal pressure gradient. This in turn produces another geostrophic current eastward.

Equatorial Current Systems

As shown above, equatorial divergence is created by the SE trade winds crossing the equator. As the wind-stressed currents approach the equator from the south, they are driven away from it (left)

by the Coriolis force (significant at $.5^\circ$). The divergence itself is a function of Ekman transport (the 90° deflection of net transport in the wind-driven layer by wind stress to the right of wind direction in the Northern Hemisphere, to the left of wind direction in the Southern Hemisphere, and in the direction of the wind at the equator). North of the equator, the faster-moving SE trade-wind-driven water masses are deflected northward (right) into the slow-moving mass of water in the doldrums, creating a convergence.

Since it is flowing east, the fast-moving equatorial undercurrent is constrained by the Coriolis force. Although it may oscillate about the equator, if it strays northward, it becomes deflected to the right and returns to the equator. If it strays southward, it is deflected left and also returns to the equator. The wavelengths of these oscillations may nonetheless stretch for thousands of kilometers.

These oscillations illustrate other types of currents important for oceanic circulation. Oscillations in response to an imbalance between the horizontal pressure gradient force and the Coriolis force are referred to as Kelvin and Rossby waves. Both are extremely large disturbance

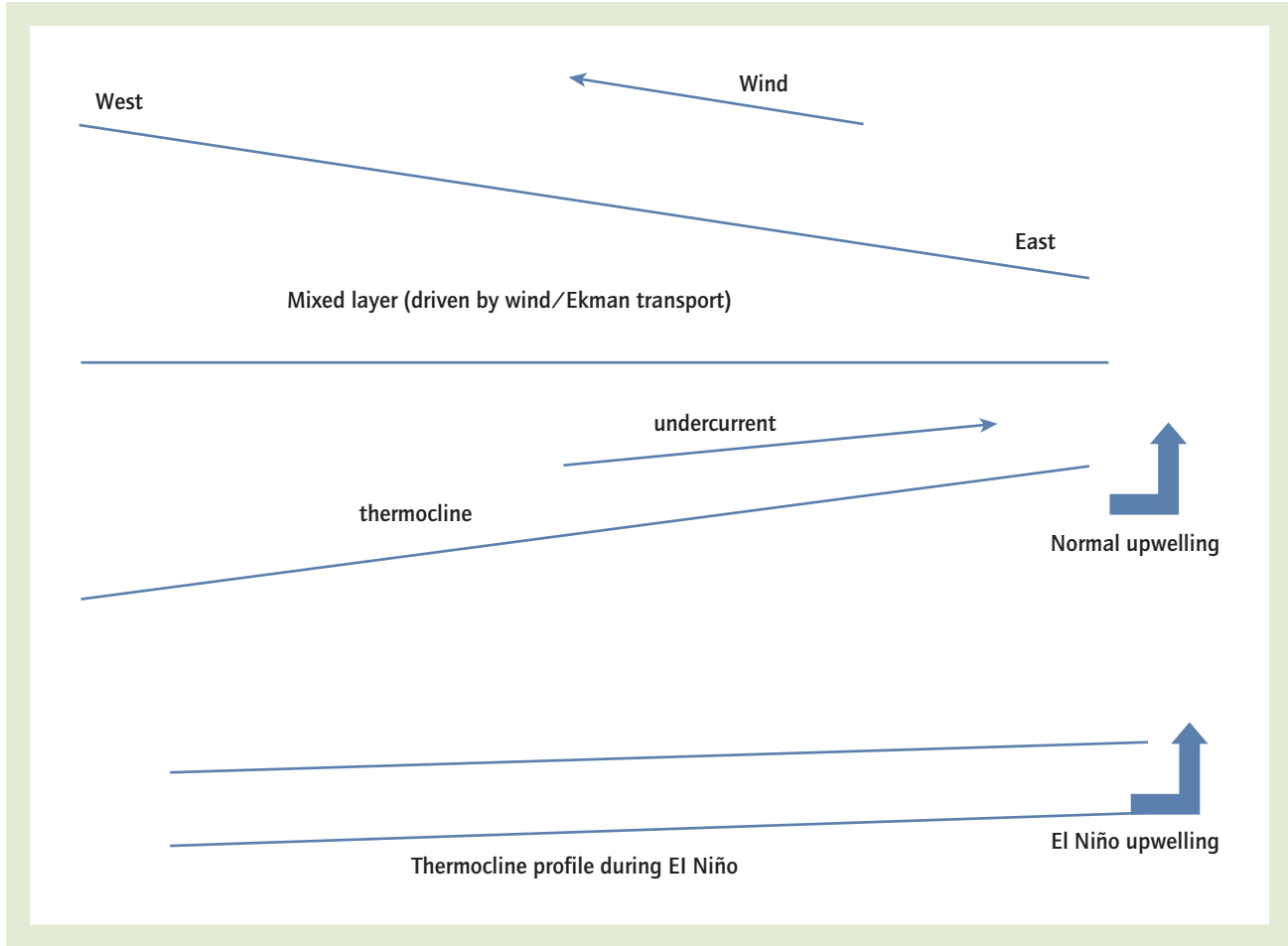


Figure 4 El Niño–induced Kelvin wave modification of the thermocline in the equatorial Pacific

Source: Author.

correction waveforms, and both can quickly propagate along the equator (Figure 4). For example, during an El Niño year, the thermocline in the east Pacific normally made shallower by steady easterlies is deepened in a pulse or series of pulses as a Kelvin wave propagates eastward along the equator through the thermocline. This propagation does not completely suppress upwelling, however; it merely confines the upwelling to a shallower, warmer zone in which there are far less nutrients from the ocean bottom. Upwelling in the tropical Pacific is mainly a function (both annually and seasonally) of the equatorial undercurrent. In addition, in the eastern basins, mid-ocean upwelling occurs as a result of the relative thinning of the thermocline there as a function of the deepening in the west.

In the tropical Atlantic, the equatorial current system is broadly similar to the Pacific except in the case of responses to changes in the wind field. In this regard, the surface waters of the tropical Atlantic respond more quickly than can be explained by the pressure gradient force derived from water “piling up” in the west. The regions of the ocean in the center and east appear tightly coupled to the west by virtue of the existence of a closer western boundary than in the Pacific. The extreme wavelength of these responses means that they are affected by the Coriolis force and are hence known as Kelvin waves. Thus, in the tropical Atlantic, a change in the west can be communicated east at ~ 200 m/s by a Kelvin wave confined within a certain distance of the equator by Coriolis forces. In the tropical Pacific, the

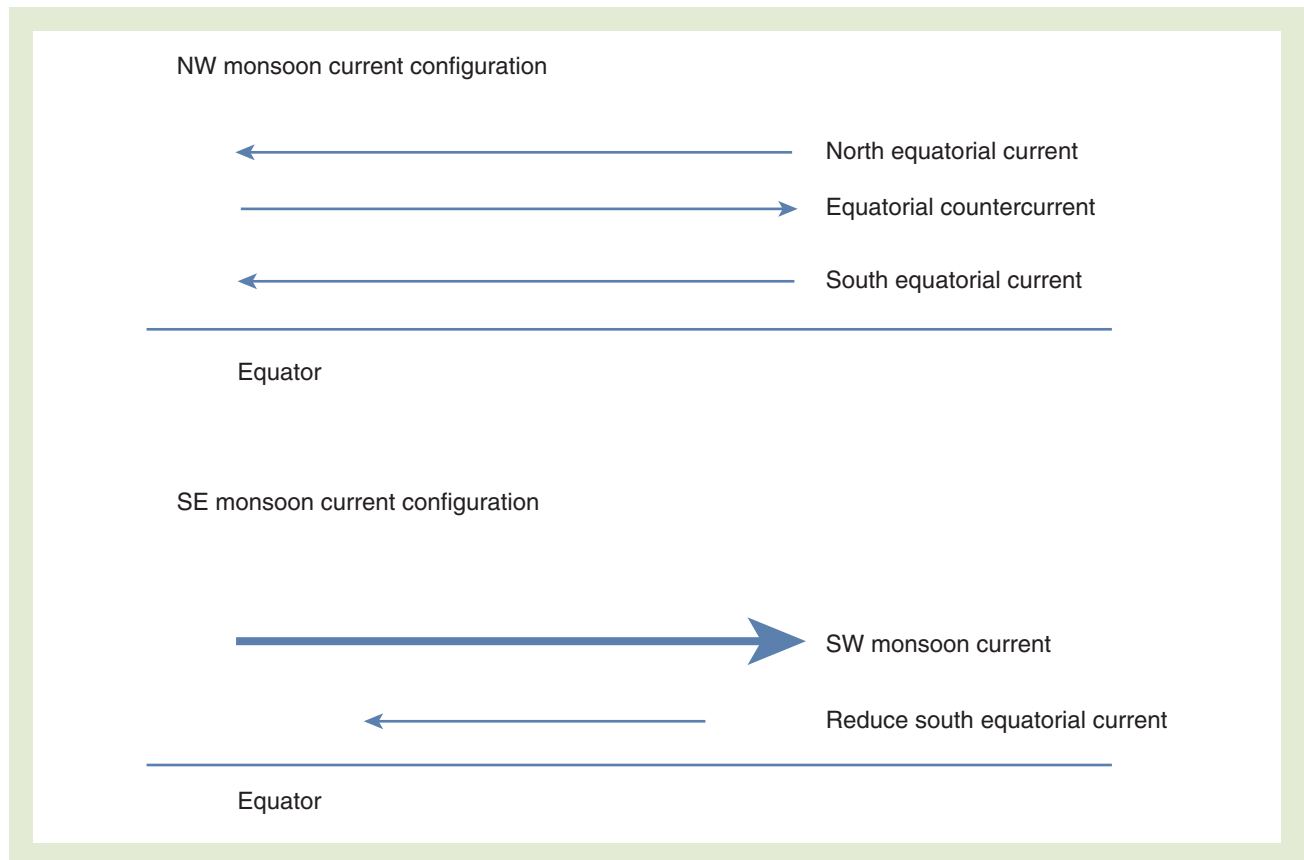


Figure 5 Monsoonal circulation of the Indian Ocean

Source: Author.

same process can occur, but the opposite sides of the basin are less tightly coupled than they are in the Atlantic. For example, when the Intertropical Convergence Zone moves northward in the western Atlantic, the abrupt change in wind stress causes a double Kelvin wave in the thermocline, a bulge down in front of a bulge up. This baroclinic disturbance is propagated more slowly east along the equatorial waveguide than a surface (barotropic) Kelvin wave.

The Monsoonal Cycle

These equatorial disturbance and adjustment cycles also occur quickly in the equatorial Indian Ocean, although circulation there is more dominated by the monsoonal cycle (Figure 5). The monsoons are seasonal reversals in the prevailing winds as they respond to the weakening from winter to summer of the high-pressure system

over the subcontinent. During the winter, the NE monsoon blows across the Indian Ocean in a manner similar to the NE trade winds. By summer, however, the pattern has reversed, and the stronger of the two, the SW monsoon, dominates, bringing humid air and rain to India. The current system responds to this shift and is most similar to other basins during the NE monsoon. At this time of the year, the typical equatorial current system is present, including the countercurrent. During the SW monsoon, however, the flow of the north equatorial current reverses, merges with a reduced equatorial countercurrent and forms the SW monsoon current.

Monsoonal Current Reversals

Most spectacularly, during the intermonsoon period (moving from NE to SW), the reversal of the north equatorial current and formation of the



SW monsoon current transforms the East African current into a major western boundary current, the Somali current. In accordance with the gyre dynamics described above, this means that the Somali current must be faster (3.7 m/s) and narrower than the eastern boundary current off Sumatra. As the Somali current crosses the equator in its northward travel, upwelling off the Somali and Arabian coast ensues. In addition, the East Arabian Current (EAC) diverges from the Somali current during this period and throughout the SW monsoon to circulate along the coastal boundary of the Arabian Sea. During the next intermonsoon period (SW-NE), the EAC dissipates as the East Indian winter jet forms and flows in the opposite direction along the west coast of India.

Another important current formed during the intermonsoon period (NE-SW and SW-NE) is the eastward-flowing equatorial jet. This jet develops as a result of westerlies-driven surface currents but is insufficient to generate a significant equatorial undercurrent year-round. Unlike the stable tropical Atlantic, the seasonal shifting winds appear unable to sustain a strong pressure gradient force outside the first few months of the year. During this period, the westward-flowing northern equatorial current is strongest, producing brief but strong periods of upwelling. Also, unlike the Atlantic, there is no open ocean divergence in response to trade winds blowing over the equator, since these wind conditions do not exist during either monsoon or intermonsoon periods.

Currents, Eddies, and Water Mass Formation

Finally, there is one way in which the Indian Ocean is similar to the Atlantic, and this is in the presence of a nonseasonal, persistent strong western boundary current—the Agulhas. This current is second only to the Gulf Stream in volume transported and moves at a top speed of 2.5 m/s. The energy transported by the Agulhas is so intense that it pinches off eddies (rings of Agulhas water encircling Indian Ocean water) from the western part of the loop in a process called Agulhas retroflexion. These eddies are transported around the southern tip of Africa into the Benguela current and up the southern Atlantic, where (like eddies

pinched from Gulf Stream) they can last many years. Such eddies illustrate how oceanic circulation, while structured by large-scale, planetary forces, can nonetheless form distinctive water masses. Oceanic circulation thus reflects the interaction of atmospheric turbulence, large-scale convection cells, ocean bottom and coastal topography, and differential heating of Earth's surface and plays the dominant role in redistributing the sun's energy throughout the Earth system.

Edward Rice

See also **Atmospheric Circulation; Atmospheric Energy Transfer; Biogeochemical Cycles; Climatology; Coriolis Force; El Niño; Hadley Cell; Hurricanes, Physical Geography of; La Niña; Monsoons; Oceans; Weather and Climate Controls**

Further Readings

- Bigg, G. R. (1996). *The oceans and climate*. Cambridge, UK: Cambridge University Press.
- Broecker, W. S. (1974). *Chemical oceanography*. New York: Harcourt Brace Jovanovich.
- Colling, A. (2007). *Oceanic circulation*. Oxford, UK: Butterworth-Heinemann.
- Pernetta, J. (2004). *Guide to the oceans*. London: Philips.
- Pickard, G. L. (1979). *Descriptive physical oceanography*. Oxford, UK: Pergamon Press.
- Tolmazin, D. (1985). *Elements of dynamical oceanography*. London: Allen & Unwin.



OCEANS

If geography is the science of space, then few spaces are more important to humanity than the world-ocean. The *world-ocean*—the term preferred by geographers for the “seven seas,” which, in fact, constitute one unified geophysical system—covers 71% of Earth's surface and contains 97% of the planet's water. More than 20% of the world's petroleum is derived from offshore sources, and 95% of world trade by weight, or two thirds by value, is carried by ship. Eighty percent of the world's fish catch comes from the



ocean, supporting the livelihoods of 140 million people. Economists have calculated that the world-ocean provides services to humanity valued at \$21 trillion per year, as opposed to only \$12 trillion per year provided by land. This entry reviews some of the ways in which geographers have approached the world-ocean, a space that is crucial to humanity but is all too often taken for granted as insulated from the influences of society.

A Missed Opportunity

Notwithstanding the important role of the ocean in the world's geography, the world-ocean historically has attracted little attention from human geographers. The history of geography is littered with prominent geographers making strident, but usually unheeded, calls for their colleagues to turn their attention seaward. Almost 2,000 years ago, the Greek geographer Strabo wrote, "We are in a certain sense amphibious, not exclusively connected with the land, but with the sea as well" (cited in Semple, 1931, p. 59). Early in the 20th century, the American geographer Ellen Churchill Semple (1911) admonished her terracentric colleagues when she proclaimed,

Our school textbooks in geography present a deplorable hiatus, because they fail to make a definitive study of the oceans over which man explores and colonizes and trades, as well as the land on which he plants and builds and sleeps. (p. 294)

Forty years later, the geographer Richard Hartshorne (1953) echoed Semple's criticism when he declared that the "fundamental error in popular geographic thought" (p. 386) was the tendency to view the ocean as simply a barrier rather than as a space of human society.

Despite these warnings, human geographers have typically ignored the ocean, probably for three reasons. First, much of modern geography has its origins in efforts by individual states to catalog and manage their resources. Even in social sciences that are less directly tied to the land (e.g., sociology, economics, political science), the state is often taken as the basic unit of society, and global processes are reduced to the category of

international relations (relations among state units). As a space that lies primarily external to the territory or sovereign authority of any individual state, the ocean has, to a large extent, literally been beyond the map of most social scientists.

A second reason why many geographers have long ignored the ocean is the tendency, in both the human and nature-society traditions, to focus on activities that happen in specific places. Geographers historically have understood key social activities, such as production, reproduction, and consumption, as well as the cultural forms that support these activities, as occurring at discrete points on Earth's surface. As the nature of these points is transformed, "places" are constructed, and the territories that encompass these places develop into societies and, ultimately, states. Although the ocean consists of specific points (e.g., fishing grounds, offshore oil platforms), when looked at from a land-based perspective, the ocean is generally seen as a surface across which people and resources (e.g., fish) move, and thus, it becomes excluded from narratives of social development.

A third reason why few geographers have studied the world-ocean is because it is often written off as a space of nature. Although human geographers have a long history of studying nature, this topic typically has either been in the context of understanding how certain natural characteristics shape the people who share the same territory as that nature (i.e., the early-20th-century environmental determinist tradition) or how a specific society transforms its local nature (i.e., the mid-20th-century cultural ecology tradition). However, because the ocean was not the space of any one society, it received little attention from environmental determinists (except, in some instances, in the context of interpreting the role of coastal waters in the development of littoral societies). Conversely, because until recently it was assumed that humans could have little impact on the nature of the ocean, the ocean was similarly of little interest to cultural ecologists. Finally, while physical geographers might have been expected to study the ocean as an integrated geophysical system, this line of research has typically been the domain of physical oceanography, leaving little room for physical geographers to conduct ocean research.



A diver helps fishermen catch tuna fish at a bluefin tuna farm around the mid-Adriatic Croatian town of Zadar, February 2007, before transporting them to Japan. The European Union and Japan agreed to slash their tuna quotas by more than 20% in an effort to prevent the immensely popular fish being hunted to extinction.

Source: STRINGER/AFP/Getty Images.

Contemporary Issues in Ocean Geography

In recent decades, the world-ocean has begun to attract more attention from geographers. In part, this is because human uses of and interactions with the ocean have been changing and intensifying. However, it is also because geographers have been adjusting their own perspectives and, in the process, opening their eyes to a geography that has always been there.

Environmental and Economic Geography

In the 17th century, when Hugo Grotius was penning the modern doctrine of freedom of the seas in his book *Mare Liberum*, he declared that the ocean beyond the coastal zone should be immune to possession by states because the ocean's resources were inexhaustible, and its environment

was invulnerable to damage from human activities. By the middle of the 20th century, this perspective on the marine environment was beginning to change. Humans had developed an unprecedented capacity to transform the ocean's nature, and technologies had advanced to the point that humans were more able to recognize the transformations in which they had long been engaged.

In recent decades, as economic competition has increased among the world's states (and as competition also has increased within states whose economies are being integrated into the world economy through the processes of neoliberalization), users of the ocean have turned to technological innovations that then have further intensified economic competition. Amid these cycles of economic and technological intensification, the marine environment has increasingly become endangered. For



Oil and gas drilling platform and provider ship in the Pacific Ocean. More than 20% of the world's petroleum is derived from offshore sources.

Source: iStockphoto.

instance, competitive pressures have led fishers to adopt new technologies. These new technologies have not only enabled higher catch rates but also have led to a situation wherein fishers have *had* to catch more fish in order to pay for their expensive equipment. In 2000, the United Nations' Food and Agricultural Organization (FAO) estimated that approximately 50% of the world's fish species were being harvested at their maximum sustainable yield, 25% were being overfished, and 25% could be fished at higher rates. The FAO also noted that the percentage of fish species being overfished had increased significantly since the early 1970s. Furthermore, declining populations of some species have been leading fishers on a race, quite literally, to the bottom, as they redirect their efforts to the ocean's depths, where they are harvesting cold-water species that previously had evaded their attention. These fish, which often are culinary delicacies, typically grow and reproduce at very slow

rates and hence are extremely vulnerable to population collapse and even extinction.

Other ocean-using industries have seen similar increases in recent decades, with equally dangerous environmental consequences. The volume of ship-borne trade has increased from 996 million tons in 1959 to 6,760 million tons in 2005, and this can have an impact on the environment, both from wrecks (most notably of oil tankers) and from normal operations (e.g., discharge of bilge water). The National Ocean Industries Association, a U.S. industry group, estimates that 44 million gallons of petroleum are released into the ocean annually by tanker ships, and additional quantities of petroleum and other pollutants are released by ships transporting goods other than petroleum. Discharged ballast water can endanger the marine environment by introducing invasive species that have been transported from a distant area of the world-ocean.



Additionally, effluents from industrialization, urbanization, and chemical agriculture on land increasingly find their way to the sea, joining waste products that are being dumped there intentionally. Furthermore, as oceanographers have gained a better understanding of ocean currents and marine geophysics, they have realized the magnitude of the connections among the world's oceans: What seems like a local environmental problem could have global implications.

In addition, as climatologists have learned more about periodic climactic events (e.g., the El Niño Southern Oscillation, the North Atlantic Oscillation) and global climate change, they have gained an appreciation of the ocean's role as both an indicator and a regulator of trends in the world's climate. An increase in the atmospheric temperature, for instance, would raise the temperature of the ocean. This, in turn, could lead to disastrous impacts for fish stocks, human populations (because of increased storm activity), and ocean circulation systems. Alterations in the ocean circulation system, in turn, could further affect local climates, creating a vicious cycle of climate change in which the ocean would play a leading role.

Increased scientific understanding of (and concern for) the marine environment has been supplemented by a growth in public awareness. The adventures of celebrity explorers like Jacques Cousteau, the writings of environmental travel writers like Carl Safina, the interventions of policy advocates like Sylvia Earle, and the warnings of environmental muckrakers like Rachel Carson have all alerted the public to the world's endangered marine environment. These authors have been assisted by images of the globe from outer space, which illustrate the significance of water on the "blue planet." They have also been assisted by the ocean's image as a pristine space of nature, a mysterious space of wonder into which one should be able to escape from the institutions and influences of human society. Environmentalists, in turn, have reproduced these ideals of a pristine, exotic ocean by focusing on iconic marine fauna and flora, such as whales, manatees, and coral reefs, in their efforts to raise global environmental consciousness.

Increased awareness of the ocean by environmental geographers is not only due to our increased ability to transform the ocean and

popular awareness of these changes but also due to changing perspectives within the discipline itself. To some extent, this changing attitude has come from political ecologists who are increasingly attentive to the ways in which the Western model of constructing nature through taming it, controlling it, binding it into private property, and "improving" it (i.e., the agricultural model) is just one way among many in which societies productively interact with nature. It has also emanated from increasingly sophisticated theorizing about nature, wherein nature is seen not as something with which societies *interact* but rather as something that societies *construct*, through combinations of economic regimes, state strategies, and applications of knowledge systems.

Political Geography

Individuals and institutions attempting to regulate the ocean as a space of nature and economic activities have had to weave between two opposing imperatives in ocean governance. On the one hand, some areas of the ocean, particularly near the coasts, are much like land. Fishing grounds and offshore oil fields are designated as places to be controlled and developed so that their resources can be mobilized for the benefit of states and societies. Presumably, the best way to foster the development of these ocean territories would be to expand the boundaries of the territorial state out into the adjacent sea.

On the other hand, the bulk of the ocean's value is derived from it being a space of mobility. Economically, more value is derived from transport across the ocean's surface than from fishing and mining activities combined, and if state territory were extended into the sea, it would interfere with the interests of shipping and navies, which depend on the sea being a relatively open space, with few boundaries, rules, or policing authorities. Indeed, shippers and navies have long been wary of efforts to govern and patrol the ocean, for fear that these efforts might encroach on the "freedom of the seas" that they enjoy. Furthermore, fish and pollutants are mobile as well. If one country chose not to fish a certain species in order to conserve it, that fish would likely move into another country's territory. Likewise, a country has little incentive to curb a pollution release



if it knows that the pollutant will likely float into another country's space.

In short, although enclosure of the ocean may be a good strategy for fostering coastal development, the ocean's physical properties and its dominant economic uses make it an unsuitable policy for extension across the world-ocean. Instead, international policymakers, over time, have agreed on a compromise, codified in the United Nations Convention on the Law of the Sea. Under the 1982 convention (which went into effect in 1994), coastal waters out to 12 nm (nautical miles) are considered territorial waters. Coastal states have most of the same rights there that they have in their land space, except that they must allow passage by ships of other states that are deemed "innocent." The rest of the ocean is the high seas, where no country controls the water but where the ship is considered an extension of the country under whose flag it flies. There are, however, two key exceptions to this delineation of ocean space. The portion of the high seas between the 12-nm limit of territorial waters out to 200 nm is the coastal state's exclusive economic zone (EEZ). Although high seas' navigational freedoms prevail in an EEZ, the coastal state retains exclusive rights to the living and nonliving resources that are found there or on the underlying seabed. Conversely, international straits that are fewer than 24 nm in width (and that thus lie entirely within territorial waters) are governed by a right to free transit that is stronger than the right to innocent passage that applies in other territorial waters.

As is the case with environmental and economic geographies of the ocean, the interest of political geographers in the ocean has been aided not only by the increased intensity of ocean governance and conflict but also by changing perspectives within the subdiscipline of political geography. Political geographers and political scientists have traditionally begun their analysis by studying individual states and the relations between them. From this perspective, the ocean, as a space outside the territory of any state, emerges at best as a space used by society: an arena in which the forces of land-based states meet as each attempts to control crucial areas of the sea (e.g., a choke point on a shipping lane) or to use the ocean as a platform from which power can be projected onto land.

In recent decades, however, two perspectives—world-systems theory and poststructuralist thought—have become increasingly popular in political geographic studies, and these have led to a reevaluation of the ocean as an integral space of society. For world-systems theorists, the world, rather than consisting of 190-odd state-society units, consists of one integrated (albeit spatially differentiated) social system. This is significant because if one thinks of the world as consisting of one society, with many constituent varieties of spaces, then the ocean shifts from being conceived of as an external space *between* the world's societies to being conceived of as one of the many spaces *of* society.

A second theoretical movement that has spurred a growing interest in the political geography of the ocean has been poststructuralist international relations theory and the aligned school of critical geopolitics. These scholars criticize the model of the world as one in which states with unambiguously bounded insides interact with each other on a preexisting (and presocial) spatial platform. Instead, for these scholars, the discursive bounding of states and the construction of the world as a universe of mutually exclusive territorial states is itself seen as an act of politics—one that is continually being performed. Since the ocean is a key borderland wherein states define their extent (and hence themselves), the ocean emerges as an important arena for state reterritorialization and not merely a surface on which ontologically preexisting states compete.

Cultural Geography

While the increased attention to the ocean in environmental, economic, and political geography is due to a combination of increased uses of the ocean and changed perspectives within the discipline of geography, the increased attention in cultural geography is almost entirely due to changes in the discipline. Although the ocean has long been a site of interaction between cultural groups and a realm within which coastal dwellers have subsisted on local natural resources, historically few geographers have devoted their attention to the cultures of fishing communities and even fewer have studied the cultures of societies engaged in uses of the deep sea (e.g., whalers, naval personnel, merchant



mariners, oceanographic and fisheries researchers, or long-distance fishers).

In recent decades, however, much of cultural studies—including cultural geography—has abandoned attempts at understanding distinct and bounded societies (which typically occur in place and, not incidentally, on land). Instead, students of culture from a range of disciplines, including anthropology, literary studies, and history, as well as geography, are increasingly turning their attentions toward the interactions that occur and the hybrid cultures that are formed in the spaces where cultures meet. As part of this trend, a range of classic works from outside the discipline have focused on the sea (or the ship) as a point of interaction and hence culture formation. Among these works are the social historian Fernand Braudel's *The Mediterranean and the Mediterranean World in the Age of Philip II*, wherein the sea is identified as a fundamental space in a Mediterranean civilization defined by commercial interaction; the sociologist Paul Gilroy's *The Black Atlantic*, wherein the African diaspora is identified as having distinct qualities because it is associated with an integrative ocean rather than a stabilizing land; and the labor historian Marcus Rediker's *The Devil and the Deep Blue Sea*, wherein the seafaring ship is seen as a crucible for the emergent labor regimes and solidarities of industrial capitalism. This focus on the sea as an arena for culture formation, in turn, has been given further weight by theorists, including Michel Foucault, Gilles Deleuze, and Felix Guattari, who stress the metaphorical significance of the ship or the ocean for understanding spaces of alterity ("heterotopia" in the case of Foucault and "smooth space" in the case of Deleuze and Guattari).

Thus, the inattention to the ocean that characterized so much of the history of geography has been turned on its head. The world-ocean was long ignored by geographers as a zone of resources or a surface for movement that was fundamentally external to society. Now, however, in a dramatic shift, the world-ocean is emerging as a space through which geographers make sense of the land spaces in which they dwell.

Philip E. Steinberg

See also **Aquaculture; Coastal Dead Zones; Coastal Hazards; Coastal Zone and Marine Pollution;**

Colonialism; Critical Geopolitics; Cultural Ecology; El Niño; Environmental Determinism; Exploration; Fish Farming; Geopolitics; Land-Water Breeze; La Niña; Magellan, Ferdinand; Marine Aquaculture; Oceanic Circulation; Oil Spills; Physical Geography, History of; Political Geography; Sustainable Fisheries; Trade

Further Readings

- Braudel, F. (1972). *The Mediterranean and the Mediterranean world in the age of Philip II*. New York: Harper & Row.
- Clover, C. (2008). *The end of the line: How overfishing is changing the world and what we eat*. Berkeley: University of California Press.
- Ellis, R. (2004). *The empty ocean*. New York: Island Press.
- Hartshorne, R. (1953). Where in the world are we? Geographic understanding for political survival and progress. *Journal of Geography*, 52, 382–393.
- Lambert, D., Martins, L., & Ogborn, M. (Eds.). (2006). Currents, visions and voyages: Historical geographies of the sea [Special issue]. *Journal of Historical Geography*, 32, 479–647.
- Psuty, N., Steinberg, P., & Wright, D. (2004). Coastal and marine geography. In G. Gaile & C. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 314–325). New York: Oxford University Press.
- Rediker, M. (1987). *Between the devil and the deep blue sea: Merchant seamen, pirates and the Anglo-American maritime world*. Cambridge, UK: Cambridge University Press.
- Sample, E. C. (1911). *Influences of geographic environment*. New York: Henry Holt.
- Sample, E. C. (1931). *The geography of the Mediterranean region: Its relation to ancient history*. New York: Henry Holt.
- Steinberg, P. (Ed.). (1999). Geography of ocean-space. *The Professional Geographer*, 51, 366–450.
- Steinberg, P. (2001). *The social construction of the ocean*. Cambridge, UK: Cambridge University Press.
- United Nations. (1983). *The Law of the Sea: United Nations Convention on the Law of the Sea with index and Final Act of the Third United Nations Conference on the Law of the Sea*. New York: Author.



- Van Dyke, J., Zaelke, D., & Hewison, G. (Eds.). (1993). *Freedom for the seas in the 21st century: Ocean governance and environmental harmony*. Washington, DC: Island Press.
- Wigen, K., & Harland-Jacobs, J. (Eds.). (1999). Oceans connect [Special issue]. *Geographical Review*, 89, 161–313.



OFFSHORE FINANCE

Offshore finance refers to financial transactions that take place in jurisdictions that are either literally or jurisdictionally separated from the major economies of the onshore world, such as the United States, Britain, Japan, or Germany. Offshore financial services are transacted from offshore financial centers (OFCs) found in dispersed locations throughout the planet. Although no firm consensus exists in the academic or business worlds as to the number of OFCs, most offshore jurisdictions are small independent or semi-independent island nations with spatial clusters found in the Caribbean basin and in Western Europe and in isolated locations in Asia and the Pacific region. This topic is of importance to geographers because the offshore world is often at the spatial margins of economic activity where many of the problems of the modern global economy are found: extremely unequal tax practices, money laundering, and terrorist financing. This entry addresses reasons for the creation of an offshore financial sector, the current distribution of OFCs, and reaction to the growth in offshore finance by the onshore world.

Development of Offshore Finance

Offshore financial transactions and OFCs became more relevant and visible as the global circuitry of capital grew in size and intensity in the second half of the 20th century. The global financial system evolved and grew in sophistication and complexity because of several developments, including the dissolution in the 1960s of the post-World War II Bretton Woods system of fixed exchange rates pegged to the U.S. dollar; the subsequent

creation of the Eurodollar market (“Eurodollars” are U.S. currency held in banks located outside the United States, and “Eurocurrency” is any major currency held in banks outside the country of issuance); the growth in Middle East petrodollar recycling in the 1970s; and technological improvements in the latter part of the 20th century in electronic telecommunications and data exchange. Current estimates show that as much as half of the world’s stock of money either resides in or flows through these places.

Spatial Distribution of OFCs

No consensus exists as to the number of OFCs transacting financial services in the global economy. Supranational regulatory and supervisory bodies such as the Organisation for Economic Co-operation and Development (OECD), the European Union (EU), the Financial Action Task Force (FATF), or the Basel Committee Offshore Group of Banking Supervisor (OGBS) vary in the number of OFCs defined and listed. In addition, trade bodies such as the Lowtax Network identify more. Table 1 shows a current list of low-tax jurisdictions as defined by Lowtax.net, with those members of the OGBS so identified. These places—many of which are small island economies—number at least 40 and are scattered throughout the planet. The factor they have in common is the use of accommodating (often described by critics as minimal) legislative, regulatory, and supervisory infrastructures to attract capital by marketing tax minimization, secrecy, and confidentiality of service and product.

Offshore-Onshore Tensions

The first serious reaction from the onshore world toward regulating the financial activities of the offshore world came with the 1998 initiative by the OECD addressing harmful tax competition as an emerging global issue. The OECD’s concern over existing inequities led to specific guidelines published in the form of a so-called blacklist of most jurisdictions labeled as tax havens, and OFCs were then charged with establishing guidelines for increased transparency when reporting financial transactions.

The EU followed the lead of the OECD by establishing initial tax-harmonization policies



Andorra	Anguilla	Aruba*
Bahamas*	Barbados*	Belize
Bermuda*	Botswana	British Virgin Islands*
Brunei	Cayman Islands*	Cook Islands
Costa Rica	Cyprus	Dubai
Gibraltar	Grenada	Guernsey*
Hong Kong	Ireland	Isle of Man*
Jersey*	Labuan ^a	Liberia
Liechtenstein	Luxembourg	Madeira
Malta	Marshall Islands	Mauritius*
Monaco	Netherlands Antilles*	Nevis
Panama*	Seychelles	Singapore
St. Kitts	St. Vincent & the Grenadines	Switzerland
Vanuatu*	Turks and Caicos Islands	

Table 1 Low-tax jurisdictions

Sources: Tax details of asterisked countries were compiled from www.lowtax.net; the rest were compiled from www.ogbs.net.

for its member states in 2000, but progress was slow as the ever-expanding EU had other pressing issues to address. A savings tax agreement was reached by 12 member states of the EU in 2003, and this directive involved the commitment by states to introduce an automatic exchange of information concerning interest income from the savings of residents of other member states. The goal of creating a level playing field for taxation has been furthered by this agreement, and even though the policy is directed initially toward the internal market, the EU also has tax policy issues directed externally. In an external savings directive, the EU specifically targeted the nonmember jurisdictions of Switzerland, the United States, and other important financial centers, including all relevant dependent or associated territories.

In 1989, in response to concern over money laundering, the FATF was created by the G-7 economies. Money laundering was defined as the processing of illegal profits from a variety of activities, including illegal arms sales, smuggling, drug trafficking, prostitution, and other activities of organized crime, as well as white-collar crimes such as embezzlement, insider trading, bribery, and computer fraud schemes.

According to FATF, criminals seek to launder illegal profits by disguising the sources or moving

the funds to a place where they are less likely to attract attention. As confidentiality is one of the major selling points of OFCs, FATF and the other onshore regulatory and supervisory bodies have tried to establish policy initiatives to promote transparency in financial transactions and to establish anti-money-laundering systems for OFCs in compliance with the FATF guidelines. The most fundamental element for offshore anti-money-laundering policies is the “know-your-customer” requirement that many offshore financial institutions and centers currently use. Know-your-customer policies require official proof of identification using passport and other official documents and include monitoring and reporting of any suspicious transactional activity.

For OFCs, the establishment and preservation of a superior reputation as a well-regulated and supervised jurisdiction is considered to be one of the most important marketing strategies for competitive advantage, and most OFCs work with FATF and other onshore organizations to remain in good standing and protect the reputation of the center.

Sharon C. Cobb

See also **Euromarket; Finance, Geography of; Money, Geographies of; Telecommunications and Geography**



Further Readings

- Hampton, M. (1996). *The offshore interface: Tax havens in the global economy*. New York: St. Martin's Press.
- Organisation for Economic Co-operation and Development. (1998). *Harmful tax competition: An emerging global issue*. Retrieved December 12, 2009, from www.oecd.org/dataoecd/33/0/1904176.pdf
- Roberts, S. (1994). Fictitious capital, fictitious places: The geography of offshore financial flows. In S. Corbridge, R. Martin, & N. Thrift (Eds.), *Money, power and space* (pp. 91–115). Oxford, UK: Blackwell.
- Warf, B. (2002). Tailored for Panama: Offshore banking at the crossroads of the Americas. *Geografiska Annaler*, 84, 47–61.



OIL SPILLS

Oil spills are the release of petroleum into the sea or inland areas and are a major threat mainly to coastal environments. In the past century, there was a notable increase in world population, in general, and in the coastal population in particular. Hence, coastal areas' vulnerability to oil spills has increased, often to the level of potential natural and human catastrophes.

Oil is mainly exported by maritime traffic from oil-exporting areas, such as the Persian Gulf, Libya and Algeria, Nigeria, and Sudan in Africa to the major oil-importing countries, namely, the United States, Western Europe, Japan, India, and China. In the 1990s, some 3.4 million tons of oil, or 0.01% of the world's total annual oil production—about 3.6 billion tons/year, went into the sea. Approximately, 47% of this volume was from oil spills from ships, the rest from industrial plants, sea oil drillings, and natural sources. Generally, major oil spills are caused by shipping accidents at sea, fires on tankers, or ship accidents on coastal barriers. The total risk, or the expected number of injuries and lives lost and amount of property damaged, is a function of the magnitude of the hazard—oil spill in this case; the number of potential economic

and environmental assets to be affected, such as beaches, ports, nature reserves, and so on; and the vulnerability of the affected area.

Oil Characteristics

Crude oil is a naturally occurring complex of liquid hydrocarbon, which after distillation yields a range of combustible fuels. Four different types can be distinguished from the viewpoint of oil spill threat to the environment:

1. Light fuels, such as gasoline, kerosene, or fuel oil
2. Medium to heavy oil, such as ship fuels and light lubricants
3. Oil rich in paraffin, such as water-oil emulsion and heavy-oil lubricants
4. Residual oil, such as asphalt and heavy-oil residuals

The following are the oil characteristics that need to be taken into account in an oil spill: (a) *density*, which determines the dispersion and floating of the oil (heavy-oil density is above 0.9, light-oil density is below 0.865, and fuel-oil density is 0.84); (b) *viscosity*, or resistance to flow; (c) *boiling point*, which determines the rate of evaporation; (d) *pour point*, namely, the temperature at which oil is transformed into a gel, depending on the oil composition; (e) *flash point*, or the lowest oil temperature to maintain a layer of vapor, an important factor to reduce fire risk; and (f) *dilution*—light fuels are easier to dilute in seawater but are poisonous to the living environment. Oil is an organic compound and is transformed in seawater by complex physical and chemical processes until it “disappears” completely. Light and medium oils dilute and evaporate in seawater after one day, but the heavy fractions with high viscosity may remain and are hard to dilute with dispersants. In such cases, removal of oil by mechanical means is best advised.

In a tropical climate, about 80% of the oil evaporates on the first day of the spill. Light fuels become diluted in seawater but are dangerous to the biota, and on reaching the shore, they are absorbed by coastal sand.



Aerial view of the Deepwater Horizon oil slick off of the Mississippi Delta on May 24, 2010. Not technically an oil spill but a pipeline gushing oil from a mile below the surface, it created the largest oil disaster in U.S. history, with devastating consequences for the local ecologies and economies of the Gulf Coast.

Source: Michon Scott, NASA's Earth Observatory, NASA Goddard Space Flight Center.

Oil Spills in the Ocean

What happens when there is an oil spill in the ocean? Despite the spillage of tens of millions of tons of oil into the oceans over many years, evidence does not exist of irreversible damage to seawater or even to the coastal environment, according to a report by the International Tanker Owners Pollution Federation. However, fragile coastal environments that become heavily polluted may suffer for many years until recovery is complete. In the initial period, the damage to densely populated coastal areas or seaside resorts may amount to great economic cost.

After the spill, oil not only undergoes a series of physical and chemical processes but is also carried by the product of two vectors: the waves and surface sea currents (Figure 1).

The “weathering” of the oil, or its dilution in seawater, is a function of several factors: the magnitude of oil spill, oil composition, oil dispersion as one body or several small patches, oil viscosity and density, air and water temperature, wind and wave velocity, and more. The oil may lie several tens of centimeters thick near the source, but after dispersion, its thickness is only a fraction of millimeter; eventually, it turns into a sheen blanket only a few micrometers in depth.

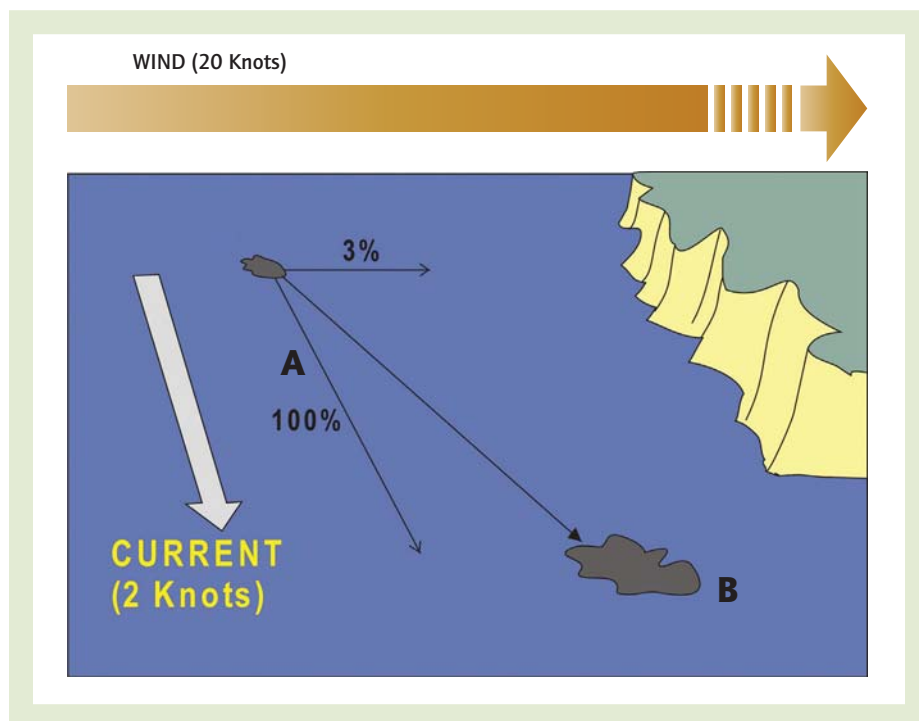


Figure 1 Oil spill carried in seawater by a vectorial result of wind and sea current forces

Source: From *Aerial Observation of Oil* (Technical Information Paper No. 1, 2009). Reprinted with permission from The International Tanker Owners Pollution Federation Ltd.

and floating obstruction devices to prevent oil flowing to the coastal area. Pumping is also used to recover part of the oil. Chemical techniques, such as dispersants or chemical devices, cause the oil to sink. Biological techniques, by means of microorganisms and chemical fertilizers, increase the bacterial activity of oil disintegration. Burning the oil is not recommended in many countries because of the atmospheric pollution, but it may be applied in critical situations. In some cases, the “don’t interfere” method may be adopted; only monitoring of the flow and direction of the oil patches is carried out.

One ton of oil may cover 1 km² (square kilometer) of seawater after just a few hours, and then it divides into long strips.

In spring 2010, the largest marine oil disaster occurred in U.S. history. The Deepwater Horizon oil rig, under contract for British Petroleum, exploded, killing 11 workers. A mile beneath the surface, a pipeline gushed crude petroleum, which rose to the surface to form an enormous oil slick. (Thus, technically, this was not an oil spill, such as happens when oil tankers leak petroleum.) The source of the oil proved to be very difficult to control. The resulting pool of petroleum gradually moved toward the coastline of Louisiana and neighboring states, threatening coastal ecosystems and local fishing and shrimping industries.

Cleaning Oil Spills

Several methods are used to clean oil spills. Mechanical techniques include containment

Environmental Sensitivity to Oil Spills

The overall sensitivity of an environmental system to oil spills has three major aspects:

1. **Vulnerability** is the ease with which oil may reach and persist in a certain ecosystem. Vulnerable ecosystems are those where oil may penetrate easily and remain for lengthy periods, where wave energy and currents that could disintegrate the oil are low, and where mechanical or manual cleaning may be difficult owing to low accessibility. In general, vulnerability may be defined as the exposure of economic and environmental assets to the oil spill.
2. **Sensitivity** refers to the particular components of the biota. Sensitive species are those that may be affected directly immediately after the spill, as biological systems become clogged with oil; species whose way of life will bring them



into close contact with the oil spill; and species with a low reproduction rate.

3. *Resilience* is the way biological populations can resume their natural behavior. Highly resilient species are those with a high reproduction rate, short life expectancy, high physiological resilience, and wide geographic dispersion.

Socioeconomic and Political Aspects

Major oil spills, such as the *Prestige* tanker spill in November 2002 off the Atlantic coast of France and Spain, generally involve a high economic cost—around US\$1 billion. In 2009, the European Parliament approved a directive to all members to impose penal sanctions against heavy and continuous pollution. Some polluters are not deterred by fines, and to save money, they continue polluting.

Here are some examples of political and economic conflicts. Between 1964 and 1990, oil exploration and drillings in the Ecuadorian Amazon region polluted an area of 4,000 km². The U.S. companies involved denied responsibility and blamed the national Petroecuador Company. Local ethnic peoples and much of the environment were affected. In 1999, a Dutch oil ship spilled about 5,300 tons of oil into the Rio de la Plata, about 100 km south of Buenos Aires. The spill was 30 km offshore and affected the beaches. The local council of Magdalena was given US\$9.5 million to develop tourist facilities. The Sea Division of the United Nations Environment Programme is responsible for international agreements between coastal nations to prevent oil spills and to coordinate management in case of a spill.

Moshe Inbar

See also **Coastal Hazards; Coastal Zone and Marine Pollution; Oceans; Petroleum; Point Sources of Pollution; Water Pollution**

Further Readings

Adler, E., & Inbar, M. (2007). Shoreline sensitivity to oil spills, the Mediterranean coast of Israel: Assessment and analysis. *Ocean and Coastal Management*, 50, 24–34.

Gundlach, E., & Hayes, M. (1978). Classification of coastal environments in terms of potential vulnerability to oil spill impact. *Marine Technology Society Journal*, 12, 18–27.

The International Tanker Owners Pollution Federation Ltd. (1987). *Response to marine oil spills*. London: Witherby.



OKABE, ATSUYUKI (1945–)

Atsuyuki Okabe received his PhD from the University of Pennsylvania in 1975 and a doctor of engineering degree from the University of Tokyo in 1977. He was the director of the university's Center for Spatial Information Science (CSIS) from 1998 to 2005. He is currently a professor at the University of Tokyo and a member of the Science Council of Japan.

Okabe was one of the first to apply Voronoi diagrams to the spatial competition problem (Hotelling problem) and showed that the equilibrium states in a two-dimensional (2D) space were drastically different from those in a 1D space. Since then, he has extensively studied Voronoi diagrams, and his outcomes were developed into a book, *Encyclopedia of Voronoi Diagrams*, which provides a general framework for studying Voronoi diagrams and illustrates hundreds of applications in various fields. It has been cited in more than 1,700 articles.

He also broadened the applications of geographic information systems (GIS) to the humanities and social sciences. One book pioneered the systematic applications of GIS to Islamic studies, which was well received and earned him the World Prize of the Book of the Year of the Islamic Republic of Iran. Another book developed the frontiers of the applications of GIS to the humanities and social sciences.

He developed new spatial analysis, namely, spatial analysis on networks. Traditional spatial analysis assumes that space is given by a plane with Euclidean distance. Okabe proposed a new paradigm, where space is represented by networks embedded in the 2D or 3D space with the shortest-path distance. In addition, he and his colleagues developed a toolbox for spatial analysis on networks called SANET. SANET is now used by researchers in more than 40 countries.



Furthermore, he published a series of articles on city systems. Okabe theoretically analyzed the relationship between the optimal city-size distribution and Zipf's rank-size rule. He developed an integrated theory that combines a macro-empirical law, the rank-size rule, and a micro-empirical law, the Clark's law of urban population distribution. Okabe and colleague Sadahiro demonstrated why Christaller's city system could be observed in the real world using spatial random point processes.

He has contributed tremendously to the development of research in spatial analysis and geographic information science. In short, he is *the* founder of these fields in Japan, both in research activity and in terms of organizing a research organization, namely, CSIS in the University of Tokyo.

Yasushi Asami

See also **Central Place Theory; Geographic Information Systems; GIScience; Rank-Size Rule; Regional Science; Urban Hierarchy; Voronoi Diagrams**

Further Readings

- Okabe, A. (1979). An expected rank-size rule: A theoretical relationship between the rank-size rule and city size distributions. *Regional Science and Urban Economics*, 9, 21–40.
- Okabe, A. (1987). A theoretical relationship between the rank-size rule and Clark's law of urban population distribution: Duality in the rank-size rule. *Regional Science and Urban Economics*, 17, 307–319.
- Okabe, A. (Ed.). (2004). *Islamic area studies with GIS*. London: Routledge.
- Okabe, A. (Ed.). (2006). *GIS-based studies on the humanities and social sciences*. New York: Taylor & Francis.
- Okabe, A., Boots, B., Sugihara, K., & Chiu, S. (2000). *Spatial tessellations: Concepts and applications of Voronoi diagrams* (2nd ed.). New York: Wiley.
- Okabe, A., & Sadahiro, Y. (1996). An illusion of spatial hierarchy: Spatial hierarchy in a random configuration. *Environment and Planning A*, 28, 1533–1552.

Okabe, A., & Suzuki, A. (1987). Stability of spatial competition of many firms in a bounded two-dimensional space. *Environment and Planning A*, 19, 1067–1082.

Okabe, A., & Yamada, I. (2001). The *K*-function method on a network and its computational implementation. *Geographical Analysis*, 33(3), 271–290.



OLSSON, GUNNAR (1935–)

Gunnar Olsson served for a decade as professor of geography at the University of Michigan and for 20 years as director of the doctoral program at the Nordic School of Planning (*Nordplan*) in Stockholm, before returning to Uppsala University in the late 1990s. He has become one of the more influential deconstructive voices within poststructuralist geography. Idiosyncratically drawing on reactionary and rebellious ideas from geometry, philosophy, theology, cartography, semiotics, and aesthetics, the political implications of Olsson's work have been a constant source of academic controversy.

Olsson completed his doctoral studies at Uppsala University in 1968. His early work dealt with distance and human interaction and was based on methods emanating from the quantitative tradition in geography. From the 1970s onward, Olsson has been a key figure in the development of post-positivist geography. He soon acquired a reputation as a radical avant-garde writer, laying out his critique of power and modern reason in texts of intimidating difficulty. Notwithstanding this, a considerable share of this work can be said to have emanated from practical experience and an early dissatisfaction with the tight collaboration between (applied) geography and modern planning practices. In Olsson's native Sweden and elsewhere, geography played a vital role by supplying planners with what was conceived as useful scientific knowledge, maps and models. Olsson's interrogation sought to dissect the taken-for-granted ideas keeping the two together. In particular, he targeted the widespread postwar planning principle that specific modes of living and behaving would result from deliberately



designed changes in institutional and spatial structures.

Olsson argued that this whole enterprise was based on false premises. Processes and forms did not necessarily correspond, and it remained impossible to predict the consequences of general schemes and actions. Instead of further advancing the modeling and mapping impulses of geography, Olsson identified an insurmountable gap between academic reflection and the pragmatic implementation of knowledge. Geography's peaceful association with planning and welfare capitalism had to be replaced by a self-reflexive, more radically humanistic geography, shifting its focus to living individuals and a trenchant scrutiny of power. Power could be seen as a game of ontological transformations, turning invisible relations into visible things, mindscapes into stonescapes, and vice versa. This theme led Olsson to the deconstruction of a whole series of frequently taken-for-granted practices and relationships, such as those between thought and action, individual and collective, certainty and ambiguity, language and phenomenon, expression and impression, stability and change, mind and body, and creativity and socialization.

Olsson's radical cartography of power earned considerable resonance internationally and was popularized for a Swedish audience in a collection of essays, *Antipasti* (1990). In the early 21st century, many of his earlier ideas were drawn together as a wholesale critique of cartographical reason in Western society—*Abysmal* (2007). For Olsson, a critique of cartographical reason concerns not simply the way in which mapping is socially employed as a material instrument of power and knowledge. A map is also a document of mistranslation, a story confronting us with absences and silences and hence with the limits of language and representation. Maps can be understood as signs closing the abysses between the five senses of the body and the sixth sense of the cultural taken-for-granted. More important than their ability to reflect reality, maps have an authoritative power to convince: They are exemplars of given- and taken-for-granted modes of thought and action. In this expansive sense, Olsson's critique of cartographical reason gestures beyond mapping and geography and involves no less than an assessment of what he sees as the

currently ruling mode of thought and action. It is concerned with the broader study of people as semiotic animals—a species whose individuals are joined and separated by the use of their signs, including maps—with the inner world of that which structures, authors, and controls, for instance, mapmaking and geography. The self-imposed task of Olsson's "heretic cartography" is to question the authority and power implied in such ostensibly prearranged givens and truths.

Tom Mels

See also **Critical Human Geography; Humanistic Geography; Phenomenology; Poststructuralism; Representations of Space**

Further Readings

- Olsson, G. (1980). *Birds in egg/legs in bird*. London: Pion.
- Olsson, G. (1990). *Antipasti*. Gothenburg, Sweden: Korpen.
- Olsson, G. (1991). *Lines of power/limits of language*. Minneapolis: University of Minnesota Press.
- Olsson, G. (2007). *Abysmal: A critique of cartographical reason*. Chicago: University of Chicago Press.



ONTOLOGICAL FOUNDATIONS OF GEOGRAPHICAL DATA

How can data users obtain geographical data that is relevant or at least closely related to their interests? One solution is to understand what geographical data really mean. How to describe the meaning of data? Metadata, which consist of information such as keywords and positional accuracy about the data, seem to solve half the problem. Metadata include geographical terms such as *river* and *mountain*, which are used to describe the content of a given geographical data set. These terms, however, are often ambiguous: Two different terms can refer to the same thing



for different people. For instance, *river* and *stream* or *hill* and *mountain* are different terms that can refer to the same feature. How can one resolve such issues, or at least mitigate the conceptual and terminological differences between the terms, so that when one looks for geographical data about rivers, the data on streams could also be considered? Current approaches, which apply exact string matching, generate only geographical data that are described with the same string. To support information retrieval, the meanings of geographical terms associated with given data should be made explicit. Making the meanings of geographic terms explicit makes it possible to carry out matching to see whether the data involved describe the same thing. This entry discusses the ontological foundations for geographical data. By comprehending its ontological foundations, one is able to describe a geographical term more precisely, which assists in retrieving closely related geographical data.

In what follows, some terms are defined to serve as the background context for the readers, including *ontology*, *ontological commitments*, *semantic heterogeneity* and *interoperability*, and *semantic similarity*. Next, the ontological foundations are explored based on the semantic, pragmatic, and spatial aspects of geographic data. On the semantic aspect, the notion of ethnophysiology, which aims to study the semantic meanings of geographical terms in different languages and cultures, is discussed. The study of geopragmatics, which focuses on representing the application contexts of geographical data, is outlined. Last, the notions of bona fide and fiat boundaries of geographic features, and the granularity of geographic space, will be described.

Background Context

The term *ontology* originated in philosophy to refer to the science of what is, that is, the kinds and structures of objects, properties, events, processes, and relations in every area of reality. From a philosophical perspective, ontology describes the constituents of reality, and the relationships among these constituents. Referring to the geographic domain in particular, geographical ontology describes geographic features

(human-made and natural), categories, relations, and processes at different scales or spatial granularities (different levels of detail in representing spatial entities). The term has also been used in the information sciences community. Slightly diverging from its meaning in philosophy, ontology in the information sciences is a logical theory about how information systems operate. This type of ontology is defined as an explicit specification of a conceptualization (with *conceptualization* often referring to the perspective of the software developers who build the systems). In other words, from the information sciences perspective, ontology is a description of the viewpoints of developers, which humans can read and that machines can process. Different ontologies can exist for different information systems. To differentiate the conceptions being used in the two domains, the term *ontology* in philosophy is used in the singular, whereas in information sciences, the term is plural—*ontologies*.

According to philosopher Willard Quine, ontology involves *ontological commitments*, that is, the ontological presuppositions embodied in different scientific theories. For example, the statement that A is a body of water entails that A exists in the real world (not simply as an idea) and contains water. Therefore, given that different groups of people (e.g., scientists, software developers, teachers) have different ontological commitments (they study different things and may give different meanings to the same group of real world observations), incompatibilities in terminology inevitably arise.

In geographic information systems, each entity (represented either by points, lines, polygons, or pixels) can be associated with attribute information of objects, such as the location, height, and colors of rivers and mountains. This attribute information indicates what feature the entity actually demonstrates in the real world. A question arises when the same dataset is described by different attributes. This issue becomes critical in sharing geographic information across different organizations and people with different worldviews. The issues resulting from semantic differences are called *semantic heterogeneities*. One way to mitigate these issues is to use ontologies, which are designed to explicitly describe information



contents and to allow one to see if the information contents to be shared refer to precisely the same thing. A paradigm that is envisioned to integrate semantically heterogeneous information contents is referred as *semantic interoperability*.

For example, is a river more similar to a lake than to the sea? The degree of conceptual closeness between two terms/concepts is called *semantic similarity*. The semantic similarity between two concepts is measured generally based on the comparisons of the characteristics of a concept in respect to the characteristics of another concept. For example, a river could be considered more similar to a lake since both contain fresh water, as opposed to the sea, which contains salt water.

Semantic similarity is not symmetric and is context-dependent. The characteristic of being asymmetric means that the degree of similarity when comparing a first concept to a second concept is not identical to the degree of similarity when comparing the second concept to the first. Two concepts are semantically asymmetric when the degree of similarity between A and B differs from the degree of similarity between B and A. For example, research shows that people tend to think of a hospital as being more similar to a building than a building is similar to a hospital, because the term *building* contains a more heterogeneous group of objects; that is, a hospital is a subset of the larger set of buildings. Semantic similarity is also context-dependent, meaning that the criteria to be considered for a measurement affect the degree of similarity. For example, if the similarities among rivers, lakes, and seas are based on the salinity of water, then a river is more similar to a lake than the sea. But, if the shape of the features is to be taken into consideration, one may think that a lake is more similar to the sea than a river, in that a lake and the sea usually have a dislike shape compared to a river, which is generally formed as a linear feature. Measuring semantic similarity is crucial in information integration and retrieving relevant information. If two information sources are highly similar in a given context, one can integrate them more confidently than if they are dissimilar. Likewise, if information content is highly similar with a query (e.g., by checking the similarity between the terms used in the information content and the query), such information content can be retrieved for the users.

Ontological Foundations

The discussion above deals with terms in English; more complex problems emerge when multilingual terms are involved. In such cases, cultural differences can also play an important role. *Ethnophysiography*, a term originally coined by David Mark and Andrew Turk, attempts to investigate how and why the terms referring to the landscape and its components are used in different languages and cultures. Mark and Turk have studied geographic feature terms from different languages such as Australian, Yindjibarndi, and Najaro.

In addition to differences in language and culture, the application context of geographical data should also be considered as another important ontological element for geographical data. For example, because different cultures have different ways of gathering and making sense of real world observations, a conceptual mismatch may occur when merging geographical data at the border of two very different cultures. A “geopragmatic” view is necessary in resolving such a mismatch. Originating from a pragmatic perspective, geopragmatics emphasizes scientific concepts related to geographical models. Geopragmatics has three core aspects: dimensions, agents, and roles. Dimensions encompass the origins (provenances), uses (deployments), and effects (consequences) of a concept. Agents are referred to as the interactions among humans, machines, and the real-world geographic features themselves. Roles consist of perspectives and versions. Perspectives are method driven (e.g., a remote sensing perspective, or an image analysis perspective), while versions are epistemically driven. More specifically, an observation can have one perspective (e.g., using a particular method such as remote sensing), but because different agents, intentions, repetitions could be involved in the same observation, different versions could be produced.

Two types of boundary can be classified for describing geographic features in the real world, the bona fide boundary and the fiat boundary. For geographic features that have the bona fide sort, their boundary has been delineated with physical demarcations such as coastlines. The border of Singapore belongs to this category, in that it is an island. In contrast, the fiat sort of boundary is intuitively formulated by humans’



mutual agreements for purposes such as land administration or political subdivisions. The state of Colorado has a boundary of this sort, in that its borders do not correspond with physiographic features. In a mathematical sense, a bona fide boundary is transitive (e.g., if x is a boundary point for a line segment y , and y is the border of Singapore, then x is also a boundary point for Singapore itself), disjunctive (e.g., if x is a part of y , and y is the border of Singapore, then x is a part of the border of Singapore also), and symmetric (e.g., if y is the border of Singapore, y is also the border of the ocean that completely surrounds Singapore), while a *fiat* boundary is transitive, disjunctive, and not symmetric because a fiat boundary is considered as an intrinsic part of the feature that the boundary binds; it does not belong to the complement of the feature.

Humans perceive the world at different levels of spatial granularity or scale. Granularity is perspective-dependent, meaning that humans can think of a specific object such as lake from a very fine-grained level to a highly coarse-grained level. At the very fine-grained level, for instance humans can imagine the lake as a very large volume of water in which millions of H_2O molecules interact with each other, and at the coarse-grained level, the lake could be imagined as a dot just like it is viewed from outer space. In the geographic domain, the notion of granularity results in geographic maps being produced in different scales, or the same geographical data set can be created in multiple representations. Granularity is critical in interpreting geographical data. If the data are presented at a fine-grained level, they could reveal detailed relationships among the features involved. If the data are at a coarse-grained level, one is able to visualize the overall patterns among features, for instance, in different clusters. As granularity determines the relationships among geographic features, any formal model attempting to represent the interrelationships of geographic features should concern the granularity of the geographic space in which the features under consideration are located.

Kean Huat Soon

See also **GIScience; Interoperability and Spatial Data Standards; Mark, David M.; Object-Based Image Analysis; Ontology; Representations of Space; Scale,**

Social Production of; Semantic Interoperability; Semantic Reference Systems

Further Readings

- Agarwal, P. (2005). Ontological considerations in GIScience. *International Journal of Geographical Information Science*, 19(5), 501–536.
- Bittner, T., & Smith, B. (2002). A theory of granular partitions. *Foundations of geographic information science* (pp. 117–151). London, New York: Taylor & Francis.
- Frank, A. (1997). Spatial ontology: A geographical information point of view. In O. Stock (Ed.), *Spatial and temporal reasoning* (pp. 135–153). Norwell, MA: Kluwer.
- Gruber, T. (1993). A translations approach to portable ontology specifications. *Knowledge Acquisition*, 5, 199–220.
- Harvey, F., Kuhn, W., Pundt, H., Bishr, Y., & Riedemann, C. (1999). Semantic interoperability: A central issue for sharing geographic information. *Annals of Regional Science*, 33, 213–232.
- Mark, D., Smith, B., Egenhofer, M., & Hirtle, S. (2004). Ontological foundations for geographic information science. In R. McMaster & L. Usery (Eds.), *A research agenda for geographic information science* (pp. 335–351). Boca Raton, FL: CRC Press.
- Rodriguez, M., & Egenhofer, M. (2003). Determining semantic similarity among entity classes from different ontologies. *IEEE Transactions on Knowledge and Data Engineering*, 15(2), 442–456.
- Smith, B. (2003). Ontology. *Blackwell guide to the philosophy of computing and information* (pp. 155–166). Oxford, UK: Blackwell.
- Smith, B., & Varzi, A. (2000). Fiat and bona fide boundaries. *Philosophy and Phenomenological Research*, 60(2), 401–420.



ONTOLOGY

Spatial ontologies are formal arrangements of geographic features based on the meaning of their terms and relation to each other. Taken from the field of philosophy concerned with *ontology*, or the study of what is real in the world, the role of



ontology in geography is to formalize knowledge bases (logical structures of geographical knowledge) and to recognize, exchange, and support common geography cultures through the use of the semantics, or meanings, that groups of people assign to geographic features and spatial relations. Within the established scope of the ontology, the features imply definitions and descriptive qualities. Relations among features have a range of meanings or specific values. Although the articulation of an ontology is a largely abstract endeavor, its elements are derived from empirical investigations. Ontologies are intended to refer to the real world.

Geographers turn to the underlying ontology of a study, as it is expressed, to examine the implications of the terms and semantics of the subject. Ontologies are discussed in the geographical literature as foundations of studies and, as such, are subject to analysis to understand the limitations and motivations of those studies within their scope. Although ontology implies the acceptance of a realist philosophy, its abstractions leave the scope of the ontology open to interpretation. Concepts of ontology often appear as the transition between epistemology and methods—a key concept in geographic thought, philosophy, and theory, with implications in specific subfields of geographic practices. Geography methods aim to capture the nature (the ontology) of their subjects, while recognizing that knowledge is affected by social (epistemological) implications.

Ontology in geography has been linked to a broader recognition of diversity, in the hope of making those differences explicit and thereby enriching the knowledge base of geographic activity. This task has been accomplished by turning to the immediate realism of interconnected themes of place, environment, society, and philosophy. Ontology is used in analyses of key concepts of geography, such as networks and globalization; urbanism and agrarianism; history, economics, and culture; and nature and the environment. Social developments such as feminism and postcolonialism have been furthered by discussions of their ontology.

Ontology can be structured by geographical concepts such as scale and generalization. Geographical features are often viewed as embedded in hierarchies of scales and taxonomies of classes. Though the formations of these classes have been studied in relation to psycho-cognitive experiences,

some categorization concepts bias views of the world by “covering up” factors and agents—for example, ideas of globalization. In contrast to hierarchies of geographical extents, flat ontology explores concepts of sites as context to geographic features and relations. These sites have both stable, structuring forces and potentials for new opportunities of expression. Through processes or the activation of relations, the mutable spaces and composition of sites emerge as new potential environments. Thus, ontology can be regarded as transformative. Concurrently, however, a central concern of history and historiography in geography is fundamentally ontological: How do we conceptualize and accept what was real about the past?

Ontology appeared prominently as a core concept in geography as Marxism critiqued Aristotelian ontology; briefly stated, this argument is that no objects are just simply “out there” in the world. Instead, elements, things, structures, and systems exist within the processes, flows, and relations that create, sustain, or undermine them. To define things relationally is different from direct observation that posits features as being self-evident rather than as a product determined by history and politics. The postmodern recognition of the importance of geography led to a new interest in the ontology of geography. Embracing spatiality, temporality, and social being as a part of the material world, ontology and postmodern geography recognize social constructs as shaping and simultaneously being shaped by the empirical world.

Ontology is seen as a framework for the interaction of society and nature beyond the dualisms of man and environment. The subject matters of physical and cultural geography are regarded by many as different entities, though recent research indicates that they have much in common. Realist epistemology, or knowledge of the world, may seem to be challenged by analyzing ontology for the limitations of its objectivity rather than for how we know phenomena through cultural and social ways. For subspecialties of cultural and physical geography to interrelate, new terms of discourse must be developed with established semantic meaning that can integrate realism and relativism. Faced with new biotechnologies, for example, writers look to ontology as a way to articulate natural subjects and their social factors, that is, the blurring of the boundaries between the natural and artificial (human-made) worlds.



The realism of ontology has been criticized as privileging materialism over semantic or epistemological relations, such as ethics. Ontology provides no groundwork for ethics, which is an experience of life. The elevation of political and social access to the level of ontology, that is, to a status of what seems to be naturalized or whose relative status is purposely concealed in the world, is the subject of critical geography.

Some geographies are organized and mediated by the expression of their ontologies through technology. In geographic information science and systems, for example, ontology is applied to the clarification of concepts and the integration of data, especially from heterogeneous sources, similar to standards that clarify ambiguous concepts and terms. The corporality of experience of geography, however, may be lost or is manipulated through technological practices, such as photography. It is important to recognize that technologies such as computerized code structure social relations through their relations to social, scientific, and cultural environments.

Several methods are used for developing conceptual ontologies, including building generalizations from detailed information such as texts of applications, extracting technical concepts from domain experts, or “reverse engineering,” a method by which the ontology is formed by automatically generalizing it from the source data. Rather than trying to devise a single ontology that encompasses a wide array of viewpoints, a series of ontologies with linkages between them may be advocated to reflect contexts with a series of articulated problems of the subject domain and their potential implications.

Dalia Varanka

See also **Epistemology; Geographic Information Systems; GIScience; Mark, David M.; Ontological Foundations of Geographical Data**

Further Readings

Fonseca, F., Egenhofer, M., Agouris, P., & Câmara, G. (2002). Using ontologies for integrated geographic information systems. *Transactions in GIS*, 6(3), 231–257.

- Golledge, R. (2002). The nature of geographic knowledge. *Annals of the Association of American Geographers*, 92, 1–14.
- Kavouras, M., & Kokla, M. (2007). *Theories of geographic concepts: Ontological approaches to semantic integration*. Boca Raton, FL: Taylor & Francis.
- Kuhn, W. (2001). Ontologies in support of activities in geographic space. *International Journal of Geographical Information Science*, 15(7), 613–631.
- Smith, B., & Mark, D. (2001). Geographical categories: An ontological investigation. *Journal of Geographical Information Science*, 15, 591–612.
- Smith, B., & Mark, D. (2003). Do mountains exist? Towards an ontology of landforms. *Environment and Planning B: Planning and Design*, 30, 411–427.



OPEN GEODATA STANDARDS

Geospatial data present unique challenges due to the complexity of the organization and storage of data concerning a broad array of spatial objects collected in different formats, with different reference systems. Geospatial data storage and transmission are complicated by the storage requirements of geospatial data (archives of multiple terabytes are common), by the need to store the location of features or imagery as well as information on their spatial reference system and associated metadata, and by the increasingly common requirement that data be accessible by multiple users from a range of different platforms. The Open Geospatial Consortium (OGC) has taken the lead in the development of open geodata standards. As defined by OGC, open standards are created in an open, participatory process that is technology neutral and in which the final specification is publicly available to all parties without royalties. Open standards provide a common, publicly available framework for the storage and transmission of geospatial data that ensures data access and service interoperability while allowing for the development of distributed geospatial applications.

Successful open geodata standards are important both for data management, by ensuring ease



of data access and archiving, and for the design of interoperable geospatial services. Lack of well-known, open standards complicates the integration of data from multiple sources when data from different sources are stored in different, proprietary formats. Conversion of geospatial data between alternative formats is often difficult due to the large storage requirements of geospatial data and the processing power needed for conversion, as well as due to the complexity of geospatial data formats. Open geodata standards allow interoperability of geospatial services without the necessity of data conversion, while also encouraging the reuse of data and program components in multiple applications with standardized interfaces.

Distributed geoprocessing and Internet location-based services require the interconnection of multiple software applications and data sets. Open geodata standards provide a common framework for data access and storage, allowing developers to build seamless applications. For instance, a user could use a Web application to access vector features from a range of Web sources conforming to the Web Feature Service (WFS) standard developed by the OGC to dynamically build a vector map. Without an established standard such as the WFS, interoperability of Web services would be problematic.

Open Geospatial Consortium

The Open Geospatial Consortium (OGC) is an international member organization that has coordinated and taken the lead in the development and dissemination of open geodata standards. The OGC operates by consensus of its member organizations to refine existing standards and to develop new standards as technologies evolve. The basic framework for the OGC body of standards is outlined in the OpenGIS Abstract Specification, which provides a conceptual model for the developing body of standards.

New OGC standards, as well as revisions to existing standards, are developed through the OGC Specification Program, a consensus process that allows members to comment on proposed standards through formalized committees. The OGC cooperates with other international standards bodies such as the International Standards

Organization/Technical Committee 211 (ISO/TC 211) in developing geodata standards. Several OGC standards have been adopted by ISO/TC 211, including the OpenGIS Simple Features Interface Standard (SFS), also published as ISO 19215, that specifies a common representation of features (such as points, lines, and polygons) within GIS systems. The SFS uses “well-known text” and “well-known binary” formats to represent the basic geometry of features. These open formats provide a common interface for software developers to exchange and store data that can be accessible in multiple applications. The standard also defines basic spatial operations, such as “intersects,” “contains,” and “overlaps,” to standardize geoprocessing procedures on these features.

The OGC has also developed a set of standards for Web services for accessing and displaying geospatial data on the World Wide Web. The Web Map Service provides a common framework for developers of Web applications returning maps in a raster format. The Web Feature Service provides for the return of vector data, while the Web Coverage Service provides a uniform standard for the return of raster data such as satellite imagery, or digital elevation models as coverages.

International Standards Organization/ Technical Committee 211

The International Standards Organization/Technical Committee 211 (ISO/TC 211) is the ISO committee responsible for the development and implementation of international standards concerning geospatial data. ISO/TC 211 oversees the development of the ISO 191** family of standards relating to the acquisition, management, transmission, and display of geospatial data. Though the work of ISO/TC 211 is not aimed explicitly at the development of open standards, it works closely with the OGC, and several standards have been concurrently adopted by both organizations.

ISO 19101:2002 outlines the Reference Model for the ISO 191** series of standards. The Reference Model describes the conceptual model by which conforming applications will interoperate and provides a framework for the ISO 191** series of standards. An important issue in geospatial data management and cataloging is the



appropriate use of metadata. To standardize metadata terminology, usage, and encoding, several ISO standards have been developed. ISO 19115:2003 and ISO 19139:2004 standardize metadata usage and encoding using well-known formats.

Alex Zvoleff

See also **Internet GIS; Interoperability and Spatial Data Standards; Open Geospatial Consortium (OGC); Open Source Geospatial Foundation; Open Source GIS; Semantic Interoperability**

Further Readings

- International Standards Organization. (2006). *Business plan* (Draft 3). Geneva: ISO Technical Committee 211.
- McKee, L. (2005). *The importance of going "Open."* Wayland, MA: Open Geospatial Consortium.
- Open Geospatial Consortium. (2008). *OGC reference model* (OGC 08-062r4). Wayland, MA: Author.



OPEN GEOSPATIAL CONSORTIUM (OGC)

The Open Geospatial Consortium (OGC) is a nonprofit international voluntary consortium of more than 370 private companies, government agencies, and academic institutions that develop publicly available, consensus-based interface specifications and interoperability standards for geospatial data. Interoperability—the ability of different systems to transparently exchange geospatial data—became a pressing concern to GIS users in the 1990s. To solve interoperability problems, the U.S. Army Corps of Engineers developed the open-source GIS software the Geographic Resources Analysis Support System (GRASS) in the early 1990s, but open systems by themselves did not prove to be a complete solution. Members of the GRASS community formed the OGC in 1994 with the vision of allowing users to access geospatial data created by others regardless of the software used.

Since its establishment, OGC has focused on developing standards for geographic information exchange. These standards are open, that is, they are technology neutral, developed by a participatory process, and with free rights of distribution.

The OGC develops standards by two methods. The Specification Program develops standards in a formal process requiring member approval. This program collaborates with the International Standards Organization and the Federal Geographic Data Committee. The Interoperability Program is a test bed activity in which a rapid, coordinated test is performed on a proposed interface standard in an open environment to refine solutions for OGC specifications.

The OGC has developed the Open GIS Abstract Specification, a suite of conceptual models to guide development of individual implementation specifications. The abstract specification includes topics such as spatial referencing, locational geometry, metadata, earth imagery, and so on. The OGC has released several widely adopted implementation standards that specify encodings for the request of raster coverages, features, and maps from distributed servers over the Internet. The OGC has also adopted Google's Keyhole Markup Language (KML) as a standard for users to create annotations and visualizations for online and mobile maps and Earth browsers.

The OGC has provided support for interoperability test beds, for example, a 2008 Canadian Geospatial Data Infrastructure interoperability project whose main objective was to test how open standards could improve collaboration among data producers and users from Canada's local, provincial, and national governments; nongovernmental organizations; and private companies.

Semantic interoperability, that is, a means for assessing the content and meaning of items encountered on the Web, is an important enabling technology for the next generation Internet. In 2006, the OGC conducted an experimental project on geospatial ontology and is developing an ontology framework and reference model.

Barbara S. Poore

See also **Geospatial Industry; Geospatial Semantic Web; Open Geodata Standards; Open Source Geospatial Foundation; Open Source GIS**



Further Readings

- Geoconnections, Natural Resources Canada. (2008). *Canadian geospatial data infrastructure interoperability pilot project*. Ottawa, Ontario, Canada: Author. Retrieved May 28, 2009, from www.geoconnections.org/en/communities/developers/technologies/fa=developersCorner.cgdiv2
- Open Geospatial Consortium: www.opengeospatial.org
- Open Geospatial Consortium. (2005). *The OGC abstract specification. Topic 0: Abstract specification overview*. Ottawa, Ontario, Canada: Author. Retrieved May 28, 2009, from http://portal.opengeospatial.org/files/?artifact_id=5659
- Open Geospatial Consortium. (2006). *Geospatial semantic web interoperability experiment report*. Retrieved May 28, 2009, from http://portal.myogc.org/files/?artifact_id=15198
- Open Geospatial Consortium. (2009). *FAQ-OGC and "openness."* Retrieved May 28, 2009, from www.opengeospatial.org/ogc/faq/openness/#2



OPEN-PIT MINING

Open-pit mining, also called opencast, open-cut, strip mining, or quarrying, is a mechanical extraction method that dates back to over 3,000 years. Ancient mines include the Tongling copper mine of China's mid Shang Dynasty 3,300 $\pm$ 60 years ago and some potential United Nations Educational, Scientific and Cultural Organization World Heritage sites—Mitterberg in Austria and the Timna mine from ancient Egypt (now located in Israel). Quarrying refers to opencast mining that extracts building materials, such as granite, limestone, marble, and slate. The method extracts resources occurring close to the surface or deeper formations that are structurally unstable or too friable to make tunneling possible. Commonly mined minerals include bauxite, copper, diamonds, gold, gypsum, kaolin, lead, manganese, nickel, phosphate, and zinc. The largest resource mined is coal, which also produces the greatest amount of solid waste.

With the rise of the Industrial Revolution, there was an urgent need for coal and iron ore, which fueled massive growth of mining. As technology

advanced, there was recognition that other metals could be of use, such as titanium, aluminum, and platinum. Peasant populations moving to cities to take advantage of new industrial jobs required greater coal extraction for electricity generation and iron ore for the building of urban infrastructure. Human wealth increased, creating a demand for gold and diamonds. As a consequence of this growth, mines expanded into huge operations, such as the Bingham Canyon copper mine in Utah, which is the largest excavation in the world, measuring 790 m (meters; 2,590 ft. [feet]) deep and 3.7 km (kilometers; 2.3 miles) wide. The mined-out, open-pit Big Hole diamond mine in Kimberley, South Africa, reached a depth of more than 1,000 m (3,300 ft.). Some of the largest opencast mines in the world are the Cerrejon coal mine in Colombia and the Grasberg-Erstberg copper mine in Indonesia, which extracts 0.24 million tons of copper ore every day.

Surface vegetation, soil material, or overburden covering the ore-bearing horizon is stripped off by earth-moving equipment, such as bucket wheel excavators, stripping shovels, and walking draglines. Rock material is broken up by explosives, and mechanical shovels separate minerals from gangue. Blasting may be preceded by drilling holes into rock to implant explosives. In coal mining in hilly terrain, overlying material is stripped following the contours around the hillside or removed off the mountaintop to expose the underlying coal seams. Deposits are mined along benches, steps, or terraces cut along the wall of the excavation. Minerals are transported by truck or train to undergo further processing. This may involve the use of chemicals such as in the cyanide leach process in gold mining. The method causes marked environmental degradation.

Environmental effects of open-pit mining include erosion, sedimentation, and landslides. It has been estimated that solid waste produced by metal mining is 8,000 million tons/year. The "shoot-and-shove" mining practices of coal mining in the Appalachian Mountains of the United States have caused widespread environmental devastation. The rock overburden above the coal seams is blasted away and then pushed into the valleys, infilling streams, and destroying river ecosystem. Hydraulic mining, in which high-pressure water is aimed at hillslopes to loosen the sediments



Open-pit gold mining at the St. Elizabeth Gold Mine, Mahdia, Guyana, in 2009

Source: Fenda A. Akiwumi.

in which the gold is contained, is commonly practiced in gold mining in developing countries. This technique leads to unstable hillslopes and enhanced erosion and sedimentation of nearby streams. Tailings from gold ore processing end up in artificial ponds and may be toxic due to the use of hazardous chemicals or associated gangue minerals such as arsenopyrite (see the second photo). Mercury is also commonly used in the extraction of gold, and approximately 3,000 tons of this toxic chemical has found its way in the past 15 years into the Amazon River due to mining activities. This has led to contamination of the environment, and biomagnification and bioaccumulation increased the toxicity of the mercury for the wildlife in the basin.

The Red Dog mine in Alaska is by far the largest producer listed in the U.S. Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI) with 615 million lb. (pounds). It is the largest zinc mine in the world and a significant source of lead production. The six largest producers

listed by EPA on the TRI are all mining operations (102–144 million lb.). The largest superfund site in the United States is the Yankee Doodle tailings pond in Montana, with a 600-ft.-high tailing pond dam, the result of copper mining in the state. Church Rock Mine in Arizona released 94 million gallons of slurry (pH 1.6) containing radon, thorium, and uranium into the Peurco River in 1979. On the day of the spill, the river had 13,000 pc/L (picocuries/liter), when the recommended limit for drinking water is 30 pc/L. The Grasberg-Ertsberg mine in Indonesia dumps 0.2 million tons of tailings into the Ajkwa River every day, causing aggradation of the coastal floodplains.

Human health effects are related to breathing in airborne particulates generated during extraction or toxic waste leaching into drinking-water supplies. The particulates (less than particulate matter 10 [$<PM_{10}$]) from coal mining can lead to respiratory illnesses such as asthma in



Tailings pond at the St. Elizabeth Gold Mine, Mahdia, Guyana, in 2009

Source: Fenda A. Akiwumi.

small children, although little research exists on this matter. Heavy exposure to coal dust has been shown to lead to black lung for miners. Mercury forms an amalgam with gold, and miners burn off the mercury, thereby breathing in the vapors leading to Minamatta Disease.

Mining companies are expected to prepare environmental impact statements prior to mining and land reclamation to rehabilitate land destroyed by mining. Both areas are not adequately addressed in mining ventures worldwide. Federal legislation such as the Surface Mining Control and Reclamation Act of 1977 in the United States, for example, requires reclamation of surface lands affected specifically by coal mining operations but not other forms of surface mineral extraction. The high cost of rehabilitation strategies and resources to ensure enforcement of laws and regulations prohibits effective enforcement.

*Fenda Aminata Akiwumi
and Philip Edward van Beynen*

See also **Coal; Environmental Restoration; Heavy Metals as Pollutants; Land Degradation; Minerals; Mining and Geography; Strip Mining; Wastewater Management**

Further Readings

- Chiras, D. D., & Reganold, J. P. (2009). *Natural resource conservation* (10th ed.). Reading, MA: Addison-Wesley.
- Hartman, H. L. (Ed.). (1992). *SME mining engineering handbook* (2nd ed.). Littleton, CO: Society for Mining, Metallurgy & Exploration.
- Lottermoser, B. (2007). *Mine wastes: Characterization, treatment, and environmental impacts*. Berlin, Germany: Springer.



OPEN SOURCE GEOSPATIAL FOUNDATION

The Open Source Geospatial Foundation (OSGeo) is a U.S.-based not-for-profit organization that supports and promotes the use and collaborative development of open-source geospatial technologies and data around the world. OSGeo offers marketing, financial, organizational, and legal help for its projects. The mission includes advocacy and marketing and encourages the development of



business models based on Open Source GIS (OSGIS). The foundation acts as an advisory body for OSGIS software projects as well as educational material and public geospatial data development projects. Communication is based on classical methods and newer Web 2.0 tools: Wikis, issue trackers, mailing lists, Web sites, Internet Relay Chat, and blogs.

History

OSGIS-related user and developer communities have existed since the early 1980s. They expanded significantly with the advent of Internet and electronic communication. Each relevant OSGIS project had its own community, in most cases only in virtual form and without formal structures. In response to the increasing need of collective support of OSGIS software development efforts, the Open Source Geospatial Foundation was officially created in February 2006 as a not-for-profit organization.

OSGeo Projects

OSGIS-related software projects that want to become part of the foundation have to undergo an incubation phase to verify if the project conforms with OSGeo principles. Accepted projects demonstrate mature project management, with open and collaborative development and user communities. Increasingly, real-time code quality assessment systems are implemented. A review of the intellectual property of source code and documentation has been performed. OSGeo software projects include geospatial-programming libraries, desktop GIS, Web mapping/WebGIS, and metadata catalogs.

In addition to software dissemination, OSGeo aims at educational outreach. Part of the mission is to promote OSGIS training among universities and other educational institutions; OSGeo is preparing and providing training materials and teaching support released under free licenses.

Third, OSGeo promotes the use of open geospatial data formats and public access to state-collected geospatial data. In collaboration with other entities, licenses for public geospatial data are developed with adaptation to various legislations.

OSGeo Governance

OSGeo is a community-driven and distributed organization with a formal seat in the United States but legal components distributed in various countries. It consists of an elected board of directors, an executive director, elected charter members (eligible to vote for the board), and members-at-large. The members collaborate through various projects, committees, and local chapters, which represent OSGeo around the world in different countries and language groups. All projects are managed through individual project steering committees (PSCs) with PSC chairpersons serving as foundation officers.

OSGeo annually presents the Sol Katz Award for Geospatial Free and Open Source Software (GFOSS) to individuals who have demonstrated leadership in the wider GFOSS community. Recipients of the award are recognized for their significant contribution in the geospatial realm to advance open-source ideals.

Since the early days of OSGIS communities, annual conferences at national and international levels were organized. In 2006, OSGeo merged several of their community events into the “Free and Open Source Software for Geoinformatics” (FOSS4G) conference series, which is hosted each year in a different country. In addition to the common conference scheme, these conferences include a 5-minute plenary, “Lightning Talks,” and “code sprints,” where project teams get together for valuable face-to-face planning and concentrated programming time.

Markus Neteler

See also **GIS Software; Open Geodata Standards; Open Geospatial Consortium (OGC); Open Source GIS; Spatial Analysis; Spatial Data Models**

Further Readings

Hall, G. B., & Leahy, M. G. (Eds.). (2008). *Open source approaches in spatial data handling* (Advances in Geographic Information Science Series). New York: Springer.

Open Source Geospatial Foundation: www.osgeo.org



OPEN SOURCE GIS

Open Source GIS (OSGIS) is a family of GIS software packages that are published along with their respective source code, in contrast to the closed-source model of proprietary GIS packages. Usually, open-source software is understood to be also free software, that is, the source code is published under a free software license with the rights to run the program for any purpose, to study how the program works, to adapt it, and to redistribute copies, including modifications. These software licenses, including the license-free public domain, are evaluated and promoted by the Free Software Foundation (FSF, www.fsf.org) and the Open Source Initiative (OSI, www.opensource.org). OSGIS is the general concept of Open Source/Free Software applied to GIS software.

History

Software Projects

GRASS (Geographical Resources Analysis Support System) is the earliest OSGIS, which reached production status and supported both raster and vector data. It was originally developed from 1982 to 1995 by the U.S. Army Corps of Engineers and since then by the international GRASS Development Team. Initially published as public domain software, its license was changed to GNU GPL (General Public License; see www.gnu.org) in 1999, one of the commonly used Free Software licenses. The GPL ensures that modified or new source code must be published again under the GPL. In the 1990s, further desktop and server OSGIS software projects were established in various GIS sectors, including libraries (PROJ4, GDAL/OGR, GEOS, Geotools, Geoserver), Desktop GIS (Quantum GIS, SAGA GIS, uDIG, gvSIG, ILWIS), Web mapping/WebGIS (Mapserver, MapGuide Open Source, degree), spatial SQL (Structured Query Language) databases (PostGIS), geostatistics (gstat, R Project for Statistical Computing), and metadata catalogs (Geonetwork opensource).

Organizations

In 1992, several organizations were merged into the Open GRASS Foundation (OGF) with

the scope to expand private sector developments for GRASS, to manage memberships, and to recruit sponsors from government, the private sector, and academia. The spread of GIS raised the need for data sharing and interoperability. With more industrial companies joining, OGF was restructured as the Open Geospatial Consortium (OGC) in 1994 with a focus on interoperability and geospatial standards.

The increasing number of OSGIS projects led in 2006 to the creation of the Open Source Geospatial Foundation (www.osgeo.org), whose mission is to support and promote the collaborative development of open geospatial technologies, data, and educational material.

Philosophy, Development Methods, and Community

Open Source in general refers to a software development method where the source code is maintained in a public repository with a group of developers, often volunteers, working on it. After peer review of code style, functionality, and quality, software packages are regularly released under a commonly accepted software license that regulates the distribution terms ensuring free redistribution, permission of modifications and derived works, and more (see “The Open Source Definition,” www.opensource.org/docs/osd; “What Is Free Software and Why Is It So Important for Society?” www.fsf.org/about/what-is-free-software). For the end user, the promise of Open Source is to receive quality software at lower cost, which is flexible, interoperable, and free of any vendor lock-in. OSGIS software packages are developed following this philosophy. Open source software can be considered commercial like proprietary software as it is also used in commercial projects by for-profit companies offering a variety of related services.

The important OSGIS software packages are interoperable and follow industrial standards for data exchange. The geospatial industry has started to integrate OSGIS libraries into their proprietary products to improve their interoperability capabilities. Additionally, and in contrast to dominant proprietary GIS software packages, OSGIS are portable, that is, they can be operated on various computer operating systems.



OSGIS is strongly linked to the opening of the Internet to the civil society and the subsequent availability of collaborative development tools and means of electronic communication. Through this, virtual developer and user communities were formed, which strongly support the evolution of software and its documentation. In some cases, companies are also involved, even pursuing the development as the main actor.

Functionality

The relevant OSGIS software packages offer functionality comparable with proprietary GIS. As in the traditional industrial market, general-purpose tools and specialized applications are available.

Available OSGIS libraries include reprojection support, optimized spatial data storage (nontopological/topological, with integration in spatial SQL databases), and data exchange in all common and also special spatial formats. Open Source Desktop GIS offer a graphical and sometimes also command line access to spatial algorithms, including import/export of common GIS data, from GIS Web services and from global positioning systems with scopes for risk analysis and assessment, map projections, raster and vector network analysis, spatialization, and geovisualization. Processing of digital terrain model data, creation of flow maps, geocoding of raw data, map generalization, terrain analysis, viewshed analysis, as well as map algebra are supported. Vector data can be generated through digitizing from scanned paper maps or through vectorization of raster data; some OSGIS also support the analysis of topological relationships. Geostatistics are either found in dedicated software packages or through dedicated GIS interfaces to spatial classes of statistical software, which directly read from the GIS database. Further functionality includes image processing with data extraction from LiDAR (light detection and ranging) and airborne laser scanning, analysis of microwave/RADAR (radio detection and ranging) data, multispectral imagery, multitemporal imaging, stereoscopy and orthoimagery, and supervised classification of aerial and satellite data. Reduced and optimized software packages are available for mobile GIS.

Open Source Internet GIS is provided as passive Web-mapping applications or as interactive

WebGIS with the capabilities of a Web processing service.

For OSGIS metadata management, dedicated catalog systems are available, which operate as online metadata harvester and retrieval systems. They access and list spatial data hosted in-house or in remote but Internet-accessible databases through specialized protocols for metadata exchange.

Markus Neteler

See also **Geospatial Industry; GIS Software; Interoperability and Spatial Data Standards; Open Geodata Standards; Open Geospatial Consortium (OGC); Open Source Geospatial Foundation; Spatial Analysis; Spatial Data Models**

Further Readings

- Mitchell, T. (2005). *Web mapping illustrated: Using open source GIS toolkits*. Sebastopol, CA: O'Reilly.
- Neteler, M., & Mitasova, H. (2008). *Open source GIS: A GRASS GIS approach* (3rd ed.). New York: Springer.



OPEN SPACE

Open space has many meanings, at multiple and overlapping spatial scales. Globally and regionally, it may refer to the extent and condition of significant biomes, such as tropical forests and deserts. A more limited definition would include only protected areas, such as parks and nature preserves. Worldwide, according to the International Union for the Conservation of Nature, 11.6% of the globe's terrestrial surface area is protected, though a great deal more of the world's land consists of vast areas of farmland, forest, desert, grassland, tundra, and snow and ice. Typically, though, the term *open space* applies to amenity-rich lands in industrialized countries and to a lesser degree to minimally developed lands in poorer countries. Often, these open spaces are in contested areas, where development pressures lead to concerns about loss of valued open spaces.

Open-space protection and management is a vital concern, for example, in both the New York



Aerial view of Central Park in New York City. Most open spaces are largely free of industrial, commercial, and residential development and are readily accessible to the public.

Source: iStockphoto.

and Shanghai metropolitan regions. New York seeks to protect watershed and agricultural lands, while Shanghai is concerned with expanding its urban greenbelt. In the United States, and across the globe, open-space management must contend with complex questions of spatial and intergenerational equity, agricultural sustainability, housing affordability, cost-effectiveness, and ecological integrity. This entry examines the values that underlie efforts to protect and manage open space and then describes approaches to open-space protection and management through regulation, purchase of open space, and collaboration.

Definitions and Values

Definitions of *open space*—sometimes referred to as *greenspace*—vary widely, ranging from urban

parkland to wilderness areas and water bodies. Most open spaces are largely free of industrial, commercial, and residential development and are readily accessible to the public. Sometimes, that access is simply visual access—as in the case of scenic vistas of privately held, entry-restricted farmland or woodland. Generally, open space is available for various types of active recreational use, and often there are conflicts over the environmental appropriateness of different uses. In the United States, with its extensive areas of open space, environmentalists tend to favor low-impact uses, such as hiking, biking, canoeing, and cross-country skiing. Conflicts frequently arise over competing demands for recreational uses—with soccer and ball fields, equestrian trails, mountain biking, and off-road vehicles often at the center of controversy. Increasingly, the value of recreational open spaces in combating America's



obesity epidemic is being promoted. Beyond their recreational values, open spaces can act to protect streams and watersheds, provide habitat for flora and fauna, function as corridors and patches in local and regional open-space networks, and sequester carbon.

Several approaches to open-space protection and management are employed.

Regulatory Approaches

Open space can be protected very effectively through regulation. Governments can restrict or prohibit development on specific lands while permitting it in places deemed environmentally and otherwise appropriate. Strong regulatory approaches, aimed at concentrating development and limiting sprawl, are especially common in Europe.

In the United States open-space regulation is complex and highly contested, with most of it taking place at the local level, in the form of municipal and county master plans, combined with zoning and subdivision requirements. Open space is preserved, in varying degrees, by local regulatory schemes, as well as market forces that simply do not support development in particular places. State- and regional-level regulatory schemes are less common, though states such as Oregon, with its imposition of urban growth boundaries; Vermont, with its statewide land use regulatory plan; and New York and New Jersey, with regional regulatory plans for the Adirondack Mountains and Pinelands, respectively, are widely viewed as leaders.

Purchase of Open Space

Land acquisition is deployed widely in the United States by governments and nongovernment organizations. Created in 1965, the federal Land and Water Conservation Fund (LWCF) provides funds for federal, state, and local land acquisition. But congressional funding allocations under LWCF have been highly inconsistent and often very meager. Additional federal support for land acquisition comes from a raft of federal programs, including the Forest Legacy Program, the Transportation Enhancement Act and Transportation

Equity Act, and legislation supporting trails, river protection, and heritage area management. Most states have their own funding programs; indeed, densely populated states support the most robust efforts, as is the case with New Jersey's Green Acres program. Municipal and county governments—particularly in the fringes of metropolitan regions, where sprawl pressures are high—have allocated substantial funds for land acquisition. Between 1988 and 2008, as detailed in The Trust for Public Land's database, voters approved a total of 1,611 ballot measures, authorizing more than US\$112 billion for various land protection efforts. Critics of acquisition point to its high costs and argue that it does not necessarily ensure permanent protection.

Collaborative Approaches

When the Reagan presidency ushered in an era of greatly restricted government, collaborative land management approaches became imperative in the United States. Nonprofit land trusts, which have proliferated since the 1980s, buy lands and secure conservation easements, which restrict or prohibit development. Land trusts can act more quickly than governments and often purchase lands or easements that are later transferred to public agencies. Watershed conservancies are also active locally, as land managers and conservation advocates. States and localities support these diverse local efforts with various grant and incentive programs, as do the federal efforts noted above. Most states and many localities have farmland protection programs. "Smart-growth" programs, increasingly popular in recent years, deploy a set of traditional, mostly incentive-based planning techniques to concentrate development in and near urbanized regions while protecting open space and promoting affordable housing. Maryland, Pennsylvania, New Jersey, and Oregon are among the smart-growth leaders.

Given the limited availability of funds and the high costs of acquisition, governments seek to expand their capacity to protect lands through collaborative approaches. Though collaborative approaches are widespread in the United States, they encounter strong opposition from "wise-use" and property rights groups, as well as some



environmental organizations that feel government is abdicating its land management responsibilities.

Robert J. Mason

See also **Greenbelts; Landscape and Wildlife Conservation; Landscape Design; Landscape Restoration; Land Use; Land Use Planning; Parks and Reserves; Zoning**

Further Readings

- Brewer, R. (2003). *Conservancy: The land trust movement in America*. Lebanon, NH: University Press of New England.
- Fairfax, S., Gwin, L., King, M., Raymond, L., & Watt, L. (2005). *Buying nature: The limits of land acquisition as a conservation strategy, 1780–2004*. Cambridge: MIT Press.
- Mason, R. (2008). *Collaborative land use management: The quieter revolution in place-based planning*. Lanham, MD: Rowman & Littlefield.
- Randolph, J. (2004). *Environmental land use planning and management*. Washington, DC: Island Press.



ORGANIC AGRICULTURE

Organic farming is defined as producing crops without the use of synthetic chemicals in insecticides, herbicides, or fertilizer; instead, farmers rely on their knowledge of their land and soil conditions to devise their ecological farming techniques. They use many types of natural and alternative methods, such as planting two or more companion crops together so that they protect each other from pests, using green manure (which is a crop that is tilled into the soil to provide natural compost), and breaking the chain of pests by rotating crops (growing different crops in succession on the same plot of land). In addition, crops themselves tend to be more varied and diverse, so that the farmer need not depend on the success of one single monocultured crop. Instead of growing

just corn or perhaps corn and soybeans, an organic farmer may grow corn, soybeans, wheat, buckwheat, alfalfa, other vegetables, and fruits for example. In the past two to three decades, the demand for organic food has grown immensely, especially in Europe and North America.

Certified organic farming in the United States is regulated through the U.S. Department of Agriculture (USDA), which established National Organic Standards that became effective in 2002. A quick reference point to remember is being chemical-free for 3 yrs. (years). A farm may not use prohibited synthetic substances for 3 yrs. prior to certification. The USDA National Organic Standards Program accredits numerous agencies across the country that act to administer the certifications in different states. This involves on-farm inspections, careful details of farm history, written proof of procedures and methods, and detailed notes about each crop. The farmers must pay for annual certification. The certification allows farmers to sell their products more widely at the national or even international level.

Since the mid 1980s, the U.S. organic food market has increased 20% annually. This is the fastest-growing sector of food consumption. Most people remember when few organic items were available in mass-market superstores, but that has certainly changed. The year 2000 marked the first year when more organic foods were sold in mainstream supermarkets than in any other venue. In fact, nearly 80% of conventional grocery stores now carry organic food items. Organic food sales are led by fresh produce, nondairy beverages, breads and grains, packaged foods, and dairy products. Organic dairy items increased by 500% in the 1990s, as a result of consumers seeking to avoid recombinant bovine growth hormone (rBGH), a genetically engineered hormone injected to increase milk production in conventional dairy cows. Since milk is not labeled in most countries, there may be no way to avoid rBGH unless one buys organic milk, in which its use is prohibited. Consumer demand for all organic products is likely linked to consumer concerns about pesticide residues and genetically modified organisms (GMOs) in food. Indeed, several studies show significantly lower pesticide residues in organic compared with conventional food. Parental concern about food safety often



motivates parents to buy organic food for their children. Recent studies show that children who eat organic food have significantly lower levels of pesticides in their urine. The Environmental Working Group Web site used 43,000 samples to develop a list of the produce with typically higher and lower chemical residues.

Organic food labels help inform consumers about the products they purchase. Foods that meet certain requirements are allowed to display the “USDA Organic” seal. There are three designated categories for items containing organic ingredients: (1) Products labeled “100% organic” contain only organically produced ingredients. (2) The “organic” label indicates products that are at least 95% certified organic. (3) The “made with organic ingredients” label is for items with at least 70% organic components. A food item containing less than 70% organic ingredients may not be marketed as an organic food.

While farmers may use organic methods, only the certified farmers may label their products as such. So some farmers opt to use similar terms: “ecological,” “natural,” or “pesticide-free.” These may be organic food products but without certification. Farmers who sell directly to consumers build up trust and may not need certification. Direct marketing is extremely important for many organic farmers, and this includes farmers’ markets, farm stands, U-pick farms, and farms established through the Community Supported Agriculture membership. These allow consumers to have a close relationship with the person who grows their food, and these personal ties often transcend the need for any official certification.

Today, organic agriculture is modern, popular, and profitable. While historical images of organic farming convey an image of hippies and



Organic farmer Phil Foster (*left*) and horticulturist Eric Brennan inspect leaves of red chard on Foster’s diverse organic farm in San Juan Bautista, California.

Source: Scott Bauer/Agricultural Research Service, USDA.

an alternative lifestyle, now efficient organic farms represent an opportunity for farmer families to make agriculture profitable.

Leslie A. Duram

See also **Agricultural Biotechnology; Agriculture, Industrialized; Agrochemical Pollution; Agroecology; Agrofoods; Crop Rotation; Environmental Certification; Fair Trade and Environmental Certification; Food, Geography of; Genetically Modified Organisms (GMOs); Sustainable Agriculture**



Further Readings

- Curl, C. L., Fenske, R. A., & Elgethun, K. (2003). Organophosphorus pesticide exposure of urban and suburban preschool children with organic and conventional diets. *Environmental Health Perspectives*, 111, 377–382.
- Dimitri, C., & Greene, C. (2002). *Recent growth patterns in the U.S. organic foods market* (Agriculture Information Bulletin No. 777). Washington, DC: U.S. Department of Agriculture, Economic Research Service.
- Duram, L. A. (2005). *Good growing: Why organic farming works*. Lincoln: University of Nebraska Press.
- Environmental Working Group. (2008). *EWG.org, food news, shopper's guide*. Retrieved September 12, 2008, from www.foodnews.org
- Goldberg, A. (2002). *Consumers Union research team shows: Organic foods really do have less pesticides*. Retrieved May 8, 2002, from www.consumersunion.org/food/organicpr.htm
- Greene, C., & Kremen, A. (2003). *U.S. organic farming in 2000–2002: Adoption of certified systems* (Agriculture Information Bulletin No. 780). Washington, DC: U.S. Department of Agriculture, Economic Research Service.



ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD)

The Organisation for Economic Co-operation and Development (OECD) is an international forum for the coordination of economic and environmental policies among most (but not all) of the world's largest economies. Its mission is to help policy-makers facilitate economic investment, growth, and trade among member states, maintain financial stability, enhance democratic governance, and promote market-oriented development. Other goals involve fighting corruption, monitoring corporate abuse, enhancing transparency, and improving public administration. At times, it is a forum for the application of international moral suasion.

Founded as the Organisation for European Economic Co-operation in 1948 as part of the post-World War II endeavor to administer the

Marshall Plan funds, it became the OECD in 1961. It is headquartered in Paris. As the number of member states grew, reaching 30 at present (Figure 1), it incorporated non-European countries as well. Today it includes most of Europe, Turkey, the United States, Mexico, Canada, Japan, South Korea, Australia, and New Zealand. Given that these countries collectively dominate the world's economy, the OECD exerts an important influence over much of the planet. Another 25 countries have observer status, and the organization has working relations with 70 others. The OECD also maintains relations with various labor unions and nongovernmental organizations.

The primary role of the OECD is to facilitate flows of information among its member states. It has been called a *think tank*, monitoring agency, and “nonacademic university.” Toward that end, it collects internationally comparable statistics, publishes books and articles on numerous topics, issues guidelines and forecasts, monitors trends, and hosts an annual meeting in which 40,000 delegates attend. It also has a series of secretariats, directorates, and centers oriented to specific issues such as education, health care, energy, agriculture, labor and employment, technological change, fiscal policy, taxation, and so on. Representative examples of recent analyses include bio-fuels, global climate change, reforms of troubled financial markets, immigration and the globalization of labor markets, aging workers, uses of nanotechnology, the digital divide of Internet access, spam minimization, and offshore tax evasion. The goal of such efforts is to identify best practices, compare policy experiences, and find answers to common problems. Although its role is largely advisory, the information it collects and produces frequently enters into international agreements and dispute settlements, as well as academic research. Its annual budget of roughly a half billion U.S. dollars is funded by member states and reflects the size of their relative gross domestic product.

Critics of the OECD allege that it shares common neoliberal goals with similar groups such as the International Monetary Fund, World Bank, and World Trade Organization, that is, the promotion of deregulated markets that favor a few at the expense of the many.

Barney Warf

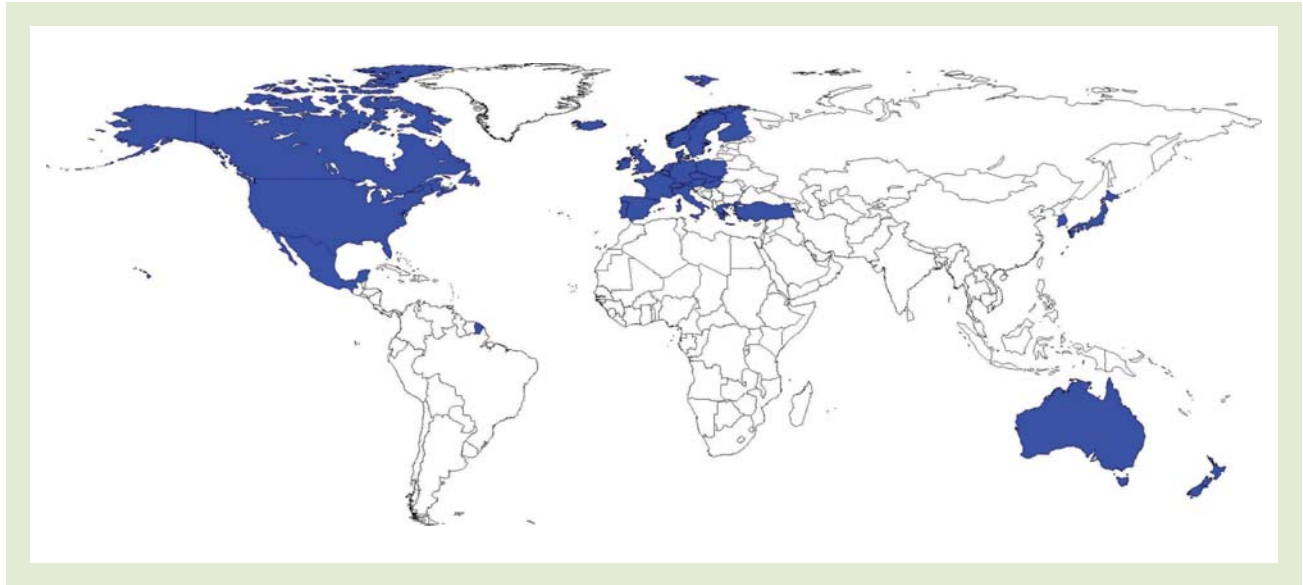


Figure 1 Map of OECD members, 2008. Starting as an organization of Western European countries as well as the United States and Canada, the OECD has expanded to 30 members worldwide.

Source: Author.

See also European Union; Globalization; International Monetary Fund; Trade; World Bank; World Trade Organization (WTO)

Further Readings

Mahon, R., & McBride, S. (2008). *The OECD and transnational governance*. Vancouver, Canada: University of British Columbia Press.
Organisation for Economic Co-operation and Development: www.oecd.org/home



ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES (OPEC)

The Organization of the Petroleum Exporting Countries (OPEC) is a cartel of 12 major oil-producing nations that was founded in September 1960. Occasionally, there are economic arrangements whereby several interdependent firms in an industry collude to set prices, output, and market share for their product or products. When this arrangement is established formally and openly,

it is called a *cartel*. While such an agreement would violate antitrust laws in the United States and other countries, because OPEC operates in international petroleum markets it is able to produce and sell oil in this manner, subject to short-term market conditions. OPEC has maintained its world headquarters in Vienna since 1965. Its ability to control international petroleum markets has varied over time, depending on demand, prices, reserve margins, and the perceived or real scarcity of oil. This entry reviews the member states, functions, and operations of the OPEC cartel, along with highlights from its 50-year history. OPEC's long-term stability is also addressed.

There are several advantages to an oil cartel. These include increased profits to the member countries and their national oil companies, decreased market uncertainty, increased price stability, and the ability to prevent entry by an unwanted competitor. It should be noted, however, that the number of member nations in OPEC has changed several times in the past two decades, and efforts to recruit Mexico and Norway as permanent members have been unsuccessful. Many economists have argued for several decades that the structural conditions of the cartel are inherently unstable, and there is incentive for some members to cheat by secretly lowering their oil



price to increase market share. Alternatively, a firm could leave the arrangement and charge less in the open market to accomplish the same goal. While such behavior has occurred among a few OPEC members, especially during the period of low oil prices in the mid to late 1980s, OPEC remains alive and well in the 21st century—its members control two thirds to three fourths of the world's proved oil reserves (though only 35%–40% of production). Moreover, demand growth for oil seems unabated, and many observers have suggested that global oil production will soon peak, if it has not already.

Member States, Functions and Operations

The original members of OPEC were Saudi Arabia, Iran, Iraq, Kuwait, and Venezuela. Between 1961 and 1975, eight other nations joined: Qatar, Indonesia, Libya, United Arab Emirates, Algeria, Nigeria, Ecuador, and Gabon. Saudi Arabia is the largest producer and controls most of the proven reserves (both for OPEC and worldwide). Somewhat consistent with economic theory, membership in the cartel has changed several times: Ecuador and Gabon left in 1992 and 1994, respectively, out of concern over the high membership fee (US\$2 million) and to expand their oil production from what was allowed by OPEC; and Indonesia withdrew at the end of 2008, having become a net oil importer and unable to meet its production quota. However, Ecuador rejoined in November 2007, and a new member, Angola, had earlier joined on January 1, 2007. In addition, Russia and Norway joined as nonpermanent members in early 2000, and other oil producers have considered joining, including Brazil, Bolivia, and Sudan.

OPEC operates under a statute that was agreed to on its formation. The oil ministers of member countries meet twice per year at the OPEC conference to determine how best to stabilize oil markets and the means to advance their interests, individually and collectively, especially the achievement of a reasonable rate of return on their investments. This has been implemented through the setting of prices and excise taxes on crude oil sales and allocation of production quotas (though Iraq has not been part of the quota agreements since March 1998). The member countries also meet periodically to discuss other matters. In some cases, OPEC will raise or lower its collective output, or that of

an individual member such as Saudi Arabia, between the ministerial meetings if it believes that oil prices are too high or too low.

History

OPEC was not formed overnight. Its origins can be traced to a 1949 meeting initiated by Venezuela to increase regular communication among the major oil producers outside the United States. The United States was the dominant global oil producer at the time, though by 1948, it began to import more oil than it exported, mostly cheap Venezuelan crude. The most accessible U.S. oil fields would be exhausted in the 1950s and 1960s. Ironically, in this environment, many large oil exporters saw their revenue streams decrease. This occurred because the U.S. oil majors lowered prices in 1959, leading to declining royalty payments on sales from foreign oil producers. More important, U.S. Presidential Proclamation No. 3279, issued by Dwight Eisenhower on March 10, 1959, established a system for granting licenses to import oil and petroleum products under the Mandatory Oil Import Program. This action forced import quotas on Venezuelan and Persian Gulf oil in favor of Canadian and Mexican sources. As a result, the five countries that would become the OPEC met in Cairo in April 1959 and in Baghdad in September 1960 and formed the cartel as a means to increase the price of oil produced on their soils. The founding members were given veto power over the admission of new members. The initial reaction of the West was skepticism regarding the ability of OPEC to influence or control oil markets, and the cartel was in fact weak until the 1970s.

A series of changes in economic and political factors in the 1960s strengthened the OPEC. These included changes in the tax system, such as increases in the excise and income taxes levied on foreign oil companies operating in OPEC nations; crude oil price increases; the separation of royalty payments from income taxes; and a reduction in deductions allowed for oil companies. A further strengthening of OPEC occurred through members nationalizing a share or even 100% of concession agreements that had previously been granted to foreign oil companies.

The political environment also gradually changed in favor of OPEC in the 1960s. First, in



the area of decolonization, Kuwait, Algeria, Nigeria, and Gabon gained independence from the United Kingdom and France in the early 1960s. Second, Israel's victory in the Six Day War against Egypt, Syria, and Jordan in June 1967 angered the Arab nations and led to the formation of the Organization of Arab Petroleum Exporting Countries as a separate, somewhat overlapping group to OPEC, which included Egypt and Syria. The culmination of these actions and events was an oil embargo by the Arab oil producers against the United States, the Netherlands, and a few other supporters of Israel from October 1973 through March 1974. Thus, the "oil weapon" was unleashed for the first time in history. Widespread panic buying, fuel shortages, and government misallocation of supplies ensued in the United States and other Western nations and Japan, which scrambled to find alternatives to imported oil.

OPEC held its greatest economic and political power from 1970 until 1986. This status can be attributed to several factors: Its largest single customer, the United States, experienced a peak in domestic oil production in 1970 and became increasingly reliant on imports; the 1973–1974 oil embargo demonstrated OPEC's considerable political muscle; a vast increase in oil revenues flowed to the OPEC nations, following an initial quadrupling in prices by 1976, plus even larger price increases in the chaos following the 1979 Iranian Revolution. Due to perceived shortages of oil, and especially more panic buying, real prices rose to record highs in 1981 (unsurpassed until 2007–2008). With the record oil prices in the first half of the 1980s, consuming nations switched away from oil-fired power plants, built and purchased more energy-efficient motor vehicles, and implemented many other conservation measures. Additionally, alternative sources of oil came on stream, including the North Sea (principally Norway and the United Kingdom), Russia, Mexico, Canada, and China, although North Sea production has been declining since 2001. Consequently, the demand for OPEC oil fell precipitously, leading to a drop in oil prices in 1986 by almost half (prices would not recover until 2000). By then, Iran was mired in a lengthy war with Iraq for regional dominance, and OPEC appeared to be in disarray.

Since the late 1980s, several OPEC members have been preoccupied with various wars, especially

Iraq. During this time, oil prices have been generally low, before the price spikes of 2007–2008. Not long after Iraq and Iran ended their 8-yr. (year) battle in 1988, Iraqi forces invaded and occupied Kuwait in August 1990, in apparent payback for Kuwait not forgiving Iraq's considerable debt amassed during its war with Iran. This, in turn, led to the U.S.-led international coalition fighting the Persian Gulf War with Iraq in early 1991. Following a lull of 12 yrs., the United States spearheaded an invasion of Iraq in 2003 (and officially claimed that the invasion was not about oil), and combat troops are still there as of 2009–2010. Despite these conflicts, the OPEC has been able to effectively maintain its function of price setting and allocation of production quotas to members, though some observers have deemed it ineffective and irrelevant. However, member nations of OPEC still control at least two thirds of the world's proved oil reserves, and a transition to alternative energy sources has been slow.

Long-Term Stability

Questions remain about OPEC's long-term stability. As noted, Iraq was at war with Iran and Kuwait in the 1980s and early 1990s, respectively. In addition, Algeria and Angola had civil wars from 1991 to 2002 and from 1975 to 2002, respectively. Given other differences between member nations, it is probably in the best interest of some countries to keep oil prices low, while others may prefer high prices. For example, a country with extensive proven oil reserves would prefer moderate prices to sustain long-term sales to major consuming nations, since high oil prices stimulate energy conservation and the development of alternative energy sources. Conversely, OPEC nations with modest reserves may prefer higher prices. Members with large reserves include Saudi Arabia, Iran, Iraq, Kuwait, United Arab Emirates, and Venezuela, while Ecuador, Angola, and Algeria have small reserves (Table 1). As for population, the more populous member nations may prefer high prices to fuel a larger economy; members in this situation include Nigeria and Iran. In the case of income levels, member nations with a low gross domestic product (GDP) per capita may also prefer higher prices to decrease poverty in their countries. On this dimension, Nigeria, Iraq, Ecuador, Angola, Algeria, and Iran would seem to prefer higher



Country	Population (in millions)	Oil Reserves (in billions of barrels)	GDP per Capita (US\$)	External Debt (US\$ billion)	% GDP
Nigeria	148.2	36.22	1,126	8.0	2.7
Iran	70.4	136.15	4,179	20.7	2.7
Algeria	33.5	12.20	4,037	4.0	1.8
Iraq	29.0	115.00	1,935	100.9	98.5
Venezuela	27.5	99.38	8,416	43.3	13.0
Saudi Arabia	24.3	264.21	15,478	58.6	10.7
Angola	17.0	9.04	3,602	8.4	8.8
Ecuador	13.6	4.66	3,282	17.1	17.3
Libya	6.2	43.66	9,260	4.8	6.5
United Arab Emirates	4.4	97.80	43,803	61.7	37.5
Kuwait	2.9	101.50	38,925	33.6	24.0
Qatar	0.9	15.21	75,426	33.1	46.3

Table 1 Profile of OPEC members

Sources: Data compiled from Central Intelligence Agency. (2008). Debt: External. In *The world factbook*. Washington, DC: Author. Retrieved December 13, 2008, from www.cia.gov/library/publications/the-world-factbook/fields/2079.html; Organization of the Petroleum Exporting Countries. (2008). *Member countries*. Vienna, Austria: Author. Retrieved December 14, 2008, from www.opec.org/aboutus.

prices. Finally, in the case of external national debt, member nations with high debt levels and debt as a percentage of GDP would seem to prefer higher prices in order to help pay off their debts. This would especially be the case for Iraq. To summarize, OPEC nations that would appear to be most interested in higher prices include Iraq, Nigeria, Algeria, Angola, and Ecuador, while nations that would appear to be most interested in lower prices include Saudi Arabia, Kuwait, United Arab Emirates, and Venezuela, with the interests of Iran, Libya, and Qatar less clear.

Barry D. Solomon

See also **Decolonization; Energy Policy; Energy Resources; Geopolitics; Petroleum; Trade**

Further Readings

Dezzani, R. (2001). Classification analysis of world economic regions. *Geographical Analysis*, 33, 330–352.

Neuburger, H. (1997). Energy use in an era of rapidly changing oil price: How OPEC did not save the world from the greenhouse effect. *Environment and Planning A*, 24, 1039–1050.

Odell, P. (1987). *Oil and world power: A geographical interpretation* (8th sub ed.). London: Penguin.

Organization of the Petroleum Exporting Countries. (2008). *Member countries*. Vienna: Author. Retrieved December 14, 2008, from www.opec.org/aboutus

Simmons, M. R. (2006). *Twilight in the desert: The coming Saudi oil shock and the world economy*. New York: Wiley.

Solomon, B. (1989). The search for oil: Factors influencing US investment in foreign petroleum exploration and development. *The Professional Geographer*, 41, 39–50.

Yergin, D. (1993). *The prize: The epic quest for oil, money & power*. New York: Free Press.



ORGANOPHOSPHATES

Organophosphates are a group of synthetic organic chemicals with some common elements in their chemical structure and the same toxic mechanism of acute toxicity. The general structure of organophosphates is characterized by a central phosphorus atom that is attached to an oxygen or a sulfur atom by a double bond and to three side chains by single bonds.



Organophosphates are mainly used as nerve gases and agricultural pesticides. In fact, organophosphate insecticides are the most extensively used pesticides for insect control in the world today. Organophosphates are also widely present in many commonly used products in modern life, such as solvents, plasticizers, flame retardants, gasoline additives, and therapeutic drugs, in both human and veterinary medicine.

All organophosphates have the same mode of toxic action for insects and mammals and can affect the nervous system by inhibiting acetylcholinesterase, an enzyme that degrades the neurotransmitter acetylcholine. Inhibition of acetylcholinesterase can result in excessive accumulation of acetylcholine at the synapses and neuromuscular junctions causing overstimulation of nerve cells. The nerve transmission will continue indefinitely and produce numerous symptoms, including slurred speech, loss of reflexes, weakness, fatigue, vomiting, headache, tremors, and eventually paralysis of body extremities and respiratory muscles.

Although some organophosphate compounds were described and synthesized in the late 1800s, organophosphate insecticides were first synthesized by Gerhard Schrader in Germany in the late 1930s and were brought to the market in 1940s. The toxic properties of organophosphates have also made them suitable agents to be developed as chemical warfare weapons. Several organophosphate compounds were developed as nerve agents and manufactured in significant quantities in Germany during World War II. However, organophosphate-based chemical weapons have rarely been used during warfare. One possible organophosphate-poisoning event in relation to war is Gulf War syndrome. After the end of the 1991 Gulf War, the U.S. and U.K. governments have conducted many studies on Gulf War veterans' illnesses. On November 17, 2008, a U.S. congressionally mandated research advisory committee has concluded that Gulf War veterans' illnesses are likely linked to exposure to neurotoxins, including a drug administered to protect troops against nerve gases and pesticides that were used against sand flies and other pests during deployment. In fact, nerve gas attack on the Tokyo subway can be considered the most well-known organophosphate-based chemical weapon event. On the morning of March 20, 1995, the Aum Shinrikyo cult carried out a sarin attack on the Tokyo

subway. This attack killed 12 people and injured more than 5,000.

Despite their high toxicity to human and wildlife health, organophosphates can break down more rapidly in the environment and persist from only a few hours to several months. Organophosphates were promoted as an attractive alternative to replace persistent organochlorine insecticides during the 1960s and 1970s. The use of organophosphate insecticides increased substantially after many organochlorine insecticides, such as DDT (dichlorodiphenyltrichloroethane), aldrin, and dieldrin, were banned in 1970s. Based on the Food Quality Protection Act of 1996, the U.S. Environmental Protection Agency has suggested that organophosphates pose the greatest risks to human health and the environment among currently used pesticides.

Mei-Hui Li

See also **Agrochemical Pollution; Agroecology; Agrofoods; Nonpoint Sources of Pollution; Pesticides; Pest Management**

Further Readings

Galt, R. E. (2008). Beyond the circle of poison: Significant shifts in the global pesticide complex, 1976–2008. *Global Environmental Change*, 18, 786–799.

ORIENTALISM

Orientalism, as an area of study, has multiple definitions: It is an academic field that seeks to study *the Orient*, as well as a term for a more general interest in all things “Oriental.” However, within geography, it is most frequently employed as a critique of these two definitions. This critique of Orientalism was first extensively developed by the famed Palestinian scholar Edward Said (1935–2003). Orientalism in this context refers to the process by which “the Orient” (the area of the Middle East, as understood by Said) has been represented in particular ways by “the Occident,” or “the West” (generally understood to be Europe and the United States), both historically and in the



present day. Orientalism reflects, and works to maintain, the political and cultural power relationships inherent in colonialism and imperialism. Within Orientalism, “the Orient” is characterized as barbaric, primitive, passive, stagnant, and feminine, while “the West” is held in direct contrast, as rational, dynamic, progressive, and masculine. These totalizing representations are not the result of individual representational constructions but can be viewed within a broader, intertextual body of literature and other texts.

This entry begins with a detailed examination of Said’s *Orientalism* (1978). As with most widely discussed ideas, Said’s review of Orientalism has a number of critiques from a diverse community of scholars. These critiques include the combination of Said’s humanism with Foucault’s anti-humanism and the problematic methodological result of this combination. Critics have also taken issue with the impossibility of escaping from the very binary that Said highlights within Orientalism, as well as his inattention to gender and sexuality within Orientalist discourse. The entry concludes with a brief synopsis of the ways in which Orientalism has been taken up by geographers within subfields of geography.

Exploring *Orientalism*

Said was influenced by a number of scholars, including Jacques Derrida and Frantz Fanon, but methodologically drew from the French philosopher Michel Foucault’s concept of discourse analysis. Said’s critique of Orientalism used this method to show how the colonization of the Orient had been enabled and justified through Orientalist discourse. While Foucault contended that the individual author was virtually insignificant in creating discursive formations, Said aimed to expose the dialectic between the author and the overarching discursive body. The texts that Said examined were primarily those of high culture from the West (largely art and literature) but united a number of seemingly disparate spheres such as policy, academic knowledge, and popular cultural production. Through his analysis, Said sought to explore the ways in which the Orient was represented as pejorative throughout history and into the modern day. He argued that Orientalism was based on an ontological and epistemological division between the West and the Orient.

Said understood Orientalism to be predicated on the separation between the Self and the Other. This separation relies not only on the assignment of difference to the Other but also a desire for that difference. Representations of the Orient and Orientals were thus shown by Said to reflect European fantasies of the exoticized Other in addition to those representations that portrayed Orientals as unskilled, infantile, and bellicose. All these representations, however, remained inherently essentialist. Using stereotypical depictions, they culturally constructed the Orient as a homogeneous whole, neglecting all nuances present in reality. Because Said saw all writing, thought, and cultural production as political, all texts were political and laced with the prevailing cultural hegemony of the time period. Said’s own lifelong political commitment to the cause of the Palestinian people was intimately bound up with his critique of Orientalism.

One of the key ideas of Said’s analysis of Orientalism is imaginative geography. Imaginative geography refers to the reconceptualization of actual, physically bounded spaces with emotionally charged definitions that exceed and extend past the realities of those spaces. Through imaginative geographies, the distances between known and unknown spaces can be reduced while at the same time the exotic and mysterious elements of foreign places are intensified. Imaginative geographies reflect the fantasies and desires of those who create them and are inscribed within systems of power. Through these constructions, space not only becomes demarcated as “ours” and “theirs” but also involves the active appropriation of space, a process that was deeply instrumental to the expansion of the colonial state, as well as current imperial projects.

Historically, essentializing representations were produced on both sides of the East/West divide; however, the expansion of European colonialism and the overwhelming assumption of power by the West resulted in the prevalence of institutional Orientalism (as opposed to Occidentalism, or stereotypes of the Western world). Over time, Orientalism moved from being a largely academic subject to being instrumental in policy making and from an alien space to a colonial one. The conception of the Orient and Oriental peoples through biological and environmental determinism resulted in the “scientific” justification of the



Oriental as backward, incompetent, uncivilized, and in need of domination and enlightenment by the West. Additionally, Orientalism's masculine worldview helped develop the Orient as static and unproductive while at the same time sensual, exotic, and feminine.

As Orientalism evolved, the Orient became something that Europe needed for its own regeneration. Said contended that the West needed the Orient to define itself in contrast to the Other and that the West gained strength through this continuous (re)definition. The (mis)representations created by Orientalism are noteworthy not because of their accuracy but because they are part of a consistent and purposefully constructed discourse of alterity. Although Said's analysis was textual, he firmly believed that these textual representations had material consequences. Orientalism relies on the inscription of meaning on spaces and places, through poetic processes, which result in the development of a discourse of difference between "us" and "them." Textual production, he argued, produced more texts that could, in time, change reality and therefore create concrete consequences. Fictionality and reality thus help inform and determine one another.

For Said, Orientalism was not simply a historic construction of textual representations but a continuing phenomenon. He argued that Orientalism has not disappeared but has been reworked in a postcolonial world now controlled largely by the United States. In his work, he argued that modern American culture continues to depict the Arab Muslim in particular and essentialist ways that help perpetuate the United States' continued project of domination over the Arab world. Said specifically addressed the Gulf War of the early 1990s, and his later work concerned the aftermath of the events of September 11, 2001.

While Orientalism has been used and critiqued widely in other fields, it has also been employed extensively in geography. Said was particularly interested in space and place and discussed geography and spatiality throughout his writings. Geographical works on Orientalism are most notably found in the works of Derek Gregory. Said's work has been foundational to postcolonial studies, and investigations of knowledge/power and colonial and postcolonial states have used the critique of Orientalism as a point of departure. The critique

of Orientalism has also been employed to highlight the essentializing nature of some textual representations in geography's subfields, such as tourism and media studies. As Said noted, however, geography as a discipline was, and in some ways potentially remains, key to the processes of colonial and postcolonial domination by the West. The discipline of Orientalism, as well as Orientalism as a process, depended on the dissemination of knowledge about distant places and peoples by objective "experts." These "experts," geographers included, acted as gatekeepers and helped legitimize and enable colonialism. Geographers have more recently acknowledged how the discipline itself, much like the discipline of Orientalism, has been complicit in the construction and maintenance of disparate power dynamics between the colonial state and its colonies.

Critiques of Said's *Orientalism*

Said's *Orientalism* was critiqued for a number of reasons. First, it was argued that Said's humanism, which is based in a Western Enlightenment tradition of humanism, could not be reconciled with Foucault's antihumanism. Said's assignment of agency to the individual author runs counter to the idea that informs it, that is, Foucault's concept of the capillaries of power. As such, it was argued that Said's methodology was inherently flawed and that he quit using his Foucauldian methodology when it interfered with his humanism.

Additionally, Said's critique of Orientalism was criticized for being simplistic. Some critics argued that in exploring the division of the world between the West and the Orient, Said not only documented but also reinforced binaries that were inattentive to more nuanced representations of peoples and places. In this vein, the critique of Orientalism did not provide space from which to break out of this dichotomous worldview. Said himself called for an alternative to Orientalism but did not elaborate on what this might look like. It has also been argued that Said gives insufficient thought to the interchanges of power and the ways in which the seemingly totalizing power held by the colonizer might be contested by the colonized, especially in localized, daily practice.

Said was also criticized for his explicit focus on British and French Orientalisms and his neglect of



other Orientalisms (e.g., German and American). He argued that this was justified because the British and French had been the most influential in the production of Orientalist discourses as well as in colonial expansion. Said's political commitment to Palestine and his interest in Egypt were undoubtedly other key components of his choice of focus on British and French Orientalisms. Other critics contended that Said neglected analysis of texts that disagreed with his thesis of the overwhelmingly dominant discourse of Orientalism. His use of texts from various time periods also led to a critique that the work was transhistorical and therefore ahistorical. His work was viewed by some as elitist in its examination of solely "high culture" and the academic discipline of Orientalism. Said never relinquished his affinity with the Western literary canon that he himself critiqued, and this also remained a point of contention among his critics.

Last, feminist scholars have noted his inattention to the place of gender within the discourse of Orientalism. While Said does discuss the feminization of the Orient, his attention to gender remained primarily in the metaphorical association of the Orient to femininity. Scholars have sought to deepen and further problematize the dichotomy between the West and the Orient, as well as to investigate the material practices and experiences of gender within Orientalism. Although it is noted that Said did open up space for the expanded exploration of gender and sexuality, it has been argued that these subjects are much more important than he made room for in his analysis. Feminist scholars have also questioned whether Said's regional and, at times, global scale of analysis undermines critiques of local institutions and politics.

Orientalism's Use Within Geographic Subfields

Said's focus on Orientalism as a phenomenon experienced only by the Middle East has more recently been extended to the former colonies, including Africa, Eastern Asia, and Australia. While much work on Orientalism has been historical in nature, geographers and other scholars continue to critically engage with the theory in a modern context. Within geography, the critique

of Orientalism has been used in a number of ways. Said's interest in literature and art has been extended by geographers concerned with other textual production such as travel writing and tourism. Within postcolonial and development geographies, the critique of Orientalism has been used to explore the ways in which essentialist representations help perpetuate relationships of dependency even within a postcolonial context.

Victoria S. Downey

See also Colonialism; Difference, Geographies of; Discourse and Geography; Gregory, Derek; Identity, Geography and; Imperialism; Other/Otherness; Postcolonialism; Race and Empire; Race and Racism; Social Darwinism; Subaltern Studies

Further Readings

- Ahmad, A. (1992). *In theory*. New York: Verso.
- Gregory, D. (1995). Imaginative geographies. *Progress in Human Geography*, 19(4), 447–485.
- Gregory, D. (2004). *The colonial present: Afghanistan, Palestine, Iraq*. New York: Wiley.
- Said, E. (1978). *Orientalism*. New York: Vintage.
- Said, E. (1981). *Covering Islam*. New York: Vintage.
- Said, E. (1993). *Culture and imperialism*. New York: Vintage.
- Varisco, D. (2007). *Reading Orientalism: Said and the unsaid*. Seattle: University of Washington Press.
- Yegenoglu, M. (1998). *Colonial fantasies: Towards a feminist reading of Orientalism*. Cambridge, UK: Cambridge University Press.



ORTELIUS (1527–1598)

Abraham Ortel (although always referred to using the Latin form, Ortelius) was born in Antwerp. He was a prominent citizen of that great trading city, and he conducted his scholarly and publishing activities from there until his death. He was one of many scholars involved in drawing and publishing maps in what was then the Spanish Netherlands (he became cosmographer to King Philip II of Spain), but his distinctive contribution



Figure 1 World map from the Theatrum Orbis Terrarum

Source: Library of Congress.



was that he was the first to produce an atlas of the world, titled *Theatrum Orbis Terrarum*, in 1570 (see Figure 1).

While there had been many collections of maps made before Ortelius, they were either updates of Ptolemy or random collections of maps copied from diverse sources and simply bound together. Ortelius's innovation lay in his overall plan for what he did: He wanted a uniform set of maps to cover the whole world as *then* (i.e., in his own time) known to Europeans. This set of maps would be compiled from all the available sources and not simply copied from whatever map was available for a particular region. This interest in having a set of maps based on the best available sources was openly indicated in the atlas in that his sources for each map are stated; and this collection of information brought Ortelius into communication with most of the geographers of his time. He also consciously set about distinguishing his contemporary maps from those that he drew to show classical civilization or the biblical lands. In making this distinction, he was the first to create a historical atlas; and eventually, he removed these historical maps into a separate atlas, the *Parergon*, in 1579, which was included in later editions of the *Theatrum*. In the *Theatrum* proper, Ortelius employed a thoroughly empirical approach to mapping; while in the *Parergon*, he adopted a different hermeneutical principle—"geography is the eye of history"—and his aim was to produce maps that would bring clarity to the study of the past and its classic, often indeed sacred, texts.

He was in close touch with another famous atlas maker of the period, Gerardus Mercator, and may have inspired aspects of the latter's work. The *Theatrum*, published originally in Latin, appeared in Dutch, German, French, Italian, English, and Spanish editions (several in the case of each of these languages) until 1624. It remained as an influence in the work of subsequent generations such as Hondius, Janssonius, and Blaeu; many of the conventions he established in the *Theatrum* remain in atlases to this day.

Thomas O'Loughlin

See also **Cartography, History of; Mercator, Gerardus**

Further Readings

- Binding, P. (2003). *Imagined corners: Exploring the world's first atlas*. London: Review.
- Goffart, W. (2003). *Historical atlases: The first three hundred years, 1570–1870*. Chicago: University of Chicago Press.
- van den Broecke, M., van der Krogt, P., & Meurer, P. (Eds.). (1998). *Abraham Ortelius and the first atlas: Essays commemorating the quadricentennial of his death 1598–1998*. Utrecht, Netherlands: HES.
- Woodward, D. (Ed.). (2007). *History of cartography: Cartography in the European Renaissance*. Chicago: University of Chicago Press.



OTHER/OTHERNESS

The classification of Other and the demarcation of Otherness refer to an identification of difference based on race, ethnicity, sex/gender, often under the guise of the exotic and the strange. This Otherness can also be understood (and experienced) as forms of marginalization and exclusion. However, Othering differs from other forms of oppression as it explicitly calls attention to the power dynamics between the person/institution, defining the "Otherness" and the person/place experiences the classification of "Other." In this entry, Edward Said's writings on Orientalism are used as a starting point for understanding how geographers working on issues of identity, urban space, power dynamics, postcolonialism and feminism approach, study, and critique the process of Othering.

Geography is drenched in imperial representations and colonial mappings of the Other. Explorations into seemingly unknown territories and populations, whether rural or urban, expose entrenched Western perspectives of geographic research. Over the past 30 years, human geography, specifically postcolonial and feminist perspectives, has critically examined the process, the placement, and the resistance generated from the position of the Other. Geographical mapping is drenched in imperial representations and colonial mappings of the Other.



The process of Othering and the demarcation of the Other are conceptually distinct yet theoretically intertwined. The process of Othering can be illustrated through Edward Said's critique of Orientalism. For Said (1979), Orientalism (generally understood as the study of "the Orient") was a "way of coming to terms with the Orient that is based on the Orient's special place in European Western Experience" (p. 1). Orientalism allowed a Western European perspective to control the image of "the Orient." It was a way to dominate, restructure, and exert authority over the Orient through the study and classification of people and places. The Orient, according to Said, was and is not a "free subject of thought or action" (p. 3). The Orient became a static object of study through the process of Othering.

Othering produced overtly generalized perceptions of particular groups of people based on behaviors associated with a stereotypical notion of place. Othering relied and relies on relational representations of the Other. The process of Othering exposes as much about the Western process of inquiry as about the object of study. Through Othering, the European culture shaped its identity and buffed what it perceived to be its strengths in relation to that which it perceived to be inadequate in "the exotic." Othering relies on subtle methodologies of power and control.

Postcolonial studies expose how certain bodies, in relation to the hegemonic notion of whiteness, are not endowed with agency and are perpetually linked to a discursive representation of place. Debates on race and culture are not the sole conceptual framework for understanding Othering. Postcolonial studies and feminist literature influenced by Simone de Beauvoir have also described the experience and placement of the disempowered Other through the constructs of colonialism, racism, and patriarchy.

In human geography, the Other is understood through discussions of space and identity. The organization of space creates spaces of marginalization and exclusion, the space of the Other. For example, legislation banning panhandling distinguishes appropriate commercial uses of the space of the sidewalk. Classifying a neighborhood as "Chinatown" creates imagery of ownership, belonging, segregation, and racialization. Geographers have examined the process of Othering

through situating the Outsider residing on the periphery of cities, countries, and social thought.

Today, most human geographers do not describe—in an Orientalist manner—detailed characteristics of the space of the Other. They critically examine and question how this demarcation of Other space and associated identities is categorized and maintained. Geographers question the process of Othering through critiquing the territorialization of space and exposing inequalities based on identity. These critiques do not explicitly use the language of the Other; instead, Othering is understood through depictions of enclosure, exclusion, and difference.

Urban geographers researching economic and legal inequalities and public claims to urban space explore Othering in the city. In addition, research conducted on national sovereignty, border anxiety, sanctuary cities, and migrant workers analyzes Othering through destabilizing the notion of territories and boundaries. Here, the concept of the Other helps destabilize concepts of territory and borders. Othering does not rely on stabilizing but forces mobility on those deemed as Other. Feminist critical race scholars and queer theorists in geography incorporate Othering into their research—from bounded spaces to a critique of heteronormative spaces, to the segregation of gendered work, to racialized identities based on place.

To fully understand the concept of Othering, one must be aware that the space occupied by those depicted as Other are not one-dimensional and neutral spaces on the periphery of society. The space of the other, the space of exclusion can be centrally visible. Similarly, the space of the Other can also be a space of resistance. A neat line between oppressor and other is not always present. Othering is also prevalent in communities that would self-classify as the Other, feminism and geography being no exception. Othering can reflect Western society at large, our discipline and personal research projects. Othering is not simply about identifying the Other as a static racialized identity. It is a process of reflection on how dominant powers represent Others.

Lisa M. Freeman

See also **Citizenship; Class, Geography and; Difference, Geographies of; Disability, Geography of; Discourse and**



Geography; Ethnicity; Feminist Geographies; Hybrid Geographies; Identity, Geography and; Nationalism; Orientalism; Postcolonialism; Queer Theory; Race and Empire; Race and Racism; Subaltern Studies

Further Readings

- Anderson, K. (1991). *Vancouver's Chinatown: Racial discourse in Canada, 1875–1980*. Montreal, Quebec, Canada: McGill-Queen's University Press.
- Browne, K. (2007). (Re)making the other, heterosexualizing everyday space. *Environment and Planning A*, 39(4), 996–1014.
- Fanon, F. (2008). *Black skin, white masks* (R. Philcox, Trans.). New York: Grove Press. (Original work published 1952)
- Haraway, D. (1991). *Simians, cyborgs, and women*. New York: Routledge.
- hooks, b. (1984). *Feminist theory: From margin to center*. Boston: South End Press.
- McKittrick, K. (2006). *Demonic grounds: Black women and the cartographies of struggle*. Minneapolis: University of Minnesota Press.
- Mohanram, R. (1999). *Black body: Women, colonialism and space*. Minneapolis: University of Minnesota Press.
- Said, E. (1979). *Orientalism*. New York: Vintage.
- Sibley, D. (1995). *Geographies of exclusion: Society and difference in the West*. London: Routledge.
- Spivak, G. (1988). Can the subaltern speak? In C. Nelson & L. Grossberg (Eds.), *Marxism and the interpretation of culture* (pp. 271–313). Chicago: University of Illinois Press.

Geographical work on outsourcing originated in the 1980s, when the Fordist system of mass production entered a worldwide crisis. The geographers Allen Scott and Michael Storper, working on industrial change in California, described the emergence of tightly interconnected networks of small firms in place of the previously integrated large businesses. Without using the term *outsourcing* directly, they described a regional pattern of firms adopting outsourcing to spread risk and contain costs. These early works introduced a spatial component in the analysis of outsourcing: The concentration of providers of outsourcing services in certain regions allowed for an easier and more efficient coordination of the production processes.

Later, the Washington Consensus of neoliberalism and the worldwide increase in international trade led geographers to shift focus from domestic to international outsourcing. Overall, they identified the distinctive character of the current phase of economic globalization as international fragmentation of production, involving a production process spread across production sites in various countries. Outsourcing and intrafirm trade within large corporations are the mechanisms allowing such fragmentation. International outsourcing is a qualitatively new phenomenon, because the earlier phases of globalization involved mostly trade of finished products.

In recent years, geographers have analyzed the economic and sociocultural consequences of outsourcing while participating in interdisciplinary schools of thought, such as (a) the Global Value Chains (GVC) Initiative, (b) the work on Global Production Networks (GPN), and (c) within the discipline, the work of economic geographers analyzing global as well as regional change.

The value chain describes the full range of activities that firms and workers perform to bring a product from its conception to its end use and beyond. The GVC Initiative investigates the global expansion of value chains through international outsourcing and direct investments, and its consequences on innovations, local firms, and labor. The work on GPN expands the analysis of value chains, arguing that “the notion of a simple single-stranded ‘commodity chain’ scarcely does justice to the complexity of the processes involved” (Jackson,



OUTSOURCING

Outsourcing refers to subcontracting a production process, or the provision of a service, to a third-party company. As a result of outsourcing, firms transfer entire business functions to external service providers. Geographers have contributed to the study of outsourcing by investigating (a) the spatial aspects of outsourcing, (b) the social and cultural effects of the trade flows generated by outsourcing, and (c) the role of outsourcing in the globalization of the economy.

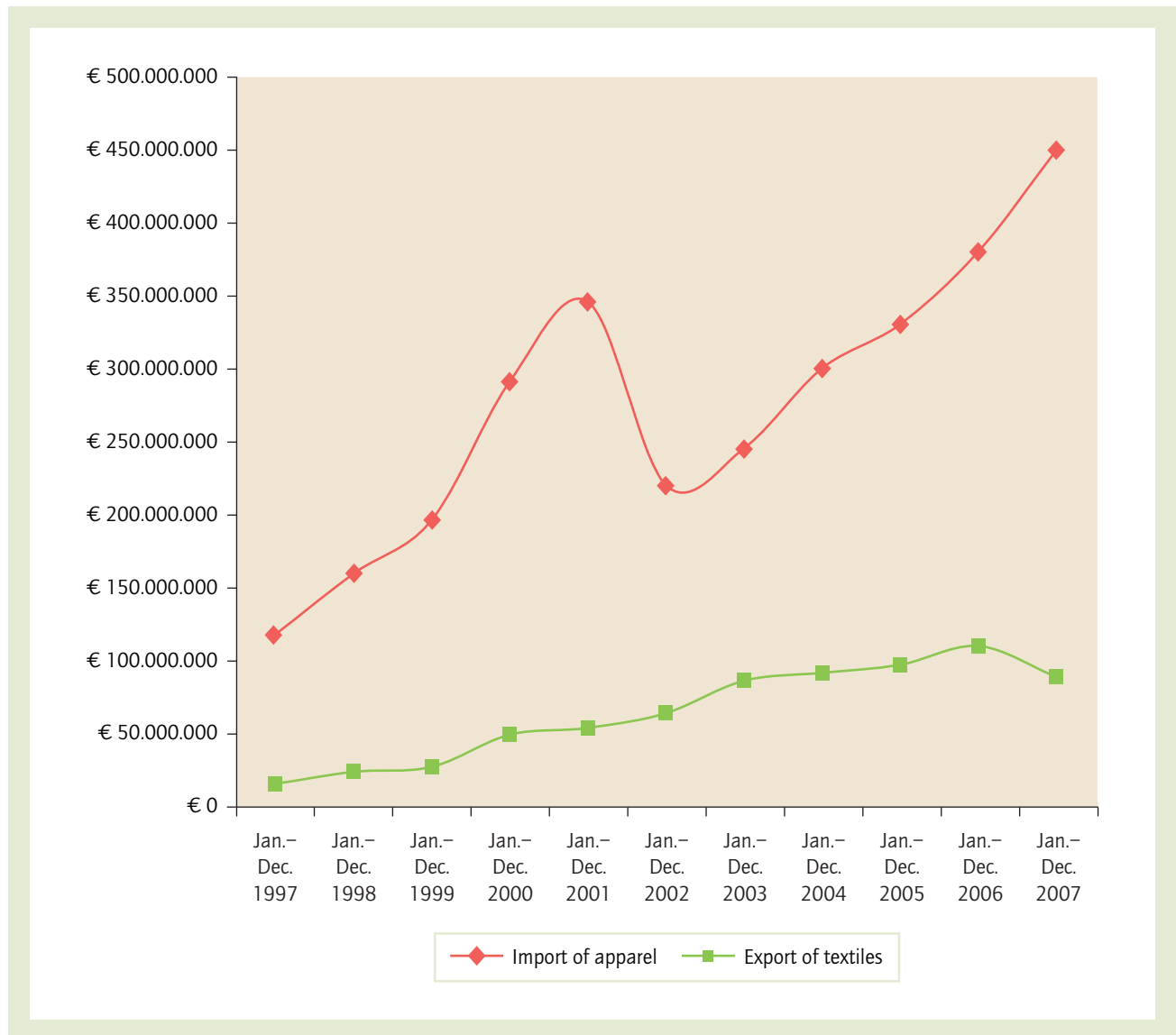


Figure 1 International outsourcing between Western Europe and Bulgaria. Firms in high-wage countries (in the table, the EU 15—the 15 Western European members of the European Union) export cloth to low- and medium-wage countries (Bulgaria). They outsource the sewing and stitching to producers in the low-wage countries and reimport the finished apparel products.

Source: Author's elaboration of COMEXT data.

Note: The data refer to knitted cloth and apparel. The values are expressed in euros.

2002, p. 6). Instead, it represents the relation among firms as complex, network-like, and regulated by a variety of institutions at different scales. One example of regional analysis is the work by John Pickles, Adrian Smith, Robert Begg, Milan Bucek, and Poli Roukova on Eastern European apparel industries. They analyzed the role of international outsourcing in revitalizing the

industry (Figure 1), its consequence on labor conditions and wages, as well as the impact of norms and regulations on the industry.

Christian Sellar

See also *Commodity Chains; Economic Geography; Flexible Production; Fordism; Globalization; Neoliberalism; Transnational Corporation*



Further Readings

- Coe, N. M., Dicken, P., & Hess, M. (Guest Eds.). (2008). Global production networks: Debates and challenges [Special issue]. *Journal of Economic Geography*, 8(3).
- Coe, N. M., Hess, M., Yeung, H., Dicken, P., & Henderson, J. (2004). Globalizing regional development: A global production networks perspective. *Transactions of the Institute of British Geographers*, 29(4), 468–484.
- Domberger, S. (1998). *The contracting organization: A strategic guide to outsourcing*. Oxford, UK: Oxford University Press.
- Global Value Chains Initiative: www.globalvaluechains.org
- Jackson, P. (2002). Commercial cultures: Transcending the cultural and the economic. *Progress in Human Geography*, 26(1), 3–18.

- Jones, R. W., & Kierzkowski, H. (2001). A framework for fragmentation. In S. W. Arndt & H. Kierzkowski (Eds.), *Fragmentation: New production patterns in the world economy* (pp. 17–34). New York: Oxford University Press.
- Overby, S. (2007, June 8). *The ABCs of outsourcing*. Retrieved December 1, 2009, from www.cio.com/article/118100/The_ABCs_of_Outsourcing
- Pietrobelli, C., & Rabellotti, R. (2007). *Upgrading to compete: Global value chains, clusters and SMEs in Latin America*. Cambridge, MA: Harvard University Press.



OVERPOPULATION

See Malthusianism; Neo-Malthusianism

P

PALIMPSEST

A palimpsest is a conceptual model of a place as a multilayered structure that emphasizes the coexistence of multiple visions and impacts of different cultures on the landscape. Originally the term referred to a type of medieval manuscript in which new text was written over previous text that had been partly erased, palimpsest has become a widespread metaphor for cultural landscapes coincidentally with the rise of interest in the symbolic properties of landscape, semiotics, and representation.

Origins of the Term

The term *palimpsest* originates from the Greek *palin* (“again”) and *psaio* (“I scrape”). The notion became a useful metaphor in the humanities and in fiction more than a century ago. It was used by scholars in humanities disciplines to depict the layering of different texts on one piece of parchment, in which subsequent layers do not erase all the traces of their predecessors. It was stressed that the earlier layers of the palimpsest did not disappear and remained visible through the more recent layers, so that one can recognize the previous layers of the text. This approach was used in architecture and urban history to describe the coexistence of material elements that originated in different historical periods in a building or urban site.

This vision was close to early-20th-century research on cultural landscape, since Carl Sauer emphasized the role of temporal change of the landscape. This notion was followed by Derwent Whittlesey’s writings on sequent occupance in the 1920s. Time passed before the vision of a landscape as multilayered came into usage in geography. The first geographer to call a landscape a palimpsest was Donald Meinig, who used the term in 1979 in the preface to his edited book *The Interpretation of Ordinary Landscapes*. What Meinig meant was that the making of the landscape is a temporal process and the landscape itself reflects some of its past properties. The historical model of landscape as a palimpsest includes the genesis of its various elements—an approach that shows that some of them remain in place for long periods of time, some have changed, some have been forgotten, others have been reinvented, and, finally, some have been totally destroyed and new elements have emerged in their place.

Symbolic Landscape as a Palimpsest

As the symbolic properties of the cultural landscape were stressed in the “new cultural geography” and emphasis was put on human interpretations and representations of a landscape, the metaphor of place as a palimpsest became popular. The emphasis in this approach was on differences in the landscape as it is “read” by social groups and individuals, differentiated



by identity, occupation, lifestyles, experience, imaginative power, and emotional factors. A palimpsest indicates that the landscape consists of different fragments of the text, which can conflict with one another. This interpretation of the term turns reading of the landscape into a process of multivocal communication and the text into an “intertext.” The *intertext*, in semiotics, is a structure of mutual references of multiple meanings; the same is true of the palimpsest in geography.

Semiotic Model of a Palimpsest

To study the relations between various layers of place as a palimpsest, the semiotic model is needed if the landscape itself is to be regarded as a text. The concept of mythogeography, which appeared in Russia in the early 2000s, suggests such a model; here, place is seen as a complex of an endless number of coexisting semiological systems. Each of these systems is one of the layers of the palimpsest, and each layer is regarded as a context, not a narrative, because it is organized around one dominant idea. Such contexts may be the geographical description of a place, place perceptions and imaginations, images and metaphors of a place, and so on. Semiotics helps analyze these layers as spatial myths, and the process of their formation is one of semiosis. The essence of this approach is in the endless interpretation of place, during which the new senses of a place emerge.

Criticisms of the Model

The model of place as a palimpsest originated in historical and cultural geography and can be described as one of several ways to describe cultural changes in a landscape. The theory of spatial diffusion is a “dynamic” alternative to the palimpsest, as the vision of a place as a sum of elements with different times of origin. Another criticism is that palimpsests represent landscapes as passive entities, only as reflections of human interpretations and perceptions. The semiological model is useful to stress the role of the landscape itself in the formation of new layers of the palimpsest.

The model of place as a palimpsest may be used in tourist destination management, marketing of territories, regional promotion, and other

activities in which the construction of new images of space and place is needed.

Ivan Mitin

See also **Cultural Landscape; Landscape Interpretation; Place; Sauer, Carl; Whittlesey, Derwent**

Further Readings

- Crang, M. (1998). *Cultural geographies*. London: Routledge.
- Meinig, D. (Ed.). (1979). *The interpretation of ordinary landscapes*. Oxford, UK: Oxford University Press.
- Mitin, I. (2007). Mythogeography: Region as a palimpsest of identities. In L. Elenius & C. Karlsson (Eds.), *Cross-cultural communication and ethnic identities* (pp. 215–225). Lulea, Switzerland: Lulea University of Technology.
- Schein, R. (1997). The place of landscape: A conceptual framework for interpreting an American scene. *Annals of the Association of American Geographers*, 87(4), 660–680.



PANCHROMATIC IMAGERY

Analog and digital sensors that acquire data from a single broad region of visible light, and sometimes from the adjacent near-infrared and ultraviolet regions of the electromagnetic spectrum, are commonly given the label *panchromatic*. The name was originally given to black-and-white photographic films that were sensitive to ultraviolet and the entire visible spectrum (*pan*, meaning “all,” and *chromatic*, meaning “colors”; both words are of Greek origin), to distinguish them from earlier black-and-white films that were only sensitive to ultraviolet and blue light. Panchromatic film was used extensively for aerial photography. In the era of digital electronic sensors, the term *panchromatic* has been retained for single-band images that represent information from a broad spectral region but not necessarily from all visible wavelengths. Panchromatic satellite images typically have relatively high spatial resolution compared with multispectral images and are useful for cartographic



Figure 1 Example of panchromatic film sensitivity and IKONOS relative responsivity. The yellow region indicates approximate wavelengths of human vision.

Source: Author.

applications and visual interpretations of land cover. Panchromatic images are sometimes also used to “sharpen” lower-spatial resolution multi-spectral images, in a procedure known as multi-resolution data fusion.

Panchromatic Film

Photography is an analog, chemical method of recording images. Silver halide crystals suspended in gelatin form an emulsion and undergo a chemical reaction on exposure to ultraviolet, violet, and blue light, thus recording the spatial patterns of light that fall on the film. However, because of the limited spectral range of the silver halide crystals, black-and-white photographs produced from this film did not provide an intuitive correspondence to human visual perception. In 1873, Hermann Carl Vogel discovered that by adding small amounts of sensitizing dye, the silver halide

crystal sensitivity to light could be extended to include green wavelengths, a type of film known as orthochromatic. Finally, in 1904, Vogel developed a dye that extended the silver halide sensitivity range to include red. The resulting black-and-white photographs were more visually intuitive than those from the earlier films, and the name panchromatic was chosen for the new film. In 1919, infrared films were developed by extending the sensitivity range even further. In contrast to all black-and-white films, including panchromatic film, color films have three emulsion layers, one for each of the red, green, and blue portions of the spectrum.

Panchromatic film is prized for its broad spectral response, from approximately 0.25 to 0.7 micrometer, and was the traditional film used in aerial photography (Figure 1). Because the atmosphere preferentially scatters shorter-wavelength light, and thus especially ultraviolet and blue light, panchromatic aerial film was



normally exposed with a yellow filter to remove the blue and the shorter wavelengths. Thus, despite the name, panchromatic aerial photography typically does not record all visible wavelengths.

A wide range of aerial panchromatic film types were produced in the past, with varying contrast, light sensitivity, and spatial resolution. In recent years, with the increased use of digital aerial sensors, many types of panchromatic aerial film have been discontinued.

Satellite-Based Sensors

During the early part of the space era, traditional photographic film was the primary medium for acquiring images of Earth, both by astronauts and by automated satellite-based sensors. Consequently, aerial film terminology was used in space-based imaging from the beginning, including for Corona, a U.S. intelligence program that was the first satellite-based Earth-imaging program. The Corona program lasted from 1960 to 1972, and the majority of Corona imagery was acquired with the equivalent of panchromatic film.

In 1972, the National Aeronautics and Space Administration (NASA) launched a terrestrial-imaging satellite, the Earth Resources Technology Satellite, which was later renamed Landsat. The Landsat program has been remarkably successful and continues to this day. A less well-known sensor on the Landsat satellite was the Return Beam Vidicon (RBV). For Landsat 1 and 2, the RBV sensor collected data in three spectral bands, but for Landsat 3, launched in 1978, the RBV sensor was redesigned to acquire just a single broad band (Table 1). Following the tradition of excluding blue wavelengths when acquiring aerial images with panchromatic film, the RBV sensor was designed not to be sensitive to blue wavelengths. Although data from the Landsat sensors were electronic signals converted to a digital format, the film term *panchromatic* was applied to the single-band RBV data.

The first satellite program designed explicitly to have an integrated combination of multispectral and panchromatic sensors was *Système Pour l'Observation de la Terre*, or SPOT. Designed by the French Centre National d'Etudes Spatiales (CNES), the SPOT-1 satellite carried a High Resolution Visible (HRV) instrument, which collected

panchromatic data with a 10-m (meter) resolution and three-band multispectral data with a 20-m resolution. SPOT 1 was launched in 1986. All subsequent SPOT satellites, up to the current SPOT 5, feature this combination of multispectral and panchromatic data, although the particular wavelengths of the panchromatic band have changed progressively between the different satellites (Table 1). For example, the SPOT-4 panchromatic band is only sensitive to red wavelengths.

A wide range of digital space-borne sensors have followed the SPOT design, with a combination of high-spatial resolution panchromatic and low-spatial resolution multispectral data. Examples include the India Remote Sensing (IRS-1C) satellite's Linear Imaging Self-Scanning sensors (LISS-III), with a 5.8-m resolution panchromatic spectral band and four bands of 23.5-m multispectral data, and Landsat 7's Enhanced Thematic Mapper Plus, with six multispectral bands with 30-m resolution, one thermal band with 60-m resolution, and a panchromatic band with 15-m resolution. The two high-spatial resolution commercial sensors, IKONOS and QuickBird, also have a combination of a high-spatial resolution panchromatic band and four lower-spatial resolution multispectral bands. Figure 1 shows that the spectral responsivity of the IKONOS panchromatic band is dominated by red and infrared, in contrast to the sensitivity of traditional panchromatic film, which includes the ultraviolet and the visible.

The combination of panchromatic and multispectral data is attractive because satellite-borne sensors are normally constrained in terms of the total information that can be acquired and communicated. Therefore, there is a trade-off between the spatial resolution (the amount of ground detail) and the spectral resolution (the number and width of the spectral bands) that can be collected by any one sensor. By acquiring a data set at high spatial resolution with just one band (low spectral resolution) and also acquiring a second data set with comparatively low spatial resolution and three or more spectral bands (of higher spectral resolution), the best of both worlds may be obtained.

Applications of Panchromatic Imagery

Panchromatic aerial photography was traditionally used for photogrammetry, especially in the



<i>Satellite</i>	<i>Launched</i>	<i>Sensor Name (if any)</i>	<i>GSD (m) Pan</i>	<i>Spectral Sensitivity (μm)</i>	<i>Number of Multispectral Bands</i>	<i>GSD (m) Multispectral Bands</i>
Landsat 3	March 5, 1978	Return Beam Vidicon (RBV)	40	0.53–0.68	0	
SPOT1	February 21, 1986	High Resolution Visible (HRV)	10	0.51–0.73	3	20
SPOT4	March 24, 1998	High Resolution Visible and Infrared (HRVIR)	10	0.61–0.68	4	20
SPOT5	May 3, 2002	High Resolution Visible and Infrared (HRVIR)	2.5	0.48–0.71	4	10
IRS1-C	May 19, 1995	Linear Imaging Self-Scanning sensors (LISS-III)	5.8	0.50–0.75	4	23.5 (70.5 for SWIR)
IRS-P5 (Cartosat)	May 5, 2005	Pan Stereo	2.5	0.50–0.85	0	—
Landsat 7	April 15, 1999	Enhanced Thematic Mapper Plus (ETM+)	15	0.52–0.90	7	30 (60 for TIR)
EO-1	November 21, 2000	Advanced Land Imager (ALI, Panchromatic band)	10	0.48–0.69	9	30
IKONOS	September 24, 1999	—	1	0.45–0.90	4	4
QuickBird	October 18, 2001	—	0.61	0.45–0.90	4	2.44
WorldView 1	September 18, 2007	—	0.50	0.45–0.89	0	—

Table 1 Characteristics of representative panchromatic bands on Earth-imaging satellites

Source: Author.

production of topographic maps. In addition, panchromatic aerial photography was used extensively for qualitative image interpretation.

Map production is also a primary application of panchromatic imagery acquired from satellites. Although panchromatic data alone are relatively rarely used in automated remote sensing land cover mapping, due to the lack of multispectral information, panchromatic data are useful for a number of spatial image analysis methods, including both automated and semiautomated road delineation. An additional use of panchromatic imagery is in multiresolution data fusion, which has become a research focus of considerable interest. Multiresolution data fusion encompasses methods that integrate the spatial detail from high-spatial resolution panchromatic data with the spectral

information from lower-spatial resolution multispectral data.

Timothy A. Warner

See also **Aerial Imagery: Data; Multispectral Imagery; Remote Sensing; Remote Sensing: Platforms and Sensors**

Further Readings

- Lillesand, T. W., Kiefer, R. W., & Chipman, J. W. (2004). *Remote sensing and image interpretation* (5th ed.). New York: Wiley.
- Toutin, T. (2009). Fine spatial resolution optical sensors. In T. A. Warner, M. D. Nellis, & G. M. Foody (Eds.), *The SAGE handbook of remote sensing* (pp. 108–122). London: Sage.



PANOPTICON

The panopticon was a prison model developed by the English social theorist and philosopher Jeremy Bentham in the late 1780s and has, subsequently, been implemented in prison design and construction around the world. The panopticon's design was such that everything (*pan*) could be seen and observed (*opticon*) at any time. Panopticism as a social theory emerged in the 1970s as a way of theorizing relationships between power, surveillance, and society. Highly influenced by Michel Foucault's famous book *Discipline and Punish*, panopticism contends that surveillance and power are intimately intertwined and manifest through particular procedures and apparatuses connected to technological inventions. Panopticism holds that these procedures, apparatuses, and technologies ultimately serve to discipline society, eliminating obfuscation through observation.

Bentham's Panopticon

Bentham is most famous for the development of the panopticon prison model, though much of his life work revolved around social reform and the advent of utilitarianism. The basic design model of the panopticon prescribed a tower in the center of the structure from which all surrounding inmate cells could be observed and noted; this tower was also kept darker than the rest of the structure. Bentham noted that this design not only enabled constant surveillance but also made inmates *feel* as if they were constantly observed, thus turning individuals into objects of surveillance instead of participants in communication. The circular aligned cells around the central observance tower allowed the warden to be omnipresent, or at least *seem* to be so. This feeling of being under constant surveillance on the part of the inmates and the sense of the warden's omnipresence exemplify the ways in which power seeped into the everyday lives of prisoners. It is this very concern on which Foucault focused.

Foucault's Panopticon

Foucault's interest in panopticism stemmed from his reading of Bentham's prison model, which he

then applied to other social institutions, such as the state, education, religion, and technology. Foucault contended that Bentham's panopticon design brought to light ideas about order and power that have long existed. In the panopticon, Foucault observed that the orbital design, which enabled inmates to be viewed at all times, meant that those people doing the viewing amass a great deal of power. In this scenario, a few people retain power, while numerous people are affected by the manifestation of such power. This same consolidation of power in which multitudes are affected by a few powerful actors, maintained Foucault, can be witnessed in myriad social institutions. Some scholars of Foucault contend that his observation of the ordering and disciplining of society emerged from a basic skepticism about modernist projects and ways of thinking.

Critical Panopticism

Foucault's panopticon reading has been influential in broader human geography discourse, especially in the critical traditions of feminism, Marxism, and poststructuralism. In feminism, heterosexuality is conceived of as a panopticon, or something due to which people discipline themselves regardless of whether their actions or lives are directly being monitored. Many women and gays fear the discriminatory heterosexual gaze, and thus, the metaphor of the closet, in which many gay people are trapped, comes into play. Marxism has been much concerned with the role of state power and surveillance in controlling classes and in consolidating power among the elites, and different trajectories of Marxist thought have expanded panopticism in numerous directions. Poststructuralists use panopticism to understand the relationships between and within subjectivity, normativity, and power, both discursively and materially. These varying critical schools of thought share the concern of how these powers and procedures are spatialized, how they affect people's interactions with and in space, and how these geographies are normalized and become part of the fabric of everyday life through careful study of the discursive and material histories of panopticon organizations.



Geospatial Technologies and Panopticons

The simultaneous increase in surveillance technology and in geographic spatial science technologies has led to new questions in surveillance studies. Scholars increasingly consider the ethical and moral dimensions of publicly available surveillance and mapping technologies. Also, the effort to spatialize the myriad types of information—that is, to be able to show information via maps and visual, spatial representations—leads to questions of for what this information will be used and whether or not people can opt out of participation from these spatial technologies. Others argue that surveillance technologies result in a lack of cohesion in neighborhoods and cities; there is no longer a need to be aware of neighbors and surrounding people, since surveillance technology is there to capture any wrongdoings. The panopticon, then, leads to order and discipline—that is, by interrupting interpersonal relationships through surveillance.

Hilary Hungerford

See also **Geoslavery; Privacy and Security of Geospatial Information; Surveillance**

Further Readings

- Bentham, J. (1995). *The panopticon writings*. London: Verso Books.
- Crampton, J., & Elden, S. (Eds.). (2007). *Space, knowledge and power: Foucault and geography*. London: Ashgate.
- Dobson, J., & Fisher, P. (2007). The panopticon's changing geography. *Geographical Review*, 97(3), 307–323.
- Foucault, M. (1995). *Discipline and punish: The birth of the prison*. New York: Random House.
- Lyon, D. (Ed.). (2006). *Theorizing surveillance: The panopticon and beyond*. London: Willan.



PARKS AND RESERVES

A *park* or *reserve* is an area that has been legally set aside for protection. The form of protection ranges from minor limitations on the use of certain materials or products to the complete exclusion of

people and communities, some of whom may have been moved from within the area designated as a park on its creation and continue to be excluded from its boundaries, to ensure complete protection of the land and resources within the park. This is a key area within the field of geography, as it involves land or ocean resources and the people who live on or use them and, as such, is a key area of people-environment interaction within the larger field of conservation. There are many forms of protection, for land, water, or biodiversity, in existence around the world today. According to the International Union for Conservation of Nature (IUCN), protected areas are land or ocean regions dedicated specifically to the protection and maintenance of biological diversity and to their associated natural and cultural resources, which are managed in some type of legal arrangement. There are many different forms of protection, however, which can be confusing, and so IUCN has also defined these various types, in terms of their level of protection, objectives, and interventions. These different types are (a) *strict nature reserve*, which is managed mainly for science; (b) *wilderness area*, which is managed mainly for wilderness area; (c) *national park*, which is managed mainly for ecosystem protection and recreation; (d) *natural monument*, which is mainly for the conservation of specific natural features; (e) *habitat/species management area*, which is managed mainly for conservation through management intervention with the purpose of ensuring the maintenance of habitats and/or to meet the requirements of specific species; (f) *protected landscape/seascape*, which is managed mainly for landscape/seascape conservation and recreation; and (g) *managed resource protected area*, which is managed mainly for the sustainable use of natural ecosystems, such as the U.S. Forest Service lands.

Global Coverage and Location of Parks

According to estimates based on these IUCN definitions of parks and reserves, there are more than 117,000 such sites, covering approximately 19 million km² (square kilometers), or approximately 4% of the Earth's surface. This is an increase in legal designations of such sites from only 9,214 in 1962, covering an area of 2.4 million km². Overall, there are approximately 20 million km² of



Earth's surface in some form of protection (some of which may not have much monitoring or effective management and so are referred to as "paper parks," reflecting the fact that while these areas appear as parks on maps or paper, they are not actively protected or managed), which represents about 15% of Earth's surface. The oceans, in contrast, have only 1 million km² in any form of protection, which represents around 0.5% of their total surface area.

Many of the world's largest parks occur in areas where the land is perhaps less suitable for other options—that is, land that is not settled or inhabited for a good reason. Such land has less worth economically speaking and was not developed, and so now it enters a park system. An example of this is the Greenland Natural Reserve, which encompasses a large area of ocean and ice caps, or the Ar Rub'al Khali Wildlife Management Area in Saudi Arabia, which encompasses a large part of the world's largest unbroken desert. In some areas, though, and increasingly with current park creation, parks are located within inhabited landscapes and on land that is more valued. In such cases, additional problems and potential conflicts can arise. Such park landscapes are often characterized by biological and sociopolitical dilemmas because of conflicts between biodiversity goals and local livelihood strategies. Throughout the developing world, parks are surrounded by landscapes that, while still containing considerable biodiversity, also have rapidly growing human populations. While areas around parks represent zones of risk and restriction, they are also potential zones of opportunity for current and potential migrant populations. This dual character of park landscapes will generate and/or intensify the distinctive patterns of land use around parks, which will in turn have important consequences for the park itself. Such conflicts will likely increase as human populations and competition for existing natural resources increase.

Development of Connected Parks or Corridors

These areas of protection are being set aside for the conservation of land, ecology, or biomes or, in some cases, to preserve a very particular

species. A major concern for conservationists, however, has been the "islandization" of parks. Increasing human populations and the expansion of agriculture are viewed as major contributing factors to this problem, whereby the park becomes an island of, for example, forest, within a larger-landscape matrix of human-dominated uses, such as various types of agriculture and settlements. Kibale National Park in Uganda is a prime example of such a situation, where the park represents a forested island within an agricultural, densely populated landscape. This park highlights many of the concerns of islandized parks, as it contains significant chimpanzee, monkey (e.g., various Colobus monkeys), and forest elephant populations within a small space on the landscape (less than 350 km²). In addition, then, to the series of parks being established worldwide, there are also other areas or reserves being established in concert, which allow connections or corridors from one park to another, as many people have begun to realize that purely islandized parks may not be the most robust solution for long-term conservation, especially for species with larger home ranges, which need to maintain diverse, healthy, and robust populations. The development of such linkages or "corridors" is still under way in many world regions as areas are created to link existing parks on the landscape to each other, often with less rigorous rules of protection but still categorized as protected in some form. In the Kibale National Park, a corridor is being developed to link this small, forested park to the larger Queen Victoria National Park to its south, although these regions differ in terms of ecosystems and species composition. Such corridor regions are expanding globally and adding to the annual increase in total land area under protection, although their success is not yet known.

Effectiveness of Parks and Reserves

There are a multitude of park and reserve forms in existence around the globe, usually with the goal of species, biome, or society conservation. Depending on the form, rules, and size of these parks, the successfulness of the venture may vary. Some parks are purely paper parks, in that while they may exist on paper in some central office



Grand Teton National Park, Wyoming

Source: Morguefile.

somewhere, there is no actual impact on the ground due to the park being there, and local communities and peoples rarely know of the park boundaries, no guards are present, and no monitoring is undertaken. At the opposite extreme is “fortress conservation,” in which there is complete exclusion of people from the park environment and the park is a restricted zone for society. Such parks can have some significant problems if a population has been excluded from it and if there are no alternative sources of goods for that population. Such parks are common throughout Africa and Asia. Due to the many different forms, rules of use, and purposes of park establishment, it is difficult to characterize the general success of park and reserve establishments.

Recent comparative studies that have attempted to evaluate the effectiveness of parks in tropical regions suggest that the creation of protected areas has had mixed outcomes. While exclusionary approaches can be successful, in some instances, at protecting forest cover, they do not account for the social ramifications of denying local inhabitants access to forest resources. Even as the area under protection continues to increase worldwide, there is an ever-greater awareness of the social consequences of creating protected areas that exclude local inhabitants from traditional ways of life. People-park conflicts are particularly acute in tropical regions, where people depend on high-biodiversity regions for their livelihood. The interest in alternative, decentralized



methods of forest management in several countries across the world can be traced to these concerns. Sustainable levels of use have been proposed as a more effective alternative, based on the argument that resources are better conserved when people can use, and therefore value, them as part of their livelihood. Thus, the trend has shifted toward encouraging decentralized, local, and participatory forms of governance in contrast to the top-down, state-centered systems of management that were extensively promoted in the 1950s. However, critics of these approaches argue that exclusionary approaches are the most effective way to conserve habitats and protect biodiversity.

A recent study by Bruner et al. evaluated the effectiveness of 93 parks in tropical regions. All the sample parks were exclusionary in their management. The study made an important contribution by attempting a broad, comparative analysis, and it concluded that exclusionary parks are successful at limiting land cover transformation when compared with the surrounding landscape. However, by focusing only on exclusionary forms of management, the research fails to consider whether alternative approaches, such as community-based arrangements, private ownership, or participatory park management, might have similar or better results. In the future, there will probably be a continued increase in park development, and many new parks may form part of a more community-based arrangement. The increasing importance of the role of private ownership within the parks and conservation arena is also expected. More studies to evaluate park and reserve effectiveness are still needed, as is the larger discourse on the type of conservation and the role it plays in the ultimate success or failure to conserve. Such studies are being undertaken and will only increase as the emphasis on the conservation of such parks and reserves continues to increase.

Jane Southworth

See also Biodiversity; Biosphere Reserves; Conservation; Conservation Zoning; Landscape and Wildlife Conservation; Patches and Corridors in Wildlife Conservation; Spatial Strategies of Conservation; Wilderness

Further Readings

- Bruner, A. G., Gullison, R. E., Rice, R. E., Gustavo, R. E., & da Fonseca, A. B. (2001). Effectiveness of parks in protecting tropical biodiversity. *Science*, 291, 125–128.
- Child, B. (2002). Review of African wildlife and livelihoods: The promise and performance of community conservation. *Nature*, 415, 581–582.
- Child, B. (2003). Review of biodiversity, sustainability and human communities: Protecting beyond the protected. *Nature*, 421, 113–114.
- Child, B. (2004). *Parks in transition: Biodiversity, rural development and the bottom line*. London: Earthscan.
- Southworth, J., Nagendra, H., & Munroe, D. K. (2006). Are parks working? Exploring human-environment tradeoffs in protected area conservation. *Applied Geography*, 26, 87–95.



PARSONS, JAMES (1915–1997)

James Jerome “Jim” Parsons was a noted cultural geographer in the tradition of Carl Sauer. He was a professor in the geography department at the University of California, Berkeley, from 1948 to 1986. He was an advisee and student of Carl Sauer, long recognized as one of the most influential modern geographers. Parsons obtained his PhD in 1948 at Berkeley and was hired to stay there. As a student of Sauer’s, and because he never left Berkeley, Parsons is often so directly linked to Sauer as to not be seen as different from his mentor.

A review of his academic work and publication record suggests that Parsons was a generalist and that the topics he researched and studied were closely aligned with the Berkeley School of geography. While advisees who completed their PhD degrees early in Parsons’s career said that their mentor’s philosophy was so closely tied to Sauer that little distinction could be made between the two, Parsons’s later students viewed him as decisively different from Sauer.



Parsons's publications show an intense interest in the "man-land" tradition of the Berkeley School, but they also indicate a substantial divergence into biogeography, especially his work on the interface between human and mammal communities and on human use of and impacts on vegetation. Examples of the former are his research on Spanish starlings and Caribbean green sea turtles. In the case of sea turtles, his 1962 book *The Green Turtle and Man* is seen as one of his most important contributions, coming at a time before the widespread international concern over species overexploitation. Parsons's work on turtles dovetails pioneering studies by the famed marine biologist Archie Carr. In that respect (and others), later students of Parsons view him as the originator of biogeography in the context of human-environment interaction, or what has been termed *cultural biogeography*.

Parsons shared Sauer's philosophy of deeply rooted and dedicated field observation. Unlike Sauer, however, Parsons turned farther from archival work and historical geography to contemporary topics that relied as much on local knowledge and practices. As president of the Association of American Geographers in 1976, Parson gave an address to the professional association that focused on his vision of geographical inquiry as "exploration and discovery." This call reflects his openness to seeking out topics in the field, learning from unorthodox sources, following up with archival research, and communicating in unobtrusive language.

Johnathan Walker

See also **Berkeley School**; **Cultural Geography**; **Sauer, Carl**

Further Readings

- Parsons, J. (1962). *The green turtle and man*. Gainesville: University of Florida Press.
- Parsons, J. (1977). Geography as exploration and discovery. *Annals of the Association of American Geographers*, 67(1), 1–16.
- Wallach, B. (1998). In memoriam: James J. Parsons, 1915–1997. *Annals of the Association of American Geographers*, 88(2), 316–328.



PARTICIPANT OBSERVATION

Participant observation is a research methodology with roots in anthropology. It has a well-established tradition in exploratory social science and geography. In practice, participant observation shares several characteristics with ethnography. One of the aims of participant observation is to uncover the everyday life of different groups within society. It is generally agreed that participant observation is a broad observational approach that is not used in isolation from other methods, such as more quantitative techniques. Participant observation has been used by geographers to explore a wide variety of populations and settings.

The methodology originated in the fieldwork of social anthropologists such as Bronislaw Malinowski, but participant observation's heritage in geography is perhaps best linked to the Chicago School of sociology during the 1920s and 1930s. Nels Anderson's classic work *The Hobo* pioneered participant observation as a research methodology in urban sociology. Anderson attempted to provide insight into and an understanding of the life of the homeless in Chicago. This tradition of seeking insight and understanding continues to this day in geography. The methodology has proved to be particularly suited to exploratory research because participant observation overcomes the potential weakness of relying on a single methodology, which may prove to be ineffective in uncovering everyday experience.

Participant observation aims to uncover the meanings and perspectives of persons living in particular places. Early definitions of the methodology talk about sharing in the daily activities, and sometimes the interests, of a group of persons. This definition has changed little over the decades. Participant observation often takes place in a case study location that has some relevance to the research question. This methodology is unique because the researcher approaches participants directly within their own environment rather than having the participants come to the researcher via, for example, a questionnaire survey. The participant observation researcher strives to uncover what everyday life is like from an "insider" perspective while remaining, inevitably, an "outsider."



Participant observation has been claimed to represent a uniquely humanistic, interpretive methodology, as opposed to the positivist tradition. The methodology usually shares the following characteristics. First, there is an emphasis on exploring the nature of a social phenomenon rather than testing a hypothesis. Second, participant observation research usually takes place over an extended period of time, often several months to years. Third, the methodology uses a wide range of unstructured data, such as verbatim quotes from participants and key informants. Fourth, the exploration usually focuses on a small number of persons and is often in the format of a case study. Last, analysis of the data involves interpretation of the meanings of human behavior and actions. The written product is often descriptive, with a rich use of quotes and photographs. Traditionally, quantitative data were either nonexistent or played a limited role. Today, this is changing, with a greater focus on the use of mixed methodologies that do not exclude the use of qualitative or quantitative data. Participant observation is increasingly experiencing something of a renaissance within social science, although it also continues to be subject to critical scrutiny and revision. Most qualitative researchers using participant observation methodology agree that the key to validity is clarity. This clarity can be framed within a set of previously established criteria to test the reliability of a particular exploration.

Perhaps one of the best examples of the use of participant observation in geography is David Ley's monograph on the black inner city as a frontier outpost. Using a wide range of techniques, he explored the variety of images of a black inner-city neighborhood in Philadelphia. His techniques included an intensive 6-mo. (month) period and a more extensive 30-mo. period of participant observation, supplemented by data gathered from documentary sources and various forms of interviewing. Ley viewed the neighborhood as a frontier outpost, having an external environment of hostility and uncertainty and an internal environment that focused on connectivity and cultural separation as a means to meet the challenges imposed by the external environment.

Graham Rowles, in his study of older people's experience of space, went beyond participant

observation to become directly involved in their lives. Rather than remaining an outside observer, he became part of the experience. His research involved sharing conversations with older persons in their homes, at community meetings, and in everyday life experiences. The result was a collection of five vignettes describing the geographical experience of the elderly blended with a theoretical framework on their experiences. Rowles's intention was to foster greater understanding of how the elderly cope with changes in their environment.

More recently, participant observation has been used in geography to answer a wide range of questions concerning the meaning of space and social conflict. Feminist geographers, in particular, have found the methodology useful in exploring and rewriting geography to include the female perspective. Participant observation will no doubt continue to contribute to the geographical enterprise, particularly as the discipline explores the relationship between the human and the physical worlds in addressing environmental concerns.

Paul Rollinson

See also **Chicago School; Everyday Life, Geography and; Humanistic Geography; Interviewing; Ley, David; Phenomenology; Positionality; Qualitative Methods; Situated Knowledge**

Further Readings

- Anderson, N. (1923). *The hobo: The sociology of the homeless man*. Chicago: University of Chicago Press.
- Buttimer, A. (1976). Grasping the dynamism of lifeworld. *Annals of the Association of American Geographers*, 66, 277–292.
- Ley, D. (1974). *The black inner city as frontier outpost: Images and behavior of a Philadelphia neighborhood*. Washington, DC: Association of American Geographers.
- Rowles, G. (1978). *Prisoners of space? Exploring the geographical experience of older people*. Boulder, CO: Westview Press.
- Tuan, Y.-F. (1977). *Space and place: The perspective of experience*. London: Longman.



PARTICIPATORY LEARNING AND ACTION

Participatory development implies an approach to planning and governance that encourages and supports the two-way exchange of information between local communities and outsiders. Participatory development recognizes that community members have valuable knowledge, legitimate concerns, and a lived experience that can contribute to exploring solutions to natural resource-related issues, to planning, and, more broadly, to redressing inequality. Currently, the term is used extensively because of the widespread and growing recognition that participation of local communities in decision making is critical to achieving sustainable development. As a result, community participation has become a central precept underpinning the development agenda.

Fundamental to participatory development practice is a clearly articulated and systematic set of strategies, methodologies, and literature that facilitate community mobilization by community development intermediary organizations (CDIOs) in the execution of local-level decision making. *Participatory learning and action* (PLA) is an umbrella term used to describe these strategies and methodologies. Robert Chambers, a central figure in PLA practice, describes it as a family of approaches, methods, and behaviors to enable poor people to express and analyze the realities of their lives and conditions and then themselves plan, monitor, and evaluate their actions. PLA has been widely used in developing countries to support planning for poverty reduction and is increasingly being employed in the global North in community development projects.

PLA incorporates rapid rural appraisal (RRA), participatory rural appraisal (PRA), and participatory action research (PAR) methodologies and techniques, among others. Yet PLA also can be understood to have grown out of these other methods, each of which represents a distinct stage in the history of participatory development.

RRA was popular in the late 1970s and 1980s. It acknowledged for the first time that experts recognized the need to formally include the poorest members of society in development planning and decision making. RRA offers an approach

and a toolbox that supported development professionals in interviewing community members using low-cost and flexible qualitative research tools (primarily semistructured interviews). The information gathered from these interviews was interpreted by professionals and thus helped inform development intervention.

By the 1990s, RRA had evolved into PRA. PRA focused on development intermediaries working with local communities to identify and articulate development needs through structured group discussions, visualization tools, and other facilitated activities. PRA differed substantially from RRA approaches in that the tools used were more interactive and involved a stronger participatory component.

By the mid 1990s, participatory approaches had evolved into PLA. PLA differs considerably from its predecessors in that it focuses on achieving the full *participation* of local community members in the process of *learning* about their needs and opportunities and in the *action* required to address them. In other words, community members are not simply providers of information that may (or may not) be used to guide development; rather, they are actively engaged as agents of change and are an intrinsic component in planning, implementing, and evaluating development activities. Through interactive learning, knowledge exchange, and flexible yet structured reflection, PLA approaches seek to mobilize local communities and stimulate action that addresses issues of social injustice.

Jon Corbett

See also Countermapping; Inequality and Geography; Participatory Mapping; Participatory Planning; Participatory Rural Appraisal; Social Justice

Further Readings

- Chambers, R. (1992). *Rural appraisal: Rapid, relaxed and participatory* (IDS Discussion Paper No. 333). Brighton, UK: Institute of Development Studies.
- Chambers, R. (1994). Participatory rural appraisal (PRA): Challenges, potential and paradigm. *World Development*, 22(10), 1–17.



- Chambers, R. (1997). *Whose reality counts? Putting the last first*. London: Intermediate Technology.
- Chambers, R., & Guijt, I. (1995). PRA—five years later: Where are we now? *Forests, Trees, and People Newsletter*, 26/27, 4–14.
- Pretty, J., Guijt, I., Thompson, J., & Scoones, I. (1996). *Participatory learning and action. A trainer's guide*. London: International Institute for Environment and Development.



PARTICIPATORY MAPPING

Participatory mapping (PM) is an umbrella term for a broad spectrum of mapping activities. Based to some extent on participatory action research and countermapping, participatory mapping describes mapping projects within which agendas, approaches, processes, techniques, and control rest in some part with the people whose territories and places are being mapped. PM projects have included the mapping of environmental hazards in neighborhoods, the “green mapping” of environmental resources and natural spaces in cities, the mapping of indigenous territorial claims, mapping for resource management, and public participation in zoning and development code mapping.

Other names for PM activities include community mapping, participatory geographic information systems (PGIS), public participation GIS (PPGIS), and participatory rural appraisal (PRA). PM based on three-dimensional (3D) terrain models is called P3DM. Mapping to balance or end control of territory by outsiders is known as countermapping or remapping.

PM projects have taken place worldwide. They have been based on a variety of mapping methods, including sketch maps, 3D models, maps traced from topographic maps, maps drawn on existing base maps, maps based on aerial photographs or satellite imagery, GIS products, global positioning system (GPS) measurements, and Google Earth displays.

Approaches to PM have ranged from grassroots projects instigated, carried out, and controlled by

local groups to top-down, externally funded and controlled projects that have granted only token participation to people from the affected communities. Participation has come to suggest such a wide range of activities and levels of control that PM has recently been viewed with suspicion.

Different levels of local participation range from top-down externally controlled to bottom-up community designed and completed projects. Simply calling a project “participatory,” however, is not a sufficient way to justify a project and does not ensure an appropriate level of participation.

The following are examples of the range of local stakeholder participation:

- Top-down design and control
- Only token local participation
- All decisions made by outsiders
- Maps made by outside experts
- Tasks assigned to community members
- Local people working together with outsiders
- Outsiders and local people sharing knowledge
- Local people setting the agenda
- Local people producing project maps
- No outsiders taking part
- Bottom-up design and control

Important questions that should be asked prior to undertaking a PM project include the following: What is the purpose of the project? Who will pay for the project? What region is to be mapped? Who decides what happens? Who are the stakeholders? Who will be excluded from the process? Who sets the priorities for the project? Who are the “key” informants? Who will learn the mapping skills? How will conflicts be resolved? Who will control the results? How will the maps be disseminated? Who will maintain the maps? Who will be responsible for the future of the project?

The work flow for a typical PM project includes the following steps:

- Recognition of need
- Community request for assistance



- Organizational meetings
- Regional meetings
- Community meetings
- Training workshops
- Pilot projects
- Mapping workshops
- Ethnographic investigations
- Boundary measurements
- Land use measurements
- GIS processing
- Map production
- Ethnography publication
- Technology transfer
- Negotiation for land rights

Land claims may not be successful just because a community makes a map. Maps may have to compete in bureaucratic and judicial arenas with the maps produced by the state or by resource management agencies. Sketches, artistic depictions of place, and 3D models may be useful at various stages of a project, but PM products may have to incorporate coordinate system grids, standardized symbols, and other cartographic conventions to compete with existing maps. GIS offers PM projects the chance to produce high-quality maps that can carry significant weight in court. Some successful indigenous-community PM projects have combined accurate and technically sophisticated maps with ethnographies, drawings, and photographs, presenting a strong case for their land tenure claims.

It should be noted that participatory mapping projects have been criticized as being reductionist and too technical, elitist, and damaging to local conceptions of territory and community. The proposed PM projects can unrealistically raise community expectations. In contested places, the mapping process can expose participants to danger. Without a plan for the future, a PM project can leave a community exposed to threats from the state or from outsiders. Maps construct territory, and so the maps from a PM process can be used and misused. Putting lines on maps where none existed is both powerful and dangerous.

Lands shared by communities can be redefined as contested spaces through a PM process.

The methods selected for a PM project can change ideas of territory. Using GPS to put boundary turning points on maps can exclude distant hunting grounds or seasonal settlements. Surveyors traversing a boundary can assume that traditions of property are the same everywhere. Using existing base maps can give imbalanced weight to features included on standard topographic maps. Map legends that use official languages may have little meaning to participants.

On the other hand, PM projects can empower communities and protect local resources. Local participation can add crucial ground truth that is difficult to obtain in any other way. GPS can be an effective tool for mapping places that may never have been mapped. GIS can aid in the mapping and analysis of subsistence strategies, sacred spaces, community extents, and shared lands. A PM project that is well designed and thoughtfully carried out can combine activism, local knowledge, and community conceptions of place to define, depict, justify, and control territory in a way that can effectively claim space and counter the power of outsiders.

Peter H. Dana

See also **Coordinate Systems; Global Positioning System; Neogeography**

Further Readings

- Chapin, M., Lamb, Z., & Threlkeld, B. (2005). Mapping indigenous lands. *Annual Review of Anthropology*, 34, 619–638.
- Dana, P. H. (2008). Surveys of people and place. In J. P. Wilson & S. Fotheringham (Eds.), *Handbook of geographic information science* (chap. 28, pp. 494–518). Oxford, UK: Blackwell.
- Flavelle, A. (2002). *Mapping our land: A guide to making maps of our own communities and traditional lands*. Edmonton, Alberta, Canada: Lone Pine Foundation.
- Society for Applied Anthropology. (2003). Human organization: Participatory mapping of indigenous lands in Latin America [Special issue]. *Human Organization*, 62(4).



PARTICIPATORY PLANNING

Spatial planning systems across the world influence the places and spaces where people work and live and are deemed to operate in the public interest to ensure that land use planning and development result in more sustainable communities. This is a complex task, given the diverse nature of public, private, and community interests affected by and involved in the planning system and process. Whether it be for ensuring that development occurs where communities need it or for the protection and enhancement of the natural and historic environment and the countryside, planning affects most people. As the outcomes from planning affect everyone, it is widely recognized that community residents should have the opportunity to play a role in delivering effective and inclusive planning. Participatory planning is therefore vitally important for the achievement of sustainable development. This entry outlines the emergence of participatory planning in the 1960s and examines why the current practice of collaborative planning came about and how participatory processes operate.

During the 1960s, there was a dramatic shift in the direction of planning from a post-World War II blueprint model to that of systems analysis and control, which built on the classical work of the British planner Patrick Geddes linking cities to the functioning of ecosystems with a greater need to understand how cities worked. This paradigm focused on four dimensions of understanding the urban system: (1) the role of persistent human activities, (2) the role of human communications, (3) the role of adapted spaces, and (4) the role of communication channels. While human activities and communication channels were highlighted in these approaches, they were very technocratic, and this led to further criticism of the role of the public in planning. Jane Jacobs asserted the view that planners imposed ideals rather than understanding processes and functions. Others provided interesting critiques of these approaches and suggested that an advocacy approach was required, causing a shift in emphasis for participatory planning. The main points of these arguments were that city and regional planners could not be value-neutral technicians, as values are part of every

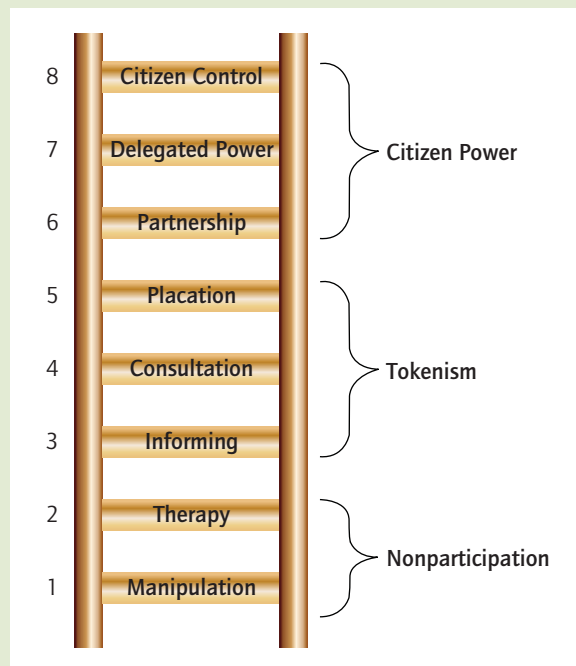


Figure 1 The eight rungs of Arnstein's participation ladder

Source: Arnstein, S. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, 35(4), 216–224.

planning process. Public planners cannot attempt to produce a plan that represents the public interest because of the diverse nature of society. Instead, it was suggested that planning should be pluralistic and should represent diverse interests. An idealized notion of participatory planning therefore needs to encourage people or stakeholders to propose their own plans, with neighborhood groups and other stakeholders involved in the plan preparation and development process.

Sherry Arnstein's famous *Ladder of Citizen Participation* (Figure 1) depicted participation as a series of rungs on a ladder. Her article argues that by recognizing these gradations it is possible to develop a clearer understanding of participation in planning. Since the publication of this article, much of the focus in planning has concentrated on process and has resolved none of the political problems that are inherent in planning. Many believe that planning is a technical discipline and that problems can be solved through a scientific understanding, with planners knowing what is best for the common interest.

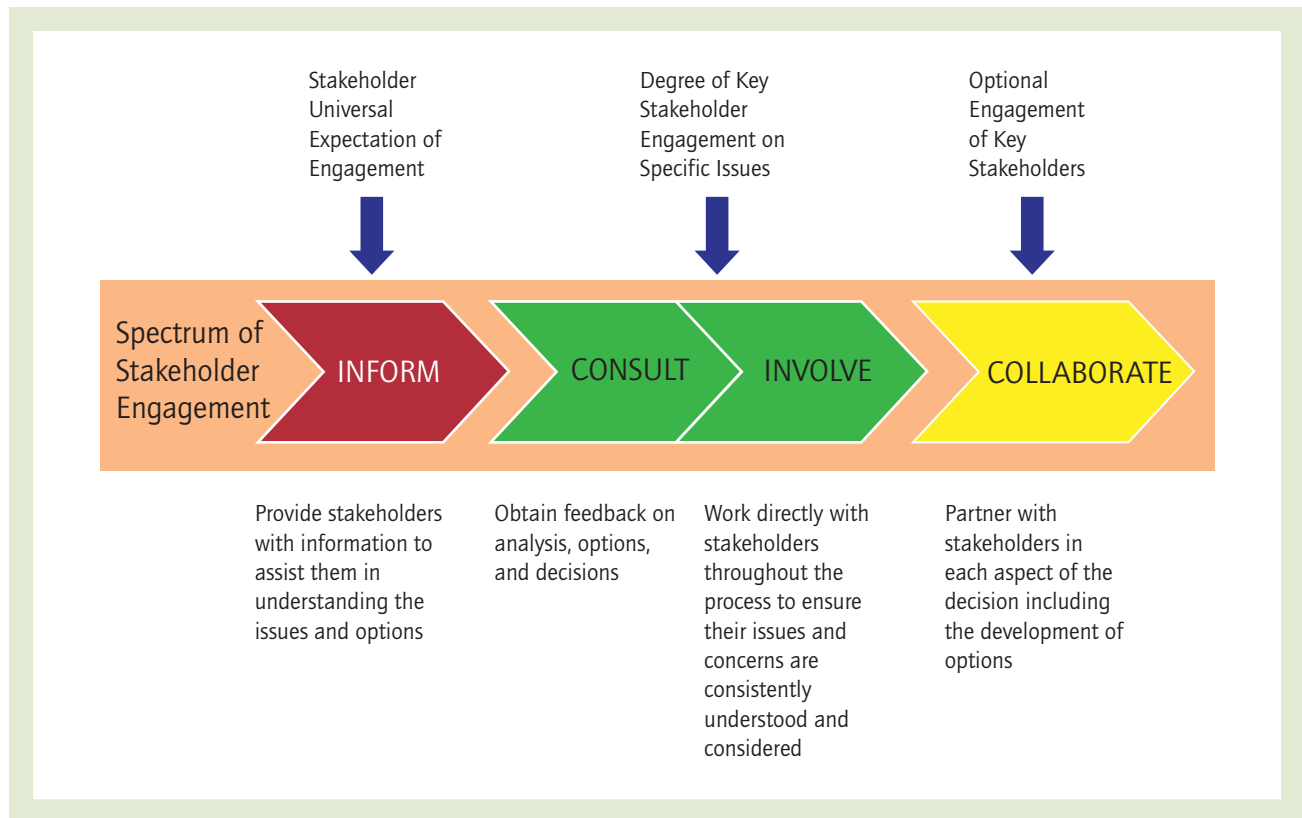


Figure 2 The spectrum of stakeholder engagement

Source: Office of the Deputy Prime Minister. (2004). *E-transformation programme: E-planning blueprint* (p. 24). London: Author.

This strategy has not worked, and during the 1980s, there was a shift toward more collaborative forms of planning.

The public participation literature is awash with nuances in terminology, with practitioners often using the following simplistic sequence to describe engagement in planning:

Consultation, through which a basic framework and scope are set and policies or proposals are drafted by the planners, while others (i.e., the community, stakeholders, etc.) are allowed to make relatively minor changes of balance and emphasis

Involvement, in which others have a greater opportunity to debate and influence policies and proposals but probably not the basic framework and scope

Participation, which ensures a more equitably balanced relationship in which others may have an opportunity to debate and genuinely influence all aspects of the process

These processes are often referred to as *collaborative planning*, *stakeholder dialogue*, *consensus building*, *social inclusion*, *holistic governance*, *community capacity building*, *developing social capital*, *partnership working*, and *collaborative advantage*. Models of participation have traditionally been, and continue to be, used to better categorize the participation in planning and planning-related processes (e.g., Figure 2). Stakeholder participation in local communities is often seen as a way in which the so-called democratic deficit of representative government can be overcome, with a greater emphasis placed on participation as an important element in government modernization.

Others have attempted to redesign Arnstein's ladder to reflect the more complicated reality of stakeholder engagement within the policy and planning process. Table 1 rearticulates the ladder in a five-variation model, removing any sense of hierarchy, whereby any of the levels



<i>Level/Stance</i>	<i>Typical Process</i>	<i>Typical Methods</i>	<i>Initiator Stance</i>
Supporting	Community development	Advice Support Funding	We can help you achieve what you want within these guidelines.
Acting together	Partnership building	Partnership bodies	We want to carry out joint decisions together.
Deciding together	Consensus building	Workshops Planning for real Strategic choice	We want to develop options and decide actions together.
Consultation	Communication and feedback	Surveys Meetings	Here are our options. What do you think?
Information	Presentation and promotion	Leaflets Media Video	Here is what we are going to do.

Table 1 Wilcox's five stances of participation

Source: Adapted from Wilcox, D. (1994). *The guide to effective participation* (p. 15). Brighton, UK: Partnership Books.

could be the correct choice depending on the individual circumstances in which participation takes place.

Further models also demonstrate the differing levels of participation that are possible while still retaining a hierarchical structure with citizen control as the pinnacle of involvement. However, as Figure 3 shows, different types of engagement are appropriate for different occasions and circumstances.

During the 1990s, the notion of collaborative planning began to emerge together with the suggestion that to understand participation in public policy it is necessary to examine the broader governance strategies that institutions may use to achieve differing levels of engagement. These can be categorized into three such strategies. First, *top-down strategies* start and finish with the government agencies that plan such schemes and the local authorities that implement them. Such initiatives occupy the therapeutic and manipulative levels of the ladder, and at best, there can be an element of negotiation. Second, *limited-dialogue strategies* involve a stronger commitment to a two-way communication process. The method and policy framework are set by national and local public bodies but with dialogue that can lead to substantial change in decisions and thinking. The final strategy is the *bottom-up strategy*.

Such a strategy is distinguished by its commitment to open discussion and the active encouragement of excluded or marginalized groups to become involved. In more recent times, the use of information and communication technologies (ICTs) to empower local communities has begun to take hold through the use of online participatory geographic information systems to complement well-established techniques such as "Planning for Real."

Participation in spatial planning has evolved over the past 40 to 50 years, but many of the early protagonists' ideas remain valid today. Despite continuing concerns by some over the potential for participation to cause delays, it has become almost universally accepted as good practice. This has more recently been reinforced by broader conceptual and ideological changes within the public policy arena, as traditional concepts of government have evolved into notions of governance and third-way politics.

Richard Kingston

See also [Community-Based Environmental Planning](#); [Governance](#); [Land Use Planning](#); [Participatory Learning and Action](#); [Participatory Rural Appraisal](#); [Public Participation GIS](#); [Urban and Regional Planning](#); [Urban Planning and Geography](#)

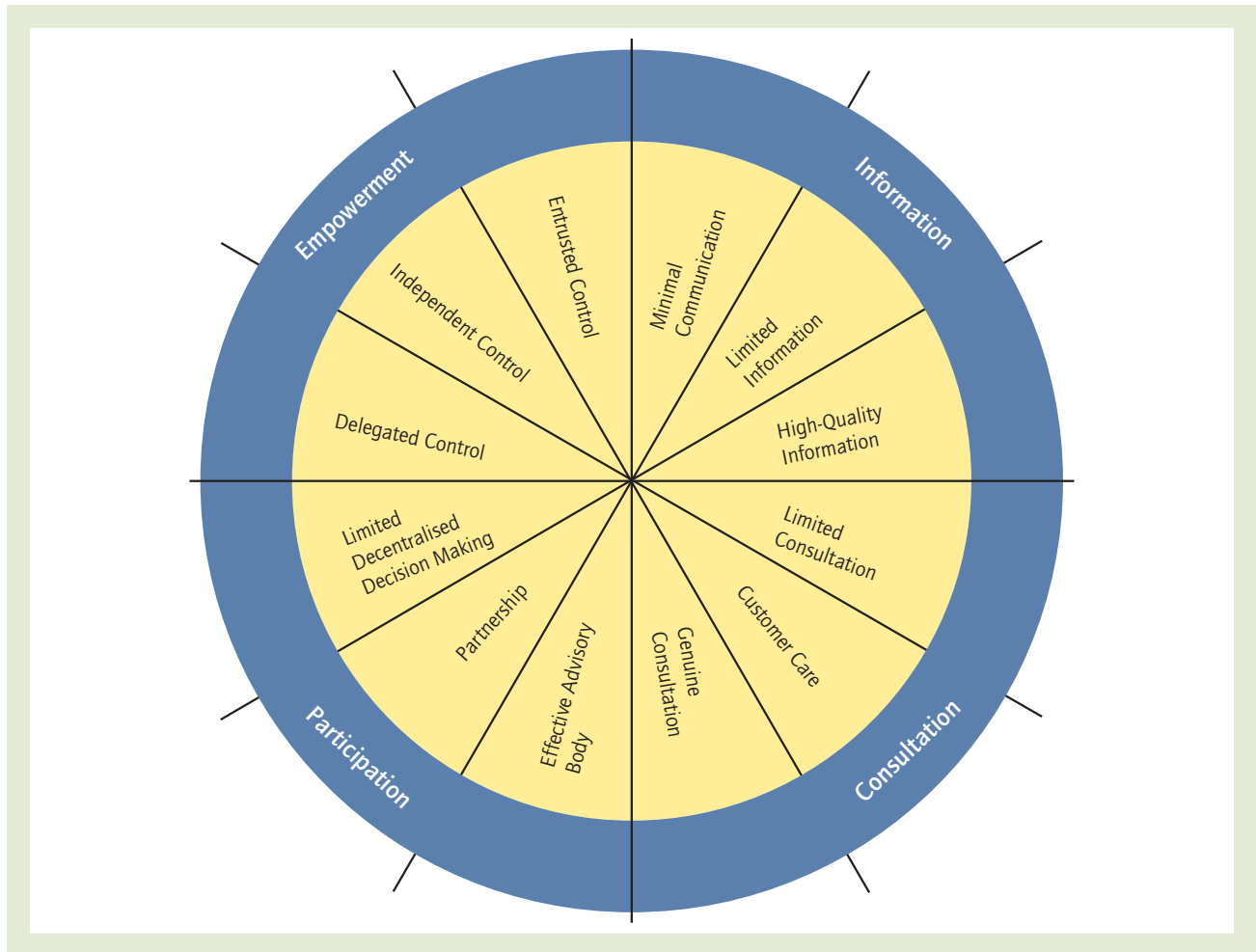


Figure 3 The wheel of participation

Sources: Adapted from Davidson, S. (1998). Spinning the wheel of empowerment. *Planning*, 1262, 14–15, and based on a figure developed by the South Lanarkshire Council, Scotland.

Further Readings

- Arnstein, S. R. (1969). A ladder of citizen participation. *Journal of the American Institute of Planners*, 35, 216–224.
- Davidoff, P. (1965). Advocacy and pluralism in planning. *Journal of the American Planning Association*, 31, 331–338.
- Davidson, S. (1998). Spinning the wheel of empowerment. *Planning*, 1262(3), 14–15.
- Forester, J. (1999). *The deliberative practitioner: Encouraging participatory planning processes*. Cambridge: MIT Press.
- Healey, P. (2005). *Collaborative planning* (2nd ed.). Basingstoke, UK: Palgrave Macmillan.

- Jacobs, J. (1961). *The death and life of great American cities*. New York: Random House.
- Kingston, R. (2007). Public participation in local policy decision-making: The role of Web-based mapping. *The Cartographic Journal*, 44, 138–144.
- Kingston, R., Carver, S., Evans, A., & Turton, I. (2000). Web-based public participation geographical information systems: An aid to local environmental decision-making. *Computers, Environment and Urban Systems*, 24, 109–125.
- Wilcox, D. (1994). *The guide to effective participation*. Brighton, UK: Partnership Books.



PARTICIPATORY RURAL APPRAISAL

Participatory rural appraisal (PRA) is a term used to describe the ever-expanding toolbox of approaches and methods that aim to empower and involve local people in decision making and planning for their future. PRA emerged in the late 1980s and early 1990s as a synthesis of the traditions and techniques of participatory research, whose historical origins lay within applied anthropology and natural resource management. However, it significantly developed most directly from rapid rural appraisal (RRA), a series of techniques that were used by development practitioners and researchers to rapidly collect and analyze data in rural areas. RRA was more extractive by nature, resulting in the emergence of PRA in response to a call for more participatory techniques to enable and empower local people to take control over their own situation. PRA approaches and methods involve local people collecting and analyzing data in projects that are facilitated (rather than controlled) by outsiders. It represents a shift in development thinking from top-down, authoritative approaches to bottom-up planning.

The term *participatory rural appraisal* is somewhat misleading, as PRA approaches can be just as applicable within an urban setting. PRA techniques and methods include, but are by no means limited to, mapping exercises, timelines, cartoons, matrix ranking, diagrammatic representations, and seasonal calendars. These techniques and methods are often broadly grouped into those related to (a) space, that is, the environment in which people are situated; (b) time, that is, time-related dimensions of people's existence; and (c) the relationships within and between various aspects of community life. The focus of PRA is more on the level of engagement with the participants and the attitudes and behaviors of the practitioners involved than the actual techniques themselves. PRA is not prescriptive, but rather, it consists of a range of techniques that are used flexibly and can be adapted for the local context in which they are applied.

PRA emphasizes local knowledge, providing a mechanism by which communities can participate in and direct research agendas. This has resulted in the wide appeal and spread of PRA, particularly throughout the developing world. However, critics point out that while the approaches and techniques draw on local knowledge and experience, the process of identifying these data is carried out through Western theoretical and methodological frameworks. This can contribute to the development of uneven power relations between participants and facilitators and has been referred to as the *tyranny of participation*. The limitations and ethical issues of PRA can vary in their significance depending on the experience of facilitators and on the support of the wider community.

Jessica Mercer

See also **Participatory Learning and Action;**
Participatory Mapping; Participatory Planning;
Public Participation GIS

Further Readings

- Chambers, R. (1994). The origins and practice of participatory rural appraisal. *World Development*, 22, 953–969.
- Cooke, B., & Kothari, K. (Eds.). (2001). *Participation: The new tyranny?* London: Zed Books.
- Kumar, S. (2002). *Methods for community participation: A complete guide for practitioners*. Warwickshire, UK: ITDG.
- Narayanasamy, N. (2008). *Participatory rural appraisal: Principles, methods and application*. New Delhi, India: Sage.



PASTORAL HERDING

See **Nomadic Herding**



PATCHES AND CORRIDORS IN WILDLIFE CONSERVATION

As human-environment interactions evolve within progressively globalized settings, natural areas become more fragmented, usually embedded in an agricultural landscape. Across varied regions, more than 90% of the natural forest has now been removed, with agriculture and managed lands occupying well over 50% of Earth's land surface. The remaining *patches* of natural habitat can be connected by *corridors* of the same or similar vegetation, providing pathways for the movement of animals and plants and serving, many believe, as a viable conservation tool in the face of continued landscape transformations. Managing such remnants with an eye toward conservation has gained support as one way to stem the impacts of human agency on Earth's varied ecosystems. The connectivity provided by corridors has theoretical foundations and intuitive appeal, but some theoretical ecologists argue against unquestioned acceptance of their conservation value. A recent approach to the patches and corridors scheme contends that the quality of the landscape "matrix" within which patches are found is important and deserving of more attention.

Fragmented Landscapes

Tropical and temperate landscapes both exhibit a high degree of "patchiness" where forest habitat has been left amid an agricultural matrix characterized by pasture lands, fallows, and annual and/or perennial cropping systems. These fragments serve as habitat and may often represent the last hope for safeguarding species in the area.

The challenge to conservationists—often in the face of rampant development—is how best to manage patches in order to maximize and preserve the wildlife they harbor. For a given species, many or all the patches in a region may contain a local population relatively or totally restricted to that patch. The small, isolated populations dotting a landscape in these patches can be grouped together as a *metapopulation*, a term coined in 1969 by Richard Levins, a theoretical ecologist who was thinking about agricultural pests at the time.

As island habitats, patches are likened to true ocean islands, adhering to the theoretical principles and processes of island biogeography. Theory predicts that small patches contain and preserve fewer species than larger ones, and more isolated patches experience higher extinction and lower colonization rates than less isolated ones. Yet with several patches in a region, any given species that goes extinct on one "island" can get reestablished via colonization (the "rescue effect") in other patches—assuming that the organism can get there. Local extinction and recolonization take place within the patches, but the overall metapopulation survives. This is where the concept of corridors comes into play. Corridors form the pathways connecting these patches, and their creation or preservation and maintenance have been recognized and debated as viable ways to protect populations restricted to patches.

The proposed advantages of corridors include the maintenance of metapopulations, the concomitant maintenance of species diversity, the possibility of a rescue effect for any patch experiencing extinction of a species, and greater genetic variability delivered from the metapopulation. Yet homogenization of the total genetic variability throughout the patches could occur, counteracting any patch-specific adaptations that might otherwise develop. Moreover, just as species of conservation concern can move between patches, so too can parasites, diseases, and exotic/invasive species. Though theoretical modeling and empirical observations have focused on the role and potential outcome of these biological corridors, the dearth of reliable data means that the benefits and drawbacks of corridors' true conservation value are debatable.

Evidence From Landscape-Level Experiments

Recent experiments at the landscape level reveal some interesting results related to patches and corridors. In a manipulated landscape in the U.S. state of South Carolina's pine forest habitat, many taxa were found to make use of corridors. Small mammals, bird-dispersed plants, and butterflies showed higher movement between connected patches than between unconnected ones. Other findings associated with this same study area found that pollen transport by butterflies, bees,



and wasps was higher between connected than between unconnected patches, suggesting that corridors facilitate pollen transport in fragmented landscapes.

Corridors can have unanticipated consequences with respect to some organisms. Bluebirds, for example, will travel alongside a corridor without really entering it, dispersing seeds from the fruits they consume. But as “edge-loving” birds, they make use of the edges of corridors, and the corridor’s internal quality matters little. Such results illuminate the concept of “functional connectivity,” which involves not only the pattern and physical arrangement of patches and corridors but the natural history characteristics of the organisms as well. Patch size, for instance, can affect frugivorous birds’ abundance, while patch connectivity can be more important to insectivores. Area, however, is not the sole answer. Time takes a toll as well. Fragments less than 100 ha (hectares) in size can lose more than half their species in less than 15 years. A “large enough” patch seems to be at least 1,000 ha, a sobering thought since such large areas in species-rich regions are so scarce.

The Matrix Matters

Connectivity can aid in the movement of primates, birds, small mammals, and several other taxa. But it has little to do with corridors and more with the matrix. The matrix has often been considered a featureless expanse across which organisms must find their way. Yet many terrestrial landscapes display great variability in terms of the interpatch milieu.

A low-resistance matrix will tend to allow a relatively easy passage of organisms from one patch to another. A high-resistance matrix, in contrast, restricts travel between patches. Organisms that are generalists (i.e., they are able to exist in a variety of habitats and can take advantage of a wide variety of resources) would likely have few problems in going from patch to patch across a landscape mosaic. But a ground-feeding species specializing on resources found in a dense understory might never brave the quiltwork-patterned matrix around its “home patch.”

A matrix highly resistant to one organism may pose little problem to others—the reasons for

which may be subtle. For instance, an antshrike bird (a forest specialist) in a tropical fragmented setting uses riparian or gallery forests (relatively narrow corridors) to move between patches of dry forest in the fragmented landscape but tends to avoid pastures and living fence rows (mixed tree species planted along roadsides). In contrast, a rufous-naped wren (a forest generalist) moves through the matrix by using the thin linearity of fencerows without hesitation.

Recent meta-analysis of data from more than 1,000 population networks of mammals, birds, reptiles, amphibians, and invertebrates on six continents evaluated the effect of habitat area, isolation, and the matrix itself. A central conclusion is that patches are less like islands than some might think. The size and isolation are indeed important factors determining species presence, but the matrix in which patches are embedded must not be ignored.

Robert A. Rice

See also **Biodiversity; Community-Based Conservation; Conservation; Conservation Zoning; Forest Fragmentation; Island Biogeography; Landscape and Wildlife Conservation; Landscape Biodiversity; Landscape Ecology; Parks and Reserves; Single Large or Several Small (SLOSS) Debate; Spatial Strategies of Conservation**

Further Readings

- Ferraz, G., Nichols, J. D., Hines, J. E., Stouffer, P. C., Bierregaard, R. O., Jr., & Lovejoy, T. E. (2007). A large-scale deforestation experiment: Effects of patch area and isolation on Amazon birds. *Science*, 315, 238–241.
- Levey, D. J., Bolker, B. M., Tewksbury, J. J., Sargent, S., & Haddad, N. M. (2005). Effects of landscape corridors on seed dispersal by birds. *Science*, 309, 146–148.
- Mann, C. C., & Plummer, M. L. (1995). Are wildlife corridors the right path? *Science*, 270, 1428–1430.
- Murphy, H. T., & Lovett-Doust, J. (2004). Context and connectivity in plant metapopulations and landscape mosaics: Does the matrix matter? *Oikos*, 105, 3–15.



- Perfecto, I., & Vandermeer, J. (2008). Biodiversity conservation in tropical agroecosystems: A new conservation paradigm. *Annals of the New York Academy of Sciences*, 1134, 173–200.
- Prugh, L. R., Hodges, K. E., Sinclair, A. R. E., & Brashares, J. S. (2008). Effect of habitat area and isolation on fragmented animal populations. *Proceedings of the National Academy of Sciences of the United States of America*, 105, 20770–20775.
- Saunders, D. A., Hobbs, R. J., & Margules, C. R. (1991). Biological consequences of ecosystem fragmentation: A review. *Conservation Biology*, 5, 18–32.
- Schelhas, J., & Greenberg, R. (Eds.). (1996). *Forest patches in tropical landscapes*. Washington, DC: Island Press.
- Tischendorf, L., & Fahrig, L. (2000). On the usage and measurement of landscape connectivity. *Oikos*, 90, 7–19.



PATH DEPENDENCE

The concept of path dependence has been popularized by economic historians and is now widely employed in economics, history, political science, sociology, and geography to describe systems and processes that are governed by their own history. More formally, a path-dependent system or process is characterized by *nonergodicity*, a term taken from the theory of stochastic systems. While an ergodic system or process will converge toward an invariant, asymptotic probability distribution regardless of its initial conditions, the asymptotic probability distribution of a nonergodic or path-dependent stochastic system evolves as a consequence of its own history. Path dependence is a label for a particular class of dynamic systems or processes, not a theory explaining how those systems behave. It is thus necessary to “develop theories and frame hypotheses regarding the economic circumstances in which path-dependent dynamics are likely to appear, and where the consequences of past events can be expected to exert greatest and most enduring influence” (David, 2007, p. 92).

Work on path dependence differs in the emphasis that scholars give to four elements included in most accounts: “causal possibility, contingency, closure, and constraint” (Bennett & Elman, 2006, p. 252). Causal possibility means that more than one path could have been taken at a specific historical juncture. If we could rerun history and end up with the same outcome every time, then that process is not path dependent. Some authors argue that early events are more important than later events in the sequence, while others distinguish between path independence and path dependence, where the former refers to those outcomes that are independent of the order of events. Contingency entails that the causal narrative be influenced by random or, in some cases, exogenous events. Closure refers to the fact that once a path is chosen, alternative paths become increasingly unlikely. And finally, once a path is chosen, a constraint is required that ties agents to that path.

In economics, three main versions of path dependence exist: path dependence as a technological lock-in, as increasing returns, and as institutional hysteresis. Paul David’s work on technological lock-in highlights the impact of contingent *accidents*, or microlevel chance events, on long-run trends and structures and stresses the importance of early events or decisions for closing alternative paths and strengthening existing ones as network externalities increase the efficiency gap between the chosen and the abandoned paths. The lock-in of suboptimal designs and systems such as the QWERTY keyboard or the VHS video system is often invoked as proof that markets do not necessarily lead to optimal outcomes. Brian Arthur’s work highlights the role of various forms of increasing returns to explain how a technology or spatial system becomes locked into a path. Arthur formalizes those processes through the so-called ball-and-urn models to demonstrate how macrostructure emerges from contingent, random micro events and behavior. Mark Setterfield’s work on institutional hysteresis recognizes that formal and informal institutions, such as conventions, habits, and traditions, change only slowly over time; structuring human behavior, interaction, and communication, these institutions keep people, places, and countries on specific evolutionary trajectories. The work suggests that the adopted technologies, spatial patterns, or

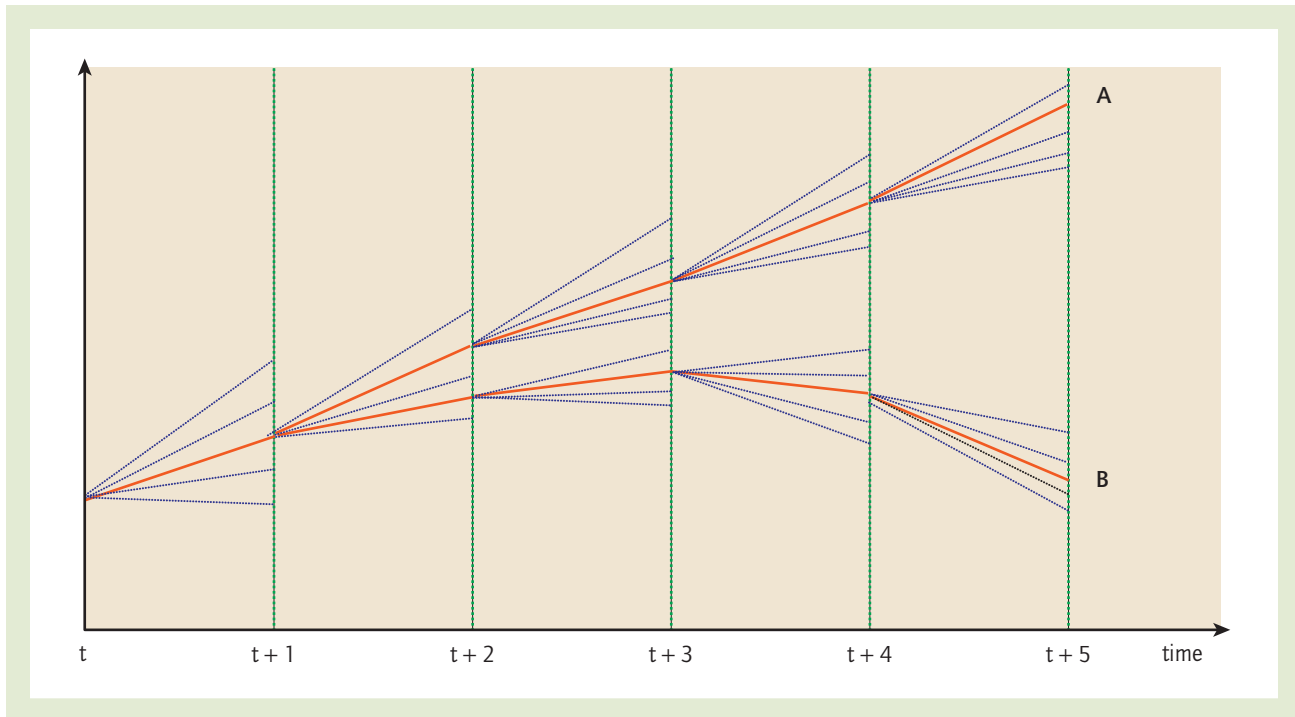


Figure 1 Development path of a regional system

Source: Adapted from Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography*, 6, 395–437.

institutions are not necessarily the most efficient alternatives. The work also stresses that the past does not determine the future but that at each moment in time, the possible future evolutionary trajectories are contingent on the past and current states of the system in question and some paths are more likely than others.

The concept of path dependence holds considerable promise for characterizing the evolution of spatial systems. Geographers have long argued that economic landscapes are the legacy of their industrial and institutional history. Once industries settle in particular places, the sunk costs, external economies, and coevolving institutional environment lock the place into a particular evolutionary trajectory. While the actualized location pattern is one of many probable ones, once contingent events confer initial advantages or disadvantages to a region, externalities will produce long-enduring patterns of uneven spatial development. Existing levels of inequality are thus long enduring but may be shaken up at so-called bifurcation points, when fundamental changes in

technological paradigms, macroeconomic shocks, or government intervention reshuffle the spatial hierarchy.

In geography, path dependence is often equated with regional lock-in. The metaphor of lock-in captures the quasi fixity of patterns of economic specialization and uneven development through strong positive and negative feedback processes. Most discussions of regional lock-in refer to the growing rigidification and declining adaptability of regions to changing economic conditions. But while lock-in is primarily understood as negative lock-in, some regions are able to propel themselves along long-enduring growth trajectories. Both forms of lock-in exist. While some regions, such as the Boston or London metropolitan areas, are able to continually reinvent themselves and remain on a growth trajectory, others, such as the Ruhr area, miss critical historical junctures such that a positive lock-in turns into a negative lock-in. Figure 1 illustrates how past choices and the present system state both enable and constrain, but do not determine, future states and



pathways. Once decisions have been made and pathways have been chosen, new possible paths open up and others close down.

There are some obvious problems with the concept of path dependence in general and with its application to spatial evolution in particular. Different authors distinguish between different types, degrees, and causes of path dependence. A narrow definition would enhance the conceptual clarity but exclude a number of interesting cases, even if the observed process is clearly history dependent. Furthermore, the distinction between path dependence and lock-in is ambiguous. For some, lock-in refers to the trapping of a system or process in an equilibrium configuration from whence only exogenous forces can recover it. According to this definition, path dependence would be inconsistent with evolutionary explanations, as evolution proceeds through the endogenous transformation of systems. The application of path dependence in geography is further complicated by the fact that a region is an ensemble of agents, technologies, firms, institutions, networks, and interdependencies, and as a result, it is unclear what the object of study is or how different path-dependent processes inside and outside the region and at different scales interact. It is also unclear why, how, and when regions become locked in and how new technological, industrial, institutional, or regional paths are created. While path dependence and lock-in can help us understand the evolution of a system once a path is chosen, they say little about the creation of new paths. Usually, their emergence is simply attributed to chance or historical accidents rather than derived from past and present economic conditions. But this type of reasoning is unacceptable since “the whole point of path-dependence is to restore the importance of causal, historical economic explanation involving sequential actions; placing too much emphasis on random accidents as the sources of path creation constrains and undermines such causal explanation” (Martin & Sunley, 2006, p. 428).

Jürgen Essletzbichler

See also **Actor-Network Theory; Economic Geography; Economies of Scale; Regional Economic Development; Structuration Theory**

Further Readings

- Arthur, B. (1994). *Increasing returns and path dependence in the economy*. Ann Arbor: University of Michigan Press.
- Bennett, A., & Elman, C. (2006). Complex causal relations and case study methods: The example of path dependence. *Political Analysis*, 14, 250–267.
- David, P. (1985). Clio and the economics of QWERTY. *American Economic Review*, 75, 332–337.
- David, P. A. (2007). Path dependence: A foundational concept for historical social science. *Cliometrica*, 1, 91–114.
- Grabher, G. (1993). The weakness of strong ties: The lock-in of regional development in the Ruhr Area. In G. Grabher (Ed.), *The embedded firm* (pp. 255–277). London: Routledge.
- Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography*, 6, 395–437.
- Page, S. (2006). Path dependence. *Quarterly Journal of Political Science*, 1, 87–115.
- Setterfield, M. (1993). A model of institutional hysteresis. *Journal of Economic Issues*, 27, 755–774.



PATRIARCHY, GEOGRAPHY AND

Patriarchy refers to a set of hierarchical power relations between men and women in which men are able to dominate women and masculinity is privileged over femininity. Such gender domination takes place at all levels of social interactions. While intersecting factors such as race, class, sexuality, and ethnicity may place men and women at different levels of the power hierarchy, patriarchy unites men in their domination over women across place and time. Patriarchy is not a random hierarchical system but rather a system in which women are particularly oppressed and their roles devalued or undervalued. Patriarchy is therefore systemic and has led to the material and ideological oppression of women and the marginalization of femininity while simultaneously benefitting men and attributes considered masculine. As a



foundational concept in the study of feminist geography, patriarchy historically places the sex/gender system as the central object of analysis in social relations. In the past 20 years, however, feminist geographers have increasingly favored analyses that focus on interlocking systems of power that include but do not privilege gender. Analyses of patriarchy are necessary in a number of fields in geography, including economic, cultural, and political geography as well as geographies of sexuality and race/racism.

In a pivotal article in feminist social theory, Heidi Hartmann outlined the main elements of patriarchy as heterosexual marriage and heterosexism or heteronormativity, female care work and household labor, women's economic oppression in the paid labor market, the state and governmentality, and diverse institutions that promote and privilege social relations among men such as the military, churches, universities, sports clubs, and the professions. While offering a closely connected list of locations of patriarchal relations, the sociologist Sylvia Walby also added the realms of sexuality and male violence as important sites of male dominance over women. Her analysis of patriarchy divides these sites into a domestic regime, which occurs primarily in the private sphere, and a public regime, which pertains to the courts, the government, and the formal labor market. Other examples of patriarchal power and control include domestic violence and sexual assault, the gendered division of labor, and discourses on motherhood and care work that promote women's unpaid labor in the home.

Some view patriarchy as universal and separate from other systems such as capitalism, while others believe that patriarchy takes on different forms and changes in particular economic, political, and social settings. Within feminist geography, these positions are defined as the dual-systems model and the single-systems model. Some have argued that patriarchy and capitalism are distinct and separate phenomena, while others believe that patriarchy exists as a result of capitalist modes of production and reproduction. These debates, which took place among feminist geographers in the pages of *Antipode* in the mid 1980s, gave rise to further discussions and connections concerning the relationship between

patriarchy and sexuality, patriarchy and race/racism, and patriarchy and ethnicity, to name a few.

These debates also highlighted the differing views of gender within feminist geography. By the mid 1990s, many feminist geographers argued that gender was not a single category but a limited and fractured analytical and material one. Patriarchy as a hierarchical system was therefore decentered, as feminist geographers explored the contextuality of patriarchal relations and the importance of overlapping, interlocking, or intersecting relations of power and domination. Importantly, this work has offered new subjectivities of women not simply as victims of their gender but also as actively engaged and not merely oppressed. For geographers, this means distinguishing between forms of patriarchy across space and place and illustrating the fluidity of power and hierarchies.

Within geography, subdisciplines such as economic geography, political geography, cultural geography, and sexuality studies have used the concept of patriarchy in their analyses and research. The works of Doreen Massey and Linda McDowell in economic geography describe how economic restructuring in Britain greatly changed the gendered division of labor and produced differences across regions. In their study on contrasting colliery and cotton villages in Northeast England from the 19th to the 20th centuries, the gendered division of labor was based highly on patriarchal discourses of women's labor and economic worth. In another example, Michael Brown and Lynn Staeheli's work in political geography highlights how feminist geographers use concepts such as patriarchy to deconstruct and reinvent distributional, antagonistic, and constitutive approaches to space and power. Finally, work in the sexuality and space literature and cultural geography critiques how the discursive dominance of the nuclear family and heterosexual marriage enforces heteronormativity and marginalizes other forms of familial relationships.

Rebecca Burnett

See also **Ecofeminism; Feminist Geographies; Gender and Geography; Marxism, Geography and; Masculinities and Geography; Sexuality, Geography and/of**



Further Readings

- Brown, M., & Staeheli, L. (2003). Are we there yet? Feminist political geographies. *Gender, Place and Culture*, 10(3), 247–255.
- Hartmann, H. (1977). The unhappy marriage of Marxism and feminism. In R. McCann & S. Kim (Eds.), *Feminist theory reader: Local and global perspectives* (pp. 206–221). New York: Routledge.
- Massey, D. (1994). *Space, place, and gender*. Minneapolis: University of Minnesota Press.
- Walby, S. (1990). *Theorizing patriarchy*. Oxford, UK: Blackwell.



PEASANTS AND PEASANTRY

Peasants are small agricultural producers, especially in less industrialized countries, who possess their own land and who use relatively simple equipment and family labor to produce mostly for their own consumption. All peasants are involved in markets, some much more than others. They live in small rural communities, although they often interact with towns, where they sell their products and buy what they need to farm and live.

Known collectively as the peasantry, peasants have existed for millennia as the majority of humankind until very recently. Peasants have lived in a large variety of historical and geographical contexts. Originally possessing land on which they supported themselves, peasants have frequently lost their land, water, and forests and have been forced to work as wage laborers. This process has been intensified with the evolution of neoliberal capitalism. Their status within capitalist economies varies, and they can be differentiated into rich, middle, and poor peasants, respectively, depending in part on whether they retain property, hire labor, or work as wage laborers themselves.

The study of peasants has been institutionalized through the establishment of interdisciplinary journals such as *Journal of Peasant Studies* in the early 1970s. The 1970s marked a resurrection of peasant studies following a quarter of a century in which the field had been relegated to relative obscurity. Peasant impoverishment and

insurrection in the Third World became important academic topics. Peasant studies occupy an interdisciplinary intellectual space. In scholarly discourses in general, and within human geography in particular, peasants have appeared in discussions of uneven economic development, including the transition to capitalism in Europe and in the Third World; of environmental change and political ecology; and of social protest, identity/agency, and the state. In terms of social theory, peasants have often been at the center of debates between Marxism and postmodernism/poststructuralism. Many of these themes are mentioned in this entry, which focuses on three areas: (1) whether peasants constitute a separate society/culture/economy; (2) the impacts of capitalism on peasants; and (3) peasant identity/agency and political action.

Peasants as a Specific Type of Society, Culture, or Economy

For many scholars, including supporters of modernization theory and populism, peasants constitute a separate type of society, culture, or economy. Important concepts in the modernization tradition are Robert Redfield's folk culture and George Foster's idea of limited good. According to Redfield, peasant communities are a kind of folk society that exists on a folk-urban continuum, where cities represent its modern urban end and peasant communities are placed near the other end. In the "limited good" model, in peasant societies, sources of income such as land and market opportunities are scarce, leading to stiff competition for such resources. On this basis, there arises a specific peasant moral and ethical imagination. Envy, fatalism, individualism, and fear of witchcraft are often parts of a specifically peasant worldview, which impedes development-as-modernization.

Some scholars (e.g., Daniel Thorner and Teodor Shanin) have used the term *peasant* to define an economy constituted by self-sufficient peasants. When Marxists refer to peasant society, as in pre-industrial Europe, they refer to class relations between peasants and feudal landowners. In a peasant society, the basic aspects of rural economic organization, such as landholding size, food output, and work motivation, are governed



Peasant farmer carrying straw on a rake in Hoi An, Vietnam

Source: Benjamin Schepp/iStockphoto.

by the size of the peasant family, the ratio of working to nonworking family members, and the necessity to meet the family's subsistence needs. Chayanov's view of a homogeneous peasantry composed of self-sufficient petty-commodity producers who are able to subsist through family labor and forced underconsumption—which constitutes a pan-historical socioeconomic category—is contradicted by the Marxist process-oriented view stressing peasantry's internal class differentiation. Critics say that peasants cannot constitute a separate economy because they have existed in a variety of historically existing modes of production including feudalism and capitalism.

Peasants and Capitalist Society

Capitalism affects peasants in various ways, including primitive accumulation, peasant differentiation, and articulation and subsumption.

In the process of what Karl Marx called *primitive accumulation* or what David Harvey calls *accumulation by dispossession*, peasants are forcibly evicted from their property (land and forests) and forced to work for private employers. An example of this process is the Enclosures Acts of early modern England, which drove many peasants into urban areas. In recent times, this process has intensified with the establishment of special economic zones created on farmland.

In the process of peasant differentiation, which occupied a prominent place in Lenin's works, the class of archetypical peasants (those who grow crops on their own land using family labor) is differentiated through the impact of market relations and technological change (e.g., the Green Revolution promoted by transnational corporations). Peasants face market competition from larger farms at the national scale and from global agribusinesses, particularly subsidized



U.S. firms. When peasants are involved in market relations, those who are resource-poor are disadvantaged because of factors such as shortage of household labor, sudden crop failure, or a sudden change in the prices of crops and inputs. They may have to borrow money at high interest rates. Over time, they may be forced to sell a part of their land to clear the debt; in the process, they may completely lose their land and become landless laborers. Some even commit suicide due to the unbearable burden of debt. When peasants are left with some land that is not sufficient for their subsistence, they are called poor peasants; apart from working on their tiny plots of land, they work mainly as tenants/sharecroppers by paying a rent and/or working as wage laborers. Peasants who do better economically may buy land and become rich peasants; they still use family labor, but most of the labor used on their farms is hired labor. Some rich peasants over time become capitalist farmers. Middle peasants—archetypical peasants—do not usually hire laborers (except in peak seasons) or hire themselves out. Thus, the peasantry tends to be differentiated into three classes of peasants (rich, middle, and poor peasants), suggesting that it is not a homogeneous class.

The extent of differentiation may have been exaggerated in the classical Marxist model. Middle peasants may not be completely separated from their land. The process of differentiation can be very slow. Some peasants can hold onto their land by decreasing their costs of maintenance and through state subsidies and remittances from city-based family-members. However, although this differentiation may take place slowly, it does occur; peasant-based production is undermined by more efficient farm production nationally and internationally, and peasants do become laborers. But peasant differentiation is uneven as market penetration and state support vary. Because of the geographical variation in the extent and the effects of peasant differentiation into poor, middle, and rich peasants with differing capacities for investment, understanding this geography is an important aspect of our understanding of uneven development as such.

In the third view of peasant-capitalism relations, which is based on the French structuralist

school, the precapitalist peasant communal mode of production is integrated into the capitalist mode of production in a subordinate relation, that is, in a marginalized status. This process happens geographically, that is, the circular migration of peasant-laborers. Precapitalist peasants as migrants are a source of cheap labor power for city-based capital. Their labor power is cheap because a part of the cost of its reproduction is borne by their household production in villages, one in which women are particularly involved. Indeed, the gender division of labor—where females produce subsistence foodstuffs within a noncapitalist mode of production and semiproletarianized males work for urban capital—makes it possible for capitalists to pay migrants a male wage rate that is insufficient for familial maintenance. The form of integration between capitalist and noncapitalist modes of production occurs at an international scale, that is, an extraction of surplus value from the latter, and transfers to the rich countries through colonialism and imperialism.

Finally, capital can subsume and exploit peasants as commodity producers as it does industrial workers. Peasants exist not outside capitalism but as an integral part of it; peasants are not precapitalist. Peasants, many of them women, use their labor power to produce commodities for the market. The price they receive from buyers (e.g., merchant capital) is less than the full value of their labor power because of unequal exchange (low farm prices and high input prices). The surplus value extracted contributes to capital accumulation in the city.

A specific form of subsumption happens through the impacts of agribusiness, which include credit, inputs, and extension services. Agribusiness firms lay down technical conditions and provide a market to peasants for a predetermined price. In contract farming, about which geographers such as Michael Watts have written, it is as if peasants-as-laborers in some places are working with other people's means of production. Some who benefit financially may attain the status of agrarian capitalists. But ultimately, the profits of agribusiness as well those of richer peasants and rural capitalists are based on the exploitation of poor peasants and landless workers working on contract farms and on the intensive



exploitation of the land and water (or aquatic) resources.

Peasants have become a part of capitalism in another way. With the spread of neoliberal capitalism, there is a tendency toward de-agrarianization of peasants, as the latter are increasingly involved in nonagricultural activities. These include petty trading and wage labor in industries, at least as part-timers. Dispossessed of their land and finding farming unviable (because of the withdrawal of state support under neoliberalism), peasants indeed have become a part of the global reserve army of labor waiting to be hired when capital needs them. As a result, there is pressure on the wages of those currently employed, with many poor countries (with massive peasantries) becoming a profitable destination for transnational corporations. Sometimes agribusinesses also appropriate peasants' knowledge about nature and farming.

Peasant Identity and Agency

As far as peasant agency is concerned, peasants are often considered to be both conservative and revolutionary. The conservative peasant, said Karl Marx, wants to consolidate his or her small holding. Smallholding peasants do not form a class that is explicitly conscious of its interests vis-à-vis the exploiting classes; rather, they constitute a mass of people lacking any potential for class action. But it is widely known that peasants did play heroic roles in antifeudal struggles in Europe. Similarly, Mao Zedong brought peasants to the center stage in China, both in practice and in theory through his writings. Also, some of the welfare-oriented programs of post-colonial capitalist states (e.g., redistributive land reforms) have been implemented because of peasant movements and, of course, with the aim of creating a national market that includes peasants as consumers.

There are at least two views concerning the source or origin of peasant agency/identity. In the non-Marxist literature, including that which is postmodern/neo-populist, peasants are seen as a homogeneous class having an innate identity, a subaltern "peasantness," that prompts them to pressure for changes inside capitalism. Peasant agency is also seen as the use of networks at

different geographical scales as a survival strategy in an exploitative society, rather than as advocacy of a revolutionary agenda.

In the post-Marxist critical peasant literature, peasant agency is looked at through the lens of class differentiation. In this view, peasants have several class-based identities. Different classes of peasants will have different kinds of agency. Middle peasants are economically independent and have greater potential for revolution than other peasant classes. Poor peasants are initially the least militant because of their dependence on landlords or rich peasants for land-on-rent, for wage work, and for loans. But in a revolutionary situation, when middle peasants mobilize themselves against landlords and rich peasants, the morale of poor peasants is raised, and they are ready to respond. The middle peasants are initially the most revolutionary, but when the revolutionary action intensifies, they vacillate about whether to persevere because of their stake in the private property system, unless their fears of losing their livelihood are allayed. Critics of this thesis say that middle peasants do depend on landowners for credit and are heavily attached to their land, making them a weaker revolutionary force than other classes. On the other hand, poor peasants (along with landless peasants as laborers), since they are the most exploited and as they form the majority of the rural population, are the most revolutionary.

In reality, peasant movements are often multi-class. Leaders of middle and rich peasants (and capitalist farmers) mobilize the entire peasantry to lobby for benefits such as more input subsidies and higher output prices. An important form of multiclass mobilization is action against landlords for land and against the capitalist strategy of state-supported primitive accumulation (the threat of dispossession of their land in the name of national industrialization/development). Multiclass mobilization of peasants is seen as problematic on many grounds. When the interests of better-off peasants are met (e.g., land is obtained from the landlords), they often withdraw from the movement. When multiclass mobilization successfully puts pressure on the state for higher food prices, such increases do not benefit poor peasants and landless peasants, who are net buyers of food. In this and many other ways, multiclass



action also de-emphasizes the interests of poor peasants and landless laborers as classes. It mobilizes social constructions of democracy, culture, and identity in ways that are unspecific in terms of their class content and are therefore populist.

Peasant agency and resistance have taken various forms. Banditry, viewed as a kind of peasant protest, has been studied by Eric Hobsbawm. It targets lawyers, moneylenders, traders, and foreigners, who are seen as oppressors. Another form of individual action is said to be the everyday form of resistance, which has engaged the attention of James Scott and others researching peasants in the tradition of the historian E. P. Thompson. Here, peasants are seen as making use of the so-called weapons of the weak, including foot dragging, desertion, false compliance, pilfering, slander, arson, and sabotage. These are reinforced by a popular culture of resistance. These forms of class struggle require little or no coordination, make use of impersonal networks, represent a form of individual self-help, and avoid direct confrontation with authority. In terms of the goals of peasant protests, these scholars also emphasize the moral economy aspect; protests tend to be focused mainly against landowners who do not respect their need to earn a subsistence income.

These views have been criticized for de-emphasizing the importance of the conscious construction of radical ideology and organizational structures to mobilize peasants. They also inaccurately essentialize peasant resistance, that is, by asserting that peasants necessarily make use of the “weapons of the weak.” It has been said that if peasants become conscious of their exploitation, they will fight against capitalism in an organized manner. Peasants have been mobilized by communist parties all over the world. An important aspect of peasant mobilization is the peasant-worker alliance, represented by the hammer and sickle in communist party symbols. If capital can exploit peasants, as it does property-less labor, by exploiting them without dispossessing them of their property, a space for a collective revolutionary alliance between workers and peasants against capital opens up. Peasants also launch organized protests against the capitalist state (including in a colonial situation), for the state acts on behalf of (foreign) capital and makes demands on peasants for resources (such as money, unpaid labor, and

in kind) for developmental interventions and war making. Corrupt, coercive, and oppressive government officials tend to be peasants’ targets, as India’s continuing Naxalite movement, which is informed by Maoism, testifies. In this context, the dialectics of the state-peasant relation is worth mentioning. To the extent that the state has played the role of trusteeship in national capitalist development, peasants seem to have suffered both when there is what the geographer Nanda Shrestha calls “failed development” (leading to, e.g., low productivity, unemployment, and low wages) and when development “succeeds” (leading to development-induced displacement, price inflation, and indebtedness). Peasants have responded partly by fighting against both large owners of property and the state.

Peasant movements are not just “economic.” Some radical scholars argue that a new form of peasant movement is emerging (new peasant movements, or NPMs). Although rooted in rural struggles, the participating peasants in NPMs are educated, are connected to the cities (where they used to be ex-miners or displaced workers and where they receive regular ideological/political training), and have a cosmopolitan view. Often independent of political parties, they engage in direct struggle rather than electoral fights. They reject economistic class analysis, but neither are they focused on issue-based identity politics. Thus, they are influenced by a mixture of Marxism and by ideas related to ecology, ethnicity and nationality, and gender. They coordinate their struggles for economic progress, democracy, autonomy, and dignity at multiple geographical scales, including the international.

Peasants have been exploited by large agribusinesses (contract farming being a specific example). In many different contexts, peasants and property-less laborers continue to engage in political actions against capital, domestic or foreign. They have also occasionally fought against the state (e.g., Mexico’s Zapatistas). As the crisis-prone nature of the capitalist system plays out differently in different countries in the global periphery, the specific ways in which various classes of peasants and rural laborers are affected, and how they respond, will vary considerably.

Raju J. Das

See also **Class, Geography and; Developing World; Development Theory; Hunger; Land Reform; Marxism, Geography and; Modernization Theory; Movimento Sem Terra; Political Ecology; Political Economy; Poverty; Rural Development; Rural Geography; Rural-Urban Migration; Social Movements; Underdevelopment; Uneven Development; Via Campesina (International Farmers' Movement)**

Further Readings

- Alavi, H., & Shanin, T. (1988). Peasantry and capitalism. In H. Alavi & T. Shanin (Eds.), *Karl Kautsky: The agrarian question*. London: Zwan.
- Bebbington, A. (1999). Capitals and capabilities: A framework for analyzing peasant viability, rural livelihoods and poverty. *World Development*, 27(12), 2021–2044.
- Brass, T. (Ed.). (2002). Latin American peasants [Special issue]. *Journal of Peasant Studies*, 29(3–4).
- Byres, T. (1996). *Capitalism from above and from below*. London: Macmillan.
- Das, R. (Ed.). (2007). Peasant, state and class [Special issue]. *Journal of Peasant Studies*, 34(3–4).
- Foster, G. (1979). *Tzintzuntzan: Mexican peasants in a changing world*. New York: Elsevier.
- Little, P., & Watts, M. (1994). *Living under contract*. Madison: University of Wisconsin Press.
- Scott, J. (1985). *Weapons of the weak: Everyday forms of peasant resistance*. New Haven, CT: Yale University Press.
- Shanin, T. (1987). *Peasant and peasant societies*. Oxford, UK: Blackwell.
- Shrestha, N. (2008). “Misery is my company now”: Nepal’s peasantry in the face of failed development. *Journal of Peasant Studies*, 35(3), 452–475.
- Veltmeyer, H. (1997). New social movements in Latin America. *Journal of Peasant Studies*, 25(1), 139–169.
- Watts, M. (1987). Powers of production: Geographers among the peasants. *Environment and Planning D: Society and Space*, 5(2), 215–230.
- Wolf, E. (1966). *Peasants*. Englewood Cliffs, NJ: Prentice Hall.

PEAT

Peat is an organic deposit formed on Earth’s surface under waterlogged conditions. In most soils, dead organic matter is consumed in the presence of oxygen by organisms such as invertebrates, fungi, and bacteria about as quickly as it is added through processes such as leaf fall and plant death. The organic matter is oxidized to carbon dioxide gas and water, and over the long term, the amount of organic material in the soil hardly changes. However, if the sediments are waterlogged, oxygen becomes scarce because gases diffuse much more slowly in water than in air and the oxygen that is consumed cannot quickly be replaced. In the absence of oxygen, decomposition is slower and incomplete. This leads to the buildup of peat. Peat thus consists of partially decomposed remains of plants (and, in much less abundance, animals) that previously lived at the site of deposition. It may also contain small amounts of material such as wind-blown dust and chemical precipitates. (Most authors draw a distinction between in situ peats and organic lake sediments containing plant material that may have originated at some distance from the location of the deposits.)

Peat deposits are found in all but the most arid environments. Tropical peats tend to occur in basins, river deltas, sheltered coastal mangrove swamps, or estuaries—anywhere where water flows slowly enough to allow stagnation and anoxia to develop. At higher latitudes, peats frequently grow above the regional water table because certain peat-forming plants, chiefly *Sphagnum*, are able to retain water like a sponge; such peatlands are called raised bogs. At very high latitudes, the low temperatures and the presence of seasonal snow and ice can aid waterlogging in reducing decomposition rates.

Peatlands are ecologically important. Peatlands fed by groundwater are often very productive and can have high biodiversity. In contrast, raised bogs, being fed only by rainwater, tend to be acidic and poor in nutrients, with a highly specialized flora and fauna. As peat accumulates, it effectively records its own history in the form of layer upon layer of subfossilized plant and animal remains. Ecologists are able to use this information to



Men cutting peat from a bog in Maamturk Mountains near Cong, Ireland

Source: Phil Augustavo/iStockphoto.

reconstruct the long-term development of these ecosystems.

Peatlands are estimated to cover more than 4 million square kilometers, or 3%, of the land surface of Earth and contain approximately one third of all carbon stored in soils. Peatland destruction may therefore contribute to the increasing concentration of carbon dioxide in the atmosphere and hence to global warming. However, peatlands also produce methane as a by-product of the decomposition processes. Methane is a much more powerful greenhouse gas than carbon dioxide, so the net effect of peatland loss on the climate system remains unclear. Climate change may itself upset the carbon balance of high-latitude peatlands, for example, by causing drying out and increased oxidation of organic matter, so peatlands may turn out to act as a positive feedback within the climate system.

The major cause of destruction of peatlands in the recent past has been drainage for forestry and agriculture; about 10% to 20% of the world's peatlands have been destroyed since AD 1800. Peat also has a range of commercial uses, notably as a fuel for heat and electricity production and in horticulture, and it is widely extracted for these purposes.

Ian T. Lawson

See also **Carbon Cycle**; **Coal**; **Soils**

Further Readings

Charman, D. J. (2002). *Peatlands and environmental change*. Chichester, UK: Wiley.



PEDOLOGY

See Soils



PEET, RICHARD (1940–)

One of radical geography's most passionate and vociferous promoters, Richard Peet has devoted his career to exposing the ways in which power and inequality are manifested in global society. Although in some senses Peet's career reveals remarkable consistency and stability—since receiving his PhD at the University of California, Berkeley, in 1968, he has been a professor at Clark University, and his commitment to Marxism has been unwavering—the focus of his analysis has shifted over the decades.

Peet was an early promoter of Marxism in geography, founding the radical geography journal *Antipode* in 1970, which he edited until 1985, as well as editing an early collection of radical geography essays in 1977. Peet's own version of Marxist geography had (and continues to have) a strong environmental focus, as he sees Marxist geography as particularly well suited for understanding the social conditions that arise out of the productive transformation of nature. This focus has led him to forge strong links with political ecology and development studies, two areas of geography that attempt to understand how nature is transformed at the local scale and how the extraction and transformation of nature are organized globally.

In the 1980s, Peet was on the frontlines of a battle between Marxists and postmodernists, whose understanding, in Peet's view, was insufficiently grounded in the material conditions of production and reproduction. Waging this battle drove Peet deeper into geographic thought and its philosophical underpinnings, as well as leading him to alternative theories of culture and meaning, culminating in the publication of *Modern Geographical Thought* in 1998.

The 1990s saw Peet return to his core interests in the global economy and in the relationship between nature and society, but now from a theoretical perspective that, although still rooted in Marxism, incorporated a broader range of

theorists, notably Cornelius Castoriadis and Michel Foucault. His work in international political economy and development theory led to the publication of *Global Capitalism* (1991) and *Theories of Development* (coauthored with Elaine Hartwick, 1999/2008), while his work in political ecology resulted in the publication of *Liberation Ecologies* (coedited with Michael Watts, 1996/2004).

In the 21st century, as countries throughout the world abandoned socialist development strategies, Peet shifted his focus to the global institutions through which neoliberalism permeates the decisions made by governments, corporations, and individuals around the world. A collaborative research project with a collective of undergraduate students resulted in the publication of *Unholy Trinity: The IMF, World Bank, and the WTO* (coauthored with 16 students, 2003) as well as his book *Geography of Power: The Making of Global Economic Policy* (2007).

Whether huddled with graduate students pasting up copies of *Antipode* in the basement of Clark University, inciting students to think about the geographies of power in their lives, or challenging a speaker at a professional meeting, Peet brings an exceptional level of enthusiasm and passion, as well as academic rigor, to radical geography.

Philip E. Steinberg

See also **Critical Human Geography; Development Theory; Marxism, Geography and; Political Ecology; Political Economy; Radical Geography**

Further Readings

- Peet, R. (1991). *Global capitalism: Theories of societal development*. London: Routledge.
- Peet, R. (1998). *Modern geographical thought*. Oxford, UK: Blackwell.
- Peet, R. (2003). *Unholy trinity: The IMF, World Bank, and the WTO*. New York: Zed Books.
- Peet, R. (2007). *Geography of power: The making of global economic policy*. London: Zed Books.
- Peet, R., & Hartwick, E. (2008). *Theories of development* (2nd ed.). New York: Guilford Press.
- Peet, R., & Watts, M. (Eds.). (2004). *Liberation ecologies* (2nd ed.). London: Routledge.



PENCK, WALTHER (1888–1923)

Walther Penck was the son of the famous German Quaternary scientist and geomorphologist Albrecht Penck. Albrecht had both a professional and a personal relationship with William Morris Davis that eventually became acrimonious. Walther Penck's claim to fame as a geomorphologist rests on the posthumous publication by his father, in 1924, of his book *Die morphologische Analyse* (*Morphological Analysis*). Written in highly convoluted German, it received very little attention in Germany but became a central and contentious topic within the English-speaking world of geomorphology due to what some perceived as a self-serving interpretation by Davis. This article remained the authoritative English source of Penck's ideas until Hella Czech and Katharine Cumming Boswell published an English translation of the work 40 years later.

The idea in Penck's work that received so much attention in the English-speaking geomorphologic world was that of the parallel retreat of slopes. Such a pathway would produce an entirely different history of both slope and landscape development from that proposed by Davis, whose convexo-concave slope profiles decline in angle with time and whose landscapes become peneplains. This alternate view of slope development became most significant in Lester King's description of landscape development that produces pediplains, not peneplains. While King and others assigned the concept of parallel slope retreat to Walther Penck, this is a misconception that was first found in Davis's interpretation. Penck initially launched his ideas cautiously, apparently trying to avoid direct conflict with Davis, but later he became more openly critical of Davisian ideas.

The reality is that Penck produced a very logical and internally consistent model of slope development that argued not for the parallel retreat of slopes but for slope replacement extending upslope from the base. However, the slope model was not Penck's primary objective; his real objective was to investigate tectonic, or crustal, movements, which he attempted to do by relating surficial form to subsurface activity. He tied his ideas on slope form closely to local tectonic

history and synthesized his views on individual slopes to produce regional assemblages such as *Piedmontreppen* (stepped erosional benches) and *Primarrumpf* (primary peneplains). Complicated German and an early death left many of Penck's ideas undetermined in detail within the English-speaking world, making him a major figure in English language geomorphology and a minor one in his native Germany.

Colin Edward Thorn

See also **Davis, William Morris; Geomorphology; Gilbert, Grove Karl; Physical Geography, History of**

Further Readings

- Bremen, H. (1983). Albrecht Penck (1858–1945) and Walther Penck (1888–1923): Two German geomorphologists. *Zeitschrift für Geomorphologie N.F.*, 27(2), 129–138.
- Davis, W. M. (1932). Piedmont benchlands and Primarrumpfe. *Geological Society of America Bulletin*, 43, 399–440.
- Penck, W. (1972). *Morphological analysis of land forms* (H. Czech & K. C. Boswell, Trans.). New York: Hafner. (Original work published 1924)
- Young, A. (1972). *Slopes*. Edinburgh, UK: Oliver & Boyd.

PERIGLACIAL ENVIRONMENTS

Periglacial environments are characterized by intense frost, often combined with the presence of perennially frozen ground, or permafrost. Periglacial environments are restricted to areas that experience cold, but essentially nonglacial, climates. They include (a) the polar deserts and semideserts of the High Arctic and the icefree areas of Antarctica; (b) the extensive tundra zones of high latitudes; (c) the northern parts of the boreal forests of North America and Eurasia; (d) the alpine zones that lie above the timberline and below the snowline in mid- and low-latitude mountains; (e) the high-elevation montane environments of Central Asia, the largest of which is the Qinghai-Xizang (Tibet) Plateau of China; and



(f) small oceanic islands in the high latitudes of both the polar regions.

In climatic terms, periglacial environments are areas where the mean annual air temperature is less than +3 °C. This can be subdivided into environments where frost action dominates (mean annual air temperature less than −2 °C) and those areas in which frost action occurs but does not necessarily dominate (mean annual air temperature between −2 °C and +3 °C). Fundamental to most periglacial environments is the freezing of water and its associated frost heaving and ice segregation.

Periglacial environments occupy approximately 20% of the world's land area. However, their human population is only 7 to 9 million, mostly living in Russia, or only 0.3% of the world's population. Thus, the larger importance of periglacial environments lies not in their spatial extent but in their natural resources. For example, the old Precambrian basement rocks that outcrop as huge tablelands in both Canada and Siberia contain precious minerals, such as gold and diamonds, and sizable deposits of lead, zinc, and copper, while the sedimentary basins of Western Siberia, Northern Alaska, and the Canadian High Arctic contain large hydrocarbon reserves. A second reason why periglacial environments are of significance is their place within the cryosphere (i.e., snow, ice, frozen ground, sea ice) and the critical role that the cryosphere plays in global climate change.

Periglacial Ecosystems

The most extensive periglacial environments are those of the high northern latitudes (Figure 1). These can be regarded as either arctic or subarctic in nature. The boundary between the two approximates the northern limit of trees, the so-called tree line. This is a zone, 30 to 150 kilometers in extent, north of which trees are no longer able to survive. North of the tree line, the terrain is perennially frozen, and the surface thaws for a period of only 2 to 3 months each summer to depths that, in vegetated areas, may be as little as 30 to 50 centimeters. Ecologists refer to the vegetated but treeless arctic as tundra (see lowland tundra photo). Where Precambrian basement rocks occur, as in the tablelands of Northern Canada

and Siberia, the tundra is barren. At higher latitudes, the tundra progressively changes into semi-desert and, ultimately, into polar desert terrain (a “frost-rubble” zone) in the high latitudes of Arctic Canada, Northeast Greenland, Svalbard, and Novaya Zembya.

The alpine environments of the midlatitudes are less extensive but equally distinct, being dominated by both diurnal and seasonal effects and by much higher solar radiation. In such environments, the timberline constitutes the boundary between the alpine and subalpine. Alpine environments are dominated by steep slopes, tundra (alpine) plants, rock outcrops, and snow and ice. The montane environments of Central Asia differ from the alpine environments in that they are more extensive, are far more arid, and consist of steppe grasslands and intervening desert-like uplands. In Antarctica, the relatively small ice-free areas are unusual, being essentially polar deserts or rock-rubble surfaces that are kept free of snow and ice by sublimation from strong katabatic winds that flow outward from the Antarctic ice sheet.

The tundra and polar deserts of both North America and Eurasia contain a surprisingly large number of plants and animals, given the severe climatic constraints. For example, large mammals such as the polar bear, musk ox, and fox are all present, although the number of mammals and plant species progressively increases southward in the tundra. In the subarctic, two major ecological zones can be recognized (see tundra photo). Near the tree line is a zone of transition from tundra to forest consisting of either open woodland or forest tundra. Here, the trees are stunted and deformed, often being less than 3 to 4 m (meters) high. Woodland caribou and grizzly bear replace the polar bear and musk ox. This zone grades into the boreal forest, or taiga, an immense zone of almost continuous coniferous forest extending across both North America and Eurasia. In North America, the dominant species are spruce (*Picea glauca* and *P. mariana*). In Siberia, the dominant species are pine (*Pinus silvestris*) and tamarack (*Larix dahurica*). The southern boundary of the subarctic is less clearly defined than its northern boundary; typically, coniferous species begin to be replaced by others of either local or temperate distribution, such as oak, hemlock, and beech, or

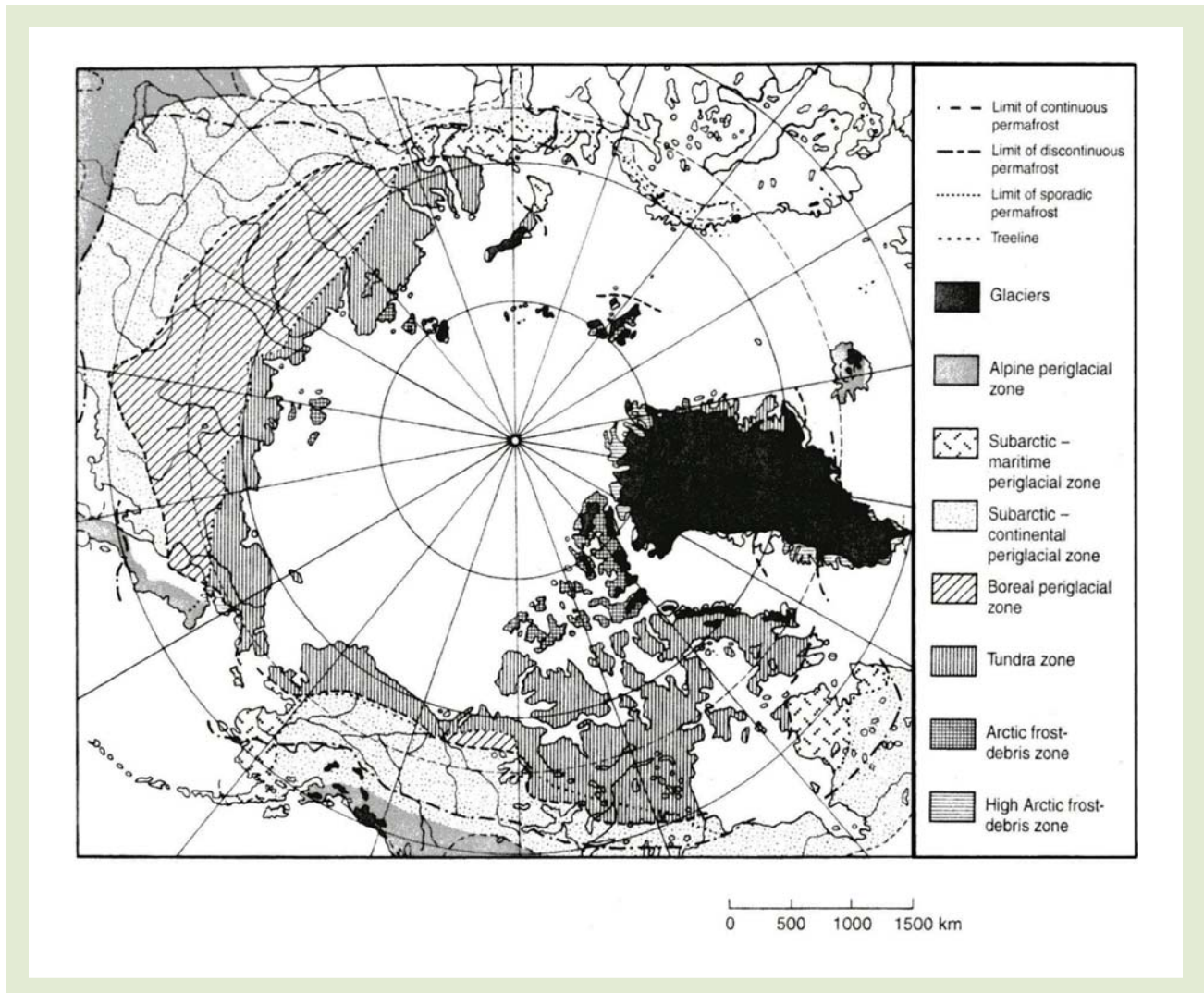


Figure 1 Regional extent of the periglacial domain in the Northern Hemisphere

Source: French, H. M. (2007). *The periglacial environment* (3rd ed., Figure 1.5, p. 12). Chichester, UK: Wiley. Copyright © 2007. Reprinted by permission of Wiley-Blackwell.

by steppe, grassland, and semiarid woodland in more continental areas. These ecosystems, which experience deep seasonal frost, represent the outer spatial extent of periglacial environments.

Periglacial Landscapes

Periglacial landscapes range between those in which the entire landscape is fashioned by permafrost and frost action processes and those in which frost action processes are subservient to others. This diversity is accentuated by the fact that (a) certain rock types are more prone

to frost action than others, (b) many regions currently experiencing periglacial climatic conditions have only recently emerged from beneath continental ice sheets and are largely glacial landscapes, and (c) the Pleistocene periglacial conditions fluctuated considerably in duration, extent, and intensity. Thus, many so-called periglacial landscapes are more accurately described as being *paraglacial* (i.e., in transition from glacial to nonglacial conditions), while the icefree areas of the Antarctic continent, being peripheral to the vast East and West Antarctic ice domes, are essentially *proglacial* in nature.



Typical lowland tundra terrain on the southern side of Banks Island, Arctic Canada. Fluvial terraces, thaw lakes, and tundra polygons are characteristic. Note the musk oxen grazing on the tundra and the soil instability on the sloping terrain in the immediate foreground.

Source: Author.

Geomorphic processes clearly unique to periglacial environments include (a) the formation of permafrost and ground-ice bodies, (b) the thermal-contraction cracking of frozen ground, (c) the thawing of permafrost (thermokarst), and (d) the creep of ice-rich permafrost. The most dramatic periglacial landform is the *pingo*, a conical ice-cored mound (see pingos photo). Equally dramatic are ground-ice slumps that occur locally wherever massive icy bodies are exposed within the permafrost. The most common feature of lowland permafrost terrain is large polygonal networks of thermal-contraction cracks. Typically, they are 15 to 30 m in dimension (see tundra polygons photo). The cracks are filled either with ice, forming tapered bodies of foliated ice known as ice wedges, or by a combination of ice and wind-blown material to form sand or composite

wedges. Thermally induced lateral movement in the near-surface layer transports material from the center of the polygon toward the periphery to form shallow ridges on either side of the thermal-contraction crack. The result is the formation of low-centered polygons. The transition to high-centered polygons usually reflects better drainage. In bedrock, thermal-contraction cracking often occurs along joints and other lines of weakness. The thaw erosion of ice-rich permafrost often leads to gulying along the ice wedges and the growth of thaw lakes and ponds. The creep of ice-rich permafrost is slow, measured in just millimeters per year, but in alpine environments, the movement of rock glaciers is more rapid.

Other processes, not necessarily restricted to periglacial environments, are important on account of their high magnitude or frequency.



The largest concentration of pingos, more than 1,350, occurs in the Mackenzie Delta region, Northwestern Arctic Canada. The majority occur in recently drained lake basins. Ibyuk Pingo, near Tuktoyaktuk, is one of the largest and best known.

Source: Author.

These center on the frost weathering of soils and surficial materials, leading to the formation of patterned ground and disturbed near-surface soil profiles and to the disintegration of exposed bedrock by frost wedging, growth of segregated ice lenses, or a complex of poorly understood physicochemical (cryogenic) and biological weathering processes. In uplands and areas of coherent bedrock, coarse, angular rock-rubble, termed *block-fields* or *kurums*, occurs widely. More resistant bedrock outcrops form cliffs, isolated hills, and tors. Frost widening of joints is also common. Wind action, in the form of abrasion and eolian sediment movement, is especially important in Antarctica and Northeast Greenland, where strong katabatic winds flow outward from the continental ice sheets, and elsewhere in the polar deserts, where the absence of vegetation allows for effective wind erosion. In the tundra lowlands, mass wasting of water-saturated near-surface materials follows the snowmelt in spring and

early summer. Commonly referred to as *solifluction*, this leads to gentle, undulating relief. Frost heaving and ice segregation in the near-surface thawed zone (the active layer) commonly result in small-scale sorted and nonsorted patterned ground (circles, stripes, and lobes), frost heaving of bedrock, and the formation of hummocks microtopography (thufurs, earth hummocks).

Human Occupancy and Environmental Concerns

Periglacial environments are part of the cryosphere. As such, if global climate change proceeds as predicted, periglacial environments will be among the first to be affected. This is because periglacial environments act as a positive feedback mechanism for climate warming. It is now understood that the hydrological cycle of the big northern rivers of North America and Eurasia links snowmelt and precipitation with river runoff, sea



Tundra polygons, 15–25 m in dimension, are characteristic of permafrost terrain. On the northern slope of Alaska, buildings, roads, and other forms of economic infrastructure are constructed on gravel pads to minimize disturbance to the thermal regime of the tundra. This photo, taken in 1979, shows a recently abandoned exploratory well site.

Source: Author.

ice, and ocean circulation in a single system. This influences deepwater formation in the Arctic basin and the corresponding global thermohaline circulation of the oceans. At the same time, any reduction in the extent of sea ice or snow cover reduces the albedo, or reflectivity, of land or ocean surface and allows more solar radiation to be absorbed.

In North America, the thawing of discontinuous permafrost at the southern (warm) limits of the discontinuous permafrost zone has been ongoing for more than 50 years. This trend is continuing, and the tree line is slowly but progressively advancing northward. In many parts of the world, the active layer is beginning to increase in thickness. The latter, monitored by the Circumpolar Active Layer Monitoring (CALM) program of the International Permafrost Association, will lead to

an increase in slope instability, changing snow-melt and hydrological regimes, and enhanced mass wasting and landscape modification in permafrost environments. Increased thaw will also affect near-surface, organic-rich layers at the active layer/permafrost boundary, especially in the subarctic. This will release significant quantities of carbon dioxide and methane, both of which are important greenhouse gases. In the alpine midlatitude periglacial environments, thawing permafrost may lead to instability of rock outcrops, which may threaten the foundations of ski lifts and other recreational installations at high elevation. Such problems are of special concern in the mountain regions of Western Europe.

In recent years, several other geotechnical and environmental concerns have come to be



The Trans-Alaska Pipeline System carries warm oil from Northern Alaska to Valdez on the Pacific coast. Where the pipe traverses warm permafrost, as near Fairbanks, Central Alaska, the pipe is elevated on vertical support members that are equipped with cooling devices (“heat tubes”) to prevent heat transfer from the pipe to the thaw-sensitive permafrost beneath.

Source: Author.

associated with periglacial environments. Geotechnical problems are widespread and relate largely to the water and/or ice content of permafrost. For example, frost heave causes significant damage to building structures and foundations. For example, in the case of pile foundations for buildings, repeated cycles of heave can progressively lift the pile, causing the structure to become unstable. The annual cost of rectifying seasonal frost damage to roads, underground utilities, and buildings in areas of permafrost and deep seasonal frost, as currently exist in large parts of Northern Canada, Alaska, Sweden, Northern Japan, and Russia, is considerable. The thaw of frozen ground also presents problems. For example, in unconsolidated ice-rich sediments, thaw consolidation may occur as sediments compact and settle under their own weight, thereby generating

high pore-water pressures that favor slope instability and slumping. There is also a significant loss of bearing strength on thawing. Another group of problems relates to the unusual hydrological and groundwater characteristics of permafrost terrain. Permafrost prevents the infiltration of surface water; restricts groundwater movement to unfrozen zones, or *tàliks*; and may cause groundwater to be highly mineralized. The availability of good drinking water is a major problem for many small communities in the permafrost regions of North America and Siberia.

Modern construction techniques aim to maintain the thermal equilibrium of the permafrost and to avoid the onset of thermokarst. The most common technique is the use of a gravel pad placed on the ground beneath the structure (see polygon photo). This compensates for the increase



in thaw that results from the warmth of the structure. Another technique is to mount the structure on wooden or concrete piles, thereby creating an air space between the ground surface and the structure. This allows air circulation to dissipate the heat coming from the structure. More sophisticated techniques include insertion of open-ended culverts, the use of insulated matting, and, if the structure justifies it, the insertion of costly refrigeration devices (“cryo-anchors”). In regions of warm permafrost and where large engineering ventures are concerned, so-called passive cooling methods are increasingly being used. These maintain thermal equilibrium by taking advantage of seasonal convection in high-permeability rock debris and are especially appropriate for road, rail, and airport embankments. The same technique is used to maintain the frozen nature of hazardous containment dykes at oil storage facilities and earthen dams constructed to contain toxic mine tailings and other contaminants.

The construction of oil and gas pipelines through permafrost terrain poses special problems. With warm-oil pipelines, the problem is the potential thaw of permafrost and the rupture of the pipe. In the case of the Trans-Alaska Pipeline System, which was constructed in the mid 1970s, the pipe was elevated above the ground on vertical support members wherever ice-rich permafrost was present (see Trans-Alaska Pipeline System photo). In the case of chilled-gas pipelines, which are usually buried and operate best when the gas is chilled to temperatures below zero, the problem is one of prolonged frost heave adjacent to the pipe and the creation of a frost bulb around the pipe. Satisfactory engineering solutions are yet to be devised to overcome this problem.

Increased economic activity in periglacial regions has been associated with human-induced terrain damage. For example, the search for oil and gas in regions such as Northern Alaska in the late 1940s and early 1950s and the Yamal Peninsula in Western Siberia in the late 1980s resulted in significant human-induced thermokarst activity following indiscriminate vehicle movement over the tundra terrain in summer. Thaw erosion along vehicle tracks that destroys surface vegetation commonly takes several decades to stabilize. The containment of waste-drilling fluids at the sites of exploratory drillings and of oil spills and

leakages from producing wells poses additional problems. Land use and regulatory problems by governments and administrative bodies are increasing in complexity and number.

Hugh M. French

See also **Biome: Boreal Forest; Biome: Tundra; Climate: Polar; Glaciers: Continental; Ice; Permafrost; Poles, North and South**

Further Readings

French, H. M. (2007). *The periglacial environment* (3rd ed.). Chichester, UK: Wiley.



PERMACULTURE

Permaculture is an adaptive, integrated, and holistic design science providing a symbiotic relationship between modern and indigenous cultures specific to a permanent place within ecological systems. The word *permaculture* was first used in the mid 1970s by Bill Mollison, an Australian ecologist, and his student David Holmgren. It involves a synergism of permanent agriculture evolving to a permanent culture. Permaculture designs patterns of ecosystems that balance human habitats with self-sufficient community food production systems. The ecological design path aims to preserve biodiversity through closed natural ecosystems. The scientific principles of permaculture lie generally within the synthesis of systems ecology and geography. The land use systems principles promote a resilient ecosystem and society.

Permaculture merges traditional cultures with local organic agriculture in urban and rural land design. The design is site specific with respect to locally adapted agrarian production techniques. It uses built environment green-building techniques such as solar and wind power, greenhouses, energy-efficient housing, and solar food cooking and drying. Permaculture integrates agroecological methods of production, using standard organic farming and gardening techniques, including cover crops, green manures, crop rotation, and mulches.



Permaculture Ethics

The ethics of permaculture provide a broad sense of three principles common to most indigenous tribal cultures. These cultures have existed in balance with their environment in a rooted community for many generations.

1. *Care of the Earth*: caring for the Earth from the soil up through a spiritual connection with all living and nonliving things in one's basic everyday decisions. The pragmatic philosophy of permaculture acknowledges the ecological limits of the Earth.
2. *Care for people*: promotes self-reliance and an interconnected web of community responsibility, reducing one's own dependence on the global economy and replacing it with local resources. Permaculture designs landscapes in which biodiversity and its members thrive in the bioregion.
3. *Setting limits to consumption and reproduction and redistributing surplus*: a sense of limits evolves from the knowledge that everything in nature has a limited lifespan and place. Monitoring one's own ecological footprint is a method to determine one's own individual needs within the capacity of the Earth. Redistributing one's local surplus of knowledge of permaculture skills or resources such as water, energy, or food helps build local community webs outside one's own bioregion.

Principles

Permaculture principles promote community change to improve global external environmental conditions. According to David Holmgren, there are 12 conceptual permaculture design principles:

1. Observe and interact.
2. Catch and store energy.
3. Obtain a yield.
4. Apply self-regulation and accept feedback.
5. Use and value renewable resources and services.
6. Produce no waste.

7. Design from patterns to details.
8. Integrate rather than segregate.
9. Use small and slow solutions.
10. Use and value diversity.
11. Use edges and value the marginal.
12. Creatively use and respond to change.

Benjamin Newton

See also Agroecology; Bioregionalism; Crop Rotation; Footprint Analysis; Green Building; Indigenous Environmental Knowledge; Indigenous Environmental Practices; Organic Agriculture

Further Readings

- Diver, S. (2002). *Introduction to permaculture: Concepts and resources* (Publication No. CT083). Fayetteville, AR: Appropriate Technology Transfer for Rural Areas, National Sustainable Agriculture Information Service.
- Holmgren, D. (2002). *Permaculture: Principles and pathways beyond sustainability*. Hepburn, Victoria, Australia: Holmgren Design Services.



PERMAFROST

Permafrost is any subsurface earth material that remains below 0 °C for at least two consecutive years, including the intervening summer. Currently, permafrost covers approximately 25% of the Northern Hemisphere land surface and approximately 25% of the Antarctic continent. Permafrost may also be found as “subsea permafrost” on the seafloor bottom, particularly on the northern continental shelves of North America and Eurasia. In regions where average annual surface air temperatures are 0 °C or less, permafrost develops and thickens because ground freezing penetrates more deeply than summer thawing can reverse. Thus, each year will bring about deeper and deeper frozen ground until the geothermal regime deep within the Earth counteracts this downward freezing process.



Ultimately, equilibrium will be established, therefore providing a stable permafrost depth. Heat conduction through rock and soil can be extremely slow, and depending on the magnitude of a potential surface temperature change, it may take thousands of years before a new thermal equilibrium is established.

Permafrost can be partitioned by areal extent and is typically defined as consisting of continuous (90–100%), discontinuous (50–90%), sporadic (10–50%), or isolated patches (0–10%) (Figure 1). The thickness of permafrost can be quite variable and generally varies between 100 and 800 m (meters) in continuous permafrost, 25 and 100 m in discontinuous permafrost, and 10 and 50 m in sporadic permafrost, yet there is always a seasonally thawed “active layer” at the surface that can vary from centimeters to meters in thickness (Figure 2). The active layer provides an extremely important stratum for activities related to regional geomorphology, vegetation, microbes, soil moisture, and soil carbon stocks. Permafrost soils can be quite complex and may vary tremendously through a vertical column. For instance, arctic soils typically contain organic material at the surface (with compositions ranging from mosses to humus) overlaying mineral soils. Moisture may not necessarily be present in permafrost layers below the active layer: “Dry” permafrost, for example, contains no liquid or solid water. In most cases, however, ice is present (sometimes even in large concentrations as ice wedges) and is a very important factor in the mechanics of permafrost.

Recent Permafrost Degradation

Near-surface permafrost is expected to exhibit significant degradation over the coming century due to current and future climate warming, although this process may somewhat lag behind trends in warming surface air temperatures. Warming air temperatures lead to permafrost thaw and degradation, which can include thickening of the active layer, talik formation, thermokarst development, expansion or creation of thaw lakes, lateral permafrost thawing, and a northward migration of the southern permafrost boundary. These changes can have significant impacts on hydrology, ecosystems, and biogeochemical cycling. Permafrost

warming and degradation may in turn be accelerated by positive feedbacks to include carbon release from freshly thawed soils, projected expansion of shrub cover, and wildfire occurrence.

Three types of permafrost degradation may occur as a result of climate warming: (1) overall permafrost thaw, (2) deepening active layers, and (3) thermokarst processes. Overall or “wholesale” permafrost thaw and thermal degradation result in widespread reductions in permafrost extent, allowing for a connection between deep groundwaters and surface water pathways. As opposed to active-layer and thermokarst processes, time lags involved with wholesale permafrost thaw can be significantly longer, where temperature changes at the ground surface may take from a few years to millennia to reach the bottom of the permafrost layers. Not only can permafrost warm and degrade from the surface as well as from the bottom, but permafrost may also degrade internally if it contains unfrozen water, as seen in some areas of Alaska. Although direct measurements of long-term permafrost dynamics are relatively rare and no real widespread pan-arctic wholesale permafrost thaw has been observed, some studies have in fact shown some substantial local and regional permafrost degradation through field observations. Active-layer thaw depths are also highly responsive to warming air temperatures and can be important indicators of permafrost stability. Deepening active layers may increase the interaction between surface waters and soils within the newly thawed portions of the active layer as well as liberate soluble biogeochemical constituents previously sequestered within the near-surface permafrost. Last, it is also important to address thermokarst processes in the context of permafrost degradation, which is the surface thawing of ice-rich ground and subsequent thaw slumping. Thermokarst is associated with warming air temperatures in discontinuous and sporadic zones of permafrost extent, but it can also occur in regions of continuous permafrost and is not always tied directly to wholesale permafrost degradation.

Impacts of Permafrost Degradation

One of the most important changes to the arctic system caused by ongoing and future warming

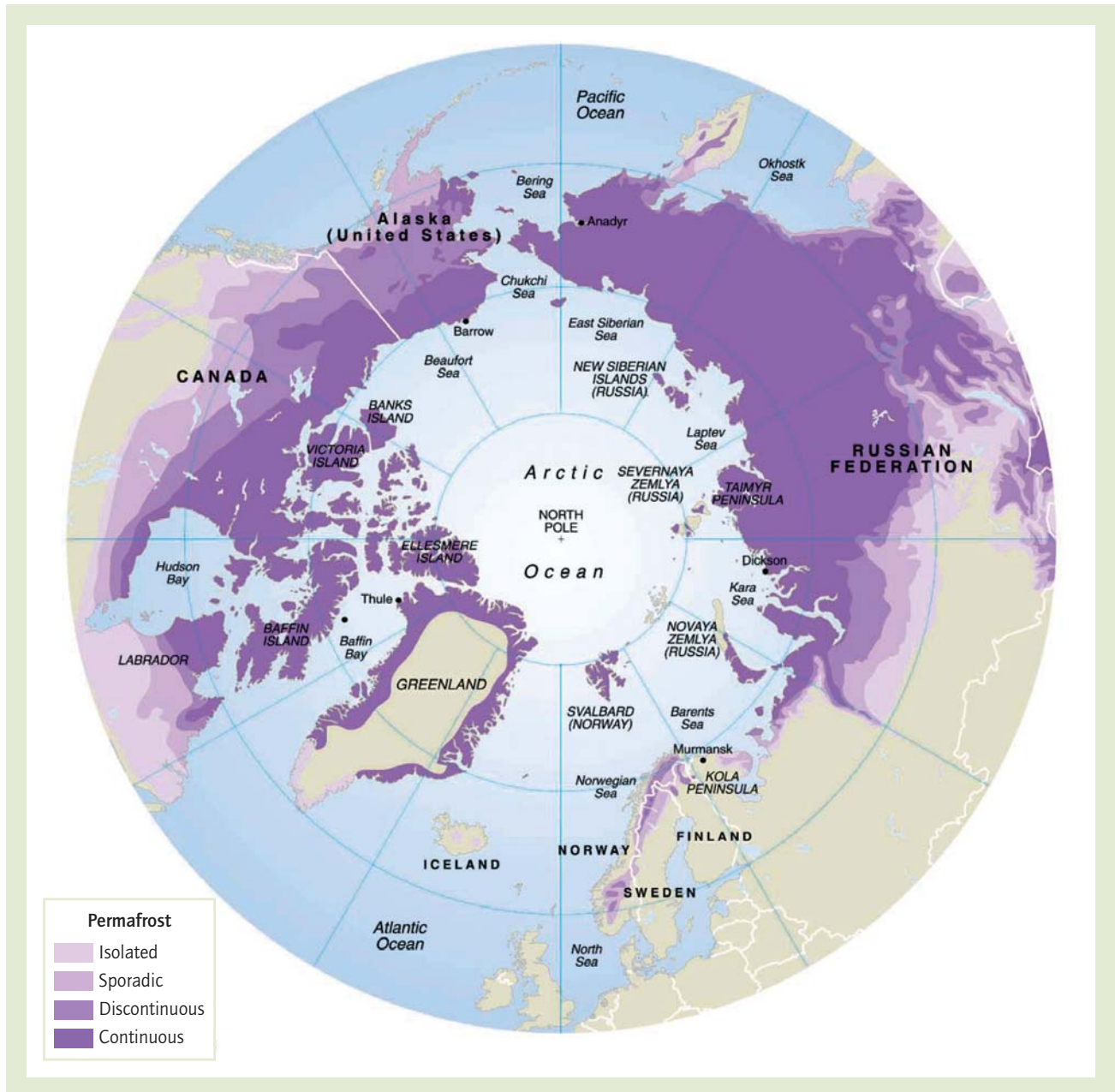


Figure 1 Distribution of continuous, discontinuous, sporadic, and isolated permafrost in the Northern Hemisphere

Sources: Map by Philippe Rekacewicz, UNEP/GRID-Arendal; data from International Permafrost Association, 1998. Circumpolar Active-Layer Permafrost System (CAPS), Version 1.0.

will be the shift from a surface water-dominated system to a groundwater-dominated system. As permafrost degrades and previously frozen soils thaw, significant changes to the flow paths of waters will occur, resulting in profound consequences for hydrology, greenhouse gas emissions,

and biogeochemical cycling. These consequences will be highly complex and will undoubtedly exhibit the spatial and temporal variability associated with current permafrost conditions, sensitivity to thawing, and environmental characteristics of the land surface (e.g., land cover, soil type, and

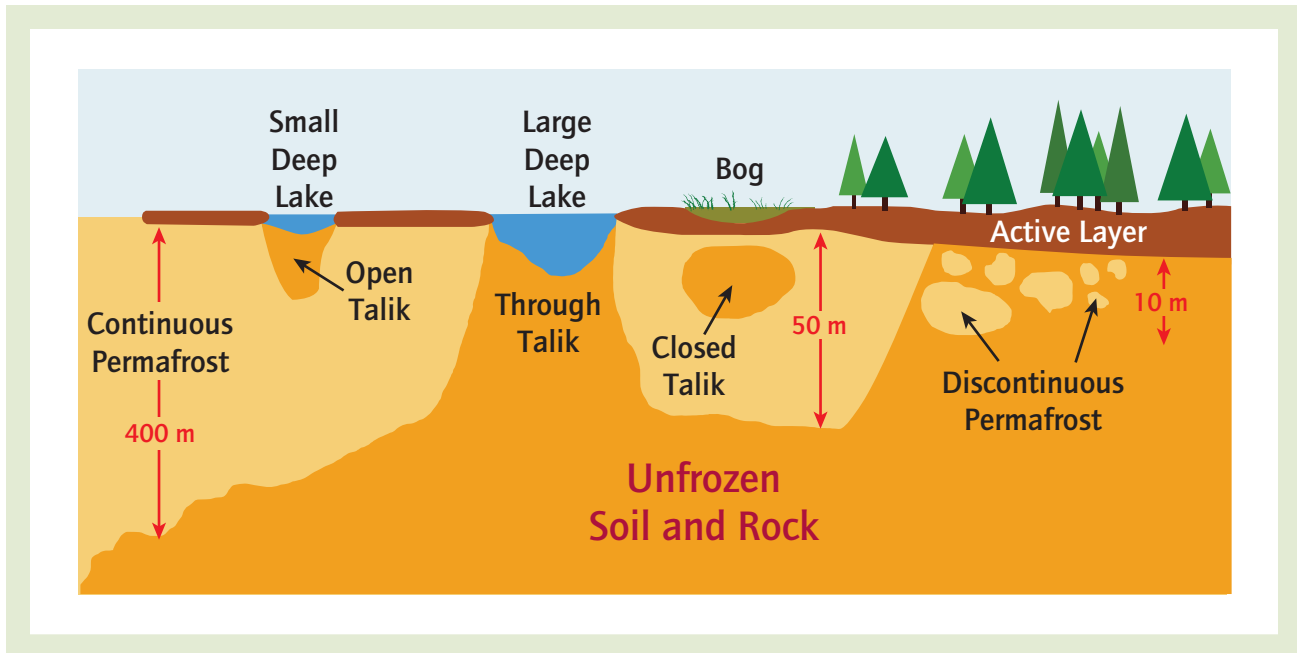


Figure 2 An example of permafrost distribution in cross section

Source: Pidwirny, M. (2006). Periglacial processes and landforms. *Fundamentals of physical geography* (2nd ed.). Retrieved February 19, 2009, from www.physicalgeography.net/fundamentals/10ag.html. Reprinted with permission.

topography). Some of the most significant impacts of permafrost degradation include those related to (a) terrain stability, (b) greenhouse gas emissions, (c) physical hydrology, and (d) stream and river biogeochemistry.

Extensive thawing of permafrost will have important implications for the stability of the terrain and cause massive surface deformation as ice-rich soil melts. Thermokarst topography is associated with an increase in the depth of the active layer and melting of ice within the ground. This melting leads to settlement and subsidence of the ground in irregular hummocks and depressions containing standing water. This ground subsidence can have massive impacts on human infrastructure such as roads and buildings. Other surface features created by permafrost thawing include retrogressive thaw slumping, active-layer detachment, creep, and enhanced coastal erosion.

Permafrost degradation may also have important implications for greenhouse gas emissions, including both carbon dioxide and methane. The current presence of permafrost in high-latitude regions inhibits percolation of surface water and allows the water table to be sustained close to the

soil surface, thereby maintaining saturated soils or open water surfaces across much of the landscape. These resulting anaerobic wetland regions can be significant sources of methane to the atmosphere. However, permafrost degradation and the subsequent draining of these surface waters exposes carbon-rich soils to aerobic decomposition, which may reduce methane emissions but significantly increase carbon dioxide emissions to the atmosphere. Furthermore, permafrost degradation and thermokarst processes beneath lakes have also been shown to be globally significant sources of methane to the atmosphere. Thawed lake sediments actively produce and emit methane and cause bubbling (or “ebullition”) of methane from lake bottoms and through lake waters to the atmosphere. This resulting methane ebullition is a large and increasing source of atmospheric methane as thermokarst lakes continue to expand with permafrost degradation.

The physical hydrology of systems may also be affected by climate warming and subsequent permafrost degradation. Arctic streams and rivers have experienced observable increases in discharge over the past several decades, with the



thawing of permafrost considered one of many possibilities contributing to this increase. Lakes have also experienced dramatic changes due to permafrost degradation. For instance, in areas of continuous permafrost, lake areas have been shown to grow as thermokarst processes force an increase in lake basin areas. However, in discontinuous permafrost areas, permafrost is sparse enough so that a breach of permafrost layers and sudden connection of lake surface waters with groundwater pathways can cause lakes to disappear entirely. This catastrophic drainage and disappearance of lakes can have many cascading implications that include impacts on the land-atmosphere exchange of carbon, water, and energy but they also may have severe impacts for migrating waterfowl that rely on these wetland and lake-rich areas as breeding grounds.

Permafrost currently underlies significant portions of the six largest Arctic watersheds (Ob', Yenisey, Lena, Kolyma, Mackenzie, and Yukon rivers) in addition to many other smaller streams and rivers entering the Arctic Ocean. As such, profound impacts will occur here with permafrost degradation, including biogeochemical cycling within these watersheds and the resulting delivery of organic matter, inorganic nutrients, and major ions to the Arctic Ocean. One of the most profound consequences of permafrost thaw projected for the future is that the arctic terrestrial freshwater system is likely to experience a transition from a surface water-dominated system to a groundwater-dominated system. Most studies observe or predict an increase in major ion, phosphate, and silica export with this shift toward greater groundwater contributions. However, there are conflicting accounts of whether the delivery of inorganic nitrogen and organic matter will increase or decrease with warming and permafrost thaw. It is clear that over the next century there will be important shifts in the river transport of organic matter, inorganic nutrients, and major ions, which may in turn have critical implications for primary production and carbon cycling on arctic shelves and in the Arctic Ocean basin interior.

Karen E. Frey

See also **Biome: Boreal Forest; Biome: Tundra; Climate: Polar; Glaciers: Continental; Ice; Poles, North and South**

Further Readings

- Frey, K. E., & McClelland, J. W. (2009). Impacts of permafrost degradation on arctic river biogeochemistry. *Hydrological Processes*, 23, 169–182.
- Kennett, J. P., Cannariato, K. G., Hendy, I. L., & Behl, R. J. (2003). *Methane hydrates in quaternary climate change: The clathrate gun hypothesis*. Washington, DC: American Geophysical Union.
- Margesin, R. (2009). *Permafrost soils*. Berlin, Germany: Springer.
- Smith, L. C., Sheng, Y., MacDonald, G. M., & Hinzman, L. D. (2005). Disappearing Arctic lakes. *Science*, 308, 1429.
- Walter, K. M., Zimov, S. A., Chanton, J. P., Verbyla, D., & Chapin, F. S., III. (2006). Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming. *Nature*, 443, 71–75.



PESTICIDES

Pesticides are chemical compounds that kill unwanted organisms, typically insects, fungi, plants, and other pests that harm humans or organisms valued by humans, such as crops and domesticated animals. Pesticides are agrochemicals, a category that includes synthetic fertilizers, which are derived from petroleum and other fossil fuels. Pesticide classification systems include those arranged by the target organisms (insecticide, fungicide, herbicide, acaricides, rodenticide, etc.), by chemical origin ("inorganic" pesticides are derived from basic chemical elements such as copper, "organic" or "synthetic" pesticides from fossil fuels, and "biological" pesticide from organisms), by chemical class (organochlorines, organophosphates, etc.), and by their effects on nontarget organisms.

Farmers producing horticultural crops began widely using inorganic pesticides for pest management in the late 1800s, while synthetic pesticides were widely adopted in many agricultural systems, especially in industrialized agriculture, starting in the 1940s. Today, more than 600 different pesticide active ingredients exist, although



national regulations on these chemicals vary substantially.

Rachel Carson's 1962 famous book *Silent Spring* helped popularize an ecological consciousness through an understanding of the environmental and health effects of chlorinated hydrocarbon pesticides, such as DDT, and the acute toxicity of organophosphate pesticides. The book also inspired the modern environmental movement and the creation of the U.S. Environmental Protection Agency in 1970. Concerns over pesticides and other environmental impacts of agriculture remain an important impetus for promoting organic agriculture. Pesticides are unique in that they are biologically active agents intended to cause harm that are released intentionally into the environment, and as such, their effects are considered externalities of agro-food systems.

Numerous disciplines and fields have become involved in research related to pesticides. Epidemiological and toxicological work has shown pesticides to harm many organisms, including humans. Some pesticides cause acute poisoning, often with long-term effects, while others are carcinogens. Impairment and disruption of the endocrine, immune, and neurological systems has been shown among lab animals at doses near levels currently found in groundwater. Neurological impairment has been demonstrated among pesticide applicators and children in intensive production areas.

Two bodies of geographical work contribute to pesticide research: environmental justice and political ecology. Environmental justice has revealed the unequal distribution of risks and harms in catastrophes such as the Bhopal disaster in 1984 in India; that agribusiness interests strongly shape pesticide regulation, including risk analysis and assessment; and that farm workers as a marginalized population have had less power to influence pesticide regulation except when organized, as the United Farm Workers in California in the 1960s and 1970s. Political ecological approaches to pesticide use involve putting land users' decision making in a broader political economic context by emphasizing agricultural development policies, agrochemical marketing, and regulations, in addition to paying attention to smaller-scale variations such as farmer experiences, land ownership, agroecology, and management and geographical

strategies. Similarly, scholars researching lawn pesticide use in First World contexts have taken a political-ecological approach to show how the chemical industry's need to increase sales shapes land user decision making by promoting a monocultural lawn aesthetic.

Ryan E. Galt

See also **Agrochemical Pollution; Agroecology; Agrofoods; Bhopal, India, Chemical Disaster; Chlorinated Hydrocarbons; Herbicides; Organophosphates**

Further Readings

- Carson, R. (1962). *Silent spring*. Boston: Houghton Mifflin.
- Galt, R. E. (2007). Regulatory risk and farmers' caution with pesticides in Costa Rica. *Transactions of the Institute of British Geographers*, 32, 377–394.
- Galt, R. E. (2008). Beyond the circle of poison: Significant shifts in the global pesticide complex, 1976–2008. *Global Environmental Change*, 18, 786–799.
- Pulido, L., & Pena, D. (1998). Environmentalism and positionality: The early pesticide campaign of the United Farm Workers' Organizing Committee, 1965–1971. *Race, Gender & Class*, 6, 33–50.
- Robbins, P. (2007). *Lawn people: How grasses, weeds, and chemicals make us who we are*. Philadelphia: Temple University Press.
- Robbins, P., & Sharp, J. T. (2003). Producing and consuming chemicals: The moral economy of the American lawn. *Economic Geography*, 79, 425–451.
- Wargo, J. (1998). *Our children's toxic legacy* (2nd ed.). New Haven, CT: Yale University Press.



PEST MANAGEMENT

The term *pest management* was coined by Australian entomologists in the mid 1960s to denote the active management of pests to human levels of tolerance. Pest management operates at scales



from the individual farm to the national environment but has come to define explicit decision-making frameworks applied to prevent, reduce, or remove the impact of pests on production systems, human health, and the environment. Pest management therefore implies a coordinated management strategy with systematized decision making, in contrast to *pest control*, which refers to the set of actions applied to combat pests in the field. The historical and geographical variation in pest management concerns and regimes, the institutional and legislative frameworks for pest management, and the controversy surrounding pest management techniques are reviewed in this entry.

Pest management emerged historically as industrialization and the mechanization of agriculture prompted a shift from uncoordinated private efforts to control pests, to private firms offering pest control services, to the emergence of public authority oversight. The variation in those species considered pests in different times and places suggests that while a pest can be defined as any organism detrimental to human interests, the production of a pest is the outcome of specific processes. These range from urban health concerns over the plague, rabies, and murine typhus, to mice destroying rice harvests, to badgers spreading bovine tuberculosis on farms, to pigeons as a public nuisance in Trafalgar Square. The history of pest management also demonstrates a broadening of concern from agriculture and public health in metropolitan areas, to environmental impacts of pests such as biodiversity loss. It is perhaps the act of protecting a particular space or desirable entity (such as a residential area, a monoculture crop, or a native ecosystem) that “creates” new pests, through competition for food and habitat between humans and other animals. Research on human-animal conflicts suggests that these are spatial conflicts and challenges to our spatial categorization processes. The classification of a species as a pest is also related to a perceived excess of population numbers (too many wolves and the animal is viewed as a virulent pest, too few and it is a highly valued endangered species). But just as such species are categorized as problems (too many in the wrong place), other people are valuing them (campaigning against badger culls,

feeding birds in urban parks, and keeping rats as pets). This demonstrates that “pest” is a subjective and context-dependent classification and not an inherent property.

Important differences emerge in the pest management problems and priorities of developed and developing countries, linked to the resources available to manage pest incursions and the vulnerability of production systems and human populations to the effects of pests. Some developing countries are battling biblical swarms of pests that decimate certain agricultural sectors and adversely affect human health in urban areas. National differences in pest occurrence also have ramifications for agricultural trade, as the classification of national spaces as contaminated with particular pests restricts the legal trade of certain agricultural products.

Pest management is legislated at the regional, national, and international levels. At the international level, the Convention on Biological Diversity stipulates that signatories prevent the impact of nonnative species on native biodiversity, and the World Trade Organization sanitary and phytosanitary legislation stipulates that member states inform the international community of the presence of certain notifiable pests. National-level policies operate as stand-alone pieces of species-by-species legislation, as a part of wider environmental or agricultural legislation or as a part of integrated biosecurity legislation. Agencies with pest management responsibilities undertake a variety of coordinating activities, including developing pest management strategies, maintaining inventories of pests and the extent of their incursions, and disseminating best practices.

Control responses are determined according to the accessed level of threat a pest poses and the costs and capacity of human interference to effect change. The aim may be to prevent a pest’s spread, to reduce its negative impacts, or to achieve localized or long-term eradication. This requires the surveillance of areas for the presence or absence of pests, the selection and use of appropriate control methods, and any follow-up or monitoring work to prevent pest reestablishment. Integrated pest management (IPM) is the most well-known holistic approach, dominating the field of pest management for the past 35 years. Rather than



Tsukasa Yamamoto (left) of Bio Energetic Synchronization Technique (BEST) Farms and Agricultural Research Service (ARS) technician Mike Klungness look over a patch of fruit fly-free tomatoes. After participating in the Hawaii fruit fly areawide pest management program, cooperators can diversify and grow once abandoned popular fruits such as persimmon.

Source: Stephen Ausmus, ARS, U.S. Department of Agriculture.

simply considering treatment options, IPM focuses on why a system is susceptible to pests and collects information on the pests' processes of range extension (linked to both dispersal modes and opportunities in host environments) for the sake of developing better management practices. IPM also integrates different types of pest control techniques, including chemical, biological, and mechanical control methods.

Chemical control methods include the use of insecticides, herbicides, and fungicides (the term *pesticides* itself subsumes organic, inorganic, chemical, synthetic, and organo-synthetic products). Administred by hand, from ground machinery, or from the air, these include selective pesticides (species specific) and general (wide

spectrum) pesticides. It is in the use of chemical control methods that significant controversy surrounding pest management arises. These include health concerns to human populations through exposure to pesticides, through proximity to spraying on agricultural land, through residues on food, or through persistence and accumulation in the food chain. Environmental concerns include the direct effects of pesticide exposure on nontarget species, the reduction of available food and habitat, the cumulative poisoning of higher-level species, and the emergence of pesticide-resistant species.

Biological control methods include the release of a pest's natural enemies. There are many historic examples, particularly from the Antipodes,



of biological control agents becoming serious pests themselves. However, rigorous prerelease testing now accompanies biological control. Mechanical control methods involve barrier methods, traps or the hunting of larger animals, and frightening techniques such as recorded distress calls to deter birds. Cultural control methods refer to improved husbandry or management techniques to reduce a system's susceptibility to pests, including the use of trap crops, companion planting, and the avoidance of monoculture planting. These form an important part of IPM and organic farming. Other pest control techniques include varietal control methods, using pest resistance, including genetically engineered crop cultivars, and interference methods, such as the release of sterile males.

Within physical and human geography, pest management receives divergent attention, with little collaboration or conversation across a "realist" divide. Physical geographers contribute to the development of monitoring and management tools and to mapping and predicting pest invasion dynamics using retrospective and predictive computer modeling. In contrast, human geographers are occupied with critical explications of the underlying binary distinction between pest and nonpest, its association to other binaries such as native/alien and nature/culture, and its spatial and temporal dimensions. Research has highlighted historically shifting cultural associations both to native landscapes and to "pests" themselves and issues surrounding public antipathy toward aspects of pest management. Geography's unique perspective is its spatial expertise, whether through the application of geographic information system (GIS) techniques to map pest spread or through the conceptualization of the spatial dimensions of species' belongings. The integration of human and physical research expertise would allow the discipline of geography to expand its contributions, particularly as the pressures of climate change come to demand a new paradigm in environmental management based on species' movement and flux.

Kezia Barker

See also **Agroecology; Environmental Restoration; Exotic Species; Herbicides; Invasion and Succession; Pesticides**

Further Readings

- Barker, K. (2008). Flexible boundaries in biosecurity: Accommodating gorse in Aotearoa New Zealand. *Environment and Planning A*, 40, 1598–1614.
- Carson, R. (1962). *Silent spring*. Boston: Houghton Mifflin.
- Radcliffe, E., Hutchison, W., & Cancelado, R. (Eds.). (2009). *Integrated pest management: Concepts, tactics, strategies and case studies*. Cambridge, UK: Cambridge University Press.



PETROLEUM

Petroleum, "rock oil" or "oil from the earth" (from the Latin *petra*, "rock" or "stone," and *oleum*, "oil"), is a complex mixture of hydrocarbons and other organic compounds. As a technical term, *petroleum* refers to liquid crude oil as well as natural gas, viscous and solid forms (bitumen), and other petroleum products and possesses a large range of colors and consistencies. In ordinary language, petroleum refers specifically to *crude oil*. Scientists believe that crude oil (measured in barrels, abbreviated *bbls*) formed during the past 600 million years in the Earth from the remains of single-celled planktonic animals and plants in ancient seas and lakes. Over time, layers of mud, silt, and sand covered these remains, forming sedimentary rock over them. Geologic heat and pressure from this weight turned the biomass into crude oil and forced it into nearby porous rocks. Several geological elements have to be present for any kind of petroleum to form. These include source rocks that are rich in organic materials to generate petroleum, porous reservoir rocks (such as sandstone) to store the petroleum, and a nonporous trap, such as faults, anticlines, or salt domes, to prevent the petroleum from leaking away. These formations exist at varying depths (mostly between 150 and 7,600 meters [500–25,000 feet]) in the Earth's crust (beneath land as well as offshore). Even though petroleum occasionally reaches the surface through seepages, most of the time, expensive drilling and pumping technologies are necessary to find, extract, and collect it.

Petroleum has been known and used in numerous regions around the world for thousands of



years: People have used it to light lamps, for caulking and waterproofing, for medicinal purposes, or as a fire weapon. New extraction technology resulted from the pioneering work of Edwin Laurentine Drake, who in 1859 innovated the technology of drilling wells on Oil Creek in Pennsylvania (later known as Titusville) by driving down pipes to keep the drill hole from filling in and thereby providing access to deeper oil fields. Kerosene, a petroleum distillate, eventually replaced whale oil for lighting, but there was no large demand for oil until advanced refining techniques and technological inventions created new uses for petroleum. In particular, the invention of gasoline-powered automobiles in 1885 to 1886 by Gottlieb Wilhelm Daimler and Karl Friedrich Benz and their later mass production along assembly lines conceived by Henry Ford around 1913 to 1914 provoked new demand for petroleum as an engine lubricant, and consumers and companies alike pushed for further oil drilling. These dynamics also generated a growing demand for *gasoline*—originally a by-product of kerosene—to fuel new automobiles. This demand spurred research for new sources and pushed companies to establish extensive distribution networks of gas stations. Thus, petroleum rose to be the most important fossil fuel of the 20th century.

Once they extracted crude oil, investors had to temporarily store, refine, and transport it. They developed cylindrical tanks made from wood or steel to provide storage before shipment or refining. Various designs emerged, with special forms for volatile liquids and other products. (The high flammability of petroleum and its products has led to numerous fires, starting with the early extraction places in Pennsylvania.) Crude oil also has to go through various refining processes, including distillation, which separates the hydrocarbon components from each other and turns the crude oil into usable products. New uses are created regularly and are present (along with autos and engines) in our everyday life, from plastics to lubricants, dyes, drugs, and many synthetic materials. Production sites for these products are often located far away from both refineries and consumers, as it is generally cheaper to move crude oil than the refined product. Railroads were an important early means of transportation, and barges carried oil on inland waterways or along

coastal areas. Now supertankers that hold 100,000 to more than 2 million bbls make possible the global transport of oil. Increased maritime traffic puts stress especially on choke points such as the Suez and Panama Canals and the Bosphorus Strait, making them important geopolitical sites.

Oil extraction, production, and resale depend on both large businesses and national governments, creating multiple transnational linkages and friction points. The oil industry has produced numerous powerful global players. Among the best known is ExxonMobil. Its roots go back to 1863, when John D. Rockefeller joined an oil-refining business in Cleveland, which in 1870 became the Standard Oil Company, which controlled the refining of 90% to 95% of all oil in the United States by 1880. Nine trustees, including Rockefeller, created the Standard Oil Trust in 1882 by merging various companies engaged in producing, refining, and marketing oil. The company became the model of economic concentration and control and successfully expanded beyond national borders, making petroleum the primary source of energy around the world. In 1911, the enforcement of federal antitrust laws led to its dissolution. The units of the complex themselves became global giants, including Exxon, Mobil, Amoco, and others (and some of them have merged again in subsequent years).

The oil business started out as a private business venture, but World War I was a turning point, as the military depended on gasoline for its ships, tanks, trucks, and cars. The growing political importance of oil and its geopolitical implications made it a major factor in colonialism, and wars—including the two world wars—have been closely linked to questions of oil ownership and availability. Oil companies and national governments have therefore closely collaborated at home and in colonial settings, leading, for example, to British government support for the Anglo-Persian Oil Company shortly before World War I under the influence of Winston Churchill and the *Compagnie Française des Pétroles* (CFP), founded in 1924 and today known as Total.

After World War II, when submarine attacks showed the vulnerability of oil tankers, the U.S. government initiated further construction of pipelines (the Big Inch and the Little Inch, built between 1942 and 1943 by War Emergency Pipelines, Inc.,

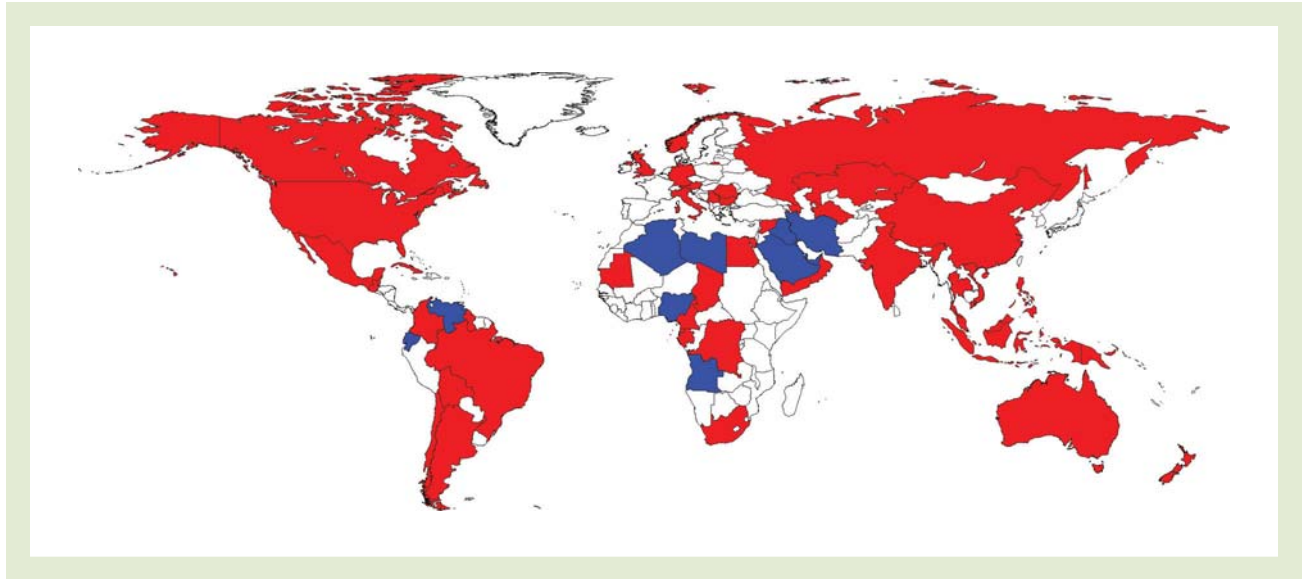


Figure 1 Major petroleum-producing countries. Some, but not all, belong to the Organization of the Petroleum Exporting Countries (OPEC).

Source: Barney Warf.

Note: blue = OPEC members, red = non-OPEC oil-producing nations.

a consortium that included the largest oil companies), as the safest mode of transport to bring crude oil from the source to the refinery and to the consumer. Thus, the density of pipelines is especially high in the United States. As oil-producing countries and those with import demands are located in different regions of the world, supplementary transnational pipelines are currently being planned in response to functional and geopolitical needs.

As oil sources in Europe and the United States peaked, the discovery of large oil fields in the Middle East, Venezuela, Nigeria, and Russia created new global players with national economies largely dependent on petroleum income. In 1960, some of them, including Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela, formed a cartel, the Organization of the Petroleum Exporting Countries (OPEC), to control oil prices and flow. OPEC influences global politics and economies, as highlighted in the oil crisis of 1973 to 1974. New global players have also created new geographies of distribution. The Black Sea has become particularly important for European energy security at the beginning of the 21st century. Several pipelines cross Russia and lead to the port of Novorossiysk on the Black Sea

or Supsa on Georgia's Black Sea coast. In efforts to reduce dependency on OPEC oil and bypass Russia, several actors, including U.S. and various European petroleum companies as well as Azerbaijan's State Oil Company, formed the Baku-Tbilisi-Ceyhan (BTC) Pipeline Company. Since 2006, the new pipeline has transported Caspian oil to the Turkish Mediterranean port of Ceyhan, where tankers pick up the oil and carry it to their destination. The creation of state-owned companies in Mexico, Venezuela, Russia, and Saudi Arabia; the expropriation of foreign oil holdings; and the nationalization of the oil industry have all limited access to the largest part of known oil reserves and added more players to the global oil economy.

The growing number of uses for petroleum and its products has transformed our environment. Highways and other streets built for cars crisscross continents, nations, and cities, allowing commuters to travel ever-greater distances between home and workplace; planes claim the airspace, and airports create new nodal spots on the outskirts of cities. Heating oil has allowed the construction of larger buildings in colder areas (i.e., structures that are largely independent, in terms of heating and cooling, of their environment) and thus the

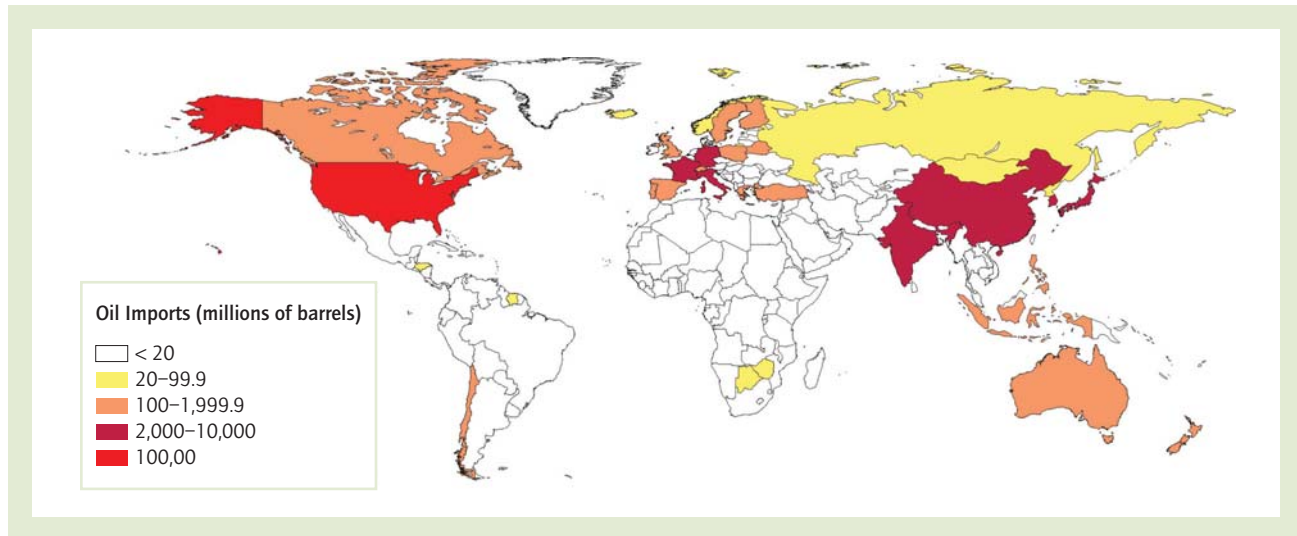


Figure 2 The geography of petroleum consumption. The enormous demand for petroleum leads to significant imports in Europe, Japan, and North America.

Source: Barney Warf.

construction of cities in places where it would otherwise not have been possible. The increased burning of fossil fuels, and the increased creation of carbon dioxide, plays a big part in current global warming and the pollution of the environment, while oil leaks can harm the natural environment, whether they are caused by ship crashes or the spilling of gasoline in an everyday environment. Rising petroleum costs, global warming, the leading industrial country's dependence on foreign oil, and the impending peaking of oil (if it has not already occurred) have led to first steps in rethinking of energy sources, which, in turn, may lead us to transform our landscapes and built environment again.

The changing transnational economic petroleum networks create capital flows and accumulation that are accompanied by cultural transfers. Company logos are visible on billboards, service stations, refineries, and headquarters worldwide; architectural and urban ideas travel as companies send their planners around the world or hire local representatives who will implement their ideas. Similarly, in countries where oil is administered by the national government, the government uses the oil money to implement its ideas and concepts in the built and urban environments. Thus, petroleum from extraction to resale

has an impact on the environment locally and globally. Its networks are an expression of the interconnection of various political, economic, social, cultural, and even religious actors across the globe and across time.

Carola Hein

See also **Climate Policy; Energy Policy; Energy Resources; Environmental Impacts of Oil Fields; Environmental Impacts of Pipelines; Industrial Ecology; Nonrenewable Resources; Oil Spills; Organization of the Petroleum Exporting Countries (OPEC)**

Further Readings

- Black, B. (2000). *Petrolia: The landscape of America's first oil boom*. Baltimore: Johns Hopkins University Press.
- Gluyas, J., & Swarbrick, R. (2004). *Petroleum geoscience*. Malden, MA: Blackwell.
- Klare, M. (2002). *Resource wars: The new landscape of global conflict*. New York: Metropolitan Books.
- Sampson, A. (1975). *The seven sisters: The great oil companies and the world they shaped*. New York: Viking Press.
- Yergin, D. (1991). *The prize: The epic quest for oil, money, and power*. London: Simon & Schuster.



PEUQUET, DONNA

Donna Jean Peuquet, professor of geography at the Pennsylvania State University (Penn State), is a renowned and distinguished scholar in the area of geographic representation, particularly in representing the dynamics of geographic phenomena.

She earned BA and MA degrees in geography from the State University of New York (SUNY) at Buffalo in 1968 and the University of Cincinnati in 1971, respectively. In 1977, she obtained her PhD in geography from the State University of New York at Buffalo. Prior to becoming a professor at Penn State, she held positions at the University of California at Santa Barbara; with the U.S. Geological Survey (USGS); in the department of geography, SUNY at Buffalo; and in the International Geographical Union.

Peuquet was awarded a John Simon Guggenheim Memorial Foundation Fellowship in 2000 to further her work in the representation of geographic knowledge. The title of this fellowship project was “A Cognitive Approach to Representing Geographic Knowledge.” This project primarily applied geovisualization to develop a cognitively informed application for knowledge discovery of large geographic databases. She also co-organized, with Barry Smith from the philosophy department of SUNY–Buffalo, an interdisciplinary workshop on “The Ontology of Fields,” which was sponsored by the National Center for Geographic Information and Analysis, in Bar Harbor, Maine, in June 1998. She is also a faculty member of the GeoVista Center, a research center at Penn State that aims to develop human-centered prototypes for scientists and decision makers. She has served as a member of the board of directors of and as lead representative to the University Consortium for Geographic Information Science. She is a member of the editorial board of the *International Journal of Geographical Information Science* and the International Society for Photogrammetry and Remote Sensing’s *Journal of Photogrammetry and Remote Sensing*.

Peuquet has been involved in a number of research projects from the National Science Foundation and the National Geospatial-Intelligence Agency, among other funding agencies. These research projects can be thought of as an effort to

advance the synergy between geographic databases and geovisualization for solving problems in areas such as crisis management and national security.

Peuquet has supervised approximately 26 PhD and master’s students. She has also published a number of articles on topics ranging from raster versus vector, geographic knowledge representation, and geographic databases to geovisualization. Her current research focuses on capturing the dynamics of geographic knowledge using multiagent systems. Recent research on geographic knowledge representation is often limited to representing a static view of the world, for example, by using ontology, a “semantic graph” that consists of concepts and relationships connecting the concepts. Such a representation can only capture “what is there” for the moment when the representation is generated. But real-world geographic knowledge is dynamic; a representation should be supported with a dynamic mechanism, such as a multiagent system, that can revise the existing representation as geographic phenomena change over time.

Kean Huat Soon

See also **Ontological Foundations of Geographical Data; Temporal GIS**

Further Readings

Peuquet, D. (2002). *Representations of space and time*. New York: Guilford Press.



PHENOMENOLOGY

In the simplest terms, phenomenology is the study and description of human experience. As used by geographers, phenomenology gives attention to the environmental, spatial, and geographical aspects of human experiences, actions, situations, values, and meanings. For example, why are places important in human life, and can their essential lived qualities be identified? How do aspects of physical space—a pathway structure, for example—draw people together informally or



keep them apart? In what ways do human beings encounter the natural world experientially, and can these various modes of encounter be described in their lived fullness? How do the qualities of individuals, groups, cultures, and environments contribute to the range and modes of geographical experience? These are the kinds of research questions that a geographer drawing on phenomenology might ask.

History and Nature of Phenomenology

Phenomenology's principal founder, the German philosopher Edmund Husserl, argued that behind the shifting flux of human experience and awareness, there are certain invariant structures of cerebral consciousness, which he claimed a phenomenological method could clarify in a way that earlier philosophical traditions could not. Husserl viewed consciousness and its essential structures as a pure "region" separate from the lived realm of experience. His approach came to be known as *constitutive* or *transcendental phenomenology*.

Other philosophers, however, argued that Husserl's transcendental structures of consciousness were reductive existentially and could not accommodate the wide range of ways in which human beings live in, experience, and encounter the world in which they find themselves. In his 1927 book *Being and Time*, Martin Heidegger argued that consciousness is not distinct from but tightly intertwined with the world in which human beings find themselves. In his 1945 book *Phenomenology of Perception*, Maurice Merleau-Ponty claimed that an integral part of this intimate commingling of people and their worlds is what he called *body subject*—that is, the invisible web of bodily intention expressed through action that smoothly conjoins human actions and behaviors with the everyday world at hand. This "existential turn" by Heidegger and Merleau-Ponty marked a significant conceptual shift from Husserl's realm of pure intellectual consciousness to the realm of lived situations, experiences, and meanings. Because Heidegger and Merleau-Ponty emphasized the nature and qualities of human existence in its everyday typicality, their approach came to be known as *existential phenomenology*. Geographers have most often used this style of

phenomenology, since their focus most often is people's experiences and understandings of real-world environments, spaces, places, landscapes, regions, and so forth.

From this existential perspective, phenomenology can be defined as the examination, description, and interpretation of phenomena, by which is meant anything that humans can experience. Any situation, event, process, living thing, or object that a human being can touch, taste, smell, hear, see, feel, sense, know, recognize, intuit, or encounter is a potential focus for phenomenological study. There can be a phenomenology of weather, of landscape, of flora and fauna, of architecture, of the home, of journey, of travel, of tourism, of learning, of privacy, of community, of conflict, of gender, of sexuality, of less-abledness, and the like. The aim is to describe the phenomenon *in its own terms*—in other words, as it is: a thing, a living being, an experience, an action, a situation, or an event in the actual lives of actual human beings in actual times and places. The goal is not ideographic portrayal, however, but the discovery and explication of underlying, lived structures and the relationships shared by many particular lived instances of the phenomenon.

Premises of Existential Phenomenology

A first central premise of existential phenomenology is that if we are to understand ourselves as human beings, we must ground that understanding in a conception and language that arise from and return to human experience and meaning. There is no world "behind" the world of lived experience, and the researcher must be skeptical of any conceptual, ideological, or methodological system that transcribes human life and meaning into secondhand, reason-based accounts—for example, positivist accounts that translate the fullness and vitality of experience into tangible, quantifiable units or social-constructivist interpretations that assume all human meanings are socially and culturally afforded and derived.

A second central premise of existential phenomenology is that human experience, action, and awareness are always *intentional*—that is, they are necessarily directed toward and finding their significance in a world of continually shifting experience, action, and meaning. Human beings



are always aware of *something*, whether a thing, an idea, a feeling, an imagination, a person, an event, or something else. Intentionality is central to a phenomenological conception of human experience because it means that people are inescapably enmeshed in their world—what Heidegger identified as *Dasein*, or being-in-the-world.

The everyday lived structure through which the sense of being in the world expresses itself is termed the *life-world*—the everyday world of taken-for-grantedness to which, typically, people give no attention. In turn, the unquestioned acceptance of the life-world is called the *natural attitude*, and one phenomenological aim of geographers is to identify and depict the lived dimensions and dynamics of the life-world and the natural attitude, which always include geographical, environmental, and spatial aspects.

Early Phenomenological Work in Geography

Though foreshadowed by the earlier work of “humanist” geographers such as Clarence Glacken, William Kirk, David Lowenthal, and J. K. Wright, phenomenological work in geography first appeared in the early 1970s, when some geographers criticized the then dominant positivist approach, which emphasized a priori theory and measurable data. One phenomenological criticism was that the positivist perspective did not work well for aspects of human experience and meaning not readily quantifiable in some way—for example, place attachment or heightened encounters with the natural world. At the same time, an emerging focus on environmental perception and behavior within the positivist tradition in geography led to research dealing with people’s environmental images, attitudes, preferences, territorial identifications, and so forth. This concern with people’s “inner worlds” in relation to the “outer” environment became an important conceptual and methodological bridge for geographers seeking a more qualitative, interpretive approach to environmental behavior and experience, including the potential use of phenomenology.

Most notable among these “humanistic” geographers, as they were often called at the time, were Anne Buttimer, Edward Relph, and Yi-Fu Tuan, all of whom drew on phenomenological ideas and methods. In her 1974 book *Values in*

Geography, Buttimer emphasized the importance of a phenomenological approach for understanding the role of personal and professional values in determining, often unconsciously, geographical ideas, theories, and results. In turn, Tuan’s 1974 book *Topophilia* drew on phenomenological principles to explore the wide-ranging lived expressions of human attachment to place.

Of these early phenomenological works, Relph’s 1976 *Place and Placelessness* was perhaps the most significant, because he delineated a phenomenology of place that was simple to understand, versatile in its conceptual and applied possibilities, and resilient in its ability to deal with the complexity and ambiguities of place. Relph argued that the existential crux of place experience is *insideness*—in other words, the more deeply one (a person or group) feels oneself inside an environment, the more does that environment become, existentially, a place. The deepest experience of place attachment and identity is what Relph termed *existential insideness*—a situation where one feels so much at home and at ease in a place that one has no self-conscious recognition of its importance in one’s life, unless it changes in some way—for example, if one’s home and neighborhood is destroyed by a natural disaster. Relph identified and described several other modes of place insideness and its lived opposite, *outsideness*—a situation where the person or group feels separate or alienated from a place in some way.

Later researchers have often drawn on Relph’s conceptual structure of place because the various modes of insideness and outsideness provide a flexible conceptual means for distinguishing the lived experience of place from its material, objectivist qualities. In addition, these modes provide a way to keep sight of the existential fact that (a) the same physical place can evoke a wide range of contrasting experiences for different individuals and groups associated with that place and (b) the same physical place can, over time, evoke vastly different place experiences for that same individual or group.

Phenomenological Research Today

The range of current phenomenological work dealing with geographical and environmental themes is considerable. Two themes are highlighted here—*place* and *lived space*—to illustrate research



directions today. Because there are many different disciplines and professions interested in studying environmental and geographical topics phenomenologically, much of the work highlighted here is done not by geographers but by philosophers, sociologists, psychologists, designers, and others.

One continuing effort is phenomenological research on place, both broadly, in terms of philosophical implications, and specifically, in terms of phenomenologies of particular places and their associated place experiences. On the one hand, the philosophers Edward Casey, Jeff Malpas, Robert Mugerauer, and Ingrid Leman Stefanovic have all written book-length works demonstrating the foundational significance of place and emplacement for understanding human being-in-the-world. On the other hand, researchers like the sociologist Ray Oldenburg and the psychiatrist Mindy Fullilove have studied real-world situations ranging from so-called *third places*—that is, public establishments such as taverns and cafés, where people informally gather and socialize—to the devastation of African American neighborhoods in American cities due to urban renewal.

A second related phenomenological theme is *lived space*—a person or group's modes of living and being in relation to space and environment. One important aim, in part guided by Merleau-Ponty's work, is to better understand the role of body-subject in affording spatial and environmental actions, behaviors, and situations. In this regard, sociologist Chris Allen has explored visually impaired children's everyday body-in-space encounters with their home and urban environment, while philosopher Kay Toombs has considered how less-abled persons' loss of mobility leads to a dramatically different manner of relationship with the surrounding physical and human world. Yet again, the architect Juhani Pallasmaa has examined how modernist architecture has regularly reduced environmental and architectural experience to an abstract aesthetic grounded in visual appearance and how an invigorated architecture might widen the sphere of experience to incorporate all the senses as well as the feelings and bodily movement one encounters.

More broadly, phenomenological work on lived space gives attention to how spatial patterns and relationships set horizons to the dynamics of human action and place, particularly with regard

to sensuous encounter and physical passage. Space, in this sense, relates to whether physical and designable elements facilitate activity and liveliness or inactivity and dullness. There is phenomenological interest in a particular kind of place structure and situation in which the spatial-temporal regularity of individuals potentially coalesces into a larger environmental dynamic that both sustains and is sustained by an attachment to and sense of place—what the phenomenological geographer David Seamon has termed *place ballet*. The urban designer Ian Bentley and his colleagues have developed a design and planning approach for creating what they call *responsive environments*—that is, places that, through their physical layout and design, provide users with a wide range of accessible choices within the immediate, walkable neighborhood. The design aim is to create permeable, high-density, and mixed-use urban districts that have a robust street life, a lively place ballet, and a vital sense of identity and community.

Criticisms of Phenomenological Geography

Since the early 1990s, phenomenological research in geography has been overshadowed by the more dominant conceptual approaches of postmodernist, poststructuralist, and critical geographies. Several recent histories of geographic thought suggest that the use of phenomenology by geographers largely ended by the late 1980s. This claim, however, is incorrect. In fact, the phenomenological tradition remains intact—that is, creatively alive—and emphatically distinct from the discipline's current “critical” emphasis, which some phenomenological geographers see as highly subjectivist, rhetorical, and arbitrary in approach and results.

Critique of phenomenological work today arises from both the academic “right” and the academic “left.” On the right are the positivists, who see phenomenology as imprecise, highly subjective, and without criteria for trustworthiness. On the left are the critical theorists of various persuasions, who distrust the phenomenological assumptions of orderly patterns, essential structures, and “things in themselves.” Currently, critique from the left dominates the evaluative discourse, and phenomenological work has been criticized variously by social constructivists, feminists, postmodernists,



and cultural-study theorists as (a) essentialist; (b) implicitly masculinist; (c) ignoring individual, social, and cultural variations and differences; (d) neglectful of power structures; and (e) assuming an ideological and ethical bias toward exclusionary, bounded places at the expense of cultural and place diversity, integration, and interrelations. Phenomenologists respond that their aims, methods of study, and conclusions are misinterpreted by these critics and that a progressive understanding of the importance of environmental and place experience for human wellbeing is essential in an increasingly placeless, mobile world of global connections, cyberspace, and virtual realities.

David Seamon

See also **Body, Geography of; Buttimer, Anne; Environmental Perception; Everyday Life, Geography and; Existentialism and Geography; Home; Human Geography, History of; Humanistic Geography; Ley, David; Place; Qualitative Methods; Relph, Edward; Sense of Place; Situated Knowledge; Tuan, Yi-Fu**

Further Readings

- Allen, C. (2004). Merleau-Ponty's phenomenology and the body-in-space. *Environment and Planning D: Society and Space*, 22, 719–735.
- Bentley, I., McGlynn, S., Smith, G., Alcock, A., & Murrain, P. (1985). *Responsive environments*. London: Architectural Press.
- Buttimer, A. (1974). *Values in geography* (Commission on College Geography, Resource Paper 24). Washington, DC: Association of American Geographers.
- Casey, E. (1993). *Getting back into place*. Bloomington: Indiana University Press.
- Embree, L. (Ed.). (1997). *Encyclopedia of phenomenology*. Dordrecht, Netherlands: Kluwer.
- Fullilove, M. (2004). *Root shock*. New York: Ballantine.
- Heidegger, M. (1927). *Being and time*. New York: Harper & Row.
- Malpas, J. (2006). *Heidegger's topology*. Cambridge: MIT Press.
- Mels, T. (Ed.). (2004). *Reanimating places*. Burlington, VT: Ashgate.

- Merleau-Ponty, M. (1962). *Phenomenology of perception* (C. Smith, Trans.). London: Routledge. (Original work published 1945)
- Mugerauer, R. (1994). *Interpretations on behalf of place*. Albany: SUNY Press.
- Oldenburg, R. (2001). *Celebrating the third place*. New York: Marlow.
- Pallasmaa, J. (1996). *The eyes of the skin*. London: Academy Editions.
- Relph, E. C. (1976). *Place and placelessness*. London: Pion.
- Seamon, D. (2000). Phenomenology in environment-behavior research. In S. Wapner (Ed.), *Theoretical perspectives in environment-behavior research* (pp. 157–178). New York: Plenum Press.
- Seamon, D. (2006). A phenomenological ecology of natural and built worlds. In M. Geib (Ed.), *Phenomenology and ecology* (pp. 53–86). Pittsburgh, PA: Duquesne University, Simon Silverman Phenomenology Center.
- Stefanovic, I. (2000). *Safeguarding our common future*. Albany: SUNY Press.
- Toombs, S. (1995). The lived experience of disability. *Human Studies*, 18, 9–23.
- Tuan, Y. (1974). *Topophilia*. Englewood Cliffs, NJ: Prentice Hall.



PHOSPHORUS CYCLE

Phosphorus (P) is an essential element for all life forms on Earth. Being a nonsubstitutable constituent of nucleoside phosphates (e.g., ADP [adenosine diphosphate], ATP [adenosine triphosphate]) and nucleic acids (e.g., DNA [deoxyribonucleic acid], RNA [ribonucleic acid]), phosphorus plays a vital role in biochemical reactions involving energy transfer and transcription of genetic information in living organisms. Moreover, phosphorus has a generally low bioavailability and is a nutrient that commonly limits the productivity of terrestrial, freshwater, and marine ecosystems. In contrast with carbon, nitrogen, and sulfur, which can exist in several oxidation states, phosphorus does not take part in reduction-oxidation reactions and is predominantly present in the +5 oxidation state as phosphate (PO_4^{-3}). On a



centennial timescale, global transfer of phosphorus occurs unidirectionally from the terrestrial system via river transport to the oceanic system. This entry provides an overview of the major phosphorus reservoirs and the rate of phosphorus exchange between these reservoirs in the global phosphorus cycle.

Containing only 0.03 Tg P (teragram of phosphorus), the atmosphere represents a very minor phosphorus reservoir globally. Compared with other major biogeochemical cycles, the cycling of phosphorus is unique in lacking a stable gaseous component. The majority of atmospheric phosphorus is adsorbed on particulate matter emitted from high-temperature fossil fuel combustion and sea spray. These particulate phosphori have a short residence time of approximately 3 days and are deposited rapidly on terrestrial land (3.1 Tg P/yr. [per year]) and surface ocean (0.6–1.6 Tg P/yr.). The global flux of phosphine gas (PH_3 , <0.04 Tg P/yr.) is not significant because of the lack of a favorable environment for microbial production and the great ease of PH_3 oxidation by air.

Phosphorus cannot be sequestered from the atmosphere by plants and microbes, unlike carbon and nitrogen. Apatite, with calcium and phosphate ions linked together in a hexagonal crystal structure, is the most abundant phosphorus mineral in the Earth's crust. The weathering of apatite rocks is the sole major source of phosphorus in the global phosphorus cycle, releasing 20 Tg P annually to the soil. Global soils in the top 60 cm (centimeters) store a total of 2×10^5 Tg P, but a large proportion of phosphorus is adsorbed on iron and aluminum oxides and is thus not readily available for biota. Although the available phosphorus concentration in soil is low, internal recycling of phosphorus helps sustain the growth of terrestrial organisms, which have a phosphorus reservoir size of 2,600 to 3,000 Tg. Assimilation of phosphorus by land biota from soils roughly equals the return of phosphorus from biota to soil, with a flux of 63 to 200 Tg P/yr.

Rivers are a major conduit of phosphorus, connecting between the terrestrial and oceanic systems. About 90% of phosphorus transported by rivers (18–20 Tg P/yr.) is associated with the particulate fraction. Natural denudation and human-induced erosion of physically weathered materials account for one third and two thirds of

the riverine particulate phosphorus flux, respectively. Most of the particle-bound phosphorus enters the ocean and settles on the shallow continental shelf quickly, without participating in the biological cycle. Dissolution of phosphorus-containing minerals is very low in the alkaline and strongly buffered oceans, but some of the phosphorus adsorbed on particle surfaces can be remobilized in seawater with high ionic strength. Rivers also carry 1.0 to 1.8 Tg P in dissolved reactive form to surface oceans annually, providing a major phosphorus source for uptake by marine biota.

The upper 300 m (meters) of the surface ocean contains a total of 2,700 Tg P. Dissolved phosphorus concentration in this zone, particularly in the top 100 m, is negligibly small owing to effective phosphorus stripping by biotic uptake and subsequent sinking of detritus. The exchange of phosphorus between surface ocean and marine biota represents the largest flux between reservoirs in the global phosphorus cycle. Biota dominated by phytoplankton incorporate 1,042 Tg P/yr. from the surface of oceans, while more than 95% of the assimilated phosphorus (998 Tg P/yr.) is regenerated in surface waters through the decomposition of dead marine organisms. In spite of the large phosphorus fluxes, the oceanic biota phosphorus reservoir of 50 to 138 Tg is relatively small, indicating a fast turnover and a short phosphorus residence time (18 to 48 days) in marine organisms. Some biogenic particles sink to the deeper layer without being mineralized, exporting 44 Tg P/yr. out of the surface ocean.

Deep oceans of the world store a substantial amount of phosphorus, totalling 8.7×10^4 Tg. Because of the absence of light, and thus photosynthesis, little reactive phosphorus is incorporated into biota at depths greater than 300 m. Moreover, as most of the particulate phosphorus is solubilized by microbes, dissolved phosphorus concentration can be as high as 3 micrometers in seawater deeper than 1,000 m. Wind currents trigger an upwelling of nutrient-rich deepwater in some places and a downwelling of nutrient-poor surface water in some others, leading to an overall net phosphorus transport of 40 Tg/yr. from deep ocean to surface ocean. A small proportion of particulate materials in deep oceans eventually reaches the seabed and is buried in sediments, at the same time removing 3.4 Tg P/yr. from the world's oceans. As



the largest phosphorus reservoir on Earth, soils below 60 cm depth, unconsolidated sediments, and nonmineable rocks together contain 4×10^9 Tg P in particulate form. Over the geological timescale of 10^7 to 10^8 yrs., crustal rocks formed from phosphorus-containing marine sediments are uplifted and subject to weathering again, thereby completing the global phosphorus cycle.

Human activities also play a role in shaping the global phosphorus cycle. Mineable phosphate rocks of the world, mostly found in North America and tropical Africa, lock up a total of 1×10^4 to 2×10^4 Tg P. Mining of these rocks for use as agricultural fertilizer enhances phosphorus availability and releases 12 Tg P/yr. to the global soil reservoir. Excessive use of inorganic fertilizers leads to increased phosphorus loss through runoff and eutrophication of freshwater and estuarine ecosystems downstream, resulting in oxygen depletion in water bodies and large-scale death of aquatic organisms. While agricultural application of phosphorus fertilizers and domestic and industrial discharge of sewage can cause phosphorus enrichment in some localized ecosystems, anthropogenic phosphorus inputs at the current rates have limited effects on the global phosphorus cycle because of the much larger magnitude of land and ocean phosphorus reservoirs.

Derrick Yuk Fo Lai

See also **Biogeochemical Cycles; Biota and Soils; Carbon Cycle; Nitrogen Cycle; Nutrient Cycles; Organophosphates; Rock Weathering**

Further Readings

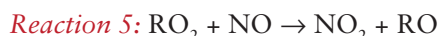
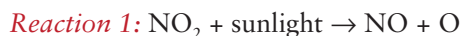
- Jahnke, R. A. (2000). The phosphorus cycle. In M. Jacobson, R. J. Charlson, H. Rodhe, & G. H. Orians (Eds.), *Earth system science: From biogeochemical cycles to global change* (pp. 360–376). San Diego, CA: Academic Press.
- Ruttenberg, K. C. (2005). The global phosphorus cycle. In W. H. Schlesinger (Ed.), *Treatise on geochemistry: Vol. 8. Biogeochemistry* (pp. 585–643). Oxford, UK: Elsevier.
- Schlesinger, W. H. (1997). *Biogeochemistry: An analysis of global change*. San Diego, CA: Academic Press.

PHOTOCHEMICAL SMOG

Photochemical smog is a noxious mixture of pollutants formed in the presence of sunlight. It is very harmful to humans, animals, and plants. The ingredients required for the production of photochemical smog are oxides of nitrogen (NO_x), volatile organic compounds (VOCs), and sunlight. NO_x and VOCs are themselves harmful, but in the presence of sunlight, they are involved in a complex series of reactions that create other harmful substances. Industry and transportation sources contribute most of the precursor gases. Photochemical smog is, therefore, most prevalent in urban areas. Ground-level ozone (O_3), a secondary pollutant created by reactions between the precursor gases, is the main component of photochemical smog.

Nitric oxide (NO) is emitted when hydrocarbons such as gasoline, diesel fuels, or coal are burned. It is a by-product of incomplete combustion. Once emitted, NO quickly oxidizes to form nitrogen dioxide (NO_2), a toxic, foul-smelling gas that gives polluted air its brownish/yellow hue. Collectively, NO and NO_2 are called NO_x . Volatile organic compounds are hydrocarbons that evaporate readily at normal temperature and pressure. Thousands of compounds fall into this category, and sources include evaporated fumes from fuel in vehicles, fuel combustion, petroleum refining, and industrial and residential solvents such as paints and cleaning fluids.

In the presence of sunlight, NO_2 will dissociate, and further reactions with oxygen gas (O_2) lead to the formation of ozone (Reactions 1 and 2). However, ozone will also dissociate in the presence of sunlight and react with water vapor to form highly reactive hydroxyl radicals (HO) (Reaction 3). If VOCs are present, the hydroxyl radicals react with VOC to produce peroxy radicals (RO_2) (Reaction 4). The peroxy radicals further react with NO to produce NO_2 (Reaction 5), and the cycle continues to create O_3 . These are simplified representations of the reactions:





Early-morning smog over Quito, Ecuador, June 2005

Source: Courtesy of Mark Welford.

Compounds such as peroxyacetyl nitrates, or PAN ($\text{CH}_3\text{-CO-OO-NO}_2$), are also formed in the process. PANs are important because they are harmful, have relatively long lifetimes in cold temperatures, and therefore can be transported to other locations where they release NO_2 . Carbon monoxide (CO), which is another by-product of fossil fuel combustion, may also be involved in reactions to produce ground-level ozone.

NO_2 concentrations are highest during morning peak hour traffic, while ozone peaks near midday. VOCs are most prevalent in summer because of increased evaporation in warm temperatures. The creation of ozone is also more profuse in summer because of the increased intensity of the sun. Ozone is not created at night, due to the lack of sunlight. Photochemical smog, therefore, leads to poorest air quality episodes on summer days, though mixing with other pollutants such as particulate matter can cause poor air quality at any time.

Other Factors

Geography and meteorology play important roles in the accumulation of pollution during smog episodes. Some urban areas, such as Mexico City, Mexico, or Denver, Colorado, are partially surrounded by mountains, which restricts the air flow. This limits dispersion by prevailing winds, causing pollution to accumulate, often to dangerous levels. Meteorological phenomena such as temperature inversions also exacerbate smog episodes. Temperature inversions occur when the temperature aloft is higher than the temperature at ground level. This results in stable atmospheric conditions with restricted vertical airflow, allowing pollution to accumulate below the inversion cap. The location and topography of some cities, such as Los Angeles, are conducive to the formation of temperature inversions.

Long-range transport of pollutants also contributes to the formation of smog in locations



downwind of the sources of pollution. Ozone, PAN, and other pollutants can be carried thousands of kilometers through the atmosphere by prevailing winds. This increases pollution from local sources in the downwind locations and also pollution in rural areas.

Health Effects

Ozone, PAN, NO_x , and VOCs are toxic pollutants that are injurious to animal and plant life. They can cause damage to the respiratory tract, leading to lung inflammation, and can also irritate the eyes and skin. The effects of short-term exposure include irritation of the nose and throat, coughing, and painful breathing. Long-term exposure can decrease lung function, retard lung development in children, and lead to premature aging of the lungs. Some VOCs are known to be carcinogenic. Photochemical smog can exacerbate cardiopulmonary diseases and may lead to premature death. Children, the elderly, and patients with cardiopulmonary diseases are the most susceptible. In plants, these pollutants are known to cause foliage damage, inhibit plant growth, and reduce yield.

Air quality criteria, set by governments in many countries, help alert the population to dangerously high levels of pollutants. In Canada, the criteria for O_3 and NO_2 are 80 ppb (parts per billion) and 200 ppb, respectively, averaged over a 1-hour period. North American cities exceed their respective criteria periodically.

Reducing Photochemical Smog

Photochemical smog is a phenomenon of anthropogenic origin and can be reduced by curtailing emissions of the primary pollutants, NO_x and VOC. This can be achieved by reducing gasoline consumption with the use of more fuel-efficient engines or the use of nonhydrocarbon energy sources. Individuals may choose alternative means of transportation, such as public transit, walking, or cycling, and reduce energy consumption at home. Industries are encouraged to adopt cleaner technologies to reduce emissions. Overall, lower consumption coupled with alternative energy sources such as solar or wind energy would help lower emissions and reduce photochemical smog.

Julie Wallace

See also **Acid Rain; Ambient Air Quality; Atmospheric Pollution; Greenhouse Gases; Point Sources of Pollution; Urban Environmental Studies**

Further Readings

Dickerson, R. R., Kondragunta, S., Stenchikov, G., Civerola, K. L., Doddridge, B. G., & Holben, B. N. (1997). The impact of aerosols on solar ultraviolet radiation and photochemical smog. *Science*, 278, 827–830.

Jacobson, M. Z. (2002). *Atmospheric pollution*. Cambridge, UK: Cambridge University Press.



PHOTOGRAMMETRIC METHODS

The main purpose of photogrammetry is to define the quantitative parameters of objects using images taken by photographic or digital cameras. The typical output of photogrammetry is a map or three-dimensional (3D) model of some real object or scene. Photogrammetry is widely used to compile topographic maps of Earth's surface.

Photogrammetry is based on principles of stereometry—a branch of geometry that studies the projections of 3D objects into 2D space; in particular, photogrammetry deals with the appearance of real 3D objects in two overlapping photographs (image stereopair). The fundamental geometric principle used by photogrammetry is triangulation. By taking photographs from two (or more) different locations, so-called lines of sight can be developed from each camera to points on the object. These lines of sight are usually called projection rays owing to their optical and geometrical nature.

A standard approach to classifying photogrammetric methods is based on the relative location of a camera and objects during a photographic process: In terrestrial, or close-range, photogrammetry, the photographic camera and the objects are both placed on Earth's surface, and the camera is pointed horizontally (parallel to the ground surface), while in aerial photogrammetry, the



camera is above the object and is pointed vertically, toward the ground.

In close-range photogrammetry, the photographs are taken by terrestrial photographic cameras (phototheodolites), placed on nonmovable tripods to take pictures from the ground. As vertical aerial pictures are taken from moving platforms (aircraft and satellites), the cameras are specifically designed to take measurable photographs while the platform flies along the path. An aerial photographic camera is an assembly of high-precision optical lenses and mechanical, electrical, and electronic components. Aerial photographic cameras are designed to take pictures using panchromatic or color photographic films that can be as long as 120 meters, with picture frames as wide as 40 cm (centimeters; 23 cm $\times$ 23 cm is a typical size of a frame image). Apart from classical photographic films, modern image acquisition systems use different digital technologies and acquire imagery directly in digital form.

When obtaining vertical aerial photographs, the aircraft normally flies in a series of lines, called flight runs. Photos are taken in rapid succession looking straight down at the ground, often with a 60% overlap between adjacent photos. The overlap ensures total coverage along a flight line and also facilitates stereoscopic viewing. The distance the camera moves between exposures is called the air base. Sequences of photographs in one single flight run form a strip of overlapping images; several runs, in turn, compose a block (mosaic) of aerial photographs covering large areas.

Aerial photographs often contain imprinted information such as the date and time of image acquisition, camera focal length, flight altitude, and other data, allowing calculation of image scale and approximate tilt of the particular frame. Fiducial marks, usually imprinted alongside photographs, allow precise measurement using photogrammetric instruments.

The accuracy of photogrammetric measurements in photographs is described in terms of micrometers (μm). A standard stereocomparator (photogrammetric equipment used for precise measurement) records the coordinates of points in an image as accurately as 5 μm ; top-precision comparators target a 1- to 2- μm accuracy of image measurements.

Metric properties of a single aerial photograph are defined by the rules of geometric optics, where all projection rays coming from an object (the object plane, e.g., Earth's surface) intersect in one single point inside the lens (the focal point, or center of projection) and then hit the film (the focal plane). The distance from the center of projection (focal point) to the focal plane (the film) is called focal length f , while the distance from the center of projection toward Earth's surface is called the flying height above the ground (altitude), H .

Central-perspective projection defines the relative position and geometry of the objects depicted in an image. The appearance of an object depicted in an aerial photo depends on the relative location of the projection point (from which the photo was taken) and the position of the object, and the orientation of the photograph itself is relative to the object plane (Earth's surface). Photographs with optical axes that are tilted less than 3° off the vertical line are regarded as vertical. The scale of a vertical photograph is approximately uniform over the photograph and is equal to the ratio of the altitude and the focal length of the camera lens. Measuring distances and directions on vertical photos is therefore easier and more accurate, and in flat areas, the vertical photos can almost be used as a map. Oblique photographs are taken with the angle from the vertical deliberately set somewhere between 3° and 90° , with preset angles of 30° and 60° . The objects have a more familiar view, which resembles the view the observer would get from a high vantage point, such as a hill or the roof of a high building.

Since the scale of oblique photographs varies over the image frame, distances and directions are not true, and measurements on such pictures are heavily burdened with object displacements.

Single images allow defining of the planimetric (X , Y) coordinates of an object, whereas in stereophotogrammetry projection, rays from two overlapping images are mathematically intersected to produce the 3D coordinates (X , Y , Z) of the points of interest. To define the 3D coordinates of a point in the object's coordinate space, the images have to be oriented relative to a particular coordinate system on Earth. This is usually done by using ground control points, identified in images and on the ground. The coordinates of



ground control points on the surface are defined by classical geodetic surveying or precise GPS (global positioning system) measurements. Modern cameras are usually connected to navigational systems such as inertial measurement units and differential kinematic GPS, allowing continuous recording of spatial position and angular orientation of the camera during the flight; this significantly reduces the amount of fieldwork.

In technological terms of image processing, photogrammetry combines the following basic activities: image measurements, optical image transformations, calculations, and drawing. With the evolution of technology, photogrammetry used three methods of image processing: analog, analytical, and digital. The analog method uses optical-mechanical instruments in all stages: from the measurements in image and optical transformations to the drawing of the final product (a map or sketch). In analytical photogrammetry, all initial measurements are done mechanically, but calculations are made by computers. Digital photogrammetry is based entirely on the computational power of modern computers in all stages of photogrammetric image processing.

Applications and subfields of photogrammetry include topographic and thematic mapping, generation of digital elevation models, industrial (engineering) and architectural photogrammetry, medical imaging, surveillance, and reconnaissance.

Gennady Gienko

See also Aerial Imagery: Data; Aerial Imagery: Interpretation; Digital Terrain Model; Geodesy; Global Positioning Systems; Image Processing; Image Registration; Imaging Spectroscopy; Panchromatic Imagery; Stereoscopy and Orthoimagery

Further Readings

- McGlone, J. C. (Ed.). (2004). *Manual of photogrammetry* (5th ed.). Bethesda, MD: American Society for Photogrammetry and Remote Sensing.
- Mikhail, E. M., Bethel, J. S., & McGlone, J. C. (2001). *Introduction to modern photogrammetry*. New York: Wiley.

PHOTOGRAPHY, GEOGRAPHY AND

For more than 150 years, geographical concerns have shaped photographic practices, and photographic technologies have nurtured and documented geographical pursuits. This complex, dynamic, and mutually influential relationship between geography and photography can be studied from historical, practical, and theoretical perspectives. In 1839, two, quite different, processes for making permanent images “from Nature” were announced. These early photographic technologies offered a new way of encountering the physical and human world. Louis Jacques Mandé Daguerre’s method of producing a unique image on a silver-coated copper plate and William Henry Fox Talbot’s paper-based negative-positive process were quickly harnessed to geographical purposes in the form of field observations, travel accounts, prints, book illustrations, and teaching aids—uses that have survived and become increasingly sophisticated in an age of geographic information systems (GIS) and digital imaging.

From the first mention of “taking photographic pictures” in Alexander von Humboldt’s *Cosmos* (1849) to Vaughan Cornish’s appreciation of landscape through photography of scenery (1946) to Denis Cosgrove’s analysis of the “One-World, Whole-Earth” images from the Apollo space mission (1994), photography has played a variety of roles in the data-gathering practices, ordering mechanisms, and myth-making processes by which people have come to know the world and situate themselves in it. When first introduced, photography’s ability to record, store, and disseminate information in visual form made it a natural complement to geography’s long-established emphasis on observation, description, and visualization.

Difficult, messy, and time-consuming processes did not stop the first photographers from carrying hundreds of pounds of equipment on the Grand Tour, up the Nile, and into the jungles of the Yucatan. Embraced as an accessory to travel and employed to produce “man-on-the-spot” accounts, photography presented the scientific traveller and the gentleman adventurer a way to bring the world home, in visual form, for contemplation or study,



Geography Lesson daguerreotype. In the 19th century, photography began to have enormous impacts on the popular sense of near and far, bringing distant worlds into the experience of large numbers of people.

Source: Claudet, A. (1797–1867). *Geography lesson*. Austin: University of Texas, Harry Ransom Humanities Research Center.

enjoyment, or analysis. Quickly, the camera became an instrument for acquiring or disseminating geographical knowledge in military operations, boundary and geological surveys, topographical mapping, immigration programs, tourism promotion, and ethnographic investigations. Practiced by travelers, photography mediated the personal encounter with unfamiliar places and peoples; collected by armchair travelers, photographs served as surrogates for travel and a first-hand experience of places.

As photography became simpler, cameras got smaller, processing became commercially available, and images in full color became a reality; three forms of photography increasingly became an integral part of geographical pursuits: aerial photography, repeat photography, and photogrammetry. Employing established, standardized methods for producing and interpreting images, these applications embrace photographs

as scientific data to be read, measured, and manipulated in the process of studying cultural landscape remains, establishing spatial coordinates, or observing physical landscape change. Early on, photographers carried their cameras (and their portable darkrooms) to the top of hills and tall buildings in order to record landscape views. True aerial photography was first attempted in the mid 19th century by the French photographer, Nadar, who, in 1858, ascended to a height of several hundred meters in a captive balloon to obtain a photographic bird's-eye view of the Earth, from which he planned to produce an exact topographic map. Two years later, James Wallace Black produced a view of Boston—according to Oliver Wendell Holmes, “as the eagle and the wild goose see it”—from a balloon 1,200 feet in the air. Since then, vertical and oblique aerial photographic techniques have been used to inventory and map natural and human-made features on the surface of the Earth. Today, geographical applications of aerial photography continue and multiply in the form of contemporary satellite imagery.

Chronologically replicated photographic views of the same subject are used to demonstrate change over time by exploiting the camera's ability to create a photographic baseline against which development or decay can be measured. Geographers are familiar with this practice through scholarly rephotography projects as well as popular then-and-now comparisons.

Phototopography, or photogrammetry, is another form of data photography intended to convey specific geographical information in visual form. First used in the late 19th century for practical surveying purposes, this application of the camera to geographical endeavor produces data to be mapped, compared, or quantified. The production and interpretation of air photographs, while in many ways very much a cartographic endeavor, employ photographs in an effort to read surface characteristics and spatial relations.

Used more generally as a means of gathering geographical information, photography became an integral part of exploring expeditions and imperial administrations, opening distant or exotic regions to 19th-century European eyes. Photographers in London, Glasgow, and Paris documented the changing geographical face of urban renewal, just as a series of stereoscopic



views produced on both sides of the Atlantic celebrated urban development in newly settled areas of the New World. Similarly, various projects to inventory the native peoples of North America, India, and the British Empire were, in themselves, photographic investigations of cultural geographies as well as visual expressions of the 19th-century penchant for ordering and labeling.

Quickly absorbed into the pursuit of geographical knowledge, photographs have been called on to explore the physical nature and negotiate the social meaning(s) of water, rocks, and animals; snow and ice; and trees, forests, and prairies. Beyond their obvious use in fieldwork, mapping, lecturing, and publishing, photographs are increasingly attracting scholarly attention as a primary source for expressing, reflecting, and shaping the relationship of people to place. Even scientifically conceived photographs are now subjected to critical scrutiny for the layers of meaning beyond the visual facts presented in the images themselves. In the wake of recent theoretical writings on representation and the relationship between knowledge and power, historical and cultural geographers have turned their attention to the role of photographs in the geographical imagination. In their studies of the ways in which photographs construct, confirm, and contest notions of landscape and identity, they have contributed to recent work on the “visual turn” in the humanities and social sciences.

Now, as environmental degradation and global warming increasingly attract media, government, and public attention and occupy the research agendas of both physical and human geographers, spatial concerns and geographical concepts are being embraced by photographers and curators, incorporated into their artistic statements, elaborated in their catalog essays, and reconceptualized in visual terms in major exhibitions such as “Imaging a Shattering Earth: Contemporary Photography and the Environmental Debate.” Large-scale sites of ecological degradation caused by human invention—industrial complexes and mining sites, dried-up lakes and flooded watersheds, landfills and waste ponds—have attracted the attention of a cadre of eminent, environmentally committed photographers such as Edward Burtynsky, John Ganis, Peter Goin, David Hanson, Jonathan Long, and John Pfahl, who have been

instrumental in inserting discussions surrounding the stewardship of our planet into the rarefied world of fine art.

Photography is also a key component in the exhibitions and events, education, and outreach of organizations such as Worldchanging, dedicated to sustainability, and the Natural World Museum, which partners with the United Nations Environment Programme, through the Art for the Environment initiative, to promote environmental awareness, attitudes, and action across social, economic, and political spheres. Using aerial views and then-and-now comparisons, the rhetoric of such organizations depends heavily on the visualization of geographical concerns through photography.

At the same time that the work of geographers, curators, and photographers increasingly converges on scholarly issues of space and place, lavishly illustrated magazines, photography exhibitions, Web sites, and coffee-table books, from *National Geographic* to Yann Arthus-Bertrand's *Earth From the Air*, continue to foster a popular geographical agenda to see and know the world and continue to employ photographs as “windows” on a world beyond our doorstep. Perhaps the most obvious use of photographs as “windows” comes in teaching and learning, where lantern slides and 35-millimeter slides have been the mainstay of classroom instruction and conference presentations. Yet even as a major technological as well as pedagogical shift takes place as slides are replaced by digital images, slide projectors give way to data projectors, and textbooks give way to WebCT, photography remains an indispensable part of our understanding and study of geography.

Joan M. Schwartz

See also **Art and Geography; Film and Geography; Media and Geography; Representations of Space; Symbolism and Place; Vision and Geography**

Further Readings

Cosgrove, D. (1994). Contested global visions: One-World, Whole-Earth, and the Apollo space photographs. *Annals of the Association of American Geographers*, 84(2), 270–294.



- Hoelscher, S. (1998). The photographic construction of tourist space in Victorian America. *The Geographical Review*, 88(4), 548–570.
- Imaging a Shattering Earth: www2.oakland.edu/shatteringearth
- Kinsman, P. (1995). Landscape, race and national identity: The photography of Ingrid Pollard. *Area*, 27(4), 300–310.
- Ryan, J. (1997). *Picturing empire: Photography and the visualization of the British Empire*. London: Reaktion Books.
- Schwartz, J. (1996). The geography lesson: Photographs and the construction of imaginative geographies. *Journal of Historical Geography*, 22(1), 16–45.
- Schwartz, J. M., & Ryan, J. R. (Eds.). (2003). *Picturing place: Photography and the geographical imagination*. London: I. B. Tauris.
- Worldchanging: www.worldchanging.com



PHYSICAL GEOGRAPHY, HISTORY OF

Physical geography has a history that spans several thousand years, which is often intertwined with developments in geography's other major field of study, human geography. Some of the first applications of knowledge involving physical geography occurred more than 4,000 yrs. (years) ago. The main purpose of these early investigations was to map the natural landscape and human settlements observed as explorers traveled to new lands. At this time, the Chinese, Egyptian, and Phoenician civilizations were beginning to explore the spaces and places within and around their homelands. The earliest evidence of such explorations comes from the archaeological discovery of a Babylonian clay tablet map that dates back to 2300 BC.

Early Greeks and Romans

The early Greeks were the first civilization to practice a form of physical geography that was more than just drawing the location of natural and human-made features on maps. The ancient

Greeks were also interested in the shape, size, and geometry of Earth. Aristotle hypothesized and logically demonstrated that Earth has a spherical shape. Evidence for this idea came from his observations of lunar eclipses. Lunar eclipses occur when Earth casts its circular shadow onto the moon's surface.

The first individual to accurately calculate the circumference of Earth was the Greek geographer Eratosthenes. Eratosthenes calculated the equatorial circumference to be 40,233 km (kilometers; 25,000 mi. [miles]) using simple geometric relationships. This calculation was unusually accurate, considering the primitive technology used. Measurements using advanced satellite technology have computed Earth's circumference to be 40,072 km (24,900 mi.).

Most of the Greek accomplishments in physical geography were passed on to the Romans. Military commanders and administrators used this information to help direct the expansion of the Roman Empire. The Romans also made several important contributions to human and physical geography. Strabo wrote an extensive 17-volume series, the *Geographica*. Strabo traveled widely across the Roman Empire, and *Geographica* records what he had observed and experienced from a geographical perspective.

During the 2nd century AD, Ptolemy made a number of important contributions. Ptolemy's publication *Geographike hyphesis*, or *Guide to Geography*, compiled and summarized much of the Greek and Roman geographic information accumulated at that time. Some of his other important contributions include the creation of three different methods for projecting Earth's surface on a map, the calculation of coordinate locations for some 8,000 places on Earth, and the development of the concepts of latitude and longitude.

Middle Ages to 1800

Little academic progress in geography occurred after the Roman period. For the most part, the Middle Ages (5th–13th centuries AD) were a time of intellectual stagnation in Europe. The Vikings of Scandinavia were the only group of people carrying out active exploration of new lands. In the Middle East, Arab academics began translating the works of Greek and Roman scholars, starting



in the 8th century, and exploring the physical and human geography of southwestern Asia and Africa. Some of the important Arab geographers include al-Idrisi, Ibn Battutah, and Ibn Khaldun. al-Idrisi is best known for his skill at making maps and for his work of descriptive geography *Kitab nuzhat al-mushtaq fi ikhtiraq al-afaq*, or *The Pleasure Excursion of One Who Is Eager to Traverse the Regions of the World*. Ibn Battutah and Ibn Khaldun are well known for writing about their extensive travels in North Africa and the Middle East. In China, academics were using sophisticated geometric techniques to produce high-quality maps of their homeland.

During the Renaissance (AD 1400–1600), numerous journeys of exploration were commissioned by a variety of nation-states in Europe. Most of these expeditions were financed because of the potential commercial returns from resource exploitation. These voyages also offered an opportunity for scientific investigation and discovery. Consequently, these explorations added many significant contributions toward understanding the physical geography of the Earth. Influential explorers of this period include Christopher Columbus, Vasco da Gama, Ferdinand Magellan, Jacques Cartier, Martin Frobisher, Sir Francis Drake, John and Sebastian Cabot, and John Davis.

The Renaissance was also a time of many technological inventions. Some of these discoveries were made to improve navigation across Earth's surface and to better the production of maps. In 1492, Martin Behaim created a spherical globe depicting the Earth in its true three-dimensional (3D) form. Behaim's invention was a significant advance over the 2D maps because it created a more realistic depiction of Earth's actual shape and surface configuration.

In the 17th century, Bernhardus Varenius published an important geographic reference titled *Geographia generalis* (*General Geography*, 1650). In this volume, Varenius used direct observations and primary measurements to present some new ideas concerning geographic knowledge. His work continued to be a standard geographic reference for about 100 yrs. Varenius also suggested that the discipline of geography could be subdivided into three distinct fields of knowledge. The first field examines the shape, dimensions, and motions

of Earth. The second field deals with the tides, the relationship of day length with latitude and time, climatic variations, and other variables that are influenced by the cyclical movements of Earth and the moon. Together, these two fields form the beginning of what is now called *physical geography*. The last field of geography examined distinct regions on Earth, studying the political, economic, cultural, and social behavior of people.

During the 18th century, the German philosopher Immanuel Kant proposed that human knowledge could be organized in three different ways. One way of organizing knowledge was to classify facts according to the type of objects studied. Accordingly, zoology studies animals, botany examines plants, and geology involves the investigation of rocks. The second way in which one can study things is according to a temporal dimension. This field of knowledge is called history. The last method of organizing knowledge involves understanding facts relative to spatial relationships. This observation elevated the importance of geography as a major form of scholarship. Kant also divided geography into a number of fields of knowledge. He recognized the following six branches: theological, mathematical, moral, political, commercial, and physical geography.

From 1800 to 1950

During the late 1700s and early 1800s, academics began questioning the belief that Earth's landscapes were the result of relatively recent catastrophic events. The prevailing view at that time was that Earth was created through supernatural means and had been affected by a series of catastrophic events such as the biblical Flood. The theory of uniformitarianism suggested that the landscape developed over long periods of time through a variety of slow natural processes. The ideas behind uniformitarianism originated with the academic work of the Scottish geologist James Hutton. In 1785, Hutton suggested at several meetings of the Royal Society of Edinburgh that Earth had a long past and that this history could be fully understood in terms of processes currently observed. For example, he suggested that deep-soil profiles were formed by the weathering of bedrock over tens of thousands of years.



Hutton's ideas did not gain significant support from the scientific community until the work of Charles Lyell. In the publication *Principles of Geology* (1830–1833), Lyell presented a variety of geologic evidence from England, France, Italy, and Spain to prove Hutton's ideas correct. The theory of uniformitarianism was also important in shaping the development of ideas in disciplines outside the geosciences. The work of Charles Darwin and Alfred Wallace on the origin of Earth's species extended the ideas of uniformitarianism into the biological sciences. The theory of evolution is based on the principle that the diversity seen in Earth's species can be explained by the uniform modification of genetic traits over long periods of time.

The 19th century saw the emergence of a number of societies interested in geographic issues in Europe and the United States. The first of these societies was established in Paris in 1821. The founding of geographical societies in Germany in 1828 and Britain in 1830 quickly followed. The American Geographical Society was formed in 1852, and by 1866, there were 18 established geographical societies worldwide. During the 19th century, many university chairs in geography were established, especially in areas of study that fall squarely in the realm of physical geography.

In 1836, at the University of Neuchâtel in Switzerland, Louis Agassiz began studying glaciers and their effect on Earth's landscape. From field observations of alpine glaciers in the Alps, Agassiz developed an excellent understanding of how glaciers modify the landscape. Four years later, Agassiz published the theory that a great Ice Age had once dominated the planet. This theory was based on his observations in the highlands of Scotland, where he saw the remnant effects of glaciers on the landscape. In 1846, Agassiz came to the United States and found evidence that past glaciation had also influenced the landscape of the North American continent.

In Germany, Alexander von Humboldt and Carl Ritter also made substantial contributions to physical geography. Humboldt's publication *Kosmos* (1844) examines the geology and physical geography of the Earth. This work is considered by many academics to be a milestone contribution to scholarship in physical geography. Ritter's work focused on the study of the connections

between humans and their natural environment. Furthermore, Ritter's ideas suggested that regional variations in the nature of the environment produced different outcomes in this relationship.

In 1847, George Perkins Marsh gave an address to the Agricultural Society of Rutland County, Vermont. The theme of this speech was that human activity was having a destructive impact on the landscape, mainly through deforestation and land conversion. This speech also became the foundation for his book *Man and Nature, or The Earth as Modified by Human Action*, first published in 1864. In this publication, Marsh explained more fully the environmental consequences of the unceasing development of the American frontier. Marsh's work marks the beginning of an important field of research in physical geography—the study of how human activities degrade the natural environment of the Earth.

Intellectual expansion in the late 19th century set the stage for the fracturing of physical geography into a number of major subfields in the early 20th century. In Russia, V. V. Dokuchaev and his associates established pedology and introduced the idea that spatial variations in soil type could be explained in relation to parent material, climate, and topographic factors. Wladimir Köppen suggested that one could classify Earth's local climates based on regional variations in temperature and precipitation. Research at the Meteorological Institute at Bergen, Norway, laid the groundwork for the development of meteorology and climatology as disciplines of study. The work of Frederic Clements and Henry Cowles led to elaborate theories of plant succession common to biogeography and ecology.

Late-19th-century contributions from W. M. Davis and G. K. Gilbert helped make geomorphology the dominant field of specialization for physical geographers over the next 100 yrs. Davisian cycles of erosion and the subsequent classification scheme of landscape development were in vogue with geomorphologists for about half a century. This success was mainly due to the fact that this theory could be applied to a variety of landscapes and required only simple descriptive data. Gilbert's alternative approach tried to use quantitative methods to determine the exact processes responsible for landscape evolution. This process-oriented approach to geomorphology did



not become popular until the 1950s because of its need for advanced numerical techniques.

The number of researchers in the various fields of physical geography increased considerably during the first three decades of the 20th century. These researchers helped develop physical geography mainly through basic data collection, the creation of classification schemes to organize the data collected, and the postulating of theories of operating processes through the use of inductive logic. Data collection included activities such as determining the elevation of land surfaces, the classification and description of landforms, the measurement of the volume of flow of rivers, the measurement of various phenomena associated with weather and climate, and the classification of climate, soils, organisms, biological communities, and ecosystems.

During the 1930s and 1940s, physical geography slid into steady decline in importance in the academic world. At the heart of this decline was the fact that the discipline was having problems attracting new students, with fresh ideas. Descriptive-based approaches to physical geography that were very popular in the late 19th and early 20th centuries had become tired and uninteresting. Physical geography needed a radical shift in philosophy to attract new scholars.

Twentieth Century: Second Half

Starting in about 1950, research in physical geography experienced a fundamental shift in philosophy. Physical geographers began adopting a different scientific approach. This approach relied on logical deductive reasoning, model building, experiments, and other quantitative techniques. This quantitative revolution was also associated with a change in the way physical geographers studied the Earth and its phenomena. Researchers now began investigating the operating processes rather than merely describing the facts associated with natural phenomena. Today, this quantitative approach is becoming even more common due to advances in software, computers, and other measurement technologies used in the field and in the laboratory to perform research.

The modeling of natural phenomena using a systems theory approach became an important component of many studies beginning in the early

1960s. Systems theory suggests that natural phenomena can be viewed as being composed of a number of parts that work together through some process to produce an outcome. The application of systems theory also allowed physical geographers to become more reductionist in their research approach without losing connection with larger systems such as Earth and its four interacting spheres (atmosphere, lithosphere, biosphere, and hydrosphere).

The growth of physical geography as a discipline exploded in the 1970s. It was now becoming common for departments of geography in the United States, Canada, Australia, New Zealand, and various European countries to have one or more faculty members specializing in climatology, geomorphology, biogeography, or hydrology. During the 1970s, remote sensing and geographic information systems (GIS) were established as valuable tools for research in physical geography. At first, these tools were mainly used to monitor Earth's surface, to collect descriptive data, or to generate maps. But this trend quickly became less important as researchers began using these technologies with spatial statistics and to build interactive models of systems.

In the last two decades of the 20th century, there was an important change in the purpose of investigation in physical geography. Because of mounting environmental problems, physical geographers moved away from theoretical studies. Instead, these scientists started applying knowledge common to their disciplines to find solutions to these problems. For instance, climatologists suggested that global warming was caused by human activities that result in the emission of greenhouse gases into the atmosphere. Biogeographers argued that losses of biodiversity were mainly due to the conversion of ecosystems to agricultural fields and urban land use. Geomorphologists identified the potential hazard associated with building human settlements near earthquake faults. Hydrologists suggested that a number of human activities were responsible for the pollution of rivers, lakes, and groundwater.

The 21st Century

Physical geography in the 21st century has been characterized by the following key developments.



First, advanced measurement technologies and information-processing capabilities are becoming more frequently used for gathering and processing data. As such, our planet is now being actively monitored by a number of satellites, each with an array of sensors for gathering information about the changing nature of Earth's atmosphere, biosphere, hydrosphere, and surface landscape. Furthermore, the vast amounts of data collected by these technologies no longer require sophisticated processing by supercomputers. Standard personal computers now suffice.

Human population growth and a steady rise in resource consumption per capita have drastically increased the number of environmental problems in need of action. Some of the more important problems include global warming, acid deposition, stratospheric ozone depletion, ocean acidification, natural land cover loss, biodiversity reduction, the introduction of exotic species, and the alteration of biogeochemical cycles. As explained earlier in this discussion, physical geographers are well prepared academically to examine these serious problems facing our planet.

Finally, collaborations between physical geographers and individuals from other natural and social science disciplines are becoming more common. This trend is being driven by the fact that single disciplines do not have all the answers required to tackle current complex environmental problems. Complete investigation of these problems often requires an economic or sociological perspective to explain why human activities create environmental degradation. Furthermore, these problems can be rectified only through economic or societal changes.

Michael Pidwirny

See also Biogeography; Climatology; Darwinism and Geography; Davis, William Morris; Environmental Determinism; Eratosthenes; Geologic Timescale; Geomorphic Cycle; Geomorphology; Gilbert, Grove Karl; Guyot, Arnold; Human Geography, History of; Humboldt, Alexander von; Hydrology; Köppen, Wladimir; Köppen-Geiger Climate Classification; Marsh, George Perkins; Maury, Matthew Fontaine; Penck, Walther; Plate Tectonics; Powell, John Wesley; Strahler, Arthur; Thornthwaite, C. Warren; Trewartha, Glenn; United States Geological Survey (USGS); White, Gilbert; Wittfogel, Karl

Further Readings

- Gregory, K. J. (2000). *The changing nature of physical geography*. London: Arnold.
- Holden, J. (2005). Approaching physical geography. In J. Holden (Ed.), *An introduction to physical geography and the environment* (pp. 3–24). Essex, UK: Pearson Education.
- Lyell, C. (1997). *Principles of geology*. London: Penguin Books. (Original work published 1830–1833)
- Marcus, M. G. (1979). Coming full circle: Physical geography in the twentieth century. *Annals of the Association of American Geographers*, 69(4), 521–532.
- Marsh, G. P. (1864). *Man and nature*. New York: Scribner.
- Rhoads, B. L. (2004). Whither physical geography? *Annals of the Association of American Geographers*, 94(4), 748–755.



PICKLES, JOHN (1952–)

John Pickles currently holds the Earl N. Phillips Distinguished Chair of International Studies and Geography at the University of North Carolina, Chapel Hill, where he is chair of the department of geography. He has also held academic appointments at the universities of Kentucky, Minnesota, and West Virginia; at the Ohio State University; at the Pennsylvania State University (Penn State); and at Natal Pietermaritzburg and Trieste.

For the past 20 yrs. (years), two main strands of scholarship have been the hallmark of Pickles's research work. The first and perhaps most well-known aspect of Pickles's scholarship concerns critical geographic information systems (GIS) and, more recently, critical cartography. The publication of the groundbreaking edited collection *Ground Truth: The Social Implications of Geographical Information Systems* in 1995 contributed to a critical rethinking of the nature of GIS as a social technology imbued with power relations. Importantly, this work injected critical social theory into understandings of technologies of control, analysis, and surveillance. More



recently, this interest has been extended to the development of a critical cartography. This research strand has involved a series of contributions to a critical social theoretic understanding of mapping and cartography, most clearly represented in the 2004 book *A History of Spaces: Cartographic Reason, Mapping and the Geo-Coded World*. This interest in critical cartographies has led to an engagement with a group of scholars and community activists in the United States and Europe aiming to produce alternative mappings of contemporary society through the Counter-Cartographies Collective.

The second area of Pickles's research and scholarship has focused on the development of a significant body of influential work on the political economies of power and development in South Africa and East-Central Europe. Much of this research has focused on the political economy of industrial and regional development and transformation through some of the most important societal transitions of the past 30 yrs.: apartheid and postapartheid in South Africa and transitions from state socialism in East-Central Europe. The work on industrial development and spatial power under late apartheid grew out of earlier PhD studies in South Africa. Part of this work focused on the emergence of Bantustan industrial production and inward investment from Taiwan, as the South African economy internationalized and as investors sought ways of overcoming the quota constraints on trade in the global apparel industry.

Since the late 1980s, following a series of bilateral U.S.-Bulgarian research exchange visits, Pickles's focus on industrial transformation, societal change, and power has resulted in a body of work on the globalization of the apparel industry in East-Central Europe. Seeking to explore the uneven integration and consequences of globalization and European integration in peripheral regions across that region, this work focused mostly on the transformation of peripheral regional economies through integration into global circuits of apparel production and export and the articulation between global commodity production and local societal forms, including ethnicity. More recently, these interests have been extended to consider the changing global economic geographies of apparel production following the end of quota-constrained trade in 2005.

There are two main hallmarks of Pickles's scholarship. The first is theoretical. Since his doctoral studies at Penn State in geography and philosophy, Pickles's work has involved a deep-seated engagement with critical social theory to try to understand the connections between space and power. This has been developed through his earlier work on phenomenology and spatiality (*Phenomenology, Science, and Geography*, 1985) and more recent work influenced by Marxist and post-Marxist social theory, from regulation theory to the ideas of Gilles Deleuze and Félix Guattari. The second hallmark is methodological. A characteristic of the majority of his scholarship is that it involves collaborative forms of research and engagement, described in Pickles and Smith (2007). From South Africa to the critical cartographies research group and engagements, to research on the globalization of apparel production in East-Central Europe, Pickles's work has involved a deep commitment to building collaborative networks not only to enhance understandings of material transformations but also to enable "local" scholars to engage in global circuits of knowledge production.

Adrian Smith

See also Countermapping; Critical GIS; Critical Human Geography; Marxism, Geography and; Phenomenology; Representations of Space

Further Readings

- Pickles, J. (1985). *Phenomenology, science, and geography: Space and the human sciences*. Cambridge, UK: Cambridge University Press.
- Pickles, J. (1995). *Ground truth: The social implications of geographical information systems*. New York: Guilford Press.
- Pickles, J. (2004). *A history of spaces: Cartographic reason, mapping and the geo-coded world*. London: Routledge.
- Pickles, J., & Smith, A. (2007). Post-socialism and the politics of knowledge production. In A. Tickell, E. Sheppard, & J. Peck (Eds.), *Politics and practice in economic geography* (pp. 151–162). Thousand Oaks, CA: Sage.
- 3Cs: Counter-Cartographies Collective: www.countercartographies.org

ENCYCLOPEDIA OF
Geography

EDITORIAL BOARD

Editor

Barney Warf
University of Kansas

Associate Editors

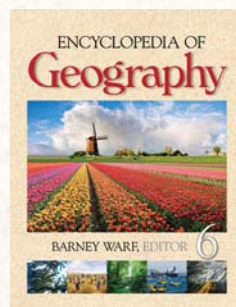
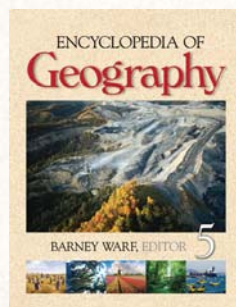
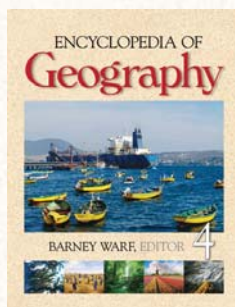
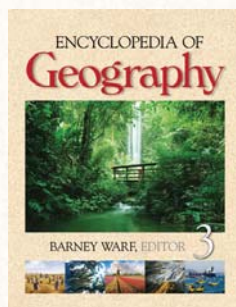
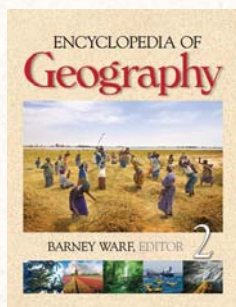
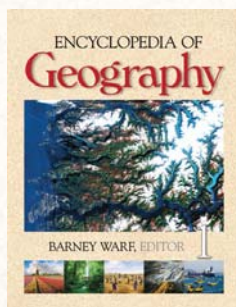
Piotr Jankowski
San Diego State University

Barry D. Solomon
Michigan Technological University

Mark Welford
Georgia Southern University

Managing Editor

Jonathan Leib
Old Dominion University



ENCYCLOPEDIA OF Geography

BARNEY WARF, EDITOR

University of Kansas

5



Los Angeles | London | New Delhi
Singapore | Washington DC

Copyright © 2010 by SAGE Publications, Inc.

All rights reserved. No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

For information:



SAGE Publications, Inc.
2455 Teller Road
Thousand Oaks, California 91320
E-mail: order@sagepub.com

SAGE Publications Ltd.
1 Oliver's Yard
55 City Road
London, EC1Y 1SP
United Kingdom

SAGE Publications India Pvt. Ltd.
B 1/I 1 Mohan Cooperative Industrial Area
Mathura Road, New Delhi 110 044
India

SAGE Publications Asia-Pacific Pte. Ltd.
33 Pekin Street #02-01
Far East Square
Singapore 048763

Printed in Singapore.

Library of Congress Cataloging-in-Publication Data

Encyclopedia of geography, volume I - VI / edited by Barney Warf.

6 v., p. cm.

Includes bibliographical references and index.

ISBN 978-1-4129-5697-0 (cloth)

1. Geography—Encyclopedias. I. Warf, Barney, 1956-

G63.E554 2010

910.3—dc22

2010009453

This book is printed on acid-free paper.

10 11 12 13 14 10 9 8 7 6 5 4 3 2 1

<i>Publisher:</i>	Rolf A. Janke
<i>Assistant to the Publisher:</i>	Michele Thompson
<i>Acquisitions Editor:</i>	Robert Rojek
<i>Developmental Editor:</i>	Diana E. Axelsen
<i>Reference Systems Manager:</i>	Leticia Gutierrez
<i>Reference Systems Coordinator:</i>	Laura Notton
<i>Production Editor:</i>	Tracy Buyan
<i>Copy Editors:</i>	QuADS Prepress (P) Ltd.
<i>Typesetter:</i>	C&M Digitals (P) Ltd.
<i>Proofreaders:</i>	Penelope Sippel, Rae-Ann Goodwin, Annette Van Deusen
<i>Indexer:</i>	Julie Sherman Grayson
<i>Cover Designer:</i>	Ravi Balasuriya
<i>Marketing Manager:</i>	Amberlyn McKay

Volume 5 cover photo: Drag line and strip pit in the Star Fire and Lost Mountain Site owned by Cyprus Realty in Hazard, Kentucky. © Karen Kasmauski/Science Faction/Corbis.

CONTENTS

5

List of Entries

vii

Entries

P 2184

Q 2323

R 2335

S 2499

LIST OF ENTRIES

- | | | |
|---|---|--|
| <p> Abler, Ronald
 Absolute Space
 Accessibility
 Acid Rain
 Actor-Network Theory
 Adaptation to Climate Change
 Adaptive Harvest Management
 Adaptive Radiation
 Adiabatic Temperature
 Changes
 Aerial Imagery: Data
 Aerial Imagery: Interpretation
 African Union
 Agamben, Giorgio
 Agent-Based Models
 Agglomeration Economies
 Aging and the Aged,
 Geography of. <i>See</i> Elderly,
 Geography and the
 Agnew, John
 Agricultural Biotechnology
 Agricultural Intensification
 Agricultural Land Use
 Agriculture, Industrialized
 Agriculture, Preindustrial
 Agrobiodiversity
 Agrochemical Pollution
 Agroecology
 Agrofoods
 Agroforestry
 AIDS, Geography of. <i>See</i>
 Disease, Geography of;
 HIV/AIDS, Geography of
 Air Masses </p> | <p> Air Pollution. <i>See</i> Atmospheric
 Pollution
 Albedo
 al-Idrisi
 Altitude
 Ambient Air Quality
 American Geographical Society
 Analytical Operations in GIS
 Anarchism and Geography
 Anaximander
 Animal Geographies
 Annales School
 Anselin, Luc
 Antevs, Ernst
 Anthropogenic Atmospheric
 Change. <i>See</i> Anthropogenic
 Climate Change;
 Stratospheric Ozone
 Depletion
 Anthropogenic Climate Change
 Anthropogeography
 Antiglobalization
 Antipodes
 Antisystemic Movements
 Applied Geography
 Appropriate Technology. <i>See</i>
 Sustainable Development;
 Sustainable Development
 Alternatives; Sustainable
 Production
 Aquaculture
 Archipelago
 Architecture and Geography
 Argumentation Maps </p> | <p> Arid Topography
 Aristotle
 Armstrong, Marc
 Art and Geography
 Asia-Pacific Economic
 Cooperation
 Association of American
 Geographers
 Association of Geographic
 Information Laboratories
 for Europe
 Association of Southeast Asian
 Nations
 Atmospheric Circulation
 Atmospheric Composition and
 Structure
 Atmospheric Energy Transfer
 Atmospheric Moisture
 Atmospheric Particulates
 Across Scales
 Atmospheric Pollution
 Atmospheric Pressure
 Atmospheric Remote Sensing
 Atmospheric Variations
 in Energy
 Atoll
 Automobile Industry
 Automobility
 Avalanches
 Aviation and Geography

 Barrier Islands
 Barrows, Harlan
 Basin and Range Topography </p> |
|---|---|--|

- | | | |
|---|--|---|
| Batty, Michael | Business Models for Geographic Information Systems | Class, Geography and Class, Nature and Client-Server Architecture |
| Bayesian Statistics in Spatial Analysis | Buttimer, Anne | Climate: Dry |
| Behavioral Geography | | Climate: Midlatitude, Mild |
| Berkeley School | | Climate: Midlatitude, Severe |
| Berry, Brian | Cadastral Systems | Climate: Mountain |
| Bhopal, India, Chemical Disaster | CAD Systems | Climate: Polar |
| Biblical Mapping | Câmara, Gilberto | Climate: Tropical Humid |
| Biodiversity | Canadian Association of Geographers | Climate Change |
| Biofuels | Cancer, Geography of | Climate Policy |
| Biogeochemical Cycles | Carbonation | Climate Types |
| Biogeography | Carbon Cycle | Climatic Relict |
| Biome: Boreal Forest | Carbon Trading and Carbon Offsets | Climatology |
| Biome: Desert | Carcinogens | Clouds |
| Biome: Midlatitude Deciduous Forest | Carrying Capacity | Clusters |
| Biome: Midlatitude Grassland | Cartograms | Coal |
| Biome: Tropical Deciduous Forest | Cartography | Coastal Dead Zones |
| Biome: Tropical Rain Forest | Cartography, History of | Coastal Erosion and Deposition |
| Biome: Tropical Savanna | Castells, Manuel | Coastal Hazards |
| Biome: Tropical Scrub | Caverns | Coastal Zone and Marine Pollution |
| Biome: Tundra | Cellular Automata | Cold War, Geography of |
| Biophysical Remote Sensing | Census | Collaborative GIS |
| Bioregionalism | Census Tracts | Colonialism |
| Biosphere Reserves | Centers of Domestication | Color in Map Design |
| Biota and Climate | Central Business District | Columbus, Christopher |
| Biota and Soils | Central Place Theory | Commodity Chains |
| Biota and Topography | Chemical Spills, Environment, and Society | Common Pool Resources |
| Biota Migration and Dispersal | Chernobyl Nuclear Accident | Common Property Resource Management |
| Biotechnology and Ecological Risk | Chicago School | Commons, Tragedy of the Commonwealth of Independent States |
| Biotechnology Industry | Childhood Spatial and Environmental Learning | Communications Geography |
| Biruni | Children, Geography of | Communism and Geography |
| Blaikie, Piers | Chinooks/Foehns | Community-Based Conservation |
| Blaut, James | Chipko Movement | Community-Based Environmental Planning |
| Blindness and Geography | Chlorinated Hydrocarbons | Community-Based Natural Resource Management |
| Body, Geography of | Chlorofluorocarbons | Community Forestry |
| Borderlands | Cholera, Geography of | Commuting |
| Borders and Boundaries | Chorley, Richard | Comparative Advantage |
| Bourghassi, Carmina | Chorology | Competitive Advantage |
| Bowman, Isaiah | Choropleth Maps | Complexity Theory |
| Brownfields | Chrisman, Nicholas | Complex Systems Models |
| Built Environment | Christaller, Walter | Conference of Latin Americanist Geographers |
| Bunge, William | Circuits of Capital | |
| Bush Fallow Farming | Citizenship | |
| Business Cycles and Geography | Civil Society | |
| Business Geography | Clark, Andrew | |
| | Clark, William | |

- Conflation
 Conservation
 Conservation Zoning
 Consumption, Geographies of
 Continental Drift. *See* Plate Tectonics
 Cook, Captain James
 Coordinate Geometry
 Coordinate Systems
 Coordinate Transformations
 Coral Reef
 Coral Reef Geomorphology
 Coriolis Force
 Corporate Voluntary Environmental Initiatives and Self-Regulation
 Cosgrove, Denis
 Cosmopolitanism
 Cost-Benefit Analysis
 Council for Mutual Economic Assistance (COMECON)
 Countermapping
 Counterurbanization
 Coupled Human and Animal Systems
 Coupled Human and Natural Systems
 Creep
 Crime, Geography of
 Crisis
 Critical Geopolitics
 Critical GIS
 Critical Human Geography
 Critical Studies of Nature
 Crop Genetic Diversity
 Crop Rotation
 Cross-Border Cooperation
 Cultural Ecology
 Cultural Geography
 Cultural Landscape
 Cultural Turn
 Cyberspace
 Cyborg Ecologies
 Cyclones: Extratropical
 Cyclones: Occluded

 Dangermond, Jack
 Darby, Henry Clifford
 Darwinism and Geography
 Dasymetric Maps

 Database Management Systems
 Database Versioning
 Data Classification Schemes
 Data Compression Methods
 Data Editing
 Data Format Conversion
 Data Indexing
 Data Querying in GIS
 Datums
 Davis, William Morris
 Dear, Michael
 Debt and Debt Crisis
 Decolonization
 Deep Ecology Movements
 Deforestation
 Deindustrialization
 Delta
 Democracy
 Demographic Transition
 Dendrochronology
 Dependency Theory
 Derechos
 Desertification
 Desert Varnish
 Deterritorialization and Reterritorialization
 Developing World
 Development Theory
 Diamond, Jared
 Diaspora
 Diastrophism
 Difference, Geographies of
 Differential Heating
 Differential Vulnerabilities to Hazards
 Diffusion
 Digital Divide
 Digital Terrain Model
 Digitizing
 Disability, Geography of
 Disaster Prediction and Warning
 Disaster Preparedness
 Discourse and Geography
 Disease, Geography of
 Distance Decay
 Distributed Computing
 Distribution of Resource Access
 Division of Labor

 Domestication Centers. *See* Centers of Domestication
 Domestication of Animals
 Domestication of Plants
 Domino Theory
 Dot Density Maps
 Drought Risk and Hazard
 Drugs, Geography of
 Dunes
 Dynamic and Interactive Displays

 Earle, Carville
 Earthquakes
 Earth's Coordinate Grid
 Eastman, Ronald
 Ecofeminism
 Ecological Economics
 Ecological Fallacy
 Ecological Footprint
 Ecological Imaginaries
 Ecological Justice
 Ecological Mapping
 Ecological Modernization
 Ecological Regimes
 Ecological Risk Analysis
 Ecological Services. *See* Environmental Services
 Ecological Zones
 E-Commerce and Geography
 Economic Base Analysis
 Economic Geography
 Economies of Scale
 Economies of Scope
 Ecoregions
 Ecoshed
 Ecosystem Decay
 Ecosystems
 Ecotone
 Ecotourism
 Education, Geographies of
 Egenhofer, Max
 Elderly, Geography and the
 Electoral Geography
 Electronic Atlases
 Electronics Industry, Geography of
 El Niño
 Emerging Markets

- | | | |
|------------------------------------|-------------------------------------|---------------------------------|
| Emotions, Geography and Empiricism | Environmental Protection | Feminist Environmentalism |
| Endogenous Growth Theory. | Environmental Racism | Feminist Geographies |
| <i>See</i> Knowledge Spillovers; | Environmental Refugees | Feminist Methodologies |
| Learning Regions | Environmental Restoration | Feminist Political Ecology |
| Energy and Human Ecology | Environmental Rights | Fertility Rate |
| Energy Models | Environmental Security | Fieldwork in Human |
| Energy Policy | Environmental Services | Geography |
| Energy Resources | Environmental Social | Fieldwork in Physical |
| Enlightenment | Movements. <i>See</i> International | Geography |
| Enterprise GIS | Environmental Movements | Film and Geography |
| Environmental Certification | Environment and Development | Filtering |
| Environmental Determinism | Epistemology | Filtration |
| Environmental Discourse | Equator | Finance, Geography of |
| Environmental Entitlements | Equinox | Fisher, Peter |
| Environmental Ethics | Eratosthenes | Fish Farming |
| Environmental Footprint. | Error Propagation | Fjords |
| <i>See</i> Ecological Footprint | Ethics, Geography and | Flash Floods |
| Environmental History | Ethnicity | Flexible Production |
| Environmental Imaginaries | Ethnicity and Nature | Flocculation |
| Environmental Impact | Ethnic Segregation | Floodplain |
| Assessment | Ethnocentrism | Floods |
| Environmental Impacts of | Eurocentrism | Flow |
| Agriculture | Euromarket | Flow Maps |
| Environmental Impacts of | European Green Movements | Folding |
| Cities | European Union | Folk Culture and |
| Environmental Impacts of | Everglades Restoration | Geography |
| Manufacturing | Everyday Life, Geography and | Food, Geography of |
| Environmental Impacts of | Existentialism and Geography | Food and Agriculture |
| Mining. <i>See</i> Open-Pit | Exotic Species | Organization (FAO) |
| Mining | Exploration | Footprint Analysis. |
| Environmental Impacts of | Exploratory Spatial Data | <i>See</i> Ecological Footprint |
| Oil Fields | Analysis | Fordism |
| Environmental Impacts of | Export-Led Development | Fordism |
| Pipelines | Export Processing Zones | Foreign Aid |
| Environmental Impacts of | Externalities | Foreign Direct Investment |
| Roads | Extinctions | Forest Degradation |
| Environmental Impacts of | Extractive Reserves | Forest Fragmentation |
| Tourism | Extreme Geography | Forest Land Use |
| Environmental Impacts of War | Exurbs | Forest Restoration |
| Environmental Impact | Factors Affecting Location | Fotheringham, A. Stewart |
| Statement | of Firms | Frank, Andrew |
| Environmental Justice | Fair Trade and Environmental | Frontiers |
| Environmental Law | Certification | Fronts |
| Environmental Management | Famine, Geography of | Gaia Theory |
| Environmental Management: | Faulting | Gama, Vasco da |
| Drylands | Fear, Geographies of | Game Ranching |
| Environmental Mapping | Febvre, Lucien | Gated Community |
| Environmental Perception | Feminist Environmental | Gays and Lesbians, |
| Environmental Planning | Geographies | Geography and/of |
| | | Gazetteers |

- Gender and Environmental Hazards
 Gender and Geography
 Gender and Nature
 General Circulation Model (GCM). *See* Anthropogenic Climate Change; Atmospheric Energy Transfer; Climate Change
 Genetically Modified Organisms (GMOs)
 Genocide, Geographies of
 Gentrification
 Geocoding
 Geocollaboration
 Geocomputation
 Geodemographics
 Geodesy
 Geographical Ignorance
 Geographical Imagination
 Geographically Weighted Regression
 Geographic Information Systems
 Geography Education
 Geolibraries
 Geologic Timescale
 Geomancy
 Geometric Correction
 Geometric Measures
 Geomorphic Cycle
 Geomorphology
 Geophagy
 Geopolitics
 Geosensor Networks
 Geoslavery
 Geospatial Industry
 Geospatial Semantic Web
 Geostatistics
 Geothermal Energy
 Geothermal Features
 Geovisualization. *See* Cartography; Dynamic and Interactive Displays; Three-Dimensional Models
 Getis, Arthur
 Ghetto
 Giddens, Anthony
 Gilbert, Grove Karl
 GIS, Environmental Model Integration and
 GIS, History of
 GIScience
 GIS Design
 GIS Implementation
 GIS in Archaeology
 GIS in Disaster Response
 GIS in Environmental Management
 GIS in Health Research and Health Care
 GIS in Land Use Management
 GIS in Local Government
 GIS in Public Policy
 GIS in Transportation
 GIS in Urban Planning
 GIS in Utilities
 GIS in Water Management
 GIS Software
 GIS Web Services
 Glaciers: Continental
 Glaciers: Mountain
 Global Climate Change. *See* Anthropogenic Climate Change
 Global Environmental Change
 Globalization
 Global Positioning System
 Global Sea-Level Rise
 Global Warming. *See* Anthropogenic Climate Change
 Globes. *See* Cartography; Map Projections
 Glocalization
 Golledge, Reginald
 Goodchild, Michael
 Goode, J. Paul
 Google Earth
 Gottmann, Jean
 Gould, Peter
 Governance
 Governmentality and Conservation
 Gravity Model
 Great American Exchange
 Greenbelts
 Green Building
 Green Design and Development
 Greenhouse Gases
 Green Revolution. *See* Environmental Impacts of Agriculture
 Gregory, Derek
 Gross Domestic Product/Gross National Product
 Ground Reference Data
 Groundwater
 Growth Machine
 Growth Poles
 Gully Erosion
 Guyot, Arnold
 Hadley Cell
 Hägerstrand, Torsten
 Haggett, Peter
 Hanson, Susan
 Harley, Brian
 Hartshorne, Richard
 Harvey, David
 Hate, Geographies of
 Haushofer, Karl
 Hayden, Ferdinand
 Health and Health Care, Geography of
 Heavy Metals as Pollutants
 Hegemony
 Herbicides
 Herodotus
 Hettner, Alfred
 Heuristic Methods in Spatial Analysis
 High-Performance Computing
 High Technology
 Hipparchus
 Historical Geography
 Historicism
 Historic Preservation
 History of Geography. *See* Cartography, History of; GIS, History of; Human Geography, History of; Physical Geography, History of
 HIV/AIDS, Geography of
 Home
 Homelessness
 Hou Renzhi

- Housing and Housing Markets
Housing Policy
Hoyt, Homer
Human Dimensions of Global
Environmental Change
Human Ecology
Human Geography, History of
Human-Induced Invasion of
Species
Humanistic Geography
Humanistic GIScience
Human Rights, Geography and
Humboldt, Alexander von
Humidity
Hunger
Hunting and Gathering
Huntington, Ellsworth
Hurricane Katrina
Hurricanes, Physical
Geography of
Hurricanes, Risk and Hazard
Hybrid Geographies
Hybridization of Plant and
Animal Species
Hydroelectric Power
Hydrological Connectivity
Hydrology
Hydrothermal Energy. *See*
Geothermal Energy
- Ibn Battuta
Ibn Khaldūn
Ice
Identity, Geography and
Idiographic
Image Enhancement
Image Fusion
Image Interpretation
Image Processing
Image Registration
Image Texture
Imaging Spectroscopy
Immigration
Imperialism
Impermeable Surfaces
Import Substitution
Industrialization
Incubator Zones
Indigeneity
Indigenous Agriculture
- Indigenous and Community
Conserved Areas
Indigenous Cartographies
Indigenous Environmental
Knowledge
Indigenous Environmental
Practices
Indigenous Forestry
Indigenous Reserves
Indigenous Water Management
Industrial Districts
Industrial Ecology
Industrialization
Industrial Revolution
Inequality and Geography
Informal Economy
Information Society
Infrastructure
Innovation, Geography of
Input-Output Models
Institute of British Geographers
Interactive Mapping. *See* Map
Animation
Intergovernmental
Environmental
Organizations and Initiatives
International Criminal Court
International Environmental
Movements
International Environmental
NGOs
International Geographical
Union
International Monetary Fund
International Watershed
Management
Internet. *See* Communications,
Geography of; Cyberspace;
Digital Divide;
Telecommunications and
Geography
Internet GIS
Interoperability and Spatial
Data Standards
Interviewing
Invasion and Succession
Isard, Walter
Island Biogeography
Islands, Small
Isopleth Maps
- Jackson, John Brinckerhoff
Jefferson, Thomas
Johnston, R. J.
Journey-to-Work. *See*
Commuting
Justice, Geography of
- Kant, Immanuel
Karst Topography
Kates, Robert
Keystone Species
Knowledge, Geography of
Knowledge Spillovers
Köppen, Wladimir
Köppen-Geiger Climate
Classification
Kropotkin, Peter
Krummholtz
Kuhn, Werner
Kwan, Mei-Po
Kyoto Protocol. *See* Climate
Policy
- Labor, Geography of
Lahar. *See* Volcanoes
Land Degradation
Landfills
Landforms
Land Reform
Landscape and Wildlife
Conservation
Landscape Architecture
Landscape Biodiversity
Landscape Design
Landscape Ecology
Landscape Interpretation
Landscape Quality
Assessment
Landscape Restoration
Landslide
Land Tenure
Land Tenure Reform
Land Use
Land Use Analysis
Land Use and Cover Change
(LUCC)
Land Use and Land Cover
Mapping
Land Use History
Land Use Planning

-
- Land-Water Breeze
 Languages, Geography of
 La Niña
 Lapse Rate
 Latent Heat
 Latitude
 Law, Geography of
 Learning Regions
 Lefebvre, Henri
 Legal Aspects of Geospatial Information
 Lewis, Peirce
 Lewis and Clark Expedition
 Ley, David
 LiDAR and Airborne Laser Scanning
 Lightning
 Lillesand, Thomas
 Linear Referencing and Dynamic Segmentation
 Literature, Geography and
 Livingstone, David
 Locality
 Locally Unwanted Land Uses (LULUs)
 Location-Allocation Modeling
 Location-Based Services
 Location Quotients
 Location Theory
 Logical Positivism
 Longitude
 Los Angeles School
 Lösch, August
 Love Canal
 Lynch, William
- MacEachren, Alan
 Mackinder, Sir Halford
 Magellan, Ferdinand
 Mahan, Alfred Thayer
 Malaria, Geography of
 Malthusianism
 Manufacturing Belt
 Map Algebra
 Map Animation
 Map Design
 Map Evaluation and Testing
 Map Generalization
 Map Projections
 Map Visualization
- Marcus, Melvin G.
 Marginal Regions
 Marine Aquaculture
 Maritime Spaces. *See* Oceans
 Mark, David M.
 Market-Based Environmental Regulation
 Marsh, George Perkins
 Marxism, Geography and
 Masculinities and Geography
 Massey, Doreen
 Mass Wasting
 Mather, John Russell
 Maury, Matthew Fontaine
 McKnight, Tom L.
 Media and Geography
 Medical Geography
 Meinig, Donald
 Mental Maps
 Mercator, Gerardus
 Metadata
 Metropolitan Area
 Microwave/RADAR Data
 Migration
 Military Geography
 Military Spending
 Miller, Harvey J.
 Minerals
 Mining and Geography
 Mitchell, Don
 Mixed Farming
 Mobile GIS
 Mobility
 Models and Modeling
 Modernity
 Modernization Theory
 Modifiable Areal Unit Problem
 Money, Geographies of
 Monmonier, Mark
 Monsoons
 Morrill, Richard
 Morse, Jedediah
 Mortality Rate
 Most Favored Nation Status
 Movimento Sem Terra
 Multimedia Mapping
 Multispectral Imagery
 Multistakeholder Participation
 Multitemporal Imaging
 Multivariate Analysis Methods
- Multivariate Mapping
 Music and Sound, Geography and
 Nation
 National Aeronautics and Space Administration (NASA)
 National Center for Geographic Information and Analysis
 National Council for Geographic Education
 National Geographic Society
 Nationalism
 Natural Growth Rate
 Natural Hazards and Risk Analysis
 Nature
 Nature-Society Theory
 Neighborhood
 Neocolonialism
 Neogeography
 Neoliberal Environmental Policy
 Neoliberalism
 Neo-Malthusianism
 Network Analysis
 Network Data Model
 New International Division of Labor
 Newly Industrializing Countries
 New Urbanism
 Nitrogen Cycle
 Nomadic Herding
 Nomadism
 Nomothetic
 Nongovernmental Organizations (NGOs)
 Nonpoint Sources of Pollution
 Nonrenewable Resources
 Nonrepresentational Theory
 Nonvisual Geographies
 North American Free Trade Agreement (NAFTA)
 North Atlantic Treaty Organization (NATO)
 Not in My Backyard (NIMBY)
 Nuclear Energy

- | | | |
|---|---|--|
| Nutrient Cycles | Patches and Corridors in Wildlife Conservation | Positionality |
| Nyerges, Timothy | Path Dependence | Positivism. <i>See</i> Logical Positivism |
| Object-Based Image Analysis | Patriarchy, Geography and Peasants and Peasantry | Postcolonialism |
| Oceanic Circulation | Peat | Post-Fordism. <i>See</i> Flexible Production |
| Oceans | Pedology. <i>See</i> Soils | Postindustrial Society |
| Offshore Finance | Peet, Richard | Postmodernism |
| Oil Spills | Penck, Walther | Poststructuralism |
| Okabe, Atsuyuki | Periglacial Environments | Poverty |
| Olsson, Gunnar | Permaculture | Powell, John Wesley |
| Ontological Foundations of Geographical Data | Permafrost | Prairie Restoration |
| Ontology | Pesticides | Prairies |
| Open Geodata Standards | Pest Management | Precipitation, Global |
| Open Geospatial Consortium (OGC) | Petroleum | Precipitation Formation |
| Open-Pit Mining | Peuquet, Donna | Pred, Allan |
| Open Source Geospatial Foundation | Phenomenology | Primate Cities |
| Open Source GIS | Phosphorus Cycle | Prime Meridian. <i>See</i> Longitude |
| Open Space | Photochemical Smog | Privacy and Security of Geospatial Information |
| Organic Agriculture | Photogrammetric Methods | Producer Services |
| Organisation for Economic Co-operation and Development (OECD) | Photography, Geography and Physical Geography, History of | Product Cycle |
| Organization of the Petroleum Exporting Countries (OPEC) | Pickles, John | Production of Space |
| Organophosphates | Pilgrimage | Psychoanalysis, Geography and |
| Orientalism | Place | Ptolemy |
| Ortelius | Place Names | Public Housing |
| Other/Otherness | Place Promotion | Public Participation GIS |
| Outsourcing | Plantations | Public Policy, Geography of |
| Overpopulation. <i>See</i> Malthusianism; Neo-Malthusianism | Plate Tectonics | Public-Private Partnerships |
| | Playas | Public Space |
| | Point Pattern Analysis | Public Water Services |
| | Point Sources of Pollution | Pyrogeography |
| | Poles, North and South | |
| | Political Ecology | Qualitative Methods |
| | Political Economy | Quantitative Methods |
| | Political Economy of Resources | Quantitative Revolution |
| | Political Geography | Queer Theory |
| | Polychlorinated Biphenyls (PCBs) | |
| | Popular Culture, Geography and | Race and Empire |
| | Population and Land Degradation | Race and Nature |
| | Population and Land Use | Race and Racism |
| | Population Density | Racial Segregation |
| | Population, Environment, and Development | Radiation: Solar and Terrestrial |
| | Population Geography | Radical Geography |
| | Population Pyramid | Radiometric Correction |
| | Portolan Charts | Radiometric Normalization |
| | Ports and Maritime Trade | Radiometric Resolution |
| | | Railroads and Geography |
| | | Raisz, Erwin |

- Rank-Size Rule
 Ratzel, Friedrich
 Real Estate, Geography and
 Realism
 Reclus, Élisée
 Recycling of Municipal Solid
 Waste
 Redistricting
 Refugees
 Regional Economic
 Development
 Regional Environmental
 Planning
 Regional Geography
 Regional Governance
 Regional Science
 Regional Science Association
 International (RSAI)
 Regions and Regionalism
 Regulation Theory
 Relational Space. *See* Relative/
 Relational Space
 Relative/Relational Space
 Religion, Geography and
 Relph, Edward
 Remittances
 Remote Sensing
 Remote Sensing: Platforms and
 Sensors
 Remote Sensing in Disaster
 Response
 Renewable Resources
 Rent-Gap
 Representations of Space
 Research and Development,
 Geographies of
 Resilience
 Resistance, Geographies of
 Resource Economics
 Resource Geography
 Resource Management. *See*
 Environmental Management
 Resource Management,
 Decision Models in
 Resource Mapping
 Resource Tenure
 Restoration Ecology. *See*
 Environmental Restoration
 Restructuring
 Retail Trade, Geography of
 Rill Erosion
 Risk Analysis and Assessment
 Ritter, Carl
 Rivers
 Rock Weathering
 Rose, Gillian
 Royal Geographical Society
 Rural Development
 Rural Geography
 Rural-Urban Migration
 Russian Geographical Society
 Satellites and Geography
 Sauer, Carl
 Scale, Social Production of
 Scale in GIS
 Schaefer, Fred
 Science, Technology, and
 Environment
 Science and Technology Studies
 Scott, Allen
 Sedimentary Rock
 Sedimentation
 Segregation and Geography
 Self-Organizing Maps
 Semantic Interoperability
 Semantic Reference Systems
 Semple, Ellen Churchill
 Sense of Place
 Sequent Occupance
 Services. *See* Producer Services
 Settlement Geography
 Sexuality, Geography and/of
 Shifting Cultivation
 Shortest-Path Problem
 Single Large or Several Small
 (SLOSS) Debate
 Situated Knowledge
 Smart Growth
 Smith, Neil
 Smog. *See* Photochemical Smog
 Social and Economic Impacts
 of Climate Change
 Social Construction of Nature
 Social Darwinism
 Social Forestry
 Social Geography
 Socialism and Geography
 Social Justice
 Social Movements
 Soil Conservation
 Soil Degradation
 Soil Depletion
 Soil Erosion
 Soils
 Soja, Edward
 Solar Energy
 Solstices
 Sovereignty
 Space, Production of. *See*
 Production of Space
 Space of Flows
 Spaces of Representation/
 Representational Spaces
 Spatial Analysis
 Spatial Autocorrelation
 Spatial Cognition
 Spatial Cognitive Engineering
 Spatial Data Infrastructures
 Spatial Data Integration
 Spatial Data Mining
 Spatial Data Models
 Spatial Data Structures
 Spatial Decision Support
 Systems
 Spatial Econometrics
 Spatial Fix
 Spatial Inequality
 Spatial Interaction Models
 Spatial Interpolation
 Spatialization
 Spatially Integrated Social
 Science
 Spatial Multicriteria Evaluation
 Spatial Optimization Methods
 Spatial Resolution
 Spatial Statistics
 Spatial Strategies of
 Conservation
 Spatial Turn
 Species-Area Relationship
 Spectral Characteristics of
 Terrestrial Surfaces
 Spectral Resolution
 Spectral Transformations
 Spit. *See* Coastal Erosion and
 Deposition
 Sports, Geography of
 Squatter Settlements
 State

- | | | |
|--|---|---|
| Steel Industry, Geography of | Textile Industry | United Nations Conference on Environment and Development |
| Stereoscopy and Orthoimagery | Thales | United Nations Environmental Summits |
| Storper, Michael | Thermal Imagery | United Nations Environment Programme (UNEP) |
| Strabo | Thornthwaite, C. Warren | United States Census Bureau |
| Strahler, Arthur | Three-Dimensional Data Models | United States Geological Survey (USGS) |
| Stratospheric Ozone Depletion | Three Mile Island Nuclear Accident | University Consortium for Geographic Information Science |
| Strip Mining | Thrift, Nigel | Unsupervised Classification |
| Structural Adjustment | Thunderstorms | Unwin, David |
| Structuralism | Thünen Model | Urban and Regional Development |
| Structuration Theory | Timber Plantations | Urban and Regional Planning |
| Subaltern Studies | Time, Geographies of | Urban Ecology |
| Suburban Land Use | Time-Geography | Urban Environmental Studies |
| Suburbs and Suburbanization | Time-Space Compression | Urban Gardens |
| Sui, Daniel | T-in-O Maps | Urban Geography |
| Suitability Analysis | Tobler, Waldo | Urban Green Space |
| Sunbelt | Tomlinson, Roger | Urban Heat Island |
| Supervised Classification | Topological Relationships | Urban Hierarchy |
| Supranational Integration | Toponymy | Urbanization |
| Surface Water | Topophilia | Urban Land Use |
| Surveillance | Tornadoes | Urban Metabolism |
| Surveying | Tourism | Urban Planning and Geography |
| Sustainability Science | Township and Range System | Urban Policy |
| Sustainable Agriculture | Trade | Urban Solid Waste Management |
| Sustainable Cities | Transhumance. <i>See</i> Nomadism | Urban Spatial Structure |
| Sustainable Development | Transnational Corporation | Urban Sprawl |
| Sustainable Development Alternatives | Transnationalism | Urban Storm Water Management |
| Sustainable Fisheries | Transportation Geography | Urban Sustainability |
| Sustainable Forestry | Trap Streets | Urban Underclass |
| Sustainable Production | Travel Writing, Geography and | Urban Water Supply |
| Symbolism and Place | Tree Farming | Usability of Geospatial Information |
| Symptoms and Effects of Climate Change | Trewartha, Glenn | |
| | Triangulated Irregular Network (TIN) Data Model | Vagueness in Spatial Data |
| Taphonomy | Troll, Carl | Vance, James |
| Taylor, Griffith | Tropical Rain Forests. <i>See</i> Biome: Tropical Rain Forest | Varenius |
| Taylor, Peter | Tsunami | Vectorization |
| Technological Change, Geography of | Tsunami of 2004, Indian Ocean | Vernacular Landscapes as Expressions of Environmental Ideas |
| Telecommunications and Geography | Tuan, Yi-Fu | |
| Teleconnections | Turner, Billie Lee, II | |
| Television and Geography | Typhoons. <i>See</i> Hurricanes, Physical Geography of | |
| Temperature Patterns | Typography in Map Design | |
| Temporal GIS | | |
| Temporal Resolution | Underdevelopment | |
| Terrain Analysis | Uneven Development | |
| Territory | United Nations | |
| Terrorism, Geography of | | |
| Text/Textuality | | |

-
- | | | |
|---|------------------------------------|---|
| Via Campesina (International Farmers' Movement) | Water Needs | Wine Terroir |
| Vidal de la Blache, Paul | Water Pollution | Wise Use Movement |
| Video Games, Geography and | Watershed Management | Wittfogel, Karl |
| Viewshed Analysis | Watershed Yield | Wood, Denis |
| Virilio, Paul | Water Supply Siting and Management | Woodfuel |
| Virtual and Immersive Environments | Watts, Michael | Woodlots. <i>See</i> Forest Fragmentation |
| Virtual Geographies | Wayfinding | World Bank |
| Virtual Globes | Weather and Climate Controls | World Cities |
| Vision and Geography | Weber, Alfred | World Court |
| Volcanic Eruptions as Risk and Hazard | Web Geoprocessing Workflows | World Health Organization (WHO) |
| Volcanoes | Web Service Architectures for GIS | World Summit on Sustainable Development |
| Voronoi Diagrams | Wetlands | World-Systems Theory |
| Vulnerability, Risks, and Hazards | White, Gilbert | World Trade Organization (WTO) |
| | Whiteness | Wright, Dawn |
| Waldseemüller, Martin | Whittlesey, Derwent | Wright, John Kirtland |
| Walker, Richard | Wilderness | Writing |
| War, Geography of | Wildfires: Risk and Hazard | |
| Waste Incineration | Wilson, John | |
| Wastewater Management | Wind | Xeriscaping |
| Water Degradation | Wind Energy | |
| Water Management and Treatment | Wind Erosion | Zelinsky, Wilbur |
| | Wine, Geography of | Zoning |



PILGRIMAGE

Throughout recorded history, the pilgrimage has been an important practice in most of the world's religions. It consists of an individual or a group leaving home and traveling to a sacred site that has a spiritual magnetism within their belief system. Pilgrims encounter both the core of the religion and their fellow believers in a new and enhanced way, before returning home somehow transformed by their journey. Such a site can be a unique center of divine presence (e.g., the Ka'bah in Mecca [Makkah]), a place that is the group's "most precious possession" (e.g., the Western Wall, in Jerusalem, of the temple destroyed in AD 70, for Jews), a place linked with primordial history (e.g., Varanasi [Benares] on the Ganges, in Uttar Pradesh, India), the tomb of a saint (e.g., the tombs of Saint Peter and Saint Paul in Rome for Christians or that of Husayn ibn 'Ali in Karbala, Iraq, for Shia Muslims), a place linked to a religion's founder (e.g., the holy places in Jerusalem for Christians), or a miraculous place of revelation or healings (e.g., Lourdes, France, for Catholics). To arrive at such a center, to engage in the rituals prescribed there, and to be in the "very place" and see, touch, and taste its sacred relics is experienced as desire fulfilled and as joy both in the object of the pilgrimage and in being part of the blessed group who have been so blessed to get there.

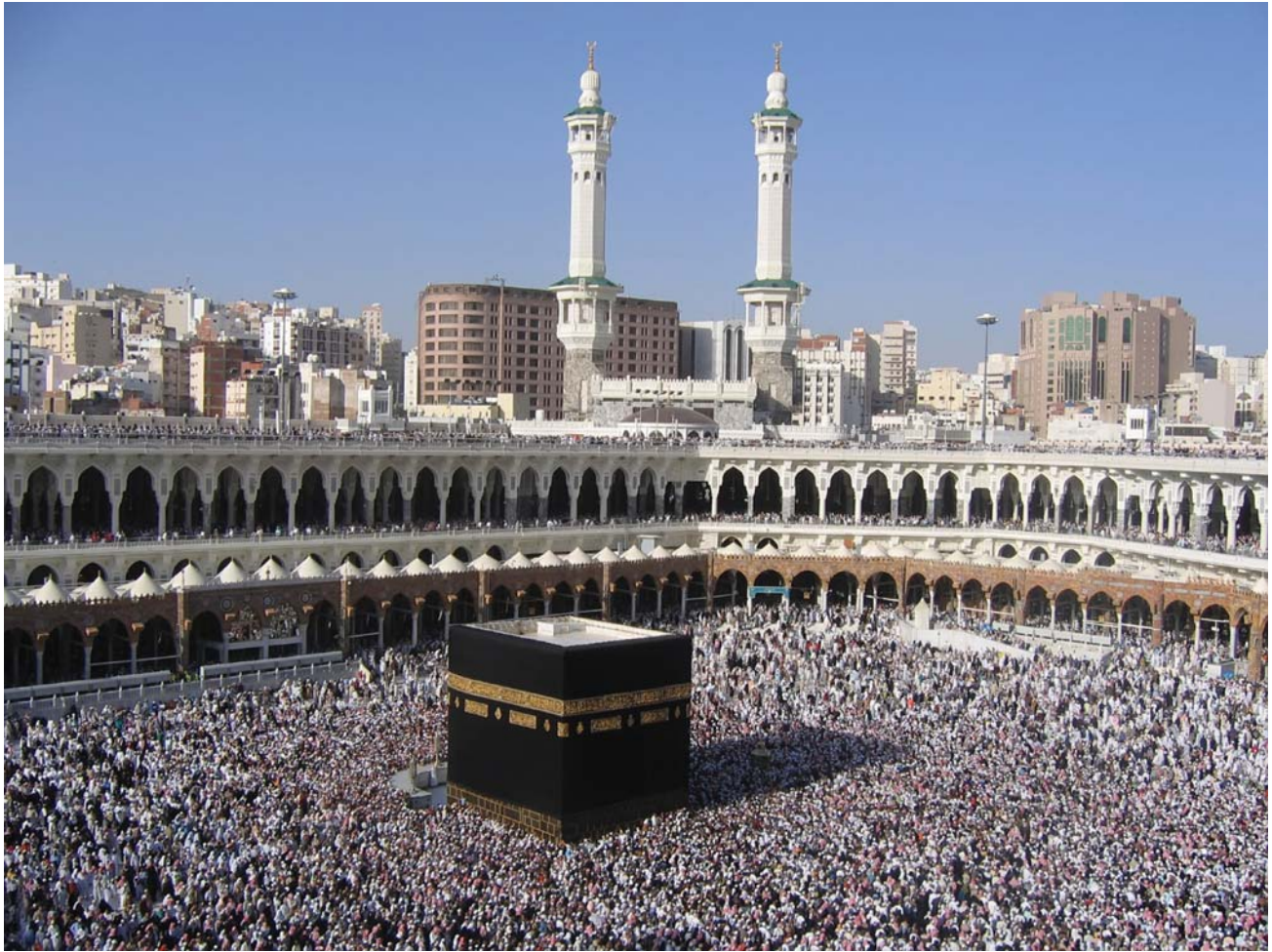
A few pilgrimage places have world renown (e.g., Varanasi, Jerusalem, Mecca, Rome), but the sacred sites that attract devotees are almost without number. In every region, there are sites drawing pilgrims: a holy well, a tomb, or some place where local tradition holds that there was an apparition. This site often provides a focal point for the region, and its annual ritual cycle establishes the fixed points in the locality's calendar (e.g., the apparition site of Tirano on the Swiss-Italian border). There are sites whose renown has spread farther afield and that have become national shrines (e.g., Thomas Becket's tomb in Canterbury, the destination of Chaucer's pilgrims in *The Canterbury Tales*). Last, there are international sites where pilgrimage activities have been responsible for the building of an infrastructure of roads, hostels, and support industries (e.g., the

routes from all over Western Europe terminating in Santiago de Compostella).

While a pilgrimage is undertaken as a response to a sacred demand (a command to travel to the place, the need to seek divine favor or make amends for sins, or the desire to be in proximity with the holy), it has all the effects on the societies involved that are associated with tourism, and it has often been an important factor in cultural and political developments. The Muslim pilgrimage to Mecca has been a key factor in creating a sense of Islam as a single transnational identity and community, with the pilgrims meeting one another as brothers and sisters. In the 11th century, Western Christians' desire for easier access to their holy places in Syria triggered the Crusades.

Pilgrimages, as an activity, usually belong to popular religion; it involves joining in group rituals such as processions at the site, touching sacred objects, wearing special clothes, and bringing home religious artifacts. As such, it often attracts criticism from a religion's intellectual corps—indeed, within Christianity, the rejection of pilgrimages as blasphemous frauds was one of the themes of the 16th-century Protestants (hence, pilgrimages are still frowned on by many who so identify themselves). Later, the rationalists saw pilgrimages as a form of primitive superstition that portrayed one place as more favored by the deity than another. Within many religions, the authorities seek to control pilgrimage activity, which often has the effect of removing the constraints of home and village among otherwise conservative people. Within Islam, however, such hesitations do not arise because the pilgrimage to Mecca (in its ideal form, the *hajj*, or the more convenient form, *'umrah*) is one of the Five Pillars of Islam and far more closely integral to the whole practice of the religion than pilgrimages in other religions.

Recent decades have seen a revival of interest in pilgrimages both in practice and among scholars. Many religions have found that modern transport has made pilgrimages far more easily undertaken, while within Christianity, a growing appreciation of the role of ritual and action in a community's life has led to a rediscovery of pilgrimage as an activity. Equally, many Western forms of Christianity are now quite happy to use



Holy Mecca in Saudi Arabia. An important practice in most of the world's religions, a pilgrimage consists of an individual or group leaving home and traveling to a sacred site, such as the Holy Mecca, which has a spiritual magnetism within the belief system.

Source: Aidar Ayazbaye/iStockphoto.

pilgrimage—with its implication of life being an open journey that has not yet reached a destination—as a metaphor for the spiritual life. From another perspective, the advent of mass tourism has blurred the distinction between the tourist and the pilgrim—many tours take in religious sites en route—while there is also a secularized pilgrimage element in many tourist programs that include visits to significant sites (e.g., battlefields) or that respond to people's desire to stand in and relate to the place of some major event (e.g., Ground Zero in New York City is emerging as such a site).

While in Western thought for much of the past five centuries, pilgrimage activity has been under

sustained assault, more recent years have seen a renewal of interest. Anthropologists and ethnologists study the phenomenon's implications for societies, while for those undertaking research on ritual and religion, this interest has moved from condemnation of the practice as superstition or a mark of primitive belief to seeing it as providing an insight into religious consciousness and how rituals shape societies. Among geographers, there have been studies aimed at distinguishing pilgrims from other travelers such as tourists.

Thomas O'Loughlin

See also **Religion, Geography and**



Further Readings

Turner, V., & Turner, E. (1978). *Image and pilgrimage in Christian culture: Anthropological perspectives*. New York: Columbia University Press.



PLACE

The idea of place is at once simple and yet very enigmatic. The term is used daily in the English-speaking world, and it is hard to get beyond the commonsense level, in which most people think of it as any meaningful location. It has become a significant theme in many disciplines, but human geography has long claimed place as a central concept, although even among geographers there is little agreement about the meaning of the term and how it should be used in scholarly discourse.

Before the mid 1960s, the central word used in geography to identify areas was *region* rather than *place*. Academic geography came to be dominated by a search for similarity, generality, and pattern, often referred to as *spatial science*. But the concept of place refused to go away, becoming intertwined in a debate over its relationships with space. Space became associated with objectivist theories and place with subjectivist theories. The two terms increasingly became seen as representing alternative conceptions of spatiality (how space/place enters into human lives and social arrangements) rather than as inherently or internally related to each other. The scholarship privileging space has often been referred to as a social constructionist (building) approach, whereby a portion of space becomes a place only when humans invest meaning in it. The latter body of scholarship is based on the premises that before all else, every person is a being in the world and that human conceptions of space, time, and place must begin with our own physical constitution as an embodied being with certain corporal orientations and sensory capacities. From this perspective, humans cannot construct anything without being first in a place; that is, they must dwell somewhere.

Building Perspectives

This position has been espoused by geographers informed by Marxism, phenomenology, feminism, and critical social and cultural theory, who had become disenchanted with the lack of concern with social issues in spatial science and the way in which its proponents ignored the production of place by capital and global forces. To Marxist geographers, the differential impacts of capitalism were feeding the exclusive forces of bigotry and nationalism, as exemplified by conflicts in many parts of the world. Place thus had negative connotations. Critical cultural geographers began to use the concept of place to reveal the connection between place, meaning, and power. Place had to be understood in terms of social and cultural conflict, and once “places” were established, they became tools in the creation, maintenance, and transformation of relations of domination, oppression, and exploitation. Yet another approach spatialized ideas deriving from structuration theory to demonstrate that places were the outcomes of both larger structural concerns and individual and group action. Other studies demonstrated that the processes of economic competition were having varying effects across the globe, producing geographical difference rather than similarity. These studies led to the conception of place as “locale,” an objective arena for everyday action and face-to-face interaction and the subjective setting in which people develop and express themselves.

Dwelling Perspectives

During the 1970s, humanist geographers wanted to rehumanize human geography and felt that the way to do this was to focus on individual and group life-worlds in an attempt to recover people’s sense of place—that is, how different individuals and groups interpret and develop meaningful attachments to those specific areas where they live out their lives. Place, for these geographers, was seen as a universal and transhistorical part of the human experience, and it was not so much particular places that interested them but “place” as an idea and way of being in the world. This work also uses “home” as a metaphor for place; home is seen as the foundation of



human identity, the dwelling place of being. In most of this work, the concepts of oneness, rootedness, authenticity, and experience were given prominence. Subsequent accounts of place in this humanistic perspective have elaborated on these ideas, based on the principle that the social and the cultural are geographically constructed. Places are seen as requiring human agents, who in turn require specific places if they are to be the selves (with identities) they are in the process of becoming: There is no place without self and no self without place. Such places are woven together by movement (practice or performance) and by the network ties that produce places as changing constellations of human commitments, capacities, and strategies.

Place also has become key in the decentering of the authoritative form of knowledge in the world today—techno-science. Sociologists of knowledge, geographers, and anthropologists have argued that one common attribute of all knowledge is localness, that it is place based. Until recently, little attention has been paid to another problem, that of “knowing” local knowledge, but a number of anthropologists and geographers have begun to use place, and especially the concept of dwelling, to inform their work among indigenous peoples. Place making, in this work is a relational matter involving activities and experiences and focuses on “practice,” or “performance,” emphasizing embodiment. Furthermore, a number of indigenous scholars in different parts of the world have identified phenomenological approaches as being parallel to indigenous thinking, as both are based on the innate human experience of place. Indigenous peoples claim a cocreative relationship with their land, making places as much as places make them, with the body seen as the source of thinking, sensing, acting, and being and the basis of all relationships.

Connecting Building and Dwelling

Although disagreement remains over which conception of spatiality should be privileged, recent scholarship has addressed how space and place are inherently related to each other.

A number of these attempts have their roots in “building” approaches. Locale studies now

include a strong social dimension: Locales are inclusive and progressive sites of social life. This work recognizes both global connections and local specificity, which create a world of hybridized identities and hybridized domains of being and thought. Another approach sees the social production of the spaces within which social life takes place as the key to understanding how the abstract space of capitalism colonizes everyday life by means of both spatial practice and representations of space and how this is countered through new understandings built on a mixture of memories and residues of older place attachments and new practices. A third new way to overcome the space-place dualism has suggested that place is associational, with all manners of spaces and times woven together through the intersection of many encounters between people and things through time and space.

There are also integrative approaches that begin from a dwelling perspective. The formulation of the concept of the “geographical self,” the human subject who is oriented and situated in place, and the use of three related concepts—self, body, and landscape—are pertinent because they resonate with, and connect to, work being done on place from a building perspective. This formulation puts the emphasis on form: If the body is the form in which a creature is present as being-in-the-world, then the world of its being-in presents itself in the form of landscape. Another highly creative approach has examined trees as agents that co-constitute places and cultures in relationship with human agency. Using the concepts of dwelling and performance, this work has demonstrated at a practical level that these are fruitful ways of dealing with the richness and dynamism of places. Likewise, another agency-oriented approach argues that differences emerge in places through both place-based experiences and human agency and that such places are never separate but always parts of larger sets of places.

Conclusion

It is doubtful whether the proponents of one approach or another to place will ever agree. However, there is beginning to be some agreement that place involves both mental constructions and human agency. There are a number of



terms that are being used by scholars with very different philosophical positions, including self, body, landscape, practice, and performance. But like the term *place* itself, they are fraught with difficulty, being frequently equivocal, often ambiguous, sometimes evasive, often taken for granted, and always contested. Earlier key concepts involving a dwelling perspective (such as authenticity, involving a fixity, a rightness, a duration in place, a oneness and rootedness, where people and landscape become joined) have been replaced by the idea that places are ongoing productions, involving a human agency, and that they are fluid and multiscalar, complex and hybrid. Perhaps the focus in much recent work on the experiences of human beings as agents and on the practice or performance of place offers a practical way of resolving some of the ambiguities of the concept of place.

Brian Murton

See also **Architecture and Geography; Body, Geography of; Chorology; Cultural Geography; Cultural Landscape; Everyday Life, Geography and; Existentialism and Geography; Hartshorne, Richard; Home; Idiographic; Jackson, John Brinckerhoff; Landscape Architecture; Mental Maps; Palimpsest; Phenomenology; Photography, Geography and; Place Names; Place Promotion; Regional Geography; Regions and Regionalism; Relative/Relational Space; Sense of Place; Structuration Theory; Symbolism and Place; Territory; Time-Geography; Topophilia; Tuan, Yi-Fu**

Further Readings

- Adams, P., Hoelscher, S., & Till, K. (Eds.). (2001). *Textures of place: Exploring humanist geographies*. Minneapolis: University of Minnesota Press.
- Agnew, J. (2005). Space: Place. In P. Cloke & R. J. Johnston (Eds.), *Spaces of geographical thought: Deconstructing human geography's binaries* (pp. 81–96). Thousand Oaks, CA: Sage.
- Casey, E. (2001). Between geography and philosophy: What does it mean to be in the place-world? *Annals of the Association of American Geographers*, 91, 683–693.

- Castree, N. (2003). Place: Connections and boundaries in an interdependent world. In S. L. Holloway, S. P. Rice, & G. Valentine (Eds.), *Key concepts in geography* (pp. 165–185). Thousand Oaks, CA: Sage.
- Creswell, T. (2004). *Place: A short introduction*. Malden, MA: Blackwell.
- Entikin, J. (1991). *The betweenness of place: Towards a geography of modernity*. Baltimore: Johns Hopkins University Press.
- Massey, D., & Jess, P. (1995). *A place in the world?* Oxford, UK: Oxford University Press.
- Pred, A. (1984). Place as historically contingent process: Structuration and the time-geography of becoming place. *Annals of the Association of American Geographers*, 74, 279–297.
- Relf, E. (1976). *Place and placelessness*. London: Pion.
- Sack, R. (1980). *Conceptions of space in social thought: A geographic perspective*. Minneapolis: University of Minnesota Press.
- Thrift, N. (1999). Steps to an ecology of place. In D. Massey, J. Allen, & P. Sarre (Eds.), *Human geography today* (pp. 295–322). Cambridge, UK: Polity Press.
- Tuan, Y. (1976). *Topophilia: A study of environmental perception, attitudes and values*. Englewood Cliffs, NJ: Prentice Hall.
- Tuan, Y. (1977). *Space and place: The perspective of experience*. Minneapolis: University of Minnesota Press.



PLACE NAMES

Place names (or toponyms) are used to identify and differentiate geographic features, both human-made (e.g., countries, cities, and streets) and physically based (e.g., mountains, lakes, and rivers). Toponyms are systems of spatial reference and symbolic expression. They are one of the most fundamental ways in which people connect with places. Traditionally, geographers have classified and mapped names as artifacts; however, newer research emphasizes the politics of place naming.



Place Name as Spatial Reference

Place names facilitate the identification and physical navigation of the landscape, using a single word or series of words to distinguish one place from another. As part of the larger structure of language, toponyms permeate our daily vocabulary, both verbal and visual. They are found on road signs, advertising billboards, and addresses. Place names are critical to the use of nearly any kind of map, contributing to geographic knowledge and the development of a sense of place.

Although names are important points of reference, misunderstanding can result from conflicts in their use and spelling. The same name is sometimes applied to different places, and a place may have more than one name. Seeking greater uniformity in naming, particularly in response to growing electronic data demands, applied geographers have worked to standardize toponyms on maps and other publications. They have also established administrative procedures for dealing with new place names, name changes, and naming controversies.

Several countries, including the United States, have set up boards to review and rule on toponymic issues. The United Nations Group of Experts on Geographical Names (UNGEGN) assists in sharing the results of these national efforts and promoting the benefits of the standardization of international names. Despite the technical justifications for standardization, the process can lead to public disputes as authorities try to choose a single name for a feature.

Place Name as Symbol

Place names are also symbols to which people attach meaning and from which they draw identity. Names evoke powerful connotations, as became evident in Fayetteville, North Carolina, when residents along Anthrax Street demanded a name change. The street name had existed for several years but was reinterpreted in light of the tragedy of September 11, 2001, and bioterrorism fears. Its new name, Allegiance Avenue, offers a more patriotic association. The image-generating power of toponyms has long played a role in

place promotion—from the intentional misnaming of Greenland to the more contemporary practice of crafting idyllic-sounding monikers for subdivisions and apartment complexes.

Humans apply place names to create a sense of order and familiarity, frequently choosing names that reflect and reinforce the importance of their point of view. Even when time has erased other evidence, toponyms can provide insight into people's religious beliefs, ethnic origins, history, environmental perceptions, and political values. Interpreting such names requires reading their many layers of meaning. In 1916, the Canadian town of Berlin, Ontario, changed its name to Kitchener, honoring the British Secretary of War who died at the beginning of World War I. On one level, the naming reflected Canada's support of the Allied effort and the strengthening of its ties with England. On another level, it symbolized a nativist rewriting of the landscape and the anti-German hysteria sweeping across Canada.

Naming also represents a means of claiming or taking ownership of places, both materially and symbolically. In many world regions, a renaming of geographic features accompanied European colonial exploration. Explorers and mapmakers not only projected their Western values onto the landscape but also excluded and devalued the naming systems of the original inhabitants, in effect writing off native knowledge. The toponymic process sheds light on power relations—that is, which social groups have the authority to name—and the selective way in which naming privileges one worldview over another.

Place names are often characterized by a permanence that outlives their creators; however, they are not static symbols. Major global shifts frequently underlie the renaming of features—decolonization, the fall of communism, the rise of Islamic fundamentalism, recognition of minority rights, and so forth. In the United States, racial and ethnic groups have actively sought the removal of names containing racial slurs and the renaming of places to recognize their historical achievements. Hundreds of streets and schools bear the name of the civil rights leader Martin Luther King Jr. These names sometimes serve as arenas for debates about culture and identity, thus exposing the divisions within society.



Dr. Martin Luther King Jr. Boulevard (West 125th Street) in Harlem's main cultural and commercial district, New York City

Source: iStockphoto.

Place Name Study

Geographers traditionally have collected, classified, and mapped toponyms as artifacts, using them to reconstruct the environmental and human history of places. Names provide clues about the direction and timing of human migrations, the location of settlements, indigenous perceptions of place, and the boundaries of vernacular regions. Naming patterns have also been used to reconstruct the original vegetation and land use of an area.

Newer approaches take a more contemporary focus and stress the politics of place naming. Rather than passive artifacts, toponyms are vehicles for reinforcing and challenging cultural and political ideologies. Studies have examined how government elites in countries such as Israel,

Germany, Romania, and the former Yugoslavia have used place names—particularly commemorative street names—to advance reinvented notions of national history and identity. Yet other scholars have examined naming as resistance; for example, marginalized groups such as the Maori of Aotearoa, New Zealand engage in toponymic struggles to establish their legitimacy within society. Mapping remains important to place name study; however, it is also necessary to study the naming process, the participants involved, and the very language used in referring to and debating toponyms.

Derek H. Alderman

See also **Cultural Geography; Historical Geography; Nationalism; Symbolism and Place; Toponymy; Zelinsky, Wilbur**



Further Readings

- Alderman, D. (2002). Naming streets after Martin Luther King, Jr.: No easy road. In R. Schein (Ed.), *Landscape and race in the United States* (pp. 213–236). New York: Routledge.
- Azaryahu, M. (1997). German reunification and the politics of street names: The case of East Berlin. *Political Geography*, 16, 479–493.
- Berg, L., & Vuolteenaho, J. (2009). *Critical toponymies*. London: Ashgate.
- Kearns, R., & Berg, L. (2002). Proclaiming place: Towards a geography of place name pronunciation. *Social & Cultural Geography*, 3, 283–302.



PLACE PROMOTION

Place promotion is the development of advertisements for the purpose of attracting investment, tourism, and economic growth. These efforts can take on many forms and today are practiced by multiple actors, including but not limited to governments, chambers of commerce, tourism and convention bureaus, and economic development corporations and agencies. Examples of place promotion are found in most media today and reflect the specific goals of the groups advertising a place.

Historical Context

Efforts to promote places as tourism destinations and attract investment capital have been undertaken since the 1840s. Early place promotion efforts were begun by private firms seeking to develop the frontier regions. In particular, U.S. railroad companies were given government land grants to exploit. Encouraging settlers to homestead in order to create demand for railroad service entailed advertising campaigns extolling (and exaggerating) the virtues of farming the frontier. Railroads and resorts partnered to promote health tourism and the qualities of beaches in the late 1800s. The evolution of mass transit in the 1900s led to the earliest promotion of suburbs, invoking images of healthy homes away from industrial city cores. With current reliance on the automobile,

the selling of the suburb continues. Attracting industries and selling the advantages that one location might have over other places led to an era of place promotion combined with the provision of incentives and policies that continues today. These efforts were often antilabor, to lure industrial plants, and tax breaks were given to attract corporates.

As cities declined during the deindustrialization of Western Europe and North America, efforts to remake city images dominated. Bereft of their industrial economic base, cities turned toward services, shopping, and the creation of spectacles. Downtown shopping centers, sports arenas, and entertainment districts were incorporated in urban redevelopment projects in the 1960s and 1990s, a practice that continues today. Cities compete for assets such as conventions, professional sports franchises, and other markers of urban success in the 21st century. Culture also became vital to the image of cities, with Europe, Canada, and the United States overseeing efforts to develop science and education centers, aquariums, and museums focused on niche sports and local cultures to attract tourists and attention.

Academic Foci

Most research on place promotion can be classified roughly into two categories. The first is the application of marketing to places, and the second is debates about whether this is effective. An important question at the heart of these marketing efforts is whether a place can be marketed in the same way as a package of toilet paper or foodstuffs; many scholars argue that, with some adjustments, it can be. Others counter that the complexity of places requires the use of strategies specific to tourism or economic development. This research aims to improve the process of place promotion and its counterpart, place marketing, to provide cities and regions with the capacity to effectively lure tourism and investment.

The second category consists of critical perspectives on place promotion. Researchers working from this perspective argue that place promotion efforts are partial descriptions of cities and regions and thus leave out many voices of people who wish to have a stake in creating the



image of the city. They argue that elite business leaders and politicians go to great lengths to control the image of a city—a city’s “brand,” as it is referred to by practitioners. This implies an undemocratic process and the exclusion of other stakeholders’ perspectives on the place being promoted. Others point out that only select parts of places are highlighted in tourism and economic promotion efforts, often reflecting the racial and class divisions that all places contain.

Much of the most recent research still focuses on cities. Since the 1990s, much work has focused on cities in Eastern Europe, which faced economic hardship during the transition to a more market-oriented economy in many countries. Other emerging bodies of work examine the efforts of Chinese cities and regions, working under communist planning systems that are embracing more free market principles. Other research examines explicitly the processes of exclusion as target markets are created and reached, thus often leaving out minorities as target audiences for place promotion efforts.

Darren Purcell

See also **Place; Symbolism and Place; Tourism**

Further Readings

- Kotler, P., & Gertner, D. (2002). Country as brand, product and beyond: A place marketing and brand management perspective. *Journal of Brand Management*, 9(4/5), 249–261.
- Waite, G., & McGuirk, P. (1997). Selling waterfront heritages: A critique of Millers Point, Sydney. *Tijdschrift voor Economische en Sociale Geografie*, 88(4), 342–352.
- Ward, S. (1998). *Selling places: The marketing and promotion of towns and cities, 1850–2000*. London: E&FN Spon.
- Wu, F. (2003). Globalization, place promotion and urban development in Shanghai. *Journal of Urban Affairs*, 25(1), 55–78.
- Young, C., Diep, M., & Drabble, S. (2006). Living with difference? The “cosmopolitan city” and urban reimagining in Manchester, UK. *Urban Studies*, 43(10), 1687–1714.



PLANTATIONS

Plantations are assemblages of trees, shrubs, or plants deliberately established on an area of land. Plantations can also be understood as a system of agro-economic production. Plantations represent a dominant mode of industrial organization and social-ecological production in modern agriculture and forestry.

As an organizational form, the plantation has a significant colonial and postcolonial history. Between the 18th and early 20th centuries, tropical plantations were a primary form of colonial enterprise, organized around the cultivation of globally traded commodities, including sugarcane, bananas, coconuts, tea, cocoa, cotton, spices, and rubber. Different labor regimes became associated with the colonial plantation. In the Caribbean and the U.S. South, indentured and slave labor was widespread, while in the Netherlands East Indies and British Malaya, plantation labor regimes were based on organized transfers of people from South Asia. Labor control in colonial plantation development often involved a radical restructuring of preexisting social relations; this history, in many cases, continues to influence ethnic politics in contemporary societies.

Scholars have long made the linkage between plantations and the characteristics of “total institutions.” Political ecologists such as Nancy Peluso have analyzed colonial and postcolonial teak plantations in southeast Asia as an expression of state control and political-economic power. For James Scott, plantations can be understood as an emblematic form of agricultural “high modernism,” amenable to state rationalities of simplification, legibility, calculation, and control. The plantation as a social and economic technology has also been linked to state initiatives to suppress rural insurgencies, as in Malaysia and Myanmar.

While there are many organizational forms, large-scale plantations typically involve variations on the following characteristics: appropriation and control over land and property, a disciplined labor regime, corporatist or state-led management structures, the commodification and improvement of high-yielding planting material,



and the employment of industrial technology and finance capital. Not all plantations have been organized along logics of entrepreneurial capitalism and surplus reinvestment. The hacienda form of plantation development, which emerged in Latin America and the Philippines, was essentially a precapitalist form, involving the direction of surplus toward powerful oligarchic ruling families. Contemporary plantations typically involve state-led reforestation schemes or private sector firms integrated with global capital flows and markets.

The Great Depression led to a collapse in global plantation commodity prices through the 1930s. World War II, followed by anticolonial struggles, ended the age of colonial plantation regimes. In

some postcolonial countries, successful “land to the tiller” reforms were initiated. New global development institutions such as the Food and Agriculture Organization of the United Nations were closely involved in the establishment and promotion of plantations in the postwar period. New plantation boom crops, including oil palm, eucalyptus, acacia, teak, rubber, coconuts, sugarcane, soybeans, coffee, and cocoa, have radically reshaped tropical forest environments and have been associated with widespread deforestation. In Indonesia through the 1990s, the clearing of peat swamps for oil palm plantations, in association with El Niño climatic events, was identified as the primary source of uncontrolled forest fires, which blanketed south-east Asia in haze. Biofuels (including sugarcane,



Tea plantation at Cameron Highland in Pahang, Malaysia

Source: Azmi Mansur/iStockphoto.



Blue agave plantation near Tequila, Mexico, in the state of Nayarit. Used to make tequila, the blue agave is grown only in Mexico, primarily in the state of Jalisco.

Source: © Can Stock Photo Inc.

corn, oil palm, and cassava) have emerged in the past decade as a new plantation boom crop linked to rising global energy prices. The convergence between agricultural and energy commodity markets is predicted to have negative implications for land use conversion, deforestation, and food security in many developing countries, although the rising prices of these agricultural commodities may also benefit some farmers.

In addition to transforming tropical and subtropical forest biodiversity, plantations have long been associated with serious land and resource conflicts with rural communities. The requirement of plantation companies for access to large areas of land, in combination with the legally insecure land rights held by many rural and indigenous communities, has led to problems of dispossession and

landlessness, as well as enclosure movements in many regions. At the same time, new social countermovements have emerged in resistance to plantation enclosures in the global South. The efforts behind community-based natural resource management systems have established improved legal recognition of local resource rights, although in many countries significant limitations remain on the ability of rural communities to actually claim legal rights over customary lands.

Many plantations in tropical countries involve the provision of state subsidies of various kinds, typically access to land through the granting of exclusive concessions at below-market rates. Some global forest policy institutions have argued against these subsidies, which promote the conversion of natural forest to plantations and



undermine the viability of smallholder farms. New market-based mechanisms of forest conservation, including programs of carbon sequestration and payments for ecosystem services (PES), are designed to increase the value of existing natural forests relative to the profits that can be made through forest conversion. In some cases, PES programs are being combined with community-based resource management systems to provide rural smallholders with more secure land rights and improved financial incentives for sustainable resource management.

Many rural communities have also engaged in the establishment of smallholder plantations, including the established smallholder traditions of cultivating “jungle rubber” in Indonesia. Rural people have also widely participated in the cultivation of various plantation boom crops, in some cases initiating a process of forest conversion, communal land privatization, and market-based dispossession. Initiatives in support of community-based resource management and forest-based sustainable livelihoods can thus at times be in tension with local and smallholder aspirations to engage with plantation markets and modernity.

There is significant controversy around the ecological effects of plantations, particularly fast-growing plantations of eucalyptus, pine, and acacia, and their putative effects on water and soil fertility. While these are complex scientific questions, the evidence supports a view that all trees access and use groundwater and soil resources and that fast-growing tree plantations use a corresponding amount of these resources. Balancing the ecological effects of plantations with other resource management objectives is considered to be a social and political question.

Plantations are not only established in the tropical or subtropical South. In the forest industries of North America, Scandinavia, New Zealand, Chile, and China, plantations of pine, poplar, spruce, and fir have widely replaced natural forest stands, leading to a decline in biodiversity as well as land conflicts with native, indigenous, or rural communities.

Keith Barney

See also **Agriculture, Preindustrial; Agroecology; Colonialism; Food, Geography of**

Further Readings

- Peluso, N. (1992). *Rich forests, poor people: Resource control and resistance in Java*. Berkeley: University of California Press.
- Scott, J. (1998). *Seeing like a state: How certain schemes to improve the human condition have failed*. New Haven, CT: Yale University Press.
- Sivaramakrishnan, K. (1999). *Modern forests: Statemaking and environmental change in colonial Eastern India*. Palo Alto, CA: Stanford University Press.

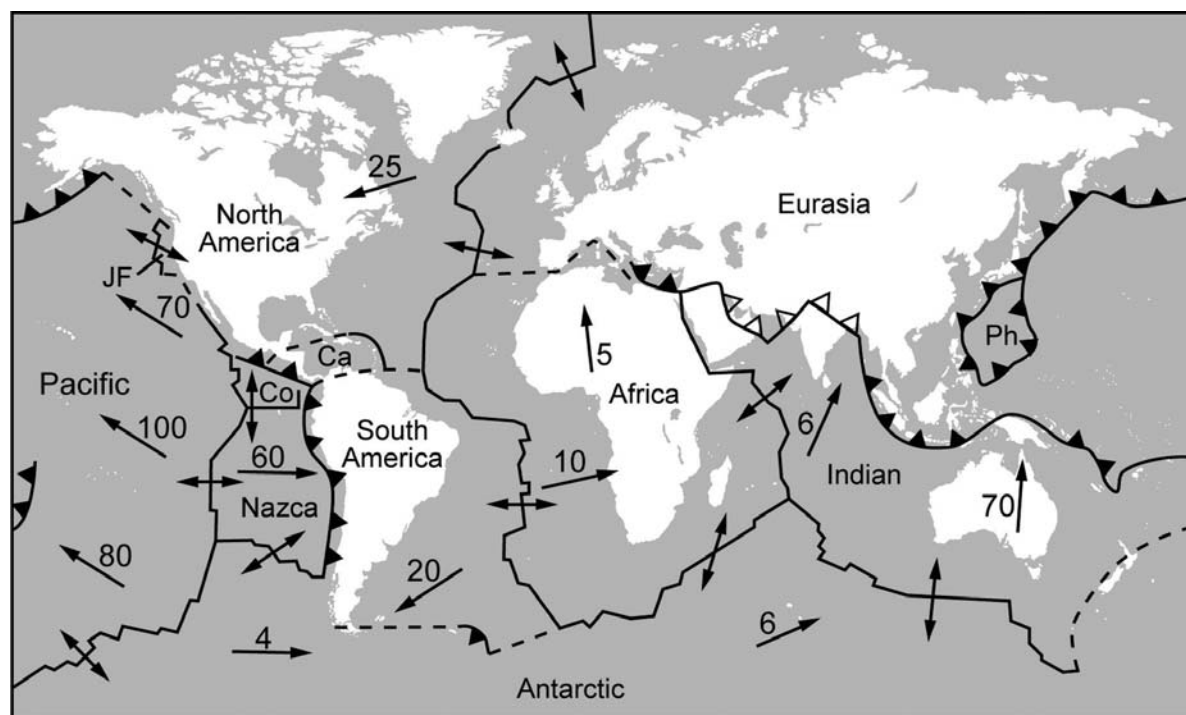


PLATE TECTONICS

Plate tectonics embraces the concepts of seafloor spreading (the creation of new oceanic crust at midoceanic ridges) and continental drift (the gradual movement of Earth's continents over geologic timescales) to provide a theory for the large-scale movements of Earth's lithosphere. This theory, together with the advent of remote imagery from satellite and aerial platforms, has led to a greater understanding of the large-scale geomorphology of Earth's crust. It has also helped us understand other aspects of physical geography, such as biogeography (which helps explain the distribution of biota across the globe), and emerging areas such as planetary geomorphology (which aids the identification of plate tectonic features on remote imagery of Mars). This entry outlines the theory of plate tectonics and its relevance to other physical geography phenomena.

Composition of the Earth

A section through Earth would reveal a rigid lithosphere that is 0 to 100 km (kilometers) thick. Although this layer behaves in a brittle-elastic manner, it can, under high loads and long time spans, deform as a plastic. The lithosphere is broken up into eight major and several minor plates, which are in motion with respect to each other and the underlying asthenosphere. The asthenosphere is a weaker mechanical layer, whose outermost portions contain some (less than 1%) partial



Key

- | | |
|---|--|
| — Divergent plate boundary (mid-oceanic ridge) | Convergent plate boundary (trench). Triangles on side of overriding plate |
| - - - Transform plate boundary (oceanic transform fault or continental strike-slip fault) | Convergent plate boundary (mountain range). Triangles on side of overthrust terrain overriding plate |
| ← Plate motion at plate boundary | |

Figure 1 The major lithospheric plates, plate boundaries, and directions and rates (in millimeters per annum) of plate movement

Source: Adapted from Summerfield, M. A. (2001). *Global geomorphology*. New York: Longman Scientific & Technical.

Notes: Ca: Caribbean Plate; Co: Cocos Plate; Ph: Philippine Plate; JF: Juan de Fuca Plate.

melt (material at $>1000^{\circ}\text{C}$). This behaves as a high-viscosity fluid. It is the interactions between the upper part of Earth's mantle (the asthenosphere) and the lithospheric plates that are significant for plate tectonics. Interaction between the plate boundaries and the resultant stresses within the plates determines to a large extent the distribution of seismic and volcanic activity, which is mainly concentrated at plate margins (Figure 1).

A tectonic or lithospheric plate is generally composed of continental or oceanic lithosphere from a few hundred to thousands of kilometers across. Plate thicknesses range from less than 15 km for young oceanic lithosphere to ~ 200 km for ancient continental lithosphere. The continental crust is composed predominantly of granitic rocks, which are made up of relatively lightweight minerals such as quartz and feldspar. Oceanic crust, however, is dominantly

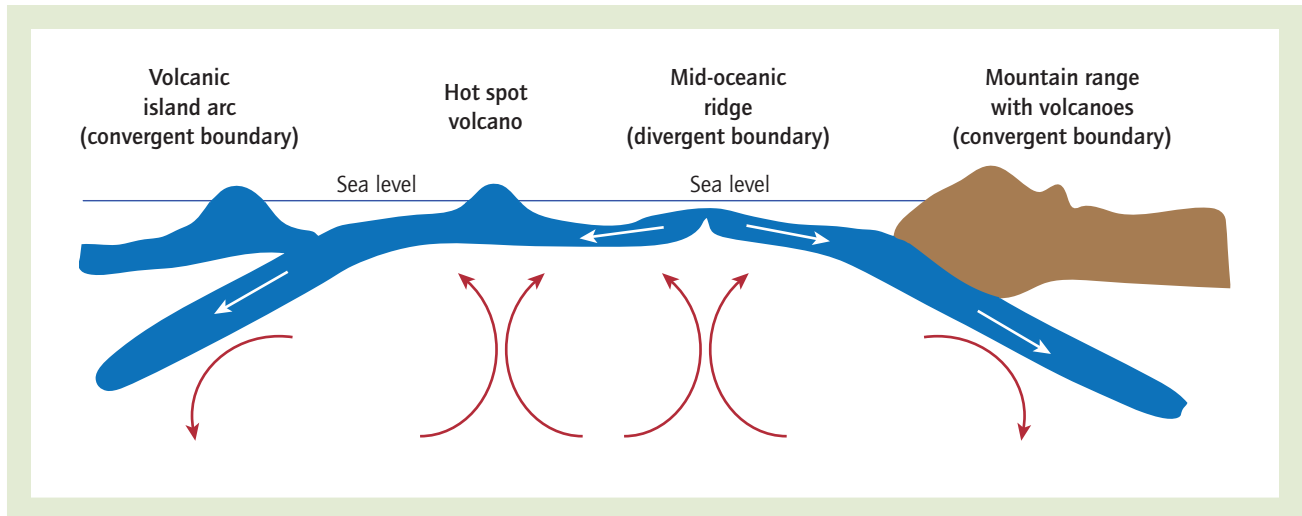


Figure 2 A schematic cross section through examples of convergent and divergent plate boundaries and their associated major landforms

Source: Author.

Notes: Blue represents oceanic lithosphere; brown represents continental lithosphere. Red arrows indicate the relative movement of convection cells in the asthenosphere (upper mantle). White arrows indicate movement of the lithosphere.

composed of basaltic rock, which is denser and heavier.

Divergent (Constructive) Plate Boundaries

Divergent boundaries occur where two plates move apart from each other and tend to originate at triple junctions, which are sometimes believed to be associated with hotspots (Figure 2). At hotspots, extremely large convective cells bring vast quantities of hot asthenospheric material near the surface, weakening the lithosphere. Beneath the oceans, extensive submarine ridge systems represent divergent plate boundaries. Here, as the plates move apart, the space is filled with new crustal material that originates from the molten magma derived from below (seafloor spreading). It is at these locations that magnetic reversals were first identified from airborne geomagnetic surveys, which revealed a symmetrical pattern of magnetic bandings either side of the ridge crests. These bandings record reversals in Earth's magnetic field and provide data on the spatial and temporal spreading rate associated with the tectonic boundary. Only rarely are the ridges large enough to become emergent. Iceland

is one such example, situated over an upwelling mantle plume (hotspot) on the mid-Atlantic ridge system. Iceland is the only significant supramarine example of this 14,000- to 15,000-km-long ridge system, which runs from the Arctic Ocean to south of Africa. The volcanism associated with the ridge, in conjunction with the latitude (near the Arctic Circle), produces a unique environment where sudden volcanically induced melting of the ice sheets creates some of the most dramatic outburst floods on Earth.

In the continental lithosphere, divergent plate boundaries are responsible for the African rift system, generating rift basins and associated volcanic and seismic activity. Subsidence has generated the accommodation space for many of the lake systems, and associated warping of the crust has led to reorganization of the low-relief drainage systems associated with Lake Victoria, in some cases reversing them. During periods of enhanced plate activity, the increased volume of midoceanic ridges has been credited with displacing water in the oceanic basins, leading to sea-level rise and thus reducing potential carbon availability from weathering of the smaller exposed land masses, as well as increasing volcanic activity



and thus increasing the availability of greenhouse gases.

Convergent (Destructive/Active) Plate Boundaries

The nature of convergent plate boundaries depends mainly on the relative density, and thus buoyancy, of the lithosphere. Oceanic crust is considered denser (less buoyant) than continental crust. Where two similar densities meet (e.g., continent-to-continent collision, such as the Himalayas, or oceanic-to-oceanic merging, such as the Aleutian Island arc of Alaska), the crust will typically buckle and one plate will be subducted beneath the other. Where two different densities occur (oceanic and continental, e.g., the Andes of South America and the subducting Nazca plate), the denser oceanic plate will be subducted. These types of margins are commonly associated with explosive volcanism (Figure 2). This phenomenon is generally considered to be the result of the release of volatiles, predominantly water, as the subducted oceanic slab is heated at depth. This lowers the melting temperature of the surrounding mantle, producing magma, with the dissolved gases generating highly explosive eruptions.

Mountain ranges and volcanic chains are thus typical large-scale landforms associated with convergent plate boundaries. These types of margins are typically associated with dramatic relief. The Andes, for example, have a relief of up to 6 km and a corresponding offshore trench some 8 km deep, giving a total relief on the order of 14 km over a horizontal distance of some 750 km. This particular boundary is associated with large, megathrust earthquakes; in 1960, the largest recorded earthquake (magnitude 9.5) and tsunami were generated. The Peruvian coastline is one of the most tsunami-prone coastlines in the world.

Transform (Conservative) Plate Boundaries

Transform plate boundaries occur where there is oblique movement along a plate boundary. In these situations, convergent and transform boundaries may exist along the same plate boundary. This occurs along the western coast of the United States (convergent in the north, transform along

the San Andreas Fault in the south) and New Zealand (convergent in the North Island and transform along the Alpine fault in the South Island). Transform faults may also offset the crests of the midocean ridges of divergent plate boundaries. Where these transform faults occur, the plates are associated with stress buildup as a result of frictional forces. This stress will build to a critical threshold (the strain threshold of rocks on either side of the fault). The accumulated potential energy is released as strain. Ductile lower crust and mantle accumulate deformation gradually via shearing, but the brittle upper crust reacts by fracture, or instantaneous stress release, causing earthquakes to be common along the transform boundaries (see, e.g., the South Island of New Zealand or California in the United States).

The Driving Forces

The driving forces for plate tectonics are not clearly understood but are considered to be mostly related to gravity. When oceanic lithosphere forms at midocean ridges, it is initially less dense than the underlying asthenosphere. As it becomes cooler and older, it becomes denser. This is important for two reasons: (1) it generates an undersea topography where the elevation is greater at the midoceanic ridge and falls away with distance from the ridge as a result of the older, denser, and thicker oceanic lithosphere sinking into the asthenosphere and (2) the oldest and densest oceanic lithosphere is located at the subduction zones, farthest from the midoceanic ridge. Thus, gravity sliding (sometimes known as ridge push) from the topographic high of the ridge occurs. At the subduction zone, slab pull resulting from the weight of the descending slab is important.

In some regions, such as the Mediterranean, the slab pull, in combination with relative plate velocities, has led to a situation where the position of the subduction zone migrates regressively with time. In the Aegean Sea, the African plate is moving northeastward at 6 mm/a (millimeters per annum) and the Anatolian (Turkish) plate southwestward at 30 mm/a. Thus, the associated Hellenic subduction zone has to migrate away from both Europe and Turkey as long as these plate velocities are higher. In part of the oldest (50 million years ago), and thus densest, oceanic lithosphere of the



Mediterranean, the lithospheric slab drops almost vertically, leading to the “rollback” (regressive migration) of the subduction hinge. Subduction rollback is still active in the Central Mediterranean and has been used to explain the morphology of the Apennine Mountains of Italy.

Although gravitational forces are believed to be the strongest force driving plate motions, we also have to explain why some plates (e.g., the North American Plate and Eurasian plates) are moving but are not being subducted. This suggests that friction from large-scale convection currents in the upper mantle on the lithosphere may play a role. This may occur at subduction zones (slab suction) or away from these areas (basal drag). More controversially, some proponents have suggested that Earth’s rotation and the tidal friction of the moon may account for the westerly component of every plate’s motion.

Anne E. Mather

See also **Biogeography; Earthquakes; Geologic Timescale; Tsunami; Volcanoes**

Further Readings

- Cox, A., & Hart, R. B. (1986). *Plate tectonics: How it works*. London: Blackwell.
- Mather, A. E. (2009). Tectonic setting and landscape development. In J. Woodward (Ed.), *The physical geography of the Mediterranean* (pp. 5–32). Oxford, UK: Oxford University Press.
- Summerfield, M. A. (2001). *Global geomorphology*. New York: Longman Scientific & Technical.



PLAYAS

The word *playa* comes from Spanish and translates into English as “shore” or “beach.” As early as the late 1800s, however, the term *playa* was adopted for use in geomorphology in reference to the ephemeral lakes in the Great Basin of North America. To complicate things, *playa* is not the only name applied to these features, and names vary geographically, sometimes even at the local scale. Terms that are used more or less

synonymously with *playa* in North America include *playa lake*, *playa-lake basin*, *prairie pot-hole*, *buffalo wallow*, *rainwater basin*, *lagoon*, *salt pan*, *salt lake*, *alkali lake*, *bolson*, and *dry lake*. A variety of names come also from other parts of the world, including *vlor* (Southwest Africa), *sebka* (North Africa), *kewire* (Iran), *sabkha* (Middle East), *rei* (India), *praia* (India), *plage* (France), *pliazh* (Russia), *salar* (Chile), *boinka* (Australia), and *salina* (Spain and elsewhere). Though geographers and other Earth scientists have not yet completely agreed on a term, *playa* and *playa lake* are the most commonly used. Similarly, a wide range of definitions for *playa* exists in the literature, but one can reduce the myriad definitions to something relatively simple: an internally drained basin that is flat, barren, or sparsely vegetated, formed in prairie to desert environments and infrequently containing either freshwater or saline water. Though many have defined *playa* with a requisite diameter measuring hundreds of meters, many functioning *playas* are 100 m or less in diameter (see High Plains photo).

In North America, *playas* are ubiquitous on the High Plains of the Great Plains, but many also occur throughout the intermountain western region. Within the southern and central Great Plains, where *playas* are densest, estimated numbers range from about 25,000 to more than 40,000. Several origins have been proposed for these *playas*, but those most commonly cited are subsidence as a result of dissolution of subsurface salt or carbonate beds, the collapse of piping (conduits created by percolating water), eluviation (the downward movement of particles or dissolved solids), deflation, or various combinations of the preceding. Of these, deflation is frequently identifiable as having at least a partial role in *playa* development, in that on the downwind side of many *playas*, crescent-shaped dunes (lunettes) of clay- to sand-size material have accumulated (see lunette photo). Because of their characteristic location on the south to southeast side of the *playa* basin, lunettes in the High Plains likely developed during the last glaciation, when prevailing winds were from the north and northwest.

Playas are crucial to the ecosystems in which they occur. In the Great Plains, *playas* function as sources



Small playa within a winter wheat field on the High Plains

Source: Author.



View northeast of playa and associated lunette. The lunette, accentuated by a contour field terrace, is visible in the lower right of the image.

Source: Author.

of recharge to the High Plains aquifer, as wetland habitats for migratory waterfowl, as water sources for animals (wild and domesticated), as biogeographic islands for native wetland vegetation, as carbon sinks, and as sites for the breakdown of

agrochemicals. Throughout history, playas have served humankind as oases, first for the Paleoindians and subsequently for the early European settlers.

William C. Johnson



See also **Climate Change; Drought Risk and Hazard; Dunes; Wetlands; Wind Erosion**

Further Readings

- Briere, P. R. (2000). Playa, playa lake, sabkha: Proposed definitions for old terms. *Journal of Arid Environments*, 45, 1–7.
- Osterkamp, W. R., & Wood, W. W. (1987). Playa-lake basins on the southern High Plains of Texas and New Mexico: Part 1. Hydrologic, geomorphic, and geologic evidence for their development. *Geological Society of America Bulletin*, 99, 215–223.
- Rosen, M. R. (1994). The importance of groundwater in playas: A review of playa classifications and the sedimentology and hydrology of playas (Geological Society of America Special Paper 289). In *Paleoclimate and basin evolution of playa Systems* (pp. 2–18). Boulder, CO: Geological Society of America.
- Smith, L. M. (2003). *Playas of the Great Plains*. Austin: University of Texas Press.
- Steiert, J., & Meinzer, W. (1995). *Playas: Jewels of the plains*. Lubbock: Texas Tech University Press.

POINT PATTERN ANALYSIS

Point pattern analysis is considered a branch of spatial statistics involving the ability to analyze the spatial patterns of “events” that occur at a set of locations, with each event representing a single instance of the phenomenon of interest. Point patterns were initially studied in plant ecology 70 years ago, when researchers tried to describe and analyze the spatial distribution of plants. Point pattern analysis was gradually introduced into a wide range of fields such as archeology, epidemiology, astronomy, criminology, and so on. Meanwhile, the analysis received much interest in geography in the early 1960s during the quantitative revolution and was used and extended to examine settlement patterns, retail establishments, and spatial characteristics of the landscape such as drumlins, volcanic craters,

and others. In general, point pattern analysis is important for uncovering and studying the spatial processes underlying many types of point data.

To understand the processes that generate particular patterns, theoretic models are usually constructed. For instance, a simple theoretical model that has often been used is the complete spatial randomness (CSR) resulting from a homogeneous Poisson process over a study region. In this process, the probability of event occurrence for any area (A) follows a Poisson distribution with mean $\lambda|A|$, where λ is the fundamental property of a point process, representing the intensity or mean number of events per unit area. In other words, under CSR, events have an equal chance of occurring anywhere in the region, and event occurrence at one location is independent of that at any other location. Hence, under CSR, the study region is completely homogeneous in all respects, and no interaction exists between event occurrences.

One important aspect of point pattern analysis is to ascertain whether there is a trend for the events to exhibit a pattern, such as regularity or clustering, using CSR as the null. This issue involves the assessment of the departure of the event occurrence under study from CSR. If events tend to significantly concentrate or form groups different from those in CSR, the resulting pattern is considered clustering. On the other hand, if events are more dispersed or spread out than those in CSR, a regular pattern is formed. A straightforward method for the assessment is to explore the pattern by plotting and visualizing the point events. However, in general it is difficult to come to a conclusion purely based on a visual judgment, especially when the data set is large and other issues such as time or other relevant attributes or marks, such as type, size, or age, are considered. Therefore, various methods have been developed to explore and examine spatial point patterns.

Quadrat methods are the earliest methods used by plant ecologists to examine point patterns. This type of method is based on quadrats—well-defined frames of a certain shape, usually rectangular, although other shapes such as a square, circle, or hexagon can be used. The quadrats can be placed over the region randomly or contiguously. Then, the number of events falling into each quadrant is counted, and the intensity for a quadrant can be derived. Under CSR, a



quadrat with an area $|A|$ should follow a Poisson distribution with mean and variance equal to $\lambda|A|$, where λ is the intensity of the events. CSR also implies quadrat independence. Hence, Pearson's χ^2 goodness-of-fit test can be used to examine the pattern against CSR by comparing the observed and expected frequencies over all the quadrats.

Quadrat methods are highly dependent on how the quadrats are defined, and transforming points in a two-dimensional (2D) region into counts of 1D is subject to the risk of losing spatial information. Therefore, quadrat methods only give a general idea of areas with high and low intensity of event occurrence. An alternative is to use a kernel estimator to derive a smooth estimate of the intensity by moving a window of a fixed size over the region. This method transforms point data into a density surface for a specific phenomenon. The kernel intensity function can also be used to test for the overall clustering pattern as well as for location of local clusters.

The methods discussed above were developed mainly for identifying the first-order properties of a spatial point pattern by studying intensity variation in the study area. Other approaches focus on the distribution of interevent distances. One approach has been built on the nearest distances either between events (W) or from point to events (X), where a point is a randomly selected location in the study region. A simple way to examine a point pattern is to estimate the empirical cumulative probability distribution function $\hat{G}(w)$ of W , or $\hat{F}(x)$ of X . Under CSR, the average of the event-to-event distance, $\bar{w}$ approximates a normal distribution for large samples, and $\sum x_i^2 / \sum w_i^2$ follows an $F_{2n, 2n}$ distribution. Other test statistics using W and X are also possible.

In addition to the nearest distance, the commonly used K function takes into account a range of distances for examination. The K function, $K(h)$, is defined as the average of extra events within a distance h of a random event divided by the event intensity (λ). Under CSR, $K(h)$ would be equal to πh^2 , with the average number of events within a distance h of a randomly chosen event being $\lambda \pi h^2$. Under clustering, $K(h)$ is expected to be larger than πh^2 , and under regularity, it would be smaller than πh^2 . For formal testing, $\hat{K}(h)$ is usually transformed to

$$\hat{L}(h) = \sqrt{\frac{\hat{K}(h)}{\pi}} - h.$$

The assessment of the significance of the pattern can be achieved by simulation of CSR and establishing the confidence bounds for the transformed function $\hat{L}(h)$.

While a variety of methods have focused on investigating the general patterns of a region, attention has also been paid to examining local variation. A local method has been developed to quantify clustering at various scales by using $L(D)$, which is similar to the K function but is applied to each event. The local indicator of spatial association (LISA) has also been defined for local clustering examination.

Daoqin Tong

See also **Geostatistics; Quantitative Methods; Spatial Analysis; Spatial Autocorrelation; Spatial Statistics**

Further Readings

- Anselin, L. (1995). Local indicators of spatial association-LISA. *Geographical Analysis*, 27, 93–115.
- Bailey, T., & Gatrell, A. (1995). *Interactive spatial data analysis*. Englewood Cliffs, NJ: Prentice Hall.
- Boots, B., & Getis, A. (1988). *Point pattern analysis*. Newbury Park, CA: Sage.
- Clark, P., & Evans, F. (1954). Distance to nearest neighbor as a measure of spatial relationships in populations. *Ecology*, 35, 445–453.
- Diggle, P. (1985). A kernel method for smoothing point process data. *Applied Statistics*, 34, 138–147.
- Diggle, P. (Ed.). (2003). *Statistical analysis of spatial point patterns*. London: Arnold Press.
- Getis, A., & Franklin, J. (1987). Second-order neighborhood analysis of mapped point patterns. *Ecology*, 68(3), 473–477.
- Perry, G., Miller, B., & Enright, N. (2006). A comparison of methods for the statistical analysis of spatial point patterns in plant ecology. *Plant Ecology*, 187, 59–82.
- Waller, L., & Gotway, C. (2004). *Applied spatial statistics for public health data*. New York: Wiley.



POINT SOURCES OF POLLUTION

Point sources of pollution are individual, localized facilities that emit air and/or water pollution into the environment. Point sources can also emit thermal, light, and noise pollution. Point sources of air pollution are often also called stationary sources and are usually industrial facilities (e.g., coal-fired power plants, chemical plants, steel mills, paper mills, copper and aluminum smelters, oil refineries). A related category, area sources, refers to small, stationary sources of air pollution such as dry cleaners, bakeries, fast-food restaurants, home fireplaces, landfills, and gasoline stations. The other major source of air pollution is transportation, or mobile sources, which has accounted for a growing share of air pollution as increasingly strict standards have been implemented in many nations for stationary sources and as the automobile fleet size has increased. In the water pollution arena, the major point sources are publicly owned sewage treatment plants and industrial effluent dischargers. The other major sources of water pollution are nonpoint, diffuse sources such as runoff from agriculture, silviculture, storm water, and cities.

Point sources of pollution are usually regulated by government requirements to control emissions or effluents from smokestacks, pipes, vents, ditches, tunnels, or conduits, either by limiting the emission rate over a short time period or by controlling the total emissions into the ambient air or water. Permits are often issued that specify these requirements for the emission source (usually a private business), including the type of pollution being controlled, which could be one or more categories. For large industrial sources, these requirements can become complicated and expensive, involving dozens of point sources and many categories of air and water pollution. Since the 1980s, governments have increasingly turned to emissions trading systems to control point sources of pollution, especially in the United States. These approaches, such as emission offsets and “cap-and-trade” systems for sulfur dioxide and nitrogen oxides, are more cost-effective and flexible for industry. In the case of water pollution, effluent trading in watersheds even allows for trading between point and nonpoint sources.

In addition to the regulation of air pollution from individual point sources, atmospheric dispersion modeling is often required to determine the effects of individual sources on ambient air quality, particularly in urban areas. Such modeling requires mathematical simulation by computer programs to determine the atmospheric concentration of pollutants downwind from a range of sources. These models are important to the efforts of government air pollution agencies to design control strategies and plans. For water pollution, water quality simulation and waste load allocation models are used to similarly determine how multiple-point source dischargers can best meet ambient standards and total maximum daily load requirements.

Barry D. Solomon

See also **Atmospheric Pollution; Environmental Law; Market-Based Environmental Regulation; Nonpoint Sources of Pollution; Water Pollution**

Further Readings

- Portney, P., & Stavins, R. N. (Eds.). (2000). *Public policies for environmental protection* (2nd ed.). Washington, DC: Resources for the Future.
- Reitze, A. W. (2005). *Stationary source air pollution law*. Washington, DC: Environmental Law Institute.

POLES, NORTH AND SOUTH

The North Pole and the South Pole are defined by the intersection of the Earth's rotation axis with its surface. In a broader sense, the poles encompass all land and ocean at the high latitudes, where ice, sea ice, and snow are perennial.

Ice and snow are important components of Earth's climate system and are particularly sensitive to local and global climate change. Changes in snow cover and sea ice have immediate effects on land and ocean heating, the strength of major ocean currents, terrestrial and marine ecosystems,



and human activities. As stated in the Fourth Assessment of the International Panel on Climate Change (IPCC), “Warming of the climate is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.” On this premise, the International Polar Year (IPY) was launched in March 2007, until March 2009. The program involves thousands of scientists from 63 nations, in more than 200 projects, to examine a wide range of physical, biological, and social research topics in the Arctic and Antarctic regions.

Unlike the South Pole, which lies on a continental land mass, the North Pole is located in the middle of the Arctic Ocean, surrounded by waters that are almost permanently covered with sea ice.

Continental ice sheets extend horizontally for hundreds to thousands of kilometers (km) and are 1 to 4 km in thickness. The two existing ice sheets over Greenland and Antarctica represent 3% of Earth’s total surface area and 11% of its land surface. They contain some 32 million km³ (cubic kilometers) of ice, equivalent to about 70 meters of sea-level change. During winter, large sections of the Arctic Ocean and Southern Ocean freeze into patches of sea ice.

Sea Ice

In the Arctic, sea ice coverage approximately doubles from 7 million km² (square kilometers) at the end of the summer melt season to 15 million km² at the peak of the winter. Around Antarctica, sea ice extent varies from 3 million km² during summer to 18 million km² at the height of winter.

Sea ice regimes and climate in high latitudes have changed during the past 30 yrs. (years). In the Arctic, sea ice has decreased markedly, reaching unprecedented low extents in the summer of 2007 (Figure 1). Scientists have calculated that ice extent in September 2007 was 50% lower than conditions from the 1950s to the 1970s. All models used in the Fourth Assessment Report of the IPCC indicate declining sea ice from 1953 to 2006. However, recent data show that the models underestimate the actual melting rate, leading to a conservative estimate of a seasonally icefree Arctic Ocean by 2030.

Antarctic sea ice extent has shown a slight increase in studies based on satellite mapping from 1979 to 2008, contrary to what the Arctic experiences (Figure 2). If the eastern part of Antarctica has seen very little change, the western part has witnessed significant declines for the past 25 yrs., and probably longer (measurements begin at the sub-Antarctic Island of Orcadas in 1901 and show a nearly monotonic warming trend). Monitoring and assessment of sea ice extent in this part of the world remain difficult because of the vastness and remoteness of the region.

Interestingly, the exact reasons behind these different trends in sea ice extent in the Arctic and around Antarctica are still mysterious and unresolved. Anomalous changes in atmospheric and oceanic circulations are currently being examined in both polar regions to explain them. In a letter published in *Nature* in 2009, Steig et al. argued for enhanced meridional flow—that is, more warm air reaches West Antarctica from farther north (i.e., from warmer, lower latitudes). This positive feedback mechanism (less sea ice, warmer water, rising air, lower pressure, and enhanced storminess) would explain the warming of the Antarctic continent over the past 50 yrs.

On average, the Arctic is warming twice as fast as the globe as a whole and the vast land masses of the region, at five times the global average. The amplified warming in the Arctic was attributed to positive feedback mechanisms that accelerate climate change, some likely triggered by the melting of sea ice, snow, and permafrost. A study by Gillet et al. in 2008, using an up-to-date gridded data set of land surface temperatures and climate model simulations, assessed the causes of the observed polar warming. They found that the observed changes in Arctic and the Antarctic temperatures are not consistent with internal climate variability or natural drivers alone and are directly attributable to human influence.

Greenland Ice Sheet

Representing almost 1/20 of the world’s ice, the ice locked atop Greenland covers 1.7 million km², for a total ice volume of 2.9 million km³. It has shed an average 150 billion metric tons more than

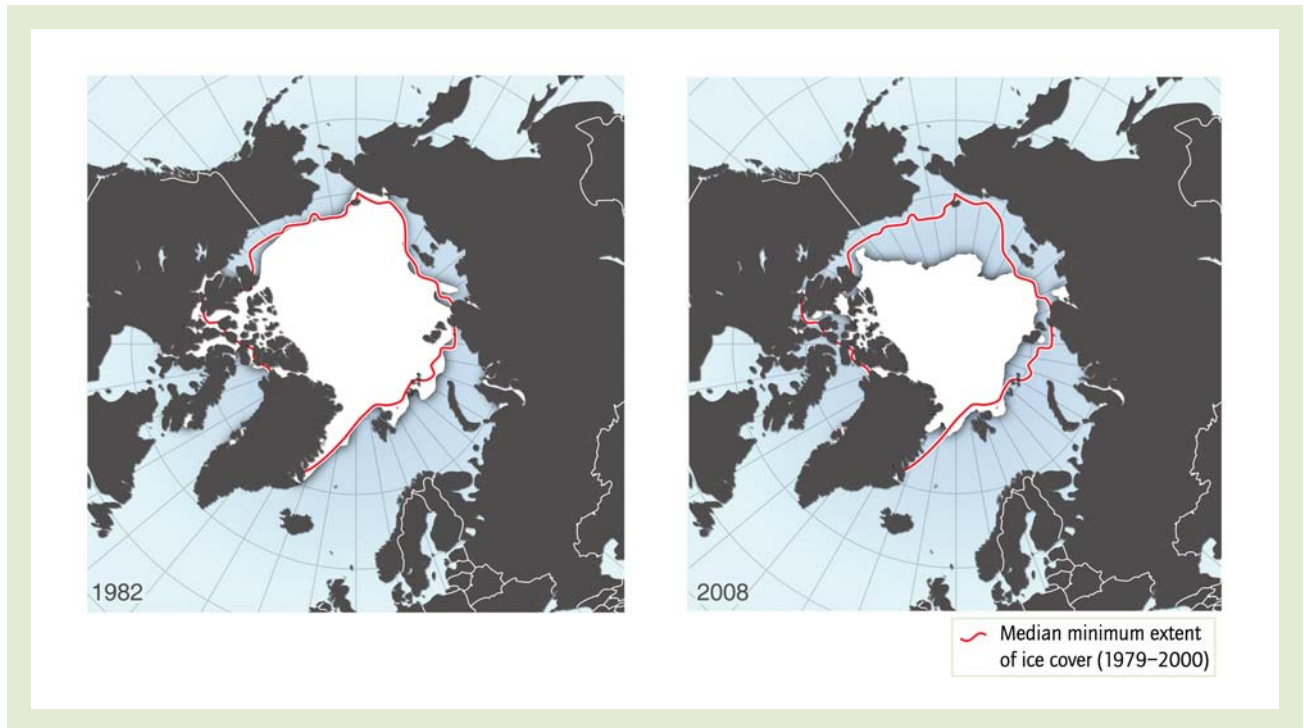


Figure 1 Arctic sea ice minimum extent in September 1982 and 2008. The red line indicates the median minimum extent of the ice cover for the period 1979 to 2000. This figure compares the Arctic sea ice extent in September for the years 1982 (the record maximum since 1979) and 2008. The ice extent was 7.5 million km² in 1982 and only 5.6 million km² in 2005 and down to 4.3 million km² in 2007. As has been observed in other recent years, the retreat of the ice cover was particularly pronounced along the Eurasian coast. Indeed, the retreat was so pronounced that at the end of the summers of 2005 and 2007, the Northern Sea Route across the top of Eurasia was completely ice free.

Sources: Hugo Ahlenius, cartographer and designer, UNEP/GRID-Arendal Maps and Graphics Library. Retrieved February 20, 2010, from <http://maps.grida.no/go/graphic/arctic-sea-ice-minimum-extent-in-september-1982-and-2008>. Data from Fetterer, F., & Knowles, K. (2002). *Sea ice index* (updated 2004). Boulder, CO: National Snow and Ice Data Center. Retrieved November 27, 2008, from http://nsidc.org/data/seaice_index/daily.html.

it gains in snow in winter over the past four summers (Figure 3). Although this is only a tiny fraction of its total ice volume, this shedding could weaken this survivor of the most recent ice age, 20,000 yrs. ago, when the climatic conditions were substantially different. It is very unlikely that the Greenland ice sheet will disappear in an instant or even a century, but the assumption that the total melting and collapse of such a large ice sheet takes millennia is being revised.

One reason for the revision is an unanticipated acceleration of outlet glaciers on the west and east coasts. The Jakobshavn Isbrae glacier on the west coast has doubled its speed from 5.7 to 12.6 km/yr. between 1992 and 2003, while the

Helheim and Kangerdlugssuaq glaciers started speeding up in 2002 and 2005, respectively. As the glaciers calve icebergs into the ocean, it relieves stress on the glaciers, allowing them to surge. One possible explanation lies in a warmer ocean bathing the coast, as data show a correlation between outlet glacier speeding up and warm ocean temperature. However, very little has been done to correlate water temperature and glacier movement so far.

Another area of interest is surface meltwater draining to the bottom of glaciers. Potentially, this could encourage movement and collapse by lubricating the interface between the basement and the glacier.



Southern Hemisphere

Whole S Hemisphere	+1.2	—
Bellingshausen Sea	−5.3%	—
Weddell Sea	+1.0	—
Indian Ocean	+1.1	—
West Pacific Ocean	+1.2	—
Ross Sea	+4.8	—

Change in annual mean sea ice
extent (% per decade)

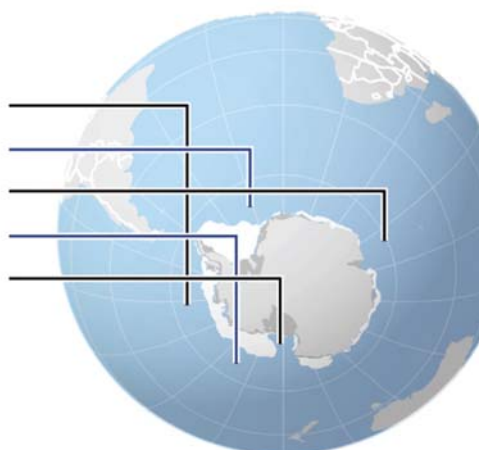


Figure 2 Regional changes in Antarctic sea ice. In contrast to the Arctic (Figure 1), there are signs of a slight increase in the extent of annual mean sea ice in the Antarctic over the period from 1979 to 2005 (+1.2 % per decade) based on the NASA (National Aeronautics and Space Administration) team retrieval algorithm. There are far fewer observations of sea ice thickness for the Antarctic than for the Arctic because of the lack of submarine measurements. It is therefore not possible to detect any trends in Antarctic sea ice thickness over recent decades.

Sources: Hugo Ahlenius, cartographer and designer, UNEP/GRID-Arendal Maps and Graphics Library. Retrieved February 20, 2010, from www.unep.org/geo/ice_snow. Data from National Aeronautics and Space Administration. (2007). *Sea ice remote sensing*. Washington, DC: Author. Retrieved March 30, 2007, from http://polynya.gsfc.nasa.gov/seaice_projects.html.

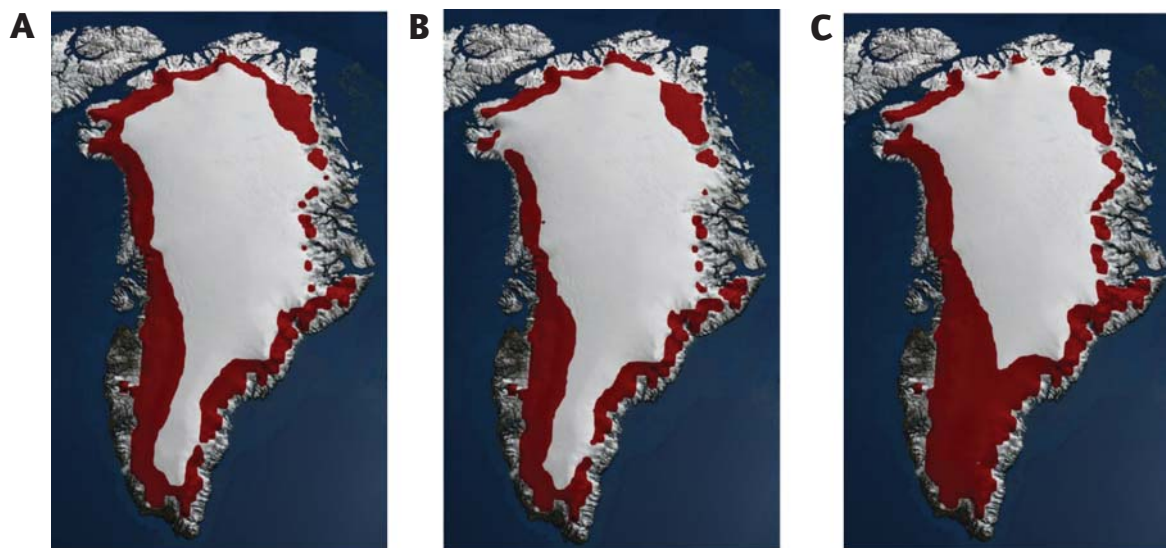


Figure 3 These images are derived by comparing satellite and aircraft laser-altimeter surveys. They show the regions of the Greenland ice sheet over which melt occurred for more than 3 days between May 1 and September 30 for (A) 1998, (B) 2003, and (C) 2007, respectively.

Source: NASA/Goddard Space Flight Center Scientific Visualization Studio. The Next Generation Blue Marble data are courtesy of Reto Stockli (NASA/GSFC). Available at <http://svs.gsfc.nasa.gov/goto?3475>.

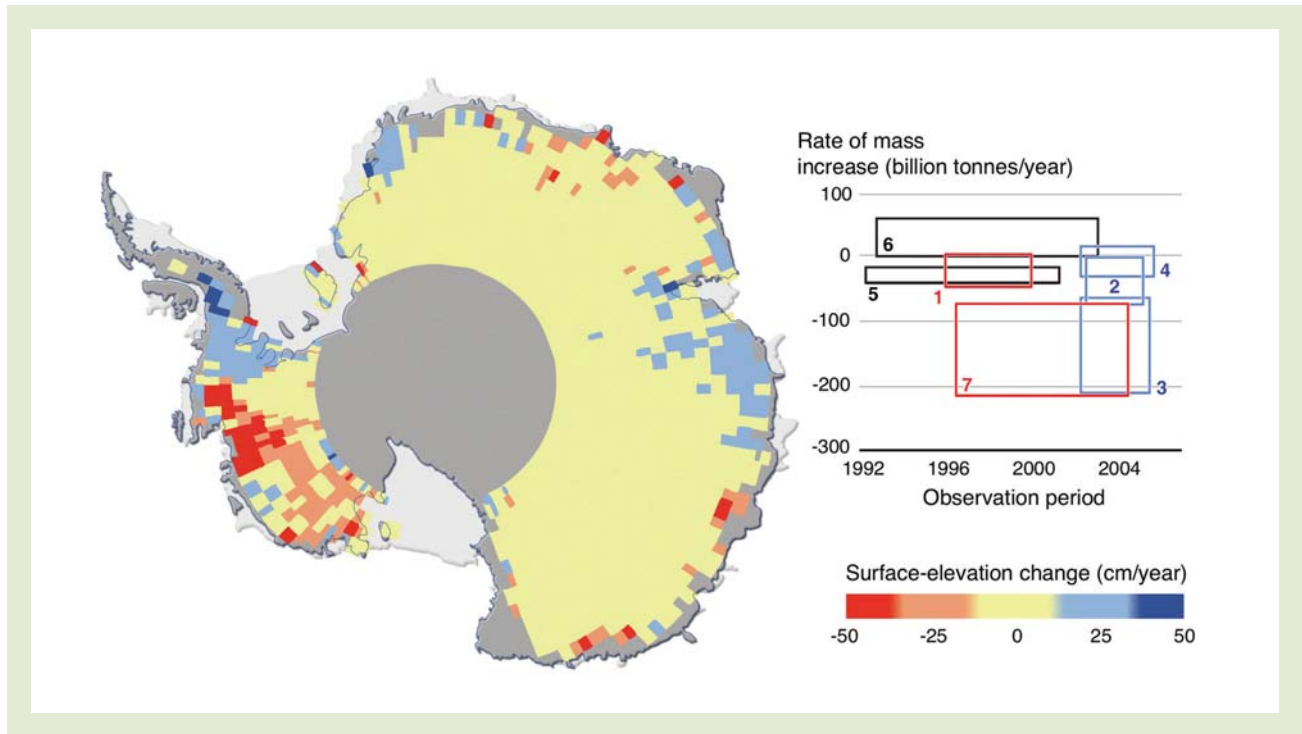


Figure 4 Antarctica, showing rates of surface elevation change derived from satellite radar-altimeter measurements

Sources: Hugo Ahlenius, cartographer and designer, UNEP/GRID-Arendal Maps and Graphics Library. Data from (corresponding to the numbers on the rectangles) (1) Rignot and Thomas (2002), (2) Ramillien et al. (2006), (3) Velicogna and Wahr (2006), (4) Chen et al. (2006), (5) Zwally et al. (2005), (6) Wingham et al. (2006), and (7) Rignot et al. (2007). Map retrieved and full source information available from http://www.unep.org/geo/geo_ice/graphics.asp.

Notes: The figure shows the rates at which the ice sheet mass was estimated to be changing based on radar-altimeter data (*black*), mass-budget calculations (*red*), and satellite gravity measurements (*blue*). Rectangles depict the time periods of observations (*horizontal*) and the upper and lower estimates of mass balance (*vertical*). Measurements by satellite techniques based on gravity indicate mass loss of ice at a rate of 138 ± 73 billion metric tons/yr. (per year) during 2002–2005, mostly from the West Antarctica Ice Sheet. However, two interpretations of satellite radar altimetry pointed to a much smaller loss of about 31 billion metric tons/yr. or a net gain of about 27 billion metric tons/yr.

Antarctica Ice Sheet

The Antarctic ice sheet covers 12.3 million km², for a total ice volume of 24.7 km³. Antarctica is also made of ice shelves—thick, floating slabs of freshwater ice extending from the coast. They cover an area almost as large as the Greenland ice sheet itself (1.5 million km²) but with a much lower ice volume (0.7 million km³).

Though there are uncertainties in the actual rate of mass loss, estimates indicate a recent shift to a net loss of Antarctic ice and suggest that the losses might be accelerating (Figure 4). Satellite missions over Antarctica are important as they

provide continuous monitoring of the ice sheets, allowing scientists to make predictions by finding evidence of trends in the data.

Using ERS and Envisat satellite missions from the European Space Agency, scientists identified new rifts (deep linear breaks in the ice) on the Wilkins Ice Shelf (WIS) on November 26, 2008 (Figure 5). The WIS is connected to two Antarctic islands by a strip of ice. That “ice bridge” has lost about 2,000 km² since the beginning of 2008, possibly leading to the opening of the ice bridge that has been preventing the ice shelf from disintegrating and breaking away from the Antarctic Peninsula. Six other

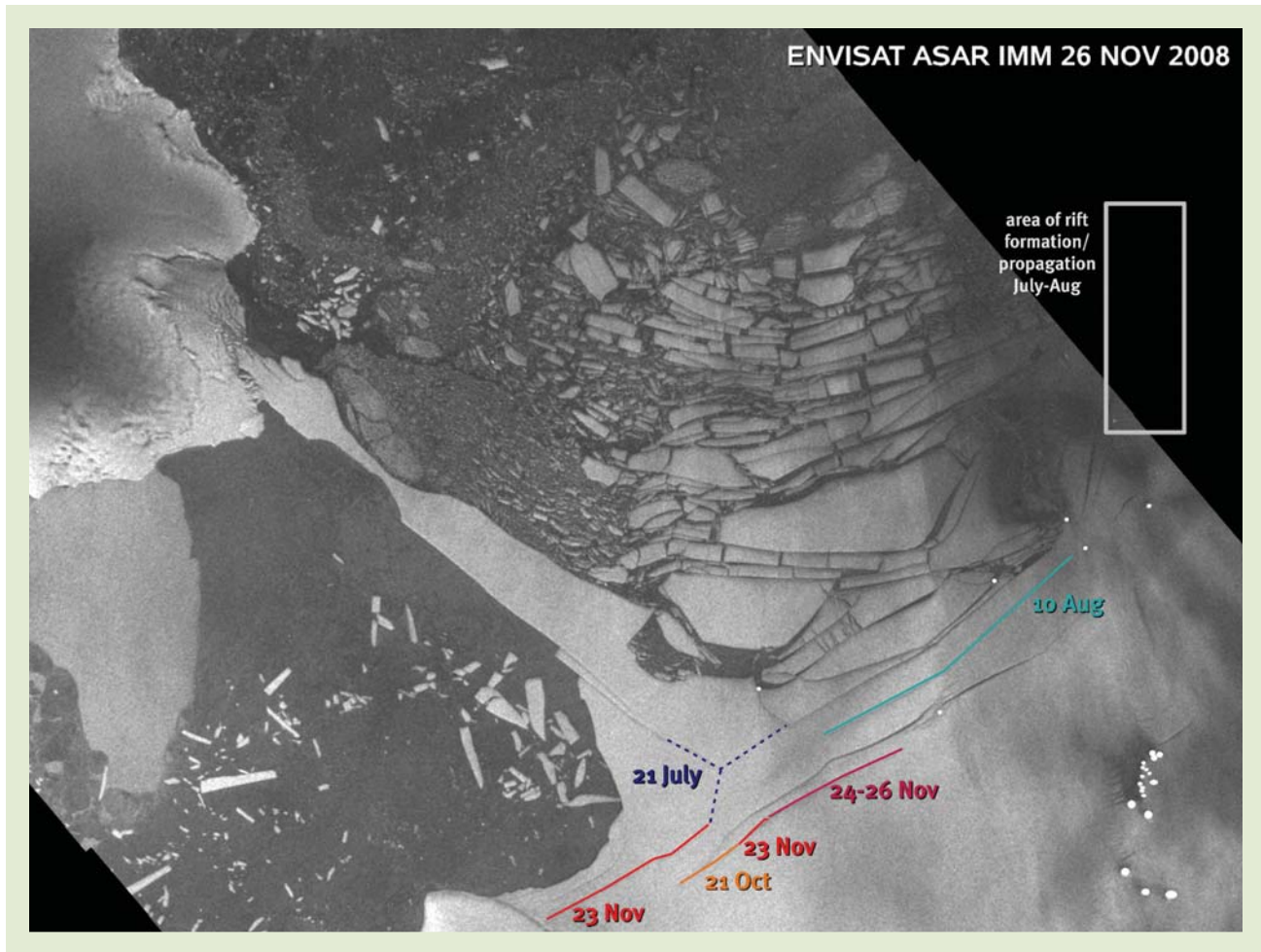


Figure 5 New rifts form on Antarctic ice shelf. Image acquired by Envisat's Advanced Synthetic Aperture Radar (ASAR) sensor. New rifts on the Wilkins Ice Shelf developed from August 10 to November 26, 2008. These rifts joined previously existing rifts (*blue dotted line*). The development of these rifts threatens to collapse the ice bridge that has been preventing the ice shelf from disintegrating and breaking away from the Antarctic Peninsula.

Sources: Interpretations based on ESA Envisat images provided by Dr. Angelika Humbert from the Institute of Geophysics, Münster University. Photo from European Space Agency. Available at www.esa.int/esaCP/SEMXXK5AWYNF_index_0.html.

ice shelves have already been lost entirely—the Prince Gustav Channel, Larsen Inlet, Larsen B, Wordie, Muller, and Jones shelves—in the past 20 yrs.

Mathieu Richaud

See also **Anthropogenic Climate Change; Climate Change; Glaciers: Continental; Global Sea-Level Rise; Ice; Periglacial Environments; Permafrost**

Further Readings

- Gillett, N., Stone, D., Stott, P., Nozawa, T., Karpechko, A., Heger, G., et al. (2008). Attribution of polar warming to human influence. *Nature Geoscience*, 1, 750–754.
- Hanna, H., Huybrechts, P., Janssens, I., Cappelen, J., Steffen, K., & Stephens, A. (2005). Runoff and mass balance of the Greenland ice sheet:



- 1958–2003. *Journal of Geophysical Research*, 110, D13108.
- Holland, D., Thomas, R., de Young, B., Ribergaard, M., & Lyberth, B. (2008). Acceleration of Jakobshavn Isbrae triggered by warm subsurface ocean water. *Nature Geoscience*, 1, 659–664.
- International Panel on Climate Change. (2007). Summary for policymakers. In S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, et al. (Eds.), *Climate change 2007: The physical science basis* (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). Cambridge, UK: Cambridge University Press.
- International Polar Year: www.ipy.org/index.php?/ipy/about
- Ozsoy-Cicek, B., Xie, H., Ackley, S., & Ye, K. (2008). Antarctic summer sea ice concentration and extent: Comparison of ODEN 2006 ship observations, satellite passive microwave and NIC sea ice charts. *The Cryosphere Discussion*, 2, 623–647.
- Schneider, D., & Steig, E. (2008). Ice cores record significant 1940s: Antarctic warmth related to tropical climate variability. *Proceeding of the National Academy of Sciences of the USA*, 105, 12154–12158.
- Steig, E., Schneider, D., Rutherford, S., Mann, M., Comiso, J., & Shindell, D. (2009). Warming of the Antarctic ice-sheet surface since the 1957 International Geophysical Year. *Nature*, 457, 459–462.
- Stoeve, J., Serreze, M., Drobot, S., Gearheard, S., Holland, M., Maslanik, J., et al. (2008). Arctic sea ice extent plummets in 2007. *Eos, Transactions of the American Geophysical Union*, 89(2), 13–14.
- Stroeve, J., Holland, M., Meier, W., Scambos, T., & Serreze, M. (2007). Arctic sea ice decline: Faster than forecast. *Geophysical Research Letters*, 34, L09501.
- United Nations Environment Programme. (2007). *Global outlook for ice and snow*. Arendal, Norway: UNEP/GRID.
- United Nations Environment Programme. (2008). *Global glacier changes: Facts and figures*. Arendal, Norway: UNEP/GRID.
- Witze, A., (2008). Losing Greenland. *Nature*, 452, 798–802.



POLITICAL ECOLOGY

Political ecology is a relatively broad term that encompasses an interdisciplinary field, a theory, and a conceptual approach that focus on how power relations in society affect—and are affected by—the natural environment. In particular, political ecology explores the role of political powers, economic interests, societal norms, and emerging conflicts in environmental decision making. The approach centers on the notion that politics and environment are thoroughly connected on multiple scales and levels, as all access and control of natural resources are structured by power relations in human society. This affects all aspects of nature-society interaction and makes environmental issues on various levels inevitably political.

Political ecology offers analytical tools for a power- or knowledge-focused analysis applicable across theoretical, empirical, and disciplinary boundaries. The field emerged from a variety of disciplines over the past decades in a growing recognition of the complexity of the social influences surrounding environmental problems. It shares theoretical concepts with many other fields, such as political economy, cultural ecology, environmental sociology, anthropology, socialist ecology and Marxist theory, common property theory, green materialism, critical environmental history, ecofeminism and feminist development studies, rural land use and peasant studies, and postcolonial and critical development theory.

Themes and Goals in Current Research

Political ecology research consists of a diverse array of themes. These can loosely be categorized into four areas:

1. The first overarching goal of political ecology is to explore the reasons behind environmental degradation and marginalization, based on an understanding of the ecological situation as a result of its larger context in political economy. Political ecology provides a comprehensive analytical tool to reconceptualize three aspects of environmental problems. First, the *social construction* of environmental problems is analyzed. Environmental change is usually termed a problem or crisis where



it affects human interests adversely. Political ecology challenges the apparent causes of environmental problems and argues that most, if not all, environmental problems are not primarily ecological but in fact rather social problems. Prominent examples are land cover change and loss of biodiversity, soil erosion, air and water pollution, famines, floods, deforestation, land degradation, and desertification. Second, *uneven exposure* and *vulnerability* in environmental crises are analyzed. Environmental problems are often perceived by the socioeconomic dimensions of their impact on society, not by their ecological significance. This indicates underlying influences of power, access, and representation on the construction of environmental problems. Resource deprivation is not a uniform process. Environmental problems such as degradation and scarcity of resources receive much more attention when powerful elites are affected rather than vulnerable groups. Third, *unequal power relations* regarding resource access are analyzed.

2. The second goal of political ecology focuses on the social definition and political implementation of environmental conservation. This work aims at the social construction of conservation and nature itself. It challenges our understanding of concepts such as “nature,” “wilderness,” “natural resources,” “sustainable resource use,” and “aesthetic landscape,” asking how they are constructed and reinforced by powerful hegemonic structures in society and how they affect our regulation of land use and protected areas. The use and protection of natural environments are socially defined (e.g., “resource,” “sustainable use,” “scientific forestry,” “illegal harvesting,” “poaching,” “invasive logging”) and underlie the powerful paradigms that are derived from and reinforced by cultural practices and social norms.

3. The third goal is to understand the actors and interests of environmental conflict in the larger context of power struggles. Actors and their roles in conflict may be driven by gender, class, race, ethnicity, or other dynamics in society. Political and economic elites have historically aimed to justify resource use systems that were characterized by highly unequal access and user rights. Marginalized groups may be able to challenge the elite claims and seek ways to overcome the existing

power structures. Political ecology seeks to highlight the conflict over resources as much as it reveals the struggle over meaning. It raises questions such as “Whose environment?” and “Whose power or knowledge?” and analyzes the conflicting values, perceptions, knowledge, and discourses that reflect the underlying power relations.

4. The fourth goal of political ecology is to understand the social and political dynamics that emerge from changes in environmental conditions and regimes. This research analyzes the power dynamics of movements, shifts, or imbalances in resource distribution and ecological justice and provides insights that are often attributed to social change in a broader sense. At the same time, environmental movements, advocacy, and resistance are themselves subject to internal power forces that socially construct environmental narratives and their critiques.

These themes can be explored on multiple spatial and temporal scales with varying scope. Applications range from the relatively broadscales of sociocultural meaning (e.g., the Western concept of national parks) to short-framed political analyses (e.g., the passing of a new environmental law), from long-term research on sociopolitical issues (e.g., toxic waste disposal in marginalized regions) to social research on rural practices and livelihoods (e.g., customary access rights in rain forest communities).

Overall, one of the most central contributions of political ecology is its call for a heightened awareness of power inequalities and their impact on nature-society systems. The approach emphasizes the multilevel pervasiveness with which power relations shape and reinforce resource access and control, benefit distribution, and overall livelihood security. It offers a theoretical level of revisiting and questioning social assumptions to explore how concepts such as “sustainable use,” “natural resources,” or “equal access rights” become defined and reinforced by the dominant power structures in society.

Early Colonial and Ecological Critiques

Political ecology is commonly referred to as a new research field, but it has very old roots. Some early



European explorers and geographers criticized the racist hegemonic structures and growing inequalities as the underlying forces of environmental destruction and colonial exploitation, often based on their own observation. In his classic *Cosmos* (1858), the German geographer and world-renowned explorer Alexander von Humboldt coined the term *inequality of fortunes* and called for equal land use and employment opportunities between indigenous peoples and colonial powers. The French geographer Elisee Reclus criticized the colonial exploitation of his time even more openly in his work *The Earth: A Descriptive History* (1871). He suggested revolutionary political actions as a legitimate evolutionary mechanism to overcome inequities in hegemonic structures. In the late 19th and early 20th centuries, however, most human-environment research had become more formalized and was dominated by rather reductionist approaches that catered to the need of Eurocentric colonial expansion for cartography and physical geography.

Political ecology suggests a strong reference to ecology, a linkage that has been critiqued from various perspectives. Over time, ecological concepts became major influences on numerous fields, including health, development studies, environmental history, geography, economic processes, and cultural ecology. The study of ecological processes emerged in the mid 19th century, at a time when evolutionary research gained importance. Charles Darwin's evolution theory triggered a wave of debate across the social sciences to explore possible parallels to human processes. The evolutionary biologist and geographer Alfred Russel Wallace immediately opposed the emerging notions of social Darwinism and became an advocate of social justice and nonracist resource rights. At the core of the debate was the role of individual competition in evolutionary strategies as opposed to the role of social cooperation: While the "survival of the fittest" principle emphasized the ubiquitous importance of individual interests behind all societal decisions, the latter called for a balancing, ecosystem-level approach to better understand the full interactions between communities of organisms.

One early scholar who addressed the problematic implications of Darwin's theory for the social sciences was the Russian philosopher, geographer,

explorer, and activist Peter Alexeivich Kropotkin. He was arguably one of the first political ecologists. His pathbreaking work *Mutual Aid: A Factor in Evolution*, published in 1902, presented biological data that indicated that the central mechanism in natural selection is not competition but cooperation. In an often uncertain and difficult biophysical environment, it is cooperation among individuals that offers the best collective benefit to ensure survival. His findings challenged social Darwinist ideas, criticized the implicit reading of social hierarchies into the natural world, and thus repoliticized our thinking of human-environment processes.

Interdisciplinary Influences

Modern political ecology has emerged with multifaceted roots in various fields, most notably political economy and cultural ecology. The approaches of political ecology often have a historical component that shares concepts or focus with environmental history. Nevertheless, the term *political ecology* created a new unifying label for a research approach that had long been evolving in various academic disciplines, although concerned with large variations in concept, focus, and scale.

Political ecology shares with political economy the interest in the interaction between individuals, their material transactions in society, and the natural world. Political economy also assumes that society and nature are socially constructed to a significant degree but otherwise deemphasizes any natural processes or the environment per se. Environmental economics, on the contrary, has developed elaborate tools that seek to quantify environmental services and externalities. Although these have been contested, they help develop a larger economic framework but do not as adequately capture the underlying reasons, interests, and consequences of nature-society interactions as political economy helps grasp. The writings of Karl Marx experienced a revival through political ecology for their conceptual lens on the sociopolitical links between environmental degradation and social oppression, and this opened a new debate on the underlying structural concerns over economic production and resource depletion.



Neo-Marxism manifested itself as an influential theoretical contribution to early-stage political ecology from the late 1970s to the mid 1980s. It reflected the broader intellectual context at the time for new radical theories seeking to reconceptualize existing problems through new analytical lenses.

Political ecology is also significantly influenced by cultural ecology. Cultural ecology had emerged since the 1950s as a multidisciplinary approach across geography and anthropology to help understand how human societies affect and adapt to their local environments—how cultural practices and institutional arrangements evolve around resource use. Major works are associated with the American geographer Carl Sauer, who also pioneered the modern tradition of cultural geography in which environmental determinism was inverted into focusing on the role of humans in changing the landscape, not the other way around.

In the 1960s and early 1970s, cultural ecology attempted to explore the future of human populations and their material activities through ecologically based models such as energy flow modeling and system analysis. These models sought to explain adaptation and change as predictable outcomes of processes within the modeled closed ecosystems, but exactly because of this, they failed to acknowledge that the local cultural and ecological systems studied were in fact the result of larger sociopolitical dynamics on a global scale. From a political ecology perspective, this apolitical and homeostatic systems approach is the central conceptual flaw of cultural ecology.

Modern Reemergence Since the 1970s

Political ecology has been recognized as an academic field for only a few decades, and it continues to grow and be refined. The term *political ecology* was coined in the 1970s and received wider use in the 1980s and 1990s, when a growing circle of scholars started to identify themselves as political ecologists. Political ecologists come from various academic backgrounds, such as development studies, geography, political science, environmental studies, human ecology, anthropology, and environmental sociology.

Some of the earliest and most prominent scholars of the field in fact did not identify themselves as part of the movement and were rather situated by others in retrospect. This made the emergence of the field difficult to grasp and define, which continues until today.

The modern wave of political ecology can be described as a confluence of several sources of thought. New critiques in cultural ecology had increasingly opened up toward previously undertheorized sociopolitical determinants of human environment use. This development was embedded in a larger paradigmatic shift through the 1970s, with merging environmental and social movements. Escalating environmental degradation and livelihood crises in the developing countries, unforeseen local adversities from conservation efforts, and worldwide disagreement over possible solutions had made the growing global debate an increasingly politicized one. Voices for social justice increasingly joined the ecological concerns and raised the societal critique of global socioeconomic and political structures to a new level. Postcolonial resource use and industrial exploitation were increasingly identified as part of the problem. Political ecology formed as a critical response particularly to two popular notions at the time. First, it criticized neo-Malthusian beliefs that environmental destruction and global resource depletion were the result of overpopulation. Second, new political ecology voices challenged the globally favored technocratic practice of technology-based solutions that approached environmental problems as a merely technical matter, not as a complex social system.

The term *political ecology* emerged diffusely as a concept to grasp the new waves of environmentalist and social movements, in loose reference to political economy and cultural ecology. It first appeared in the writings of the journalist Alex Cockburn, the anthropologist Eric Wolf, and the environmental scholar Grahame Beakhurst. The first works in the academic realms of the field called for new concepts to explore the missing link between environment and society. They criticized the strong dominance of apolitical approaches in environmental research, the lack of postcolonial awareness in relation to it, and the limited application of alternative and radical thinking to conceptualize the growing threat of



resource depletion and overpopulation. These works were among the first in what was later termed *Third World political ecology*.

In the 1980s, the term *political ecology* was explored and enriched by key scholars such as Piers Blaikie, Michael Watts, and Suzanna Hecht. The research on power relations and human-environment interaction increased significantly, most prominently on land degradation issues, as book-length texts by Piers Blaikie and Harold Brookfield contributed significantly to the consolidation and formalization of the emerging research field.

Until the 1990s, the core focus of political ecology research remained in rural, agrarian, and Third World contexts. Political ecology slowly grew beyond its original core concern of Third World contexts and into a broadened, more theoretically consolidated and deepened school of thought that now increasingly addressed resource management and access to environmental resources, explored among others by Nancy Peluso and Karl Zimmerer. New streams complemented and diversified the field.

Critiques and New Directions

Political ecology has been critiqued on various levels over the decades. Its growth was rather iterative in nature due to constant exploration, elaboration, and reinvention of the field. Until today, a substantial part of its literature continues to be written in neighboring fields that form a heterogeneous and dynamic area of research rather than a coherent new field with clearly identified boundaries. Political ecology remains, in consequence, a fragmented and often incoherent field of research.

The disparate character of the field is often regarded as its central weakness. Some regard the disparate nature of the field as a weakening feature in need of a unifying voice and self-attributing coherence to move beyond the early stages of a new field. It has been argued that the term *political ecology* is too broad to capture all its different streams and nearly dissolves itself by trying to do so. It lacks consistent depth across the field, cannot determine its own conceptual boundaries, fails to agree on a coherent theoretical framework, and

does not offer a normatively derived framework to assess environmental processes or outcomes. For the same reasons, political ecology is also incapable of offering one big representative story or unified approach in response to current environmental debates.

Others, however, see the incongruent, heterogeneous nature of the field as possibly its greatest virtue because it reflects the ideas of political ecology at its very core. It pays tribute to its philosophical roots of pluralism, nonhierarchical discourse, and the teleological apprehension with which political ecology challenges all underlying connotations in the construction of knowledge and opinion for any political or academic discourse. Regardless, many critics agree to a certain extent that the emergence of the field mirrored an eclectic time of paradigmatic shifts in the social sciences, making way for the exuberant growth of nongoverned academic diversity and multidisciplinary.

Significant criticism emerged over what political ecology failed to address or addressed in research very late. Political ecology has been criticized for concentrating on land-centered research in its early phase and for failing to address air quality or water management sufficiently. The discipline also initially remained silent on gender issues and feminist geography approaches and needs to extend its theoretical tools to include research on the human body and health issues, urban contexts, and organizations and institutions in political-ecological conflicts. Others point out that although political ecology is centrally concerned with sociopolitical dynamics elsewhere, it failed to address the internal politics of the emerging field. In general, a wider shift toward discourse-oriented analyses in the social sciences since the 1990s has led to calls for more political ecology-based research on the power dynamics in the generation of knowledge, the social construction of inquiry, and teleological questions of motives and objectives in science and its possible merits and risks in technology-based applications. In the future, this opens up themes such as the expanding applications of geospatial methods and their construction of knowledges, shifting nature-society power relations through public participation tools, ecological modernization, and new debates on alternative political ecologies.



The critical debate on the future of political ecology thus indicates significant potential beyond the traditional realms of environment-related research. Ultimately, political ecology is not about nature. The initial references to ecology are increasingly contested, suggesting that political ecology needs to break away from a possibly outdated understanding of ecological concepts and dynamics. Some argue that nature-specific foci are in fact an early development stage of the discipline. The theoretical application of political ecology has started to widen beyond environmental issues and into the broader realms of sociopolitical research, ranging from postcolonial theory to urban planning and HIV/AIDS. Political ecology offers a multiscalar set of analytical tools to deconstruct social norms and unravel the underlying power structures in a wider context, and it is receiving growing attention from other society-related research.

Conny Davidsen

See also Agroecology; Class, Nature and; Conservation; Critical Studies of Nature; Cultural Ecology; Deep Ecology Movements; Ecofeminism; Ethnicity and Nature; Feminist Political Ecology; Gender and Nature; Human Ecology; Industrial Ecology; Landscape Ecology; Malthusianism; Marxism, Geography and; Nature; Nature-Society Theory; Neo-Malthusianism; Political Economy; Political Economy of Resources; Population and Land Degradation; Population and Land Use; Race and Nature; Social Construction of Nature

Further Readings

- Blaikie, P., & Brookfield, H. (1987). *Land degradation and society*. New York: Methuen.
- Bryant, R. L. (1992). Political ecology: An emerging research agenda in Third World studies. *Political Geography*, 11(1), 12–36.
- Peet, R., & Watts, M. (2004). *Liberation ecologies* (2nd ed.). New York: Routledge.
- Robbins, P. (2004). *Political ecology: A critical introduction*. Malden, MA: Blackwell.
- Zimmerer, K., & Bassett, T. J. (2003). *Political ecology: An integrative approach to geography and environment-development studies*. New York: Guilford Press.



POLITICAL ECONOMY

Political economy is a field of research and a body of theory concerned with the integrated study of political and economic decision making. It analyzes the behavior of political agents who make decisions in the presence of institutional and economic opportunities and constraints. Political economy has attracted growing interest within the social sciences, since the standard paradigm in economics of fully rational economic agents has failed to explain the continued prevalence of underdeveloped and even stagnating economies throughout the world. Similarly, political scientists have increasingly recognized the need to take economic constraints into account in analyzing political behavior. Political economy is currently one of the most intense fields of social science research. Many of the major recent theories in political economy consider geography to play a key role in understanding economic and political outcomes. This entry first describes the field of political economy and then provides an overview of some key areas of research: general geography, biogeography, disease environment, country size, natural resources, and trade.

Key Concepts in Political Economy

In the older literature—for instance, the works of Adam Smith, David Ricardo, Thomas Malthus, and Karl Marx—*political economy* referred to a more general analysis of how production was organized within states. Sometimes, political economy was even used as a synonym for “economics.” Some variants today are still Marxist inspired. The current use of the term *political economy* is, however, typically more narrowly confined to an interdisciplinary analysis of politics and economics. It is often indistinguishable from the field of public choice theory, associated with prominent scholars such as James Buchanan and Gordon Tullock. Public choice was for decades considered to be a “school of thought” on the side of mainstream economics, but as most of its key ideas (self-interested, optimizing political agents that act under institutional constraints) are now considered to be part of



standard economic theory, the field is usually referred to as political economy.

A typical feature of modern political economy models is to assume the presence of self-interested political agents who aim to remain in power and who try to maximize their own utility or the financial rewards for their own party or constituency. In this sense, political economy increasingly shares the fundamental assumptions made in microeconomics, where models are based on utility-maximizing individuals who are constrained by economic circumstances or strategic political limits rather than by morals or ideology. Political economy is further closely related to the field of institutional economics, which analyzes the importance of formal and informal rules of behavior for economic outcomes, such as norms of cooperation, private property rights, courts, parliamentary systems, and constitutions. Political economy is more focused on the interactions between political agents, their institutional framework, and economic constraints. In recent years, game theory has often been used for analyzing these interactions. As in economics, there has also been an increasing orientation toward empirical work.

The field reached a prominent position in social science with major publications such as Anthony Downs's economic theory of democracy (1957), and even more so with James Buchanan and Gordon Tullock's book *The Calculus of Consent* (1962). In that work, the authors analyze the voting systems in constitutional democracies and argue that there is an important trade-off to be made, in the sense that near-unanimity voting rules presumably have little external costs (few voters suffer damage from the chosen policy), whereas there are likely to be substantial decision-making costs before such a policy can be unanimously agreed on. Another key work from the same period is Mancur Olson's *The Logic of Collective Action*, published in 1965, which presents a theory of how small interest groups can obtain a disproportionately large influence over government policies. Recurring topics in the political economy literature over the years have been rent-seeking politics, interest group behavior, politically induced business cycles, the study of bureaucracy and corruption, and the impact of constitutions on economic outcomes.

General Geography

At least since antiquity, people have been aware that geographical conditions have a major impact on political and economic processes in society. In one of the first historical treatises ever written—*The Histories* by Herodotus—there are numerous references to the specific geography of the many places visited and how these conditions have affected societies. Most premodern philosophers and scholars also developed theories on the political impacts of geography, for instance, Plato, Machiavelli, and Montesquieu.

In modern times, a central work on the political economy of geographical conditions is Karl Wittfogel's book *Oriental Despotism*, published in 1957. Wittfogel developed his theory about "hydraulic empires," that is, how many of the early civilizations were founded on the need to control flooding and to construct irrigation facilities on the fertile river plains of the Nile, the Euphrates and the Tigris, the Indus, and the Yangtze and the Hwang Ho, the two major Chinese rivers. The sophistication and scale of these operations led to the emergence of centralized bureaucracies, economic specialization, social stratification, and the rule of autocrats who were often worshipped as gods. Tribute from unfree peasants or forced labor formed the basis of the wealth and power of a small ruling elite. According to the hydraulic hypothesis, there is a direct link between geography (fertile river plains in semiarid areas) and political economy. Many writers have proposed that a link can still be traced from these early conditions of statehood to more recent autocratic rule in Egypt, Iraq, and China. The hydraulic hypothesis has been criticized by scholars on Chinese history, who argue that the nature of despotic rule in ancient Egypt and Mesopotamia in fact had little in common with Chinese history. Furthermore, theory of a particular type of Oriental, riverine despotism misses the fact that the huge Indian subcontinent is fragmented and has not hosted major empires for long periods.

In the tradition of the hydraulic hypothesis, many scholars have contrasted the old riverine empires with the political economy of Europe. Europe has no large fertile river plains, and its general fragmented geography, with several



mountain ranges, peninsulas, large islands in the Mediterranean, indented coastlines, and hardwood forests, contributed to a continent that naturally featured a multitude of political core areas. By the same logic, geographically extensive empires were difficult to sustain in the longer run, which is one of the reasons why the earliest civilizations did not arise in Europe. This geographical fragmentation led to intense military and economic competition between smaller political units. The tax tribute needed to finance wars could be tolerated by the majority of the population only after the executive power had committed to limiting its power over its citizens. This in turn implied an economy that was more dynamic, open to new ideas, and fostered several “proto-capitalist” episodes even in preindustrial Europe.

This view of the benefits of a fragmented, competitive Europe is argued by some to be a “Eurocentric” analysis in that it does not give an accurate account of history. Europe has, for instance, hosted some very powerful political units, such as the Roman and Frankish empires, and its military competition has also been enormously costly in terms of capital and human lives. Some studies also indicate that living standards or levels of technological sophistication were not substantially higher in Europe before AD 1500 and that the source of European economic and political prominence is really to be found in the internal institutional and political changes that colonization brought about. The impact of colonization on European countries’ political economy was further quite diverse. In the Netherlands and in the United Kingdom, the inflow of revenue from the colonies strengthened mainly the merchant class, who in turn demanded more political power, a realignment of policy toward free trade, and strengthening of property rights. In Spain, however, the inflow of bullion from America led to inflation, an even more autocratic executive, increased government expropriation of private property, and eventually a bankrupt government.

Political Ecology

A very influential and more recent theory of the long-run political economy of the world is offered in Jared Diamond’s famous 1997 book *Guns,*

Germes, and Steel: The Fates of Human Societies. His basic argument is that regions experiencing an early transition to agriculture, civilization, and statehood gained a head start and an initial advantage over other regions that was still present when the race for colonies started around 1500. This longer experience of statehood explained why political units from Western Eurasia could colonize America, Africa, and large parts of Asia, which in turn shaped the broad contours of the international dispersion of wealth and power. Hence, to understand Western hegemony, one must understand why some areas adopted agriculture earlier than others. According to Diamond’s hypothesis, the main reason for an early transition is to be found in the greater access to suitable plants and animals for domestication in, for instance, the Middle East and along the Chinese rivers. The Americas also had independent centers of agricultural origin based on plant domestication in, for instance, the Andean highlands and Mexico, but the absence of suitable draught animals put substantial constraints on military technology, as well as on economic development. It also meant that the native population had not developed any resistance against the microbes (of animal origin) that the Spanish brought on their arrival, which led to the death of tens of millions of people from smallpox and other diseases.

Disease Environment

The geography of disease is another factor believed to have had a significant impact on colonial policy and hence on subsequent political and economic developments. According to the theory proposed by Daron Acemoglu, Simon Johnson, and James Robinson, the disease environment partly determined whether European colonists chose to settle and build European-style communities or resorted to unproductive extraction of natural and human resources. In tropical areas such as Western Africa, mortality among Europeans as a result of illnesses such as malaria and yellow fever prevented colonization of the continent for centuries. Instead, white merchants resorted to slave trading until the late 19th century. The colonization of Africa witnessed a



large-scale exploitation of its human and natural resources. Where the climate was more similar to that of Europe—as in the temperate “settler colonies” of South Africa, Australia, the United States, and Canada—institutions were installed that were based on private property rights and governments’ responsibility to an electorate. As a result, the political economy in these colonies acquired features similar to those of, for instance, the United Kingdom. In large parts of Africa, on the other hand, the extractive institutions created by the colonists prevail even now. According to the theory, the disease environment can thus partly explain the pattern of rent seeking, corruption, and patronage politics that still constitutes a major hindrance to African economic development.

Country Size

The size of political units has been an object of intense study among political philosophers since antiquity. Both Plato and Aristotle believed that the typical Greek city-state, with roughly 5,000 free men, was the ideal size of a political unit. Montesquieu also warned that large countries were more likely to host accumulated wealth, which could easily become the object of predatory struggles, and that socially optimal policies would be the exception since governments must devote all their energies to balancing numerous separate interests.

Country size should, however, in the long run be endogenously determined by geography as well as by institutional, economic, and military factors and events. Alberto Alesina and Enrico Spolaore proposed a theory where the optimal country size is determined through a trade-off between economies of scale in public goods provision, on the one hand, and preferences for heterogeneity in such goods, on the other. Large countries on average have a lower per capita cost of public goods such as defense, it was argued. Large countries, however, also contain a greater number of conflicting interests and groups. Their hypothesis further predicts that countries tend to be smaller under democratic and free trade regimes.

Alesina and Spolaore’s framework has been criticized for not being applicable to former

colonies, where borders often have not been the result of the type of rational calculations suggested above. Jeffrey Herbst argues that for Africa, colonial borders are often quite unnatural, crossing in the middle of ethnic as well as environmental zones. An important part of Africa’s political problems since independence stem from the fact that most countries are states without nations in the European sense. Still, Herbst argues that African borders also are an asset in governments’ state-making ambitions and in their attempts at broadcasting power from a core to a peripheral part of their territory.

Natural Resources

Empirical studies have repeatedly demonstrated that natural resource abundance has a significant negative effect on economic growth. This effect has become commonly known as the “curse of natural resources,” where natural resources are often defined as primary products, including oil, minerals, and agricultural products. One potential explanation for this curse is the “Dutch disease,” in which a booming natural resource sector draws labor away from the manufacturing sector and causes an appreciation of the real exchange rate, as occurred in the Netherlands after discovery of a large natural gas field in 1959. The negative effects on both the manufacturing sector and international trade are thought to be responsible for the poor growth performance of resource-rich countries in this case. Another potential problem associated with natural resource abundance is the reallocation of resources away from productive activities and toward rent seeking. Rent seeking can take many forms, from tariff protection and corruption to outright appropriation. In the extreme, the desire to control the rents from natural resources can lead to armed conflict and civil war. The primary result of increased rent-seeking activities is a decline in productivity, which in turn has a negative impact on economic growth.

The potential causes of such a “resource curse” are generally poor policies rather than natural resource abundance per se. Support for this claim can be found in a number of empirical studies that demonstrate that countries with sufficiently



strong institutions are able to escape the resource curse. Therefore, natural resource abundance only appears to constitute a curse in countries where the quality of the institutions is low.

It is also possible that resource abundance has a direct impact on the quality of institutions that are established in resource-rich countries. A low level of property rights protection allows the ruling elite to appropriate a greater portion of the country's natural resource rents. Therefore, the ruling elite in a resource-rich country may have the incentive to retain weak institutions or even weaken them further. This, in turn, makes it less likely that resource-rich countries will develop sufficiently strong institutions to escape the resource curse.

Trade

International trade has long been linked to economic growth and development. More recently, however, research has turned its attention to the effect of international trade on political variables such as corruption and rule of law. There are two avenues through which trade can influence political variables. The first is indirect, via higher national incomes. Empirical evidence has shown that countries that are more open to trade tend to have relatively higher national incomes. National income is in turn positively associated with stronger political institutions, as richer countries can afford to invest more in improving their institutional framework. The second avenue through which trade can affect institutions is direct. Proponents of this view argue that international trade acts as a disciplinary measure; countries that engage in trade are induced to improve their institutions in order to be competitive on the international stage.

Geography is believed to play an important role in determining the extent to which a country is open to international trade. A country's level of "natural openness" depends to a great degree on its geographical characteristics, such as length of coastline, remoteness, and island status. Furthermore, transportation costs are significantly affected by geography. Access to the sea or navigable rivers has historically been very important for trade, while natural barriers act to hinder

trade. Europe, composed to a great extent of peninsulas and large islands and with several large, navigable rivers, is characterized by a high degree of natural openness to trade. In contrast, Africa has little coastline relative to its geographical area, many landlocked countries, and few navigable rivers, with the Sahara acting as a large natural barrier. As a result, Africa is characterized by a low degree of natural openness to trade. These geographical differences can account for some of the observed differences in trade openness exhibited by the two continents and may as such contribute to the differences in the quality of their political institutions.

Even within Europe, there is reason to believe that geography has had an important effect on trade, which has carried over to political institutions. Daron Acemoglu, Simon Johnson, and James Robinson argue that Atlantic trade was largely responsible for the rise of Western Europe between the years 1500 and 1850. Atlantic trade not only brought about economic growth but also acted as an impetus to significant institutional change. Therefore, European countries with access to the North Atlantic gained an advantage in both economic and institutional terms.

Ola Olsson and Heather Congdon Fors

See also [Class, Geography and](#); [Class, Nature and](#); [Colonialism](#); [Critical Geopolitics](#); [Critical Human Geography](#); [Decolonization](#); [Dependency Theory](#); [Development Theory](#); [Diamond, Jared](#); [Economic Geography](#); [Environment and Development](#); [Environmental Justice](#); [Feminist Geographies](#); [Feminist Political Ecology](#); [Gender and Geography](#); [Globalization](#); [Governance](#); [Harvey, David](#); [Inequality and Geography](#); [Justice, Geography of](#); [Labor, Geography of](#); [Law, Geography of](#); [Malthusianism](#); [Marxism, Geography and](#); [Nature-Society Theory](#); [Neoliberalism](#); [New International Division of Labor](#); [Political Ecology](#); [Political Economy of Resources](#); [Political Geography](#); [Poverty](#); [Race and Nature](#); [Radical Geography](#); [Regulation Theory](#); [Resource Geography](#); [Scale, Social Production of](#); [Segregation and Geography](#); [Social Geography](#); [Socialism and Geography](#); [State](#); [Sustainable Development](#); [Trade](#); [Uneven Development](#); [Urban and Regional Development](#); [Urban Geography](#); [Walker, Richard](#); [Watts, Michael](#); [Wittfogel, Karl](#); [World-Systems Theory](#)



Further Readings

- Acemoglu, D., Johnson, S., & Robinson, J. (2005a). Institutions as the fundamental cause of long term growth. In P. Aghion & S. Durlauf (Eds.), *Handbook of economic growth* (pp. 385–464). Amsterdam: Elsevier.
- Acemoglu, D., Johnson, S., & Robinson, J. (2005b). The rise of Europe: Atlantic trade, institutional change and economic growth. *American Economic Review*, XCV, 546–579.
- Alesina, A., & Spolaore, E. (2003). *The size of nations*. Cambridge: MIT Press.
- Buchanan, J., & Tullock, G. (1962). *The calculus of consent*. Ann Arbor: University of Michigan Press.
- Diamond, J. (1997). *Guns, germs, and steel: The fates of human societies*. New York: W. W. Norton.
- Jones, E. (1981). *The European miracle*. Cambridge, UK: Cambridge University Press.
- Olson, M. (1965). *The logic of collective action*. Cambridge, UK: Cambridge University Press.
- Olsson, O. (2005). Geography and institutions: Plausible and implausible linkages. *Journal of Economics*, 10(Suppl. 1), 103–128.
- Persson, T., & Tabellini, G. (2003). *The economic effects of constitutions*. Cambridge: MIT Press.
- Wittfogel, K. (1957). *Oriental despotism: A comparative study of total power*. New Haven, CT: Yale University Press.



POLITICAL ECONOMY OF RESOURCES

Political economy refers to interdisciplinary studies drawing on economics, law, history, and political science to explain how political institutions, the political environment, and economic systems affect the factors of production, namely, labor, land, and resources. Originally, political economy focused on the conditions under which production and consumption were organized within and among nation states. Thomas Malthus, Adam Smith, David Ricardo, and Karl Marx were proponents of this tradition. Today in geography, political economy refers to neo- and post-Marxian interpretations of labor, land, and natural resource

exploitation and development and underdevelopment in the global economy. This entry will focus on the latter factor, the political economy of resources.

Dependency Theory and the World Systems Approach

Dependency and world systems theories explain economic development in various parts of the world at different times in history. In the 1960s, dependency theory and the world systems approach used the terms *core* and *periphery* to describe and analyze global political and economic systems. According to both theories, core countries have high levels of industrial production capacity, use advanced technologies, and dominate international trade, while the periphery describes agrarian societies and those with modest industrial infrastructures, which largely serve core country resource and market needs. The core holds political and economic power over the periphery, which is reflected in control over trade and finance. This pattern was particularly prevalent under colonial rule, when, for example, transportation systems were developed mainly to provide the core countries access to the resources and markets of the periphery. This situation formally ended with decolonization following World War II, but the legacy of colonialism lives on in many parts of the world, and dependency in terms of trade and finance assures the core of continued economic and political dominance. The semiperiphery, with its newly emerging economies, has a higher level of autonomy and has experienced significant economic development over the past few decades based on the comparative advantage of low-cost labor and, in some cases, abundant resources.

The world systems approach examines core-periphery relations as the functional evolution of the world capitalist economy. The needs and problems of the underlying system of economic and political relations is its focus. Dependency theory adopts the standpoint of the periphery to examine the functioning of core-periphery interactions. Its adherents developed an extensive explanation of comprador elites in the periphery who facilitate colonial or neocolonial interests.



Economic Globalization and Resources

During the past quarter-century—guided by neoliberal economic and political theory—global investment production and foreign trade increased rapidly. The World Trade Organization, the International Monetary Fund, and the World Bank have promoted neoliberal policies to spur economic globalization. However, the major players behind the increase in worldwide resource exploitation and economic production are multinational corporations.

The rise and dominance of multinational corporations are closely related to advanced technological development (in communication and transportation in particular) and advanced global corporate management aided by free trade regimes. As a consequence, economies of scale and marketing and the exploitation of resources have expanded geographically. Traditionally (under colonial regimes), core-country industrial corporations would invest in resource extraction in countries of the periphery and process resources as raw materials in factories in the core country. Today, global markets create a new geographical division of labor whereby core corporations not only invest in raw materials extraction (through mining or from plantations) but also relocate labor- and resource-intensive manufacturing to peripheral countries where low-cost labor and sometimes less restrictive environmental regulations prevail. In pursuit of growth and profit, multinational corporations contract with local mining companies, plantation owners, or agribusinesses to secure raw materials and establish finance and trade networks to move not only materials but also their economic value to the global market.

Today, multinational corporations invest in countries that still have large deposits of coal or other cheap energy sources to be used in process manufacturing of aluminum, iron, steel, cement, and concrete and in paper and pulp production. China, India, Brazil, and Russia (in the semiperiphery) are among the countries of interest, and their economies have been growing rapidly. Also, corporate capital uses cheap labor in countries with few regulatory controls to operate a global assembly line for the production of electronic information technologies. This pattern of

development has led critics to question the desirability of economic globalization.

Resources and Sustainable Development

Economic development of the periphery and semiperiphery forces the poor in these countries to bear the brunt of unsustainable growth. Severe damage to ecosystems that support local livelihoods has been widely noted. In response, local communities increasingly protest against the entry of large mining and oil companies and other foreign businesses. Conflicts in the Niger Delta and the Amazon rain forest are examples of the effects of global-scale exploitation of resources. Livelihood-linked environmental consequences include depleted soils, deforested lands, polluted groundwater, ecosystem destruction, climate change, and extinction of species and ways of life.

In response, core countries and multinational corporations have sought a remedy in the idea of sustainable development, defined by the World Commission on Environment and Development as development that meets the needs of the present generation without compromising the ability of future generations to meet theirs. The proposal suggests that economic growth can be sustained while averting or reducing many environmental and livelihood threats. International programs and treaties ranging from the Millennium Development Goals to the United Nations Framework Convention on Climate Change attest to the popularity of the idea.

The experience with the practice of sustainable development has left many to doubt its efficacy. The problem of climate change illustrates some of the dilemmas related to the promise of sustainable development. Among these is the fact that the continued economic growth of the core countries has so far exacerbated the buildup of greenhouse gases. Despite the rapid introduction of so-called clean and green technologies, in the new century, the largest source of greenhouse gas emissions by far are the core countries of North America and Europe and Japan, Australia, and New Zealand. On a per capita basis, this bloc averages emissions in excess of 15 tons/yr. (year), while the peripheral countries of Asia, Africa, and Latin America average less than 3 tons/yr. The requirement to avert further warming is reduction of the world per capita



average to 3.3 tons. Recent research has shown that this target can only be met if the United States and other core countries dramatically lower their emissions over the next 10 to 20 yrs.—a task that requires a shift to “steady-state” rather than growth-based economies. Additionally, the only mechanism to date to regulate greenhouse gas emissions focuses on countries but, significantly, not multinational corporations. Yet many of the decisions that affect the volume of greenhouse gas emissions have been made by corporate capital acting beyond the reach of governments. Failure to address the so-called corporate greenhouse compromises the world’s ability to address the most comprehensive threat to livelihoods and the health of the planet.

The field of political economy of natural resources has now embarked on a search for a genuinely equitable and sustainable future. There is increasing interest in “bottom-up” strategies proposed by civil society to construct a postglobalist political economy in which the geography of economy, politics, and the environment is centered on empowered communities rather than on global capital and technologies.

Yda Schreuder and John Byrne

See also **Common Pool Resources; Dependency Theory; Development Theory; Ecological Economics; Energy Resources; Globalization; Mining and Geography; Nonrenewable Resources; Petroleum; Political Economy; Population, Environment, and Development; Renewable Resources; Resource Economics; Sustainable Development; Underdevelopment; Uneven Development; World-Systems Theory**

Further Readings

- Byrne, J. B., Kurdgelashvili, L., & Hughes, K. (2008). Undoing atmospheric harm: Civil action to shrink the carbon footprint. In P. Droege (Ed.), *Urban energy transition* (pp. 27–53). Oxford, UK: Elsevier Science.
- Dicken, P. (2007). *Global shift* (5th ed.). New York: Guilford Press.
- Frank, A. G. (1967). *Capitalism and underdevelopment in Latin America*. New York: Monthly Review Press.

Knox, P., Agnew, J., & McCarthy, L. (2008). *The geography of the world economy* (5th ed.). London: Hodder & Stoughton.

Schreuder, Y. (2009). *The corporate greenhouse*. London: Zed Books.

Wallerstein, I. (2004). *World-systems analysis*. Durham, NC: Duke University Press.

World Commission on Environment and Development. (1987). *Our common future*. Oxford, UK: Oxford University Press. Retrieved January 22, 2010, from www.worldinbalance.net/intagreements/1987-brundtland.php



POLITICAL GEOGRAPHY

Political geography is concerned with the interplay of politics and geography. Precisely how the geographical informs the political, as well as how the political informs geography, is open to discussion, interpretation, and debate. For instance, at the turn of the 20th century, political geography was preoccupied with explaining how the physical and environmental characteristics of the Earth shaped and dictated the world of the great powers of Europe, but over time, such explanations would be rejected. At the beginning of the 21st century, political geography is far more diverse in its subject matter, more cosmopolitan in extent, and open to examining a range of questions concerning, for example, territory, sovereignty, identity, and power at the supra- and subnational scales of analysis. Despite these shifts, contemporary political geography remains engaged with fundamental questions about the complementary linkages between geography and politics.

History of Political Geography

Origins

As one of the three traditional pillars of human geography, social or cultural and economic geography being the other two, political geography can trace its historical roots to the German geographer, Friedrich Ratzel. In 1887, Ratzel published *Politische Geographie*, in which he introduced the idea that the size of a state is a



measure of its cultural prowess. Moreover, for societies to survive and prosper, territorial expansion at the expense of weaker states was considered to be a natural and necessary process. Ratzel used the term *Lebensraum*, or living space, to describe such areas of expansion. Making such direct and causal linkages between environment, society, and culture was not uncommon in the field of geography, which at the time was primarily found in European universities, and such approaches were in fact considered to be scientific in nature.

Paralleling Ratzel's writings and ideas concerning the organic nature of states were those of the English geographer Sir Halford Mackinder. In his 1904 work, *The Geographical Pivot of History*, Mackinder established the underpinnings for his heartland theory, which states, "Who rules East Europe commands the Heartland/Who rules the Heartland commands the World-Island [i.e., Eurasia]/Who rules the World-Island commands the World" (p. 186). Mackinder's heartland theory was used to illustrate the geostrategic threats that the British Empire faced, namely, from Germany and Russia. Subsequently, in the aftermath of World War I, Mackinder would apply his ideas as he and other geographers were consulted about the redrawing of national borders in Europe at Versailles.

Geopolitics and Its Critics

Though Ratzel and Mackinder are often considered to be the founding fathers of political geography, it was their use and application of geography to serve the national interest that led to the development of what the Swedish geographer Rudolf Kjellén called "geopolitics." Primarily concerned with territorial disputes and claims between Norway and Sweden, Kjellén was the first to use the term to describe the practice of creating geographical justifications in the pursuit of national goals. Considered to be an integral component of political geography today, geopolitics emerged in the early 20th century as a tool to justify and shape foreign policy.

During the interwar period of the 20th century, several Germans were drawn to the ideas developed by Ratzel and Mackinder, and they developed a particular type of geopolitics that aimed to

serve the German state. The most prominent German geopolitician was Karl Haushofer, who is credited with developing and promoting the idea of the "pan-region." According to the German school of geopolitics established by Haushofer, the world could be divided into four autarkic, or self-sufficient, pan-regions (i.e., Pan-America, Eur-Africa, Pan-Russia, and the East Asian Co-Prosperity Sphere), with Germany acting as the ruling state of the Eur-African pan-region. Though Haushofer had connections with the Nazi leadership, the influence of his geopolitical ideas and visions on Nazi expansionism remains debatable.

Concurrently, the American geographer Isaiah Bowman engaged in a political geography that was more concerned with taking stock of the world's political problems than promoting the national interest, though he was not entirely neutral, since he was chief geography advisor to the U.S. government in the years following World War I. Bowman authored *The New World: Problems in Political Geography* in 1921. His work covered an enormous range of topics—many of which are just as salient at the beginning of the 21st century as they were at the beginning of the 20th—such as border issues and disputes around the world, the political geography of natural resources, and the status of ethnic minorities. Despite Bowman's efforts to distinguish political geography as scientific and objective, versus a geopolitics driven by state interests and ambitions, the enterprise of political geography would be tainted by its association with geopolitics, in particular, the geopolitics of the Third Reich.

Political geography and geopolitics remained very uneasy bedfellows throughout the Cold War. Due, in part, to the damning associations that geopolitics had with Nazi aggression and atrocities, political geography quickly faded into the background in both policy and academic circles. With little innovative or substantive research emerging to support or to advance thinking in the subfield during this period, political geography was relegated to the classroom. Perhaps the most notable exception to the retreat of political geography during this period came from the works of the French-trained geographer Jean Gottman. The central premise underlying Gottman's work was that state formation, and the system of states at large, was a function of centripetal and centrifugal



social forces. The integration of the state system was therefore determined by the degree to which these competing forces balanced each other out. Gottman can be considered ahead of his time, because his work did little to resuscitate or revive the subfield, though it would later be considered pathbreaking by many. This is not to say that political geography, and in particular geopolitics, disappeared entirely during the Cold War; rather, it was being practiced by policymakers, academics, and others, who were careful not to invoke the term *geopolitics*. In its place, an entirely new set of stylized terms and ideological concepts emerged, for instance, “the Truman doctrine,” the “strategy of containment,” and “domino theory.” Though such ideas were clearly grounded in geographically informed foreign policies and strategies, at the time, they were not considered to be geopolitical or geopolitics per se.

The Quantitative Revolution

It was not until the 1960s that political geography began to emerge from its marginalized position, especially when compared with its counterparts, social and economic geography. Drawing from developments and advances across geography and other social sciences, but most notably political science, political geographers began to move beyond providing descriptions of the geographic distribution of states and inventories of their attributes. In large part motivated by what is referred to as the quantitative revolution in social science, geographers began to apply statistical techniques and quantitative methods to their own research. Moreover, it was during this period that theories to explain spatial patterns and behavior were constructed and used to guide research. The blending of quantitative methods and location theory spawned what is referred to as spatial analysis, which in turn attracted many new geographers to the discipline.

One topic within political geography that was identified to be especially well suited for such spatial analyses was elections. Though electoral geography can trace its roots back to the ecological analyses of the French geographer Andre Siegfried and his work in the Ardeche region of France, it was not until the 1960s that political geographers began to systematically analyze and

attempt to explain democratic outcomes from a geographic perspective. Several political geographers began to concern themselves with explaining voting patterns, assessing the geographical influences on voting (e.g., neighborhood effects), and evaluating how votes are translated into seats across a democracy. Though elections can indeed be characterized as the ideal political geographic event to examine with spatial analysis, the politically charged atmosphere of the 1960s would also have profound and lasting impacts on the social sciences, political geography included.

Political Economy

The sociopolitical movements, unrest, and upheavals that swept across the United States and Europe in the late 1960s ushered in notable intellectual changes in both British and American universities during the 1970s. Perhaps the most influential change in political geography came with the adoption of political-economy approaches across the social sciences, based on Marxist thought, to understand and explain the historical bases, conflicts, and consequences of capitalism. Such approaches allowed political geographers to reorient, reexamine, and reevaluate questions in political geography in intellectually innovative and engaging ways. From core-periphery relationships to the inequalities and inequities that the capitalist world economy produced, the topics that Marxist political economy addressed spawned and invigorated an entire generation of so-called radical geographers. Moreover, such radical approaches provided an attractive alternative for many who found the spatial analytic approach too staid and limited in theoretical power. Despite differences and divisions concerning how political geography was to be engaged in, the beginning of the 1980s marked a resurgence of interest in the subfield.

Postmodernism and Poststructuralism

Just as political economy approaches to understanding the world economy transformed the social sciences in the 1970s, the diffusion of so-called postmodern and poststructuralist perspectives in the late 1980s and early 1990s attempted to reorient and challenge modes of



inquiry, thinking, and knowing across the social sciences. In particular, notions of objectivity and the singular nature of theory in social science were questioned, as was the neutrality of language and discourse. Though criticized for their failure to extend or contribute to knowledge in itself, such approaches were embraced by several political geographers. One of the most noteworthy developments within political geography during this period was the development of “critical geopolitics.” Concerned with how and why geopolitical discourses are constructed by elites, and practiced and understood vis-à-vis foreign policy, the emergence of critical geopolitics marked the reclamation of the term *geopolitics* by political geographers and also permitted political geographers to shed much of the baggage once associated with German geopolitics.

The Role of the Nation-State

Notwithstanding discussions about how social science, including political geography, should be practiced, the dramatic transformation of the world political map during the late 1980s and 1990s provided much fodder to renew interest in and expand research and extend thinking on matters of great relevance to the subfield. The end of the Cold War, marked by the fall of the Berlin Wall, the collapse of communism across Eastern Europe, and the subsequent disintegration of the Soviet Union, not only altered the balance of world power but also forced many—and especially political geographers—to reflect on and reexamine their worldviews. Similarly, the emergence of new political arrangements and economic realities across the globe, for instance, the creation of a multinational coalition to wage war in the Persian Gulf and the consolidation of the European Union, raised questions about the role and future of the nation-state. With the diverging processes of, on the one hand, geo-economic integration (e.g., the European Union) and, on the other, geopolitical disintegration (e.g., the break-up of the Soviet Union, war in the Balkans), political geographic research tackled more and more questions beyond the traditional “global,” “nation-state,” and “local/urban” scales of analysis and focused more on the politics of nonstate actors and groups.

Political Geography in the 21st Century

This trend of examining and analyzing issues beyond and below the scale of the nation-state continues within political geography at the beginning of the 21st century. Events such as the terrorist attacks against the United States in September 2001, the subsequent “war on terror,” the rise of religious fundamentalism, ongoing ethnic conflicts, and the increase in the number of democratic elections held around the world have indeed served to reinforce the significance of political geography. Furthermore, the social reactions to, and political consequences of, these events have also generated new and notable areas of interest for political geographers. For instance, the events surrounding the terrorist attacks of September 2001 and the wars waged in Iraq and Afghanistan continue to raise several questions about the nature of democracy, territory, sovereignty, and identity as well as unforeseen issues regarding citizenship, privacy, and individual human rights.

Complementing these “political” questions are those related to “geography,” which arguably represents a relatively new thematic area for political geographers in the 21st century. In part due to the development and rapid diffusion of geographic information technology, namely, geographic information systems (GIS), the global positioning system (GPS), and remote sensing (RS), environmental issues and awareness have indeed reentered political geography, and public discussion more generally. Though there may be a relatively high level of consensus regarding whether or not climate change and global warming are indeed occurring, the politics of climate change and global warming—or what can be done about them, who will do it, and where it will be done—remains far more uncertain, if not contested. Similarly, conflicts over scarce natural resources, such as water, land, and oil, are becoming more common, not only between states but also at the supra- and substate levels. Finally, the application of geographic information technology itself, to watch over individuals and groups, to monitor the environment, to measure natural resources, to control public and private spaces, and to wage and sustain war, also raises a host of new and unexpected political geographic questions, consequences, and concerns.



It can be surmised that contemporary political geography is both a broad and a deep field of inquiry, like its progenitor, geography. Whether or not the diversity of subject matter and approach in political geography is its greatest strength, or most noteworthy shortcoming, remains open to discussion. Nevertheless, perhaps one of the most significant developments within political geography over the past century is the recognition that knowledge, understanding, and geography itself are historically contingent. In other words, to understand the concepts, objects, and subjects of political geography, an awareness of the sociohistorical context from which they emerged and in which they exist is central. A parallel development that is just as significant is the expansion of the subfield beyond the Anglophonic realm. In this regard, political geography is currently far more cosmopolitan, diverse, and inclusive in terms of those who practice it, what it is concerned with, and how it is engaged in than at any other time in history.

The circumstances, events, and approaches discussed above have also led to the rediscovery of political geography, and geography at large. Some come to political geography fairly knowledgeable about its history and methods, while others are far less aware of its evolution and implications. Though recent discussions about the environment and geography as they relate to politics are unlikely to invoke the particular ideas of Ratzel or his contemporaries, it is not uncommon to come across ideas in the mass media or popular science that suggest environmental determinism. In this respect, has political geography come full circle in a little more than a century, with relatively little to offer, and are we doomed to repeat history? On the contrary, and as alluded to above, at no other time in history have political geographers been more keenly aware of and more actively engaged with understanding how geography shapes and informs politics and, conversely, how politics shapes and informs geography. It is precisely this understanding that makes contemporary political geography a vital and key component of geography. From long-standing questions about the geopolitics of inter- and intrastate conflict to critical approaches to how scales of analysis are themselves politicized, political geography will continue to be a vibrant and engaging enterprise.

Michael Shin

See also Agnew, John; Anarchism and Geography; Antiglobalization; Borders and Boundaries; Citizenship; Cold War, Geography of; Colonialism; Communism and Geography; Critical Geopolitics; Cultural Geography; Decolonization; Democracy; Domino Theory; Electoral Geography; Geopolitics; Globalization; Haushofer, Karl; Hegemony; Human Geography, History of; Identity, Geography and; Imperialism; Law, Geography of; Military Geography; Nation; Nationalism; Political Ecology; Political Economy; Race and Empire; Ratzel, Friedrich; Redistricting; Resistance, Geographies of; Sovereignty; State; Supranational Integration; Territory; Terrorism, Geography of; Urban Policy; War, Geography of; World-Systems Theory

Further Readings

- Agnew, J. (2002). *Making political geography*. London: Arnold.
- Agnew, J., & Corbridge, S. (1995). *Mastering space: Territory, hegemony and international political economy*. London: Routledge.
- Agnew, J., Mitchell, K., & Toal, G. (Eds.). (2007). *A companion to political geography*. New York: Wiley-Blackwell.
- Cox, K., Low, M., & Robinson, J. (Eds.). (2007). *The SAGE handbook of political geography*. Thousand Oaks, CA: Sage.
- Flint, C., & Taylor, P. (2007). *Political geography: World-economy, nation-state and locality*. New York: Prentice Hall.
- Gallagher, C., Dahlman, C. T., Gilmartin, M., & Mountz, A. (2009). *Key concepts in political geography*. Thousand Oaks, CA: Sage.
- Ó Tuathail, G. (1996). *Critical geopolitics*. Minneapolis: University of Minnesota Press.



POLYCHLORINATED BIPHENYLS (PCBs)

Polychlorinated biphenyls (PCBs) are a class of odorless, liquid, synthetic organic chemicals containing chlorine, hydrogen, and carbon that persist in the environment following use. PCBs have many applications, including dielectric fluid in electrical capacitors and transformers, hydraulic



fluids and lubricants, flame retardants, plasticizers, and carbonless copy paper. PCBs have been manufactured and used worldwide since their introduction in 1927, with Monsanto controlling the U.S. market since 1935 and accounting for half the global production.

PCBs have been widely used for more than 75 years, with about 1.65 million tons of cumulative production worldwide. These chemicals have several advantages: fire resistance, low electrical conductivity, high resistance to thermal breakdown, and high chemical stability. Unfortunately, due to their persistence, bioaccumulation, and biomagnification, they can cause several adverse health effects as they collect in fatty tissues in humans and other exposed animals in both terrestrial and aquatic systems. These include liver and immune system disorders, irritation of the skin and eyes, reproductive and developmental effects, and probably several types of cancer.

The United States banned the manufacturing, processing, distribution, and use of PCBs with the passage of the Toxic Substance Control Act in 1976. Internationally, PCBs are one of nine chemicals slated for elimination by the 2001 Stockholm Convention on Persistent Organic Pollutants, which took effect in May 2004 and will be fully implemented by 2025. Despite these efforts, large volumes of PCBs still exist in the environment. Disposal options include incineration, ultrasound, irradiation, chemical and thermal treatment, and special landfills for PCB-contaminated sediments and articles.

PCBs have been implicated in several major incidents of environmental contamination. Probably the first major case was in 1968 in Kyushu, Japan, where nearly 1,800 residents fell ill after eating Kanemi rice bran oil (yusho) contaminated with PCBs. Subsequently, more than 50 people died. A similar incident occurred in Taiwan in 1979. In several areas of the United States, thousands of chickens and hogs had to be slaughtered because they ate PCB-tainted feed. General Electric (GE), a large user of PCBs, dumped 1.3 million pounds of the chemicals into the Hudson River, New York, from 1947 until 1977. An early case of environmental justice involved the creation, in 1982, of a landfill for PCB-contaminated soil in rural Warren County, North Carolina, a predominantly poor African American community.

Following years of PCB dumping by paper mills into the Fox River and Green Bay, Wisconsin, a natural resource damage assessment was conducted, leading to a settlement in 2004 of \$60 million in compensation and restoration costs. Additional PCB dumping, causing concern over fish and shellfish contamination, has been widespread in the Great Lakes region. High levels of PCBs have even shown up in native peoples and wildlife in Northern Canada and Alaska due to long-distance transport. Most recently, nine pig farms in Ireland had used PCB-contaminated feed, resulting in the withdrawal and disposal of pork-containing products purchased in Ireland between September and December 2008.

Barry D. Solomon

See also **Chemical Spills, Environment, and Society; Chlorinated Hydrocarbons; Environmental Justice; Waste Incineration**

Further Readings

Visser, M. J. (2007). *Cold, clear, and deadly: Unraveling a toxic legacy*. East Lansing: Michigan State University Press.



POPULAR CULTURE, GEOGRAPHY AND

The term *popular culture* is often used colloquially and by commentators in ways that are complex and contradictory. Common to all definitions, though, is the idea that popular culture is associated with mass consumption. Popular culture can thus be seen to include everything from magazines, movies, and television to Internet phenomena such as Facebook and MySpace. Popular culture generally refers to the field of material culture and practice that is associated with everyday people, usually in opposition to “high” culture, which refers to the material culture and practice associated with socioeconomic elites. Alternatively, popular culture can refer to a globalizing



Western culture that is seen in opposition to local folk cultures. In either case, popular culture is usually framed in negative terms, although this has changed in the social sciences and humanities over the past few decades.

Geography has engaged with popular culture in two ways. In the first, popular culture is theorized as a commodity, with a few sites emerging as sites of production, complemented by broader patterns of consumption. In the second formulation, popular culture is theorized as a purveyor of ideology, with geographers considering the messages and ideologies contained within it—either as a source of anxiety and danger or as a tool for creating communities. This entry first examines the origins of popular culture and then discusses the popular geographies of production and consumption. It then explores the ways popular culture is theorized in opposition to folk culture as part of the larger analysis of globalization and concludes with a look at poststructuralist approaches to popular culture and its meaning.

Origins of Popular Culture

In its original usage, *popular culture* was pejorative, referring to the culture of the masses, which was seen as normatively inferior to that of socioeconomic elites (high culture). This social denigration and devaluation by and large continue to the present day in popular discourse and to a certain extent in academic discourse as well. However, as cultural authority has been increasingly undermined in Europe and North America since the 1960s, the line between popular and high cultures has become increasingly difficult to define. Indeed, the rise of technologies associated with Web 2.0 (including user-generated fare) has ostensibly led to a process of aesthetic democratization, with fans now exerting more and more control over creative processes, and even populist cultural commentators such as *Rolling Stone* magazine and MTV are losing their authority. This relationship between high and popular culture, however, is not static. High culture draws inspiration from popular culture and vice versa, thus blurring the distinctions between them. This is most apparent when these two forms of culture share a medium. When opera legend Luciano Pavarotti performed alongside the rock band U2

(in “Miss Sarajevo,” 1995), was the performance popular or high culture? While aesthetic quality is purportedly the criterion on which such a distinction is based, in reality, it has more to do with market segmentation. The more popular a cultural artifact becomes, the more “debased” it is perceived to be. Thus, the aesthetic assessment of culture should be understood to be just as much about identity and subjectivity as it is about the cultural artifact itself.

Popular Geographies of Production and Consumption

The use of the term *popular culture* masks a great variety of strands within consumerist culture. For example, within popular culture, there exists a strand of artisanal popular culture, which consists of the more popular versions of high culture, complete with a focus on the auteur and the individual producer. As an example, one could easily turn to Stephen King’s novels or the graffiti of London’s Banksy. Another strand of difference to be found within popular culture is that of the mass media—such as television, magazines, music, radio, and some of the more traditional aspects of the Internet. These are generally the most corporate of popular culture artifacts, requiring large institutions to prepare and distribute material on a regular basis. A final strand worth noting is participatory popular culture, which includes fashion, sports, and the aforementioned Web 2.0 phenomena. What unites this strand is the more active role of the consumer (or participant); rather than just consuming a prepackaged product, the participant shapes the activity itself.

These three strands of popular culture reflect various scales of production, with the mass media generally at the macroscale, artisanal popular culture at the mesoscale, and participatory culture produced in and through consumers’ bodies. However, these scales are simply categories and do not reflect the interconnections between scales in the production of popular culture; for instance, while fashion is intimately connected to bodies and individual stylistic choices, it is also connected to corporate design and distribution networks. Networks such as these, although relatively stable, are always shifting in an effort to maintain the popularity on which their products are based. Thus, while certain cities have



Captain America, foreground, and Spiderman greeted many Pentagon-assigned service members and their children on April 28 for the unveiling of a custom comic book for members of the armed services. One of the oldest and most recognizable superhero characters in American comic books, Captain America sprang from the wartime political culture during World War II.

Source: Tech. Sgt. Cherie A. Thurlby, United States Air Force (<http://www.defenselink.mil/news/newsarticle.aspx?id=31325>).

emerged as command-and-control centers for the popular culture industries, such as Los Angeles, New York City, London, Paris, Milan, Cairo, Mumbai, and so on, this centrality is contingent on the ability of these centers to market difference from other “exotic” destinations. For instance, denim jeans have become de rigueur around the world despite their origins in the American West. Similarly, reggae music from the Caribbean has become commodified and sold around the world by record companies based in the United States and elsewhere.

The distribution of popular culture around the world has been eased by several rounds of time-space compression. The earliest of these relevant to popular culture was the invention of the printing press, which boosted the distribution of copies of the Bible in vernacular languages and in turn boosted literacy rates. Thus was the market for pamphlets and other literature constructed. While this initial foray into mass media took quite some time to get under way, its impacts are still manifest today. In a world with rapidly innovating media,



such as radio, television, and the Internet, that are used to distribute popular culture (and news about popular culture), public and private spaces alike are colonized and commercialized. This has led to concerns over the content and impact of popular culture even as it becomes nearly impossible to geographically remove oneself from its grasp.

Globalization of Popular Culture

Linked to these concerns is a long-standing tradition within the subdiscipline of cultural geography. For many decades, cultural geographers have analyzed the impact of time-space compression on cultural forms around the world. This time-space compression is often referred to as globalization. *Globalization* is itself a much debated term, but in this context, it is couched as shifts in labor and other markets resulting from the transportation and communication revolutions and consequent changes in the global division of labor. Certainly in the West, and to a lesser extent in other parts of the world, goods from various parts of the world are on sale and at low prices heretofore impossible. This not only has economic implications but also has implications for perceptions of heterogeneity/homogeneity and cultural distinctiveness.

Popular culture itself has come to reflect these changes, not only outsourcing production of cultural artifacts to sites of lower wages and regulation but also seeking commodifiable difference to market and sell, as described above. Some believe that this growth of a “global culture” is a normative good, leads to declines in ethnic and religious intolerance, and heads off conflict through increased interaction with cultural “others.” Obvious examples include the growth of the practice of yoga in the West as a form of exercise and meditation and the growth of “ethnic” restaurants in small towns. Others view this as the co-optation of folk cultures, which are local, relatively stable cultures that are distinct from outside cultures. These cultures find themselves essentialized and frozen in a premodern position of “exotic-ness.” An obvious example of this is the new genre of “world music,” which depends on its “exotic” inputs to differentiate it from domestic music production. Both of these perspectives, the positive and the more pessimistic, are linked in that they view the cosmopolitan West as universal, or

incorporative of all cultures, while other regions are defined by their particularity and uniqueness.

Thus, either perspective can be understood as engaging in Orientalism, in which the West is considered progressive and tolerant, while the remaining regions of the world are relegated to their particular “ethnic” pasts. Globalization in this perspective can be seen as contributing to the discursive elevation of the West above other parts of the world through this claim to universalism. A criticism of that claim is that the inclusion of others’ cultures comes only on the terms of the West and its consumers. This criticism is most often leveled at the United States, which, as the global economic hegemon, has been asserting its desire for free trade and increased globalization over the past several decades. When this criticism is leveled at one country in particular (such as the United States), or at an elite few, that country is charged with cultural imperialism, because it is seen as constructing an artificial centrality in another country’s social life; whereas imperialism makes a country dependent on trade with its colonizer, cultural imperialism makes a country dependent on its relationship with the hegemon for self-understanding. Thus, the distribution of popular culture is about much more than markets—it is about identity, subjectivity, and intellectual decolonization.

In the popular/folk culture dichotomy, the difference is expressed through temporality, with popular culture being modern and folk culture being premodern or traditional. Modern social scientists have long anticipated (while the subalterns have feared) the final eradication of folk culture at the hands of a rapidly globalizing (Western) popular culture. However, this horizon of cultural homogeneity seems as far away as ever. Explanations tend to incorporate as an assumption that market domination creates cultural homogeneity, but this has simply not turned out to be true. This assumption overly conflates consumption with culture. Indeed, culture far exceeds consumption, including religion, language, diet, ritual, and so on. Thus, even if two people watch the same Will Ferrell movie, their reasons for watching the movie may be quite different. For instance, watching Will Ferrell could be a way to demonstrate youth, economic class, or something else entirely. In other words, the cultural meanings that the movie is laden with still vary according to



geography; thus, globalization of popular culture artifacts is not necessarily the same as Americanization. The domination of popular discourse by the frame of globalization for the past 20 years has led to the equation of popular culture with the commodities that are consumed. However, as this last example hints, popular culture is not just artifacts but what is done with them—identities are performed and meanings are inscribed.

Meaning and Ideology in Popular Culture

Much as the original printing press led to political shifts within the world of Christianity (i.e., the Reformation), new media technologies have often led to anxiety on the part of authorities, who feared that their alienation from flows of information would undermine their power. For example, the rise of new technological platforms at the nexus of information and entertainment (such as instant messaging, video-to-phone downloads, etc.) has generated a rash of concern by parents about the messages that their children are receiving, in part because the technological competence of parents is often less than that of their children. Similarly, governments have often used propaganda on their own or other populations but feared their own population's susceptibility to the same. This governmental desire to control the mediation of geopolitical content led to some of the first academic studies of audiences and the media. Inherent in this framing of "the problem" was an understanding of audiences as fundamentally accepting of propaganda, based on the then recent success of Nazi and Fascist propaganda in Europe. Fear of a similar communist ascendancy animated the Frankfurt School, a collection of scholars including Theodor Adorno and Max Horkheimer. Their analysis of the "culture industry," the aggregation of entertainment-focused corporations that claim to respond to consumer desires but instead produce (and standardize) those self-same desires, adopted the same perspective of passive audiences as the earlier studies of propaganda did but used it to advance an argument about capitalism and the way in which it is perpetuated. They argued that the effect of the culture industry was increased consumer passivity in the face of injustice, drawing parallels to the "bread and circuses" of ancient Rome.

Antonio Gramsci, who was writing at roughly the same time as Adorno and Horkheimer (but whose work became available in English much later through translation), was a communist jailed during the Fascist era in Italy. He turned his attention to the apparent ability of the capitalist state to forestall the communist revolution that Marx had argued was inevitable. He argued that the capitalist state produced a hierarchy in which bourgeois culture was superior to that of the masses. Thus, workers were alienated from their own culture as they sought to associate themselves culturally with more privileged groups. Gramsci's theory of hegemony was thus very similar to that of Adorno and Horkheimer in that it theorized popular culture to be a placebo that duped people into fundamentally irrational behavior (in that they ignored their own interests). The key difference between these two theories, however, is that hegemony implies some degree of compromise—elites have to make their culture interesting and recognizable to the lower classes. In both cases, however, the denigration of popular culture can be understood as a weapon used to alienate workers from their own popular culture. Gramsci argued that the communist revolution would remain on hold until an independent popular culture could foster an "authentic" class consciousness.

The next major rethinking of ideology and popular culture began in the 1960s with a school of thought that has come to be known as Cultural Studies. It takes as a starting point that popular culture is important and relevant but generally eschews the pessimism that is associated with earlier views of popular culture. Most of the work associated with Cultural Studies now has moved away from structural accounts, although Marxism remains a strong influence. However, post-structural theorists have taken center stage and have begun to change the working assumptions of popular culture, namely, that the audience is a passive recipient of others' ideologies. For example, Michel de Certeau has argued that institutions (e.g., Adorno and Horkheimer's culture industry and Gramsci's capitalist state) enact strategies to achieve their goals, while individuals, who are by definition more nimble than institutions, enact tactics to achieve their own goals. In the context of popular culture, this means that consumers of popular culture can take it and



rework it into something useful to them, taking the parts that they like, leaving others, or perhaps re-imagining the whole thing. An often cited example is the rise of “slash” fan fiction, in which (presumably) heterosexual characters from popular culture (e.g., Kirk and Spock from *Star Trek*, Xena and Gabrielle from *Xena: Warrior Princess*) are rewritten by fans as being in homosexual relationships with each other. Often this is done against the express wishes of the copyright holders, and it illustrates the problem with the propagandistic model of audiences—it simply does not explain the complexity of audience responses.

Audience responses, however, are not random and instead are rooted in interpretive communities that are often geographic in origin. David Livingstone’s work on the re-interpretation of theory as it travels has argued that there are two particular geographies to the interpretation of texts (and this can be broadly extended to include all forms of popular culture). The first, cartographies of textual reception, generally refers to differences in the interpretation of texts between regionally based cultural/linguistic communities. The second, cultural geographies of reading, refers to the structuring elements found in the processes of meaning making among networked identities (university students, evangelical Christians, etc.). Reading is thus not an isolated act but rather one that occurs in a social context. Therefore, the meanings that are available to any given reader are limited by the social context in which that reading is undertaken. This tension between the conceptualizations of popular culture as a structuring force on identities, and simultaneously as a cultural resource to be used tactically by consumers as a way of performing their own identities, is a realm of ongoing work by geographers.

Jason Dittmer

See also **Art and Geography; Consumption, Geographies of; Cultural Geography; Cyberspace; Everyday Life, Geography and; Film and Geography; Folk Culture and Geography; Food, Geography of; Hybrid Geographies; Media and Geography; Orientalism; Postmodernism; Spaces of Representation/Representational Spaces; Symbolism and Place; Television and Geography; Text/Textuality; Video Games, Geography and; Virtual Geographies**

Further Readings

- Adorno, T., & Horkheimer, M. (2002). *Dialectic of enlightenment: Philosophical fragments* (G. Noerr, Ed. & E. Jephcott, Trans.). Palo Alto, CA: Stanford University Press. (Original work published 1944)
- Anderson, B. (1991). *Imagined communities: Reflections on the origin and spread of nationalism*. New York City: Verso Books.
- Billig, M. (1995). *Banal nationalism*. Thousand Oaks, CA: Sage.
- Crothers, L. (2006). *Globalization and American popular culture*. Lanham, MD: Rowman & Littlefield.
- de Certeau, M. (1984). *The practice of everyday life*. Berkeley: University of California Press.
- Dittmer, J. (2005). Captain America’s empire: Reflections on identity, popular culture, and post-9/11 geopolitics. *Annals of the Association of American Geographers*, 95(3), 626–643.
- Dittmer, J. (2010). Popular culture, geopolitics, and identity. Lanham, MD: Rowman & Littlefield.
- Dodds, K. (2003). Licensed to stereotype: Popular geopolitics, James Bond and the spectre of Balkanism. *Geopolitics*, 8, 125–157.
- Gans, H. (1999). *Popular culture and high culture: An analysis and evaluation of taste*. New York: Basic Books.
- Gramsci, A. (1971). *Selections from the prison notebooks*. New York City: International Publishers.
- Kitchin, R., & Kneale, J. (Eds.). (2005). *Lost in space: Geographies of science fiction*. London: Continuum.
- Livingstone, D. (2005). Science, text and space: Thoughts on the geography of reading. *Transactions of the Institute of British Geographers*, 30, 391–401.
- Norcliffe, G., & Rendace, O. (2003). New geographies of comic book production in North America: The new artisan, distancing, and the periodic social economy. *Economic Geography*, 79, 241–264.
- Sharp, J. (2000). *Condensing the Cold War: Reader’s Digest and American identity*. Minneapolis: University of Minnesota Press.
- Storey, J. (2003). *Inventing popular culture: From folklore to globalization*. Oxford, UK: Blackwell.



POPULATION AND LAND DEGRADATION

The debate about population and land degradation has spanned decades, if not longer, with contrasting perceptions of whether people are victims of land degradation or land is a victim of anthropogenic influences. While the debate rages on, the impacts of land degradation on human well-being and development are self-evident. *Land degradation* is commonly defined by the United Nations Convention to Combat Desertification (UNCCD) as the reduction or loss of biological and economical productivity and of the complexity of terrestrial ecosystems. This includes soils, vegetation, other biota, and the ecological, biogeochemical, and hydrological processes that operate within ecosystems. This definition does not characterize degradation as entirely anthropogenic, despite unsustainable land use by humans being a key driver of land degradation.

Population Growth

Human population growth has been cited as a leading factor in land degradation and environmental change in general. Global population increased from 5 billion in 1987 to 7 billion in 2009, an average annual growth rate of 1.4%, with Africa and West Asia recording particularly high growth rates (Figure 1). This increase in population, together with the increase in the gap between the rich and the poor, in the relative access to goods, and in income-earning opportunities, has led to increased demand for food and energy, putting pressure on available environmental resources such as freshwater, fisheries, agricultural land, and forests.

Population changes are further influenced by forced and economic migration, which in turn affects settlement patterns, resulting in migrant refugees who are internally displaced. An estimated 25 million people have been forced to migrate as a result of environmental factors, with approximately 200 million threatened by displacement not only from environmental factors but for political and ethnic reasons as well. An estimated 2 billion people depend on dry lands that bear a legacy of land degradation, and 90% of them live in developing countries.

Migration

Rural to urban migration, or urbanization, is an especially prevalent trend in developing countries. An urban increase of 44%, from 28% to 29%, has been noted in northeast and southeast Asia and is predicted to reach 59% by 2025. An estimated 1 billion people reside in informal urban settlements around the world, with no proper housing or basic services, which has contributed significantly to urban and suburban spread and uncontrolled land transformation. High concentrations of the urban population reside along coastal areas, exerting undue pressure on coastal and marine ecosystems. While these direct causes of land degradation are important, it is the formal urban settlements that have been shown to exert greater pressure indirectly on land.

The multifaceted relationship between migration, urbanization, and, in turn, environmental change leads to natural disasters and land and ecosystem degradation, while consequently changing land use and the demand for ecosystem services. For example, the persistent shift from cereal to animal products and the recent move toward biofuels add to the demand for increased farm production, with unfavorable consequences for farmland rather than forestland. Negative impacts of urbanization, such as pollution, have been detrimental to human health. In Africa, it has been argued that children living in sub-Saharan cities in slums are more likely to die from waterborne diseases than are rural children. Ultimately, the population burden on natural resources and sustainability may increase as populations increase.

While population increase is a key driver of land use change and degradation, it is not the only factor involved. Economic development, poverty, and globalization are but some of the exacerbating factors driving unparalleled land use change and degradation. Globalization alone has economic, environmental, technological, political, and cultural dimensions, creating not only new opportunities but threats as well.

The Population and Land Degradation Debate

Population growth has resulted in increased demand for agricultural productivity, higher

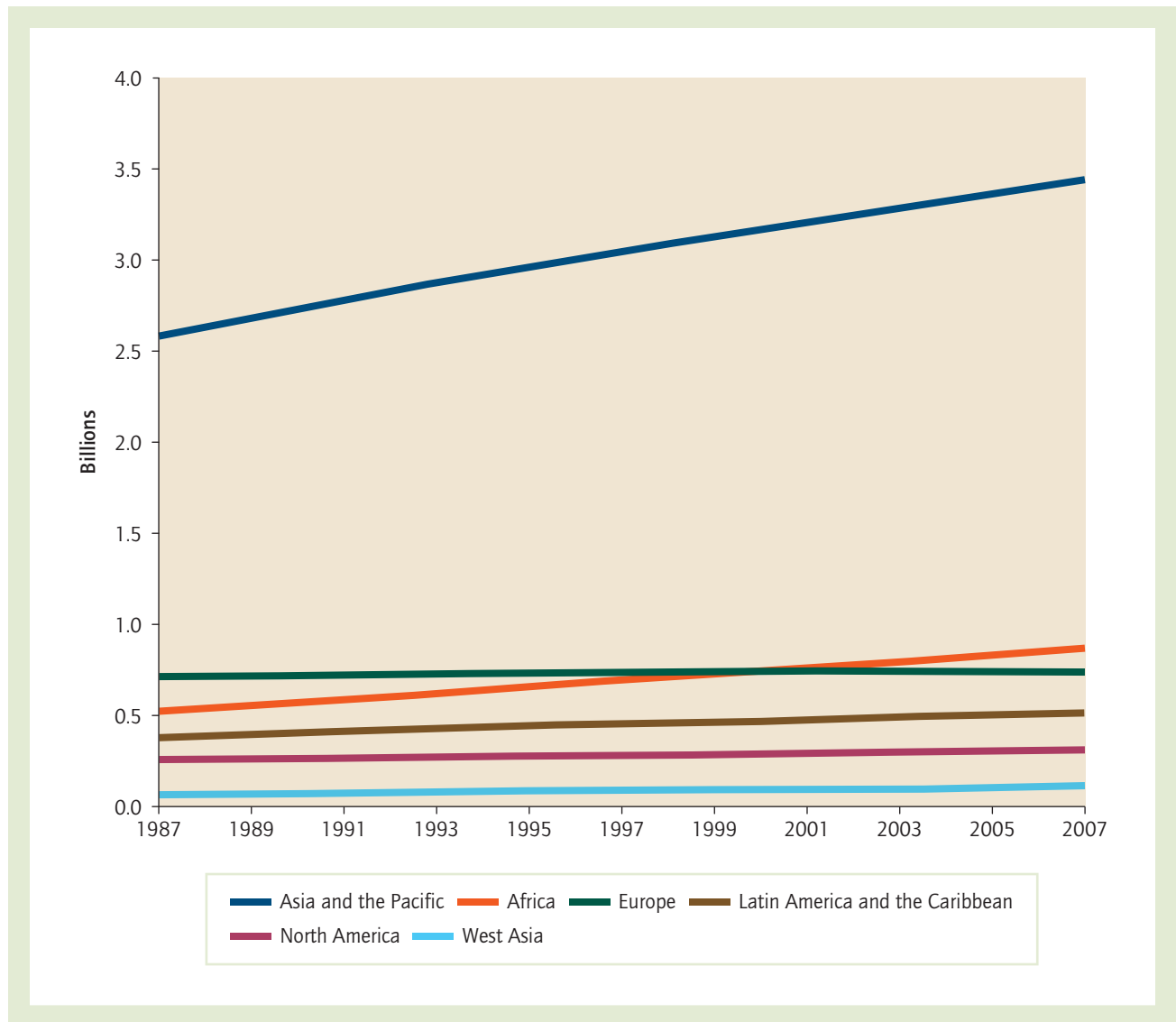


Figure 1 Population growth by region

Source: United Nations Environment Programme. (2007). *Global Environment Outlook: Environment for development* (GEO-4; Figure 1.4, p. 21).

incomes, and changes in consumption patterns. Inequitable land distribution, a legacy of colonialism and societal/cultural conflicts, has exacerbated the problem. While the causes of this multifaceted phenomenon have been contentious, the growth of the human population and the increase in anthropogenic influences receive the most blame for the current state of land degradation, especially in developing countries, where a significant portion of the population is dependent on subsistence farming.

Poverty also is a major cause of land degradation, with population growth and poverty mutually reinforcing each other to bring about a spiral of degradation. The neo-Malthusian hypothesis warns about the risks and impacts of population growth outstripping the natural resource demand for food and shelter. The neo-Malthusian theory further regards population growth and the environment to be in conflict, with the quest for food security coming at huge inevitable environmental costs, ultimately leading to an escalation in land



degradation, a decline in agricultural productivity, and greater food insecurity. The argument effectively states that the world would literally run out of food unless drastic steps are taken to protect the environment from people. Simultaneously, common property tenure systems also exacerbate the use of common property resources, leading to overuse and degradation due to practices such as overgrazing. People (especially the rural poor) have been blamed for misusing the resources at their disposal for short-term gains. Such land misuse is accentuated within the coping strategies employed in the face of food insecurity.

In contrast to the Malthusian view, food security and the environment are considered to be complementary and interdependent, with a healthy natural resource base providing food security. Population increase and income growth are argued to drive technological inventions such as agricultural intensification to solve food production constraints, thus achieving environmental and economical sustainability. It is further argued that the neo-Malthusian perception disregards the potential for economic development within sustainable environments when confronted with rapid population growth, assuming that agroecological zones have limited carrying capacities. Population growth, food security, and a healthy natural resource base are viewed as interdependent and mutually reinforcing for positive gain to both.

Case Study: Machakos, Kenya

Machakos, Kenya, is a case in point with respect to the intertwined nature of population growth, food security, and land degradation. In Machakos, despite a sixfold increase in population over roughly 50 years, there was a fourfold per capita increase in agricultural output while controlling and reversing land degradation of natural resources. While the success of Machakos has been attributed to financial aid and investments, traditional conservation practices such as terracing were made compulsory for agriculture, first by the government then by the farmers themselves. Agricultural intensification occurred in the areas of high population and high land potential, proving that population growth does not necessarily jeopardize the environment.

Land Degradation Impacts on Human Populations

Land degradation as a global development issue directly affects the natural resource base that supports subsistence livelihoods, agriculture, and manufacturing, limiting development opportunities for current and future generations. For example, deforestation and biodiversity loss affect income from tourism and contribute to food insecurity, challenging the eradication of extreme poverty and hunger, the first Millennium Development Goal. Nevertheless, unlike climate change, land degradation is for the most part politically invisible and ignored, with most of the countries that ratified the United Nations Convention to Combat Desertification (UNCCD) not formally addressing it. This inaction in tackling land degradation has resulted in a collective historical legacy from which recovery will be difficult (if not impossible).

Land degradation manifests through various processes including loss of vegetation, soil erosion leading to loss of fertility, deterioration of the physical structure, and loss of soil biodiversity. Also included is soil compaction, which leads to reduced infiltration and increased runoff salinity and sodicity. Downstream effects of degradation processes include water pollution, siltation of watercourses and reservoirs, and loss of animal and plant diversity, leading to loss of ecological function within the affected ecosystem. In turn, land degradation is viewed as a precursor of and a trigger for natural disasters such as landslides.

Globally, land use and land cover changes tend to increase and accelerate land degradation, especially in less developed countries. Land use change has both negative and positive effects on human well-being and on the provision of ecosystem services. Positively, the increase in food and forestry products has resulted in increased income and secure livelihoods for many. Negatively, land degradation, biodiversity loss, and disturbances of biophysical cycles (e.g., water and nutrients) are unfavorable for human welfare in many regions. Reduction in the quality and quantity of ecosystem goods and services through land degradation negatively affects access to material resources, eventually



leading to the inability of people to live lives they value.

The effects of soil erosion, particularly in the tropical regions where the majority of the population resides, could reduce agricultural yields, resulting in increased food insecurity, famine, and poverty, as well as forced migration, especially for impoverished people in poor countries. The demand for more food production may contribute to overexploitation of good agricultural soil and expansion into wooded and marginal areas that are highly susceptible to degradation. Human activities such as clearing of woodlands, logging, firewood collection, and charcoal production lead to deforestation, a component of land degradation. Studies have revealed that the highest rates of deforestation occur in areas where hunger is prevalent.

Land degradation impacts, leading to a possible decline in forest products and wild foods, increase the levels of poverty and malnutrition, especially since these resources are harvested often as coping strategies in the face of droughts, floods, and diseases such as the human immunodeficiency virus and acquired immune deficiency syndrome (HIV/AIDS). Although the poverty and degradation nexus has been a subject of debate, it still is a factor exacerbating land degradation in developing countries.

While agricultural intensification has resulted in more food being produced per hectare than previously, this has been at great environmental costs in the form of loss of habitat and biodiversity, less soil water retention, disturbance of the biogeochemical cycle, increased soil erosion leading to nutrient depletion, salinity, eutrophication, pollution from agrochemicals, and so on. Salinity is induced by irrigation and by the replacement of natural vegetation by crops and pastures that use less water, resulting in increased groundwater infiltration. These processes have led to hazards from floods, dust, pests, and landslides.

Land degradation is acute in mountainous regions, characterized by steep slopes, which allow high rates of soil erosion, and heavy rainfall, resulting in the loss of water retention capacity and conservation, nutrient depletion, and landslides. This problem is exacerbated by the poor and marginalized societies often residing in these areas. Apart from their ecosystem functions,

mountains are home to many unique cultures, which are threatened by the loss of ecosystem services such as water conservation and regulation; provision of food, fuel, and fiber; cultural richness; and diversity. Mountains are also home to significant biodiversity, which may be lost through land degradation. For example, in the United Nations University's Pamir Mountains project sites in Central Asia, the flora contains a unique mix of boreal, Siberian, Mongolian, Indo-Himalayan, and Iranian elements, including at least 5,500 known species of vascular plants, 1,500 of which are endemic.

Degraded lands require more resources to manage them. Poor people do not, however, have the resources due to unfavorable economic returns from agricultural production and poverty, which may constrain rural people from investing in environmentally sustainable practices and soil conservation.

Conclusion

Confronting the complex phenomenon of land degradation requires a global response aimed at increasing the productivity of land ecosystems and making sustainable agricultural production a priority, particularly in view of the urgent need for adaptation to climate change and biodiversity protection. These responses need to take into consideration the multifaceted nature of land degradation and provide solutions that are not only about stabilizing population growth but also include more livelihood options and capacity building through equity in opportunities and the distribution of environmental benefits and improvement in tenure and governance rights, among other factors.

Julia Mambo

See also Deforestation; Desertification; Developing World; Environmental Services; Environment and Development; Forest Degradation; Global Environmental Change; Hunger; Land Degradation; Malthusianism; Neo-Malthusianism; Peasants and Peasantry; Population and Land Use; Population, Environment, and Development; Poverty; Soil Degradation; Soil Erosion



Further Readings

- Devereux, S., & Maxwell, S. (Eds.). (2001). *Food security in sub-Saharan Africa*. Rugby, UK: Practical Action Publishing.
- Eswaran, H., Lal, R., & Reich, P. F. (2001). Land degradation: An overview. In E. M. Bridges, I. D. Hannam, L. R. Oldeman, F. W. T. Pening de Vries, S. J. Scherr, & S. Sompatpanit (Eds.), *Responses to land degradation*. Proceedings of the second international conference on land degradation and desertification, Khon Kaen, Thailand. New Delhi, India: Oxford University Press.
- Tiffen, M., & Mortimore, M. (2008). Environment, population growth and productivity in Kenya: A case study of Machakos District. *Policy Development Review*, 10(4), 359–387.
- United Nations Environment Programme. (2007). *Global Environment Outlook: Environment for development* (GEO-4). Retrieved December 29, 2008, from www.unep.org/geo/geo4/report/GEO-4_Report_Full_en.pdf



POPULATION AND LAND USE

The neoclassical economic model of population and land use originates from von Thünen's theory of agricultural land use, wherein the "highest and best use" of land depends on the cost of transporting the various crops it can yield to a central marketplace. Because different candidates (crops) have different transport costs—and offsetting market values—those with relatively high (low) transport costs end up being produced close to (far from) the marketplace. So, for example, if tomatoes cost more to transport than wheat, tomato farmers will outbid wheat farmers for locations adjacent to the marketplace.

In the 1960s, William Alonso, Edwin Mills, and Richard Muth (jointly credited but working independently) generalized the Thünen theory of agricultural land use to a theory of modern human settlement patterns. The framework describes a locational rent gradient that falls away from its peak around a business district located at the center of a circular region with a dense transportation network that is situated on an otherwise flat,

featureless plain. At market equilibrium, all households, which are assumed to be identical, attain exactly the same level of "utility" (satisfaction received from consuming a good or service), so the rent gradient reflects the trade-off between location and the cost of travel to and from the central business district. Meanwhile, a corresponding density gradient emerges as a result of households occupying greater amounts of space toward the urban fringe. To maintain a fixed level of utility, households consume more land through substitution with other goods as rent declines. The density gradient, and, with it, development, ends altogether once locational rent reaches zero, and the highest and best use of land is for agriculture or some other natural resource-oriented activity.

Somewhat more formally, the theory underpinning the models of population and land use assumes that households have a common utility function, say $U(z,s)$, which contains a composite good, or numeraire, z , and urban space, or land, s . An individual household's budgetary constraint is determined by its income, y , less the cost of travel, k , between the central business district and its location at radial distance, d :

$$y - k(d) = z + r(d)s,$$

where $k(d)$ is a continuous function that increases with d and $r(d)$ is the locational rent per unit of space at d . Within this framework, households maximize their utility by choosing some combination of the numeraire and land, subject to their particular—spatially explicit—budgetary constraint. The outcome of this choice is a household's bid-rent, $\rho(d,u)$, which is the maximum price it is willing to pay for land at distance d while maintaining a fixed level of utility, u . Simply put, bid-rent is the most that a household's members are willing to pay per unit of space to secure the right to occupy their location of choice, given that they derive happiness from both the land and other forms of consumption. In addition to land prices, bid-rent yields a household's optimal amount of land consumption, or lot size, $\varsigma(d,u)$, which is what ultimately gives the built environment its character (Figure 1).

Figure 1 illustrates how the bidding process translates into a physical pattern of settlement. It displays the marginal rate of substitution, described

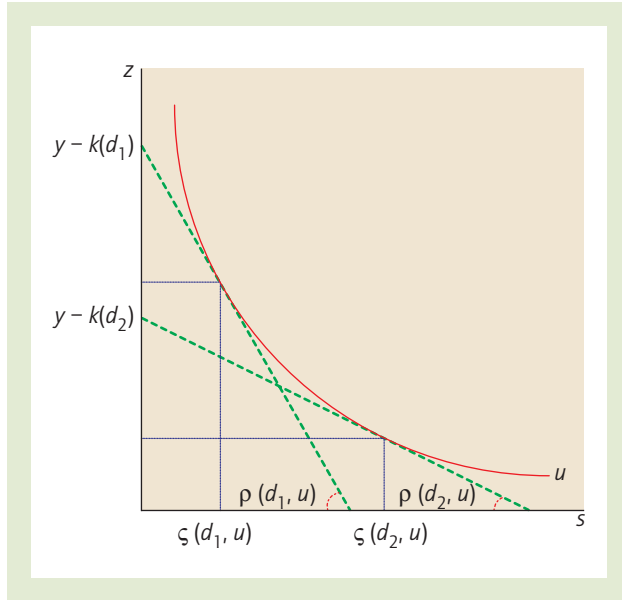


Figure 1 The bid-rent process and land use

Source: Carruthers, J. I., Lewis, S., Knaap, G. J., & Renner, R. N. (2009). Coming undone: A spatial hazard analysis of urban form [Electronic version]. *Papers in Regional Science*. Retrieved February 28, 2010, from www3.interscience.wiley.com/journal/122455515/abstract.

by an indifference curve (the *arc*) for a fixed level of utility, u , between the numeraire, z , and land, s , plus the budget constraints (the *dashed lines*) and corresponding consumption bundles (the *dotted lines*) associated with two households located at distances d_1 and d_2 from the central business district, where $d_1 < d_2$. Because the cost of travel to and from the central business district, $k(d)$, is lower at d_1 than it is at d_2 , the net income of the household located at d_1 is greater than the net income of the household at d_2 , or $y - k(d_1) > y - k(d_2)$. The two budget constraints, which must be tangent to the indifference curve for their respective households to each achieve utility level, u , show that (a) the bid-rent, which is equivalent to the slope of the budget constraint, for the household located at d_1 is greater than the bid-rent for the household located at d_2 , or $\rho(d_1, u) > \rho(d_2, u)$, and (b) the optimal lot size for the household located at d_1 is less than the optimal lot size for the household located at d_2 , or $\zeta(d_1, u) < \zeta(d_2, u)$.

In short, households located closer to the center of a region pay a higher price per unit of land and, so, consume less of it by substituting more of

the numeraire than households located farther out. Together, these basic precepts make up the so-called monocentric model of urban form, and they readily generalize more elaborate polycentric models having multiple business districts.

John I. Carruthers, Selma Lewis,
Gerrit Jan Knaap, and Robert N. Renner

Authors' note: This entry is adapted from Carruthers, Lewis, Knaap, and Renner (2009).

See also Models and Modeling; Thünen Model; Urban Land Use; Urban Sprawl

Further Readings

- Alonso, W. (1964). *Location and land use: Toward a general theory of land rent*. Cambridge, MA: Harvard University Press.
- Anas, A., Arnott, R., & Small, K. A. (1998). Urban spatial structure. *Journal of Economic Literature*, 36, 1426–1464.
- Brueckner, J. K. (1987). The structure of urban equilibria: A unified treatment of the Muth-Mills model. In E. S. Mills (Ed.), *Handbook of regional and urban economics* (Vol. 2, pp. 821–845). Amsterdam: North-Holland.
- Brueckner, J. K. (2000). Urban sprawl: Diagnosis and remedies. *International Regional Science Review*, 23, 160–171.
- Brueckner, J. K., & Fansler, D. A. (1983). The economics of urban sprawl: Theory and evidence on the spatial sizes of cities. *Review of Economics and Statistics*, 65, 479–482.
- Carruthers, J. I., Lewis, S., Knaap, G. J., & Renner, R. N. (2009). Coming undone: A spatial hazard analysis of urban form [Electronic version]. *Papers in Regional Science*. Retrieved February 28, 2010, from www3.interscience.wiley.com/journal/122455515/abstract
- Fujita, M. (1987). *Urban economic theory: Land use and city size*. Cambridge, UK: Cambridge University Press.
- Mills, E. S. (1971). *Studies in the structure of the urban economy*. Baltimore: Johns Hopkins University Press.
- Muth, R. F. (1969). *Cities and housing*. Chicago: University of Chicago Press.



POPULATION DENSITY

Population density is an arithmetic average expressing the number of people, animals, or plants per unit of area for a given spatial unit. For example, Denmark has an average of 121 persons/km² (square kilometer), and the island of Manhattan has 27,267 persons/km². Population density is an important indicator of the ecological relationship between populations and natural resources. In human populations, density has important impacts on the way people live and interact and on the efficiency and environmental impact of their settlements.

Density in Ecology

The defining theme of the science of ecology is the distribution and abundance of organisms—that is, their population densities. Ecologists and biogeographers have developed concepts and methods for the analysis of density patterns applicable to individual animal and plant populations (e.g., species) and to interacting populations within a given area. They have developed and refined the inherently geographical notions of range, carrying capacity, competition for resources, ecological niche, habitat, invasion, succession, and dispersal. Ecologists examine both the effects of environment on animal/plant population densities and the impacts of population densities on the environment (particularly on food resources and competing populations).

Ecological perspectives on density have been applied in anthropology, sociology, and human geography; to examine human evolution and dispersal; to assess the density impacts of hunting, gathering, and agricultural systems; and to study spatial competition and conflict between human groups. The Chicago School of human ecologists (Park, Burgess, and others) applied ecological notions of competition, invasion, and succession to patterns of ethnic and racial groups in large cities.

Global and Rural Population Densities

The term *ecumene* is derived from the ancient Greek word *oikoumene* and refers to the inhabited

(or inhabitable) portion of Earth's surface. This concept relates directly to population density, in that a cutoff density of 1 person/km² (approximately 2.5 persons/mi.² [square mile]) is frequently employed. Below this density level, human groups typically exist as widely scattered hunters, gatherers, or herders and lack permanent settlements. The major nonecumenic areas clearly relate to climate and specifically to areas of desert climate (e.g., the Sahara, outback Australia) or high-latitude areas with insufficient growing seasons for agriculture (e.g., the Canadian north, Siberia). Exceptions occur in the lowland tropics (e.g., Amazonia, interior Africa), where tropical diseases and poor transport access have deterred agricultural settlement, at least until recently. Another low-latitude exception is the Tibetan plateau, which mostly exceeds 4,000 meters in elevation.

The world's major population concentrations were all initially based on subsistence sedentary agriculture, with rural population densities ranging from 25 to 500 persons/km² or more. The three great *islands of mankind* (a term coined by the North American geographer William Bunge) are in East Asia, South Asia, and Europe. After several millennia of agricultural expansion, their limits are now clearly shaped by climate and terrain. Smaller concentrations of more than 25 persons/km² occur in southeast Asia, West Africa, the Central African highlands, and the highlands of Mexico, Central America, and South America. Their limits are partly related to the physical environment, but they are also shaped by factors such as farming technology, warfare, transport access, and disease. Both Edward Ackerman and Ester Boserup have provided authoritative reviews of the environmental, economic, technological, and cultural factors shaping world and regional density patterns.

Rather than using crude (arithmetic) density, population geographers prefer to calculate rural density levels based on the amount of arable land available (variously termed *agricultural*, *physiological*, or *nutritional density*). Factoring in land quality and agricultural practices, the maximum density, or *carrying capacity*, of the land may then be assessed. Though criticized as a crude application of Malthusian thinking, more applicable in biogeography than in human

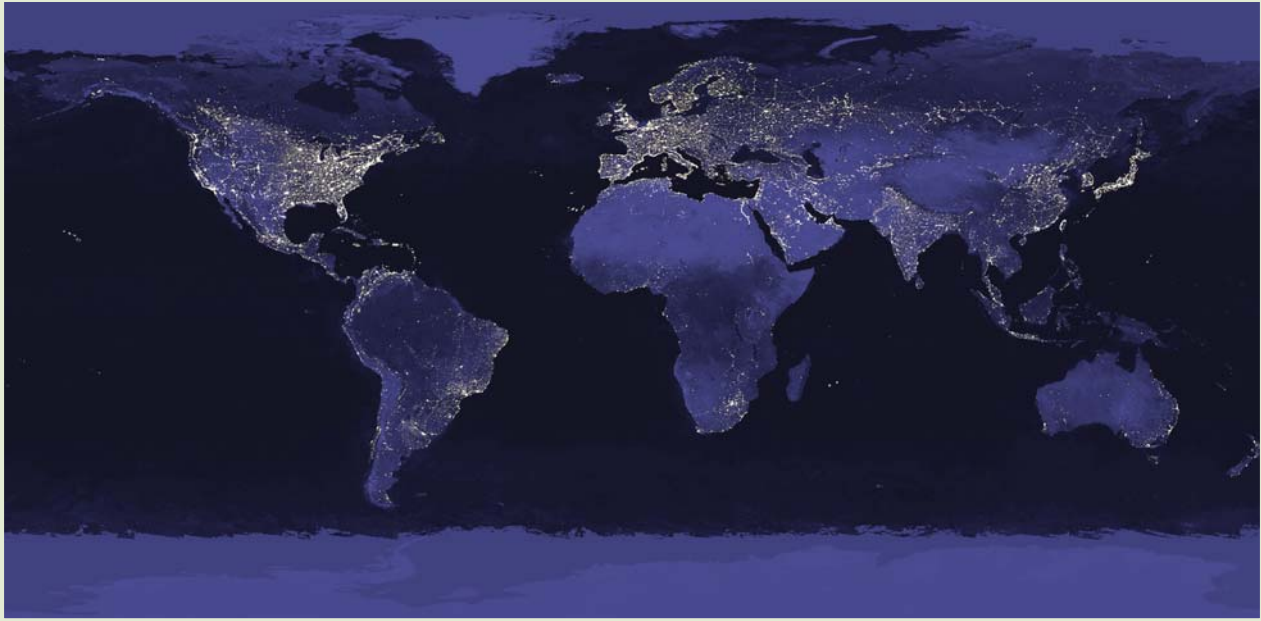


Figure 1 As shown in this satellite image of Earth's city lights from NASA's Visible Earth project, the brightest areas of Earth are the most urbanized but not necessarily the most populated. For example, compare Western Europe with China and India.

Sources: Data courtesy of Marc Imhoff of NASA GSFC and Christopher Elvidge of NOAA NGDC. Image by Craig Mayhew and Robert Simmon, NASA GSFC. http://visibleearth.nasa.gov/view_rec.php?id=1438.

geography, the notion of carrying capacity has recently been recast in the language of environmental sustainability. Overpopulation (unsustainability) is signaled by malnutrition, land degradation, and net out-migration (e.g., the American Dust Bowl of the 1930s or the rice terraces of Luzon today). Conversely, underpopulated regions may have larger landholdings and more prosperous farmers but densities insufficient to develop community ties or to justify the supply of essential government services. National governments have frequently sponsored mass migrations to underused agricultural frontiers to relieve population pressure in their core areas (e.g., the “transmigrations” from Java to Borneo and from the Brazilian Nordeste to Amazonia).

Urban Population Densities

Half the world's population is now urban, and these urbanites live at very high densities on a small fraction of the world's land area. Density is seen as a key attribute of urban life, and owing to its ease of

measurement, it is frequently employed to officially identify and delimit urban and rural areas. For example, the U.S. Census Bureau defines “urbanized areas” as contiguous census units with a minimum population density of 1,000 persons/mi.² and a total population of at least 2,500. Canada uses approximately the same density threshold (400 persons/km²) but a minimum total population threshold of only 1,000. Japan's “densely inhabited districts” are delimited using a density threshold of 4,000 persons/km², reflecting that nation's much higher densities in both rural and urban areas.

Prior to 1900, cities everywhere were compact, and the typical urbanite lived in an apartment or rooming house, at a neighborhood density exceeding 10,000 persons/km². Automobile commuting greatly extended the city and allowed much lower densities. From 1945 until recently, suburban extensions of the North American city typically comprised detached houses at 10 to 15 houses/ha (hectare) of residential land. With about 3.5 people per family, net population densities in these suburbs are 3,500 to 5,000 persons/km², and gross densities



(computed using all the developed land) are only 2,000 to 3,000 persons/km². In “exurban” areas on the rural-urban fringe, the need to separate wells from on-site septic fields keeps lot sizes in the 0.2- to 0.5-ha range, so that the net population densities in subdivided areas fall below 1,000 persons/km².

Urban gross population densities decline from the center toward the periphery for historical reasons (the impact of automobile commuting) and also in response to land value (central land is more valuable and should be used more intensively). Colin Clark demonstrated that the *density gradient* for large cities may be modeled with considerable accuracy by a negative exponential function, and Bruce Newling refined his statistical model to include a central density “crater.” It has been shown that in North American cities the overall gradient has declined through time, peak density levels have declined and moved away from the center, and the central density crater has deepened and enlarged.

Suburban density clusters are a recent feature of urban density patterns. They are typically coextensive with areas of multiple-family housing and are aligned to transit routes. Land use and transport planners have deliberately fostered the development of such high-density clusters and corridors to improve the viability of mass transit and reduce automobile commuting. The policy is known as transit-oriented development (TOD). Planners are also concerned to minimize urban sprawl onto agricultural lands by using a two-pronged strategy: (1) raising density levels in new greenfield developments (“densification”) and (2) reversing the decline of inner-city densities through upzoning and infill development (“redensification”). Not only do such smart-growth policies minimize the size of the urban footprint, but they also support transit usage, reduce greenhouse gas emissions, and reduce the per capita costs of urban services (roads, water supply, sanitary sewers, police, fire protection, etc.).

Hugh Millward

See also **Carrying Capacity; Ecological Mapping; Land Use Planning; Population and Land Use; Population Geography; Urban Sprawl**

Further Readings

- Ackerman, E. (1959). Population and natural resources. In P. Hauser & O. Duncan (Eds.), *The study of population: An inventory and appraisal* (pp. 621–648). Chicago: University of Chicago Press.
- Boserup, E. (1981). *Population and technological change: A study of long-term trends*. Chicago: University of Chicago Press.
- Hanski, I. (1999). *Metapopulation ecology*. Oxford, UK: Oxford University Press.
- Millward, H., & Bunting, T. (2008). Patterning in urban population densities: A spatiotemporal model compared with Toronto 1971–2001. *Environment and Planning A*, 40, 283–302.



POPULATION, ENVIRONMENT, AND DEVELOPMENT

Geographers have a long-standing interest in the patterns and processes associated with human population growth and distributions, the impacts of population on the environment, and sustainable development. Human population growth has increased exponentially over the past 150 yrs. (years) and is significantly affecting native ecosystems through the exploitation of freshwater, arable lands, forests, and oceans. There is great interest in addressing these challenges through sustainable development in all world regions.

Population

The world’s population was half a billion in 1650 and reached 1 billion in 1804. By 1927, the population had doubled to 2 billion, and it reached 3 billion in 1959. In 2009, there were 6.8 billion people on the planet, and the world’s population is projected to reach 9 billion by 2050. This rapid increase in human population can be attributed primarily to a dramatic decrease in the death rate, to technological advances, and to migration. The average life expectancy of people in developed countries has increased from 47 to 77 yrs. in the past century, while the average life expectancy in



developing countries has increased from 30 to 55 yrs. Advancements in technology, especially in agriculture due to the Green Revolution (the 1960s), have resulted in greater food availability. The advent of hybrid seeds with a range of environmental tolerance and the use of fertilizers have increased the production of crops, while food distribution methods improved both regionally and globally to satisfy demand. Improved sanitation (i.e., drinking water, waste management) and vaccinations for diseases (e.g., measles and smallpox) have also significantly contributed to the increase in the size of the world's population and in life expectancies. The migration of people to new regions of the world and increases in urban populations have resulted in cities with extremely high population densities over the past 200 yrs., especially in Asia. Indeed, currently, over 50% of the world's population lives in cities.

The world's population and growth rates are not evenly distributed around the globe. Until 1900, most of the world population resided in temperate regions. However, there has been a dramatic increase in the world's population in tropical regions and a significant increase in urban populations in the past 100 yrs. Geographically, Asia comprises 60% of the world's population, Africa 14%, Europe 11%, North America 8%, and South America 6% (Figure 1).

The six most populated countries in 2009 were China with 1.3 billion people, India with 1.2 billion people, the United States with 307 million people, Indonesia with 240 million people, Brazil with 199 million people, and Pakistan with 176 million people.

Models by the World Bank, the United Nations Population Division, and the Population Reference Bureau project population growth to reach a minimum of 9 billion people on the planet by 2100 if couples continue to have children at the current rate. The reason why the world's population is projected to exceed 9 billion to 10 billion people is the momentum built into very young age profiles. For example, half of the population in sub-Saharan Africa or Mexico is below 18 yrs. of age. Couples would have to have only one child for the next 30 yrs. to stabilize at the current levels. This pattern holds true even for countries such as China, which has had a one-child policy since the 1970s (though only enforced in

urban areas), which has resulted in couples having families that are less than replacement size. However, China adds 514,000 new people every month because of the momentum built into the age profile, and it is projected to add another 100 million people by 2050.

There can be no question that the world's population would be higher if it were not for the efforts of national and international public health and family planning organizations. Family planning programs currently focus on local control that is sensitive to cultural beliefs, with an emphasis on access-based contraception distribution, and they primarily target women. Couples in Thailand, South Korea, Taiwan, and China often have just one or two children so that they can provide more prosperity for themselves and their children. Most efforts to lower birth rates through steps such as improving the status of women and providing better education, more social security, and better and more productive jobs result in a higher standard of living.

Environment

The environment includes all living and nonliving things that occur on Earth. The human use of the environment and associated nonrenewable resources have increased significantly over the past 150 yrs. The impacts of population growth on the environment are a function of the numbers of people being added; the income or affluence of the population; the science and technology that sustain populations, especially in urban areas; and the capacity of the environment to provide renewable and nonrenewable resources. However, the exponential growth rate in human population is greatly stressing the world's environmental resources. Human population growth is related to the availability of natural resources such as freshwater, arable land, forests, and fisheries and the quantity of wastes, air pollution (especially in large cities), and greenhouse gas emissions (especially in the United States and China).

As a result of the increase in human population, water pollution and depletion have had a significant impact on fresh water. Water quality in almost all major riverways on Earth is increasingly undrinkable due to increases in sediment,

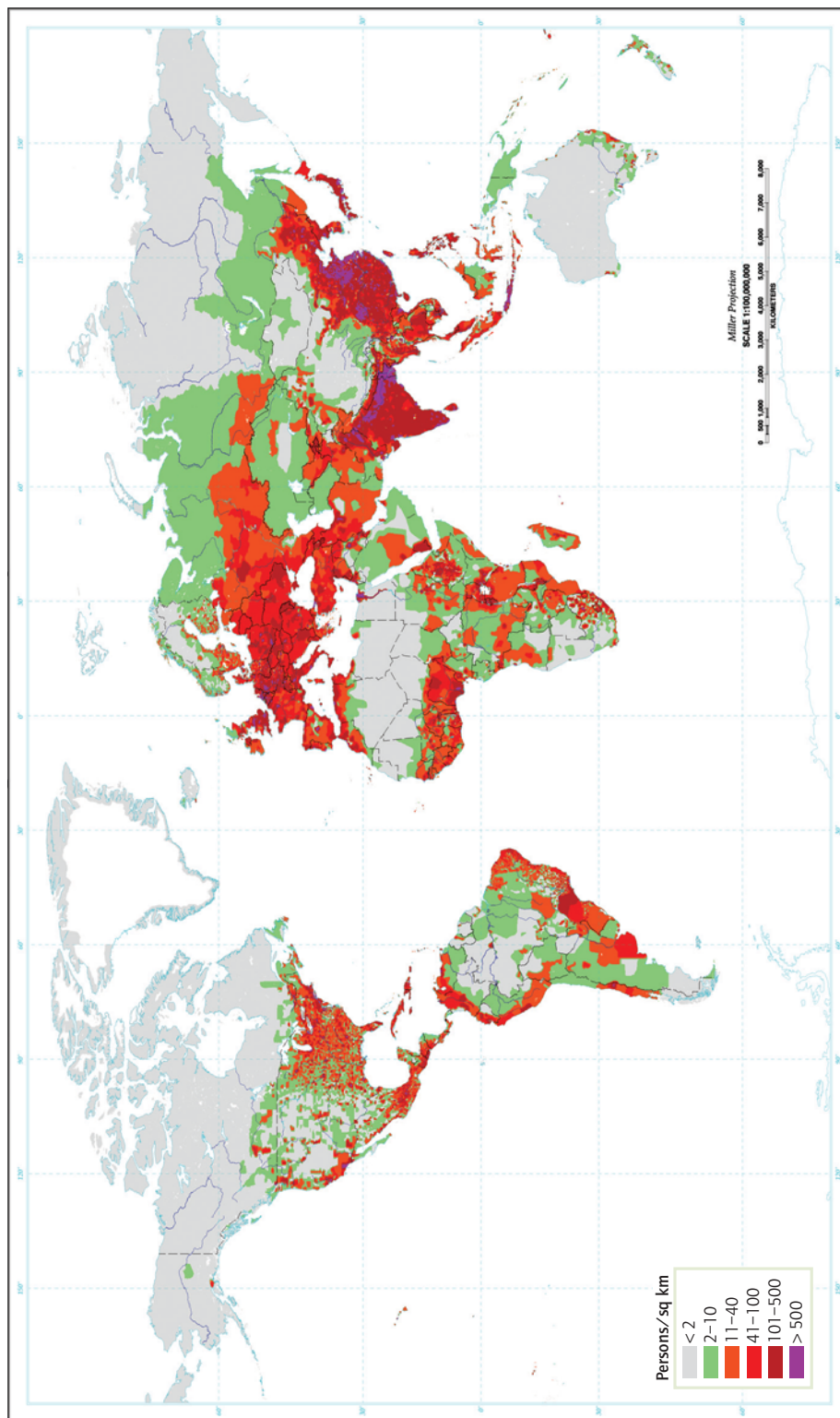


Figure 1 Global population density (per square kilometer), 1994

Source: U.S. Department of Agriculture, Natural Resources Conservation Service.



human and animal wastes, and agricultural, industrial, and household pollutants. Freshwater lakes have been affected in many regions of the world by increased levels of salt, depletion for agricultural irrigation, and water pollution from sewage. Many freshwater lakes are also undergoing eutrophication due to increased nutrients, which significantly changes the chemical and biological composition of lakes. Aquifers and freshwater lakes in many regions of the world have also been significantly reduced due to the demand for freshwater for agriculture and drinking purposes.

It is currently estimated that 37% of Earth's land surface is covered by agriculture. Three agricultural crops—rice, wheat, and corn—feed a majority of the world's population. Indeed, rice alone feeds two thirds of humanity and provides over 50% of the calories needed for 1.6 billion people to survive. These subsistence crops are generally planted as monoculture in areas with rich soils and low topographic relief. Another environmental impact of agriculture is the increased use of fertilizers and pesticides associated with certain crops. Fertilizers used to increase the yield of annual crops such as sugarcane can be transported to freshwater systems, and pesticides used on crops such as tomatoes and cotton can poison both people and soils. There has been a significant expansion of export crops such as coffee, bananas, and palm oil, which are generally planted as monoculture and have resulted in the conversion of native ecosystems such as tropical forests. The harvesting of timber has also resulted in the conversion of native forests into monoculture plantations of select timber species.

Oceans have been heavily exploited over the past 100 yrs., and global consumption of fish has doubled since 1973. Fishing techniques such as trawling, use of drift nets, and long lining have resulted in the dramatic reduction of densities of most marine mammals, reptiles, and fish. Currently, 32% of the world's fisheries stocks have collapsed, and 39% are overexploited. Other nearshore habitats such as extremely diverse coral reef ecosystems have also been significantly affected. Over one third of the planet's coral reefs, which combined cover an area the size of British Columbia, have been degraded by increased sediment runoff, water pollution, and overfishing.

The extent of human use of ecosystems varies around the globe. Over the past 150 yrs., native ecosystems in Mediterranean climates, temperate grasslands, deciduous forests, and tropical dry forests have undergone great alteration for agriculture, timber production, and urbanization, while other native ecosystems such as tundra, deserts, and tropical rain forests near the equator have remained largely intact. However, in all world regions, there has been an exponential increase in the rates of species extinction and endangerment. Freshwater fish, amphibians, large mammals, and species endemic to islands have been the most adversely affected, and all species could be affected by projected rapid increases in global temperatures.

Development

Development geography is the study of the Earth with reference to the standard of living or the quality of life of the world's people. The Earth can be divided into regions with high human development (e.g., North America, Europe), medium human development (e.g., Asia), and low human development (e.g., West and Central Africa) (Figure 2).

High human development occurs in countries that are industrialized and that have low population growth and infant mortality rates and high per capita income. Low human development occurs in countries with low levels of industrialization, very high population growth and infant mortality rates, and low per capita income. However, the increase in population and natural resource use is currently not sustainable in most regions of the world. There is currently great interest in development and sustainability in all regions of the world to maintain a state in which population and natural resource use rates are sustainable at the local, regional, and global spatial scales. Development has resulted in improved lifestyles and livelihoods for a majority of people in the countries with high human development. However, one-child and two-children families in developed countries burn the most fossil fuels and inefficiently dispose of the most waste. Indeed, the United States contains only 4.5% of the world's population but accounts for 23% of the world's energy consumption, while developing

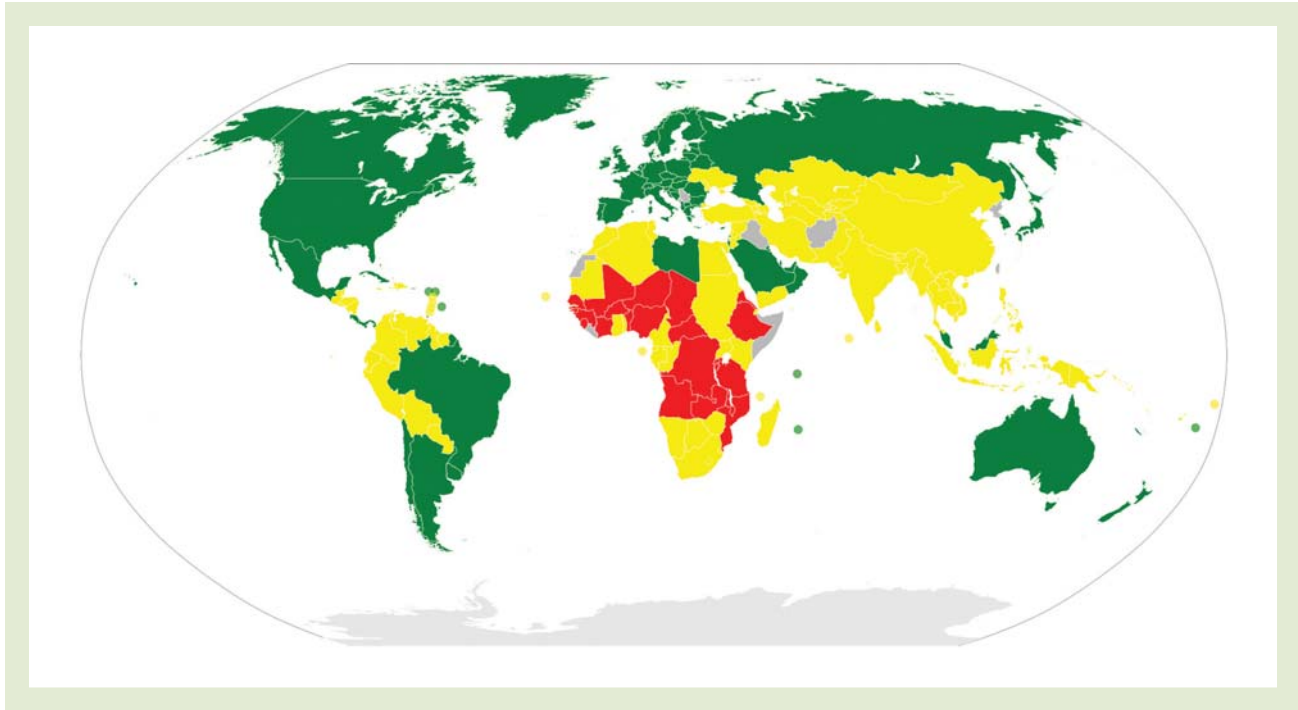


Figure 2 Three levels of development geography of the world

Source: Retrieved from [http://commons.wikimedia.org/wiki/File:UN_Human_Development_Report_2007_\(1\).svg](http://commons.wikimedia.org/wiki/File:UN_Human_Development_Report_2007_(1).svg) and available from <http://hdr.undp.org/en/reports/global/hdr2007-2008>.

Note: Green = high human development; yellow = medium human development; orange = low human development.

countries such as India contain 18% of the world population and account for only 4% of the world's energy consumption. If everyone in the world had the same level of consumption as the population of the United States, it is estimated that it would take the natural resources and land area of five Earths. Since it is currently not possible for all countries to achieve high development standards without outstripping natural resources, development in general focuses on improving sustainability in countries with high and medium development and increasing the quality of life via food, education, and social justice in low-development countries, where more than 850 million people face hunger and food insecurity.

To achieve these goals of sustainable development, international institutions and governments have tried to address the balance of population growth and natural resource use in ways that reduce the impact of the human population on Earth's natural resources. International institutions, often under the auspices of the United

Nations or the World Bank, have mandated treaties and security arrangements to accommodate and protect the well-being of all sovereign nations. Conferences on improving the status of women, achieving population stabilization, protecting biodiversity, and accommodating the rapid spread of technology have resulted in global charters, regulations, and accords. International treaties such as the Montreal Protocol on Substances that Deplete the Ozone Layer have significantly reduced the release of chemical pollutants that affect the ozone layer, and significant advances have been made via the Kyoto Protocol to the United Nations Framework Convention on Climate Change to address issues of global warming and climate change. There has been progress on the enforcement of population and environmental treaties related to deforestation, protection of biodiversity, and the law of the seas, though much more is needed.

Within countries, environmental legislation, incentives, and enforcement are important tools



for working toward sustainability at regional and local spatial scales. Several geographical tools, such as censuses, geographic information systems, and satellite imagery, can be used for monitoring and assessing the status of populations and the environments as related to sustainable development. Although stabilizing human population growth and sustainable development of Earth's natural resources are still significant challenges that current and future generations will have to face, there have been significant advances in ideas and policies over the past 50 yrs. to meet these global challenges.

Thomas Gillespie and Robert Welch Gillespie

See also **Developing World; Environment and Development; Land Degradation; Malthusianism; Neo-Malthusianism; Population and Land Degradation; Population Density; Population Geography; Soil Degradation; Sustainable Development; Sustainable Development Alternatives; United Nations Environment Programme (UNEP)**

Further Readings

- Berger, L. R., & Hager, M. C. (2008). *Visualizing environmental science* (2nd ed.). New York: Wiley.
- De Blij, H. J., & Murphy, A. B. (2003). *Human geography: Culture, society, and space* (7th ed.). New York: Wiley.
- Ehrlich, P. R., Ehrlich, A. H., & Holdren, J. P. (1978). *Ecoscience: Population, resources, environment* (3rd ed.). San Francisco: W. H. Freeman.
- United Nations Development Programme. (2007). *Human development report 2007/2008*. Retrieved June 12, 2009, from <http://hdr.undp.org/en/reports/global/hdr2007-2008>



POPULATION GEOGRAPHY

Population geography asks two basic questions about the distribution of people, namely, "Where?" and "Why there?" In other words, population geography is specifically concerned

with the geographic distribution of people, their composition in terms of age and gender, and the three main processes that determine an area's population growth, namely, fertility, mortality, and migration. While the boundary between population geography and demography has become blurred, population geographers contribute significantly to population studies and/or demography in their own unique way by offering a geographic perspective to the study of population.

While demographers measure and analyze demographic data with an emphasis on time, historians trace the evolution over time of such data, and sociologists seek the causes of the trends in demographic analysis and their repercussions on societal processes, population geographers focus on the characteristics of population distributions that change in a spatial context and why those changes take place. The population geographer uses geographic tools and techniques such as population density maps and hatch, choropleth, isoline, and dot maps to show the ways in which factors of population change such as fertility, mortality, and migration are distributed in space and attempts to explain those distributions by a careful examination of the underlying processes. In short, population geography can be defined as a systematic and regional analysis of area patterns of population distribution, composition, migration, and growth, as well as their causes and the effects they have on cultural and economic landscapes. This entry briefly examines the roots and growth of population geography, the contents of population geography, and its future prospects.

Roots and Growth of Population Geography

The benchmark in the development of population geography is often cited as the 1950s, after Glenn Trewartha gave his presidential address in 1953 to the Association of American Geographers. However, the roots of population geography can be traced back several centuries earlier. While Trewartha's address was a defining moment in the development of population geography as a subdiscipline of geography, there were before him others who had been working in this field elsewhere, particularly in Germany, France, Britain,



and Russia. These precursors to the modern subdiscipline of population geography concentrated on the examination of population statistics, population mapping, and the study of human elements in geography.

By the 1800s, the discipline of geography had experienced great improvements in its methods, such as the introduction of statistical methods, quantitative indices, and better cartographic techniques. These improvements required the existence of high-quality data, which were in short supply at that time. Thus, geographers and cartographers throughout Europe, and particularly in Germany, banded together to begin compiling and evaluating different sources of quantitative data. The leading geographic and cartographic center was the Geographische Anstalt Justus Perthes in Gotha, Germany. These data were then used to compile maps that depicted, among other things, the sizes of settlements with respect to their population. These early private efforts at compiling data were then taken up by the League of Nations and later the United Nations and the member states of these institutions. However, the seeds of population geography had been sown in these early periods, and to this day, geographers continue to supplement government statistics by gathering their own population data during field investigations.

With the growing availability of population-related data, population geographers perfected their mapping techniques to show global and local population distributions. While this topic continues to remain the central focus of population geographers, other population characteristics were also being mapped as early as the 1820s. For example, maps of literacy, crimes, and marriages in France and England appeared during the 1820 to 1870 period. During the interwar years, European geographers concentrated on producing population maps at national or continental levels, with special reference to Europe. Many of these maps attempted to portray the localities of different ethnic groups in Europe. This preoccupation with generating population maps went on well into the 1960s. In short, population maps have a long history, dating back from the 1800s to the present-day global, national, and regional atlases.

The third important development that contributed greatly to the development of population

geography as a subdiscipline of geography was the development of human geography. Friedrich Ratzel is usually credited with establishing this subdiscipline of geography in Germany, which he termed *Anthropogeographie* in 1842. Although Ratzel is depicted as the founder of the environmental deterministic school in geography, he brought into the limelight the study of population and its characteristics and the relationship between people and their environment and how the two interact to shape each other. The French school of thought (*geographie humaine*) in the late 19th century also contributed greatly to the growth of human geography. This school espoused a more moderate approach to the interpretation of human-Earth relationships and succeeded in redirecting other geographers to the study of population and its characteristics and impact on the environment.

Although the roots of population geography go back to the 1800s, it was not until the 1950s that the term *population geography* came into vogue. Many credit the emergence and recognition of population geography as a new field within geographical studies to the influential statement of Trewartha in 1953. In his presidential speech to the Association of American Geographers in 1953, Trewartha noted that population geography had been a neglected aspect of the discipline of geography. He pointed out that population was a pivotal element in human geography and that its continued neglect would seriously affect the development of the discipline. Initially, the response by geographers to Trewartha's clarion call was lukewarm, and it took years for this subbranch of geography to develop into what it is today.

Between the 1950s and 1960s, other developments occurred that gave impetus to population geography. For example, the tremendous proliferation of population data since the 1950s with the formation of the United Nations and the regular census taking by most countries provided pertinent data on births, deaths, mobility, marriages, divorces, and so on. The rise of demography to a separate discipline in the 1950s also had a stimulating impact on the rise of population geography. Demography has developed a rich body of highly sophisticated methods for population analysis, which greatly enriched research in population geography and the wider field of



population studies. The rapid growth of the global population since the end of World War II heightened the need to examine population issues closely. Geographers, demographers, and other scientists began to wonder about the implications of rapid population growth on food and nutrition, deforestation and habitat destruction, air and water pollution, depletion of energy and mineral resources, and other social, economic, and environmental ills.

It was not until the appearance of several influential textbooks on population geography in the mid 1960s that this component of geography became recognized as a full-fledged component of the discipline, a component that could offer fruitful avenues of research and teaching. These books included Pierre George's *Géographie de la population*, published in Paris in 1965; John Innes Clarke's *Population Geography*, published in 1965; Jacqueline Beaujeu-Garnier's *Geography of Population*, published in 1966; and Wilbur Zelinsky's *A Prologue to Population Geography*, published in 1966. These textbooks offered a major stimulus to the emergence of the discipline of population geography. Although none of these books by themselves succeeded in comprehensively covering the content of population geography, together they offered a holistic treatment of the content and methodology of population geography, which at this early point in time was concerned with the distribution of population and understanding the geography of a wide range of population phenomena.

Since then, a number of influential textbooks on population geography have appeared in North America, Europe, and elsewhere in the world. For example, in North America, two influential textbooks on population have endured the test of time: Gary Peters and Robert Larkin's *Population Geography: Problems, Concepts and Prospects*, first published in 1979 and now in its 8th edition, and John Weeks's *Population: An Introduction to Concepts and Issues*, now in its 10th edition. Weeks's book illustrates the synergy and blurring of boundaries between population geography and demography in North America and is widely used in population geography courses as well as demography courses, bringing in the much needed cross-fertilization between the two disciplines. Indeed, demography and population

geography are concerned with the same subject matter, namely, the study of human populations. Both disciplines are quantitative in their approach and rely heavily on statistical data. However, in spite of the blurring of subject material and approaches between the two fields, the main difference is that demographers continue to place emphasis on time, whereas geographers emphasize analysis using geographic units or space as the major vehicle within which to place population characteristics.

Population Geography Courses

Population geography has become well entrenched in many departments of geography at institutions of higher learning, particularly in North America and Europe. The content of such courses has been shaped by the recognition that the scientific study of human populations is an interdisciplinary endeavor that involves disparate disciplines, including demography, sociology, anthropology, psychology, political science, economics, biology, and others. However, the three main components or processes of population change remain central to the content of population geography syllabi. These are fertility, mortality, and migration.

In population geography syllabi, these three components form the basis for an examination of more specific topics, such as sources of population data, population growth and change, population structure/composition and spatial distribution, theories of population change (e.g., the Malthusian and Marxist perspectives and demographic transition theory), population processes (e.g., patterns and trends in fertility and mortality, migration and mobility), and the relationships between population on the one hand and the environment, food supply, and other socioeconomic factors on the other.

Much of this content goes back to Trewartha's vision for population geography, in which he viewed a discipline that was more systematic in its treatment of population. Trewartha essentially advocated a descriptive approach that was to include other aspects of population such as social, cultural, and economic characteristics. His vision saw the study of population geography being divided into three main areas of research, namely, historical population geography, population



numbers, and qualities and regional distribution. Historical population geography would examine the regional variations in population growth and decline over time, while population numbers would examine gross patterns of numbers, fertility and mortality dynamics, population density, and migration. Regional population geography would examine population characteristics such as race, nationality, sex, age, health, and other socio-economic characteristics such as religion, education, occupation, family structure, urban/rural residence, and cultural customs. The unifying factor for the three areas of inquiry and teaching was to be the region. While Trewartha emphasized systematic description in his vision of population geography, other scholars have refined his vision to broaden the field to an examination of dynamic rather than static spatial processes. Although the methods of approaching the study of population geography have changed over time, the substantive topics outlined by Trewartha continue to form the basis for population geography today.

Research Foci in Population Geography

Population geographers have been active in research and publications. Their geographic approach offers the spatial perspective that examines population variables cartographically (via the use of maps and now geographic information systems) and/or statistically in an attempt to examine the underlying factors that explain the exhibited spatial patterns of the variables, be it fertility, mortality, or migration. Two main phases of research foci can be discerned, namely, the 1950s to 1970s and the 1980s to 1990s.

During the 1950s and 1970s, research in population geography concentrated on the examination of four topic areas. The first was the description of demographic structures in geographic space using empirical and positivist approaches. Population geographers believed that to create scientific knowledge about demographic structures in space, there was a need to produce the evidence through field observations and descriptions of population phenomena. Through the positivist approach using the scientific method, the empirically observed trends would lead to the affirmation or negation of hypotheses. The observed patterns were summarized via the use of maps

and quantitative methods, many of which were being developed in the discipline of demography. Topics of research in this area included population concentration or dispersal, population density, urban population segregation, population flows, and so on. The second area of research was describing demographic change via the use of the population balancing equation and spatial demography. A good example here is the tracking of the centroid of the U.S. population over time and in space. The third area was explaining demographic changes in space and in time, such as age-sex distributions, population growth, and the major variables of population change, fertility, mortality, and migration. Using positivist and empirical approaches, population geographers contributed significantly in the areas of demographic transition theory and theories of migration. One of the greatest contributions of population geographers to population studies was a greater understanding of migration and the forces that cause people to move.

The 1980s and 1990s saw both continuity and critical reflections on population geography's research directions. During this period, research in population geography focused on four main areas, with migration dominating the volume of research. While research on migration differentials, migration systems, and regional and international migration continued, population geographers began to engage in critical debates about the geopolitics of mobility, the racialized and gendered nature of migration, immigrant labor markets, and so on. The other three areas of research focus included issues of reproduction and health inequality, the implications of aging, and population and the environment. In the post-September 11, 2001, period, population geographers have been moving into new areas of research, such as population movements as they relate to national security, neoliberalism, the transnational migrant in an era of globalization, and geopolitics.

The Future of Population Geography

Population geography has done well over the past 50 years. From its inception, it experienced steady growth and development, with undergraduate and graduate-level courses being developed at colleges and universities in Europe, North



America, and elsewhere. The elevation of population geography to one of the official specialty groups within the Association of American Geographers in the 1970s meant its acceptance as a significant part of geography.

In spite of these successes, population geographers began to be critical of their discipline and to cast self-doubt on population geography's effectiveness and contributions to scientific and social inquiry. Two main contending camps appeared on the scene. The first advocated maintaining the status quo, arguing that the discipline was sound and did not need to be tampered with. The second camp wanted population geography to expand its methodologies and approaches to include other perspectives and be more conceptually inclusive. The argument here was that population geography should not solely rely on empirical and positivist approaches in research but rather adopt a mixed- and pluralistic-methods approach. What, for example, were the boundaries between population geography and other fields such as medical geography, spatial ecology, demography, and population studies? The launch in 1995 of the *International Journal of Population Geography* and its subsequent change in name in the mid 2000s to *Population, Space and Place* brought into sharp focus these divisions. The broad coverage and the publication of six issues a year appears to have favored those in favor of a pluralistic coexistence within the field. Indeed, this journal is advertised as offering an energetic forum to debate, inform, and review the latest developments in areas such as population and society, fertility, mortality and migration, quantitative and qualitative methods of population analysis, aging populations, census analysis, spatial demography, population policies, theory and population, population distribution and change, and population and development.

The pluralist approach in population geography appears to be the future trajectory of this subdiscipline. This notion implies the existence of a varied group of population geographers who are committed to interrogating population issues using varied methodologies and theoretical approaches. Indeed, a good number of population geographers are deploying new theoretical approaches that go beyond positivist and empirical approaches. Today, research using approaches

such as social constructivism, poststructuralism, postcolonialism, and structuration theory is becoming common in population geography.

Ezekiel Kalipeni

See also Demographic Transition; Fertility Rate; Hunger; Malthusianism; Migration; Mobility; Mortality Rate; Natural Growth Rate; Neo-Malthusianism; Population and Land Degradation; Population Density; Population, Environment, and Development; Population Pyramid; Trewartha, Glenn; Urbanization; Zelinsky, Wilbur

Further Readings

- Bailey, A. (2005). *Making population geography: Human geography in the making*. London: Hodder Arnold.
- Gober, P., & Tyner, J. (2003). Population geography. In G. Gaile & C. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 185–199). Oxford, UK: Oxford University Press.
- Peters, G., & Larkin, R. (2005). *Population geography: Problems, concepts and prospects* (8th ed.). New York: Kendall/Hunt.
- Trewartha, G. (1953). The case for population geography. *Annals of the Association of American Geographers*, 43, 71–97.
- Weeks, J. (2007). *Population: An introduction to concepts and issues* (10th ed.). Belmont, CA: Wadsworth.



POPULATION PYRAMID

Except for total size, the most important demographic feature of a population is its age-sex structure. The age-sex structure affects the needs of a population as well as the supply of labor; therefore, it has significant policy implications. A rapidly growing population implies a high proportion of young people under the working age. A youthful population also puts a burden on the education system. When this cohort enters the working ages, a rapid increase in jobs is needed to

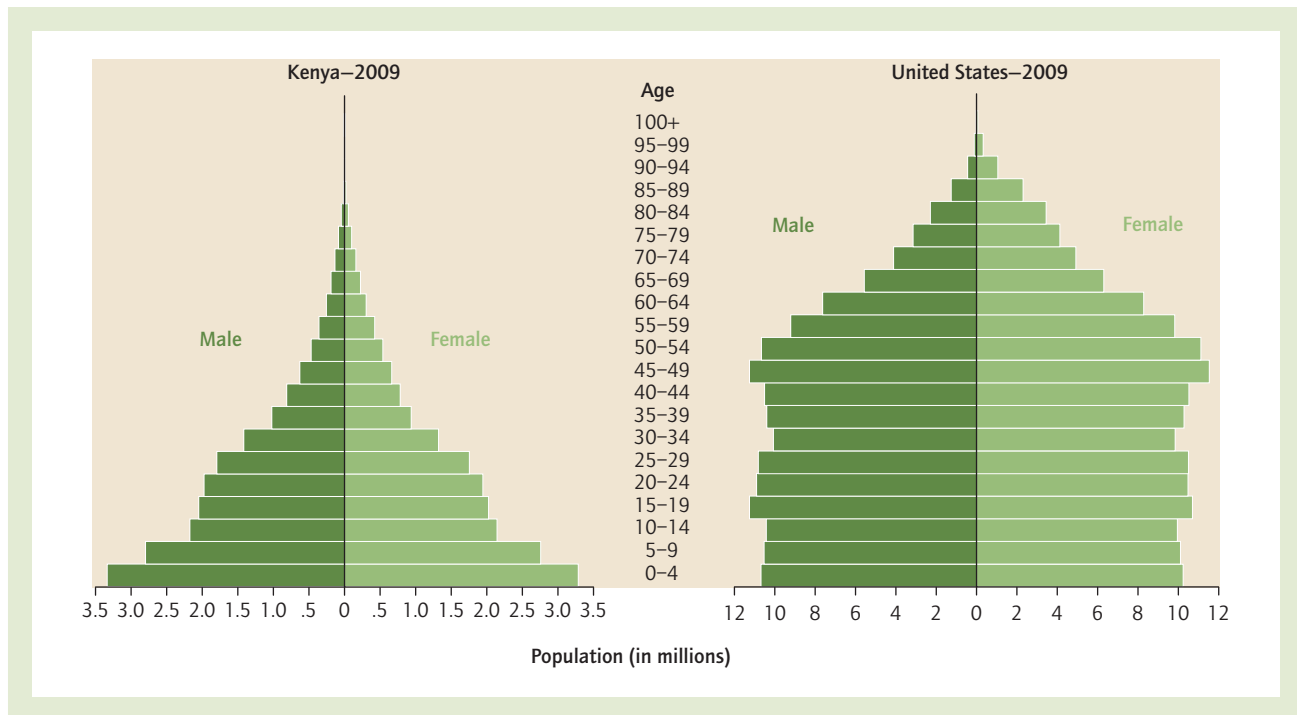


Figure 1 Population pyramids for developing countries typically exhibit a wide base, reflecting high fertility rates, while those in economically developed parts of the world portray a population more evenly distributed across age groups.

Source: U.S. Census Bureau, International Data Base. www.census.gov/ipc/www/idb/country.php.

accommodate it. In contrast, countries with a large proportion of older people must develop retirement systems and medical facilities to serve them. Therefore, as a population ages, its needs change from schools to jobs to medical care.

The age-sex structure of a country or region can be conveniently summarized or described through the use of population pyramids. They are divided into 5-year age groups, the base representing the youngest group, the apex the oldest. Population pyramids show the distribution of males and females of different age groups as percentages of the total population. The shape of a pyramid reflects long-term trends in fertility and mortality and the short-term effects of “baby booms,” migrations, wars, and epidemics. It also reflects the potential for future population growth or decline.

Two basic, representative types of pyramid may be distinguished (Figure 1). One is the squat, triangular profile. It has a broad base, concave sides, and a narrow tip. It is characteristic of

developing countries having high crude birth rates, with a young average age and relatively few elderly. Natural growth rates in such societies tend to be high.

In contrast, the pyramid for economically developed countries, including the United States, describes a slowly growing population. Its shape is the result of a history of declining fertility and mortality rates, augmented by substantial immigration. With lower fertility, fewer people have entered the base of the pyramid; with lower mortality, a greater percentage of “births” have survived until old age. In short, the structure of the population pyramid closely reflects the stage of the demographic transition in which a country is positioned.

Barney Warf

See also Demographic Transition; Fertility Rate; Mortality Rate; Natural Growth Rate; Population Geography



Further Readings

Yaukey, D., & Anderton, D. (2001). *Demography: The study of human population*. Long Grove, IL: Waveland Press.



PORTOLAN CHARTS

Portolan charts were produced in Mediterranean lands primarily during the 13th through 16th centuries. Originally single-sheet maps that were drawn on rolled scrolls of sheepskin and used by sailors in the Mediterranean region, they were soon joined by portolan atlases that typically covered the Atlantic coast of Europe and the Black Sea as well as the Mediterranean and that likely served a more decorative function. In both formats, however, portolan charts are striking for their relatively “modern” appearance and their apparently accurate representation of coastlines, leading the early 20th-century cartographic historian Charles Beazley (1904) to call portolan charts “the first true maps” and to assert that “in them, true cartography, the map-making of the civilised world, begins” (p. 161).

Perhaps the most distinctive feature of the portolan chart is the network of rhumb lines—usually colored red, green, and/or brown—that cross over ocean space and in some cases continue across land space. Together with a portolan—a list of directions for sailing from one port to another along a coastline—these rhumb lines were used for navigation. For instance, a sailor wishing to cross the Mediterranean could find his source and destination cities on the portolan chart, note the rhumb line whose angle corresponded to the angle of a line drawn between the two cities, determine the corresponding compass heading, and then sail by dead reckoning along that heading until he reached the opposite coast. On reaching the coast, assuming that the boat did not land precisely on target, the sailor could use an accompanying portolan to navigate coastwise to reach his ultimate destination.

Portolan charts also are notable for their simplistic projection, in which longitude lines are drawn as straight, parallel lines without any

compensatory adjustment in the spacing of latitude lines (e.g., as is achieved in a Mercator projection). This projection, and the accompanying system of navigating by dead reckoning along a compass heading as one traversed a conceptually placeless ocean, was suitable for trans-Mediterranean travel, where north-south distances are relatively small, currents and tides are minor, magnetic variation is insignificant, and storms are rare during the sailing season. However, attempts to transfer this projection and its corresponding technique of navigation to longer-distance ocean voyages would be disastrous, and thus, it seems likely that the frequent presence of rhumb lines on 17th-century world maps was purely decorative or, perhaps, was intended to reference an earlier era of Mediterranean voyaging.

Despite the break between the navigational practices enabled by and reflected in the portolan chart and those in later maps, some scholars have noted that portolan charts nonetheless embody a perspective that prefigures modern conceptions of territory and mobility. As on a modern map, the ocean on a portolan chart is typically devoid of emotive, natural, or human signifiers (e.g., sea monsters, ships, toponyms). Instead, the ocean is represented as an empty space that can be rationally crossed by sailors following geometric logic and the natural law of magnetic north. In this sense, the portolan chart established the norm of the ocean as an easily crossable but empty (or non-exhaustible) and hence nonpossessable space, which was later to be codified by 17th-century jurists such as Hugo Grotius and which has gone on to inform the modern law of the sea. Likewise, the coastline on portolan charts is represented as a series of destinations (names written along the coastline) whose social significance is buttressed with numerous flags. Here, too, a modern norm is prefigured, as civilization is associated with naming and political territorialization. Behind the coastline, the interior—especially on Iberian portolan charts—is depicted as a fecund space of opportunity, filled with bustling human settlements and exotic nature, prefiguring a colonial mindset where the interior of distant lands—the space to be encountered *after* an ocean voyage—is presented as inaccessible yet ripe with opportunity (as well as dangers). Finally, islands on portolan charts are represented as territorially unified entities wherein



Map of the Western Mediterranean from a portolan atlas by Battista Agnese, ca. 1544

Source: Library of Congress, Geography and Map Division. Available at <http://memory.loc.gov/ammem/gmdhtml/gnrlagn.html>.

the seemingly incontrovertible boundary between land and sea is used to naturalize a political boundary between the internal space of the state and the outside space beyond its control. This depiction foreshadowed the ideal of the territorial state that was to become a political (and cartographic) norm on land in the centuries that followed.

In short, while Beazley might well be accused of ethnocentrism in his identification of certain maps as being “true” and in associating them with a singular “civilization,” his broader point—that the spatial conceptions inscribed in the portolan chart foreshadowed perspectives on space that were to inform emergent systems of exploration, colonialism, and merchant capitalism—is well taken. Long celebrated for their beauty and “accuracy,” portolan charts should also be appreciated for the ways in which they inscribed ideas about divisions between fixity and movement, land and ocean, and territory and an external space that is

immune to possession. These idealized divisions, expressed so succinctly in the portolan chart, went on to guide the spatiality of the modern era.

Philip E. Steinberg

See also **Cartography, History of; Map Projections; Mercator, Gerardus; Oceans**

Further Readings

- Beazley, C. (1904). The first true maps. *Nature*, 71(1833), 159–161.
- Campbell, T. (1987). Portolan charts from the late thirteenth century to 1500. In J. Harley & D. Woodward (Eds.), *The history of cartography* (Vol. 1, pp. 371–463). Chicago: University of Chicago Press.



- Lanman, J. (1987). *On the origin of portolan charts*. Chicago: Herman Dunlap Smith Center for the History of Cartography, Newberry Library.
- Mollat du Jourdin, M., & de la Ronciere, M. (1986). *Sea charts of the early explorers*. London: Thames & Hudson.
- Steinberg, P. (2005). Insularity, sovereignty, and statehood: The representation of islands on portolan charts and the construction of the territorial state. *Geografiska Annaler, B* 87, 253–265.



PORTS AND MARITIME TRADE

The enduring characteristic of maritime transportation is its ability to move large quantities of cargo over long distances. This activity is shaped by the maritime geography of the world, mainly the configuration of oceans, coasts, seas, lakes, and rivers. Where possible, the construction of canals, channels, locks, and dredging have facilitated maritime circulation and reduced the discontinuity imposed by geography.

A Fundamental Role in Global Trade

Maritime transportation is as old as global trade, and historically, the scope and extent of long-distance trade were determined by developments in maritime transportation technology. Between the 16th and 19th centuries, the galleon was the linchpin of long-distance colonial trade, and the refinement of sailing technology led to fast clipper ships in the mid 19th century, which essentially reflected the optimal in wind-propelled maritime technology. Clipper ships were, however, short-lived and were supplanted by steamships, which led to a remarkable specialization of ship function with liners, battleships, cargo ships, tankers, and container ships, to name just a few. Yet the role of maritime transportation in the movement of passengers is marginal; it is almost exclusively the domain of freight. International trade and seaborne trade are thus interrelated. In 2006, seaborne trade accounted for about 90% of global trade in terms of volume and 70% in terms of value.

Maritime transportation rests on the existence of regular itineraries, better known as maritime routes. They draw arcs on Earth's water surface, as intercontinental maritime transportation tries to follow the great circle distance. Maritime transportation operates in a space that is at the same time geographical with respect to its physical attributes, strategic by virtue of its military importance, and commercial in its usage. While geographical considerations tend to be constant in time, strategic and especially commercial considerations are much more dynamic. For instance, strong industrial growth in Pacific Asia has been accompanied by a surge in port activities along the Chinese coast as well as growth along trans-Pacific and trans-Indian Ocean shipping routes.

Shipping has traditionally faced two drawbacks. It is slow, with speeds at sea averaging 15 knots (26 kilometers per hour). Second, delays are encountered in ports where loading and unloading take place. The latter may require several days of handling when break-bulk cargo (that which is not containerized) is involved. These drawbacks are particularly constraining when goods have to be moved over short distances or when shippers require rapid service deliveries. However, technical improvements tend to blur the distinction between bulk and break-bulk cargo, as both can be unitized on pallets and increasingly in containers. For instance, it is possible, and increasingly common, to ship grain and oil, both bulk cargoes, in containers. Maritime shipping is dominated by bulk cargo, such as petroleum, minerals, and grains, which combined account for roughly 70% of total ton-miles shipped. These flows supply the world's energy generation, manufacturing, and food transformation systems. The share of break-bulk cargo is decreasing steadily, mainly because of containerization. Consequently, the amount of containerized freight has grown substantially, and the majority of the global shipment of manufactured goods is now carried in containers; the 20-foot-equivalent unit, or TEU, is a common measure of volume.

Ports: Valuable Resources

Although the physical geography of the world conveys a staggering amount of coastline, only a limited amount is effectively suitable for port operations. Port terminals handle more freight



than all other types of terminals combined. To perform their role, port infrastructures jointly have to accommodate transshipment activities both on ships and on land. They are points of convergence between land transport and maritime systems. Considering the operational characteristics of maritime transportation, the location of ports is constrained to a limited array of sites, mostly defined by geography. Most ports, especially those that are ancient, owe their initial emergence to their site, as the great majority of harbors take advantage of a natural coastline or a natural site along a river. The suitability of port sites continually changes with technical changes in maritime shipping and coastal urbanization. Such sites have become valuable and rare resources.

A Matter of Scale

The principle of economies of scale is fundamental to the economics of maritime transportation because the larger the ship, the lower the cost per unit transported. This trend has particularly been apparent in bulk and containerized shipping. For instance, the evolution of containerization, as indicated by the size of the largest available containership, has been a stepwise process (Figure 1). Changes are often rather sudden and correspond to the introduction of a new class of containership. Since the 1990s, two substantial steps took place. The first step involved a jump from 4,000 to 8,000 TEUs, effectively moving beyond the “Panamax” threshold. This threshold is particularly important, as it indicates the physical capacity of the Panama Canal and thus has for long been an important operational limitation in maritime shipping. The second step took place in the 2000s, as the maximum size reached the 13,000- to 14,000-TEU level. This is essentially a “Suezmax” level, or a “new Panamax” class, that is, the largest size of ship that will be able to pass through the expanded Panama Canal after it is completed in 2014. From a maritime shipper’s perspective, using larger containerships is a straightforward process, as it conveys economies of scale and thus lowers costs per TEU carried. From a port terminal perspective, such ships bring intense pressures in terms of infrastructure investments, namely “portainers.” Thus, the matter of economic scale leads to a paradox—the greater

the economies of scale applied to maritime shipping, the smaller the number of ports that are able to handle such ships.

Maritime Gateways and Hubs

The current geography of ports and maritime trade has been the most transformed by containerization, since it permitted an entirely new class of ships, new companies (or the transformation of existing companies), new port locations, new networks, and new flows.

For a long period, the world’s most important ports were North American (e.g., New York) and Western European (e.g., Rotterdam). Containerization completely changed the world’s commercial geography with the emergence of an array of new port locations (Figure 2). This geography indicates a high level of traffic concentration around large port facilities, the top ones being Pacific Asian ports along the Tokyo-Singapore corridor. As export-oriented economic development strategies took shape, the number of containers handled in Pacific Asian, notably Chinese, ports surged in volume. There is also an emerging geography of container ports characterized by a specialization in which some act as gateways and some as hubs. Gateway ports command the access of large manufacturing or market regions. Hong Kong, Los Angeles, and Rotterdam are notable examples. Hub ports (or offshore hubs) act as intermediary locations where containers are transhipped between different segments of the global maritime transport system. Singapore and Dubai are among the most prominent.

The conventional bulk shipping network is point-to-point, with two ports directly serviced and with the ship coming empty for the backhaul (the return voyage to the port of origin). This system typically reflects the pattern of oil, mineral, and grain shipping, with origins corresponding to extraction regions and destinations being large, urbanized regions. Containerized shipping permitted the emergence of new networks, namely, pendulum services. They involve a set of sequential port calls along a maritime range, commonly including a transoceanic service from ports in another range and structured as a continuous loop. Their purpose is servicing a market by balancing the number of port calls and the frequency

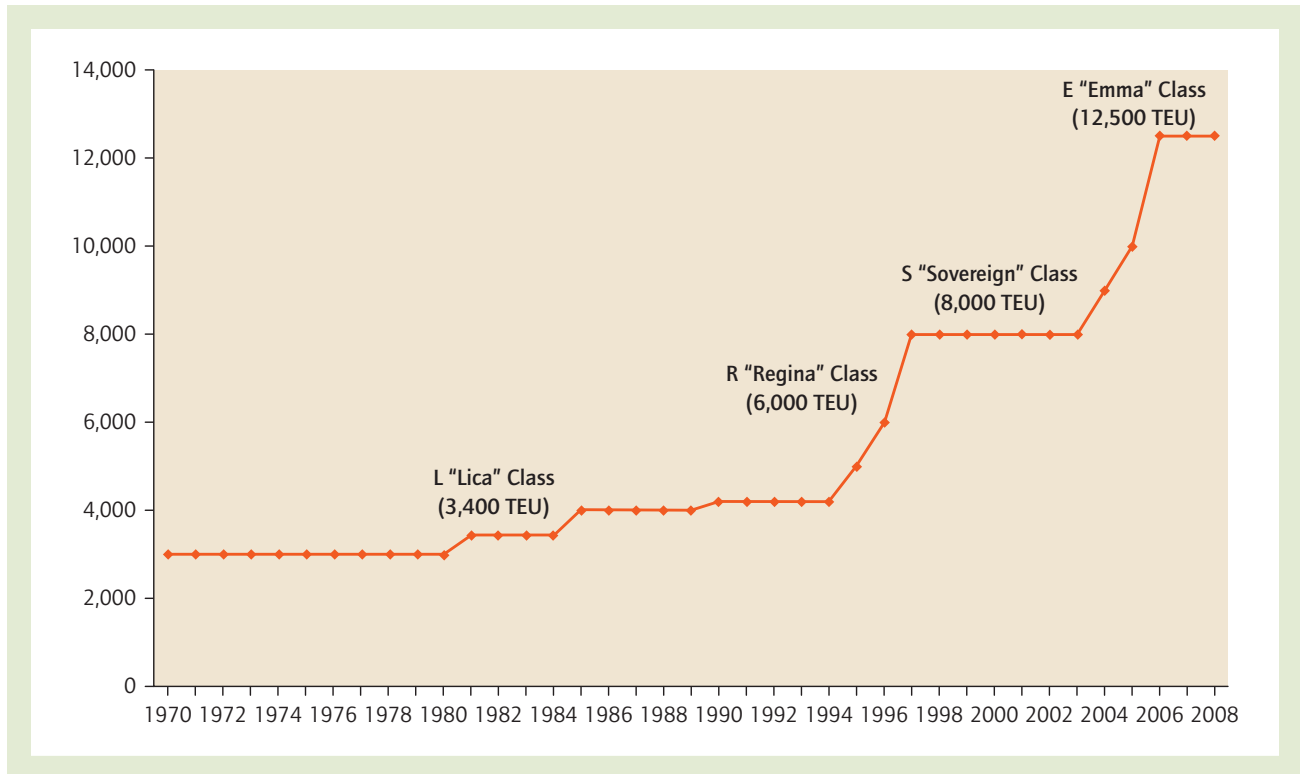


Figure 1 The largest available containership, 1970–2007 (in TEUs [20-foot-equivalent units])

Source: Data compiled by Jean-Paul Rodrigue and T. Notteboom.

of services. For instance, pendulum services between Asia and Europe have on average 8 to 10 containerships assigned and involve 8 to 12 port calls. Most transatlantic pendulum services have 6 to 8 containerships and involve 6 to 8 port calls. A pendulum service is fairly flexible in terms of the selection of port calls, particularly on maritime ranges that have nearby and competing ports grouped as regional clusters (e.g., the North American east coast, Western Europe). This implies that a maritime company may opt to bypass one port to the advantage of another if its efficiency is not satisfactory and if its hinterland access is problematic. The shipping network consequently adapts to reflect the changes in market conditions.

The global shift in the location of manufacturing activities as well as changes in supply chain management have led to new flows of maritime shipping. Flows of raw materials handled by maritime shipping have adapted, and emerging manufacturing clusters have seen significant growth. However, new flows are mostly evident

in patterns of container shipping. As exemplified by Figure 2, the new geography of production entails a new geography of distribution and its related flows. Because of a global trade structure characterized by imbalances, this structure implies its own new sets of flows. Many containers are moved empty, generating no income but carrying a cost that must be assumed in one way or the other. Either full or empty, a container takes the same amount of space on a ship or in a storage yard and takes the same amount of time to be transhipped. For instance, there are three times as many full containers moving from Asia to the United States as there are from the United States to Asia. In 2005, about 70% of the slots of containerships leaving the United States were empty, with major container ports such as Los Angeles handling large amounts of empty containers. Other major maritime trade routes, such as the Asia-Europe segment, are facing a similar but less acute imbalance. Thus, production and trade imbalances in the global economy are clearly

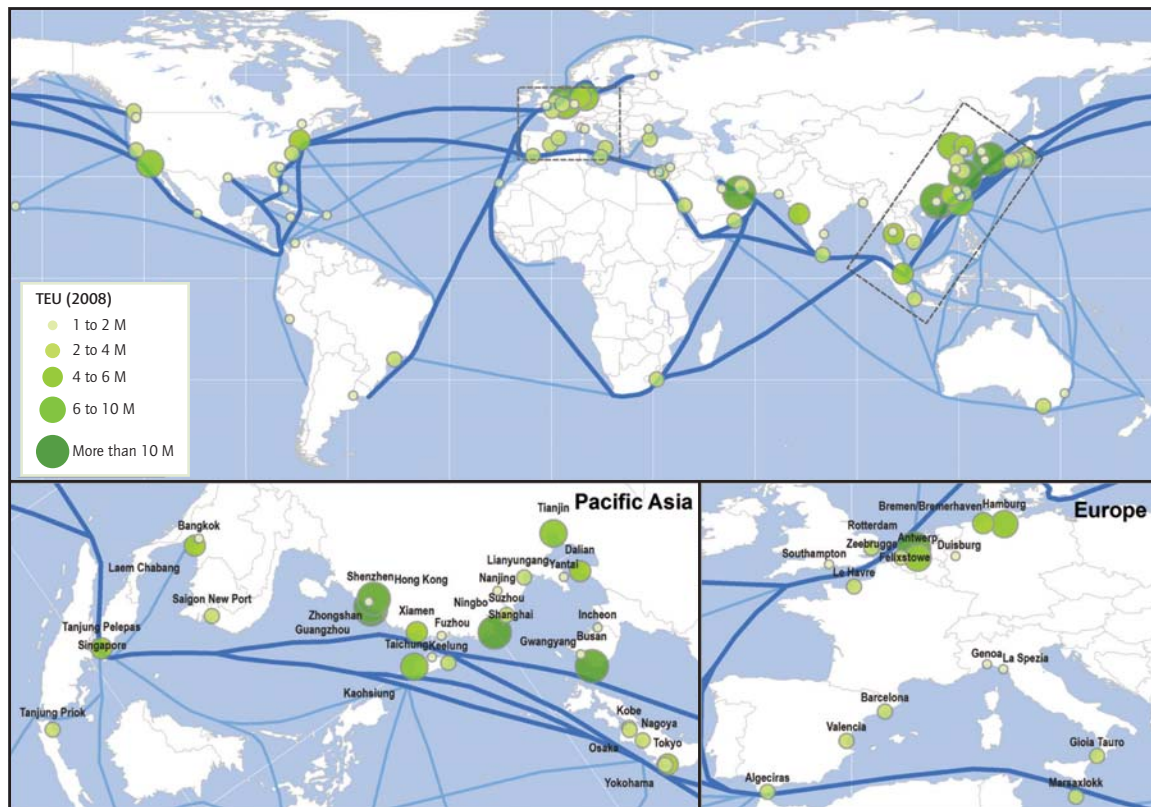


Figure 2 Traffic at the 50 largest container ports, 2006

Source: Containerization International. Cartography by author.

reflected in imbalances in physical flows and transport rates. For trans-Pacific trade, it costs more per TEUs for eastbound flows than for westbound flows, making freight planning a complex task for container shipping companies. For Asia-Europe flows, westbound rates are higher than eastbound rates.

Maritime Shipping Companies and Port Operators

The maritime transport industry is one of the most globalized industries in term of ownership. Maritime shipping companies and the majority of the largest port terminals are privately owned or operated. Such large assets must be efficiently managed, which entails extensive capital requirements. The trend in recent years has been a convergence

between the maritime segments of global trade and inland freight distribution. Global port operators, such as APM (Denmark), DPW (Dubai), HPH (Hong Kong), and PSA (Singapore), have been active in acquiring a portfolio of terminal assets in almost all the major ports of the world. Some, such as APM, are a direct subsidiary of a maritime shipping company—Maersk, the world's largest, in this case. Thus, a growing convergence between maritime shipping, ports, and inland operations enables large private conglomerates to achieve a level of control over global supply chains. This is particularly important as global trade is more than a matter of capacity; it is also concerned about the timeliness and reliability of the distribution.

The emergence of global private operators marks a reversal in the trend of considering ports to be



public entities, since many became inefficient and unable to cope with market pressures. The top five terminal operators account for about half of the world's port container throughput. In an era characterized by lower levels of direct public involvement in the management of transport terminals, specialized companies involved in the management of port terminals are finding opportunities at the global level. They tend to be horizontally integrated entities focusing on terminal operations in a variety of locations. The main tool used by global port operators to gain control of port terminals has been concession agreements. A concession agreement is a long-term lease involving the requirement that the concessionaire undertakes capital investments to build, expand, or maintain the cargo-handling facilities, equipment, and infrastructure. The range of port terminals controlled by port holdings covers several of the largest freight markets. As globalization permitted the emergence of large multinational corporations managing assets in a variety of locations, global port holdings are a similar trend concerning the management of port terminal assets. This has been a very profitable business, with substantial positive impacts in the efficiency of ports and maritime trade.

Jean-Paul Rodrigue

See also **Economies of Scale; Globalization; Oceans; Trade; Transportation Geography**

Further Readings

- Levinson, M. (2006). *The box: How the shipping container made the world smaller and the world economy bigger*. Princeton, NJ: Princeton University Press.
- Nottebbom, T. (2004). Container shipping and ports: An overview. *Review of Network Economics*, 3, 86–106.
- Rodrigue, J.-P., Comtois, C., & Slack, B. (2006). *The geography of transport systems*. London: Routledge.
- Slack, B., & Fremont, A. (2005). Transformation of port terminal operations: From the local to the global. *Transport Reviews*, 25, 117–130.
- Stopford, M. (1997). *Maritime economics* (2nd ed.). London: Routledge.



POSITIONALITY

Positionality is the notion that personal values, views, and location in time and space influence how one understands the world. In this context, gender, race, class, and other aspects of identities are indicators of social and spatial positions and are not fixed, given qualities. Positions act on the knowledge a person has about things, both material and abstract. Consequently, knowledge is the product of a specific position that reflects particular places and spaces.

Issues of positionality challenge the notions of value-free research that have dismissed human subjectivity from the processes that generate knowledge and identities. Consequently, it is essential to take into account personal positions before engaging in research, especially qualitative research. Consideration of the positioning of those engaged in the production of knowledge reveal that research is always and inevitably shaped by the actions and values of the researcher. Therefore, truly value-free research, if not impossible, is at least nearly impossible to obtain; the researcher's circumstances of life, his or her personal beliefs, and the mere fact of being a member of a society position the researcher in specific places and spaces and shape his or her values, assumptions, priorities, and ethics. This notion makes the idea of having an independent position from which one can freely and fully observe the world or be detached from the circumstances taking place in the research arena particularly unlikely.

Confronted with issues of positionality, scholars and researchers have responded in different ways. One strategy that attempts to address the issue of positionality in the context of conducting research is the use of the third person in reports, notes, interviews, questionnaires, and other research-related manuscripts. For researchers, writing in the third person aims to establish an outside view and a detached position, and therefore an objective tone. However, this practice has been frequently criticized. From the critic's standpoint, writing is much more than a set of facts or statements, because it also deals with representing and interpreting the researched subjects. In that context, each work affiliates itself with other works and with specific groups and institutions, and in doing



so, such works and positions can create not only knowledge but also the reality that they consciously or unconsciously seem to describe. Consequently, every author must locate herself or himself in what she or he writes and be aware of the kind of narrative voice, images, themes, and motifs adopted in her or his text. This is not simply a problem of finding a position but also the question of selecting which texts are the ones best suited for the research. In this notion, location is as important as awareness of personal positions. There is a strategic location that describes the author's position in a text, but there is also a strategic position that analyzes the way in which different modalities of the text (i.e., symbols used in the text, types of text, and textual genres) materialize among themselves and thereafter in the culture at large.

Another strategy researchers use to acknowledge their positionality is self-criticism. Scholars and researchers use self-criticism to locate biases of both inclusion and exclusion. In this context, researchers dismiss the notion of value-free research and recognize that claims to objectivity and neutrality serve only to make biases and human subjectivity invisible. Making the researcher's biases visible through a self-reflexive understanding of his or her positioning and fieldwork relations can help the researcher avoid invalid generalizations. This approach requires a commitment to understanding how the values and subjectivity of the researcher are part of the construction of knowledge.

These issues of positionality suggest that there is always a relationship between the researcher and the researched. This relationship deals with power and interpretation, as the researcher is in the position of interpreting the lives of others. From this perspective, it is essential to draw attention to the ways in which representations do not merely reflect social reality but are also constitutive of it. The politics of positionality demand that attention be paid to the structures of power that privilege certain voices while silencing others and endorse some points of view while dismissing others. In other words, researchers cannot ignore the problematic nature of what representation involves. As part of an in-depth self-reflection, one must know how to position oneself before drawing the line that makes the distinctions between "us" and "them." Positionality is not just acknowledging personal positions; it also

involves understanding how labels (such as race, ethnicity, and gender) are being constructed and represented through judgments made with the purpose of "othering." Therefore, no production of knowledge can ever dismiss or disclaim its author's involvement and positionings.

To be effectively self-reflective and fully locate themselves in their research, it is essential that researchers understand the differences between the positions of insider and outsider. Sharing the same background or similar identity, having things in common, or simply having an affinity with the researched subject(s) can influence the research outcomes. On the one hand, such insider positions can facilitate the collection of data, communication, movement, and so on. On the other hand, such a position can be somewhat problematic, as personal positions can restrict the development of the research by providing only a partial view and by not allowing the researcher to reflect on views that are opposed to her or his own. Likewise, failure to understand the differences between positions as insider and outsider can misdirect the potential research results, the production of knowledge, and the formation of identities. Nevertheless, given the difficulty involved in the task of completely understanding the self, it may be virtually impossible to be completely self-reflexive and fully aware of self-positionings.

Luis Sánchez

See also **Ethics, Geography and; Feminist Geographies; Fieldwork in Human Geography; Gender and Geography; Humanistic Geography; Interviewing; Orientalism; Qualitative Methods; Phenomenology; Situated Knowledge**

Further Readings

- Hay, I. (Ed.). (2005). *Qualitative research methods in human geography*. Oxford, UK: Oxford University Press.
- McDowell, L. (1992). Doing gender: Feminism and research methods in human geography. *Transactions of the Institute of British Geographers*, 17, 399–416.
- Rose, G. (1997). Situated knowledge: Positionality, reflexivity and other tactics. *Progress in Human Geography*, 21, 305–320.



POSITIVISM

See Logical Positivism

POSTCOLONIALISM

Postcolonialism is a vast and diverse area of study that seeks to examine the experiences of peoples and places—colonized and colonizers alike—both during and following the period of formal colonialism. By using postcolonial theory, postcolonial studies attempt to lend voice to the colonized and offer alternative interpretations of the process of colonization and the experiences of colonialism and empire. They also seek to challenge the naturalized assumptions of Western power and knowledge while creating space for alternative (and equally valid) knowledges and power dynamics.

While postcolonial studies originated in the fields of literary and cultural studies, they have since become interdisciplinary engagements that bridge the humanities and social sciences, including human geography. This entry offers an overview of the various meanings of postcolonialism, postcolonial theory, postcolonial studies, and postcoloniality, followed by an exploration of the historical development and critiques of postcolonialism. These include the critique of postcolonial representational analyses' immateriality, the debatable strength of real-world applicability of postcolonial critiques, and the question of the real beneficiaries of postcolonial destabilizations. It concludes with an examination of the subfields within geography that have employed a postcolonial framework.

Postcolonialism's breadth has aided in the development of multiple, sometimes hotly debated forms of the term *postcolonialism* itself. In a very basic and literal sense, postcolonialism refers to the period of time following colonialism, or the postindependence time period. However, this simplified notion ignores the continued connectivities, dependencies, exploitations, and forms of neo-imperialism that persist between the formerly colonized states and their former colonizers. The

"post" in "postcolonialism" suggests that the era is finished, but as many scholars have pointed out, postcolonialism (like other "posts") might be better viewed as a process of alteration with lingering colonial links. Postcolonial theorists actively work toward achieving more accurate and sensitive historiographies and representations, an equitable distribution of resources, and a rethinking and restructuring of Western knowledge production. However, to assume that such a goal has ever actually been, or ever will be, achieved is misguided.

Scholars working on postcolonialism use *postcolonial theory* to refer to the wide range of ideas that form the core of postcolonial studies. The works of foundational thinkers such as Edward Said, Homi Bhabha, and Gayatri Spivak, among others, have been particularly central to the field. Postcolonial studies have used these theories in a variety of ways, from work on political economy to identity and sport studies. *Postcoloniality* refers to the condition of living in a period of time after colonialism. This incorporates everything from material conditions, including the frequently unequal distribution of resources, to the less material realms, such as the ways in which newly independent peoples perceive their own identities. In addition to the creation of new words, postcolonial scholars have also debated whether or not the word *postcolonialism* should be hyphenated and even whether the single word *postcolonialism* does justice to the multiple, varying postcolonialisms in existence throughout the world.

Historical Development

Edward Said's *Orientalism* (1978) is frequently cited as the most influential work in the rise of postcolonial theory. Said employed a Foucauldian framework to critique Orientalist discourse, exposing the ways in which "the West" represented "the Orient" as barbaric, irrational, and "Other." Part of Said's influence on postcolonial theory has been to encourage a continued focus on the critique of discursive representations. Investigations of textual representations within colonial and postcolonial discourses examine not only how places, peoples, and things are represented but also who is allowed to do the



representing and the ways in which this is done. Representational analyses have examined colonial power within governmental bodies and within official discourses, but they have also included less formalized, cultural institutions and popular discourses. Because it can be argued that all representations require a degree of essentialism and are therefore inherently flawed, the question of the possibility of equitable representations arises. Spivak's (1988) answer to this issue was strategic essentialism, or the acknowledgment of the need for some simplified reduction in the representations of peoples and places for a particular political agenda.

Postcolonialism developed most extensively in the 1980s and 1990s, but a number of the scholars and activists who influenced those working within a postcolonial framework predated this period. Frantz Fanon's work on colonialism in Algeria and the Caribbean and the work of the Martinique author Aimé Césaire have remained important texts within the field. More recent influences have included Homi Bhabha's work on race and hybridity and Gayatri Spivak's Marxist-feminist assessment of postcolonial and subaltern studies. Although some have considered it to be separate from postcolonial studies, the field has also been influenced by the work of the Subaltern Studies Collective. This group, composed primarily of historians, has read Indian history against the grain, seeking to rethink and rewrite history from below or from the position of the silenced subaltern subject.

Key topics of consideration within postcolonial studies have included historical projects that revisit the colonial archives to highlight the ways in which the perceived separation of the cultures and institutions of the metropole and the periphery can be contested. Said's "contrapuntal reading" critically examined the Western literary canon to point out the silencing of colonial peoples and the concealment of the darker side of colonialism. Scholars working within the realm of postcolonialism have also employed a critical Marxist framework to display the unequal distribution of political and economic power and resources within the postcolonial world, in addition to the hybrid forms of colonialism, imperialism, and neocolonialism that persist throughout the world today.

Critiques of Postcolonialism

Postcolonialism and postcolonial theory have had their fair share of critiques. Some have voiced concern that postcolonial studies are overly preoccupied with "the West" at the expense of the rest of the world. For instance, it has been asked whether postcolonial theories actually reflect the desires of colonized, formerly colonized, and subaltern peoples or if they merely serve the interests of self-conscious academics located in the global North. Most postcolonial texts are written and published in English, inspiring some to argue for publication in the languages of those people whom postcolonial studies claim to represent. Critics have challenged the notion of postcolonial studies' ability to destabilize and decenter European geographic knowledges, stating that instead they merely reposition the same knowledges at the center. The call for increased appreciation of difference is viewed by some as a return to stagnant liberal multiculturalism. Additionally, postcolonial studies have tended to be dominated by Anglophonic geography and largely concerned with British imperialism. This recognition has resulted in calls to investigate imperialisms and colonialisms located elsewhere.

Postcolonial studies' origin in literary and cultural studies has also led to a critique from disciplines within the social sciences that these textual and discursive analyses lack materiality and sacrifice substance in their focus on the immaterial. Because postcolonial theory was in its origin influenced by poststructuralist and postmodern French theory, it has been argued by others that the very core of postcolonial theory contradicts its stated aims of pluralizing knowledges and power regimes. Among other critiques of postcolonialism is its perceived simplicity. Just as postcolonialism's meaning, "after colonialism," has been problematized, the creation of dichotomous categories of "colonizer" versus "colonized" has recently been critiqued for its lack of attention to multifaceted hybridities and complicated identities not only between, but also within, those categories.

Geography's Postcolonial Subfields

Postcolonial theory within the discipline of geography has gained wide purchase. Although



postcolonialism has obviously been popular across academia, Said's discussion of the development of "imaginative geographies" piqued geographers' interest. Postcolonial geographers have investigated the spatiality of colonialism, empire, and postcolonialism from a number of different vantage points. One of the greatest impacts of postcolonialism on geography has been the acknowledgment of geographers' involvement in the colonial project. This recognition that geography has been complicit in imperial projects historically (and, some would add, today) has led to calls to decolonize the discipline. Proponents have called for the incorporation of voices outside the metropole as well as a move away from the Eurocentric geographies frequently cited in colonial contexts. Historical geographers interested in disciplinary history have been particularly interested in the creation of imperial maps, the exoticization of colonized places, the imaginative geographies constructed about those places, and the racist and determinist treatment of peoples there. Cartographers have worked to critique and rethink the normalized Western map and the collection, representation, and dissemination of various knowledges of spaces and places.

Feminist and critical historical geographies have attempted to account for the inconsistencies and silences present even within the colonial powers, noting the lack of inclusion of other voices save that of white males as well as the nonstandard historical accounts, such as travel diaries. Feminist scholars have also criticized what they consider premature self-congratulation regarding the inclusion of alternative voices. By critiquing postcolonialism from within, postcolonial feminists have sought to occupy a paradoxical position both within and without the genre. Postcolonial feminist geographies have also been particularly attentive to methodological considerations, including self-reflexivity and the negotiation of power dynamics in research praxis.

The latter part of the 20th century saw a heightened interest in identity politics throughout many academic disciplines. Geographers working within a postcolonial framework took up identity and heritage to understand how postcolonial peoples, from both the metropole and the periphery, view themselves. The celebration and reclamation

of heritage has also been a focus for geographers attending to the specificity of place and group identities. Others within geography have studied transnational migrations and the diasporas that have frequently followed and, in some cases, helped perpetuate postcolonial linkages between former colonial powers and their colonial states. These linkages have also been the central focus of postcolonial critiques of tourism and other cultural entities, such as sport. Tourism geographers have stressed the economic and cultural influences and dependencies that continue today and the continuation of colonial practices of leisure by Western travelers.

Critical development geographers have also recently employed postcolonial theory in their critiques of uneven distributions of wealth, political and cultural power, and resources. Work in this field, as well as investigations of political economy, has ranged from a challenging of the preferred nomenclature over time—from Third World/First World and periphery/core to less developed/more developed and, most recently, global South/global North, to critiques of the overwhelming domination of the World Bank and the International Monetary Fund by the Western, former colonial powers. Like the work done in postcolonial literary studies, critical development geographies have sought to challenge Western ideas of "progress" and "modernity." Actions such as the forced privatization of social services in the global South in the name of modernity have been used to expose the neo-colonialism being perpetuated by Western states and multinational companies. Reactions to the policies of Western development organizations have included both non-Westerners and radical-activist Westerners. These anticolonial acts of solidarity have become another example of anticolonial struggles in a world engaged with many forms of postcolonialism.

Victoria S. Downey

See also **Antiglobalization; Colonialism; Developing World; Discourse and Geography; Globalization; Gregory, Derek; Hybrid Geographies; Imperialism; Orientalism; Other/Otherness; Poststructuralism; Race and Empire; Representations of Space; Social Darwinism; Subaltern Studies**



Further Readings

- Gandhi, L. (1998). *Postcolonial theory: A critical introduction*. New York: Columbia University Press.
- Jacobs, J. (2003). Introduction: After empire? In K. Anderson, M. Domosh, S. Pile, & N. Thrift (Eds.), *Handbook of cultural geography* (pp. 345–353). London: Sage.
- King, A. (2003). Cultures and spaces of postcolonial knowledges. In K. Anderson, M. Domosh, S. Pile, & N. Thrift (Eds.), *Handbook of cultural geography* (pp. 381–397). London: Sage.
- Power, M. (2003). *Rethinking development geographies*. New York: Routledge.
- Said, E. (1978). *Orientalism*. New York: Vintage Books.
- Schwarz, H., & Ray, S. (2000). *A companion to postcolonial studies*. Malden, MA: Blackwell.
- Spivak, G. (1988). Can the subaltern speak? In C. Nelson & L. Grossberg (Eds.), *Marxism and the interpretation of culture* (pp. 271–313). Basingstoke, UK: Macmillan.



POST-FORDISM

See Flexible Production



POSTINDUSTRIAL SOCIETY

Postindustrial society represents a major conceptual underpinning of geography and geographical discourses, with particular salience for social, economic, and urban geography as well as for allied disciplines and fields. Initially framed by the American sociologist Daniel Bell as a forecast of social change and as an explanation of social tendencies among advanced societies and states during the wrenching experiences of industrial restructuring in the latter half of the 20th century, the idea of the postindustrial society was also positioned as a critique of Marxist theories of production, labor, and social class formation and, more specifically, Marx's insistence on a

dominant social binary of capital and proletarian classes.

Initial references to the idea of the postindustrial society include David Riesman's (1958) interpretation of the term to connote leisure rather than work and an earlier invocation of postindustrial society as a hoped-for return to artisanal workshop vocations by the British Guild Socialist Arthur Pentty (*Old Worlds for New: A Study of the Post-Industrial State*) in 1917. The definitive usage was established by Daniel Bell in his seminal work *The Coming of Post-Industrial Society* (1973). Before committing to postindustrialism as a descriptor of change, Bell had experimented with the idea of alternatives such as the "knowledge society," the "information society," and the "professional society," and he also gave consideration to Dahrendorff's thesis of a post-capitalist society in *Class and Class Conflict in an Industrial Society* (1959). Bell's (1973) preference for postindustrial society as a descriptor of social transformation was derived from his sense that

we are in the midst of a vast historical change in which old social relations (which were property bound), existing power structures (centered on narrow elites), and bourgeois culture (based on notions of restraint and delayed gratification) are being rapidly eroded. (p. 37)

The sources of this historic "upheaval" are acknowledged as scientific and technological but "are also cultural, since culture, I believe, has achieved autonomy in western society" (p. 37).

According to Bell's formulation, the five dimensions or components of postindustrial society are the following:

1. **Economic sector:** The change from a goods-producing to a service economy
2. **Occupational distribution:** The preeminence of the professional and technical class
3. **Axial principle:** The centrality of theoretical knowledge as the source of information and of policy formulation for the society
4. **Future orientation:** The control of technology and technological assessment
5. **Decision making:** The creation of a new "intellectual" technology



Bell (1973) acknowledged a debt to Colin Clark, who postulated that income growth would lead to the expansion of services, and asserts that the “simplest characteristic of a post-industrial society is that the majority of the labor force is no longer engaged in agriculture or manufacturing but in services” (p. 15). Bell made a crucial distinction between the menial, low-value service employment that characterized developing societies such as India and the specialized, knowledge-intensive services that increasingly define advanced societies. These include occupations in health, education, research, and government and provided the basis for a “new intelligentsia” and, in turn, the “pre-eminence of the professional and technical class” (p. 15).

Bell’s prediction of a secular decline in industrial production and the laboring classes, and the ideological shift implied in this transition, achieved a powerful resonance within the academic and policy communities as well as fierce contestation. Criticisms of postindustrialism included opposition to the notion of an expansionist, autonomous service sector decoupled from manufacturing and industry. More specifically, scholars affirmed that the fastest-growing, most knowledge-intensive, and most deeply professionalized service industries were those most intimately linked to production: the so-called producer services. Other scholars, notably those associated with variants of Marxism, objected strenuously to the ideological tenor and policy implications of a postindustrial agenda, which implied a discounting of the value of industrial labor, class, and communities and a corresponding privileging of the interests of capital, epitomized by the neoliberal state regimes of Margaret Thatcher and Ronald Reagan.

Over the past three decades, the original emphasis on the nation-state as the unit of analysis for the study of postindustrial society has been adapted by social, urban, and economic geographers to apply principally to the urban-regional scale and, indeed, to measures of social change at the district, community, and neighborhood scales. The rise of the services class, and more particularly the managers and professionals who occupied the higher echelons of the postindustrial economy, implied far-reaching changes in advanced cities, as Bell predicted (and to some

extent deplored), expressed in political values, social attitudes, housing choices (locations, styles, forms of tenure), lifestyles, and behaviors. An early marker of class change in the city was the infiltration of professionals and managers into the old residential neighborhoods of the inner city, producing an insistent social upgrading and displacement trajectory. This process generated in turn both a policy crisis and an important new urban discourse of gentrification, pioneered by Ruth Glass in her study of occupancy change in London. By the 1990s, the process of manufacturing collapse had essentially run its course in many cities, with the postindustrial city now characterized by a dominant “new middle class” of elite service workers, including highly paid banking and financial workers, producer service professionals, entrepreneurs, and knowledge economy workers, fulfilling in large part Bell’s prophecy. At the local scale, this new middle class evinced a preference for a more “livable” and “convivial” city than that represented by the industrial city, with its manifest conditions of exploitation, materialism, segregation, and alienation. But in practice, this postindustrial, sociopolitical constituency enabled the state-supported dislocation of manufacturing and allied workers in urban districts, intensifying professionalization tendencies and pressures for social polarization.

More recently, the rise of the putative “creative class” postulated by Richard Florida and his followers presaged a new chapter in the evolution of postindustrial society. This creative class represented the social correlate of the cultural economy and workforce, seen as following “neo-Bohemian” housing and lifestyle patterns distinct in some respects from those of the new middle class, much as the behaviors of the latter constituted a departure from those of the industrial classes. But others contest this proposition of a quasi-autonomous creative class, instead asserting that cultural workers were always encompassed within the parameters of the new middle class and indeed were acknowledged as constitutive elements of Bell’s postindustrial society. This contemporary debate underscores the continuing relevance of Bell’s postindustrial theory for urban studies.

Thomas A. Hutton



See also **Class, Geography and; Development Theory; Education, Geographies of; Flexible Production; Information Society; Innovation, Geography of; Knowledge, Geography of; Producer Services**

Further Readings

- Bell, D. (1973). *The coming of post-industrial society: A venture in social forecasting*. New York: Basic Books.
- Florida, R. (2004). *The rise of the creative class*. New York: Basic Books.



POSTMODERNISM

The term *postmodernism* appeared in academic geography in the late 1980s, although it had been circulating earlier in several disciplines and professions. The term is often used in two different ways. First, it designates an object of study whereby researchers examine some feature that is seen to be postmodern in style, character, or design. Commonly identified postmodern objects include buildings, cities, cultures, societies, and economies, although this last object is often described using the related term *post-Fordist*. The clustering of such postmodern objects together may be seen to imply that people are, in at least some places in the world, living in a distinctive epoch or condition of postmodernity. The other way that the term *postmodernism* is often used is to imply an approach (or as it has also been described, attitude, method, or sensibility) to viewing and understanding the world and how it operates.

This entry briefly outlines how these two views of postmodernism arose and considers how they interconnect in the work of two geographers, David Harvey and Michael Dear. The entry also examines the impact of postmodernism, identifying three contrasting interpretations.

Postmodernism as Object

One of the fields where postmodernism emerged initially was in architecture, where the term

was used as an identifier of a new style that was different from and, indeed, critical of modernist design, which had risen to prominence in the 20th century but whose focus on the adoption of functionality, efficiency, and separation from the past had by the 1960s become subject to widespread criticism. It was at this time that architects such as Peter Eisenman, Frank Gehry, Peter Johnston, and Robert Venturi began to create new architectural designs that were promoted as being more in tune with and, indeed, learning from the performance of everyday human life. The rectilinearity and standardization characteristic of modernist architecture were replaced by an emphasis on diverse surfaces, textures, and forms, which often combined elements from both contemporary popular culture and a range of prior architectural styles.

The ideas circulating within architecture began to infuse academic studies of urban design and social life, notably through the work of Christopher Jenks and Frederick Jameson, and in the late 1980s, geographers began to make reference to the term *postmodernism*. In many of these studies, the term was not only applied to the design of particular buildings but also used to characterize whole cities. Edward Soja, for instance, presented Los Angeles as the quintessential postmodern city because it was composed of a plethora of urban forms reflective of a series of different divisions and fractures that came together to produce a collage of fragmentary images and experiences. David Harvey made a similar argument, albeit generalizing it to a range of North American cities that he suggested exhibited postmodernity through numerous cultural signs and images that constituted a sort of messy social collage, or pastiche, of meanings within which there was no apparent order. Postmodern architects, artists, filmmakers, and other cultural image makers were, in effect, codifying and representing a condition of social life that was already being experienced by many urban inhabitants.

Harvey's work, while clearly centered on cities, clearly illustrates how postmodernism could be identified in all manner of objects. At least two features tie these postmodern objects together. First, they are seen in some sense or other as new objects that can be contrasted with



something that went before and that was designated as modern. The “post” prefix in part therefore encompassed notions of temporal change, with postmodernism being viewed, in part, as a periodizing concept, although this usage was contested by a series of authors who argued that the term should not necessarily imply a clean break with modernism but could also be viewed as a continuation, albeit in a slightly new form.

A second aspect of postmodern objects is that they are seen to be highly complex and fluid, in contrast to what went before, which was seen to be regular and largely static in form. In relationship to buildings and urban form, postmodernism was seen to involve a movement from redevelopment focused on the construction of large rectilinear buildings and street layouts with clear and static divisions of land use, often bearing no relation to earlier forms of development, to regeneration whereby existing buildings were often modernized rather than replaced and new buildings were slotted into the fabric of existing buildings, both physically and symbolically, with many drawing on local building styles that were combined, sometimes quite ironically, with other, more modernistic and globalized elements. The result was a complex mix or pastiche of architectural styles and land use, often within a complex, multilayered street plan that involved multiple and changeable use of space.

Complexity and fluidity are also evident within other postmodern objects. Attention has been drawn, for instance, to the multiplicity, changeability, and hybridity of identities in contemporary pop music; leisure, recreation, and tourism; films and television programs; and the marketing and purchase of consumer commodities. Some scholars have also drawn attention to organizational changes in economic production whereby so-called post-Fordist economies have seen the rise of flexible and just-in-time production, often oriented to the production of niche and fashion products, and how these are connected to the cultural changes associated with postmodernism. Most prominent in this respect was David Harvey's book *The Condition of Postmodernity*, published in 1989, which argued that postmodernity was the product of a shift in capitalism toward flexible accumulation.

Postmodernism as Attitude

An emphasis on complexity and fluidity is also characteristic of “postmodernism as attitude,” although these descriptors are here applied to the conduct of finding out about the world as well as to the character of that world, or to put it more formally, postmodernism involved radically different epistemologies and ontologies from those previously enacted within geography.

Postmodern Ontologies

Connecting ideas of complexity and fluidity identified in various postmodern objects to the research process, postmodernism as attitude stressed at least two lines of ontological arguments. First, it was argued that modernist approaches tend to draw on “metanarratives” or “grand theories.” Metanarratives can be seen as “big stories” that serve to organize phenomena or events into some seemingly meaningful temporal order or pattern, centered around some central principle or plot, such as the growth of knowledge/reduction of ignorance or false belief, the realization of the human spirit, increasing control of nature, or emancipation from social control. All these narratives have been influential in geography at points in the recent past: the first of these, for example, underpinning positivist approaches to geography; the second, many strands of humanistic geography; and the third and fourth forming elements of Marxist approaches as well as a range of more liberal perspectives.

Many metanarratives involve grand theories, which are claims to understand how the world operates through the identification of concepts viewed as corresponding or referring to some central mechanisms or processes considered as propelling phenomena and events within much of the world. So, for instance, many positivist approaches drew on concepts such as economic rationality and profit maximization, humanistic geographies on notions such as authenticity and belonging, and Marxism on concepts such as modes of production and class struggle. While identifying quite different key concepts, and therefore often being seen as quite incompatible with each other, these approaches arguably all



shared a similar ontological stance in that the world is seen to be conditioned or ordered according to some central logic.

Postmodernism as attitude expresses, minimally, skepticism about the value of metanarratives and grand concepts and often complete rejection, as in Michael Dear's (2000) claim that the ideal of postmodernism is for a philosophical culture "free from the search for ultimate foundations of everything" (p. 35). Such a view, often characterized as a relativist position in which there are no singular, absolute truths but rather a range of different and equally valid perspectives, attracted considerable criticism, particularly in the late 1980s and early 1990s, when even some of the advocates of postmodernism expressed concern. However, it is clear that strands of postmodernist arguments have come to be widely accepted within geography, even among those who would not explicitly consider themselves to be postmodernist. From the late 1980s, for instance, there has been a growing recognition of the disorderly and contingent within geographical studies and how many aspects of the social and physical worlds do not seem to fit within some overarching logic or structure. There has been increasing resistance to the notion of developing general and hierarchical ontologies, whereby some features or processes are seen to be more significant, more foundational than others. In contrast, postmodernism can be seen to imply nonhierarchical and localized ontologies, whereby events, phenomena, and processes emerge because of the particular relationships that come to exist between all manner of elements that are copresent within particular times and spaces. Such a viewpoint creates a new, more humble role for theory, as explanations cannot be specified in advance of a particular study or transferred directly from one context to another. It also creates a stronger role for description than had been the case in many earlier, modernist perspectives, with attention being drawn, for instance, to notions of thick description and local knowledges as advanced by the anthropologist Clifford Geertz, as well as increasing attention being paid to the value of qualitative research methods, which arguably can be seen as part and parcel of a postmodernist approach to geography, just as quantitative methods had become widely equated with positivist philosophies.

A second ontological concern of postmodernism closely associated with its concern to avoid grand theory is a concern with difference. In part, this involved questioning of the assumption made within many modernist perspectives that explanation relied on seeking out the similarities between events, objects, or processes and suggesting that such approaches often resulted in crucial aspects of situations being overlooked. Moreover, it involved questioning of the categories of difference that entered into the accounts being created, suggesting that these were often far more diverse, complicated, and fluid than was often presupposed in modernist theories. Chris Philo, in a discussion of postmodernism in rural geography, for example, suggested that people had largely been portrayed as essentially similar to each other, and to those who were studying them, in that there was an implicit focus on people who were white, male, middle class, middle-aged, able-bodied, sound minded, and heterosexual. He suggested that this focus on "the same" needed to be supplemented by a study of "neglected others," people who were, in one way or another, different from the societal norm.

The study of "others" formed a focus for much geographical work in human geography from the late 1980s, with Michael Dear, one of the earliest proponents of postmodernism in geography, arguing in his book *The Postmodern Urban Condition* that postmodernism has had a liberating effect on previously marginalized voices, including women, people with disabilities, gays and lesbians, people of color, and the economically and socially disadvantaged. There has been an enlarging portfolio of people studied by human geographers, although concern has been expressed about practicalities, the ethics and politics of studies of "the other," and the possibility that postmodern ontologies and epistemologies are not fully compatible with the projects of other perspectives that have sought to give voice to neglected groups and interests, such as feminism, postcolonialism, and queer theory. Attention has also been drawn to "differences within the same," that is, how people who might be seen in many respects to fit into a societal group may in some respects be quite different from others in that group. Hence, for instance, one impact of postmodernism has been to foster attention on the



differences between women, a focus that has been described as characteristic of postmodern feminism and/or postfeminism.

Postmodern Epistemology

In relation to epistemology, postmodernism can be considered as involving a rejection of, or at least a movement away from, modern views on knowledge. At least since the European Renaissance, and probably well before, the acquisition of knowledge has been widely seen as emancipatory, holding, at least potentially, prospects of freedom from social and natural constraints. This viewpoint was quite explicitly articulated in the European Enlightenment of the 17th and 18th centuries and can be seen to infuse the metanarratives that have informed many of the philosophical perspectives that have, as noted earlier, been processed through geography through the course of the 20th century. However, a key strand of the postmodern critique of grand narratives has been to question, and in some cases completely reject, Enlightenment perspectives, not only highlighting that acquisition of knowledge frequently does not seem to lead to emancipation from necessity and social control but also, in the work of people such as Jean-François Lyotard, Michael Foucault, and Jacques Derrida, suggesting that knowledge and writing are themselves forms of power, containing strategies of both exclusion and suppression.

Three ideas have often been foregrounded in the postmodern critique of Enlightenment notions of knowledge and truth. First, and closely connected to the critique of grand theory discussed previously, there have been calls to recognize the limits and partial character of theory. Many arguments here focus on the issue of representation, with skepticism being expressed both about the ability of theoretical concepts to “cognitively map” the complexity and fluidity of the postmodern world and, more fundamentally, about whether concepts could ever be seen to correspond, in a meaningful way, to the phenomena they purportedly represent. There is a clear line of connection between the latter argument and poststructuralist criticisms of representational theories of truth. While modernist epistemologies

often draw implicitly on mimetic or correspondence theories of truth, whereby the truth or falsity of concepts is seen to reflect the degree to which they accurately align with/reflect the phenomena to which they refer, a range of writers associated with poststructuralism, including Baudrillard and Derrida, have questioned whether concepts have any linkage to anything beyond other concepts or signs.

As well as stressing the problems of representation, postmodern discussions of epistemology have also highlighted the situatedness of knowledge: how knowledge is always constructed from a position somewhere within society. This view is contrasted with the objectivist position of many modernist epistemologies that situated the researcher as ideally being some disembodied viewer surveying a world from which he or she had become detached. Not only was this positioning criticized as being impossible to realize, but in the 1990s, a series of other, explicitly situated positionings came to be advanced, including calls to view things “from below,” “from the margins,” “from the inside-out,” “from the streets,” “from the borders or contact zones,” and “from the in-between,” as well as through “traveling” and “nomadism.” As well as these calls for particular spatialized epistemologies, there were also more general calls for geographers to create more contextualized epistemologies by reflecting on and making reference to their own situatedness and positionality and how who one is determines what knowledge one generates.

A third epistemological aspect of postmodernism, closely connected to issues of positionality and situatedness, is the particularization of critique. While many postmodern geographers still retain an allegiance to some notion of critical geography committed to considering not only “what is” but also “what could be,” many are skeptical about the quite general, collective, transcendence of the present espoused by earlier radical, Marxist, and feminist geographers. Postmodernists have instead tended to focus on more partial and personally situated critiques centered on the interests, experiences, and problems of particular social groups. As a consequence, postmodernism has both drawn on and fostered perspectives such as postcolonialism, queer theory, and some strands of feminism.



Postmodern Objects and Modern/Postmodern Approaches

The consideration of postmodernism as both object and approach provides the possibility that the former can be approached both in a postmodern way and in a way that might be described as modernist, a possibility that has been clearly realized in the studies of the postmodern city by David Harvey and Michael Dear. As previously noted, the former's book *The Condition of Postmodernity* was one of the first geographical studies identifying cities as postmodern objects. Harvey, however, adopted a modernist approach in arguing that the conditions of living in postmodernity were themselves conditioned, or created, by processes that could be identified through Marxist conceptions of capitalism. This argument developed earlier work by Jameson that claimed that postmodernism represented the "cultural logic" of late capitalism.

Such viewpoints have, however, been strongly criticized, not the least by those who draw on ideas from postmodernism as approach. Michael Dear, in *The Postmodern Urban Condition*, for example, argues that Harvey fails to engage sufficiently with the issues of difference, epistemology, and politics highlighted by postmodernism as approach. Dear, in contrast, seeks to embrace the challenges posed by postmodernism as approach, constructing a series of explicitly personal and partial accounts of selected aspects of postmodern cities, particularly Los Angeles, which are not seen to necessarily make sense when taken together and among which none is seen as more explanatory than any of the others. Dear explicitly argues that he expects his embrace of a postmodern approach to urban postmodernity to be received skeptically by many, but his work bears similarities to notions of new urbanism advanced by people such as Ash Amin and Nigel Thrift. New urbanism shares an emphasis with postmodernism on the complexity and fluidity of urban life and on the limited power of theory, although here inspiration comes primarily from the work of people often associated with poststructuralism and actor-network theory.

Impacts of Postmodernism

The impacts of postmodernism on geography, and indeed most other disciplines in the social sciences and humanities, have been both considerable and highly contested, although people coming upon them now may find it difficult to appreciate their significance in that there is perhaps a feeling that, to use a periodizing concept of "post," human geography and many other disciplines and professions may be in a post-postmodern era or condition. David Ley, for instance, has suggested that usage of the term in the social sciences peaked in 1992 and a decade later had entered a phase of "unlamented decline." He adds that postmodernism's relatively short period of prominence could be interpreted in a range of different ways. It could, for one, be seen as reflective of a problematic concept, with postmodernists failing to transcend the limitations that they had identified in modernism. Alternatively, it could be argued that its impact was limited to the creation of a form of intellectual capital that, although significant in terms of building the career of a generation of human geographers in the 1990s, became subsequently devalued as its distinctiveness declined. A third interpretation is that the lack of explicit reference to postmodernism today is actually reflective of success, with postmodernism becoming part of the established way of doing human geography and other social sciences. Postmodernism has in effect become less remarked on as it has become naturalized, perhaps even domesticated. Furthermore, many of its concerns have clearly come to be pursued using new or reworked labels, such as poststructuralism, postcolonialism, postfeminism, queer theory, nonrepresentation theory, and critical theory/geography. This clearly does not mean that all the issues raised by postmodernism have come to be resolved in these other approaches, and hence, the challenge of postmodernism may still very much be a continuing one for human geography.

Martin Phillips

See also **Critical Human Geography; Dear, Michael; Discourse and Geography; Enlightenment;**



Epistemology; Flexible Production; Harvey, David; Ley, David; Human Geography, History of; Modernity; New Urbanism; Ontology; Positionality; Poststructuralism; Situated Knowledge; Soja, Edward; Structuralism; Text/Textuality

Further Readings

- Amin, A., & Thrift, N. (2002). *Cities: Reimagining the urban*. Cambridge, UK: Polity.
- Cloke, P., Philo, C., & Sadler, D. (1991). *Approaching human geography*. London: Paul Chapman.
- Curry, M. (1991). Postmodernism, language and the strains of modernism. *Annals of the Association of American Geographers*, 81(2), 210–228.
- Dear, M. (1988). The postmodern challenge: Reconstructing human geography. *Transactions, Institute of British Geographers*, 13(3), 262–274.
- Dear, M. (2000). *The postmodern urban condition*. Oxford, UK: Blackwell.
- Dear, M., & Flusty, S. (Eds.). (2002). *The spaces of postmodernity*. Oxford, UK: Blackwell.
- Geertz, C. (1973). Thick description: Towards an interpretative theory of culture. In C. Geertz (Ed.), *The interpretation of cultures* (pp. 3–27). New York: Basic Books.
- Geertz, C. (1983). *Local knowledge*. New York: Basic Books.
- Gibson-Graham, J.-K. (1994). “Stuffed if I know!” Reflections on post-modern feminist social research. *Gender, Place and Culture*, 1(2), 205–224.
- Gregory, D. (1989). Areal differentiation and post-modern human geography. In D. Gregory & R. Walford (Eds.), *Horizons in human geography* (pp. 67–96). Totowa, NJ: Barnes & Noble Books.
- Harvey, D. (1987). Flexible accumulation through urbanisation: Reflections of “postmodernism” in the American city. *Antipode*, 19(3), 260–286.
- Harvey, D. (1989). *The condition of postmodernity*. Oxford, UK: Blackwell.
- Harvey, D. (1992). Postmodern morality plays. *Antipode*, 24, 300–326.
- Jameson, F. (1984). Postmodernism, or the cultural logic of late capitalism. *New Left Review*, 146, 53–92.
- Jameson, F. (1988). Cognitive mapping. In C. Nelson & L. Grossberg (Eds.), *Marxism and the interpretation of culture* (pp. 347–358). Urbana: University of Illinois Press.
- Jameson, F. (1988). Postmodernism and consumer society. In A. Kaplan (Ed.), *Postmodernism and its discontent: Theories, practices* (pp. 13–29). London: Verso Books.
- Jameson, F. (1991). *Postmodernism, or the cultural logic of late capitalism*. London: Verso Books.
- Jenks, C. (1984). *The language of post-modern architecture*. London: Academy Editions.
- Ley, D. (1993). Postmodernism, or the cultural logic of advanced intellectual capital. *Tijdschrift voor Economische en Sociale Geografie*, 84, 171–174.
- Ley, D. (2003). Forgetting postmodernism? Recuperating a social history of local knowledge. *Progress in Human Geography*, 27(5), 537–560.
- Liotard, F. (1984). *The postmodern condition: A report on knowledge*. Minneapolis: University of Minnesota Press.
- Phillips, M. (2005). Philosophical arguments in human geography. In M. Phillips (Ed.), *Contested worlds: An introduction to human geography* (pp. 13–25). London: Ashgate.
- Soja, E. (1986). Taking Los Angeles apart: Some fragments of a critical human geography. *Environment and Planning D: Society and Space*, 4(3), 255–272.
- Soja, E. (1989). *Postmodern geographies: The reassertion of space in critical social theory*. London: Verso Books.
- Strohmayr, U., & Hannah, M. (1992). Domesticating postmodernism. *Antipode*, 24(1), 29–55.
- Turner, T. (1995). *City as landscape: A post post-modern view of design and planning*. London: Taylor & Francis.
- Warf, B. (1993). Postmodernism and the localities debate: Ontological questions and epistemological implications. *Tijdschrift voor Economische en Sociale Geografie*, 84(3), 162–168.



POSTSTRUCTURALISM

Though not always easily defined or clearly separated from postmodernism, poststructuralism was a groundbreaking shift in epistemology that occurred throughout the social sciences beginning in the late 1960s. It can be generalized as a system of thought that rejects the possibility of a single knowable “truth” by acknowledging a multiplicity of meanings that are constantly in the process of being created and changed. Poststructuralism, furthermore, emphasizes the power of discourse to create reality and inscribe subjects and uses this knowledge to create politically active theory and research. This entry discusses the origins of poststructuralism and the ways in which geographers have used poststructural theory.

Origins of Poststructuralism

Poststructuralism emerged in continental philosophy in the 1960s as a response to structuralist theories. Structuralism began as a linguistic theory espoused by Ferdinand de Saussure but then morphed into theories used throughout the social sciences. Saussure’s main contribution was to argue that the relationship between any given language’s words (signifiers) and the objects or ideas they represent (signified) was not a given fact but was, instead, arbitrarily produced through the differentiation of various signs or symbols from other signs. Saussure argued that, given this fact, it was impossible to see language as merely a Platonic reflection of the “real” world. Rather, a person must make the effort to understand the structures or rules that govern the application of signs to specific objects in order to understand how any language works.

This theory of language was then reinterpreted and applied in numerous other fields, but of particular importance to geography was its application in anthropology. Claude Lévi-Strauss applied Saussure’s theories to the study of culture in an effort to move away from teleological explanations of cultural evolution. Lévi-Strauss argued that the specific cultural traits of any society, such as rules regarding succession or kinship, were simply surface phenomena that reflected the deeper, structural rules shared by all societies. If

an anthropologist could look below the surface cultural phenomena, Lévi-Strauss argued, he or she could find the base structures that governed *all* cultures. The classic example for Lévi-Strauss would be the incest taboo, which he argued formed the basis for mating and procreation rules for all societies.

Other structuralist thinkers emphasized different bases for their analyses, but the basic explanatory rules remained the same; surface phenomena could be explained only through an analysis of the base mechanisms that controlled them. Structural Marxists such as Louis Althusser, for example, argued that in capitalist societies, all activity is predicated on and dictated by the economy. While other motivations may appear to hold sway, in the end, it is the economic that will determine surface activity.

Poststructural analysis began in earnest with the French philosophers Roland Barthes and Jacques Derrida in the mid 1960s. It was during this time that Barthes began to talk of the “death of the author,” arguing that the meaning of texts lay not with the author or with some sort of underlying structural rules but rather with the reader, who brought his or her own experiences and interpretations to any work. Meaning was not inherent in any work, but was subjective, something that was created by the interaction of the reader and the text, a text and society (context), or a text and other texts (intertext). Meaning under these terms became relational—that is, made and not given—not something that simply existed but rather something that came into being through interaction or mutual construction. This line of thought had important significance, not just for literary analysis but also for social science in general. Because meaning is not a given, there is no single “truth” that exists separate from social context and simply awaits “discovery.” There are instead multitudes of meanings and truths, and these meanings are all historically and (perhaps most important to geographers) spatially specific. Where structuralists saw systems and meanings that were closed and rigidly defined, poststructuralists see systems of meaning that are multiple, constantly evolving, and re-created through interactions with other systems.

Jacques Derrida questioned the very logic of identity and meaning in modern society. Through



the use of his methodology of deconstruction, Derrida exposed the flaws in the modernist project of constructing meanings through binary oppositions, which he called logocentrism. Derrida argued that these binary constructions included inherent value judgments that rendered the negative side of the binary, for example, the “not male” side of the male/female binary, as inherently less valuable. The goal of deconstruction is to expose the flaws in the logic behind these binaries, to force an acknowledgement of multiple possibilities. Feminist geographers have proven particularly effective in using this critique to show the masculinist tendencies in much geographical analysis. Female economic geographers, for example, have used deconstruction to show the way in which traditional definitions of economic activity have elided the productive economic work done by women. In doing so, they have exposed new spaces of economic activity, formerly defined as sites of reproduction rather than production, and opened them up to analysis.

Geography and Poststructuralism

Geographers have taken to poststructural theory in a number of important ways, particularly in economic geography, whose fields it has helped reinvigorate, and in the field of cultural geography, which it rescued from academic irrelevance. Poststructural theory opened new objects for analysis, for nearly anything could be read as text and all meanings were inherently multiple and contested. The acknowledgement of multiple meanings has been particularly fruitful for geographers, as they have sought to give voice to groups that have been marginalized in earlier forms of analysis, relocating the importance of discourses from the center to the margins. Furthermore, in acknowledging that the views and meanings of certain groups have been privileged in the past, poststructural geographies have become adept at analyzing the creation of both power and resistance.

Finally, poststructural theory has allowed the idea of space itself to be dramatically reconfigured. The realization that the meaning of texts is not inherent but subjective and that any object can be read as a text has opened up all sorts of

subjects to new geographical analyses. In this regard, the study of landscapes has been particularly invigorated by the adoption of poststructural techniques. Under the Berkeley School, landscapes were read as artifacts of culture, but their role in cultural production was not considered or even acknowledged. Poststructuralist geographers now look at the role that landscapes play in re-creating culture. Landscapes represent cultural discourses made concrete. They reflect the values and power relations that brought them into being. Furthermore, these manifestations of discourse are part of everyday occupied space. As such, they perform cultural work on all those who occupy them, either reaffirming the values that created them or encouraging acts of resistance.

Michel Foucault, the famed French philosopher, offered much to the development of a poststructural geography. A primary interest for Foucault was the connection between knowledge and power and the ways in which discourses of knowledge could be used to proscribe and discipline others. Foucault exposed the connections between discourse, knowledge, and power through the twin methodologies of archaeology and genealogy. In his early works of archaeology, such as *Madness and Civilization*, Foucault emphasized how discourses (broadly accepted facts and expertise, along with their accompanying institutions and social practices) limited what was conceivable at any given moment. By tracing the changing definition of insanity, Foucault showed how institutions created discourses that defined terms such as *madness* and, in doing so, created subjects who were then labeled as mad. By showing the historical specificity and politicized nature of various discourses, Foucault challenged notions of permanence or singular truth. Foucault also noted that the creation of new discourses often required the creation of new spaces for the enactment of those discourses (asylums, prisons, institutions, etc.). In this phase, Foucault showed that discourses, far from being consistent and independent, are historically situated and specific and are frequently co-constitutive of spaces.

In his genealogy phase, Foucault became increasingly interested in the power enacted around discourses. Here, he explored how discourse becomes



practices manifested in subjects. Thus, the body becomes the site where discourse is made manifest. Foucault's studies created a sort of geography of power. The ability of a discourse to be enforced on a body is a clear display of power. Sometimes, as in the case of Bentham's panopticon, in which prisoners are observed by an unseen, presumably all-seeing guard, who watches from on high in a central tower, power is centralized. But more often, Foucault was interested in the ways power from discourse acts in a decentralized manner. Because discourse is given the status of fact, subjects regulate themselves to conform to it. He argued that to truly understand the workings of power, one mustn't start at the center and analyze outward, but instead, one must start at the fringes and work inward. One needs to understand how power works on the micro- or local level rather than from top down. Furthermore, power is not always wielded by one group against another but is in constant flux and circulation.

Foucault's methods of analysis and exploration of discourse have been taken up by a number of geographers exploring the traditionally marginalized groups in Western thought. Edward Said's classic text, *Orientalism*, used Foucauldian analysis to explore how Europe defined itself by applying discourses of "otherness" on Asia. Other geographers have taken up genealogy to show how groups outside the global North are often constructed by its discourses. The anthropologist Arturo Escobar traced the discursive creation of the "Third World" to show how development has operated as a discourse that pathologizes the social and economic practices of countries that are deemed to be "developing." More recently, economic geographers have begun to analyze the genealogy of the discourse of globalization in an attempt to shatter the illusion of that process's inevitability. Geographers of gender have also used Foucauldian analyses to explore the pathologization and subsequent spatialization of gender and sexuality on the landscape.

The philosophizing of space has also been invigorated by poststructuralist thought. Previously a taken-for-granted entity, under poststructuralism, all space is relational. It is not an empty, value-less plane on which activities occur; rather,

it is created by the actions of the actors within it. Space, therefore, can have multiple meanings and uses, and because it is made through the interaction of actors, space is never closed or cut off but is always in the process of being made, of becoming. To the extent that one spatial formation can become dominant at a given moment, space is also the site of both power formation and acts of contestation and resistance.

Bruno Latour, a French sociologist, conceived of space as created by a series of networks connected through linkages. The operation of these networks helps better explain how Foucault's ideas of power at the micro- or local level (e.g., in an asylum or within an institution) can be extended to unconfined space. Nodes in the network are added through the processes of recruitment and translation. A central actor recruits nodes that consent to become a part of the network because they share its goals in some way. But in enrolling in the network, they are translated by it, inexorably changed to meet the demands of the network. This translation is a form of discipline. Networks gain strength by their number of connections. Thus, a network is composed of actors, but it is also an actor itself, working to achieve some goal. This combination of roles as both actor and network gives name to this particular mode of analysis—actor-network theory.

To Latour and other actor-network theorists, space does not exist outside a network; it is created through the actions of networks in bringing people and materials together. Networks create space, and that space exists at all scales. Individual actors perform functions at the local level, but networks extend as far as they have connections; therefore, they are capable of being at once both global and local. Geographical analysis, then, means following a network wherever it may lead. This means the investigator can assume no preexisting hierarchical structure but must simply follow the connections between nodes. This type of analysis once again problematizes the idea of a central concentration of power. Power in the network is diffused, spread between nodes, flowing inward and outward, as the actors at each node have their own agency. Further complicating this web of interaction is the fact that multiple networks can and do exist simultaneously. This means that individual places have



multiple meanings at any given moment. Society under this mode of analysis is simply a collection of multiple overlapping networks.

Theorists such as Gilles Deleuze and John Law prefer to think of space as even more complicated than the multiple spaces of actor-network theory. They argue that space is fluid, never fixed, but forever in the act of becoming. Since space is an area of contested meaning, with multiple actors or networks competing to define it, it is never stable or singular; it is always in the process of becoming something else. In this sense, space is unknowable. To these theorists, space is not a plane but is rippled, folded, and ruptured. Objects that are distant in a Euclidean sense can be seen as folded close together in topological space due to their connectivity via networks, while objects in close proximity may exist on entirely different planes, in different spaces. This theorizing of fluid space attempts to take into account groups or individuals who may not be incorporated in any network.

While poststructuralism and its intellectual cousin, postmodernism, have been criticized for being “anything goes” types of theory, this is far from the case. Poststructuralist analysis is a political act, designed to decenter ideas that have been accepted as fact in order to open readers and investigators to new possibilities of futures and presents previously unimaginable under modernist logical conventions.

Aaron Gilbreath

See also Actor-Network Theory; Critical Human Geography; Dear, Michael; Discourse and Geography; Epistemology; Human Geography, History of; Hybrid Geographies; Massey, Doreen; Orientalism; Panopticon; Postmodernism; Relative/Relational Space; Representations of Space; Scale, Social Production of; Soja, Edward; Structuralism; Text/Textuality; Time-Space Compression

Further Readings

Bingham, N. (1996). Object-ions: From technological determinism towards geographies of relations. *Environment and Planning D: Society and Space*, 14, 635–657.

- Bingham, N., & Thrift, N. (2000). Some new instructions for travelers: The geography of Bruno Latour and Michel Serres. In M. Crang & N. Thrift (Eds.), *Thinking space* (pp. 281–301). London: Routledge.
- Boggs, J., & Rantis, N. (2003). The “relational” turn in economic geography. *Journal of Economic Geography*, 3, 109–116.
- Deleuze, G., & Guattari, F. (1987). *A thousand plateaus: Capitalism and schizophrenia*. Minneapolis: University of Minnesota Press.
- Doel, M. (1999). *Poststructuralist geographies: The diabolical art of spatial science*. Lanham, MD: Rowman & Littlefield.
- Escobar, A. (1995). *Encountering development: The making and unmaking of the Third World*. Princeton, NJ: Princeton University Press.
- Foucault, M. (1979). *Discipline and punish*. New York: Vintage Books.
- Foucault, M. (1988). *Madness and civilization*. New York: Vintage Books.
- Gibson-Graham, J. K. (1996). *The end of capitalism as we knew it: A feminist critique of political economy*. Oxford, UK: Blackwell.
- Harrison, P. (2006). Post-structuralist theories. In S. Aitken & G. Valentine (Eds.), *Approaches to human geography* (pp. 122–135). Sage: London.
- Latham, A. (2002). Retheorizing the scale of globalization: Topologies, actor-networks, and cosmopolitanism. In A. Herod & M. Wright (Eds.), *Geographies of power: Placing scale* (pp. 115–144). Oxford, UK: Blackwell.
- Massey, D. (2005). *For space*. Thousand Oaks, CA: Sage.
- Murdoch, J. (2006). *Post-structuralist geography: A guide to relational space*. Thousand Oaks, CA: Sage.
- Said, E. (1979). *Orientalism*. New York: Vintage Books.
- Sheppard, E. (2002). The spaces and times of globalization: Place, scale, networks, and positionality. *Economic Geography*, 78, 307–330.
- Warf, B. (2008). From surfaces to networks. In B. Warf & S. Arias (Eds.), *The spatial turn: Interdisciplinary perspectives* (pp. 59–76). London: Routledge.



POVERTY

Poverty is deprivation of material essentials such as food, shelter, drinking water, and clothing. It is also associated with the lack of education, freedom, and dignity. The uneven distribution of poverty at various scales, from the global to the household, via the national, regional, and local, suggests the importance of geographic factors in explaining its prevalence and understanding its nature.

Poverty Measures

There is disagreement on how best to measure poverty. The first distinction exists between absolute and relative measures. Absolute measures identify a minimum level of income or consumption below which individuals or households are considered poor. For example, the World Bank defines extreme poverty as less than \$1 per day and moderate poverty as less than \$2 per day, with purchasing power parity adjustments allowing comparisons between countries. Because standards of living vary dramatically across places, most countries have established their own absolute poverty lines. In the United States, the poverty threshold was established in 1965 based on the cost of food, taking into account household size and composition but making no adjustment for regional differences in cost of living. The threshold is adjusted annually for inflation. For example, in 2007, the federal poverty threshold for a family of three, with one adult and two children, was \$16,705—far above the extreme world poverty measure but well below the national average income.

Income-based measures have led to some criticism that monetary amounts do not directly translate into human well-being. The Nobel laureate Amartya Sen argues that poverty is the deprivation of basic capabilities to lead the kind of life one chooses. Although income is instrumental in reaching this goal, its impact is conditional and varies between different communities, families, and even individuals. To address these shortcomings, in 1997, the United Nations constructed the Human Poverty Index (HPI) based on three components: life expectancy, education, and economic provisioning. Although correlated with per capita

income, the HPI does not yield the same ranking of countries as the World Bank's extreme poverty measures, suggesting that social structures, government policies, and other local attributes can influence the quality of life.

Relative poverty measures conceptualize poverty as socially constructed and dependent on the social context. Within this perspective, the poverty threshold is defined in relation to a national or regional benchmark rather than in absolute terms. One of the most common measures sets the poverty cutoff at a given percentage—usually 50% or 60%—of the national or regional median income. Another approach defines poor people as those in the bottom percentiles of the income distribution. Thus, relative poverty and inequality are connected to the extent that the former results from a sense of deprivation emanating from a substandard economic position. Relative poverty measures are used more extensively in developed nations, where extreme poverty is less prevalent but people with incomes significantly lower than the median experience economic deprivation, social exclusion, and limited ability to participate in society.

The Distribution of Poverty

Poverty varies both demographically and geographically. In 2004, there were close to 1 billion people in the world living on less than \$1 per day, a decrease of 250 million since 1990 and a step toward reaching the United Nations' Millennium Development Goal of reducing extreme poverty by half by 2015. Poverty, however, is not distributed evenly (Figure 1). Most of its recent decline can be attributed to East Asian countries. Although the majority of poor people remain in South Asia, poverty has increased most rapidly in sub-Saharan Africa, where almost 300 million people, or 41% of the population, live on less than \$1 per day. Poverty recently increased in Western Asia and remains fairly constant in Latin America. Many Latin American countries such as Ecuador, Argentina, and Nicaragua fare better on the HPI than on income poverty. This contrasts with African countries such as Morocco, Egypt, Algeria, Senegal, and Burkina Faso, where the HPI rankings are worse than expected, given the poverty rates.

Some of the gains in absolute poverty are overshadowed by increases in inequality and

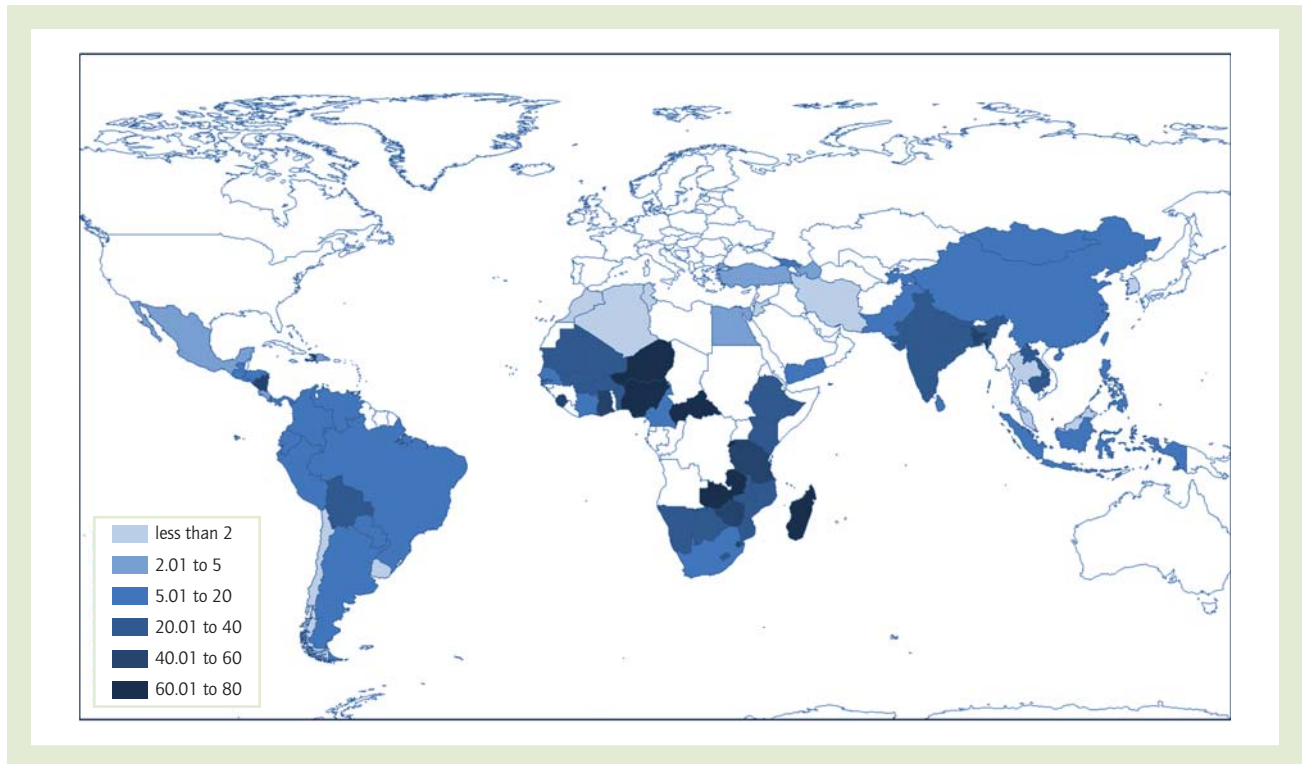


Figure 1 Percentage of population living on less than \$1 per day

Source: Data from United Nations Development Programme. (2007). *Human development report 2007/2008*. New York: Palgrave Macmillan.

worsening relative poverty in most of the developing world, where the poorest quintile accounts for less than 4% of national consumption. Inequality is particularly acute in Latin America, the Caribbean, and sub-Saharan Africa.

Although extreme poverty is virtually nonexistent in the Organization for Economic Cooperation and Development (OECD) countries, national measures indicate the presence of economic deprivation. For example, in the United States in 2006, 38.8 million people, or 13.3% of the population, fell below the federal poverty line.

Of course, important variations exist within regions and nations. Although poverty rates are usually higher in rural areas, a large and growing number of poor people live in urbanized areas, with a significant degree of concentration and clustering in specific neighborhoods and informal settlements. Throughout the world, racial, ethnic, and religious minorities; indigenous populations; and women and children are more likely to suffer from poverty.

Causes of Poverty

Multiple factors operating at various interconnected scales cause poverty. Globally, uneven trade and capital flows lead to poverty through exclusion from the benefits of economic growth. Access to water and natural resources, transportation, and climate also shape physical abilities and economic opportunities. International and national policies influence poverty directly, through aid, subsidies, and antipoverty programs, and indirectly, through economic policies that affect the allocation of resources between people, regions, and industries. While some argue that individual characteristics such as education and the work ethic are paramount in explaining poverty, others insist that social and economic structures define capabilities based on gender, class, caste, race, religion, and other forces. Women are often denied access to education, paid employment, health care, financial resources, and political participation because of their gender. While



these socially embedded practices deprive women of economic opportunities and basic freedoms, they also contribute to poverty indirectly through fertility and child care.

In the United States, the rise of “working poverty” has been linked to economic restructuring and the decline of the welfare state. The role of these factors varies from place to place and underscores the importance of geography in understanding poverty.

Pascale Joassart-Marcelli

See also *Class, Geography and; Dependency Theory; Developing World; Development Theory; Homelessness; Hunger; Inequality and Geography; Justice, Geography of; Malthusianism; Neo-Malthusianism; Peasants and Peasantry; Regional Economic Development; Social Justice; Spatial Inequality; Underdevelopment; Uneven Development; Urban Underclass*

Further Readings

- Kodras, J. (1997). The changing map of American poverty in an era of economic restructuring and political realignment. *Economic Geography*, 73, 67–93.
- Sen, A. (1999). *Development as freedom*. New York: Anchor Books.
- United Nations Development Programme. (2007). *Human development report 2007/2008*. New York: Palgrave Macmillan.
- Webster, B., Jr., & Bishaw, A. (2007). *Income, earnings, and poverty data from the 2006 American Community Survey*. Washington, DC: U.S. Census Bureau.



POWELL, JOHN WESLEY (1834–1902)

John Wesley Powell, an American explorer, scientific frontiersman, teacher, military leader, geologist, naturalist, government administrator, ethnographer, and geographer, is best known for having been the first to explore the length of the Colorado River through the Grand Canyon. According to William Morris Davis, Powell laid the

foundation for American geomorphology and profoundly influenced those who came after him.

Born in Mount Morris, New York, Powell spent many of his early years in Ohio, Wisconsin, and Illinois. His father, a dedicated Methodist abolitionist preacher and farmer, moved the family frequently to serve various congregations. John had obligations on the farm owing to his father's frequent absences. Irregularly educated, he received considerable natural history training from a neighbor, who provided a classroom, a small library, a laboratory, and field instruction.

By age 18, he was teaching school, studying, traveling, and collecting specimens locally, and he furthered his own education by planning and executing trips on the Ohio, Des Moines, Illinois, and Mississippi rivers. Though he never graduated, he did manage to complete approximately 2 yrs. (years) of university training.

At the outbreak of the Civil War, having enlisted in the Twentieth Illinois Infantry, he was very quickly promoted to sergeant and to second lieutenant. Assignments included engineering roads and bridges and establishing camps and battlements. Struck in the lower right arm by a rifle shot at Shiloh, his lower arm was amputated; however, he remained in the army for 3 more yrs. and was later stationed at Vicksburg, where he commanded artillery. During one of his military leaves, Powell married Emma Dean from Detroit.

After the war, he took a professorship at Illinois Wesleyan University and Illinois Normal School, teaching a variety of science classes. An advocate for increased science and fieldwork in college curricula, he organized a field trip in 1867 across the Great Plains to the Rocky Mountains with his wife and students. This event led him to organize his first trip down the Colorado River in 1869.

Embarking on May 24, 1869, the expedition included four wooden boats, manufactured in Chicago and delivered by rail to Green River, Wyoming; supplies for months of travel; and 10 men from various backgrounds. They floated on the Green, through the Uinta Mountains to the junction with the Grand River and into the Grand Canyon. Vertical cliffs, giant rapids, and steep falls made progress slow and difficult. Even with near disasters, including the loss of supplies, scientific equipment, and most of the food, the party emerged from the canyon more



than 3 months after departure. During the journey, Powell documented geologic columns, identified fossils, recorded elevations with a barometer, and kept careful scientific records. He later conducted further research in the plateaus of the Colorado, focusing on geology, geomorphology, and ethnology.

Powell's contribution to geology, geomorphology, and geography are considerable. He classified landform regions of the United States, mountain types, and stream drainage systems. He developed concepts such as the graded stream, the base level of erosion, superposition, and antecedent rivers, which led later geomorphologists to unifying theories. He recognized that landforms evolve as the result of differential removal of materials; he explained surface processes and landforms and that uplift and erosion are slow processes. These concepts reinforced the notion of uniformitarianism, the doctrine that processes operate in the same way over geologic time. He carefully observed and documented landscape features, having measured stratigraphy, lithology, and fossils throughout the Grand Canyon and Colorado plateaus.

Powell possessed great vision about the future of the Western United States, particularly its water issues, cautioning in various reports that the western lands were fragile and that water would be a controlling factor in settlement. He recognized that only a small percentage of the western lands were suitable for agriculture owing to water scarcity. He also knew that water allocation in the west must be treated differently than in the Eastern U.S. model, in which water rights go with the land. Powell also encouraged further hydrologic studies to understand the behavior of water. He advocated stream discharge measurements, careful record keeping, and the identification of potential reservoir sites.

Powell enjoyed a second career as an administrator in Washington, D.C., after having developed associations with Congress and governmental officials while fund raising for expeditions. He had developed sympathy, trust, and respect for Native Americans during his explorations, and his study of Native Americans led to his appointment as ethnographer of the Smithsonian in 1879. He served as the director of the Smithsonian's Bureau of Ethnology until his death in 1902. At the Smithsonian, Powell assembled a group of

talented scholars, and significant ethnographic projects emerged. Under his authority, the Indian Linguistic Families of North America report and map were published.

Powell became the second director of the young U.S. Geological Survey (USGS) in 1881. Under his direction, the USGS budget grew. He developed an effective team of experts and produced many outstanding reports. A significant contribution to the USGS was the development of topographic maps with contour lines representing topography rather than the European hachure model. He insisted that these maps be simple, produced for the entire country, and useable by miners, cattlemen, farmers, and geologists. In 1894, he resigned from the USGS, as appropriations began to shrink due to pressure on Washington decision makers for unbridled western development. His ideas about the west and its water issues were getting in the way of developers. As a result, he stepped down from the USGS directorship.

Powell was significantly involved in the establishment and leadership of many local and national scientific societies, including the American Anthropology Association; the National Geographic Society, which, at that time, published a scholarly scientific journal; the American Association for the Advancement of Science; and the Geological Society of America.

Bryon D. Middlekauff

See also Davis, William Morris; Exploration; Physical Geography, History of

Further Readings

- Chorley, R. J., Beckinsale, R. P., & Dunn, A. J. (1973). *The history of the study of landforms* (Vols. 1–3). London: Methuen.
- Davis, W. M. (1915). *Biographical memoir of John Wesley Powell*. Washington, DC: National Academy of Sciences.
- Powell, J. W. (1961). *The exploration of the Colorado and its canyons*. Toronto, Ontario, Canada: Dover. (Original work published 1895 as *Canyons of the Colorado*)
- Worster, D. (2001). *A river running west: The life of John Wesley Powell*. New York: Oxford University Press.



PRAIRIE RESTORATION

Across the world, prairies are among the most manipulated landscapes as prime sites for grain crops such as wheat and corn. Found in semiarid regions such as the North American Midwest and the Russian steppe, their mix of grasses and forbs (broadleaved herbs) sends roots deep. The native plants support a rich mix of animals, insects, and birds; the substitution of monocultural grain crops harms them. Prairie restorations are attempts to recover diversity by reintroducing a wide array of native plants. Full prairie restoration includes disturbances from periodic fires, which clear surface plant matter while reinvigorating the soils, and migration by native animals, whose hooves break up the topsoil layer to make way for new fresh growth once they have passed.

Early pioneers in prairie restoration include Midwesterners such as Jens Jensen (1860–1951)

and Aldo Leopold (1887–1948). Jensen, a landscape architect, was instrumental in developing an aesthetic of native plants, seeing them as worthy rather than as weeds. Leopold's *Sand County Almanac* simply and beautifully describes the year he spent bringing back a degraded Wisconsin property. His writing celebrates unappreciated native plants such as the delphinium, which serendipitously survived, ignored along the railroad right-of-way. Leopold used his experience to develop a land ethic based on honoring the complexity of ecosystems and on an acknowledgment that health requires maintaining the interactions between species—the basis of prairie restoration. Leopold's ideas inspired many in the tallgrass prairie region, and groups in states such as Wisconsin, Iowa, Illinois, and Kansas have been leaders in prairie restoration. Academics and universities, land restoration organizations such as The Nature Conservancy, and citizen groups acquire land and develop prairie research and



Land managers set fire to a prairie burn with drip torches to stimulate new growth and recycle nutrients at Konza Biological Research Station, Manhattan, Kansas.

Source: Jeff Vanuga, U.S. Department of Agriculture, Natural Resources Conservation Service.



restoration programs. The Society for Ecological Restoration is the professional association committed to such efforts.

Restoration in the more western, drier, short-grass prairie has been a bit less active, perhaps because more of the ecosystem remains intact, though degraded particularly by the loss of animal species. Lands that have been grazed but not put to cultivation of crops still harbor native plants that revive when management mimics preagricultural patterns. Short-grass prairie restoration tends to emphasize native animals; for the American Prairie Foundation in Montana and the Grasslands National Park in Saskatchewan, for example, bison restoration is central. These efforts bring to life the concept of the *Buffalo Commons*, a term coined by Deborah and Frank Popper, advocating the reinvigoration of the North American Great Plains by using ecological restoration as the guiding principle for future development. Restored prairie addresses the problems of erosion and declining and contaminated water tables while providing economic opportunities both for high-quality ecotourism and for scientific research.

Prairie restoration is growing around the world. Severe dust storms in the Chinese grasslands, which caused extensive crop loss and animal deaths and damaged houses, have spurred restoration efforts there. Pilot projects involve collaboration between scientists and local communities to reduce animal-stocking numbers, to reseed overgrazed areas, and to reanalyze how the relatively new irrigation systems can be used strategically to support agricultural production without increasing erosion vulnerability. Russian restoration experiments date back to the 1960s. They remain small in scale and acreage, but, as elsewhere, interest and commitment to the effort are increasing.

Deborah E. Popper

See also Biome: Midlatitude Grassland; Environmental Restoration; Everglades Restoration; Landscape Restoration; Prairies

Further Readings

Leopold, A. (1968). *A sand county almanac and sketches here and there*. New York: Oxford University Press. (Original work published 1949)

Manning, R. (1997). *Grassland: The history, biology, politics, and promise of the American prairie*. New York: Penguin.

Packard, S., & Mutel, C. (Eds.). (2005). *The tallgrass prairie restoration handbook*. Washington, DC: Island Press.



PRAIRIES

Areas that were mostly covered with grasses and subdominant forbs (broadleaved herbs) prior to human intervention are known as *grasslands*. Extensive tracts of these grassland ecosystems in the drier interiors of continents, particularly in North America, are known as *prairies*. Grasslands occur where there is not enough precipitation to support a forest but there is enough for herbaceous plants. The grasses and lack of precipitation are just two of the characteristics that set apart the prairies from the other ecoregions of North America.

The beginnings of the North American grasslands occurred during the Miocene-Pliocene transition, perhaps 5 million to 7 million years ago. This time period is associated with widespread drying. The increased aridity resulted from the cooling of the oceans as the Antarctic ice sheet spread and from the uplift of the Rocky Mountains. The mountains provided a partial barrier against the moist Pacific air.

There is limited precipitation in this central region, with very warm ground and air temperatures in the summer and extremely cold temperatures in winter. The prairies extend several hundred kilometers, from north-central Mexico to the southern sections of the Canadian provinces of Alberta, Saskatchewan, and Manitoba. The terrain is most often level, though it may also include rolling topography such as the Flint Hills, which stretch from north-central Oklahoma to the north-eastern section of Kansas. Prairies are often categorized into three types: short-grass prairies, tallgrass prairies, and mixed-grass prairies.

The western sections of the prairie consist primarily of short grasses, which often grow in tufts. In this region, temperatures are higher in summer than in the prairies to the east, and the annual precipitation may fall below 25 centimeters. The grasses are generally less than 0.65 m (meters) in



height and can adapt better to occasional drought conditions and extreme temperatures. This type of prairie is often found not only in the semiarid climate of the Great Plains of North America but also in Eurasia, where it is referred to as *steppe*.

Tallgrass prairies once covered 140 million acres of North America, but now only 4% remain. These prairies are predominantly composed of taller grasses, sometimes reaching a height of 2.5 m. These grasses also have extensive and deep root systems. Nutrients have a stronger tendency to remain in the soil rather than leaching, since there is less rainfall here than in the forests. The intricate root systems are very efficient at using whatever water is available. The roots also stimulate carbonates and other nutrients such as calcium and magnesium to join the humus-rich surface layer.

A mixed-grass prairie is a landform where the grass composition is constantly shifting between tall and short grasses. This species transformation occurs as climate, precipitation, fires, and frequency of grazing vary from season to season.

North American prairies developed under the influence of grazing by a diverse group of native herbivores. Because the growth of grasslands is linked with a rise in the number of grazing and browsing animals, the association of grasses and grazers is most likely an ancient one. Several commonly known inhabitants were deer, antelope, and vast herds of bison that liberally fed themselves as they roamed. However, their constant nibbling did not destroy the grasses. Unlike woody plants, grass plants adapt well to grazing. The growing tissues in grasses are found at the base of the leaves near the ground surface. Therefore, when animals graze on the leaf blades, the continued growth process of each plant is protected. The adjacent forbs also survive because they may have thorns, tough structures, or simply a bad taste that discourages grazing.

Prairies also developed under the historical effect of fires, some set by Native Americans and some occurring naturally, such as those sparked by lightning. These fires removed predators and undesirable insects. Fires provided the necessary disturbances to deter the growth of invasive woody species and encouraged the increased growth of grasses and forbs in the North American prairies.

Temperatures in the prairies change seasonally, from extreme heat in the summer to bitter cold

in the winter. The winters can bring powerful blizzards, particularly in the Northern United States and in Southern Canada. With blizzards in the winter, droughts in the summer, and precipitation varying so much from year to year, it can be difficult to place the prairies into firm climatic categories.

Pioneer wagons on their way west most often passed through the grasslands, because the elevation change was gradual and travel easier over the level terrain. However, they seldom stopped to settle, because farmers from the east were accustomed to plenty of water for their crops and animals and were not readily prepared for the overall dry conditions. They were also used to an abundance of wood for building, fencing, and heating, and in the prairies, wood was scarce.

Between 1825 and 1865, rainfall was low in much of North America but especially in the central portion. Storms with high winds, hail, and tornadoes were common. In the winter, there were cold temperatures and blasts of wind that produced immense snowdrifts. Much of the prairie was too difficult to farm. The grasses' strong root systems made it extremely difficult to plow the land, and some farm implements that normally took one or two animals to operate often required the strength of numerous animals. For housing, however, settlers were able to use large bricks cut from the prairie sod to construct durable and sturdy homes.

In 1837, John Deere invented the steel plow, which made it possible to break apart the strong roots of the thickly interlaced sod. Barbed wire was developed in the 1870s, giving the rancher an alternative to the traditional wooden fence. The wet and dry periods continued, but with the expansion of the railroad and numerous agricultural innovations, such as the steel plow, more people were able to cultivate the land. The population increased, and human activity brought additional changes to the grasslands.

After the end of World War I and following several years of adequate rainfall, a wave of new farmers moved into this region. As agricultural activities increased, much of the grasslands were transformed to grow crops. At the same time as plowing increased, dry weather ensued, and with the previous deep root systems removed, the topsoil began to erode at alarming rates. Winds brought dust storms that would last for several days.



Williams Prairie, part of the 14 preserves west of Houston, Texas, that are managed by the Katy Prairie Conservancy

Source: Katy Prairie Conservancy/Wikimedia Commons: http://commons.wikimedia.org/wiki/File:Williams_Prairie.JPG.

For 3 days in March 1935, the department of geology at the University of Wichita (now Wichita State University) in Kansas “weighed” the atmosphere. Over the city and surrounding region, they studied an area of 78 km² (square kilometers), scanning up into the atmosphere approximately 1.5 km. The scientists estimated that 4.5 million metric tons of dust was suspended over this one area. From 1933 to 1935, a time of many “dusters” (as the storms were often called), an estimated 150,000 people moved out of these central states.

Today, however, the land is again sustained with crops such as wheat and corn. Range managers work to preserve the prairies in areas such as Wind Cave National Park in South Dakota and the Tallgrass Prairie National Preserve and the Konza Prairie, both in Kansas. Controlled fires are set in the early spring to increase grass productivity and help control nonnative invasive plants. Large grazing animals are used to promote the long-term diversity of plant species. Together, these two

ancient activities are being used to ensure that there are healthy grasslands for the future.

Antoinette W. Satterfield

See also **Biome: Midlatitude Grassland; Ecoregions; Land Use; Prairie Restoration**

Further Readings

- Bradshaw, M. J. (1977). *Earth, the living planet*. New York: Halsted Press.
- Collins, S. L., & Wallace, L. L. (Eds.). (1990). *Fire in North American tallgrass prairies*. Norman: University of Oklahoma Press.
- Haddock, M. J. (2005). *Wildflowers and grasses of Kansas*. Lawrence: University Press of Kansas.
- Orme, A. R. (Ed.). (2002). *The physical geography of North America*. New York: Oxford University Press.
- Weaver, J. E., & Alberston, F. W. (1956). *Grasslands of the Great Plains*. Lincoln, NE: Johnsen.



PRECIPITATION, GLOBAL

Precipitation is the principal link between global water and energy cycles, weather and climate, and the activities of humankind. Natural and anthropogenic processes can alter the frequency, distribution, and magnitude of precipitating weather systems (e.g., the El Niño Southern Oscillation, urban heat islands, and deforestation). Changes in precipitation characteristics can affect Earth's energy balance through the redistribution of solar and terrestrial energy and latent heat fluxes. Planetary atmospheric circulation is largely driven by Earth's energy balance; thus, global precipitation patterns are a key element in climate variability. Therefore, the critical task is to continue to develop methods that allow for consistent, high-quality global observations of precipitation in order to gain better insight into the Earth system and weather and climate variability through improved forecasts. This entry discusses in situ measurements and remote sensing techniques used in the study of precipitation processes.

In Situ Measurements

Given that precipitation processes often evolve rapidly and are stochastic in nature, our understanding of their characteristics is limited in part by our ability to observe and accurately represent precipitation over a variety of time and space scales. This is especially true for developing countries and remote regions around the world, including equatorial (e.g., Amazonia, South America) and oceanic regions, where in situ observational (rain gauge) networks are severely limited. In addition to the insufficient global density of rain gauges, other drawbacks are that rain gauges are point measurements that often fail to effectively represent precipitation variability across relatively large areas. For example, it is not uncommon for a single thunderstorm to produce intense rainfall over an area that is not covered by rain gauges, systematically missing out on the occurrence of precipitation. Unfortunately, any sufficiently large rain gauge network would likely be highly expensive and impractical to implement. Other effects such as wind, evaporation, and water sticking to the side of the gauge can lead to underestimation of precipitation. Furthermore, there are often inconsistencies among rain gauge types and in calibration efforts.

Despite these pitfalls, one very important advantage of the use of rain gauges is their use of a metric that is based on the actual collection of precipitation. Another advantage includes excellent temporal sampling. Ultimately, rain gauges alone cannot adequately represent global precipitation due to the lack of coverage in the major part of the world. But since rain gauges physically measure precipitation at the surface, these instruments remain very important with respect to the verification and calibration of other instruments and approaches, including radars and satellites.

Remote Sensing Techniques

In an attempt to compensate for the deficiencies of rain gauges, the use of active and passive remote sensing techniques has steadily increased since the mid to late 20th century. While the use of remote sensing often increases the spatial sampling of precipitation (when compared with in situ observations), this approach is not without limitations. The primary disadvantage is that the radiometric properties of precipitating systems are used to infer the occurrence and intensity of precipitation. These inferences are algorithmically derived from various cloud attributes, including cloud-top temperatures, cloud-type and height discrimination, and the emission and scattering properties of hydrometeors, among others.

Active Microwave

Many surface-based radar systems now have the capability of sampling 0.25 km (kilometer) by 0.5° at a range of 300 km (e.g., WSR-88D Super Resolution), with a temporal sampling frequency on the order of minutes. However, similar to rain gauges, surface-based radars' precipitation estimates are limited near shorelines, over the oceans, and in remote regions around the world. While a mosaic of surface-based radar coverage can reach much of the area that is not covered by rain gauges, certain topography (e.g., mountainous areas) can hinder the radar's ability to sample a full swath (Figure 1). Surface-based radars also typically rely on a transformation factor that relates the poor physical connection of radar reflectivity (Z) to precipitation rate (R), which has been shown to produce considerable error in precipitation estimates. Additional sources of uncertainty in surface-based radar estimates stem from signal calibration and

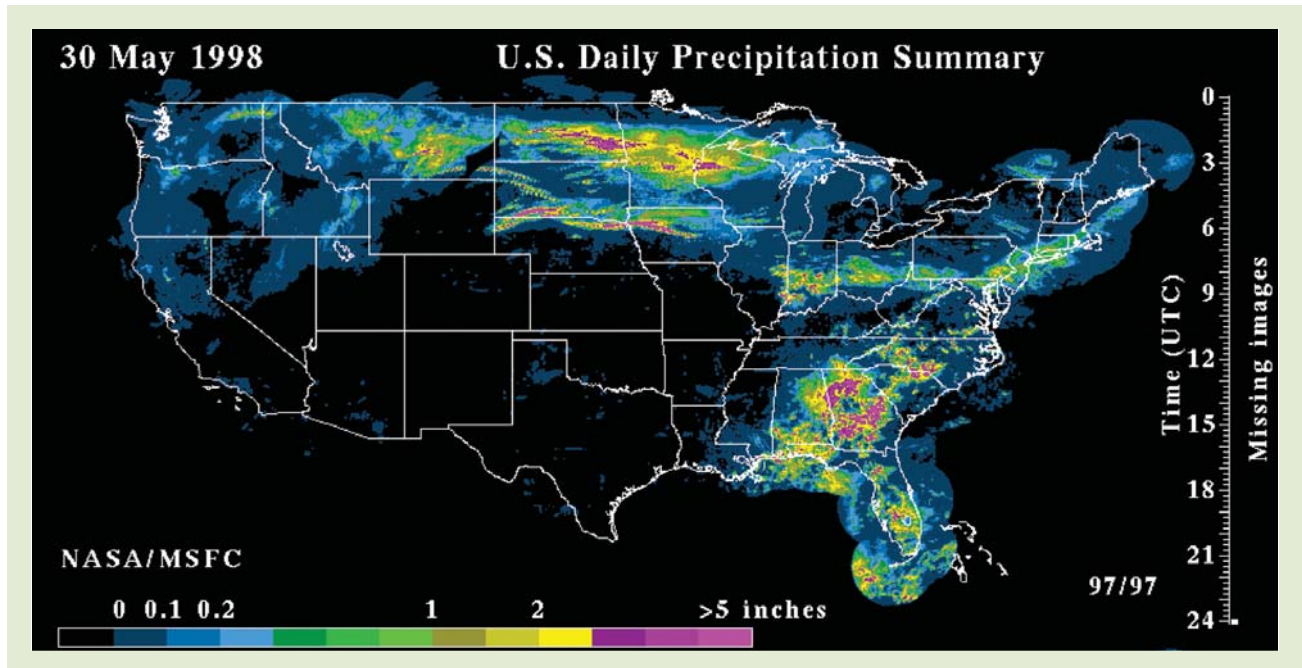


Figure 1 Radar-estimated accumulated precipitation for the United States on May 30, 1998

Source: National Aeronautics and Space Administration.

corrections required for anomalous propagation, attenuation, ground clutter, and beam filling. While surface-based radars' precipitation estimates provide an excellent supplement to rain gauge observations, the majority of the world's precipitation remains unsampled by these instruments due to their fixed position, limited sampling range, and relatively high operation and maintenance costs. With these concerns, scientists have developed a suite of space-based approaches to examine precipitation around the world.

Visible and Infrared Radiation

Since clouds are opaque to visible and infrared (VISIR) radiation, VISIR methods use various cloud attributes as a proxy for precipitation estimation. Specifically, the algorithms used to indirectly estimate precipitation from VISIR radiometers on board geosynchronous satellites (e.g., Geostationary Operational Environmental Satellite [GOES]) relate cloud-top reflectivity and brightness temperatures (a metric of radiation in the form of the temperature of a blackbody object with equal emittance of radiation at a given wavelength) to cloud height and thickness and precipitation rate. Following this logic, heavier (or less or no) precipitation is inferred

from colder (or warmer), brighter (or less bright) clouds. These assumptions can sometimes work well with deep convective storms. However, the primary flaw is that VISIR approaches often have difficulty discriminating between relatively warm, wet clouds (e.g., stratus) and cold clouds with no precipitation (i.e., cirrus). This can be especially problematic for convective complexes beneath a unified cirrus canopy.

Many VISIR techniques have been developed to address these concerns and help improve the accuracy of these indirect approaches. In one method, cloud indexing derives the probability and intensity of precipitation from different classes of clouds or temperatures (e.g., the GOES Precipitation Index [GPI]). Bispectral methods combine radiances from cold, bright and warm, dark clouds to determine precipitating and nonprecipitating clouds. This method is particularly useful for identifying cirrus clouds. Life history methods relate precipitation intensity as a function of the growth and decay of the cloud system. Other cirrus and low-level cumulus discrimination methods include the use of split-window channels (11 and 12 micrometers). Cloud models attempt to replicate cloud microphysics in an attempt to differentiate between convective and stratiform precipitating systems.



While VISIR approaches lack direct observation of precipitation processes, these approaches benefit from relatively good spatial and temporal resolution from geosynchronous satellites. Specifically, VISIR precipitation data are typically available every 15 minutes, with spatial resolutions of 4 and 1 km, and are best suited for larger-scale climatological precipitation studies.

Passive Microwave

Precipitation particles (water droplets and ice crystals) are the primary source of attenuation of a passive microwave signal. Therefore, rather than inferring precipitation processes from cloud-top characteristics, passive microwave instruments provide a more accurate portrayal of instantaneous surface precipitation, given that microwave radiances (hydrometeors) are directly sensed within the cloud.

Two fundamental algorithms are used in passive microwave-estimated precipitation. The first deals with the absorption and emission of water droplets in clouds, whereby precipitation intensity varies as a function of brightness temperature differences. Relatively warm brightness temperatures stem from the emission of numerous water droplets and are linked to greater precipitation intensities. Likewise, relatively cool brightness temperatures are associated with little or no precipitation. Therefore, the emissivity of cloud liquid water droplets and the associated precipitation is best discerned over regions with relatively cooler backgrounds (i.e., oceans). Given that the emissivity of ocean and land is 0.4 to 0.6 and 0.8 to 0.9, respectively, the pitfall with this algorithm is that low-frequency channels (i.e., <22 GHz [gigahertz]) generally fail at discerning precipitation processes over land surfaces with similar emissivity properties.

The second algorithm uses high-frequency channels (i.e., 85 GHz) to detect ice scattering within the cloud. Heavier (or little or no) precipitation is associated with relatively cooler (or warmer) brightness temperatures, that is, with greater (or little or no) scattering. Since the ice-scattering signal is independent of surface effects, the application of this algorithm is universal for land and ocean. However, ice-scattering algorithms are not sensitive to warm-cloud precipitation processes and are best suited for convective precipitation processes.

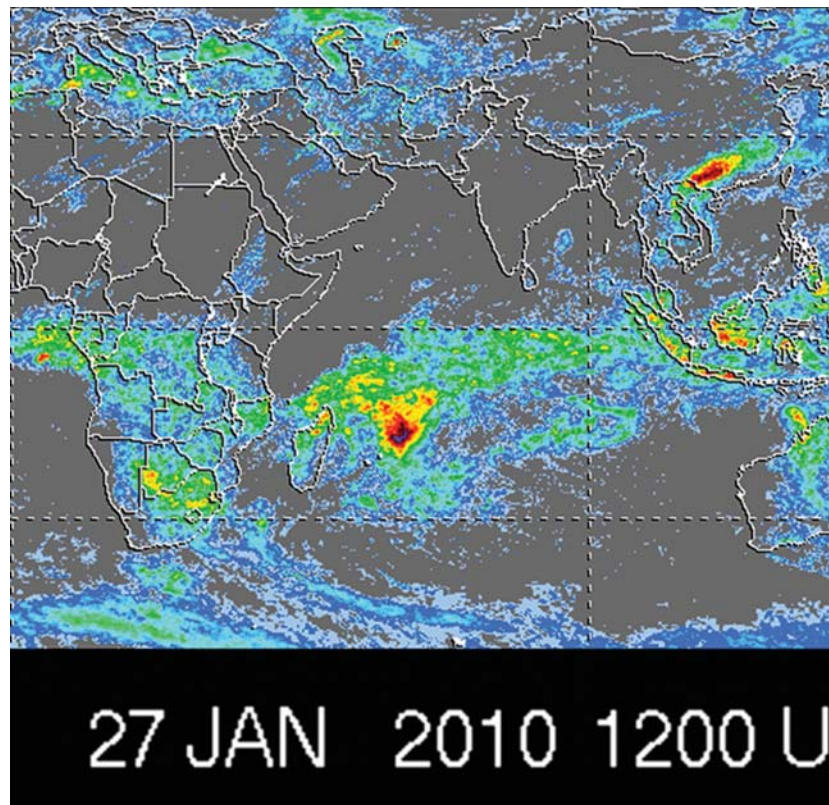


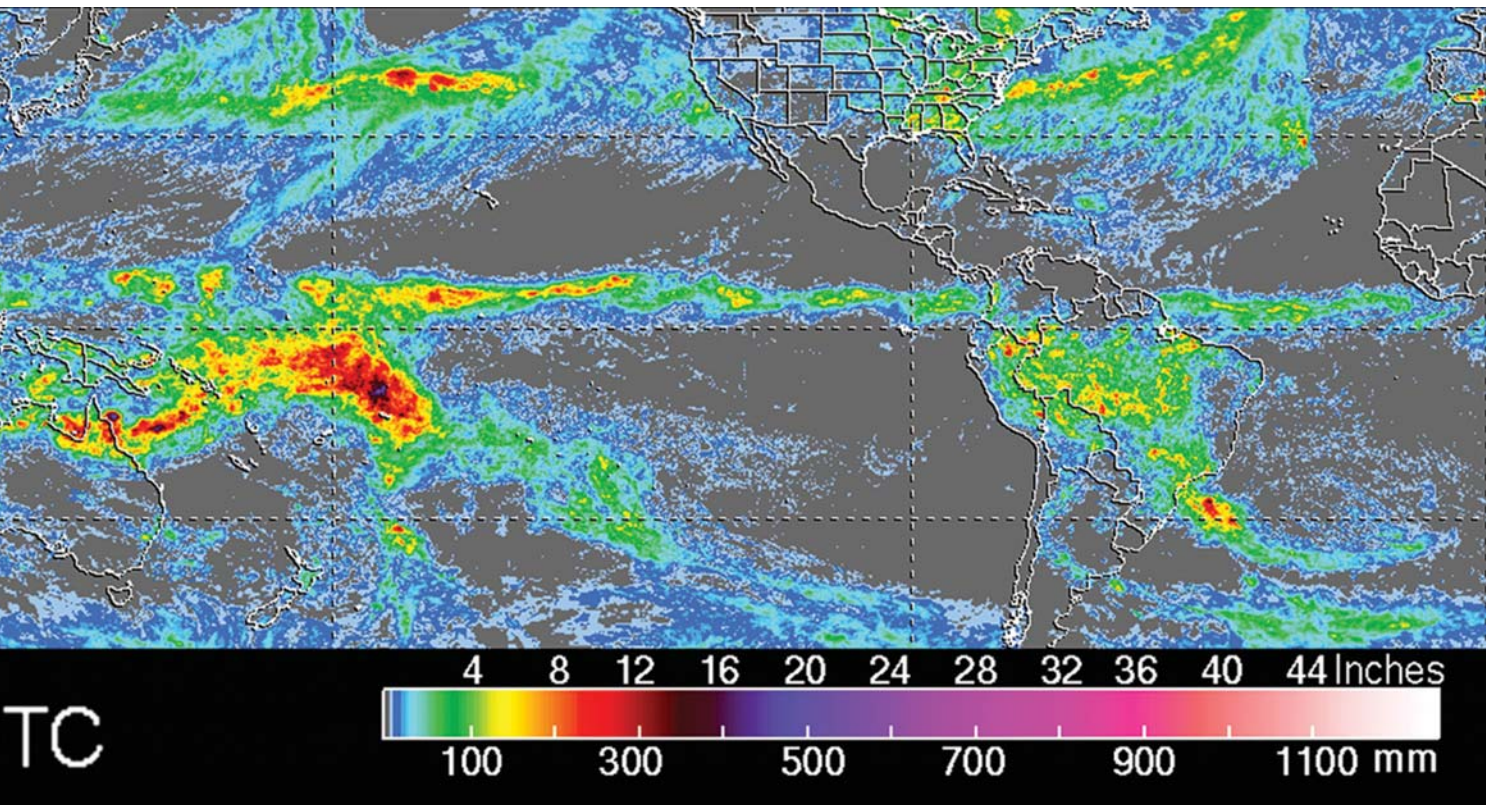
Figure 2 TRMM-accumulated 3-hourly rainfall estimates for January 27, 2010, at 1200 Coordinated Universal Time (UTC)

Source: National Aeronautics and Space Administration.

While passive microwave instruments (e.g., the Special Sensor Microwave/Imager [SSM/I], Advanced Microwave Sounding Unit [AMSU], Advanced Microwave Scanning Radiometer-Earth Observing System [AMSR-E], and Tropical Rainfall Measuring Mission [TRMM] Microwave Image [TMI]) provide a more direct inference of precipitation when compared with VISIR approaches, these instruments suffer from poor sampling frequency aboard polar-orbiting satellites. Depending on the frequency channel, the spatial resolution from passive microwave precipitation estimates ranges from 5 to 40-plus km. Moreover, microwave sensors often experience beam-filling issues with precipitation and land surface features.

Blended Techniques

In a continuous effort to minimize the deficiencies and errors associated with single-sensor/instrument methods and to increase the spatial and



temporal sampling of precipitation around the globe, scientists have concentrated on multisensor/instrument approaches. The idea is to use the advantages of each approach (e.g., direct observation from rain gauges, excellent sample frequency from VISIR, and better accuracy from passive microwave estimates) to develop a “best” estimator or high-quality determination of precipitation processes around the world. Some specific examples of various techniques used to derive blended precipitation products include the TRMM Multi-Satellite Precipitation Analysis (TMPA), Climate Prediction Center Morphing Method (CMORPH), Hydro-Estimator, Naval Research Laboratory Global Blended-Statistical Precipitation Analysis (NRLgeo), Precipitation Estimation From Remotely Sensed Information Using Artificial Neural Networks (PERSIANN), Passive Microwave-Calibrated Infrared algorithm (PMIR), Global Precipitation Climatology Project (GPCP), and Adjusted GOES Precipitation Index (AGPI). Given multiple precipitation observation sources, one problem inherent in blended or merged precipitation products is that operational errors from a single data source can considerably reduce the accuracy of the end precipitation product. For intercomparisons and validation studies of

multisensor/instrument approaches, the reader is encouraged to consult the efforts put forth by the Program to Evaluate High Resolution Precipitation Products (PEHRPP).

One of the goals of blended precipitation products is to globally observe precipitation using passive microwave sensors with a sampling frequency similar to that of VISIR instruments. Eliminating the inference of precipitation based on cloud attributes and moving to a physical-based passive microwave product would increase the accuracy of precipitation estimates. One international program that is devoted to achieving better accuracy of global precipitation is the Global Precipitation Measurement (GPM) mission.

The foundation for the GPM mission stems from the success of the TRMM. One of the objectives of TRMM during its launch in December 1997 was to use a multisensor/satellite approach to collect relatively high spatial and temporal resolution precipitation data for poorly sampled regions around the world (viz., the tropical oceanic regions). With the success of the TRMM, precipitation data are available every 3 hours, globally between 50° N and 50° S (0.25° × 0.25° resolution) from January 1998—near real time (TMPA 3B42, Version 6) (Figure 2).



Figure 3 Schematic overview of Global Precipitation Measurement

Source: Japan Aerospace Exploration Agency.

The GPM mission is the next generation suite of satellites aimed toward improving our understanding of global precipitation and its effect on the natural environment, by using a constellation of passive microwave radiometers, and the first space-based Dual-Frequency Precipitation Radar (DPR; TRMM contains the first space-based single-frequency precipitation radar). Combined with the onboard microwave imager Global Mapping International (GMI), the GPM mission will improve on the capabilities of the TRMM by providing full global coverage of precipitation, with the additional ability of measuring relatively lighter rainfall and frozen precipitation (Figure 3).

While passive and active sensors on board geosynchronous satellites are considered optimal for observing global precipitation, the technological limitations of such an approach mandate missions such as GPM. The launch of GPM is currently slated for 2013 to 2014.

Joshua D. Durkee

See also **Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Remote Sensing; Atmospheric Variations in Energy; Climate Change; Clouds; Hydrology; Precipitation Formation; Thunderstorms**



Further Readings

- Ebert, E. E., Janowiak, J. E., & Kidd, C. (2007). Comparison of near-real-time precipitation estimates from satellite observations and numerical models. *Bulletin of the American Meteorological Society*, 88(1), 47–64.
- Kidd, C. (2001). Satellite rainfall climatology: A review. *International Journal of Climatology*, 21, 1041–1066.
- Levizzani, V., Bauer, P., & Turk, F. J. (2007). *Measuring precipitation from space: EURAINSAT and the future*. Berlin, Germany: Springer.
- Michaelides, S. C. (Ed.). (2008). *Precipitation: Advances in measurement, estimation, and precipitation*. Berlin, Germany: Springer.
- Sapiano, M. R. P., & Arkin, P. (2009). An intercomparison and validation of high-resolution satellite precipitation estimates with 3-hourly gauge data. *Journal of Hydrometeorology*, 10(1), 149–166.
- Turk, F. J., Arkin, P., Ebert, E., & Sapiano, M. R. P. (2008). Evaluating high resolution precipitation products: The first workshop of the program for the evaluation of high resolution precipitation products. *Bulletin of the American Meteorological Society*, 89(12), 1911–1916.



PRECIPITATION FORMATION

The formation of precipitation is a complex process by which suspended atmospheric moisture in the form of very small cloud droplets ultimately transitions into the larger frozen or nonfrozen precipitation observed at the surface. This entry describes four aspects of precipitation formation. First, the presence of a lifting mechanism is necessary to lift the air vertically. Second, condensation or ice nuclei are essential for the formation of precipitation in the atmosphere. Third, there are two fundamental processes by which precipitation forms; both of these processes are described and referenced by their typical geographic locations of occurrence. Finally, the unique formation of particular precipitation types is discussed.

Processes of Precipitation Formation

Some type of lifting mechanism is required to create rising air, which leads to cloud and precipitation formation. In the absence of a lifting mechanism, it is possible to experience light precipitation such as mist or a drizzle. Four common lifting mechanisms are (not in order of importance) convection, convergence, orographic, and frontal. Convection refers to the vertical transfer of heat energy through rising buoyant air near the surface. It is an important warm-season lifting mechanism leading to precipitation formation. Convergence refers to the lifting of air when there is an inflow of air into a region near the surface. Its spatial scale is normally larger than convection, but convergence is generally a weaker lifting mechanism than convection. Orographic lifting occurs when air is forced to ascend a mountain barrier, thus resulting in condensation and precipitation on the windward side of the mountain. Frontal lifting can occur with a variety of weather situations, but it is most common with a migrating wave cyclone where contrasting air masses are colliding.

If a lifting mechanism is in place, the next ingredient is something solid for tiny cloud droplets to attach onto. Condensation nuclei are small atmospheric particles (0.2 μm [micrometers]) with normal atmospheric concentrations ranging from 100 to 1,000 nuclei per cubic centimeter. They are composed of many different substances, with the most common being sea salt, dust (clay and silt), and gases such as sulfur and nitrogen oxide. They can be divided into two types: (1) hygroscopic, or attracted to water, such as sea salt and sulfates, and (2) hydrophobic, or water repellant, such as soot and organic carbon. They are vital to the precipitation process because water in the form of cloud droplets (20 μm) requires a nongaseous surface to attach and transition from the gas phase to the liquid phase. Cloud condensation nuclei attract cloud droplets, and droplets then grow in size through coalescence, becoming larger cloud droplets (100 to 500 μm) and possibly raindrops (2,000 μm). The processes by which cloud droplets grow into raindrops are described in more detail in the following paragraph on precipitation formation processes.

There are two established processes by which precipitation forms: (1) collision and coalescence



and (2) Bergeron/Findeisin. Although these two processes have fundamental physical differences, precipitation frequently forms (especially in the midlatitudes) as a result of both processes working in unison. In the midlatitudes, precipitation may initially form as a result of the Bergeron process and then undergo collision and coalescence closer to the surface.

Collision and coalescence is frequently referred to as warm weather precipitation as it occurs in atmospheric temperatures $>0^{\circ}\text{C}$. Naturally, this process is common in the tropics and subtropics for much of the year, and it is also common in the midlatitudes during the warmer months. During collision and coalescence, larger cloud droplets begin to acquire higher terminal velocities. As the fall speed increases for the larger droplets, they become collectors of smaller droplets through collisions. However, as the collector droplet falls, air resistance may split the droplet into several smaller droplets, thus recycling the process back to its beginning. When the larger collector droplets have attained a sufficient size and velocity to offset the rising motions within the cloud, precipitation then falls to the surface in the form of rain.

The Bergeron/Findeisin process (commonly referred to as Bergeron Process) best explains precipitation formation at mid and high latitudes, where a large portion of the atmosphere is $<0^{\circ}\text{C}$. The coexistence of ice crystals and supercooled water (water in liquid state albeit $<0^{\circ}\text{C}$) is important for the Bergeron process. Water can exist in a supercooled state if there is no condensation or ice nuclei present for the water to attach to. This is common in the upper troposphere, where condensation nuclei are scarce. When ice and supercooled water coexist, the ice crystals function as ice nuclei and will grow at the expense of the water droplets. This is because the saturation vapor pressure is lower for ice than it is for water at temperatures below freezing. In the Bergeron process, precipitation initially begins as snow before undergoing transitions based on the temperature profile of the atmosphere.

Types of Precipitation

Depending on various combinations of synoptic scale weather patterns and the vertical temperature

profile of the atmosphere, a variety of precipitation types may fall to the surface. The most fundamental type of precipitation is rain, which is observed at the surface when there is a deep vertical layer of air $>0^{\circ}\text{C}$. In contrast, snow is observed at the surface when there is a deep vertical layer of air $<0^{\circ}\text{C}$. Sleet is observed at the surface if precipitation initially falls as snow in the upper troposphere and then encounters a shallow melting layer or more than one melting and freezing layers in the middle troposphere before partially regaining some of its crystal structure as it approaches a surface near or just below 0°C . Freezing rain or glaze forms if precipitation initially falls as snow in the upper troposphere but then encounters a deep melting layer in the middle troposphere. As terminal velocity increases in the melting layer, the rain does not have time to refreeze in the $<0^{\circ}\text{C}$ layer of air near the surface. The supercooled water then freezes on contact with the surface, creating hazardous conditions.

Jason C. Senkbeil

See also **Atmospheric Moisture; Clouds; Hydrology; Precipitation, Global; Thunderstorms**

Further Readings

- Hudson, J. G. (1993). Cloud condensation nuclei near marine cumulus. *Journal of Geophysical Research*, 98(D2), 2693–2702.
- Ritter, M. (2006). *The physical environment: An introduction to physical geography* [Online textbook]. Retrieved February 22, 2010, from www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html
- Sumner, G. (1988). *Precipitation: Process and analysis*. New York: Wiley.



PRED, ALLAN (1936–2007)

Allan Pred was a longtime professor of geography at the University of California, Berkeley, and one of the discipline's leading practitioners of urban geography and social theory. Pred's



career took him through diverse conceptual approaches in a series of shifts that both reflected and contributed to geography's intellectual transformations.

In the 1960s, Pred's work centered on the historical geography of American manufacturing and its linkages to the country's urban growth patterns. His perspective was resolutely historical, emphasizing the contextualized nature of urban growth rather than abstract processes independent of historical time. Increasingly, the early focus on manufacturing was supplemented by a growing interest in the role of information and its relations to the differential growth of cities. Much of this phenomenon was theorized in terms of circular and cumulative feedback loops. In particular, he noted the powerful role of the telegraph in the long-distance transmission of information in the 19th century, a technology that greatly reduced uncertainty and accelerated the penetration of the Midwestern regions by east coast capital.

In the 1970s, Pred turned toward the time-geography initiated by Torsten Hägerstrand and began to apply this framework to the U.S. context. Places, he maintained, are always and everywhere times—that is, always coming into being—and geography can never be fruitfully portrayed as a static landscape frozen at one temporal moment. This move led him on the one hand to delve more deeply into issues of individual consciousness, including the notion of sense of place advocated by humanistic geographers, and to integrate individual life trajectories with broader questions of social reproduction on the other.

Pred became a fierce advocate of Anthony Giddens's notion of structuration and worked assiduously to integrate it with geographers' notions of place and locale. In this reading, the socialization of the individual and the reproduction of society and place are two sides of the same coin—that is, the macrostructures of social relations are interlaced with the microstructures of everyday life. For Pred, people reproduce the world, largely unintentionally, in their everyday lives, and in turn, the world reproduces them through socialization. In forming their biographies every day, people reproduce and transform their social worlds primarily without meaning to

do so; individuals are both produced by and producers of history and geography. Because people are endowed with the capacity to resist hegemonic power relations, the production of places is always contingent. Empirically, Pred offered applications to Boston, examining the lives of merchants in the 19th century as the city was catapulted through waves of mercantile capitalism, industrialization, and a rapidly changing world economy.

One facet of this line of thought led Pred to a sustained concern for the role of language in the making of place and people. As a set of representations of the world that simultaneously shape consciousness and define the meanings given to place, language came to assume a central role in his analysis of social reproduction and local politics.

Historical context, the world economy, time-geography, structuration, and language were all parts of his ambitious analysis of 19th-century Stockholm. Having spent considerable time in Sweden, with access to its rich census data, Pred traced the contingent reconstruction of the city's streets and neighborhoods as an emerging bourgeois identity was firmly imposed on its landscapes, both annihilating older, preindustrial meanings and simultaneously defeating alternative, working-class ones. This project lay at the core of a broader agenda to uncover the historical roots and implications of modernity in general.

Pred's fascination with Sweden included a growing critical strain. Even in ostensibly the most tolerant of societies, he argued, racism was widespread. Pred thus became a pioneer in geography's examination of ethnicity and race, which, under the impact of poststructural critiques, revealed race to be a set of economic, political, cultural, and discursive relations that shape individual and collective life chances and identity. By contextualizing race as an ideology, as a socially constructed relation, not a biologically determined "given," Pred illustrated the complex ways in which race is constructed, experienced, and negotiated in everyday existence; how it intersects with class and gender; and the manner in which racial relations of domination and subordination play out over space and time. Like gender, racial and ethnic identity



is fundamentally a power relation that typically reflects, reinforces, and naturalizes existing lines of inequality.

Barney Warf

See also Giddens, Anthony; Gregory, Derek; Hägerstrand, Torsten; Structuration Theory; Time-Geography

Further Readings

- Pred, A. (1977). *City systems in advanced economies*. New York: Wiley.
- Pred, A. (1981). Social reproduction and the time-geography of everyday life. *Geografiska Annaler*, 63, 5–22.
- Pred, A. (1984). Place as historically contingent process: Structuration and the time-geography of becoming places. *Annals of the Association of American Geographers*, 74, 279–297.
- Pred, A. (1984). Structuration, biography formation and knowledge: Observations on port growth during the late mercantile period. *Environment and Planning D: Society and Space*, 2, 251–275.
- Pred, A. (1990). *Lost words and lost worlds: Modernity and the language of everyday life in late nineteenth century Stockholm*. Cambridge, UK: Cambridge University Press.
- Pred, A. (1990). *Making histories, constructing human geographies*. Boulder, CO: Westview Press.
- Pred, A. (1997). Somebody else, somewhere else: Racisms, racialized spaces and the popular geographical imagination in Sweden. *Antipode*, 29, 383–416.
- Pred, A. (2000). *Even in Sweden: Racisms, racialized spaces and the popular geographical imagination*. Berkeley: University of California Press.

their population sizes, spatial extent, or territorial size and the importance of their economies. Primate cities are the largest cities in their respective countries, as they dominate the economy as well as being the top ranking in terms of territorial extent and population size. Geographer Mark Jefferson coined the term in the 1930s and defined a *primate city* as one that is twice as large as the next largest city in the urban hierarchy of a country and twice as significant economically. A primate city also dominates in terms of the centralization of the country's transport and communications, industrial and commercial institutions, trade, education, culture, and other phenomena.

Primate cities around the world tend to be many times larger than the next largest cities in their respective countries, including London (about six times the size of the second largest city) and Paris (about eight times the size of the next largest city). Other examples from the developed world include Copenhagen, Prague, Budapest, Vienna, Brussels, and Dublin. In the developing world, Bangkok, the capital of Thailand, is at least 35 times the size of the next largest city, Chiangmai, in terms of population. Bangkok's economic role is even more significant, and this primate city is believed to generate half of the country's jobs and gross domestic product. Other developing country examples include Addis Ababa (Ethiopia), Lagos (Nigeria), Kampala (Uganda), Bogotá (Colombia), Jakarta (Indonesia), Baghdad (Iraq), Tehran (Iran), Manila (Philippines), Mexico City, and Buenos Aires (Argentina). Primacy in the urban hierarchy is seen to reflect uneven development in a country, with a highly developed metropolitan core or center surrounded by peripheral areas that are lagging behind in economic and social progress. These areas largely serve to provide the material resources and labor supply to the primate city.

There is no single cause for the development of primate cities, since they are not necessarily confined to developing countries. Yet many of the developing countries with such primate cities have been European colonies, where these cities served as the gateways to the natural wealth being exploited by colonial administrations. These administrations concentrated the



PRIMATE CITIES

A primate city is the dominant city among a country's urban areas. Countries have urban hierarchies comprising large and small cities in terms of



Primate cities around the world such as Buenos Aires tend to be many times larger than the next largest cities in their respective countries.

Source: Winfield Parks/National Geographic/Getty Images.

development of infrastructure and services such as rail transport and ports in these primate cities. They may be areas of substantial agglomeration economies as well.

Primate cities, because of their sheer size and the economic activities concentrated in them, serve as magnets to migrants from rural areas and smaller cities or towns. Many are attracted by the promise of better economic opportunities and lives in the primate cities. Such migration has added to the primacy of the cities, many of which are capital cities as well as cities that have grown beyond their earlier administrative boundaries. Bangkok is a metropolitan region extending into surrounding areas through sprawl and suburbanization as well as peri-urban growth. This process has been encouraged by businesses and households seeking to escape the congestion and related problems

such as pollution, inadequate housing, and traffic jams in the inner-city areas.

Giok-Ling Ooi

See also [Rank-Size Rule](#); [Rural-Urban Migration](#); [Urban Hierarchy](#); [Urbanization](#); [World Cities](#)

Further Readings

- Henderson, V. (2003). The urbanization process and economic growth: The so-what question. *Journal of Economic Growth*, 8, 47–71.
- Jefferson, M. (1939). The law of the primate city. *Geographical Review*, 29, 226–232.
- Mutlu, S. (1989). Urban concentration and primacy revisited: An analysis and some policy conclusions. *Economic Development and Cultural Change*, 37, 611–613.



PRIME MERIDIAN

See Longitude



PRIVACY AND SECURITY OF GEOSPATIAL INFORMATION

The concept of privacy of geospatial information pertains to the amount of personal or otherwise sensitive information that can be gleaned directly from the contents of one data source or indirectly when one source is analyzed in combination with other data sources. The concept of security of geospatial information relates to the set of rules or practices that enforces who can access what data, under what circumstances, and by what means. The collection, storage, dissemination, and use of geospatial information are often seen as requiring special care with regard to both of these concepts because these data are highly descriptive and often contain personally identifying or potentially damaging, dangerous, or sensitive information. The wide variety of types, uses, and content of geospatial information requires that notions of privacy and security cover a vast range of topics, including an individual's right to privacy and control over information about herself or himself, the rights of scientists to obtain and use information on behalf of the public good, and the rights of governments and organizations to guard information from public view. Each of these is a contentious issue that has been debated since well before the introduction of digital geospatial data. However, with the advent of modern geospatial information techniques and technologies, these issues continue to gain ardent and vocal supporters on all sides.

At the individual level, privacy and security are issues with regard to geospatial information because these data often contain personally identifiable information along with the characteristics of an individual or group. Because geospatial information consists of sensitive data, many people view the collection, storage, and dissemination of these data as infringing on an individual's right to privacy. Essentially, this issue is an extension of

the personal privacy debate into the geospatial information domain. This has been driven for the most part by the ease with which geospatial information can be easily linked to other forms and sources of information about individual or group characteristics and processed rapidly in huge volumes with digital techniques. The application of geodemographics to product marketing has been at the center of the debate on the appropriateness of this practice since its inception. However, as geospatial data and services become increasingly available and mainstream, individuals and policy-makers will be confronted with trade-offs between personal convenience and potential loss of personal privacy. Location-based services are a direct example of this because they have the potential to provide highly tailored, timely, and useful data and services but require that an individual surrender a portion of his or her personal privacy to facilitate the process.

Many in the public service and health sectors view the availability and use of geospatial data at the individual level as essential to public security, health, and welfare. Geospatial information containing personally identifiable information and characteristics is seen by many as key to stopping crime and reducing the burden of diseases on society. For instance, in some cases, criminals are required by law to register their places of residence within geospatial databases. The public availability of these data is thought by some to thwart potential future crimes by raising public awareness, thereby increasing the public's security at the potential cost of the criminal's personal privacy. Similarly, some federal and state laws mandate the collection and submission of personal-level health-related geospatial information to disease registries. Some argue that beneficial outcomes such as the identification of pandemics and the advancement of scientific knowledge about the cause, treatment, and prevention of diseases would not be possible without the collection of individual-level, highly private personal data at the level of completeness and accuracy that the mandates were designed to facilitate. However, not all patients are aware of these disease surveillance practices using geospatial information derived from their personal records, and it is likely that not all patients would have consented had they known.



From the perspective of a data consumer, the privacy and security of geospatial information are sometimes seen as a hindrance. For example, to protect personal privacy, health-related geospatial information is not typically released to researchers without clear conditions and restrictions on who may obtain it and for what purposes it may be used. Furthermore, the display of these data in tabular or graphic form must typically meet requirements of anonymity, and geographic masking techniques are therefore required to be applied. Data release is a particularly contentious issue with regard to geospatial information created through the use of public funds by governments and organizations at the federal, state, and local levels. Many who wish to obtain these data feel that they should be made available to all citizens at the cost of reproduction, while others feel that charging a premium for these data is justified to support the ongoing costs of their production, storage, and upkeep. There are other forms of data that some feel should be completely out of the realm of public consumption due to the inherent public security concerns their release could foster. In all situations, the trade-offs between geospatial data privacy and security and scientific knowledge and public welfare must be weighed carefully when determining the suitability of their release.

Daniel W. Goldberg

See also **Crime, Geography of; Geodemographics; Geoslavery; GIS in Health Research and Health Care; Legal Aspects of Geospatial Information; Location-Based Services; Panopticon; Surveillance**

Further Readings

- Baker, J. C., Lachman, B. E., Frelinger, D. R., O'Connell, K. M., Hou, A. C., Tseng, M. S., et al. (2004). *Mapping the risks: Assessing the homeland security implications of publicly available geospatial information*. Santa Monica, CA: RAND.
- Cho, G. (2005). Geographic information and privacy. In G. Cho (Ed.), *Geographic information science: Mastering the legal issues* (pp. 207–291). West Sussex, UK: Wiley.

- Gittler, J. (2008). Cancer registry data and geocoding: Privacy, confidentiality, and security issues. In G. Rushton, M. P. Armstrong, J. Gittler, B. R. Greene, C. E. Pavlik, M. M. West, et al. (Eds.), *Geocoding health data: The use of geographic codes in cancer prevention and control, research, and practice* (pp. 195–223). Boca Raton, FL: CRC Press.
- Onsrud, H. J., Johnson, J. P., & Lopez, X. (1994). Protecting personal privacy in using geographic information systems. *Photogrammetric Engineering and Remote Sensing*, 60, 1083–1095.



PRODUCER SERVICES

Producer services are a set of industries that have markets primarily with businesses and governments, as opposed to markets mostly with households. These services include accounting, engineering, architecture, legal services, real estate, insurance, financial services, management consulting, advertising, design, administrative support services, temporary help, and research. In contrast, services such as retail trade, health care, education, repair of automobiles, and movie theaters have households as their primary source of demand. There are varying definitions of producer services; some include parts of transportation services and real estate and insurance. Clearly, some industries that are dominantly part of the producer services sector also have household markets, such as legal and banking services.

Producer services have grown rapidly in recent years, employing 40 million people in the United States in 2006, or approximately 23% of the civilian labor force. This number has risen from 9 million in 1969, when producer services accounted for 10% of the civilian labor force. The United States has a relatively high fraction of its labor force in producer services, compared with some other advanced economies and compared with most developing countries. In part, this growth is due to the tendency for open-market procurement of many of these services in the United States, whereas in countries such as Germany, there is a tendency for more of this type of work to be performed in-house in manufacturing and service industries.



Much producer service work is unstandardized, requiring face-to-face meetings between clients and suppliers and between subcontractors. For example, a firm developing architectural drawings for a client may need to meet on the construction site to discuss possible approaches to development. A management consultant needs to come to the offices of the client to assess their consulting needs. An engineering firm may need to work with an architect to conceptualize alternative ways for designing a particular structure—in conference settings, in conversations on the telephone, via e-mail, or on the ground at a project site. Frequently, this work involves documents that get revised numerous times as tasks or projects are conceptualized from preliminary visions to final articulations. While the Internet and digital means of communication have made it possible to manage these logistics more efficiently, the creative element in face-to-face meetings is still an important part of the work in this part of the economy.

There are various explanations for the relatively rapid growth of producer services as a share of total employment. One argument is that there is low productivity in these services compared with other sectors of the economy, partly because the ability to increase labor efficiency in work that involves face-to-face creative effort is restricted. Another argument is that firms have outsourced work that they previously undertook in-house. Every business faces the “make or buy” decision, and some argue that businesses have chosen to turn to an outside contractor who can supply producer services at a lower cost than can be provided in-house. However, evidence is mixed on this behavior, especially when there is a very careful definition of the type of services that were produced in-house versus those that are being procured in the open market. Research shows that another force at work is the increasing complexity of service provision, related to the development of new and more detailed or sophisticated service concepts, often driven by advances in information technologies intimately related to the production and delivery of producer services.

A good illustration of how information technologies have changed service provision may be given with regard to accounting services. In the precomputer era, accountants used mechanical

calculators to derive balance sheets and profit-and-loss statements for their clients. Today, the clients can use accounting software to produce these documents for themselves, but they need accountants to advise them on the legal aspects of their bookkeeping practices as well as to give them financial management advice. The knowledge base used by accountants has changed, as have the capabilities of their clients. Also, government regulations require more independent audits.

In many cases, firms know that they need the specialized expertise available from a producer service firm and that they lack the capability to produce this specialized expertise in-house. The need for this service may be driven by government regulations or by the client’s perception that service providers should avail themselves of these specialized services. In other cases, the scale of demand for the specialized service is below the minimum size possible for an in-house department, leading firms to turn to specialized outside suppliers.

In yet other cases, there have been innovations in the supply of new services that were not produced in-house, and these have been adopted in the market. Examples abound in the use of computing services of these types of innovation, which have created huge markets for software giants such as Microsoft as well as tens of thousands of other niche market specialists.

Geography of Producer Services

Producer services have a very uneven geographical distribution. Headquarters functions of large corporations are a type of producer service, and they have been disproportionately concentrated in the largest cities, such as New York, London, Tokyo, and Frankfurt. Stock exchange functions and central banking also exhibit very high levels of concentration. More routine producer services, such as accounting or some types of legal services, are distributed much more broadly. There has been some de-concentration of the very highest-order producer services to suburbs and down the urban hierarchy, but this segment of advanced economies remains strongly agglomerated. Some argue that this clustering is due to the interactions needed between buyers and sellers in the face-to-face environment. Others argue that it is due to “nontraded interdependencies,” where expertise is shared



between individuals living in a city in environments ranging from bars to industry associations.

There is growing evidence that producer services can be traded interregionally or internationally, just like many categories of manufactured goods. This is particularly the case for “niche market specialists,” which constitute a sizeable share of producer service firms. These businesses have considerable locational freedom, often locating where their founder wants to live. Barriers to trade in producer services exist, in the form of licensing requirements, the need for practitioners to pass competency examinations, and differences in the business environment between nations and regions. Institutions such as the General Agreement on Tariffs and Trade (GATT) have been pressed to reduce these obstacles in recent years.

William Beyers

See also **Cyberspace; E-Commerce and Geography; Economic Geography; Finance, Geography of; Information Society; Innovation, Geography of; Knowledge, Geography of; Offshore Finance; Postindustrial Society; Telecommunications and Geography; Tourism**

Further Readings

- Bagchi-Sen, S., & Sen, J. (1997). The current state of knowledge in international business in producer services. *Environment and Planning A*, 29, 1153–1174.
- Beyers, W. (2000). Cyberspace or human space: Wither cities in the age of telecommunications? In J. Wheeler, Y. Aoyama, & B. Warf (Eds.), *Cities in the telecommunications age: The fracturing of geographies* (pp. 161–180). New York: Routledge.
- Beyers, W. (2006). Services and regional development in the United States. In J. Bryson & P. Daniels (Eds.), *The handbook of service industries* (pp. 126–148). Cheltenham, UK: Edward Elgar.
- Beyers, W., & Lindahl, D. (1996). Lone eagles and high fliers in rural producer services. *Rural Development Perspectives*, 12(3), 2–10.
- Greenfield, H. (1966). *Manpower and the growth of producer services*. New York: Columbia University Press.

Lindahl, D., & Beyers, W. (1999). The creation of competitive advantage by producer service firms. *Economic Geography*, 75, 1–20.

Rubalcaba, L. (2007). *The new service economy: Challenges and policy implications for Europe*. Northampton, MA: Edward Elgar.

Wood, P. (1991). Flexible accumulation and the rise of business services. *Transactions of the Institute of British Geographers*, 16, 160–172.



PRODUCT CYCLE

One of the more influential theories in economic geography in the mid 20th century was the product cycle, which integrated the supply and demand dimensions of corporate behavior and locations as they changed systematically over time. This view posits an idealized sequence in which goods move from being newly introduced innovations to becoming more widely accepted, until they finally reach a “mature” status. Different stages in the product cycle are associated with different market conditions, varying organization of production, and changes in geographic locations.

Drawing on the perspectives of innovation adoption widely used in marketing, this view begins with the changing nature of demand for a firm’s product over time, which is typically a bell-shaped curve, with new innovations adopted by a small group of risk takers. Adopters tend to be younger, more educated, and trendier than the population as a whole. As the product becomes better known and more widely accepted, larger numbers of more risk-adverse people will adopt it, sales increase, the market expands, and the firm can be confident of a consistent stream of future revenues. Finally, when the product becomes widely known, rates of new purchases will slow down as the market becomes saturated.

As the product proceeds through its cycle, the supply conditions change accordingly. With new innovations, where the information content is high, firms must expend considerable sums for research and development. Firms with monopolies over the production of products in their early years (e.g., as patent holders) may enjoy



superprofits for a limited time. Such companies tend to be relatively small, use higher proportions of skilled labor, and face a great deal of uncertainty in the market. Because they must produce in relatively small quantities, they are not likely to enjoy economies of scale and compete more on the basis of quality than price. Small firms in the early stages of the product cycle accept the market price—that is, they are price takers rather than price setters. As the product becomes more widely adopted and the market expands, firms can shift to producing larger quantities, standardizing the production process. As larger firms outcompete the smaller ones, the industry becomes more capital intensive in nature and more reliant on economies of scale, and the market becomes increasingly oligopolistic. Often, this transition is accompanied by a process of vertical integration, in which different stages of the production process become incorporated “in-house,” within the firm.

Raymond Vernon offered a series of geographic correlates for different stages of the product cycle. The original analysis was framed at the international scale, although subsequent ones extended this approach to national and regional ones. Thus, in the early stages of the product cycle, firms tend to prefer locations close to large pools of skilled labor, typically in economically developed countries. In subnational modifications of the product cycle, the optimal locations are in the cores of metropolitan regions, where firms can take advantage of agglomeration economies and dense networks of specialized contacts and information. Spatial cores are thus “seedbeds” of innovation. At the national scale, such locations were found in the traditional northeastern-midwestern Manufacturing Belt. As the product moves through the cycle, and the production process becomes more capital intensive, the need for centralized locations declines, and firms can relocate to the metropolitan periphery or, in the context of the national space of the United States, to the Sunbelt. Core regions are left to begin a new cycle of production by innovating in skilled, labor-intensive goods. Thus, the product cycle leads to the hypothesis that the decentralization of manufacturing is accompanied by the process of capital intensification as oligopolistic firms spin off their branch plants to peripheral locations in their search for cheaper and less skilled labor. At the

international scale, this process leads to multinational corporations investing in developing countries. This perspective sustains the view that exports from regions with comparative advantages early in the product cycle should be relatively labor intensive, while those with advantages later in the cycle should be more capital intensive. As product cycles play out continually over the landscape, markets will reproduce uneven development, in contrast to expectations that the free flow of labor and capital would result in a convergence of economic growth among regions.

Despite its comprehensiveness and appeal, the product cycle has been criticized as being simplistic. Although its description of the empirical nature of industrial change is essentially correct, the approach does not delve deeply enough into the dynamics of the production process, failing to embed it in any wider comprehension of social relations. Thus, it rests on an implicit notion of technological determinism. The model assumes that firms are single-product entities, always given over to capital intensification and vertical integration in a unilateral trajectory of growth and expansion, which is not always the case in practice.

Barney Warf

See also **Agglomeration Economies; Comparative Advantage; Competitive Advantage; Economic Geography; Economies of Scale; Factors Affecting Location of Firms; Flexible Production; Innovation, Geography of; Regional Economic Development**

Further Readings

- Norton, R., & Rees, J. (1979). The product cycle and the spatial decentralization of American manufacturing. *Regional Studies*, 13, 141–151.
- Storper, M. (1985). Oligopoly and the product cycle: Essentialism in economic geography. *Economic Geography*, 61, 260–282.
- Taylor, M. (1986). The product-cycle model: A critique. *Environment and Planning A*, 18, 751–761.
- Vernon, R. (1966). International investment and international trade in the product cycle. *Quarterly Journal of Economics*, 80, 190–207.



PRODUCTION OF SPACE

Globalization has made it increasingly difficult to understand what is meant by “space” and “place” and how to delineate the two concepts. From a commonsense perspective, a region, a city, or a town may be seen as a “place.” But geographers have become critical of such an understanding. While physical geographers often work with a notion of absolute space, as if it were a merely objective, easily delineated and marked or mapped backdrop to life, in human geography there is a shift toward a notion of space as brought into existence by economic, political, and social relations.

This attention given to the social production of space by human geographers and the increasing popularity of this theme relate to globalization. Globalization brought about the idea that we have witnessed a time-space compression, a term introduced by David Harvey, who drew on Henri Lefebvre for the development of his arguments. Fast-travel possibilities, new media, and flows of capital and labor across the globe all affect the ways in which we experience and assign meanings to places as material sites.

Henri Lefebvre's Influence

Time-space compression stimulates the trend for different sites to become more alike (homogenization) and simultaneously also the need for distinction and specificity (differentiation). So instead of looking at objects and artifacts and even human beings in space, Henri Lefebvre (1901–1991) developed a theory of the social production of space that has heavily influenced most scholars who have tried to work with the idea that space is not but *becomes* in dynamic ways. To Lefebvre, there was not one understanding of space but a whole range of struggles over the meaning of space, especially in the framework of capitalism. Space, to Lefebvre, was a commodity: It was not defined by its physical attributes but as a product of capitalism. While globalization according to Lefebvre meant that each and every thing becomes subordinated to the workings of the capital market, countermovements aim to establish

alternative understandings of space, and hence, the result is an increasingly symbolically differentiated notion of space. Place, then, is a specific form of space produced through labeling and providing symbolic meanings.

This theme, developed later by geographers such as Doreen Massey, in terms of place making, and Anthony Giddens, as created space, thus criticized geography for taking space for granted and considering place as unproblematic. Now, many human geographers see places as those spaces produced by the lived experiences of people.

The Social Constructionist Perspective

Lefebvre, Harvey, and Massey worked on an understanding of space as socially produced, in relations and through inequalities understood through a neo-Marxist perspective. A second, albeit not fully independent, understanding of the production of social space can be traced in a sociological tradition influenced by social constructivism as developed by Berger and Luckmann. Especially since the 1960s, there has been an increase in attempts to analyze how urban meanings come about. The study of space as socially constructed has been central in cultural analyses that have focused on the city, as in Raymond Williams's work. Constructivism asserts that people make social life through their interactions. This is sometimes narrowly understood as verbal and nonverbal language. Often, it is understood more broadly as all patterns of everyday life and everything, including apparently “fixed” matters such as nature or the built environment and the meanings they have taken on, which are often taken for granted. Indeed, as Lefebvre maintained, practices and experiences create meanings just as much as does discourse. For the social production of space, then, this implies that the street corner, the plaza, and the urban neighborhood do not *have* meanings that are stable, obvious, and out there to be grabbed—for example, by the researcher—and that have clear-cut boundaries. Instead, they are seen as contested sites, where meanings are attributed through processes of appropriation.



This, concretely, means that police behavior, safety measures, and also expressions such as graffiti serve to determine symbolic ownership of sites that are inherently forming boundaries, including some and excluding others. While such processes are inherent to social life in general, the forms mentioned are those in which contestation becomes most obvious. Less obvious forms of the production of social meanings of places are those in which accounts of histories of, for example, neighborhoods or villages, focus on certain narratives while omitting others. They, hence, represent a partial account that feeds into a specific understanding of what a particular place “is.” Neighborhood reputations, especially when historically embedded and when emulated by their residents, are good examples of less obvious contested forms of appropriation of sites and thus of the production of space.

The Absence of Fixed Meanings

Finally, there are scholars who have attempted to figure out how to read urban spaces, such as Walter Benjamin. He concentrated in particular on how the everyday experiences of people give them a sense of the urban and how they hence develop an understanding of the city through the lens of their own life events. Along with Benjamin, many recent geographers and social scientists have thus argued that space has no fixed meanings that are inherent and monolithic but instead that people experience built forms and create memories while doing so; the meanings that they hence attribute to space may be very different from those intended by the designers of the physical spaces. From this perspective, then, spaces are inherently social.

Talja Blokland

See also **Absolute Space; Actor-Network Theory; Cultural Turn; Everyday Life, Geography and; Lefebvre, Henri; Marxism, Geography and; Massey, Doreen; Place; Relative/Relational Space; Spaces of**

Representation/Representational Spaces; Spatialization; Time-Space Compression

Further Readings

- Benjamin, W. (1978). *One way streets and other writings*. London: Verso Books.
- Berger, P., & Luckmann, T. (1966). *The social construction of reality: A treatise in the sociology of knowledge*. London: Penguin.
- Harvey, D. (1989). *The conditions of postmodernity*. Oxford, UK: Blackwell.
- Lefebvre, H. (1991). *The production of space*. Oxford, UK: Blackwell.
- Massey, D. (1994). *Space, place and gender*. Cambridge, UK: Polity Press.
- Savage, M., Warde, A., & Ward, K. (2003). *Urban sociology, capitalism and modernity* (2nd ed.). London: Palgrave.



PSYCHOANALYSIS, GEOGRAPHY AND

Psychoanalysis is a discipline founded by Sigmund Freud (1856–1939) at the beginning of the 20th century and subsequently developed by analysts such as Anna Freud, Jacques Lacan, Melanie Klein, and Donald Winnicott. Psychoanalysis consists of theories of human subjectivity and therapeutic practices that are primarily concerned with the amelioration of neurotic symptoms. It differs from conventional psychiatry and cognitive-behavioral therapies in its use of free association as a technique for accessing unconscious mental processes, its insistence on the importance of sexuality in the formation of psychical conflict, and its refusal to equate the ego with the subject.

In Freudian-Lacanian analysis, the analyst attempts to position himself or herself as a screen for the analysand's unconscious projections. Instead of engaging in conventional conversation, the analyst offers only enigmatic remarks



and polyvalent interpretations in an attempt to rouse the analysand's curiosity and bring his or her unconscious desire to the fore. The alleviation of psychical suffering that analysis aims for occurs through the eventual articulation of the analysand's unconscious desire. This includes the analysand's recognition of himself or herself as a "split subject"—that is, forever divided between the conscious ego and the unconscious, as well as by the gap between language and desire. For Lacan, analysis concludes only when the analysand comes to terms with his or her "fundamental fantasy," or the unconscious beliefs that structure the self's relationship to reality.

Psychoanalytic concepts such as the unconscious, the gaze, the Other, and the pleasure principle have had an indelible impact on the development of 20th-century literary theory, Marxism, feminism, postcolonialism, art history, and film criticism. Geography's engagement with psychoanalysis began in the 1990s with explorations of the spatiality of psychoanalytic categories such as the unconscious and discussions of the psychical dimensions of sociospatial phenomena. Psychoanalytic geography has thus far followed three main trajectories. First, geographers have used Freudian dream analysis to analyze cities through the unconscious desires and fantasies that create and sustain them. Geographers have also employed Freud's formulation of the Oedipus complex to illustrate how racial oppression under slavery was invested with repressed sexual desires within the slave-holding family. Second, geographers have used object relations theories to read sociospatial exclusions such as ethnic and economic segregation as part of processes of "othering," where dominant groups seek to produce a purified cultural "self" as against an excluded "other." In concert with this reading, geographers have looked to object relations' concept of "potential space," where children use objects such as pacifiers or blankets in ways that blur the distinction between self and object—interior and exterior—as a way of reconfiguring their understandings of space. Finally, geographers have drawn on Lacanian concepts of "extimacy," where subjectivity and emotions

are located outside the body, as well as his notion of "jouissance," which is enjoyment experienced as suffering, to explain how social phenomena such as violence and racism cannot be entirely reduced to social constructions but are always constituted through unconscious desire and anxieties about the Other.

More recently, some geographers have argued for the necessity of engagement with psychoanalytic methodologies. Some concrete proposals for methods have included "sandplay," where participants create a "potential space" by sculpting forms in sand with the researcher, to facilitate discussions of spaces and memory. Geographers have also debated using psychoanalysis to analyze interviews, though they have also cautioned that while psychoanalytic interpretation of interview data may be useful, geographers should not attempt to psychoanalyze their research participants.

The use of psychoanalysis within geography has been vigorously contested from a variety of positions. Critics have argued that psychoanalysis has been "tamed" through attempts to bring it into line with existing social-constructionist paradigms, while others have argued that psychoanalysis is masculinist, universalizing, and depoliticizing. While there certainly are politically problematic aspects in Freud's writings, most often products of the prejudices of his time, Freud's work has been used across the humanities and social sciences to destabilize fixed categories of gender and sexuality. Beyond Freud's own work, subsequent theorists and analysts have pushed psychoanalysis to the point of its auto-critique, forcing it to contend with the profound implications of an unknowable unconscious, a de-essentialized sexuality, and a radically indeterminate subjectivity.

Jesse Proudfoot

See also **Behavioral Geography; Body, Geography of; Everyday Life, Geography and; Feminist Geographies; Gender and Geography; Humanistic Geography; Masculinities and Geography; Other/Otherness; Race and Racism; Sexuality, Geography and/of; Structuration Theory**



Further Readings

- Callard, F. (2003). The taming of psychoanalysis in geography. *Social & Cultural Geography*, 4, 295–312.
- Kingsbury, P. (2007). The extimacy of space. *Social & Cultural Geography*, 8, 235–258.
- Nast, H. (2000). Mapping the “unconscious”: Racism and the oedipal family. *Annals of the Association of American Geographers*, 90, 215–255.
- Pile, S. (2005). *Real cities: Modernity, space and the phantasmagorias of city life*. London: Sage.



PTOLEMY (AD 87–150)

Of all Roman intellectuals, Claudius Ptolemaeus, or Ptolemy, perhaps more than any other classical scholar, did the most to influence subsequent European notions of geography for the next millennium by dominating the popular and literary view of Earth throughout the Middle Ages. Little is known of his private life. Greek by birth, as were many scholars during the Roman Empire, he spent his career in Roman Egypt at the famous museum at Alexandria, then the epicenter of intellectual life. Ptolemy was, among other things, a mathematician, an astrologer, and an astronomer who studied optics and refraction; the Arabs later credited him with the invention of the astrolabe. His greatest work in this domain was the geocentric *Almagest*, or “Great Treatise” concerning the movement of the sun, moon, and planets, the only surviving ancient text on astronomy.

But his greatest fame was in geography, which he took to mean the description of Earth as a whole. He differentiated between *geography* as the study of universals, *topography* as the study of localities, and *chorography* as the means of integrating the two scales. Ptolemy ridiculed Strabo’s emphasis on individual regions, arguing instead for a holistic view encompassing the entire globe; he maintained that the regional emphasis was akin to painting a person by only showing his or her eye or ear.

In his famous eight-volume *Geographia*, a compilation of data about the geography of the Roman world, Ptolemy synthesized and extended

Hipparchus’s grid system of latitude and longitude for plotting the surface of the Earth, dividing it into 360 degrees and dividing each degree into seconds. It consists of the first known projection of a sphere onto a plane. The *Geographia* thus deployed a view of space as abstract, geometric, and homogeneous, invoking concepts derived from Euclidean geometry. He also attempted to map the known world with a map stretching from the Atlantic to China and speculated about the *terra incognita* (unknown territory). The *Geographia* became a canonical text in medieval Europe.

Although no Ptolemaic map survives, his descriptions formed the foundation on which the Western geographic imagination would be based well into the 16th century. His works were translated from Greek into Arabic in the 9th century and into Latin in 1406. During the Renaissance, Ptolemy, for all his errors, remained the chief classical authority to whom geographers turned in making sense of the newly unfolding world. When Columbus set forth on his voyage in 1492, it was Ptolemy’s conception of the world that he relied on, although Ptolemy’s estimate of the size of Earth was too small. Ultimately, however, colonial voyages of discovery and conquest put to rest Ptolemaic conceptions of Earth and opened the way for newer, more pragmatic accounts.

Barney Warf

See also **Cartography, History of; Earth’s Coordinate Grid; Exploration; Human Geography, History of**

Further Readings

- Bagrow, L. (1945). The origin of Ptolemy’s *Geographia*. *Geografiska Annaler*, 27, 318–387.
- Berggren, J., & Jones, A. (2000). *Ptolemy’s geography: An annotated translation of the theoretical chapters*. Princeton, NJ: Princeton University Press.
- Boorstin, D. (1983). *The discoverers*. New York: Random House.
- Brotton, J. (1999). Terrestrial globalism: Mapping the globe in early modern Europe. In D. Cosgrove (Ed.), *Mappings* (pp. 71–89). London: Reaktion Books.



Figure 1 Ptolemaic world map from the 15th-century codex of Nicolaus Germanus
Source: National Digital Library of Poland.



PUBLIC HOUSING

Broadly defined, *public* or *subsidized housing* is a federally funded effort to provide basic shelter and amenities for disadvantaged members of the population. It is a direct form of state intervention in which government housing authorities maintain property ownership and lease dwelling units to tenants at rates lower than the local private housing market.

In the United States, public housing grew out of public works programs initiated during the

Great Depression as a way to strengthen the economy. In 1937, the Housing Act was established to clear rapidly expanding slums and stimulate the construction industry. As part of Lyndon Johnson's Great Society legislation, the Department of Housing and Urban Development was created in 1965 as a cabinet-level agency to execute housing policy. Public housing was "established to provide decent and safe rental housing for eligible low-income families, the elderly, and persons with disabilities." Though ostensibly, this provision seems like an incontrovertible social good, historically, the geography of public housing has



The complex of white high-rise buildings in the center of the photo is the William Green homes, known as the "Whites." Completed in 1962, they were among the last of the 51 buildings that constituted the Cabrini-Green project. Most of the Cabrini-Green buildings were demolished amid controversy concerning the inclusion of mixed-income housing as part of redevelopment.

Source: Library of Congress, Historic American Engineering Record, HAER ILL, 16-CHIG, 148.



Guste New Homes Public Housing community, New Orleans, for seniors and mixed-income families, which was under construction prior to Hurricane Katrina

Source: U.S. Department of Housing and Urban Development.

been much more complex. Public housing has proved to be a contested space articulating a highly uneven human geography deeply informed by race and class struggles. In particular, the specific location of public housing projects has tended to be an issue pitting the interests of government agencies, low-income tenants, and local private owners against one another. Historically, economic constraints and resistance from local community groups have forced public housing officials to place projects in urban areas near industrial zones, railroad tracks, and areas with high rates of crime and drug abuse, creating racially segregated ghettos, an involuntary process of de jure segregation.

In addition to the specific location of such housing, cost restrictions have tended to foster the construction of architecturally monotonous modern, high-rise towers, often labeled “the projects.” Sociologists have pointed to the palpable stigmatism associated with living in these emblematically dysfunctional areas. Though now largely considered anathema, the design of high-rise public housing projects often takes undue blame for the problems endemic to public housing. One iconic example perpetuating this notion is St. Louis’s infamous Pruitt-Igoe project. Designed by the architect Minoru Yamasaki in 1951, it was demolished in

the 1970s by the federal government after it fell to disrepair and vagrancy. Critics of those emphasizing the centrality of poor architectural design suggest that the reasons for the demise of Pruitt-Igoe and projects like it are much more complex and socioeconomically informed. Another image of the failure of U.S. housing policy is the Chicago Housing Authority’s Cabrini-Green housing project, most of which has been demolished and is being redeveloped. Cabrini-Green was popularly displayed on the 1970s sitcom *Good Times*. While putting forth a progressive social message in an aestheticized and distortedly large space, *Good Times* was paradoxically premised on a metanarrative of public housing or “the projects” as malfunctioning and as an object of ridicule. The weekly show functioned to normalize the living conditions within public housing while marginalizing that space and popularizing the notion that public housing was, indeed, a failed endeavor. With the global liberalization of economies from the 1970s onward, federal funding for public housing in many countries has dramatically decreased. Emphasis instead has turned to the creation of lower-density, mixed-income “projects” by public-private partnerships.

While public housing has largely fallen into disrepute in the United States and elsewhere, by



no means are these attitudes universal. Instead, public housing manifests itself differentially across diverse political geographies. Different cultures and their respective governments have varied views on public housing and implement policy in numerous ways. For example, in Singapore, where an overwhelming majority of citizens reside in government-run facilities, public housing generally does not carry the stigma and association with crime and poverty that it does in the United States. Conceptually, the provision of public housing can be seen as hinging on the question of whether or not housing is deemed a basic human right. How this debate is waged and manifests itself spatially constitutes the complex geography of public housing.

Joseph Godlewski

See also **Home; Homelessness; Housing and Housing Markets; Poverty; Urban Policy**

Further Readings

- Balchin, P. (2002). *Housing policy: An introduction*. London: Routledge.
- Vale, L. (2002). *Reclaiming public housing: A half century of struggle in three public neighborhoods*. Cambridge, MA: Harvard University Press.



PUBLIC PARTICIPATION GIS

Public Participation GIS (PPGIS) is the use of geographic information systems (GIS) in efforts to broaden public involvement and influence in matters such as public policy, urban planning, environmental management, and rural development. Geographers engage with PPGIS as both a topic of academic research and an applied practice. While the roots of PPGIS are diverse, the term itself emerged in response to debates in the 1990s over the social, ethical, and political implications of GIS. Three related concerns, in particular, have had a lasting influence in the trajectory of PPGIS research and practice: (1) the antidemocratic implications of the growing role of GIS in

spatial governance and decision making due to inevitable disparities in access to data, technology, and expertise; (2) the ways in which the rigid data and representational structures of conventional GIS privilege and legitimize particular kinds of spatial knowledge while marginalizing others; and (3) the role of social, economic, and political power in shaping the social construction of GIS technologies and institutionalized practices. PPGIS scholars seek out ways to progressively address these problems in practice. Described below are three general approaches to PPGIS: (1) participatory GIS, (2) collaborative decision support GIS, and (3) Web-based grassroots GIS. Each is distinct with regard to the “public” it serves, the forms of “participation” it facilitates, and the objectives it seeks to bring about.

Participatory GIS

The first approach, often labeled *participatory GIS* (PGIS), involves explicitly working to empower groups that are marginalized rather than facilitating greater involvement among the public at large. Such efforts are often rooted in the theory and methodology of participatory action research, in that the GIS scholars and practitioners work *with* community members to both examine a social problem and work to create social change. For example, Trevor Harris and Daniel Weiner use the term *community-integrated GIS* to describe their work with local communities in South Africa to examine and transform postapartheid land reform policies. The authors acknowledge that GIS remains an “expert system” and cannot be under the control of community members, who do not have the capacity to direct the research themselves. Nonetheless, their community-based research methods explicitly focus on democratizing participation, broadening access to spatial data, incorporating local knowledge, and surfacing (rather than suppressing) the conflict inherent in spatial decision-making practice. In other words, to the extent possible, GIS is not used to impose a particular spatial framework that structures how reality can be represented. Rather, it is used as a way to juxtapose multiple and potentially conflicting realities that reflect the socially differentiated perspectives of participants.



Scholars and practitioners have developed several specific methods that can be used to facilitate PGIS research. These include participatory 3D (three-dimensional) modeling, photo mapping, sketch mapping, and resource mapping. In general, these methods are designed to enable low-cost and inclusive participation for community members who may not have computer literacy or access. Such methods also allow for the flexibility to incorporate unconventional forms of local spatial knowledge and storytelling. However, one criticism of these methods, and of participatory GIS more generally, is that they tend to rely on conventional GIS software and have done little to advance the technology in ways that address fundamental limitations in data structure and system design.

Collaborative Decision Support GIS

A second approach to PPGIS finds its roots in research into spatial decision support systems (SDSS). SDSS scholars have long promoted the utility of information technology and GIS for structuring complex spatial problems to aid decision makers in identifying optimal solutions. These systems have been applied to problems such as water resource management, locating public facilities, and land use planning. In many cases, SDSS rely on problem-structuring methodologies such as multicriteria analysis or agent-based modeling, which require predefining many important aspects of the problem to make the process of identifying a solution more tractable. In recent years, scholars have begun adopting SDSS concepts and methodologies to develop new GIS applications designed to support collaborative group decision making under the rubric of “participatory GIScience” (geographic information science) and “collaborative GIS.” These systems often enable sophisticated analytical capabilities that far exceed those found in most PGIS methods. However, these systems also tend to predefine the problem in question in advance of any collaborative process as a necessity for data gathering, system design, and software development. As a result, collaborative SDSS approaches lack the flexibility that PGIS methods have for incorporating different problem understandings and local knowledge.

Unlike PGIS, collaborative decision support approaches to PPGIS assume a clean distinction

between the problem space (i.e., the criteria under consideration) and the decision environment (i.e., the social and political context). These approaches also tend to assume a homogeneous group of participants who all understand the problem in approximately the same way but who may value the solution criteria differently. PGIS approaches do not make this assumption, and they often enable participants to construct their own spatial representations of problems, which may be very different from those preconceived by the researchers or system designers. These distinctions point to a fundamental tension and trade-off at the heart of any effort to support collaboration with GIS—between enabling analytical problem solving activity and enabling the exploration of diverse problem understandings.

Web-Based Grassroots GIS

A third approach to PPGIS is still in its early stages of fruition. Recent advances in “Web 2.0” technologies have enabled the creation of sophisticated Web-mapping applications, which are freely available to anyone with an Internet connection, a Web browser, and basic surfing skills. Notable among these are Google Maps and, more important, the thousands of “mashups” created using the Google Maps application programming interface (API). Mashups are Web applications that combine disparate sources of data and functionality. For example, the Web site ChicagoCrime.org displays crime data published by the Chicago Police Department using the Google Maps interface. The result is easy and widespread public access to an important data resource previously unavailable to all but the most extremely determined. Christopher Miller describes a harbinger of the next stage in the evolution of Web mapping mashups—a Web site that enabled New Orleans residents affected by Hurricane Katrina and its aftermath to share spatially referenced text messages on a Google Map interface. Miller argues that this simple application—developed by two college students in Texas in the days after the storm hit—was able to facilitate essential communication needs among residents that were unfulfilled by the massive federal disaster response efforts. Since then, there has been a proliferation of Web applications that enable anybody to publicly post and



share their own spatial data and georeferenced local knowledge, including WikiMapia, OpenStreetMap, Google Earth, and Google Maps. Additionally, the advent of “geotagging” in blogs and photo-sharing Web sites allows people to simply add geographic metadata to information they’re already posting online.

PPGIS scholars and practitioners are only beginning to consider the implications of Web services and applications such as these, which decentralize the control and dissemination of geographic data while facilitating a flood of new “volunteered” geographic data into the public domain. While some point to the highly structured and top-down model of “citizen science” (e.g., the Christmas Bird Count) as a precursor, Web mapping applications—particularly of the mashup variety—often facilitate less predictable flows of spatial information that reflects the disparate perspectives and subjectivities of the creators themselves. In other words, we may be witnessing the emergence of a “grassroots” PPGIS no longer dependent on the assistance of planners or university researchers. This approach is epitomized in thematic projects such as GhostBikes.org, which collects local knowledge from readers about locations where bicycle riders have been hit or killed by cars. The locations are both mapped online and memorialized by a white junker bike placed at the location of the incident. Projects such as this raise public awareness of socially significant spatial stories. By shaping the meanings ascribed to public space, these projects have the potential to empower communities in debates over how to manage and develop that space.

Each of these approaches addresses the concerns regarding the social implications of GIS in different ways. Yet all three of the concerns are still relevant today. Despite the advances in Web-based grassroots GIS, the wide disparities in access, expertise, and resources still shape who can construct, display, and disseminate spatial data online—much less advocate effectively for social change. While multimedia capabilities now enable the representation of some new kinds of local spatial knowledge, broader institutional and political structures still privilege some forms of spatial knowledge over others in decision processes. Although mashups have enabled the (social) construction of Web mapping applications by anybody with basic

programming skills, almost all rely on a single mapping interface designed by a corporation (Google) fundamentally concerned with the potential for boosting advertising revenues, not democratizing spatial decision making. In other words, GIS is (and will always be) a simultaneously empowering and disempowering technology. Each approach to enhancing public participation in governance (or mapping more generally) creates some new opportunities while foreclosing others. This explains why a great deal of PPGIS scholarship is in the form of case studies, which report on the social, political, and economic complexities that shape the form and effectiveness of PPGIS endeavors. As the field of PPGIS matures, researchers and practitioners are beginning to revisit previously underexamined assumptions about what it means to “empower” participants and what forms of “democracy” we should endeavor to bring about. Such questions are vital in an era of neoliberal governance reforms that often seek devolution of political authority and increased community involvement in spatial decisions while at the same time privileging market forces and economic growth. In other words, PPGIS is necessarily a *political* project in which public participation works to challenge or solidify established forms of spatial governance.

Kevin Ramsey

See also **Geographic Information Systems; Humanistic GIScience; Neogeography; Participatory Mapping; Participatory Planning; Participatory Rural Appraisal**

Further Readings

- Aitken, S. C., & Michel, S. M. (1995). Who contrives the “real” in GIS? Geographic information, planning and critical theory. *Cartography and Geographic Information Systems*, 22(1), 17–29.
- Balram, S., & Dragicevic, S. (2006). *Collaborative geographic information systems*. Hershey, PA: Idea Group.
- Couclelis, H., & Monmonier, M. (1995). Using SUSS to resolve NIMBY: How spatial understanding support systems can help with the “not in my backyard” syndrome. *Geographical Systems*, 2, 83–101.



- Curry, M. R. (1995). Geographic information systems and the inevitability of ethical inconsistency. In J. Pickles (Ed.), *Ground truth: The social implications of geographic information systems* (pp. 68–87). New York: Guilford Press.
- Elwood, S. (2002). GIS use in community planning: A multidimensional analysis of empowerment. *Environment and Planning A*, 34, 905–922.
- Goodchild, M. (2007). Citizens as sensors: The world of volunteered geography. *GeoJournal*, 69, 211–221.
- Harris, T., & Weiner, D. (1998). Empowerment, marginalization, and “community-integrated” GIS. *Cartography & Geographic Information Systems*, 25(12), 67–76.
- IAPAD: Participatory Avenues, the Gateway to Community Mapping, PGIS & PPGIS: www.iapad.org
- Jankowski, P., & Nyerges, T. L. (2001). *Geographic information systems for group decision making: Towards a participatory, geographic information science*. New York: Taylor & Francis.
- Miller, C. C. (2006). A beast in the field: The Google Maps mashup as GIS/2. *Cartographica*, 41(3), 187–199.
- Pickles, J. (1995). Representations in an electronic age: Geography, GIS, and democracy. In J. Pickles (Ed.), *Ground truth: The social implications of geographic information systems* (pp. 1–30). New York: Guilford Press.
- Ramasubramanian, L. (1999). Nurturing community empowerment: Participatory decision making and community based problem solving using GIS. In M. Craglia & H. Onsrud (Eds.), *Geographic information research: Trans-Atlantic perspectives* (pp. 87–102). New York: Taylor & Francis.
- Ramsey, K. (2008). A call for agonism: GIS and the politics of collaboration. *Environment and Planning A*, 40, 2346–2363.
- Ramsey, K. S. (2009). GIS, modeling, and politics: On the tensions of collaborative decision support. *Journal of Environmental Management*, 90(6), 1972–1980.
- Rundstrom, R. (1995). GIS, indigenous peoples, and epistemological diversity. *Cartography and Geographic Information Systems*, 22(1), 45–57.
- Sheppard, E. (1995). GIS and society: Towards a research agenda. *Cartography and Geographic Information Systems*, 22(1), 5–16.



PUBLIC POLICY, GEOGRAPHY OF

The geography of public policy concerns spatial and human-environmental aspects of the origin, formulation, implementation, monitoring, and evaluation of public policy. Many American geographers have made important contributions to domestic public policy, including Henry Gannett on census geography in the late 19th century, Gilbert White on water issues in the mid 20th century, and Brian Berry on metropolitan issues in the late 20th century. Other American geographers have made important contributions to American foreign policy, including Isaiah Bowman, who served as America's Chief Territorial Specialist during the Versailles Treaty negotiations at the end of World War I; Lewis Alexander, who contributed to U.N. Law of the Sea negotiations in the mid 20th century; and George Demko, who dealt with international humanitarian and boundary issues as Director of the Office of Geographer in the U.S. Department of State in the late 20th century. This entry describes the field of public policy geography and the function of public policy in American life, both as a source of employment and, more broadly, as a dimension of the collective life of citizens. It then examines the models that have been used in research on public policy, along with the settings in which it occurs and the various ways in which it is manifested. One area of particular interest to geographers is the expanded role of public sector employment related to geographic information systems (GIS) and remote sensing.

Definition of Public Policy Geography

Rather than as a subdiscipline of geography, such as biogeography, economic geography, or political geography, *public policy geography* is perhaps more appropriately regarded as an approach that crosscuts subdisciplinary boundaries to engage problem-oriented research in both human and physical geography. Public policy geography can be thought of as a spatial and environmental approach to interdisciplinary public policy analysis. The methodology of public policy analysis draws from



and integrates elements from many disciplines, including economics, geography, law, political science, and sociology, as well as agronomy, cartography, demography, ecology, international affairs, mathematics, military science, operations research, public health, remote sensing, and statistics. Public policy geography thus contributes to a wide interdisciplinary realm of investigation, but with special attention to the spatial and human-environmental aspects of public policy analysis.

It is pertinent to note that the etymological origins of the word *policy* show derivation from the Sanskrit *pur*, or “city,” and the Greek *polis*, or “city-state,” which evolved into the Latin *politica*, or “state,” and later into the Middle English word *policie*, which referred to the administration of the state or the conduct of public affairs. The modern words *policy*, *politics*, and *police* thus share related origins, all of which reflect the polity as that specialized sector of society whose rules, regulations, and laws can be imposed on all affected citizens, whether willingly or not. The Latin word *populus*, or “people,” evolved into the Middle English *publique*, for “all the people,” and later into *public*, meaning “relating to or affecting all the people.” And *geography* is derived from the Greek word *geographia*, or “Earth description.” So *public policy geography* links Earth description with politics and government activities as well as with the direct or indirect interests of all the people within a society or community.

Public Sector Employment

While all people are at least potentially affected by public policy, those actually engaged in public policy decision making or implementation are the most directly involved. Using aggregate local, state, and federal government employment for 2005 as a rough indicator, about 24 million Americans, or about 8% of all U.S. residents, have some sort of formal responsibility for legislating, administering, enforcing, adjudicating, conducting, or defending public policy within the United States. Public sector employment included 13.9 million local government workers, 5.1 million state government workers, 2.7 million federal domestic workers, and 2.2 million federal defense workers. Although many public employees are

more responsible for implementing than for formulating public policies, including public school teachers, zoning administrators, park rangers, air traffic controllers, the local police, public health workers, and welfare workers, they nevertheless constitute one of the largest pressure groups in the United States. It is a fact, for example, that there are more primary and secondary school teachers (about 3.4 million) than farm operators and farm workers (about 3.3 million) in the United States, so that the National Education Association potentially could mobilize a larger lobbying effort than the American Farm Bureau.

Public Policy and Collective Existence

While only about 1 in 12 Americans actually works at a government job, all Americans have a varying degree of interest in each and every matter of public policy, either as taxpayers or as citizens. The urge to keep the private sphere of collective existence as large as possible, based on the Jeffersonian principle that “that government is best which governs least,” persists as a foundational tenet of American political ideology. But the public sector has expanded enormously, so that by early in the 21st century, in 2005, nearly one third, or 31.3%, of the U.S. gross domestic product (GDP) was appropriated through government budgetary processes. Federal outlays alone constituted 20.2% of GDP, including grants to state and local governments, which were about 3.5% of GDP; state and local outlays from their own revenue sources constituted another 11.1% of GDP. Many Americans receive direct pecuniary benefits from government in the form of retirement income, unemployment support, medical assistance, or other transfer payments, which now constitute nearly half of all federal outlays as well as a significant fraction of state and local government expenditures.

Direct financial dealings with governments in the form of taxes paid or expenditures received are only one facet, albeit a very important one, of each citizen’s overall stake in public policy. For example, most Americans are born in public hospitals, educated in public schools and colleges, drive vehicles on public roads, drink water from public water supplies, flush waste down public sewers, send trash to public landfills, and so on.

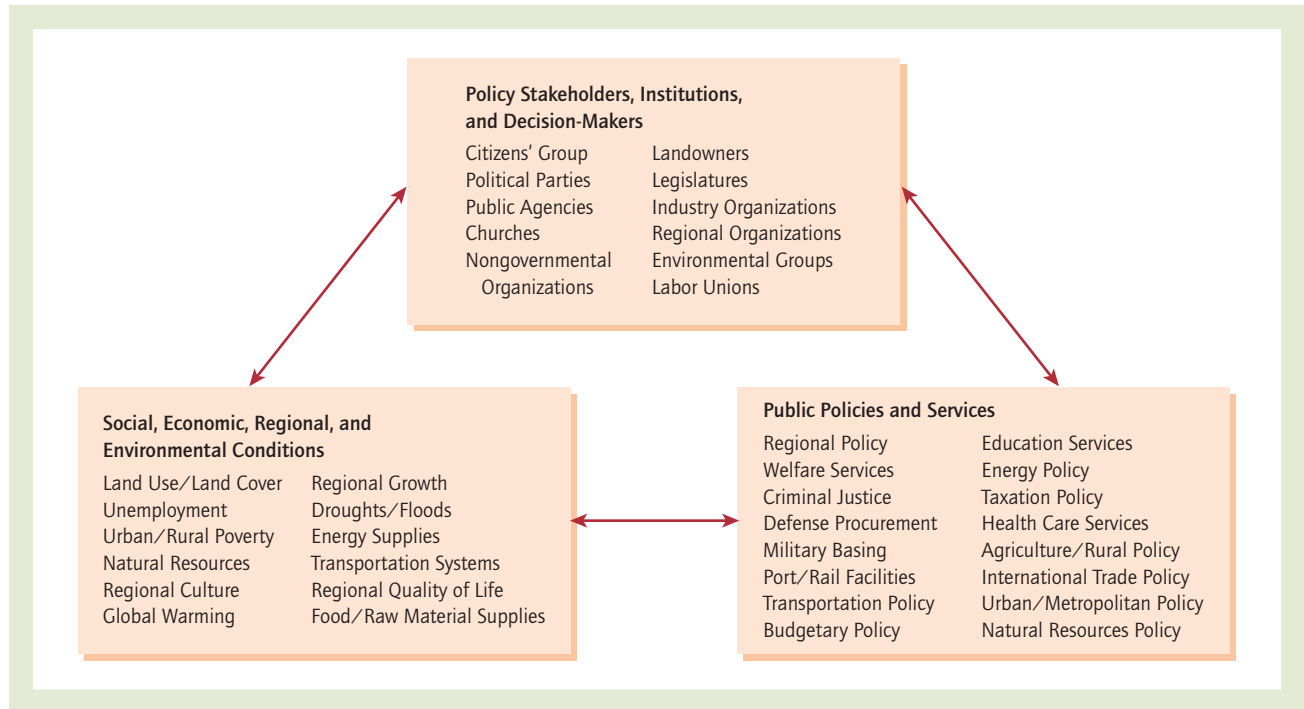


Figure 1 A schematic drawing of the public policy system. Public policy is a complex, contested outcome reflecting the local socioeconomic environment, state imperatives, and the interests and powers of multiple stakeholders.

Source: Author, compiled from multiple sources.

And the places where they work are zoned for commercial, industrial, or institutional uses; regulated by various worker protections; powered by public utilities; linked to other places of work by public highways, maritime terminals, or airports; and so on. In short, matters of public policy permeate virtually every imaginable aspect of collective existence in a modern society, so much so that any investigation of public policy inputs, processes, or outcomes tends to be very difficult to circumscribe in a suitable manner.

Conceptual Frameworks

Complexity is a recurrent theme in books on public policy analysis. Modeling strategies can help focus on the most salient aspects of public policy issues, but even the potential range of modeling frameworks that have been applied in public policy research is quite broad. These include institutional models, group models, elite models, incremental decision-making models, game theoretic models, public choice models, systems models, as well as

others. Some public policy models have been expressed as sets of verbal axioms or inferences, while others have been formalized in complex mathematical or complex statistical terms. A very simplified graphical model can be used to illustrate some of the most commonly recognized components of a public policy system (Figure 1). Policy stakeholders and institutions include the people or groups likely to be directly or indirectly affected and the public as well as private bodies likely to be directly or indirectly involved in influencing or determining public policies. Examples of possible stakeholders include property owners, citizens' groups, workers, environmental activists, farmers, students, teachers, or any other identifiable set of interested parties who could be affected. Examples of policy-relevant institutions include federal, state, or local legislatures; executives, agency heads, justices, judges, and other officials on the public side; and labor unions, business groups, professional organizations, churches, nongovernmental organizations (NGOs), and other entities on the private side. Although legislatures, and sometimes courts,



may make the final determination, the impetus for and perhaps even the specific wording of part or most of a bill or ruling is apt to be traceable to an earlier administration's "white paper" or to a private "model statute."

The Policy Environment

Social, economic, and environmental conditions constitute what political scientists or policy analysts are likely to call the "policy environment." Policy-relevant problems can arise in any sector of collective existence and are likely to manifest subjective as well as objective properties. Objective properties are the observable and measurable features of a circumstance, such as income distribution, acres cultivated, or ethnic residential separation. Subjective properties reflect the values and interpretations of interested parties, who may be in considerable disagreement with one another. For example, different parties might well express differences over issues such as the specification of a poverty threshold, an agricultural zoning criterion, or a housing discrimination indicator. Indeed, there is in American society, as in most other societies, a general reluctance to address any other than the most compelling "demands" for collective action, so that massive "mobilization" efforts through advertising, lobbying, and other "pressure group" activities are likely to be needed to put a particular social, economic, or environmental issue on the public agenda, and each effort to do so is apt to be challenged by individuals or groups likely to prefer the "status quo" over any possible changes. As just one indicator of the contentiousness of the public agenda-setting process, hundreds of millions of dollars are contributed to and spent by primary and general election campaign organizations in the process of electing a president of the United States; and many more hundreds of millions of dollars are contributed to and spent by office seekers at other levels of American governance.

Public Policy Outputs

Public policies and public services include the laws, regulations, programs, services, and other relevant public policy instruments that emerge as

outputs from the public policy system. These outputs can be expected to generate or alter the incidences of benefits/costs that are enjoyed/borne by various groups of people in various geographical settings. Different policy categories, such as educational services, defense procurement, welfare assistance, criminal justice, drought or flood prevention or mitigation, and so on, are apt to show geographically distinctive patterns of impact, depending on the social and environmental conditions, stakeholder mobilization and influence, decision makers' policy priorities, and so on. Issues of confidentiality, national security, benefit spillovers, data collection costs, and other problems can make geographical impacts very difficult to ascertain for some policy categories, such as for various types of defense or national security policy, business or financial sector regulation, environmental hazard mitigation, or the direct and indirect regional impacts of foreign trade imbalances, to list just a few examples.

The likely validity of an a priori expectation of geographical variability can be illustrated by considering the state-level distribution of U.S. federal expenditures for Fiscal Year 2005 (Figure 2). In terms of function, the Department of Health and Human Services (26%) and the Social Security Administration (24%) together account for about half of all federal outlays. Next in line are the Department of Defense (17%) and the Veterans Administration (3%), which together account for about one fifth of all federal spending. The remaining third includes all other federal agencies, with the Department of Agriculture (4%) and the Postal Service (3%) having appreciable shares. While retirement, disability, and other direct payments may tend to equalize federal outlays in relation to population distribution, federal wages and salaries, procurement contracts, and some grant programs may tend to have much more geographically concentrated impacts, with the result that the overall pattern is one of considerable geographical complexity. States with well below average levels of federal outlays per capita are found in New England, the Midwest, and the West, but so too are states with well above average levels of federal outlays per capita. Large agricultural assistance payments in low-density states help explain the high levels in the northern Great Plains, while defense and other federal

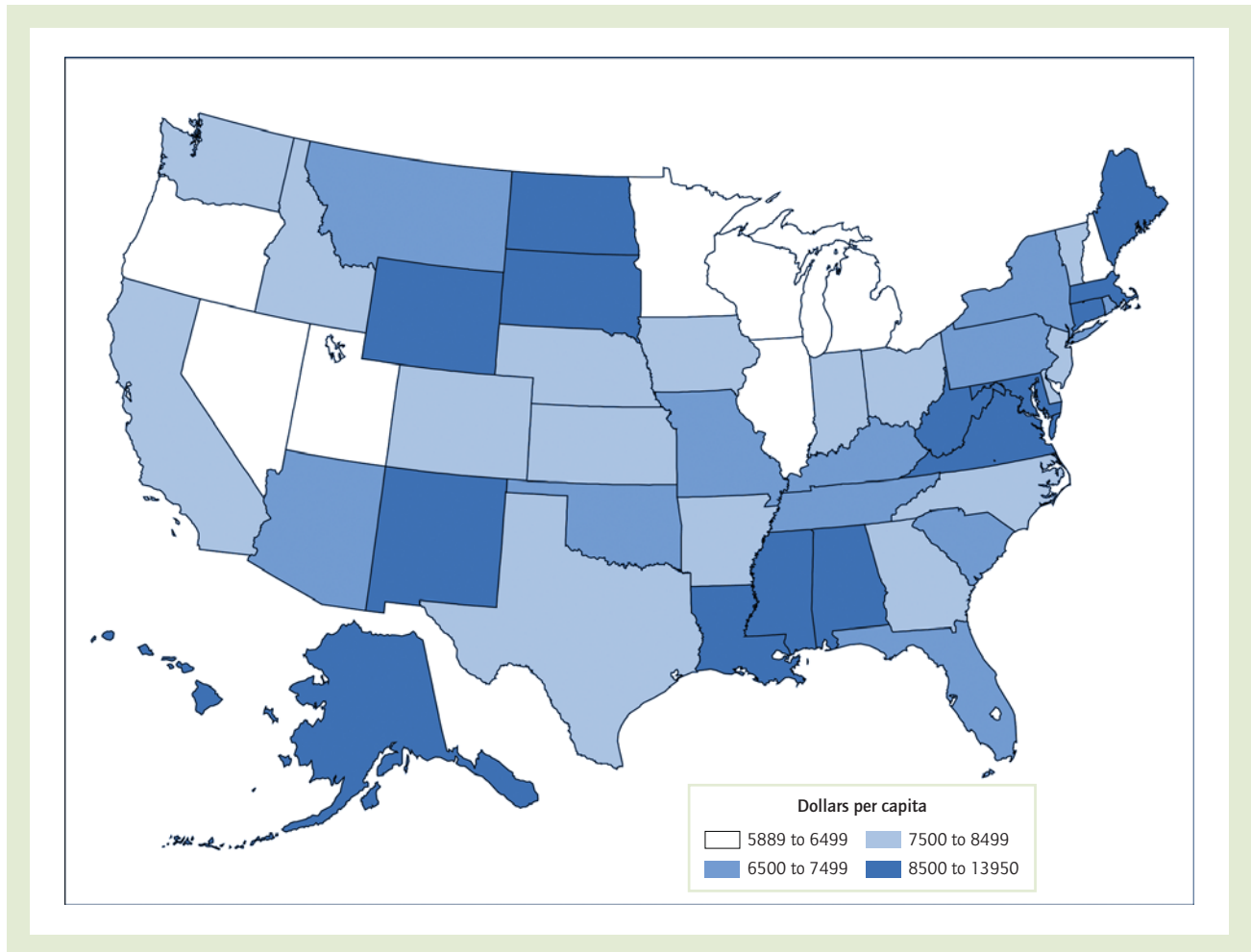


Figure 2 U.S. federal government outlays per capita, 2005. Federal government expenditures per person are, ironically, often highest in small, lightly populated states that often view federal authority with suspicion

Source: Data from the U.S. Bureau of the Census. (2007, September). *Consolidated federal funds report for fiscal year 2005* (p. 21). Washington, DC: Government Printing Office.

activities help explain the high levels in several states adjacent to the nation's capital or along the Atlantic and Caribbean coasts. But the overriding impression is one of geographical complexity, with few unexceptional trends being apparent. The complexity theme so often encountered in public policy analysis literature is thus reinforced by examining the overall state-level geography of federal government activity in the United States.

Public Policy and GIS

One area of rapid expansion in public policy related to geographical research and public sector

employment of persons with geographical training involves the mapping sciences of cartography, GIS, and remote sensing. At state and local levels of public sector employment, many geographers with mapping science skills can be found working in planning, natural resources, transportation, utilities, economic growth, health services delivery, and many other areas in which computer-produced maps and other forms of geographic analysis can help inform public policy making or evaluation. At the federal level, geographers with mapping science skills can be found in many agencies, including the departments of Commerce, Defense, Health and Human Services,



Homeland Security, Housing and Urban Development, the Interior, State, and Transportation. And, of course, much of the impetus for and financing of important modern advances in GIS and remote sensing have directly come from the federal government. Although military and international security applications have prompted many advances in GIS, remote sensing, and global positioning systems (GPS), domestic applications have also played an important role. For example, much of the pioneering work in developing topological data structures, which are now essential to many domestic and commercial applications of GIS, was undertaken by geographers in the Geography Division of the U.S. Bureau of the Census, in developing the DIME system for the 1970 Census and the TIGER system for the 1990 Census. Early-21st-century pizza delivery, emergency vehicle routing, school attendance districting, and, of course, electoral gerrymandering would be much less efficient without TIGER-powered GIS!

J. Clark Archer

See also **Applied Geography; Census; Climate Policy; Energy Policy; Environmental Management; GIS in Public Policy; Housing Policy; Justice, Geography of; Law, Geography of; Military Spending; Political Geography; Public Housing; Public-Private Partnerships; Public Water Services; Redistricting; Risk Analysis and Assessment; Social Justice; Spatial Decision Support Systems; State; Terrorism, Geography of; United States Census Bureau; Urban Policy; Urban Water Supply; Watershed Management; Zoning**

Further Readings

- Baldwin, R., Forslid, R., Martin, P., Ottaviano, G., & Robert-Nicoud, F. (2005). *Economic geography and public policy*. Princeton, NJ: Princeton University Press.
- Dye, T. (2007). *Understanding public policy* (12th ed.). Englewood Cliffs, NJ: Prentice Hall.
- Wise, S., & Craglia, M. (Eds.). (2008). *GIS and evidence-based policy making*. Boca Raton, FL: CRC Press.



PUBLIC-PRIVATE PARTNERSHIPS

Public-private partnerships (PPPs) are contracts or formalized relationships between a public sector institution and a private sector institution, usually relating to the provision of public services or infrastructure. All PPPs involve the transfer of risk between the parties, through the transfer of ownership, control, financing, or operation of the service. In contrast to wholesale privatization, the responsibility for a PPP is shared between the private and the public sectors and regulated by the latter.

There are significant national variations in the definition and practices of these partnerships, and their levels of formalization range from simple commercial contracts to the establishment of autonomous organizations with various degrees of authority. Countries as diverse as Canada, Ireland, and South Africa have set up governmental PPP units. Particular PPP policies and models, such as the Public Finance Initiative in the United Kingdom and the build-operate-transfer model, which is well established in Australia and Asia, have gained popularity among policymakers and have consequently been imported and adapted by other states. Leading international financial institutions and development agencies, such as the United Nations and the World Bank, have shown strong support for PPPs as a strategy for development and poverty reduction, and the private sector is now a dominant actor in public service delivery in many developing countries.

PPPs are, like privatization, subject to political contestation. Proponents of this model often claim that PPPs can bring in finances and resources otherwise unavailable to the public sector. It is also argued that PPPs represent "value for money," as private sector business principles are more efficient and because PPP involves the transfer of risk to a private contractor. In contrast, opponents see the profit motive as unsuitable for the realm of public services, which is seen as constituted by the notion of public need. It is held that private contractors can only make a profit on public services through wage and benefit cuts and the introduction of



cost recovery as a pricing principle. Another criticism that has been raised is the effect of PPPs on public accountability and their perceived lack of democratic input. While proponents include “third-way” governments, business interests, and conservative political parties, the opposition to PPPs is often spearheaded by trade unions, social movements, and leftwing political organizations.

In the critical human geography tradition, PPPs are seen as important components of neoliberalism and in the historical evolution of this paradigm. It is argued that the privatization programs and competitive tendering schemes that were initiated by Anglo-American governments in the 1980s were increasingly faced with their own socioeconomic contradictions. Neoliberal regimes were looking for ways to increase market involvement in public services without surrendering control over the politics of reproduction. PPP models and new, sophisticated models of regulation emerged as a response to the lack of coordination that characterized this early neoliberalism. Gaining popularity throughout the 1990s, these partnerships blurred the distinction between the private and the public sectors in many countries. These new forms of state control and intervention combined with increased private sector involvement is often termed *neoliberal governance*. There are also scalar dynamics to these processes, as the PPP approach, accompanied by a discourse of decentralization, has become prominent in local authorities in the United Kingdom and elsewhere.

David Jordhus-Lier

See also **Governance; Neoliberalism; Public Policy, Geography of; Regional Governance; Urban Policy**

Further Readings

- Flinders, M. (2005). The politics of public-private partnerships. *British Journal of Politics and International Relations*, 7, 215–239.
- Peck, J., & Tickell, A. (2001). Neoliberalizing space. *Antipode*, 34(3), 380–404.



PUBLIC SPACE

Many different meanings come to mind when one thinks of public space. Most definitions of public space involve what are usually thought of as communal “civic” spaces, such as public squares, city parks, public streets, sidewalks, and plazas. These spaces represent the stage on which communal life unfolds and where the ebb and flow of human exchange takes place. In this vein, public spaces are communal spaces where social, political, and economic activities take place. Other definitions of public space include those public domains that go beyond the local scale and that affect everyday communal life, such as global institutions or even the “spacelessness” of the Internet.

Public space is a necessary element of human existence, providing channels for movement, nodes for communication, and common areas for play and recreation. Access to public space helps people satisfy everyday needs, exercise significant aspects of human rights, and protect special cultural meanings. Government buildings, such as public libraries and many other similar buildings, are also public spaces. But not all state-owned buildings fall under definitions of public space. Some spaces are “semipublic,” where the right to occupy public space is restricted based on certain economic restrictions. Entry to public parks can also be restricted based on the ability to pay a fee or based on a user’s residence. Some privately owned spaces, such as cafes, are sometimes thought of as public spaces, but they are public only to the extent that one has money to spend. Shopping malls are public in the sense that everyone has legal access, but private controls over speech and behavior frequently apply.

What we normally think of as public space today stretches back to premodern concepts of the public marketplace in Mesopotamian cities and in ancient Greece and Rome. Sometimes called the *agora*, these were sites of great importance, serving as places for formal and informal communication and economic exchange. In later years, these open marketplaces incorporated open spaces for political assembly, sports, and religious gatherings. Public spaces as sites for economic, cultural, political, and social activities are still very much a vital part of communal life in many parts of the



San Marco Square and Palazzo Ducale, Venice

Source: Morguefile.

world today. Various cultures place different emphases on the value of public space. For example, Latin American cultures place great emphasis on displays of wealth and religious power in palaces, town halls, and churches that face the main street and public squares. Yet in the Muslim world, there is limited public space, apart from public markets and shopping centers. Instead, private spaces such as the home, the mosque, and religious schools are rich in architectural design and cultural expression, and it is here that much of communal life resides. Hence, the idea of a public-private balance is unique to each culture.

Beginning in the 18th century, universal access to public space was an important aspect of democratizing societies. But in practice, public access was anything but universal. Public space was

restricted by economic class, race, ethnicity, and gender, existing alongside class exploitation, slavery, and the oppression of women. In other words, universal access to public space is never guaranteed, never universal, and always a struggle. Feminist geographers have argued that notions of public space serve to spatially entrap women in terms of the built environment. Public spaces of the city, for example, are coded as masculine spaces—that is, the places of productive work accomplished primarily by male breadwinners. The suburbs represent private, feminine spaces, which are places of nonwage domesticity where reproductive work and child care are relegated primarily to women.

In recent decades, geographers have begun to examine how the nature of public space as a space



of everyday encounters is at risk, an increasingly problematic issue considering the rapidly diversifying urban populations in many places throughout the world. Indeed, public spaces are being privatized at an alarming rate, isolating people and diminishing the kinds of social networking inherent in public space. Neoliberal economic policies, along with technologies that place less emphasis on face-to-face personal communication, have only served to exacerbate the problem. Increasingly, public space is placed under tighter surveillance to improve security, mostly in the name of fighting the “War on Terrorism.” These current struggles have everything to do with contemporary debates that affect the nature of social relationships within the realm of public space, particularly for those on the margins of society, who have little power and influence. Indeed, the basic rights that reinforce any coherent sense of the public sphere are still very much constrained by the geographies of race, class, and national origin. In a world increasingly defined by private property and security fears (whether real or perceived), public spaces as spaces for human interaction and communal life are still very much tied in with dimensions of social difference and struggles for inclusiveness.

Many speculate that the nature of public space has not diminished but has been transformed by developments in communications technology. They maintain that the electronic spaces of the media and computer networks have opened up a new frontier of public space in which the material public spaces of the city are now superseded by the forums of television, cell phones, and the Internet. For many scholars, modern communications technology is now the primary site for public activity in general and politics in particular. But the question remains as to what this means when being part of “the public” no longer requires being *in* the public but instead can be accomplished in a private home by switching on the television or logging on to the Internet.

Approaches to public space involve balancing the public and private spheres by examining the ways in which contemporary public space is fragmented, both in a physical and in a metaphorical sense. Access to public space is about human relationships and the subsequent power struggles for recognition that result from social, cultural, economic, and political inequality. In a physical

sense, public space is about how these inequalities work through visual cues, such as barriers or boundaries. How people conceptualize these various definitions of public space is vital to how—and where—they grapple for legitimacy from the state or the community. Powerful institutions such as the state have their own ways of conceptualizing public space. Understanding these differences is vital for those who wish to contribute to particular visions of the term *public space* and its implications for creating a more just world.

Thomas Chapman

See also **Citizenship; Justice, Geography of; Neoliberalism; Social Justice**

Further Readings

- Carr, S. (1992). *Public space*. Cambridge, UK: Cambridge University Press.
- Light, A., & Smith, J. (1998). *Philosophy and geography II: The production of public space*. New York: Rowman & Littlefield.
- Mitchell, D. (2003). *The right to the city: Social justice and the fight for public space*. New York: Guilford Press.
- Orum, A., & Neal, Z. (2009). *Common ground? Readings and reflections on public space*. New York: Routledge.



PUBLIC WATER SERVICES

Public water services encompass the provision of collective services to a given community, typically an urban center. Water supply entails the abstraction of raw water from a natural source, such as surface water (e.g., rivers and lakes) or groundwater (i.e., aquifers); its treatment to make it fit for human consumption; and, finally, its distribution to households and commercial users via an underground pipeline network. This entry discusses public water services as a natural monopoly, the history of public water service organizations in Organisation for Economic Co-operation and Development (OECD) countries, public water services in developing countries, global trends concerning the



public versus private provision of water services, the restructuring of public water operations, and the principles underlying successful public sector reform.

A Natural Monopoly

The technical characteristics of water supply and sanitation services affect their organization and regulation. Because, at current technology levels, it is excessively expensive to set up more than one pipeline network to allow more operators to compete with each other, water supply is regarded as a typical natural monopoly. This implies that only one operator, whether public or private, is allowed to operate in a given operation area (e.g., in a municipality). If the water supply operator is a public undertaking, it is often appointed without competition for an unlimited duration and is subject to the scrutiny of public authorities. In recent years, the international practice in case of appointment of a private company as water supply operator is that this is subject to competition for the market, in the form of competitive bidding whereby the successful bidder enters into a long-term contract (typically up to 30 years).

Regulation is intended to be a substitute for or at least a complement of competition, whose introduction in the water sector is limited. Throughout the duration of the contract, the private operator is often subject to the scrutiny of local authorities or regulation by a specialized agency to try to prevent it from abusing its monopolistic position at the expense of consumers and the environment (e.g., by overcharging consumers or underinvesting in the system). If the introduction of competition is limited due to the technical characteristics of the sector, regulation is also problematic due to the asymmetry of information between the regulator and the regulated undertaking. In fact, the operator usually knows more about the state of the system and the conduct of operations than the regulatory agency, and it is thus able to exploit this advantage to pursue its interests (e.g., profit maximization in the case of a private operator) to the detriment of consumers, the environment, or the local community. It is thus important to identify governance mechanisms that will result in aligning the interests of the operator with those of the community.

Public Water Service Organization in OECD Countries

In Europe, urban water systems began developing in the 17th or 18th centuries as a limited service to affluent customers and as a public assistance for fire control. As cities grew in the 19th and 20th centuries, the demand for water consumption grew, and public health issues became more acute. While the initial systems were usually started by private companies, during the 19th century, the utilities were fairly soon taken over by municipalities in nearly all European countries.

There were a common set of reasons for this, ranging from the limited capacity of private operators to extend public water services to the urban population to the need to avoid the excessively high costs of private sector provision. In addition, municipal governments gained the right to borrow money to cost-effectively invest in the development of their own systems. The extension of water systems in European cities thus almost entirely took place under public operators and thanks to public finance.

The same process occurred in the United States. By 1897, 82% of the largest cities were served by municipal operations. At the end of the 20th century, the proportion was broadly the same and was not expected to change significantly.

Today, France and the United Kingdom are the only two OECD countries whose water operations are mostly run by private companies. However, even in these two cases, universal coverage was achieved only through the predominant role of public operators and public finance. Historically, private operations, market forces, and competition have not been central to attaining vital social objectives.

Developing Countries, Independence, and the Colonial Legacy

The development of water supply as a universal public service in developing countries has a different history. In the colonial period, while Europeans were extending public networks in European cities, in the colonies, water supply was focused on the colonial elite, and the systems failed to provide for the general population. This colonial development left a physical legacy of chaotic and



incomplete networks in cities under colonial control, such as Baghdad, Bombay (now Mumbai), and Lagos. In Kampala, Uganda, the British colonial power's insistence on cost recovery through tariffs meant that access to the service was unaffordable for ordinary Africans.

Colonial rule also left a socioeconomic legacy of more unequal societies, which makes today's problems more acute. In Africa, the colonial legacy of water systems designed to serve primarily the urban elites was exacerbated following independence by the decline in the terms of trade of the principal outputs and exports, which took place in the 1970s. This resulted in the decline in government funding of the capital expenditure necessary to extend service coverage and a general worsening of the national economy.

The failure to achieve universal coverage in developing countries can thus be explained by a combination of factors, including fragile institutions, unequal societies, inadequate public finances, and deteriorating economic conditions.

Recent Trends: History Repeating?

It is estimated that, to date, more than 90% of public water services worldwide are provided by public operators. Public sector predominance in the operation of public water services remains even after almost two decades of the so-called Washington Consensus, favoring market-based solutions and private sector participation. Supported by international financial institutions and bilateral agencies, water multinationals expanded considerably from the 1980s to the end of the 1990s. However, the fortunes of international water supply companies have collapsed dramatically in recent years, due to their failure to make adequate profits in developing countries. Since 2003, the multinational companies have halted and reversed their expansion. One key reason for this is that the developing countries could not support the rate of return required by international equity capital.

The failure to achieve an adequate return on capital is partly due to the remarkable amount of public campaigning against water privatization, a global phenomenon. The uprising that led to the termination of the private water contract in Cochabamba (Bolivia) in 2000 was the first and most dramatic of a series of reversals. The collapse of the

Argentinean economy led to the ending of water concessions in Buenos Aires and Santa Fe. In Africa, contracts were terminated in Gambia, Mali, Chad, Nkonkobe (South Africa), and Dar es Salaam (Tanzania). Privatization has faced similar rejections and reversals in developed countries, too: for example, in Atlanta and Grenoble (France).

Contrary to theoretical expectations, the private companies failed to show greater efficiency than public sector operations. A growing body of empirical evidence from all continents shows that ownership does not appear to make any significant difference to efficiency.

This can be explained by the problems observed under private water operations in developed as well as developing countries, which range from corruption, aiming to secure access to the local market and capture local decision makers and regulators, to a variety of rent-seeking practices that resulted in inflated pricing. These include the manipulation of tariff formulas, the systematic renegotiation of prices upward and postponement or downward revision of investment commitments, and overestimation of required investments. Furthermore, private water operators might resort to transfer pricing across vertically and horizontally integrated transactions. This takes place through privileged access to subcontracting or payment to the mother company for the purchase of costly managerial expertise and technical assistance.

Restructuring of Public Water Operations

Despite the widespread belief that public operators are inherently inefficient, there are many examples of effective public sector water services in developing countries, based on various criteria. These cases can be observed in all continents, not just in affluent countries. These are not acknowledged as often or as loudly as they should be, partly because the recent emphasis on private sector activity has obscured the achievements by the public sector. As the limitations of the Washington Consensus become more apparent, the attainment of social and developmental objectives will largely depend on strengthening and scaling up positive public sector experiences. Empirical evidence suggests that, once the different context is considered, the principles underlying successful reform of public



water operations might equally apply to developed as well as developing countries.

Principles of Successful Public Sector Reform

Unlike private companies, which see profit maximization as their overarching goal, public water operators have no single set of objectives. In principle, public sector undertakings pursue a plurality of objectives to promote the public interest from an economic, social, and environmental point of view. In practice, due to the monopolistic nature of water service provision, the success of public water operations in achieving the intended objectives relies on the effectiveness of accountability mechanisms.

Public water operations appear more suitable than private ones to contemporarily address a variety of public interests and sustainability objectives at the political and institutional, economic, social, and technical and environmental levels. When this happens, economic objectives are not prioritized over social and environmental goals but are seen as instrumental to fostering the sustainability of service provision. This is not a necessary outcome of public water operations but requires the introduction of accountability and transparency mechanisms such as advanced forms of democratization and public participation so that the management and local authorities can be made responsible to civil society for their decision and conduct. Though the introduction of advanced participatory mechanisms is not associated with all public operations, they are never to be found under private operations. The reason for this is that because private companies have an imperative to maximize profit, they cannot accept “intrusion” from stakeholders such as consumers’ representatives and pretend to exert absolute control over the management of operations.

The predominance of public water operations at the global level, historically and today, is a sign of the difficulties of achieving the intended development and sustainability objectives under private operations. This state of affairs is likely to continue in the future, as long as the technical characteristics of the service remain fundamentally the same. The fact that successful public sector reform is possible suggests that public sector

predominance should be seen as an opportunity in the pursuit of the Millennium Development Goals rather than as a hindrance. The efforts of international financial institutions and governments should be directed at making public water operators accountable and effective service providers through in-house restructuring under public ownership and management. When local capacity is the problem, this can be addressed by cooperation among public sector entities, as is the case under public-public partnerships.

Finally, institutional strengthening and capacity building should be pursued in parallel to efforts to sustainably finance the expansion and maintenance of infrastructure. This requires renewed attention to the potential of public finance and public subsidies based on (progressive) general taxation as a cost-effective and equitable financial instrument.

Emanuele Lobina and David Hall

See also **Neoliberal Environmental Policy; Neoliberalism; Public-Private Partnerships; Regulation Theory; Urban and Regional Development; Urban Metabolism; Urban Storm Water Management; Urban Water Supply; Water Needs; Water Supply Siting and Management; Watershed Management; Watershed Yield**

Further Readings

- Dagdeviren, H. (2008). Waiting for miracles: The commercialization of urban water services in Zambia. *Development and Change*, 39(1), 101–121.
- Hall, D., & Lobina, E. (2006, March). *Pipe dreams: The failure of the private sector to invest in water in developing countries*. Retrieved February 24, 2010, from www.psir.org/reports/2006-03-W-investment.pdf
- Hall, D., & Lobina, E. (2006, December 15). *Water as a public service*. Retrieved February 24, 2010, from www.psir.org/reports/2007-01-W-waaps.pdf
- Lobina, E., & Hall, D. (2003, June). *Problems with private water concessions: A review of experience*. Retrieved February 24, 2010, from www.psir.org/reports/2003-06-W-over.doc

- Lobina, E., & Hall, D. (2007). Experience with private sector participation in Grenoble, France and lessons on strengthening public water operations. *Utilities Policy*, 15, 93–109.
- Lobina, E., & Hall, D. (2008). The comparative advantage of the public sector in the development of urban water supply. *Progress in Development Studies*, 8(1), 85–101.

PYROGEOGRAPHY

Fire puts asunder what photosynthesis hath joined together. The alchemy of fire can be described physically as a biochemical reaction requiring the simultaneous presence of fuel, heat, and oxygen. Pyrogeography is a multidimensional subfield of geography concerned with the study of the complex space-time interactions between fire and people. Humans have always been the keepers of the flame; thus, pyrogeography is, true to its geographic roots, integrative—spanning the physical, biological, and social sciences. It is an exemplary coupling of natural and human systems.

The fireshed—the pyrogeography equivalent of the watershed—consists of four variables: fuel, weather, topography, and people. *Fuel* refers to combustible biomass. *Weather* describes precipitation, temperature, and relative humidity variations that control ignition probability. *Topography* determines the position of fuels on the fireshed. This aspect controls a fuel's productivity and curing via intercepted solar radiation, moisture, and the flows of wind; slope steepness mediates fire spread via effects of radiative and convective heating. *People* affect and are affected by fire, extending fire's reach beyond the biophysical environment into the human realms of culture, politics, and economics.

Origins

Before humans, climate determined the general fire patterns in accord with climate-soil-vegetation relationships. Precipitation produced fine grass fuels. Seasonal lightning propagated fire from grassy lowlands into forested uplands and vice versa. Fire recycled nutrients and thus promoted



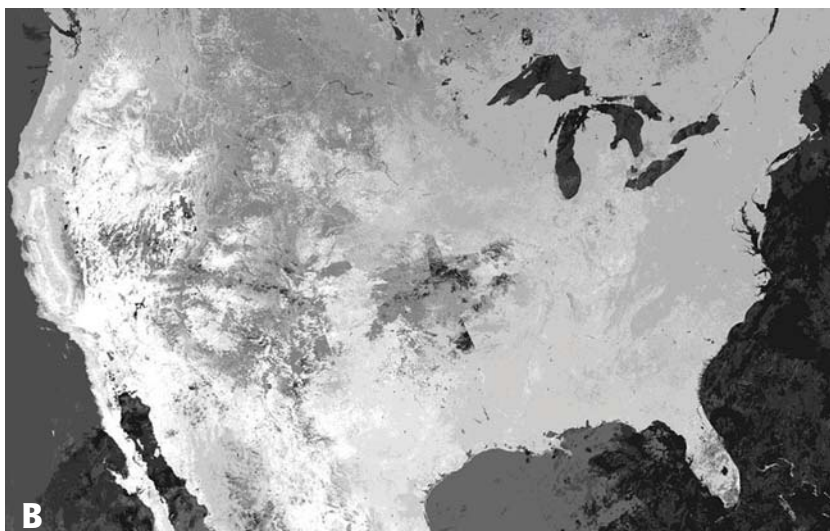
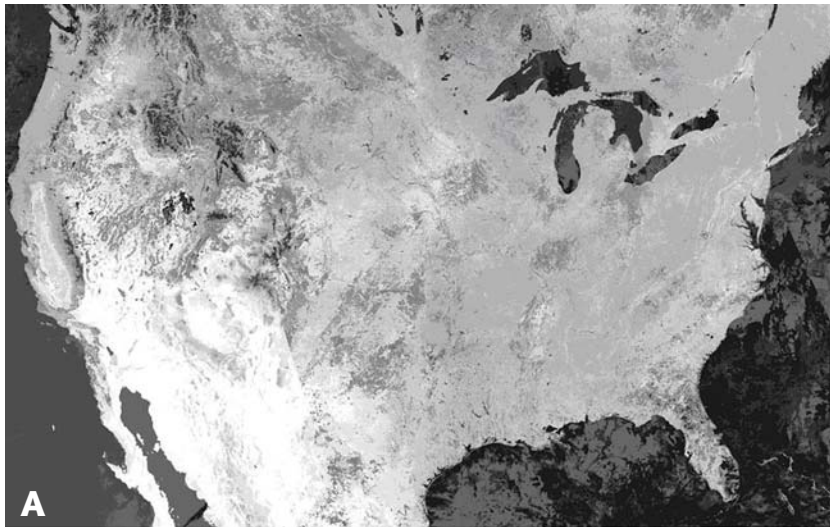
Surface fire reduces ground fuels, recycles nutrients, and maintains open, healthy conditions.

Source: U.S. Forest Service.

biodiversity. It was by this process that fire renewed the landscape (see surface fire photo).

Processes

Fire is a keystone ecological process, standing among the few natural phenomena humans can control. Pyrogeography seeks to clarify the evolutionary importance of fire and human culture. Before humans, fire was ignited primarily by lightning and occasionally by geological actions (e.g., volcanism and rock falls). Today, many wildfires are started by people. Combustion potential is controlled by vegetative fuel moistures: Live fuel moistures respond seasonally to broadscale interannual variations in precipitation, whereas dead fuel moistures can respond hourly to local meteorological conditions (e.g., relative humidity, wind).



(A) Bright areas represent high live-fuel moisture stress, thus an elevated fire potential. Southwestern North America shows particularly high stress in June. (B) The arrival of monsoonal rains in summer eases live-fuel moisture stress across southwestern North America by September.

Source: Yool, S. R. (2004). Wildfires. In J. Stoltman, J. Lidstone, & L. M. DeChano (Eds.), *International perspectives on natural disasters* (chap. 5, pp. 107–130). London: Kluwer.

Fuels are both a source and a sink for atmospheric carbon: Emissions from biomass burning are sources of particulates and carbon dioxide (CO_2) that affect Earth's radiant energy budget and atmospheric chemistry, influencing climate on regional and global scales. Live fuels harvest atmospheric CO_2 and thus complement Earth's oceans as terrestrial sinks for planetary carbon. Fire scars in tree rings and charcoal in

sedimentary deposits record terrestrial carbon exchanges through deep time, showing the close coupling between climate, fire, and vegetation. Modern fire atlases from ground observations and satellites show increased fire activity in many regions. Complex combinations of climate warming and drying, land use change, and the spread of pyrogenic invasive plant species likely explain these recent changes.

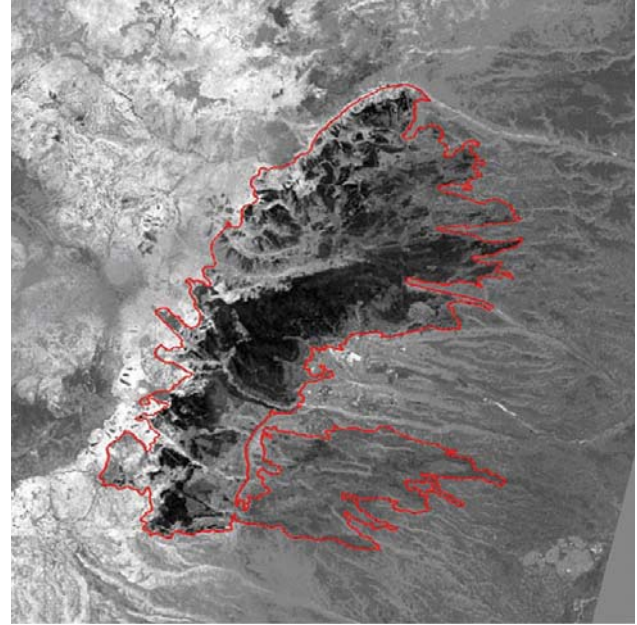
Technologies

Geospatial mapping technologies, powered by the human intellect, can coax complex pyrogeography from raw data. Maps showing the global distribution of fire serve to inform questions of how climate-fire interactions explain contemporary and predict future Earth surface patterns. Such maps can be used by ecologists interested in fire regimes, by Earth systems scientists monitoring fire-related carbon fluxes to the atmosphere, by historians and economists describing the culture and risk of fire, and by geographers investigating space-time variations in fire hazards. Pyrogeographers studying wildfire hazards, for example, use maps as their principal medium of communication. Geospatial technologies, including remote sensing and geographic information systems (GIS), facilitate mapping and modeling of wildfire hazards and effects from local to global scales. Remote sensing technologies include airborne and spaceborne remote sensing systems to determine prefire fuel moistures (see southwestern North America photos), active fire spread (see ASTER photo), and postfire severity and resilience (see Landsat photo). (Resiliency is the response to severity: the ability of a fireshed to recover after a fire.) GIS technology unifies these



This National Aeronautics and Space Administration (NASA) Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) image captures the Old Fire/Grand Prix Fire Complex, October 26, 2003, in the San Bernardino Mountains, 80 kilometers east of Los Angeles.

Source: National Aeronautics and Space Administration.



This Landsat Thematic Mapper image collected after the Cerro Grande Fire (May–June 2000, Jemez Mountains and Los Alamos, New Mexico) expresses the classic “signature” of a fire scar. This image was enhanced by computer processing to show fire-induced changes.

Source: Yool, S. R. (2004). Wildfires. In J. Stoltman, J. Lidstone, & L. M. DeChano (Eds.), *International perspectives on natural disasters* (chap. 5, pp. 107–130). London: Kluwer.

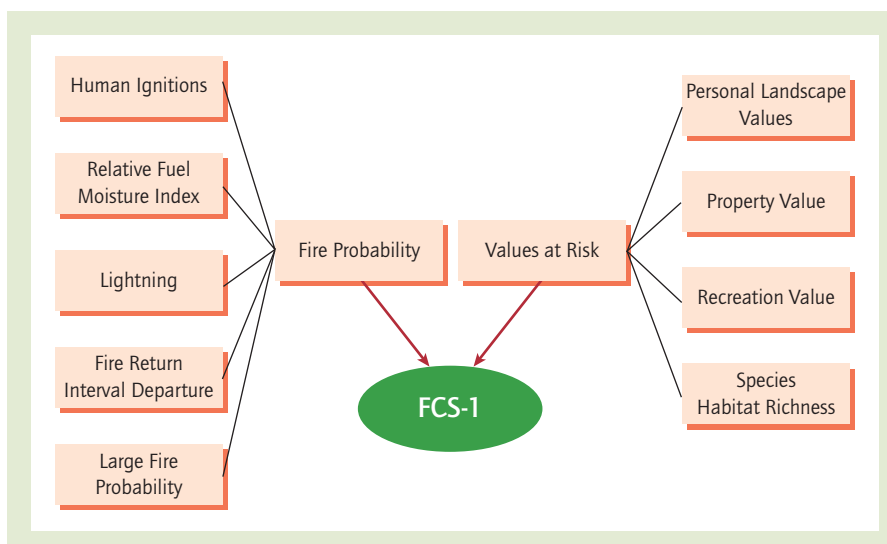


Figure 1 The first integrated Fire-Climates-Society (FCS-1) GIS model in schematic form: There are nine primary GIS data layers, forming the fire probability and values-at-risk submodels used to produce the FCS-1 composite priorities map.

Source: Yool, S. R. (2004). Wildfires. In J. Stoltman, J. Lidstone, & L. M. DeChano (Eds.), *International perspectives on natural disasters* (chap. 5, pp. 107–130). London: Kluwer.

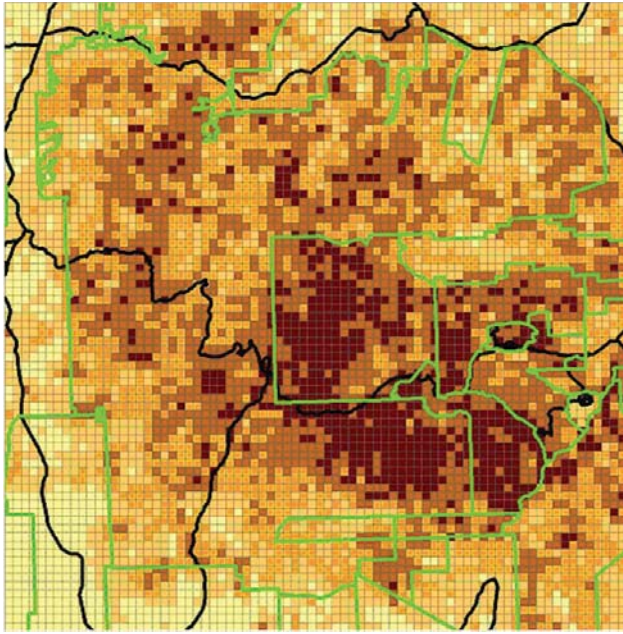


Figure 2 Sample FCS-1 composite map of wildfire hazard for a region within the Jemez Mountains, New Mexico. The AHP computes weights for each data layer (Figure 1) based on stakeholder responses.

Source: Yool, S. R. (2004). Wildfires. In J. Stoltman, J. Lidstone, & L. M. DeChano (Eds.), *International perspectives on natural disasters* (chap. 5, pp. 107–130). London: Kluwer.

Note: The darkest cells represent the highest wildfire hazard priority areas.

fire-related data, enabling predictive modeling and facilitating fire management.

Integrations

Geospatial information technology allows integration of natural and cultural data into wildfire management alternatives. A first-generation Fire-Climate-Society model (FCS-1) is a GIS that integrates geospatial information and user preferences (Figure 1). Composite wildfire hazard maps depict priority areas for management activities, including prescribed burning or mechanical thinning.

The FCS-1 model translates user preferences into fire hazard maps via the Analytic Hierarchy Process (AHP). The AHP enables complex decisions involving data that are difficult to quantify. Stakeholders are presented all unique pairwise

combinations of the nine primary data layers. Each stakeholder produces a relative weighting for each unique pair. AHP derives from this set of pairwise comparisons a weight for each primary data layer. Weights are multiplied by actual data values. The sum of these products produces a custom composite priorities map that exemplifies pyrogeography in practice (Figure 2).

Stephen R. Yool

See also *Drought Risk and Hazard; Resilience; Vulnerability, Risks, and Hazards; Wildfires: Risk and Hazard*

Further Readings

- Biswell, H. H. (1989). *Prescribed burning in California wildlands vegetation management*. Berkeley: University of California Press.
- Bowman, D., & Balch, J. (2008). *Pyrogeography: Fire's place in Earth system science*. Retrieved September 7, 2008, from www.nceas.ucsb.edu/summaries/bowman
- Chuvieco, E. (Ed.). (2003). *Wildland fire danger estimation and mapping*. River Edge, NJ: World Scientific.
- Moritz, M., & Krawchuk, M. (2008). Global pyrogeography: Macro-scaled models of fire-climate relationships for understanding current and future conditions. *Geophysical Research Abstracts*, 10, EGU2008-A-11511.
- Pyne, S. J., Andrews, P., & Laven, R. (1996). *Introduction to wildland fire* (2nd ed.). New York: Wiley.
- Saaty, T. L. (1980). *The analytic hierarchy process*. New York: McGraw-Hill.
- Westerling, A. L., Hidalgo, H. G., Cayan, D. R., & Swetnam, T. W. (2006). Warming and earlier spring increase Western U.S. forest wildfire activity. *Science*, 313, 940–943.
- Yool, S. R. (2004). Wildfires. In J. Stoltman, J. Lidstone, & L. M. DeChano (Eds.), *International perspectives on natural disasters* (chap. 5, pp. 107–130). London: Kluwer.



QUALITATIVE METHODS

Qualitative methods can be characterized by their concentration on subjective experiences and the subjective dimensions of the social. These methods are labeled as qualitative because their aim is to investigate deeply into each single case rather than produce a more abstract and concentrated set of quantitative data. Even if the results gained with the help of qualitative methods are not, in general, statistically representative, their outcomes and interpretations are somewhat more than the descriptions of individual cases. Because each single case is considered as being a part of society, reflecting wider processes, qualitative research produces results that can be generalized. Today, qualitative methods are in common use in the social sciences, including human geography. Qualitative methods are used sometimes in combination with quantitative methods. After identifying a problem with a quantitative approach, it may be further investigated with qualitative research (and vice versa). This entry describes the development of qualitative methods in geography, examines the main characteristics of such research, and reviews the methods used to gather and analyze data.

The Development of Qualitative Methods

The main theoretical and practical development of qualitative methods was carried out in sociology and anthropology. Geographers adapted these

insights to and enhanced them in their own research. Anthropologists such as Bronislaw Malinowski and Franz Boas pioneered the use of qualitative methods with observations in ethnographic field studies at the start of the 20th century. In the 1920s, members of the Chicago School of sociology and urban geography, such as Robert Ezra Park and Ernst Burgess, applied—in addition to some quantitative methods—mainly qualitative methods, such as participant observations, to investigate different patterns of social life in diverse parts of Chicago. This type of research was highly influenced by one strand of argument in the so-called *Methodenstreit*. This methodological dispute took place in late-19th-century Germany. It was argued by social scientists such as Georg Simmel and Max Weber that because human beings are complex and creative social subjects, their behaviors are neither caused nor explainable by standardized laws; thus, there is a fundamental difference between natural science and social science that requires the use of different methodologies.

The specific aspects of human interactions are notably elucidated by the social psychological theory of symbolic interactionism, according to which the activities and consciousness of the individual are considered part of social interactions. With the rise of positivism since the late 1920s, the use of qualitative research methods came under fierce attack. As a result of the argument that social research methods should lead to measurable and objective results, some methods



similar to those of the natural sciences came into common use. These are characterized by the statistical analysis of data gathered by experimental and survey research. Critics of this approach argued that positivists research a simplified, overly abstract version of the real world that ignores the rich meanings people construct and use in everyday life. According to this criticism, such research neglects the unintended influence on the research process by the researcher in his or her specific role. This argument is analogous to one from the natural sciences, that is, the uncertainty principle developed in 1927 by the physicist Werner Heisenberg, who demonstrated that the position of extremely small particles such as electrons could not be exactly specified because the process of its measurement itself changes the momentum and direction of the particle.

With the growing influence of positivist philosophy and statistical methods, however, qualitative methods lost much of their influence in the social sciences, particularly during the quantitative revolution in geography, starting in the 1950s. In consequence, the use of qualitative methods in human geography declined greatly in importance. Humanistic geographers such as Yi-Fu Tuan and Anne Buttimer in the 1970s, however, argued for a qualitative research perspective that was highly influenced by the philosophy of phenomenology. This approach is based fundamentally on the notion that the perception of one's surroundings is deeply conditioned by the biases, cultural norms, and cultural attitudes of the perceiver. Accompanying the growth of social theory in geography, the use of qualitative methods has flourished since the 1980s. Taking the appreciation of culture on the basis of individual everyday activities to be significant for research has greatly expanded the use of qualitative methods.

Characteristics of Qualitative Methods

The main characteristics of qualitative research methods are difficult to delineate, as several research methods are in use under the cover of this umbrella term. Some qualities can, however, be identified that are to a greater or lesser extent essential for the methods to be classified as qualitative research: Qualitative methods focus on the

profound implications of some individual cases and aim to explore observed cases in an open-ended manner instead of deducing their implications from rigidly conceived theories a priori. Furthermore, they incorporate the role of the researcher.

In-depth data—representing the meanings and routines of individual lives—are produced with qualitative methods through their focus on the deep structures of some individual cases. The people being researched are investigated in their role as subjects, considered as members of wider social contexts. The methodological aim is to conceive individual social activities as an integral part of a broader cultural context. During the interpretation process, the social logic and meaning that underlie these individual events must be teased out. This notion is at the heart of the concept of “thick description,” introduced by Clifford Geertz in his influential book *The Interpretations of Culture* (1973). Social interactions and experiences lie at the center of attention; for example, the meanings and routines in narratives are analyzed by observing everyday activities or by examining subtle body movements recorded on video.

Qualitative methods are open to the previously unknown because they do not attempt to test a hypothesis formulated before the research is executed. This task can be managed by providing those in the focus of research room to shape the process of inquiry itself. The specific meanings used by the investigated subjects should be included and taken seriously when formulating, and later reformulating, the research questions. As the subjects leave their marks on the process, the social scientist must act in a flexible manner. For this reason, qualitative methods can vary and can be applied in different ways.

As a consequence of the assumption that the results of research are not objective, subjective elements are considered as part of the qualitative research process. For example, the setting of the interview—where and under which circumstances it is conducted—must be considered. Qualitative research takes into account the perspective of the researcher, that is, his or her biases, assumptions, priorities, and positionality, and its influence on the research, since the researcher is situated and does not occupy a neutral position. The role and impact of the social scientist's subjectivity



and identities are considered in a self-reflexive way. The technique of self-reflexivity has been prominently developed in anthropology, as well as in the work of the sociologist Pierre Bourdieu, since the 1970s. In human geography too, self-reflexivity has its place; an example is the research on gender by Linda McDowell. This perspective is also prominently developed in postcolonial studies—for example, in the work of the geographer Alison Blunt. Postcolonialists demonstrate that the perceptions and outlook of many former colonized regions and their peoples are deeply conditioned by common stereotypes grounded in a lasting colonial perspective, the so-called imperial eye. This view can also be read as a critique of earlier anthropological field studies, which did not include sufficient self-reflexivity of their colonial perspective.

Producing Qualitative Data

Human geographers make use of a wide set of techniques for producing qualitative data, including several types of interviews, field observations, and analysis of objects and texts. Research projects often combine different techniques. In gathering data, it is essential to select a sampling strategy, which involves considering the choice of cases with respect to differences, for example, in ethnicity, class, gender, sexuality, religion, or age.

The most typical methods are various forms of interviews. Qualitative interviews are characterized by having the character of a more or less structured open discussion, where the interviewee is stimulated to influence the interview's content and course. The interviewer tries to gain knowledge of the interviewee's experiences and thoughts about his or her own life, or about topics where the interviewee has knowledge. Interview forms differ in the degree of their preliminary structure. While expert interviews are conducted with the help of an interview guide and contain at least broad questions or topics of interest, an ethnographic interview has a more spontaneous character and is held in a completely open manner. The autographic narrative interview form allows the interviewee to speak freely about his or her own biographical events. In its most radical form, such a format avoids interviewer-interviewee interaction within the interview, in consequence

of which it tends less toward an interview and more toward a monologue. In addition to one-on-one interviews, more people can be involved in the technique of focus group interviews. The strength of this interview form lies in the fact that speaking about a common topic or experiences with others allows people to have more time to reflect on and to recall their own experiences. Something that one person mentions can stimulate memories in others. In interviews, data are produced in the form of written transcripts. Depending on the kind of research, prepared transcripts range in their level of detail from simple notes to an exact (recorded) reproduction of the precise language used in the interview.

Observation methods are crucial, for example, in research on the interaction between everyday human activities and geographic places, which lies at the heart of human geography. In addition to the researcher's observations, participant observation is also used. In this method, the researcher participates in the everyday activities of the people being observed. In its most developed form, this approach can go as far as the researcher becoming a member of the observed social group and adopting their outlook and behaviors. As with interviews, data are created in the form of written field notes, as well as visually in photographs and video. These notes include observations about the situation being studied and occasionally some reflections on the researcher's own perspective and involvement.

Analyzing Qualitative Data

Data produced by qualitative methods require relevant analytical techniques. In addition to interview transcripts and field notes, sources for analysis are different forms of text, such as maps, landscape paintings, archival documents, diaries, films, or photographs, as well as material artifacts.

One of the main tasks of data analysis is that of coding and classifying the material. This job is best developed in the grounded-theory approach. In various steps, and often with the help of computer programs, the entire data corpus is thematically structured and linked. With this procedure, the same topics recurring in different interviews can be analyzed. Interpretations can be developed



on the basis of several examples, making it possible to identify similarities or dissimilarities.

In content analysis, the frequency with which different topics arise can also be identified and analyzed with the help of statistics. In discourse analysis, the topics that are included and the ways in which they are expressed can be investigated. Modes of thinking, talking, and acting that are not present in the material can be identified. Discourses are identified by their use in specific forms of talking or acting, as well as in distinctive patterns of places and architecture. Discourse analysis, which is grounded in the research of Michel Foucault, has been used in human geography since the late 1980s.

As qualitative data analysis can be carried out as a step-by-step procedure, at the same time as interpretations are organized and the internal logical structure of the argument is tested, the process of writing itself can also be part of the analysis.

Lars Meier

See also **Cultural Turn; Discourse and Geography; Ethics, Geography and; Ethnocentrism; Eurocentrism; Everyday Life, Geography and; Fieldwork in Human Geography; Humanistic Geography; Interviewing; Participant Observation; Situated Knowledge; Text/Textuality; Writing**

Further Readings

- Denzin, N., & Lincoln, Y. (Eds.). (2005). *The SAGE handbook of qualitative research* (3rd ed.). Thousand Oaks, CA: Sage.
- Geertz, C. (1973). *The interpretations of culture*. New York: Basic Books.
- Hay, I. (2005). *Qualitative research methods in human geography* (2nd ed.). Oxford, UK: Oxford University Press.
- Kitchin, R., & Tate, N. (2000). *Conducting research in human geography: Theory, methodology and practice*. Harlow, UK: Prentice Hall.
- Lofland, J., Snow, D., Anderson, L., & Lofland, L. (2005). *Analysing social settings: A guide to qualitative observation and analysis* (4th ed.). Belmont, CA: Wadsworth.



QUANTITATIVE METHODS

The sudden rise of quantitative methods in geography in the 1950s and 1960s is often regarded as one of the greatest achievements in the discipline. Quantitative methods can be traced as far back as Thales and Eratosthenes, who were in their own right mathematical geographers in ancient Greece. However, the 1950s are thought to be the origin of modern quantitative methods in the discipline. The closing of Harvard's geography department in 1948 was an early indication of a crisis in the discipline concerning its inability to meaningfully explain processes or phenomena; this limitation included a lack of quantitative analysis that relegated the discipline to a classroom setting and inhibited its growth and utility in both private and public sectors. This entry describes the evolution of quantitative methods in geography during the 1950s and 1960s, reviews the use of descriptive and inferential statistics in the field, and examines the place of quantitative methods in the discipline of philosophy today.

The crisis of the 1950s confronted geographers with the task of deciding in which direction to take the discipline. Richard Hartshorne advocated a descriptive, traditional geography, while Fred Schaefer pushed for a quantitative analytical approach. Schaefer attacked Hartshorne's emphasis on idiographic regional distinctions in favor of nomothetic, lawlike statements to explain spatial patterns. This critique encouraged geographers to rethink the direction of the discipline in a way that would make it more quantitative, a reconsideration that led to the quantitative revolution. Some observers suggest that the quantitative revolution was logical positivist in nature, as positivism is an epistemology that privileges scientific methods, general explanatory laws, and quantitative data and methods as the highest and best form of knowledge. However, it is now acknowledged that quantitative geography and positivism are not synonymous, that is, positivists do not have a monopoly on the use of quantitative techniques (e.g., quantitative Marxists also use these methods).



Origins of Quantitative Methods in Geography

The use of quantitative analysis and spatial science in geography began at the University of Iowa and the University of Washington, as well as Northwestern University, during the 1950s. Elsewhere, Torsten Hägerstrand at Lund University was pioneering quantitative research in the 1950s in relation to innovation diffusion. In United Kingdom, Richard Chorley's work stands as a milestone. By the 1960s, the interplay of multivariate statistics, mathematics, computers, models, and an underlying scientific philosophy cemented the foundation of quantitative geography in the discipline.

The type of quantitative analysis often employed by geographers in the early years of the revolution was primarily descriptive. Inferential statistics or the drawing of conclusions from statistical samples became popular shortly thereafter. By 1970, geographers were using computers to help conduct multivariate quantitative analyses.

In human geography, quantitative techniques today are increasingly analyzed in conjunction with an understanding of social and economic processes and theories. The adoption of statistics in geography unfolded differently in different fields of the discipline. Economic and urban geography, for example, were far more receptive to quantitative analysis than cultural, political, or historical geography. In geographic information science (GIScience), physical geography, and remote sensing, statistics are used to measure and calibrate a phenomenon or technique. GIScience, for example, arose from GIS (geographic information systems) partly because of its ability to combine quantitative analysis and computer cartography. While quantitative geography waned slightly in importance during the retreat of positivism in the late 20th century, geomatics, GIScience, regional science, and remote sensing have reinvigorated the use of statistics in geography.

Descriptive and Inferential Statistics

Quantitative methods in geography are either descriptive or inferential in nature. Descriptive statistics are typically used to produce numerical

and graphical summaries about a data set or a sample population. Measures of dispersion, frequency, and central tendency typify descriptive statistics. Measures of dispersion include standard deviation, variance, range, and interquartile range. Frequency counts help describe the modal pattern of a sample or population; for example, is it normally distributed, bimodal, or skewed? Measures of central tendency are based on procedures that describe the mean, medium, or mode. All these descriptive techniques can be illustrated in tables, graphs, histograms, box-and-whisker plots, or box plots. In geography, means are often compared over time and space. For example, the mean temperature of various geographical areas by year can be analyzed to determine if climate warming or cooling is taking place on a temporal-spatial level. In geography, quantitative temporal-spatial analyses are typically conducted to analyze natural or human phenomena, such as tornadoes, hurricanes, earthquakes, rainfall, poverty, corporate headquarters, gentrification, or diseases, to name a few. The discipline of geography has come a long way in interpreting phenomena within a spatially autocorrelated framework, and it is now an academic leader in this area of quantitative interest.

Nonparametric techniques vary from parametric techniques in that they help show relationships within or between nominal or ordinal variables and are classified as being distribution-free. For example, the chi-square test is based on categorical or nominal data, and Spearman's rank correlation coefficient is based on ranked or ordinal data. Parametric statistics, on the other hand, such as analysis of variance (ANOVA) or Pearson's coefficient, assume normally distributed samples or populations. In the absence of such normality, a nonparametric technique is useful.

Inferential statistics are used to make inferences or generalizations from a sample to a population. The objective here is to make as accurate an inference as possible about a population and to determine if the relationship is statistically significant. To help determine the significance of an inferentially derived statistic, estimate, probability, or error values are calculated in conjunction with defined hypotheses. There are two sources of error that may prevent a sample from accurately



summarizing a population. These are sample error and sample bias. One quality of inferential statistics is that they attempt to control for sample error. On the other hand, sample bias cannot be controlled. One example of hypothesis testing would be to determine if the inventive capabilities of people from two regions are significantly different as measured by the number of patents. Using z or t test can help determine if any differences are statistically significant.

Inferential statistics also include bivariate and multivariate analyses. In this case, relationships between variables are typically examined using simple correlation, bivariate regression, Pearson's R , or pairwise correlation analysis. With respect to multivariate statistics, factor, principal component, cluster, discriminant, and multiple regression analyses are frequently employed. Geographers are particularly interested in using these techniques with spatially referenced data. For example, in an inferential multivariate analysis where each case is a region, researchers can extract and then map the residuals or scores from a regression, factor, cluster, or discriminant analysis to identify broad patterns or anomalies. Furthermore, by categorizing regions and their people, based on cluster or discriminant statistics, for example, one can yield invaluable spatial-consumer information. Such information is prized and sought in business and marketing. This approach, as well as other types of applied quantitative analyses in geography, has helped substantially to increase awareness of the discipline in the private sector.

Impacts of Quantitative Methods

The adoption of quantitative methods in geography has had a notable impact on the discipline. Their introduction facilitated positivist thinking as well as the use of neoclassical economic modeling. In this regard, techniques were borrowed from other disciplines and used to explain spatial processes and relationships. For example, the bid-rent curve, contextualized in von Thünen's land use model, is an example of neoclassical modeling that uses basic numeric methods. Waldo Tobler may have been the first to create a law in geography based on the gravity model. The model uses mathematical procedures to show that things, such as cities, are interrelated

and that near things are more related than distant things. Tobler's model has its inspiration in Newton's law of universal gravitation and has helped create statistical procedures unique to geography, known as geostatistics.

Quantitative analysis in geography helped with theoretical developments in the discipline. Today, modeling in geography has become much more sophisticated, as is the case with artificial neural network analysis in GIScience. The post-positivist movement has helped bring the discipline a long way from positivist quantitative analysis, and its impact has been real. For example, there is greater acceptance of economic geography courses on fashionable topics such as globalization, which seem less quantitative and positivist model based. Geomatics, on the other hand, is becoming increasingly quantitative and is helping to keep geography from sliding back on the quantitative "slide rule." One of the reasons for this is better data sources, for example, on the census or climate, which are becoming increasingly digitized and elaborate.

The nonpositivist approaches to geography in the 1970s led to resistance to quantifying human behavior. The notion that positive spatial science could provide realistic models was attacked. Though geographers could quantify the location and extent of urban poverty, for example, solutions to the problem seemed absent from the quantitative models. The growth of humanistic thought during the 1980s led to a further critique of quantitative models in geography as being inappropriate when applied to the behavior of thinking human beings. As simplified as the early quantitative models in geography seem, they continue to be useful in many respects. The bid-rent curve, for example, continues to help explain the distribution of economic activities within urban space. Similarly, the gravity model is useful in studying traffic patterns or migration. For example, gentrification often occurs near key transportation routes (particularly public transportation) and is bounded partly by distance to these routes. Today, quantitative methods in geography often incorporate or address social or scientific theories within different epistemological approaches. This meshing has lessened the quantitative/qualitative divide in the discipline. Quantitative methods are becoming increasingly more refined and powerful



in geography with the help of geotechnical innovations. For example, traditional regression modeling is overlapping geographically weighted regression and spatial autocorrelation analysis. These refined quantitative methods are helping to substantiate geography's role in the social and natural sciences.

Brian Ceh

See also Fotheringham, A. Stewart; Geographically Weighted Regression; Geostatistics; GIS, History of; GIScience; Gravity Model; Human Geography, History of; Input-Output Models; Location Theory; Logical Positivism; Models and Modeling; Multivariate Analysis Methods; Quantitative Revolution; Regional Science; Spatial Analysis; Spatial Autocorrelation; Spatial Econometrics; Spatial Interaction Models; Spatial Optimization Methods; Spatial Statistics; Thünen Model; Tobler, Waldo

Further Readings

- Fotheringham, S., Brunson, C., & Charlton, M. (2000). *Quantitative geography: Perspectives on spatial data analysis*. Thousand Oaks, CA: Sage.
- Haining, R. (2003). *Spatial data analysis: Theory and practice*. Cambridge, UK: Cambridge University Press.



QUANTITATIVE REVOLUTION

Quantitative revolution is the not very felicitous term that arose to describe the partial transformation of geography from a merely descriptive science into one that included the development of a theory of spatial organization and behavior, formal modeling of these processes, and the use of appropriate statistical methods to test the expectations from theory.

Participants preferred the term *scientific*, emphasizing a fundamental shift from an ideographic (descriptive) to a nomothetic (formal theory) epistemology. *Revolution* is accurate, as there was assuredly an intentional break with what had come to be viewed as an inherently

interesting and integrative field of study but one that had embarrassingly failed to go beyond “what” to the unsolved questions of “how” and “why.” Instead of providing maps and data as part of general education and for scientists in other disciplines to theorize about, participants were determined to begin to explain the patterns of human as well as physical processes on the land. The term *quantitative* arose from the novelty of the use of inferential statistics and the embracing of simple mathematical models, although the publications of almost all the “pioneers” of the revolution concerned mainly theory of spatial structure and movement.

The inspiration for the quantitative revolution was primarily theoretical, not statistical, most obviously in the work of Walter Christaller (central place theory), Torsten Hägerstrand (Lund University, diffusion and simulation), and Fred Schaefer and Thomas McCarty (University of Iowa), and at the University of Washington, Edward Ullman and especially William Garrison in turn influenced by the rise of regional science, which was initiated by Walter Isard. Beginning in 1958, a cadre of students spread the movement with revolutionary fervor, as courses in location theory and statistics arose in Chicago, Northwestern, Michigan, and, in the United Kingdom, Bristol and Cambridge. Systematic theory and statistics began to be incorporated into the wider curriculum in both physical and human geography.

Although it originated in the 1950s, by 1963 the new movement had succeeded in becoming a vocal and active presence at dozens of institutions, including most major departments with doctoral programs in geography. National Science Foundation (NSF)–sponsored symposia on quantitative geography facilitated the rapid growth, via the circulation of ardent and informative “discussion papers,” beginning at the University of Washington in 1954, and through publications in the leading journals.

The second decade (1964–1973) was one of institutionalization, as the theoretical revolution in fact succeeded in transforming geography, and then of the expected critique and counterrevolution. Institutionalization took two forms. Most important, yet underreported and underappreciated, was that the need and quest for theory



became incorporated into the fabric of the discipline, in research, in teaching and publication, and in all branches of the field. Less universally, common statistical procedures were used almost routinely in evaluating the results of research. Significant numbers of theoretical expectations about locations of firms and activities, urban structure and change, trade and transportation, administrative organization and electoral behavior; migration and communication, just to mention a few areas in human geography, were verified or found wanting. By 1973, the “new geography” had been incorporated in texts as well as journals, for example, *Geographical Analysis*, which began in 1969.

The second form of institutionalization was through specialization and deepening of both method and theory and continuing through the present. Having originally adopted the already prevalent statistical procedures and models, geographers increasingly developed new methods of spatial analysis, including those dealing with serious issues of spatially ordered data, and laid the foundation for GIS (geographical information systems) and a further revolution in spatial representation. Methodology expanded to encompass qualitative approaches, if they contributed to verification of theory; that is, research might use both quantitative and qualitative tools. Theories of location, spatial organization, movement, and diffusion became more sophisticated and realistic and were broadened to deal with complex social structures and uncertainties of behavior and with the interface of physical and social processes. As even severe critics have acknowledged, the wider legacy of the quantitative revolution has been a deeper appreciation of the central role of theory.

The successful institutionalization of scientific theory and method within geography had two overwhelming benefits. Most essentially, it saved geography’s standing as an advanced and respected discipline, as marked, for example, by its presence in the National Academy of Sciences and its role in the GIS revolution. Practically, it led to the creation of myriad opportunities for consulting and nonacademic jobs in the private and public sectors, as well as enabling the enormous growth of the discipline—with room for its critics and detractors!

Revolutions spawn counterrevolutions. Again, this took two forms, both under what came to be called “critical” geography. The dominant critique was on the substance of much of statistical and theoretical work, which early on seemed to concentrate on explaining how the existing social system was supposed to work but which neglected wide areas of human experience and social reality—other social systems and the inherent vast inequalities in power in the dominant social system in terms of gender, class, place, race, or level of development. These critiques unleashed new waves of fervent development of theory, but they should be viewed as challenging and renewing the spatial analytic, spatial science paradigm of geography, not replacing it—for example, poverty and racial inequality as geographic manifestations of social processes. On the other hand, to the extent that theory was expounded that was intentionally untested or untestable, geography has been diminished.

A secondary critique, in part valid, is that for too many geographical methods, techniques and technology have replaced or substituted for theory; that is, there is undue concern about precisely measuring the socially irrelevant and unimportant. The philosophical critique of quantitative methods is more basic and questions the very idea of scientific truth or the need to verify theory—that knowledge itself, and the language we use, is relative and changeable. The legacy of the quantitative revolution is the very existence and strength of a geography transformed into a modern science, devoted to theory that explains spatial organization and behavior and is generalizable, communicable, and verifiable. The quantitative revolution may be over as a phenomenon, but the battle over the meaning of geography as a science continues.

Richard Morrill

See also Berry, Brian; Central Place Theory; Christaller, Walter; Economic Geography; Human Geography, History of; Isard, Walter; Location Theory; Logical Positivism; Models and Modeling; Morrill, Richard; Nomothetic; Physical Geography, History of; Quantitative Methods; Regional Science; Schaeffer, Fred; Tobler, Waldo



Further Readings

- Barnes, T. (1998). The history of regression: Actors, networks, numbers and machines. *Environment and Planning A*, 30, 203–223.
- Berry, B., & Marble, D. (Eds.). (1968). *Spatial analysis*. Englewood Cliffs, NJ: Prentice Hall.
- Billinge, M., Gregory, D., & Martin, R. (1984). *Recollections of a revolution: Geography as spatial science*. London: Macmillan.
- Bunge, W. (1962). *Theoretical geography* (Lund University Series in Geography C, No. 1). Lund, Sweden: C. W. K. Gleerup.
- Burton, I. (1963). The quantitative revolution and theoretical geography. *The Canadian Geographer*, 7, 151–162.
- Critical quantitative geographies 1: Beyond the critical/analytical binary [Focus section]. (2009). *The Professional Geographer*, 61, 283–365.
- Garrison, W. (1959). Spatial structure of the economy. *Annals of the Association of American Geographers*, 49, 232–239.
- Haggett, P. (1966). *Locational analysis in human geography*. New York: St. Martins.
- Harvey, D. (1969). *Explanation in geography*. New York: Edward Arnold.
- Isard, W. (1956). *Location and space economy*. Boston: New Technology Press.
- Schaeffer, F. (1953). Exceptionalism in geography. *Annals of the Association of American Geographers*, 43, 226–249.



QUEER THEORY

While “queer” as an analytical category emerged out of a poststructural critique of identity in the humanities, queer theory has been adopted by geographers as a tool to both understand and complicate topics as (seemingly) divergent as theorizations of identity and globalization. Although the earliest impact of queer theory in geography was most obvious in scholarship on sexuality and space, its influence can now be seen within a much greater variety of research.

In scholarship and in public fora, the word *queer* is commonly used both as a synonym for gay, lesbian, bisexual, transgender, and/or

questioning (GLBTQ) identities, or to indicate a combination of these identities, and as a term to signal the instability, or refute the stability, of these very identity categories. As many suggest, however, the use of *queer* as an umbrella term for sexual identity oversimplifies its potential as a theoretical tool. Instead, the utility of queer theory stems from its function to question or disrupt that which is considered “standard” and “normal” and to attend to the permeability of the boundaries, and binaries, on which “normal” is predicated. Under this framework, identity is understood as fluid and constructed in a way that is neither static nor essential, nor neatly bound by a heterosexual/homosexual binary that is otherwise presumed to be natural. Moreover, queer theory decouples gender identity from sexuality, desire, and sexual practice; in doing so, it calls into question the heterosexual matrix, or the socially prescribed relationship between sexual expression, body identity, and gender performance that is often taken as a given rather than as a historically and contextually specific regulatory framework.

Yet challenging the taken-for-granted organization of (sexual) identity is only one facet of queer theory. More broadly, it is applied to question normative constructs and social institutions: Queer theory seeks to both make visible and deconstruct formations, such as nation and capital, that have emerged from a particular, approved set of social relations. Luibhéid and Cantú (2005), for example, demonstrated that processes such as migration, citizenship, and nation building operate in relation to notions of normative sexuality, even as sexual identity remains a central issue for individual migrants (through institutional procedures such as reunification for spouses or other permitted familial relations). Sexuality, however, is situated within a broader context of power relations; to continue with the above example, migrants are policed on the basis of various categories, such as race and national origin, over and above sexual identity. Ideally, then, queer theory must account not only for the role and function of sexuality but also explore how sexual identifications and enactments are differently marked along lines of race, class, ability, gender, and other identity markers. For Luibhéid, among others, a queer analysis of migration requires attention to various



Supporters of same-sex marriage wave flags before the start of a rally at the Pentacrest in Iowa City, Iowa, celebrating the Iowa Supreme Court ruling upholding a lower-court decision legalizing same-sex marriage on April 3, 2009. The rainbow flag as we know it today was developed by San Francisco artist Gilbert Baker in 1978. Baker explained that his colors each stood for a different aspect of gay and lesbian life: hot pink for sexuality, red for life, orange for healing, yellow for the sun, green for nature, blue for art, indigo for harmony, and violet for spirit. The pink stripe was later removed because the color was not available commercially for mass reproduction.

Source: AP Photo/The Gazette, Liz Martin.

mutually constitutive processes through which migrants, “citizens,” and the nation are continually (re)produced.

Not all queer theorists take an intersectional approach to multiple axes of power, however. Thus, the theory has been critiqued for reproducing racial exclusions under the guise of a de-raced and de-gendered subject, which has the effect of recentering a universal white gay male subject while ignoring the material privileges available to this subject position. Queer theory does take up the question of privilege, but it often does so through a critique of assimilation. Accordingly,

gay and lesbian liberation movements that seek to assimilate within, rather than contest, larger societal structures are construed as homonormative and a sanitized version of radical queer politics. The U.S. same-sex marriage movement is often cited as an example of an assimilationist strategy. Critics charge that the effort by gays and lesbians to seek an equal right to marry in an unequal, consumption-driven society is akin to ignoring the logic of an unjust system that rewards gays who are focused on their domestic, individual needs and punishes those who do not conform to this normative model. As Natalie Oswin (2005)



points out, though, there is a danger in positioning a complicit, consumer-oriented gay in opposition to an “authentic,” radical queer; Oswin argues that we must reexamine the framework that situates radicalism and complicity as an invariable binary.

Oswin is among the many geographers who have contributed to and applied queer theory. Unsurprisingly, a critical engagement with the relationship between sexuality and space has been a central contribution. Many argue, however, that much of this scholarship remains confined to the treatment of gay, lesbian, and bisexual identities. These scholars advocate a move beyond these limits, to examine how *all* sexualities are historically, temporally, and spatially constituted and, therefore, how they are performed in myriad contexts, times, and spaces. Furthermore, as Puar, Rushbrook, and Schein (2003) suggest, putting queer theory to work in the discipline entails disrupting neatly defined boundaries within and beyond the scope of sexuality. For Puar et al., queering geography means examining the ways in which positivism is enabled by and dependent on dichotomous and absolute relationships and the ways by which positivist binaries reify neocolonial epistemologies.

Tiffany Muller Myrdahl

See also Body, Geography of; Critical Human Geography; Gays and Lesbians, Geography and/of; Gender and Geography; Identity, Geography and; Sexuality, Geography and/of

Further Readings

- Brown, M., & Knopp, L. (2003). Queer cultural geographies: We're here! We're queer! We're over there, too! In K. Anderson, M. Domosh, S. Pile, & N. Thrift (Eds.), *Handbook of cultural geography* (pp. 313–324). London: Sage.
- Browne, K., Lim, J., & Brown, G. (Eds.). (2007). *Geographies of sexualities. Theory, practices and politics*. Cornwall, UK: Ashgate.
- Luibhéid, E., & Cantú, L., Jr. (Eds.). (2005). *Queer migrations: Sexuality, U.S. citizenship, and border crossings*. Minneapolis: University of Minnesota Press.
- Oswin, N. (2005). Towards radical geographies of complicit queer futures [Electronic version]. *ACME*, 3(2). Retrieved from www.acme-journal.org/Volume3-2.htm
- Puar, J., Rushbrook, D., & Schein, L. (2003). Guest editorial. *Environment and Planning D: Society and Space*, 21, 383–387.

R

RACE AND EMPIRE

The legacies of geography's historical complicity with the racialized logic of empire are profound and have had significant impacts on the ways in which race, racism, and racialization have been approached within geography. The geographies of empire from the late 19th century through the early 20th century demanded attention to a theorization of race; however, as Britain's imperial ambitions waned, the centrality of the study of race within the discipline was displaced. Race became closely entwined with various colonial efforts, and geographers were often complicit in this process. This is not to say that the study of race ceased to be part of geographic thought, but it certainly did not hold the same place within the discipline following World War I. In understanding the history of the geographic study of race, one must understand the role that geography played in the theorization of environmental determinism and its use as a tool of empire.

While the notion of geographic determinism certainly predates modern geography—it can be found within the pages of Aristotle's *Politics*—the mobilization of a scientific study of the geography of race took on new dimensions during the 19th century as the imperial ambitions of Western Europe and the United States relied on the modern discipline of geography to underscore and justify the racist thinking at the heart of their geographic expansion. The cementing of the

complicit relationship between geography, race, and the ambitions of empire marks a significant event in the history of the discipline. As Peet (1985) put it, “Environmental determinism was geography’s entry into modern science. Determinism attempted to explain the imperial events of the late nineteenth and early twentieth century capitalism in a scientific way” (p. 310). Thus, it is as a tool of imperialism, through the theorizing of the relationship between race and geography, that geography secured its place within the modern academy (Figure 1).

In fact, the history of geography and its role in carving up the globe to facilitate the domination of Western imperial powers is well documented. As Kobayashi and Peake (2000) explain,

From its origins in exploration and scientific classifications, the discipline played a founding role in establishing the systems of imperialist expansion and colonial power through which the Western world became a dominant center and its white inhabitants became normative, authoritative, and privileged. . . . The discipline of geography received its own legitimization as a result of the inimitable relationship established between colonial power and the map as a “rhetorical device of persuasion to justify the authority of its practitioners” assertions. (p. 399)

In this way, geography provided the “scientific” underpinnings for the common notion that the world’s cultures were entirely reflective of the physical environment, particularly climate. In

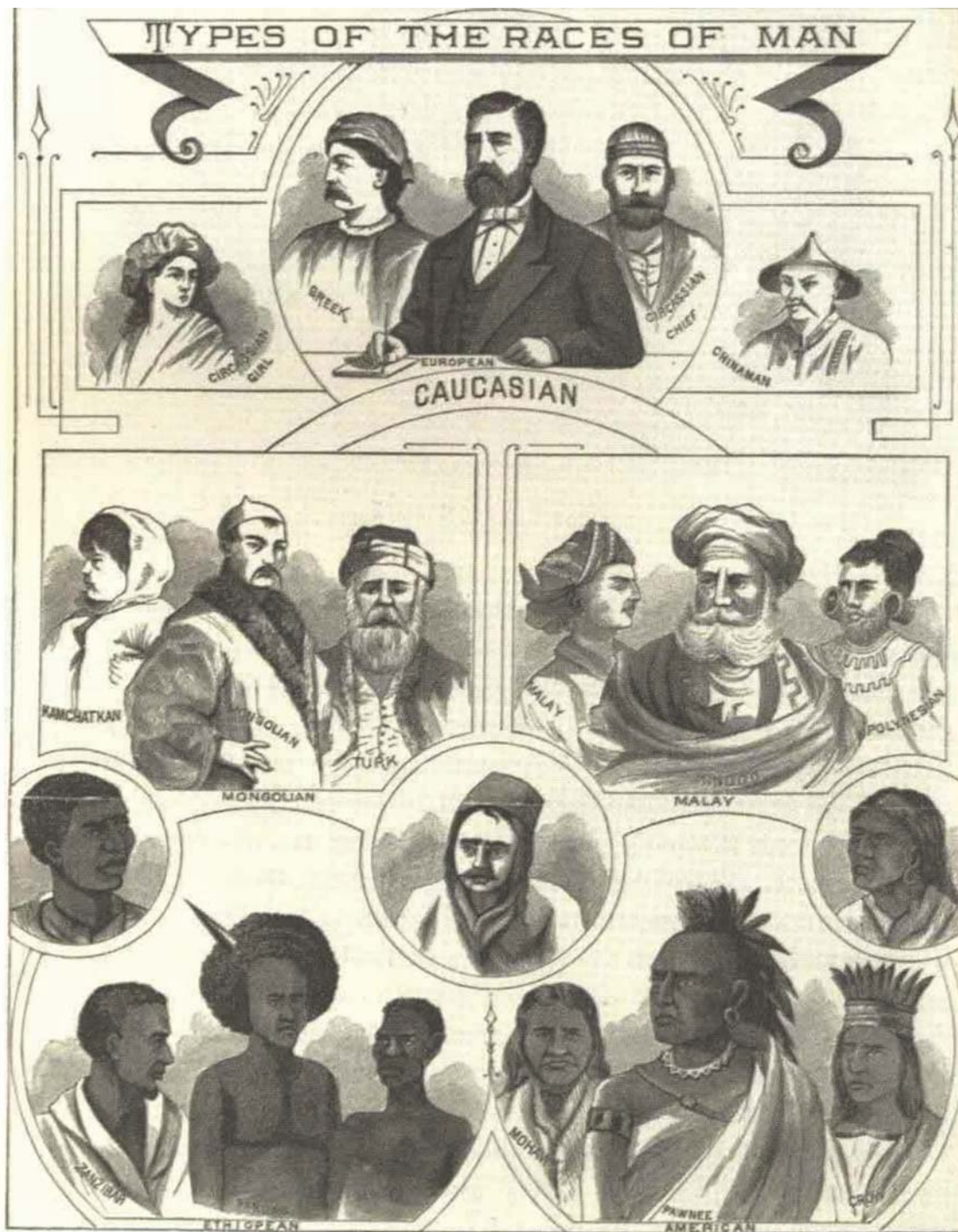


Figure 1 Geography school atlas illustration from 1883 illustrating the world's hierarchy of races as asserted by European colonialists. As Europeans conquered the world, racism became a significant part of their worldview, often used to legitimize their domination of non-Western peoples.

Source: Cram's *Unrivaled Family Atlas of the World* (1883), reproduced in Schulten, S. (2001). *The geographical imagination in America, 1880–1950* (p. 36). Chicago: University of Chicago Press.



doing so, the science of geography reinforced a racialized conception of the world that established whites as the “natural” masters of the globe’s diverse peoples.

Moreover, geography’s previous role in providing the theoretical tools for the racialized logic of empire continues to cast shadows on present-day theorizing. “The contemporary discipline remains insufficiently critical of its past, and therefore reinscribes many of the racialized metaphors upon which it was established” (Kobayashi & Peake, 2000, p. 399). However, the shadow of the legacy of geography’s role as a science of empire has not handcuffed the discipline entirely. Much of the most exciting contemporary work of theorizing and critiquing the present forms of racialized imperialism has come from geographers and others using the insights of geographic theorization.

Some of the work that has broken from this norm and connected the past practices of imperial geography and colonial cartography to present-day forces of empire includes an examination of Western property rights and planning regimes and the legacies of dispossession on the marginalization of Aboriginal people in urban spaces within Canada, work tracing the shadow of the British Empire on the landscape of contemporary world cities, theorizations of ongoing racialized violence within white-settler societies, projects exploring the long shadow of slavery and exploitation on black geographies, and work on the “colonial present” in the Middle East. For many scholars, the discipline of geography provides the theoretical tools for understanding and challenging contemporary racialized logics of the projects of empire. What is clear is that the racialized forces of empire extend beyond the geopolitical order of the 18th and 19th centuries. Given the fundamental way in which an empire maintains a clear spacialized logic, the discipline of geography is well positioned to provide the tools of theorizing the present-day forces of empire and race.

David J. Roberts

See also **Colonialism; Environmental Determinism; Ethnicity; Ethnicity and Nature; Eurocentrism; Geopolitics; Imperialism; Orientalism; Political Geography; Race and Nature; Race and Racism; Social Darwinism**

Further Readings

- Bartlett, R. (2001). Medieval and modern concepts of race and ethnicity. *Journal of Medieval and Early Modern Studies*, 31(1), 39–56.
- Bonnett, A. (1996). Constructions of race, place and discipline: Geographies of racial identity and racism. *Ethnic and Racial Studies*, 19(4), 864–883.
- Gregory, D. (2004). *The colonial present: Afghanistan, Palestine, Iraq*. London: Blackwell.
- Hudson, B. (1972). The new geography and the new imperialism: 1870–1918. *Antipode*, 9(2), 12–19.
- Jacobs, J. (1996). *Edge of empire*. New York: Routledge.
- Kobayashi, A., & Peake, L. (2000). Racism out of place: Thoughts on whiteness and an anti-racist geography in the new millennium. *Annals of the Association of American Geographers*, 90(2), 392–403.
- McKittrick, K. (2006). *Demonic grounds: Black women and the cartographies of struggle*. Minneapolis: University of Minnesota Press.
- Peet, R. (1985). The social origins of environmental determinism. *Annals of the Association of American Geographers*, 75(3), 309–333.
- Razack, S. (2002). *Race, space, and the law: Unmapping a white settler society*. Toronto, Ontario, Canada: Between the Lines.



RACE AND NATURE

Race and nature typically appear to be “natural” rather than social categories. People inherit their race genetically, and nature—whether in the form of a wilderness area or a person’s fundamental character—is by definition that which lies outside culture. Yet two bodies of scholarship, critical race and social nature studies, have challenged the naturalness of race and nature. This entry explains the main tenets of critical race and social nature scholarship and explores some of the ways in which critical geographers and other researchers have brought together in productive ways insights from the two areas of study.



Critical Race Theory

Critical race theorists, seeking to understand the making and maintenance of racial hierarchies, have shown how racial categories shift over time and across space and have thus effectively challenged the notion that race has a basis in biology. Instead, they find race rooted in history and culture and consider European imperialism key to the creation and naturalization of racial categories and to the assignment of social significance to the physical markers of difference.

In her 1992 influential work on European travel writing, Mary Louise Pratt examined how the Swedish naturalist Carl von Linné's (Carl Linnaeus) plant classification system, first introduced in 1735, reordered the natural world according to a European logic while at the same time making it appear that the system simply described the world as it already existed. But, Pratt shows, Linné classified more than plants. By 1758, he had classified humans into distinct types, which included the Wild Man, the American, the European, the Asiatic, and the African. Linné assigned physical and behavioral characteristics to each type, and the types appeared to exist as a part of nature. The European, for instance, appeared fair, blue-eyed, inventive, and governed by laws, while the African was black, flat-nosed, indolent, and governed by caprice. As Pratt points out, Linné's Eurocentric system not only encouraged comparison among human types but also naturalized the myth of European superiority.

The belief in European superiority, as many scholars have pointed out, was central to the colonial project. If Europeans existed on the highest plane of civilization, then surely the imposition of their religion, laws, and values onto "less civilized" peoples and lands was a justified and even noble pursuit. With the rise of scientific racism in the mid 19th century, European superiority and non-European inferiority came to appear as biological facts rather than surmountable cultural conditions, and various "scientific" strategies emerged for assessing the relative position of human races—for example, measuring the length and shape of heads of people of different races. Although the scientific value of such strategies has been undermined, scientific racism worked to make both race and racial hierarchies appear

natural and, thus, to justify European colonialism and its embedded racism.

Critical race theorists, in tracing the social production of race both historically and in the contemporary moment, denaturalize racism as well as race by revealing it as the practice of appealing to markers of difference that are culturally rather than naturally constructed. Racism connects to power because race seems natural. Revealing race as social therefore presents one way of disempowering racism.

Social Nature Scholarship

While appreciating their insights as foundational to her own work, the cultural geographer Kay Anderson has pointed out that critical race theorists have largely avoided interrogating the nature of nature, often taking nature for granted as the nonsocial ground on which social race is built. In her recent book on race and nature, Anderson suggests that race scholars are, not surprisingly, hesitant to invoke nature, since they have struggled to remove race from the category of the natural, showing it instead to belong to the sphere of culture and politics. Yet, and as shall be discussed further below, Anderson considers questioning nature central to a project that aims for a rigorous understanding of the history of race as a social creation.

In asking questions of nature, Anderson is joined by a group of scholars, many of whom are geographers, who contend that nature is not as natural as it seems. Like race, nature is social. Social nature scholars do not mean to suggest that humans physically make all parts of the non-human world or that humans are the only subjects involved in the construction of nature but rather to assert that there exists no ahistorical, apolitical, external nature. Humans have always constructed nature, both physically, by cutting down trees and building dwellings, for example, and imaginatively, for instance, by considering a wilderness preserve to be a natural area and an urban park to be a cultural space.

Social nature scholars, who often take their cue from feminist critiques of the nature-culture binary, consider Western cultural practices to be largely responsible for creating a false opposition between nature and culture. The appearance of



two separate realms of nature and culture is a product of culture rather than nature, and in reality, there exists only one hybrid realm of nature and culture. Certainly, the lake water piped into city dwellers' homes and the trees turned into newspapers on their doorsteps disrupt the idea of any clear distinction between external nature and human culture.

Research in social nature tends to examine the social and historical processes and relationships of power and inequality through which nature has come to appear separate from (especially Western) culture. In his 1996 seminal work on wilderness, for example, William Cronon shows how the concepts of the sublime and the frontier allowed upper-class white men in the 19th century to create the American wilderness as a site of culture-free nature. This human construction of nature did not exist solely in the imaginations of those who could afford wilderness vacations but was also engraved as nature into the landscape of the United States—for instance, in the form of national parks. Cronon's observation that the idea of an uninhabited wilderness could not exist without the prior eviction of the First Nations peoples from their territories underlines both the materiality and the power of social constructions of nature. Through placing Aboriginal peoples on reservations, the imagined empty wilderness came to exist in reality, while Aboriginal bodies and claims to territory were erased from the landscape. Like race scholars, those interested in examining the interplay of nature and culture are often concerned with issues of justice, studying not only how but also for whom and with what consequences nature has been socially constructed in different historical moments and geographical locations. Social nature scholars usually emphasize the environmental as well as the social impacts of particular constructions of nature, thus drawing the nonhuman world into their sphere of concern.

Cultural Politics of Race and Nature

Although critical race and social nature scholars both question the categories that seem self-evidently natural, their work has not overlapped to any great extent. Recently, however, a body of scholarship that traces connections between

social and historical constructions of race and nature has emerged and has demonstrated that race and nature often work together to make particular social formations and hierarchies appear natural. This scholarship is concerned not with what race and nature *are*—beginning instead from the premise that neither race nor nature possesses an inherent essence—but rather with what they *do*—that is, how they work together in different geographical locations and historical timeframes to effect and naturalize specific power relationships among humans and between humans and the nonhuman world. Scholarly work within the field of what Donald Moore, Jake Kosek, and Anand Pandian have referred to as the cultural politics of race and nature has the potential to deepen critical geographers' understanding of the complex interconnections between race and nature.

European Racial Thought During Colonialism

One key area that scholars of race and nature have illuminated is the study of European imperialism and colonialism, showing that the diverse projects of European rule worked through the co-constitution of race and nature (alongside other social categories such as gender). Bruce Braun, for example, has detailed historical and contemporary processes through which British Columbia's temperate rain forest came to be imagined and treated as a site of empty nature. He argues that there is nothing natural about the wilderness character of the region and shows how one cultural construction of nature came to dominate over others while appearing to be the result of nature rather than culture, power, and politics. Central to this process was not only the representation common within the colonial discourse of Native peoples as primordial and uncivilized and therefore undeserving of land but also the construction of the land itself—in geological surveys, art, forest industry rhetoric, and environmentalist representations—as an empty wilderness to be exploited or protected. As Braun shows, the characterization of the British Columbia forest as a natural space has had the effect of displacing the First Nations' cultural understandings of, and claims to, the same

land, thus authorizing the non-Native people—the government, the forest industry, and the environmentalists—to regulate, harvest, and speak on behalf of the forest.

Kay Anderson has taken a different approach from Braun on the question of race and nature to better understand European racial thought during colonialism. While Braun examines the implication of social constructions of nature in the operation of colonial rule, Anderson focuses on the ideas about race and nature embedded in European definitions of humanity. Specifically, she sets out to explain why the idea of race as innate rather than cultural arose in mid-19th-century European thinking and argues that the rise of what she calls “innatism” must be understood within a longer history of European thinking about the nature of humanity as it was shaped by colonial encounters with the indigenous Australian peoples and landscapes.

While Europeans defined humanness as the ability to transcend external nature (through agriculture) and corporeal nature (through reason), their encounters in Australia with peoples and places that bewildered their systems of understanding led them to a crisis in their belief in human distinctiveness. But this crisis, instead of leading to the breakdown of the belief that there existed a clear divide between humans and the nonhuman world, resulted in a new division of humanity into biological races, which allowed for the preservation of the idea that at least some (primarily European, male) humans could still fit comfortably into the category of the human. By attending to how European concerns about race, nature, and humanity shaped the emergence of innatism, Anderson’s account leads to a more nuanced understanding of the operation of race in colonialism than an approach that considers race only as a means of legitimizing empire.

Jocelyn Thorpe

See also *Class, Nature and; Colonialism; Critical Studies of Nature; Environmental Racism; Ethnicity and Nature; Eurocentrism; Gender and Nature; Imperialism; Nature; Nature-Society Theory; Race and Empire; Race and Racism; Social Construction of Nature; Social Darwinism*

Further Readings

- Anderson, K. (2001). The nature of “race.” In N. Castree & B. Braun (Eds.), *Social nature: Theory, practice, and politics* (pp. 64–83). Oxford, UK: Blackwell.
- Anderson, K. (2007). *Race and the crisis of humanism*. London: Routledge.
- Braun, B. (2002). *The intemperate rainforest: Nature, culture, and power on Canada’s west coast*. Minneapolis: University of Minnesota Press.
- Cronon, W. (1996). The trouble with wilderness; or, getting back to the wrong nature. In W. Cronon (Ed.), *Uncommon ground: Rethinking the human place in nature* (pp. 69–90). New York: W. W. Norton.
- Haraway, D. J. (1992). The promises of monsters: A regenerative politics for inappropriate/d others. In L. Grossberg, C. Nelson, & P. Treichler (Eds.), *Cultural studies* (pp. 295–337). London: Routledge.
- Moore, D. S., Kosek, J., & Pandian, A. (Eds.). (2003). *Race, nature, and the politics of difference*. Durham, NC: Duke University Press.
- Pratt, M. L. (1992). *Imperial eyes: Travel writing and transculturation*. London: Routledge.
- Wade, P. (2002). *Race, nature and culture: An anthropological perspective*. London: Pluto Press.



RACE AND RACISM

Race is a marker of difference among humans based on physical features such as skin color or hair color/texture. Historically, race was treated as a biological or “scientific” method of human classification, in which racial “groups” were defined by the presence or absence of particular inheritable traits. This argument was tied to failed theories such as social Darwinism—which applied Darwinian notions of competition among species to competition within the human population—and environmental determinism, which argued that particular social traits were inherent to people living in particular places due to the environmental and climactic characteristics of each place. These theories were developed during the colonial era and were used by those in



power to rationalize the exploitation or extermination of particular “racial” groups. The scientific basis for race has since been refuted, as multiple studies have shown that there is greater genetic diversity within racially defined groups than exists among those groups.

Simply put, there is no biological basis for race. Yet, despite its failings as a scientific concept, race today exists as an extremely important socially constructed conceptualization of differences among humans. That race is such an important concept is the result of racism. Racism is the ideology of difference, which takes as its foundation the idea that particular (usually negative) attributes regarding behavior, intelligence, or culture are inherent within particular racial groups. This ideology is then used to justify arguments for the superiority of one racial group relative to another, which leads to the production of inequality between racial groups.

The normative understanding of racism is often limited to acts of violence, malice, or economic exploitation that are motivated by racial prejudice. Examples of these types of racism are hate-based crimes, or decisions by employers not to hire workers on the basis of their race. This narrow definition of racism does not acknowledge the informal ways in which racist ideology has been incorporated into economic, legal, educational, and other societal structures. The following sections discuss the dominant theoretical engagements with race and racism in geography, as well as some of the methodological challenges inherent to research on race/racism issues.

Critical “Race” Studies in Geography

Critical racial theorists engage in a type of ethically motivated antiracism research agenda. Rather than treating race as an objective category, they use social constructionist theories to illustrate the way in which the idea of race is mobilized in various contexts to exploit, disadvantage, or otherwise disempower particular racially defined groups of the population. In critical racial theory, racial categories provide the framework for a set of power relations that protects the dominant group’s position of power. The process through which racial ideology is applied to social actors (who should be understood as not just

people and processes located in places but also as landscapes, systems of governance, education, or any other socially produced phenomena) is known as *racialization*.

The Social Construction of Race

The argument that race is a socially constructed category and ideology rather than a biological or “natural” method of human classification is based on social constructionism, which challenges arguments for the “naturalness” of human organization systems, the categories within those systems, and the ideologies on which those systems are founded. In this perspective, the argument for the “naturalness” or “commonsense” use of particular methods of social categorization is rejected outright. These ideologies are then subjected to critical examination, which can serve to expose the power relations that make clear the basis for defining the concept in a particular way given the specific historical and geographic context.

In the case of race, critically examining the way in which racial groups are defined varies geographically and has varied significantly throughout history. These variations and historical redefinitions typically have served to rationalize the exploitation of one population by another. The term *race* has been applied almost exclusively for the purpose of rationalizing the subjugation of one group by another, regardless of the particular characteristic by which the supposedly inferior group was defined. For example, the British comfortably interchanged the concept of race with political nationality in their subjugation of the Irish “race.” The Nazi Party in World War II sought to exterminate the Jewish “race,” despite the fact that religion is not a biologically inheritable trait.

That race exists only as a social construct does not lessen the power of racism as a mode of social organization. The fact that people believe and behave as if race does exist makes it a social reality with material effects.

Geographic Contingency of Race/Racism

One of the ways in which geographers have contributed to research on race and racism is by illustrating how racialization processes are



geographically contingent. Racialization refers to the process by which one comes to be viewed and/or views oneself as belonging to a particular racial group. The way in which people are racialized is highly dependent on where this process takes place. Socialization processes are both embedded in place and connected through space such that socialization processes and geography are interdependent, not simply complementary. Geographers understand places as socially produced as well. Within this framework, places are not lifeless boxes within which social production occurs. Racialization processes are themselves shaped by, and affect, the social construction of places. This constitutive relationship between social processes and places creates a larger racialized landscape, which provides the context for how racial categories are normatively defined.

Critical theorists argue for a relational understanding of race and racism. This means that the way racial categories are understood—the meanings attached to a specific racial group—can only be understood as they relate to other races. This relational understanding allows for a movement away from understanding race as a binary relationship (civilized/uncivilized, white/nonwhite) to an understanding of racism as a set of power relations acting in a specific time and place. These power relations restrict individual and group access to power and resources relative to the dominant group, which in Western societies is most often defined as the whites. The severity of this disempowerment depends on the particular racial identity of the group in question, as well as the geographic context.

Relational perspectives on race understand racism as the result of racial hierarchies within a social system of white privilege. White privilege refers to the set of power relations that supports the status quo position of whites as the recipients of any number of advantages simply due to their being white. In this system, “whiteness” is the norm against which all other races are evaluated. These privileges are wide-ranging and include access to better educational and economic opportunities, access to better housing than equally qualified minorities, and being underexposed to pollution relative to minority groups, just to name a few. Geographers have done a great deal of research investigating how

these types of inequalities are spatially distributed and maintained through spatial relations. Economic relations—segregation and housing—and environmental racism are research themes that guide geographic research investigating each of the specific material effects of racism and white privilege listed above, respectively.

Racial hierarchy is a metaphor used by advocates of the relational perspective to map the effects of power relations on multiple racial groups in a particular time and place. In a racial hierarchy, racial (or ethnic) groups are positioned in a hierarchical manner based on their disempowerment relative to all other racial groups. Within the social system of white privilege, whites would be at the top of the racial hierarchy, with all other racial groups somewhere below. Racial groups’ positions are conceptualized as distinct but subject to change in particular geographic and historical contexts. The ability to affect the position of other racial groups within the racial hierarchy is yet another aspect of white privilege.

Racialized Landscapes

Processes of racialization are not limited to human bodies and processes of identity formation. Because race is a hegemonic ideology in contemporary society, all elements of social life are racialized. Processes of racialization attach racial understandings to places and landscapes at every scale: continents, nations, states, cities, neighborhoods, and even within the home. Racialized landscapes are a particularly important part of geographical understandings of race and racism because popular understandings of landscape provide context for people’s life experiences. Therefore, racialized understandings of landscape shape the way in which individuals interpret their own life experiences, and simultaneously serve to reinforce existing hegemonic understandings of racial categories. A few common examples of racialized landscapes in the United States are “the ghetto” and “the border,” which are “minority” landscapes, and “suburbia,” which is a “white” landscape. These racialized understandings of landscape police who or what “belongs” in a particular place and have material effects on a wide range of social issues, from property values to law enforcement practices.



Quantitative Approaches

Despite the widespread acknowledgment that race is a socially constructed and problematic method of human classification, many researchers still use race as a social category for quantitative analysis. In quantitative research, race is treated as an objective category and method of human differentiation. This is not to say that these researchers are unaware of the problematic nature of defining racial categories. There is a wide spectrum of researchers involved with race-based research, within which there are great disparities in the level of critical engagement with the idea of race. What all quantitative approaches to race studies have in common is their dependence on race counting.

Among those engaged in antiracism work, there is considerable debate regarding the merits of race counting. On the one hand, racial counting provides quantitative data that researchers and activists can use to demonstrate the material effects of racism in society. On the other hand, the practice of recording data according to race supports the very ideas about racial difference on which racism is based. Herein lies the greatest challenge for those who wish to eliminate racism as a hegemonic form of social organization in society. For example, it would be impossible to demonstrate the extent of residential racial segregation without collecting data that categorize residents by racial group. One could demonstrate spatial inequalities in access to public transit or economic opportunities without using racial data; however, without using data that categorizes people according to race, it would be impossible to demonstrate that those spatial inequalities disproportionately affect neighborhoods with a high percentage of minority residents. Antiracism researchers are thus faced with an ideologically contradictory choice, because they cannot quantitatively demonstrate the material effects of race-based disempowerment in society without implicitly supporting the idea of race as a system of social categorization.

Assigning Race and Counting Racial Groups

The history of recording racial data for enumeration purposes is firmly based on institutional

racism during the pre-Civil War era in the United States. The first U.S. Census included racial data, in accordance with the Three Fifths Compromise, which was negotiated between the southern states, in which slavery was legal, and the northern, “free states,” where it was illegal. The purpose of the compromise was to increase southern political representation in Congress. In this agreement, each African American slave was to be counted as three fifths of a person for the census and representational purposes.

The racial categories used for population research vary depending on the scale and location of the survey. Over time, the U.S. Census has been adapted to better incorporate “new” races, such as “Native American” or “Asian or Pacific Islander” and to allow for members of any racial group to self-identify as ethnically Hispanic or non-Hispanic. For the first time, the 2000 U.S. Census allowed respondents to self-identify as more than one race. The incorporation of multi-racial responses on the 2000 U.S. Census created 63 racial categories. This creates new challenges for geographers and demographers attempting to project changes in the racial composition of a population. Because of the seemingly constant adaptations being made to the racial enumeration process, some argue that the way in which racial categorization is done says more about the racial politics of the era than any future trends that can be projected based on the data created. If this is indeed the case, then the recent changes to the U.S. Census can be understood as a government response to the collective demand of individuals who identify themselves as multiracial for a more accurate representation in census records.

Some have argued that the increasing complexity of race-counting processes will inevitably lead to “the end of race” because quantitative population projection models simply cannot account for the shifting cultural perspectives on interracial marriage and interracial birthrates, death rates, infant mortality, and so on—all of which are vital to the accuracy of population projections. In this limited sense, society may indeed be nearing the end of race-based studies. It would be quite premature, however, to argue that the failure of models that depend on racially differentiated data sets is indicative of “the end of race” in society. In fact, the diversification of racial counting



practices can impede the efforts of antiracism activists. Racism is not the result of self-selected identity categorizations. Rather, racism is a system of differentiation in which dominant groups assign membership in a particular racial group to individuals. For example, individuals with parents of different “races” may view themselves as multiracial and still face the same discrimination and disempowerment as those who self-identify as belonging to a single minority racial group. Therefore, racism cannot be eliminated as a hegemonic system of social organization simply by altering the ways in which individuals understand their own racial identity or by expanding the number of racial categories in a census.

Sean M. Crotty

See also Colonialism; Critical Human Geography; Environmental Racism; Ethnicity; Ethnic Segregation; Ethnocentrism; Eurocentrism; Ghetto; Identity, Geography and; Justice, Geography of; Orientalism; Population Geography; Poststructuralism; Race and Empire; Race and Nature; Racial Segregation; Radical Geography; Social Darwinism; Social Geography; Social Justice; Urban Underclass; Whiteness

Further Readings

- Ellis, M. (2000). “Mark one or more”: Counting and projecting by race on the U.S. Census 2000 and beyond. *Social and Cultural Geography*, 1, 183–195.
- Jackson, P., & Penrose, J. (Eds.). (1993). *Constructions of race, place and nation*. Minneapolis: University of Minnesota Press.
- Pulido, L. (2006). *Black, brown, yellow and left: Radical activism in Los Angeles*. Berkeley: University of California Press.

segregation researchers make their homes in numerous disciplines such as geography, sociology, demography, political science, and urban studies. Research on racial residential segregation shares a history with the examinations of immigrant settlement and assimilation, which began with the Chicago School of Sociology in the early 20th century. Historically, spatial integration of foreign-born groups with the white majority population has long been viewed as reflective of a broader structural assimilation. However, numerous critiques have been leveled at many of the assumptions underlying the now multiple variants of immigrant assimilation models, many of which trace the geographic trajectories of residential settlement over time.

The vast majority of racial segregation research in North America since World War II has focused on the degree to which African Americans and whites share (or do not share) residential space in contemporary urban contexts. Most studies have used U.S. Census data to examine residential patterns within and across large metropolitan areas, frequently tracing identifiable segregation patterns over time. Over the past few decades, segregation researchers have employed multiple segregation indices developed to assist in measuring the degree of spatial separation between racial groups. The most common of these indices undoubtedly remains the Dissimilarity Index, which measures the degree of spatial evenness in the residential distribution of one racial/ethnic group across subunits of a geographic area. Thus, the Dissimilarity Index is interpreted as the percentage of members of a given racial/ethnic group that would have to move to a different neighborhood for the percentage of each neighborhood to equal the percentage of that group across the larger geographic area (typically an entire metropolitan area). As measured by the Dissimilarity Index, segregation between African Americans and whites in U.S. metropolitan areas reached its height in the 1960s and 1970s and was exacerbated by increased suburbanization and “white flight.”

In a seminal paper, Massey and Denton (1988) outline four other indices that measure different forms of segregation: exposure/isolation, centralization, clustering, and concentration. Massey and Denton propose that when groups are segregated along four of the five aforementioned dimensions,



RACIAL SEGREGATION

Although racial segregation is inherently a geographic phenomenon, social scientists from numerous disciplines continue to contribute to the research literature. Today, racial residential

they are “hypersegregated.” Analyzing the 1980 U.S. Census data, Massey and Denton found that such “hypersegregation” was characteristic of the experiences of African Americans in 16 metropolitan areas (when measuring African American/white segregation patterns). A follow-up study by Kaplan and Holloway (1998) using the 1990 Census data showed little change, as African Americans remained hypersegregated from white residents in 14 of those 16 metropolitan areas, while several additional metropolises joined the hypersegregated list. Wilkes and Iceland (2004) concluded that by 2000, there was an overall decrease in the number of black-white hypersegregated metropolitan areas in the United States (which had decreased from 29 to 23), yet new hypersegregated cities had emerged when examining the degree to which Hispanics/Latinos share urban space with white residents. Because of the broader demographic shifts that have occurred over the past three decades across the United States, racial segregation researchers have begun to widen their foci to examine the contemporary spatial residential relations of Hispanic and Asian residents in many metropolitan areas.

While the geographic patterns may be relatively clear, the causes and consequences of racial segregation vary immensely depending on the geographic and historical contexts. Early-20th-century segregation patterns resulted from institutionalized (often legal, state-sanctioned) discriminatory practices in mortgage lending and housing opportunities in many North American cities. Today, economic status frequently serves as a focus for segregation researchers seeking to untangle the complex web of factors responsible for continued residential segregation. Similarly, researchers have examined the impact of choice or preference in efforts to account for extant racial segregation patterns. Studies have consistently concluded that economic status does not fully account for the geographies of racial segregation in contemporary



Man drinking at “Colored” water cooler in streetcar terminal, Oklahoma City, Oklahoma, 1939

Source: Library of Congress Prints and Photographs Division, LC-USZ62-80126.

America. Similarly, voluntary or self-segregation alone does not adequately explain the persistent residential segregation by race and/or ethnicity in metropolitan areas of the United States today. Although no longer legally sanctioned and defended, discrimination in housing and mortgage lending continues to adversely affect minority groups disproportionately, such that “race,” although a social construct, remains a very real factor shaping contemporary geographies of residential settlement in the United States in the 21st century. Finally, isolation of minority groups particularly in urban areas can be seen as both a cause and a consequence of persistent poverty in these contexts. Regardless of the potential causes outlined previously, such spatial isolation of minority groups in cities frequently constricts opportunities in education and occupation for many residents. Although residential segregation and poverty are not inextricably linked, some of the same structural forces are at work in contributing to the current patterns of segregation and poverty in North American cities.

Recently, more critical approaches to studying “race” in the social sciences have begun to question the use of “white” as the standard or norm against which the racial segregation of minority



groups is measured and discussed. It should be noted, furthermore, that numerous researchers studying “race,” racism, and processes of racialization today are somewhat wary of the use of racial categories and quantitative data sets, such as the U.S. Census, citing their potential to perpetuate problematic notions of presumed biological/natural racialized identities, which are in actuality social constructions. Therefore, researchers engaged in racial segregation research today increasingly are wont to approach their work with the caveat that they view racial categories as socially constructed and thus malleable and shifting across both space and time.

Robert Yarbrough

See also Chicago School; Ethnicity; Ethnic Segregation; Ghetto; Housing and Housing Markets; Justice, Geography of; Race and Racism; Social Justice; United States Census Bureau; Urban Spatial Structure; Urban Underclass

Further Readings

- Clark, W., & Blue, S. (2004). Race, class and segregation patterns in U.S. immigrant gateway cities. *Urban Affairs Review*, 39, 667–688.
- Glaeser E., & Vigdor, J. (2001). *Racial segregation in the 2000 census: Promising news*. Washington, DC: Brookings Institution Press.
- Jargowsky, P. (1997). *Poverty and place: Ghettos, barrios, and the American city*. New York: Russell Sage Foundation.
- Kaplan, D., & Holloway, S. (1998). *Segregation in cities* (Resource Publications in Geography). Washington, DC: Association of American Geographers.
- Massey, D., & Denton, N. (1988). The dimensions of residential segregation. *Social Forces*, 67, 281–315.
- Massey, D., & Denton, N. (1993). *American apartheid*. Cambridge, MA: Harvard University Press.
- Wilkes, R., & Iceland, J. (2004). Hypersegregation in the twenty-first century. *Demography*, 41, 23–36.
- Wright, R., Ellis, M., & Parks, V. (2005). Re-placing whiteness in spatial assimilation research. *City and Community*, 4, 111–135.



RADIATION: SOLAR AND TERRESTRIAL

Radiation is the only commonly occurring form of energy that can travel through the vacuum of outer space. Solar radiation arriving at the Earth from the sun provides the energy that creates our climates and, through photosynthesis, plays a major role in the activities of the biosphere. Terrestrial radiation, emitted by Earth’s surface and atmosphere, returns that energy to space. The amount of energy in both forms varies with time and space: Short-term variations are responsible for producing weather, lengthier ones create seasons, and long-term fluctuations lead to climate changes. The major factors causing variations can be considered by tracing the solar radiation downward through the atmosphere to the surface and the terrestrial radiation up from the surface through the atmosphere and out to space. Over the long term and on a global scale, there is an approximate balance between incoming solar radiation and the outgoing terrestrial radiation, ensuring that climate changes are slow and small. Human activity, including the introduction of additional greenhouse gases into the atmosphere, is currently changing that balance and thus influencing climate.

Electromagnetic Radiation

Radiation is a form of energy emitted by everything that has a temperature above absolute zero. Formally it was known as “electromagnetic radiation” since it involves electromagnetic forces with the components of an atom. Our current understanding of this form of energy gives it a dual nature. First, it can be conceived as a series of small bundles of energy, called photons, which travel at the speed of light and vibrate as they travel; the greater the number of photons, the greater the amount of energy. Because of this vibration and forward movement, photons appear to be propagated as a series of waves, so our second concept is of radiation as a series of moving waves. The two concepts are closely related, and the fundamental laws governing radiation indicate that the higher the temperature of the



emitting body, the shorter the wavelength and the higher the energy of the radiation.

In practical terms, we can conveniently divide the “bodies” doing the emitting into two classes: (1) the sun, which is very hot and emits great amounts of energy at a range of short wavelengths, and (2) Earth and everything on its surface and in its atmosphere, which are much cooler and emit much less energy and at a range of much longer wavelengths. Within the range of wavelengths emitted by the sun—the solar spectrum—there is a small portion that stimulates our eyes and that we sense as light. The shortest of these we sense as blue light, the longest as red light. So we can divide the solar spectrum into three regions: ultraviolet, visible, and (near) infrared. We do not sense the energy emitted by Earth and its atmosphere in any similar way. But it is sometimes, confusingly, called “infrared” energy, particularly when photographs using special films that are sensitive to these longer wavelengths are involved.

The emission of energy is a cooling process for the body doing the emission, while absorption leads to heating. So, in general, the absorption of solar energy by our planet warms the planet. As the temperature increases, the amount of terrestrial radiation the planet emits increases. In a static universe, planet Earth would reach a constant temperature where the amount of solar energy absorbed would be exactly balanced by the amount emitted to space. However, we do not have a static situation. Fundamentally, the changing position of the sun in the sky gives a changing solar input. Meanwhile changes, natural or anthropogenic, in the atmosphere and on the surface influence the fate of that solar energy. We can think of the planet as constantly striving to achieve this equilibrium temperature. This entry describes the changes that are primarily a response to the changing solar input.

Solar Radiation at the Top of the Atmosphere

The sun emits a tremendous amount of energy; however, because of the distance between Earth and the sun, only a small portion arrives at the top of Earth’s atmosphere. Once allowance is made for the varying distance between Earth and

the sun created by the varying geometry of Earth’s orbit, the amount of energy arriving on a surface at right angles to the sun’s rays at the top of the atmosphere is constant—the solar constant. Even that varies depending on the amount of activity—mainly sunspots—on the surface of the sun. However, for most purposes and for periods of a few years, we can take it as constant. Most of the time, it is more useful to consider energy on a horizontal surface. This notion depends on the angle between the surface and the sun, usually expressed as the zenith angle—the angle between the sun and the local vertical. This angle is the same whether we are at the top of the atmosphere or on the surface immediately below it. The greater the angle, the lower the sun is in the sky and the less intense the radiation onto the surface. The angle is determined by astronomical conditions and depends on the time of day, the time of year, and our latitude. These astronomical conditions control the path of the sun across the sky, our day length, and our seasons. However, the time of maximum solar radiation input—the summer solstice for the Northern Hemisphere—is not the time of maximum temperature on Earth’s surface. Energy has to be transferred down through the atmosphere to the surface, which itself has to respond to the changed conditions, before that maximum can be reached. That process commonly takes several weeks or, in the case of the ocean, several months.

Transmission of Solar Radiation Through the Atmosphere

As solar radiation passes through the atmosphere, it can be absorbed or scattered by the gases of the atmosphere. Absorption amounts are small except in the ultraviolet, where ozone is an important absorber. Some absorption by clouds and pollution is possible, but overall, there is relatively little heating of the atmosphere by direct absorption of solar radiation.

Scattering is much more important. Air molecules scatter the incoming radiation in all directions. This process, known as Rayleigh scattering, is much more effective for short wavelengths than for longer ones, preferentially scattering downward the energy we see as the blue sky light. Rarely



is the atmosphere composed only of dry air molecules. Commonly, there are bigger, but still microscopically small, water droplets present. These are involved in Mie scattering, where most of the energy is scattered in the forward directions, with all the visible wavelengths being scattered more or less equally. As a consequence, while the dry desert air gives deep blue skies and crisp vistas over long distances, a more humid region produces paler skies and more hazy panoramas.

Aiding the Mie scatter process are many other naturally occurring atmospheric particles, ranging from windblown dust to tree pollen. In addition, particles resulting from human industrial and agricultural activity are now also a common constituent of the atmosphere and enhance Mie scattering.

The water droplets that make up clouds also scatter solar radiation. Although a towering cumulus cloud may reflect the radiation downward off its sides, most clouds tend to reflect the incoming energy back to space. So less radiation reaches the surface of the Earth, there is less absorption and heating, and cloudy days tend to be cooler than sunny days.

Radiation at the Surface of the Earth

On average, about 50% of the solar radiation at the top of the atmosphere reaches the surface, either as sky light or as the direct beam of the sun. Some of this incident light is reflected, the ratio of reflected to incident light being the albedo. The albedo is dependent on the type of surface. Snow and ice tend to reflect almost all the energy that falls on them and thus have a high albedo, absorb little energy, and are slow to heat. Water has a low albedo, except at large zenith angles, and serves as a tremendous storehouse for energy. Most land surfaces have intermediate albedo values.

The absorption of solar energy, by whatever type of surface, heats the planet, thus increasing the temperature and the amount of terrestrial radiation that is emitted upward into the atmosphere. However, the solar energy absorption plays three other roles that influence the surface temperature, the terrestrial radiation emission, and the climate of the Earth. First, there is a flow of energy into or out of the land or water underlying the absorbing

surface. This influx provides a small amount of surface cooling in summer and heating in winter, but annually the downward and upward flows are approximately equal. The second process, the transfer of energy between the surface and the atmosphere by heat conduction and convection, called the sensible heat flow, can also operate in either direction. However, upward transfer dominates throughout the year. Finally, the movement of energy by evaporation and condensation processes can also be two-way, but upward motion again dominates.

These three processes, acting in response to the variable incoming solar radiation and in association with the outgoing terrestrial radiation, control our surface temperatures and their variation over space and time. Here, we need only say that the amount of terrestrial radiation leaving the surface of the Earth, being a function of the surface temperature, also varies with space and time and that, since surface temperatures never fall to absolute zero, there is a continuous, 24-hour-per-day, emission of terrestrial radiation.

Geographical Aspects of Solar Radiation

In the previous sections, we have treated solar radiation entirely as an energetic process, of prime interest within geography as the creator of weather and climate. But it has other roles to play, particularly when we consider the wavelengths of the visible portion of the spectrum. For example, the generalized view of surface albedo is adequate when considering atmospheric energetics, but the actual albedo varies greatly with wavelength. Grass reflects very strongly radiation with wavelengths corresponding to green light but absorbs strongly at some longer wavelengths. The consequence is that grass appears green to us, while it can use the absorbed photons at specific energy levels in the process of photosynthesis.

More generally, the dependence of the various scattering processes on the atmospheric composition, which itself is variable both regionally and locally, influences the quality of light at any place. And that often has a profound influence on the sense of place—an important component of many geographic discourses.



Terrestrial Radiation in the Atmosphere

The terrestrial radiation emitted by the surface of the Earth involves a broad range of wavelengths. Most of the naturally occurring atmospheric gases, particularly nitrogen and oxygen, allow transmission through the depth of the atmosphere into space. However, two relatively abundant naturally occurring gases, water vapor and carbon dioxide, absorb strongly at selected wavelengths, while a few trace gases absorb in a minor way. The general result is a two-part view of terrestrial radiation transmission through a clear atmosphere. At one set of wavelengths, known as the atmospheric window, the radiation passes unimpeded into space. At the other wavelengths, outgoing radiation is absorbed. The absorption leads to heating. This heating is combined with that arising from the latent heat release associated with cloud condensation and with that caused by the sensible heat flow from the surface. This combination not only heats all the atmospheric gases but also stimulates the emission of terrestrial radiation from those same gases that absorb that energy. This radiation is emitted in all directions but can be considered for convenience as both up to space and down to the surface. The former is lost to us, the latter is absorbed at the surface and contributes to the heating there. Ultimately, it stimulates more radiation emission, so that apparently circular radiation flow is continuously maintained.

This description implies that all the radiating gases are at the same level in the atmosphere and at the same temperature. This is by no means the case. Although carbon dioxide is commonly well mixed, water vapor is likely to occur in various discrete layers and in discrete regions. So in practice, there are vertical exchanges between the layers as well as horizontal interchanges between regions. The processes are further modified when clouds are present. The water droplets in the clouds tend to absorb at all terrestrial wavelengths, and the atmospheric window is “closed.” Energy that would normally have gone out through that window is absorbed, and at least a part of it is reradiated to the surface. To some extent, more radiation is also emitted from the cloud tops and out to space. But these tops are considerably cooler than the bottoms, so less

energy is emitted. The result is that cloudy conditions allow less heat energy to escape into space, more to return to the surface. The general observation that cloudy nights tend to be warmer than clear ones is a direct consequence of this process.

The Global Energy Budget

On a long-term basis, the amount of energy emitted by the planet and sent to space should roughly balance the amount of solar radiation absorbed by the planet; otherwise the energy content of the planet changes. This change in turn leads to changes in temperature and, potentially, to all aspects of the climate. A short-term balance is unlikely to occur because of the ever-changing energy input from the sun, the natural changes within our planet, and the time required to accomplish the complex interactions sketched above. Over the lifetime of the Earth, there has been a rough balance between the radiation absorbed and emitted, and the climate has tended to fluctuate around a global temperature not too far above freezing. But there have always been fluctuations, and the climate has never been constant.

Relatively recent actions by humans are influencing all the components of the radiation streams. Particulate matter is influencing the transmission of solar radiation. Changes on the surface are influencing the relationships between sensible and latent heat flows and terrestrial radiation emission, while changes in the atmospheric composition are modifying the interaction of terrestrial radiation with the atmosphere. The first two are currently primarily local or regional in scope, but the last is a global effect. Consequently, most attention has been paid to changes in atmospheric composition. The increased concentrations of carbon dioxide and some trace gases, which are transparent to solar radiation but absorb terrestrial radiation, lead to a worldwide modification of the balance between incoming solar radiation and outgoing terrestrial radiation.

Peter J. Robinson

See also **Anthropogenic Climate Change; Atmospheric Particulates Across Scales; Atmospheric Pollution; Greenhouse Gases; Land Use and Cover Change (LUCC); Latent Heat; Stratospheric Ozone Depletion; Temperature Patterns; Urban Heat Island**



Further Readings

- Hartmann, D. L. (1994). *Global physical climatology*. San Diego, CA: Academic Press.
- Minnaert, M. (1954). *The nature of light and colour in the open air*. Mineola, NY: Dover.
- Petty, G. (2006). *A first course in atmospheric radiation* (2nd ed.). Madison, WI: Sundog.
- Rapp, D. (2008). *Assessing climate change: Temperatures, solar radiation and heat balance*. New York: Springer Praxis Books.



RADICAL GEOGRAPHY

Radical geography is not a coherent epistemology, methodology, or area of research, but rather, it represents a shift by academics and scholars from seeking to represent the world toward producing one where social and spatial inequalities are eliminated. It emerged in the late 1960s and early 1970s as a reaction to events both in the world and within the discipline of geography itself. First, it was a reaction to the civil rights movement in the United States, the Vietnam War and the politics of imperialism, the deepening awareness of poverty within inner cities, and other monumental changes occurring throughout the world. Second, radical geography was a reaction against the positivist epistemology and its reliance on empiricism to understand present realities, which dominated the discipline in the 1950s and 1960s. Radical geographers actively questioned mainstream geography's relevance to everyday social life. Together, these factors provided the impetus for geographers to engage in new areas of research, both thematically and theoretically.

Origins of Radical Geography

Three developments were critical in ushering in this new geographical perspective: (1) the establishment of the Detroit Geographical Expedition and Institute in 1968, (2) the founding of *Antipode: A Radical Journal of Geography* (1969), and (3) the publication of David Harvey's *Social Justice and the City* (1973). The Detroit Geographical Expedition

and Institute (DGEI), created by the geographer William Bunge and local community activists, sought to expand both the accessibility of geographic knowledge and the process of knowledge production to poor, largely minority communities in Detroit. It incorporated these communities in all parts of the knowledge production: the identification of the research problem, fieldwork, the analysis, and its dissemination. Consequently, it broke down traditional barriers between researcher/researched and expert/activist. *Antipode* was established in 1969 to provide a forum for scholars and activists to publish materials addressing spatial and social injustices, scholarship frequently rejected from other geographical journals. Early work in *Antipode* commonly documented racial and economic inequalities, examined economic development and natural resources, and analyzed the role of colonialism and imperialism within the world political-economic system. All these issues were at the forefront of the social movement activism across the globe but received relatively little attention in many Anglo-American geography departments and mainstream journals at the time. While early *Antipode* articles drew attention to the uneven development occurring at all spatial scales, it was Harvey's work that shifted the focus from simply describing these processes to explaining them. *Social Justice in the City* chronicles Harvey's intellectual shift from positivist, empirical, quantitative research to his engagement with Marxist political economy. Central to Harvey's contribution was moving geography beyond describing areal differentiation, or modeling locations to maximize efficiency for a diverse set of industries, to a radical geography that examines the spaces produced by the capitalist economic system while interrogating the internal dynamics and contradictions within that system that make social and spatial unevenness necessary. With the work of Harvey, radical geography of the 1970s and 1980s took on a resolutely Marxist identity.

Radical geography rooted in Marxist political economy provided a number of significant contributions to the discipline during this time. In 1982, Harvey's *Limits to Capital* was published. In it, Harvey spatializes Marx's historical materialism and demonstrates how capital accumulation relies on the appropriation of space through a series of "spatial fixes." In understanding



capitalism, Harvey offers historical-geographical materialism as a stronger method for both tracing the origins of contemporary capitalist relations and suggesting its possible futures. Harvey's theorizing was crucial to the development of many subsequent works that expanded his theory and method to other spaces and social relations. In 1984, Neil Smith published a widely influential volume, *Uneven Development*. In it, Smith uses a historical-geographical materialist approach to trace the production of "nature," what he refers to as second nature. In addition, he outlines the creation of surplus value within urban land markets. Smith's examination of nature is significant as one of the first efforts at theorizing nature within radical geography. Doreen Massey also used Harvey's work in her book *Spatial Divisions of Labor: Social Structures and the Geography of Production* (1984), which provided a framework for examining the concentration of particular industries and labor in specific locales. These works and others further solidified the linkages between radical geography and Marxist political economy.

The Feminist Critique

By the end of the 1980s, critiques of radical geography's Marxist foundation were increasingly common. One avenue of critique emerged from a growing body of feminist geography. Feminist geography's development was aligned closely, both temporally and socially, with radical geography. Many early feminist geographers used Marxist theoretical frameworks and were active in radical geography debates and scholarship. However, they also documented significant flaws in early Marxist radical geography. Feminist geographers illuminated radical geography's conception of a world without women by focusing on solely masculinist social relations. Its focus on production and class relations often overlooked the critical aspect of social reproduction, vital in the reproduction of the broader capitalist economy. In addition, socialist feminists argued that the abstract nature of Marxist categories often obscured the role of women within the capitalist economy. Furthermore, feminist geographers suggested that Marxist

radical geography ignored the numerous examples of noncapitalist economies. Besides advocating for different types of radical geography within a predominately Marxist framework, feminist geographers were also at the forefront of another challenge to radical geography. This challenge went beyond the objects of analysis and instead focused on the epistemology and ontology of radical geography itself.

Postmodern and Poststructural Influences

In the late 1980s and 1990s, interventions from poststructural and postmodern theory complicated radical geography's linkage with Marxism. At its heart, postmodern and poststructural critiques questioned the two foundations of earlier radical geography scholarship. The first denounced the decisively modernist vision of Marxist radical geography that suggested the possibility of producing a more socially just world through the attainment of knowledge of the "real world." These critiques owe their intellectual genealogy to the work of Jacques Derrida on linguistics and literary critiques. Poststructural and postmodern theorists argued that language and texts interact with both the producers of knowledge, texts, and landscapes as well as those who encounter them. In this way, knowledge and space are constructed through a process of intertextuality—the interplay between the producers of knowledge, the receivers, and the context within which that interaction occurs. Second, postmodern and poststructuralist theorists eschewed grand metanarratives, such as the role of capitalism, in structuring social life. The belief that social life is created through a host of different relations and contexts is the crux of this critique. Through the work of poststructural and postmodern geographers such as Edward Soja and Michael Dear, as well as the work of feminists such as J. K. Gibson-Graham, the meaning of radical geography began to become increasingly diversified from its earlier Marxist roots.

Redefinitions of Radical Geography

The destabilization of radical geography's meaning and content in the 1990s fostered an entire



new lexicon among geographers working within leftist political scholarship. Left-wing geographical scholarship, once known as radical geography, became left, critical, Marxist, feminist, poststructural, postmodern, and postcolonial geographies. Radical geography became fractionized across a host of epistemologies, ontologies, methodologies, and themes. This led to a process of internal soul searching regarding the meaning of radical geography. The debate over the meaning of radical geography is diverse, but two distinct themes have reoccurred frequently: (1) the theoretical commonalities within radical geography and (2) how radical geography is practiced (praxis).

Theoretically, several interventions into the meaning of radical geography have emerged. One aspect of this discussion is illustrated in the work of Amin and Thrift (2005). They argue that the growing pluralism within radical geography in the 1990s and 2000s is a strength and should be celebrated. They see in a new pluralist radical, left, or critical geography an opportunity to develop new politics that can contribute to the objectives of the radical project as initially conceived. In addition, they reaffirm the theme introduced by postmodernism that no one overarching theory can offer a holistic view of social relations. Others have sought to reaffirm the materialist bases of early scholarship in radical geography, arguing that it is the best theoretical framework for understanding the extreme inequalities that allow some to live in overwhelming comfort and abundance while others live with a constant struggle for survival. These authors express the significant internal debate regarding radical geography's theoretical foundation.

The practice or *praxis* of radical geography has also received considerable attention among geographers in recent years. Numerous radical geographers have interrogated the question of where and how to practice radical geography. What began as an intervention into the disconnect between radical geography research and theory and its "on the ground," "out there" activism quickly expanded. In its early manifestation, this debate addressed the relevance of radical scholarship to activists, communities, and policy. Efforts were made to encourage or cajole radical geographers to engage with the

world outside the academy, both theoretically and in practice, and to critically examine the contributions made by radical geographical research to radical politics in practice. However, others have questioned the necessity of radical scholarship engaging in activism in the community. Recently, Mitchell (2004) suggests that radical geographers can provide activists with the resources and tools necessary to create a radical vision of social justice and equality by focusing on doing good analysis itself. This vision of radical geography contests the notion that radical geography must engage in activist practice outside the academy and highlights the resources within the academy that make radical geographers uniquely positioned to contribute to activism through their scholarship: financial resources, time, the safety of tenure, and the power of good theory. This line of radical geographic praxis is currently at work in the recent Right to the City movements, which rely on the work of Lefebvre and Mitchell.

In recent times, geographers have expanded Mitchell's notion of doing good work within the academy. There has been a growing body of work pushing radical geographers to put as much energy into a radical pedagogy and teaching activities as they might into activism outside the academy or in radical research. In addition, emphasis has been placed on radical geographical work seeking to actively change the working conditions of the labor force closest to radical geographers: the university. This has led to a vibrant discussion at conferences and in journals of the corporatization of the academy and the working condition of both academic and nonacademic labor. In addition, discussion among radical geographers has also focused on the process of publication and the professionalization of radical geography's first journal, *Antipode*.

Peter Hossler

See also Bunge, William; *Circuits of Capital*; Critical Human Geography; Feminist Geographies; Harvey, David; *Human Geography, History of*; Justice, Geography of; Lefebvre, Henri; *Marxism, Geography and*; Massey, Doreen; Peet, Richard; *Political Geography*; Smith, Neil; *Social Justice*; Soja, Edward; *Spatial Fix*



Further Readings

- Amin, A., & Thrift, N. (2005). What's left? Just the future. *Antipode*, 37, 221–238.
- Castree, N. (2000). Professionalisation, activism, and the university: Whither “critical geography.” *Environment and Planning A*, 32, 955–970.
- Gibson-Graham, J. K. (1996). *The end of capitalism (as we knew it): A feminist critique of political economy*. Cambridge, MA: Blackwell.
- Harvey, D. (1973). *Social justice and the city*. Baltimore: Johns Hopkins University Press.
- Harvey, D. (1982). *The limits to capital*. Chicago: University of Chicago Press.
- Heynen, N. (2006). “But it's alright, Ma, it's life, and life only”: Radicalism as survival. *Antipode*, 38, 916–929.
- Hudson, R. (2006). On what's right and keeping left: Or why geography still needs Marxian political economy. *Antipode*, 38, 374–395.
- Levebvre, H. (1991). *The production of space*. Cambridge, MA: Blackwell.
- Massey, D. (1984). *Spatial divisions of labour: Social structures and the geography of production*. London: Macmillan.
- Mitchell, D. (2004). A polemic on making a difference outside the academy. In D. Fuller & R. Kitchin (Eds.), *Radical theory/critical praxis: Making a difference beyond the academy*. Kelowna, British Columbia, Canada: Praxis (e)Press.
- Peet, R. (2000). Celebrating thirty years of radical geography. *Environment and Planning A*, 32, 951–953.
- Rose, G. 1993. *Feminism and geography: The limits of geographical knowledge*. Minneapolis: University of Minnesota Press.
- Smith, N. (1984). *Uneven development: Nature, capital, and the production of space*. Oxford, UK: Blackwell.
- Smith, N. (2005). Neo-critical geography, or, the flat pluralist world of business class. *Antipode*, 37, 887–889.

scale. Radiometric correction is one of several corrections performed on satellite image data prior to the retrieval of land, atmosphere, and ocean information. These preprocessing procedures are essential for ensuring high-quality information from remote sensors. Radiometric correction ensures that measurements and methods yield self-consistent and accurate geophysical and biophysical data, even though the measurements are made with a variety of different satellite sensors under different observational conditions and the parameter retrieval methodologies vary.

Overview

Radiometric correction is important for the successful conversion of digital image data from satellites to calibrated surface quantities in the Earth science context. Figure 1 shows the many possible paths that photons take from their source—the sun—to the entrance aperture of the satellite sensor imaging Earth, with five main pathways and associated interactions.

Radiometric corrections of optical sensor data consider sensor radiometric calibration, surface reflectance retrieval, spectral characterization, and georadiometric effects on image radiometry. By convention, raw image data and calibrated radiances at the top of the atmosphere (TOA) are referred to as Level 0 and Level 1 data, respectively. For analysis in quantitative applications, Level 2 data, consisting of radiometrically calibrated and geolocated physical variables such as surface reflectance, emittance, temperature, and so on, are preferred or required. Still higher data product levels consist of information products that are integrations, temporal aggregates, or spatial aggregates of lower-level data.

Sensor Radiometric Calibration

Sensor radiometric calibration is a broad and complex field that imposes the greatest limitations on quantitative applications of remote sensing. The methods and instrumentation involved can be grouped into three domains: (1) on the ground prior to launch, (2) onboard the spacecraft post-launch (including reference to lamp sources and/or solar illumination or lunar illumination), and



RADIOMETRIC CORRECTION

Radiometric correction is important to ensure that terrestrial variables retrieved from optical satellite sensor systems are calibrated to a common physical

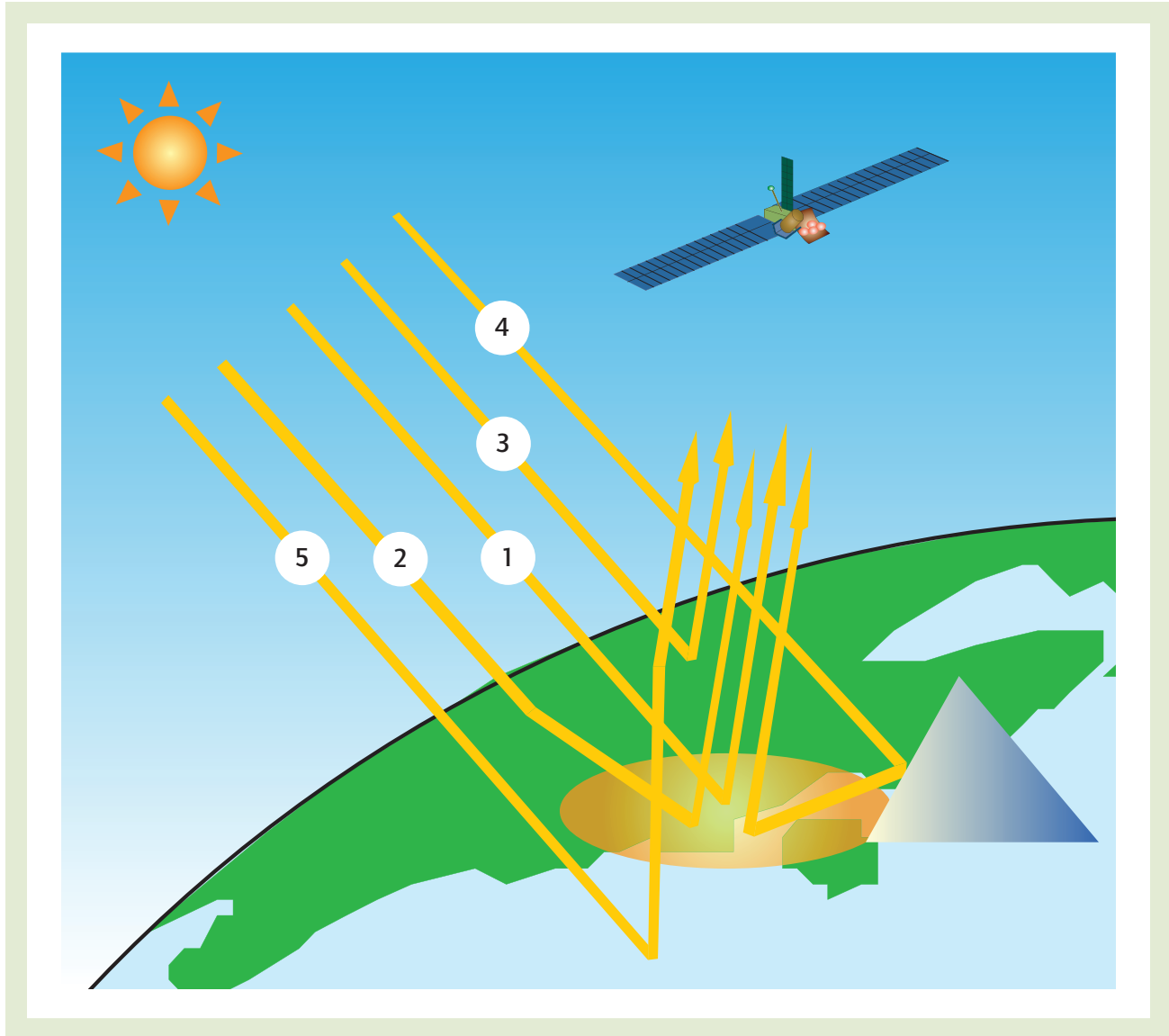


Figure 1 Radiometric correction

Source: Adapted from Teillet, P. M. (2005, September/October). Satellite image radiometry: From photons to calibrated Earth science data. *Canadian Journal of Physics*, 61(5), 301–310.

Note: Schematic of photon pathways from the sun to the entrance aperture of the satellite sensor: (1) direct solar illumination, (2) diffuse sky illumination, (3) atmospheric path radiance, (4) background object reflections, and (5) adjacent target effects.

(3) vicarious approaches using Earth scenes imaged in flight.

Surface Reflectance Retrieval

In many applications, surface reflectance is the geophysical variable of particular interest in the

solar reflective part of the electromagnetic spectrum. However, scattering and absorption due to gas molecules and aerosols in the atmosphere modify surface reflectance propagated through the atmosphere to the satellite sensor. Given that the optical properties of Earth's atmosphere are not uniform spatially or temporally, image



corrections for these effects in the solar-reflective spectral bands are needed on a case-by-case basis to put satellite data on the same radiometric scale for investigations intended to monitor terrestrial surfaces over time and space.

Spectral Characterization

Spectral bands are designed for specific applications, and data products are susceptible to post-launch variations in spectral bandpasses or to spectral band differences between different sensors used in a given applications algorithm or model. In practice, there is little that users can do to take into account the changes in the spectral band performance. However, even when spectral bands perform as designed, users should be aware that similar information products derived from different sensors with analogous spectral bands that do not match exactly are not necessarily directly comparable.

Philippe M. Teillet and Craig A. Coburn

See also **Radiometric Normalization; Radiometric Resolution; Remote Sensing**

Further Readings

- Schott, J. (1997). *Remote sensing: The image chain approach*. Oxford, UK: Oxford University Press.
- Teillet, P. M. (2005, September/October). Satellite image radiometry: From photons to calibrated Earth science data. *Canadian Journal of Physics*, 61(5), 301–310.



RADIOMETRIC NORMALIZATION

Remote sensing applications often use image time series or mosaics of various images or image parts. *Radiometric normalization* generally refers to empirically reducing the differences between images in time series or mosaics related

to differences in the image acquisition time or date. These differences can affect the accuracy of image interpretation. In satellite-based optical remote sensing, these differences include differing atmospheric conditions, target illumination, sensor calibration, or surface phenology. Radiometric normalization is applied both to images that have undergone atmospheric correction and to those that have not.

Image radiometric normalization is warranted when

1. the spectral signatures from one image will classify other images without other normalization,
2. the particular approach to time-series analysis requires that the radiometric differences between images be minimal, or
3. a single linear model that does not account for image date will classify an image mosaic.

Radiometric normalization is mathematically superfluous when change detection consists of stacking images through time and then simultaneously classifying them empirically, as with a maximum-likelihood classification. Radiometric normalization may also be unnecessary when using machine-learning models, to classify an image mosaic, if the reference data for the classification model represent all image dates.

To radiometrically normalize images to a reference image or to each other, calibration models are estimated from pixels in the images and then applied to the imagery. Normalization models estimated from linear regression between manually selected, spectrally stable features, such as human-made structures, are unreliable if the goal is to normalize differences in surface phenology. Models estimated from all overlapping pixels, with linear regression, histogram matching, or regression tree normalization, are more stable. When pixels that have not undergone real change dominate images, removing changed pixels before estimating the model is statistically unnecessary. Regression tree normalization matches vegetation phenology more closely than histogram matching, and histogram matching may yield better results than linear



regression. Localized approaches estimate a separate model for each pixel based on overlapping pixels within a surrounding window. Of all these approaches, only regression tree normalization and localized approaches can normalize nonlinear image differences in vegetation phenology, but these approaches can also result in some loss of image detail.

Eileen H. Helmer

See also **Radiometric Correction; Radiometric Resolution; Remote Sensing**

Further Readings

- Gao, F., Masek, J. G., Schwaller, M., & Hall, F. (2006). On the blending of the Landsat and MODIS surface reflectance: Predicting daily Landsat. *IEEE Transactions on Geoscience and Remote Sensing*, 44(8), 2207–2208.
- Helmer, E. H., & Ruefenacht, B. (2007). A comparison of radiometric normalization methods when filling cloud gaps in Landsat imagery. *Canadian Journal of Remote Sensing*, 33, 325–340.
- Hong, G., & Zhang, Y. (2008). A comparative study on radiometric normalization using high resolution satellite images. *International Journal of Remote Sensing*, 29, 425–438.
- Loew, A., & Mauser, W. (2007). Generation of geometrically and radiometrically terrain corrected SAR image products. *Remote Sensing of Environment*, 106, 337–349.
- Scheidt, S., Ramsey, M., & Lancaster, N. (2008). Radiometric normalization and image mosaic generation of ASTER thermal infrared data: An application to extensive sand sheets and dune fields. *Remote Sensing of Environment*, 112, 920–933.
- Song, C., Woodcock, C. E., Seto, K. C., Pax-Lenney, M., & Macomber, S. A. (2001). Classification and change detection using Landsat TM Data: When and how to correct atmospheric effects? *Remote Sensing of Environment*, 75, 230–244.



RADIOMETRIC RESOLUTION

Radiometric resolution is the radio-frequency sensitivity of a remote sensing platform. Usually captured from airplanes and space-based satellites, remotely sensed data provide a uniform view of geographic space. This view of Earth can extend beyond the visible range of wavelengths.

Remote sensors have four resolutions: spatial, temporal, spectral, and radiometric. Commonly referred to as the pixel bit depth of a sensor, radiometric resolution is the sensitivity to reflected radiation across the spectral resolution of the sensor. Consumer digital cameras, for instance, detect visible spectrum light using a CCD or CMOS sensor with 8 bits of radiometric resolution for red, green, and blue bands. This translates to 256 possible shades of each color band for an aggregate 24 bits of radiometric resolution, resulting in more than 16 million different colors for each pixel. The Multispectral Scanner (MSS) on Landsats 1–3 had a radiometric resolution of 6 bits for 64 levels for each of the four bands: red, green, blue, and near-infrared. The Landsat Data Continuity Mission (LDCM) proposal specifies a new array of sensors with 8 bits of radiometric resolution for each of the nine bands of radiation. Radiometric resolution presents a trade-off as with spatial resolution due to data collection and transmission limitations. Increasing the radiometric resolution directly increases the volume of data transmitted. Furthermore, increasing the radiometric resolution has been shown to mostly increase the noise versus the desired signal.

Eric B. Wolf

See also **Radiometric Correction; Radiometric Normalization; Remote Sensing; Remote Sensing: Platforms and Sensors; Spatial Resolution; Spectral Resolution; Temporal Resolution**

Further Readings

- Jensen, J. R. (2007). *Remote sensing of the environment: An Earth resource perspective* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.



National Aeronautics and Space Administration. (2008). *Landsat Data Continuity Mission*. Retrieved December 7, 2009, from <http://ldcm.nasa.gov>

U.S. Geological Survey. (2008). *Earth Resources Observation and Science (EROS)*. Retrieved December 7, 2009, from <http://edc.usgs.gov/index.html>

RAILROADS AND GEOGRAPHY

One of the central technologies of the Industrial Revolution, and perhaps the most important child of the steam engine, was the railroad, which, along with steamships, played a central role in giving birth to radically new geographies of social and economic life. Railroads were central to the rise of modern capitalism and the opening up of continental interiors through rapid, cheap, and dependable transportation and were thus the most explicit symbol of the vast wave of time-space compression unleashed throughout the 19th century. In addition to their ability to shuttle people, railroads could move heavy loads over long overland stretches, but not in areas with too steep a grade, reducing land transport costs by as much as 95%.

This entry first reviews the evolution of the railroad in Europe and the United States, as railroad lines contributed to the growth of capital cities, expanded markets, and increased the accessibility of previously remote areas. The entry then explores the impacts of rail transportation not only on the experience of travel but also on national and international commerce.

Historical Development

Britain

British railroads, the world's first, began with the Penydarren Tramroad in Wales in 1804, although it did not rely on steam power. In 1814, George Stephenson unveiled the first steam locomotive, and the British system expanded rapidly, including the Stockton and Darlington Railway

in 1825, one of a series of famous Newcastle railways. In 1830, the first interurban railroad connected Liverpool and Manchester. Early railroads achieved speeds between 20 and 30 mph (miles per hour), or three times that achieved by stagecoaches; later ones achieved speeds of up to 70 or 80 mph. By 1838, the London to Birmingham route opened to immediate success, reducing the time needed to travel the 112 mi. (miles) in between from 12.5 to 5.5 hrs. (hours). Other travel times fell accordingly: London to York, for example, took 96 hrs. to walk in 1754, 36 hrs. by stagecoach in 1776, and 20 hrs. by railroad in 1830.

During a period of intense, widespread, and rapid urbanization, railroads soon became the dominant sign of the Industrial Revolution in much the same way as the Internet came to symbolize postmodern capitalism. The enormous costs of constructing and maintaining such networks, however, required high volumes of traffic to amortize expenses over numerous clients. Fortunately, the velocities of the new system were popular: British passengers increased from 5.4 million in 1838 to 170 million in 1862. Originally, British railroads deployed the 4-foot, 8-inch gauge of the coal mines. The integration of wider markets, however, required standardized tracks, which led other countries eventually to adopt the British standard. The standardization of different European rail gauges was finally accomplished with the International Railway Conference of 1882, which took more than a decade to unfold.

Russia

In Russia, railroads helped forestall a decline into Third World country status. With the opening of the Moscow-to-St. Petersburg line in 1851, Russia's railroads zoomed from 700 total mi. in 1860 to 12,500 mi. in 1878, to 21,000 mi. in 1894, and 36,000 mi. in 1900. The first leg of the Trans-Siberian railroad opened in 1903, stretching 6,000 mi. from Moscow to Vladivostok; by reducing journey times between Europe and Asian Russia from months to days, it brought the vast resources of Siberia into the tsarist spatial division of labor. Within a decade, 2.5 million Russian settlers were living in northeast Asia. The Trans-Siberian railroad was therefore central in making



Russia a formidable land power, a point important to the geopolitics of Halford Mackinder.

Japan

As Japan moved rapidly from a feudal to a capitalist society in the late 19th century, its railroad network sutured the country's diverse local economies into a nationally integrated system. The Japanese rail system first linked Tokyo and Yokohama in 1872. Other lines reinforced the centrality of large urban centers, including Osaka.

Italy

In Italy, the railroad became an instrument of national unification—a process achieved in the face of the growing economic and political ascendancy of the North at the expense of the peninsula's southern districts. Transportation integration in Italy came late, however, with the Florence-to-Rome line completed only in 1933.

France

The French railroad system, centered, naturally, on Paris, soon made the capital accessible to people throughout the nation; equally important, it made the French peripheral territories accessible to Parisian capitalists (Figure 1). During the 19th century, the French rail system generated a condensed geography in which all cities approached Paris, and vice versa, deeply reinforcing the centrality of the capital. Lines ending at different stations in Paris reflected the dominant conception that railroads did not go *through* Paris, they simply ended there.

This pattern in several different countries reflects the profoundly uneven national geographies of industrialization facilitated by the railroad—that is, the rising prominence of cores of capital accumulation at the center of national transport systems. Similarly, the British railroad heavily favored London and brought most of the island within a 10-hr. traveling time from the capital.

The United States

The American rail experience paralleled that of Britain in generating a transport surface increasingly ubiquitous across national space.

Beginning with the first line in Quincy, Massachusetts, in 1826, Boston became the world's first rail hub, with three radial lines. It took only 43 years to move from the first rail line in 1826 to the famous transcontinental connection of the Union Pacific and Central Pacific lines at Promontory Point, Utah, on May 10, 1869, connecting the multitude of farms, towns, and cities stretched across North America.

American railroads had inestimably profound impacts on the country's social, urban, and economic geography, opening the coal mining districts of Appalachia and the meat and grain belt of the Midwest alike. The time-space effects of the railroad system were highly uneven geographically, integrating the northeast and the Midwest far more than they did the northeast and the South. Just as there were significant differences in the urban and regional impacts of railroads between Britain and France, so too in the United States did the consequences of railroads vary. Because American labor was relatively expensive and land was cheap—the exact opposite of Europe—railroads in the United States tended to curve much more around hills and valleys. American railroads were instrumental in opening up the vast wilderness of the continental interior, and train travelers across the prairies compared trains with ships on land. In essence, this wave of time-space compression turned the Great Plains and Prairies into a giant agricultural bread basket, a process that established Chicago as the premier center of capital accumulation in the continental interior. The completion of national rail networks also facilitated the specialization of individual cities, which often realized comparative advantages based on local resources, strategic locations, and contingent pools of labor skills. Chicago witnessed particularly explosive growth in the 1840s due to its location as a transportation hub. The huge wave of time-space compression that railroads unfolded across North America catapulted Chicago from a tiny backwater to the world's first commodity market and futures exchange center. The accelerated velocity and improved reliability of shipments brought the Midwest steadily into the orbit of the eastern capital. Shortly after the Civil War, the Rocky Mountains and the west coast were incorporated into the American space economy,

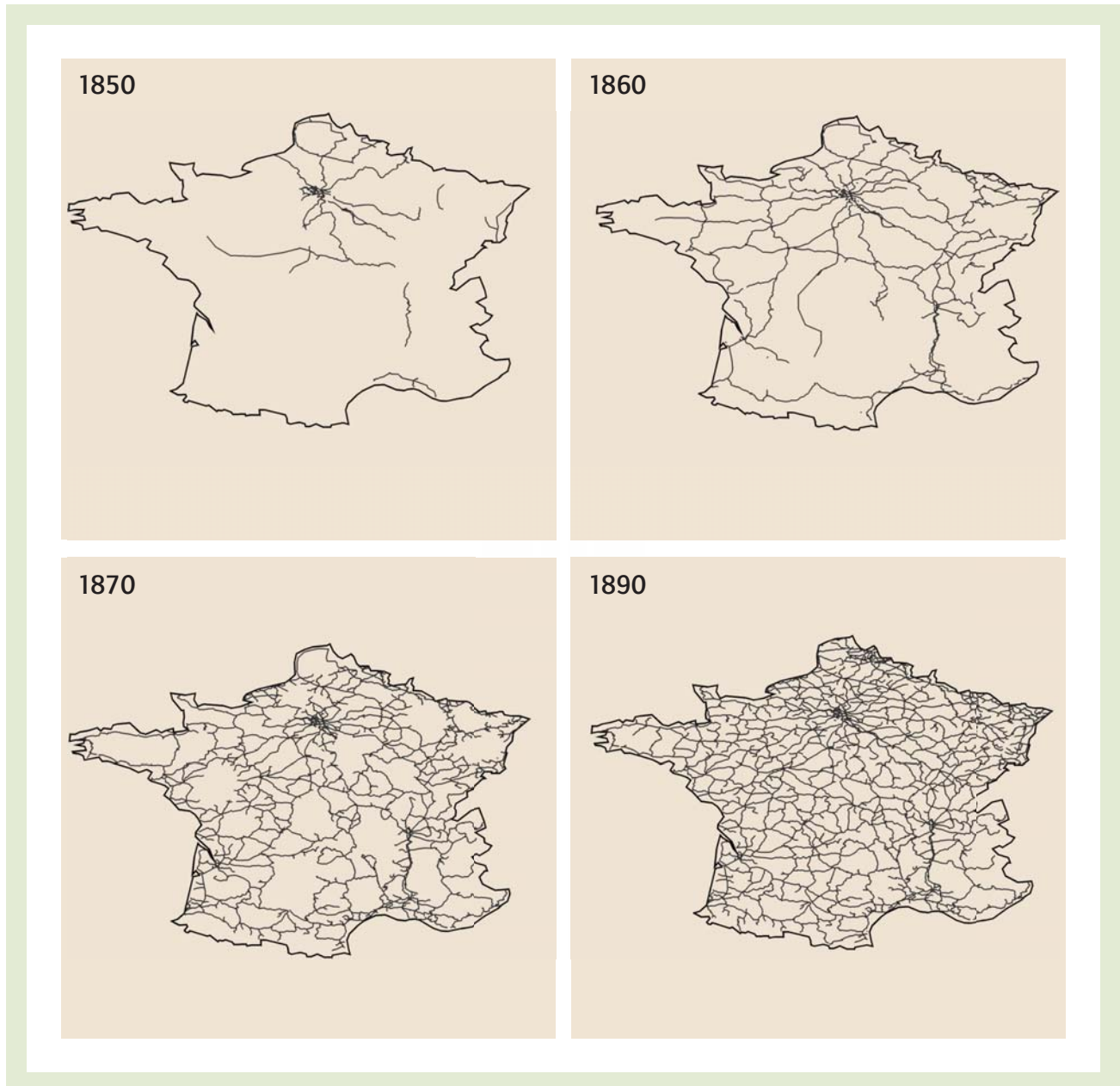


Figure 1 The evolving French railroad system. In France, railroads greatly enhanced the centrality of Paris.

Source: Author.

which soon thereafter became the largest in the world, surpassing Britain in the 1890s. The gulf between the east and the west coasts was finally breached by the telegraph wires in 1861 and railroads in 1869. Throughout the late 19th century, the U.S. railroad network formed a dense web over the eastern half of the country (Figure 2), a system that represented 40% of the

world's railroad capacity. The railroads adopted the telegraph enthusiastically, to send news of construction, accidents, and changes in schedule. Railroads were particularly enthused because the telegraph allowed information about train position to be relayed accurately, thus improving safety and omitting the need for double tracks.



The city of Chicago has been a major railway hub for more than a century. In October 1848, the steam locomotive *The Pioneer* began carrying construction supplies and workers over the Galena & Chicago Union Railroad, inaugurating rail service to the city. By the 1880s, Chicago was served by nearly 20 long-distance rail carriers and several switching and terminal companies. Today, it remains the largest railroad hub in the United States. Shown above are tracks leading south from Chicago's Union Station to Amtrak's Chicago Yard and 14th Street Shop and control tower, about 1 mi. south of Chicago's central business district. On the right are additional tracks to stage Metra commuter trains for rush-hour runs, with Metra's own shops just outside the photo. The viaduct crossing the tracks is Roosevelt Road, and the trees across the river are growing on rail yards abandoned as industries using rail have moved further from the central core and rail passenger service has largely been replaced by air and car travel.

Source: Eric Mathiasen.

Impact of Railroads on the Experience of Travel

Railroads also dramatically changed the subjective experience of travel. Accelerated speeds transformed the dominant former means of travel, horse-drawn carriages, into something slow, whereas previously it had been the quickest way to go. Moreover, the older, animal-driven technologies, Schivelbusch (1977) maintains, preserved a "mimetic relationship" to the space traversed, permitting travelers to perceive space intimately. With

the introduction of steam power, however, animal-based transportation was rendered hopelessly anachronistic, and the close relationship between traveler and the traveled space was uncoupled. Unlike animal transportation, which was irregular and bumpy (horses' hooves needed traction), railroads moved smoothly at a constant rate, and the mechanism of propulsion was largely invisible, incomprehensible, or misunderstood by most travelers. Many early descriptions of railroads liken them to projectiles or rockets. The sheer speed of rail travel appeared unnatural to many early riders



U.S. Railroad System in 1860 and 1890 over modern state boundaries

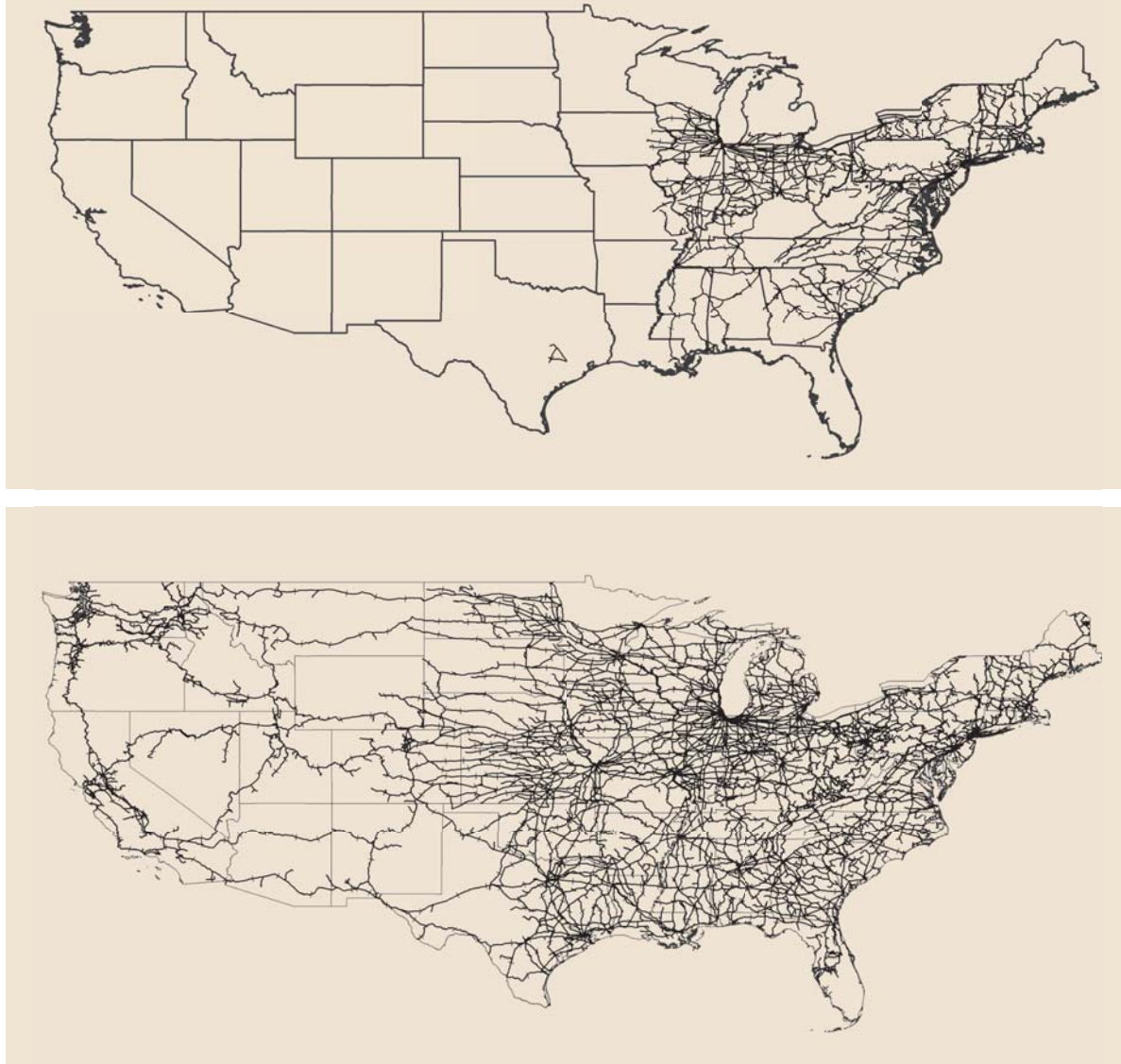


Figure 2 Growth of the U.S. railroad network. Transcontinental railroads facilitated the formation of national markets and large oligopolies in the United States.

Source: Author.

and prevented them from close observation of their surroundings. Railroads ushered in new perceptual landscapes, divorcing travelers' bodies from their traditional experiential linkage to external space, forcing them to construct new forms of consciousness to interpret the landscape as it whizzed by.

Among other things, this new phenomenology of movement entailed a much greater ability to deflect irrelevant stimuli. Unable to hear sounds in the places they passed by and unable to look ahead, passengers confronted a rapidly passing blur that substituted for the foreground. Slow, careful views



of nearby objects were replaced by rapid, superficial scans of distant ones in the background, making passengers feel disembodied from the places through which they flew, leaving them with a fleeting, impressionistic understanding of their surroundings. Medical doctors of the time associated the rail experience with the new health problems of eye strain and stress. Thus, despite the economic gains unleashed by industrial time-space compression, the process also entailed experiential losses: The quantitative size of spaces traveled through expanded greatly, but the qualitative appreciation of the experience declined.

Railroads also fostered an outlook that emphasized precision rather than the old “inexact” habits. With the railroad, speed became an established principle of public life and a synonym for progress. Punctuality became increasingly regarded as socially normative: A few minutes meant the difference between catching or missing a train. The new environment democratized access to velocity: For example, women were able to travel alone without a male escort, an unheard-of phenomenon prior to the railroad. The psychic transformation wrought by rail travel carried over even into the simple process of embarking or disembarking.

Within cities, too, railroads were potent in restructuring urban land markets, initiating rounds of change in the urban rent surface that amplified some land values and eroded others. Railroads simultaneously intruded on older cities, destroying the traditional fabric of urban space and giving rise to new ones. As the commodification of urban space intensified, specialized districts of production and social reproduction materialized apace within divisions of labor that became spatially extended and more integrated. Outside urban areas, railroads allowed the rhythms of the city to penetrate the countryside. By making distant lands accessible, railroads dramatically extended the rent surfaces of urban areas, commodifying land in hitherto inaccessible regions and encouraging farmers, settlers, and planters to assault distant, relatively untouched ecosystems.

Economic Effects of Rail Transportation

Far from constituting some mythical process of “free market” expansion, the growth of the railroads was actively abetted by the state, including

the land grants introduced in 1850. In the United States, the Interstate Commerce Act of 1887 standardized rail gauges. Thus, rather than unfettered supply and demand, the state intervened actively to facilitate the time-space compression of industrial capitalism. This process effectively allowed politically powerful commercial interests located on the east coast to gain easy access to the resources and markets situated in the Midwest and west.

One of the most significant long-term impacts of the relational geographies that the railroad fostered was the rise of dramatically expanded markets on the scale of the nation-state. Prior to the Industrial Revolution, with markets highly localized and self-sufficient, long-distance trade was comparatively rare. In 1817, for example, it took 52 days to ship goods from Cincinnati to New York by river using wagons. Between 1830 and 1857, most of the country was within a few days’ travel of New York City. Interregional commerce tended to be export oriented and controlled by merchants in large east coast cities. As long as production and consumption were confined to regional markets, goods retained the identity of their origin. Railroads, however, allowed large-scale commercial providers to lower costs, increase productivity, and raise profits while using the new technologies to conquer space in ever more effective ways, expanding their operations by diminishing geographic barriers. Within the new, larger markets, prices tended to equalize quickly. This process generated “economies of speed” in which maximization of throughput set the stage for the emerging Fordist regime of production. All this was central to the transition from small, isolated, and localized markets to larger national ones, a new geographic formation that was highly conducive to the rise of larger, capital-intensive, vertically integrated, multi-establishment firms and oligopolies as companies internalized their commodity chains.

Other Social Impacts

Railroads had other social impacts as well, including on the media. For example, there were hardly any mass-circulation magazines prior to 1850. Their emergence in the United States, based on the economies of scale offered by large markets, was made possible by the completion



of the transcontinental railroads in 1869 and the Postal Act of 1879, which allowed for cheap distribution of commercial material. Another consequence of railroads was in the expanding geographies of mass tourism. Prior to the railroad, for example, high transport costs kept isolated areas far from the reach of the urban masses and were often the recreational preserves of wealthy elites. The railroad made the Grand Tour of Europe—a *de rigueur* rite of passage for the educated *petit bourgeoisie* on both sides of the Atlantic—obsolete as hotels, newspapers, and the new technologies of transportation all made the process of mass tourism more comfortable, safe, and reliable, facilitating the mass movement of people across and within national boundaries and encouraging widespread appreciation of cultural differences. In the 1840s, Thomas Cooke began to organize cheap train trips to the coasts of Britain for working-class families. Railroads in the 19th century and airplanes in the 20th century opened up exotic places to the middle classes, who frequently took them over, often destroying the very uniqueness that made them attractive in the first place. Places, like goods, became standardized and commodified, locked into an increasingly national, then global, system of production, circulation, and consumption.

In European colonies, too, the railroad unleashed enormous impacts, although in contrast to the colonial countries, these were generally designed to favor the broader process of exploitation. In India, for example, the British railroads began in 1853 but rose rapidly following the Sepoy Mutiny of 1857 to become the largest railroad system in the colonial world, primarily to facilitate cotton and jute exports to the textile mills at home and troop movement to control the native population. By 1870, the British had laid 4,500 mi. of track, which by 1936 expanded to 43,000 mi.—the fourth largest network in the world. Investors in Indian railroads were guaranteed a 5% annual rate of return by the British government. Similarly, in Southern Africa, rail lines were central to Cecil Rhodes's pacification program. By the 1920s, the vast majority of the population of the economically developed world lived within 10 mi. of the "civilizing rails," blanketed by a network that suggested near-ubiquity

of access. Conversely, relatively few people in Asia, Africa, or Latin America did so.

Railroads and the Standardization of Time

One of the most explicit repercussions of railroads was the standardization of time. England, the first to build railroads, was also the first to adopt a standard railroad time: In 1847, the British Railway Clearing House suggested that all rail stations adopt Greenwich Mean Time (GMT), the special preserve of the Royal Observatory located there, which was founded in 1675. Because Greenwich time was distributed via the telegraph wires, it was long known as "railway time." By 1855, GMT became the legal standard throughout the country.

In the United States, given its vastly greater size, a somewhat different set of conditions prevailed. In 1870, the United States still had roughly 200 local times and 80 different railroad times, generating great confusion among railroad passengers and companies. In that year, Charles Dowd suggested four time zones based on four standard meridians, the easternmost of which passed through the U.S. Naval Observatory in Washington, D.C. Uniform time was voluntarily adopted on November 18, 1883, the "day of two noons" because clocks had to be set back to generate a national railway time. By adopting Greenwich as the Prime Meridian, the United States and Canada provided a model for the international adoption of the same innovation.

Railroads in the 20th Century

In the 20th century, railroads faced growing competition from automobiles and trucks for the movement of people and goods, respectively, and their significance declined accordingly. Currently, though freight trains still play an important role in shuttling commodities cheaply over long distances, especially with the introduction of containerization and double stacking, the aggregate impacts are considerably lower than they were during the golden era of the late 19th century. An important development was high-speed trains, which form a key part of interurban transit systems in densely populated, economically advanced countries with strong state backing (but not the



United States), including the Japanese *Shinkansen* (“bullet trains”); France’s *Train à Grande Vitesse* (“high-speed train,” TGV), which cover the 275 mi. from Paris to Lyon in just 2 hrs., operating at roughly 180 mph; Germany’s *Neubaustrecke* (“newly constructed routes,” NBS); Spain’s *Alta Velocidad Española* (“Spanish high-speed train,” AVE); and the British Inter-City 125, which brought all of England within 3 hrs. of London. With speeds of up to 300 kph (kilometers per hour), such systems are competitive with air travel for distances of up to 500 km (kilometers). The driving force behind these systems has been primarily economic, particularly the need to shuttle well-paid executives between corporate offices. Not surprisingly, the heavy European emphasis on such systems was tied to the creation of a single internal market under the European Union. High-speed trains invariably shrank the relative spaces between large cities by skipping over smaller, intermediate nodes.

Barney Warf

See also **Industrial Revolution; Time-Space Compression; Transportation Geography**

Further Readings

- Fogel, R. (1964). *Railroads and American economic growth*. Baltimore: Johns Hopkins University Press.
- Hugill, P. (1993). *World trade since 1431: Geography, technology, and capitalism*. Baltimore: Johns Hopkins University Press.
- Jefferson, M. (1928). The civilizing rails. *Economic Geography*, 4, 217–231.
- Schivelbusch, W. (1977). *The railway journey: The industrialization of time and space in the 19th century*. Berkeley: University of California Press.
- Schivelbusch, W. (1978). Railroad space and railroad time. *New German Critique*, 14, 31–40.
- Vance, J. (1995). *The North American railroad: Its origins, evolution, and geography*. Baltimore: Johns Hopkins University Press.
- Whitelegg, J., Hulten, S., & Flink, T. (Eds.). (1993). *High speed trains: Fast tracks to the future?* Hawes, UK: Leading Edge Books.



RAISZ, ERWIN (1893–1968)

Erwin Raisz played a key role in the professionalization of cartography within the discipline of geography, and deservedly he is ranked with early luminaries in the field such as John Paul Goode, Arthur Robinson, and Richard Harrison. His major contribution was in the area of landscape representation, and beginning at least a decade before World War II, he published literally thousands of maps, both large and small scale, depicting landforms throughout the world. Many were made to illustrate books, and even today his maps often continue to be used as book illustrations. He also authored *General Cartography*, which for decades was the only textbook in the English language on the subject.

The direction of Raisz’s career seemed to have been established at his birth in 1893 in Levoca, a town in today’s Eastern Slovakia. His father, a Hungarian civil engineer, was temporarily stationed there. Raisz has been quoted as saying that as a young child he occasionally carried his father’s surveyor’s rod and peeped into his transit. Following more or less in his father’s footsteps, he studied engineering and architecture at the Royal Polytechnicum in Budapest and received his diploma with honors in 1914. Following military service in World War I, much of it in action, he briefly worked in Hungary, but in 1923, he emigrated to the United States, where he found employment in New York with a map company.

Shortly after his arrival, he entered graduate school at Columbia University’s department of geography, receiving his doctorate in 1929. Raisz’s cartographic skills began to be recognized during his student years at Columbia, not only by his professors, who used his maps to illustrate their research, but also by publishers who needed map illustrations. Raisz’s own students also admired his skill at depicting landforms from contour maps. Raisz would enter the classroom with a roll of Kraft paper, from which he would unroll a long strip and pin it to the blackboard. Then, he would depict the map’s surface with an array of colored chalk and a U.S. Geological Survey (USGS) contour map.

Raisz’s landscape depiction skills led him to gain employment at Harvard’s newly established



Institute of Geographical Exploration, where he remained for 20 years, his employment ending in 1950, when, shortly after the closing of Harvard's department of geography, the benefactor of the Institute withdrew his support. By then, Raisz's reputation as a cartographer was well established, and he carried on his work at home and as a visiting lecturer at universities in Virginia, Florida, and British Columbia. Raisz continued to work until his death in 1968 in Bangkok, Thailand, en route to a meeting of the International Geographic.

Morton D. Winsberg

See also **Cartography**; **Cartography, History of**

Further Readings

Stewart, G. (1953). *Erwin Raisz*. New York: Houghton Mifflin.



RANK-SIZE RULE

The rank-size rule is a mathematical description of the sizes of cities within a given urban hierarchy. It states that the rank of a city with size S relative to the largest city in that hierarchy is proportional to some negative power. It was first proposed by George Kingsley Zipf in 1949. The negative power should be close to 1 in absolute value, which implies that the second largest city is half the size of the largest, the third largest city is one-third the size of the largest, and so on. In cases where this power is greater than 1, it suggests that the second largest city is more than half the size of the largest city, the third largest city is more than one-third the size of the largest city, and so on.

The rank-size rule is commonly expressed as follows:

$$R_i = \alpha S_i^{-\beta}, \quad (1)$$

where R_i is the rank of the i th largest city, S_i is the city's size, and β is the exponent coefficient.

A log transformation can be used to estimate β as follows:

$$\log(R_i) = \alpha - \beta \log(S_i). \quad (2)$$

The rank-size rule has two striking features. One is its excellent empirical fit. Numerous studies have shown that a linear regression of log-rank on log size (as shown in Equation 2) generates an excellent correlation (high R^2 value). For example, Rosen and Resnick (1980) used data from 44 countries and found that R^2 values were above 0.95 for 36 countries, with only Thailand having an R^2 value lower than 0.9. This astonishing regularity led Paul Krugman (1995) to say that the rank size is "a major embarrassment for economic theory: one of the strongest statistical phenomenon we know, lacking any clear basis in theory" (p. 44).

The other striking observation is about the power exponent. For the 44 countries studied by Rosen and Resnick (1980), the estimated coefficient ranges from 0.809 for Morocco to 1.963 for Australia.

Several studies have noted that estimating Equation 2 of the rank-size rule yields an ordinary least squares (OLS) bias through standard errors. The following version corrects for the bias, giving the standard errors of the exponent the form $(2/\bar{n}_i)^{0.5} \hat{\beta}$, where $\bar{n}_i$ is the corresponding subsample size. Instead of Equation 2, they offered the following:

$$\log(R_i - 0.5) = \alpha - \beta \log(S_i). \quad (3)$$

This corrected version is known as the "rank minus half" rule. The estimated coefficients ($\hat{\beta}_s$) are slightly higher for the OLS-bias-corrected model than for the original uncorrected version.

The rank-size rule is remarkably consistent and frequently referenced. Its causes are highly debated, with some suggesting that it is purely a statistical phenomenon. The applications of the rank-size rule are growing and leading to interesting questions.

Fungisai Nota

See also **Primate Cities**; **Urban Geography**; **Urban Hierarchy**; **Urbanization**



Further Readings

- Gan, L., Li, D., & Song, S. (2006). Is Zipf's law spurious in explaining city-size distributions? *Economic Letters*, 92, 256–262.
- Krugman, P. (1995). *Development, geography, and economic theory*. Cambridge: MIT Press.
- Rosen, K., & Resnick, M. (1980). The size distribution of cities: An explanation of the Pareto law and primacy. *Journal of Urban Economics*, 8, 165–186.
- Zipf, G. (1949). *Human behavior and the principles of last effort*. Cambridge, MA: Addison-Wesley.



RATZEL, FRIEDRICH (1844–1904)

Friedrich Ratzel was a famous German geographer, zoologist, and anthropologist. His extensive work on the links between the physical environment and society and the organic nature of the state (*Lebensraum*, meaning “living space”) laid the foundations for geopolitics and political geography.

Apprenticed as an apothecary, it was not until age 21 that Ratzel read zoological studies at Heidelberg University, which introduced him to Darwinism, as interpreted by his then mentor, Ernst Haeckel. After Heidelberg, Ratzel briefly worked as a travel correspondent and was awarded the Iron Cross after enlisting in the Baden Infantry during the Franco-German War (1870). Following the war, he studied with Moritz Wagner at Munich, whose Lamarckian views on species migration later influenced Ratzel's own anthropogeographic works. In 1886, he was awarded a professorship at Leipzig University, a position he held until his death in 1904 following a stroke.

Ratzel's writing was extensive and wide ranging; he was a rare geographer who published both human and physical works. His most notable works are *Anthropogeographie* (Vol. 1, 1882; Vol. 2, 1891) and *Politische Geographie* (1897). *Anthropogeographie* is a two-part study of the relationship between society and the physical environment, with many commentators seeing the first

volume as an application of geography to human history and the second as a description of the geographic distribution of humankind. These works were slow to reach Anglophone geographers, with their eventual dissemination largely credited to Ellen Churchill Semple, an early adopter of the Ratzelian program outside Germany. These works have been the subject of much debate as to their links to environmental determinism and discourses of race. This idea, however, owes more to Semple's interpretation of Ratzel's ideas rather than Ratzel's initial aims of his work.

Politische Geographie considered the state as an organism expanding into space to grow, thus states required *Lebensraum* to grow. This work draws on biogeographical and Lamarckian language relating to evolutionary theory and is considered as part of a wider volume of theory regarding social Darwinism. Karl Haushofer's Geopolitik School (between 1920 and the 1930s) later adopted elements of Ratzel's work, stressing the need for state expansion to create *Grossraum* (“big space”). This idea became politicized and was adopted by the National Socialist (Nazi) movement as justification for its expansionist policies. Ratzel never imagined *Lebensraum* as part of a Nazi agenda—a movement he distanced himself from—instead suggesting that *Grossraum* would be a site of cultural intermixing for the good of the state.

Nicholas Gray

See also **Anthropogeography; Environmental Determinism; Geopolitics; Haushofer, Karl; Human Geography, History of; Political Geography; Semple, Ellen Churchill; Social Darwinism**

Further Readings

- Bassin, M. (1987). Imperialism and the nation state in Friedrich Ratzel's political geography. *Progress in Human Geography*, 11, 473–495.
- Livingstone, D. (1992). *The geographical tradition: Episodes in the history of a contested enterprise*. Oxford, UK: Blackwell.
- Wanklyn, H. (1961). *Friedrich Ratzel: A biographical memoir and bibliography*. Cambridge, UK: Cambridge University Press.



REAL ESTATE, GEOGRAPHY AND

Real estate market analysis is executed using highly sophisticated geospatial analytic procedures, geospatial technology, and geospatial databases. The objective of geospatial real estate market analysis is to improve real estate decisions regarding all kinds of real property. Beneficiaries of real estate geography include individual real estate consumers, individual real estate investors, large Real Estate Investment Trusts (REITs) and pension funds, financial institutions, multibranch retailers, advisory firms, economic development agents, and others holding real estate assets.

Real estate market analysis is the “location, location, location” of real estate. Real estate market analysis is essentially “information arbitrage,” that is, the generation of small but important advantages in useful information about real estate opportunities (Thrall, 2002) and transacting on that knowledge. Geographic information systems technology, geospatial analysis, and geospatial data are core to the acquisition and utilization of information in the real estate market.

Geospatial technologies change real market analysis from a solely financial decision to a holistic one tied to location, submarkets, aggregate markets, and geographic interdependencies. Real estate market analysis is a process that culminates in a decision regarding property, as well as a prediction of future real estate trends across space and time. It involves taking past and current information and assessing current market conditions and predicting future market conditions for specific sites, submarkets, aggregate markets, and the range of other real estate asset categories.

A real estate geographer often proceeds geographically top-down, beginning at a very broad level, such as a nation or state/province, then interpreting geospatial data related to a smaller area, such as a specific county, then identifying submarkets, and last zeroing in on a set of specific sites for comparative evaluation.

Anyone involved in real property markets benefits from and likely currently uses real estate geography. Developers must understand factors such as rent levels, absorption, construction costs, underserved markets (gaps), and the cost

of capital to make intelligent decisions about when, where, and the “go” or “not go” development decision. Those who plan to lease space create geospatial due diligence documentation, including analysis of current market rents and the likely future trajectory of rents; the due diligence informs how much to spend on rent and how long the lease should be. Purchasers, both users and investors, create geospatial due diligence documentation, including an analysis of current market values and the likely future trajectory of market values; the geospatial due diligence is input into the financial analysis, which together informs how much to invest and the expected or desired holding period. The value that a real estate broker has to a buyer or seller is the value of their “information arbitrage.” Brokers need to have real-time access to geospatial information and geospatial analysis of the marketplace to be credible at marketing space and representing tenants. Government officials can benefit from the skills of the real estate geographer to anticipate infrastructure need that results from new development and to coordinate economic development initiatives.

Real estate geographers work with a development team. Financial analysts depend on the business geographer to provide information for the evaluation of the necessary return to investors in order to compensate for risk and opportunity cost. Other team members include those who evaluate the cost to either newly construct or replace the real estate asset within a given geographic submarket. The real estate geographer receives this information and then estimates the tipping points between investment and disinvestment—namely, when to go into the market and when to exit the market.

Geospatial Tests for Successful Real Estate Decisions

To ensure a positive outcome, all real estate decisions must have answers to five geospatial feasibility questions:

1. Does the forecasted supply and demand relationship for the trade area of the property asset indicate success?
2. Is the proposed project the “highest and best” (i.e., most profitable) use of a site?



3. Will the asset perform at levels for the time period necessary to achieve the required return on investment?
4. Considering risk and all other factors, is the expected performance of the proposed project greater than alternative project opportunities at the same or alternative locations?
5. What are the tipping points for profitability, and what conditions can bring about those tipping points?

The real estate geographer's geospatial feasibility model is shown in Figure 1, which shows the interdependence between geospatial market feasibility, geospatial location/site feasibility, and financial feasibility. Omnipresent in the background are the forces of political and social change, at the local to the global geographic scales. Financial feasibility analysis requires qualitative and quantitative data from the other two geospatial feasibilities to be executed. Interdependently, the three geospatially linked feasibilities are fed into the judgmental decision regarding the real estate asset, and this must be done in the context of risk emanating from political and social

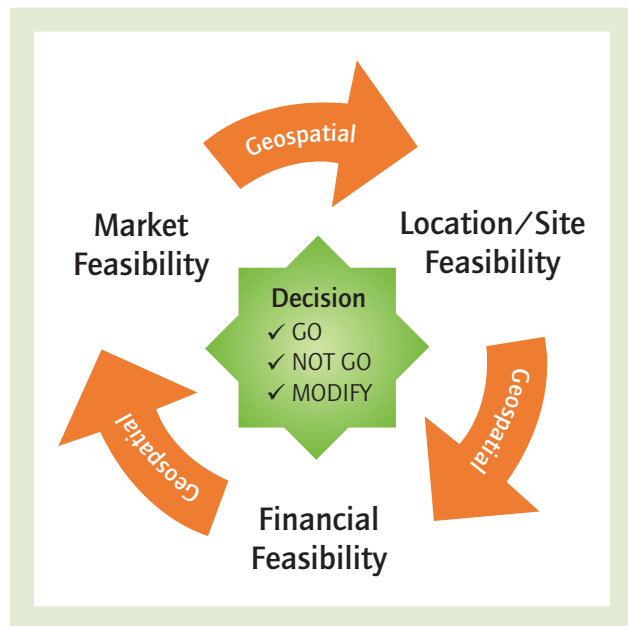


Figure 1 The geospatial feasibility model

Source: CCIM 102 *Real Estate Market Analysis*. Chicago: CCIM Press.

change. The geospatial feasibility model shows that business judgment is a process of integrating analyses of market feasibility, location/site feasibility, and financial feasibility. Because the business decision is geographically site specific, the supporting analysis must also be geographically site specific.

Geospatial due diligence documentation required to support the core business decisions to “go,” “not go,” and “modify” in Figure 1 include the following:

- Calculation of the trade area, the submarket, and the aggregate market
- Calculation of existing competitive supply within the relevant geography and relevant time period
- Estimation of future competitive supply known as “the pipeline” within the relevant geography and relevant time period
- Estimation of demand for the particular real estate asset, at the specific location for the current and the relevant future time period
- Estimation of the demand and supply gap for the real estate asset class within the relevant geography over the relevant time period
- Evaluation of risk arising from geopolitical and geosocial issues

If projected demand for the particular type of real estate within the relevant geographic submarket exceeds the total supply, then a gap is identified and a profit opportunity for investors may exist. The real estate geographer's analysis of market feasibility might then indicate support for the proposed development. This dynamic iterative process is shown in Figure 2.

Financial feasibility depends on the magnitude of profit opportunity. Here, the site-specific analysis becomes integrated with national and international financial markets. Also, the profit opportunity is accompanied by a level of risk that diminishes the expected return. Investors must be convinced that they will receive an above “tipping point” expected return. Hence, the financial feasibility component and the geospatial components are necessarily interdependent, each feeding back on the other and each necessary for the business decision. The site-specific development decision is

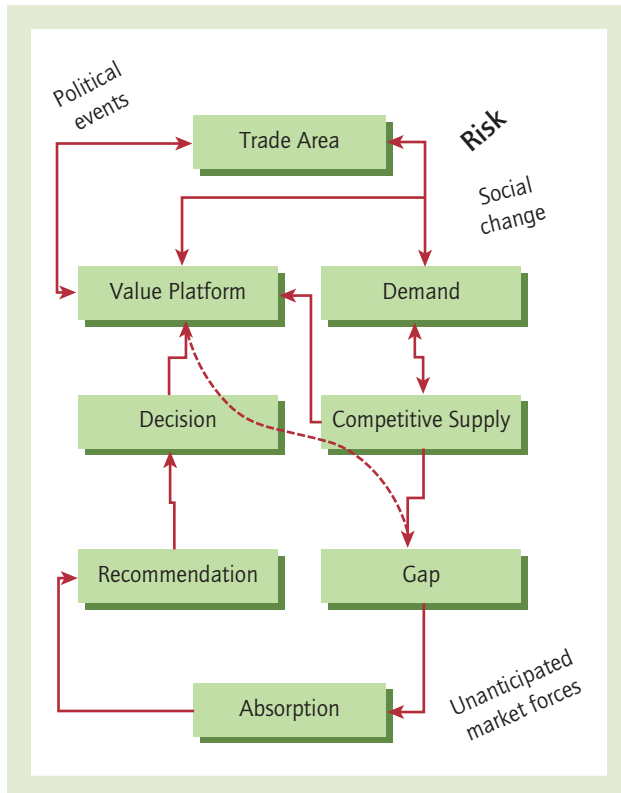


Figure 2 Dynamic iterative process of real estate geography. Real estate change involves a series of feedback loops between perceptions, social conditions, and risk.

Source: CCIM 102 *Real Estate Market Analysis*. Chicago: CCIM Press.

therefore inseparably linked to financial markets geographically remote from the development.

Conclusion

The real estate geographer creates due diligence documentation, and based on that documentation, he or she either recommends decisions or makes judgment regarding questions such as the following:

Where are new projects likely to emerge, and what effect could they have on investment decisions?

Which submarkets are most defensive from the perspective of supply and demand balance?

Where are the best opportunities, considering risk, for the most profitable investment?

Where are the opportunities within mature, emerging, or active markets for specific product types? Where are the attractive market niches?

What specific locations and which real estate asset types are likely to experience the greatest level of appreciation and/or be the most resilient if the market turns?

The real estate decision must satisfy conditions of the “geospatial feasibilities”: geospatial market feasibility and geospatial location/site feasibility. The real estate decision must also satisfy conditions of financial feasibility. Evaluation of financial feasibility depends on both the input of the real estate geographer and the input of financial data arising from markets geographically remote from the project site. Omnipresent in the background is the consideration for risk from the tumults of geopolitical and geosocial interaction with the real estate asset. In these ways, the real estate geographer brings to the business decision the “location, location, location” component of real estate, and “information arbitrage.”

Grant Thrall

See also **Applied Geography; Business Geography; Business Models for Geographic Information Systems; Geographic Information Systems; Housing and Housing Markets; Urban Spatial Structure**

Further Readings

Thrall, G. (2002). *Business geography and new real estate market analysis*. London: Oxford University Press.



REALISM

Realism is a philosophy that understands the world as relational, causality as contingent, and knowledge as socially produced. It gained prominence in geography during the 1980s as an analytical framework for thinking about and “practicing” both social science (critical realism) and natural science (transcendental realism). This distinction between the social and natural sciences



is inherent to a realist separation between natural and social “kinds”: Society is recognized as an open system that can never replicate the closed conditions of a laboratory, and institutions and actors are understood to be in a constant state of flux as compared with the more intransitive physical phenomena of the natural world. This is consonant with a realist ontology, which posits the existence of a reality outside human consciousness that is independent of the social construction of nature. As an epistemology, realism asserts that we can actually know something about this world beyond our cognition of it.

To “know” something about the world in the realist sense is to explain phenomena—both physical and social—in terms of their causality. Realism, however, rejects the conflation of explanation with prediction under logical positivism, which explains phenomena in terms of the repeatability and replicability of experimental results. In contrast, realism maintains that explanation warrants an understanding of the structures that allow things—events and phenomena—to happen. Structures are the elements internal to a phenomenon that demonstrate, or have inherent susceptibilities toward, particular kinds of “behavior” or action. Causal powers are enacted and expressed through the mechanisms of a structure. The realization or activation of this autonomous force, however, depends on the circumstances or the context in which things occur.

Realism explains how things happen by analytically separating out these mechanisms of causality. There are two kinds of relations between phenomena and their generative causes: (1) necessary and (2) contingent. Necessary conditions are the internal properties of a relation, wherein the event or phenomena observed cannot “be” or occur as essentially that which “it is” in the absence of a particular relation. For instance, a “slave” can only be a slave in relation to a “master.” For a mechanism to be causal, it must be a necessary condition for a phenomenon. Contingent conditions are the external properties of a relation or coincidences of coexistence. They describe the possibility for things to happen in terms of both the properties of phenomena and the circumstances of context. Andrew Sayer provides the example of gunpowder: Gunpowder has certain properties, such as the ability to

explode; explosion, however, depends on a spark to cause that explosion.

Mechanisms and structures are not always empirically discernible and must therefore be elucidated via rational abstraction. This holds in particular for causality in the social world, where the mechanisms that operate are both myriad and often unobservable. Abstraction involves the theoretical identification and conceptual isolation of the essential features or salient attributes of an event or phenomenon on the basis of its relations with, as opposed to similarities to, other entities. Abstraction is the basis for concrete research, which involves the “testing” of abstraction in the real world via empirical study to assess the “fit” or explanatory power of those abstractions. Empirical evidence may then lead to an adjustment of the abstraction such that the conceptualization yields a consistent picture of the world. This is an iterative process as it is through repeated abstraction—and grounding in empirics—that the difference between necessary and contingent conditions for causation can be elicited.

In the natural sciences, abstraction seeks to eke out the causal mechanisms generative of the observed events of scientific experiments. This emphasis on the causal contingency of scientific phenomena constitutes a rethinking of positivistic approaches to science, which involve the generalization of relations among empirical events, thereby failing to provide an account of causation by considering outcomes of experimentation as sufficient for cause.

In the social sciences, realism seeks to explain causality in terms of the internal relations between agency and structure, as in structuration theory. Realism maintains that there is no constant relating causes to events in the social world because social phenomena are unbounded and the effects produced by any one combination of relations will produce radically different results at any one time. The ways in which structures and their inherent properties intersect with other structures and human actors, however, create complex networks of interconnectivity that influence how people and other institutions act in society. The ability of a person to act—their agency—is often tied to their relations to other actors and structures such as social institutions. These structures are themselves simultaneously the outcomes of interrelations between other structures and agency.



Realism thus addresses how we come to know how structure and agency operate. Whereas structuration represented a deepening of Marxism by acknowledging both structure and agency, realism provided an analytical framework for integrating structure and agency in human geographic analysis. In so doing, realism relegated the role of “science” in geographic inquiry by allowing for the possibility of an emancipatory social science in acknowledging a material ground in which to enact meaningful social change.

In acknowledging that empirical observation is the fundamental way in which structures are discovered, realism moved geography away from the notion that theory alone can serve as the basis for explanation by clarifying the need for both theory and empirics in its insistence on theoretically informed concrete research. Most important, realism elevated the position of geography in the social sciences by arguing that structures of social relations are indelibly bound up with their spatial configuration. Space is central to this configuration because it is a contingent circumstance: “Things” may or may not be realized depending on *where* (and when) they occur. Structures moreover do not exist independently of, or somehow prior to, space: They are ontologically inseparable. In geography, this manifests itself particularly as a concern with economic and urban processes, giving rise to localities research in the 1980s. Its emphasis on analysis, however, opened realism to critiquing on the basis that it was blind to the politics of representation by postmodernist and poststructuralist frameworks, which privileged description over abstraction.

Agnieszka Leszczynski

See also Empiricism; Epistemology; Locality; Logical Positivism; Marxism; Geography and; Ontology; Postmodernism; Poststructuralism; Structuralism; Structuration Theory

Further Readings

- Bhaskar, R. (1975). *A realist theory of science*. Leeds, UK: Leeds Books.
- Niiniluoto, I. (1999). *Critical scientific realism*. New York: Oxford University Press.

Sayer, A. (1984). *Method in social science: A realist approach*. London: Hutchinson.

Sayer, A. (2000). *Realism and social science*. London: Sage.

Yeung, H. (1997). Critical realism and realist research in human geography: A method or a philosophy in search of a method? *Progress in Human Geography*, 21, 51–74.

RECLUS, ÉLISÉE (1830–1905)

Élisée Reclus was an influential 19th-century geographer, even though he did not hold an official university position until late in his career. He was widely recognized for his scholarly writings on anarchism and geography, which informed his political activism.

His revolutionary mien reflects diverse influences. He was born into a large family in the Gironde Département of southwestern France. His father served as a Protestant pastor in a rural culture dominated by Catholicism. He eventually abandoned organized religion, but he retained a missionary zeal for political dissent and social equality, inculcated in him by his family. His formal university training included stints at several Protestant religious schools in France and Germany. He also attended lectures at the University of Berlin given by the celebrated German geographer, Karl Ritter. Events in the wider world also affected his intellectual development. He was a political activist, vocally protesting the 1851 coup d'état by Louis-Napoleon. Fearing reprisal, he fled France, eventually traveling to the United States, where he settled in Louisiana. The idealized notion he had of Southern plantation culture was quickly dispelled. He was horrified by American slavery, which he viewed as just one more instance of the injustice of capitalism.

By the 1860s, Reclus had returned to France and embarked on a prolific publishing career. His most notable works include the 19-volume *Géographie Universelle* (1876–1894) and the 6-volume *L'Homme et la Terre* (1905–1908), published posthumously. He combined his interest in geography and egalitarianism with ideas from Karl Marx, Pierre Joseph Proudhon, and Michael



Bakunin. Reclus, like his contemporary Peter Kropotkin, was concerned about the social inequality wrought by capitalism and statism. In response, Reclus advocated a society based on decentralized communities that embraced principles of cooperation, self-determination, and egalitarianism—including gender and racial equality. More than Kropotkin or other anarchist geographers, Reclus urged communities to coexist with nature rather than to dominate it. He was not afraid to put his intellectual beliefs into practice. For example, he participated in the 1871 Paris Commune, which ultimately led to his expulsion from France.

Reclus had a lasting impact on geography and planning. His regional approach influenced later geographers such as Vidal de la Blache. Reclus also inspired Ebenezer Howard's Garden City movement and Patrick Geddes's decentralized regional planning. More recently, French geographers used the acronym RECLUS (*Réseau d'Etudes des Changements dans les Localizations et les Unités Spatiales* [Network Studies of Changes in the Localizations and Spatial Units]) to describe research initiatives focused on localities. One hundred years after his death, Reclus remains a vital figure in the field of geography.

Christopher D. Merrett

See also **Anarchism and Geography; Human Geography, History of; Justice, Geography of; Kropotkin, Peter**

Further Readings

Dunbar, G. (1978). *Élisée Reclus: Historian of nature*. North Haven, CT: Archon Books.

Fleming, M. (1988). *The geography of freedom: The odyssey of Élisée Reclus*. Montreal, Quebec, Canada: Black Rose Books.



RECYCLING OF MUNICIPAL SOLID WASTE

The term *recycling* has become commonplace in the lexicon of environmentalists since the so-called environmental crisis of the 1960s and early 1970s. Indeed, recycling is commonly associated

with a process whereby materials are remade into the same or different products. This process needs to be distinguished from a plethora of other terms such as *waste reduction* or *minimization* (the process of actively seeking to reduce waste by not purchasing or using materials in the first place), *reuse* (the use of a product or material for the same or other purpose without a change to the material itself), and the rise in charitable giving, which is a formalized system of reusing materials. This entry explores recycling by examining both its cultural-historical context and the current theoretical and policy-driven research being undertaken by geographers.

In discussing recycling, caution should be exercised in the ways in which researchers approach the notion of *waste*, which is largely a term that has developed in industrial and postindustrial societies, where the economics of resource use are such that materials can be “wasted.” Accordingly, these everyday terms need to be placed within a cultural and historical context. First, recycling is still undoubtedly a term applied more widely in Western industrialized societies, although the emerging economies of China and India are now beginning to grapple with the major issues of waste management at a range of scales. Second, recycling of waste has a far longer history than many people appreciate and one that was not conventionally linked to environmental concerns. These “traditional” forms of recycling have been focused on economic imperatives that have necessitated the innovative reuse or recycling of products, particularly in times of economic strain, such as the National Salvage Campaigns developed during and after World War II in Britain. Third, it should be noted that the contemporary social constructions of wastes are closely aligned to the conspicuous levels of consumption that emerged after World War II in Western countries and to the debates surrounding how people and governments address waste, which needs to be seen in the wider context of what we can term *sustainable consumption*.

This entry also explicitly considers contemporary notions of waste recycling and is focused on what is termed *municipal solid waste* (MSW). This refers to household and other commercial (nonindustrial) waste, commonly collected from individual households and retail and catering businesses.



The Wheelabrator waste-to-energy plant in Worcester, Massachusetts, converts 2,000 tons of garbage to electricity every day.

Source: Bill Eager, National Renewable Energy Laboratory.

Although both academic and policy-related attention has focused on MSW, it should be noted that for most countries, this is a relatively minor proportion of the total waste stream. For example, in England and Wales, the total amount of waste collected during 2004 was 335 million tons. Of this, only 9% was household waste.

In terms of the political imperatives for recycling of MSW, a range of initiatives has developed to encourage governments and individuals to recycle their waste. Perhaps the boldest international statement was that provided in Chapter 21 of the United Nations Agenda 21 document, where waste was highlighted as a key issue. From this international scale, both economic regions (e.g., the European Union) and national states have developed comprehensive policies for tackling the waste problem, finally percolating down to local authorities. This effort has been given greater impetus recently with concerns over the role played by methane gases emitted from waste landfill sites in

contributing to global climate change. For this reason, and also given the lack of suitable space for land-filling wastes and opposition to waste incineration, the key environmental issue for many local authorities and communities is how to respond to the growing amounts of MSW.

Research exploring recycling of MSW has generally been focused on the problems associated with low levels of recycling, particularly among households and individuals. This research has a long tradition and has been dominated by behavioral studies, mostly undertaken in North America by social and environmental psychologists. Researchers in this field have identified a range of sociostructural and psychologically based variables that influence participation in recycling schemes, which usually depends on the type of recycling activity concerned (e.g., curbside collection or “bring” sites) and the material involved. Indeed, in line with research on other environmental behaviors (e.g., energy or water conservation),



Cardboard recycling at Waste Management in Englewood, Colorado

Source: Warren Gretz, National Renewable Energy Laboratory.

evidence has emerged that different groups in society, with discrete lifestyle aspirations and behaviors, will react in different ways to recycling initiatives, with the potential for policymakers to target specific initiatives at specific groups through a form of social marketing.

However, emerging research agendas have also developed in recent years, which have either focused attention away from households or have explored alternative theoretical approaches to studying waste in the home environment. First, a growing body of research explores the relationships between MSW and government decision making, through exploring the governance structures and processes at the community, regional, and national scales. Second,

there has been increasing interest in the ways in which policies and practices of waste management differ within different contexts, notably in the workplace and in leisure and tourism spaces. This research has sought to develop existing theories of waste management and behavioral commitments to explore the potential differences between these contexts. Third, an emerging discourse in the social science of waste (or “rubbish”) is developing around a critique of the so-called throwaway society, in which the assumptions made by many social scientists that “waste” is related to a simple process of consumption are problematized. This emerging approach asserts that understanding the ways in which objects (or “things”) relate to social



relations and interactions is critical in appreciating the ways in which objects become used and wasted in the home.

Recycling therefore represents a politically and intellectually dynamic theme in geographical research and is a theme that will continue to develop as debates concerning resource management, climate change, and human responses to these challenges develop.

Stewart Barr

See also **Behavioral Geography; Consumption, Geographies of; Urban Solid Waste Management; Waste Incineration**

Further Readings

- Barr, S. (2002). *Household waste in social perspective*. Aldershot, UK: Ashgate.
- Cohen, M., & Murphy, J. (2001). *Exploring sustainable consumption*. London: Elsevier.
- Davies, A. R. (2008). *The geographies of garbage governance*. Aldershot, UK: Ashgate.
- Gregson, N., Metcalfe, A., & Crewe, L. (2007). Identity, mobility, and the throwaway society. *Environment and Planning D: Society and Space*, 25, 682–700.
- Riley, M. (2008). From salvage to recycling: New agendas or same old rubbish? *Area*, 40, 79–89.
- United Nations Conference on Environment and Development. (1992). *Agenda 21: The final communiqué* (chap. 21). Rio de Janeiro, Brazil: Author.



REDISTRICTING

A traditional focus for political geographers, particularly those interested in U.S. politics, is redistricting—the process of changing the boundaries of electoral districts to maintain equal populations. It is a critical part of the maintenance of constituency-based systems, particularly those with single-member districts. In international contexts, redistricting is often called boundary delimitation, and in Commonwealth countries, it is called redistribution. In

the United States, the term is sometimes used interchangeably with reapportionment, although the latter word more precisely refers to the redistribution of congressional seats among states following the decennial census. Manipulation of redistricting for electoral advantage is called *gerrymandering*.

Interest in redistricting stems from the fact that the way district boundaries are drawn can have a far-reaching impact on the distribution of political power. Placing large numbers of one group of voters in a single district (packing) or spreading them out over many districts (cracking) are just two of the strategies used by map drawers intent on tilting the balance in favor of one side or the other. Redistricting contributes to the levels of bias and responsiveness in single-member district systems. Bias, the degree to which the ratio of votes cast to seats won varies from 1:1, can undermine the basic fairness of an electoral system. The responsiveness of district-based systems, or their ability to translate temporal changes in voter preferences to changes in the distribution of seats, is constrained by the creation of safe districts and enhanced by competitive ones. The creation of safe districts—a usual result of gerrymandering—is often blamed in the United States for contributing to the polarization of the two main parties, as the party primarily becomes the key contestant and appeal to independents and crossover voters is devalued.

Redistricting in the United States

After the constitutional requirement for population equality, redistricting in the United States is driven by the intersecting interests of partisanship and race. It is also heavily litigated. Although a few states involve nonpartisan commissions in their redistricting process, most allow the party in control of the legislature and the governor's mansion to use the redistricting process to boost their political fortunes. The U.S. Supreme Court, while not completely closing the door on the possibility that a partisan gerrymander might violate the Constitution, has thus far refused to intervene. Judges have been much more active, however, in redistricting cases in which racial or ethnic minority groups are alleged to have been disadvantaged. The Voting Rights Act, originally passed in 1965 and renewed repeatedly by Congress since, allows the federal government and private plaintiffs to



This is the original cartoon of “The Gerry-Mander,” the political cartoon that led to the coining of the term *gerrymander*. The district depicted in the cartoon was created by the Massachusetts legislature to favor the incumbent Democratic-Republican party candidates of Governor Elbridge Gerry over the Federalists in 1812.

Source: Gilbert Stuart. Originally published in the *Boston Centinel*, 1812.

challenge state and local redistricting plans that they allege dilute the ability of minority voters to elect candidates of their choice. The result has been racial gerrymandering by those states with significant numbers of minority voters. Since the 1990s, racial gerrymandering has faced an increasingly skeptical Court, starting with the 1993 decision in *Shaw v. Reno*, in which a 5–4 majority struck down the formation of a serpentine North Carolina 12th congressional district, which for much of its length was no wider than the interstate highway it followed. The Court’s tolerance of the continued use of racial and ethnic data to draw redistricting plans remains very much in doubt.

Redistricting in the United Kingdom, Canada, and Australia

Reformers in the United States often look to the models used by the United Kingdom, Canada, and Australia, where line drawing has been turned over to commissions in an effort to reduce or eliminate partisan maneuvering. In Britain, four Boundary Commissions review and amend parliamentary constituency boundaries periodically, while in Canada, Electoral Boundaries Commissions in each province are responsible for changing district lines. In Australia, redistricting is performed by the Australian Election Commission and its state and territorial equivalents, and political interference is a crime.



Despite these steps, scholars have found significant bias even in such regulated nonpartisan processes. Geographers in Britain, for example, found that pro-Labour bias in the 2005 general election resulted from that party's strength in the smaller constituencies, helping it win 56.5% of the parliamentary seats with only 36.2% of the votes cast.

Scholarly Geographic Interest in Redistricting

A number of facets of redistricting and district design have particularly drawn the interest of geographers. The criteria, both formal and informal, used by map drawers and legislators in formulating their plans has been a constant focus, since criteria such as the compactness of districts (a focus in *Shaw*), district contiguity, and respect for communities of interest and existing political boundaries have obvious spatial qualities. Generally, geographers have been skeptical of oddly shaped districts, interpreting their presence as a sign of gerrymandering. This skepticism has been most pronounced among political cartographers; others have argued that this view privileges district aesthetics over racial or political fairness. In any case, an adequate quantitative measure of noncompactness has proven elusive.

Increasingly, redistricting has relied on geographic information systems (GIS) to handle the massive spatial, political, and demographic data used to draw new district plans. Particularly since the 1990s, the widespread use of GIS has led to the rapid creation of alternative district plans and fine-grained analysis of the impact of specific plans on political parties and racial and ethnic groups. Some have seen a pernicious impact, however, arguing that the improved technology has encouraged map drawers to ignore the existing political boundaries and to refine the gerrymanders and led to the creation of the sort of oddly shaped districts that triggered Supreme Court censure and public disdain. Despite these fears, future rounds of redistricting will continue to rely heavily on GIS.

Toby Moore

See also **Democracy; Electoral Geography; Morrill, Richard; Political Geography**

Further Readings

- Monmonier, M. (2001). *Bushmanders and Bullwinkles: How politicians manipulate electronic maps and census data to win elections*. Chicago: University of Chicago Press.
- Morrill, R. (1981). *Political redistricting and geographic theory*. Washington, DC: Association of American Geographers.
- Rossiter, D., Johnston, R., & Pattie, C. (1997). Estimating the partisan impact of redistricting in Great Britain. *British Journal of Political Science*, 27, 299–331.
- Shaw v. Reno, 509 U.S. 630 (1993).



REFUGEES

The concept of a refugee is an inherently geographical one, a barometer of political instability and the embodiment of forced migration. In current usage, the term has two main meanings; one is colloquial and often political, while the other is legal. In the wake of the humanitarian disaster that emerged after Hurricane Katrina hit the southern coast of the United States in August 2005, the media called those Americans huddled on the rooftops of their homes awaiting help and people who had sought shelter in the local sports stadium “refugees.” Many refused the term, saying that they did not want to be racialized as poor, African, or other. Yet others defended the term as appropriate, saying that the Bush administration was neither able nor willing to assist and protect its own citizens in this time of need. In both cases, the term was politicized for specific reasons, yet in legal terms, the survivors of Hurricane Katrina were not legal refugees but rather internally displaced persons. Likewise, references are made to “environmental refugees” affected by global warming or natural disasters.

The legal meaning of *refugee* is more straightforward; it is rooted in the Westphalian state system in which citizens, or nationals, belong to sovereign states that provide protection to them. Refugees are seen, then, as a kind of aberration to these norms of statehood. The Protestant



Huguenots who fled France under the rule of Louis XIV in 1685 are thought to be the first modern refugees. The French king revoked protection for the Huguenots to worship their religion without persecution from the state, which led to their displacement.

According to international law, specifically the 1951 Convention Relating to the Status of Refugees, a refugee is any person who

as a result of events occurring before 1 January 1951 and owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his [*sic*] nationality and is unable or, owing to such fear, is unwilling to avail himself of the protection of that country; or who, not having a nationality and being outside the country of his former habitual residence as a result of such events, is unable or, owing to such fear, is unwilling to return to it.

One of the major tenets of refugee law, then, is the principle of *nonrefoulement*—that is, a refugee will not be returned to her or his country by force (*refoulement*).

Refugees fall under the rubric of international human rights law as well as refugee law, though as Hannah Arendt noted after World War II, the actual protection afforded by such rights was and remains questionable. In 1966, two legally binding human rights instruments were created to protect civil and political rights, on the one hand, and economic, social, and cultural rights, on the other. The International Covenant on Civil and Political Rights most closely expresses the emphasis of the Convention. It ensures respect for democratic principles and nondiscrimination. The Covenant on Economic, Social, and Cultural Rights includes provisions that are more applicable to developing countries than to the highly industrialized ones, such as the right to food, shelter, and basic medical and educational services.

Despite the fact that 144 states were party to the 1951 Convention or its 1967 Protocol in 2007, the definition of refugee remains both explicitly and implicitly Eurocentric. The Refugee Convention demarcated geographical and historical limits: It applied to refugees in Europe displaced by events that occurred prior to 1951. The

Convention's definition of refugee is spatially coded as European. Substantively, its emphasis on persecution based on civil and political status as grounds for refugee status expresses the particular ideological debates of post-World War II European politics, particularly the perceived threats of communism and another Holocaust. The 1967 Protocol, relating to the status of refugees, amended the 1951 Convention. While it rescinded the spatial and temporal restrictions of the Convention by lifting the European-centered, pre-1951 stipulations, it merely created equal access for all member nations to a legal instrument that remained substantively Eurocentric in focus.

Two correctives to the Eurocentrism of the 1951 Convention and 1967 Protocol are worth noting. First, the 1969 Organization of African Unity (OAU) Convention Governing the Specific Aspects of Refugee Problems in Africa not only broadened but also reformulated the definition of refugee. It included the 1951 Convention definition but added the provision that

the term refugee shall also apply to every person who, owing to external aggression, occupation, foreign domination or events seriously disturbing public order in either part or the whole of his [*sic*] country or origin or nationality, is compelled to leave his place of habitual residence in order to seek refuge in another place outside his country of origin or nationality. (Article 1.2)

As a legal convention, this provision recognized that histories of colonialism were themselves the basis of conflict and displacement, regardless of the persecution element. Second, in 1984, the Cartagena Declaration on Refugees was adopted by 10 Latin American states. Like the OAU Convention, it represents a regional approach to recognize and improve on the inadequacy of the Convention definition. The definition derived from the Cartagena Declaration goes further than that of the Convention to include claims based on internal conflicts and massive violations of human rights and the idea of group designation. However, as a declaration and not law, it is not binding.

Geographers today have argued that legal definitions and protections afforded to refugees through the international protection regime are increasingly irrelevant as many of the signatories



In this October 22, 2009, photo, two residents of the State House settlement in Hargeisa in Northwest Somalia walk amid makeshift shelters housing refugees displaced by civil war. The conflict in South and Central Somalia is forcing Somalis to flee northward with their children to safety—a perilous weeklong journey by truck that exposes them to armed gangs that assault them sexually and deprive them of their last few possessions. The northern regions of Puntland and Somaliland, with their relative political stability, attract tens of thousands of the displaced, depleting still further the scant resources of sometimes unwelcoming local communities.

Source: Roberto Schmidt/AFP/Getty Images.

to the Convention and Protocol in the global North seek to prevent all uninvited migrants, including asylum seekers, from entering their territory. Some have called the use of geographical tactics of exclusion to preclude seeking asylum as *neorefoulement*. If would-be refugees cannot make asylum claims, international laws governing their eligibility become irrelevant.

Such geopolitics of externalization efforts by countries in the global North to manage refugees in the global South where possible may well contribute to a growing issue: protracted refugee situations. The United Nations High Commissioner for Refugees (UNHCR, 2006) defines a protracted refugee situation as one in which refugees find themselves in a long-lasting and intractable state

of limbo: “Their lives may not be at risk, but their basic rights and essential economic, social and psychological needs remain unfulfilled after years in exile” (p. 106). Sometimes refugees live in camps for years on end; *refugee warehousing* is another term used to describe the plight of those waiting in confined quarters (U.S. Committee for Refugees and Immigrants [USCRI], 2007). The USCRI reported that there were 8.8 million people in protracted refugee situations at the end of 2006. The average waiting time for refugees to obtain a durable solution has increased from 9 yrs. (years) in 1993 to 17 yrs. in 2003.

Geographers and anthropologists have also analyzed the politics of representation among refugees. Humanitarian actors who respond to



their plight often render them as objects of camp management or as populations where disorder is ordered. Malkki (1996) argues that “history tends to get leached out of figure of the refugee, as imagined by their administrators” (p. 385). Malkki adds that these standardizing discursive and representational forms that have the tendency to silence people categorized as “refugees” have made their way into the media that report on forced migration.

Jennifer Hyndman

See also **Citizenship; Diaspora; Human Rights, Geography and; Immigration; Migration**

Further Readings

- Hathaway, J. (1991). *The law of refugee status*. Vancouver, British Columbia, Canada: Butterworths.
- Holborn, L. (1975). *Refugees: A problem of our time: The work of UNHCR, 1951–72*. Methuen, NJ: Scarecrow Press.
- Hyndman, J. (2000). *Managing displacement: Refugees and the politics of humanitarianism*. Minneapolis: Minnesota University Press.
- Malkki, L. (1996). Speechless emissaries: Refugees, humanitarianism, and dehistoricization. *Cultural Anthropology*, 11, 377–404.
- United Nations High Commissioner for Refugees. (2006). *State of the world's refugees*. Oxford, UK: Oxford University Press.
- U.S. Committee for Refugees and Immigrants. (2007). *World refugee survey 2007*. Washington, DC: Author.



REGIONAL ECONOMIC DEVELOPMENT

Regional economic development (RED) refers to changes in the economic structure of a region that increase the range and value of economic activity conducted within it. The geographic scale generally refers to areas circumscribed by the regular home and work locations of most people. This is

usually a territory smaller than the nation-state; in poorer, rural cultures it may be the village, while in wealthy urban cultures it may be an extended metropolitan area.

To take an 18th-century liberal view of political economy, the purpose of an economy and of economic development is to improve people's material well-being where they live. Since the employment, education, and health of people depend on the opportunities available in their regions, RED and its sustainability across generations are important processes. Individuals, families, and governments have huge psychological, social, and economic investments in local regions: a sense of history and shared future, personal wealth in the form of real estate, and investment in the form of physical infrastructure. These are powerful forces that motivate governments at all levels toward a concern for regional economies.

What allows for sustainable employment of the people, land, and resources of a region? Given the context of a subnational region, capital, people, products, and ideas can move among regions, so that the question may be rephrased as follows: What situations can lead to the continued development of a region's capital, labor, and resources to increase its level of economic activity? This entry explores three requisites: (1) capital to provide the power to organize resources, infrastructure, and labor before they realize a return; (2) competencies to organize these factors in ways that sustain demand and returns to capital; and (3) infrastructure and institutional arrangements that support capital investment and individuals' and organizations' competencies.

Attracting and Retaining Capital

Capitalism is motivated by the demand for ever higher returns to the owners of capital, and those returns are generally sought through increasing the technical and social division of labor—across larger scales—by establishing divisions among social groups (e.g., women, minorities, immigrants), so that ever newer groups can be exploited as they are given elements of production, to move some operations to places where labor is cheaper, or by taking over (or making



more use of) other firms or other sectors. Capitalist accumulation requires some displacement of costs outside what we might call the formal accounting system: to geographic spaces outside the system (e.g., other countries), to members of the family (generally women and children) as unpaid labor, to parts of the natural world that have not been valorized (e.g., the creation of value from little-known species or from human genes), to particular social groups, or to future generations.

Under the neoliberalism that has taken hold over much of the world, regions attract capital based on the following:

1. New frontiers for exploitation are present—unlimited land, labor, or resources and the government subsidy of capital investment and corporate operations. For example, the rapid growth of investment in many Chinese cities, which have become the center for the world's consumer goods manufacturing, is motivated in part by the influx of workers from inland, rural areas, and the returns are earned in part from externalizing the costs onto the physical environment at a dizzying rate.
2. The premium paid for local availability of scarce resources, such as extracted natural resources, an excellent harbor, or highly specialized labor, reduces the mobility of capital to be invested to gain a return from those resources.
3. More subtly, capital investment is attracted toward the regular creation of new ideas and ways of operating that are unique to the local region. This local knowledge creates new (and therefore monopolized) products or that which uniquely increases the returns to operating in that region.

One can name other sources of capital attraction. Some, such as the investment in booming retirement communities in warm, coastal areas of the United States, can be traced to (1) above: available land, attractive climate, and government subsidy in the form of low taxes and limited public support for infrastructure such as schools. Rapidly growing regions can then benefit from a deepening division of labor, through which

specialized services are established to increase the profitability of capital investment in enterprises that can avail themselves of these services. Finally, in some contexts, capital is invested by government fiat. In the United States, military bases exemplify this limited government deployment of capital resources.

Knowledge and Competencies as Sources of Advantage

Much recent writing has argued that useful knowledge is a linchpin of capital productivity and that despite the seeming mobility of “knowledge,” some of its development and use is tied to particular places. “Organizational competence” is the ability of an organization to make use of information to improve its operations. This concept suggests a distinction among information (“data”), knowledge (understanding processes), and competence. Individuals make use of prior education, training, and experience to turn tasks, information, and experience into knowledge—whether their tasks entail product development, process improvement, shop floor production or service, marketing, or supply chain management. Individuals receive information all day long and have to create useful knowledge from their experiments and experiences. However, organizations or even regions can have competencies distinct from (and less mobile than) the knowledge of the individuals within those organizations.

Organizations gain competencies beyond the knowledge of individuals through the division of labor—the specialization of tasks and knowledge so that no individual possesses the ability of the whole. In addition to the division of information and knowledge, the more general process of creating organizational practices and procedures reduces the dependence of the organization on individuals, except insofar as individuals develop tacit ways of working with—or around—each other. Defined this way, organizational competence is *sine qua non* for a successful organization, which must manage its resources in response to varying characteristics and changes in its suppliers, buyers, regulations, and so on. However, as technological, marketing,



and financial sophistication become widespread, capitalists who want to see more than a bare-minimum return need to find new competencies: new products, cheaper production methods and locations, and new ways of managing supply chains and product distribution.

Organizations can increase this type of competence through concerted efforts to integrate knowledge among their members; to communicate codified and tacit knowledge among organizations; to work with public sector sources of education, training, and knowledge production; and to develop intermediaries that broker knowledge and skills among organizations. Through the agglomeration of people and institutions, some of these competence-building activities result in localized and sustainable advantages of particular regions for particular activities.

Institutions and Infrastructure

Individuals, societies, and organizations can undertake a range of actions to develop and use new knowledge and competencies:

Governments spend funds on education, research, and development and design incentives for individuals and organizations to engage in knowledge generation. Governments also lay the regulatory framework for firms' ability to lay claim to intellectual property, including, in some settings, knowledge originating in the public or common realm.

Firms (and other formal organizations) can gain knowledge and expertise from outside: through market purchases of equipment or specialized services, through observation and imitation, through hiring new people, or through formal collaborations.

Firms can work internally on technical development; systems improvement in finance, marketing, and procurement; and generating systems for continuous process monitoring and improvement. Despite the cost of such internal development, this ability to develop and deploy new systems, and to assess their value, is key to sustainable knowledge and competences.

Individuals within the organization gain capability

and confidence, and the resultant knowledge is unique to the organization.

Yet capital, competencies, and individuals remain more geographically mobile than a region itself. What sources of regional advantage tend to attract and bind capital investment? Table 1 offers a simple answer to this question. Private capital (or in a mixed economy, mobile capital whatever the source) is what's required for any large-scale development and employment of local resources. The last five rows describe geographically fixed assets of regions, important to sustain the economic development of knowledge-based activity.

RED policy has increasingly recognized that residents and institutions are the "stickiest" regional assets. Rather than chasing and subsidizing private capital investment, state, provincial, and local governments should attempt to draw residents into the labor force (through education, child care, transit), subsidize their occupational attainment and further training, provide high-quality physical infrastructure, and catalyze mixed-sector forums for information sharing about their human resource needs.

Conclusion

From a trade theory perspective, each region needs to develop comparative advantage in economic activities based on

- its unique configuration of resources—efficiency insists that these resources be used to their mutual advantage—and
- institutional arrangements (organizations; interorganizational formal institutions, rules, and public policies; and informal norms such as communication and cooperation), which influence the ability of individual agents to maximize the use of the region's resources.

In other words, it is necessary to identify regional assets that are relatively fixed and public investment and policies that support and improve those assets. Whether the resources are primarily natural and the activities are extractive or agricultural, or the resources are primarily human and the activities are new products and services, infrastructure, institutions, and organizational



<i>Asset or Source of Advantage</i>	<i>Mobility</i>	<i>Sustainable Across Generations?</i>	<i>Importance to Knowledge-Based Activity</i>
Public subsidy (tax breaks) ^a	Extreme ^b	Perhaps	Somewhat
Externalization of environmental costs	Extreme	No	Not very
Private capital	Extreme	Yes, so long as the investors receive high returns	Very
Inexpensive labor ^c	Moderate	So long as interregional wage differentials exist	Somewhat
Specialized labor	Moderate	Yes, so long as the public, the corporate, and/or the household sectors invest	Very
Sources of new knowledge	Moderate	Yes, so long as the public and/or the corporate sectors invest	Very
Specialized suppliers and services	Moderate	Yes	Very
Networks for communication and synergy of new knowledge	Moderate	Yes	Very
Public infrastructure	None	Yes, so long as the public sector continues to invest	Very

Table 1 Mobility, sustainability, and importance of regional assets for knowledge-based activity

Source: Author.

a. Implies externalization of costs onto households or more heavily taxed businesses.

b. Mobile in the sense that other regions can offer the same or better advantages by decision or fiat.

c. The result of migration from low-wage or rural settings, government discouragement of labor unions, lack of a binding minimum wage; implies externalization of costs onto the public sector, the household, or low-wage workers themselves.

competencies are required to attract and hold capital and mobile residents.

James W. Harrington Jr.

See also **Agglomeration Economies; Comparative Advantage; Competitive Advantage; Economic Geography; Economies of Scale; Export-Led Development; Export Processing Zones; Factors Affecting Location of Firms; Flexible Production; Globalization; Import Substitution Industrialization; Industrial Districts; Infrastructure; Innovation, Geography of; Knowledge, Geography of; Knowledge Spillovers; Learning Regions; Location Theory; Neoliberalism; Spatial Fix; Sustainable Development; Technological Change, Geography of; Trade; Uneven Development**

Further Readings

- Belussi, F., & Gottardi, G. (2000). Models of localised technological change. In F. Belussi & G. Gottardi (Eds.), *Evolutionary patterns of local industrial systems: Towards a cognitive approach to the industrial district* (pp. 13–47). Aldershot, UK: Ashgate.
- Carlsson, B., & Eliasson, G. (1994). The nature and importance of economic competence. *Industrial and Corporate Change*, 3, 687–711.
- Clarke, S., & Gaile, G. (1998). *The work of cities*. Minneapolis: University of Minnesota Press.
- Jessop, B. (2000). The state and the contradictions of the knowledge-driven economy. In J. Bryson,



- P. Daniels, N. Henry, & J. Pollard (Eds.), *Knowledge, space, economy* (pp. 63–78). London: Routledge.
- Markusen, A. (1996). Sticky places in slippery space: A typology of industrial districts. *Economic Geography*, 72, 293–313.
- Morgan, K. (1997). The learning region: Institutions, innovation and regional renewal. *Regional Studies*, 31, 491–503.
- Porter, M. (2000). Location, competition, and economic development: Local clusters in a global economy. *Economic Development Quarterly*, 14(1), 15–34.
- Sayer, A., & Walker, R. (1992). *The new social economy: Reworking the division of labor*. Cambridge, MA: Blackwell.
- Stabler, J. (1968). Exports and evolution: The process of regional change. *Land Economics*, 44(1), 11–23.



REGIONAL ENVIRONMENTAL PLANNING

Regional environmental planning can be either a statutory process or a less formal one, undertaken, in either case, by subnational scales of government to promote sustainable development within their jurisdiction. Planning regulations and procedures were formalized in developed countries during the 20th century as a means of controlling land use. Proposed changes to land use (e.g., building a road or constructing domestic or industrial premises) were made subject to a review process under the auspices of the local government and with opportunity for public participation. This was effectively a form of environmental governance, before either popular or institutional concern for the environment became commonplace. These procedures are still fundamental to land use regulation but have been enveloped in a complex multiscale framework designed to contribute more actively to the promotion of sustainable development. This entry focuses on the formal process of regional environmental planning, as seen in the European Union concept of spatial planning, using the practice of the United Kingdom as an example.

It briefly reviews other practices and relevant scholarly work.

Increasing interest in environmental issues since the 1970s has coincided with an era of enhanced governmental involvement in the promotion of economic development at the regional and local scales. Reconciling these interests, alongside social considerations (both the provision of essential services and spatial equity in the distribution of economic activities are seen as undesirable neighbors), is fundamental to the promotion of sustainable development. The concept of spatial planning, as institutionalized in the European Union (EU), was designed to accomplish this. Spatial planning is in part a matter of provision of services needed for existing and projected development (e.g., schools, transport, hospitals, energy generation, waste, minerals), recommending where within the jurisdiction of the plan relevant facilities should be located and also minimizing the impact of necessary development on the environment at both the site of development and beyond. Importantly, the various services should be considered in an integrated fashion—that is, the planning should involve cooperation both between different local authorities and also between different areas of responsibility, both within and between local authorities.

The “region” can vary in scale according to context from the subnational to multinational and might or might not be politically defined. The EU vision of spatial planning considers both supranational regions within the EU and subnational regions within the member states. In the United Kingdom, a subnational regional scale for planning was established with the creation of the Regional Assemblies. The presently recognized regions (devolved administrations and groups of preexisting local government units [i.e., county councils and unitary authorities] within England) were defined for the purposes of both economic development and regional planning by the creation of the Regional Development Agencies Act of 1998. Although presently subject to reorganization, the regional scale continues to be the level of governance at which spatial planning is based through the medium of the Regional Single Strategy. The latter involves the cooperation of multiple local authorities as well as nongovernmental organizations (Table 1) and forms the context within which more detailed planning occurs at



<i>Scale</i>	<i>Constituent Bodies</i>	<i>Relevant Function</i>	<i>Example: Planning</i>	<i>Example: Waste</i>
Supranational	European Union	Environmental protection and harmonization	Strategic Environmental Assessment Directive	Waste Framework Directive and Landfill Directive
National	National government	National regulations		
	Department of Communities and Local Government	Oversees planning policy	Planning policy statements and guidance	
	Infrastructure Planning Commission		Oversees applications for nationally significant infrastructure projects	
	Department for Environment Food and Rural Affairs	Oversees sustainable development, including environmental protection		Waste Strategy for England 2007
	Environment Agency	Consulted on plans/projects with potentially significant environmental impact		Regulates waste operators via environmental permitting regime
Regional	Local Authority Leaders' Boards; Government Office, Regional Development Agency; input from Local Authorities; Local Strategic Partnerships, regulatory bodies; industry, conservation bodies	Regional Single Strategy	Combined economic and environmental plan integrating multiple sectors (e.g., energy, transport, housing) and subject to strategic environmental assessment	
Local	Unitary authorities, county councils district/metropolitan councils	Local Development Framework: Plans (e.g., waste) subject to strategic environmental assessment	Review and decide on planning applications relating to specific projects	Waste collection and/or disposal
				Statutory targets to meet for recycling household waste;
Site specific	Public and/or private bodies	Proposing development covered by the above regulations/plans	Subject to environmental impact assessment and permitting	Individual waste facilities (e.g., energy from waste or recycling centers)

Table 1 Policy context of regional environmental planning in England

Source: Adapted from Deutz, P., Neighbour, G. B., & McGuire, M. A. (2010). Integrating sustainable resource management into product design: Sustainability as a functional requirement. In *Sustainable Development*, 18(6). DOI: 10.1002/sd.469.



the local authority level and for specific services. Regional and local authorities are required to undertake appraisals of the environmental impact of their plans under a Strategic Environmental Assessment (SEA) Directive. Proposals for specific developments (e.g., a wind energy farm or wastewater treatment facility) are then subjected to the more internationally widespread practice of environmental impact assessment.

Outside the EU, the process of regional environmental planning is less formalized and less integrated into the broader considerations of sustainable development. In the United States, for example, there is no national drive to promote an integrated approach to regional planning comparable with that in the EU. There are, however, ideas such as Smart Growth that promote consideration of the environment in North American regional and urban development. Regional environmental planning takes place with respect to specific issues, for example, air or water pollution control, or conservation, particularly in metropolitan regions.

There are several difficulties with environmental planning on a regional scale. Regions are not politically independent territories. Policy is mandated from both national and supranational levels, and delivery can be the responsibility of smaller-scale units of governance (Table 1). Furthermore, in areas of service provision where privatization has taken the responsibility for day-to-day operations out of the control of local authorities, the local or regional government has limited potential to bring about the developments it may consider advantageous. Additionally, public concerns about development that have long found a voice through the planning process are also raised by the prospects of developments (e.g., wind farms) that may be considered environmentally beneficial on a national scale.

Scholarly work on regional environmental planning takes many forms. One line of research investigates the governance structures associated with planning and the associated assessments. This includes work that links regional environmental planning with the concept of the “new regionalism” approach to economic development. Other work is directed toward providing insights and/or knowledge that would be, or could be, usefully applied to regional environmental planning. Such

work includes studies of sustainability indicators—quantitative measures by which planners and others can assess progress toward sustainability. Related to this is work investigating the application of geographic information system (GIS)–based modeling to regional environmental planning and management. Work is also in progress to tackle regional environmental planning from the point of view of limiting the impact of natural hazards.

Pauline Deutz

See also **Environmental Impact Assessment;** **Environmental Planning;** **Externalities;** **GIS in Environmental Management;** **Land Use Planning;** **Regional Governance;** **Smart Growth;** **Sustainable Development;** **Urban and Regional Development**

Further Readings

- Cowell, R., & Owens, S. (2006). Governing space: Planning reform and the politics of sustainability. *Environment and Planning C: Government and Policy*, 24, 403–421.
- Deutz, P., Neighbour, G. B., & McGuire, M. A. (2010). Integrating sustainable resource management into product design: Sustainability as a functional requirement. *Sustainable Development*, 18(6). DOI: 10.1002/sd.469.
- Peterson, A., McAlpine, C., Ward, D., & Rayner, S. (2007). New regionalism and nature conservation: Lessons from south east Queensland, Australia. *Landscape and Urban Planning*, 82, 132–144.
- Thorne, J. H., Huber, P. R., Girvetz, E. H., Quinn, J., & McCoy, M. C. (2009). Integration of regional mitigation assessment and conservation planning. *Ecology and Society*, 14(1), 47. Retrieved November 3, 2009, from www.ecologyandsociety.org/vol14/iss1/art47



REGIONAL GEOGRAPHY

In the popular conception of geography, the discipline is concerned with the study of regions and little else. Geographers have examined regions at a variety of spatial scales and from a diversity of conceptual perspectives. Regions have long been



a central means by which geographers organized data and made sense of the world's natural and social landscapes. Few topics have been more central to geography's history and disciplinary identity. Regions continue to form a mainstay of elementary geography pedagogy, and many geographers specialize in the analysis of particular regions, ranging from tiny places to entire cultural realms. Regions mean different things at different times and can be defined in different ways depending on the particular issue involved. Regions are important in structuring popular geographical imaginations as well as public and private economic strategies. While this topic may appear to be relatively free from controversy, in fact the use of regions and their philosophical significance has been the source of considerable debate. Indeed, regional geography, which has declined in significance since its heyday in the mid 20th century, continues to play an important part of the discipline, albeit one that jostles uneasily alongside other, less regionally oriented perspectives.

Classical Regional Geography

Since the Classical Age of Greece, regions have played a central role in geography as a means to collect, organize, and give meaning to spatial distributions. Many classical scholars, such as Ptolemy, wrote encyclopedic accounts that were largely regional descriptions of the known world. In the 17th century, Bernhard Varenius (1622–1650) wrote the *Geographia Generalis*, a volume that became a major textbook in Europe for the next 150 years and was translated into English by Newton. Varenius distinguished between *specific geography*, which was concerned with the unique character of places, and what he called *general geography*, which was concerned with universal laws.

In the 19th century, three figures loomed large in the formalization of regional geography. Carl Ritter (1779–1859) wrote the 19-volume *Erdkunde* (1818), a comprehensive world regional geography text, which emphasized the comparison and synthesis of facts through a regional approach, largely with religious goals in mind. Geography's purpose was to detect the holistic character of places. Comparative local studies

were to be the basis through which generalizations could be made. Ritter claimed to see evidence of divine plans in the world's geography, advocating a religious, teleological interpretation. Second, Paul Vidal de la Blache (1845–1918), widely seen as the founder of modern French geography, developed the notion of *genres de vie*, or local lifestyles, which celebrated the uniqueness of rural landscapes in the French *pays* (local, typically agrarian regions). Noting the variations across France in the face of a common climate, he maintained that culture, not nature, was primarily responsible, using this theme to bludgeon environmental determinism and introduce possibilism. Third, Alfred Hettner (1859–1941), in the Kantian tradition, defined geography in chorological terms, believing that the discipline's importance was maintained by its comprehensive, regional approach rather than its subject area and that synthesis was its greatest strength.

Areal Differentiation

The American version of regional geography reached its apex between the two World Wars with the ascent of this school of thought, variously labeled as areal differentiation, chorology, or regional description. The ascent of this view was to be found in the aftermath of environmental determinism, when the discipline's retreat from theory sharply differentiated it from other social sciences, which were then making great strides. Its embodiment is Richard Hartshorne (1899–1992) and his definitive landmark text *The Nature of Geography* (1939). Having studied under Hettner and thus heavily Kantian in outlook, Hartshorne made a variety of claims regarding regional geography as the definition of the discipline's core and claim to uniqueness within the academic division of labor. Geography was synthetic, like history, integrating the analysis of different phenomena as they were manifested in unique combinations in particular places. Regions allowed the analysis of both human and physical phenomena, transcending the growing schism between the two parts of the discipline. Because the complexity of the world is overwhelming, Hartshorne advocated the study of small regions with relatively little internal variation; accreting this into a mosaic that would



encompass larger areas. This view subscribed to a crude spatial determinism in which proximity came to stand for causality: Where things were was enough to ascertain their nature, and closer phenomena were more likely to be related than more distant ones. He well understood that regions are only tools and, in the vein of Kant, maintained that regions are only mental constructs—simplifications of the world the mind uses to impose order on the world.

Hartshorne considered regions to be essentially static and held little regard for the need to engage in the study of explanatory processes—that is, regional geography was to be only about appearances. This approach represented a spatialized version of the philosophy of empiricism—the assumption that facts and data are true or false without appeal to theory—with its roots in the British Enlightenment. In contrast, more recent approaches argue that all data are theory laden—that is, it is theory that informs us what facts are relevant to an issue at hand. There are no pure facts, as observations are always couched in terms of a theory: Observation requires interpretation, which requires theory in turn. Hartshornian chorology was the essence of inductive empiricism, and its Achilles heel was the inability to engage in abstraction.

American regional empiricism suffered a devastating set of setbacks in the 1950s as it was pushed aside by an increasingly assertive school of logical positivists. A famous paper by Fred Schaefer published in 1953 charged that Hartshorne's claim that geography alone studied the unique was naive, arrogant, and immature. All sciences face the problem of uniqueness, and explanation, as opposed to regional description, consisted of embedding the unique within a wider understanding of laws and causal processes. Schaefer opened the door to a heated debate about whether geography should be primarily concerned with the nomothetic—that is, the law seeking—or should be content with the idiographic (i.e., the unique). The rise of positivism saw the triumph of the nomothetic approach, and the discipline shifted from the study of all aspects of one place to one aspect of many places—a move that entailed a reorientation from the concrete to the abstract, from induction to deduction (i.e., an interest in theory and broad, abstract

principles), and from a concern with the specific to the pursuit of the universal. Ultimately, the demise of chorology saw the discipline change from a concern with regions without explanatory laws to one obsessed with laws devoid of regions. Some observers, such as Hart, maintained that regional geography nonetheless played an important role in minimizing armchair theorizing and in popularizing the discipline at large.

The New Regional Geography

In the 1980s, as postmodernism swept the field, geographers saw a renewed concern for regionalism, often called the localities school. Unlike the atheoretical, empiricist chorology of areal differentiation, this approach took theory seriously, embedding regions within wider understandings of capitalism, uneven development, and the spatial division of labor. Originally British in inspiration, it began with observations that ostensibly uniform processes such as deindustrialization occurred very differently in different places—that is, local contexts made a substantial difference to how that process unfolded. Doreen Massey used this line of thought to develop a geological metaphor of regional landscapes, in which their position within changing divisions of labor sedimented layer upon layer of investments on the landscape. Regions consist of a palimpsest unique to that place and reflecting their historical trajectory.

More broadly, the localities school implied that no social process unfolds in exactly the same way in different places. From the standpoint of the new localities school—*where* processes occur affects *how* they occur—causality and location are intertwined. This argument reflected the broader insertion of space into social theory in general and the mounting concern for a contextual social science. Such a line of thought dovetailed neatly with the growing popularity of views that emphasized the creative capacities of people and the contingency of social life. Localities were celebrated as spaces where the rich world of everyday life plays out. Thus, under chorology, the region was fetishized; under logical positivism, the region was dismissed; and under postmodernism, the region is celebrated as a source of difference in contrast to the smothering homogeneity of globalization.



The recognition of local uniqueness has become widespread throughout human geography today, and the region has, ironically, recaptured some of its time-honored status. Typically, such approaches tend to be multiscale in focus, invoking social processes at a variety of spatial scales. For example, regional geography today would do more than say that all places are embedded in a global economy: Rather than a simple process of telescoping from the global to the local, the global and the local should be seen as intertwined, or global in nature.

In sum, regions have played a central role in the history of geography as a discipline. Although geographers have long since jettisoned simplistic regional descriptions in favor of far more theoretically sophisticated views that seek to integrate broad processes with local contexts, regions continue to interest many scholars and students. As arenas in which diverse processes are seen to coexist and interact, regional geography will continue to shape the field's intellectual trajectory as well as popular interest in matters geographical.

Barney Warf

See also **Chorology; Empiricism; Hartshorne, Richard; Human Geography, History of; Idiographic; Locality; Logical Positivism; Nomothetic; Place; Quantitative Revolution; Regional Economic Development; Regional Science; Regions and Regionalism; Territory**

Further Readings

- Berry, B. (1964). Approaches to regional analysis: A synthesis. *Annals of the Association of American Geographers*, 54, 2–11.
- Hart, J. (1982). The highest form of the geographer's art. *Annals of the Association of American Geographers*, 72, 1–29.
- Hartshorne, R. (1939). *The nature of geography*. Washington, DC: Association of American Geographers.
- Lewis, M., & Wigen, K. (1997). *The myth of continents*. Berkeley: University of California Press.
- Massey, D. (1984). *Spatial divisions of labor: Social structures and the geography of production*. New York: Methuen.

Sack, R. (1974). Chorology and spatial analysis. *Annals of the Association of American Geographers*, 64, 439–452.

Schaefer, F. K. (1953). Exceptionalism in geography: A methodological examination. *Annals of the Association of American Geographers*, 43, 226–229.

Warf, B. (1993). Post-modernism and the localities debate: Ontological questions and epistemological implications. *Tijdschrift voor economische en sociale geografie*, 84, 162–168.



REGIONAL GOVERNANCE

The concept of regional governance refers to a mode of self-regulation that incorporates both public and private actors' strategic planning and regional development initiatives. The approach is linked to the late modern transformation of statehood and can be understood as a reaction to state and municipal deficits in governing. Although the term has its origins in Britain, the phenomenon can be observed in many other Western countries, such as the United States and Germany. For this reason, it is appropriate for geographical research to focus on international comparisons of regional development strategies, evolutionary pathways, and conflicts.

Criteria of Regional Governance

In recent decades, large-scale societal changes have radically undermined the idea of a strongly intervening nation-state. As the nation-state has been gradually displaced as the center of regulation, new centers of power have emerged at the supranational and subnational levels. The concept of regional governance denotes the shift of governance to the subnational level. It emerges where national policies lack suitable implementation and where specific regional institutions are necessary for developmental solutions. In addition, regional governance emerges where problems exceed their local borders and where conventional modes of regulation turn out to be not adequate.

Regional governance must be analytically distinguished from regional government. While the



latter refers to state institutions, formal rules, and practices to administrate political subdivisions, regional governance relates to a mode of self-regulation in which regional problems are treated by cooperative actors operating at a regional level. This view incorporates both public and private actors into a pluralistic network that results in “multi-actor level play.”

Since regional governance involves actors from different political subsystems, the strategy for encouraging cooperation has been changed. Besides intrasystemic relations (e.g., intermunicipal cooperation, strategic alliances, and public engagement), other types of intersystemic interactions (e.g., public-private partnerships, corporate citizenship, and public participatory channels) become increasingly prominent. Thus, the term *regional governance* refers not to an entirely new phenomenon but to a group of large changes that appeared during the past decades. Regional governance represents the reality of complex interdependencies and interactions among numerous institutions. It refers to a comparatively loose coupling of participating stakeholders acting voluntarily.

Although regional governance is characterized by direct and flexible interplay, the establishment and consolidation of a minimum of institutional capacities are nevertheless central preconditions. As those institutions may differ regionally, certain governance arrangements may be more effective than others. In many cases, a core is constituted that canalizes interactions, minimizes transaction costs, and increases the reliability of expectations. In doing so, the organizational core forms the “administrative infrastructure” but without formal bureaucratic procedures. In addition, a charismatic leader often presides over the organizational core. Because of the power to integrate the actors of different proveniences, such leaders are essential for regional cooperation to succeed.

In analytical terms, regional governance can be characterized by changes in the logic, principles, and instruments of governance. A shift from state-centered, top-down interventional strategies to bottom-up and network-like strategies of regional actors becomes increasingly apparent. Thus, state control and coordination are displaced by public and private cooperation, and

the state’s instruments of regulation (e.g., licensing procedures, regional policy) are increasingly accompanied by communicative processes (e.g., moderation and mediation).

Regional governance structures have many advantages. For example, they promote intersystemic communication, typically through meetings and discussions for various political and administrative actors; private actors can profit from direct access to political decision makers. Due to these collective efforts, which exceed any individual actor’s ability to act, synergistic effects become possible. Furthermore, regional governance may initiate learning processes (e.g., best practices) as well as conflict management.

Addressing the advantages, however, does not deny the possibility of governance failure; in critical situations, actors can refuse to participate in a governance network. It is even more problematic when actors with very different interests block decision making or establish competing interconnections. This problem may cause a lack of trust and lead to frustration. As a consequence, governance failure may endanger the competitiveness of regional regimes.

Therefore, many efforts have been made to integrate actors into regional governance structures. These efforts include professional communication strategies as well as regional image and identity campaigns. To minimize the possibility of a governance failure, these initiatives are intended to establish loyalty, solidarity, and responsibility for the entire region. For this reason, it is not only formal institutions and organizations that guarantee successful regional governance; “soft” politics of persuasive control also are significant.

Regional Governance in the United Kingdom

Although persuasive control can contribute to successful regional governance, it may also be used by interest groups seeking to prevent the implementation of certain policies. This obstacle is particularly obvious in the development of governance structures in British regions. Against the backdrop of a comprehensive reform of Britain’s government in the 1980s, there have been many attempts to decentralize and regionalize the country’s regional policy (“devolution”). This trend occurred not



only because of Celtic efforts for greater autonomy in Scotland, Wales, and Northern Ireland but also due to European Union (EU) integration. To allow for the implementation of EU policies, a regional level was essential for the United Kingdom.

The regional level of governance has traditionally been rather weak in the United Kingdom. When it took over the government in 1997, the Labour Party initiated a systematic shift of executive and legislative functions from the national state to the regional level. This shift primarily benefited the Celtic regions, where the new Scottish parliament and the Welsh and Northern Irish national assemblies developed proposals across various fields of policy (i.e., education or health care in the Scottish parliament). Accordingly, decentralization and regionalization have also been discussed for the English regions, which led to the attempt to establish regional governance structures in the English regions. The aim was to set up the organizational framework for regional development strategies and, thus, to activate a regional level of governance.

As this example shows, the establishment of a regional governance level has not been an easy undertaking. In northeastern Britain, for instance, an economically driven movement to resist policy devolution has been established to prevent the implementation of regional governance structures. The resistance was ignited by attempts to establish so-called regional assemblies to ease municipal administration as well as to advance the control of the Regional Development Agencies' activities. The critique focused on the implementation of an additional bureaucratic barrier and the presumed waste of taxpayers' money it would foster. By means of that persuasive argumentation, the northeastern opposition was able to mobilize its supporters and defeat the proposal for regional assemblies.

Despite the difficulties of decentralization and regionalization, regional governance is still a major concern in political and academic discussions. However, regional governance is increasingly connected to metropolitan-wide development issues. So far, the academic discussion has largely been centered on the United States and the European continental-wide debate about regional governance. The focus lies on the development of coherent metropolitan forms of governance that have been created using a diversity of actors.

Regional Governance in the United States

In the United States, political and academic concepts dealing with the reform of governance at the metropolitan level were developed relatively early. The two dominant paradigms (metropolitan reform and public choice) have concentrated on actors and structures within local political and administrative institutions as well as socioeconomic developments at the municipal level. Initially, metropolitan reformers focused on the question of appropriate formal institutions for governing metropolitan conglomerations. They attempted to find institutional solutions for balancing diverse functional demands with local political borders. In contrast, advocates of the public choice concept focus on the optimal satisfaction of needs by multiple cities, emphasizing the advantages of the efficient allocation of common goods as an incentive to promote interurban competition.

Similar to academic research, the current governance discussion is focused on metropolitan issues. Distinctive patterns of sociospatial segregation, urban sprawl, and the attempts to develop competitive but sustainable urban development strategies constitute a significant stimulus for consideration of political and academic governance. In contrast, however, the new concept of governance concentrates on the political and administrative system of major urban agglomerations or on regional resource allocations. Against the backdrop of late modern political, administrative, and socioeconomic changes, processes of local self-regulation are analyzed in terms of their feasibility.

Although the term *regional governance* is not widely used by politicians or political scientists in the United States, there are parallels to the British debate about regional governance and the corresponding concepts of "city regions." In the United States, however, the discussion centers on "metropolitan governance," "new (metropolitan) regionalism" or "urban regimes." This terminological shift may be ascribed to the dominant concepts of metropolitan reformers and public choice, where decision-making processes were in the foreground. The current discussion, however, concentrates on the cooperative and network-like interplay between political and economic actors



and civil society. Despite the similarities in research, the American debate appears more heterogeneous. Depending on the way one looks at the issue, different theoretical foci (e.g., neoinstitutionalism) as well as different empirical contexts can be observed. The most sophisticated work is in a neo-Marxian tradition that analyzes the processes of political, administrative, and socioeconomic restructuring due to the transformation of global capitalistic accumulation as well as the rise of the neoliberal state.

Regional Governance in Germany

The German discussion of regional governance was a response to a fundamental economic weakness and the corresponding deficit in public finances. As a consequence, the social safeguards of the national welfare state came under pressure, and local strategic planning and regional development were needed to ameliorate predicaments set into motion by these national changes. The necessity of enhancing the economic growth potential of major urban agglomerations was highlighted in the 1990s. Furthermore, a discussion about self-regulation was initiated to mobilize metropolitan self-empowerment as well as interurban competition without using additional national financial assistance.

The concept of European metropolitan regions represents the attempt to stimulate competitive political and economical practices. Meanwhile, 11 metropolitan governance regions have emerged, and the ability to stimulate cooperative interplay among the different local actors became the most important precondition for their formation. In many cases, the metropolitan areas show an organizational core that coordinates diverse territorial actors. The federal state, which has played a traditionally intense role, has now become a *primus inter pares* and does not intervene very much in regional self-regulation processes.

With regard to theoretical and empirical research, regional governance has been analyzed by both political scientists and geographers. Researchers focus on questions concerning regional actor network structures (polity), their contents (policy), and the modes of operation (politics). This work uses various perspectives,

including control theory, neoinstitutionalism, structuration theory, and Luhmann's theory of social systems, which emphasizes communicative intra- and intersystemic interactions.

The critical point is that regional governance is not a silver bullet to solve problems of modern societal regulation. Although the formation of regional governance structures may open up the potential to act, which was limited by the nation-state, empirical studies often show that regional governance has its own problems in achieving efficiency as well as legitimation. For this reason, it is fruitful to consider normative aspects when dealing with regional governance.

Tobias Federwisch

See also [Deterritorialization and Reterritorialization](#); [European Union](#); [Globalization](#); [Governance](#); [Metropolitan Area](#); [Neoliberalism](#); [New Urbanism](#); [Political Geography](#); [Scale, Social Production of](#); [State](#); [Urban and Regional Development](#); [Urban and Regional Planning](#); [Urban Geography](#); [Urban Sprawl](#)

Further Readings

- Brenner, N. (2000). Building "Euro regions": Locational politics and the political geography of neoliberalism in post-unification Germany. *European Urban and Regional Studies*, 7, 319–345.
- Brenner, N. (2004). *New state spaces: Urban governance and the rescaling of statehood*. Oxford: Oxford University Press.
- Dowding, K. (2001). Explaining urban regimes. *International Journal of Urban and Regional Research*, 25, 7–19.
- Fürst, D. (2005). Metropolitan governance in Germany. In H. Heinelt & D. Kübler (Eds.), *Metropolitan governance: Capacity, democracy and the dynamics of place* (pp. 151–168). London: Routledge.
- Hamilton, D. (2004). Developing regional regimes: A comparison of two metropolitan areas. *Journal of Urban Affairs*, 26(4), 455–477.
- Healey, P. (2006). Transforming governance: Challenges of institutional adaptation and a new politics of space. *European Planning Studies*, 14, 299–320.



- Jones, M., & MacLeod, G. (2004). Regional spaces, spaces of regionalism: Territory, insurgent politics and the English question. *Transactions of the Institute of British Geographers*, 29, 433–452.
- Staeheli, L., Kodras, J., & Flint, C. (1997). *State devolution in America: Implications for a diverse society*. Thousand Oaks, CA: Sage.



REGIONAL SCIENCE

Regional science is among the youngest of the social sciences. This introduction to regional science covers its definition, history, topics, and methods.

Definition

According to its founding father, Walter Isard, regional science uses diverse combinations of analytical and empirical research to study social problems with regional or spatial dimensions. While major concerns of many social disciplines involve regional or spatial dimensions, regional science exhibits a multidisciplinary aspect in both its research topics and its research methods. Accordingly, scholars in regional science, called “regional scientists,” may be educated in the disciplines of regional science, economics, demography, political science, sociology, geography, civil engineering, urban planning, law, and public policy, among others. Due to this multidisciplinary feature, regional scientists have experienced difficulties in delivering a widely accepted definition of regional science. Nevertheless, Walter Isard has suggested three indispensable components of regional science: regions, social issues, and science.

Regional science focuses primarily on regions. A region might be a county, a city, a group of counties, a state, or a megaregion involving more than one state. It is generally a geographic unit smaller than the nation in which it is found. Regional science also concerns social issues. Unlike Earth scientists or physical geographers interested in physical attributes on Earth’s surface, regional scientists focus on human activity or social issues in a region and address interactions between

human beings and the region where they are located. Last, regional science is labeled as science. Regional science not only borrows scientific methods from the disciplines of mathematics, economics, and statistics, as many other social sciences do, but it also develops its own analytical tools (e.g., spatial statistics and spatial econometrics).

History

Social scientists have been studying regions for a long time. Early influential work in regional science includes agricultural location theory, developed by Johann Heinrich von Thünen; industrial location theory, developed by Alfred Weber; and central place theory, developed by Walter Christaller and August Lösch, all of which are part of location theory, which addresses factors affecting the location choice of economic activity. In the 1940s, some social scientists, led by the MIT economist Walter Isard, felt that the importance of regions in the social sciences was inadequately addressed and thus endeavored to build a research field as well as a scholarly association that focused on the interactions between human beings and regions. The launch of the Regional Science Association in 1954 signified the formation of a multidisciplinary field, “regional science,” and enabled better codification of methods and exchange of ideas among economists, geographers, sociologists, statisticians, and urban planners.

Regional science was recognized by a large number of social scientists soon after its formal establishment in the 1950s and experienced a remarkable expansion thereafter. Several path-breaking publications drove the development of regional science and fostered its international acceptance as an independent yet interdisciplinary research field. Brigitte Waldorf identifies *Location and Spatial Economy* and *Methods of Regional Science* by Walter Isard, *Location and Land Use* by William Alonso, *Entropy in Urban and Regional Modeling* by Alan Wilson, *Spatial Econometrics* by Luc Anselin, and *The Spatial Economy* by Fujita et al. as important books central to regional science. The growing influence of this research field paralleled the international expansion of the Regional Science Association



(renamed as the Regional Science Association International in 1990). By 2008, it consisted of more than 4,000 scholars from all over the world and has developed into the umbrella organization of three supranational organizations, North American/Americas Association, the European Regional Science Association, and the Pacific Regional Science Conference Organization, which further oversee many subnational, national, and cross-cutting, language-based regional science organizations (e.g., the Western Regional Science Association in the United States; the French Section, the German Section, and the Nordic Section in Europe; and the Japanese Section in Asia Pacific). The two decades following the establishment of the RSA also saw the creation of academic programs in regional science in some universities, notably the University of Pennsylvania, Cornell University, and the University of Illinois at Urbana-Champaign. Graduates from those programs later became the leading scholars in regional science—for example, William Alonso, Masahisa Fujita, and Luc Anselin. Meanwhile, journals focusing on regional science were founded, including *Papers in Regional Science* (1955), *Journal of Regional Science* (1958), the *Annals of Regional Science* (1967), *Regional Science and Urban Economics* (1971), and *International Regional Science Review* (1975). These journals contributed considerably to the development of the regional science field.

Regional science entered its mature years in the 1990s. The replacement of “thinking regionally” with “thinking globally,” beginning in the 1980s, witnessed the stabilization of expansion of regional science and the closure of several regional science programs in universities, for example, the first ever and flagship regional science department at the University of Pennsylvania. Not being a “foundation discipline” organized along traditional academic lines, regional science has faced difficulties in being identified as an indispensable academic field. Nevertheless, regional scientists (e.g., Scott Loveridge) are still optimistic about the future of regional science, given the growing popularity of understanding regional change and the technical improvement particularly in geographic information systems and spatial econometrics through which regional models and data can be better married.

Topics

Regional science may cover a wide array of topics, given that social issues exhibit spatial or regional dimensions. Regional scientists nevertheless distinguish themselves from other social scientists by putting regions at the center of their attention. Walter Isard argues that economists pay only peripheral attention to regions, while their key concerns are more likely to be investment, employment, price, tax, trade, and other economic indicators of the regional system. Scott Loveridge identifies six classic regional science “questions”:

1. What are the determinants of industrial location?
2. What are the regional economic impacts of the arrival or departure of a firm?
3. What are the determinants of internal migration patterns and land use change?
4. What factors influence regional specialization and exchange?
5. What are the potential environmental impacts of social and economic change?
6. What are the geographic associations of economic and social conditions?

While those classic questions, together with the new development of regional science, suggest many topics, the major concerns of regional scientists can be traced from those classic regional science publications, including a focus on issues of economic and social aggregates and disaggregates across spatial units.

Regional science was created primarily out of the traditions of location theory. Walter Isard developed a mathematical formulation (similar to that of production theory) that addressed the most traditional location theories, centering on Johann Heinrich von Thünen, Alfred Weber, and August Lösch. He highlighted the central role of transport in determining locational equilibrium in economic activity. Walter Isard also built modern location theory by introducing industrial complex analysis into traditional location theory as a determinant of location choice and an expression of the interdependence of firms.



While Walter Isard focused on location theory of business, his student William Alonso addressed the pattern of residential land use in the urban context and laid the foundation for urban economics. Assuming all employment in the central business district (CBD), he argued that the incentive for a household to move farther from the CBD lies in the lower commuting costs rather than the usually marginal land cost savings. Richard Muth expanded Alonso's model by considering the effect of income on household commuting costs. The evolution of the monocentric urban structure was further extended by Edwin Mills, who investigated the decentralization of jobs and residences and the formation of subcenters as part of his development of the new urban economics of the late 1970s.

Both location theory and traditional urban economics are based on transportation costs. Such costs, especially the cost of moving goods, experienced a significant decline during the 20th century. This change challenges the theoretical base of classic regional science. In this context, there has been a growing concern over agglomeration among regional scientists. Nevertheless, it is not a new concept, since many early regional scientists, including Alfred Weber, Walter Isard, and Edwin Mills, have been concerned with economies of scale and agglomeration effects. However, it becomes remarkably important when transportation costs arguably are no longer the dominant factor of location choices of firms and residents. Some urban economists, notably Jane Jacobs and Edward Glaeser, highlight the role of cities in fostering knowledge spillovers or human capital externalities, a different agglomeration effect from the traditional approach of transport cost savings. In addition, the new economy geography developed by Paul Krugman, Masahisa Fujita, and Anthony Venables explains agglomeration using not only traditional elements such as economies of scale, transportation costs, and proximity to consumers but also issues of choice and variety in a rather mainstream, economics-oriented framework.

The topics mentioned above may be studied within a region. Regional scientists are also interested in interregional flows of goods (trade) and population (migration). Besides applying traditional visions (e.g., comparative advantage theory

and the Heckscher-Ohlin theorem) to regional analysis, regional scientists also have their own views on trade. The interregional input-output model developed by Walter Isard is important in that context. The investigation of migration highlights the effects of both personal characteristics and locational characteristics on migration patterns. Among other topics, Amitrajeet Batabyal and Peter Nijkamp consider the environment as an increasingly salient part of regional science research. Not necessarily embedded into one specific social topic, spatial interaction modeling and spatial data analysis as methods play a central role in explicating the role of regional science.

Methods

Regional science methodologically uses various forms of quantitative analysis in a formal scientific procedure. As an interdisciplinary field with diverse topics, it borrows a variety of methods that have been used in other sciences or social sciences. Walter Isard's early work employs many ideas and techniques in economics, such as equilibrium analysis, profit maximization, and input-output analysis. The new economic geography may not be new in its use of agglomeration theory, but it is still considered as a path-breaking step in regional science, primarily because it resorts to mainstream economic models (e.g., the Dixit-Stiglitz model of monopolistic competition) and extends them into a regional context, particularly as they relate to growth, urbanization, agglomeration, and regional differentiation. Similarly, many other mathematical inferences used in economics can be widely seen in regional science publications.

Spatial data analysis has highlighted the importance of statistical and econometric methods in regional science. General statistical and econometric methods, however, do not necessarily work well in the regional context, as a result of the effects of spatial dependency and spatial heterogeneity. To solve this problem, regional scientists have made exceptional contributions to statistics and econometrics by developing spatial statistics and spatial econometrics. Methods in regional science also rely on concepts used in physics, for example, in the gravity model discussed by Kingsley Haynes and A. Stewart Fotheringham and in the entropy approach of Alan



Wilson, which have dominated spatial interaction estimation.

Kingsley E. Haynes and Haifeng Qian

See also **Agglomeration Economies; Anselin, Luc; Central Place Theory; Christaller, Walter; Economic Geography; Factors Affecting Location of Firms; Gravity Model; Input-Output Models; Isard, Walter; Land Use; Location Theory; Logical Positivism; Models and Modeling; Quantitative Methods; Regional Science Association International (RSAI); Spatial Autocorrelation; Spatial Econometrics; Spatial Interaction Models; Spatial Statistics; Thünen Model; Urban and Regional Development; Weber, Alfred**

Further Readings

- Alonso, W. (1964). *Location and land use*. Cambridge, MA: Harvard University Press.
- Bailly, A., & Gibson, L. (2004). Regional science: Directions for the future. *Papers in Regional Science*, 83(1), 127–138.
- Batabyal, A., & Nijkamp, P. (2004). The environment in regional science: An eclectic review. *Papers in Regional Science*, 83(1), 291–316.
- Boyce, D. (2004). A short history of the field of regional science. *Papers in Regional Science*, 83(1), 31–57.
- Cliff, A., & Ord, K. (1981). *Spatial processes: Models and applications*. London: Pion.
- Fujita, M., Krugman, P., & Venables, A. (1999). *The spatial economy*. Cambridge: MIT Press.
- Glaeser, E., & Kohlhase, J. (2004). Cities, regions and the decline of transport costs. *Papers in Regional Science*, 83(1), 197–228.
- Isard, W. (1956). *Location and space economy*. Cambridge: MIT Press.
- Isard, W. (1960). *Methods of regional analysis*. Cambridge: MIT Press.
- Isard, W. (1975). *Introduction to regional science*. Englewood Cliffs, NJ: Prentice Hall.
- Haynes, K., & Fotheringham, A. (1984). *Gravity and spatial interaction models*. Beverly Hills, CA: Sage.
- Krugman, P. (1991). Increasing returns and economic geography. *Journal of Political Economy*, 99(3), 483–499.

- Lösch, A. (1940). *The economics of location*. Jena, Germany: Gustav Fischer.
- Loveridge, S. (2000). Introduction to regional science. In S. Loveridge (Ed.), *The web book of regional science*. Morgantown: West Virginia University, Regional Research Institute. Retrieved December 19, 2009, from www.rri.wvu.edu/regscweb.htm
- Waldorf, B. (2004). Path-breaking books in regional science. *Papers in Regional Science*, 83(1), 59–89.
- Wilson, A. (1970). *Entropy in urban and regional modeling*. London: Pion.



REGIONAL SCIENCE ASSOCIATION INTERNATIONAL (RSAI)

The Regional Science Association International (RSAI), according to its official Web site, www.regionalscience.org, is “an international community of scholars interested in regional impacts of national or global processes of economic and social change.” The following paragraphs briefly introduce its history, organizational structure, meetings, and journals.

Formerly known as the Regional Science Association (RSA), the RSAI was founded in 1954 in the United States as a result of the then MIT-based economist Walter Isard’s efforts to draw together multidisciplinary social scientists, whom he called “regional scientists,” to analyze interactions between human beings and regions. Isard served as the first president of the RSA. With its expansion all over the world, the Regional Science Association was renamed as the Regional Science Association International in 1990. As of 2008, the RSAI and its member organizations consisted of more than 4,000 scholars from disciplines of economics, sociology, demography, political science, geography, civil engineering, urban planning, and public policy, among others.

Structurally, the RSAI has developed into the umbrella organization of three supraregional organizations: (1) the North American Regional Science Council (NARSC) before it expanded to the Regional Science Association of the Americas



by including the Brazil and Chile sections in 2008 and the Colombia section in 2009; (2) the European Regional Science Association (ERSA), and (3) the Pacific Regional Science Conference Organization (PRSCO). Each of these three organizations further oversees some national, subnational, or cross-cutting, language-based regional science organizations. The NARSC or the Regional Science Association of the Americas serves as the umbrella organization of the Mid-Continent Regional Science Association, the Northeast Regional Science Association, the Southern Regional Science Association, and the Western Regional Science Association in the United States and other regional science associations in Canada, Brazil, Chile, and Colombia. The ERSA oversees the British and Irish Section, the German Speaking Section, the French Speaking Section, the Nordic Section, and the Portuguese Section, among others in Western, Central, and Eastern Europe. Members of the PRSCO include regional science sections based in Australia and New Zealand, Bangladesh, Western Canada, Indonesia, Japan, Korea, Malaysia, Mexico, and Taiwan. Membership in these supraregional organizations is still expanding.

The RSAI and its member organizations hold conferences regularly. The first meeting was held December 27–29, 1954, in conjunction with annual meetings of the American Economic Association and some other organizations in Detroit, witnessing the birth of the RSA. With the structural changes in the RSAI, meetings today occur at different levels. The RSAI has been organizing its World Congress every 4 yrs. (years) since 1980. At the middle level, the NARSC meeting and the ERSA Congress are held annually, in contrast to the PRSCO conference, which meets every 2 yrs. Most national, subnational, and language-based members of these three supraregional organizations have their own regular meetings.

There are several journals associated with the RSAI. The official journal of the RSAI, *Papers in Regional Science*, also known as *Papers of the Regional Science Association*, was first published in 1955. Many sections of the RSAI also have their own journals, but only the *Annals of Regional Science*, the official journal of the Western Regional Science Association, involves a commercial publisher. Other regional science journals, though not directly linked to any regional science

organizations, are mostly founded and edited by members of the RSAI. For instance, *Journal of Regional Science* and *International Regional Science Review*, both founded by Walter Isard, are among the core journals of regional science and have earned their reputation even beyond regional science.

Kingsley E. Haynes and Haifeng Qian

See also Isard, Walter; Regional Science

Further Readings

Boyce, D. (2004). A short history of the field of regional science. *Papers in Regional Science*, 83, 31–57.



REGIONS AND REGIONALISM

Regions are a means for geographers to classify, categorize, or simplify Earth's surface. A primary concern of geography is how and why one part of the Earth is different from other parts. Given the vast size and variety of environments, both natural and human, on Earth's surface, it is practical for geographers to divide the Earth into more manageable pieces. Regions are tools that allow geographers to focus their inquiries onto manageable areas. The division into manageable pieces extends from global to very local scales, since regions may be as large as continents and as small as neighborhood blocks.

Regions are based on a commonality, sameness, similarity, or homogeneity. The homogeneity may be based on characteristics of the physical environment (climate, vegetation, or landforms), on human cultural traits (religion, language, settlement, economic activity, and ethnicity), or on a synthesizing combination of both physical and human elements. The key concept is that regions share common properties that differentiate them from each other. Regions can be considered to maximize their commonality within themselves and maximize their differences among one another. To accomplish that goal, regions have



both relative and specific locations, areal sizes, and boundaries or borders. Borders of regions may be absolute and concrete or may be transitional or gradual. Regions can even have transitional areas between other regions.

Regions are to geographers as eras are to historians. Just as historians categorize the past into eras or periods, geography and geographers categorize Earth into regions on the basis of commonalities in cultural traits such as religion, language, and ethnicity and in physical traits such as climate. Geographers from Carl Sauer to John Fraser Hart believed that one of the principal purposes of geography is to learn about regions and why they differ from each other. According to that school of thought, regions are based on how people have lived on the land, used resources, and interacted with their environment through time. Many schools and universities offer an introductory geography course, often titled “World Regional Geography.” Such courses typically cover the entire Earth during an academic term. In world regional geography courses, the planet is usually divided into the seven major regions of Europe, North America, Latin America, sub-Saharan Africa, East and southeast Asia, South Asia, North Africa and the Middle East (or West Asia), and Australia and Oceania. Additionally, those regions are often taught in separate regional geography courses. The key concept is that the areas within those regions share commonalities in terms of physical and human geography. The purpose of those courses, from global to regional, is to explain how and why regions differ from each other. For example, areas within North Africa and the Middle East are alike with respect to climate, religion, and languages, which differentiate them from other regions such as Europe or sub-Saharan Africa.

Additionally, many colleges or universities offer courses in systematic geography (often named “human geography” and “physical geography”). Human geography courses take a systematic approach in the study of worldwide patterns of language, religion, population, and other human traits and activities. Regions are also covered in these courses. For example, Europe is a region of Indo-European languages. Within this region of languages, there are subregions of Romance and Germanic Languages, and within

the region of Romance Languages rest regions of Spanish, French, and Italian. Within an Italian-speaking region, there are regional dialects that can be mapped, creating more regions. Courses in physical geography make use of the concept of region in showing different regions of climate, vegetation, and landforms. With regard to climate regions, the Köppen system, which creates climate regions based on vegetation, temperature, precipitation, and seasonality of precipitation, is perhaps the best known. The Köppen system recognizes tropical, temperate, continental, polar, and dry climate regions. The goal in these systematic courses, whether human or physical, is, for example, to explain why there are different regions of language and climate.

Functional Regions

Functional regions are usually based on an economic or civil activity within a delineated area. Media markets, sales territories, and school districts can be considered functional regions. Urban systems with a large metropolitan area and a hinterland of suburbs and rural areas form a type of functional region based on the functional properties and relationships between the city and hinterland. Often these regions are cobbled together from existing political jurisdictions. Metropolitan Statistical Areas created by the U.S. Office of Management and Budget are based on county boundaries. These regions consist of the counties housing a large central city, its suburbs, and a rural hinterland. Functional regions are more limited in their chosen characteristics, since they function as regions for a particular purpose. The practice of creating functional regions for planning or for jurisdictional purposes can be considered regionalism.

Regionalism

Regionalism can refer to the practice of creating regions in a country or political jurisdiction for management, planning, and governance. Regionalism can also be considered a philosophy or method for solving problems by employing the concept of region. Regionalism, related to the field of regional science, often seeks mathematical, statistical, and formulaic approaches employing the scientific method as closely as possible in



answering questions and tackling issues such as economic or social inequality between regions. Park districts, school districts, or transportation authorities created by combining local governmental jurisdictions are examples of regionalism. Metropolitan councils, which provide governance or planning for multiple municipal jurisdictions, are formed to provide more efficient governance, public services, and planning. The theory is that integrated metropolitan councils can more efficiently solve problems and take a larger regional view benefiting the entire region instead of satisfying more parochial interests. At larger scales, the Tennessee Valley Authority (a congressionally created, multistate public utilities and emergency services provider in the southeastern United States) and the European Union are also examples of regionalism. Regionalism can be synonymous with regional planning or regional development.

John Heppen

See also **Chorology; Idiographic; Place; Regional Geography**

Further Readings

- DeBlij, H., Murphy, A., & Fouberg, E. (2007). *Human geography: People, place, and culture* (8th ed.). New York: Wiley.
- Hart, J. (1982). The highest form of the geographer's art. *Annals of the Association of American Geographers*, 72, 1–29.
- Hartshorne, R. (1939). *The nature of geography*. Washington, DC: Association of American Geographers.
- Lewis, M., & Wigen, K. (1997). *The myth of continents: A critique of metageography*. Berkeley: University of California Press.



REGULATION THEORY

Regulation theory emerged in France during the 1970s as an extension of Marxist political economy. The theory is especially associated with ideas developed in Michel Aglietta's seminal book

A Theory of Capitalist Regulation (1976). In its basic form, regulation theory posits that when capitalism changes over time, new institutions develop to support the prevailing economic system. These clusters of economic and political institutions form distinct societal paradigms during separate phases of capitalist development.

The historical background to regulation theory is the tumultuous end of the 1960s, with its social upheavals and growing economic uncertainties—a period when the capitalist economy appeared weaker than at any point since the Great Depression. However, a decade later, it was clear that capitalism would not disintegrate due to its inherent contradictions, as orthodox Marxism suggested. In fact, it proved to be quite resilient. Faced with an economic and political crisis, capitalism was capable of “reinventing” itself by relying on new industrial organization, new global strategies, and a rethinking of state economic policies. This reinvention process, according to regulation theory, involved a change in the *regime of accumulation*—the transition from Fordism to post-Fordism. A regime of accumulation aims to create a stable relationship between consumption and production. It outlines the basic economic relationships in society, such as the conditions of production, private and public consumption, savings and investment, and the general scope and proper role of government. The specific social and economic institutions, cultural norms, and major government policies that must be in place and work together in a coherent fashion to support the regime are collectively referred to as a *mode of regulation*. These ideas in regulation theory draw, at least implicitly, on the concept of a “social contract” that emphasizes the idea of underlying informal agreements in society, providing common rules for cooperative behavior between groups and individuals. A mode of regulation is an outcome of collective action, political decisions, and various semi-independent variables, such as technological change; therefore, it involves periodic adjustment of the procedures and institutions.

Fordism and Its Demise

More specifically, regulation theory outlined how Western capitalism was organized after World



War II and how large societal institutions were crucial for the particular regime of accumulation called Fordism. The term *Fordism* has Gramscian roots, but it was expanded and popularized by regulation theory and remains one of its most enduring concepts. On the production side, the Fordist regime was associated with assembly-line-style mass production. Just as Henry Ford's story tells us that his company paid his workers above the industrial wage at the time so that they could purchase the automobiles they produced, it became the goal of the state to institute a consumption norm for the good of the overall economy. Raising the wages and living standard of the working classes became not only a moral but also an economic imperative. The Fordist consumption norm was mainly a demand-led approach used to generate markets for new products and services. Consumption was underpinned by a mode of regulation that included high union-negotiated wages, the welfare state, social security, and government loan guarantees, ensuring high consumption levels. A far-reaching compromise existed in a tripartite power structure: business, labor, and government. This description of recent economic history is not unique to regulation theory; however, it synthesized multiple events and policies into a well-articulated "grand theory."

The mode of regulation as described here was not identical in all countries or regions. The mass consumption model was best developed in the United States, while the labor relations model was taken further in Western Europe. The Fordist social contract in many European countries (particularly Scandinavia) was deeper and more comprehensive than in the United States. The role of labor unions was more institutionalized into a corporative political system, where wages were determined by national negotiations. Even the political decision-making system integrated the different participants of the labor market. Although under pressure, the model remains partially in place in Western Europe today. In the United States, the right to unionize was established by federal laws starting in the 1930s, but the laws also allowed for the development of "peripheral Fordism" through right-to-work provisions adopted by some, mostly southern, states. The term *peripheral Fordism* originally referred to the labor-intensive economies of Southern

Europe, but it has similarly been used to describe regions such as the North American South, which were not quite ready, politically and economically, to fully embrace the emerging mass consumption model and its accompanying social relations. Nevertheless, many institutions of Fordism were national in scope, and the expanding Fordist government became a geographic equalizer of wealth.

In the late 1960s, Western economies suffered a slowdown, which was not simply an economic crisis caused by the latest business cycle or other problems solely within the economic realm. According to the regulation school, the relationship between political regulation and accumulation was out of sync, leading to a more deep-seated crisis. The contradictions of the Fordist model became increasingly evident. The rigidly negotiated wages accepted in the name of expanded consumption became counterproductive, creating a major rift in the labor-management compromise. As gains in wages and influence are not easily surrendered, labor conflicts compounded the existing problems. Economic decline created a search for new forms of institutions and policies, best exemplified by the conservative revolutions of Ronald Reagan and Margaret Thatcher.

The Nature of Post-Fordism

Fordism is generally considered by regulation theorists to have been replaced in the late 20th century by a new regime referred to as *post-Fordism*. Its nature is not fully realized, and researchers often stress the unpredictability of regime formation. Some prefer not to proclaim it a regime, only a "disorganized form of capitalism" that has emerged after Fordism and is guided by few principles other than market dictates. More recently, the term *neoliberalism* has been widely adopted instead of post-Fordism, which indicates a general dissatisfaction with regulation theory among many geographers. (For consistency's sake, however, the term *post-Fordism* is used throughout this entry.)

From the economic-geographic perspective, no single coherent system characterizes the post-Fordist industrial sector, although fundamental changes in the way production is organized have occurred. Flexible specialization provides a clear alternative to Fordism, with its craft-style, small-batch



production localized in certain industrial districts. However, it has not become the all-encompassing principle of industrial organization. Nor has the Japanese-inspired just-in-time production or European industrial organization, which has retained some of its Fordist character with its strong collective agreements. This lack of coherence has led to valid concerns about the viability of post-Fordism as a concept in industrial geography.

Moreover, in an era of global capitalism, the old national Fordist institutions are less effective. The transition to post-Fordism has found support in monetarist/supply-side policies in the wake of an economic crisis that the old macroeconomic model—Keynesianism—could not predict, explain, or cope with. Adjusting the deficiencies of the market is now attempted by encouraging supply instead of demand, through lowering taxes, deregulation, reducing inflation, and curbing government spending. The result is the subordination of social policy to economic growth incentives based on competitiveness and innovation.

Regulation theory interprets this as a realignment between economic policy and the emerging logic of capitalism. Economic policies have had the intended effect of increasing profits. Corporate management considers its overwhelming responsibility to be the accumulation of profit for shareholders, not necessarily adherence to a pattern of sustainable growth. Therefore, the new capitalism of hyperaccumulation appears less concerned with long-term goals and more interested in instant monetary gratification. The question is what constitutes a mode of regulation in such a system. Regulation theory has been vague on that issue, but the answer may lie in a rescaling process and changes to the territorial mode of regulation.

Although a process of economic nationalization took place under Fordism, economic geographers argue that post-Fordist competitiveness is based on local or regional conditions. Together with the aforementioned globalization, the outcome is a so-called hollowing out of the national state, which leaves more power in global, regional, and local hands. The responsibility for accumulation of supporting functions (ideological, reproductive, or production oriented) is particularly divested to the local level. If power devolves, the federal government has less capacity to implement the

policies that characterized the Fordist regime. Instead, there is a role for the local state in building new institutions to support education, infrastructure, and public-private policy interaction that, perhaps, represents emerging local modes of regulation. Such a turn of events has moved regulation theory closer to urban geography and away from its macroeconomic origin.

Critique of the Theory

Over time, empirical and theoretical work based on the regulation school has altered and extended the original propositions. Aglietta's hypothesis of what comes after Fordism was perhaps as good as anyone's at the time, but in retrospect, it was inaccurate. In light of almost three decades of economic change, a series of valid concerns regarding the approach have emerged. Many have rightly pointed out that the theory was too focused on the manufacturing economy and especially on workplace relations. The postindustrial turn makes it necessary to rethink the mode-of-regulation concept. In fact, the central tenants of the regime argument have been detached from the manufacturing floor.

One of the most important critiques highlights the tendency of the theory to compartmentalize economic development into discrete time periods. In reality, regimes are processes constantly challenged and undergoing change, which means that they are not necessarily coherent, with sharp, detectable breaks, as regulation theory assumes. It has been suggested that a stable mode of regulation is the exception rather than the rule; and instead, regulatory failure and crisis are the norm. Moreover, assuming temporally distinct regimes has a tendency to reify the theory. Should post-Fordism, then, be interpreted as an uncoordinated system rather than a new, stable regime of accumulation? This interpretation elicits additional comments. First, it is doubtful whether the current and old societal paradigms should be judged by the same yardstick. It might be irrelevant that post-Fordism does not conform to the standards handed down by the earlier regime (if Fordism was, in hindsight, as monolithic and stable a societal paradigm as portrayed). From this viewpoint, regimes should be regarded as archetypes more than empirical absolutes because policy is always



complex, incoherent, and fragmented. If more power is placed in the “invisible hand” of the market, the same level of coordination is not possible. Society has embraced, even institutionalized, perpetual change, which is fundamentally different from the Fordist preoccupation with stability. Even if the critique of the sharp periodization of economic history is relevant, a regulationist would argue that current society is different enough from the past to render post-Fordism a useful concept.

An additional critical comment made by geographers is that the spatial scale of analysis is neglected. This criticism is pertinent to the original proposition, but much work has emerged since then. Although the nation-state was originally stressed as the locus for the formation of various modes of regulation, place-sensitive analysis has been growing. Lipietz’s notion of peripheral Fordism added a necessary international dimension to the theory. It has also been acknowledged that each locale has its own regime based on particular conflicts and compromises. Particularly, scholars from geography and social science disciplines other than economics have been more active in exploring the local implications of regulation theory. It is doubtful, however, whether much research explicitly using a regulation theory framework is forthcoming in the near future, as the concept of neoliberalism appears to be favored by those in critical urban and economic geography today. Instead, regulation theory remains a source of inspiration for much geographic research, but not as the dominant overarching theory.

Ola Johansson

See also **Business Cycles and Geography; Economic Geography; Flexible Production; Fordism; Industrial Districts; Marxism, Geography and; Neoliberalism; Radical Geography; Urban Geography**

Further Readings

- Aglietta, M., & Fernbach, D. (2001). *A theory of capitalist regulation: The U.S. experience*. London: Verso.
- Amin, A. (Ed.). (1995). *Post-Fordism: A reader*. Cambridge, MA: Blackwell.

- Boyer, R., & Saillard, Y. (Eds.). (2002). *Regulation theory: The state of the art*. London: Routledge.
- Brenner, R., & Glick, M. (1991). The regulation approach: Theory and history. *New Left Review*, 188, 45–119.
- Lauria, M. (Ed.). (1996). *Reconstructing urban regime theory: Regulating urban politics in a global economy*. Thousand Oaks, CA: Sage.
- Lipietz, A. (1987). *Mirages and miracles: The crisis of global Fordism*. London: Verso.
- Lipietz, A. (1992). *Towards a new economic order*. New York: Oxford University Press.



RELATIONAL SPACE

See Relative/Relational Space



RELATIVE/RELATIONAL SPACE

In contrast to absolute space, which is fixed, asocial, and timeless, relative or relational space reflects the wide varieties of ways in which distance is measured and conquered, that is, space as socially made and remade over time. Relative space thus portrays geographies as fluid, mutable, and ever changing. (Some observers differentiate relative from relational space, while others treat them as synonymous; see quote by Harvey below.)

The genesis of relative space may arguably be traced to the famed 17th-century intellectual Gottfried Leibniz, Isaac Newton’s great rival in the invention of calculus and the founder of a perspective on spatiality sharply at odds with the prevailing Euclidean/Cartesian emphasis on absolute space. In contrast to Newton, who held that space exists independently of how it is measured or what it contains, Leibniz held that time and space are relative, that is, comprehensible only with reference to specific frames of interpretation. Distance, for example, may be understood only through appeal to the space between two or more objects situated in space. Relative space, however, remained subordinate to absolute space



for many years, at least until the massive changes of the Industrial Revolution reworked the meaning of spatiality itself.

Marxism, too, offered a surprisingly early vision of relative space, tying it to the historical process by which capitalism reached out and conquered new spaces, enveloping them within ever-broader spatial divisions of labor. Marx (1973) argued in the *Grundrisse* that

while capital must on one side strive to tear down every spatial barrier to intercourse . . . it strives on the other side to annihilate this space with time, i.e., to reduce to a minimum the time spent in motion from one place to another. (p. 539)

David Harvey's extension of Marxist analysis into geography, which drew on the influential works of Henri Lefebvre and initiated a simultaneous spatialization of Marxism, linked the construction and reconstruction of relative space to the endless search for ever-greater profits and outlets for surplus value. The need to "annihilate space by time" is thus fundamental to the operation and survival of capitalism on an ongoing basis, that is, its ability to reproduce itself at ever-expanded spatial scales and to accelerate temporal rhythms of capital accumulation. Harvey (2006b) offers useful definitions of *absolute*, *relative*, and *relational space*:

Absolute space is fixed and we record or plan events within its frame. This is the space of Newton and Descartes and it is usually represented as a pre-existing and immovable grid amenable to standardized measurement and open to calculation. Geometrically it is the space of Euclid and therefore the space of all manner of cadastral mapping and engineering practices. . . . The relative notion of space is mainly associated with the name of Einstein and the non-Euclidean geometries that began to be constructed most systematically in the 19th century. Space is relative in the double sense: that there are multiple geometries from which to choose and that the spatial frame depends crucially upon what it is that is being relativized and by whom. . . . The relational concept of space is most often associated with the name of Leibniz who . . . objected vociferously to the absolute view of space and

time so central to Newton's theories. His primary objection was theological. Newton made it seem as if even God was inside of absolute space and time rather than in command of spatio-temporality. By extension, the relational view of space holds there is no such thing as space or time outside of the processes that define them. . . . Processes do not occur *in* space but define their own spatial frame. (pp. 121–123)

Similarly, Anthony Giddens's (1984) structuration theory portrayed relative space in terms of time-space distancing, the "stretching of social systems across time-space on the basis of mechanisms of social and system integration" (p. 377), as "disembedding mechanisms" such as symbolic systems and transportation technologies allow social interactions to extend across ever wider time-space distances.

Kern's famous book *The Culture of Time and Space 1880–1918* addressed the changing meanings of spatiality in the midst of late-19th- and early-20th-century social and technological changes. Wave upon wave of innovation altered the capacities of people to defeat the friction of distance, to interact with one another, and to learn about distant places, leading to a widespread reconfiguration of notions of proximity. The telegraph, telephone, bicycle, automobile, and airplane, and impressionism, cubism, photography, cinema, and the theory of relativity, all served to blur conventional meanings of near and far, bringing into mutual contact peoples and societies that had long been isolated. This transformation rendered traditional views of distance, and thus absolute space, less meaningful and elevated the concept of space as a product of changing social circumstances.

The theory of relativity, prefigured by the great French mathematician of non-Euclidean geometry, Henri Poincaré, in the 1890s, included an outright rejection of absolute time and space as inherently, objectively "correct." Albert Einstein, with the special theory of relativity that he articulated in 1905, extended Poincaré's analysis by showing mathematically that the results of experiments with time and motion inevitably depended on the viewer's choice of space-time coordinate definitions, a conclusion with enormous repercussions not only for physics, cosmology, astronomy, and other fields but for



social analyses of space as well. Relativity views energy and matter as curving four-dimensional space-time so that it wraps around itself, forming a warped surface over which light rays glide. The measurement of time is predicated on the observer's location in space, his or her velocity relative to other places, and the gravitational mass that shapes the local universe. Thus, gravitational fields slow down the speed of light by warping space and time. Relativity repositioned time and space, suturing them to the materiality of the physical world by emphasizing how mass warps and stretches these dimensions around itself. Gravity, therefore, is not an independent force but the effect of warped space and time. Moreover, rather than existing independently of their contents, and thus extending equally throughout the universe, time and space are organized by the specifics of local matter and motion; with Einstein, the "now" became confined to the "here." Einstein argued that the dilation of time is generated by the relative motion between an observer and what he or she observes, a view that soundly rejects absolute time and space because absolutes could only exist if they were being measured objectively. Relativity thus implies a return from objective time and space to a vision that takes the individual observer as its point of departure.

Smith (2003) argues that the end of the colonial era in the early 20th century was marked by the pragmatic need to view space in relative rather than absolute terms. At this historical juncture, the scale of capital accumulation exceeded the boundaries of the nation-state, creating a problem that could only be solved through the spatial fix of global empire. For the first time, the expansion of one state was only possible through its incursion into the territories held by another. As a result of this state of affairs, no longer was it possible to conceptualize political problems and predicaments in isolation from one another, a cultural turning point that coincides precisely with the rise of modern geopolitics. The famed British geopolitical theorist Sir Halford Mackinder aptly captured this transformation in his analysis of the geopolitics of imperial rivalry, in which the seafaring hegemony of Britain would be challenged by the growing land-based power of Russia and its conquest of space through the railroad. In putting forth this view, he became perhaps the first theorist of the world as an integrated entity.

With the invention of the airplane, distance became increasingly trivialized, and as with the railroad, telegraph, and telephone, the experience of flying was regularly described as "annihilating space." Generally, the more rapid is the form of transportation or communication, the more intervening spaces disappear. Rapid time-space compression thus disembeds places in between, favoring origins and destinations at the expense of intermediate locales. Airplanes in this sense formed "worm-holes" through global time-space, paths in which locations en route ceased to exist or matter. Air travel could ignore the traditional physical and social barriers between places, rendering old divisions between land and water meaningless: Even islands such as Britain were effectively islands no longer. As flying became increasingly accepted among the public, distances between pairs of cities were conceptualized with increasing frequency in terms of hours rather than absolute distances.

The notion of relative space is central to the notion of time-space compression. Whereas absolute distances do not change, relative ones, as measured by travel time or cost, change constantly; given the rising transport velocities, in relative space, places draw closer to one another even as the absolute distance between them remains constant. For example, drawing on the famous example offered by Don Janelle, travel between Lansing and Detroit, Michigan, took approximately 1,300 min. (minutes) by stage-coach in 1840; by the 1870s, with the arrival of the steam locomotive, travel time had been reduced by two-thirds, to 180 min.; and with the introduction of the automobile, the journey was further reduced to only 80 min. Thus, while the absolute distance between the cities remained the same, the relative distance was reduced by 1,220 min. over 120 yrs. (years), or roughly 10 min./yr. In the 1960s and 1970s, as the impacts of space-adjusting technologies became clearer, relative space steadily gained in popularity, a shift accompanied, not accidentally, by the abandonment of logical positivism, with its fetishization of absolute space, and the move into a variety of relativistic epistemological views. Thus, relative space has an important epistemological counterpart in relativism more broadly: Just as space and time have been repeatedly folded, distorted, remade, reconstituted, and reinterpreted, there is no one,



single, “objective” viewpoint to which spatiotemporal reality presents itself.

In the contemporary historical moment, globalized, postmodern capitalism has given birth to complex geographies in which proximity and transport costs play relatively marginal or even insignificant roles. The airplane, satellites, television, and telecommunications, including the Internet, for example, have steadily led to forms of social interaction in which physical distance is rendered irrelevant. The result has been a series of convoluted landscapes marked by wormholes and tunnels, complicated spatialities of which globalization is the dominant but by no means only indication. Postmodern capitalism, thus, has elevated Leibnizian relative space to a historically unprecedented level of significance. Contemporary theorizations of relative space, marked by views such as actor-network theory and Doreen Massey’s power geometries, thus portray it in origami-like fashion.

In all these cases, ontological changes in transportation, communication, and representation have been accompanied by equally dramatic shifts in ideologies and ways of thinking. Modern science shook the doctrine of objectivism at its roots, substituting multiple times and spaces for the dominant Cartesian view hegemonic since the Renaissance, substituting new representations of diverse, fragmented realities and reordering the meanings of time and space. Relative space, in short, is a shorthand for the rapid declines in the friction of distance evident throughout the history of capitalism, industrialization, and modernity, one in which the significance of location does not disappear but is reconfigured along new and equally meaningful lines.

Barney Warf

See also **Absolute Space**; **Harvey, David**; **Lefebvre, Henri**; **Space of Flows**; **Spatial Fix**; **Time-Space Compression**

Further Readings

Harvey, D. (2006a). Neoliberalism as creative destruction. *Geografiska Annaler*, 88B, 145–158.

Harvey, D. (2006b). *Spaces of global capitalism: Towards a theory of uneven geographical development*. London: Verso.

Kern, S. (1983). *The culture of time and space, 1880–1918*. Cambridge, MA: Harvard University Press.

Knowles, R. (2006). Transport shaping space: Differential collapse in time-space. *Journal of Transport Geography*, 14, 407–425.

Marx, K. (1973). *Grundrisse: Foundations of the critique of political economy* (M. Nicolaus, Trans.). London: Penguin. (Original work published 1857)

Smith, N. (2003). *American empire: Roosevelt’s geographer and the prelude to globalization*. Berkeley: University of California Press.

Warf, B. (2008). *Time-space compression: Historical geographies*. London: Routledge.



RELIGION, GEOGRAPHY AND

The geography of religion is a substantial subdiscipline of human geography that provides significant insight into the breadth and depth of religious traditions in their multifaceted contexts. The geography of religion involves the spatial study of religious systems and phenomena and includes a robust array of themes at numerous scales, including, but not limited to, religious diffusion, religious distributions, religious regions, religious diversity, religious fundamentalism, sacred space, religious landscapes, religion and the environment, and more recent developments in critical human geography.

Geographers of religion explore a multiplicity of faith traditions but tend to be more concerned with the social, cultural, and environmental associations of religion than with religion itself, though this is an internal point of debate among scholars. The geography of religion is therefore differentiated from religious geography, which, according to Petri Raivo, focuses instead on the role of religion in shaping human perceptions of the world and the place of humanity in the world.

The field is often described as the geography of religion and belief systems due to nuances and deficiencies in the term *religion*, which has no formally agreed on definition. The inclusion of belief



The city of Cuzco, Peru, with the Cathedral of Santa Domingo in the foreground. It was built on the site of Kiswarkancha, an Inca palace that was destroyed by the Spanish conquistadors. Completed in 1654, the cathedral is a UNESCO World Heritage site.

Source: © Can Stock Photo Inc.

systems in the description of the discipline allows for a more inclusive study and permits investigation into phenomena such as civil religion.

The geography of religion has a strong institutional presence internationally, especially in the field of cultural geography, and is represented by formal groups of specialists in the United States, Germany, and Eastern Europe. Yet many scholars in fields such as religious studies or cultural geography, who are not overtly geographers of religion, also make important contributions to the field through research that is simultaneously religious and geographic.

Religious Diffusion, Distributions, and Regions

Traditionally, the geography of religion, as a sub-discipline of cultural geography, was especially concerned with the spatial nature of religious institutions and their material implications and characteristics across scales. Religions evolve through space and time and disperse across

geographical space through diffusion, migration, and competition for space. Religions diffuse in ways similar to those of other innovations, but they have unique modes of dispersion, including the migration of believers, contact conversion, and organized missions. Two key principles in the study of diffusion, carriers and barriers, apply to the diffusion of religion: Anything that moves must be carried, and the rate at which it moves is determined by what gets in its way.

Religions tend to exist within ranges and territories. Hence, mapping and understanding patterns of adherence is a significant area of study. A challenge in this field involves the complexity of obtaining data on religious affiliations, particularly in nations where the government does not collect such information in a census. Another complexity involves issues of aggregation and disaggregation, which are highly prone to the ecological fallacy.

Religious distributions have been reported in atlases and textbooks for more than 500 years through maps produced by Christian theologians, who describe religious hearths and borders.



The Yamunotri Temple in the Indian Himalayas. One of the four sites on the Char Dham pilgrimage, it is visited by Hindu pilgrims from across South Asia.

Source: Wikimedia Commons, http://en.wikipedia.org/wiki/File:Yamunotri_temple_and_ashram.jpg.

However, this does not mark the beginning of the field. One of the first major regional geography texts was written by Al-Muqaddasi, an Islamic scholar who, in AD 985, authored an important atlas with significant religious content. A contemporary dimension of the geography of religious distributions involves mapping religious regions and determining local denominational or religious predominance. In the United States, this task is accomplished by mapping aggregated county-level data. These studies can then be analyzed to determine religious diversity and other patterns of distribution in the local or regional religious mosaic. Most of the published studies of this type have occurred in India, Britain, and the United States, with Wilbur Zelinsky's work remaining the most well known. Zelinsky described the cultural regions of the United States, with a particular emphasis on religion. His efforts made prominent

the Mormon cultural region in the United States, which is now considered one of the easiest religious regions to identify and map. Another important and more recent text in this field is Edwin Gaustad and Philip Barlow's *New Historical Atlas of Religion in America*, which uses choroplethic aggregated county boundary maps of adherents to display the history and contemporary distributions of denominations in North America.

Sacred Space and Pilgrimage

Sacred places are locations deemed by believers to be particularly holy or sacred due to historical or ritualistic religious associations. In this sense, sacred space is contrasted with *nonsacred space*, which is described in the literature as profane space. Sacred places are, therefore, understood completely in terms that are religious by believers.



The Hajji Alija Mosque at Počitelj, in Bosnia and Herzegovina. Built in the 16th century, the mosque was destroyed during bombing by Serbian forces in 1993. The mosque and its minaret were later reconstructed.

Source: Michael Goodine.

Sacred places are frequently religious structures or artifacts, but they can also include natural entities such as rocks, hills, or trees. Geographers of religion explore many important questions involving sacred space, including why a particular culture deems a site as sacred and what implications such a designation has on the place and on the culture surrounding it. Related to this is the study of the

political power required to control a sacred site or the land surrounding a sacred place. Sacred sites are often at the heart of local, regional, or international conflict, as are the Temple Mount in Jerusalem and the Kashmir region on the borders of Pakistan, India, and China.

Belden Lane (2002) describes four axioms of sacred space: (1) “sacred space is not chosen, it chooses”; (2) “sacred place is ordinary place, ritually made extraordinary”; (3) “sacred place can be tread upon without being entered”; and (4) “the impulse of sacred place is both centripetal and centrifugal, local and universal” (p. 19).

A concept intricately linked with sacred space is pilgrimage. Pilgrimages are profoundly spatial, and so they are one of the more common and direct avenues of study in the geography of religion. *Pilgrimage* is defined as the physical traversing of distance to encounter a holy place and subsequently return to the point of origin. Pilgrimage is, then, a concept involving the circulation, rather than migration, of pilgrims, who promote the diffusion of ideas from religious nodal centers. Classification of pilgrimage is done through the identification of scale, frequency, and routes. Hindu, Jain, Mormon, Muslim, and Christian pilgrimages have been the major objects of study, especially in South Asia, Western Europe, and the Americas. In some circles, pilgrimage study is closely associated with the geography of

tourism, with the only distinction being the motivation for travel.

Religious Landscapes

Another important area of study in the geography of religion involves the impact of faith on the cultural landscape through architecture, centers of



worship, religious structures, cemeteries, place names, and sacred meanings given to natural phenomena. A theme common in cultural landscape geography is that landscape is a text or manuscript that can be interpreted to understand the cultural history of a locality. Cultural landscapes tend to be saturated with religious meanings that reproduce ideologies and connect landscape to other cultural phenomena such as regional or national identity. Landscapes can contain specific forms of religious phenomena such as domestic altars, roadside chapels, and church and temple architecture.

A field associated with religious landscape geography is the geographic study of cemeteries, known as *necrogeography*. As landscapes of death, graveyards are interpreted to understand the regional and communal attitudes, practices, and values of a culture. Specific areas of necrogeographic analysis include disposal of the dead, graveyard site selection, cemetery architecture and morphology, attitudes toward the afterlife, and residential segregation in cemeteries.

Religious taboos on food and wildlife can also produce an impact over space, as can religious belief in social norms such as dress, behavior, patterns of activity, and commerce. Food taboos can create sharp contrasts in agricultural practices within the same region. Similarly, work taboos that limit labor on certain occasions or in certain places affect the way land is used. Finally, religion affects landscape through place names, also known as *toponyms*, with religious associations to other sacred locations or saints.

Religion and the Environment

Nature and the environment have significant power to shape religious belief and practices. Likewise, a significant role is played by religion to influence worldviews and shape environmental attitudes and behavior, greatly influencing ecologies at scales from the local to the global. Some scholars even argue that religious value systems underpin the present ecological crisis. For instance, Lynn White traces the roots of the contemporary environmental crisis to medieval Christianity, which encouraged exploitation of resources based on the biblical command in Genesis to rule over the Earth and subdue it. Many Christian scholars protest this hypothesis, instead

interpreting the Bible as holistically mandating a stewardship approach rooted in caring for creation. Still, the hypothesis is indicative of the power of religion to affect the environment.

Recent Contributions

Newer cultural and critical geographic perspectives take into account the politics and poetics of sacred space, recognizing that the sacred is deeply interconnected with social and political dimensions. Sacred space is frequently contested space, and sacred spaces often lie at the heart of religious and secular conflict. Therefore, religious attitudes and symbolism are frequently part and parcel of political and ideological contestation across scales.

Other recent developments stem from theories concerning the social construction of identity. Religious identity is developed and sustained through the construction and maintenance of boundaries. Religion helps produce a sense of self and simultaneously a sense of community based on faith and belief.

Another recent development comes from the field of religious studies. Thomas Tweed's recent theory of religion, known as *crossing and dwelling*, employs spatial metaphors to understand religious flows moving through time and space, as religious individuals find their place by making homes and crossing boundaries. While Tweed is not a geographer of religion, his theory is profoundly geographic in nature, and many geographers of religion are using his work.

Conclusion

Religion is a significant factor in contemporary society, affecting the ways in which much of the world's population structure their daily lives. Geography is also a robust and integrative science, providing a helpful framework to study connections between religious practice and its implications over space. Therefore, the geography of religion shows no sign of waning in the near future. The field is varied in content and approach, has acquired increasing coherence in recent decades, and provides substantial insights into diverse religious traditions and their relationships with geographical contexts. The study of the



geography of religion will continue to be an important academic pursuit, albeit one that evolves with new internal approaches and developments in related fields such as religious studies and cultural geography.

Michael P. Ferber

See also **Biblical Mapping; Cultural Geography; Cultural Landscape; Diffusion; Pilgrimage; Zelinsky, Wilbur**

Further Readings

- Gaustad, E., & Barlow, P. (2000). *New historical atlas of religion in America* (3rd ed.). London: Oxford University Press.
- Kiong, T., & Kong, L. (2000). Religion and modernity: Ritual transformations and the reconstruction of space and time. *Social and Cultural Geography*, 1, 29–84.
- Kong, L. (2001). Mapping “new” geographies of religion: Politics and poetics in modernity. *Progress in Human Geography*, 25, 211–233.
- Lane, B. C. (2002). *Landscapes of the sacred: Geography and narrative in American spirituality*. Baltimore: Johns Hopkins University Press.
- Park, C. (1994). *Sacred worlds: Introduction to geography and religion*. New York: Routledge.
- Proctor, J. (2006). Theorizing and studying religion. *Annals of the Association of American Geographers*, 96, 165–168.
- Raivo, P. (1997). Comparative religion and geography: Some remarks on the geography of religion and religious geography. *Temenos*, 33, 137–149.
- Stoddard, R., & Prorok, C. (2003). Geography of religion and belief systems. In G. Gaile & C. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 761–768). London: Oxford University Press.
- Stump, R. (2000). *Boundaries of faith: Geographical perspectives on religious fundamentalism*. Boulder, CO: Rowman & Littlefield.
- Stump, R. (2008). *The geography of religion: Faith, place, and space*. New York: Rowman & Littlefield.
- Tweed, T. (2006). *Crossing and dwelling: A theory of religion*. Cambridge, MA: Harvard University Press.
- Vincent, P., & Warf, B. (2002). Eruvim: Talmudic places in a postmodern world. *Transactions of the Institute of British Geographers*, 27, 30–51.
- Warf, B., & Winsberg, M. (2008). The geography of religious diversity in the United States. *The Professional Geographer*, 60, 413–424.
- Zelinsky, W. (2001). The uniqueness of the American religious landscape. *Geographical Review*, 91, 565–585.



RELPH, EDWARD (1944–)

Throughout his professional career as a geographer, Edward Relph has explored the nature and importance of places, landscapes, environments, and other taken-for-granted geographical dimensions of peoples' everyday lives. His books include *Place and Placelessness* (1976), one of the earliest and most accessible phenomenologies of place; *Rational Landscapes and Humanistic Geography* (1981), a powerful explication of philosopher Martin Heidegger's notion of *appropriation* as a potential vehicle for a lived environmental ethic grounded in respect and care for the natural world; and *The Modern Urban Landscape* (1987), an exploration of why modern cities look the way they do. The empathetic effort to see, describe, and understand everyday places and environments as thoughtfully and as thoroughly as possible is at the heart of Relph's geographic research and writings.

Born in 1944, Relph grew up in a small village in Southern Wales. At the University of London, he completed a bachelor's degree in geography in 1965 and a master's in 1968. He did his doctoral work in geography at the University of Toronto and in 1973 completed his dissertation, *The Phenomenon of Place*, which was revised and published as *Place and Placelessness* in 1976. From 1973 to the present, Relph has been a professor of geography in the Division of Social Sciences at the University of Toronto at Scarborough, a suburban Toronto campus.

During the 1970s, Relph became associated with humanistic geography. Like other geographers of the late 20th century, such as Anne Buttimer, David Ley, Marwyn Samuels, David Seamon, and Yi-Fu Tuan, Relph sought to move



geographic research away from objectified, measurable phenomena studied through positivist science and toward an understanding of geographical and environmental behaviors, experiences, and meanings as they could be interpreted through the Continental philosophical approaches of existentialism, phenomenology, and hermeneutics.

Of all the work in humanistic geography arising from this period, Relph's *Place and Placelessness* has had the most lasting influence because it explained, in simple but versatile language, why places are an integral part of human life and how their existential core can be described phenomenologically in terms of insideness—that is, the degree to which an individual or group feels a sense of belonging and attachment to a locale or environment, which thereby existentially is transformed into a place. In this sense, place gathers human worlds spatially and environmentally, marking out centers of human intention, meaning, and action that, reciprocally, help make place.

After *Place and Placelessness*, Relph continued to examine the existential and geographical aspects of place and its opposite, placelessness—present-day environments and landscapes of standardization, uniformity, and disconnection from human and environmental context. In *The Modern Urban Landscape*, for example, Relph considered how shifts in architecture, technology, planning, and social developments have been largely responsible for the changing physical appearance of Western cities in the past century. In *Rational Landscapes and Humanistic Geography*, he sought ways of seeing and understanding that might facilitate a gentle caretaking of places, people, and the things of nature—what Relph called an environmental humility. Relph (1981) argued that if the current human relationship with nature is to improve ecologically *and* existentially, the primary need is “for guardianship, for taking care of things merely because they exist, for tending and protecting them. In this there is neither mastery nor subservience, but there is responsibility and commitment” (p. 187).

Most recently, Relph has sought to clarify the conceptual and lived differences between spirit of place (the singular qualities of a particular landscape or environment that infuse it with a unique ambience and character) and sense of place (the synesthetic and largely unconscious facility of

human beings to feel and sense the uniqueness of a particular landscape or environment—i.e., its spirit of place). Relph has also probed what he calls a “pragmatic approach to place”—that is, a style of geographical reflection and practice that looks inward toward the uniqueness of particular places but also realizes that those places are integrally related to the larger-scale realm of other places and global interconnectedness. Relph argues that this mode of geographical understanding is crucial if humankind is to circumvent looming 21st-century challenges such as climate change, globalization, ethnic nationalism, and the depletion of inexpensive energy sources.

David Seamon

See also Buttner, Anne; *Existentialism and Geography*; Home; Humanistic Geography; Phenomenology; Place; Sense of Place; Tuan, Yi-Fu

Further Readings

- Relph, E. (1976). *Place and placelessness*. London: Pion.
- Relph, E. (1981). *Rational landscapes and humanistic geography*. Boulder, CO: Rowman & Littlefield.
- Relph, E. (1987). *The modern urban landscape*. Baltimore: Johns Hopkins University Press.
- Relph, E. (1997). Sense of place. In S. Hanson (Ed.), *Ten geographic ideas that changed the world* (pp. 205–226). New Brunswick, NJ: Rutgers University Press.
- Seamon, D., & Sowers, J. (2008). *Place and placelessness* (1976): Edward Relph. In P. Hubbard, R. Kitchin, & G. Valentine (Eds.), *Key texts in human geography* (pp. 43–51). London: Sage.



REMITTANCES

Remittances, in their most common usage, are the transfer of a portion of a migrant worker's wages back to his or her family. A more encompassing definition of remittances includes so-called social remittances: the sending of products (foodstuff, electronics, automobiles, etc.) and the transfer of ideas formed and beliefs adopted from migrant

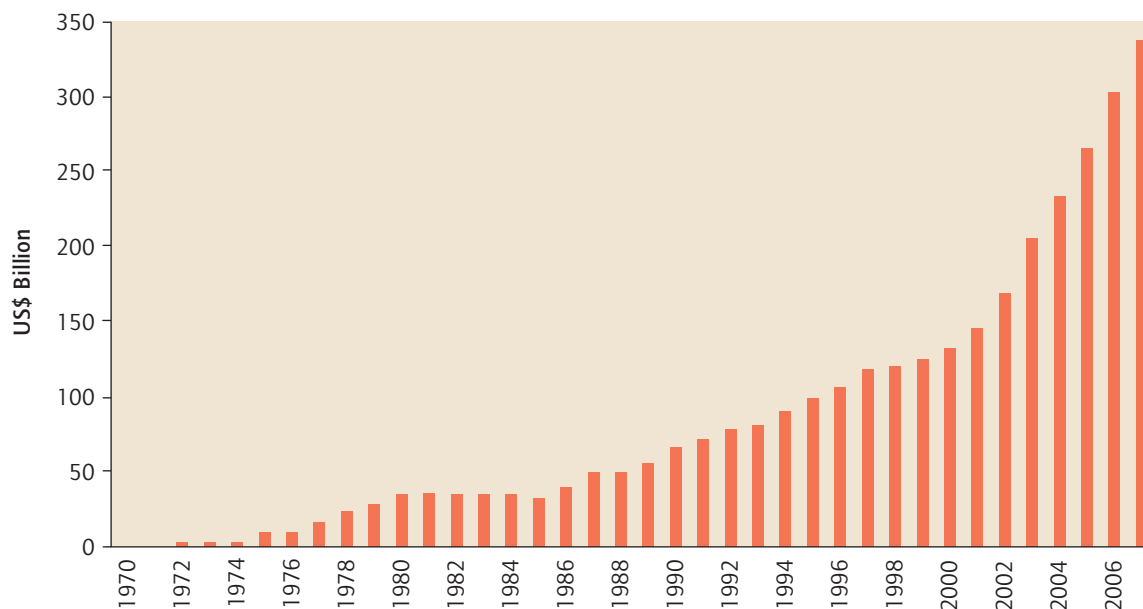


Figure 1 Global remittance flows 2007

Source: International Monetary Fund. (2008). *Balance of payment statistics yearbook*. Washington, DC: Author.

destination workplaces to native communities. In this entry, *remittances* will refer to the simple monetary definition.

Remittances are an important geographic phenomenon due to the sheer volume and extent of monetary flow from more affluent to poorer nations and the fact that they are disproportionately received by poorer members of these developing countries. Such wealth transfer allows households to make important economic decisions concerning health, education, occupation, and daily living conditions. In many poorer nations, remittances have been shown to effect broadscale poverty and mortality reduction through increases in household income and better access to health care.

Geographic Explosion of Remittances

Prior to the 1970s, relatively little remittance income flowed among nations. Since that time, remittance transfers have increased dramatically in volume. Between 2000 and 2007, global remittance flows more than doubled, from \$132 billion to \$337 billion (Figure 1). The developing

world alone received \$251 billion in 2007. To put these numbers into perspective, Ireland's gross domestic product (GDP) was \$255 billion in 2007. Perhaps more important, remittances represent substantial contributions to overall GDP for many developing world economies. In 2006, remittances constituted more than 10% of the GDPs of 24 poorer nations.

Most world regions have received substantial remittance income. Latin America and the Caribbean received the plurality of remittance income (\$61 billion), closely followed by East Asia, with Europe and South Asia not far behind, in 2007 (Figure 2). On a per-country basis, India, China, and Mexico each received over \$25 billion in remittances in 2007 (International Monetary Fund, 2008). Lamentably, the area most in need of international assistance, sub-Saharan Africa, received only \$11.7 billion in remittance transfers in 2007.

Remittance Uses

The use of remittances is widely variable and highly dependent on the economic status of the

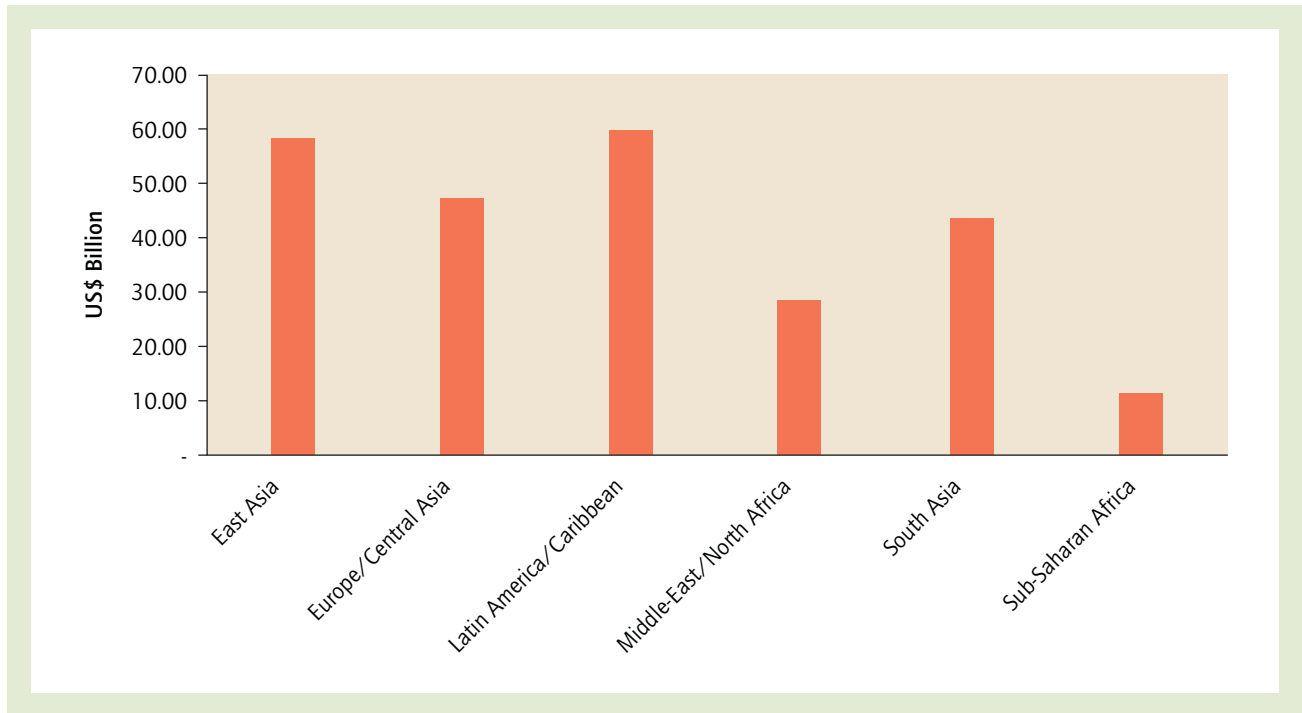


Figure 2 Regional remittance inflows 2007

Source: International Monetary Fund. (2008). *Balance of payment statistics yearbook*. Washington, DC: Author.

recipient household. Poorer households, especially those that practice subsistence agriculture, often use remittances for family maintenance, including diet diversification through the purchase of food grown off their farms. They are more apt to purchase medicines, improve the condition of their homes, and allow their children to spend more time in school. At times, when a household's primary breadwinner is away, remittances are used to contract agricultural workers to tend a household's land.

More economically stable remittance-receiving households have been criticized for the disproportionate use of remittances to increase their conspicuous consumption. It is common to encounter multilevel "trophy" homes in communities that receive large volumes of remittances. Other nonessential items purchased with remittances include packaged food, electronics, and high-end clothes and automobiles. There is also a strong expectation in many villages that migrants will host large celebrations on their return.

However, more affluent remittance-receiving households do not spend all their remittance

income on conspicuous consumption. Occasionally, remittance receipts are used to establish small businesses or to expand and improve the condition of farming operations. Additionally, they are used to pay for the construction of a parent's home or to fund the migration—often illegal—of other family members. And, just as with lower-income remittance recipients, a large volume of remittances is used to improve the education of children through the purchase of school supplies, placing children in private schools, and the financing of higher education.

Remittances as an Economic Diversification Strategy

Throughout much of the developing world, many households use remittance transfers as an economic diversification strategy. The most common type of remittance transfer is from migrant workers sending money from the developed world to a household in the developing world. Within-country urban-to-rural remittance transfers are also common.



There are a multitude of reasons for using migration and the sending of remittances as an economic diversification strategy. For families that have fallen on hard times, it is not uncommon to send one or more members to an economically more robust area to earn sufficient income to ride out the tough times. In many agrarian communities, the sending of migrant workers during slow periods of agricultural productivity, following crop failures, or to make ends meet between harvests is not uncommon.

Remittances and Development

It has long been argued that remittances have not lived up to their potential as catalysts for development in poorer countries. Many early studies on the topic concluded that the bulk of remittances are used for family maintenance and consumption rather than as seed money to start businesses. While it is indisputable that remittances fuel consumption, some argue that their delivery to poorer communities does spur development as they cycle their way through local and regional economies. Even when remittances are used to fuel conspicuous consumption, it is argued that secondary and tertiary recipients (local vendors and suppliers) of remittance income will use this infusion of money to create or expand their businesses, which will have a positive impact on local and regional development. As a final note, remittance income is also used to further the education of recipient household children and to reduce household poverty—both of which are certain long-term economic investments.

Jason Davis

See also **Immigration; Labor, Geography of; Migration**

Further Readings

- Adams, R., Jr. (2006). International remittances and the household: Analysis and review of global evidence. *Journal of African Economics*, 15, 396–425.
- Durand, J., Parrado, E., & Massey, D. (1996). Migradollars and development: A reconsideration of the Mexican case. *International Migration Review*, 30, 423–444.

International Monetary Fund. (2008). *Balance of payment statistics yearbook*. Washington, DC: Author.

Kanaiaupuni, S., & Donato, K. (1999). Migradollars and mortality: The effects of migration on infant survival in Mexico. *Demography*, 36, 339–353.

Reichert, J. (1981). The migrant syndrome: Seasonal U.S. wage labor and rural development in Central Mexico. *Human Organization*, 40, 56–66.

World Bank. (2008). *Quick reference tables*.

Retrieved September 30, 2008, from <http://siteresources.worldbank.org/DATASTATISTICS/Resources/GDP.pdf>



REMOTE SENSING

Coined in the 1960s by a geographer named Evelyn Pruitt, the term *remote sensing* refers to the collection of data about Earth's surface (and atmospheric) features or phenomena without being in direct contact with such features or phenomena. This entry first provides background on electromagnetic radiation (EMR), which is the information link that enables the collection of data about Earth's surface without being in contact with the surface. Next, the entry discusses sensors that capture EMR and are mounted on platforms (aircraft or satellite), which enables the remote collection of different types of imagery. Finally, the principles and strategies of image interpretation for extracting geographic information are covered.

There are advantages and disadvantages in using remote sensing technology for geographic research and applications, relative to more conventional, ground-based or in situ (i.e., direct) observation methods. The primary advantage is that remote sensing enables spatially continuous and contiguous, large-area sampling of Earth's surface and atmosphere. This means that data are comprehensive, synoptic (i.e., many features are observed simultaneously), and efficiently collected. Other advantages are the noninvasive, nondisturbing nature of sensing remotely and the ability to collect data for areas that are inaccessible or inhospitable for making observations on the ground. Often, historical information on geographic features or



conditions can only be derived through interpretation of archived imagery captured in the past. The main disadvantages of remote sensing are that remote observations are less detailed and precise and more uncertain than direct measurements made on the ground. Also, the sensing process, the image-processing steps, and the act of image interpretation all can yield more artifacts (i.e., false information) than would normally result when making in situ observations.

Electromagnetic Radiation: The Information Link

EMR is the important link that enables information about Earth's surface to be extracted. As the term suggests, both electric and magnetic fields are associated with EMR transfer, which can occur even in the absence of matter (i.e., in a vacuum). The orientation of the electric field determines the polarization of EMR. EMR travels at the same speed (the speed of light, or 300,000,000 m [meters] per second) through outer space and, effectively, through Earth's atmosphere, irrespective of wavelength or frequency. Wavelength and frequency are inversely related (i.e., short-wavelength EMR is high-frequency EMR).

All matter emits EMR, and the wavelength of emitted radiation is an inverse linear function of the temperature of the emitting material. A change in the electrical charge of matter, which can result from atomic-level changes in energy states or molecular-level motions such as vibration and rotation, causes EMR to be emitted. The sun emits shortwave radiation in an amount that is approximately equal to a *blackbody* (defined as a perfectly absorbing material that is in thermal equilibrium) having a temperature slightly less than 6,000 Kelvin. Earth's surface reflects incoming solar radiation (called solar irradiance) and emits long-wave radiation. The actual amount of radiation emitted by Earth surfaces also depends on the emissivity properties of different materials, which pertains to the efficiency of emission relative to a blackbody at the same temperature. Most of the EMR emitted by Earth surfaces is radiated within the thermal-infrared (TIR) part of the EMR spectrum at wavelengths ranging from 3 to 30 μm (micrometers), where $1\ \mu\text{m} = 10^{-6}\ \text{m}$.

Most remote sensing of the environment is based on passive imaging of solar reflective EMR, primarily in the wavelength range between 0.3 and 3.0 μm . This range includes the longer portion of the ultraviolet (0.3–0.4 μm), visible (0.4–0.7 μm), near-infrared (0.7–1.2 μm), and shortwave-infrared (1.2–3.0 μm) portions of the EMR spectrum. Passive optical remote sensors on aircraft or satellites capture EMR that reflects and/or is emitted from Earth surface materials and scatters off of or is emitted from atmospheric constituents. In most geographic applications, the surface-leaving radiation (called *exitance*) is the signal of interest, and the scattered or emitted atmospheric radiation is noise.

Solar radiation passes through the atmosphere in its path to Earth's surface and then, on being reflected, passes through the atmosphere again en route to a sensor on an aircraft or satellite platform. Atmospheric constituents such as gas molecules, small particles called *aerosols*, larger particles called *particulates*, and water in liquid and solid form (e.g., cloud droplets, raindrops, and ice) have the ability to absorb (intercept) and/or scatter (redirect) EMR. Of these interactions, scattering is the most important factor for solar reflected radiation, while absorption is more important when sensing long-wave emitted radiation. Atmospheric scattering diffuses the direct solar irradiance, reduces the amount of reflected solar radiation traveling to a sensor, and redirects solar radiation into the view of the sensor. Absorption limits which wavebands within the EMR spectrum are useful for sensing Earth's surface properties. For long-wave (TIR and microwave) sensing, absorption reduces the magnitude of emitted radiation leaving a surface and results in the atmosphere reradiating EMR into the view of a sensor.

The spectral signature of a surface material or object is the characteristic pattern of the magnitude of reflected or emitted EMR as a function of wavelength. As a type of inversion problem, information about the composition or condition of surface features can be extracted from spectral signatures represented in remotely sensed data. The amount of reflected EMR captured by a remote sensor is primarily a function of the reflectance properties of the surface materials. However, the reflected EMR leaving a surface is also



influenced by the magnitude and direction of the solar irradiance and the view direction of the remote sensing instrument. The amount of emitted long-wave radiation leaving a surface is primarily a function of the surface temperature and, to a lesser extent, the emissivity of the surface. Radar sensing is achieved by a process in which microwave EMR is actively transmitted from an antenna and the backscattered EMR is received by the antenna, which is operated in a side-looking mode. The amount of backscatter, and therefore the strength of the received signal, is primarily a function of the moisture, microroughness, and geometric characteristics of surface materials and features.

Types and Sources of Remotely Sensed Imagery

Numerous types and sources of remotely sensed image data are available. The selection of the most appropriate image type should be based on a close match between the spatial, temporal, and attribute aspects of one's information requirements and the spatial, spectral, radiometric, and temporal characteristics of the available imagery. Two important specifications associated with these characteristics pertain to two data properties: (1) resolution or grain and (2) extent or coverage. Spatial resolution and extent aspects of an image characterize the fineness of spatial detail and the areal extent covered by an image, respectively. Each spatial characteristic must be traded off relative to the other; that is, high spatial resolution comes at the expense of limited coverage, and vice versa. Spectral resolution pertains to the range of wavelengths for a particular spectral waveband, while the number and location of wavelength bands in the EMR spectrum determine the spectral coverage. Radiometric resolution and coverage pertain to the fineness and range of EMR energy levels quantified by a remote sensor. The finer the radiometric resolution, the greater the ability to quantify fine differences in surface properties or identify subtle differences in surface material composition. Finally, temporal resolution and duration, which are mostly determined by aircraft or satellite mobility characteristics, represent the time interval between remote sensing observations and the record length of available data, respectively.

The primary differences between imagery types are associated with the type of (1) platform (airborne vs. satellite) and (2) sensor (photographic vs. digital and optical vs. microwave). Airborne imagery is captured by sensors on fixed-wing (e.g., airplanes and jets) and rotary-winged (e.g., helicopters), or lighter-than-air (e.g., blimps) platforms. Airborne platforms operate at lower altitudes and tend to be more flexible and mobile than satellites. They are able to provide imagery with higher spatial and temporal resolution but usually with more limited spatial and temporal coverage. Satellites normally provide regular, large-area image coverage at set times and with coarser spatial resolution. The two principal types of satellite orbits, sun synchronous (i.e., polar orbiting) and geostationary (i.e., equatorial orbiting), determine spatial and temporal resolution and coverage characteristics. Sun-synchronous satellite systems are able to provide higher-spatial-resolution images less frequently, while geostationary systems provide frequent images that cover much of the globe simultaneously but with coarser spatial resolution. Photographic cameras capture imagery on film, providing very high spatial resolution and fidelity but limited flexibility in spectral range and image formats. Higher spectral and radiometric qualities are achieved with digital sensors such as digital camera systems and optical-mechanical scanners, which directly measure EMR levels in an electronic, computer-compatible manner. Aerial photographic film can be electronically scanned to produce digital images. Digital images are more readily corrected, enhanced, and converted into geographic information system (GIS)-compatible form. Digital image data can be transferred by electronic means through microwave downlink and wired communications.

Particular platform-sensor combinations tend to be used to capture the most commonly available imagery, though any type of imaging sensor can operate on either airborne or satellite platforms. The most common airborne imagery has been aerial photography. The use of airborne digital cameras and linear array sensors to capture high-spatial-resolution images of land areas is increasing rapidly. Aerial photographic film is available in black-and-white panchromatic, black-and-white infrared, true-color infrared



(CIR), and false-color infrared formats. Most satellite imagery is captured by digital imaging radiometers, since it is difficult to retrieve photographic film from a satellite. These sensors capture images through *pushbroom* sampling, using a large linear array of detectors, or *whiskbroom* sampling, using oscillating mirrors and a few detectors.

The three primary means for acquiring image data are as follows:

1. Obtaining existing imagery from an archive source
2. Capturing one's own imagery
3. Hiring a commercial firm or public agency to acquire new imagery coverage

Obtaining existing imagery is the least expensive, since the cost of acquisition has been subsidized. However, with this approach, one has no control over the spatial, spectral, radiometric, and temporal characteristics of the imagery. Of course, this is the only means for acquiring historical imagery. If current imagery is needed or no source of useful imagery exists, one can capture one's own airborne imagery. Consumer-level digital cameras and video sensors enable convenient imaging from a rented aircraft. To capture vertical imagery, one may need to design, build, and install a camera mount. Though not suitable for precise mapping, such imagery can be useful for reconnaissance and qualitative landscape assessments, particularly along linear features such as streams, roads, or utility corridors and for inventorying (i.e., making counts of) surface features.

If current imagery is needed and/or particular spatial or spectral image characteristics are required, then imagery must be purchased from a commercial vendor. Aerial survey firms can provide new and archived aerial photography and/or digital airborne imagery. Similarly, satellite



Landsat 7 image of Cape Cod, Massachusetts; data generated through NASA's Commercial Remote Sensing Program

Source: NASA.

imagery with high (starting in 2000) and moderate (since 1972) spatial resolution can be obtained from both public and commercial suppliers around the world.

Interpreting Remotely Sensed Images

Image interpretation is the act of analyzing remotely sensed images and extracting useful information about a scene, the Earth surface area represented by an image. Interpreting images is



both an art form and a science. Humans have innate interpretative abilities, but interpretative ability improves with experience. By following scientific principles of systematic investigation and establishing interpretative rules, information extraction can be optimized and subjectivity can be minimized.

There are four general types of image interpretative tasks that an image analyst may wish to accomplish. In order of complexity, these tasks are as follows:

1. **Detection:** Locating the occurrence of a particular type of feature or phenomenon; a binary or dichotomous search process (e.g., detecting standing water or the presence of vegetation)
2. **Identification:** Locating or delineating and determining the types of features or phenomena (e.g., identifying vegetation community types)
3. **Measurement:** Quantifying the length, area, or number of occurrences of objects (e.g., measuring the length of a road segment or counting the number of dwellings in a neighborhood), once such objects have been detected or identified
4. **Analysis:** Examining the spatial relationships and geographic attributes of a scene (i.e., the ground area covered by an image), often by incorporating information derived from detection, identification, and measurement of scene objects and phenomena (e.g., analyzing the socioeconomic characteristics of a neighborhood or inferring habitat quality from vegetation patterns)

These general image interpretation tasks are performed for a variety of geographic applications, including

1. renewable resource management;
2. exploration and engineering geology;
3. urban and transportation planning and engineering;

4. emergency response, law enforcement, and military reconnaissance; and
5. scientific explorations.

Appropriate tools and strategies for image interpretation vary depending on whether images are in hardcopy or digital form. Most hardcopy images are aerial photographs, which are not normally geographically referenced. As for a map, the spatial scale of a hardcopy image is specified by the representative fraction, the ratio of the length of a feature on an image to its actual length on the ground. The representative fraction should be expressed as a dimensionless ratio per unit image length (e.g., 1:10,000 scale or 1/10,000 scale). However, it is common practice for local government agencies in the United States to use dimensioned-scale equations in nonmetric units (e.g., 1 in. [inch] = 2,000 ft. [feet]). Dimensioned-scale equations can be readily converted to a dimensionless representative fraction by converting the units of one side of the equation to match the units of the other side (e.g., 1 in. = 2,000 ft. → 1:2,000 scale; 1 in. = 24,000 ft. → 1:24,000 scale). Since the representative fraction increases when the denominator (called the *scale factor*) decreases, a large-scale image portrays a smaller areal extent with greater spatial resolution than a small-scale image. The scale of uncorrected aerial photographs captured over varying terrain varies across the image, making it difficult to measure lengths and areas in an accurate manner.

Hardcopy images can be interpreted with the aid of analog optical viewing tools such as magnifying film loops or microscopes. Aerial photographs are often captured with approximately 60% overlap to enable stereoscopic viewing. A *stereoscope* is a device that forces each eye of the interpreter to simultaneously view each overlapping portion of the photographic pair, such that the interpreter observes the scene in three dimensions. Being able to see topographic features and terrain variations in stereo is very effective in visualizing landscape relationships or mapping terrain-controlled features such as vegetation. If a digital GIS layer is to be generated from an analog map, the map must be digitally encoded by scanning or manually digitizing the interpreted features.



Digital images can be displayed and viewed on a computer monitor or printed onto a variety of hardcopy media. Computer-based image processing and display systems enable interactive viewing, processing, and interpretation in a very flexible and efficient manner known as *on-screen interpretation*. While a novice image analyst may not attempt to exploit the semiautomatic image interpretation (e.g., image classification or object recognition) and quantification capabilities of image-processing software, on-screen interpretation is readily achievable and powerful. The purpose of more automated approaches is to generate and update geospatial data sets in a faster, cheaper, more repeatable, and more reliable manner. Though the reliability of semiautomated approaches is improving, some form of manual, interactive editing and quality checking of the resultant products is required.

Up to three different wavelength bands, enhanced images or dates of imagery can be displayed simultaneously in the three color planes (red, green, and blue) of a computer image display. A single-band, panchromatic (i.e., broad visible wavelength band) satellite image can be displayed simultaneously in all three color planes to yield a gray-tone (i.e., black and white) image. True-color images are displayed when red-, green-, and blue-wavelength bands are displayed in red, green, and blue color planes, respectively. When other waveband/color plane combinations are displayed, the resultant images are called *false-color composites*. The most common is the false-color infrared composite, where near-infrared, red, and green wavelengths are displayed in red, green, and blue color planes, respectively. As with the color representation of CIR photographs, healthy green vegetation appears bright red, and inorganic urban surfaces (e.g., concrete and roofing materials) are portrayed in blue-gray.

Many image analysis and mapping tasks can be performed with digital images displayed on a computer monitor. An analyst can conveniently modify the scale and tone/color of a digital image and, using image-processing software, correct and enhance spatial and radiometric characteristics. (Image corrections and enhancements can also be performed by image suppliers prior to obtaining the imagery.) Spatial scale may be changed by digitally zooming, which means that there is no

inherent representative fraction associated with an image displayed on a computer monitor. Once an image is enhanced and displayed, an analyst can visually interpret the image on the computer monitor. Point, line, and polygon objects can be counted, measured, and/or digitized interactively by cursor control devices (e.g., mouse). Information attributes (e.g., category names) about these spatial objects must be encoded manually. These encoded objects can be saved to a digital file. If the image has been georeferenced, then a file of image-digitized features with encoded attributes is essentially a GIS layer. Similarly, a dated GIS file can be overlaid graphically with a more current georeferenced image and be updated interactively through this “heads-up digitizing” approach.

Conclusion

Remote sensing provides an efficient means for deriving geospatial data and information about Earth's surface (and atmosphere). Many geospatial data and information requirements can be met through visual interpretation of remotely sensed images. Digital imagery and image-processing software are becoming more accessible, allowing for more efficient and reliable interpretation and digital encoding of geospatial data.

Remote sensing is a rapidly advancing technology and the availability, cost, and characteristics of remotely sensed imagery change constantly. Most of these changes are positive, meaning that the imagery is becoming higher quality and is available in a more convenient, timely, and economical format.

Douglas Alan Stow

See also **Aerial Imagery: Data; Aerial Imagery: Interpretation; Atmospheric Remote Sensing; GIScience; Image Enhancement; Image Fusion; Image Interpretation; Image Processing; Image Registration; Image Texture; Imaging Spectroscopy; Microwave/RADAR Data; Multispectral Imagery; Multitemporal Imaging; Photogrammetric Methods; Radiometric Correction; Radiometric Normalization; Radiometric Resolution; Remote Sensing; Platforms and Sensors; Remote Sensing in Disaster Response; Scale in GIS; Spatial Resolution; Spectral Resolution; Temporal Resolution**



Further Readings

- Beck, L. R., Lobitz, B. M., & Wood, B. L. (2000). Remote sensing and human health: New sensors and new opportunities. *Emerging Infectious Diseases*, 6, 217–227.
- Campbell, J. B. (2002). *Introduction to remote sensing* (3rd ed.). New York: Guilford Press.
- Jensen, J. R. (2005). *Introductory digital image processing: A remote sensing perspective* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.
- Jensen, J. R. (2007). *Remote sensing of the environment: An earth resource perspective* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.
- Jensen, J., Campbell, J., Dozier, J., Estes, J., Hodgson, M., Lo, C., et al. (1989). Remote sensing. In G. Gaile & C. Willmott (Eds.), *Geography in America* (pp. 376–418). Columbus, OH: Merrill.
- Kramer, H. J. (2002). *Observation of the earth and its environment: Survey of missions and sensors* (4th ed.). New York: Springer.
- Lillesand, T. M., & Kiefer, R. W. (2003). *Remote sensing and image interpretation* (4th ed.). New York: Wiley.
- Quattrochi, D., Walsh, S., Jensen, J., & Ridd, M. (2003). Remote sensing. In G. Gaile & C. Willmott (Eds.), *Geography in America at the dawn of the 21st century* (pp. 376–418). Oxford, UK: Oxford University Press.
- Rees, W. G. (2001). *Principles of remote sensing* (2nd ed.). Cambridge, UK: Cambridge University Press.



REMOTE SENSING: PLATFORMS AND SENSORS

Remote sensing in geography is recognized as the technology of acquiring geographically referable information on the land, ocean, and atmosphere without having physical contact with the object under study. A wide range of sensors for acquiring the data about Earth and its environment are in use in remote sensing. Sensors are required to be fixed in a stable platform for recording, storing, and transmitting the data into ground-based receiving stations.

Platforms

In remote sensing, the vehicle or structure that carried a sensor is called a *platform* (Table 1; Figure 1). Airborne or space-borne platforms are often used in remote sensing of the environment. Aircraft or balloons are some examples of airborne platforms, while satellites or space shuttles can be considered as space-borne. Balloons, considered to be the cheapest airborne platforms, are often used for academic training, experiments, and rapid damage assessment purposes. However, ground-based platforms are also in use. Towers, scaffoldings, and cars can be used as ground-based platforms to record detailed information about the surface for experiments to validate data collected from other sources.

Platform	Altitude	Remarks
Geostationary satellite	36,000 km	GMS, NOAA-GEOS, DMSP, INSAT, etc.
Circular orbit satellite	500~1,000 km	IRS-1C, LANDSAT, ALOS, Quickbird, etc.
Space shuttle	240~350 km	SRTM project
High-altitude jet plane	10~12 km	Reconnaissance, aerial surveys, etc.
Low-altitude plane	500~8,000 m	Aerial surveys
Helicopter	100~2,000 m	Aerial surveys
Radio-controlled plane	~500 m	Airplane, helicopter
Hang-plane	50~500 m	Hang-glider, paraglider, etc.
Hang-balloon	~800 m	Hydrogen balloon
Ground based	0~200 m	Tower, crane, car, cherry pickers, etc.

Table 1 Types of platforms

Source: Adapted from Japan Association of Remote Sensing (Ed.). (1999). *Remote sensing notes*. Tokyo: National Space Development Agency of Japan/Remote Sensing Technology Center of Japan.

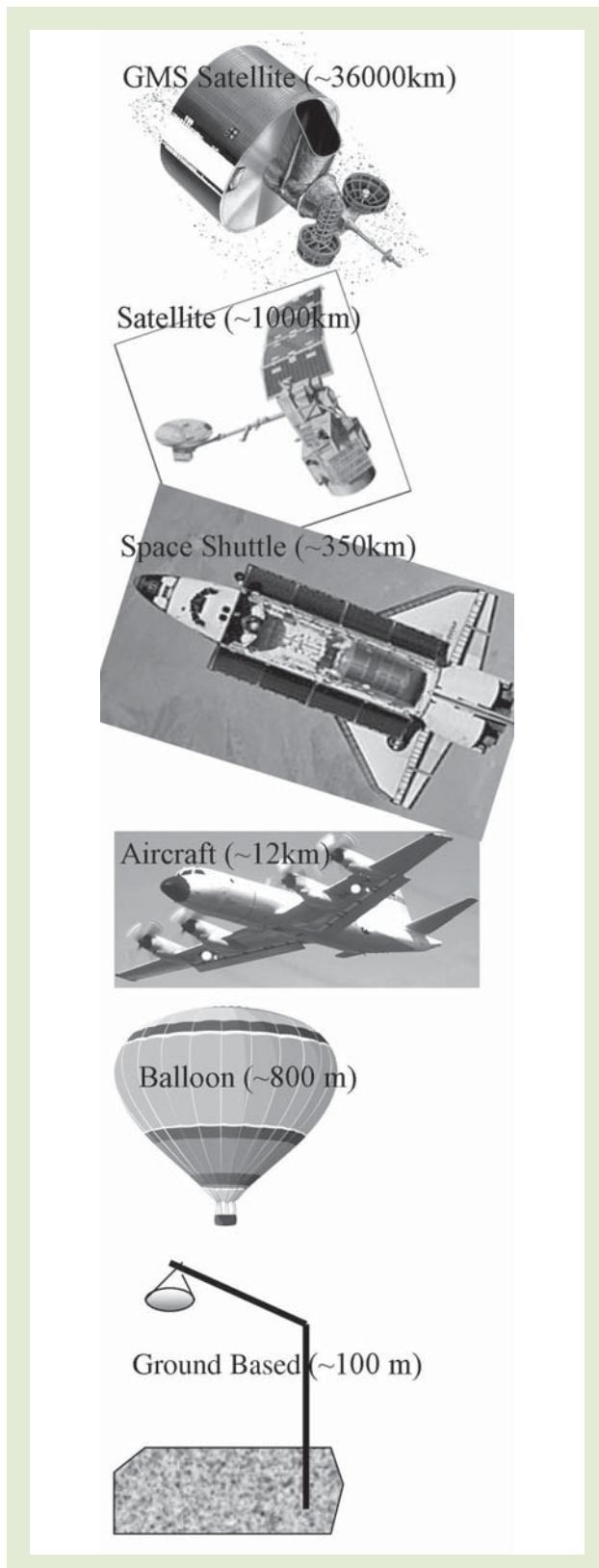


Figure 1 Remote sensing platforms

Source: Authors.

Aircraft are commonly used platforms to collect detailed images and facilitate the collection of data about Earth's surface at desired times. Cameras mounted on aircraft have been used to monitor land use practices, locate forest fires, and produce detailed and accurate maps of Earth's surface based on aerial photographs captured with aircraft-mounted cameras. Remote sensing can be also conducted using space shuttles. The NASA Shuttle Radar Topographic Mission (SRTM) 90-m Digital Elevation Data for the entire world was one of the examples of using a space-borne platform, namely, the space shuttle. However, with the advancement of technology, satellites are becoming commonly used space-borne platforms in remote sensing.

Satellites are placed outside the atmosphere at a large distance, orbiting around the Earth at a designated time frequency. Because of their flight path, satellites permit repetitive coverage of Earth's surface on a continuing basis. The Landsat, SPOT, RADARSAT, IKONOS, ALOS, and NOAA satellites are some examples of satellites that have been providing data about the Earth at various scales for more than four decades. The data acquired by each platform may possess specific data characteristics within the constraints imposed by the individual sensors.

Some satellite platforms are *sun-synchronous*, while some are *geosynchronous*. A sun-synchronous satellite passes over the same part of Earth at roughly the same local time each day. RADARSAT, Landsat, SPOT, and COSMOS are examples of sun-synchronous satellites. A geosynchronous satellite has an orbital track around Earth that it repeats regularly over time. For example, if a satellite's orbit lies over the equator and the orbit is circular, it is called a *geostationary* satellite. Geostationary meteorological satellites and NOAA satellites are examples of geosynchronous satellites.

Sensors

Remote sensing devices are called *sensors*. Sensors are designed to record *electromagnetic radiation* (EMR). EMR is energy transmitted through space in the form of electric and magnetic waves. Sensors record specific wavelengths of the electromagnetic spectrum (a range of electromagnetic

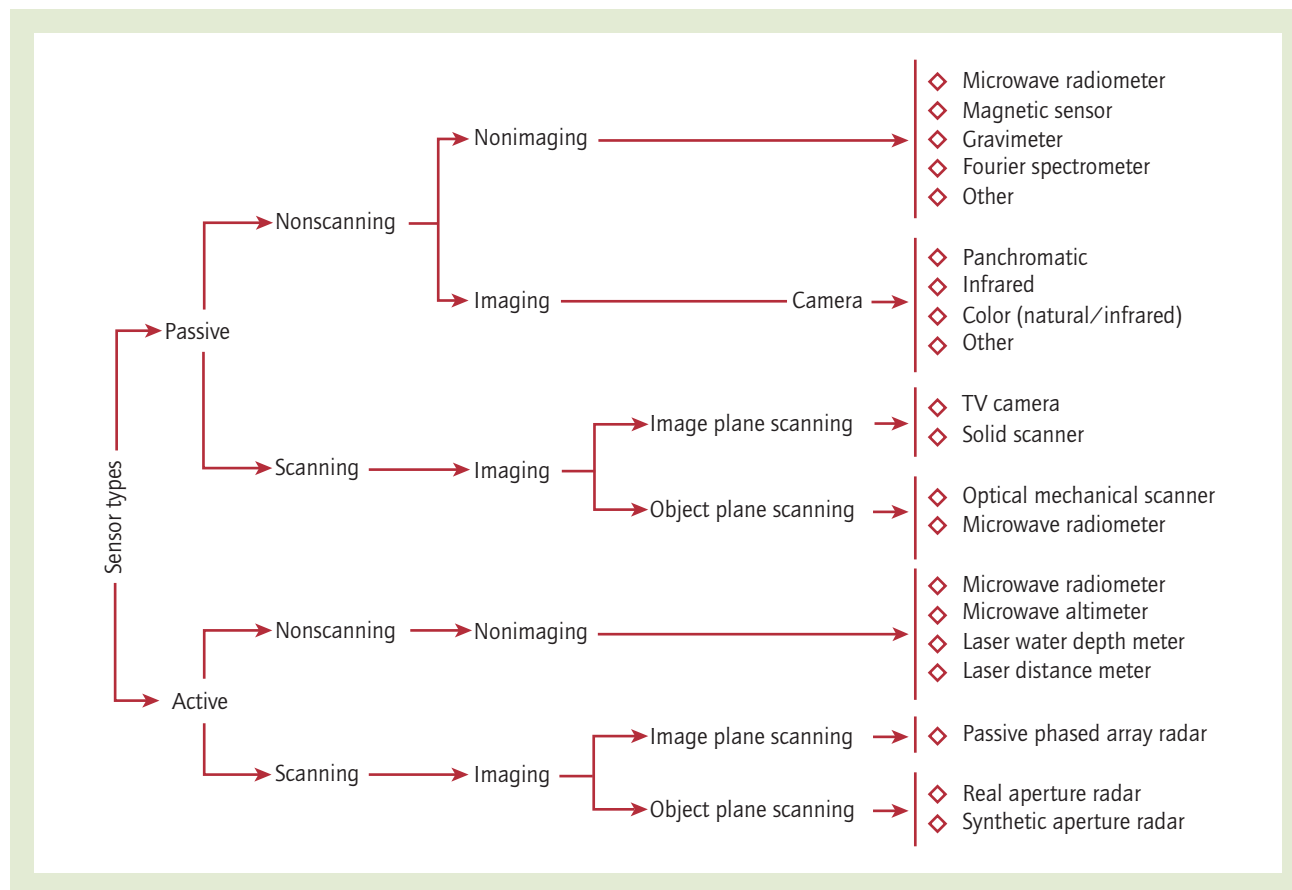


Figure 2 A general schematic diagram of sensor types

Source: Adapted from Short, N. M. (2009, February). *Remote sensing tutorial*. Retrieved April 20, 2009, from <http://rst.gsfc.nasa.gov>.

radiation extending from cosmic waves to radio waves) in various bands (most importantly in the visible, infrared, and microwave bands) to use the benefits of the absorption or transmission properties of Earth and the atmosphere.

Sensors may be fixed on space-borne, airborne, and terrestrial platforms to acquire geophysical data from global to local scales. A platform may carry several sensors. For example, Landsat ETM, a space-borne platform, has multiple sensors that record electromagnetic energy reflected from Earth's surface in different bands ranging from visible to infrared and thermal bands at various spectral resolutions. Application of data generated from the remote sensing techniques depends on sensor resolution capabilities. Some of the sensors mounted on an airborne platform, especially in aerial photography, are capable of data acquisition at the 0.08-m (meter) level, while

some sensors fixed in space-borne platforms such as Quickbird provide data up to 0.6 m of spatial resolution.

Sensors are most often classified into two categories: passive and active (Figure 2). *Passive sensors* detect the reflected or emitted electromagnetic radiation from natural sources. Sunlight is the most common natural source of radiation measured by the passive sensors. Those sensors that use lenses in the visible and reflective infrared region are often called *optical* sensors. The wavelength region usually extends from the visible and near-infrared (VNIR) to shortwave infrared (SWIR). Aerial survey cameras, space cameras, radiometers, fourier spectrometers, and multi-spectral scanners are some of the examples of passive sensors.

In general, remote sensing sensors include panchromatic, multispectral, and hyperspectral



sensors. *Panchromatic* sensors record information in a wide range of wavelengths, including the visible and near-infrared spectrums, into one band, while *multispectral* sensors cover two or more spectral bands, recording the bands simultaneously. *Multispectral scanners* (MSS), widely known sensors used in the early Landsat series, record radiation in multiple-wavelength regions of the visible, near-infrared, middle-infrared, and thermal-infrared parts of the electromagnetic spectrum. *Hyperspectral sensors* cover spectral bands narrower than multispectral sensors and record the image data from several hundred bands at the same time, offering greater spectral resolution than the multispectral sensors. The airborne visible/infrared imaging spectrometer (AVIRIS), an example of a hyperspectral remote sensing sensor, delivers calibrated images in 224 contiguous bands. The passive sensors are unable to penetrate the clouds over the target, and the quality of data mostly depends on daytime sunlight. Since the information spectrums recorded by passive sensors are strongly affected by atmospheric scattering, the usefulness of these devices may be limited by atmospheric conditions. MODIS, ASTER, IRS-1C, and SPOT satellites are some of the platforms that have carried passive sensors.

Active sensors detect reflected responses from objects that are irradiated from artificially generated energy sources. The platforms that have active sensors carry their own flashlight-emitting microwaves to illuminate their targets. In this case, the image of the object surface is formed by measuring the microwave energy scattered by the ground or sea back to the sensors. Because the artificial energy source system, especially on satellite platforms, requires large solar collectors and storage batteries, it may not operate continuously; some satellites are limited to 10 minutes of operation per hour.

RADAR can be considered as an example of an active remote sensing sensor, where the time delay between emission and return is calculated to locate the geographical position and height of stationary objects and also the directionality of moving objects. Furthermore, the antenna is a key element of a radar sensor. For a given position in space, the resolution of the remotely sensed image is a function of the antenna size, in what is called *real-aperture radar*, or RAR. The

data collected by the RAR is limited by the antenna size regardless of sensor path. Therefore, the synthetic aperture radar (SAR) system was developed to remove the antenna constraint by synthetically propagating the antenna. Laser spectrometers, laser altimeters, and microwave radiometers are a few other examples of active sensors. The advantage of an active sensor over a passive sensor is the capability of the former to record information about the environment regardless of night and cloud cover. An ALOS platform consists of both passive (AVNIR-2) and active (PALSAR) sensors, while RADARSAT carried only an active sensor.

Future Directions

Currently, many innovative research projects directed at the development of platforms and sensors are in progress, with the overarching goal of ushering in a wider availability of remotely sensed data, reducing the data cost, and enabling a widespread analysis of environmental change. Low-cost space-borne platforms such as microsatellites are being developed to collect data over a geographic location for a specific application or purpose. Small, unmanned, radio-controlled aerial-survey aircrafts are also being developed for a faster response to natural disasters such as wildfires. Other efforts promise to provide higher spatial, temporal, and radiometric resolutions in the days to come. For example, further improvement of hyperspectral remote sensing will include ultraspectral frequencies that may result in thousands of imaging bands providing the data at a fraction of today's wavelengths. It is expected that the next generation of remote sensing sensors will be able to provide data at higher spectral and spatial resolutions to expand our understanding of geological processes and mineralogy, climate change, health, and human-induced processes. However, the increasing volume of data coming from hyperspectral and hyperspatial sensors will challenge data mining, processing, backup, and retrieval capabilities.

Rajesh Bahadur Thapa and Yuji Murayama

See also *Photogrammetric Methods; Remote Sensing; Spectral Characteristics of Terrestrial Surfaces; Spectral Resolution*



Further Readings

- Canada Center for Remote Sensing. (2008, January). *Outreach materials*. Retrieved April 15, 2009, from http://ccrs.nrcan.gc.ca/resource/index_e.php
- Japan Association of Remote Sensing. (Ed.). (1999). *Remote sensing notes*. Tokyo: National Space Development Agency of Japan and Remote Sensing Technology Center of Japan.
- Melesse, A. M., Weng, Q., Thenkabail, P. S., & Senay, G. B. (2007). Remote sensing sensors and applications in environmental resources mapping and modelling. *Sensors*, 7, 3209–3241.
- Short, N. M. (2009). *Remote sensing tutorial*. Retrieved April 20, 2009, from <http://rst.gsfc.nasa.gov>



REMOTE SENSING IN DISASTER RESPONSE

Remote sensing is the observation of phenomena at a distance, using a range of sensors for object identification based on their spectral signature, that is, the degree to which they absorb, reflect, backscatter, or emit light at various segments of the electromagnetic spectrum. Remote sensing can be accomplished from aircraft, from Earth-observing satellites, and from specialized in situ devices. Remote sensing technology has been used to facilitate first-responders' decision support for a wide array of biogenic (naturally caused) and anthropogenic (man-made) disasters. Such natural disasters include landslides, snow disasters, volcanic eruptions, floods, hurricanes, earthquakes, tsunamis, droughts, famines, epidemics, and epizootics. Anthropogenic disaster responses that have benefited from remote sensing data include both inadvertent disasters (e.g., pollution, mining accidents, hazardous chemical and oil spills, train derailments) and deliberately caused disasters (e.g., acts of terror, arson-related fires).

Aircraft have the advantage of capturing high-resolution panchromatic, multispectral and hyperspectral data from low-altitude flights, thereby providing high spatial and high spectral resolution, with a minimum of atmospheric distortion; but due to the infrequency of airborne sensor flights, they

lack the high temporal resolution offered by satellite remote sensing. Geostationary satellites, whose orbits are in sync with Earth's rotation, capture data 24 hours per day, 7 days a week, while polar-orbiting satellites, depending on their revisit time, may collect data over the same area several times per day. Current analytical software for image analysis can minimize the impact of atmospheric distortion for both multispectral and hyperspectral orbiting sensors. Moreover, satellites with radar sensors can penetrate cloud cover.

In situ devices, ranging in sophistication from simple rain gauges to seismometers to NEXRAD Doppler Radar installations, monitor variables such as local precipitation, temperature, humidity, barometric pressure, water levels and quality, soil moisture, seismic activity, biological and chemical pollutants, and so on. Such in situ data can be used to supplement both aircraft-borne and space-borne sensor data. For disaster management purposes, other sources of data are also crucial, including demographic data, socioeconomic data, structural data, transportation network data, epidemiological data, and so on. Advanced technologies for in situ remote sensing are exemplified by micro unmanned aerial vehicles (MUAV), which can be deployed with sensors to detect explosives, toxic liquids or gases, radiation, biological or chemical weaponry, as well as hazardous industrial effluent.

The mechanism for integration of such diverse sources of information is typically a spatial database or geographic information system (GIS), which allows for multiple data layers and the means to analyze them in specific combinations. Online shared GIS allows end users to serve as sentinels during major disasters and participate in damage assessment. The other space-based technology that plays a vital role in disaster response is the constellation of geopositioning satellites, which can give exact location (i.e., latitude/longitude or Universal Transverse Mercator (UTM) information). There are now four such geopositioning constellations, the United States' Global Positioning System (GPS), the European Union's Galileo, Russia's GLONASS, and China's Beidou (Compass).

The International Charter—Space & Major Disasters (www.disasterscharter.org) is a consortium of satellite-owning governments and companies that freely distributes satellite data through authorized users to areas that have experienced a



declared disaster. Such data are used for evacuation support, search and rescue, determining the extent of damage, facilitating access to medical and humanitarian shelter facilities, and so on. Since its first activation in February 2002, as of July 10, 2009, the charter has been activated 198 times, providing free satellite data to countries worldwide for virtually every known catastrophic event. Charter members and their space-based resources include the U.S. Geological Survey's Landsat, the National Oceanic and Atmospheric Administration's (NOAA) POES and GOES, Canada's RADARSAT, France's SPOT, Argentina's SAC-C, the European Space Agency's ENVISAT and ERS, India's IRS, Germany's Terra SAR, China's FY, SJ, and ZY satellites, Japan's ALOS, and, from the private sector, GeoEye-1, Digital Globe's Quickbird, and Qinetiq's TopSat. The charter also includes the Disaster Monitoring Constellation (DMC). On July 29, 2009, a Russian Dnepr Rocket launched two satellites, Spain's Deimos-1 and the United Kingdom's DMC-2, that are part of the multicountry DMC, which include Algeria's AISAT-1, Turkey's BilSAT (decommissioned in 2006), Nigeria's SAT-1, the United Kingdom's DMC, and China's Beijing-1.

Other international agencies and initiatives directly involved in disaster response include the United Nations Disaster Relief Organization (UNDRO) and the recently created UN SPIDER (Space-Based Information for Disaster Management and Emergency Response), a division of the United Nations Office for Outer Space Affairs (UNOOSA), which is specifically chartered to develop optimal applications of space-based technologies for societal benefit. The North Atlantic Treaty Organization (NATO) has also funded development of the Kamal Ewida Earth Observatory: real-time remote sensing ground stations at two universities in Cairo, Egypt, in collaboration with universities in Turkey and the United States, to support early warning and mitigation of disasters, including epidemics. This initiative was preceded by the World Summit on the Information Society (WSIS) Summit II, held in Tunis in 2005, addressing the remote sensing role with respect to natural disasters, as well as by the (ongoing) agenda of the African Association of Remote Sensing of the Environment (AARSE)

There is an increasing awareness that remote sensing's utility goes far beyond disaster response,

in that the technology has a role to play in decision support at every stage of the entire disaster management life cycle: vulnerability assessment, disaster preparedness, early warning, disaster mitigation, emergency response, humanitarian relief, damage assessment, postdisaster reconstruction planning, refugee resettlement, and societal rehabilitation. There has also been a steady evolution in the sophistication of modeling techniques that integrate remotely sensed data, specifically for disasters. The U.S. Federal Emergency Management Agency's (FEMA) HAZUS-MH for flood events, hurricanes, and earthquakes; the U.S. Coast Guard's CAMEO for oil and chemical spills; the U.S. Army Corps of Engineers's HEC-RAS for flooding; and IBM's public domain Spatiotemporal Epidemiological Modeler (STEM) for disease outbreaks are all examples of models for multiple hazards, which use satellite data as input.

Current trends in disaster management include recognition that while some disasters are more imminent than others, the potential intensity of certain longer-term disastrous events is such that they also demand immediate attention. These include the global and regional impacts of climate change, which could exacerbate drought and desertification in the African Sahel, thereby affecting food security and potable water availability, as well as the acceleration of polar ice melting, thereby raising sea levels, which would threaten island nations and coastal communities. Global warming is also associated with increasing the breeding season for the insects that serve as vectors for infectious diseases. Remote sensing has accordingly been applied to identifying and monitoring vector habitat and mapping disease prevalence in order to mitigate epidemics among human populations and epizootics among animal populations.

In an attempt to intensify research on disaster mitigation and to train the next generation of scientists dedicated to improving disaster management methodologies, several government laboratories and universities worldwide have established real-time remote sensing ground stations. These facilities use high-performance computing resources to develop spatial data products in near-real time to support early warning and mitigation of disasters and an effective response to time-critical disaster events, as well as geospatial

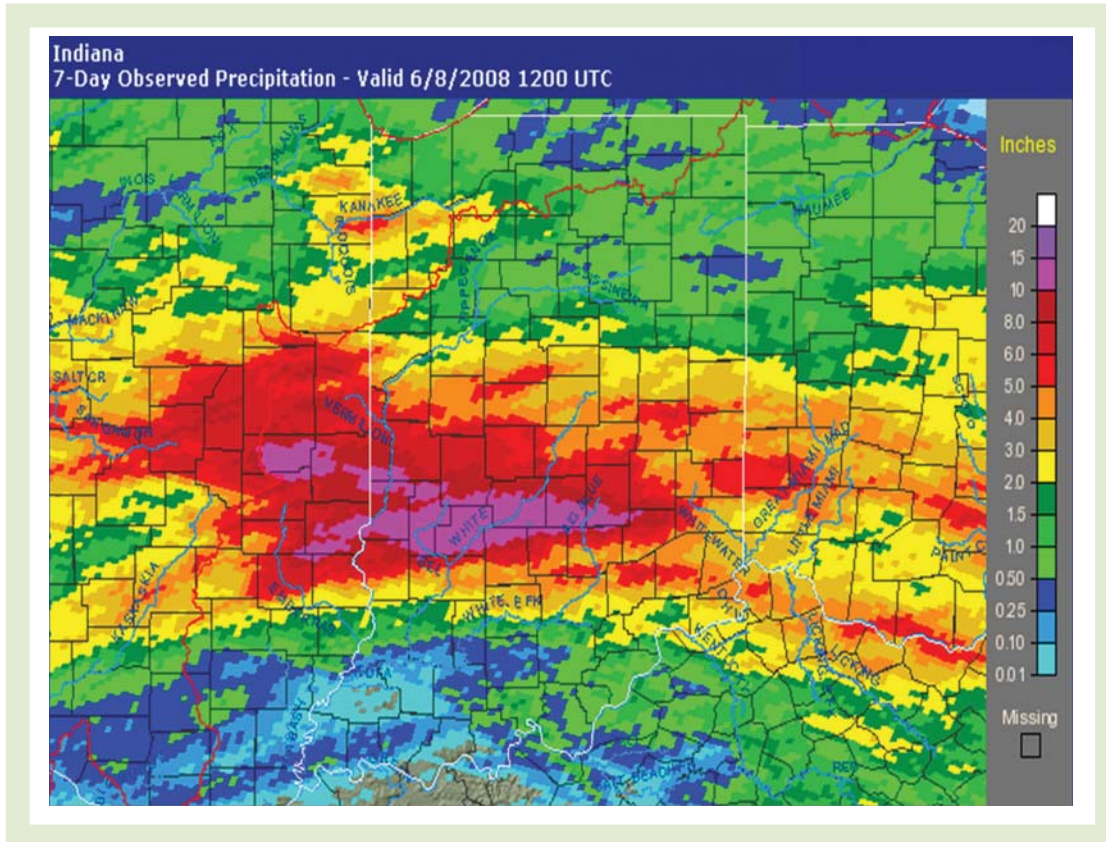


Figure 1 June 2008 flood in Southern Indiana: 7 to 11 inches of rain fell in June 6–7

Source: National Oceanic and Atmospheric Administration's (NOAA) Indianapolis National Weather Service. Retrieved December 15, 2009, from www.crh.noaa.gov/ind/?n=june0708flood.

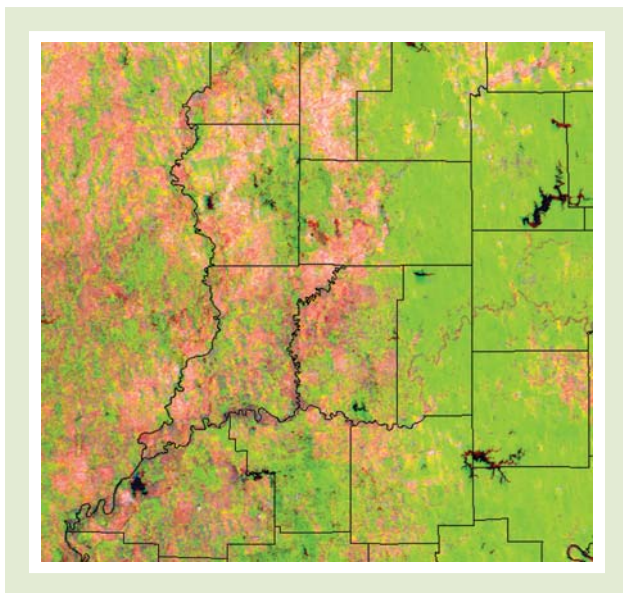


Figure 2 June 2008 flood in Southern Indiana: May 28—before the flood

Source: Larry Biehl, Systems Manager, Purdue Terrestrial Observatory.

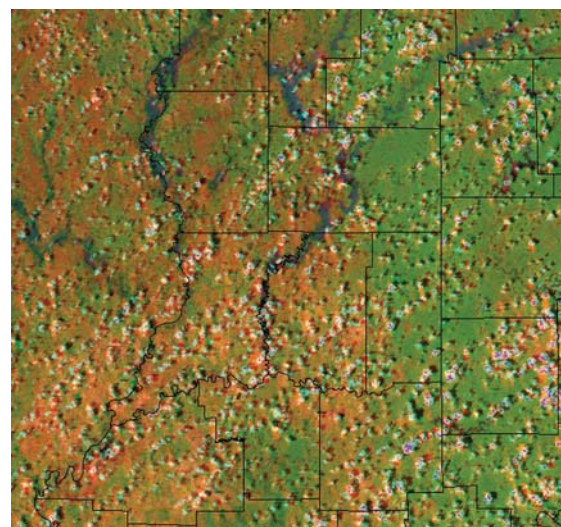


Figure 3 June 2008 flood in Southern Indiana: June 8—after the rain

Source: Larry Biehl, Systems Manager, Purdue Terrestrial Observatory.

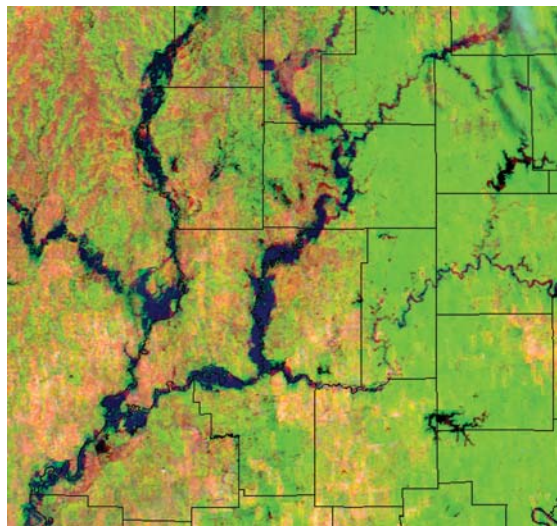


Figure 4 June 2008 flood in Southern Indiana: June 11—after the rain

Source: Larry Biehl, Systems Manager, Purdue Terrestrial Observatory.

analysis methodologies to intelligently merge heterogeneous data sources.

The populations at greatest risk of being negatively affected by a wide range of disasters are those living in poverty. As a consequence of their impoverishment, they live in areas more prone to natural disasters, lack the means to easily evacuate even when early warning is given, do not have the resources to rebound readily after a disaster, and are more likely to suffer from the synergistic relationship between malnutrition and infection. Although remote sensing has been of help in poverty mapping and in supporting decision makers' disaster response, it will require political will on the part of the highly industrialized countries to confront poverty as the principal underlying factor in disaster vulnerability, whether among the low-income communities in Africa, Asia, and Latin America or in the United States, as Hurricanes Katrina and Rita dramatically demonstrated.

Gilbert L. Rochon

See also Disaster Prediction and Warning; GIS in Disaster Response; Natural Hazards and Risk Analysis; Remote Sensing; Vulnerability, Risks, and Hazards

Further Readings

- Dewan, A. M., Islam, M. M., Kumamoto, T., & Nishigaki, M. (2007). Evaluating flood hazard for land-use planning in Greater Dhaka of Bangladesh using remote sensing and GIS techniques. *Water Resources Management*, 21(9), 1601–1612.
- Focardi, S., Corsi, I., Mazzuoli, S., Vignoli, L., Loiselle, S., & Focardi, S. (2006). Integrating remote sensing approach with pollution monitoring tools for aquatic ecosystem risk assessment and management: A case study of Lake Victoria (Uganda). *Environmental Monitoring and Assessment*, 122(1–3), 275–287.
- Gitas, I. Z., Polychronaki, A., Katagis, T., & Mallinis, G. (2008). Contribution of remote sensing to disaster management activities: A case study of the large fires in the Peloponnese, Greece. *International Journal of Remote Sensing*, 29(16), 1847–1853.
- Jha, M. N., Levy, J., & Gao, Y. (2008). Advances in remote sensing for oil spill disaster management: State-of-the-art sensors technology for oil spill surveillance. *Sensors*, 8(1), 236–255.
- Kalluri, S., Gilruth, P., Rogers, D., & Szczur, M. (2007). Surveillance of arthropod vector-borne infectious diseases using remote sensing techniques: A review. *Plos Pathogens*, 3(10), 1361–1371.
- Koudelka, O., & Schrotter, P. (2007). Satellite services for disaster management and security applications. *Acta Astronautica*, 60(12), 986–991.
- Laituri, M., & Kodrich, K. (2008). On line disaster response community: People as sensors of high magnitude disasters using internet GIS. *Sensors*, 8(5), 3037–3055.
- Li, P., & Tao, X. X. (2009). Integrating RS technology into a GIS-based earthquake prevention and disaster reduction system for earthquake damage evaluation. *Earthquake Engineering and Engineering Vibration*, 8(1), 95–101.
- Natural disasters and the role of satellite remote sensing—economic and legal considerations: The Tunis II declaration. (2006). *Space Policy*, 22(3), 214–215.
- Ning, S. K., Chang, N. B., Jeng, K. Y., & Tseng, Y. H. (2006). Soil erosion and non-point source pollution impacts assessment with the aid of multi-temporal remote sensing images. *Journal of Environmental Management*, 79(1), 88–101.



- Rochon, G. L., Niyogi, D., Chatturvedi, A., Madhavan, K., Arangarasan, R., Biehl, L., et al. (2008). Adopting multisensor remote sensing datasets and coupled models for disaster management. In S. Nayak & S. Zlatanova (Eds.), *Remote sensing and GIS technologies for monitoring and prediction of disasters* (chap. 5, pp. 75–100). Heidelberg, Germany: Springer.
- Voigt, S., Kemper, T., Riedlinger, T., Kiefl, R., Scholte, K., & Mehl, H. (2007). Satellite image analysis for disaster and crisis-management support. *IEEE Transactions on Geoscience and Remote Sensing*, 45(6), 1520–1528.
- Wang, J. F., & Li, L. F. (2008). Improving tsunami warning systems with remote sensing and geographical information system input. *Risk Analysis*, 28(6), 1653–1668.
- Yamazaki, F., & Matsuoka, M. (2007). Remote sensing technologies in post-disaster damage assessment. *Journal of Earthquake and Tsunami*, 1(3), 193–210.



RENEWABLE RESOURCES

Renewable resources are commonly understood to be the environmental components—wind, sunlight, water, forests, crops, fisheries, and so on—of complex socio-ecological systems that, if managed properly, can meet human needs for raw materials, energy, and food on a long-term, sustainable basis. Societal interest in renewable resources stems from increased awareness of the problems resulting from reliance on nonrenewable resources (fossil fuels and minerals). Overdependence on these resources contributes greatly to air and water pollution, global climate change, geopolitical conflict, resource wars, economic instability, and other major difficulties that many believe can be addressed only by a global transition to economies that are based on renewable resources. Practically and conceptually, such a transition requires an appreciation of the complex socio-environmental character of resources and renewability. This entry considers this character and explores how issues of scale, uneven resource distribution, and political power influence the potential for renewable resource systems to emerge.

Resources do not simply exist, they *become*, observed geographer Erich Zimmerman in 1939. They do so through the coevolution of ecological systems and human societies, and their degree of “renewability” depends on how one bounds the analysis. To explore this way of looking at resources, take the case of solar energy, a potentially highly renewable resource. The sun provides Earth enough solar radiation to power the planet’s climate and life support systems and is expected to continue doing so free of charge, maintenance, or pollution for another 5 billion years in quantities far exceeding human demand. The “waste” associated with these solar flows is heat that warms the planet before radiating harmlessly into space. Solar energy is thus highly renewable and sustainable from both an energy supply and an ecological standpoint.

Solar energy becomes a human resource, however, through socio-environmental technologies that capture and convert its potential energy into commodities and services. Plants, for example, are “natural” devices for solar capture and circulation (e.g., as food or biofuels), but they constitute renewable resources only to the extent that people help maintain the conditions under which the desired plant species can thrive and be harvested repeatedly despite human and ecological perturbations. Fisheries, forests, and soils are likewise viable renewable resources when managed through social institutions that prevent their being overwhelmed by pollution, petrochemicals, overharvesting, habitat loss, or competition from less desired species.

Other solar harvesting devices appear more “technical” in nature. Windows, for example, may seem to be relatively simple and ubiquitous manufactured products that allow people to use sunshine to light and heat buildings. They are only possible, however, in “collaboration” with nature, which provides the raw materials, energy, and the rules by which the combination of these inputs will produce glass. Even less visible are the political, scientific, and entrepreneurial dimensions of windows; these are perhaps best revealed through the effort by sustainable energy advocates in recent decades to get states to mandate the use of higher-performance windows in buildings. The effort has spurred technical innovation in, marketing of, and ultimately the installation of windows that can better manage flows of sunlight and heat into and out of buildings—to, in effect, allow solar energy



The Mammoth Pacific geothermal plant, located in the eastern Sierra Nevada mountain range in California, showcases the environmentally friendly nature of geothermal power. Three air-cooled binary units generate a total of 28 megawatts of electricity and release essentially no emissions into the atmosphere or land surface. Geothermal power plants such as Mammoth use many of the same components used by traditional power-generating plants. However, the geothermal resource is relatively cool, and the wells can produce fluids, steam, or brine.

Source: Geothermal Resources Council.

to *become* a more powerful and renewable resource.

Similarly, to reduce climate change while also extending electricity service to the 1.5 billion people who presently lack access, significant effort has gone into creating the conditions for rapidly expanding the market share of solar, wind, geothermal heat, and other renewable resources beyond their 2% current contribution to global electricity generation. The critical issues for expanded development turn not on the adequacy of the renewable resource base, which is vast, but instead on how energy markets are designed and how inventors, entrepreneurs, financiers, and others perceive the risks and rewards of renewable resource investments. Historically, market rules and government policies have strongly favored developers of nonrenewable fossil fuel

resources, whose economic and hence political power has stemmed from the ability to control and exploit, through economies of scale, the geographically uneven distribution of these fuels. It is only recently, through sustained advocacy and a renewed sense of crisis in the West concerning oil and coal dependence, that investment in wind and solar power has exploded, bringing down costs and increasing capacity at unprecedented rates.

The extent to which such investments effectively promote renewable resource development involves issues of scale and “whole-systems” analysis. Corn-based ethanol fuel production, for example, looks far less renewable when its large fossil fuel inputs and adverse food system impacts are considered. Similarly, small run-of-river microturbines working within intact riparian ecosystems are qualitatively



different from massive hydropower dams that are among humanity's largest and most ecologically (and often socially) disruptive projects. A fundamental challenge to meeting human energy and materials needs through renewable resources is the constantly expanding demand for goods and services driven by increasing population and the continual pursuit of "economic growth" in most capitalist and noncapitalist societies. What may be renewable on a small scale often is not on a larger scale.

To date, industrial(izing) societies have generally sought to meet their economic growth imperative by substituting nonrenewable, depletable resources for renewable resources—living off nature's "capital" rather than its "income." As information technologists and other high-tech entrepreneurs have become interested in bringing concepts of mass production, short innovation cycles, and fast product development to the energy sector, there is a growing potential for breakthroughs in renewables, especially because historically the sector has directed most of its meager research and development effort into massive, conventional energy facilities.

The dynamic, socio-environmental conception of renewable resources presented here seeks to highlight not only the environmental attributes and adequacies of various resources but also the social and technical dimensions that help or hinder their development.

Scott Jiusto

See also **Common Pool Resources; Distribution of Resource Access; Energy and Human Ecology; Energy Resources; Nonrenewable Resources; Political Economy of Resources; Sustainable Development; Sustainable Development Alternatives; Water Needs**

Further Readings

- Hall, C. A. S., Cleveland, C. J., & Kaufmann, R. (1992). *Energy and resource quality: The ecology of the economic process*. Niwot: University Press of Colorado.
- Hawken, P., Lovins, A. B., & Lovins, L. H. (1999). *Natural capitalism*. Boston: Little, Brown.



RENT-GAP

One of the more popular explanations for gentrification, the rent-gap hypothesis, first advocated by Neil Smith, approaches this issue in terms of the profitability of land in the urban core. In centrally located sites, actualized ground rents generally decline over time as the buildings and infrastructure age. During the post-World War II boom, low rents on the urban periphery were a major attraction to capital. Deindustrialization and the flight of people and capital to suburbia throughout the late 20th century played a major role in lowering the profitability of land, or devalorizing it, in the central business district (CBD). Low-income residents were incapable of generating rents that guaranteed a high rate of profit. Disinvestment from the urban core was manifested in abandoned buildings and lack of repairs.

However, in contrast to actualized rents, the *potential* rents in such locales remained high. As neoclassical economists tend to frame the issue, urban land was not being put to its so-called "highest and best use," that is, generating the maximum possible rate of profit. In particular, the rapid growth of producer services over the past three decades and their reliance on agglomeration economies elevated the importance of locations in maximally accessible places. Thus, a significant discrepancy arose between potential and actual rents, in other words, a rent-gap. Real estate developers and others with a vested interest in land sensed that higher rates of profit (rental streams) may be earned by attracting corporate capital or higher-income residents. Lured by the potential profitability of these sites, capital, much of it speculative, began to flow into urban cores in vast quantities as corporations reclaimed the spaces of inner cities, stimulating a building boom in luxury residential uses and commercial ones such as offices, waterfront developments, and sports stadia. The emergence of such land uses is usually accompanied by an influx of well-paid professional labor. Typically, such a process involved the invasion and displacement of low-income, working-class, often ethnic minority communities. The rent-gap thus closed, at least temporarily, until future fluctuations in the economy threaten to re-create it.



The rent-gap thesis ties waves of building construction in the landscape to the dynamics of capital accumulation, investment, and uneven development. It offers a structuralist, production-oriented explanation of gentrification that does not rely on demographics or the residential preferences of yuppies. Thus, it posits gentrification in terms of the structural dynamics of class, labor, and capital rather than individual preferences or lifestyles. Critics have alleged that the thesis is economic and functionalist, leaving little room for human agency.

Barney Warf

See also **Central Business District; Gentrification; Smith, Neil; Urban Geography**

Further Readings

- Smith, N. (1987). Gentrification and the rent-gap. *Annals of the Association of American Geographers*, 77, 462–465.
- Smith, N. (1996). *The new urban frontier: Gentrification and the revanchist city*. New York: Routledge.

REPRESENTATIONS OF SPACE

Broadly, representations of space encompass all the ways in which humans bring geography into consciousness, including symbols, maps, remote sensing, models, art and photography, and textual descriptions. More specifically, however, the term *representations of space* comes from the French philosopher Henri Lefebvre's famous work, *The Production of Space* (1991). This entry provides an overview of Lefebvre's theory, describes some of the factors that create new representations of space, and examines the manifestation of representations of space in physical space. It then reviews some of the representations of space that have been produced by geographers, such as cartography, and discusses the impact of the quantitative revolution and the cultural turn on the representations of space created by geographers.

Lefebvre's Theory of Space

For Lefebvre, a neo-Marxist, representations of space, along with spatial practice and representational space, formed the conceptual triad through which he analyzed the social production of space. Lefebvre's goal in using this triad was to introduce a unifying theory of space that he hoped would encompass physical space, mental or metaphoric space, and social space under one theory that could de-fetishize space, revealing the social relations and modes of production that are embedded within it. Lefebvre argued that historically specific spaces embody the modes of production and social relations that help them come into being and, at the same time, are necessary for those social relations to exist. However, space had become so fragmented by philosophy and other disciplines that these social relations had become incoherent in existing analyses. As both determinant of social relations and determined by them, space is presented as a crucial factor in understanding society. Whenever society changes in a revolutionary way, a corresponding new space must also be created. However, like a palimpsest, these new spaces do not erase older ones completely.

A second part of the triad includes spatial practice, sometimes referred to by both Lefebvre and others as *perceived space*, which is the daily spatial reality of a society, the domain of production and social reproduction. Representations of space, or conceived spaces, are associated with the codification of space and how social relations are inscribed on space. Representations of space fall under the control of "experts," who map and define what is possible in any given space. Thus, representations of space reflect the dominant ideology of a given society.

Finally, representational spaces, or lived spaces, are associated with the imagination, with symbols, and with clandestine meanings. This is the space of art and dreams and is often made unrecognizable by representations of space. This is also the space from which challenges to hegemonic ideologies are launched, the space of possibility and contingency.

Lefebvre noted that all representations of space are, by necessity, reductions. It is impossible to represent or describe all things that occur within a particular space. For any given society or mode of production, it is the hegemonic discourse



within that society that dictates what aspects or objects are removed or reduced in a representation of space. Therefore, most representations of space work in favor of power. Furthermore, these representations are always presented as scientific and produced by experts, and they are presumed to be received uncritically. For this reason, Lefebvre argues that representations of space, taken alone, serve only to confuse and obfuscate analyses of space. Challenges to hegemonic social relations are not found in representations of space but rather are forced underground into the realm of representational spaces.

Impact of Shifts in Social Relations

As noted above, major shifts in modes of production or social relations could not occur or be expected to endure without the creation of new spaces and representations of space. One such example, drawn from the work of Denis Cosgrove, is the creation of geographical perspective in landscape art in 13th-century Tuscany. This new representation of space came into existence just as the Tuscan economy began to shift toward an accumulationist regime in which vast amounts of wealth were produced through trade and the emergence of a new urban class of craftsmen. This new representation of space has been likened to a new way of seeing, one that was intimately associated with questions of ownership, power, and the new regime of wealth accumulation. The perspective of the paintings was that of a single, controlling eye, with mastery over what it surveyed. Those who worked on the land or produced the landscape were removed from the scene, their toil elided. Their removal served two functions: First, it gave the illusion of total control to the viewer, often the owner of the land and the person who had commissioned the painting; second, the landscape produced a false ideal of nature, expertly manicured and crafted and devoid of conflict or tension.

Effects of Representations of Space on Physical Space

Representations of space, being the realm of experts and the reflectors of ideology, can and have had a profound effect on physical space. Lefebvre argued that ideology, in fact, can only

endure if it takes on a spatial body. Using Christianity as his example, he argued that it would not have endured as a cultural practice if it had not created spaces—churches, confessionals, cathedrals, and so on—that gave physical space, a body, to its message. In similar ways, all sorts of representations of space are made into physical spatial reality. An architect's plans, once constructed, stand as a physical manifestation of the representation of space. In the realm of cartography, the U.S. Public Land Survey System existed first as a series of maps dictating ranges and townships around meridians and base lines and then was made manifest on the landscape in the form of country roads, fields, and town plots.

It should by now be clear that geographers have always been and continue to be in the business of producing representations of space. However, the methods they have used to do so, and the ideologies that have been written into the representations of space that have been produced, have varied over the long course of the history of geography as a discipline.

Cartography

Perhaps the most obvious representation of space produced by geographers has been the map. Until very recently, little thought was given to the ways in which ideology and discourse are included not just in the production of the map itself but in the very act of mapping. Because cartography is treated as a science, and maps are supposedly judged on their "accuracy" in presenting real-world phenomena, little thought has been given to the purposes for which maps have historically been produced.

Practically from the moment of its creation, cartography has been associated with conquest and empire. From the Ottomans to the Moguls to the Romans and Egyptians, early leaders all employed or patronized cartographers to produce maps for military, religious, and propaganda purposes. Often, these maps preceded empire, in that they showed both lands that were controlled and those yet to fall under the empire's dominion. Military expeditions into the modern era almost always included a cartographer to document the new acquisitions of the empire. These maps legitimated and codified power. They de-socialized conquest, erasing conquered



peoples and eliding the violence inherent in territorial acquisition. It goes without saying that maps were employed in these same processes during the era of colonialism and the conquest of North and South America, and they continue to be so employed today.

As representations of space, maps are necessarily reductive, excluding certain peoples and phenomena and emphasizing others. Historically, maps have been produced by and for those in power. As the tools of people in power, maps can serve to preserve the status quo or to create new spaces of accumulation and power. Maps and surveys facilitated the shift from feudalism to capitalism and the privatization of land ownership in Europe. As local rural areas were mapped at the behest of the wealthy to establish ownership, the small cottages and cabins of existing residents were frequently removed from these maps, legitimizing the claims of the mapmakers. The capitalization of agriculture and the global division of labor were both facilitated by the production and use of maps.

Other Types of Representations of Space

Maps, however, are not the only types of representations of space that have been produced by geographers.

Regional Studies and Cultural Analysis

In the first half of the 20th century, particularly in North America, the primary representations of space produced by geographers were of two distinct forms. The first was regional studies as proposed by Richard Hartshorne and formalized in *The Nature of Geography* in 1939. This form of representation divided the world into coherent, geographically distinct regions. The job of geographers, according to Hartshorne and others, was then to describe those regions and to firmly establish their uniqueness. This form of representation was most strongly associated with economic geography. The second dominant representation of space, this time associated with cultural geography, was the analysis of cultural landscapes and morphology as espoused by Carl Sauer and the Berkeley School. Like regionalism, these representations of space were largely

descriptive in nature. Sauer was interested in how different cultures manifested themselves on the land and altered their “natural” landscapes to fit their own cultural needs. In practice, this type of representation generally resulted in little more than chorology, as in the all too often cited example of counting barn types and mapping their diffusion.

The Quantitative Revolution

Beginning in the 1950s, the practice of geography began to move to yet another distinct form of spatial representation. Often referred to as the *quantitative revolution*, this movement represented a deliberate attempt to turn geography into a “spatial science” and redeem it in the eyes of the academy. The ideology behind this shift was positivism. Rather than focus on describing distinct regions or landscapes, this school of thought sought to discover the universal mathematical rules that dictated human movement and behavior in space. For this reason, space during the quantitative revolution was thought of as an undifferentiated isotropic plane rather than in terms of unique places or spaces. Representations of space were formulas or theories that could explain and predict the spatial activity of society. Theories and mathematical formulas were developed that harkened back to the locational theories developed by German geographers such as von Thünen, Lösch, and Christaller. These formulas and theories were valued when they were found to mirror real-world phenomena.

The Cultural Turn

Beginning in the 1980s, yet another shift in representation took place. This shift is often called the *cultural turn*. Largely based on the work of Continental European philosophers such as Lefebvre, Foucault, Saussure, Derrida, and many others, as well as British cultural studies, the cultural turn called into question the very possibility of representation. With the adoption of postmodern and poststructural theories, the field of geography was forced to acknowledge that any representation of space is by definition situated, limited, and reductionist. Geographers now attempt to position themselves within their particular representations and to position those



representations within the field of geography, thereby eliminating much of the illusion of authority associated with representations of space. They attempt to denaturalize the discourses and ideologies present in their work, making them visible and exposing the gradients of power inherent in any act of representation.

Not surprisingly, the representations of space produced during and after the cultural turn have been multifarious and complex. Some have marked a return to former representations, such as the rereading of maps for discourse or the current reassessment of cultural landscapes, while others have produced completely new representations of space. Actor-network theory, for example, represents space as an abstract series of networks connecting actors both living and inorganic in nodes of interaction that stretch infinitely outward across the globe. Many geographers today seek to represent space as it is experienced by groups found on the margins of most hegemonic discourses, be they racial, sexual, or cultural. In doing so, some now question the right of geographers to represent others or others' perceptions of space at all. Others have begun to challenge the primacy of vision in most forms of representation. Nonrepresentational theory and theories of practice seek to emphasize senses other than sight in the experience and representation of space. However, as Lefebvre noted, newer representations of space do not simply erase those that came before them. Today in geography, there are still many geographers who produce representations of space more akin to those associated with landscape morphology or the quantitative revolution. The rise of GIS, for example, is often represented as a continuation of the imperial practices of cartography and the abstract positivism of the quantitative revolution.

Aaron Gilbreath

See also **Art and Geography; Cartography, History of; Cosgrove, Denis; Critical Geopolitics; Critical Human Geography; Cultural Geography; Cultural Landscape; Cultural Turn; Discourse and Geography; Harley, Brian; Lefebvre, Henri; Nonrepresentational Theory; Orientalism; Photography, Geography and; Spaces of Representation/Representational Spaces; Subaltern Studies; Symbolism and Place; Wood, Denis**

Further Readings

- Barnes, T., & Duncan, J. (Eds.). (1992). *Writing worlds: Discourse, text and metaphor in the representation of landscape*. London: Routledge.
- Cosgrove, D. (1984). *Social formation and symbolic landscape*. London: Croom Helm.
- Cosgrove, D. (1985). Perspective and the evolution of landscape. *Transactions of the Institute of British Geographers*, 10, 45–62.
- Duncan, J., & Duncan, N. (1988). (Re)reading the landscape. *Environment and Planning D: Society and Space*, 6, 117–126.
- Duncan, N., & Sharp, J. (1993). Confronting representation(s). *Environment and Planning D: Society and Space*, 11, 473–486.
- Harley, J. (2001). *The new nature of maps*. Baltimore: Johns Hopkins University Press.
- Lefebvre, H. (1991). *The production of space*. Malden, MA: Blackwell.
- Smith, J. (1996). Geographical rhetoric: Modes and tropes of appeal. *Annals of the Association of American Geographers*, 86, 1–20.



RESEARCH AND DEVELOPMENT, GEOGRAPHIES OF

Geographies of research and development (R&D) involve the study of spatial patterns and processes that emerge from the production of basic and applied research, on the one hand, and from how R&D activities articulate within the communities in which they are so deeply embedded, on the other. The significance of R&D in the current global context emerges from the critical role that technology and innovations have come to play in economic development. Intrinsic to understanding the significance of R&D is the need to appreciate the interaction between regions and economic processes and how spatial ideas such as distribution, arrangement, clustering, agglomeration, and so on, permeate the notion of interconnection and interdependence across space. A predominant characteristic of the current phase of globalization is economic restructuring resulting in deindustrialization and lay-offs, restructuring in the methods



of production, and the emergence of new manufacturing and service sector activities resulting from the emphasis on flexible production systems. This new mode of production has displayed a heavy reliance on new knowledge and on access to and processing of appropriate information. These ideas owe their debt to conceptualizations in Michael Porter's famous book *The Competitive Advantage of Nations*, where he established the relationships between high technology and competitive strategy in the wake of global economic restructuring. Porter's work provoked a new research agenda among those who were interested in regional economic development.

Contextualizing R&D

From a regional economic development perspective, the significance of R&D is that it helps enhance competitiveness and employment. As such, R&D indicators are seen as drivers of economic development. Indicators such as academic R&D, employment in high-technology establishments as a share of total employment, industry-performed R&D as a share of private industry output, net high-technology business formations as a share of all business establishments, R&D as a share of gross national product, and venture capital have been studied statistically to give operational empirical meaning to the geographies of R&D. However, in the literature on regional economic development, the term *research and development* has not been defined categorically. The closest that researchers have come is in terms of its indicators, while others continue to consider R&D as a subset of science and technology. In fact, there has never been a formal attempt by geographers, economists, or regional scientists to distinguish R&D from science and technology.

In the United States, from a federal government perspective, while the terms *R&D* and *science and technology* have been used interchangeably, they do not mean the same thing. There are two aspects of the government perspective: the military and the civilian. From the military angle, science and technology activities are a subset of R&D activities, while from the civilian angle, R&D activities are a subset of science and technology activities. From within the civilian side of

the federal government and in particular for departments such as NASA, DOE, and NSF, R&D activities are a subset of science and technology activities.

While some regions in North America, Europe, Latin America, and Asia have demonstrated their growth as technology-based economies (multimedia, biotechnology, health care, and other medical technologies), many others continue to lag behind. The development of any region as a technology-based economy depends on factors such as the R&D industry, the diversity of metropolitan areas, a sophisticated workforce, local sources of capital, and strong research universities. Thus, space has emerged as a basic organizing concept in understanding the geography of R&D. In the past few decades, the literature on R&D has grown to include a variety of theoretical and empirical works wrapped around overlapping and related concepts of local economic development, innovation, knowledge or learning regions, new industrial spaces, technology-based development, knowledge spillovers, the new economy, corporate complexes, social and human capital, and embeddedness, to name a few. It is in this context that most studies on R&D have focused on clusters and agglomerations.

Clustering and R&D

In light of the above, the observed geography of centers of R&D, also known as *knowledge regions*, has been thoroughly influenced by cluster-based strategies so that regional or local economic development may be achieved. This trend has been further bolstered by the idea of increasing returns to scale, embedded within which are notions of trust, loyalty, and partnership between firms. These concepts were central to the birth of Silicon Valley, Boston's Route 128, and the Research Triangle Park in North Carolina. Similar knowledge-based regions also emerged in Europe, such as Lombardy in Italy, Baden-Württemberg in Germany, Rhones-Alps in France, and Catalonia in Spain, and formed a loosely tied association to market themselves internationally as "The Four Motors of Europe." These technology-oriented complexes, or *technopoles*, have become famous for the impacts of the high-tech activities therein. Elsewhere, these



knowledge regions have also been conceptualized as the “new” industrial districts.

Partnerships and collaborations have emerged as the dominant feature in the growth of R&D due to the high initial fixed costs in the creation of services and the need for standardization as customers get “locked in.” For instance, writing a computer program for managing a client database is the same regardless of the number of clients or the number of copies that need to be reproduced. Furthermore, most software programs require compatibility with hardware, which means that there is a need for a partnership with ancillary service providers such as that between Microsoft and IBM’s SPSS (*Note:* SPSS was acquired by IBM in October 2009) or, for that matter, between car manufacturers using GPS technology and the producer of GPS. With the globalization of production and the concomitant problems associated with deindustrialization in the metropolitan regions of the United States, Canada, and Europe under conditions of neo-Fordism, the significance of R&D has increased manifold as local, regional, and national implications of the complex interactions of globalization are experienced. In fact, throughout the 1980s and 1990s, high-tech activities have emerged as a very significant factor of production, affecting spatial divisions of labor not only in the advanced capitalist countries of the world but also in the peripheral regions, thus bringing about spatial reorganization of the core economies.

The growth of high-tech activities complemented and fueled the flexible accumulation processes that were characterized by deregulation, flexibility, and decentralization. In fact, R&D has almost become the pivot of national and global stimulus worldwide. Operating at a number of spatial scales, R&D has been induced by many factors such as rising per capita incomes, the growing demand for health care and educational services, an increasingly complex division of labor, increasing international trade in services, and rapid growth in outsourcing service functions. Furthermore, the twin processes of decentralization and consolidation were informed by the inherent desire of economies to remain cost-effective with the use of new knowledge and appropriate information.

University Spinoffs and R&D

The role of strong research universities in technology-led economic development has emerged as critical throughout the growth of existing knowledge regions in the United States, Canada, Europe, and elsewhere. No longer are universities merely science-based monodisciplinary institutions providing degrees to their students; today, research universities have undergone dramatic changes under the impact of globalization and have become knowledge hubs providing services to technology-based enterprises and financiers, besides playing a new role as incubators of new science or technology-based enterprises. These kinds of activities have brought about a linkage between university research and high-tech activity, contributing to local economic development not only in the Silicon Valley, Boston’s Route 128, and the Research Triangle Park of North Carolina but also in other places. Top research universities such as Harvard University and Massachusetts Institute of Technology in the Boston metropolitan area, the University of California at Berkeley and Stanford University in the Bay Area of California, and the University of North Carolina at Chapel Hill, North Carolina State University, and Duke University in the Raleigh/Durham/Chapel Hill metropolitan area have all revealed how such institutions can contribute to the development of regional economic clusters. Similar high-tech activities have clustered in many leading metropolitan areas of other advanced capitalist countries of the world, such as Tokyo, Paris, London’s M-4 corridor, Seoul-Inchon, Taipei-Hsinchu, Singapore, and Shanghai, to name a few. It is within this context that today’s university-industry relationships have become symbiotic. Thus, the growing role of universities as centers of entrepreneurship has further evolved a dynamic interconnection between university, industry, and the government, also known as the “triple helix” model. In fact, so critical are universities in the articulation of regional and local economic development that even peripheral regions have begun to emulate conditions that are likely to attract a critical mass of high-tech activity so that local and regional governments can address the downward spiraling multiplier effects of deindustrialization in other parts of advanced capitalist countries.



In the United States, the Experimental Program to Stimulate Competitive Research (EPSCoR) has played a significant role in recognizing the relationship between high-tech activities and the state economic development function. The program was created in 1978 by a congressional mandate through the National Science Foundation (NSF) to support academic R&D in states that historically have been among the most underdeveloped in terms of not only their scientific and technical capability but also their capacity for economic development. While EPSCoR was created in the context of the proliferation of knowledge-based economies and an emerging mode of production called flexible specialization, a larger impact of economic restructuring has been that geographers have begun to ask regional policy questions largely under the impact of elasticity and competitiveness never seen before.

R&D and Spatialized Public Policy

Space itself has come to have a whole new meaning in a world in which digital technologies are having a tremendous impact on traditional notions of distance, region, location, and place, as well as spatial notions of distribution, clustering, agglomeration, and so on. Geographers and economists collectively began to ask questions such as the following: Why do some regions grow and others stagnate? Why and when does economic activity become concentrated in a few regions, leaving others relatively underdeveloped? How does technological change affect regional economic growth? What institutions and processes lead to advancement in technological change? Regional policy questions such as access to infrastructure and communications networks, the capacity to share information on these networks, differential access to information, and inequalities among the user base are all significant. These new concerns in regional economic development policy create opportunities and obstacles that shape how spatial policies will be designed. The role of spatial public policy has increased in the development of regions, since increasingly, local economic developments are associated with innovations. Even in a regime of flexible production, it was a spatialized regional development policy undertaking that created the Silicon Valley in California and other

outcomes such as the Third Italy, the knowledge region in Southern Germany, the scientific city of the Paris basin, or, more recently, knowledge regions such as Bengaluru—India's Silicon Valley. Thus, R&D has the capacity to change spatial economic structures.

Rajiv Thakur

See also **Agglomeration Economies; Clusters; Economic Geography; Education, Geographies of; Flexible Production; High Technology; Industrial Districts; Innovation, Geography of; Knowledge, Geography of; Knowledge Spillovers; Learning Regions; Technological Change, Geography of**

Further Readings

- Castells, M., & Hall, P. (1994). *Technopoles of the world: The making of 21st century industrial complexes*. London: Routledge.
- Krugman, P. (1995, Winter). The localization of the world economy. *New Perspectives Quarterly*, pp. 34–38.
- Malecki, E. (1987). The R&D location decision of the firm and creative regions. *Technovation*, 6, 205–222.
- Porter, M. (1990). *The competitive advantage of nations*. New York: Free Press.
- Saxenian, A. (1994). *Regional advantage: Culture and competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.



RESILIENCE

The term *resilience*, as applied outside the discipline of physics, was originally developed as an ecological concept by Crawford Holling to describe the capacity of a system to maintain itself despite disturbances. He specifically used the term as a measure of an ecosystem's ability to absorb change and still persist, contrasting it with the concept of stability of an *ecosystem*, defined as the ability to return to a state of equilibrium after a temporary disturbance. Hence, an initial clear distinction needs to be made between two meanings of *resilience*: (1) a system's dynamics when



the system is close to equilibrium (termed by Crawford Holling *engineering resilience* and relatively identical to the stability property of systems); and (2) the dynamics of a system when it is far from any equilibrium steady state, called *ecosystem resilience*. The latter term is used interchangeably with other terms, such as *ecological resilience* or simply *resilience*, and it is the type of resilience that is discussed in this entry.

Although the theory of resilience is originally ecological in nature, it not only has immense applicability potential in the field of geography but also has been substantially enhanced through multitemporal and cross-scale geographical research. Given the resilience view of the world as a linked socio-ecological system organized hierarchically, the assimilation and further development of resilience theory in the various geographical subdisciplines can contribute not only to increasing unity in geography but also to cementing the role of geography in emerging research directions, such as sustainability science and global environmental change.

Broadly speaking, resilience theory conceptualizes systems as constantly changing, focusing on self-organization, reorganization, and renewal rather than stability, as well as scale, uncertainty, alternate state regimes and threshold effects, and nonlinear responses. With these ideas, resilience theory has changed how mainstream growth and efficiency are perceived both in natural and in anthropogenic systems. If the focus is solely on making growth more efficient, ecosystems and societies alike can become a lot more unstable and vulnerable to external shocks than when these are anticipated and internalized and the focus shifts to include necessary recoveries and reorganization phases. In short, resilience theory advocates that we view systems as governed by constant change, diversity, and multiple regime states and that we make flexibility, learning, and recovery the main components of system-level management and conceptualization.

More recently, the notion of resilience has begun to be used in a vague manner as a research approach to study multiscale and multitemporal social or natural changes or as a boundary object, a concept that facilitates communication across the borders of various scientific disciplines. As a result, resilience has become a complex and

multi-interpretable concept employed in an increasingly large range of interdisciplinary work regarding human-environment interactions. Another major conceptual distinction in resilience theory is between ecosystem/ecological resilience and social/socioeconomic resilience, but this divide is being bridged by the increased recognition of the linked nature of social and ecological systems, thus the term *socio-ecological resilience*. Despite the lack of established approaches to measuring resilience among the disciplines using the concept, Carl Folke has argued that managing for resilience in both ecological and social systems increases the potential of sustaining desirable pathways for development in environments subject to change, in which the future is hard to predict and surprise is likely.

Historical Perspective on the Development and Key Elements of Resilience Discourse

According to the *Oxford English Dictionary*, *resilience* is defined as (a) the act of rebounding or springing back and (b) elasticity. Departing from this mechanical concept and based on studies in the 1960s and 1970s of interacting predator-prey populations and functional responses related to the stability theory, the ecologist Crawford Holling documented in 1973 the existence of multiple stability domains or basins of attraction in natural systems. He illustrates their relationship to various ecological processes, disturbances, and spatial and temporal variability and heterogeneity. Supported by ecological research findings from various universities, the resilience approach began to influence fields outside of ecology, such as human geography, ecological economics, cultural theory, anthropology, environmental psychology, and other social sciences. Starting from the 1980s onward, the resilience framework became the foundation for work in active adaptive ecosystem management and was later strongly influenced by the theory of complex adaptive systems proposed by Simon Levin. Using large-scale studies of managed terrestrial, freshwater, and marine ecosystems, Holling and his colleagues described the cross-scale morphology of landscapes, which was later formulated into panarchy theory, that is, the notion of nonhierarchical systems of interaction.



In 1992, Holling introduced the extended keystone hypothesis, which postulates that important changes in ecosystem dynamics occur as a result of the hierarchical interaction across space and time, for a minimum of three orders of magnitude, of at least three key variables (and not more than five) that differ qualitatively according to speed. This hypothesis brought forth the concepts of slow and fast variables, and thus different temporal scales of analysis, which interact continuously with different spatial scales and heterogeneity to create multistable states, nonlinearities, and surprises in ecosystem behavior.

The description of these emergent system properties then led to the formulation of the heuristic model of adaptive renewal cycles by Lance Gunderson and Crawford Holling in 2002. Based on observations of ecosystem dynamics, the adaptive renewal cycle describes four phases of system development, separated by discontinuous processes and events, which repeat themselves continuously throughout the life cycle of a system and reemphasize the idea that disturbances are an inherent part of system development. In this model, the four periods are

1. periods of exponential change (the r , or exploitation, phase),
2. periods of growing stasis and rigidity (the K , or conservation, phase),
3. coexisting or complementing periods of readjustments and collapses (the Ω or release, phase), and
4. periods of reorganization and renewal (the α phase).

This model had enormous implications for natural resource management, which had conventionally been concerned only with the exploitation and conservation phases and had ignored the release and reorganization phases, also known in resilience as the *backloop*. This model and further work therefore introduced the idea of adaptive environmental and resource management, in which the key for managers was to learn to manage by change. They had to accept not only that change, surprise, and uncertainty are inherent in ecosystem dynamics but also that managers cannot afford to merely react to change but must expect it and learn to live and manage with it.

Terms such as *learning* and, later, *adaptation* became major components of the resilience discourse and practice. All the above models and concepts apply equally to ecological and social systems and in fact are being increasingly applied in other disciplines, such as sustainability science, economics, planning, political science, sociology, and the globalization discourse, at scales ranging from a farm to communities, cities, regions, nations, and the world.

Means of Building Resilience in Coupled Socio-Ecological Systems

Currently, despite the dilution of the meaning of *resilience* through the use of the term across disciplines, the overarching research and practical question is how to operationalize resilience. The first step in estimating or quantifying the resilience of a system is to specify the resilience “of what” and “to what.” The “of what” part includes specifying which socio-ecological processes and set of variables are of primary concern, establishing the boundaries of the system and the current regime, and determining at which spatial and temporal scales the interrelations in the system are to be examined. The “to what” part specifies to what exactly an ecosystem regime should be resilient, for example, the type, frequency, and intensity of the disturbance, whether human (prescribed burns, pollution pulses, deforestation) or natural (floods, hurricanes, volcanic eruptions, earthquakes). Steve Carpenter and his colleagues in the Resilience Alliance (a network of scientists actively involved in stimulating resilience research to inform the global policy process on sustainable development) have summarized, after nearly three decades of research, three major dimensions of socio-ecological system resilience:

1. The amount of disturbance a system can absorb and still remain in the same state or domain of attraction
2. The degree to which the system is capable of self-organization
3. The degree to which the system can build and increase its capacity for learning and adaptation

As such, resilience is one property that influences adaptive capacity, becoming a major component



in research aimed at devising the means of coping with and adaptation to global environmental change.

A resilient system is not necessarily in a desirable state from a management point of view; highly degraded systems can be very resilient and thus be trapped in a basin of attraction from which it is extremely difficult to extricate them. For example, a degraded savanna ecosystem that has shifted from a desirable open grassland state to an encroaching scrubland can be very difficult to return to a desirable state without major, long-term, and sustained management interventions. Typically, managers and practitioners aim to identify the “desirable” configuration for a system using historical analyses, traditional knowledge, or existing theories and maintain or enhance a system’s resilience in the face of climate, socioeconomic, political, or cultural change. The property of maintaining a system’s trajectory or altering its current trajectory to make the system more or less resistant to external disturbances is known in resilience as *adaptability*. However, when a system is in an undesirable state, as described above, and it cannot be returned to a known desirable regime, it can be transformed into a different system altogether, a property known as *transformability*.

Carl Folke and colleagues outlined two potentially useful tools for building resilience in socio-ecological systems, structured scenarios and active adaptive management, which require multilevel governance centered on learning and increased adaptive capacity and flexible and transparent institutions appropriate for the scale of management. Apart from the institutional aspect, building resilience also implies a drastic change in mentality, incorporated in four factors:

1. Learning to live with change and uncertainty
2. Recognizing and encouraging diversity irrespective of its form
3. A combination of types of knowledge and information to facilitate learning
4. Sustaining self-organization and cross-scale linkages and interactions

All the above elements work together to contribute to sustaining the adaptive capacity of a system, which is related to biodiversity, genetic

diversity, and landscape diversity in ecological systems and adaptive, open, and multifunctional institutional and networks in social systems.

A successful combination of resilience-building tools and strategies can lead to increased resilience and minimization of system vulnerability, of which resilience is a major component along with exposure and sensitivity. An effective approach to increasing resilience can further contribute to increased sustainability by creating (a) a policy that recognizes the strong interrelationships between the biosphere and society and (b) the necessary framework of cross-scale collaborations to achieve resilience and long-term sustainability. Although the main criticism of resilience science remains its lack of straightforward operationalization and quantification, the underlying science is indisputably accurate, and the potential for significant contributions from the field of geography is immense.

Narcisa Gabriela Pricope

See also Carrying Capacity; Complex Systems Models; Conservation; Coupled Human and Natural Systems; Ecosystems; Environmental Restoration; Landscape Ecology; Sustainable Development; Vulnerability, Risks, and Hazards

Further Readings

- Berkes, F., Colding, J., & Folke, C. (2003). *Navigating socio-ecological systems*. Cambridge, MA: Cambridge University Press.
- Carpenter, S. R., Walker, B. H., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: Resilience of what to what? *Ecosystems*, 4, 765–781.
- Folke, C. (2006). Resilience: The emergence of a perspective for socio-ecological systems analyses. *Global Environmental Change*, 16, 253–267.
- Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. *Ambio*, 31, 437–440.
- Gunderson, L. H., & Holling, C. S. (Eds.). (2001). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.



- Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4, 1–23.
- Holling, C. S. (1992). Cross-scale morphology, geometry, and dynamics of ecosystems. *Ecological Monographs*, 62(4), 447–502.
- Holling, C. S. (1996). Engineering resilience versus ecological resilience. In P. C. Schulze (Ed.), *Engineering within ecological constraints* (pp. 31–44). Washington, DC: National Academies Press.
- Klein, R. J. T., Nicholls, R. J., & Thomalla, F. (2003). Resilience to natural hazards: How useful is this concept? *Environmental Hazards*, 5, 35–45.
- Levin, S. A. (1998). Ecosystems and the biosphere as complex adaptive systems. *Ecosystems*, 1, 431–436.



RESISTANCE, GEOGRAPHIES OF

Geographers' use of the term *resistance* refers to three different, but interrelated, arenas of research: (1) social movements, (2) social protest, and (3) everyday and psychic forms of resistance. Thus, while the word *resistance* is something of a catch-all term and carries considerable intellectual baggage, it has come to serve as a useful mechanism by which a variety of different approaches to the study of social conflict, opposition to domination, and the assertion of power can be understood.

What unites all such seemingly disparate studies is the key belief that not only is the study of resistance critical to understanding social and cultural change, but also all geographies are forged by a negotiation between methods of control and modes of contestation. In other words, geography is not a fixed “backdrop” to social life but instead is a transformative agent in itself. Thus, the *where* of resistance is important—though this might equally be in a figurative, psychic, or virtual space—but of equal consequence is the fact that resistance is always mobilized *through* spaces and is thus shaped and given meaning by geography. Conversely, as the term *social movements* implies, resistances generate reconfigurations of spaces as the *actants* (humans as well as other nonhuman “things”) and meanings move. For example, after the revolution of 1789, the Parisian Bastille was

understood no longer as a space of oppression but instead as a symbolic place of liberation. This spatiality is often rather more complex and multi-layered, with resistances generating multiple and constantly shifting meanings. A capital-intensive factory, say, can be transformed without the knowledge of the management into a space of dissent by workers' feigning ignorance over quality procedures. In whichever way it is manifested, resistance is a profoundly spatial project. This entry first describes the development of geographical analysis addressing resistance. It then reviews some of the criticisms of this concept as it has been used in geography, as well as current research that has emerged in the wake of such critiques.

Evolution of Geographies of Resistance

The concept of resistance, while having a long intellectual history in the broader social sciences and humanities, is a relatively new field of study for human geographers. Thus, while historians and sociologists have long studied the iconic American and French Revolutions of 1775–1783 and 1789, respectively, geographers' interest is more recent. While it is possible to locate traces of interest in geographies of resistance before the 1970s, most notably in the work of the 19th-century geographer Élisée Reclus, the so-called radical turn brought the study of class struggle and urban social movements firmly to the fore of human geographical research. Central to this new enthusiasm were the armed struggles in several developing countries, the riots in American ghettos in the late 1960s, and the student riots in Paris—and elsewhere—in the spring of 1968. Against such pressing problems, the abstract mathematical modeling of spatial science seemed extraordinarily socially inert.

Meanwhile, “historians from below,” most notably Christopher Hill, Eric Hobsbawm, George Rudé, and E. P. Thompson, had, through the application of Marxist theories, blazed a trail in the study of popular movements. Marxism's central acceptance of the Hegelian concept of dialectics positioned social conflict as something central to all societies and thus, by definition, to the study of human geographies. Class conflict, as many Marxists would suggest, is not only the inevitable product of dialectical tensions between



the bourgeoisie and the proletariat but also the result of the dialectical emergence of “antisystems” in opposition to the institutionalized state. This understanding that societies are never inert but always volatile due to their composition of competing social groups and diametrically opposed class interests necessarily places a strong degree of emphasis on revolutionary change and associated social movements. David Harvey’s *Social Justice and the City* (1973), the book that blazed a trail in applying Marxist thought to the study of geographical change, offered a rather more nuanced approach. Indeed, the beauty of Harvey’s book—and the key to its huge intellectual influence in the discipline—was that, as it displayed Harvey’s structuralist understandings and belief in the pursuit of one united democratic socialist movement, it offered for the first time a geographical take on Marxist thought. Moreover, its analysis of the North American city highlighted not potentially revolutionary actions but, instead, the resistances offered to the white, upper-middle-class political and economic hegemony.

Notwithstanding the importance of *Social Justice and the City*, there was no sudden surge in studies of resistance. Indeed, few of the possibilities suggested by Harvey’s analysis were fully explored by geographers at the time. With the arguable exceptions of the early work of Andrew Charlesworth and David Sibley, most geographers adopted a more straightforwardly Marxian analysis centering on collective labor organization and class struggle. Thus, while the rich possibilities for researching geographies of resistance were now well understood, they were not widely adopted. Moreover, the field was fractured between those engaged in historical research and those working on the there-and-then. Indeed, while many radical geographers often sought to open their students’ minds to the world of resistance by turning to a copy of E. P. Thompson’s *The Making of the English Working Class* (1963)—a textual talisman to social historians and historical geographers—they more often than not failed to make parallel connections to what their historical geography colleagues were doing.

The concurrent emergence of postcolonial studies and feminist geography in the late 1970s and early 1980s helped renew interest in the less dramatic, more everyday forms of resistance. The

shared perspective of the study of the ability of nondominant groups to survive under—and even challenge—conditions of domination placed a greater emphasis on the ability of repressed individuals and groups to mobilize alternative ideologies in forging new social worlds. Such acts of resistance, so this perspective suggests, can take many forms, not all of which have any visible manifestation, for instance, mental resistance to psychic domination. Moreover, while some such protests might be recognized by oppressors as deliberate acts of resistance, other acts might either not be recognized (e.g., false compliance) or not be considered believable (e.g., anonymous political placards created by supposedly apolitical slaves). Thus, while such resistances are necessarily motivated in response to a dominant power, they might not always seek to rebalance power relations.

It has not escaped the attention of geographers that this analysis bears a strong resemblance to the work of the anthropologist James Scott. The central premise of Scott’s seminal *Weapons of the Weak* is that while individual acts of insubordination and evasion make no headlines, thousands of such acts create their own barriers of resistance, just as millions of polyps create a coral reef. The spatiality of such protests inevitably occurs, so the analysis goes, within the realm(s) of domination, which, in the case of Scott’s thesis, were the plantations of northwestern Malaysia.

This relationship has been called into question on two central counts. Michel de Certeau has asserted that the “tactics” of resistance come from a place outside the practices of domination but seek to “insinuate” themselves into the realm of domination. Resistance thereby occurs in—or between—the fault lines of power, spaces beyond conventional surveillance—or, as Edward Soja labeled such “gaps,” *thirdspace*. It is important to note, though, that according to Foucault, as we all internalize the systems of surveillance used to assert power against us, there are no gaps. Resistances occur, therefore, when we reject our self-surveillance, a shift that is without bounds yet is not aspatial. What does not differ between Scott’s and Certeau’s analyses, though, is the shared emphasis on the malleability of identity. Individuals can take on multiple personas to suit different situations, for instance, false deferential efficiency in the company of management or



Some 10,000 people take part in a demonstration against the International Monetary Fund and the World Bank meeting, September 27, 1988, in West Berlin. Banners state the demonstrators' belief that credit policies by the industrialized nations threaten the Third World.

Source: AP Photo/Jockel Finck.

foot-dragging resentment at other times. They might also assume an identity as a tool of resistance, for instance, as vegetarians in opposition to factory farming, or use their identity as a position from which to protest against societal attitudes. Of course, the assumption of an identity does not necessarily need to occur in response to a local context. Indeed, mass (international) media and forms of electronic communication, not the least the Internet, have allowed for the distancing between the “event”/“power” that is being resisted and the “act” of resistance. Being there and being known can be an irrelevance. As the recent worldwide protests over the repressive policies of the Burmese (Myanmar) junta have highlighted, resistances can occur outside both spatial and experiential contexts.

Critiques of Geographical Concepts of Resistance

Through such understandings and intellectual positions, resistance became one of the key topics of the so-called cultural turn in human geography. The concept was not, however, without critics. In particular, the tacit acknowledgment that signs of resistance could be read in all acts—the choice of one brand over another being a protest against a corporation, a raised eyebrow a personal slight—has been called into question. The first substantive challenge was raised, albeit implicitly, by Tim Cresswell's research on the spaces of transgressive practices. The conclusion from the case studies in Cresswell's *In Place, Out of Place* is that while to resist is intentional, to transgress is often unintentional, the



crossing of a border/line that has no sign or meaning to the “perpetrator.” The act, though, still functions as a form of protest, for all transgressions are judged by those who react to the practice. To resist, conversely, requires the actor alone to make a judgment. As such, reading bodily practices as acts of resistance—or otherwise—requires keen attention to both the sociolegal and the spatial contexts in which the practice is performed.

Another critique was issued by those who not only queried the worth of such an all-embracing concept—if everything could be considered to be an act of resistance, what is left for other human geographers to study?—but also by those who found such definitions lacking in political meaning. Indeed, political geographers have questioned whether some distinction ought not to be made between, on the one hand, political struggles and, on the other hand, cultural politics and personal resistances. This is not to deny the power or importance of such alternative forms of resistance but instead is an acknowledgment of the increasing political potency and power of social movements in the late 20th and early 21st centuries. Indeed, within the past decade, there has been a discernible shift to empirically rich studies of indigenous people’s movements in the developing world and anti-corporate/globalization protests.

Directions in Current Research

While this trend has clear resonances with earlier studies within “radical geography,” recent research has been sensitive to the ways in which current movements often use a range of tactics that combine overt protests and political demonstrations with other techniques that are not easily understood as being “organized.” For instance, Paul Routledge has described the anticorporate, antiglobalization forum People’s Global Action not as an organization but instead as a “convergence space” of other groupings whose primary function is to *inspire* acts that oppose corporate domination. Such groupings often rely on the “flattened” hyperlinked spaces of the Internet to allow action to be negotiated in non-hierarchical, democratic ways and thus allow for oppositional tactics to be developed in secret through encrypted e-mails. In a sense, therefore, if Soja’s thirdspace meaningfully exists, a strong argument could be made that it is the Internet.

Routledge’s concept of heterogeneous global grassroots “networks” also acknowledges that resistances invariably rely on and often directly critique the social enrollment of nonhuman things. For instance, the so-called Luddite protests of the 1810s primarily attacked job-supplanting machinery rather than the machinery owners. Moreover, actor-network theory suggests that since the world can usefully be described as a network of all things—animals, machines, plants, buildings, money, people, and so on—where power and meanings are generated by the relationship between things, then resistances are given form by the nature of the links in the network.

Carl J. Griffin

See also Actor-Network Theory; Anarchism and Geography; Antiglobalization; Antisystemic Movements; Class, Geography and; Feminist Geographies; Harvey, David; Hegemony; Justice, Geography of; Labor, Geography of; Marxism, Geography and; Radical Geography; Reclus, Élisée; Social Justice; Social Movements

Further Readings

- Creswell, T. (1996). *In place, out of place*. Minneapolis: University of Minnesota Press.
- Griffin, C. (2008). Protest practice and (tree) cultures of conflict: Understanding the spaces of “tree maiming” in eighteenth- and early nineteenth-century England. *Transactions of the Institute of British Geographers*, 40, 91–108.
- Harvey, D. (1973). *Social justice and the city*. London: Edward Arnold.
- Pile, S., & Keith, M. (Eds.). (1997). *Geographies of resistance*. London: Routledge.
- Routledge, P. (2008). Acting in the network: ANT and the politics of generating associations. *Environment and Planning D: Society and Space*, 26, 199–217.
- Scott, J. (1985). *Weapons of the weak: Everyday forms of peasant resistance*. New Haven, CT: Yale University Press.
- Soja, E. (1996). *Thirdspace: Journeys to Los Angeles and other real-and-imagined places*. Oxford, UK: Blackwell.
- Thompson, E. P. (1963). *The making of the English working class*. London: Victor Gollancz.



RESOURCE ECONOMICS

All production and consumption require the use of natural resources. Resource economics seeks to determine the optimal extraction rate of these resources. Key to the determination of optimality is the need for extracting firms to balance the benefits that accrue today against the costs and benefits of leaving the resources for a later time.

Resource economists propose that nonrenewable resources should be valued differently from goods that can be regenerated or produced, because the former can be extracted only once. Developing this idea further, Harold Hotelling showed that the *scarcity rent* rate, which is the opportunity cost of using resources today, would rise at the rate of interest. The limited ability of renewable natural resources to regenerate themselves and the potential for stocks to be depleted below recovery levels need to inform their use over time. Depending on the resource type, various rules for optimality have been derived, such as the Faustmann rule for forestry resources or the concept of maximum sustained yield for fisheries. The Faustmann rule determines an optimal timber resource rotation age through optimization of the net present values of all revenue flows; it states that an optimal rotation age will occur when the marginal benefit and marginal cost of delaying harvest are equal. Similarly, the maximum sustainable harvest for fisheries assumes a steady-state stock size, which occurs at the point where the net natural growth rate is at its maximum. This point is called the *maximum sustained yield*.

Issues in Determining Optimal Extraction Amounts

Nonrenewable resource models have been criticized because little empirical support exists for the Hotelling rule and in part because, as Matthias Ruth suggested, the model does not account for individual firm characteristics. Renewable resource models have been criticized for their inability to provide meaningful advice to resource managers, as well as for how resource economics values the benefits provided by natural resources. Renewable resource models vary according to the biological characteristics of the resource. For

instance, biomass stock models for fisheries are a function of species population, carrying capacity, and growth rates. However, growth rates, selling price, and efficiencies of fishing operations, as well as other biological factors, are typically considered exogenous in calculating the optimal harvest for renewable resources; because of their noninclusion, the applicability of the models for use by resource managers is limited.

Costanza and Daly proposed that renewable resource ecosystems not only yield goods through their harvest but, if left in place, provide services as well, such as erosion control or water catchments. In choosing an optimal extraction path, the costs of extraction, including the impacts on the local environment, have been largely explored. However, the benefits of leaving the resource in situ have predominantly been ignored, and ideally, the costs and benefits should be calculated simultaneously.

It has been argued that in calculating an optimal extraction path, the impacts of human actions on ecosystems are often overlooked. For example, the impact of the intensity and duration of extractive actions are not accounted for in calculating annual extraction amounts. It is possible, under one set of assumptions in which the needs of an ecosystem are overlooked, to arrive at an extraction path that is spread over many years, placing constant pressure on the resource. Alternatively, taking the ecosystem's needs into consideration, a more intensive extraction path may be selected with less overall disruption to the natural habitat.

Due to the long-term nature of resource extraction, future profits are typically discounted to facilitate the identification of intertemporally optimal extraction paths. The discount rate reflects an individual's time preference, which captures tolerance of risk and uncertainty, as well as the impacts of technological progress on resource discovery, extraction cost, recycling, and the creation of substitutes. There is controversy in discounting future profits because of intergenerational equity issues and the assumption that technological progress tends toward cost and resource savings. Robert Solow argued that present generations should be allowed to extract more of a resource because future generations, due to technological progress, will be able



to do more with less. Alternatively, Robert Costanza and Herman Daly suggested that individual behavior in the short run is inconsistent with long-run best interests for both the individual and society, as people are misled by short-run reinforcements of current behaviors that may come, for example, from monetary incentives, social acceptance or admonishment, and physical pleasure or pain. Consequently, instead of using a private discount rate, public policy decisions to guide resource extraction should be based on a much lower social rate.

Resource Economics: Past and Future

Many resource management and extraction models were developed with the goal of preserving and managing natural resources for future generations. Over the past century, these ideas have continued to develop and expand, as shown by the growth of subfields of economics such as resource and environmental economics and the intermingling of conservation and economic growth under the paradigm of sustainable development. In fact, managing economic growth through sustainable development has emerged as a methodology in itself, transcending multiple disciplines and giving rise to ecological economics.

The role of government in resource management is likely to increase for two reasons. First, if, as Costanza and Daly suggest, a discrepancy exists between our short-run behavior and long-term best interests, there is a need for intervention to guide sustainable development; second, with the expanding scale of resource management issues in the international arena, governments will likely take on a larger role. However, management and extractive issues, when managed at an increasingly global level, will require a better understanding of microlevel firm and individual behavior.

Robert Deacon and colleagues have suggested that the role governments play in regulating natural resources, including the policy tools chosen and the nature of a firm's responses, is largely a black box; to address this shortfall, future modeling efforts are likely to include more historic and institutional variables. Other subfields, such as development economics, that have experience with these variables offer a platform from which

to analyze policy interventions, while also providing case studies for policy implementation.

Andrew Blohm and Matthias Ruth

See also **Common Pool Resources; Common Property Resource Management; Commons, Tragedy of the; Community-Based Natural Resource Management; Distribution of Resource Access; Ecological Economics; Energy Resources; Environmental Management; Environment and Development; Nonrenewable Resources; Political Economy of Resources; Renewable Resources; Resource Geography; Resource Management, Decision Models in; Resource Mapping; Resource Tenure**

Further Readings

- Costanza, R., & Daly, H. (1991). Natural capital and sustainable development. *Conservation Biology*, 6, 37–46.
- Deacon, R. T., Brookshire, D. S., Fisher, A. C., Kneese, A. V., Kolstad, C. D., Scrogin, D., et al. (1998). Research trends and opportunities in environmental and natural resource economics. *Environmental and Resource Economics*, 11, 383–397.
- Fisher, A. C. (1981). *Resource and environmental economics*. New York: Cambridge University Press.
- Ruth, M. (1993). *Integrating economics, ecology and thermodynamics*. Dordrecht, Netherlands: Kluwer.



RESOURCE GEOGRAPHY

The study of human valuation and use of Earth's materials lies at the core of the modern discipline of geography. Indeed, investigation into the character, production, and distribution of natural resources might be said to be a quintessential pursuit for a discipline that has in large part been fashioned on the relationships between humans and their environment. Linked to political geographies by concerns over territoriality and proprietorship, to economic geographies through networks of production and consumption, to social and cultural geographies by collective practice and meaning making, and to environmental geographies through



the modification of natural systems, the study of resource geographies requires consideration of both the “human” and the “physical” sides of the discipline. As such, it is well conceived as a specialty where contemporary disciplinary concerns over the constitution of socionatural assemblages might profitably proceed.

This entry presents three broad imperatives that have marked natural resource investigations during the development of the modern Anglo-American discipline: (1) the creation of imperial inventories, (2) the management of natural capital, and (3) the analysis of political-economic systems and political-ecological networks. While each is a part of a genealogy of scientific engagement with the stuff of Earth, the respective imperatives identified here have differentially marked resource studies in geography during succeeding phases of the discipline's history. The imperial inventory period spanned the late 18th through the early 20th century; concerns over the expansion and management of natural capital took center stage in the middle to latter decades of the 20th century and persist today; and efforts to deconstruct and analyze the political-economic and political-ecological networks that produce natural resources became a preoccupation in the decades leading up to the turn of the 20th century and continue into the 21st. Thus, in presenting an overview of each period and the dominant imperative driving natural resource study, the aim of this entry is to situate the development of the subfield of resource geography within the broader context of the changing intellectual terrain of the discipline as a whole.

Empires and Resources

The roots of the modern discipline were born of European exploration and empire. First in the service of the Enlightenment ideals of scientific discovery and human progress and then in aid of 19th-century colonialism and commerce, the geographers and other scientists who served Europe's kings and queens compiled vast catalogs and accounted for the distribution of the flora, fauna, topographies, and climates of faraway places. Embodied by men such as Alexander von Humboldt, Charles Darwin, and the scientists sailing under Captain James Cook, geographical study of Earth's resources in the late 18th and

early 19th centuries was dedicated to uncovering the character and complexity of Earth and communicating the knowledge thus produced to audiences in Europe.

Contemporary reviews of this early history of the discipline have called into question the tendency to regard the period of Enlightenment exploration as benign in its environmental and cultural effects and therefore morally superior to the period of colonialism and commercial exploitation that would emerge in many European overseas possessions as the 19th century wore on. Rather, recent scholarship has demonstrated that the representations (journals, reports, paintings) produced by scientists to communicate the environmental qualities of far-off territories to decision makers in imperial centers served to initiate the construction of those territories as potential spaces of capital accumulation through resource extraction. Thus, by the early decades of the 19th century, a European sense of the value of the various parts of the Earth was being discerned through the eyes and instruments of scientists who were charged with simply uncovering the true nature of the Earth.

Exploration and empire were seldom far removed from one another, however. From Napoleon's armies of geographical scientists in Egypt to the British efforts to map the Indian subcontinent, the production of knowledge of environmental resources by trained scientists formed a central front in the effort to control territories claimed by other peoples. With this knowledge, both governance and capital accumulation through resource extraction became possible for the imperial powers. In the case of North America, this project of colonial resource cataloging was engaged well past the ending of formal colonial relationships and the advent of federated nation-states. In the western portions of North America, government-sponsored scientific expeditions were mounted in the late 19th century to ascertain environmental characteristics and the possibilities for commerce and settlement. Political leaders in the long-settled and urbanized areas of Eastern Canada and the United States viewed western territories as natural extensions of national spaces and understood their environments to be unclaimed and awaiting exploitation by a young and industrious settler society. Thus, parties were dispatched, often with Native guides, to lands unknown by the members



of settler society. Under the guidance of experts trained in the geographical sciences, these parties were charged with recording topographical characteristics, noting the irrigation potential, surveying timber stands and mineral deposits, and generally going about the business of constructing as complete a natural inventory as possible of as yet unsettled lands.

The knowledge produced by such survey parties served to construct particular resource geographies for particular peoples. In recounting the experience and legacy of John Wesley Powell's surveys of the Colorado Plateau in the 1870s, a recent study notes the enterprise's effect of both emptying the landscape of its Native inhabitants and rendering its nature visible to decision makers in Washington, D.C., such that settlement and irrigation policy might be set. In the Canadian context, researchers have noted similar colonial effects flowing from the work of the geologist George Dawson on the west coast of British Columbia. However, in this case, minerals, rather than water, formed the resource of interest. Location and resource aside, such work demonstrates that the production of knowledge about the resource base of western territories preceded and ultimately facilitated colonial settlement by the two young nation-states.

Managing for the Nation

As the 19th century ended and the 20th began, the identification and description of natural resources by geographers shifted in emphasis away from colonial cataloging and toward the service of the nation-state's social and economic development. In response to two world wars, the dust bowl of the 1920s, and the Great Depression of the 1930s, governments in North America were faced with co-coordinating economic recovery and survival for citizens and corporations alike. To this end, experts, working in universities and beyond, were enlisted by government agencies to tackle environmental problems of regional and national importance—the decline of forest and fish stocks, soil erosion, uneven water availability, the lack of energy resource security, and so on. In this climate, geographers found themselves called on to contribute to the management of public natural resources, often by providing “statistical pictures”

of inventories and distributions as well as analyses of the efficiency and sustainability of levels of exploitation of particular materials. The geographer as a useful scientist was given the chance to shine—a characterization cherished by the discipline, particularly in the years following World War II. Under this imperative, geographical study of natural resources was, and in many quarters continues to be, regarded as central to the progressive development of the liberal democratic nation-state and the social and economic well-being of its citizens. Through the deployment of a range of geographical techniques and tools, from field observation to geographic information system (GIS) modeling, geographers have a long history of helping states and their citizens manage their natural resources for collective social and economic goals.

Critical Approaches

Recent work in geography has noted the considerable authority wielded by scientists in presenting a complex “statistical picturing” of the natural inventory of the Western United States and Canada in the Progressive Era of the early 20th century, as well as the power of that authority to shape the making of social, economic, and environmental policy. From this period through to the present, and with a relative confidence in the ability of scientific inquiry to assist in more efficient and sustainable resource use, geographers have mobilized their skills in cartography and the natural and social sciences to address issues of resource distribution, health, and sustainability. However, a critical strain of analysis has emerged alongside the more classically liberal imperatives that have marked the managerial approach within the discipline. For several authors, the contested definition and use of natural resources demands consideration of who wields the authority to represent nature's character and toward what end. Thus, recent papers in geography journals have pointed to exclusions in the scientific, managerial, and political ranks along the lines of both gender and race. And, as a complement to the consideration of the politics of identity and representation, the critical literature has also highlighted the ways in which the production of natural resources has



been embedded in colonial projects and capitalist socioeconomic relations that have led to marginalization and oppression.

As the studies mentioned above in reference to colonial cataloging indicate, European scientists encountering New World environments effectively represented them in terms consistent with modern Western worldviews. Research conducted on late-20th-century resource management in Canada and Australia reveals that Eurocentric ways of knowing continue to dominate resource management across the former British settler colonies at the expense of Aboriginal populations, who are steadily regaining territorial and self-governance rights. Proponents of a more culturally diverse approach to resource management argue, in part, that in light of the environmental deterioration that has been allowed to occur under modern scientific regimes, humility demands that attention be paid to and lessons be learned from the localized environmental knowledge and durable social, political, and economic systems of the Aboriginal peoples. Given the rise in Aboriginal political power over the previous generation and considering that many Native peoples' territorial claims conflict with the established resource rights of non-Aboriginal parties, the insights offered by this stand of critical resource scholarship demand attention.

While a rather large literature has developed on issues of culturally specific ways of knowing and managing resources, less attention has been paid to the place of gender in the scientific and managerial ranks. As the few papers that address the issue make clear, however, the study and management of environmental resources has historically been a male domain. Identifying the masculine images of the hearty field scientist and the idealized laboratory scene of the rational man in the long white coat, critics argue that the very practice of geographical (and other) science has been constructed as a male endeavor. Additionally, this area of research in resource geography has demonstrated that the environmental concerns held by women are rarely accorded attention by resource researchers and managers; issues of family health, quality of life, and social justice (in this formulation constituting a set of socially constructed feminine concerns), critics claim, are ignored on the

altar of economic efficiency and competitive capitalism (in this formulation constituting a set of socially constructed masculine impulses and institutions). As with the demand for inclusion of Aboriginal voices and perspectives in resource study and management, the call for greater gender diversity has resonated ever more loudly over the previous generation and, it would seem, can no longer be marginalized.

In the literature that addresses identity and the politics of representation in resource geography, management at the level of the community is often identified as desirable. Implicit within this stance is the idea that state-level management is too detached, bureaucratic, and hierarchical to respond effectively to local social and environmental conditions. Researchers have responded by investigating community efforts at managing local resources. While several studies have uncovered examples of increased economic diversity, greater community control and pride, and enhanced environmental stability resulting from local management arrangements in the North American West, others have noted the challenges encountered by some communities that have taken on significant resource management responsibility. In particular, both the capacity (though capitalization, managerial skill, technical expertise, etc.) and the credibility (in terms of inclusion, interests, and obligations) of local communities to engage in sustainable resource development have been found to be uneven. Linkages to national and global political-economic systems, this literature suggests, can at times render local communities unable to effectively manage natural resources. Thus, the idealization of community resource management needs to be tempered by an understanding of the multiscale networks that mark modern resource economies.

A separate, yet related, strand of critical scholarship in resource geography has uncovered the relationships between capitalist production and resource landscapes at a variety of scales, from the regional to the national. This literature has considered the development of natural resource geographies in terms of both environmental impacts and social effects. On the one hand, treating the materials of the Earth as inputs in a system of production, work in this area has traced the ways in which the profit motive has intersected with the



limits of natural systems, both renewable and nonrenewable, to produce environmental degradation. Alternately, other studies have focused on the distribution of the wealth derived from the production of resources and analyzed the resultant phenomenon of uneven development within and between societies. In each case, however, the analyses share an approach, rooted in Marxist political economy, that treats capitalism as an overarching influence that draws bodies and materials scattered across space together into productive relations that have concrete social and material outcomes. In this way, the literature emphasizes the extralocal forces that intrude on efforts at community management of resources.

Dissatisfied with the rigid structuralism of political economy approaches to resource geographies, several authors have recently attempted to untangle the ways in which individual actors and environments are engaged by and engage with the overarching framework of capitalist resource production to produce unique political-ecological arrangements. Of particular interest to researchers has been the rise of neoliberal economic ideology (a hyperfetishization of “the market” and a corresponding distrust of the utility of government) and its engagement within resource policy and management circles. Work in this area has shown a remarkable diversity of community response to proposals to deregulate resource industries from fishing to forestry, with successful outcomes (social and environmentally sustainable practices) resting as much on the capacity and credibility of communities to engage national and global markets as on their ability to re-regulate resource management in the context of local circumstances and desires. By highlighting local actors and environmental characteristics and their reciprocal relations with overarching structures such as capitalist political economies, work in the poststructural vein points to the complex and multiscale social and environmental networks that make up present-day resource geographies.

Conclusion

As this overview indicates, the area of resource geography is broad, encompassing many subdisciplines of geography. As such, it has formed a central concern throughout the history of the

modern discipline and in many ways mirrored geography’s ever-shifting political and intellectual commitments. Marked by succeeding, yet overlapping, imperatives driven by those commitments, the study of natural resources by geographers has shifted from serving as an imperial cataloging enterprise to providing a position from which to critically evaluate the interconnections between cultures, politics, economies, and environments. Thus, in a discipline often divided between “human” and “physical” concerns, the study of resource geographies provides an opportunity to bridge the nature/culture dualism that so permeates our lives.

David A. Rossiter

See also **Common Pool Resources; Common Property Resource Management; Commons, Tragedy of the; Community-Based Natural Resource Management; Conservation; Coupled Human and Natural Systems; Distribution of Resource Access; Ecological Economics; Energy Resources; Environmental Management; Environment and Development; Feminist Environmentalist Geographies; Nonrenewable Resources; Political Economy of Resources; Renewable Resources; Resource Economics; Resource Management, Decision Models in; Resource Mapping; Resource Tenure**

Further Readings

- Bradshaw, B. (2003). Questioning the credibility and capacity of community-based resource management. *The Canadian Geographer*, 47, 137–150.
- Braun, B. (2000). Producing vertical territory: Geology and governmentality in late-Victorian Canada. *Ecumene*, 7, 7–46.
- Clapp, R. A. (1998). The resource cycle in forestry and fishing. *The Canadian Geographer*, 42, 129–144.
- Clayton, D. (2000). On the colonial genealogy of George Vancouver’s chart of the north-west coast of North America. *Ecumene*, 7, 371–401.
- Howitt, R., & Suchet-Pearson, S. (2006). Rethinking the building blocks: Ontological pluralism and the idea of “management.” *Geografiska Annaler Series B, Human Geography*, 88, 323–335.
- Kirsch, S. (2002). John Wesley Powell and the mapping of the Colorado Plateau, 1869–1879: Survey science, geographical solutions, and the economy of



- environmental values. *Annals of the Association of American Geographers*, 92, 548–572.
- Mansfield, B. (2004). Rules of privatization: Contradictions in neoliberal regulation of North Pacific fisheries. *Annals of the Association of American Geographers*, 94, 565–584.
- Reed, M. G., & Mitchell, B. (2003). Gendering environmental geography. *The Canadian Geographer*, 47, 318–337.
- Walker, R. (2001). California's golden road to riches: Natural resources and regional capitalism, 1848–1940. *Annals of the Association of American Geographers*, 91, 167–199.



RESOURCE MANAGEMENT

See Environmental Management



RESOURCE MANAGEMENT, DECISION MODELS IN

There are a wide variety of natural resource management issues that are addressed using a suite of different management tools. Primary among these are decision models. Natural resource management problems include developing structures and procedures to provide reliable water supply for domestic and industrial use, irrigation, recreation, and flood control; ensuring that productive wetlands are preserved and maintained; providing conservation lands to ensure maintenance of biodiversity; managing air and water quality; and fisheries management, among many others. A wide variety of decision models are also available to address these issues, ranging from simple sequential pairwise comparisons of options to more sophisticated models requiring vast amounts of data and computing power. Decision models help generate plausible alternatives for action and help choose among these alternatives. There are also many ways to categorize these decision models; Figure 1 provides a brief typology.

A decision problem for natural resource management can consist of the overall goals (objectives) for wise management—for example,

providing a “safe yield” of a renewable resource to ensure its sustainability or efficiently using a limited natural resource such as fossil energy. The discrete choices to be made are the alternatives (e.g., which forest stands to harvest, choosing among multiple reservoir projects, choice of fuels for generating electricity). For each of the alternatives, several attributes may be important for the decision (e.g., in the case of conservation lands, this may be their cost, location, and habitat value for different species). The discrete choice models in Figure 1 differ as to whether a single criterion or multiple criteria are used and if time sequencing and uncertainty are major factors.

Cost-benefit analysis has been long and widely used, particularly for large-scale, publicly funded projects in water resource management and in environmental regulatory decisions. When choosing among alternative projects, procedures, or standards, the monetary costs and benefits for all attributes of each alternative are established. The choice is based on the maximization of a single objective: economic efficiency. This requires choosing the alternative whose net benefits (total benefits – total costs) are the largest. To account for a time sequence of costs and benefits, discounting (valuing all benefits and costs in current dollars) is used. A difficulty in the use of this technique involves the valuation of all attributes for all alternatives, especially benefits, particularly when they are not traded in the markets.

Multi-criteria evaluation (MCE) decision models have been used when more than one criterion (objective) is employed and/or when the attributes for each alternative can be measured in their natural units, obviating the need for strict valuation. Often, the measures of the attributes for each of the alternatives are standardized. This is usually linearly scaled from 0 to 1 or 1 to 100, or through the use of value functions or fuzzy set functions, with the purpose of allowing fair comparison among the measures. The criteria (or objectives) are then weighted using the decision makers' preferences. A weighted linear combination is obtained for each alternative by summing the product of the criteria importance weight and the alternatives value on each of the attributes; the decision rule then is to choose the alternative having the largest value. These weights can be elicited directly by simply assigning weights,

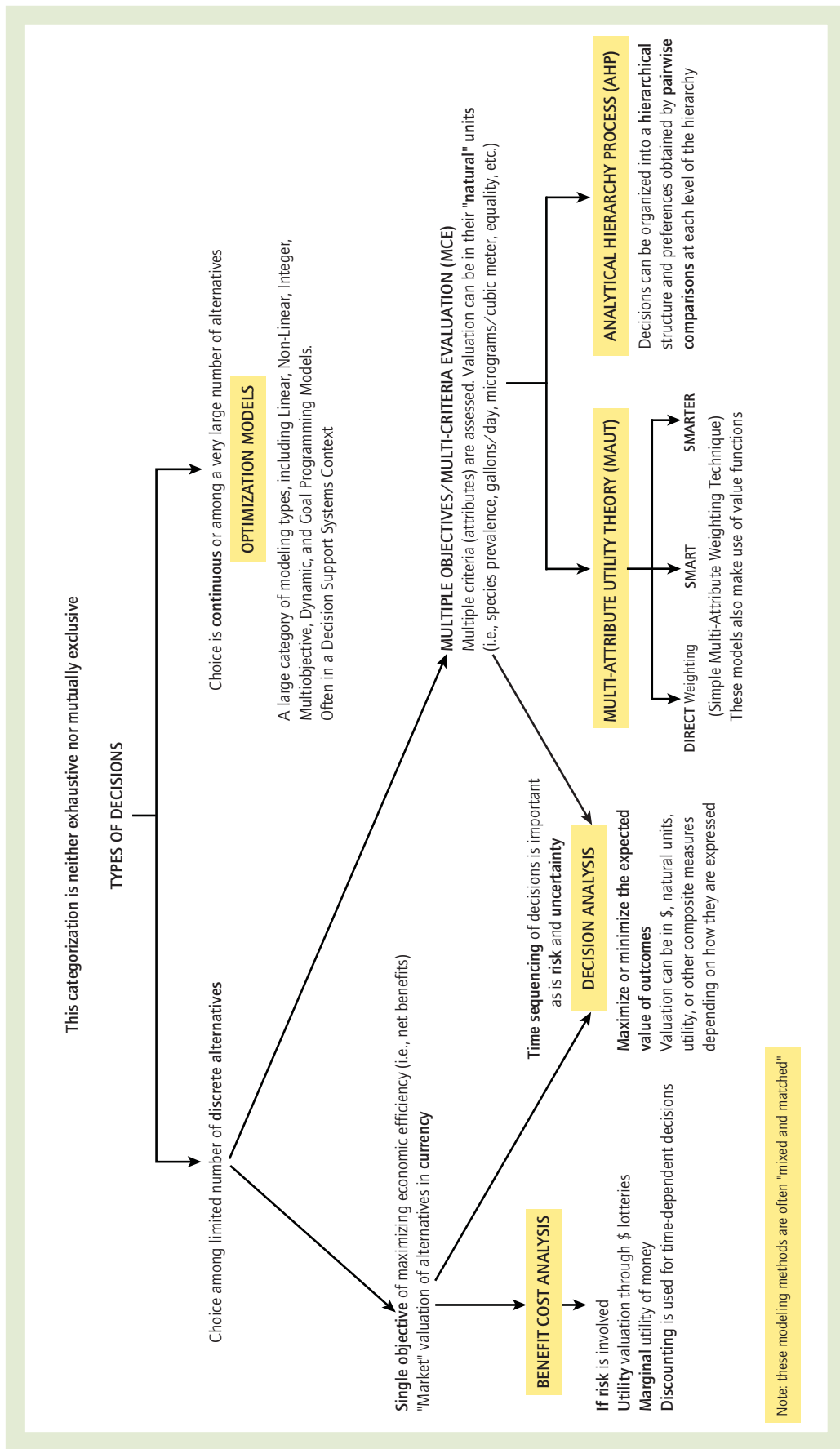


Figure 1 A brief typology of decision methods for natural resource management
Source: Author.



through structured transitive comparisons (multi-attribute utility theory, or MAUT), or by making a series of pairwise comparisons of the alternatives (the analytic hierarchy process, or AHP).

If the resource management decision involves several sequential choices, and uncertainty is part of the process, decision analysis is often employed. The decisions are formulated in a “decision tree,” with objective or subjective probabilities at specific nodes of the tree representing the chance occurrences. The optimal prescribed decision sequence is the path along the decision tree providing the largest expected outcome.

When the resource management choices are continuous, or there are too large a number of discrete options, decision models based on mathematical optimization are often employed (called mathematical programming models). The generic structure of these models has a mathematical function that is to be maximized or minimized (the overall objective for the decision process), comprising variables that represent the decisions that are to be made and constraints that describe the natural resource system or restrictions on the optimal solution (such as budgets or physical limitations). Mathematical programming models can have a single objective or, similar to MCE models, can have multiple objectives—and incorporate the relative importance weighting schemes mentioned above. They often form part of a comprehensive decision support system (DSS) composed also of integrated programs for data collection, manipulation, analysis, and display (i.e., geographic information systems, or GIS, and remote sensing). These programs may often have provisions for participation of communities that may be affected by the resource decisions; an example is the “Shared Vision Planning Framework” developed by the U.S. Army Corps of Engineers.

Applications of mathematical programming models and DSS have been extensive in natural resource management. For example, there are numerous mathematical programming models designed to assist in decisions concerning the number, locations, sizes, and operating characteristics of water reservoirs that must meet residential, commercial, irrigation, and industrial water supply needs and also provide for recreation uses and flood control (multiple and often conflicting objectives). Other programming

models are used to determine the optimal time and space sequencing of dredging operations on economically important navigation channels. These types of decision models have also been used in forest management to prescribe optimal cutting patterns to ensure ecologically and economically sustainable forests; in fisheries management to prescribe optimal control mechanisms, limiting the number of fishing vessels and fishing days, specifying the type of gear, and restricting fishing areas; and in conservation planning to choose an optimal pattern of land acquisitions to preserve biodiversity under competing ecological and economic objectives.

Samuel Ratick

See also Community-Based Natural Resource Management; Cost-Benefit Analysis; Distribution of Resource Access; Ecological Economics; Energy Models; GIS in Environmental Management; GIS in Land Use Management; GIS in Water Management; Models and Modeling; Nonrenewable Resources; Political Economy of Resources; Renewable Resources; Resource Economics; Resource Geography

Further Readings

- Eastman, J. R., Jiang, H., & Toledano, J. (2007). Multi-criteria and multi-objective decision making for land allocation using GIS. In E. Beinat & P. Nijkamp (Eds.), *Multicriteria analysis for land-use management* (pp. 227–252). Dordrecht, Netherlands: Kluwer Academic Press.
- Osleeb, J. P., & Kahn, S. (1998). Integration of geographic information. In V. H. Dale & M. R. English (Eds.), *Tools to aid environmental decision making* (pp. 161–190). New York: Springer.
- Ratick, S. J., & Du, W. (1992). Development of a reliability based dynamic dredging decision model. *European Journal of Operational Research*, 58, 318–334.
- Sexton, K., Marcus, A. A., Easter, K. W., & Burkhardt, T. D. (1999). *Better environmental decisions*. Washington, DC: Island Press.
- Stokey, E., & Zeckhauser, R. (1978). *A primer for policy analysis*. New York: W. W. Norton.



RESOURCE MAPPING

Resource mapping refers to the cartographic depiction of natural resources such as land, water, soil, minerals, forests, biological species, wind power, and so on. Thus, the phrase refers to the process of acquiring, analyzing, representing, and presenting information about the geographic distributions of these resources. The resulting resource maps visualize the spatial variation of the resources being mapped and are a means to analyze and store such information. The spatial variation information is fundamental to inventorying, monitoring, and modeling the resources; therefore, mapping is usually a key operation in resource management, conservation, use, and planning. Resource mapping is a routine practice in many governmental and non-governmental agencies or organizations.

The history of resource mapping may be as long as the history of the map itself. It is not hard to imagine that our ancestors used graphics to indicate the locations of water sources or to keep records of the sizes and shapes of lands. An example of modern resource mapping is the Canada Land Inventory of 1963–1995. This project was a massive effort begun by the Canadian government in the 1950s to identify the nation's land resources as well as their existing and potential uses. What makes this project particularly significant is that it developed the first geographic information system (GIS), the Canada Geographic Information System (CGIS). The development of this system was motivated by the need to accurately and quickly measure land areas.

Nowadays, modern geospatial information technologies, including GIS, remote sensing, and the global positioning system (GPS), have revolutionized the process and output of resource mapping. Remote sensing may provide data that are both spatially and temporally detailed and often cover vast areas and long time spans. A GPS can accurately and precisely associate ground sample data with remotely sensed data, so that models can be built to translate the data obtained through remote sensing, for example, a vegetation index, into the information about resources, for example, vegetation type. A GIS is the platform and tool to integrate all kinds of data, build and run models, and design and create the final maps.

Figure 1 shows a map generated through the integration of these modern technologies. The map shows the spatial distribution of biomass resources that are usable for energy production in Guangdong Province, China. The calculation of the amount of usable biomass at each location started with remotely sensed data, including MODIS/Terra and LandSet. The remotely sensed data were processed in a GIS by a series of physical, biological, economic, and ecological models built based on ground samples (located by a GPS) and the literature, to derive the usable biomass value at each location and generate the map. With this biomass information and the information about a road network (also shown in the map), further modeling can be performed to evaluate the feasibility of establishing biomass electric power plants in this area and locate optimal locations for such plants based on transportation costs.

Besides the adoption of the modern spatial information technologies, another trend in today's resource mapping is the shift from vector to raster format to store, represent, or display spatial data in digital form. The data for today's resource mapping, as exemplified by remotely sensed data and digital elevation models (DEMs, which are being increasingly derived from remotely sensed data), are increasingly available in raster rather than vector format. The implication of this data format change is more profound than simply how the data are organized and stored. The capability of raster data to accommodate high resolutions in both spatial and attribute aspects facilitates the representations of continuities in both geographical and parameter spaces, which in turn facilitates the application of new modeling methods, such as fuzzy (continuous) classification, in resource mapping. In *fuzzy classification*, an object can belong to more than one class and is not required to be fully typical of a predefined class. For those resources that change continuously over Earth's surface (e.g., vegetation and soil), raster mapping using fuzzy classification usually preserves more information and better reflects human knowledge than the traditional vector mapping using crisp classification. Raster mapping using fuzzy classification not only changes the way people generate and interpret resource maps but may also change the way they represent the knowledge of the

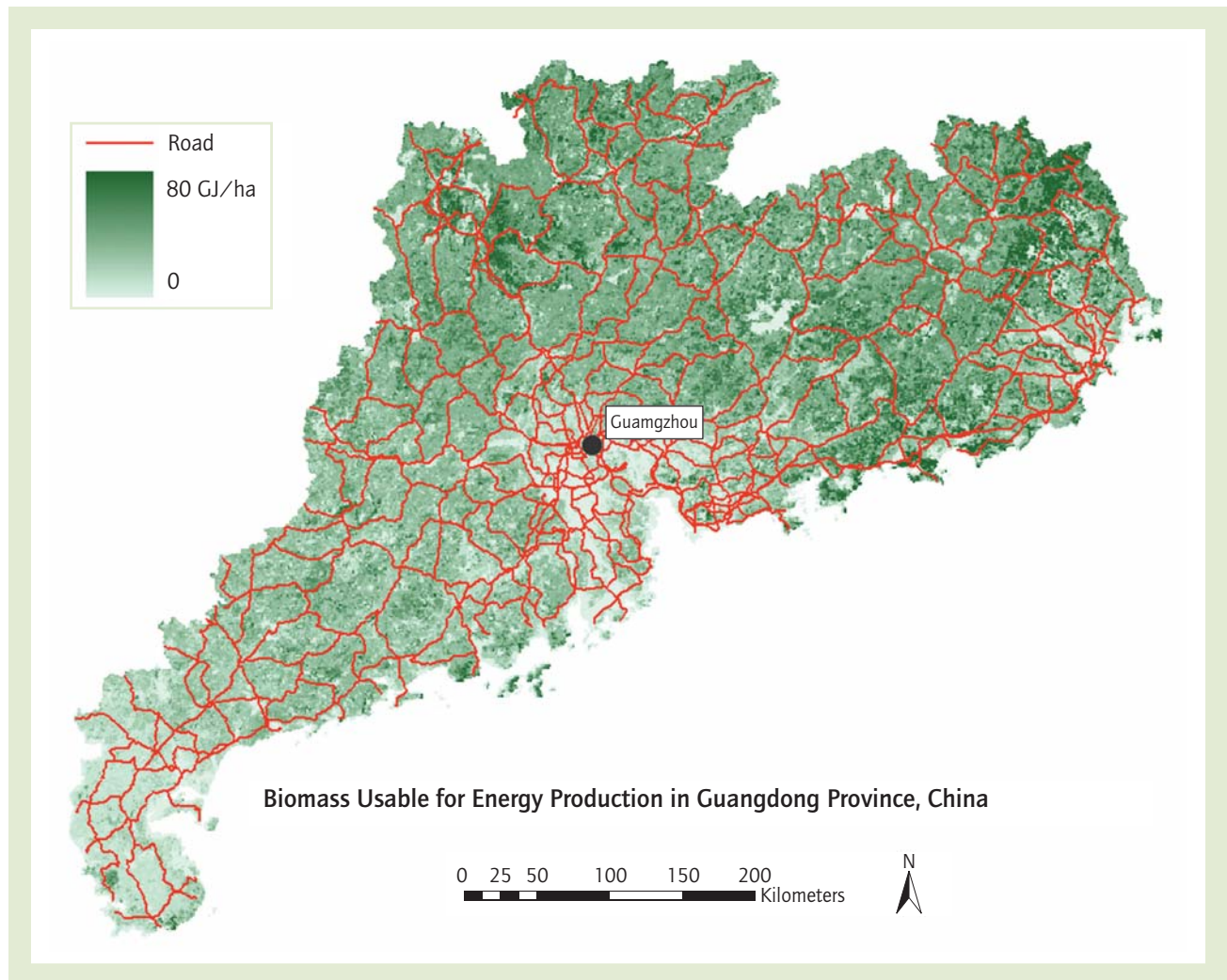


Figure 1 Resource map: an example

Source: Author.

resources that they want to include in the maps. Specifically, with vector mapping using crisp classification, our focus would be on where to draw the boundary between two classes, whereas in raster mapping using fuzzy classification, our focus would be on what the most typical features are for a given class. The influence of this fundamental change in spatial data management on resource mapping remains to be seen.

Xun Shi

See also [Ecological Mapping](#); [GIS in Environmental Management](#); [GIS in Land Use Management](#); [GIS in Water Management](#)

Further Readings

- Lang, L. (1998). *Managing natural resources with GIS*. Redlands, CA: ESRI Press.
- Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science* (2nd ed.). New York: Wiley.
- Shi, X., Elmore, A. J., Li, X., Gorence, N. J., Jin, H., Zhang, X., & Wang, F. (2008). Using spatial information technologies to select sites for biomass power plants: A case study in Guangdong Province, China. *Biomass and Bioenergy*, 32, 35–43.



Wing, M. G., & Bettinger, P. (2008). *Geographic information systems: Applications in natural resource management* (2nd ed.). New York: Oxford University Press.

Zhu, A. X., Hudson, B., Burt, J., Lubich, K., & Simonson, D. (2001). Soil mapping using GIS, expert knowledge, and fuzzy logic. *Soil Science Society of America Journal*, 65, 1463–1472.



RESOURCE TENURE

Legal tenure arrangements for natural resources such as minerals, fisheries, forest products, petroleum, among others, are fundamental to economic relationships in any human society and the cultural landscapes they create. At any geographical scale, claims to resources and systems to manage and use them must address the economic, environmental, cultural, and political dimensions of resources and the places in which they occur.

Geographically uneven distribution of natural resources is a key spatial characteristic of the environment. Social, political, and cultural responses to this spatial differentiation are fundamental to the proposition that geography continues to matter in the contemporary world, where it is often suggested that globalization foreshadows the “end of history” and the “end of geography.”

Resource geographies demonstrate that access to, control of, and identification with natural resources remain fundamental—even defining—elements in human social formations. Indeed, some political scientists suggest that social claims to and conflict over resources are central in all human politics. We can easily define politics and resources as interdependent, with various human activities at different scales involved in obtaining, using, and distributing the resources required to produce and reproduce biological, social, and economic life constituting the basis of all human politics.

In all contemporary states and environments, the economic, cultural, and legal constitution of property rights in resources and the institutionalization of these rights in systems of legal

tenure are an important facet of governance and political economy. Most societies recognize a collective claim to territory and a right, even an obligation, of the members of the collective to protect their shared interests through the exercise of exclusive rights (including a right to exclude others from their territory and the enjoyment of its resources). The boundedness of different societies varies, with modern states typically seeking strict border controls and rigid control of (some) aliens. In smaller-scale societies, the porosity of the edges of society and territory often reflects diverse environmental, social, and geographical circumstances. For example, in arid areas of Central Australia, there are competing conceptualizations of groups and resources, depending on whether environmental and economic circumstances are considered a “feast” (in which case, social strategies of inclusion and the extension of obligation are emphasized to increase the range across which people are able to secure sustenance) or a “famine” (in which case the generosity of inclusion is limited as far as possible to the closest family and kin). In modern nation-states, where the metaphor of a “level playing field” seems to propose that global trade can occur in defiance of geographical differentiation and ecological (and cultural) diversity, the edges of society and territory are often porous only to capital and privilege, with human bodies disciplined through strategies of control and exclusion.

States have created tenure systems built on claims of universality. In settler societies, preexisting indigenous systems of resource governance and the political geographies they support were largely ignored and erased—assumed to be “inferior” to European imperial systems underpinned by Christian ideologies of divine providence and the economic imperatives of accumulation. Colonial and postcolonial states established a claim of ownership over resources, sometimes allowing surface and subsurface property rights to adhere to land tenure rights, as in the United States, and elsewhere reserving resource rights to the state and allocating them separately through systems of distinctive tenures for specified resources, as in most former British colonies.

The colonial encounter historically brought quite different systems of resource tenure into



confrontation. In small-scale traditional societies, where modest technologies focused on harvest and the use of natural resources through economies based on hunting, fishing, gathering, and various sorts of husbandry of natural resources (including gardening, burning, clearing, etc.), tenure systems tend to emphasize the overlapping interests of resource managers and resource users. In other words, these societies tend to create tenure systems in which responsibility is shared in ways that reinforce the importance of social and environmental relationships and mutual obligation (including mutuality between people and their environments). One's rights and responsibilities in these systems depend not simply on "knowledge of" but also the "relationship with," "responsibility to" and "contextualized understanding of" places and their resources and characteristics. In contrast, modern property systems seek to decontextualize resources from their social and environmental settings, allowing their separation for purposes of governance, trade, and ownership. For example, separation of "water rights" from "subsurface mineral rights" and "surface property rights" creates opportunities to manage different resources for different purposes, producing the historical absurdities of overallocated river systems, where more than 100% of annual flow is "owned," as a legally enforceable property right, while market and environmental circumstances make it impractical to use water allocations productively. Examples of such circumstances can be found in arid areas of Australia, North America, and Central Asia.

Resource theorists seeking to understand the development of modern Western legal concepts of resources have suggested that the imperatives for technological innovation and wealth accumulation in industrial societies have produced specific ways of thinking about "resources" that allow this separation of certain properties of natural resources from their context—trees' functional properties as timber, for example, being separated conceptually from diverse and integrated properties contextualized as forest ecosystems.

In establishing tenure systems that entrench resource exploitation as the driver of resource management systems, industrial societies have separated the properties of specific natural

resources (timber, water, fisheries, minerals, etc.) from their geographical, ecological, and cultural contexts and relationships. In separating responsibility for management, use, and regulation, such systems vastly increase the capacity for production—as do the drivers of industrial societies' insatiable appetites for materials, land, and labor. Such separation, however, also creates the risk of vastly exceeding the ecological, cultural, or technological capacity of resource systems to recover from damage inflicted and reduces all such costs to a compensable economic surrogate rather than a geographically specific set of place-based relationships and capacities.

Richard Howitt

See also Common Pool Resources; Common Property Resource Management; Commons, Tragedy of the; Community-Based Natural Resource Management; Conservation; Distribution of Resource Access; Ecological Economics; Energy Resources; Environmental Management; Environment and Development; Governmentality and Conservation; Indigenous Environmental Knowledge; Nonrenewable Resources; Political Economy of Resources; Renewable Resources; Resource Economics; Resource Geography; Resource Management, Decision Models in; Resource Mapping

Further Readings

- Howitt, R. (2001). *Rethinking resource management*. London: Routledge.
- King, L. (2004). Competing knowledge systems in the management of fish and forests in the Pacific Northwest. *International Environmental Agreements*, 4, 161–177.
- Klawitter, S., & Qazzaz, H. (2005). Water as a human right. *International Journal of Water Resources Development*, 21, 253–271.
- Leftwich, A. (1983). *Redefining politics: People, resources and power*. London: Methuen.
- Muller, S. (2008). Community-based management of saltwater country, Northern Australia. *Development*, 51, 139–143.
- Robbins, P. (2000). The rotten institution: Corruption in natural resource management. *Political Geography*, 19, 423–443.



RESTORATION ECOLOGY

See Environmental Restoration



RESTRUCTURING

Restructuring refers to a process in which significant and rapid changes dismantle an existing structure and lead to the formation of a new one. Rooted in Marxist analysis, the concept of restructuring in the discourse of social science suggests qualitative changes in the relations between constituent parts of a capitalist economy that affect the way society is organized and operated.

The term *restructuring* is most frequently applied to dramatic economic transformation and is thus often used to mean economic restructuring. The concept of economic restructuring can be applied at different scales. On a micro scale, *restructuring* refers to a process of making a major change in the organizational structure of an enterprise to make it more profitable. This process, also known as *corporate restructuring*, often involves strategies such as reducing management levels, changing some major organizational components through divestiture and/or acquisition, altering the size of the work force, developing new models of corporate control with altered ownership structure, and redefining the firm's core activities and internal and external boundaries. These changes at the firm level result in changes in the way economic activity is organized across geographical space.

At macro levels, restructuring denotes a transition from an old economic structure to a new one with distinct spatial manifestations. On a global scale, economic restructuring (or industrial restructuring) represents the shift in industrial production from industrialized economies (i.e., the core) to the economies of the global periphery. Theories of economic restructuring have gained currency since the 1970s, when a recession, sparked by the 1973 oil crisis, hit the world capitalist economy and ended the long postwar boom. The system of the world capitalist economy responded to the crisis of the old structure through rearranging production space, a process

that Logan and Swanstrom (2005), following David Harvey, called the "territorial fix." Manufacturing jobs began to be outsourced from North America and Europe to developing countries in Asia and Latin America. Capital outflows in the form of foreign direct investment operate on a global scale, typically looking for cheap production sites. With internationalization of production spearheaded by transnational corporations and the spread of industrialization, especially in a number of rapidly growing, newly industrializing economies (NIEs), a new international division of labor emerged. At the national level, parallel to the new industrialization in other areas, advanced industrial nations have experienced a transition toward service economies in their process of deindustrialization. Since the 1990s, the new international division of labor has strengthened itself with the outsourcing boom of (low-end) services to the NIEs.

Industrial restructuring has acted as a driving force, leading to major spatial realignments at the regional and city levels. As the traditional manufacturing regions of North America and Western Europe went into apparently terminal decline and became the "Rust Belt," factories and employment relocated to low-cost, nonunionized locations with environmental amenities. The new regions of growth, such as the Southern United States (the so-called Sunbelt), were built on new industries (e.g., services, oil exploration, aerospace) and certain old industries (e.g., manufacturing, defense). This regional shift exacerbated the prevailing urban decline in cities of the Rust Belt and propelled urban growth in the Sunbelt. At the city level, urban industrial restructuring unfolded in parallel with national trends. Services began to replace manufacturing as the leading industries in urban economies. Producer services, in particular, became new engines of growth, with a concentration in major cities.

A process associated with changing the geography of industry and employment, economic restructuring represents a response to changed conditions, which may be induced by factors such as technical change, labor-capital conflicts, and the inherent competitive social relations of capitalism. The process may also be closely related to changing regimes of accumulation (i.e., from the Fordist regime of accumulation to a new regime

of flexible accumulation), accelerating circulation of capital, increasing globalization of the world economy, and (consequential) heightened competition.

Restructuring, or the process of moving from one structure to another, is often viewed as a process independent of human will that takes place according to some logics inherent to capitalism (as described above), especially the logic of capitalist competition and cost reduction. In this sense, restructuring is a spontaneous process that generates impacts at different geographical scales.

One the other hand, *restructuring* has been increasingly used to refer to a neoliberal political-economic strategy or policy agenda of the government. Thatcherism and Reaganism, for instance, represented particularly aggressive programs of neoliberal restructuring during the 1980s. State power was mobilized behind “state-authored restructuring projects” characterized by marketization and deregulation, aimed at the central institutions of Keynesian-welfarist settlements. Since the 1980s, neoliberal programs of economic restructuring have been extended globally by the G-7 to peripheral and semiperipheral states. Bretton Woods institutions such as the World Trade Organization, the World Bank, and the International Monetary Fund, which were transformed into agents of transnational neoliberalism, actively promote trade and market economy principles, as well as Western values of democracy and human rights. These institutions use their financial instruments to get countries in the Third World that face economic hardships involved in various structural adjustment and decentralization/deregulation programs. Economic restructurings in these less developed capitalist economies are more or less “responsive” (or “passive”), as they are to a large extent imposed from outside or “above.”



Poor children stand in a plot of land where a new shopping mall will be constructed in Gurgaon, Haryana, India (2005). Since 1991, economic reforms have transformed India into one of the fastest-growing economies in the world.

Source: Amit Bhargava/Corbis.

While restructuring theory originated in, and has mostly been applied to, (advanced) capitalist economies, it can be extended to other political economic settings. The abrupt transition of the former socialist countries, including the Soviet Union and Eastern European countries, to capitalism during the late 1980s represents an extreme of structural change. Parallel to capitalist restructuring, several years of *perestroika* (restructuring) in the Soviet Union during the mid 1980s, a “revolution from above,” had profound consequences. While the intended consequences included a fundamental transformation of the Soviet economic system and creation of a market economy (of a social democratic type), the unintended consequences



included the dissolution of the Soviet state and the end of the Cold War.

Less abrupt but still profound restructuring has been occurring in other socialist countries such as China and Vietnam. Unlike perestroika in the 1980s or “shock therapy” from the early 1990s in Russia and Eastern Europe, reform of the economy in China has followed a gradual approach whereby Communist Party control is maintained alongside a gradual establishment of a market economy framework. China’s three decades of economic reform have dramatically changed the nation’s economic landscape. Major structural changes include, but are not limited to, a rapid structural shift in employment activities and output, diversified ownership structures of firms and industries, a shrinking state sector in most industries, and increased foreign trade and foreign investment. Economic restructuring has its strong spatial manifestations. Alongside the structural changes of the economy, regions display changing patterns of uneven development. Meanwhile, Chinese cities are also undergoing profound transformation, with rapid suburbanization, new patterns of urban land use, a changing spatial structure, and the formation of new social and cultural spaces. Somehow inspired by China’s experiences, socialist countries such as Vietnam and, to a lesser extent, Cuba have also adopted a gradual approach toward economic reform.

Restructuring should not be restricted to the economic domain alone. The concept can refer to different processes of change, for example, structural changes in the organizational form of economic, social, and political institutions. Restructuring of capitalist economies is often driven by capital-labor relations; on the other hand, economic restructuring can also shape capital-labor dynamics and transform social relations. If left to itself, for instance, the process of restructuring may exacerbate class inequalities. As discussed earlier, restructuring often requires the involvement of the state and/or transforms state capacity. From the culture perspective, economic restructuring has been associated with postmodernity, just as it has been associated with flexible accumulation.

Enru Wang

See also **Business Cycles and Geography; Deindustrialization; Economic Geography; Flexible Production; Industrialization; Marxism, Geography and; Neoliberalism; New International Division of Labor; Newly Industrializing Countries; Regulation Theory; Spatial Fix; Structural Adjustment; Uneven Development**

Further Readings

- Beauregard, R. (1989). Postwar spatial transformations. In R. Beauregard (Ed.), *Atop the urban hierarchy* (pp. 1–45). Totowa, NJ: Rowman & Littlefield.
- Brenner, N., & Theodore, N. (2002). Cities and the geographies of “actually existing neoliberalism.” *Antipode*, 33(3), 349–379.
- Brown, A. (2007). *Seven years that changed the world: Perestroika in perspective*. Oxford, UK: Oxford University Press.
- Frobel, F., Heinrichs, J., & Kreye, O. (1980). *The new international division of labour*. Cambridge, UK: Cambridge University Press.
- Clark, G. (1994). Strategy and structure: Corporate restructuring and the scope and characteristics of sunk costs. *Environment and Planning A*, 26(1), 9–32.
- Gibson-Graham, J.-K., Horvath, R., & Shakow, D. (1988). Restructuring in US manufacturing: The decline of monopoly capitalism. *Annals of the Association of American Geographers*, 78, 473–490.
- John, R., & Swanstrom, T. (2005). Urban restructuring: A critical review. In N. Kleniewski (Ed.), *Cities and society* (pp. 28–42). Malden, MA: Blackwell.
- Latapi, E. A., & Rocha, G. M. (2002). The restructuring of labor markets, international migration, and household economies in urban Mexico. In J. Chase (Ed.), *The spaces of neoliberalism: Land, place, and family in Latin America* (pp. 187–212). Bloomfield, CT: Kumarian Press.
- Lovering, J. (1989). *The restructuring debate*. In R. Peet & N. Thrift (Eds.), *New models in geography* (Vol. 1, pp. 198–223). London: Unwin Hyman.
- Ma, L., & Wu, F. (Eds.). (2005). *Restructuring the Chinese city: Changing society, economy and space*. London: Routledge.



- Massey, D. (1984). *Spatial divisions of labor: Social structures and the geography of production*. New York: Methuen.
- Peck, J., & Tickell, A. (2002). Neoliberalizing space. *Antipode*, 34(3), 380–404.
- Schoenberger, E. (1988). Multinational corporations and the new international division of labor. *International Regional Science Review*, 11(2), 105–119.
- Scott, A., & Storper, M. (Eds.). (1986). *Production, work, territory: The geographical anatomy of industrial capitalism*. Boston: Allen & Unwin.

RETAIL TRADE, GEOGRAPHY OF

Retail trade is one of the world's largest economic sectors and is the final step in the distribution of merchandise from producers to consumers. The geography of retail trade is concerned with the spatial patterns of stores, the behaviors of consumers, and the spatial interactions between them. Research on retail trade contributes to a better understanding of economic processes. For example, retail trade can be analyzed in terms of consumer demand and its behaviors, and store supply and its strategies can be examined in the context of various geographic scales. Retail studies show that there are significant demographic differences in the retail attraction of stores, each of which has a different distance decay effect. Different socioeconomic profiles of customers have also influenced retail trade. For example, income is a good indicator of store choice. The spatial dimension of retail trade is important since every store's trade area is influenced by its location, its proximity to different types of customers, and the layout of other competitive stores.

Retail stores vary greatly in size—from small local shops to large supercenters that form part of national chains. The best way to understand retail trade is to know the customers and where they are located. Both demographic and behavioral analyses are approached in retail trade research to understand consumer behaviors. Demographic studies use basic population characteristics such as age, income, marital status, and so on. These

demographic factors often account for buying patterns. Behavioral analyses emphasize consumer attitudes, values, and perceptions; social factors that shape consumer behavior; perceptions of different stores; and attitudes toward shopping as an activity, which vary by age, income, gender, ethnicity, and location.

Retail Trade Establishments and Spatial Changes

Retailing represents sales of new and used goods in small quantities to the general public for personal or household consumption, as it is located in retail outlets without including the informal retail sector. There are three main components in store-based retailing: sales, outlets, and selling space. Retail sales represent the value added in the distribution of goods and services to consumers, excluding value-added or sales tax. Retail outlets are business units that are used principally for retail trade; therefore, each store within a shopping mall is counted separately. Retail selling space refers to floor space within a retail store used for trading; it is also known as sales floor area, trade area, trading area, sales area, and retail square footage.

Among retailers, grocers are the geographically dominant retailers, selling foods, beverages, tobacco, and other everyday household items at supercenters, supermarkets, discounters, and small grocery retailers. Supercenters are retail outlets selling groceries and nonfood merchandise with a minimum retail sales area of 26,910 ft.² (square feet). They are usually located in suburban malls or shopping centers as the anchor store that is easily accessible by automobile. Exemplary brands include Walmart, Target, Kmart, and so on. Supermarkets sell groceries with a selling space of between 4,306 and 26,910 ft.², selling at least 70% groceries. Supermarkets grew quickly across the United States with the growth of suburban development after World War II. Most North American supermarkets are located in suburban strip malls as a “draw tenant” along with other small retailers. They are generally regional rather than national in their company branding. Representative names include Kroger, Safeway, and so on. Kroger is one of the most nationally oriented supermarket chains in the United States.



Discounters sell mainly private-label or budget brands selling core, high-volume grocery products; the size is typically 3,229 to 9,688 ft.², stocking 1,000 to 4,000 product lines. Aldi and Save-a-Lot are good examples of discounters. Their relatively small size has helped discounters penetrate urban markets, where real estate is generally more expensive than in suburban locales, and also allowed the companies to carve out a niche in neighborhoods that supermarket chains neglect. Aldi, for example, has about 950 stores in 29 states and plans to open more in Connecticut, Missouri, and Texas. Unlike supercenters and supermarkets, accessibility to public transport is one of the important criteria in the location decision by discounters. Relatively speaking, they are easily accessible by foot, by bicycle, or by public transit, compared with supermarkets or supercenters.

Retail stores chased the middle class to the suburbs. The small and scattered retail stores in the suburbs were replaced by large shopping malls, which need land for the construction of their “big boxes.” Enormous parking lots built on relatively cheap land are necessary for shopping malls in the suburbs. The entry of supercenters or supermarkets affects employment patterns in the metropolitan areas, especially local retail employment. For example, Walmart employs 1.3 million people in the United States; a typical Walmart store with 100,000 ft.² employs 150 to 350 people, and a Walmart supercenter employs 400 to 500 people. Suburban growth is accompanied by regional shopping malls, which also are major creators of employment. The concentrations of employment in peripheral urban areas have created a need for retail services, and regional malls and shopping centers and have affected housing patterns.

Theories and Models of Retail Trade Location

Retail location decisions offer many opportunities for differentiation because each location is unique. Even contiguous locations may produce large differences in sales volume, sometimes for reasons that can really never be determined. Recent advances in geographic information systems (GIS) have made the retail location decision a relatively easy process. Location variables of retail trade, including population, traffic flows,

competitive locations, and related factors, are input into location models that provide detailed assessments of alternative sites. GIS continue to change the landscape of retail trade. Retailers use GIS to identify underserved regions and overlapping trade areas of influence, to compare various markets from a national perspective, and to target specific stores for relocation due to intensification of competition. Retail trade areas can be mapped with the help of census or ZIP code boundaries. Using U.S. Census data such as blocks or block groups, detailed demographic information can be studied. Linking information to location is a process that applies to many aspects of retail trade. Retail trade area analysis makes decisions regarding the types of market areas that should be serviced, the locations that should be used, the size of new facilities, and related decisions that serve as a foundation for site selection. It also analyzes demographic and competitive information, looking for cities or neighborhoods where new store potential is the highest.

The federal government’s Census of Retail Trade enumerates retail establishments in the United States. The data include number of establishments, sales, payroll, and employment and appear in reports by geographic areas, by industry, and by major retail centers. Consumer expenditure data can be obtained from the Bureau of Labor Statistics. The *Consumer Expenditures Annual Reports* are published annually at the national level and summarize various consumer demographic characteristics. Income and household information are also available for download from the U.S. Census Bureau. A customized database on retailers can be obtained from Trade Dimensions, which provides the retailer locations, sales volumes, and so on.

Early ideas in retail models used the central place theory, assuming that both customers and retailers make decisions that maximize their utilities. Concepts of the range and threshold of a good were adopted in explaining retail trade within settlements. According to the theory, different goods would have different ranges and thresholds. Others applied various forms of the gravity model: The law of retail gravitation, for example, allows analysts to draw trade area boundaries around cities using the distance between the cities and the population of each city.



A Walmart in Southern California

Source: Steven K. Martin.

According to the model, the larger a city, the larger a trade area it has. The extent of a trade area of a city is determined by the breaking point between multiple cities or centers. The model presumes that the cities are on a flat plain without any rivers, freeways, political boundaries, consumer preferences, or mountains to modify an individual's progress toward a city. A probabilistic retail model considers two components of retail attraction: (1) the store size and (2) the travel time or the distance between the consumer and the store.

Spatial interaction models—a family of gravity models—can be used to predict the flows of consumer dollars from residential areas to retail destinations. Spatial behavior in spatial interaction models is not different from that in the central place theory. With demographic characteristic inputs such as population and household income

values as well as consumer expenditure data into a spatial interaction model, it is possible to predict consumer interactions between consumers and individual retailers. Interactions are measured in terms of revenue and are correlated directly with store attractiveness and inversely with distance between consumers and retail centers. Such a model would greatly improve on the multitude of existing retail planning methods. While GIS currently support limited retail analysis functions, they are capable of supporting spatial interaction modeling through advanced data manipulation. The implications of spatial interaction modeling in retail trade would be valuable in predicting potential revenues for various site locations. There has been extensive academic research on the application of spatial interaction models to retail trade to explain how the models should work.



Retail Trade Without Distance

Internet-based retail trade rose with the Internet, which changes the geography of retail trade. The 21st century has seen a seismic move in the way in which store-based retailers have viewed their online operations. Online retailing, also known as e-commerce, is the latest form of retail trade. The growth of e-commerce is inevitable. As store sales fall, many retailers have found Internet sales as a way to reconnect with consumers. Major retailers begin to see the potential of using online retailing as a lower-cost way to explore their options in national markets. Recent retailing sectors have grown in electronic retailing and in the integration of e-commerce operations within traditional retailing strategies. One of the attractions of electronic shopping to customers is the ability to shop from home and the ability to compare prices from geographically dispersed sellers and order the most favorable combination of product, delivery, and customer service. In this context, location has been seemingly less critical. It is still arguable if the importance of location has decreased over time due to Internet technology. More and more retailers offer customers the option of shopping electronically and picking up purchases at their local stores. Internet retailing as a percentage of total retailing was 3.7% in 2007 and was expected to keep increasing in the United States. Exemplary companies adopting this trend include Barnes & Noble, Best Buy, Circuit City, JCPenney, and so on. The scope of geography of retail trade is already global in character. Firms are operating retail outlets in foreign countries and markets that are beyond domestic boundaries.

Retail trade is continuously changing and is competitive. New retail sites are founded in peripheral locations, new organizational forms of retail trade are always emerging, and e-commerce transfers locations into a virtual world. The spatial effects of the changes in retail centers, the globalization of retail trade, or the retail trade in transit areas and at junctions are topics of current retail trade research.

Changjoo Kim

See also **Applied Geography; Business Geography; Business Models for Geographic Information Systems; Consumption, Geographies of; E-Commerce and Geography; Gravity Model; Spatial Interaction Models**

Further Readings

- Birkin, M., Clarke, G., & Clarke, M. (2002). *Retail geography and intelligent network planning*. New York: Wiley.
- Brunn, S. (Ed.). (2006). *Wal-Mart world*. London: Routledge.
- Jones, K., & Simmons, J. (1990). *Location, location, location: Analyzing the retail environment*. Toronto, Ontario, Canada: Methuen.
- Krafft, M., & Mantrala, M. (2006). *Retailing in the 21st century: Current and future trends*. New York: Springer-Verlag.
- Longley, P., & Clarke, G. (1999). *GIS for business and service planning*. New York: Wiley.
- Wrigley, N., & Lowe, M. (2002). *Reading retail: A geographical perspective on retailing and consumption spaces*. London: Arnold.



RILL EROSION

Rill erosion is the process by which numerous sub-parallel and randomly occurring small channels are formed on slopes by running water. Usually, if channel cross sections are smaller than 900 cm² (square centimeters; 30 cm × 30 cm), they are called *erosion rills*. If they are bigger, they are called *erosion gullies*, and the erosion process associated with them is called *gully erosion*. Between the rills, the removal of soil is done by sheet (inter-rill) erosion, dominated by raindrop splash and sheet flow. Rill erosion is the most effective sub-process of soil erosion by water, contributing up to 80% of the total (rill + interrill) soil erosion.

Rills occur when overland flow starts to become concentrated. Overland flow with sufficient kinetic energy generates a shear stress that can detach soil particles. At locations where such detachment occurs, the soil's surface is lowered slightly. Such lowered areas form preferential paths for subsequent flow and, thus, will be eroded further. This process results in small, linear concentrations of flow known as "microrills" or "traces," with a width and depth of few millimeters. If they grow further, they become erosion rills. Rill networks tend to be dendritic in form on natural soil surfaces but are constrained by the directions of



Ephemeral gully erosion and severe rill erosion wash away young corn plants from the ground as well as the topsoil and the nutrients from loess soils in this Western Iowa field.

Source: Lynn Betts, USDA Natural Resources Conservation Service.

tillage on agricultural lands. Once rills form, their migration upslope occurs by retreat of the headcuts on the steep banks at the top of the channel. The rate of retreat is controlled by the cohesiveness of the soil, the height and angle of the headwall slope, and the discharge and velocity of the flow. Downslope extension of rills is controlled by the flow and the strength of the soil.

Rills are often associated with the “midslope,” as they may become enlarged on the lower part of the slope to give way to gullies. Therefore, the usual sequence of erosion processes downslope is rill and interrill erosion followed by gully erosion.

The density of rills depends on slope steepness and length, runoff rate, soil texture and erodibility of the soil, and the presence or absence of rainfall. On highly erodible soil, where the limiting factor

of erosion is transport capacity, rills have similar size along the slope and exhibit high densities. On less erodible soil, where erosion is detachment limited, the width of rills varies along the slope, and their density is lower.

Typically, rills present no obstacle to normal tillage operation and can be easily removed.

Matija Zorn

See also **Gully Erosion; Soil Erosion**

Further Readings

Brunton, D. A., & Bryan, R. B. (2000). Rill network development and sediment budgets. *Earth Surface Processes and Landforms*, 21(1), 35–47.



- Favis-Mortlock, D. (2004). Rill. In A. S. Goudie (Ed.), *Encyclopedia of geomorphology* (Vol. 2, pp. 852–853). London: Routledge.
- Morgan, R. P. C. (1995). *Soil erosion and conservation*. Harlow, UK: Longman.
- Nearing, M. A., Norton, L. D., Bulgakov, D. A., Larionov, G. A., West, L. T., & Dontsova, K. (1997). Hydraulics and erosion in erosion rills. *Water Resources Research*, 33(4), 865–876.



RISK ANALYSIS AND ASSESSMENT

Risk analysis consists of risk assessment and management. Risk assessment combines laboratory and field data with mathematical models, assumptions, and judgments to estimate the likelihood and consequences of human and ecological risks. Risk management uses legal, economic, political, communication, and other social instruments to reduce risk and help those affected to recover from harmful events.

Risk Assessment

Personal, indoor, and outdoor environments contain obvious hazards such as hurricanes, earthquakes, tsunamis, oil tankers, landfills, and industrial facilities and less apparent ones such as tobacco products, alcohol, drugs, contaminated food, stairs, and slippery sidewalks. Risk assessment is a set of formal processes to estimate the likelihood of danger associated with hazards. Typically, the process is divided into four steps: (1) hazard identification, (2) dose-response assessment, (3) exposure assessment, and (4) risk characterization.

Hazard Identification

Is a substance or activity a hazard? Information comes from laboratory experiments that use bacteria, mice, rats, and other specially bred species to test biological, chemical, or physical hazards and activities for their toxicity, mutagenicity, carcinogenicity, and other undesirable effects. Data

also come from observing the consequences of human exposures. Both laboratory tests and human studies are valuable, but there are instances where they have not worked. For example, the chemical diethylstilbestrol, developed to treat morning sickness in pregnant women, had been tested in laboratory animals, yet it caused birth defects in humans. Likewise, drawing inference from human observations is hindered by confounding factors, which make it difficult to separate the effects of different hazards. For example, diesel fumes are potentially carcinogenic, but human studies have found it difficult to separate the effects of diesel fumes from tobacco smoke and other occupation exposures.

Another complication is that some studies show that a substance is a hazard, but others do not. A recent widely publicized example is electromagnetic fields created around lines that carry electrical power across the landscape. Some studies show that electromagnetic fields can cause cancer. Others, including nearly all the recent ones, show no effect. Many hazard studies are inconclusive, especially if the substance or activity is a weak hazard, or a hazard for one animal but not for another.

Dose-Response Assessment

This second stage evaluates the amount of exposure that produces a harmful effect. Dose-response assessment is essential because harmful effects are detected at high doses. Most human carcinogens, for example, were detected in a workplace where employees were exposed for many years to high doses. Animal tests in laboratories are expensive, and hence, the number of animals tested may be limited; and the doses are high and enhanced by solvents that increase the chance of producing a cancer. If a chemical, biological, or physical agent is dangerous at high exposure levels, is the same agent dangerous at a low exposure? Risk assessors look for exposure levels where a substance is not a danger or for the so-called no observed adverse effect level, or NOAEL.

Thresholds are different for every chemical, biological, and physical agent. Many heated debates have occurred over which mathematical curves statisticians should use to estimate dose and



response. For example, the human body is able to repair cell damage caused by low-level exposure to radiation, which suggests that there is a threshold that produces no effect. In fact, some scientists believe that a small dose is beneficial (hormesis), triggering the immune system into an accelerated protective mode. But hormesis, which was shown to exist for food nutrients such as selenium and some other metals, is highly debatable in the case of radiation (also, e.g., cigarette smoke). Regulatory agencies assume that there is no threshold for radiation with regard to cancer; in other words, any exposure increases the probability of cancer. This is not the case for other outcomes (e.g., birth defects), which use threshold models.

Exposure Assessment

Exposure assessment evaluates how hazards reach and injure people and the environment. Sometimes, as in the case of vehicle crashes, the exposure pathway and the cause of damage are apparent (e.g., blunt force, explosion, fire, smoke). But the vast majority of hazards impose risk by more subtle pathways—by discharging hazardous substances into the air, land, and water. The process of learning how hazardous chemical, biological, and physical, agents move through these media is called “fate and transport.” Fate and transport may be simple; for example, if a worker spills a strong pesticide or solvent and then tries to wipe up the contamination without gloves, she or he may develop a skin rash.

Exposure pathways often are complicated. A hazardous discharge can vaporize into air and later fall to Earth at a different location; it can move through soil and rock and into underground water supplies, later to be consumed by someone who relies on her or his own well for drinking water. A massive spill or chronic discharge of pesticides or solvents can flow into a river, a lake, or a local aquifer, killing fish, birds, and other species. In addition, fish, birds, and other animals can drink water polluted by the spill or eat contaminated plants and animals, thereby introducing the contamination to the food chain. Assessing complex fate and transport pathways involves using mathematical models and applying assumptions about the concentration of the hazard, the direction of the emission, and the duration and

frequency of the exposure. The results of this part of exposure assessment are estimates of how much exposure takes place in different places and times.

The next part of exposure assessment is understanding how the hazard enters the body. This is accomplished by examining its properties in the environment and determining whether the exposure will be through the skin, inhalation, ingestion, or multiple routes. Route of exposure assessments are critical because some substances are much more dangerous through one route of exposure than through others. For example, mustard gas (a chemical warfare agent) can be harmful to the skin but can be fatal if inhaled, which is why gas masks are required for individuals who may come into contact with it.

Exposure assessments examine both short-term and long-term emissions. Short-term emissions, sometimes called acute episodic emissions, assume accidents, ruptures, failures, or other unexpected events. Long-term emissions, often called chronic emissions, assume routine discharges. Because there are literally an infinite number of exposure conditions, federal agencies specify the conditions for studying the hazard concentration, the frequency and duration of their discharge, and the type of exposure. This avoids markedly different risk estimates because of different assumptions. Notably, these specifications almost always are conservative—that is, they are protective of human health by assuming relatively high concentrations of hazard, high frequency of hazard, long duration of the hazard, and exposure entry points to the hazard that are the most serious.

Risk Characterization

The final stage of risk assessment involves integrating the results of the first three steps into an overall assessment. Critical to this final step is indicating the degree of scientific confidence in the data and tools and specifying the key uncertainties. Uncertainties are caused by lack of understanding, inadequate data, small size of experimental databases, using test species that are not representative of humans, and other variable experimental conditions. Typically, risk assessments will report the most probable results and at least one reasonable worst case one. The latter is



the worst possible case, which is likely to be implausible (e.g., a person living near an incinerator stack for 70 years). Overall, a good risk assessment should contain credible estimates of the likelihood of death, injury, or other losses associated with a hazard.

Risk Management

Risk management is the process of making choices about risks. Before describing risk management, it is important to note that risk assessment, while intended to be an entirely scientific endeavor, does contain embedded management decisions. As noted above, in the absence of credible information, agencies typically require conservative protective assumptions. Risk managers also take other nonhazard factors into account—most notably, economics, ethics, public reaction, and politics.

Economics

Many people believe that we should not put a value on human life. But courts often do and society through its political processes explicitly or at least implicitly does. Every risk-related decision produces economic winners and losers. Analysts use benefit-cost, cost-effectiveness, and other economic methods to evaluate economic consequences. For example, if a hazard is likely to produce 100 additional cases of cancer over a 10-year period and it costs \$1 billion to eliminate the risk, managers will doubtless debate if spending \$10 million per cancer case is an appropriate benefit. Economic tools range from those that estimate the value of an individual life to those that estimate the regional and national economic impacts of risk-related decisions. Benefit-cost analysis is a highly developed subfield of economics and risk analysis, with much debate about the assumptions, metrics, and models of each method.

Many current risk-related policy issues involve economic considerations, raising a variety of questions such as the following: Should the United States look for oil in environmentally sensitive areas? Should a new bridge or tunnel be built between New York and New Jersey? Should the United States ship used nuclear fuel to Yucca Mountain in Nevada, or should it remain at each nuclear power plant? These policies and

many others have important economic and risk consequences.

Ethics/Morality

Right and wrong, ethical and unethical, and moral and immoral are dichotomies routinely offered about risk management decisions. For some people, drilling in the Arctic wilderness is an immoral act; for others, it is a practical response to high oil prices. Some argue that nuclear power is a Faustian bargain that future generations will have to deal with, while others believe that it is a relatively safe approach to electricity generation and a better choice than fossil fuels. Some would preclude locating hazardous, unsightly, and odorous facilities in neighborhoods if the neighborhood is disproportionately occupied by minority and economically disadvantaged populations. The principle is that poor and disadvantaged minorities should not be disproportionately burdened with locally unwanted land uses and activities. Others would rely solely on “scientific” risk and environmental analyses to determine the location—that is, no location should be precluded unless there is an undue risk. Notably, many believe that the most important change in environmental policy in the United States during the past two decades has come about because of the environmental justice movement. Projects that otherwise would have ignored the demographic composition of the surrounding population now explicitly take that into account during the design and planning stages.

Also, many observers recognize an environmental ethic, which is a set of principles that urge people to live in harmony with Earth rather than attempt to conquer it. This ethic is now considered worthy of formal inclusion in public risk management debates rather than being dismissed as an idealistic irrelevance.

Public Reaction

Public perception of hazards can affect decisions. During the 1970s, the environmental impact assessment process and events began to alert U.S. residents to the impact of potential problems with deepening rivers, building dams and bridges, oil spills, power plants, factories, hazardous waste



sites, hurricanes, earthquakes, and many other human and natural events. We have learned that the public disproportionately fears hazards that they are unfamiliar with and hazards that can have catastrophic consequences. We also know that negative information is generally remembered longer and has a much greater impact on perception than positive information. This leads to the reality that the U.S. general public and most others are more concerned about nuclear power plants and waste management sites than about cigarette smoke, alcohol abuse, and driving without a seatbelt, irrespective of scientific data that show a much greater risk from the latter than from the former.

Politics

Risk management decisions are ultimately political decisions. Formally, the U.S. government—the state and local governments pass laws—and their departments use rules and regulations to manage risk. Government leaders issue executive orders to make decisions when laws and rules are not in place. The courts are drawn into disagreements about risk management decisions.

The formal decision-making process is paralyzed by an informal one. Decision makers understand and must deal with the reactions of elected officials who may control their budgets, industry, not-for-profits, the mass media, and other interest groups that have a stake in the decision. Elected officials want to know the likely public reaction to their decisions about energy technology, transportation, waste management, and many others. Public perception may not alter political decisions, but elected officials may attempt to communicate the reasons for their decisions to the public rather than risk the public's wrath.

A Risk Analysis Dilemma: Remediating Former Nuclear Weapons Sites

One of the most challenging issues that risk analysts have addressed involves remediation of sites where the United States developed, manufactured, and tested nuclear weapons and where waste products are stored. These massive sites (hundreds of square miles in area) are Hanford (Washington), Idaho National Laboratory,

Nevada Test Site, Oak Ridge (Tennessee), Los Alamos (New Mexico), and Savannah River (South Carolina). Some of the deserts, forests, prairies, and wetlands surrounding these large sites are contaminated with radioactive materials released from the facilities.

The question is how much remediation should be done at these sites. Because these locations are so far from urban areas, risk assessments show that they pose relatively little risk to human health, except perhaps for workers who would be injured during remediation. Yet radiation and sometimes chemical exposure to the animals and plants can be a risk. Should the U.S. Department of Energy (DOE) spend billions of dollars to remove contaminated materials? The DOE's position is that remediating these sites is legally required by agreements it made with state governments and other parties.

Almost 80% of DOE land on these sites is not contaminated, a good deal of which is protected for research, preservation, or recreational use and by prohibition of public access since the sites were opened in the late 1940s or early 1950s. Some of these DOE lands are the ecological jewels of these regions.

If the DOE remediates the contaminated land to remove any residual human and ecological radiological and chemical hazards, it is likely to cause irreparable damage to these ecosystems. Contamination can be reduced by removing the soil. This also requires roads to carry the contaminated soil to a resting place, which is almost surely going to be on the same site. Such remediation, many risk analysts believe, will likely injure animal and plant populations more than the existing radiation. The remediation will destroy intact ecosystems that will not recover because of the degree of soil or other loss. Remediation could be so harmful, for example, that it would destroy the indigenous seed bank and allow external invasive species to move in, eliminating native species. Also, the disruption will cause animals and other species to move out of the area and into adjacent inhabited areas in order to escape remediation. The risks imposed by some of the legacy radioactive elements will slowly decrease if there is no new contaminant release, because radioactive substances decay over time. (For some, with long half-lives, there will be no appreciable decrease for centuries.)



Finally, remediation has the potential to reintroduce presently controlled contaminants into the environment because of the disruption and exposure of plants, soils, sediments, and underground and surface water supplies. For ecosystems, the best approach is to leave the contaminants where they are, except where there are clear risks because of a radiological or chemical hot spot. If necessary, remediation should be done with as few new roads and other disruptions as possible. In short, the greatest risk to an ecosystem is from the actual physical disruption that destroys the ecosystems themselves rather than the residual radiation and chemical contamination. The dilemma is that the federal government is required by legal agreement to remediate these sites. The risk analysis suggests reconsideration.

Conclusion

Risk assessment and management are not new ideas. Every day, each of us takes small, medium, and sometimes big risks. Many of us eat foods that raise our cholesterol, are outside when lightning strikes, smoke cigarettes, and in other ways engage in activities that increase our risks. Most people are willing to take risks that they control and assume voluntarily. A good skier believes that she or he controls a downhill run and assumes the risk of injury because she or he enjoys skiing. For others, the idea of strapping on sticks and going down a steep hill at 6 a.m. is an unacceptable risk.

From a society perspective, new products and activities are being created, and old products and activities are reaching new customers, placing more people at risk. Our ability to detect hazards has dramatically increased during the past two decades, and so when there is a hazard in the environment, we are more likely to know about it. And we are more likely to care about it because the deadly risks of a century ago that kept the average lifespan below 60 years largely have been controlled, allowing more focus on a new set of hazards. We need risk assessment and management to provide information to decision makers who are the stewards of our limited resources to protect public health and environment. Risk analysis is not a panacea for decision makers, but it has helped them make better decisions.

Geographers have been involved at all levels of risk analysis process. Many work on risks and environmental assessments for the government and private organizations. Others have become leaders in the Society of Risk Analysis, a multidisciplinary international organization.

Michael R. Greenberg

See also **Biotechnology and Ecological Risk; Carcinogens; Cost-Benefit Analysis; Disease, Geography of; Ecological Risk Analysis; Environmental Ethics; Environmental Impact Assessment; Environmental Justice; GIS in Health Research and Health Care; Locally Unwanted Land Uses (LULUs); Medical Geography; Natural Hazards and Risk Analysis; Nuclear Energy; Vulnerability, Risks, and Hazards**

Further Readings

- Bouder, F., Slavin, D., & Lofstedt, R. (2007). *The tolerability of risk: A new framework for risk management*. London: Earthscan.
- Greenberg, M. (2008). *Environmental planning, policy and practice*. New Brunswick, NJ: Rutgers University Press.
- Lipmann, M., Cohen, B., & Schlesinger, R. (2003). *Environmental health science*. New York: Oxford University Press.
- Moeller, D. (2005). *Environmental health* (3rd ed.). Cambridge, MA: Harvard University Press.
- Risk Analysis*. (1981–present). Retrieved December 10, 2009, from www.wiley.com/bw/journal.asp?ref=0272-4332
- Robson, M., & Toscano, W. (Eds.). (2007). *Risk assessment for environmental health*. San Francisco: Jossey-Bass.
- Siegrist, M., Earle, T., & Gutscher, H. (Eds.). (2007). *Trust in cooperative risks management: Uncertainty and skepticism in the public mind*. London: Earthscan.



RITTER, CARL (1779–1859)

One of the great intellectual giants of 19th-century geography, Carl Ritter was an influential professor in Frankfurt and Berlin. He is often described as one of the two principal founders of



modern geography, compared with his contemporary, Alexander von Humboldt.

Son of a doctor, Ritter became from 1798 to 1814 a tutor for the children of Bethmann Hollweg, a wealthy local banker who financed his university education. In school, he studied botany, art, theology, philosophy, and history, and he taught himself Greek and Latin. His first geographical publication appeared in 1804, and by 1816, he had acquired a reputation as a geographer. After a year as professor of history in Frankfurt, he moved to the University of Berlin as a professor of geography, occupying the first German university chair in that discipline. He became deeply interested in Africa and was a militant abolitionist and opponent of racism. He became a member of the Prussian Academy of Sciences, and in 1828, he founded the Berlin Geographical Society. His early works included textbooks about the geography of Europe.

Ritter, who did not travel much and never outside Europe, is most well-known for his massive 19-volume magnum opus, *Die Erdkunde im Verhältniss zur Natur und zur Geschichte des Menschen* [*The Science of the Earth in Relation to Nature and the History of Humanity*], consisting of more than 20,000 pages, which he wrote between 1817 and 1859 (and never completed). It concerns only Africa and Asia and dwells on the relations between humans and the biophysical environment. The work became enormously successful and helped move geography beyond the study of maps to include the various ways in which people responded to the world's varying climates and ecologies.

Ritter viewed the world's regions through the conceptual lens of religious teleology, seeing in the world's geography evidence of divine purpose. The Earth, he held consistently, was designed by God for people and could only meaningfully be viewed in this way. In this respect, he differed greatly from the more secular and scientific Humboldt. Ritter's focus lay primarily on human geography rather than the natural environment. He attempted an ambitious comparison and synthesis of enormous amounts of data through a regional approach at a continental level, contrasting the Northern and Southern Hemispheres as well as the New World and the Old World. Geography's purpose, he held, was to detect the whole character of places—to

identify unity within diversity. Disdaining simple lists of facts, Ritter advocated comparative local studies through which broader generalizations could be made. However, his approach was purely inductive, and he distrusted deduction as a matter of principle; in this respect, his ideas resembled the chorology of Richard Hartshorne, who, not surprisingly, admired Ritter greatly. His view tended toward an organic theory of the state, which was becoming popular in emerging geopolitical conceptions of the world.

Ritter was a highly popular teacher. His students included Élisée Reclus and Arnold Guyot, and he heavily influenced Friedrich Ratzel and Alfred Hettner. He died in 1859, the same year as von Humboldt.

Barney Warf

See also **Chorology**; **Human Geography**, **History of**; **Humboldt, Alexander von**; **Regional Geography**

Further Readings

- Beck, H. (1979). *Carl Ritter, genius of geography: On his life and work* (K. Hamnett, Trans.). Bonn, Germany: Inter Nationes.
- Kramer, F. (1959). A note on Carl Ritter. *Geographical Review*, 49, 406–409.



RIVERS

A river is a physical landform that conducts (primarily fresh) water, sediment, and nutrients downslope under gravity from topographically higher land toward depressions at a lower elevation, most often into bodies of water. The total volume of water in the global hydrosphere that can be found in rivers is miniscule (0.0001%), yet rivers are a key part of the hydrologic cycle, conducting water delivered to the landscape via precipitation, springs (groundwater), or glacial meltwater to oceanic environments. The river channel, or depression of varying width and depth, contains water at least sporadically, if not constantly, depending on its geography. A river's physical character is a direct result of its local



climatic and geologic conditions, which may vary with distance along its course. As both erosional and depositional agents, rivers are highly dynamic and adjust their forms over time as a response to the active processes that influence them. Rivers are recognized as one of the most influential physical forces on Earth, each year reworking about 19 trillion tons of suspended and dissolved solids. Rivers are responsible for shaping a majority of continental and coastal landscape features and provide unique ecosystem environments that foster the development of biological diversity rivaling that of both rain forests and oceans.

Most rivers across the globe have been diverted, dammed, or drained as a result of human activity. Rivers are also a hazard to the global population, with floods destroying human infrastructure and taking thousands of lives each year. With the effects of global climate change beginning to unfold, rivers are responding in concert. Flow regimes are changing to reflect both human influences and climatic shifts. Changes in flow cause geomorphic responses such as aggradation or degradation of the channel bed, reduced interactions between the river and its floodplain, and altered floral and faunal cues that affect the health of riparian ecosystems. This entry outlines the fundamentals of river science, including river geography, the impact of geology and climate on rivers, drainage networks within watersheds, and river processes and the resulting landforms (fluvial geomorphology). It then examines both the impacts of rivers on humans and the impacts of humans on rivers.

River Geography

Rivers can be found on every continent and in every climatic region. Variations in their latitude, altitude, and physiography combine to create characteristics unique to each system. Within each drainage basin, a river's makeup will change as it flows through varying topography, geology, and climate; thus, a river's headwaters will likely bear no resemblance to its mouth. The surface area of land that a river drains is called a drainage, or catchment basin. These land areas, also termed *watersheds*, are divided by rises in topography at their outer boundaries. As a river grows in size via the addition of tributaries to the

network, so does its drainage area. The largest rivers drain continental interiors and create depositional landforms, called deltas, at their mouths. Deltas are accumulations of sediment that over time form specific patterns depending on their sediment supply and the local oceanic currents.

The largest river on Earth in total length is the Nile (Africa), while the largest in total discharge is the Amazon. The Amazon is also the longest river in South America. Globally, the longest rivers on each continent are the Mississippi (North America), the Yangtze (Asia), the Darling (Australia), the Onyx (Antarctica), and the Volga (Europe).

River Formation Variables: Geology and Climate

A river's physical expression is the result of in situ landscape conditions and its response to local climatic events. Geology and climate are two defining factors in the geomorphology of a river.

Geology determines slope of the channel and sediment size and distribution; floodplain size and shape; and the groundwater/surface water relationship. As a river flows through its drainage basin, the local geology may change, and as a result, the physical characteristics of the stream adjust as well.

Climate provides the amount of water delivered to the channel via overland flow processes and is a major factor in determining the volume of flow. A river is formed when the subsurface is saturated to such a degree that no greater amount of water can be absorbed, and thus, the water begins to run across the surface. Rivers are categorized by the frequency of water presence in their channels: Perennial channels contain water virtually year-round, ephemeral channels contain water only periodically (mainly after a precipitation event), while intermittent channels are climatically driven and, typically, flow only during wet seasons.

Drainage Networks

Drainage networks are formed when streams of increasing size converge and form a pattern. River nomenclature is not universally defined, where the terms *stream* and *river* are often used interchangeably. Typically, a stream is smaller in



The Amazon River flowing through the Amazon rain forest. The Amazon is also the longest river in South America.

Source: Screenshot from NASA's globe software World Wind.

width, depth, and discharge than a river, but not always. Rivers create drainage patterns that are identifiable from above. These patterns are typically referred to as a river's planform, or planimetric geometry, and take on distinct shapes depending primarily on their underlying geology. Drainage networks can be categorized as dendritic, radial, trellis, or rectangular.

As a stream network begins to form, it drains the landscape in the most efficient way; hillslopes converge and dissect the land in a branching pattern; hence, the root of the word is from the Greek *dendro*, for "tree." Dendritic networks are the most common type and are scale independent. They are self-similar in nature, meaning that regardless of the scale of observation (stream size)

the drainage pattern when viewed from above does not change. Other drainage patterns are more geologically controlled, as the underlying rock structure plays a dominant role in the surficial expression of the stream network. A radial drainage pattern is typically found in an environment where a landform feature creates a cone-shaped structure, like a volcano, and the resulting drainage pattern looks very much like the spokes of a wheel. Trellis drainage is common in mountainous areas where ridge and valley geology dominates, and the rivers create a network of flow that parallels the mountain's ridges. Rectangular networks are structurally controlled by the underlying bedrock. Streams follow faults or bedding planes in the rock beneath the surface, as



these are areas of weakness that steer flow directionality and cause the rivers to make abrupt changes in flow direction (sometimes 90° turns) that are only possible in natural environments under such conditions.

River Processes and Forms

Processes

Dynamic Equilibrium

A river's energy and physical matter are in a state of constant flux. Rivers seek balance between dependent (sediment load and discharge) and independent (climate and geology) variables. Termed *equilibrium*, this self-regulation is the catalyst for river form adjustment. When one variable changes, the river adjusts and will continue to do so until it again reaches a stable form. For example, below a dam a river will attempt to balance its reduced sediment load and modified downstream discharge regime by entraining sediment and thus degrading the channel bed.

Flow Mechanics and Regime Factors

Channel cross-sectional area is determined by measuring the channel's width and depth at a particular location along its reach. A river's cross-sectional area, however, is not descriptive enough to determine the characteristics of the channel. Two rivers of vastly different widths and depths can have the same cross-sectional area. The amount of friction that water creates at the river's bed and banks, instead, is a function of its cross-sectional shape and is represented by a width-depth ratio. Channel bed and bank configuration determines the amount of available energy, called velocity, and the amount of friction generated at the riverbed by the volume of water above it. Velocity, or the rate at which water flows at a particular point in time at a specific location along its course, is directly related to the width-depth ratio: Bed and bank contact creates frictional drag and slows water, and thus, velocities are greatest where this frictional drag is least. Water velocity is directly related to several factors, including the channel gradient (slope), channel size and shape, bed and bank roughness, and discharge.

Discharge is the amount of water that is flowing in a river at a given place and time and is measured as a volumetric rate (cubic feet per second or cubic meters per second). The amount of discharge is calculated at a particular place and time by multiplying the channel cross-sectional area (channel width by channel depth) by the water velocity. Discharge is directly proportional to the size of the watershed upstream that is being drained. As watersheds increase in size in the downstream direction, so does the river width, depth, velocity, and discharge. River discharge varies with distance along its course, fluctuating both diurnally and seasonally, and is highly responsive to localized precipitation events; snowmelt in mountainous regions sends volumes of frothing water and sediment downstream each spring, while regional climatic events, such as monsoons, can cause massive flooding in low-lying areas.

A river's flow regime can be described through the following metrics: frequency, duration, timing, magnitude, and rate of change of flow. Determining a stream flow rate is achieved by measuring the stage or discharge at a particular location on a stream, at a given time. In 1889, the U.S. Geological Survey established the first stream-gauging station on the Rio Grande River to measure the daily stream discharge. The program blossomed into a national network, which in 2007 included about 7,500 stations, with more than 150 million "at-a-station" daily discharge values recorded since the program's inception. Due to the massive volume of data over an extended time period, this resource is invaluable for completing change detection in the hydrologic regimes of rivers. The number of stream-gauging stations has fluctuated throughout the past century, depending on national need or budgetary conditions. Now, other nations throughout the globe have begun concerted efforts to gauge rivers and create data sets useful for determining long-term trends and the effects of global climate change.

River science reveals the complex relationships between system variables. A river's suspended sediment load, width, depth, and velocity are all directly related to its discharge. As a river network increases in size in the downstream direction, its stream order increases, as does the number of streams, the mean stream length, and the mean drainage area.



Sediment Transport and Deposition

A river's slope and velocity determines how much sediment it can pick up and entrain (carry) downstream. Sediment in transport is called a load and can be subdivided into three categories:

1. Dissolved load is sediment in solution.
2. Suspended load is sediment carried in the water column.
3. Bed load is the sediment that saltates or skips along the bottom of the channel.

Dissolved load is most often introduced via groundwater contributions to river flow, where the rocks that it flows through leach minerals into the water. Suspended load has been picked up and carried downstream after enough friction has been generated at the riverbed to do so: Entrainment depends on the material type and the river velocity as clay particles are easily transported once entrained and only settle in placid environments, while sand particles are more easily entrained but settle more quickly as velocities are reduced.

Forms

Bed and Bank Configurations

River forms are the physical result of local geomorphic processes at work. Bed, bank, and channel pattern adjustments occur in response to system disturbance. Bed and bank configurations are unique to the volume of discharge and sediment generated by the upstream watershed, riparian vegetation, material composition, and channel slope. Due to these dynamic factors involved in river formation, river beds almost always undulate and are rarely flat. As a result of varying velocities on the bed and banks, different forms result. The primary material composition that makes up the bed also plays a defining role in channel characteristics; bedrock, silt clay, sand, gravel, and boulder beds generate considerably different fluvial geomorphologies.

Channel Slope and the Longitudinal Profile

A river flows downslope from its headwaters to its mouth and terminates at either a lake or an

ocean (baselevel). Gradient is usually steepest at the headwaters and flattens out with river distance. Elevation change that occurs along its entire course can be graphically represented in a longitudinal profile and typically follows a concave-shaped curve.

Channel Patterns

Horizontal adjustments counteract changes in the longitudinal direction and cause specific channel patterns. Planimetric geometry is the result of several forces at work on the channel: sediment size and sediment load (bed and bank erodibility) and channel slope and river discharge (stream power). In nature, a straight channel is an anomaly. Straight channels are most often the result of structural (geologic) controls over a short distance or channel engineering by humans. Thousands of miles of naturally meandering rivers have been straightened and channelized for navigation or other purposes.

Because the determinants of channel pattern are directly related to continuously changing variables in the longitudinal direction, selecting a pattern for a particular channel reach must be done on a continuum, where the threshold separating meandering and braided channel patterns may vary with system geography. Rivers tend to initiate migration from side to side within their floodplain as a function of in situ flow and sediment interactions. These migrations, called meanders, vary in their number and geometry depending on the river system of study. Sinuosity, or the amount of meandering within a defined river distance, is calculated by dividing channel length by straight-line valley length. Meandering channels are most common in nature. When a river meanders, water velocity and erosive power are focused toward the outside of the meander bend, creating cut banks and causing the meanders to migrate downstream and change shape over time. On the inside of the meander bends, velocity is reduced and sediment settles to create in-channel forms such as midchannel bars and point bars.

Braided channels occur in environments where sediment load exceeds the river's carrying capacity. Braided rivers have many subchannels that are interwoven between unvegetated bars of sediment that are constantly being mobilized and redistributed. Braided rivers are most commonly



found in environments where there are easily eroded channel banks, excessive bed loads, highly variable discharge, and steep valley slopes, such as in glacial outwash plains.

Impacts of Rivers on Humans

Humans have used rivers for public water supplies, food sources, waste disposal, energy creation for mechanization and electricity, and recreational and aesthetic opportunities; as modes of travel and transportation; and as accesses for military conquests and barriers for defense. Rivers provide religious, social, and economic benefits and also have political roles, serving as borders between all levels of political jurisdiction. Rivers, through human modification and the development of irrigation systems, have allowed for settlement in arid environments previously unsuitable for habitation. For example, the fertile crescent of the Tigris and the Euphrates rivers in modern-day Iraq is deemed the birthplace of civilization, made possible only through the presence of these important rivers. Egypt's Nile River also provided an oasis for human habitation, with its seasonal flooding delivering vital nutrients to the farmed floodplains, allowing for the rise of one of the most advanced societies in human history. Despite these widespread benefits, rivers also pose a hazard for human populations that live within their floodplains. Floods caused by climatic events or dam failure have the potential to cause catastrophic damage to human-made infrastructure and to take countless human lives.

Impacts of Humans on Rivers

Humans have been modifying rivers since prehistoric times. In modern times, humans have had significant impacts on river systems, where in countless cases such as the Los Angeles River of California in the United States, the channel no longer resembles a river but a storm water conduit. In many watersheds, such as the Los Angeles example, water diversion from the river channel along its course results in a complete dewatering in its lower reaches. Most damaging has been the widespread effects of dams. River regimes are substantially different from natural flows. Flooding

is suppressed from downstream environments, and floral and faunal species can no longer depend on seasonal flooding events to act as reproductive cues. Sediment now stored behind dams fails to reach river mouths, build deltas, and nourish beaches. Dams block fish passage to spawning grounds and have led to the deterioration of entire species and the economies they support, such as the salmon industry of the Pacific Northwest in the United States.

Pollution generated by human activities has also been detrimental to riverine environments. Many rivers in the developing world act as a means for waste disposal, and untreated human waste and garbage flows freely to oceans. In the past four decades, the developed world has begun to pass laws to protect rivers from these activities. The Clean Water Act of 1972 began to regulate point and nonpoint source pollution in the United States from the perspective of discharges to rivers. The negotiation of international water laws is in its infancy, however, and will become increasingly necessary in the future due to the shared nature of river resources between nations and the pressure placed on them due to increasing populations and the effects of global climate change.

Tara M. Plewa

See also Floodplain; Floods; Flow; Geomorphology; Groundwater; Hydrology; Surface Water; Urban Water Supply; Water Needs; Water Pollution; Watershed Management; Watershed Yield

Further Readings

- Benke, A. C., & Cushing, C. E. (Eds.). (2005). *Rivers of North America*. Amsterdam: Elsevier Academic Press.
- Bloom, A. L. (1998). *Geomorphology: A systematic analysis of cenozoic landforms*. Upper Saddle River, NJ: Prentice Hall.
- Bridge, J. S. (2003). *Rivers and floodplains*. Oxford, UK: Blackwell Science.
- Graf, W. L. (1988). *Fluvial processes in dryland rivers*. Berlin, Germany: Springer-Verlag.
- Knighton, D. (1998). *Fluvial forms and processes*. New York: Oxford University Press.



- Tarback, E. J., & Lutgens, F. K. (1996). *Earth: An introduction to physical geography* (5th ed.). Upper Saddle River, NJ: Prentice Hall.
- Wahl, K. L., Thomas, W. O., Jr., & Hirsch, R. M. (1995). *Stream-gaging program of the U.S. Geological Survey* (U.S. Geological Survey Circular 1123). Reston, VA: U.S. Geological Survey.
- Wohl, E. E. (2004). *Disconnected rivers: Linking rivers to landscapes*. New Haven, CT: Yale University Press.



ROCK WEATHERING

Weathering is the in situ alteration, by disintegration or decomposition, of rocks and minerals. By weathering, rocks and minerals reach a new equilibrium (chemical, pressure, and/or thermal) with the surface environment. Disintegration refers to the in situ mechanical production of smaller particles without chemical change, while decomposition refers to chemical alteration that results in both smaller particles as well as dissolved ions. Mechanical and chemical weathering are convenient subdivisions for discussion, though it is understood that the mechanical and chemical weathering processes are symbiotic and often inseparable.

Weathering is of vital importance to numerous Earth systems (and is therefore a subject for transdisciplinary study). Weathering is one of several geomorphic processes, as weathering alone or in conjunction with other geomorphic processes is responsible for creating and modifying landforms. In petrology, weathering is a key function of the rock cycle, in which all the major rock types exposed on Earth's surface are ultimately vulnerable to weathering. Sediments, and sedimentary rock, could not exist without weathering first, and weathering is a primary means of recycling Earth materials. Soil is another feature that directly depends on weathering, as the mineral proportion of soil derives entirely from weathering by-products. Last, and of recent scientific attention, weathering is seen as an important function of biogeochemical cycles, as weathering is one of the true interfaces between all of Earth's

geosystems (land, water, air, and life). Weathering plays a role in liberating or sequestering elements and in transferring these elements between biota, air, and water.

Types of Weathering

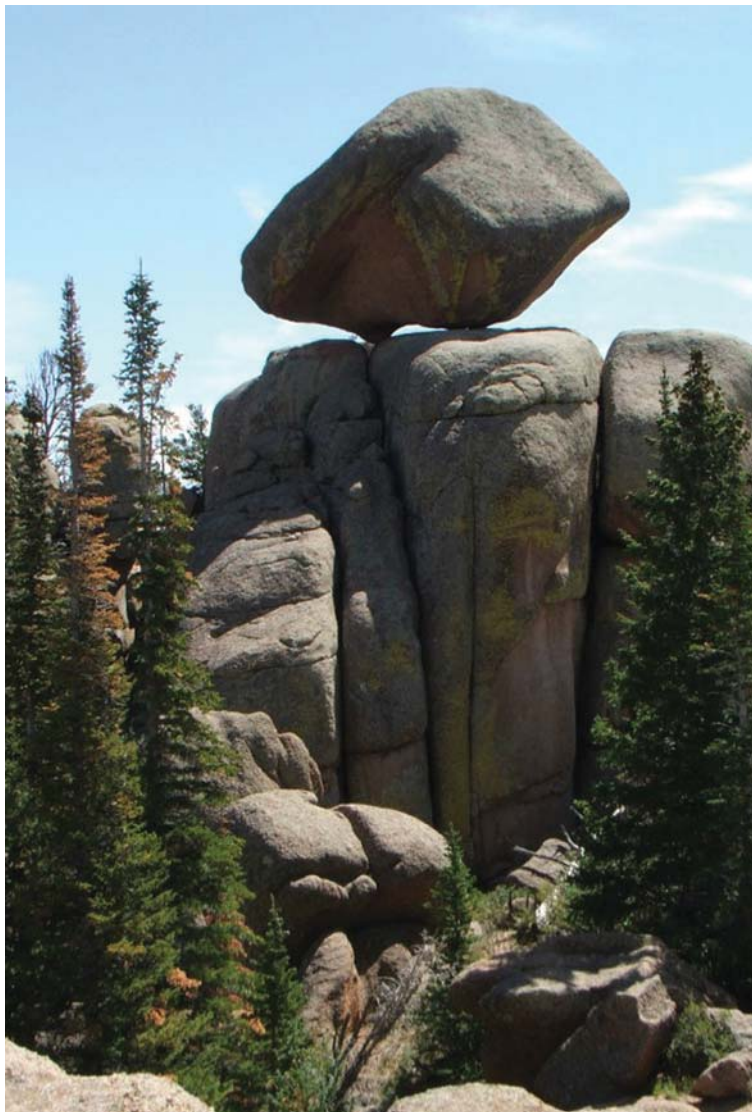
Mechanical Weathering

Mechanical weathering involves physical forces (compressive, tensile, and shear) that cause rocks and minerals to fracture (i.e., exceed the limit of plastic deformation). A number of physical forces are present in terrestrial environments.

Cryostatic pressure involves the compressive stress due to the expansion of water ice. Sometimes referred to in many writings as "frost" weathering, the process is not limited to the presence of frost crystals. Water ice is unique in its tendency to expand on the change of state from liquid to solid. Typically, liquid water works into the voids of existing rock weaknesses such as cracks, sutures, bedding, voids, or mineral or grain boundaries. In the confined spaces of the rock weakness, ice crystal growth exerts considerable pressure, forcing the rock or mineral apart. As the rock weakness void grows, confined pressures decrease, and the ability to continue cryostatic weathering decreases. Intense or prolonged stress will eventually completely separate the fragments. The products of cryostatic weathering are angular rock fragments, frequently observed in alpine, subarctic, and arctic regions.

Cryostatic pressures can be emphasized in environments with diurnal freeze-thaw cycles, in which ice crystal growth, melting, and regrowth allow repeated physical force. Freeze-thaw cycles are expected in temperate or midlatitude climates, though in polar areas rock surfaces exposed to sunlight can reach above-freezing temperatures even in winter. Cryostatic weathering is suspected on Mars in locations where water is or has been present.

Like ice, *expansion and growth of other crystals* in confined spaces also exerts compressive pressure to cause or enlarge fractures. Iron minerals, calcite, and expansive clays are examples of crystal growth weathering. However, salt (any of the alkaline minerals, including NaCl) is the chief and most common example cited and observed. Salt can enter the



A tor, near Crow Creek, southeastern Wyoming. Existing joints are widened by mechanical weathering such as ice, while chemical weathering results in disintegration and rounding. Lichens growing on much of the rock surface enhance chemical weathering. Erosion of weathered material leaves the spectacular remnant boulders.

Source: Courtesy of Jeffrey Pope.

rock or mineral by way of solution in water. As water evaporates, the salt is left behind and will expand as it crystallizes. Similar to ice, salt weathering will produce angular shards of by-product rock. Salt weathering is prevalent in arid and semiarid climates, where rapid evaporation is more apt to leave salt precipitates within the surface rocks rather than flushed by solution into deeper soil or groundwater. Salt weathering may be prevalent in polar

deserts, where lack of liquid precipitation allows salts to accumulate at or near the surface. Thus, what is often assumed to be ice weathering may in fact be attributed to salt. Salt weathering is also seen in coastal areas, where sprays from waves can move inland up to several kilometers by way of atmospheric transport. Stone conservationists have noted salt weathering on building stones. Salt sources in urban areas include atmospheric aerosols, streets and sidewalks, and mortars.

Hydrostatic pressure is exerted by thin water films in small pores and fractures. Almost always present even in dry environments, hydrostatic pressure may be responsible for prying apart microfractures in rock. Water microfilms can exist in the presence of subfreezing temperatures, such that liquid water may in fact be responsible for some of the weathering attributed to ice.

Rapid or extreme temperature changes are believed to create variations in the volume of rocks or minerals themselves. Rock expansion due to heating and rock contraction due to cooling may therefore exert compressive and tensile forces, respectively. There is some debate as to how much plastic deformation a rock will tolerate before fracture, thus a debate about how important temperature changes can be toward weathering. Still, most experts would agree that temperature changes have at least some impact. The critical factor pertains to diurnal temperature change. Diurnal ranges of 40 °C per day are not uncommon in deserts, while surface changes of 20 °C per hour are possible in temperate

continental climates. *Thermal* weathering is a term applied to environments of extreme heat, for instance, on dark rocks in tropical deserts or in proximity to fires. *Cryogenic* weathering pertains to environments of extreme cold.

Pressure unloading involves a volume adjustment of rocks formerly under considerable mass and pressure. Most rocks (apart from surface-cemented or solidified volcanic rock) are produced



deep in the crust under immense pressures. When erosion exposes these rocks to the surface, the atmosphere exerts pressure at $\sim 1/1,000,000$ th that of the crustal interior. Rock will then expand somewhat plastically to a point where a brittle fracture occurs. Unloading fractures tend to occur just below the rock surface and parallel or concentric to the surface. Slabs of rock millimeters to meters in thickness spall off (often aided by gravity and water). Landforms resulting from pressure unloading often appear dome shaped (e.g., Half Dome in Yosemite, Sugarloaf in Rio de Janeiro), with “onion” layers of slabs yet to fall.

Biomechanical processes of plant roots and animals are specialized weathering agents. A common image of tree roots attached to rock crevasses suggests the tenacity of plants and their ability to fragment rock. In reality, roots take advantage of preexisting fissures, and the physical pressure of root growth has been shown to be negligible except in soft and fragile rocks. Fine roots are known to expand and contract due to variable moisture content, and this may be a factor in mechanical weathering at smaller scales. Most likely, the very active chemical environment of roots contributes a synergistic weathering environment.

There are a few instances of weathering by animals. A species of desert-dwelling snails consume endolithic lichens and, in so doing, also consume parts of the rock substrate at appreciable rates. Species of bivalve mollusks are known to bore small holes into rock by a combination of chemical excretions and physical consumption of the mineral material. Other rock- and soil-dwelling animals (earthworms, insects, etc.) may similarly attack rocks by a combination of mechanical or chemical means, though the subject is poorly researched.

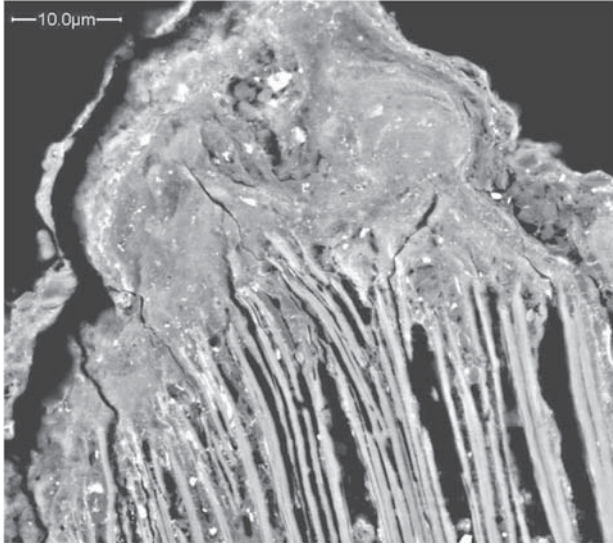
Chemical Weathering

Chemical weathering involves the decomposition of rocks and minerals at the elemental or molecular level by means of chemical reaction with exogenic weathering agents. Rather than attacking structural weaknesses as mechanical weathering does, chemical agents attack weak molecular bonds, removing elements to solution, consequently weakening the mineral and rock

fabric. Chemical weathering therefore removes material in the form of ions and promotes further decomposition of rock by means of granular disintegration (between crystals or particles).

Solution, or congruent dissolution, is the simplest form of chemical weathering. It involves water in the complete solution of the mineral into aqueous ions without precipitation of secondary minerals in the solution process. Water is all that is necessary for solution weathering, though acids and organic chelates can greatly enhance the solution potential. Calcium carbonate (calcite), calcium sulfate (gypsum), and silica (quartz) are examples of minerals that are subject to solution weathering. Of these, quartz is the least soluble by several orders of magnitude—a testament to its resistance, though not permanence, in the terrestrial environment.

Hydrolysis or incongruent dissolution is sometimes referred to as complexing, and rightly so. The complete process takes place in several steps with intermediate by-products and precipitates. Hydrolysis refers to the H^+ ion available in aqueous acids, carbonic acid being common in the terrestrial environment by way of naturally acidic rain, though organic acids are also important in soils and surface water, and sulfuric acid can be present near hydrothermal areas and in the presence of old mines (“acid mine drainage”). Polluted air in industrial and urban areas may contain both sulfuric and nitric acids, and acid precipitation may drift by prevailing winds into pristine regions. The weathering of aluminosilicate minerals (such as feldspars and micas), the most common in Earth’s crust, is most apt to be from hydrolysis. The process yields dissolved cations (such as potassium, sodium, and calcium), silicic acid, silica precipitates, and clay minerals (such as kaolinite, illite, and smectite). High-resolution electron microscopy of minerals attacked by acid reveal incipient molecule-sized etch pits, while more extensive weathering results in a skeletal lattice of remnant mineral (see photomicrograph image). An ultimate residual of aluminosilicate hydrolysis is aluminum oxide, Al_2O_3 , a stable mineral known as bauxite that is highly resistant to further weathering. Both bauxite and kaolinite are valuable economic minerals, the former for aluminum metal and the latter for a variety of ceramic, paper, and medicinal materials.



Photomicrograph, from backscatter scanning electron microscope, of a weathered biotite mineral, illustrating microscale chemical weathering. Hydrolysis dissolves and opens the crystal layers, while silica and dissolved rock varnish are seen infiltrating as precipitates near the mineral surface.

Source: Photomicrograph courtesy of Dr. Ronald Dorn, Arizona State University.

Hydration is a relatively simple absorption of water molecules into the mineral, which disrupts the crystalline structure (and creates a new mineral). Hydration causes an increase in volume and mechanical pressure. Hydrated micas are partially responsible for granular disintegration of coarse-grained igneous and metamorphic rocks. Hydrated shrink-swell clays achieve similar stresses. Amorphous glass (e.g., silica glazes and obsidian) can also hydrate and decompose. *Dehydration* is the removal of water molecules under hyperaridity or high temperatures (such as extreme wildfires). Dehydration leads to a collapse of the mineral structure and a decrease in volume.

Oxidation is a chemical process by which mineral ions are lost due to the introduction of an oxygen ion in the presence of water. Iron is the most common subject of oxidation, and iron-bearing minerals such as the amphiboles, pyroxenes, olivine, and biotite are vulnerable. Removal of Fe^{2+} (ferrous iron) combines with the oxygen

ion to form Fe^{3+} (ferric iron), a much less soluble ion that precipitates easily. Resultant by-products of the reaction include hydrous and oxidized minerals of iron such as hematite, limonite, and goethite. Rocks containing iron-bearing minerals first exhibit reddish or brown halos around the minerals, while more complete oxidation can tint the entire rock (see rock weathering photo). Oxidized iron-rich cements account for the red color in many sandstones, and iron mineral residua is responsible for rubification in soils.

Chelation is a complex chemical process by which metallic ions are selectively removed in the presence of organic substances. Large organic acid molecules (such as ethylene diamine tetraacetic acid [EDTA] and amino acids) are examples of chelating agents and, unlike hydrolysis reactions, attach to the metallic ions through numerous (rather than single) bonds. Chelates, by way of decomposed organic material or within the roots of plants, aid in the release of nutrients to plants. Lichens are thought to have strong chelating agents, one factor that allows these pioneering symbiotic plants to use bare rock for sustenance. Lichens are responsible for the creation of incipient soils and soluble ions in environments that are lacking in other chemical weathering agents.

The Geography of Weathering and Weathering Factors

The extent and intensity of rock weathering is moderated by a number of factors (Figure 1). Many of these factors are highly geographic in nature; hence, weathering has a real variability from small to large scales.

Time, Scale, and the Geomorphic System

Weathering is among the slowest of geomorphic processes; considerable time elapses before significant modifications to the landscape occurs. Weathering over a given time produces a weathering rate. Rates of weathering vary considerably due to the availability of weathering agents, nature of the parent material, and environmental parameters, most relevant at small scales. Weathering is generally not a straight-line and constant process over time but more usually a decaying

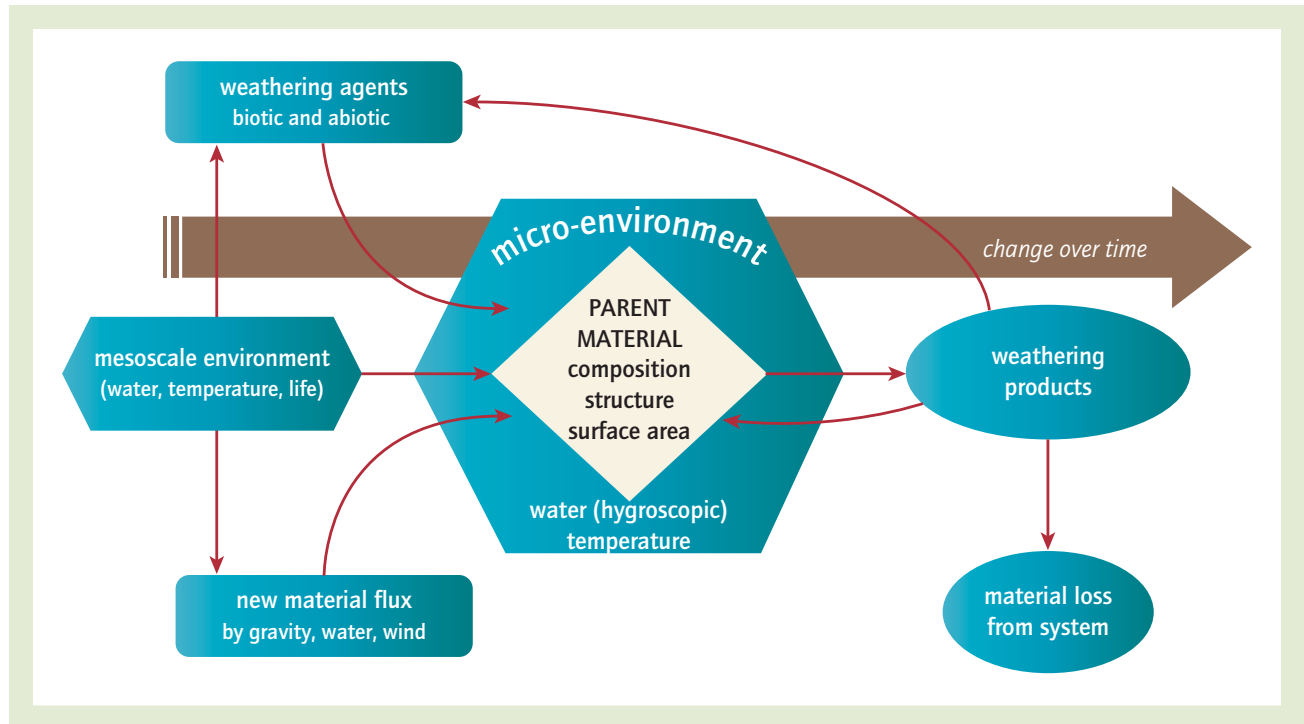


Figure 1 Relationships of environmental and microscale factors relevant to the weathering system

Source: Author.

rate over time until reaching an equilibrium state, consistent with any chemical and physical reaction. There are some instances where weathering rates may increase over shorter durations of time—for instance, when dissolution opens up greater surface area to attack, resulting in more and faster weathering. However, this also reaches an eventual equilibrium. Weathering rates are most likely to be polycyclic and metastable, not unlike most geomorphic systems.

Weathering rates are well studied around the world as they give an indication of landscape evolution and environmental change. In some cases, weathering rates are so well established that they can reliably indicate elapsed time and hence can be used as a relative and occasionally calibrated numeric dating method. Examples of these applications include the width of stone weathering rinds (see granitic stone photo), the diameter of tafoni and rock basins, and the proportional abundance of less weatherable minerals in sediments and soils. Most often, significant geomorphic modification is a synergistic combination of weathering with other geomorphic processes (the



A granitic stone exhibiting a well-developed weathering rind. Orange tint is from oxidation; the rind itself is indurated with secondary silicate precipitates derived from hydrolysis. Width of the rind can be correlated to the exposure age.

Source: Photo by author; rock courtesy of M. Anderson.



Tafoni, or honeycomb weathering, on a sandstone wall in arkosic sandstone near Cañon City, Colorado. Multiple weathering agents and factors include salts, water, microclimate, and petrology. Size and shape exhibit qualities of self-organization.

Source: Author.

combined process referred to as *denudation*). Erosion is capable of exerting larger landscape modifications when preconditioned by weathering, in which weathering weakens and softens the rock prior to erosion. Landscapes are sometimes referred to as “weathering limited,” meaning that the efficacy of erosion and transport is held back by slower rates of weathering, or “transport limited,” in which weathering is aggressive but erosion is not capable of keeping pace by removing

the weathered material. Weathering and transport limits are frequently cited in support of tectonic and climatic models for landscape evolution, though relief, lithology, vegetation, and land use are equally relevant.

Landscapes dominated by weathering processes (but helped by other geomorphic processes) are some of the most dramatic on Earth. Examples include the deep regoliths of the Brazilian shield; the tower karst of Guilin, China; and remnant tors and inselbergs in Dartmoor (England), East Africa, and Australia. In mountainous landscapes, the work of weathering is less recognizable but still highly significant. Owing to the increased exposure of fresh, unaltered rock, new mountain ranges promote rapid weathering and the addition of a heavy solute load to the surrounding streams and rivers. Studies in the Rocky Mountains and Scandinavia attest to high levels of chemical weathering despite cooler temperatures. A recent (though contested) theory suggests that very active orogeny in the late Cenozoic Era (e.g., Himalayas) allowed increased chemical weathering and profligated an atmospheric drawdown of carbon dioxide, perhaps decreasing the greenhouse effect enough to trigger climate change.

At smaller scales, weathering at focused points and with aggressive agents can cause significant modification over shorter time periods. These myriad small-scale landforms reflect a diversity of interacting processes, type localities, and odd names—for instance, *gnammas* (rock basins), *tafoni* (honeycomb-like hollows), *karren* (solution channels), and *hoodoos* (rock pinnacles). Small-scale weathering forms are the product of differential weathering and erosion and sometimes exhibit process positive feedback as well as self-organized geometry (see tafoni photo).



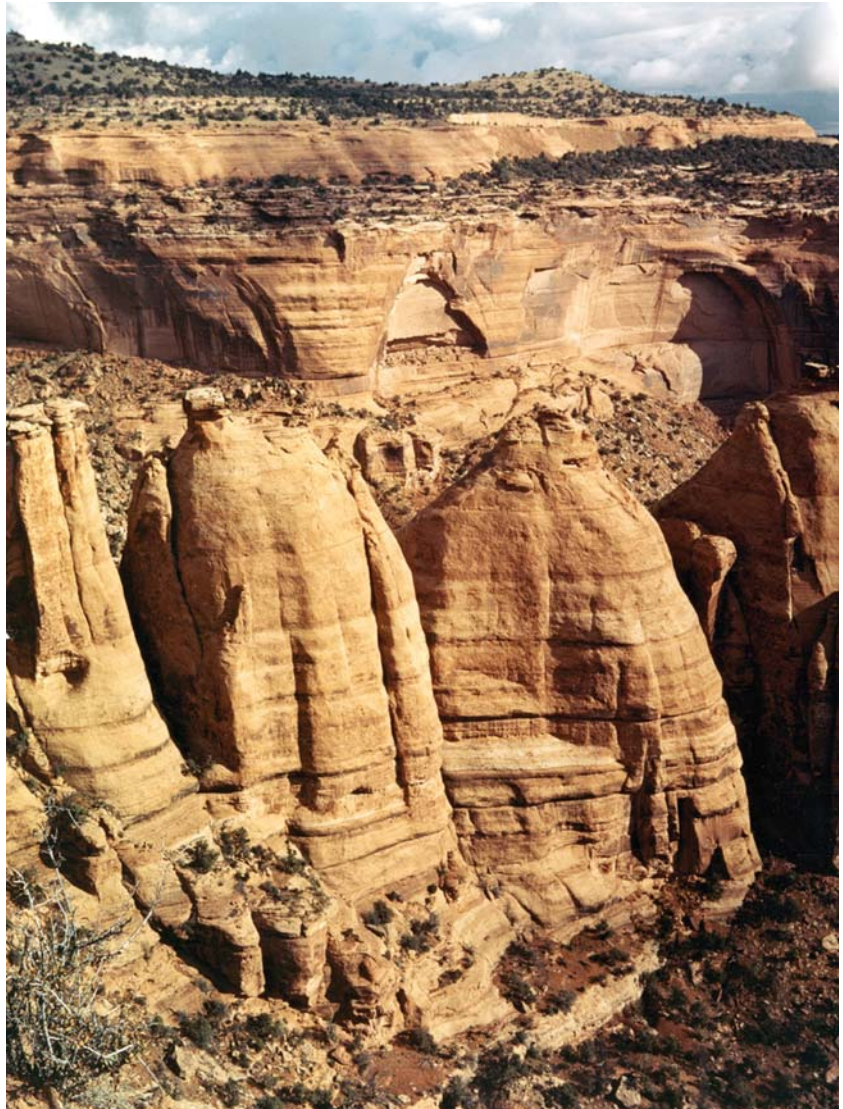
Not limited to the natural environment, small-scale weathering is also a matter of concern in the case of buildings, and the processes and mitigation of damage in them are an important focus of research.

Petrology, Mineralogy, and Geologic Structure

Weathering is easiest and proceeds fastest along rock and mineral weaknesses, these weaknesses being the product of rock and mineral formation and crustal stresses. Rock and mineral weakness is a factor across scales, from submicrometers to many kilometers. Minerals have a range in resistance to weathering owing to both crystal structure and composition. This attribute translates up in scale to the composition of the rock and to lithologic differences.

Fractures present avenues of weakness as well as paths of contact with weathering agents. Fractures are present at the smallest scales, within mineral grains. At the largest scales, networks of fractures (including fault zones) allow fluids to penetrate and create greater surface area. Quarries are ideally situated in rock outcrops relatively devoid of fractures, minimizing the chances for weathering and easing the ability to remove large intact slabs of workable stone.

Over larger scales, the variation in lithology (by composition or structure) would factor into variations in weathering and erosion rates, resulting in differential landscapes of landforms resistant to positive relief and less resistant to negative relief. Resistant landforms (such as bornhardts, inselbergs, buttes, tors) have been described as having a more resistant composition compared with the surrounding rock, fewer fractures, or both.



Colorado National Monument, Colorado. Weathering away of the protective caprock of the overlying Kayenta Formation has produced rounded tops on all but the left-hand shaft, which is still protected by the Kayenta.

Source: U.S. Geological Survey.

Source of Weathering Agents, Climate and Biotic Influences

The abundance and efficacy of weathering agents is a factor in the geography of weathering (Figure 1). Concentration of weathering agents will yield faster weathering rates and more intense weathering. Because of the ubiquity of water in almost all terrestrial environments (possible exceptions in hyperarid deserts, though the



persistence of this condition over weathering timescales is debatable), chemical weathering is nearly always available. At least one type of mechanical weathering is present in terrestrial environments. Again, variation of weathering agents is evident at changing scales. For example, at regional scales, increased precipitation, perhaps aided by enhanced levels of atmospheric acid, may account for increased chemical weathering (evident in increased solute load in streams). Certain biomes would be more conducive to increased levels of organic acid (e.g., pine barrens or sphagnum bogs). Certain climate regions are more favorable for mechanical weathering (e.g., due to freeze-thaw cycles or salt). Variations in weathering agents at centimeter-to-meter scale account for differential weathering. Individual plants (e.g., lichens, trees) can locally enhance the chemical weathering environment. Microclimatic difference can influence temperatures and the availability of water and organisms. Small-scale declivities in the land or rock walls can concentrate weathering agents as well as influence the microenvironment. In contrast, small-scale armor-ing (rinds, rock coatings) protects rock from weathering by retarding the access of chemical agents or indurating the rock against mechanical stresses. Finally, the efficacy of weathering agents can decline over time as the material evolves from higher to lower weathering potential.

Gregory A. Pope

See also **Biota and Soils; Geomorphology; Rill Erosion; Sedimentary Rock; Soil Erosion; Soils; Wind Erosion**

Further Readings

- Birkeland, P. W. (1999). *Soils and geomorphology* (3rd ed.). Oxford, UK: Oxford University Press.
- Bland, W., & Rolls, D. (1998). *Weathering: An introduction to the scientific principles*. London: Arnold.
- Colman, S. M., & Dethier, D. P. (Eds.). (1986). *Rates of chemical weathering of rocks and minerals*. Orlando, FL: Academic Press.
- Martini, I. P., & Chesworth, W. (Eds.). (1992). *Weathering, soils, and paleosols*. Amsterdam: Elsevier.

- Nahon, D. (1991). *Introduction to the petrology of soils and chemical weathering*. New York: Wiley.
- Ollier, C., & Pain, C. (1996). *Regolith, soils, and landforms*. Chichester, UK: Wiley.
- Robinson, D. A., & Williams, R. B. G. (Eds.). (1994). *Rock weathering and landform evolution*. Chichester, UK: Wiley.



ROSE, GILLIAN (1962–)

Gillian Rose has long encouraged geographers to contemplate the gendered construction of geographical knowledge. Her research ranges from analyzing the cultural politics of landscape to exploring notions of the performative and visual methodologies. She is perhaps best known for her 1993 book, *Feminism and Geography*. Through an explicit critique of geography's masculinist leanings, Rose reveals that geographers have constructed geography in ways that legitimize masculine forms of geographical knowledge at the expense of feminist ones. Rose has also intervened in key debates about feminist geographical methodologies, drawing on insights from Judith Butler to critique assumptions in feminists' use of reflexivity as a way to construct geographical knowledges. Referring to the ways in which gendered sameness and difference are constituted through geographical traditions, in "Tradition and Paternity" Rose (1995c) emphasizes that "given th[e] persistent erasure of women, the construction of geographical traditions might . . . be described as the construction of geography's paternal lines of descent" (p. 414). She insists that

feminists . . . need to critique the transparent territorialization of tradition . . . we need to focus on the boundaries at which difference is constituted . . . this project entails thinking about geography through a different spatiality: a multiple space. (p. 416)

Rose draws on feminist discourses on the maternal body, or woman as mother, to subvert masculinist structures of knowledge in geography. Her work has been strongly influenced by psychoanalysis, and this has largely shaped her understanding and theorization of space. The sophistication of Rose's arguments, especially her continual



questioning of the epistemology and ontology of the discipline, suggests that the notion of an “explicit sexualisation of knowledges” (Grosz, 1993, p. 188) must be taken seriously by geographers.

Rose’s 2001 book, *Visual Methodologies*, examines methods in visual culture approaches, from discourse analysis techniques to the study of audiences. Drawing on her interest in psychoanalytical theory, Rose argues that sexual difference is articulated through visual practice. This book offers a comprehensive study in methods to examine visual culture, from discourse analysis techniques to the study of audiences. Examining how we interpret images and how these processes are laden with power and cultural meaning, Rose provides a critical visual methodology, where she examines the visual in terms of cultural significance, social practices, and complex power relations. Drawing again on her understanding of psychoanalytical theory, Rose persuasively discusses the ways in which sexual difference is articulated through visual practice. Rose’s argument about critical visual methodologies has already been effectively extended into the arena of geographic information system imaging and has proven an important contribution in geography and representation.

Rose’s work in the late 2000s began to examine the ways in which visibility is experienced in urban environments, contributing to a sensuously embedded geography of vision. In developing a new urban aesthetics, Rose insists on the importance of a self-reflexive understanding of the researchers’ position on fieldwork, thus echoing a similar but not identical commitment toward reflexivity as her work in the 1990s demonstrated. Her 2009 article “Who Cares for Which Dead and How?” draws on the notion of necropolitics as a theoretical jumping-off point for the analysis of the British press coverage of the 2005 London bombing. Rose shows that newspaper coverage of the attacks was gendered and racialized, forcing the reader to consider the complex relationship between caring, necropolitics, and its accompanying visualities and spatialities.

Minelle Mahtani

See also **Feminist Geographies; Feminist Methodologies; Gender and Geography; Situated Knowledge; Vision and Geography**

Further Readings

- Grosz, E. (1993). Bodies and knowledges: Feminism and the crisis of reason. In L. Alcoff & E. Potter (Eds.), *Feminist epistemologies* (pp. 187–216). New York: Routledge.
- Rose, G. (1993). *Feminism and geography*. Minneapolis: University of Minnesota Press.
- Rose, G. (1995a). Distance, surface, elsewhere: A feminist critique of the space of phallogocentric self-knowledge. *Environment and Planning D: Society and Space*, 13, 761–781.
- Rose, G. (1995b). Geography and gender: Cartographies and corporealities. *Progress in Human Geography*, 19, 544–548.
- Rose, G. (1995c). Tradition and paternity: Same difference? *Transactions of the Institute of British Geographers, New Series*, 20(4), 414–416.
- Rose, G. (1996). As if the mirrors had bled: Masculine dwelling, masculinist theory and feminist masquerade. In N. Duncan (Ed.), *Bodyspace* (pp. 56–74). London: Routledge.
- Rose, G. (1997). Performing inoperative community: The space and the resistance of some community arts projects. In S. Pile & M. Keith (Eds.), *Geographies of resistance* (pp. 184–203). London: Routledge.
- Rose, G. (1997). Situating knowledges: Positionality, reflexivity and other tactics. *Progress in Human Geography*, 21, 305–320.
- Rose, G. (2001). *Visual methodologies*. London: Sage.
- Rose, G. (2009). Who cares for which dead and how? British newspaper reporting of the bombings in London, July 2005. *Geoforum*, 40, 46–54.



ROYAL GEOGRAPHICAL SOCIETY

The Royal Geographical Society (RGS; with the Institute of British Geographers [IBG]) is the United Kingdom’s (UK) learned and professional society for geography and geographers. It is a dynamic institution, with a distinguished history and a powerful modern reputation and brand. Founded in 1830, the RGS-IBG is the largest geographical



society in Europe and one of the largest and most active in the world. It operates at the international, national, and regional levels from its London-based headquarters and nine regional branches.

The society's purpose remains the same today as when it was first founded—namely, the “advancement of geographical science” (enshrined in its Royal Charter in 1859). However, the manner in which this goal has been pursued has expanded greatly over the years. Today, the society is involved in a broad and integrated program of activities supporting geographical research, from education and outdoor learning, to public engagement and knowledge transfer, to policy making. As well as supporting and helping develop geography, the society actively promotes, advises on, and represents the discipline to a wide range of stakeholders. It is governed by a board of trustees, a council, elected from its fellowship.

The history of the society for many of its earlier years was closely allied with colonial exploration in Africa, the Indian subcontinent, the polar regions, and Central Asia, especially associated with names of explorers such as Livingstone, Stanley, Scott, Shackleton, Hunt, and Hillary. The society's collections are an unrivalled repository of this history, with more than 2 million items tracing 500 yrs. (years) of geographical discovery and research that continue to the present day. Included are more than 1 million maps and atlases, 500,000 images (photographs, sketches, art works, and films), and books, reports, and manuscripts. Recent initiatives have focused on “unlocking these archives”—that is, opening public access and adding educational value. Reinterpretations by community groups are at the core of the current Crossing Continents project and associated exhibitions, for example.

The society has devoted much attention to education and was responsible for both the incorporation of the study of geography in schools at the turn of the 20th century and the first university positions in the discipline. With the advent of a more systematic study of geography, the IBG was formed in 1933 by some society fellows as a sister body to the society. RGS and IBG coexisted for 60 yrs. until they merged in January 1995 to create the RGS (with the IBG).

Today, the society continues to influence educational discussion and debates both in schools and

higher education—the director serves in an advisory role to government—and is integrally involved in developing benchmark statements for the discipline and advocates for the position and funding of the discipline in schools and universities. The society established the case for further support for geography teaching at school in discussions with government between 2004 and 2006. As a result, since 2006 the RGS-IBG has been a lead partner, with the Geographical Association, in the Action Plan for Geography. This 5-yr. initiative, funded by the U.K. government, aims to inspire and support school teachers in their task to inform, engage, and enthuse young people with geography. In addition, through Geography Outdoors, the focus of much of the society's work with young people remains on fieldwork, exploration, and discovery, engaging youth from many backgrounds in the United Kingdom and overseas.

In terms of advancing geographical research, the society publishes three leading, international academic journals—*Transactions of the Institute of British Geographers*, *Area*, and *The Geographical Journal* (currently in its 175th volume)—and the RGS-IBG book series of scholarly monographs. It supports 27 research groups; organizes an annual conference attended by more than 1,200 international scholars; runs more than 20 different grant programs for geographical research, fieldwork, and teaching in the United Kingdom and overseas, supporting hundreds of geographers at different career stages; and is the hub for information, networking, and support for departments across the United Kingdom. The society is an active contributor to IGU (the International Geographical Union) and the EUGEO (a society of scholarly geographical societies, associations of geographers, and other membership organizations representing geographers and geographical sciences in the European Union countries).

Broader initiatives to promote the wider understanding, relevance, and enjoyment of geography are supported by a rich program of public lectures (including the flagship “Monday night lectures”), discussions and debates, online resources, and publication of the popular *Geographical Magazine*. The society also leads the promotion of the recognition and understanding of the relevance of geography



and geographical information to policy, placing geography firmly in the debates about the future of places, environments, and communities. This work is advanced through policy-briefing papers, proactive media work, and events providing a forum for dialogue between government, parliamentarians, researchers, NGOs, and business.

The society recognizes, through its medals and awards, geographers who have contributed to the advancement of the discipline—the most prestigious of which are the gold medals. Recipients include William Morris Davis (1919), Sir Halford Mackinder (1945), L. Dudley Stamp (1949), Richard Chorley (1987), David Harvey (1995), Nicholas Shackleton (2005), and Derek Gregory (2006).

Since 2002, the society has been granted the power to award the status of Chartered Geographer—a professional accreditation for those applying their geographical knowledge, understanding, and skills in the workplace. The society also warmly welcomes those who wish to join as fellows and members in the United Kingdom and across the world.

For details about the society and its activities, and references to papers and books on the RGS-IBG, see the Web site www.rgs.org.

Rita Gardner and Catherine Souch

See also **Institute of British Geographers**

Further Readings

Royal Geographical Society. (2005). *To the ends of the Earth: Visions of a changing world—175 years of exploration and photography*. London: Bloomsbury.



RURAL DEVELOPMENT

Rural development is the practical and intellectual effort to improve the economic welfare of people living in rural areas.

History of the Concept

The conceptualization of rural development is closely associated with the emergence of the “rural” as a social and geographical category in the early 20th century. In the beginning, such development was closely linked to a nascent rural geography, and until the 1960s, it was difficult to differentiate between the two. Practitioners constructed the rural as an abstract space that could be manipulated to stimulate development (typically framed through the discourse of “modernization”) in areas where demographics indicated a dispersed population and extensive land use. Issues, staffs, and programs were organized largely along the sectoral lines of state bureaucracies such that rural development itself became a highly fragmented enterprise involving multiple agencies concerned with agriculture, labor management, entrepreneurship and small business, environment and resources, and social services.

The 1970s saw the rise of an “integrated” approach to rural development premised on the coordination of the environmental, economic, technological, and policy aspects of agricultural production. Beginning in the 1980s, rural development experienced a marked shift in conceptualization and implementation as scholars and practitioners alike began to retheorize the concept of rurality itself. In practical terms, this led to an increased focus on cultivating local human and natural capital in rural communities through participatory and collaborative initiatives that featured the direct involvement of multiple groups of stakeholders. Collectively, these new, regenerative approaches are referred to as “endogenous” development. Contemporary rural development approaches such as these have emerged in a political-economic climate characterized by state devolution of environmental and social management authority to local communities and organizations.

Central Questions

The history of rural development, and by extension its various approaches and schools of thought, can be interpreted as responses to a pair of fundamental questions.



Who or What Is Rural?

First, who or what is rural? The forerunner of modern, government-led rural development can be found in policies and conceptualizations related to the “frontier” zones of state expansion and settlement during the 19th century. Over the following decades and on into the 20th century, state governments were instrumental in promulgating a modernist approach to development that defined rural space as an area distinct from the urban-industrial cores of economic and political activity. In the context of so-called modernization, development consisted largely of “top-down” efforts focused on issues unique to rural space—the dominance of primary sector activities (i.e., forestry, agriculture, fishing, and mining), the entrepreneurial work culture, and small-scale production. State intervention was central in this regard as it often involved the construction of significant infrastructure (e.g., dams, roads, towns) to attract the external investment needed for modernist transformation. The 1933 Tennessee Valley Authority project in the United States and the 1949 Industrial Development Authority in Ireland are exemplary in this regard.

Modernist development was often coupled with a “growth pole” strategy, whereby urban centers in the region provided jobs and services for an entire hinterland region, while rural areas offered the necessary human and natural resources. This spatial arrangement proved problematic, however, in that it failed to adequately address the rural-urban (and local-global) linkages as well as socioeconomic change more generally, if for no other reason than that rural areas evolved in tandem with the processes of urbanization and suburbanization. Some critics questioned whether the development effects promised by rural modernization ever did in fact “trickle down” from growth centers to hinterlands.

More recently, development scholars and practitioners have answered the question of what constitutes the “rural” by emphasizing the fluidity and malleability of the concept. Instead of seeing the rural as a distinct geographical area, newer approaches favor a conceptualization of the rural as *discourse*. The result is that now many different and more diverse areas, communities, and stakeholders can effectively be considered within

the scope of a rural development paradigm. The rural is increasingly being seen less as an inert space to be managed and more as an actively constituted set of identities and practices that by necessity involve myriad actors and processes working at local, regional, national, and global scales.

In terms of development practice, new definitions of rurality have found expression in the European Union’s LEADER (*liason entre actions de développement de l’économie rurale* [links between actions for development of rural economy]) program, small-town regeneration initiatives, burgeoning farmers’ markets, community forestry, and local visioning activities. Critics of “bottom-up” approaches to rural development contend that as the state offloads development authority to local communities, the result is inefficiency in the planning and implementation process as well as an increasingly uneven geography of regeneration and deterioration across rural space as some communities are more successful than others in achieving development goals.

On What Should Rural Development Focus?

Second, what is the appropriate focus for rural development? As states expanded through colonization and resettlement in the 19th century, rural policy was largely concerned with the acquisition, distribution, and management of *land* through the coordination of preemption and sale of public property. Twentieth-century industrialization and the concomitant consolidation of state power across national space added the *commodity*—particularly the agricultural commodity—to rural development discourse. Policy thus came to focus on managing and in many cases subsidizing the production and distribution of agricultural goods, services, and labor. It was in this context that rural development came to be organized along sectoral lines, which had the effect of dividing rural communities by occupation and interest groups while simultaneously serving to stabilize rural space, both by discouraging endogenous protest and change and by fragmenting prospective political resistance and mobilization.

In the last quarter of the 20th century, intense rural restructuring undermined the twin priorities



Chinese villagers work at the construction site for a new bridge in China's rural Danzhai County, Guizhou Province (2006). The "No. 1 Document" of the year points out that with the nation in an era of insufficient grain production, expanding urban-rural disparity, and soaring national fiscal income, China's main priority is in revitalizing the countryside, as reported by the Xinhua News Agency. (The first document issued by the central committee of the Communist Party of China and the State Council each year is called "the No. 1 Central Document.")

Source: Reinhard Krause/Reuters/Corbis.

of land and commodity in development discourse. Generally speaking, states are now less interested in supporting rural capitalism as fiscal problems have mounted from decades of subsidies and as governments are increasingly pursuing neoliberal economic strategies in both domestic and foreign policy. In addition, rural communities have become more diverse as decades of outmigration have depleted the primary sector population and new residents and stakeholders increasingly promote alternative, nonindustrial uses and meanings for rural space.

Development policies have evolved in this situation of flagging state support and diversifying rural constituencies. In terms of an appropriate development focus, the net effect has been to place (certain types of) *people* at the center of the rural question, with the consequence that development has taken on an increasingly collaborative, participatory, and even place-based character in both conceptualization and practice. Indeed, some contemporary practitioners have equated rural development with local development, while others have preferred to conceptualize it in terms



of the place-based management of land, resources, and communities.

Measurement and Assessment

Changes in the measurement and assessment of rural development mirror the broader political-economic transformations outlined above. When concerned solely with land and commodities, rural development was conceived of as a state intervention designed to maximize production, stimulate external investment, and minimize input costs for firms and workers. A successful development program, then, was characterized by higher yields, incomes, and capital investments coupled with an increasingly favorable cost-benefit structure that could, in turn, justify government expenditures on social services such as health care, education, and unemployment insurance.

As rural development increasingly concerned itself with people, however, assessment has become much more complicated. While conventional economic measures are still used, scholars and policymakers are increasingly favoring alternative benchmarks that include the level of civic engagement in development projects, the enhancement of the targeted area's social and natural capital, and the overall effect of a development program on "social sustainability" (loosely defined as a community's level of cultural tolerance and commitment to its own long-term viability). Similarly, development efforts can be gauged by observing their capacity to empower traditionally marginalized groups such as women and indigenous peoples.

Connections to Social Theory

The theoretical basis for rural development has shifted over time as programs and initiatives experienced shortcomings, limitations, and even failure and as economic restructuring created new problems and opportunities for development practitioners. Social Darwinism found expression in the 19th- and early-20th-century development efforts concerned with state expansion and drew from the idea that community fitness was linked to land acquisition and modification, known discursively as "improvement." In this context, the state undertook rural development as a central

part of its own project to consolidate and legitimize control over nonmetropolitan space.

In the early 20th century, the Great Depression and postwar reconstruction infused development policy with socialist and Keynesian ideas concerning the role of the state in protecting minimum standards of social welfare in rural areas. A number of postwar welfare states emerged that actively managed labor and natural resources in rural areas for external (domestic and foreign) investment, mostly in primary sector activities such as hydroelectricity and aluminum production, agriculture, forestry, and mining. Actual development work on the ground was largely implemented and assessed within an empiricist framework in which the efficacy of rural policy could be measured and monitored using conventional economic indicators of production yields and levels of income, unemployment, education, and consumption.

In the 1970s, systems theory ushered in an "integrated" approach to rural development that sought to transcend the sectoral barriers created by the earlier welfare paradigm. Despite some success, this approach has been criticized for failing to account for the social and geographic variation associated with the different contexts in which such development was attempted.

In recent decades, the rise of the neoliberal state coincided with an explosion of theoretical work in rural studies drawing from cultural studies, structuralism, political ecology, and a variety of poststructuralist literatures. While rural development theory is now more diverse than ever before, it is generally concerned with the discursive nature of rural development praxis and the central role of social power in the constitution, implementation, and measurement of development itself.

Contemporary Research

An informal 2008 survey of leading geography and rural studies journals reveals the breadth and scope of contemporary research in rural development. Research continues in the areas of model and program construction and assessment, representing continuity in a longstanding line of inquiry in the field. Particularly notable in this regard is the introduction of actor network theory in the 1990s to understand and model the development



process and, still more recently, the elaboration of cooperative capitalism as an alternative model for endogenous programs grounded in local-global networks. Current thematic work also concerns social organizing, civic engagement, and participation; the role of development in empowering historically marginalized groups; the effects of development on local and regional power structures; and the political ecologies of development programs and initiatives, particularly in the developing world.

Parallel to these trends is ethnographic and historical work on local resistance to and accommodation of development, both imposed and endogenous, largely in the form of case studies that analyze the complex social and environmental consequences of implementing particular programs, initiatives, and projects. Case study research, for instance, has examined local protests against hydroelectric and flood control dams, government land use regulations, state schemes to relocate people and communities for industry or infrastructure, and the state's attempt more generally to attract external investment to resource-rich hinterland areas.

Concurrently and related to this case study work, another thread in contemporary literature on rural development focuses on the application of social theory to critique the assumptions and contradictions inherent in the project of development itself. Central to this critical effort is work in political ecology, discourse analysis, cultural materialism, and feminism.

Soren C. Larsen

See also Actor-Network Theory; Agriculture, Industrialized; Development Theory; Discourse and Geography; Growth Poles; Modernization Theory; Participatory Rural Appraisal; Peasants and Peasantry; Restructuring; Rural Geography; Rural-Urban Migration; Sustainable Agriculture; Uneven Development

Further Readings

Lapping, M., Daniels, T., & Keller, J. (1989). *Rural planning and development in the United States*. New Haven, CT: Guilford Press.

Marsden, T., Murdoch, J., Lowe, P., Munton, R., & Flynn, A. (1993). *Constructing the countryside: An approach to rural development*. London: University College of London Press.

Moseley, M. (2003). *Rural development: Principles and practice*. Thousand Oaks, CA: Sage.

Ray, C. (1997). Towards a theory of the dialectic of rural development. *Sociologia Ruralis*, 37, 345–367.

Singh, K. (2009). *Rural development: Principles, policies and management*. Thousand Oaks, CA: Sage.

RURAL GEOGRAPHY

Rural geography is the study of place-based economies and cultures characterized by (a) low settlement densities, low levels of connectivity, and hence a certain degree of isolation; (b) livelihoods that are predominantly agricultural or organized around other forms of direct dependence on natural resources and landscapes; and (c) attachments to long-standing traditions that often make them emblematic of cultural differences. Geographic meanings of the rural have been approached through contrasting urban and rural places within specific national contexts as well as across the international realm.

While urban geography is usually viewed as constituting a well-defined subfield, rural geography has often been a less visible subdisciplinary endeavor, though agricultural development has been a key topic within the broader rubric of economic geography. The prominence of urban geography, however, should also be linked to the predominance of urban populations within advanced economies, especially North America and Western Europe. In less developed contexts, especially South and southeast Asia, a majority of the population continues to be directly linked to agriculture, highlighting the significance of rural geography for an understanding of global diversities. More recently, rural issues have come to the fore across developed and less developed contexts, partly due to increased conflicts over natural resources. Within the United States, the



urban-rural divide has become a new site of conflict due to increased migration of urban populations into rural areas as part of the processes of exurban growth.

Major themes in rural geography can be distinguished into broadly economic, cultural, and political categories, even as these aspects of rural places cannot be strictly separated from one another. The first step in understanding rural places, however, has to be in terms of clarifying the meanings of and approaches to the rural.

Understanding the Rural

The idea of the “rural” usually refers to physical arrangements (low-density, dispersed settlement patterns), agriculture and agriculture-related activities (which could also encompass other forms of direct dependence on nature), and cultural distinctiveness (relatively homogeneous communities usually resistant to rapid change). It has also been argued, however, that instead of speaking of the specific characteristics of exclusively rural places, it might be more useful to focus on the rural-urban continuum, or even on the ways in which urban and rural spaces merge into one another rather than being strictly separated. A recent focus, for instance, has been on urban agriculture and the ways in which it marks the presence of what is usually associated with the rural within developed urban contexts. As opposed to this view, rural landscapes have also been key to symbolizing a unique regional or national identity, which heightens the significance of associating a clearly defined meaning with rural places. This notion is a feature of the rural that is likely to increase in value given contemporary concerns over the loss of cultural differences due to globalization.

Within the broader disciplinary framework, rural geography can be considered part of the regional approach to geography, which focuses on partitioning space into distinctive units. Thus, whereas the systematic approach concentrates on the distribution of one specific element across space, the regional approach is attentive to the combination of characteristics that constitute specific subdivisions of space and render them internally homogeneous as well as distinguish them from their surroundings. Rural geography also

has the potential to be located within a newly formulated environmental geography, which seeks to study places as both natural and social and, thus, seeks more overtly to bridge the divide between human and physical geography.

Rural Economies

Rural geography has focused on forms of agricultural operations, which vary from small-scale subsistence farming among peasant populations to large agribusiness corporations usually headquartered in more developed economies. Rural livelihoods are also connected to natural resource economies, including forestry, mining, and dam building. While such extractive industries are often associated with economic development, their consequences in terms of pollution and degradation have also devastated rural landscapes.

Rural agricultural landscapes vary from the mixed cropping patterns of small-scale farms (in South and southeast Asia) to the more homogeneous landscapes of industrial agriculture (classically represented by the American Midwest). In less developed contexts, farm fragmentation, usually due to systems of inheritance, has been a concern in terms of the viability of peasant livelihoods. More recently, the increasing role of technological inputs—including high-yielding seeds, fertilizers and pesticides, mechanization of farm activities, and access to irrigation—has led to shifts from subsistence to market-led production, this shift being more feasible for farmers with large landholdings. This technological shift in agriculture, designated as the Green Revolution, while credited with increasing food production, has thus also been criticized for exacerbating inequalities within rural contexts. In the case of more developed economies, the independent family farm has declined within the agricultural sector, which is now mostly controlled by large-scale corporations. Industrial forms of agriculture are reflected here through monocropping that requires intensified dependence on chemicals.

In the context of globalization, connections between urban and rural places are being discussed in terms of the increasing reach of commodity chains, so that urban consumers in high-income countries are now directly connected to rural producers in low-income contexts through



the medium of multinationals. The distance between sites of production and sites of consumption also means that urban areas no longer draw solely from their surrounding rural hinterlands. Thus, traditional land use models (e.g., von Thünen's model of agricultural land use) have to be modified to be more attentive to the role of global demand and competition in shaping local rural livelihoods. This becomes a matter of concern when the tastes of urban consumers in advanced economies serve to tie rural communities in less developed contexts to the uncertainties of global demand, in the process destroying local adaptations to the environment. In the context of the United States, coffee commodity chains have been examined to outline such repercussions of global commodity chains on local communities.

The isolation of rural places has always been a concern in terms of state-level planning as service delivery, including both education and health services, has been less easily spread into rural communities. More recently, however, the isolation of rural places has made them important locations for otherwise undesirable land uses, including prisons within the United States or polluting industries and waste within less developed contexts. Rural economies are also becoming part of ecotourist initiatives—as in Western Europe—through notions of heritage associated with rural lifestyles. The focus of rural economic geography has shifted in such contexts from the production of crops or animals to the consumption of scenery or landscapes. The consumption of rural landscapes is also reflected in the rise of residential developments within rural areas in the United States; these developments are often being promoted as a means to access a “rural quality of life.” The continuing decline of agriculture in the United States is reflected in these forms of exurban growth.

Rural Cultures

Rural people are widely considered to represent the more traditional aspects of culture, linked to older ways of interacting with the environment through agriculture or hunting, and more old-fashioned forms of attachments to place-based communities. Rural places are thus likely to be viewed as isolated from more mainstream,

cosmopolitan forms of culture. While this may be less and less true, given the rise of global connections, whether through extended commodity chains or the influx of new residents as well as tourists into rural areas, it is probably accurate to argue that rural areas are less open to the diverse forms of social interactions that are available in urban contexts, in part because rural places have lower densities of transportation networks.

Migration is one way in which rural places remain connected to a wider world, both in terms of the rural depopulation that has characterized demographic development in advanced economies as well as in the streams of rural-to-urban migration that are key to expanding economic opportunities for rural populations in less developed contexts. A number of studies have documented such rural migrations, and the focus has now expanded to include rural-to-urban migration across international realms. An especially productive area of study in terms of the migration of rural populations has been the gendered consequences of such migrations, whether through the experiences of women who are left behind by male migrants or the ways in which women and men differentially experience access to new economic and social opportunities through migration.

The meanings of gender in rural contexts have also been approached in terms of the division of agricultural work, with specific tasks often being designated as either male or female and valued differently as a consequence. In fact, the appellation “farmer” is itself redolent with gendered meanings, as it is usually understood to designate a masculine identity, which renders women farmers invisible within rural landscapes as well as devalues women's contributions to farming. More recently, the marginalization of different social identities within rural contexts has been increasingly highlighted to argue that rural societies are neither homogeneous nor immune to the kinds of cultural struggles, over the presence of immigrants or the expressions of sexualities, that characterize mainstream society.

Rural Politics

In terms of national politics, urban and rural populations are usually considered to be separate constituencies, and electoral campaigns are often



Harvesting on an Amish farm in Lancaster County, Pennsylvania

Source: Klaas Lingbeek-van Kranen/iStockphoto.

sensitive to these differences. While wholly rural-based political parties are relatively rare in the current context, specific agricultural interests are often sufficiently organized to matter in terms of national electoral campaigns. Within advanced economies, the politics of rural places are often cast as uniformly conservative in terms of both social and economic issues. In less developed contexts, however, where rural populations sometimes constitute a significant part of the population, rural interests have often served to establish populist, or even progressive, political parties in power.

Across developed and less developed contexts, rural communities have also become the site of struggles over meanings of conservation, as areas set aside for environmental protection often directly impinge on rural livelihoods, including dependence on hunting and forest products. Given that conservation areas in Africa, Latin America, and Asia are often geared toward Western tourists, such struggles have also brought global inequalities in the consumption of nature to the fore. The role of rural people within environmental struggles, however, should be viewed as divergent

across developed and less developed contexts, with rural people often being part of environmentalist agendas in less developed contexts even as they are viewed as opposed to environmental preservation policies in more developed places.

The recent neoliberal turn in global policy toward privatization of resources means that rural places have become key to questioning the inequalities that constitute globalization. Thus, rural, indigenous communities in Latin America, Africa, and Asia have become the site of social movements against forcible appropriation of land without adequate compensation. This has also exposed collusions between states and multinational interests. The rise of China and India has also brought rural-urban differences to the fore in terms of both the economic and the political losses experienced by rural places due to the withdrawal of the state and the increasing value of rural people as low-wage labor in new economies.

Contemporary forms of agriculture have also led to activism around two kinds of environmental concerns—related to notions of quality and community. In terms of quality, organic food movements have focused on the problems posed



by industrial agriculture to the integrity of natural and animal environments as well as the health of human bodies. In the context of community, local food movements have focused on the possible decline of rural places as they become economically disconnected from nearby urban markets. Such concerns can be considered as part of a larger turn toward environmentalism, especially in advanced economies, but they have also been raised by activists with less developed contexts as they criticize the loss of local traditions of farming due to the increasing industrialization and commercialization of agriculture. Concerns with quality and community, however, have also been criticized for privileging the needs of urban consumers over those of rural producers in both developed and less developed contexts.

Future Directions in Rural Geography

Rural geography is significant to understanding the contemporary world as rural products remain a crucial component of global flows, rural landscapes increasingly figure in elite consumption practices, and dispossession associated with natural resources extraction continues to prominently affect rural communities. Rural geography can thus be said to exemplify the contradictions of globalization: as rural places show how isolation is no longer a possibility, even as they also draw attention to the local attachments that continue to matter and often get magnified for some rural communities. The notion of spatial justice, which highlights the need to be attentive to place-based inequalities, can also be fruitfully followed on the basis of urban-rural contrasts, especially since rural geographies provide a framework for the inclusion of a large part of the population of Asia and Africa. Rural places also contribute to new understandings of the interconnections between nature and society—for instance, due to the genetic engineering of seeds and livestock and the controversial diversion of crops toward energy supply through the production of biofuels. Thus, even as it is widely predicted that the world will be more urbanized in the future, such claims need to be tempered by the continuing presence and significance of rural places in the current global economy.

Pratyusha Basu

See also **Agricultural Land Use; Agriculture, Industrialized; Agriculture, Preindustrial; Cultural Ecology; Food, Geography of; Organic Agriculture; Peasants and Peasantry; Remittances; Rural Development; Rural-Urban Migration; Sustainable Agriculture**

Further Readings

- Cloke, P., Marsden, T., & Mooney, P. (Eds.). (2006). *Handbook of rural studies*. London: Sage.
- Goodman, D., & Watts, M. (1997). *Globalising food: Agrarian questions and global restructuring*. London: Routledge.
- Woods, M. (2005). *Rural geography: Processes, responses, and experiences in rural restructuring*. Thousand Oaks, CA: Sage.



RURAL-URBAN MIGRATION

Rural-urban migration is both a socioeconomic phenomenon and a spatial process involving the movement of people from rural areas into cities, either permanently or semipermanently. At present, it occurs mainly in developing countries as they undergo rapid urbanization. Job opportunities created by industrialization attract the surplus rural labor to the cities to seek higher salaries through employment in the industrial sector. Rural-urban migration is widely considered an inevitable component of the development process, though it has a broad range of consequences and implications.

Theoretical Frameworks

The main theoretical bases to understanding rural-urban migration include neoclassical economic theories and the household strategy approach.

Neoclassical Theories

The Harris-Todaro model and the Lewis dual sector model are two of the representative neoclassical economic theories illustrating the dynamics of rural-urban migration.

The Harris-Todaro model argues that rural-urban migration is mostly an economic decision



based on expected income differentials between rural and urban areas. Individuals or households make a cost-benefit calculation by comparing the expected earnings in the cities with the prevailing wages in the rural areas, and if the former exceeds the latter, migration will take place. Therefore, rural-urban migration will continue as long as the expected urban real income at the margin surpasses real agricultural returns. Migration can be seen as an equilibrating force that equates rural and urban expected incomes in the long run.

According to the Lewis dual sector model, migration occurs between the traditional agricultural sector and the modern industrial sector. The rural agricultural sector is characterized by low productivity, low wages, and excess labor, whereas the industrial sector in cities is defined by higher productivity, higher wage rates, and more job opportunities. Due to the wage differential between the agricultural and manufacturing sectors, the rural surplus labor will tend to transfer from the agricultural to the manufacturing sector over time to garner higher monetary reward. Eventually, the agricultural wage will rival the manufacturing wage, and the agricultural marginal product of labor will keep pace with the manufacturing marginal product of labor.

Household Strategy Approach

In the household strategy approach, rural-urban migration is a strategy adopted by households to maximize and diversify their earnings and minimize their risks against market failures as well as natural catastrophes. Net family gain, rather than net personal gain, encourages migration. The decision is rarely an individual one. It is usually made collectively by immediate and extended family members. Split households may take place as a result of adopting this strategy. Sometimes the husband pursues migrant work in the city and the wife stays behind to take care of the family as well as hold on to the land. During the busy season in agriculture or when family needs become urgent, migrant(s) may return temporarily to help. The remittances that migrants send back help pay the living and agricultural expenses and alleviate poverty in the household. The reason for split migration may be that the

family would want to reduce risk as well as migration cost, which can be expensive. It also allows migrants to straddle and benefit from both the rural segment and the urban segment. When migrants settle down in cities and achieve economic success and stability, family migration may occur, which means that the rest of the family members will join the migrants in the cities.

Demographics

Empirical studies have shown that the majority of migrants to cities are young and have a higher education attainment than those who do not move. They migrate because they have higher prospects of earnings and are more likely to be employed in the urban areas. It is also observed that men are more likely to migrate from rural to urban areas than women in areas where the status of women is lower, such as in most countries of Africa and Asia. Connected to the increased status of women, rural women are slightly more likely to move than their male counterparts in the countries of Latin America and the Caribbean, although most are following their husbands or family members.

Due to lack of access and the fewer skills they possess compared with the urban population, rural migrants are usually channeled into the urban informal or secondary sector. The jobs they take tend to be labor intensive, physically demanding, and low in pay. Typical jobs include manufacturing work, construction work, and domestic service. Migrants may have to face poor working conditions as well as living conditions in cities. Many of them cluster in the urban slums and shanty areas and have very limited access to basic services. Since a lot of migrants only take migration as a temporary means to increase income for the household and take the rural residence as their permanent home, they put up with the terrible living conditions in cities and maximize their savings.

Impacts of Rural-Urban Migration

Rural-urban migration has multifaceted consequences on the sending and receiving areas. The impacts are believed to be both beneficial and detrimental. From an economic perspective, migration plays a positive role in raising cash earnings, diversifying income sources, increasing the level of



A migrant worker in Beijing sorts through a mound of plastic bags at a recycling center for industrial and household waste. During 2005 alone, China's household waste reached 150 million tons, mostly collected and disposed of by migrant workers. According to China's National Bureau of Statistics, the rural migrant worker population in 2008 was more than 130 million. Rural Chinese provide the nation's cities with a workforce that is heavily represented in the manufacturing, construction, and social service industries.

Source: Michael Reynolds/EPA/Corbis.

productivity, and reducing unemployment/underemployment and poverty in the rural areas. In many developing countries, the flows of remittances are vital to the livelihoods of the family members left behind by the temporary migrants in rural areas. On a national scale, rural-urban migration helps narrow the gap between the urban and rural societies, given the distortion of opportunities in favor of cities in most developing countries. Socially, migration contributes to the empowerment of women by providing them with opportunities to work outside the home and earn income.

On the other hand, researchers believe that rapid rural-urban migration can cause excessive urbanization in developing countries, which may result

in serious issues. First, rural-urban migration contributes to unemployment and underemployment in the urban areas, which can be observed by the large numbers of unemployed or underemployed young people in many Asian, African, and Latin American cities. Second, rapid and massive population growth in cities puts extra pressure on urban infrastructure such as housing, transportation, sewage systems, clean drinking water, and other amenities. Finally, excessive urbanization causes city congestion, higher crime rates, disorder in urban management, pollution, and urban environmental degradation.

Wenfei Winnie Wang



See also **Developing World; Informal Economy; Migration; Remittances; Rural Development; Rural Geography; Squatter Settlements; Urbanization**

Further Readings

- Fan, C. (2008). *China on the move: Migration, the state, and the household*. London: Routledge.
- Harris, J., & Todaro, M. (1970). Migration, unemployment and development: A two-sector analysis. *American Economic Review*, 60(1), 126–142.
- Lewis, W. (1954). Economic development with unlimited supplies of labor. *The Manchester School of Economic and Social Studies*, 22, 139–191.
- Stark, O. (1991). *The migration of labor*. Cambridge, UK: Blackwell.



RUSSIAN GEOGRAPHICAL SOCIETY

Founded in 1845, the Russian Geographical Society (RGS) is the oldest geographical society in Russia. Headquartered in St. Petersburg, the society has gone through a series of name changes in its history, reflective of changes in Russian/Soviet history. It was known as the Russian Geographical Society from its founding in 1845 until 1849, again from 1917 to 1925, and from 1993 up to the present. It has also been known at various times as the Imperial Russian Geographical Society, the Russian State Geographical Society, the RSFSR (Russian Soviet Federated Socialist Republic) State Geographical Society, the All-Union Geographical Society, and the USSR (Union of Soviet Socialist Republics) Geographic Society.

The RGS was founded in the same era as the other great national geographical societies (such as those begun in London, Paris, Berlin, and New York). The organization's charter outlined its mission: "to gather, process, and spread in

Russia geographical, ethnographic, and statistical information in general and concerning Russia in particular, and to disseminate trustworthy information about Russia in other countries." In the 19th century, the society's main mission was to fund and sponsor expeditions "exploring" lands controlled by Russia, with an emphasis on the Asiatic portions of the Russian Empire to the east (especially Eastern Siberia and Central Asia). This eastward exploration was an integral component of the rise of Russian nationalism, with this eastward focus and attention by Russian nationalists serving as a counterweight to their growing negative views toward Western Europe.

As with many other national geographic societies, the Russian Geographical Society's emphasis today has shifted from exploration to more academic and applied pursuits. Today, the RGS is one of nearly 30 scientific organizations associated with the Russian Academy of Sciences (the RGS has had formal ties with the academy since 1938). Research interests of RGS members today span the breadth of human, physical, and regional geography and geographic techniques, with an emphasis on studying the challenges facing modern Russia from Kaliningrad to the Russian Far East. The organization's 13th Congress, held in August 2005, was attended by approximately 400 members.

Jonathan Leib

See also **Human Geography, History of; Kropotkin, Peter**

Further Readings

- Bassin, M. (1983). The Russian geographical society, the "Amur Epoch," and the Great Siberian Expedition 1855–1863. *Annals of the Association of American Geographers*, 73, 240–256.
- Martin, G. (2005). *All possible worlds: A history of geographical ideas* (4th ed.). New York: Oxford University Press.



SATELLITES AND GEOGRAPHY

The world's network of satellites and earth stations constitute a critical, and often overlooked, element in the global telecommunications infrastructure. While most treatments of this topic typically depict it in technologically deterministic, apolitical terms, satellites are deeply embedded in terrestrial political relations.

Satellites in orbit appear in a variety of sizes and degrees of technological sophistication. Large satellites capable of handling international traffic sit 35,700 km (22,300 miles) high in geostationary orbits, which are by far the most valuable orbital slots because only in that narrow sliver of space do satellites and Earth travel at the same speed relative to each other, making the satellite a stable target for signals transmitted upward from earth stations. Because such orbital arcs are a scarce resource, their distribution is strictly controlled through international organizations. The cost of launching satellites and the fuel needed to maintain them in their proper orbit are also constraints to their economic viability. Satellites typically have a 10-yr. (year) life span, primarily because they exhaust their available fuel, necessitating their eventual replacement by a new, frequently much improved, generation. From its vantage point, a broad-beam geostationary satellite can transmit to (i.e., leave a "footprint" over) roughly 40% of Earth's surface, creating instantaneous time-space convergence, so that only

three or four are sufficient to provide global coverage. Because the cost of satellite transmission is not related to distance, it is commercially competitive in rural or low-density areas (e.g., remote islands), where the high marginal costs dissuade other types of providers, particularly fiber optics providers.

The terrestrial counterpart of the satellite is the earth station. There are tens of millions of earth stations located worldwide, ranging in size from 0.5 to 30 m (meters). The vast majority, however, can only receive information, not transmit it (i.e., downlink only). When microwave signals are sent over great lengths and become broadly diffused, earth stations require large, powerful antennas to receive them. The distribution of the world's 483 publicly owned earth stations designed for international traffic in 2004 reveals that they are concentrated in the largest and wealthiest countries, particularly the United States, which, with 70, has vastly more than any other state.

A Brief History

The origins of the satellite industry lay in rocketry developed during World War II. Starting with the Soviet Union's launch of Sputnik in 1957, satellites played a key role in the militarization of space during the Cold War. The first U.S. satellite, Explorer I, was put into orbit 1 yr. later. Throughout the Cold War, satellites were instrumental in the discursive scripting of geographic



space, its ideological construction within hegemonic modes of understanding, shared by politicians, military planners, and the media, that were typically infused with the indiscriminate “othering” of the communist foe. The world’s first spy satellites, a series of 95 launched under the Pentagon’s Corona project, revolutionized Western understanding of the Soviet Union. Draped in secrecy, the Corona reconnaissance system offered accurate images of the vast Eurasian landmass, allowing the location of military facilities (especially long-range missile silos) to be pinpointed. The United Nations’ Outer Space Treaty of 1967 attempted to limit the militarization of space, an inconvenience to military planners that has largely been cast aside. In 1969, American military satellites were coordinated in the Defense Satellite Program to provide continuous, comprehensive, and seamless coverage of the Earth’s surface.

As the resolution and accuracy of military satellite imagery progressed over time, civilian uses followed accordingly. The visual power of satellites is usually expressed in terms of the length of the smallest feature that analysts can see when photographic processing is pushed to its limits. The exponential improvements in this capacity are evident in the changes from the early Landsat photos of the 1970s, with a resolution of 60 m, to the current generation of spy satellites, which can identify objects 5 centimeters in length. When satellites were the exclusive purview of the military worldwide, nations jealously hid the abilities of their surveillance systems so that foes would be less likely to evade and counter them; today, commercial providers boast openly about their systems’ powers of resolution.

Gradually, civilian applications assumed an increasingly important role in the satellite industry’s development. The first of these included the Landsat satellites launched by NASA (National Aeronautics and Space Administration) in the 1970s. The major difference between military and civilian purposes involved the shift in emphasis from surveillance to communications; although the technology remains important in both respects for military purposes, in the civilian domain, communications remains the dominant application. In 1962, the United States launched AT&T’s Telstar, the world’s first communications satellite. In the 1960s, NASA initiated the Syncom

series, which allowed television companies to initiate satellite transmission of programs, ultimately leading to an explosion of home broadcasting in the 1990s. The first privately owned satellite, Early Bird (Intelsat 1), was launched in 1965 and operated by Western Union. The first Soviet civilian satellite, Molniya, launched in 1965, was intended for purely domestic communications, in contrast to the American Early Bird, which was designed for international purposes.

Since the late 1950s, the world has launched more than 5,500 satellites; the vast majority were sent into orbit by the United States, which launched 1,854 before 2004, and the USSR (or Russia, since 1991), which launched 3,183. However, expanding commercial prospects gradually induced other countries to acquire the capacity to launch satellites. In 1973, Canada inaugurated the Anik satellite; France followed suit with the Spot and Telecom systems in the 1970s and 1980s, respectively; in 1977, Italy launched Sirio and Japan, its Sakura.

Regulating the Global Satellite Industry

International regulation has long been an important force shaping access to satellite technology, market structure, pricing, and its uses over time. The international regulation of telecommunications dates back to the International Telegraph Union in 1865, which later evolved into the United Nations’ International Telecommunications Union (ITU). The United Nations’ Outer Space Treaty, signed in 1967, constitutes the legal basis for extending international law into outer space, including the principles governing its exploration and use for purposes of communication.

A key issue in international regulation concerns orbital “parking spots,” particularly the coveted “geostationary gold,” which are allocated by the ITU. The ITU as an arena in which satellite geopolitics unfold confronts a dilemma between states already occupying slots and newer entrants demanding their own, who often feel that early users enjoy an unfair advantage. Newer claimants, typically developing countries, call for abolition of the currently existing “first come, first served” policy, which favors the economically advanced states. Such tensions reflect the fact that



satellites created a new resource—geostationary slots—but the world community lacks the means to allocate it with considerations other than profitability. Because the total number of orbital slots is limited by the physics of rotation and problems of bandwidth spillover, the steady growth in satellites has generated increasingly crowded conditions, with fewer degrees of orbital arc between them. Within countries, national communications boards (in the case of the United States, the Federal Communications Commission, or FCC) assign slots to private firms, generally via open auctions.

Two related issues closely associated with international regulation concern the allocation of electromagnetic frequency spectra and spillovers from satellite footprints. The former, the ITU's most successful area of jurisdictional competence, is accomplished through the World Administrative Radio Conference (WARC), which, through a series of international conferences and agreements, provides legal protection for the engineering lifetime of a satellite but does not allow states to enjoy unlimited control over a given frequency. The ITU must also address the conflict between the technological capacities of satellites and national sovereignty that occurs when signal footprints exceed the borders of a target country, which depends on the size of the footprint and the performance of the receiving earth stations. States that seek to restrict the imports of foreign media—including much of the Muslim world and the former Soviet bloc—have typically found it impossible to assert national control over global flows of information beamed from above. Such “externalities” point to the bleeding of the distinctions between foreign and domestic policy that communications technology has accelerated in this period of rapid globalization.

By far the largest and most comprehensive organization involved in the regulation of global satellite traffic is the International Satellite Organization (Intelsat), a private organization headquartered in Washington, D.C., with representatives from governments around the world. To expedite the entry of commercial providers in the satellite market, the U.S. government initiated a regulatory framework conducive to the growing interests of private firms. In 1962, Congress passed the Communications Satellite Act, which

established the privately owned Communications Satellite Corporation (Comsat), which enjoyed a monopoly over international satellite service to and from the United States for the next generation of satellites. Comsat became the nucleus of Intelsat in 1964, with Early Bird providing its early fleet, and originally owned one half of its shares; it remains the intermediary between Intelsat and the U.S. government and telecommunications industry. The organization started with 19 signatories from the economically developed world but excluded the Soviet bloc; today, 201 states are represented.

Intelsat is not regulated by any public body and is accountable only to its owner members, the stock holders. Political power is concentrated in the Board of Governors, in which voting power is proportionate to the share of ownership, with a dues structure similar to that of the United Nations. Not surprisingly, the United States is the largest contributor, responsible for almost one quarter of Intelsat's total revenues. Most international telephone calls (which generate two thirds of its revenues) are routed through Intelsat's satellites, each of which carries tens of thousands of voice circuits, although international television is its most rapidly growing source of revenue. Other services include radio, integrated digital services, business-to-business services (e.g., orders, inventory control), financial data transmission, rural community services, news gathering, and weather reports. Although it was initially erected to serve only international traffic, Intelsat began to offer domestic services as well in 1976. Today, it remains by far the world's largest provider of domestic (as well as international) satellite services through leased transponders and provides a means to regulate orbits and frequencies as well as for international pooling of financial resources and sharing of risk.

Intelsat's infrastructure dwarfs that of any single state or organization. It owns and operates a fleet of 25 high-powered spacecraft in geosynchronous orbit over the Atlantic, Pacific, and Indian oceans—far more than any other network; indeed, Intelsat's size allows it to boast of being virtually the only truly global satellite system. Intelsat's 433 earth stations, which constitute 79% of the world's earth stations capable of international traffic, give it a near-monopoly



status. While Intelsat's clients are primarily corporate, it maintains a nonprofit side as well, a policy designed in part to ameliorate concerns among less developed nations that the organization serves only the interests of the West. The Intelsat signatory agreement calls for global averaging of prices between high-traffic routes to subsidize the less profitable ones, a measure intended to ease the costs on poorer nations; thus, all nations pay the same price, regardless of the actual service costs—an attempt to provide ubiquitous coverage. Similarly, Peacesat (the Pan Pacific Education and Communication Experiments by Satellite Project) provides health, education, and research services over the Pacific Ocean using NASA satellites.

Because Intelsat's member states were allied with the United States during the Cold War, it was long viewed by the Soviet Union as an instrument of U.S. domination over the world telecommunications network. To counteract Intelsat's hegemony, the USSR developed its own system, Intersputnik, headquartered in Moscow. Although Intersputnik was proposed in 1968, it did not begin operation until 1974, and today it consists of eight geostationary satellites (and several nongeostationary ones) and 32 earth stations capable of international traffic. Traffic on the Intersputnik system, however, is only a fraction of Intelsat's. During the 1980s, Intersputnik's members were limited to the USSR and client states in Eastern Europe, as well as Iraq and Syria. With the collapse of the USSR in 1991, other nations sought access to its network, leading the United States, Canada, Japan, and China to join, while the Central Asian republics dropped out.

In contrast to Intersputnik, which was intended to rival Intelsat, three other, smaller satellite systems were erected to complement the organization. Concerned that the prevailing networks provided insufficient coverage of maritime regions, the International Maritime Organization, the UN agency concerned with safety at sea, initiated Inmarsat in 1973 to provide maritime satellite services. Because maritime communications are a low-volume and hence low-revenue market, they had been ignored by Intelsat, which catered to corporate interests. Headquartered in London, Inmarsat is a nonprofit cooperative of

28 countries, including the United States, Russia, China, India, Japan, Australia, Brazil, and most of Europe. Today, its network consists of four geostationary satellites and 23 earth stations that assist aviation and shipping firms, governing, among other things, distress calls, ship-to-shore communications, ship-to-ship telephony, electronic data interchange, and weather updates and providing safety information about high-traffic regions and potential hazards.

The European Telecommunications Satellite Organization formed Eutelsat in 1977 to complement Intelsat services over the European continent, including television, telephony, and data communications for computer networking. Coordinated by the European Space Agency and headquartered in Paris, Eutelsat wholesales its capacity (24 satellites and 23 earth stations) to national carriers, which in turn sell it to retailers. The end of the Cold War allowed Eutelsat to expand into Eastern Europe, so that today 23 nations are its members, including Germany, Turkey, Armenia, and Belarus.

Developing countries also complemented Intelsat with their own regional systems. In 1976, the Arab League formed Arabsat, a regional satellite system. With only 17 members, three satellites, and 18 earth stations, however, Arabsat is small, and its capacity is largely underused. One half of its shares are owned by Saudi Arabia. Political differences among Arab nations have hindered its growth: For example, Egypt was barred from membership between 1979 and 1989 because it signed the Camp David Accords. Given the authoritarian control exerted by many Arab governments over flows of information, frequent prohibitions exist against the import of satellite programs deemed immoral or decadent. Other, similar systems include the Regional African Satellite Communications System (Rascom) and, in South America, the Condor Alliance of Andean Nations. This brief overview demonstrates the key role of the nation-state in the changing regulatory organization of the industry, the contradictions between state and market imperatives, their changing boundaries and relative significance, and the intractably geographical nature of the industry. Despite the fact that satellites were designed to annihilate space via instantaneous communications, uneven social and spatial access

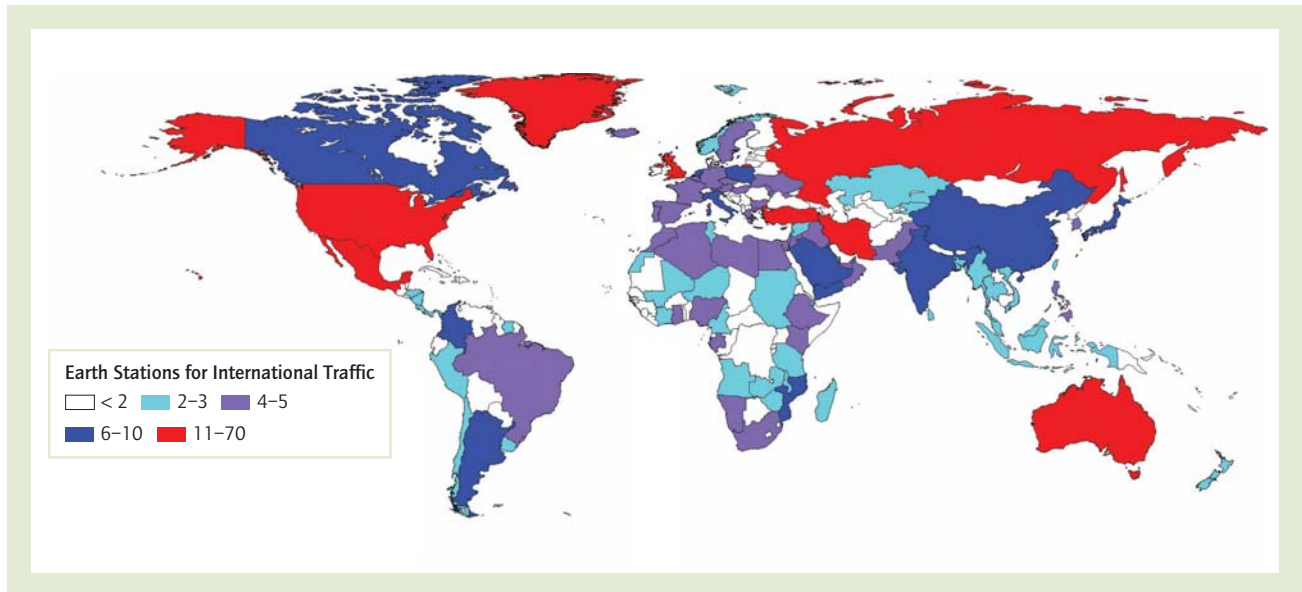


Figure 1 Location of the world's international satellite earth stations. In 2004, 483 earth stations were sufficiently large to upload or download information from satellites in geosynchronous orbit.

Source: Author.

to satellite technology has been a key feature of the industry since its inception (Figure 1).

The Contemporary Satellite Industry

In the post-Cold War era, Intelsat has been faced with two major sources of competition. The first stems from national satellite systems erected by individual nations. Indonesia, the first developing nation to use satellites for domestic connectivity, launched several generations of its Palapa ("Unity") satellites in the 1980s to provide services to all 27 provinces and recently began to sell them to neighboring ASEAN (Association of Southeast Asian Nations) countries as well. India initiated the Indian National Satellite System (Insat), primarily to provide low-cost educational services to remote villages and, in 1981, launched its first indigenous telecommunications satellite, the Ariane Passenger Payload Experiment. In the 1990s, India put into orbit three Insat satellites, thus joining the small group of nations that not only build but also launch these devices. Brazil's BrazilSat system leased its first satellite in 1974 and launched two more in the 1980s, expanding its domestic network with 21 earth stations. In the

same vein, Mexico, China, France, Turkey, and Thailand all initiated national satellite systems, some with their own launch capabilities. Unlike complementary networks such as Inmarsat or Eutelsat, national satellite systems are designed explicitly to bypass Intelsat.

The rapidly growing market for satellite services has been driven by the explosive growth of cellular telephones, which now outnumber landlines worldwide. Wireless technology (cell phones and satellite television) was made feasible through the deployment of a series of Direct Broadcast Satellites (DBS) that can transmit directly to small rooftop antennae or cellular towers. Unlike the large, expensive geostationary satellites, DBS can orbit in a variety of orbits designed to maximize the flexibility and utilization rate of the network. The growth of the wireless market in some respects has given the satellite industry a new lease on life, and it has become an increasingly important source of revenue.

Finally, the satellite industry as a whole has been besieged by mounting competition from fiber optics carriers, the mode of choice for many large service firms due to the security they offer. The competitiveness of satellites versus fiber lines depends on the transmission distance; generally,



satellites are more cost-effective over very long distances. However, fiber optics allows for greater security and is heavily favored by large corporations for data and voice transmissions and by financial institutions for electronic funds transfer systems. Capacity growth in the fiber optics industry has been particularly explosive, and transmission costs have dropped accordingly, which extended the break-even distance with satellite competitors, sharply eroding the latter's market share. Today, fiber optics carriers represent 86% of worldwide transmission capacity, including 87% across the Pacific Ocean and 80% across the Atlantic Ocean. The results of this conjunction of circumstances—deregulation, heightened competition within the industry, and devastating inroads made by fiber optics carriers—have led to the recent slump in the satellite industry, with decreased demand, bankruptcies, and declining orders for new satellites.

Conclusion

Satellites as both mechanisms of observation and a means of communication reflect, and in turn feed back into, terrestrial politics in many ways. Born of Cold War rivalry, satellites played a key role in the militarization of space: The footprints of those in geostationary orbit create a spatial field of power subject to the gaze and manipulation of military planners. Although the military's role in the satellite industry has declined, military uses continue to remain an important segment distinct from civilian applications. The geography of large international earth stations, the foundational technology on which participation in this sector relies, reflects the persistent schism between the developed and underdeveloped worlds, and, to a lesser extent, the legacy of the Cold War. Hence, while satellites float thousands of kilometers overhead, the determinants of access and use are firmly grounded in terrestrial politics.

Barney Warf

See also **National Aeronautics and Space Administration (NASA); Remote Sensing; Remote Sensing: Platforms and Sensors; Telecommunications and Geography**

Further Readings

- Day, D., Logsdon, J., & Latell, B. (Eds.). (1998). *Eye in the sky: The story of the CORONA spy satellites*. Washington, DC: Smithsonian Institution Press.
- Gaffney, T. (2000). *Secret spy satellites: America's eyes in space*. New York: Enslow.
- Mack, P. (1990). *Viewing the Earth: The social construction of the Landsat satellite system*. Cambridge: MIT Press.
- Warf, B. (2006). International competition between satellite and fiber optic carriers: A geographic perspective. *Professional Geographer*, 58, 1–11.
- Warf, B. (2007). Geopolitics of the satellite industry. *Tijdschrift voor Economische en Sociale Geografie*, 98, 385–397.



SAUER, CARL (1889–1975)

Carl Sauer was a towering figure in geography and in the intellectual life of America during the middle of the 20th century. The term *polymath* has often been applied to him because of his wide knowledge in the humanities and natural sciences, especially where these impinged on his research interests in Ibero-America, plant domestication, early humans during the Pleistocene, and the destructive exploitation of Earth. He displayed an ability to link diverse evidence together and then take bold, intuitive leaps and speculative sweeps. The historical past, ecological thinking, and methodological diversity were all central to his understanding of the contemporary cultural landscape. Cultural geography became associated with his name, and his many students spread the word about the Berkeley School of cultural geography. He held strong views about the importance of scholarship. His work was characterized by independence of thought, opposition to academic bureaucracy, sympathy and identification with rural folk, a concern for cultural diversity and environmental quality, and a distaste for the technological and scientific “fix,” particularly the solutions offered by the emerging social sciences after 1940.



Background and Reputation

Sauer was born in Warrenton, Missouri, on December 24, 1889. He took his first degree at the Central Wesleyan College, Warrenton (now defunct), moved to Northwestern University in 1908, and then completed his PhD in the first full-fledged department of geography at Chicago University in 1915, under the varied and different influences of Ellen Churchill Semple, Harlan Barrows, and the geologist and charismatic head of department, Rollin Salisbury—all of whom had a lasting influence on him. During those years, he was commissioned by the state geological department to write a geography of the Upper Illinois Valley, and he also completed the fieldwork for his PhD on the Ozarks. He then taught at the University of Michigan until 1923, when he moved to Berkeley, where he taught for 34 yrs. (years), 32 yrs. as chair of the geography department) and established one of the most distinctive graduate schools of American geography, one that would always be associated with cultural geography. He was also one of the chief advisors to the Guggenheim Foundation from 1935 to 1955 and to the social sciences division of the Rockefeller Foundation for nearly as long. After he retired in 1955, he enjoyed 20 remarkably productive years that saw the publication of four books and a score of influential papers.

The Cultural Landscape

Sauer rejected the prevailing ethos of human geography as environmental determinism, and in his work on the Ozarks, Illinois, and the Economic Land Survey of the Michigan Cutovers, he promoted a more humane and culturally nuanced human geography that took full account of the natural sciences, ecology, and the historical record and exhibited an empathetic understanding for both the people and the landscape. Much evidence was gathered through fieldwork, on which he put special emphasis.

On arriving in Berkeley, he found the social anthropologists Alfred Kroeber and Robert Lowie agreeable intellectual companions, which reinforced the cultural bias. In a famous essay, “The Morphology of Landscape” (1925), he established the primacy of human agency in the

formation of cultural landscapes fashioned from a natural landscape by a culture group and the importance of a time-based approach. “Morphology” became one of the most influential and debated papers in American geography during the ensuing decades. During the 1930s, he started substantive fieldwork on early settlement and society in Southern California, Arizona, and Mexico. These investigations drew him into the controversy about New World plant domestication and origins and into collaboration with botanists, archaeologists, and ethnologists, whom he considered as more congenial intellectual company than most geographers, whom he found to be shallow, intellectually ignorant, and consequently ignored.

Destructive Exploitation

Even in his student days, Sauer was struck by the ability of humans to deform and destroy the Earth. From the Ice Age onward, humans had changed vegetation types and distributions. His work on the Michigan Land Economic Survey, and his later role as advisor to the U.S. Soil Conservation Service, working in the eroded lands of the Southern Piedmont, reinforced this conviction. His fieldwork and knowledge of Latin and Central America and their history suggested that the Spanish conquest had led to a similar devastating and permanent impoverishment of the land and of its cultures and societies, causing catastrophic population decline. The diffusion of technologically superior societies could affect cultures and human life just as much as it could physical resources. Papers written by him between 1936 and 1938 on the human impacts were truly revolutionary in their condemnation of the destructive social and environmental impact of European imperialism and colonialism.

Agency of Humans on Earth

Sauer’s scholarly reputation led to his being asked to organize a major symposium of international scholars on “Man’s Role in Changing the Face of the Earth” in 1956. But because of his pessimism about the future world, he handed over part of the organization to Marston Bates and Louis Mumford and “retreated” into a consideration of “how we got to where we are.”



Somehow, humans had to rise above their mindless, short-term exploitative mode and try to conserve “a good Earth.”

Diversity and Scholarship

In later life, Sauer became increasingly critical of Western technology, ways of life, and intellectual trends. Americans seemed to think it a civic duty to “live beyond one’s means,” while communities were disintegrating under the pressures of mass production (“commodity fetishism”). Globally, the “imperialism of production” was as bad as the old, colonial imperialism, and mass culture was destroying older and less robust societies. Social theory, according to Sauer, was insidious as it led to cultural hegemony and homogeneity and the end of diversity and individual action and scholarship. It was the inherent pluralism and diversity of nature and culture that stimulated curiosity about the world, which was the essence of geography.

Sauer’s simply articulated ideas and pithy language had a resonance with many intellectuals and activists, who extolled his work as an example of cultural and ecological sensitivity and respect, tinged with deep historical insight and scholarship. Sauer, however, was a paradox, because although he was deeply conservative, his nonconformity and questioning were deeply inbred. He was aware that he was “out of step” with his colleagues and other intellectuals, yet his profound concern with conservation was never formally “environmentalist,” and indeed, he thought that the early movement was little more than an “ecological binge.” The legacy of his work in geography and Earth history is wide-reaching because he anticipated brilliantly society’s disenchantment with progress, science, the elimination of diversity, and the degradation of the environment and the need to bridge the gap between the social sciences, the humanities, and the life sciences.

Michael Williams

See also Berkeley School; Cultural Geography; Cultural Landscape; Environmental Determinism; Human Geography, History of; Parsons, James; Semple, Ellen Churchill

Further Readings

- Callahan, R. (Ed.). (1981). *Selected essays 1963–1975: Carl O. Sauer*. Berkeley, CA: Turtle Island Foundation.
- Kenzer, M., & Mathewson, K. (2003). *Culture, land, and legacy: Perspectives on Carl Sauer and Berkeley School geography*. Baton Rouge: Louisiana State University Press.
- Leighly, J. (Ed.). (1963). *Land and life: A selection from the writings of Carl Ortwin Sauer*. Berkeley: University of California Press.
- Sauer, C. (1925). The morphology of landscape. *University of California Publications in Geography*, 2, 19–54.
- Williams, M. (1983). “The apple of my eye”: Carl Sauer and historical geography. *Journal of Historical Geography*, 9, 1–28.



SCALE, SOCIAL PRODUCTION OF

One of geography’s core ideas, scale has become a hotly contested, even chaotic, concept. Until the 1980s, scales (such as the national or regional scales) were frequently employed, but little time was devoted to theorizing scale itself. Scale was a taken-for-granted concept used to impose organization and order on the world. A much vaunted “scale debate” emerged during the 1980s, developed through the 1990s, and erupted in the early 2000s. The debate centers on whether scale is a mental device for categorizing and ordering the world or whether scales exist as material social products.

A Marxist “Theory of Scale”

Linked to processes of globalization, localization, and regionalization, scale became a fundamental concept for political geographers in the 1980s. The works of Peter Taylor and Neil Smith were pivotal in identifying the different levels at which processes of the world economy are manifest. Both identify a nested hierarchy of scales running from the global to the local. Taylor’s three-level model of the modern world system identified the



world economy, nation-state, and locality, while Smith highlighted urban, regional, national, and global as critical scale categories. Introducing for the first time a “theory of scale,” this approach was not without its critics. Scales were rather more fixed than is commonly accepted today. The result saw scale categories reified as distinct levels of analysis, each with its own disciplinary following. Integration of analysis across scales and/or at multiple scales therefore proved difficult, with many arguing that scale lacked practical as well as rhetorical value. Finally, this first cut at a theory of how scales are produced was heavily inscribed with Marxist ideas of materialism. This is to say that scales are real social products (not simply handy conceptual mechanisms for ordering the world) and they emerged out of the dynamics of capitalist accumulation.

Scale as a Dynamic Construct

Rather than see scale as a nested hierarchy, debate in the 1990s focused on discursive and relational notions of scale that moved away from scale as a taken-for-granted to scale as a dynamic concept. This debate took place largely in the journal *Political Geography*, with social constructivist approaches demonstrating how scales are the negotiated outcome of social and political struggle. More than this, they showed how scales are always in the process of being produced and reproduced, and it was in this context that the concept of a politics of scale was introduced and developed. To compensate for the overreliance on the rhetorical value of scale in the 1980s, accounts from the 1990s also argued that scale politics are not found in theoretical discourse but in real-world practices of social conflict and struggle. Notable empirical studies from this time focused on telecommunications, labor restructuring, and political parties to highlight how scales are socially constructed, not ontologically pre-given. Scales such as the national and regional were no longer seen to be part of some logical hierarchy between global and local but as *actively* created by political and economic processes. In other words, scales are not “out there” waiting to be used but must be brought into being and given meaning.

In such an approach, the scales at which social actors and processes operate cannot be conceived

of as disconnected from the actors and processes that create them. Often quoted here is the example of the transnational corporation, for these firms do not simply adapt their activities to a pre-defined global scale but must themselves become global by actively constructing their own global scale of operation. Emphasizing this constructivist approach to scale is the notion that firms go global by globalizing their operations to keep up with the increased hypermobility of globalized capital.

One criticism to emerge from this body of work was against the assumption made by some materialists that the local is a “natural” or “default” scale. In making this argument, all social actors begin as “local” actors before moving on to become regional, national, and, finally, global actors. The global scale was thus something for actors to aspire to. Being global was a measure of success and reinforced this hierarchy of scales from local to global. In response, it was argued that the local is no more natural than the other scales and is produced in the same way. In a world where many predicted the “death of distance” and the “end of geography,” authors quickly highlighted the importance of nurturing place-based and site-specific nodes of dense economic, social, and political activity in a globalizing world. Understanding the processes by which social actors embed themselves locally was thus seen to be as important as understanding how they extend themselves globally. In sum, scales were not conceived of as fixed entities static in space but in terms of a process where social life is constantly being made and remade by social actions.

Scale or No Scale: That Is the Question

The most recent debates over scale have been found in journals such as *Progress in Human Geography* and, later, the *Transactions of the Institute of British Geographers*. Work at the beginning of the 21st century has focused on moving the debate outside the narrow economic confines of theorizing how scales are forged out of struggles around capitalist production and its uneven development. These productionist views were criticized for overlooking how issues of social reproduction and consumption have shaped, and continue to shape, the construction of scales. In expanding the concepts of scale to



encompass issues of reproduction and consumption, noncapitalist social relations (such as patriarchy) have been shown to underpin the production of certain key spaces (e.g., the home) and scales (e.g., the household/domestic scale). However, this expansion has not been without its critics. Calls for *household*, *domestic*, and *neighborhood* to be more centrally located alongside *local*, *regional*, *national*, and *global* in a broader scalar lexicon raised concerns over the degree to which geographers use scale when referring to things that could just as easily be deemed place, locality, territory, or space. Most recent work has thus centered on the degree to which the analytical powers of the concept of scale have been diluted by its perceived overuse and misuse and, most important of all, what this means for the future of the concept in human geography.

Arguing that the concept of scale has been misused and, therefore, diluted by those seeking to understand the political struggles taking place *within* relatively self-enclosed spatial units (such as the household or territory), those seeking to “protect” the concept of the politics of scale suggest that its analytical power should be maintained and can be retained if applied only to exploring processes of spatial scaling *among* geographical scales. In other words, the geographical concepts of place, locality, territory, and space should be invoked to refer to political struggles taking place within relatively self-enclosed spatial units, and the concept of the politics of scale should be used to refer specifically to the process of scaling, where multiple spatial units are established, differentiated, and hierarchized in relation to one another. Drawing a distinction between the “production of space” and the “production of scale”—to affirm the analytical power of the concept of the politics of scale—has, however, been challenged by those who continue to see notions of scale as privileging a view of the world as hierarchically constituted. Notions of scale are hereby seen to convey the sense that activism and politics operate through vertical hierarchies and a related tendency to see one scale (especially “the global”) as privileged over others. From this perspective, the problem with scale is not the misuse of the concept but the concept itself. In 2005, Sallie Marston, John Paul Jones III, and Keith Woodward took the previously unheralded

step of calling for scale to be expurgated from the geographic vocabulary and notions of scale to be abandoned. For them, scalar analysis operates within a conceptual straitjacket, limited to viewing change as either downward (from global to local) or upward (from local to global), while attempts to integrate vertical imaginaries with network formulations are deemed inadequate for overcoming this “foundational weakness” of hierarchical scale. Rejecting not only the “up-down vertical imaginary” but also the “radiating (out from here) spatiality” of horizontal thought, Marston et al. argue for an alternative, “site-based” ontology that does not rely on *any* transcendent predetermination—be it the “local-to-global continuum” in vertical thought or the “origin-to-edge imaginary” in horizontal thought. Put forward as an alternative to scale, this site-based ontology is deemed to flatten space into multiple interconnected sites and thus render scale a redundant concept in human geography.

The most provocative of interventions into the scale debate has witnessed an explosion of interest in scale and scalar geographies. Most reactions argue for a retention of scale, despite its weaknesses and the varying degrees of sympathy with authors’ frustration with these. One point most critics agree on is the false dualism created by debunking scale and privileging site (i.e., scale vs. site), a symptom of what many are coming to see as the theoretical, methodological, and empirical trap of one-dimensionalism—the privileging of a single dimension of sociospatial relations (in this case “networks”) over another (“scale”). This, it is argued, sees the bending of a concept to expand its analytical and empirical scope in order to include an ever-increasing portfolio of phenomena, a process that over time renders the concept increasingly imprecise, diluted, and blunt. With this in mind, perhaps the question for the next decade is not whether scale should be retained but how a carefully defined abstraction of scale interconnects with the other dimensions of sociospatial relations (e.g., territory, place, networks).

John Harrison

See also **Critical Human Geography; Globalization; Glocalization; Locality; Scale in GIS; Smith, Neil; Taylor, Peter; Territory**



Further Readings

- Brenner, N. (2001). The limits to scale? Methodological reflections on scalar structuration. *Progress in Human Geography*, 25, 591–614.
- Herod, A., & Wright, M. (2002). *Geographies of power: Placing scale*. Oxford, UK: Blackwell.
- Jessop, B., Brenner, N., & Jones, M. (2008). Theorizing sociospatial relations. *Environment and Planning D*, 26, 389–401.
- Jonas, A. (2006). Pro scale: Further reflections on the “scale debate” in human geography. *Transactions of the Institute of British Geographers*, 31, 399–406.
- Jones, K. (1998). Scale as epistemology. *Political Geography*, 17, 25–28.
- Marston, S. (2000). The social construction of scale. *Progress in Human Geography*, 24, 219–242.
- Marston, S., Jones, J. P., III, & Woodward, K. (2005). Human geography without scale. *Transactions of the Institute of British Geographers*, 30, 416–432.
- Moore, A. (2008). Rethinking scale as a geographical category: From analysis to practice. *Progress in Human Geography*, 32, 203–225.
- Paasi, A. (2004). Place and region: Looking through the prism of scale. *Progress in Human Geography*, 28, 536–546.
- Sheppard, E., & McMaster, R. (Eds.). (2004). *Scale and geographic inquiry*. New York: Wiley-Blackwell.

SCALE IN GIS

Scale has many connotations in geographic information systems (GIS) research and education. Among its most frequent uses, scale captures the relationship between distances in the real world and the distances among objects on GIS maps and in spatial databases. In this sense, scale is the level of reduction associated with representing Earth's features in GIS and cartographic databases. There is also the related concept of spatial scale, which deals with the level of resolution or granularity of spatial objects in terms of what are the finest discernable details. Along similar lines, the temporal scale associated with spatial data

indicates how frequently data are collected for the same area. Last, the notion of a scale is often used in GIS project management and modeling to gauge the effort required to complete a given set of tasks and/or to describe the extent of the area covered by the study.

Map Scale

In map design and production with GIS, it is very useful to think of scale as the ratio of distance on the map to distance on the ground. This is the representative fraction, and with a map of 1:2,500, 1 inch on the map equals 2,500 feet on the ground (metric units may be used as well). A map at 1:2,500 is known as a large-scale map because the fraction (1/2,500) is large compared with other possible map scales. Large-scale maps are particularly good at showing local-level details over a relatively small area.

As seen in Figure 1, land parcel boundaries for a neighborhood are mapped at a scale of 1:2,500. It is easy to pick out the detail and characteristics of the parcel objects at this scale. If we change the scale to 1:35,000, which is generally considered to be a medium scale, many more of the parcel boundaries come into view for this particular area. But it becomes very difficult to visualize subtle differences in the parcel objects' shapes. Some parcel boundaries are visible at this scale, although there is a great deal of obfuscation in denser areas. Changing the scale to 1:1,000,000, we can no longer see any detail within the study area, and the general shape of its exterior boundary is no longer crisp. As such, maps with scales in the neighborhood of 1:1,000,000 are known as small-scale maps and are good at showing less detailed features over large areas. To put this scale into better context, the U.S. counties surrounding this neighborhood are also shown in the figure. The many large counties are well represented at this scale, but the neighborhood-level detail is lost. Therefore, a key issue in dealing with scales is to select one that is appropriate, given the mapping task at hand.

Spatial Scale

The spatial scale of a given data set is the smallest discernable unit of geography contained therein.

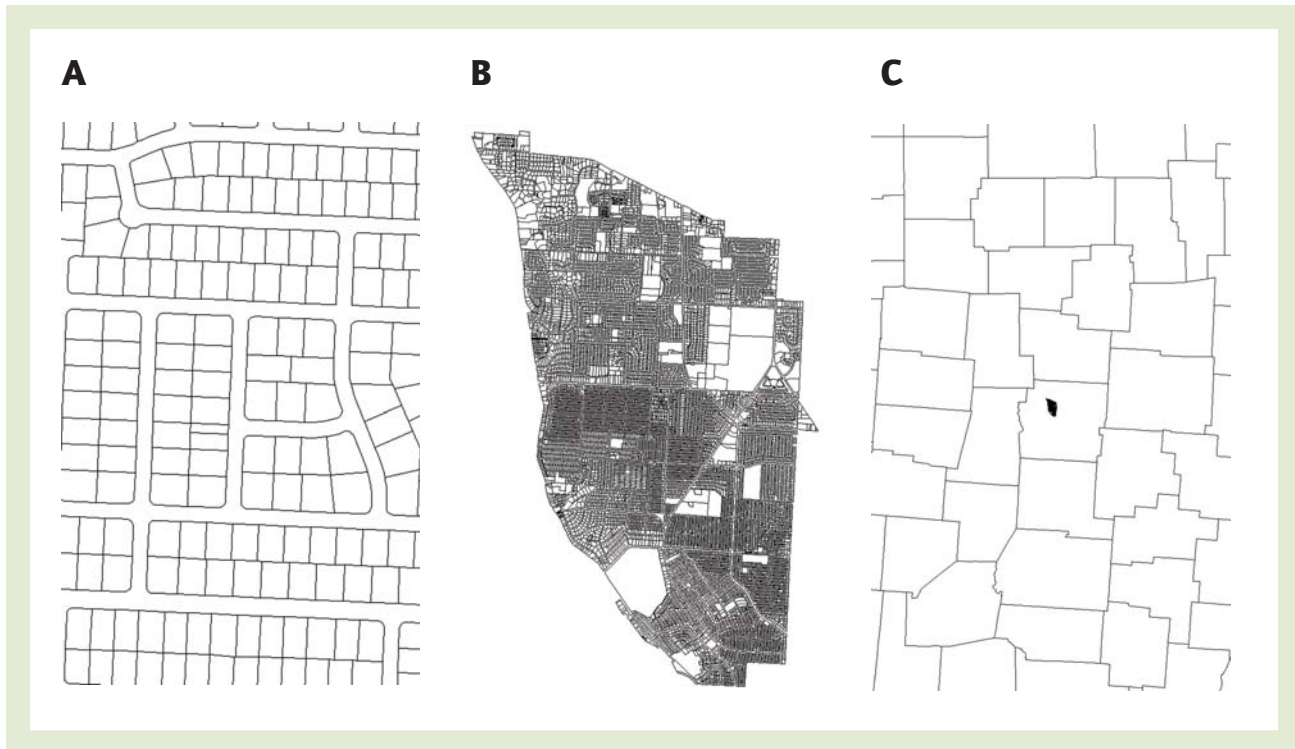


Figure 1 Sample neighborhood mapped at three scales: (A) 1:2,500, (B) 1:35,000, (C) 1:1,000,000

Sources: Parcel data from Franklin County Auditor, Ohio; county data from the U.S. Census Bureau.

It is also known as spatial resolution. Imagery data, for example, are widely evaluated based on how small a unit area one of its individual pixels or cells represents. Imagery captured from aerial photography routinely has a high resolution such that pixels represent areas of less than 1 m² (square meter). Imagery captured from a satellite station may also approach the resolution of imagery taken via aerial photography, but many satellite platforms offer much coarser resolutions, some greater than 1,000 m. The temporal scale of a data set, or the frequency of data collection for a given area, is also of relevance. Depending on the area, aerial photography, for example, can be quite variable in terms of how often new data are collected. On the other hand, many satellite-based forms of spatial data collection follow a regular temporal cycle. Spatial data collected at such regular cycles are useful in many applications, particularly those where careful monitoring of the changes in the landscape is required. In this way, users must not only consider the level of detail

associated with a data set, they must also consider its frequency of collection if there is a temporal dimension to their study.

There are many analytical situations where the spatial scale of the input data is an important concern. Many socioeconomic variables, particularly those associated with irregularly shaped census and enumeration units, are often available at a variety of spatial scales or aggregations. For example, median household income is available not only for counties in the United States but also for each census tract composing the counties and each block group composing the tracts. Generally, it is best to use the most disaggregated or resolute spatial data one can find given the aims of the study. This is because finer spatial data do a better job of representing the true spatial distributions of phenomena as they involve less generalization. However, there are cases where having extremely detailed data may not be necessary and may even limit some analytic capabilities. Some operations (e.g., facility location models) are sensitive to the number of



input units and may require a prohibitive amount of computer processing time if used with too detailed a data set. Thus, balancing the representativeness of the data with the limitations and constraints imposed by the specific GIS tools or modeling techniques is often a concern.

Project Scale

Certain aspects of designing and completing GIS projects may be qualified in terms of scale. For example, if a government agency or private business were building itself a GIS department from the ground up, the size of that department as perhaps measured by the level of staffing required and/or its hardware needs might be qualified as a small- or large-scale GIS implementation project. In a slightly different context, the work involved in completing a particular GIS-based project may be a matter of scale. For instance, if substantial primary data collection were involved or a large amount of time is spent on data manipulation, processing, and/or analysis, such efforts could be described in terms of their scale. Last, scale may be used to indicate the extent of the area analyzed in a given GIS project, with larger-scale projects referring to studies involving greater coverage. Clearly, each of these examples shows that the use of scale to describe aspects of GIS projects is subjective—for example, one person's large-scale project may be another's small-scale project.

Mark W. Horner

See also **Cartography**; **GIScience**; **GIS Design**; **GIS Implementation**; **Map Generalization**; **Scale**, **Social Production of**

Further Readings

- Demers, M. N. (2009). *Fundamentals of geographical information systems* (4th ed.). Hoboken, NJ: Wiley.
- Lo, C. P., & Yeung, A. K. (2007). *Concepts and techniques of geographic information systems* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science* (2nd ed.). Hoboken, NJ: Wiley.



SCHAEFER, FRED (1904–1953)

Fred Schaefer was a founding member of the department of geography at the University of Iowa, remaining there until his death in 1953. Schaefer is revered as a pioneer of the “quantitative revolution” in geography, for providing the greatest philosophical impetus for a scientific geography, although he died before many of its subsequent adherents met him.

Schaefer was born in Berlin and was an undergraduate at the University of Berlin (1928–1931) and a statistician for the city. But as a member of the Social Democratic Party, he fled from Nazi Germany in 1931 to Britain and then to the United States in 1938. He worked at an American Friends Service Committee refugee camp in Iowa before he joined the University of Iowa. His radical politics led to a degree of harassment in the period from 1946 to 1952.

His fame rests on the 1953 publication, which appeared just after his death, of an article in the leading American geography journal, the *Annals of the Association of American Geographers*, titled “Exceptionalism in Geography: A Methodological Examination.” The paper had an electrifying effect on the discipline. Schaeffer had written about the possibility of a theoretical scientific geography as early as 1943 and taught the works of the leading location theorists (e.g., Christaller, Loesch, Thünen, Hoover) as early as 1950.

That the manuscript was published is remarkable; he was helped by Harold McCarty, chair at Iowa and an early advocate of the quantitative revolution. This revolutionary document was at the same time a methodological and philosophical attack on the dominant paradigm of geography as “idiographic,” or as a synthetic, descriptive field, as laid out in Richard Hartshorne's *Nature of Geography*, and a call for a normal scientific approach to geography based on a search for geographic laws concerning spatial relations—a “nomothetic” approach. The article was denounced by Hartshorne and other defenders of traditional geography but became an article of faith for the younger generation of economic geographers (after 1955), who were determined to develop geography as a spatial science.

Richard Morrill



See also **Hartshorne, Richard**; **Human Geography**, **History of**; **Logical Positivism**; **Quantitative Revolution**

Further Readings

Bunge, W. (1979). Fred K. Schaefer and the science of geography. *Annals of the Association of American Geographers*, 69, 128–132.

Schaefer, F. (1953). Exceptionalism in geography: A methodological examination. *Annals of the Association of American Geographers*, 43, 226–245.



SCIENCE, TECHNOLOGY, AND ENVIRONMENT

The relation between science, technology, and environment is one of the key issues of late modernity. At the beginning of the 21st century, the impacts of science and technology on human life and the natural environment are greater than ever. Whereas an affirmative view on this development for a long time presumed that science and technology help solve the problems of humanity, critical perspectives on the human-nature relationship increasingly found voice during the second half of the 20th century (among others, the social scientists Max Horkheimer and Theodor Adorno, the philosopher Hans Jonas, and more recently the sociologist Ulrich Beck). Of course, this is not a new phenomenon, since skepticism regarding science and technology is as old as science and technology themselves. But because the negative effects of modern domination of science and technology over both human and nonhuman life as well as on abiotic realities have reached a global scale, the demand for a reconfiguration of the use of science and technology to transform nature emerges. Thus, issues pertaining to the consequences of science and technology are currently being discussed by politicians as well as by social and natural scientists. Geography, which as a discipline, throughout its historical development, was concerned with nature and the environment (from the first descriptions of the Greek

explorer Herodotus in the 5th century BC until the modern-day analysis of geo-ecosystems, or the study of the social construction of nature), is a key science in environmental discourse.

Irrespective of their arguments, most critics refer to the rationalization and instrumentalization of the natural environment that has attended modernity. Rationalization means an abstract, mathematical representation of nature, based on reason rather than faith or myth. Instrumentalization, on the other hand, focuses on the benefit to humans in human-nature relationships. Both processes, critics say, lead to an alienation of humans from nature followed by the form of maladjustment of people to the environment that is currently called the ecological crisis. Despite a consensus about the critical role of science and technology in the process of modernization, there is confusion about the differences between them. Therefore, a review of these two social activities will be given in this entry. Also, the role of science and technology in the development of the ecological crisis will be examined.

Science and Technology

It is often presumed that science and technology differ in the following way. Science produces knowledge about the world, regardless of practical ends. Technology, in contrast, is the application of scientific knowledge to meet human needs. From this perspective, science precedes technology, which is a mere application of the scientifically discovered rules and laws of nature. This idea of the relationship between science and technology is flawed in at least one way. It misses the fact that science and technology are two interrelated but different domains of human activity, distinct in their aims, procedures, and historical development.

Science

The term *science* has its origins in the Latin word *scientia*, or knowledge. Thus, *science* describes the attempt of human beings to produce objective, reliable knowledge about the world. Sometimes the term *science* is also used to designate the outcome of this search—that is, the body of (scientific) knowledge. But this notion does not



capture the most important feature of science—that it is a social activity.

It is by the application of certain methods that the outcome of the search for knowledge is regarded to be *scientific*. Consider other areas where particular capabilities are necessary. Craftsmen, for instance, also possess knowledge about the functioning of the world, but we would not necessarily agree that their knowledge is scientific. When scientists do their work, however, in the majority of cases they follow rules that their fellow scientists agree to and produce knowledge that is testable (verifiable or falsifiable). A clear illustration of this is provided by the role of experimentation in physics. A laboratory experiment has to be reproducible in order to obtain status as scientific knowledge.

Historically, the first objective of science was to describe and explain natural phenomena. Thus, science was first of all natural science, which was concerned with finding or formulating general laws of nature. Newtonian physics is a classic example of the functioning of modern science. Even though there was “scientific” research during Greek and Roman antiquity, as well as in the Middle Ages, the foundations of modern science were laid in the 16th century. In the course of the “Scientific Revolution,” works of astronomers such as Galileo Galilei, Johannes Kepler, and Sir Isaac Newton were a major step forward in understanding the physical world. Equally, the later works of the founder of modern chemistry, Robert Boyle, and the zoologist Carl Linnaeus established the notion of nature and the environment as scientifically comprehensible and technically manageable.

In contemporary understanding, however, the explanation of natural phenomena is only one domain of science. Science can now be divided into two branches: the natural sciences and the social sciences. The social sciences try to understand human action. As a distinct field of research, the social sciences are relatively young, beginning only by the end of the 19th century. First shaped according to the model of the natural sciences, the social sciences soon developed their own concepts and theories. Two of the key figures of the emancipation of the social sciences from the natural sciences were the French sociologist Emile Durkheim and the German sociologist Max Weber. They successfully pointed out that

the methods of natural science were not appropriate for analyzing social phenomena. Since the sphere of the social consists of meaning, or meaningful action, a type of science that does not capture meaning cannot make reasonable claims about this sphere.

Both the social and the natural sciences are, or can be, concerned with nature. Whereas the nexus of the natural sciences to nature is obvious, the social sciences, among other things, investigate human-nature interactions. Social scientists, for instance, pointed out that there is an important connection between cultural or religious systems and the way in which nature is perceived and used by humankind. They also advanced the notion that nature and the environment are socially constructed and the natural sciences have no exclusive access to the “real” nature but are one mode of construction among others.

As regards the role of science in modern society, scientific knowledge has ample influence on what people think about nature and the environment. Even though there might be other ways of knowing the environment (to which the specific standards of scientific knowledge do not apply), science seems to dictate the concepts of nature’s “real” nature.

Technology

The second dominant way in which humans relate nature to themselves is by technology. The term *technology* stems from the Greek words *technē*, meaning “craft,” and *logos*, which means “reasoning.” Thus, etymologically *technology* means knowledge about techniques. Techniques are human acts of transforming nature (or the physical world) and the results of these acts. A very simple technique is thus the transformation of a stone and a piece of wood into a hammer (which as a tool is then used for further transformative acts). Another technique is the domestication of the biotic environment, in the form of growing cultural plants. A third and very sophisticated technique is genetic engineering.

What these techniques share is that they involve the production of an artifact—an object (or biological structure) that would not have existed naturally and that serves a certain purpose. Hammers are used to extend a human’s muscle strength.



Using global position system equipment on a farm for precision application of fertilizers, pesticides, and herbicides, Northern Louisiana

Source: Bob Nichols, U.S. Department of Agriculture Natural Resources Conservation Service.

Plants are used for food supply. Genetic engineering is used to make organisms resistant to certain environmental influences. In this regard, the production of a hammer and the manipulation of DNA are nearly the same. What these techniques, on the other hand, do not share is the degree to which they influence the environment. While a hammer commonly has only a local, small-scale impact on its environment, the interference in biological structures such as DNA can change whole ecosystems up to the global scale.

The question of the implications of techniques points to the concept of technology, as opposed to technique. Technology in the strict sense is best conceived as the systematic analysis of the human use of techniques. As such, it not only involves knowledge about specific techniques in certain fields (e.g., expert knowledge about crop behavior

under different environmental circumstances) but also knowledge about the framing or use of the techniques—that is, the social context in which the transformation of nature takes place.

The everyday use of the term *technology* in both scientific and nonscientific areas points to a merging of the notions of technology and technique. Simply put, in the Anglophone tradition, the terms *technology* and *technique* are often used interchangeably. For instance, the concept of “information technology” involves both concrete technical solutions to problems of information, transport, and processing and knowledge about interrelations in this field.

By identifying goal orientation as the distinctive feature of technology, the differences between technology and science become obvious. Whereas scientific conduct invariably involves compliance



with rules and standards to secure objectivity to its findings, the only criterion that technology is judged by is its pragmatic success. Of course, modern science cannot be separated from the use of technologies, since science and technology closely relate to one another. Science uses technologies to make its findings, while scientific knowledge is applied to develop new technologies. Both science and technology contributed to or enabled the aforementioned rationalization and instrumentalization of nature in modernity. Science incorporated the abstract, mathematical conception of nature, and technology or technique is by definition goal orientation.

Finally, both science and technology are social activities. In other words, they are performed by agents, embedded in a system of beliefs, and equipped with certain stocks of knowledge and a set of needs and desires. What results from this understanding of science and technology is that the environmental change that is driven by (natural) science and technology can only be comprehended by drawing attention to the social dimensions of the two phenomena. One approach to highlight the role of science and technology in the process of modernization is Ulrich Beck's diagnosis of the ecological crisis and the risk society.

Ecological Crisis and Risk Society

The indication of the unintended consequences of the nexus of science, technology, and environment is not exclusively a phenomenon of late modernity. As early as 1864, the U.S. environmentalist and geographer George Perkins Marsh warned of environmental hazards caused by human action. The problems that emerged in the shift from preindustrial to industrial and then from industrial to postindustrial societies, however, reached a hitherto unknown dimension. The clearest manifestation of this process is the development of technologies, namely, nuclear fission, that potentially can exterminate all life on Earth. Furthermore, the widespread use of technologies such as synthetic pesticides has led to irreversible damages to both humans and the environment.

According to Ulrich Beck, the latter developments are signs of a new, reflexive type of modernization. Reflexivity in this context means that the "nontechnical" question of improving

human efforts to dominate nature is the prime concern of society today, but the technological development itself becomes the focus of critical questioning. Nuclear power is the best example of this process. Nuclear power, conceived as a form of taming nature to meet human needs, becomes reflexive in the sense that the risks and side effects of this technology are much more dangerous than nature itself. Late modern societies thus must face nature-related problems that they themselves have produced.

The role of (natural) science in this context is ambiguous. On the one hand, the complexity of the highly technologized world permanently demands expert knowledge. On the other hand, in late modernity, science no longer has the prerogative of providing an interpretation and definition of nature. To an increasing degree, politics and moral instances are part of environmental discourse. Hence, geography, as a discipline in both the natural sciences as well as the social sciences tradition, has a crucial role in the age of ecological crisis.

Karsten Gaebler

See also Critical Studies of Nature; Environmental Discourse; Global Environmental Change; Human Ecology; Hybrid Geographies; Marsh, George Perkins; Modernization Theory; Nature; Nature-Society Theory; Science and Technology Studies; Social Construction of Nature; Sustainability Science

Further Readings

- Agassi, J. (1966). The confusion between science and technology in the standard philosophies of science. *Technology and Culture*, 7, 348–366.
- Beck, U. (1992). *Risk society*. Newbury Park, CA: Sage.
- Carson, R. (1962). *Silent spring*. Boston: Houghton Mifflin.
- Jonas, H. (1985). *The imperative of responsibility*. Chicago: University of Chicago Press.
- Marsh, G. P. (2003). *Man and nature*. Seattle: University of Washington Press. (Original work published 1864)
- White, L., Jr. (1967). The historical roots of our ecological crisis. *Science*, 155, 1203–1207.



SCIENCE AND TECHNOLOGY STUDIES

Science and technology studies (STS) is defined as the interdisciplinary study of the social, cultural, and political dynamics that inform and shape science and technology and how these in turn inform and shape future society, politics, and culture. The premise adopted in STS is that science and technology are not value-free, apolitical activities as has tended to be assumed in “realist” accounts. Rather, science and technology are assumed to be informed by values, to be “framed” in ways that privilege particular (often expert) groups, to reflect particular “ways of seeing” the world, and to “perform” social relationships. For this reason, much of STS has sought to develop “socially constructivist” approaches aimed at understanding the role of science in apprehending, measuring, defining, and legitimating social reality.

This entry reviews the history of STS and how it has come to constitute a distinctive body of thought. STS is a subdiscipline with its own professional societies (notably the *Society for the Social Studies of Science* [or 4S] and the *European Association for the Study of Science and Technology* [EASST]), several high-profile interdisciplinary journals (*Social Studies of Science*; *Science, Technology, & Human Values*; *Science as Culture*; *Minerva*; *Public Understanding of Science*; *Science and Public Policy*), a series of *Handbooks of Science and Technology Studies*, and numerous university departments, courses, and degree schemes.

Phase 1: The Sociology of Scientific Knowledge

Throughout the 1970s, a program of research was developed aimed at destabilizing the epistemological belief that scientists had special access—through the application of the proper use of the scientific method, empirical observation aimed at development of theory, and so on—to underlying and unquestionable truths. Conceiving of science as a social practice and building on the discipline of the history and philosophy of science, practitioners in the sociology

of scientific knowledge (SSK) sought to unravel the ways in which scientific “fact” and theory emerge out of various and multiple social processes. Rather than assume an a priori objectivity, in which scientific knowledge is presented as a mirror of external reality (i.e., nature), SSK developed a method and approach in which all knowledge claims were to be examined with equivalent and symmetrical skepticism and where the object of inquiry was to examine the conditions under which claims to knowledge came to be seen as legitimate and true. A “strong program” developed committed to a relativist and empirical program aimed at studying the microsocial dynamics of science through which scientific reality came to be socially constructed through laboratory study and experiment.

Perhaps not surprisingly, such an overt attack on the authority of science led to a concerted counterattack from many in the scientific establishment who tended to criticize such interventions as unjustified, premised on faulty logic, sloppy in scholarship, and even politically motivated. The so-called science wars, between “postmodernists” or social constructivists on one side and scientific realists on the other, raged especially throughout the 1990s in several largely unproductive and often acrimonious exchanges. One highly published event was the “Sokal affair,” arising from a paper written by the physicist Alan Sokal purportedly to argue that quantum physics supported constructivist criticisms of the objectivity of science. Following publication in the journal *Social Text*, Sokal revealed the paper to be a hoax and cited the publication as demonstrable evidence of the poor standards and dogma that existed in postmodernist circles.

The field known as “science studies” extended its gaze to embrace the “technological” through a series of formative books in the 1980s. Arguing against technological determinism—the belief that technologies follow their own developmental path and trajectory, outside human influences—this body of work sought to highlight the human choices and values that are embedded in technological design, that constrain or enable innovation pathways, and that open the “black box” of technology to allow the socioeconomic patterns embedded in innovation processes to be exposed and analyzed.



Phase 2: From Epistemology to Politics and Public Engagement

Throughout the 1980s, a body of scholarship developed, concerned less with “internalist” matters of epistemology and scientific truth and more with “externalist” matters concerning the use of scientific knowledge in “live” public arenas and the potential for wider public involvement in scientific and technical decision making. This more overtly political variant of STS, with a normative commitment to social change, arose out of a dynamic interplay between SSK, controversy studies, legal scholarship, and risk theory. The analysis of public controversy proved to be a fertile ground for STS scholarship.

Brian Wynne was a formative influence as a scholar who sought to mobilize STS insight to assist wider recognition of marginal voices and conflicting framings of the scope and meaning of controversial issues. Analyzing the controversy over the proposed nuclear power–reprocessing plant THORP at the 1977 Windscale public inquiry in the United Kingdom, Wynne realized that the argument between the objectors and the protagonists was ostensibly one of framing: Whereas the official and expert-derived terms of reference related to the risks and implications of this plant alone, for the objectors the issue concerned the wider consequences of its construction, including the use of reprocessed plutonium for future bombs and the transport of spent fuel and other dangerous materials in the so-called plutonium economy. Without taking an explicit stance, Wynne argued (unsuccessfully) for a wider debate as to the extent to which the public inquiry should deliberate on these wider responsibilities. A similar account was provided of the North Sea Brent Spar oil platform controversy, analyzed by STS scholars as a conflict over the framing of what constitutes the salient issue. For Royal Dutch Shell and the U.K. government, the salient issue concerned the risks posed by the dumping of a single oil platform in the deep Atlantic Ocean, while for Greenpeace and other objectors, the core issue concerned the precedent the dumping would provide for disposing of all kinds of wastes, including radioactive waste. Furthermore, STS insight was brought to bear on, *inter alia*, the importance of framing to issues as

diverse as the bovine spongiform encephalopathy (BSE) mad cow controversy, the human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS), genetically modified (GM) foods and crops, xenotransplantation, nature conservation and wildlife, the addition of fluoride to public water supplies to prevent tooth decay, and intelligent design.

Of key concern across the above case studies was the way in which expert and scientific communities defined, established, and maintained official definitions of what is salient and what is erased from public attention. The politics of research was one of critical engagement with expert policy framings of significant public issues—themselves often reinforced by reductionist processes of scientific risk assessment—where the normative task was one of making public and other marginalized knowledge claims available to expert groups. A tradition of policy-oriented academic research emerged that used small groups as a deliberative space where lay publics could share their experiences, values, and knowledge and where STS scholars could bring recognition of such local knowledge in the quest of making decision making more socially robust.

Interestingly, and following a series of acute and politically damaging technological risk controversies (notably in the United Kingdom and Europe around BSE and GM foods), such scholarship contributed toward a more explicitly deliberative turn in technological governance. Whereas earlier technological decision-making processes had been grounded in notions of “sound science” and expert advice, where public opposition to technological innovation was represented as due to faulty and unreasonable logic, the new governance regime was more conciliatory to different kinds of knowledge claims, and the institutional task was to open up decision-making processes through dialogue with publics and other stakeholders. A series of influential reports were written, all calling for more proactive public involvement and deliberation in debates about the social and ethical dimensions of science and technology. In the United Kingdom, these included the formative 3rd report by the House of Lords Select Committee on Science and Technology, *Science and Society* (2000), and the 21st report by the Royal Commission of Environmental Pollution,



Setting Standards (1998), while in Europe this new deliberative move was captured in a series of reports and action plans on science and society. And indeed, in recent years, a range of policy institutions have attempted to democratize aspects of their decision-making processes through assorted participatory mechanisms that include consensus conferences, deliberative polling, citizen juries, citizen panels, and focus groups.

Several core intellectual resources have been developed to assist and structure STS inquiry. These include the concept of “coproduction,” an idea developed by Sheila Jasanoff and colleagues to examine the dynamics through which science and social orders become mutually constituted; the idea of “civic epistemology,” again pioneered by Jasanoff to refer to the culturally specific practices of knowledge production that characterize public life and civic institutions and that are used as a basis for making collective choices; and the approach of “actor network theory,” developed by Michel Callon and Bruno Latour as a method for analyzing the relationship between things, ideas, people, and technologies, both as actors and as networks.

Phase 3: Critical Debates

In more recent years, a series of debates have been taking place within STS, concerning its relationship to institutional practice, to expertise, and to innovation research and development. The first concerns the development of a more critical and reflexive relationship between STS and institutional models and approaches to public engagement. Whereas STS had previously tended to advocate public participation and citizen engagement in science as an *a priori* good, an emerging body of scholarship is proposing a more analytically skeptical approach, asking whether and under what conditions public participation can deliver its promised benefits, such as enhanced public trust, more socially robust decisions, and a better understanding of scientific and technological risk issues. Harry Collins, Robert Evans, and colleagues have initiated a conversation on the need to distinguish between different kinds of expertise and between different types of publics or lay citizens and on the need for more critical scrutiny of the ways in which public deliberation

is being used in science-based policy making. Alan Irwin, for example, has analyzed the ambivalence that exists within policy institutions, which have embraced public dialogue and transparency on the one hand while sustaining a professional and expert-derived “risk and consequences” framework on the other.

Brian Wynne has criticized institutional public engagement activity for its emphasis on “downstream” questions of risk and harm, calling instead for public deliberation to be directed “upstream,” to the scientific visions and “imaginaries” that are shaping the purposes and trajectories of scientific and technological research. This attempt to provide a more substantive role for STS in scientific and technological innovation has been developed into programs of research in the Netherlands, what is termed *constructive technology assessment*, and in the United States, called *real-time technology assessment*. Both attempt to provide a method in which relevant actors, including publics, are brought together in a process that aims to inform and shape innovation and decision-making practices.

Phil Macnaghten

See also **Critical Studies of Nature; Nature; Nature-Society Theory; Postmodernism; Poststructuralism; Science, Technology, and Environment; Social Construction of Nature; Technological Change, Geography of**

Further Readings

- Bijker, W., Hughes, T. P., & Pinch, T. (Eds.). (1989). *The social construction of technological systems*. Cambridge: MIT Press.
- Hackett, E. J., Amsterdamska, O., Lynch, M., & Wajcman, J. (Eds.). (2007). *The handbook of science and technology studies* (3rd ed.). Cambridge: MIT Press.
- House of Lords Select Committee on Science and Technology. (2000). *Science and society*. London: Her Majesty's Stationery Office.
- Irwin, A., & Wynne, B. (Eds.). (2004). *Misunderstanding science? The public reconstruction of science and technology*. Cambridge, UK: Cambridge University Press.



Jasanoff, S., Markle, G., Petersen, J. C., & Pinch, T. (Eds.). (1995). *Handbook of science and technology studies*. Thousand Oaks, CA: Sage.

MacKenzie, D., & Wajcman, J. (Eds.). (1985). *The social shaping of technology*. Milton Keynes, UK: Open University Press.

Royal Commission of Environment and Pollution. (1998). *Setting environmental standards: 21st report*. London: Her Majesty's Stationery Office.

SCOTT, ALLEN (1938–)

One of economic and urban geography's most influential contemporary figures, Allen J. Scott introduced some of the fundamental concepts of contemporary urban political economy, including industrial organization and change and, more recently, the cultural economies of cities.

British in origin, he attended Oxford University, completing his BA in 1961 and MA in 1965. He earned his PhD at Northwestern University in 1965. He taught for several years at the University of Toronto before moving to the University of California, Los Angeles (UCLA) in 1981, where he has since remained as a professor of geography and public policy. He has written 10 single-authored books and coedited 9 more, as well as numerous journal articles; has served as visiting lecturer in various locales; and is the recipient of numerous awards, prizes, honors, and distinguished fellowships.

While Scott's training and early work lay in the domain of mathematical modeling, including location-allocation analysis, the bulk of his contributions lay in dissecting the space economy of metropolitan regions. Specifically, he articulated views of cities as changing systems of production, incorporating older Marxist ideas of the division of labor in novel and intriguing ways. In reviving the older tradition of transactions costs analysis, he was instrumental in sketching the contours of industrial restructuring in the form of the rise of flexible production and accumulation (or "post-Fordism") in the 1980s. His projects stressed the powerful role played by corporate vertical integration and disintegration in reshaping urban

labor markets and spaces, including the rise of "new industrial spaces" distinct from the traditional spatialities of Fordism. Thus, the importance of agglomeration economies fluctuates over time depending on the predominant system of subcontracting, the degree of risk involved, and other factors that reshape the input-output relations among firms. In fusing circuits of commodity production and social reproduction, Scott revealed how the changing division of labor spins off various dimensions in the labor market, such as job gains and losses and the presence or absence of particular complexes of occupations, technologies, and spatial differences in skill sets. Concomitantly, such changes led to associated social geographies, as exemplified by urban gentrification on the one hand and low-income, working-class ghettos on the other. Scott's efforts also helped discredit neoclassical economic myth of a "free market" by pointing out the inevitable role of the state and urban planning in rationalizing urban land use predicaments. His views thus provided a theoretically powerful, integrated synthesis of longstanding but undersocialized notions in geography such as input-output analysis, the product cycle, agglomeration economies, transactions costs, the geography of labor, state intervention, and technological change.

Scott brought these notions to bear on the specific case of Southern California through a series of detailed case studies on the aerospace, the electronics, and particularly the film industry, among others, thus becoming one of the informal founders of the influential so-called Los Angeles School of urban and regional analysis.

His works on Southern California became widely influential in the revival of regional analysis in geography in the late 20th century, a view that positioned local production complexes within wider national and global divisions of labor. Situating regions within worldwide commodity chains led to an informative fusion of the global and local in the analysis of particular places. Scott extended such analysis from iconic regions such as Silicon Valley and Italy's Emilia-Romagna to dense complexes of service firms at the core of large urban regions found worldwide.

More recently, given the cultural turn within economic geography, Scott has emphasized the powerful constitutive role of cultural industries



such as the Hollywood film complex. Specifically, the interiors of many large urban spaces have become transformed into spaces for the production of symbolic and cognitive capital—locales of leisure for the legions of workers employed in such industries and centers for the creation of taste, images, style, and fashion—and other dimensions of representational and informational commodities.

Scott also offered powerful and elegant critiques and analytical histories of geographic thought and epistemology, emphasizing the social origins and contexts of discourses within the discipline rather than the common view of ideas as self-propelled abstractions devoid of material foundations.

Barney Warf

See also Dear, Michael; Economic Geography; Electronics Industry, Geography of; Flexible Production; Fordism; Harvey, David; Los Angeles School; Marxism, Geography and; Political Economy; Regulation Theory; Storper, Michael; Urban Geography; Walker, Richard

Further Readings

- Dear, M., & Scott, A. (Eds.). (1981). *Urbanization and urban planning in capitalist society*. New York: Methuen.
- Scott, A. (1981). *The urban land nexus and the state*. London: Pion.
- Scott, A. (1986). Industrialization and urbanization: A geographical agenda. *Annals of the Association of American Geographers*, 76, 25–37.
- Scott, A. (1986). Industrial organization and location: Division of labor, the firm, and spatial process. *Economic Geography*, 62, 215–231.
- Scott, A. (1988). *Metropolis: From the division of labor to urban form*. Berkeley: University of California Press.
- Scott, A. (1988). *New industrial spaces: Flexible production, organization and regional development in North America and Western Europe*. London: Pion.
- Scott, A. (1993). *Technopolis: High-technology industry and regional development in Southern California*. Berkeley: University of California Press.

- Scott, A. (2000). *The cultural economy of cities*. London: Sage.
- Scott, A. (2001). Globalization and the rise of city-regions. *European Planning Studies*, 9(7), 813–826.
- Scott, A. (2005). *On Hollywood: The place, the industry*. Princeton, NJ: Princeton University Press.
- Scott, A. (2008). *Social economy of the metropolis: Cognitive-cultural capitalism and the global resurgence of cities*. Oxford, UK: Oxford University Press.
- Scott, A., & Storper, M. (Eds.). (1986). *Production, work, territory: The geographical anatomy of industrial capitalism*. London: Allen & Unwin.



SEDIMENTARY ROCK

Sediments are loose, unconsolidated rock particles and ions (i.e., charged atoms) dissolved in aqueous solutions. Sedimentary rocks, which constitute about 75% of all rocks exposed at the surface of the Earth, form when the particles are cemented together or when crystals precipitate from the solutions. Sedimentary rocks (particularly sandstones) are important because they host petroleum deposits and most of the uranium used for generating nuclear energy. There are three types of sedimentary rocks: (1) clastic (or detrital), (2) biochemical, and (3) chemical.

Clastic sedimentary rocks constitute more than 75% of the total sedimentary rocks. These rocks are formed from cemented grains and particles derived from the breakdown of preexisting rocks of any type (e.g., igneous, sedimentary, or metamorphic). The classification of clastic sedimentary rocks is based mainly on the size of the grains. A clastic sedimentary rock formed by gravel (i.e., grains bigger than 2 mm [millimeters] in diameter: granules, pebbles, or boulders) is called conglomerate (if the grains are rounded) or breccia (if the grains are angular). A clastic sedimentary rock formed by grains between 1/16 and 2 mm in diameter is called sandstone. Sandstones can be further classified according to the most abundant minerals they contain. Sandstones formed mostly



Colorful sedimentary layers in a road cut at Artist's Point in the Colorado National Monument near Grand Junction

Source: Linda Armstrong/iStockphoto.

by grains of the mineral quartz are called quartz sandstones (or quartz arenites), whereas sandstones formed mostly by grains of the mineral feldspar are called arkoses. Sandstones that include high amounts of fine-grained clay are called graywackes. Conglomerates, breccias, and sandstones are formed by grains that are coarse enough to be seen with the naked eye. In contrast, grains of silt (between 1/256 and 1/16 mm in diameter) and clay (smaller than 1/256 mm in diameter) are too small to be seen with the naked eye. Silt and clay grains, when cemented together, form the clastic rocks siltstones and claystones, respectively. Siltstones and claystones are sometimes collectively called mudstones. A mudstone that easily splits in different layers is a shale.

Biochemical sedimentary rocks are formed from the remains of organisms. Peat and bituminous coal are formed from plant fragments. Peat is commonly brown and porous, with plant fragments that are still visible. In contrast, bituminous coal is black without distinguishable plant remains. Fossiliferous limestone is formed from fossil shells and coral and is the most common biochemical sedimentary rock.

Sedimentary rocks belonging to the last type (chemical) form by precipitation from aqueous solutions. These rocks are classified according to their chemical composition. Some common chemical sedimentary rocks are limestone (formed by CaCO_3), dolostone ($\text{CaMg}(\text{CO}_3)_2$), chert (SiO_2), rock salt (NaCl), and rock gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). Limestone is the rock that most commonly is responsible for the development of karst topography.

Alessandro Zanazzi

See also **Coral Reef; Geologic Timescale; Karst Topography; Minerals; Peat; Petroleum; Rock Weathering; Sedimentation**

Further Readings

- Press, F., Siever, R., Grotzinger, J., & Jordan, T. H. (2003). Sediments and sedimentary rocks. In F. Press, R. Siever, J. Grotzinger, & T. H. Jordan (Eds.), *Understanding Earth* (pp. 163–191). New York: Freeman.
- Prothero, D. R., & Schwab, F. (Eds.). (2003). *Sedimentary geology*. New York: Freeman.



SEDIMENTATION

Sedimentation involves the response of motion of molecules or particles to gravitational, centrifugal, or electrochemical forces. Sedimentation literally means the manner in which a sediment is taken out of whatever transportation process it is dissolved or entrained in (water, wind, gravity, waves, etc.), resulting in a deposit of sediment. Thus, sedimentation can occur naturally from the



Sediment data collection in the Little Colorado River a kilometer upstream from the Colorado River, Grand Canyon, Arizona

Source: Advisory Committee on Water Information.

various fluids or the media of movement, or it can occur artificially in different human environments (e.g., inside a laboratory vessel or water and wastewater treatment plants). The net result is that material is removed from further direct interaction with its entraining agent and is generally blocked by a hard boundary against which it is then lodged. This then constitutes a new collection of sediments. Many different genetic forms of sedimentation can result, but only those of the natural world are considered in this entry.

Sedimentation resulting from cessation of gravity-induced motion without significant entrainment by fluids includes the many forms of mass movement or landslides as well as the results of subsidence, or isolated motions of creep, talus accumulation, rock glaciers, and other such forms. Both mass movement and subsidence result in accumulations of mixed up, unsorted, unstratified

clastics and organics in colluvium. Glacier ice also moves downhill under the influence of gravity, which is similarly unsorted and unstratified, although these deposits commonly have grain-surface characteristics that enable differentiation from colluvium.

The motion of air and water can entrain vast quantities of clastics and organics as well as dissolved solute loads. With both fluids, once the velocity of the transporting medium drops below a certain amount required to keep the load in motion, sedimentation occurs and deposition results, commonly sorted into different forms such as clay, silt, sand, and various sizes of gravel and boulders. Sedimentation of sand from wind results in dunes, which can be easily remobilized once the wind picks up again. On the other hand, once the sedimentation of silt and clay dust occurs, the small particles are not easily entrained



again, resulting in loess blankets across the landscape. Water, unlike wind, has the capacity to dissolve some rock, as well as move many different grain sizes, depending on the velocity. As with wind, the clastic load undergoes sedimentation as the velocity decreases so that bars and deltas, beaches, lakebeds, and alluvial fans all result in deposits of sorted and stratified alluvium. Where water evaporates, the solute load comes out of the solution and produces the sedimentation of salt flats or the dripping deposition of stalactites and stalagmites in caves. One unusual form of sedimentation from solution involves the precipitation of pure silica (SiO_2), which when it occurs in layers commonly colored by iron forms semi-precious agates and other kinds of colorful silica compounds that are quite durable. When, however, the silica is precipitated in a very regular fashion, where the individual silica molecules are lined up very precisely in rows covered with clear silica, the new sediment can separate light like a refraction grating to produce iridescent opals.

John F. Shroder

See also **Creep; Landslide; Sedimentary Rock; Soil Erosion**

Further Readings

Bridge, J., & Demicco, R. (2008). *Earth surface processes, landforms and sediment deposits*. Cambridge, UK: Cambridge University Press.



SEGREGATION AND GEOGRAPHY

Segregation derives from the Latin verb “to separate” or “to divide,” and in the social sciences, it defines the separation of a group of people from the rest of the population. Segregation does not have to be a particularly geographical phenomenon—it can involve any manner of separation—but it often takes geographical forms and is most apparent in cities where the social patterns of people are distinct. The study of segregation has become

an important topic in human geography. It also lends itself well to the tool kits of geography, from maps to spatial statistics to ethnography. Geographers have discussed segregation in several ways: from helping describe it, to revealing the processes that cause it, to an understanding of what segregation means to those who experience it.

Any group of people can be segregated, and these patterns are apparent in the city. Segregation on the basis of income defines the broad social areas in cities, with neighborhoods divided between low, middle, and higher incomes. Segregation on the basis of life cycle considers the tendency of neighborhoods to be dominated by people at certain stages of their lives, from young adult singles to families with children, to empty nesters and elderly enclaves. There may also be segregation based on lifestyle, as arts-oriented individuals congregate in neighborhoods more suited to their tastes. However, it is on the basis of race and ethnicity that segregation is most often discussed. In diverse cities—which describe most cities—different cultural groups are more or less likely to cluster together. This creates an uneven geography as certain groups may be found in specific parts of the city and almost absent from other districts. Social scientists are more concerned with this sort of segregation because it seems to be less voluntary than the other forms, indicates profound social tensions, or stems from discrimination.

Measures of Segregation

Thematic maps that display the density or proportional representation of particular groups provide a good depiction of how segregation appears. While maps illustrate the stark patterns and divisions between groups, it can be useful to develop more precise measurements. Both sociologists and geographers helped popularize a simple measure of segregation known as the *index of dissimilarity*, or *D*. The *D* index ranges from 0, which indicates that a particular subgroup is evenly dispersed throughout the entire population of a city, to 100 (or 1.0), which indicates complete segregation. With this index and a few others that are calculated in slightly different ways, it is possible to compare the segregation levels of different groups,



examine segregation in different cities, or trace the segregation experiences of a group over time. Segregation indices have played a profound role in characterizing the experiences of ethnic and racial groups in cities around the world and have had a powerful effect in shaping public policy.

Traditional segregation measures used census units and were impervious to the geographical relationships between those units. In other words, this information could not account for whether African Americans, say, were concentrated in one census tract but were absent in an adjacent one. New geographic technologies have allowed researchers to modify segregation indices to measure the spatial relationships between units and to offer a more refined measurement.

It is more problematic that such measures are prisoners of the categories provided by official government agencies and so are only as good as the data derived. Many governments choose not to report data by certain categories. For instance, the U.S. Census does not provide information on religious affiliation, whereas Statistics Canada does provide this information. The clustering of ethnic North Africans in French cities, for example, is of social concern. Recently, there has been a spate of riots in the suburbs, where many North African ethnics live in relatively impoverished conditions. But the French statistical service (INSEE) does not report information on different ethnic, religious, or nationality categories at a small enough scale to permit useful analysis.

Types of Segregation

Segregation stems from many different causes, and these help determine the nature of the segregation experience. One distinction can be made regarding so-called *de jure* segregation, in which the separation and concentration of a particular group is mandated by law. Historically, societies could require that members of a particular group occupy a single district or a ghetto. South Africa's former apartheid regime enforced *de jure* segregation through the Group Areas Act.

Most cities today are more likely to experience *de facto* segregation, which means that segregation exists but is not legally mandated. Depending on the groups and the contexts involved, much of this segregation derives from negative

factors. Often, segregation is bound up with socioeconomic status. Many minority populations are also poor and so are disproportionately represented in the poorest districts of the city. In North America, segregation was also caused by overt discrimination, whereby banks, realtors, property owners, and others compelled individuals of a particular ethnicity or race to live in some places by restricting their access to other areas. Immigrants who arrived in the late 19th and early 20th centuries experienced such discrimination, and it was particularly pronounced against some groups, such as the Chinese population on the Pacific coast of the United States. With the urbanization of African Americans in the 20th century, this level of overt discrimination reached an extreme as a variety of mechanisms, including property covenants and housing discrimination, enforced strict patterns of black residential segregation. While most such mechanisms have been overturned, many scholars believe that there still exist a number of more subtle discriminatory practices as well as a legacy that continues to keep African American segregation patterns high, regardless of socioeconomic standing.

Reasons for Segregation

Members of an ethnic group may themselves have reasons to segregate, even if they are not subject to discrimination or socioeconomic constraints. Such "preferences" can stem from varying motives. For some groups, segregation provides protection from other, hostile groups. In politically tense cities such as Belfast, Beirut, Baghdad, and Sarajevo, groups will form virtual fortresses from neighborhoods, complete with walls and security patrols. A more benign form is where a group seeks to segregate as a type of cultural defense. English speakers in Montreal cluster as a way to retain their culture within an increasingly French city. Many groups may segregate to be close to religious institutions; for example, many Orthodox Jewish populations cluster within walking distance of the synagogue. Finally, segregation may be viewed as an outcome where people choose to live close to people like themselves. Surveys have indicated that proximity to similar people makes residents more comfortable, although groups vary in their tolerance for neighborhood diversity. Such



Loyalists march past one of the Peace Lines separating Catholic and Protestant neighborhoods in Belfast on their way to Belfast Town Hall, November 23, 1985. They were protesting against the previous week's signing of the Anglo-Irish Agreement between the United Kingdom and Ireland, which gave the Irish government an advisory role in Northern Ireland's government.

Source: Kaveh Kazemi/Hulton Archive/Getty Images.

preferences are a double-edged sword, of course, since one group's preference for its own kind effectively excludes other groups from living nearby.

Consequences of Segregation

The consequences of segregation vary and are partly related to whether the segregation results from constraint or choice. Many groups that are forced to occupy particular neighborhoods suffer from this enforced segregation. Such patterns have been linked to diminished accessibility to jobs, shopping, and banks and to higher levels of poverty and social dislocation. It is because of these ill effects that public policy has endeavored to diminish segregation.

More positive outcomes can result when segregation is a matter of choice. The clustering of

members of the same ethnic group often provides the thresholds necessary to support a variety of institutions, including religious ones. But larger concentrations of ethnics can also sustain specialty grocery stores, services geared toward ethnic needs, and sometimes even ethnic banks. Entire ethnic economies can benefit from such proximity. What is more, concentration of ethnics allows for greater political influence as they have the necessary votes to send one of their own to the regional or national legislature. Ethnic majorities can elect the government for a city or town. For instance, Cuban Americans have marshaled tremendous political potency by virtue of their concentration in the Miami metropolitan area. Even when segregation is not a matter of choice, sometimes disadvantaged groups can wring some advantage from it.



A large component of what makes human geography interesting is the examination of patterns. The segregation of particular ethnic groups is a fundamental pattern in most cities that results from many factors that lead people to cluster in groups and live apart from other groups. Such segregated patterns can also have major consequences for all residents of the city and become a determining factor in modern urban life.

David H. Kaplan

See also **Ethnicity; Ethnic Segregation; Housing and Housing Markets; Human Ecology; Neighborhood; Race and Racism; Racial Segregation; Urban Spatial Structure**

Further Readings

- Berry, K., & Henderson, M. (2002). *Geographical identities of ethnic America: Race, space and place*. Reno: University of Nevada Press.
- Clark, W. (2002). Ethnic preferences and ethnic perceptions in multi-ethnic settings. *Urban Geography*, 23, 237–256.
- Iceland, J., Weinberg, D., & Steinmetz, E. (2002). *Racial and ethnic residential segregation in the United States: 1980–2000*. Washington, DC: U.S. Census Bureau.
- Peach, C. (1996). Good segregation, bad segregation. *Planning Perspectives*, 11, 379–398.
- Wong, D. (2003). Implementing spatial segregation measures in GIS. *Computers, Environment and Urban Systems*, 27(1), 53–71.
- Zelinsky, W., & Lee, B. (1998). Heterolocalism: An alternative model of the sociospatial behaviour of immigrant ethnic communities. *International Journal of Population Geography*, 4, 281–298.

attributes rather than a space of geographic coordinates. Methodologically, SOM computation relates to the suite of multidimensional scaling (MDS) methods (e.g., principal components analysis [PCA], factor analysis, *K* nearest-neighbor method, and many others) that attempt to project multidimensional variables to limited dimensional (often 2D and 3D) spaces, so that humans can discern meaningful patterns through visualization and analysis. More specifically, Teuvo Kohonen, the inventor of SOM, suggested that SOM is an ordered structure of “local PCA” in that the non-linearity of data vectors precludes the appropriateness of common principal components to explain all data vectors. Instead, an SOM presents 2D grouping of data vectors, and the first and second principal components vary from one group to another over the SOM.

Compared with many MDS methods, SOM method is fundamentally a nonparametric regression approach with neural network learning algorithms. SOM handles each data item as a vector of values in an ordered array of variables. An SOM is built by a sequence of iterative processes:

1. Determining the topological structure of neighborhoods
2. Determining the first set of reference vectors (usually random or based on known structures in the data)
3. Calculating the distances of individual data vectors to reference vectors and determine first grouping
4. Calculating the next generation of reference vectors based on a mathematical definition of “generalized median” vectors from the defined neighborhood of the previous grouping
5. Reiterating the steps until the reference vectors converge into a predefined structure

Neighborhoods of hexagons are preferred over squares because hexagons show the same range from the center to all sides. As an SOM is built through iterative learning processes in the determination of reference vectors and grouping, the size of the neighborhood and the number of iterations can influence the learning factor and degree of convergence in the final map. Kohonen recommended that the neighborhood size start at



SELF-ORGANIZING MAPS

Self-organizing maps (SOMs) are not cartographic maps; rather SOMs are mathematical transformations of data to a predefined two-dimensional (2D) structure to reveal data clusters based on similarity. Conceptually, the basic idea of SOM corresponds well to Tobler’s first law of geography, but SOMs consider distances in a space of multiple



half the diameter of the network (i.e., the defined size of the SOM, analogous to spatial extent), reducing over time during the computation to perhaps the cell unit in the end of the computation. Furthermore, according to Kohonen's rule of thumb, the number of iterations should be at least 500 times the number of network units (i.e., the defined size of the SOM cell unit, analogous to resolution) to ensure good statistical accuracy; a typical number of iterations used in building SOM is 100,000.

How to measure distance is central to determining similarity among data items and, therefore, SOM outcomes. There are several ways to measure distance; Euclidean distance (simple linear distance between two points), Hamming distance (the number of steps to make two binary lists identical), Levenshtein distance (the total number of required steps—replacements, insertions, and deletion—to make two strings identical), or simply binary distance (0 or 1) are commonly used distance metrics. Because the distance measures will be computed in a vector space with variables that may have distinct value domains, standardization of variables is critical to avoid variables with high values overpowering other variables and dominating the computation of distance. Often, variables are standardized based on statistical parameters (such as means and standard deviation) or other means appropriate for the data on hand.

SOM has been expanded with complexity, such as hierarchical SOM or latent semantic indexing SOM. Of most interest to geographers is GeoSOM, which adds geographic coordinates into the attribute vectors, so that the resultant SOM accounts for groupings in both attribute space and geographic space. Consequently, GeoSOM shows that interpretation of clusters can be spatially dependent; that is, the first and second principal components that can best explain clusters vary across geographic space. For example, social clusters in the northern part of a city may be mostly employment related, and clusters in the southern part of the city may be strongly correlated with household income.

Applications

SOM has been used broadly in many domain applications since 1981. Many SOM applications

developed from the late 1990s are related to geographic studies. SOM has been used to investigate extreme climate events, regional precipitation patterns, and distributions of nonnative species. SOM has also been used for image processing, solving location-allocation problems, comparison of cities, integrated environmental assessment, visualizing demographic trajectories, comparing community health, and many more. The wide range of applications demonstrates SOM's capabilities to reveal hidden data orders for visual analysis. Cartographers with an interest in visualization consider SOM as one of the spatialization methods that can transform nongeographic data into spatial representation. As geographers dig into nonlinear, complex geographic systems, SOM can become one of the key tools to simplify complexity by reducing data dimensions yet discerning the fundamental data orders to facilitate interpretation.

May Yuan

See also **Map Algebra**; **Map Visualization**; **Topological Relationships**

Further Readings

- Bação, F., Lobo, V., & Painho, M. (2005). The self-organizing map, the Geo-SOM, and relevant variants for geosciences. *Computers and Geosciences*, 31, 155–163.
- Basara, H. G., & Yuan, M. (2008). Community health assessment using self-organizing maps and geographic information systems. *International Journal of Health Geographics*, 7, 67.
- Céréghino, R., Mastrorillo, S., Santoul, F., & Compin, A. (2005). Using self-organizing maps to investigate spatial patterns of non-native species. *Biological Conservation*, 125, 459–465.
- Chang, H. C., Kopaska-Merkel, D. C., & Chen, H. C. (2002). Identification of lithofacies using Kohonen self-organizing maps. *Computers and Geosciences*, 28, 223–229.
- Crane, R. G., & Hewitson, B. C. (2003). Clustering and upscaling of station precipitation records to regional patterns using self-organizing maps (SOMs). *Climate Research*, 25, 95–107.



- Endo, M., Ueno, M., & Tanabe, T. (2002). A clustering method using hierarchical self-organizing maps. *Journal of VLSI Signal Processing Systems for Signal, Image, and Video Technology*, 32, 105–118.
- Hsieh, K. H., & Tien, F. C. (2004). Self-organizing feature maps for solving location-allocation problems with rectilinear distances. *Computers and Operations Research*, 31, 1017–1031.
- Kohonen, T. (2001). *Self-organizing maps*. Berlin, Germany: Springer.
- Mather, P. M., Tso, B., & Koch, M. (1998). An evaluation of Landsat TM spectral data and SAR-derived textural information for lithological discrimination in the Red Sea Hills, Sudan. *International Journal of Remote Sensing*, 19, 587–604.
- Mazanec, J. A. (1995). Competition among European tourist cities: A comparative analysis with multidimensional scaling and self-organizing maps. *Tourism Economics*, 1, 283–302.
- Skupin, A., & Fabrikant, S. I. (2003). Spatialization methods: A cartographic research agenda for non-geographic information visualization. *Cartography and Geographic Information Science*, 30, 99–119.
- Skupin, A., & Hagelman, R. (2005). Visualizing demographic trajectories with self-organizing maps. *GeoInformatica*, 9, 159–179.
- Tran, L. T., O'Connell, M., Knight, C. G., O'Neill, R. V., & Smith, E. R. (2003). Self-organizing maps for integrated environmental assessment of the mid-Atlantic region. *Environmental Management*, 31, 822–835.

(SOA) describes the interaction among the service provider, the service broker, and the user. The provider registers the service at a registry maintained by the service broker. The broker publishes the service interface and, hence, allows the service to be retrieved and finally executed by the user. The interface describes how to access the service and which data, if any, are exchanged. Besides human users, other services can also request a service via its interface, forming service chains. The interface description guarantees syntactic interoperability, that is, the possibility to exchange data on a technical level. Besides the used Internet protocol and access restrictions, this especially includes the used data types. For instance, an interface of a Web-based gazetteer may announce that it requires a place name as input and delivers the place type and spatial footprint as results. The place name and place type would be specified as text strings, while the footprint would be defined according to a particular spatial reference system. What a place type (such as a lake or canal) means, that is, what is required for a particular place to be classified as a lake or canal, is not covered by the interface description. This is a serious shortcoming as users accessing the service may assume that the services' conceptualization of the place type fits their own. Consequently, relying only on the names and data types of service parameters is not sufficient. This is especially important for service chains where one service relies on the adequate output of another service without manual control by a human user.

In contrast, to avoid misunderstandings, semantic interoperability requires a shared understanding of the meaning of the exchanged data, such as the place types in the gazetteer example. To achieve this, unambiguous specifications of the service functionality as well as the meaning of the input and output parameters are necessary. These specifications have to be readable to both human users and machines and also have to be published in a service registry to support discovery. With respect to the gazetteer, the service needs to provide the specifications for the place types. For instance, lakes can be defined as natural bodies of water inside a landmass. Based on such definitions, users (or other services) can decide whether the requested service fits their requirements. In information science, the technology to specify such conceptualization is called an *ontology*. Ontologies support



SEMANTIC INTEROPERABILITY

With geographic information systems (GIS) moving away from monolithic software to distributed network services, the question of how to ensure that these services operate with each other gains in importance. Typically, these services encapsulate a particular functionality exposed through a Web-based interface for communication as proposed by the Open Geospatial Consortium (OGC). The service-oriented architecture



logical reasoning, which is a prerequisite for information retrieval and interpretation. To achieve semantic interoperability between services, their ontologies, called application ontologies, are compared to analyze whether the service parameters are based on the same conceptualization. Such an analysis, however, requires a common base vocabulary used for the specifications.

An analogy to explain the need for a base vocabulary and the comparison of conceptualizations in application ontologies are semantic reference systems (SRS). Like spatial reference systems, SRS defines a multidimensional (semantic) coordinate system and operations within such a system. One of these operations is semantic similarity, which is defined as the inverse distance between two conceptualizations. It is analogous to the distance between coordinates in a spatial reference system. Consequently, while the distance between two places represented in a gazetteer service can be measured based on their spatial footprints, the semantic similarity of the place types can be computed based on their formal specifications. While the question of how to achieve semantic interoperability remains an open research challenge, two approaches can be distinguished.

Top-Level Ontology

A top-level ontology contains the commonly agreed on base vocabulary independent of an application-specific perspective, for example, a particular service. For instance, a top-level ontology distinguishes between abstract and physical objects and defines units of measure. These specifications are then used as building blocks for domain ontologies, which specify the vocabulary shared by a particular domain such as hydrology or geography. The domain ontology itself is used by the service provider to develop the application-centric ontology necessary for the service interface. In case of the gazetteer service, the provider specifies what is categorized as a lake, using definitions from the domain ontology, such as the topological inside relationship or the concept of water body. The mathematical notion of a relationship is defined in the top-level ontology. Based on this top-down approach, the specifications used by particular services can be compared as they rely on the same base vocabulary. This also

allows for computer-aided search in service repositories and enables users to find the services that fit their needs. Semantic similarity is such a technology to support retrieval based on comparing the specifications for overlap and is a step toward establishing semantic interoperability.

Folksonomies

While the definition and maintenance of top-level and domain ontologies are up to computer scientists and domain experts, so-called folksonomies are a bottom-up approach to establish a common understanding of the used vocabulary. Folksonomies are a crucial part of the Web 2.0, where users actively contribute content instead of passively consuming it. By assigning labels (tags), users categorize content on the Web. For instance, in a Web 2.0 gazetteer, users might assign tags as place types to mark particular places on a map. Technologies to analyze these tags and hence establish a common understanding based on user-provided information are a promising new research direction.

Krzysztof Janowicz

See also **Interoperability and Spatial Data Standards; Ontological Foundations of Geographical Data; Ontology; Semantic Reference Systems; Web Service Architectures for GIS**

Further Readings

Kuhn, W. (2005). Geospatial semantics: Why, of what, and how? in semantic-based geographical information systems [Special issue]. *Journal of Data Semantics* (Lecture Notes in Computer Science, No. 3534), 1–24.

SEMANTIC REFERENCE SYSTEMS

Geographic information systems (GIS) operate on spatial, temporal, and thematic data. The interpretation of the first two kinds of data is given by well-known spatial and temporal reference systems



such as coordinate systems and calendars. Based on these reference systems, we can transform between coordinates and time stamps or measure distance in space and time. We can also project three-dimensional coordinates into two-dimensional representations for paper maps. What is needed is a reference system for the third kind of data. In analogy to spatial and temporal reference systems, semantic reference systems (SRS) allow the transformation and projection of thematic data or the calculation of semantic distance (called semantic similarity). Typical applications for such an SRS include the transformation or comparison of different conceptualizations between information communities, and information retrieval in general. In the first case, this would allow mediation between the conceptualization of water bodies as used in hydrology and the one used in tourism. In the second case, one could retrieve similar water bodies or kinds of water bodies (such as a lake, river, or reservoir) based on a user's query. An SRS consists of two parts: (1) the semantic reference frame, that is, a formal system such as an ontology, and (2) particular semantic datums to ground the meaning of the terms used in the reference frame.

Ontologies as Reference Frames

An ontology specifies the conceptualization of a particular information community by providing formal definitions for the terms used in this community. To do so, ontologies need to introduce primitive terms for the definition of more complex ones. For instance, the term *river* could be specified by introducing the term *spring* and the relation *has_origin* between rivers and springs. One could also define attributes, such as *flow_velocity* and *water_gauge*, and introduce kinds of rivers, such as *forest_river*. In turn, we also have to specify the meaning of terms such as *spring* and also the attributes and relations used to specify the meaning of *river*. We continue with the specification process until only primitives are left, that is, terms, relation, and attributes for which no formal definition can be given within our ontology. To ensure consistency in the interpretation of these terms, and hence to achieve semantic interoperability, we need to ground these primitives in observable reality by introducing semantic datums.

Summing up, ontologies restrict the potential meanings of terms used in an information community. However, to restrict the possible interpretations exactly to the intended ones, a semantic datum is needed. Besides specifying a vocabulary, ontologies support logical reasoning, which is a prerequisite for information retrieval. For instance, if we define particular attributes such as *flow_velocity* for *river*, we can infer that each water body that has been classified as a river has a flow velocity. Semantics-aware search engines use reasoning to deliver more flexible results. If a user types in *stream* as a keyword, the search engine would also include kinds of streams, such as rivers and creeks, and also similar water bodies (such as reservoirs if the user is querying for *lake*) in the result set.

Semantic Datums and Sensors

A semantic datum provides a particular interpretation for the primitives of a frame of reference to something outside it. An interpretation is a function from all symbols (terms, attributes, and relations) in an ontology to some particular other structure that preserves the truth of its sentences. Typically, an ontology allows for more than one interpretation that satisfies its sentences, and therefore it has an ambiguous meaning. As all nonprimitive symbols in an ontology are definable from the primitive ones, a semantic datum can fix one particular interpretation. The structure in which the symbols are interpreted can be other ontologies as well as observable real-world structures. We say that an ontology is grounded if there exists a semantic datum for an interpretation into observable real-world structures. Examples of interpretations into observable real-world structures are measurement scales. This can be illustrated by the analogy to spatial reference systems. Spatial reference frames are grounded. A datum in a spatial reference frame fixes the position of the origin, the orientation of coordinate axes of the reference frame relative to Earth, and the length measurement scale that fixes the units of measurement. All coordinates and their relative locations are defined in origins and units of such a reference frame.

There are two ways of establishing a semantic datum for a semantic reference frame. First, there is a physical sensor available that grounds primitive symbols directly into observable real-world



structures. A sensor can be considered as a physical device that implements such an interpretation. In our example, a directly observable semantic datum for the Bessel ellipsoid is, for instance, a named spot on the Earth's surface, such as "Rauenberg" near Berlin (Potsdam Datum). Second, there is a criterion available to define the primitive in a second reference frame. The point of origin and the units of a map projection, such as a Gauss-Krüger strip, are, for instance, definable from a reference ellipsoid, such as Bessel. In terms of the water body example, a river's gauge is defined with reference to its bankfull stage (as datum). The bankfull stage is the level of the water surface measured when the river's banks are under water. The level of water surface in turn is the vertical distance measured between the idealized water body surface to the air and the idealized surface to the river bed.

Krzysztof Janowicz and Simon Scheider

See also **Ontological Foundations of Geographical Data; Ontology; Semantic Interoperability; Spatial Data Mining**

Further Readings

Kuhn, W. (2003). Semantic reference systems [Guest editorial]. *International Journal of Geographical Information Science*, 17(5), 405–409.

Kuhn, W., & Raubal, M. (2003). Implementing semantic reference systems. In M. Gould, R. Laurini, & S. Coulondre (Eds.), *AGILE 2003: 6th AGILE conference on geographic information science, Lyon, France* (pp. 63–72). Lausanne, Switzerland: Presses Polytechniques et Universitaires Romandes.



SEMPLE, ELLEN CHURCHILL (1863–1932)

Born in Kentucky in 1863, Ellen Churchill Semple was a leading American geographer of the early 20th century and a pioneering female geographer. She was a charter member of the Association of American Geographers in 1904 and became the

first female president of an academic organization in 1921.

Semple received her bachelor's degree from Vassar College in 1882 and a master's degree in 1891. In the 1890s, Semple studied at the University of Leipzig in Germany under the world's most prominent human geographer, Friedrich Ratzel. Due to the prevailing sexual discrimination at the time, Semple could not enroll in the doctoral program at Leipzig while studying with Ratzel and was even required to sit apart from her male colleagues (she would face discrimination throughout her career, for example, as a faculty member earning a lower salary than her male counterparts).

During her academic career, Semple published three major books and numerous journal articles. Her first book, *American History and Its Geographic Condition*, was published in 1903. Three years later, in 1906, she accepted an appointment in the University of Chicago's geography department. In 1921, she moved to Clark University, where she accepted a position as professor of anthropogeography. Semple suffered a heart attack in 1929 and died 3 years later in Florida around the time of publication of her last major book, *The Geography of the Mediterranean Region*. Semple was a major intellectual force in American geography in the early 20th century, and her influence through her work and graduate students continued for decades afterward.

Semple is best known for her 1911 book, *Influences of Geographic Environment on the Basis of Ratzel's System of Anthro-Geography*, in which she introduced and reinterpreted her mentor's ideas to American geographers. In this and other works, Semple attempted to demonstrate the benefits of the scientific study of human geography. However, she did this through her role as a leading American proponent of the, long since discredited, theory of environmental determinism, for which she is most remembered today. Semple argued that the environmental conditions under which humans were born, were raised, and lived, and in which their societies developed over time, played a major role in shaping intelligence, temperament, and culture (indeed, Semple's 600-page tome begins with the statement, "Man [*sic*] is a product of the earth's surface"). Through her formulations of environmental determinism,



Semple came to dubious conclusions, from assuming that people living in mountain passes were more likely to be bandits to associating world climate types with distinctive human characteristics. The latter led to racist conclusions linking climate and “race temperament,” with Northern Europeans being “energetic” and “thoughtful,” Southern Europeans being “easygoing” and “emotional,” and positive characteristics giving way to “grave racial faults” among black Africans. While she was not alone in holding these beliefs, Semple’s work on and ideas about environmental determinism had a major impact on the shaping of American geography in the 1910s and 1920s.

Jonathan Leib

See also **Environmental Determinism; Human Geography, History of; Ratzel, Friedrich; Social Darwinism**

Further Readings

Colby, C. (1932). Ellen Churchill Semple. *Annals of the Association of American Geographers*, 23, 229–240.

Peet, R. (1985). The social origins of environmental determinism. *Annals of the Association of American Geographers*, 75, 309–333.

Semple, E. C. (1911). *Influences of geographic environment on the basis of Ratzel’s system of anthropo-geography*. New York: Henry Holt.

Among myriad approaches to sense of place, a key strand begins with the individual. Each person brings his or her own personality, background, and previous experiences into the process of forming a sense of place. People draw on their own use of the human senses, their own sense of aesthetics, and their own intellectual and emotional responses that they have developed with regard to places; these are based on their experiences and perceptions and the development of cognitive understandings of places. One’s reactions and responses are not static, however, and the way one looks at places continues to evolve as one’s life cycle develops and as the landscapes and places around one are transformed. Through those processes, it can be argued that people develop (at varying levels of sophistication) their own landscapes of memory and previous experiences. In some cases, this leads to bonding with places—love of place—while in others, it can lead to ambivalence, disinterest, and/or rejection, that is, the placelessness of interchangeable superficial identities that can be found anywhere. Furthermore, in invoking sense of place, many humanistic geographers and others from the humanities are attempting to understand the nonreductionist uniqueness of individual responses, as well as the distinctiveness that different places possess, and to open the minds of people to the richness of the world through place-based approaches and, specifically, to think about the role that places play in their lives.

Many individuals share a sense of place with others in a subgroup or across broader social and cultural lines. Within other social and behavioral sciences, and for some geographers as well, there are attempts to understand the psychological aspects of a subgroup’s perceptual and behavioral approaches to sense of place. Some group studies of places have been conducted in the humanities and by the cultural landscape school of geography, and they usually involve historically tracing an understanding of places at local and regional levels or through folklore and hand-me-down stories.

In contrast, other geographers and some space/environment disciplines tend to look more at the role specific places play in that process, including studying the character of places themselves and why particular places evoke a sense of



SENSE OF PLACE

Sense of place refers to subjective human reactions to places. With roots in early forms of humanistic geography, the concept appears in various forms in a considerable body of works expanding on human experience, memory, imagination, emotion, and meaning; accordingly, it is a core value in a broad and varied range of endeavors from theory (i.e., placing humans in Earth’s time-space continuum) to practice (e.g., building “green” or selling places as commodities). In sum, the sense of place contributes depth and understanding to what it means to be human.



awe or attachment. Thus, the shift is away from studying humans toward a concern for the qualities or attributes of places that move the individual; this has been called *genius loci*, or the spirit of place. Along this line, most humans have their favorite places (often stemming from their early experiences) as well as a memory bank of their own special landscapes. Most people are searching ultimately for a place to live that “feels right” to them and that they can call home. Some studies of sacred and indigenous places have focused on the concept of the power of place that in some cases has existed through time and many generations.

This focus on the character of special places resonates with many writers, poets, filmmakers, artists, and most other people, and the kinds of places they are attracted to range in scale from microsettings in the natural or cultural landscapes to neighborhoods, lake or river regions, mountain ranges, cities, or even states, nations, and global geopolitical regions. However, as one moves away from direct experiences and memories involving close human contact with places into a larger generalized framework (especially how large numbers of people share their thoughts about places), the result is a more general and reductionist perspective. In going well beyond the direct gaze, they attempt to factor in a larger cultural milieu involving both natural and cultural landscapes as places of meaning (i.e., a knowledge of climatic, ecological, and natural interconnections, and built environments), adding layers of depth to the cognitive world of sensing a place.

A particularly apparent and accessible arena for sense of place lies in the representations of place; they act to capture and convey senses of place via various media. Imaging places in the visual arts makes powerful use of the sense of place. Similarly, many writers feature sense of place in literature, poetry, and metaphors of place. As evocative as these may be, the media production of place in digital news, entertainment, and advertising, through its sheer volume and ubiquity, trumps all (e.g., senses of place of current war zones such as Iraq, inaccessible places such as North Korea’s capital city Pyongyang, places of desire such as those on many television series, and purpose-built resorts such as those in Cancun, Mexico).

Accordingly, the sense of place is fertile ground not only for representing and imagining places but also for creating and contesting it. Thus, the making of place, resistance and place, visualizing and performing place, designing and building places, and geopolitics and place—to name just a few—are all examples of how geographers and others have sought to employ sense of place to better understand certain spheres of human action and interaction. Furthermore, the sense of place can also act as a mediator between a host of analytical binaries, such as transposing conservation with profit; an evocative sense of place not only pleases but is also good business. Even as an ever-increasing placelessness has been identified, new senses of place are also emerging due to human dynamism and creativity. The idea of a global sense of place has been proposed, and everyone who’s ever e-mailed, blogged, networked, or instant messaged through personal computing and the Internet is acquainted with cyberspace—a burgeoning world of new virtual senses of place. Clearly, sense of place can be viewed from many different entry points from which individuals can enter into or continue previous intellectual journeys in their studies of place.

Richard Wilkie and George F. Roberson

See also Buttner, Anne; *Environmental Perception; Existentialism and Geography; Humanistic Geography; Phenomenology*; Relph, Edward; *Symbolism and Place*; Tuan, Yi-Fu

Further Readings

- Buttner, A., & Seamon, D. (Eds.). (1980). *The human experience of space and place*. New York: St. Martin’s Press.
- Cresswell, T. (1996). *In place/out of place: Geography, ideology, and transgression*. Minneapolis: University of Minnesota Press.
- Jackson, J. B. (1994). *A sense of place, a sense of time*. New Haven, CT: Yale University Press.
- Lowenthal, D. (1961). Geography, experience, and imagination: Towards a geographical epistemology. *Annals of the American Association of Geographers*, 51, 241–260.



- Relf, E. (1976). *Place and placelessness*. London: Pion.
- Ryden, K. (1993). *Mapping the invisible landscape: Folklore, writing, and the sense of place*. Iowa City: University of Iowa Press.
- Saarinen, T. (1976). *Environmental planning, perception and behavior*. Boston: Houghton Mifflin.
- Tuan, Y. (1974). *Topophilia: A study of environmental perception, attitudes and values*. Englewood Cliffs, NJ: Prentice Hall.
- Wright, J. (1947). *Terrae Incognitae: The place of the imagination in geography*. *Annals of the American Association of Geographers*, 37, 1–15.



SEQUENT OCCUPANCE

Sequent occupance is a model of landscape change that was widely adopted by American geographers from the 1930s through the 1950s. It views the landscape as a series of superimposed patterns accumulating as culturally distinct ways of life (modes of occupance) that leave their imprint on the land. Each mode is hypothesized to rework the prehuman landscape and earlier cultural layers in distinctive ways, leaving traces visible in the present landscape. The term was introduced by Derwent Whittlesey in 1929. The word *occupance* was in use, denoting the whole complex of human interactions with the land, to which Whittlesey added the idea of a succession of discrete historical layers. In his original paper, he offered as an exemplar a hypothetical small area of New England for which he proposed the following stages: (a) hunting and gathering by Native Americans, (b) farming, (c) the “present” stage (1929) of declining agriculture and rising secondary forest, and (d) a predicted future stage of forestry by nonresident owners.

Whittlesey used ecological and developmental language in his definition. He saw human occupance as a biotic phenomenon and suggested that it obeys rules analogous to a human organism, an analogy that echoes William Morris Davis’s normal cycle of erosion; indeed, in later work, Whittlesey invoked the Davisian idea of rejuvenation. In keeping with the same developmental metaphor, Whittlesey emphasized endogenous changes,

arguing that human occupance contained the “seed of its own transformation.” Nevertheless, he recognized the role of exogenous forces such as the impact of midwestern farming on New England agriculture. Although sequent occupance assumes human adaptation to the environment, it also posits the active reshaping of landscape and can thus be seen as part of the contemporary reaction against environmental determinism.

Until 1928, Whittlesey was at the University of Chicago, associated with a group of midwestern geographers engaged in intense discussion over the nature, content, and technical vocabulary of the emerging discipline. Preston James and Cotton Mather noted the importance of these interactions in the midwestern spring field conferences begun by Carl Sauer and Wellington Jones in 1923. Whittlesey attended many of these conferences, which focused on small-area fieldwork. Other regular attendees included scholars who took up the idea of sequent occupance, including Preston James and Stanley Dodge. Many dissertations and articles employed the concept during the 1930s and 1940s, and James used it in his influential text *An Outline of Geography* (1935). Important exemplars of the method include Stanley Dodge’s work on the Illinois Prairie, Alfred Meyer’s study of the Kankakee Marsh, Lewis Thomas’s work in Missouri, and Edward Ackerman’s study of the influence of Boston on Concord, Massachusetts. Details of these and many other applications can be found in Marvin Mikesell’s account.

A clear aspiration of Whittlesey’s original article was generalization and regional comparisons; he thought it likely that relatively few “sequence patterns” had ever existed. In fact, as studies proliferated, there was little consensus about the number of stages or the criteria by which they were to be defined and very little explicit comparative work. Despite the aim of encompassing the whole complex of human interactions with the environment, stages were most commonly identified with modes of economic exploitation and land use either at a high level of abstraction (e.g., hunting and gathering, agriculture) or at a finer scale of resolution (e.g., dairying, truck farming). Stages were also sometimes identified with indigenous or immigrant ethnic groups. Whittlesey’s original illustrative area in Northern New England had been small (15 square miles),



but subsequent researchers applied the idea across a great range of geographic scales.

One methodological refinement rapidly emerged, argued by Richard Dodge among others. Visibility of relics in the present-day landscape was taken as a necessary condition for the inclusion of past features in descriptive analysis. Thus, sequent occupance came to incorporate a present-centered view of historical time linked to a cross-sectional treatment of the past, conceptually subordinating historical process to present geography. This view of historical geography was akin to that developed by Richard Hartshorne and contrasts strikingly with the emphasis placed on the continuous unfolding of cultural processes by Carl Sauer and the Berkeley School, whose historical accounts tended to avoid cross-sectional analysis.

In its time, sequent occupance offered a useful refinement of geographic vocabulary and a beguilingly simple organizational structure for historical and cultural work. It represents a legacy of an enthusiastic, formative period when American geographers were striving to develop technical terms and procedures distinct from those of other disciplines. The term is occasionally used metaphorically and survived until recently in introductory textbooks. But sequent occupance faded from the research literature of geography during the 1950s. Marvin Mikesell offers some plausible reasons for this decline. Its cross-sectional treatment of the past was not useful for historical geographers and held little appeal for present-oriented systematic specialists, while its emphasis on endogenous change belied the facts of migration and diffusion. Its monolithic treatment of culture and its elision of agency, symbolism, structure, and political economy render it equally uncongenial to most cultural and historical geographers today.

John S. Pipkin

See also **Cultural Geography**; **Cultural Landscape**; **Palimpsest**; **Sauer, Carl**; **Whittlesey, Derwent**

Further Readings

Baker, A. (2003). *History and geography: Bridging the divide*. Cambridge, UK: Cambridge University Press.

Dodge, R. (1938). The interpretation of sequent occupance. *Annals of the Association of American Geographers*, 28, 233–237.

James, P. (1935). *An outline of geography*. Boston: Ginn.

James, P., & Mather, C. (1977). The role of periodic field conferences in the development of geographic ideas in the United States. *Geographical Review*, 67, 446–461.

Mikesell, M. (1976). The rise and decline of “sequent occupance”: A chapter in the history of American geography. In D. Lowenthal & M. J. Bowden (Eds.), *Geographies of the mind: Essays in historical geography in honor of John Kirtland Wright* (pp. 149–169). New York: Oxford University Press.

Whittlesey, D. (1929). Sequent occupance. *Annals of the Association of American Geographers*, 19, 162–165.



SERVICES

See **Producer Services**; **Retail Trade, Geography of**; **Telecommunications and Geography**



SETTLEMENT GEOGRAPHY

Settlement geography was defined by Fred Kniffen and Henry Glassie as “the interpretable record of the historical events and cultural processes imprinted on the land” and by Kirk Stone as “the description and analysis of the distribution of buildings by which people attach themselves to the land.” Settlement not only has been studied independently but is also included as a component of human/cultural, historical, or population geography. The study of settlement geography historically has chiefly been anthropocentric and was concerned with rural buildings, especially dwellings that offer a snapshot of the cultural background, place, and time of construction.



Panoramic view of Liausson, a small village in France

Source: Fanelie Rosier/iStockphoto.

More recently, the study of settlement has evolved into the interaction of humans with the physical and ecological world. This more holistic study is concerned with sustainability and seeks to better understand the present landscape and plan the future.

Settlement geography has been and continues to be studied far more in European universities. The Germans and the French spearheaded European study a century ago by examining rural farmstead and village patterns. The focus capitalized on the long-lasting European cultural hegemony and impact in world affairs and the rich architectural styles that intertwined over time in the complex patterns that settlement deciphers.

American settlement geography adopted the architectural and spatial pattern concepts of European studies. Settlement geography in America flourished during the time of Carl Sauer's cultural geographic perspective. American settlement studies have generally been either regionally based or mapped on European ethnic groups in America.

Settlement geography has depended on the rural landscape for its subject matter. Rural vernacular farm buildings have been studied for patterns, functions, origins, and relationships to agricultural production. Shapes and functions

often reflect cultural preadaptation (competitive traits possessed by an ethnic group) and simplification (modifying, inventing, or borrowing new traits). The arrangement of land survey systems and roads has also created patterns to be interpreted by settlement. Over time, as America became more urban, the rural landscape evolved into progressively larger urban sites from hamlets to the metropolis. The study of settlement geography remained concentrated on rural settlement patterns, while urban geographers deal with city patterns.

American geographic study reached its apex from the 1920s through the 1970s, during which Isaiah Bowman, Fred Kniffen, Loyal Durand Jr., Glen Trewartha, and Kirk Stone wrote about the topic. Henry Glassie, Terry Jordan, Karl B. Raitz, and William Wyckoff more recently contributed to the field in the United States. Beginning in the 1920s, Isaiah Bowman studied pioneer farming settlement to identify global areas of potential colonization. This type of settlement study is seldom practiced today, having given way to the more historical and European-like study of house types, barns, and agricultural outbuildings. In the 1930s, Sauer's student Fred Kniffen began to study folk housing in Louisiana and then across the Midwest. Louisiana State University carries



forth his methods to interpret vernacular culture research in the Gulf South. Durand, Trewartha, and Stone worked in settlement geography at the University of Wisconsin. Loyal Durand was an economic geographer who studied rural agricultural production of milk from the 1940s through the 1960s and as a by-product studied the shapes of barns throughout the midwestern milk shed. Allen Noble and John Fraser Hart continued regional barn studies into the 1980s.

In the 1940s, Glen Trewartha, a physical geographer, studied settlement types and then applied what he found to the local landscape and patterns. His work explained the rural settlement patterns of compact villages that were often settled by homogeneous groups, as well as hamlets and villages that are differentiated by their size and the number of retail establishments. Kirk Stone was concerned with the definition of settlement and argued for a settlement geography that focused on dwellings within areas of primary production. He also worked in Alaska on a variety of subjects, including the settlement of the Matanuska Valley during the New Deal period, which could be read as a continuation of the Bowman tradition of pioneer settlement.

More recent studies in settlement include the work of Terry Jordan, who specialized in Texas settlement patterns and also folk architecture, village life, and agricultural practices. Henry Glassie, a Kniffen protégé, is a professor of folklore who is known for his material culture and vernacular architectural studies around the world as well as in the United States. Karl Raitz contributed to the study of ethnic groups and American landscapes, the National Road, and Appalachian studies. William Wyckoff published on Western settlement and its ecological imprint on the landscape. In Canada, Cole Harris contributed several works on the historical and settlement geography of the Canadian frontier. Many others have studied the settlement patterns within their home or adopted states. However, the specific study of settlement has declined.

The study of American settlement has historically been within rural America, where the classical authors studied ethnic patterns on the vernacular rural landscape. In time, authors began to study the transition from rural to urban landscapes and, more recently, the less than sustainable, sprawling

urban landscape patterns. Traditional settlement geography may be renewed because of its emphasis on local materials and as a learning tool for sustainable community building. Settlement today can also be studied for the demands it places on land, the environmental impacts, and the altered ecological systems. The current study of settlement geography can learn from past settlement patterns, investigate current patterns, and re-create new patterns that are more ecologically sustainable and community oriented.

Chris Mayda

See also [Architecture and Geography](#); [Cultural Landscape](#); [Folk Culture and Geography](#); [Frontiers](#); [Rural Geography](#); [Urban Geography](#); [Urban Hierarchy](#)

Further Readings

- Bowman, I. (1926). The scientific study of settlement. *Geographical Review*, 16(4), 647–653.
- Bowman, I. (1932). Planning in pioneer settlement. *Annals of the Association of American Geographers*, 22(2), 93–107.
- Durand, L. (1943). Dairy barns of southeastern Wisconsin. *Economic Geography*, 19(1), 37–44.
- Glassie, H. (2000). *Vernacular architecture*. Bloomington: Indiana University Press.
- Harris, C. (1997). *The resettlement of British Columbia: Essays on colonialism and geographic change*. Vancouver, British Columbia, Canada: University of British Columbia Press.
- Jordan, T. (1984). A reappraisal of Fenno-Scandian antecedents for midland American log construction. *Geographical Review*, 73, 1.
- Kniffen, F. (1965). Folk housing: Key to diffusion. *Annals of the Association of American Geographers*, 55(4), 549–577.
- Raitz, K. (Ed.). (1996). *The national road*. Baltimore: Johns Hopkins University Press.
- Stone, K. (1965). The development of a focus for the geography of settlement. *Economic Geography*, 41(4), 346–355.
- Trewartha, G. (1946). Types of rural settlement in colonial America. *Geographical Review*, 36(4), 568–596.
- Wyckoff, W., & Cronon, W. (2006). *On the road again*. Seattle: University of Washington Press.



SEXUALITY, GEOGRAPHY AND/OF

Geographies of sexuality focus on the idea that there is a spatial component to the connections between sexuality (in all its forms), power, and knowledge. This body of work, following on the heels of the poststructural turn in the social sciences and humanities, is a direct outgrowth of feminist geography. Social and spatial constructions of both gender and sex are invoked through issues of *heteropatriarchy*, which challenges the unequal power relations between those at “the center” (usually heterosexual males) and all other gendered and sexual identities. Lesbians in particular suffer even greater oppression due to the dual constructions of gender and sexuality. As seen through the eyes of lesbian feminist geographers, perceptions of space and place are very important when played out through these manifestations of heterosexual patriarchal power. Sometimes called *heteronormativity*, this assumed or “compulsory heterosexuality” is challenged in geographical research, giving credence and voice to those sexual minorities that are oppressed and marginalized because of their “difference.” Hence, there is a heavy emphasis on identifying how geographical space plays a critical role in defining (and performing) one’s sexual identity. In other words, notions of space and place reveal how particular sexualities materialize themselves on the material landscape.

Much of this work on spatializing sexuality is relatively recent. In the 1970s, a number of things began to take shape that put geographies of sexuality on the map, but not without a struggle. Indeed, the simple act of arranging meetings of gay and lesbian geographers at national and regional academic meetings was often met with hostile denouncements from established scholars within the discipline. During the 1980s, a small number of geographers, mainly associated with the gay and lesbian rights movement, began drawing attention to the way sexual space is produced and acted on.

The earliest significant work in sexuality and space was in urban geography, as scholars sought to map out the most visible lesbian and gay spaces within the North American city. Among the first to publish geographies of the “gay landscape”

was the urban sociologist Manuel Castells, whose treatise *The City and the Grassroots* (1983) was widely cited. His study on the boundaries of the Castro District in San Francisco postulated that gay men (as men) were actively more territorial than lesbians (as women), who relied on informal social networks more than the “brick-and-mortar” commercial spaces (bars, bathhouses, etc.) that were so closely associated with gay men. This was perhaps the first work that drew attention to the spatialized aspects of homosexuality, and it readily drew geographers’ attention. Analyzing the locations of social networks, particularly of lesbian communities, is another theme. It is argued that these networks are fragile and fluid, given the threat of male violence against women in general and lesbians in particular. A third theme explores the intersections of sexuality with everyday life in rural areas. Arguing against an urban-metropolitan bias in sexual geographies, rural spaces are explored, showing that these spaces are numerous, complex, and influential.

Another aspect of geographies of sexuality revolves around “nature-society” relationships, a popular theme in geography that studies the relationship between human beings and their natural or biological environments. In particular, medical geographers, epidemiologists, and others have attempted to map and model the spread of AIDS and HIV globally and nationally. Many of these studies have come under heavy criticism, as they omitted the social and cultural dimensions of sexuality that affect prevention and infection. But recently, a “critical health geography” has emerged, which shows the importance of making sense of the geographies of HIV/AIDS by examining the spaces of the disease and its treatment, as well as the influence of sexual subcultures, institutions, and political activism.

During the 1990s, geographical work on sexualities took on a wider perspective, in part because of the influence of queer theory, which postulates that sexual expression is much more varied and fluctuating and embeds itself within multiple human identities and cultural expressions that play out across time and space. Today, a multiplicity of work exists that varies widely in geographical scale, from sexualized transnational and global spaces to the most intimate of scales, that of the body.



One such narrative deals with cognitive accounts of public spaces at varying scales, ranging from the street and the park to the neighborhood and the community. This research focuses on territorializing and identity formation through urban design, the formation of gay ghettos, public sex as a political act, and issues of domination and control through surveillance. Related to this is the notion that sexuality is deeply embedded, and at the same time external to, capitalist spatial constructions of the individual, the family, the community, and the globe. Sexual minority communities therefore become part of a political-economy narrative, such as the role of sexual minorities (in particular, gay men) in effecting the urban processes of gentrification. Sexuality-driven cultures and spaces, therefore, are folded into economic envelopes of cultural commodification and consumption.

Another aspect of geographies of sexuality revolves around intersections of space and sexual politics, in particular how various sexualities interact with the state at different geographical scales. In line with the postmodern “turn,” this work focuses on aspects of political identity rather than on the processes of urban political economy. This marked a change in focus from urbanized landscapes to how heterosexualized nationalism and citizenship are socially constructed and very much contested. For example, much has been written on the relationship between the state and sexual minorities. A good example is the recent scholarship on the place dynamics of the same-sex marriage issue in the United States. In terms of social, political, and legal rights, the state sometimes excludes gay men and lesbians from full citizenship based on the idea that legal rights and state entitlement programs are reserved for heterosexual family units. Examples include tax benefits for married couples, inheritance rights, custody and adoption rights, and so on. Legal, health, and welfare systems are also based on criticisms of the institutionalization of heterosexuality. Consequently, sexual minorities are discriminated against. Inequalities within social and physical space are created and contested through the politics of intolerance, oppression, and subversion. Related to this notion is a small body of literature on quantitative analyses of voting patterns in gay rights referenda and elections, most

of which argues that both the diffusion of political ideas related to “gay rights” and the so-called culture wars can better be understood by looking at correlations between voting patterns and socio-demographics.

An examination of geographical scale at the level of the body reveals that all bodies are categorized as “sexed” and are socially constructed as male versus female and heterosexual versus homosexual. In this vein, many geographers have made use of Michel Foucault’s account of *biopolitics*. Foucault theorized that beginning in the late 19th century, heterosexual bodies were rigorously defined by the medical and religious communities as “normal,” thereby constructing all other sexualities as “deviant.” As these notions have shifted across time and space, geographers point out that there is no way to escape the cultural and social settings in which our bodies are placed. Human bodies, therefore, become sexualized spaces themselves, in which particular bodies in particular places can disrupt traditionally accepted notions of sexuality. In other words, bodies can be “out of place,” that is, they disrupt fixed categories of identity and space. One particularly interesting example is Michael Brown’s work on how the spatial metaphor of being “in the closet” works to describe the concealment, denial, and ignorance of gay men’s presence in the world and how this is a spatial practice of power and knowledge. This is a geographic extension of previous research on “the closet,” which has come largely from literary criticism and the humanities. Brown situates the closet in different locations and at different spatial scales and shows how this has implications for a wide variety of contemporary social theories and debates.

Criticisms of scholarly work on sexuality from the point of view of mostly white, North American and European gay males have spawned a new body of literature that includes views from perspectives of sexuality as just one of many cultural markers that make up human identities. Multiple identities that combine sexuality with race, economic class, gender, and disability have now become increasingly important in examining sexualized community space. Most recently, research on sexualized geographies has turned toward issues of transnational capitalist global space. For example, various issues are being addressed, such



as how international border crossings, mass migration, and increased mobility have affected sexual minority communities, culture, and politics. Related to these issues of globalization and sexuality is a growing interest in arguments that Western notions of “gay” and “queer” are themselves potentially “neocolonial” and “neo-imperialist.” These mobility/sexuality issues are also being addressed through research on gay and lesbian tourism and travel.

These themes of location, space, place, and movement exemplify how geographers study issues of sexuality. As with any human identity, sexuality is integral to the construction of spatial difference, which requires an understanding of the geographical spaces through which these identities are constructed, performed, and contested.

Thomas Chapman

See also **Critical Human Geography; Feminist Geographies; Gays and Lesbians, Geography and/of; Masculinities and Geography; Other/Otherness; Queer Theory**

Further Readings

- Bell, D. (Ed.). (1995). *Mapping desire: Geographies of sexuality*. London: Routledge.
- Berg, L., & Longhurst, R. (2003). Placing masculinities and geography. *Gender, Place and Culture*, 10, 351–360.
- Brown, M. (2000). *Closet space: Geographies of metaphor from the body to the globe*. London: Routledge.
- Brown, M., & Knopp, L. (2003). Queer cultural geographies: We’re here! We’re queer! We’re over there, too!” In K. Anderson, M. Domosh, S. Pile, & N. Thrift (Eds.), *Handbook of cultural geography* (pp. 313–324). London: Sage.



SHIFTING CULTIVATION

Shifting cultivation, also known as swidden or slash-and-burn in the scientific literature and by countless local names where it is practiced, is one of the oldest and most widespread agricultural

land use systems on Earth. For decades, it has been an important topic of research for geographers who study indigenous and peasant forest dwellers, as well as deforestation and land degradation in the tropics. Shifting cultivation covers an estimated 7.7 million square miles (20 million square kilometers) of arable land and supports 270 million people, or 4% of the global population in 2008. Most shifting cultivators inhabit sparsely settled tropical forests in Africa, South and Southeast Asia, Oceania, and the Americas. In terms of land area, shifting cultivation is most extensive in Brazil, the Congo, and Indonesia and makes an important contribution to food production in these and other nations of the developing world. It is regarded as a major cause of tropical deforestation but has persisted for centuries without serious environmental degradation where low population densities permitted sufficient fallow periods, during which the land is left uncultivated and allowed to return to forest. Although sensitive to population growth and economic change, shifting cultivation systems are now increasingly regarded by researchers and policymakers as repositories of local environmental knowledge that can be critical components of strategies that combine sustainable development with the conservation of agrobiodiversity in tropical rain forest regions.

General Characteristics of Shifting Cultivation

Shifting cultivation involves farmers cutting, clearing, and burning forest vegetation to plant a variety of short-term and long-term crops, typically on small landholdings with little or no use of chemicals, machinery, or other agro-industrial inputs. Shifting cultivators generally do not till the soil, relying instead on fire to clear their fields and on sticks and other hand tools for planting. Shifting cultivation is an extensive system of land use in which farmers grow staple crops in new fields for only a few years before converting them to agro-forestry production or leaving them to forest regrowth. The same plot of land may not be cleared again for staple crops for years or even decades, although the length of time varies according to local environmental, demographic, sociocultural, and economic factors. In this regard, shifting cultivation systems rely on land rotation rather than on crop rotation and fertilizers to maintain soil



fertility. Shifting cultivation systems are remarkably diverse in form and practice, but all mimic to some degree the ecological processes associated with natural forest disturbance and succession.

The production cycle of most shifting cultivation systems starts at the onset of the dry season, the timing of which varies by latitude and region throughout the tropics. Farmers first identify suitable plots for new fields and then clear them with axes, machetes, and other hand tools, as well as chain saws, which are increasingly common in all but the most isolated areas. Forest clearance is one of the most labor-intensive phases of production, and farmers often take the help of relatives and neighbors, who are remunerated for their work through labor reciprocity or with payments of cash or food. The cut vegetation is left to rot where it falls and forms a thick layer of debris that protects the exposed soils during the dry season. In some areas, farmers plant beans (*Phaseolus* spp. and *Vigna* spp.) and other rapidly maturing crops in newly cleared fields amid the decomposing vegetation.

The harvest of dry-season crops, another period of high labor demand, occurs just before the beginning of the wet season. After harvest, farmers burn the dried plant debris in their fields. Under ideal conditions, the vegetation burns well, but often, multiple burns are needed. Burning serves several purposes. It clears the surface of the field and prepares it for wet-season cultivation. It reduces soil acidity and enriches surface soil horizons with carbon, potassium, magnesium, calcium, and other essential plant nutrients in ash. Burning also temporarily eradicates weeds, insect pests, and diseases. As such, insufficient burns due to a short dry season, bad timing, or other factors may lead to a host of problems that hinder the subsequent productivity of a field.

At the beginning of the wet season, farmers plant a variety of staple crops. These vary by geographical region but generally include grains such as maize (*Zea mays*), rice (*Oryza* spp.), sorghum (*Sorghum* spp.), and millet (*Setaria italica*), as well as tubers such as manioc (*Manihot esculenta*), sweet potatoes (*Ipomea batatas*), yams (*Dioscorea* spp.), taro (*Colocasia esculenta*), and dasheen (*Xanthosoma* spp.). Perennial crops such as bananas or plantains (*Musa* spp.), pineapples (*Ananas comosus*), and sugarcane (*Saccharum*

spp.) are also planted at the onset of the wet season, as are a wide variety of fruit and nut trees and other agroforestry crops.

Staple grains may be cultivated once or twice in the same field during a single wet season depending on local climatic and environmental conditions. Weeding becomes important as these crops mature. Shifting cultivators weed by hand, either timing their work to specific growth stages of their crops or weeding continually from germination to harvest. Weeding is tedious work, and farmers often rely on family and neighbors for help. Intercropping, a near-universal practice in shifting cultivation, involves planting different grains and tubers together or alongside beans, squash, and other vegetables. Each crop is then harvested by hand as it reaches maturity. By maximizing the surface area under production, intercropping inhibits weed growth, minimizes crop loss due to pests, and permits a wide variety of crops to be cultivated in the same field, thereby contributing to the subsistence security of shifting cultivator households.

Farmers generally do not cultivate staple grains for more than one wet season, whereas root crops and perennials may remain productive for another year or two. Even after the end of the first wet season, fields become increasingly weedy. *Cecropia* and other secondary species establish a new forest canopy and begin to shade out most perennial crops. At this stage, farmers may decide to leave the field to secondary forest regrowth for a variable number of years before clearing it again for staple crops. In other cases, farmers may convert fields to agroforestry plots and continue to grow bananas and plantains alongside a wide variety of tree crops. Agroforestry, which requires less labor than staple crops, is a long-term investment that contributes to nutrition while providing a perpetual source of natural medicines, building materials, and other household products, as well as potential cash income. As tree crops die out after decades of production, old agroforestry plots are again cleared for staple crop cultivation.

Ecological and Economic Dimensions of Shifting Cultivation

Shifting cultivation is one of the oldest systems of agricultural land use on Earth, and its origins



likely date to the beginnings of farming around 10,000 years ago. Because it requires no plowing and little more than fire, wood-cutting tools, seeds, and minimal amounts of labor for food production, shifting cultivation was likely the original system of forest farming across the tropics and in the midlatitudes of Eurasia and the Americas. Population growth and landscape change led to the gradual adoption of more intensive agricultural systems in the midlatitudes, but shifting cultivation endured in the forested regions of the tropics. Recent archaeological evidence from Central and South America, West Africa, and Southeast Asia suggest that it may have played an important role in prehistoric food production throughout the tropical world, coexisting alongside more intensive systems of agriculture and even replacing them during periods of socio-political upheaval and demographic collapse.

Contemporary shifting cultivation is often associated with agricultural colonization in the humid tropics and as such is seen as a major factor of tropical deforestation. Since the mid 20th century, growing numbers of poor, landless colonists, attracted by government land distribution schemes, infrastructure development, and hopes of economic advancement, have encroached on the last remaining tropical forest regions on Earth. Lacking capital and technology, these peasant colonists typically practice shifting cultivation for subsistence. As the populations along tropical forest frontiers grow, colonists must often shorten their fallow periods in response to increased settlement densities and land scarcity, often compromising the ecological integrity of their land use systems and inciting deforestation and soil degradation. If frontier populations continue to rise, colonists generally move elsewhere in search of new land, thereby fueling renewed frontier expansion, or abandon shifting cultivation to become laborers for large-scale enterprises engaged in logging, ranching, and plantation agriculture.

Agricultural colonization in the tropics also affects the shifting cultivation systems of indigenous forest dwellers, some of which are remarkably complex and based on sophisticated knowledge of rain forest environments. In recent decades, shifting cultivation by indigenous forest dwellers has been disrupted by agricultural colonization and greater integration with market

economies, with the most frequent consequences being the shortening of fallow periods and the abandonment of agroforestry production. Some forest dwellers are able to maintain long-term ties with outside markets without sacrificing their subsistence needs or the integrity of their land use practices. In most cases, this is the result of specialization in profitable agroforestry crops such as Brazil nuts (*Bertholletia excelsa*), cocoa (*Theobroma cacao*), vanilla (*Vanilla planifolia*), or various latex bearing trees (e.g., *Castilla elastica*), which are valuable agricultural commodities that provide a steady source of cash income. In the absence of such cash crops, however, shifting cultivation becomes marginalized and is often replaced by more lucrative land use activities as forest dwellers become more oriented toward cash economies.

Shifting cultivation has the potential to be either ecologically sustainable or destructive depending on how it is practiced, but most frequently, it has been portrayed in a negative light. Accounts by early travelers in the humid tropics often described it as a primitive and inefficient mode of agriculture. Likewise, colonial administrators generally regarded it a threat to timber resources and sometimes attempted to suppress its practice. Even today, shifting cultivation is most recognized for its role in deforestation despite growing evidence of its sustainability where farmers maintain sufficient fallow periods and ensure regeneration of forest soils and vegetation. In a properly functioning system, most land is devoted to agroforestry crops or secondary forest regrowth, with only a small portion of land used for staple crops. In this sense, the impact of shifting cultivation on rain forest environments is considerably more benign than the impact of logging, cattle ranching, or commercial agriculture.

Growing awareness of the potential sustainability of shifting cultivation has begun to foster change within the international development community and among academic researchers. Many now regard this simple land use practice as a model of sustainability and an example of how human populations can simultaneously use and protect tropical rain forest ecosystems. Shifting cultivation is also valued for its role as a repository of local environmental knowledge and in situ



agricultural biodiversity. Although it remains vulnerable to disruption from a variety of factors, shifting cultivation is now increasingly regarded as an integral part of initiatives that seek to combine biodiversity conservation with efforts to strengthen the cultural identities and improve the livelihood opportunities of indigenous rain forest dwellers across the humid tropics.

David M. Cochran Jr.

See also Agriculture, Preindustrial; Agrobiodiversity; Agroforestry; Biome: Tropical Rain Forest; Bush Fallow Farming; Deforestation; Indigenous Agriculture; Population and Land Degradation; Population, Environment, and Development

Further Readings

- Cochran, D. M. (2008). Who will work the land? National integration, cash economies, and the future of shifting cultivation in the Honduran Mosquitia. *Journal of Latin American Geography*, 7, 57–84.
- Conklin, H. C. (1957). *Hanunóo agriculture: A report on an integral system of shifting cultivation in the Philippines*. Rome, Italy: Food and Agricultural Organization of the United Nations.
- Denevan, W. M., & Padoch, C. (Eds.). (1988). Swidden-fallow agroforestry in the Peruvian Amazon. *Advances in Economic Botany*, 5, 1–107.
- Dove, M. R. (1985). *Swidden agriculture in Indonesia: The subsistence strategies of the Kalimantan Kantu*. Berlin, Germany: Walter de Gruyter.
- Geertz, C. (1963). *Agricultural involutions: The process of ecological change in Indonesia*. Berkeley: University of California Press.
- Ruddle, K. (1974). *The Yukpa cultivation system: A study of shifting cultivation in Colombia and Venezuela*. Berkeley: University of California Press.
- Thrupp, L., Hecht, S., Browder, J., Lynch, O., Megateli, N., & O'Brien, W. (1997). *The diversity and dynamics of shifting cultivation: Myths, realities, and policy implications*. Washington, DC: World Resources Institute.



SHORTEST-PATH PROBLEM

The shortest-path problem is one of the most basic and widely applied forms of network analysis used in computational geometry and geographic information systems (GIS). Networks, or graphs, are used to model linear features such as roads and streets using a series of connected nodes (vertices or points) and links (edges or lines). Nodes typically represent the locations of origins, destinations, and intersections, while links are constructed as line segments that connect the nodes. Each link in the network is assigned a weight or cost that is associated with moving from the starting to the ending node. Weights can be assigned based on segment length, weighted distance, or other cost, such as expected travel time. The shortest-path problem then is used to determine the optimal pathway along the network that connects origin and destination nodes such that the sum of the constituent links in the pathway is minimized. If a weighted cost is used in the problem, the shortest path is often termed a *least-cost* path.

Four basic types of shortest paths are recognized, and they are classified based on the number of origin and destination nodes specified in the problem. The simplest is the one-to-one shortest path, which defines a single pathway connecting an origin to a destination node. The one-to-many shortest-path problem determines the set of shortest paths for a single origin to numerous destinations, while the many-to-one problem is used for multiple origins to a single destination. Finally, the many-to-many problem is used to compute shortest paths between all pairs of origin and destination nodes in a data set. These types of shortest-path problems are typically solved using computer algorithms developed for GIS or other software. These algorithms are typically developed for a specific type of shortest-path problem, such as Dijkstra's algorithm, which solves the one-to-many problem, and the Floyd-Warshall algorithm, which solves the many-to-many problem.

Shortest-path problems are widely applied for transportation and routing problems in GIS and related fields. The most common application is for determining driving directions from a starting



to an ending location on a road network, where the goal is to determine the shortest or quickest route between locations. Web-based mapping applications that provide driving directions use shortest-path algorithms to compute their solutions. Shortest-path problems are also used as an input to many other spatial analyses in geography, particularly for location-allocation models, analyses of urban spatial structure, and vehicle routing problems. For example, in a study of commuting patterns in an urban area, the shortest paths between people's residences and work places might be used to estimate the lengths of their daily commutes.

Joni A. Downs

See also **GIS in Transportation; Location-Allocation Modeling; Network Analysis; Network Data Model**

Further Readings

- Daskin, M. S. (2001). *Network and discrete location models, algorithms, and applications*. New York: Wiley.
- Longley, P. A., Goodchild, M. F., Maguire, D. F., & Rhind, D. W. (2005). *Geographical information systems and science* (2nd ed.). New York: Wiley.



SINGLE LARGE OR SEVERAL SMALL (SLOSS) DEBATE

The single large or several small (SLOSS) debate, which occurred in ecology, conservation biology, and biogeography from 1975 through the 1980s, dealt with the relevance of the dynamic equilibrium theory of island biogeography to the design of refuges or reserves for conservation. This entry describes the equilibrium theory of island biogeography, its application in “habitat islands,” and its use by conservationists seeking to design reserves or refuges for species preservation. It then describes a controversy ignited by the theory and evaluates its relevance today.

Equilibrium Theory of Island Biogeography

In the 1960s, Robert MacArthur of Princeton University and Edward O. Wilson of Harvard University proposed a new explanation for the distribution of animal and plant species on islands: the equilibrium theory of island biogeography. They envisioned the biota of an island to be a dynamic rather than static entity, with species new to the island arriving occasionally (“immigration”), while ever so often the population of some species on the island would dwindle to the point that the species disappeared (“extinction”). They asserted further that the immigration rate would be a declining function of the number of species present on the island (because the more species that are already on an island, the fewer there would remain in the vicinity that could possibly immigrate), while the extinction rate would be an increasing function of the number of species already present (because the more the species that are present on the island, the smaller the population sizes of each would be, on average, and therefore the more at risk of extinction each would be). A rising extinction curve would cross a falling immigration curve at a particular point, which would constitute a dynamic equilibrium number of species (Figure 1). A further consequence predicted by this model was that, other things being equal, a large island would have a larger equilibrium number of species than a small island because the extinction curve would be lower. This would follow from the fact that if two islands had the same number of species, the larger one would have larger population sizes, on average, of each species, so extinctions would happen less frequently. Another prediction of the model is that, other things being equal, the more isolated an island is, the fewer the species that would exist at equilibrium (because immigration rates would be lower).

The equilibrium theory struck a highly responsive chord among biogeographers and ecologists, who quickly began seeking data on island biological communities, or parts of communities (such as all the bird species, or all the mammals, or all the plants), to attempt to match them to the predictions of the theory. Especially common were studies showing that, within single archipelagoes, larger islands tended to have

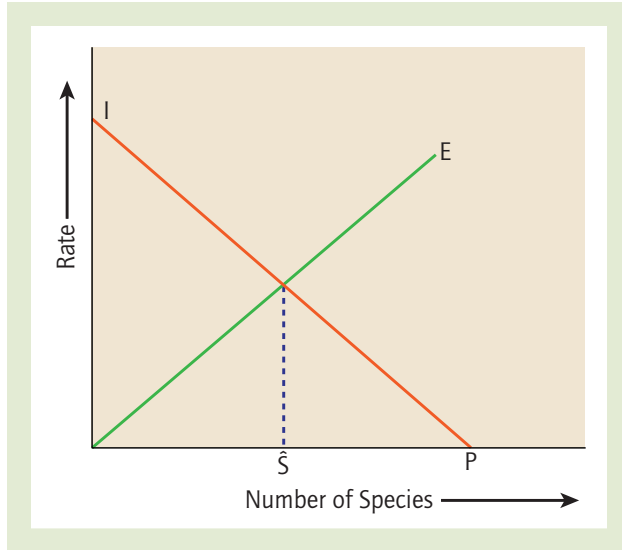


Figure 1 The dynamic equilibrium model of biogeography

Source: Adapted from MacArthur, R. H., & Wilson, E. O. (1967). *The theory of island biogeography*. Princeton, NJ: Princeton University Press.

Note: P is the number of species in the entire regional species pool, and $\bar{S}$ is the equilibrium number of species attained when the extinction rate E equals the immigration rate I .

more species than smaller ones, just as the theory predicted.

Application of the Theory to Habitat Islands

In their original exposition, MacArthur and Wilson suggested in passing that their theory should apply not only to oceanic islands but also to “habitat islands”—pieces of one habitat embedded in a matrix of another. Examples include freshwater lakes, woodlots or small forest patches in an agricultural landscape, and small abandoned fields amid large tracts of forest. The 1960s and 1970s saw the growth of interest in two other areas that intersected strongly with this suggestion by MacArthur and Wilson. First, beginning in the 1940s but increasingly in the 1960s and 1970s, biologists and geographers published papers showing that certain habitats were being progressively destroyed and fragmented, so that what had formerly been continuous “seas” of some habitat had become a series of increasingly small and isolated fragments in a sea

of some sort of human habitat, such as agricultural fields and housing subdivisions. Well-known and widely publicized examples of this sort of change depicted the fragmentation of formerly continuous forest in an area of Wisconsin and of heathland in Southern England, so that forest patches in the first case and remnants of heath in the second became isolated habitat islands. The authors of these publications frequently expressed concern about the consequences of this fragmentation for the species that had evolved in these habitats and were adapted to life in a continuous rather than fragmented range. Would they be able to persist in small, isolated habitat patches?

Habitat Islands and Conservation

The 1960s and 1970s also saw rapidly increasing concern about environmental and conservation matters in general. The first Earth Day in the United States was in 1970, the U.S. Endangered Species Act was passed in 1973, and the U.S. National Forest Management Act was passed in 1976. Newspapers were rife with articles on the loss of species and habitats, and many popular books on aspects of these problems appeared at this time—for example, Paul Ehrlich’s book *The Population Bomb* in 1968. It was inevitable that the theory of island biogeography would quickly be applied to habitat fragments in a conservation context, and this application happened with a vengeance with three papers that appeared almost simultaneously in 1975, by John Terborgh, by Jared Diamond, and by Edward O. Wilson and E. O. Willis. All suggested the relevance of the dynamic equilibrium theory of island biogeography to the design of refuges or reserves for conservation. The latter authors diagrammed a series of rules for refuge design that they associated with the equilibrium theory (Figure 2), and this rule set diagram was subsequently adopted in the World Conservation Strategy of the International Union for Conservation of Nature in 1980. The first rule is that a single large reserve is superior to a set of small ones of equal total area. This rule quickly became known by its acronym SLOSS.

Conservation planners and policymakers, desperate for effective ways to conserve biodiversity in an increasingly difficult sociopolitical context, and with species disappearing regionally and even

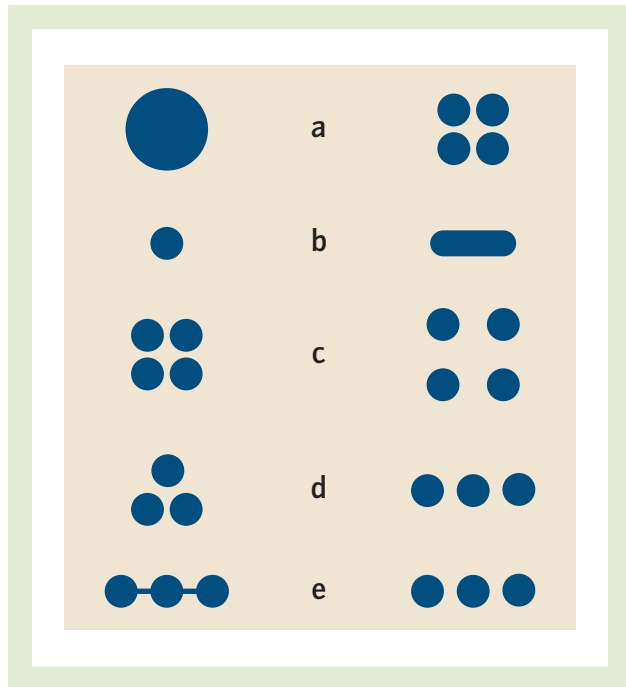


Figure 2 The rules of refuge design. In each case, the configuration on the left is deemed superior to that on the right. Rule (a) is the SLOSS rule.

Source: Adapted from Wilson, E. O., & Willis, E. O. (1975). Applied biogeography. In M. L. Cody & J. M. Diamond (Eds.), *Ecology and evolution of communities* (pp. 523–534). Cambridge, MA: Harvard University Press.

globally at an increasing pace, eagerly turned to these new straightforward, simple rules, which quickly appeared in introductory textbooks, journal articles, and even the guidelines of the World Bank for the environmental aspects of development loans. In practice, many factors other than ecological ones go into decisions about which lands to attempt to preserve in specific cases. Economic, political, and sociological considerations all come into play. However, the rules, and especially the SLOSS rule, at least provided an apparently simple target that planners might aim for. The rule also suggested a shift in what was a dominant conservation strategy at the time: buying up small tracts of land that included known populations (in some cases, the last known population) of an imperiled species. If very small populations, and even collections of several very small populations, were doomed to quick extinction, then it would surely be more efficient to sacrifice

some of the total area in order to sequester larger continuous tracts of land.

The SLOSS Controversy

The SLOSS rule soon ignited substantial controversy that raged for over a decade. It was shown that most of the rules for refuge design, including the SLOSS rule, were not really consequences of the equilibrium theory but rather rules of thumb inspired by the metaphor of refuges as islands in a sea of development. They might still be good rules, but this would be an empirical matter that could be determined only by studying specific situations and determining in particular circumstances whether there was any trend for a single large site to contain more species than several small sites of equal total area.

Also, certain considerations cast some doubt on the dictum that a single refuge, even a rather large one, is always a better design than several small ones. Briefly, in several instances of real oceanic archipelagoes, introduced predators have eliminated populations of a particular species on every island they reached, and the species persists only on one or a few islands, usually small and isolated, that remain predator-free. For example, in the Seychelles Islands in the Indian Ocean, the Seychelles magpie robin persisted only on Frigate Island, which is small and isolated, when cats on the island were removed only after they had eliminated the species everywhere else in the archipelago. Subsequently, the species has been reintroduced in three other islands where cats have been eliminated or controlled. If the Seychelles had been only one large island, this species would be extinct. This example suggests that the optimal refuge design might be different if the area under consideration is the sole repository of a species of concern, rather than simply a site or a set of sites that contains good representatives of more widely distributed species, and depending on what specific factors threaten the existence of that particular species. On the other hand, it is evident that if all the sites in a network of small sites are so small that none can sustain a viable population of some species of concern, then such a network, even if it contained many sites, would be inferior to a single site of equal total area.



Many biologists, seeking empirical guidance on the utility of the SLOSS rule, compared the actual numbers of species in sets of small oceanic or habitat islands with the numbers in single large islands of approximately equal total area. Although there was much variation in the results of such comparisons, the surprising pattern was that, in most cases, the set of small islands had as many species as the single large island or even more. This result does not lead conclusively to a rejection of the SLOSS rule, however, for two main reasons. First, these studies looked at sets of sites that had existed in their current form for long periods of time—at least centuries and often many millennia—and the species on them might thus have been adapted to the fragmented geographic configuration. In contrast, conservationists are concerned particularly with saving sets of sites in landscapes that are rapidly fragmenting in the short term, and it could be that some species in the original continuous habitat cannot adapt evolutionarily, at least in the time frame of concern, to existence in a set of small fragments.

Second, this entire exercise, and in fact the theory of island biogeography that inspired SLOSS, is aimed at simply maintaining the largest number of species in the reserve or set of reserves. However, conservationists are not nearly as concerned about the number of species in a specific site as in saving species from regional or global extinction. If a set of small sites had many species in total, but all of them were quite common and widespread, this would be less important from a conservation standpoint than if a single large site had fewer species in total but among those species were one or more not found anywhere else. In short, the requirements of restricted and rare species generally trump the desire to maximize the number of species in every reserve. And there is abundant evidence that many species do require large sites for a variety of reasons and that among these species are many that are quite rare. For example, large carnivores need large sites simply for purposes of sustenance—they require more prey for subsistence than can be found in small sites. Many plant species are restricted to the interior of forests; some are never found less than hundreds of meters from a forest edge. A set of small sites would not suffice to conserve these, no matter how many small sites there are.

A final consideration is that conservationists, though not neglecting isolated small populations of imperiled species, are increasingly trying to preserve entire landscapes so as to preserve the ecological processes that maintain the habitats required for whole suites of species. Sometimes this is difficult or impossible to achieve unless large, quite continuous areas are preserved. For instance, many forest types, including the longleaf pine forests that used to dominate the southeastern United States, are fire disclimaxes, maintained only by frequent low-intensity fires. In the absence of such fires, other plant species replace the species typical of these fire disclimaxes, and the entire community, both plants and the animals that live in and on the plants, changes greatly. In the Southeast, such fires are initiated fairly frequently by lightning; such fires used to sweep unimpeded over many kilometers, so the whole landscape routinely burned. Today, old-growth longleaf pine forests are restricted to small fragments isolated in a sea of agriculture, highways, and other human constructs. The likelihood of a lightning strike within any one fragment is low, and even if a fire is initiated in a fragment, it cannot spread to other longleaf patches. An expensive technology of prescribed fire must now be used to maintain longleaf forest communities.

Today, SLOSS and other rules—those originally inspired by island biogeographic theory and others deriving from more recent sources—are viewed as rough guidelines at best, and the idiosyncratic factors, both biological and nonbiological, that obtain in any real conservation situation are taken into account. These include the habitat requirements, distributions, and evolutionary distinctness of the species particularly targeted for conservation; the economics of different refuge options; the security of possible refuge configurations with respect to introduced species and anthropogenic damage; and the social and economic concerns of the various stakeholders. In this light, SLOSS can be seen as an early attempt to formalize some of the biological considerations of importance to long-term conservation and as a continuing heuristic device to be used, along with other inputs, in an attempt to optimize conservation planning.

Daniel Simberloff



See also **Biodiversity; Biogeography; Diamond, Jared; Extinctions; Island Biogeography; Islands, Small; Patches and Corridors in Wildlife Conservation**

Further Readings

- Diamond, J. M. (1975). The island dilemma: Lessons of modern biogeographic studies for the design of natural reserves. *Biological Conservation*, 7, 129–146.
- Losos, J. B., & Ricklefs, R. E. (Eds.). (2009). *The theory of island biogeography revisited*. Princeton, NJ: Princeton University Press.
- MacArthur, R. H., & Wilson, E. O. (1967). *The theory of island biogeography*. Princeton, NJ: Princeton University Press.
- Simberloff, D. (1988). The contribution of population and community biology to conservation science. *Annual Review of Ecology and Systematics*, 19, 473–511.
- Terborgh, J. (1975). Faunal equilibria and the design of wildlife preserves. In F. Golley & E. Medina (Eds.), *Tropical ecological systems* (pp. 369–380). New York: Springer.
- Wilson, E. O., & Willis, E. O. (1975). Applied biogeography. In M. L. Cody & J. M. Diamond (Eds.), *Ecology and evolution of communities* (pp. 523–534). Cambridge, MA: Harvard University Press.

variety of different subfields, including cultural and political ecology, geographic information systems (GIS) and society, and economic geography. Specific research foci deal with the customary knowledge systems of indigenous peoples, transformation and representation of local knowledge as a means of democratizing GIS, and spatiality of knowledge in postindustrial societies and global capitalism. Geographers and other researchers use various terms to refer to this concept, with *local*, *indigenous*, *informal*, *expert*, and *traditional knowledge* being most common. The variations in terminology may reflect subtle nuances in meaning, but all refer to alternative knowledge systems that arise, often experientially, as a result of differences along the lines of ethnicity, gender, class, culture, occupation, and other factors.

Ethnoecology, or ethnoscience, studies the customary knowledge of indigenous peoples and traditional rural societies and is the oldest, most well-established area of research on situated knowledge. Since its emergence from anthropology in the 1950s, ethnoecology has grown into a dynamic, interdisciplinary field in which geographers, particularly those specializing in cultural and political ecology, have made important contributions. Much of the early ethnoecological research by geographers took place in isolated settings such as tropical forests, mountain regions, and deserts and produced detailed accounts of subsistence and resource management practices from which researchers examined the ecological rationality and knowledge of local peoples. More recently, geographers have sought to contextualize their work within broader scientific debates on topics such as agroecology, sustainability, biodiversity conservation, and protected area management. Some have explored native perceptions of space, place, and the environment, demonstrating that the knowledge of the inhabitants of isolated regions around the world is often more accurate and detailed than Western science. Others have studied situated knowledge from the standpoint of power by examining the interactions between indigenous peoples and mainstream society, the state, and international organizations. A number of geographers have also used participatory methods in a variety of applied research contexts to integrate



SITUATED KNOWLEDGE

A growing consensus in the social sciences and humanities regards knowledge as inescapably situated within the broader spatial, temporal, socio-cultural, and political economic contexts. This view has contributed to a rejection of logical positivist science as the only legitimate source of knowledge and has fostered acceptance of the idea that multiple epistemologies, or ways of knowing the world, are valid. An emergent body of research on situated knowledge explores these alternative epistemologies and their linkages with mainstream knowledge and global society. Geographers have focused on this concept in a



the customary knowledge of local peoples with conservation, protected area management, land reform initiatives, and natural hazards mitigation.

An emergent body of literature that focuses on GIS and society, or the social implications of GIS, has also contributed to scholarly research in geography on situated knowledge. Some argue that GIS itself, and especially the human organizational frameworks in which it is embedded, is a form of situated knowledge. Participatory and public participation GIS explores how the situated knowledge of marginalized peoples can be integrated with geospatial technologies so that its original contexts and meanings are preserved and accurately represented. Much of this work examines the efforts of nonprofit organizations to use GIS as an advocacy tool for low-income residents of cities in the United States and elsewhere in the industrialized world. Rich in case studies, participatory and public participation GIS research is contributing to new methods of transforming the experiential knowledge of the urban poor to bring about progressive change in their lives. Some researchers have pursued these goals by revising the organizational model of GIS to more effectively integrate situated knowledge as data. Others have sought to develop enhanced metadata systems that provide greater flexibility of data storage and that allow multiple file formats, particularly multimedia, to be incorporated as ancillary information. Still others have used computer programming to engineer solutions that enhance the usability of GIS or to custom-design GIS applications that meet the specific needs of disadvantaged populations.

A third area of research on situated knowledge is in the subfield of economic geography, where recent studies have examined the linkages between industrial location and expert knowledge in global society. The rise of the digital age has brought about the unprecedented decentralization of information and production in the global capitalist system. This transformation of global society, however, has coincided with a contradictory trend in which critical sectors of the information economy have become spatially clustered. Most high-technology centers are products of long-term investments on the part of industry, governments, and universities. Decades

of incentives have not only created conditions for information economies to take root but also led to the spatial concentration of capital, resources, and labor around high-tech hearths. This is particularly true of information professionals, who generally live near centers of high technology and whose expert knowledge forms an important component of human capital within the global economy. Researchers have found that transnational corporations must maintain a local presence in high-tech areas to successfully attract qualified knowledge professionals while cultivating their international scope to remain globally competitive.

David M. Cochran Jr.

See also Environmental Perception; Epistemology; Ethnocentrism; Eurocentrism; Indigenous Environmental Knowledge; Interviewing; Participant Observation; Political Ecology; Positionality; Qualitative Methods; Writing

Further Readings

- Foucault, M. (1980). *Power/knowledge: Selected interviews and other writings, 1972–1977*. New York: Pantheon Books.
- Geertz, C. (1983). *Local knowledge: Further essays in interpretive anthropology*. New York: Basic Books.
- Malmberg, A., Solvell, O., & Zander, I. (1996). Spatial clustering, local accumulation of knowledge and firm competitiveness. *Geografiska Annaler B*, 78, 85–97.
- Nazarea, V. (1999). *Ethnoecology: Situated knowledge/located lives*. Tucson: University of Arizona Press.
- Poore, B., & Chrisman, N. (2006). Order from noise: Toward a social theory of geographic information. *Annals of the Association of American Geographers*, 96, 508–523.
- Robbins, P. (2000). The practical politics of knowing: State environmental knowledge and local political economy. *Economic Geography*, 76, 126–144.
- Sieber, R. (2004). Rewiring for a GIS/2. *Cartographica*, 39, 25–39.



SMART GROWTH

Smart growth, a term that appeared in the urban geography and planning literature in the mid 1990s, signifies the need to adopt policies as countermeasures for urban sprawl. The latter is defined as the outward expansion of the limits of an urban area through the development of low-density suburbs, where it is uneconomical to sustain public transportation systems. The results are excessive use of the private automobile, an increasing number of work hours lost in traffic congestion, and a rising volume of automobile emissions. The latter is associated with greenhouse gases that are responsible for global warming and the

deterioration of urban air quality with the formation of ozone and smog, which have significant detrimental effects on human health and the city infrastructure.

Other detrimental effects that smart growth would remedy are the loss of agricultural land near urban areas and the deterioration of inner cities. The latter comes about by the reduction in housing demand at the city core, the associated drop in housing prices, and the reluctance of homeowners to expend capital for the maintenance of their property. Furthermore, the proponents of smart growth point to low-density suburban development as responsible for the reduction in social interaction and the weakening of the bonds that characterize a healthy society.



Aerial view of Premier Gardens Zero Energy Home Community in Sacramento, California. Designed to save homebuyers up to 60% on utility costs, this community combines innovative construction and energy-efficient appliances with renewable energy to create homes that not only are energy efficient but also produce their own electricity.

Source: Sacramento Municipal Utility District.



While there is no widespread acceptance among planners, decision makers, and researchers as to the path that would lead to smart growth, two types of policies have been proposed and implemented. The first can be labeled *land use* policies and relates to restrictions in land development, the most common of which is the imposition of a greenbelt boundary around an urbanized area, beyond which development is not allowed. Critics argue that such a policy may encourage *leapfrog* development outside the greenbelt, thereby increasing the detrimental effects of sprawl.

The second type of policies considers sprawl as an *economic* process and proposes the design of instruments that will stabilize and even reverse the process. Sprawl is viewed as the result of population growth, rising household incomes, and the falling cost of commuting. These phenomena set the stage for processes that are not fully accounted for in the market (externalities), including the full cost of suburban infrastructure development and maintenance and the social cost of congestion. Remedies proposed are development and congestion taxes levied on consumers. The most common of such instruments is the imposition of a toll on those entering with a vehicle into a city center that is usually well served by public transport. The most well-known example of such a toll is in London.

Pavlos Kanaroglou

See also **New Urbanism; Suburbs and Suburbanization; Urban Land Use; Urban Planning and Geography; Urban Policy; Urban Sprawl; Zoning**

Further Readings

- Boyle, R., & Mohamed, R. (2007). State growth management, smart growth and urban containment: A review of the US and a study of the heartland. *Journal of Environmental Planning and Management*, 50(5), 677–697.
- Brueckner, J. K. (2000). Urban sprawl: Diagnosis and remedies. *International Regional Science Review*, 23(2), 160–171.

SMITH, NEIL (1954–)

Neil Smith is among the most influential and famous of living geographers. He is currently Distinguished Professor of Anthropology and Geography at the City University of New York (CUNY) and was the founding director of the Center for Place, Culture and Politics in the Graduate Center at CUNY.

Smith was born in Scotland in 1954 and studied for a BSc degree in geography at the University of St. Andrews. In 1977, he left Scotland for Baltimore, where he began his PhD research on gentrification under the supervision of David Harvey at Johns Hopkins University, graduating in 1982. Though younger than Harvey, Smith underwent a similar academic and political transformation to that of his supervisor. This trajectory entailed a rejection of the kind of geography taught to him as an undergraduate—the so-called new geography or spatial science that Harvey's late-1960s writings embodied—and an embrace of the Marxist approach that Harvey pioneered in his 1973 book, *Social Justice and the City*. It is above all as a Marxist geographer that Smith has made his name.

Like Harvey, Smith has built carefully and creatively on the late political-economic writings of Karl Marx. He has made germinal contributions in four areas—three of them beginning with his book *Uneven Development*, published 2 yrs. (years) after he graduated from Hopkins. First, he is responsible for the “rent-gap” thesis on studies of gentrification and urban redevelopment. In opposition to theories that posit urban professionals as welcome “pioneers” returning to blighted inner-city neighborhoods, Smith's thesis focused on the political economy of gentrification, suggesting that only when the gap between the actual and potential ground rent is sufficiently high do waves of gentrification occur. This thesis pointed to the class dynamics of land use and the power of rentiers and investors to govern the uses of urban space. Highly political questions thereby arise about who has a “right to the city.”

Second, Smith popularized the counterintuitive idea of the “production of nature.” His claim in *Uneven Development* is that in a capitalist world, nature is no longer natural but, instead, is actively



produced at a discursive and material level in the service of capital accumulation. This “denaturalizing” move usefully focused some geographers’ analytical attention on the processes that remake nature (e.g., in commercial agriculture), and it also posed a challenge to those whose politics is founded on ideas of a nonsocial nature with supposedly intrinsic capacities and values.

Third, also in *Uneven Development*, Smith presented a powerful Marxian account of uneven geographical development (UGD). Unlike some other theories of UGD, Smith did not look to the “natural differences” in geography to explain the phenomenon. Instead, he argued that capitalism both produces and needs UGD: It is part of the system’s operating hardware, as it were. This means that UGD is a socially constructed phenomenon and thus, in theory, entirely preventable. Finally, *Uneven Development* also advanced the challenging idea that geographical scale is socially produced and a tool of power—thus being more than simply a mental category that we use to divide the world up. Smith argued that capitalism (including the capitalist state) actively organizes commodity production, distribution, exchange, and consumption at certain scales at certain historical moments. These constructed geographical scales become containers, constrainers, and enablers of different sorts of activities undertaken by different groups—producers, rentiers, politicians, financiers, trade unionists, and so on. Geographical scale, for Smith, thus enters into the very fabric of capitalist life and struggles to alter and transcend it.

Smith has advanced his work in all four areas both empirically and theoretically over a 30-yr. period. He is a prolific writer and speaker. He is also a founder member of the International Critical Geography Group (ICCG), which seeks to bring together left-wing scholars and activists of various stripes who are committed to radical reform of the current world order and, better still, revolutionary change. He has also, in his recent *Endgame of Globalisation*, sought a more public profile for his otherwise quite academic writing.

Noel Castree

See also **Critical Human Geography; Gentrification; Harvey, David; Marxism, Geography and; Rent-Gap; Scale, Social Production of; Uneven Development**

Further Readings

- Castree, N. (2004). Neil Smith. In P. Hubbard, R. Kitchin, & G. Valentine (Eds.), *Key thinkers on space and place* (pp. 264–268). London: Sage.
- Smith, N. (1990). *Uneven development* (2nd ed.). Oxford, UK: Blackwell.
- Smith, N. (1996). *The new urban frontier*. London: Routledge.
- Smith, N. (2005). *The endgame of globalisation*. London: Routledge.



SMOG

See Photochemical Smog



SOCIAL AND ECONOMIC IMPACTS OF CLIMATE CHANGE

Climate change is mainly concerned with the impacts on people, beyond narrow interests in natural science. For instance, the tundra may be thawing in the polar regions, which can be of scientific interest in its own right. But the more important question is what difference it makes for economies, societies, governance, and human well-being. This question is growing in salience as the knowledge base about climate change improves. About *whether* climate change is happening, there is now a very broad consensus that global warming is a reality. About *why* it is happening, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reports persuasive evidence that human activities are an important cause. The remaining issue is “*So what?*” Humanity has been adaptable throughout its history to innumerable challenges. Is climate change something that will present important challenges, or is it just one of many driving forces of social and economic change over the next century and beyond?



Current Knowledge About Social and Economic Impacts

Some impacts of climate change are already being observed, mainly in the polar areas, where traditional societies are finding it difficult to sustain their ways of life and modern societies are facing the impacts of a thawing tundra on physical infrastructures. But in most cases, the recent major climate events in the United States—such as Hurricane Katrina in 2005 and Hurricane Ike in 2008, along with a summer heat wave in 2006 and regional water shortages in the winter of 2007–2008—cannot be attributed to climate change because climate has historically been so variable. These events can be considered examples of the impacts that could become more frequent with climate change, which is very instructive; but they cannot be interpreted with a high degree of confidence as impacts of climate change itself.

The more serious issues lie ahead. What might climate change mean for economies and societies in the long run? Climate change is expected to mean increases in average temperatures, more severe toward the poles; changes in both the total amount and the intensity of regional precipitation; changes in the intensities and locations of severe weather events; and sea-level rise. Clearly, such changes could be important in many locations, but projecting the impacts on human systems in the long term is complicated since other things will also be changing over that period, such as demographic patterns, global economic relationships, available technologies, and institutional structures and practices. The socioeconomic effects of climate change will depend on how climate change interacts with these other kinds of change. Consider, for example, how much climate change might increase by 2080 the vulnerabilities of people living in coastal areas subject to sea-level rise and seasonal storms. By that time, populations in vulnerable areas will have had three generations of experience with storms and coping strategies, from risks of storm disruptions and damages to increased costs and reduced coverage of losses from private insurance. Voluntary retreats from vulnerable coastal areas may have reduced potential damages considerably.

For this reason, assessments of socioeconomic impacts of climate change generally focus not on

projections of long-term impacts, based on quantitative scenarios of direct climate change over periods of a century or more, but on climate change risks and vulnerabilities. In other words, rather than assuming a particular level of climate change in the far future, without equivalent assumptions about changes in socioeconomic contexts, analysts look at the sensitivities of human systems to climate variables: For example, based on experience with climate variability and other known factors, what difference would a change in average temperature or precipitation make, for instance, for energy requirements, for snowfall on ski resorts, or for disease vectors affecting human health? What is the range of effects of different magnitudes and rates of such a change in climate? In many cases, quantitative analysis is used not to produce hard numerical answers but to inform robust qualitative judgments about the large versus small, the urgent versus cautionary, the known versus unknown, and other guidelines for both decision making and further research.

Assumptions about the possible range of magnitudes and rates of climate change are usually drawn from quantitative scenarios such as the IPCC's Special Report on Emission Scenarios (SRES) family of depictions of possible futures, widely used in the late 1990s and through most of the first decade of the 21st century. Such scenarios commonly use average global warming (in degrees centigrade [$^{\circ}\text{C}$]) as a proxy for the host of physical changes, not necessarily meaning to imply that temperature changes are the most important of those changes. Most of the SRES project average warming in the range of about 2.5 to 3 $^{\circ}\text{C}$ by 2100.

Present knowledge of the social and economic impacts of climate change is limited because support for impact research has been scarce compared with support for climate change modeling. IPCC assessments, however, have indicated that at levels of warming below about 3 $^{\circ}\text{C}$, impacts are likely to be a mixture of positives and negatives, while above that level, impacts are likely to be very largely negative (Figure 1).

At this still early stage in the evolution of understanding of climate change impacts and responses, the greatest concerns about socioeconomic impacts are for vulnerable low-income areas with limited adaptive capacities and resources (including the

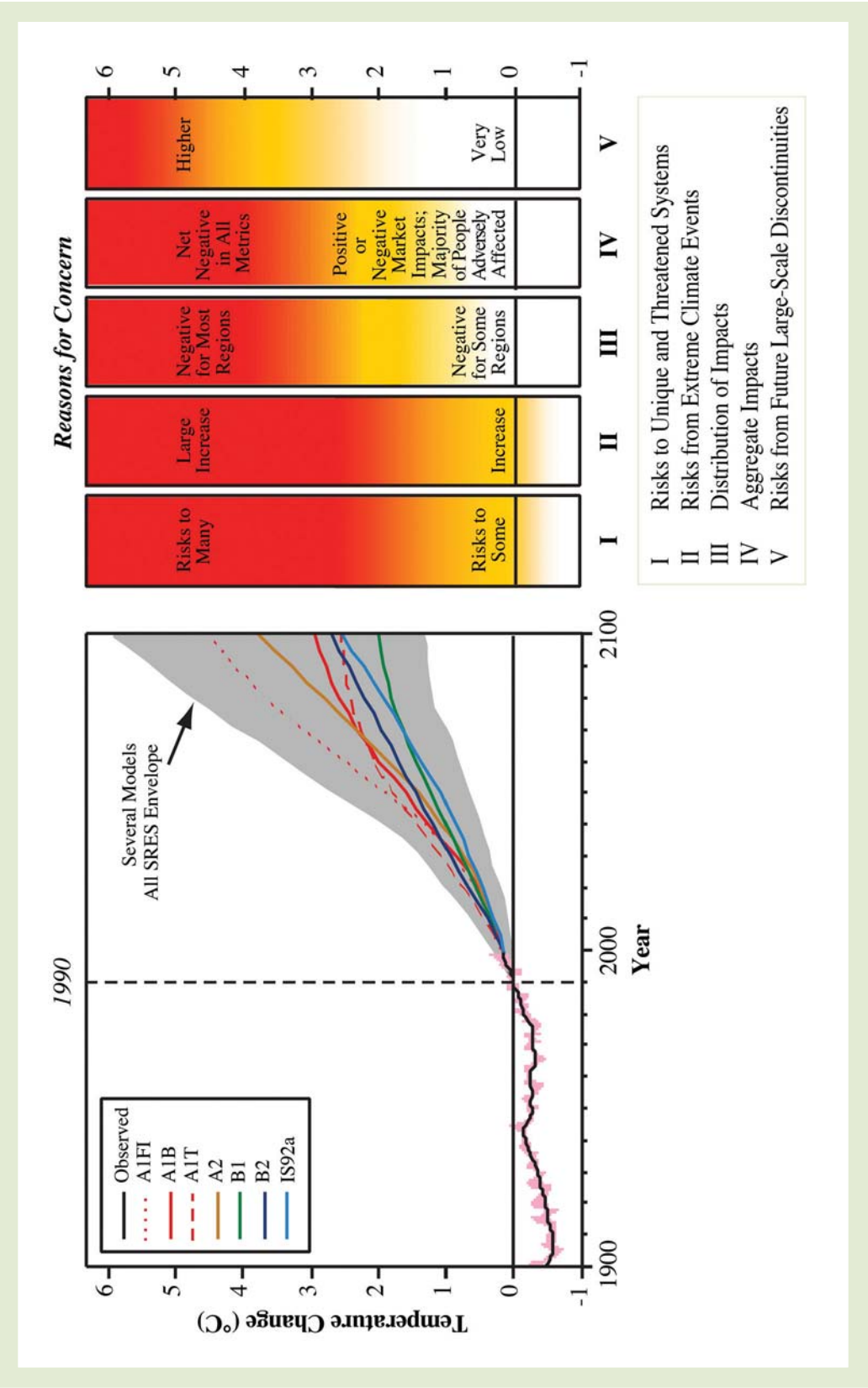


Figure 1 Reasons for concerns about projected levels of climate change
Source: International Panel of Climate Change (IPCC), 2001.



polar regions, low-lying island or coastal nations, and much of Africa), increased risks of disruptive extreme weather events (such as the effects of a combination of sea-level rise and more intense tropical storms on densely populated Asian megadeltas), and potential for abrupt (rather than gradual) changes (such as a significant change in the behavior of the Gulf Stream in the Atlantic Ocean).

More specifically, but still in very general terms, dry areas are expected to become drier and wet areas are expected to become wetter, while water storage in snow cover and glaciers will decline. Many ecosystems will face stress thresholds, especially if the average temperature increase exceeds 3 °C. Global food production could increase at lower levels of warming, but it is expected to decrease at levels above 3 °C. Potentially serious health effects are projected, especially for vulnerable populations.

These kinds of effects vary in their impacts by sector as well as by region. Sectors that inherently have greater sensitivity to climate—such as agriculture, commercial forestry, and recreation/tourism—are relatively more vulnerable, as are sectors with concentrations of activities in vulnerable regions such as coastal areas, river valleys, and areas of water scarcity—such as energy facilities in the U.S. Gulf Coast region.

But in nearly every case, the socioeconomic impacts are not well estimated from averages. Particular regions, sectors, and population groups are more often affected by where they stand with respect to variance around the mean change and by associated extremes (*very* high or low, even for relatively short periods). Analyzing such impacts with any accuracy, along with the potential benefits of reducing impacts and the costs of failing to reduce them, requires attention at a relatively detailed scale: geographically, sectorally, socially, and temporally. In many cases, for instance, an assessment of impacts at a large geographic scale may conclude that the risks are relatively small at that scale, while risks to an exposed local area could be quite large at that scale. Both can be true. An example is estimating the economic costs to the United States as a whole from a major coastal hurricane (very small as a proportion of the national economy) compared with the economic costs to a locality directly in

the path of the hurricane (dramatically large for a period of many months).

Responses to Concerns About Impacts

Where prospects of climate change impacts raise concerns, the risk management responses are mitigation and adaptation. Mitigation includes fuel switching, away from fossil fuels to renewable energy sources or nuclear energy; energy efficiency improvement; increasing uptakes by biomass, soils, or the ocean; and technology breakthroughs such as affordable carbon capture and sequestration during energy combustion/conversion processes. Adaptation includes increasing the resilience of vulnerable systems, emphasizing cost-effective steps that also reduce current stresses; increasing the range of alternatives and resources available to reduce the risks of impacts; and improving emergency response capabilities. Most analyses indicate that reducing climate change impacts enough to avoid painful costs to many social and economic systems in some parts of the world will require doing the best we can with both mitigation and adaptation. Success with mitigation can keep climate change moderate, so that adaptation can cope with a majority of the impacts. Adaptation can enable less demanding and more realistically plausible targets for mitigation to avoid dangerous impacts.

The greatest concern is that, because of the slow progress with global mitigation efforts to date, especially due to the growing carbon emissions from large developing economies in Asia, climate change by the latter part of the 21st century will be more severe than previous assessments had considered likely, posing the possibility of dramatic social and economic impacts in many cases. Observations during the first decade of the 21st century indicate that the physical impacts of climate change, such as glacier retreat or ice sheet thinning, are emerging more rapidly than projected even a few years earlier, and they indicate that global greenhouse gas emissions are growing by more than 3% per year, compared with about 1% during the 1990s. Given these observed trends, impact analyses are beginning to consider scenarios that could result in average global warming of 5 to 6 °C by 2100, rather than the earlier prediction of 2.5 to 3 °C. Early analyses



indicate the likelihood of very severe impacts by the latter part of the century if the world continues on its course toward higher levels of impacts. As an example, a study of possible climate change impacts on nine northeastern U.S. states, using the highest of the SRES as one of two cases, projected that with this relatively severe climate change, the 100-yr. (year) flood in the Atlantic City, New Jersey, area would by the end of the century be expected to occur every 2 yrs.

Contributions of Geographic Perspectives

Academic disciplines are means to social ends, not ends in themselves; the socioeconomic impacts of climate change are transdisciplinary. But geographers have been leaders in developing the science and art of climate change impact assessment, at least in part because many of geography's perspectives are useful. First, climate change is a classic nature-society issue, and geography is one of the very few disciplines whose traditions and research literatures span that gap. Second, geography is the leader, in both science and practice, in focusing attention on the value of place-based studies (and, by extension, other small-scale analyses) for integrated evaluations of climate change impacts. Third, spatial systems are important in evaluating the impact risks of and vulnerabilities to climate change, not only as a place-specific issue but also in terms of linkages with other places. For instance, among climate change impacts are threats to bridges, highways, communication networks, and other facilities that link different places and activities together. Moreover, the impacts of climate change on a particular place are not limited to what happens at that geographic location; that place can also be affected by climate change in other places that are its sources of inputs, its markets, and its competitors in the global economic marketplace. Finally, climate change impact assessment is closely linked with integrative regional knowledge, because social and economic impacts depend so substantially on other aspects of a region's environment, economy, and society. In these ways and others, geography is a key contributor to assessments of the social and economic impacts of climate change.

Thomas J. Wilbanks

See also [Adaptation to Climate Change](#); [Anthropogenic Climate Change](#); [Climate Change](#); [Climate Policy](#); [Global Sea-Level Rise](#); [Hurricane Katrina](#); [Symptoms and Effects of Climate Change](#)

Further Readings

- Arctic Climate Impact Assessment. (2004). *Impacts of a warming Arctic*. Cambridge, UK: Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2001). *Climate change 2001: Impacts, adaptation, and vulnerability* (Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change). New York: Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: Impacts, adaptation and vulnerability* (Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). New York: Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: The physical science basis* (Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change). New York: Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2007). *Climate change 2007: Synthesis report, summary for policymakers* (Fourth Assessment Report of the Intergovernmental Panel on Climate Change). New York: Cambridge University Press.
- National Research Council. (1997). *Rediscovering geography*. Washington, DC: Author.
- Union of Concerned Scientists. (2007). *Confronting climate change in the U.S. northeast*. Cambridge, MA: Author.
- U.S. Climate Change Technology Program. (2005). *U.S. Climate Change Technology Program strategic plan*. Washington, DC: Author.
- Wilbanks, T. J., Leiby, P., Perlack, R., Ensminger, J. T., & Wright, S. B. (2007). Toward an integrated analysis of mitigation and adaptation. *Mitigation and Adaptation Strategies for Global Change*, 12, 713–725.



SOCIAL CONSTRUCTION OF NATURE

There is a long tradition within geography in which study of the human relationship with nature is central. What nature is considered to be would thus seem to be of crucial importance to this tradition. Yet until very recently, the nature of nature has not been considered much. Nature is usually assumed, absorbed as taught, unquestioned, and generally commonsensed to be something independent of the human world. According to this view, the human world affects nature, but the two realms remain distinct.

The notion of the social construction of nature resulted from the attempt made by many scientists to reconsider this common understanding of nature in relation to humans. To do this requires questioning all received wisdom with regard to both sides of the nature-society relationship, and even the idea that this is a relationship between two distinct phenomena. Characterizing nature as socially constructed is meant to be provocative because the received wisdom is so entrenched. Specifically, how nature is considered from the perspective of social construction is twofold. First, what humans understand as nature is considered as always an interpretative construct, a nature for humans. This does not mean that no nonhuman nature exists, only that what humans can know about this nature is only through their own interpretations.

The second way in which nature is considered is more novel. This is the idea, particularly among those who speak of the social *production* of nature, that humans actively construct social natures in the process of materially reproducing themselves and their societies. In this view, humans are considered not as separate from nature, influencing it from without, but rather as an active part of nature, imagining and influencing it thoroughly from within, whether in the scientific laboratory or in the process of material reproduction. In terms of the latter, cities are as much a part of natural ecosystems as the nearest estuary.

What follows is a brief consideration of the idea of the social construction of nature on the basis of this analytic; but in reality, the distinction

between those who consider nature to be interpretatively constructed and those who consider nature to be constructed by human activity is not very clear-cut, because those who take the latter view recognize that human action is driven by interpretation.

How Do We Know Nature?

The notion of the social construction of reality emerged and rapidly gained popularity amid the growing critical debate concerning the conduct of science and the activities of scientists that began in the 1960s in virtually all disciplines, including geography. This debate concerned the then prevailing image of science as a process by which an objective view of reality, or nature, could be attained via an objective or “positive” scientific method followed closely by individual scientists. This prevailing positivist image of science came under increasing attack by those who argued that the practice of science was, instead, a thoroughly social affair, both in terms of how scientists conduct their research as well as in terms of how external social influences determine the problems on which scientists work. This emerging post-positivist critique of scientific practice—hereafter called the internalist perspective—was initiated by Thomas Kuhn with his book *The Structure of Scientific Revolutions*, in which he argued that scientists always work within a worldview, a “paradigm” of largely unquestioned assumptions, which determines their view of reality. The implication of Kuhn’s argument is that scientists, regardless of the methods they use, can never have direct access to an objective reality; all that is known to them is filtered through a paradigmatic or interpretive lens. Scientists, in this respect, do not observe and passively record reality. They construct a paradigmatic version of it, which may or may not be true of reality itself.

These criticisms of the positivist conception of science were heightened since some disciplines, particularly the natural and physical sciences, were considered more scientific or objective than others because their objects of study were more conducive to the use of the scientific method. This scientism, or idealization of a certain method as the only objective method by which the real world can be understood correctly, rendered



these sciences worthy of greater support and recognition as privileged purveyors of scientific certainty about reality. If, as the social constructionists argue, these sciences do not have a privileged access to the real world, than the certainties they purvey are no better than those purveyed in the so-called soft sciences of society and culture, the practices of which are much less conducive to the use of a particularly conceived scientific method.

Other critics of positivism focused their attention on how wider social issues and activities affected the conduct of science. This externalist focus was taken by those who argued that the social influences on scientists, such as religion, class, ethnicity, gender, research-funding opportunities, and political persuasion, cannot be avoided in the conduct of science, and therefore a truly objective reality cannot be determined, regardless of which method is used in investigation. This view of science as a social practice was reinforced by the social turmoil in the streets in the 1960s, when virtually all received social truths came under attack.

The idea of the social construction of nature thus emerged from within these general critical, post-positivist perspectives. What one considers nature to be is determined by the interpretive framework within which one views it, and this framework is variously constructed both within the process of doing science and on the basis of potentially numerous other socially derived biases on the part of scientists themselves. Again, the reality of nature is therefore not found and recorded readymade but, rather, interpretively constructed by human observers.

The Construction of Invasive Species

The apparent problem of invasive species can serve as an example. Such species prosper in locations other than their native ones and often, according to some observers, wreak ecological havoc by not fitting in well with the native species. Specifically, invasive species tend to reproduce themselves faster than natives, adversely change the established relations among natives by not fitting in, and are said to be leading to lower biodiversity as they overwhelm the native natural environments by homogenizing them, as a result of proving to be more fit to survive than the

natives. On the basis of this characterization of the problem, many environmentalists argue for a concerted effort to control or curtail such invasions for the good of nature itself.

Of interest here is that this abbreviated characterization of the problem of invasive species suggests a specific interpretation of nonhuman nature. Already established nonhuman nature is privileged over change in this interpretation, or at the very least, some ecological changes are considered better than others for nature itself. But is this not simply a specific human interpretation of what is best for nonhuman nature? After all, do we not also scientifically consider nature to be in a process of constant change via evolutionary processes? Those species considered native at one time were invasive in the initial colonization phase. What makes these now nativized species more valuable or naturally appropriate than recent immigrants to the extent that some call for the complete species cleansing of the latter?

In short, if humans do not have direct noninterpretive access to the reality of nature, the way nature is represented determines not only how we know it but also our actions toward what we perceive it to be. Privileging some species as native is not a simple reflection of what is but a human value judgment that renders species that came to exist at some point in space-time more worthy of existence than those that came later. But is not the spatial migration of species the very stuff of natural evolution? The zebra mussel currently invading the U.S. Great Lakes, for example, in addition to clogging humanly constructed water intake and discharge pipes and promoting the mass extinction of native freshwater mussels, is also, via its rapid filtering process, clarifying the Lake waters and providing, via its rapid proliferation, a more diverse food supply for migratory diving ducks. Perhaps the zebra mussel is leading to a decline in local biodiversity in the short term due to its ability to outcompete the native species. Yet who is to say what will happen along these lines in the evolutionary long term, with or without human action?

Constructing Ecosystem Science

Another illustration of the social construction of nature concerns the characteristics and reality of



ecosystems, one of the fundamental concepts in the environmental sciences, including geography. The notion of an ecological system, biotic and physical, as a specifiable unit of nature dates from the 1930s and established itself as the dominant conception in the environmental sciences in the 1950s and 1960s. Yet actually defining an ecological system, let alone discovering such units as a result of empirical investigation, is fraught with difficulty. This difficulty is well elaborated in the scholarly literature and includes how to delineate the boundaries of such units, what criteria to use in defining the system, what size of system is appropriate to study, or even whether the chosen size of the investigative site itself determines what is called a system, implying a potentially unlimited number of extant ecosystems. These definitional problems translate directly into what some call a fatal problem for empirical investigation, rendering ecosystems merely subjective and therefore arbitrary, solely in the minds of observing scientists.

Nevertheless, the idea of the ecosystem eventually became hegemonic within the dominant paradigm of the environmental sciences as most scientists, and their students, operate within the normal science that accepts its facticity. Why this is the case, given the conceptual and empirical difficulties it entails, can be determined from the perspective of social construction. General systems thinking, for example, became all the rage in academia in the immediate post-World War II era, linked tightly to the emerging field of cybernetics and early computing. This rage was fueled by a technological optimism resulting from the innovations of the war effort. Systems science was cutting-edge, in this respect, as it promised a unique methodology that could conceivably model the real complexity of the natural and social world in a holistic manner. Every scientific discipline went through a phase in the 1950s and 1960s that privileged systems science as the newest, best scientific practice.

This privileging of systems science was reinforced by the new postwar, GI Bill recruits into academic science and technology disciplines with more diverse and practical views of the scientific project. Systems science, to them, was the basis for engineering the way to the solution of whatever environmental or social problem was at

hand. That systems thinking took over the environmental sciences is not a mystery within this social context.

But this is not the end of the story. Other social aspects of the 1960s and 1970s played an important part in the acceptance and growing hegemony of the ecosystem idea. These include the growing rebellion against all established norms on the part of those born after the war as well as the emerging environmental movement. Newly minted PhDs were more likely to adopt the latest methods of their respective sciences, confronting established beliefs with novelty as an indication of “progress.” Finally, ecosystem science also provided a valuable tool for the emerging environmental movement. If the goal is to “save” as much nature as possible, what better argument could there be than the “fact” that all things in nature are systematically related? That is, if one touches one part of nature adversely, all these other parts of nature will be damaged as well. Thus, if you want to save the spotted owl, the entire old-growth forest must be preserved. Indeed, such an argument has been ramped up to include the notion that the whole planet is one big natural system in increasingly bad shape because of human activity.

That there is a growing minority of scientific critics of the ecosystem approach, however, suggests that it may not be the mirror of reality that its paradigmatic adherents assert. Of interest here is that the reaction to these criticisms actually helps confirm the perspective of social construction. Reacting to what pejoratively has been called the “postmodernism” of the critics of ecosystem science, ecosystem scientists have often impugned the assumed political motives of their scientific critics. That is, such critics must be in the back pocket of developers hoping to open up more of nature to human intrusion. That it is impossible to adjudicate this scientific dispute by an “objective” look at the “facts” of the matter simply underscores the socially constructed nature of nature.

From the Construction to the Production of Nature

The idea that humans actually produce a socialized nature—as a reality, not just a conceptuality—is initially intended to underscore that humans are an active part of nature, not an external, extranatural



force that “affects” it from without. The nature of nature is thus different from this perspective. The focus here is on how human material activities produce both what we consider to be nature and the surrounding landscapes that are considered natural. An implication of this perspective is that because what humans consider to be nature and natural are only artifacts of their own material activities, they are fully historical and open to change as human material activities change over time. Nature is always social nature, in this respect, not something outside social reproduction to be merely observed, protected, saved, restored, conserved, or otherwise managed by somehow extranatural humans. Nature is what results from the various cultural and historical ways in which humans socially (re)produce both their sciences and their societies.

As in the case of social construction, there have been two, not entirely separable, ways in which this production of nature perspective has been pursued. There are those, most notably Bruno Latour and Donna Haraway, who study very closely how scientists produce nature in their laboratories as a result of their established networks of investigative methods and instruments as well as their discursive relations with other scientists. That is, from this internalist perspective, nature and the natural are brought forth or made observable only by the investigative activities of, and technologies used by, scientists in the act of doing science. Scientists, in this respect, produce what is considered nature—they do not discover it in their research. Nature is thus always a socialized, human-nonhuman, fully hybrid phenomenon and, as such, can be questioned and changed as a result of changing human interests and actions.

Another version of the social production of nature perspective emphasizes the extrascientific, social nature of this process. Expressed most directly in geography by Neil Smith and Erik Swyngedouw, this externalist version focuses on how humans appropriate, modify, and otherwise make use of nonhuman nature as a result of the particular social relations they enter into in the process of materially reproducing themselves. That these social relations of production have changed in the past and can change in the future suggests again that what is considered nature and

the natural are entirely social constructs, which can be socially deconstructed as a result of changes in these social relations. The emphasis is on the material reproduction of what can be called social natures, whereby humans and human constructions such as cities and other built infrastructures are considered as much a part of nature as the nonhuman parts. The key is that viewing nature as socially produced suggests the possibility that a different nature can be had through changes in social production. If this is so, then what are considered environmental problems are always a function of specific forms of social nature and not that of a universal “relation” between humans and a separate nonhuman realm called “nature.”

The political intent of this seemingly absurd notion of the social production of nature is clear. It is not meant to suggest that there are no nonhuman natural processes or that human reproductive activity is never limited or otherwise affected by such processes. Indeed, the overall ontological view entailed is that human and nonhuman natural processes mutually adapt to become social nature. This is an optimistic view, which considers that the so-called environmental problems, such as the tragedy of the commons, overpopulation, pollution, global warming, and so on, have everything to do with the ways in which humans actively produce social natures at both local and global scales. Solving environmental problems necessitates recognizing their source within a particular, historical form of social nature and then moving to change this latter. Environmental problems, in this view, are never absolute, the result of some universal human-nonhuman nature nexus, but, rather, always entirely relative to the form of social nature that is produced thereof. Such problems are thoroughly social and historical, and recognizing this is the first step toward their resolution by conscious human action.

Kevin Archer

See also **Class, Nature and; Ecofeminism; Ecological Imaginaries; Environmental Determinism; Environmental Imaginaries; Ethnicity and Nature; Feminist Environmentalism; Gender and Nature; Human-Induced Invasion of Species; Hybrid Geographies; Nature; Nature-Society Theory; Political Ecology; Race and Nature**



Further Readings

- Botkin, D. (1990). *Discordant harmonies: A new ecology for the 21st century*. New York: Oxford University Press.
- Braun, B., & Castree, N. (Eds.). (1998). *Remaking reality: Nature at the millennium*. London: Routledge.
- Castree, N. (2005). *Nature*. London: Routledge.
- Demeritt, D. (2002). What is the “social construction of nature”? *Progress in Human Geography*, 26, 767–790.
- Kuhn, T. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
- Latour, B. (2004). *Politics of nature*. Cambridge, MA: Harvard University Press.
- Simberloff, D. (2003). Confronting introduced species: A form of xenophobia? *Biological Invasions*, 5, 179–192.
- Smith, N. (1990). *Uneven development: Nature, capital and the production of space*. Oxford, UK: Blackwell.
- Soule, M. E., & Lease, G. (Eds.). (1995). *Reinventing nature? Responses to postmodern deconstruction*. Washington, DC: Island Press.
- Swyngedouw, E. (2004). *Social power and the urbanization of water*. Oxford, UK: Oxford University Press.
- Warren, C. R. (2007). Perspectives on the “alien” versus “native” species debate. *Progress in Human Geography*, 31, 427–446.



SOCIAL DARWINISM

Although Charles Darwin himself never sought to apply his ideas of evolution through natural selection to the social world, numerous advocates of Darwinism selectively and erroneously applied this line of thought to the analysis of cultural relations. Thus, *The Origin of Species*, published in 1859, was enormously influential not only in the biological sciences but in the social sciences as well. The (mis)application of Darwin’s ideas to social analysis is called social Darwinism, and its effects were enormous as well as uniformly reactionary. Some of its tenets preceded Darwinism

itself, including, for example, the works of Thomas Malthus. By posing as a science, the pseudoscience of social Darwinism dismissed criticisms as unscientific. The heyday of social Darwinism occurred in late-Victorian Britain and in the United States during the Gilded Age of the late 19th century.

An important moment in the translation of Darwin’s ideas to the social world was marked by the work of the French biologist Jean Baptiste Lamarck (1744–1829), who preceded and influenced Darwin. Lamarck’s view of evolution centered on the inheritance of acquired characteristics—that is, organisms pass on characteristics that they adopt to survive in different environments. Neo-Lamarckism posited that culture is carried biologically as a “social mind”—thus discounting the notion of random chance, which played such a large role in Darwinian thought—and therefore that evolution occurred much more rapidly than via Darwinian natural selection. Social Darwinism effectively became a search for supposedly universal laws of people and their relations to nature, a view that, when coupled with place, led to notions of regions as an organic entity in which blood and territory were inseparably fused. Such a perspective was influential, for example, in late-19th- and early-20th-century cultural geography, as in the *pays* (a French word defining an area whose inhabitants share common geographical, economic, cultural, or social interests) of Vidal de la Blache.

Herbert Spencer (1820–1903), a conservative 19th-century British defender of Lamarck, who fanatically opposed all government programs to aid the poor, became the best-known advocate of social Darwinism. It was Spencer, not Darwin, who coined the term *survival of the fittest*. His work found far more favor in the United States than in Britain, where it justified and naturalized the inequities of laissez-faire capitalism. Spencer was the foremost intellectual in the late 19th century to deploy social Darwinism to legitimize the excesses and inequalities of the Gilded Age. Numerous respected intellectuals and tycoons preached that competition in the market enshrined whoever emerged on top, naturalizing the status of the wealthy as inevitable and indeed fortunate for all: Millionaires are deserving of their wealth because they are simply stronger and work harder than do the lazy poor. Not



surprisingly, social Darwinism was often invoked to justify racial and ethnic inequalities as well, and its ultimate manifestation was in the 20th-century eugenics movement, which advocated the sterilization of ethnic minorities, the handicapped, and the socially disadvantaged to weed out “undesirable” genes.

Internationally, social Darwinism became a model of the global hierarchy of societies, with the white, Western world at the top, of course. Ostensible social evolution was posited to occur in stages, a view highly conducive to the dominant interests of 19th-century imperialism: Indeed, it is unlikely that social Darwinism would ever have enjoyed much popularity were it not for its role in legitimating the Western domination of the non-West. Because race and nation were typically held to be synonymous, with white countries seen as the more advanced and civilized compared with those in Africa, Asia, and elsewhere, social Darwinism gave a scientific veneer to racist doctrines. Nineteenth-century textbook portrayals of the globe, for example, framed the Western geographical imagination around a series of continents, typically conflated with simplistic notions of race, that were hierarchically organized in terms of their alleged level of temporal progress and, thus, similarity to European and North American whites, a schema that gained respectability through appeal to various forms of social Darwinism and environmental determinism. Social Darwinism and the geopolitical view it sustained thus not only explained colonial rivalry and conquest but also legitimized it with an aura of scientific respectability.

The most famous expression of social Darwinism in geography was through Friedrich Ratzel's ideology of geopolitics, in which states are held to follow the rule of survival of the fittest, constantly needing more territory (*lebensraum*), and inevitably conflict with one another (*kulturkampf*). Ratzel conceptualized states as organic entities that grow as plants grow. He drew on social Darwinism to argue that only the fittest states would survive. Ratzel moreover posited that states go through a life cycle from amalgamations of tribes to civilizations to senescence. Thus, primitive societies are “immature”; they then become vigorous and eventually senile. His biologization of international relations explicitly

used Darwinism to naturalize geopolitics and merged perfectly with the perceived need of the Anglo-Saxon/Teutonic race to conquer and lead the world's “inferior” races. Ratzel was read with interest by Adolf Hitler, and his views contributed to the emerging Nazi doctrines of racial superiority and inferiority during the Holocaust. This perspective, which later mutated into environmental determinism, is an example of the philosophical assumption of naturalism—that is, that the physical and social worlds can be understood in the same conceptual terms.

Social Darwinism also infiltrated the first paradigm of urban structure offered by the Chicago School theorists, particularly McKenzie, which centered on the metaphor of the city as an urban jungle. For example, the displacement of one ethnic group by another in a given neighborhood was framed as a process of invasion and succession, a view that drew directly from ecological studies of how one plant species displaced another through successive stages in the evolution of ecosystems.

Ultimately, social Darwinism was discredited on numerous pragmatic and ethical grounds. The end of formal imperialism and the horrors of World War II undermined its utility in justifying oppressive social policy. Its simplistic misapplication of Darwin's ideas to the social world was criticized by biologists, many of whom pointed to the lack of significant differences in intelligence among ethnic groups or between the sexes. Social scientists pointed toward its conflation of existing social orders with what social Darwinists posited to be morally necessary (that which is must therefore always be), denying any active role for culture, consciousness, historical context, and contingency in the making of social life. Social Darwinism's “might makes right” perspective was ultimately jettisoned in an age more attuned to the social nature of inequalities, one that celebrates differences rather than condemns them in hierarchical terms.

Barney Warf

See also Darwinism and Geography; Environmental Determinism; Geopolitics; Human Geography, History of; Malthusianism; Orientalism; Race and Racism; Ratzel, Friedrich; Semple, Ellen Churchill



Further Readings

- Bannister, R. (1989). *Social Darwinism*. Philadelphia: Temple University Press.
- Hawkins, M. (1997). *Social Darwinism in European and American thought, 1860–1945: Nature as model and nature as threat*. Cambridge, UK: Cambridge University Press.
- Hofstadter, R. (1992). *Social Darwinism in American thought*. New York: Beacon Press. (Original work published 1944)
- Numbers, R., & Stenhouse, J. (Eds.). (2001). *Disseminating Darwinism: The role of place, race, religion, and gender*. Cambridge, UK: Cambridge University Press.
- Peet, R. (1985). The social origins of environmental determinism. *Annals of the Association of American Geographers*, 75, 309–334.



SOCIAL FORESTRY

Social forestry belongs in the same category with terms such as community forestry, joint forest management (JFM), and farm forestry, but it is not synonymous with them. The term *social forestry* was first used by Jack Westoby in his address to the Ninth Commonwealth Forestry Congress at Delhi, India, in 1968—"Changing Objectives of Forest Management"—and subsequently at the 1978 Eighth World Forestry Congress in Jakarta, Indonesia. Influential papers heralding a change in forestry were also published by the World Bank and by the Food and Agriculture Organization of the United Nations (FAO). In this context, social forestry stands for a shift of focus in forestry in developing countries away from production-oriented and revenue generation-oriented forestry toward forestry for the needs of local users. This was later followed by a shift from centralized to decentralized forest management in the form of community forestry and JFM. In the context of India, which is the birthplace of social forestry, the term is applied in a more narrow sense to state-sponsored tree-growing programs on unused or degraded land.

In India, a social forestry program was initiated by the National Commission on Agriculture

in the 1970s, and it provided the framework for subsequent forest legislation, such as the Forest Policy of 1988, which recognized local users' rights and stated that forests were no longer to be managed for revenue generation only, and the contemporary JFM policy, which was drafted in 1990. However, Dietrich Brandis, Inspector General of Forests in India from 1864 to 1883, can be considered the first proponent of social and community forestry in India. Contrary to most members of the British Colonial Forest Service, who pursued a policy of putting forests under government control, Brandis believed in the capacity of local communities to manage their resources and advocated a parallel system of commercially important state reserves managed by the Forest Department and village forests outside of state reserves managed by farmers in collaboration with Forest Department rangers. He published a series of reports on this issue from 1868 onward, which led to a proposal to provide scope for community management of forests under the 1878 Forest Act. Brandis's proposal was rejected, however, and the 1878 Forest Act was firmly based on the principle of state monopoly over forests.

The concept of forestry for local people was resuscitated in India following popular protests against state forest policies, which started in 1904, took the form of a forest movement with labor strikes and the burning of forests in 1921, and culminated in the Chipko Movement of the 1970s against the logging of pine forests. The government of independent India, which had initially attempted to continue the policy of the British administration of maintaining or even increasing control over forests, backed down and started a process of developing policies for integration of and collaboration with local users.

The practice of social forestry in the context of India can be defined as growing trees on all land available for the purpose, especially on land outside traditional forest areas, with involvement of the local people and with a view to reduce pressure on forests and to provide a wide range of goods and services for local users, especially fuel and fodder. Tree-growing programs on unused land, such as along roadsides and reservoir walls, were pioneered by several states, for example, Gujarat and Tamil Nadu. In 1985, a National Wastelands Development Board (NWDB) was



created to coordinate tree growing on degraded or unused land on a national scale. The practice of social forestry was criticized as an attempt by the state forest departments to extend their control onto land outside their domain, but it also brought onto the scene international donors, especially the Swedish Sida, and nongovernmental organizations, which engaged in social forestry programs all over India. Social forestry programs in India were also criticized for the selection of controversial tree species such as the eucalyptus and for allowing only a limited scope for community participation.

Social forestry is often associated with terms such as *farm forestry*, *community forestry*, *participatory forestry*, and *JFM*. Farm forestry has been supported in India under social forestry programs and is an initiative to encourage or support individual farmers to grow trees on their farmland in order to meet domestic demands. Farm forestry is practiced in Nepal under the name “private forestry.”

Community forestry sprang from the same roots as social forestry. While social forestry programs in India and their various components were implemented mainly by state agencies for the benefit of local users but with only limited involvement of local users, community forestry focuses more strongly on community participation and community development through tree growing on community land, not on private land. Community forestry has been defined as involving some element of community participation in forest management and some commitment to the provision of forest products to rural people. Community forestry was particularly successful in Nepal. In India, collaboration between the state and forest protection committees was carried out under JFM, first in the state of West Bengal and later in other parts of India. While social forestry has remained associated largely with practices in India, community forestry is now practiced in many countries, especially in Asia.

Dietrich Schmidt-Vogt

See also Agroforestry; Chipko Movement; Community-Based Natural Resource Management; Community Forestry; Indigenous Forestry; Sustainable Forestry; Tree Farming

Further Readings

- Food and Agriculture Organization of the United Nations. (1978). *Forestry for local community development* (Forestry Paper No. 7). Rome, Italy: Author.
- Guha, R. (2001). The prehistory of community forestry in India. *Environmental History*, 6, 213–238.
- Kumar, S. (2000). *Social forestry*. New Delhi, India: Reliance.
- Negi, S. S. (1983). *A handbook of social forestry*. Dehra Dun, India: International Book Distributors.
- Regional Community Forestry Training Center for Asia and Pacific. (2003). *Community forestry: Current innovations and experiences*. Bangkok, Thailand: Author.
- Webb, E. L., & Shivakoti, G. (Eds.). (2008). *Decentralization, forests and rural communities: Policy outcomes in South and Southeast Asia*. New Delhi, India: Sage.



SOCIAL GEOGRAPHY

Social geography is the branch of human geography that analyzes social phenomena in space, both tangible artifacts and intangible phenomena. It involves the study of a wide variety of social phenomena ranging from individual children and adults to social problems such as poverty and crime. In all instances, social geographers are interested in the ways in which space and place shape social phenomena and, in turn, how social phenomena influence the construction of places and space. This two-way relationship has been examined in diverse settings around the world and by analyzing a wide variety of social phenomena. Social geography plays a crucial role in human and physical geography, reminding us that all geographies reflect the influence of people and the social organizations within which they live. Diversity is the hallmark of contemporary social geography, which adopts many different approaches to the analysis of social phenomena. This entry outlines the major questions addressed



by social geography and, in roughly chronological order, the various ways in which geographers have viewed these topics. The emphasis is on the assumptions about people and their social relations that underpin each approach. The different research methods used within each approach are also described. The discussion ends by reviewing three current debates about the future direction of social geography.

Questions Guiding Social Geography

Social geographers have analyzed people's uneven knowledge of places, often asking them to draw maps of the world, their countries, and the cities and neighborhoods where they live. In addition to examining people's awareness of individual locations and their positions relative to each other, geographers also explore how people evaluate places, asking why one neighborhood is considered attractive while others repel or evoke indifference. Increasingly, social geographers examine the meanings that people attach to different locations by asking them where they feel at home and where they feel out of place. Investigating the social and built characteristics of public spaces where women feel unsafe at night, geographers have recommended design changes that will ensure that women as well as men are at ease in public spaces.

Different questions have motivated social geographers' studies of diverse social groups. Some geographers have studied people who live in specific neighborhoods, municipalities, and regions, while others have analyzed particular segments of society, such as the elderly, children, racial minorities, income groups, hate groups, and various occupational groups. In both cases, geographers seek to understand how space and place shape the behaviors and beliefs of and the links between people in particular groups. Attention is paid to the social ties through which information and influence are transmitted among members of a social group and their spatial patterns. At the core of many studies are questions about the ways in which space and place shape power relations among social groups.

Institutions such as government, nongovernmental organizations, ethnic and religious groups, and for-profit institutions are a third topic of interest

to social geographers, who want to understand how place shapes institutions and their social impacts and how social institutions shape space and place. For example, looking at the provision of services for psychiatric survivors, social geographers have highlighted the processes that lead to concentrations of such services in poor neighborhoods, where the housing stock is often in poor condition and residents are kept isolated, far from commercial establishments and recreational facilities. Other geographers have examined how concentrating services for marginalized groups in poor urban neighborhoods stigmatizes them.

A fourth stream of social geography examines the spatial dimensions of social problems such as poverty, crime, and homelessness. Geographers often begin by creating atlases that draw attention to the locations of social problems and the circumstances that exacerbate social problems. Some of the best-known atlases document women's experiences of violence, poverty, and oppression around the world, poverty in the United States, and the living conditions of racial minorities in specific metropolitan areas. Having described the spatial patterns of a social problem, social geographers then explore the geographical variations in the factors that cause them. For example, to understand the spatial patterns of poverty, geographers have analyzed plant closures and unemployment rates as well as geographical variations in welfare policies.

History of Social Geography

The diverse body of research currently undertaken under the rubric of social geography has a long history. The beginning of social geography is often attributed to Charles Booth, who studied poverty in London between 1886 and 1903. Booth carefully documented the incidence of poverty in London in maps that survive to this day. Turning to the causes of poverty, Booth examined how occupation was related to income and how the activities of charitable and religious organizations and local governments influenced the living conditions of the poor. He concluded by proposing policies to mitigate poverty. Since the production of Booth's maps and reports, social geographers have investigated the spatial patterns of social phenomena and their causes using



numerous philosophical, theoretical, and methodological approaches.

To understand urban life, social geographers delineated natural areas with homogeneous social and built characteristics and clearly identifiable boundaries. In many American cities, geographers and sociologists identified a central business district, the commercial heart of the urban area, surrounded by a zone in transition where residential land was being converted to industrial use. Suburban housing radiated out from the zone of transition, with the newest housing located on the urban-rural fringe. As land uses changed, the social characteristics of residents in each zone also changed. The ecological approach encouraged geographers to recognize and describe diverse urban neighborhoods; however, it paid little attention to the processes shaping the spatial patterns. It was assumed that the housing market invariably segregated people on the basis of income, household type, and ethnic background. Few scholars asked why housing should be allocated on the basis of ability to pay or how income was distributed among households.

Responding to criticisms that social geography was descriptive rather than explanatory, three alternative approaches to social geography emerged: the first examining individual decision making, the second focusing on the meanings that people attribute to places, and the third emphasizing how the built and social environments are shaped by capitalism and, in turn, shape capitalism. Although the three approaches came to prominence in roughly chronological order, each has deep roots in social geography, and each has persisted into the present.

The Behavioral Approach

The behavioral approach aimed to develop mathematical models that would predict people's spatial behavior. Behavioral geographers analyzed how people decided among alternative locations, examining awareness of alternatives, their evaluation, and the decision processes by which people selected one alternative over others. Peter Gould showed that children's geographical knowledge of the world centered on their neighborhoods, towns, and countries of residence. Distant places were less likely to be known, and even if known, they

were located inaccurately. The initial mental map studies are precursors of the sophisticated analyses of wayfinding that now dominate the literature.

Beginning from the microeconomic assumption that people are rational decision makers interested in maximizing the utility of their decisions and minimizing the time, effort, and cost invested in them, geographers studied how people choose among competing locations to live, how they travel on a daily basis, and how they plan shopping trips. Studies of residential decisions confirmed that many decisions are based on incomplete information that is spatially biased. When looking for a place to live, most of us only consider a few neighborhoods. Realtors reinforce spatial biases by steering clients to vacancies in areas already dominated by people from the same social backgrounds, often reinforcing the segregation of minority groups, age groups, and occupational groups. Residential decisions are also influenced by the available housing. As housing prices rise, people abandon their plans to relocate, settling for unsatisfactory housing within their price range. The emergence of large numbers of blocked movers in areas with rapidly increasing housing prices revealed the shortcomings of the behavioral approach, which did not take account of people's subjectivity and the social, political, and cultural constraints on individual decisions. In response, many social geographers turned to humanistic and structural approaches.

Humanistic Approaches

Humanistic approaches in social geography pay attention to the meanings that people attach to locations. Harking back to earlier assertions that social geography goes beyond documentation of the spatial patterns of artifacts, humanistic geographers evaluate how beliefs about locations shape places and how places shape people's beliefs and behaviors. Humanistic geographers now investigate the emotions that places inspire, exploring how different people feel about a single place or how one group of people feels about different places. Home has been the focus of much of this research as geographers have investigated what it means for different social groups to be at home and how the meaning of home changes over our lifetimes.



With its attention on how people are represented and how they identify themselves, the humanistic approach to behavioral geography has many parallels with cultural geography. Adopting a subjective perspective, humanistic geographers explore the discourses that different people use to describe places. By analyzing text and visual representations as well as descriptions of people's behaviors and opinions, humanistic geographers aim for an empathetic understanding of place. In a pioneering study in Philadelphia, David Ley compared the meanings attached to a poor African American neighborhood by residents and outsiders, highlighting how the positive views of residents contrasted with the negative opinions and beliefs of government officials and other people living outside the neighborhood.

Structuralist Approaches

In parallel with the resurgence of humanistic approaches, social geography was transformed by historical-materialist approaches grounded in Marxist theory. Focusing on social inequality and the processes that give rise to it, geographers explored how capitalism molds social class and inequality. Although historical materialism was new, the critical stance has a long history in social geography. In the 1960s, social geographers had studied the geographical patterns and causes of social inequality through projects such as the Detroit Expedition, which documented racial inequality in all aspects of everyday life in the city of Detroit. Other geographers intervened in efforts to desegregate schools by publicizing the unequal expenditures on minority students and the unfair burden that many busing proposals imposed on them. In his pathbreaking book *Social Justice and the City*, David Harvey drew attention to Marxist theory as a coherent theoretical basis for structural approaches to social geography. His analysis demonstrated how contemporary geographies are shaped by capitalism and how space is fundamental to contemporary capitalism, a theme Harvey and others have continued to explore in their attempts to rewrite Marxist theory from a geographical perspective.

Geographers working within a Marxist approach have sought to uncover the local contingencies that frame the impacts of capitalism.

They have explored the past and present geographies of production, documenting how capitalism is shaped by local circumstances and the layers of investment in different means of production that shape the way capitalism operates in different places. The role of the state in the production and maintenance of urban inequality has also been a recurring theme.

The diverse viewpoints that characterize social geography are the basis of lively debates, illustrated by the competing explanations for the revival of residential areas in many North American and Western European cities, where professionals have renovated housing vacated by working-class families since the 1980s. Historical-materialist geographers emphasized that renewal was sparked by the undervaluation of property in central neighborhoods. Humanistic geographers argued that growing numbers of professionals were seeking convenient places to live in, near jobs and urban amenities. Although economic change underpins both explanations of gentrification, one emphasizes changes in property values, while the other puts more weight on the emergence of a new occupational group seeking an urban and urbane lifestyle. As differences of opinion concerning gentrification were debated in the pages of scholarly journals, the distances between the three approaches to social geography increased and hardened.

Recent Developments

In the 1990s, new subfields of social geography challenged the boundaries between the three approaches to social geography, raising questions about the theoretical basis of social geography and the associated research methods. Feminist geography has transformed much of social geography. With the goal of reducing women's oppression and redressing the power imbalance between men and women, geographers have explored the connections between gender and geography. Moving well beyond their initial comparisons of the spatial patterns of men and women, feminist geographers now highlight how our ideas about gender shape people's behaviors and attachments to place. Variations in these ideas and behaviors across neighborhoods, cities, regions, and countries have been the focus of much research that



illuminates the social construction of femininity and masculinity in different settings. Feminist geographers have enriched our understanding of gender inequality by studying the geographical relations between home and workplace. In Worcester, Massachusetts, Hanson and Pratt showed that the occupational segmentation of women was inherently geographically influenced by the spatial relations between home and workplace.

As international migration has transformed the ethnic and racial composition of cities around the world, social geographers have renewed their analysis of racialization, ethnicity, and segregation. Recent studies have explored multiethnic neighborhoods, neighborhood effects on minorities, and the evolving geographies of religious minorities. Geographers have examined how religious minorities lay claim to public space, the reasons for and impacts of residential concentration on religious minorities, and the contested links between religious identity and place. Their findings underscore the complex geographies of religious affiliation, a welcome reminder that no one is or should be defined solely on the basis of his or her religion.

A third stream of social geography abandons the pretense of universal heterosexuality to explore how sexuality and sexual orientation influence people's use of space, their attachment to place, and their sense of belonging in different spaces. Claims to space by gays, lesbians, and transsexual and bisexual people are an integral aspect of their struggle for recognition and equal rights. Gays have colonized entire neighborhoods, transforming them into vibrant centers of gay culture, while lesbians, transsexuals, and bisexuals have demanded the right to participate in public events such as parades and festivals. Recent research emphasizes how different aspects of identity intersect in people's claims to space. Lesbians' interpretations of public and private spaces are shaped as much by their gender and social class as by their sexual orientation. Sexuality studies have exposed social geographers to fertile theoretical arguments about embodiment and the performance of identities, encouraging them to explore new topics such as motherhood and fatherhood.

As social geographers acknowledge the complexity inherent in people's social identities and behaviors, more attention is also being paid to

the geographies of children and youth. Social geographers are examining how the experiences of childhood and youth are framed differently by other dimensions of identity such as social class, race, and religion in specific places. The impact of the Internet on the spatial patterns of children's and youth's social networks and activities is another topic attracting researchers. Parents' use of space to discipline and control children and youth has confirmed that social constructions of femininity and masculinity are inherently spatial.

Current Issues

Since the publication of Harvey's *Social Justice and the City* in 1973, social geographers have debated the roles of social structures and individual agency in explaining contemporary social geographies. Many favor the explanatory power of a structural perspective, as exemplified by the incorporation of Marxist theory in social geography. Drawing on the humanistic and behavioral traditions, others place more weight on individual agency to explain spatial behavior. Growing numbers of geographers now acknowledge the explanatory power of social and spatial structures that constrain individual actions in the short run, while recognizing that individuals transform social and spatial structures in the long run. Although sometimes labeled as eclecticism, this perspective provides a dynamic framework for examining how people's behavior is shaped by space and place in the short term and how people in turn change places and spaces in the long run.

Currently, there is also a renewed appreciation of the merits of applied and theoretical research in contemporary social geography. Some had objected to the emphasis on theory and the interpretation of texts and visual representations that accompanied the cultural turn in social geography. They argued that social geography was losing its relevance to contemporary social issues and public policy. An accommodation is now emerging in which many social geographers recognize that theoretical research and empirical research fruitfully inform each other.

Several people have recommended that geographers abandon social geography to concentrate on emerging subfields such as feminist geography, geographies of children and youth, and



geographies of sexuality. The debate is fueled by the blurring boundaries of social geography. Influenced by the cultural turn in human geography, social geographers are paying more attention to people's cultural backgrounds and using unobtrusive methods and discourse analysis to explore how culture shapes sociospatial relations. Acknowledging that economic relationships are one of the main sources of social power, they are also examining in detail the changing nature of paid work, the relations between paid and unpaid work, and the intersecting effects of gender, race, and class on individual work experiences. With its history of multiple approaches and subfields, debates about the boundaries of social geography are likely to continue. Despite these tensions, social geography will persist because of the integral links between place, space, and social relations. Labels may change, the theoretical underpinnings will evolve, but the interest in how geography shapes social relations and, in turn, how social relations shape place and space will persist.

Valerie Preston

See also Behavioral Geography; Body, Geography of; Children, Geography of; Civil Society; Class, Geography and; Consumption, Geographies of; Crime, Geography of; Critical Human Geography; Cultural Geography; Cultural Turn; Difference, Geographies of; Disability, Geography of; Education, Geographies of; Elderly, Geography and the; Everyday Life, Geography and; Fear, Geographies of; Feminist Geographies; Gays and Lesbians, Geography and/of; Gender and Geography; Ghetto; Health and Health Care, Geography of; Home; Homelessness; Human Geography, History of; Human Rights, Geography of; Identity, Geography and; Immigration; Justice, Geography of; Labor, Geography of; Ley, David; Literature, Geography and; Malthusianism; Marxism, Geography and; Masculinities and Geography; Media and Geography; Migration; Mobility; Music and Sound, Geography and; Nation; Nationalism; Neighborhood; Neo-Malthusianism; Orientalism; Other/Otherness; Patriarchy, Geography and; Political Economy; Popular Culture, Geography and; Population Geography; Postcolonialism; Postmodernism; Poststructuralism; Poverty; Queer Theory; Race and Racism; Radical Geography; Refugees; Religion, Geography and; Representations of Space; Resistance, Geographies of; Rural Geography;

Scale, Social Production of; Segregation and Geography; Settlement Geography; Sexuality, Geography and/of; Social Justice; Social Movements; Sports, Geography of; State; Structuration Theory; Subaltern Studies; Symbolism and Place; Television and Geography; Territory; Time-Geography; Topophilia; Tourism; Urban Geography; Virtual Geographies; Vision and Geography; Whiteness; Zelinsky, Wilbur

Further Readings

- Pain, R., Burke, M., Fuller, D., & Pain, J. (2001). *Introducing social geographies*. New York: Oxford University Press.
- Panelli, R. (2004). *Social geographies: From difference to action*. Thousand Oaks, CA: Sage.
- Seager, J. (2009). *The Penguin atlas of women in the world*. New York: Penguin Books.
- Valentine, G. (2001). *Social geographies: Space and society*. New York: Prentice Hall.



SOCIALISM AND GEOGRAPHY

Socialism is a concept that has been subjected to many interpretations. Such diversity in the use of the term *socialism* has led to the creation of different bodies of knowledge. Socialist theories, writings, ideas, and beliefs generally explain, seek, and advocate social justice and equality. In other words, socialism is seen as an instrument to attain a better and fairer society; social justice and equality are achievable through a social system based on common ownership of the means of production and the equitable spatial distribution of wealth. Therefore, socialism is a system of thought and practice whose ideas are contrary to the system of material accumulation, concentration, and exploitation found under capitalism.

Forms of Socialism

As a result of the diverse uses of the term *socialism*, it has often been confused with the term *communism*. Commonly, these two terms have been considered synonymous: They have both been



used to describe a social system structured contrary to the logic of capitalism, namely, a system in which the means of production are not privately owned and material interests do not prevail over the common interest. In practical terms, both socialism and communism share this advocacy of the common interest; both bodies of knowledge critique the social and territorial injustices of capitalism. Yet regardless of their similarities, socialism and communism are not synonymous. Socialism is a necessary precondition to achieving full communism, but there is a fundamental difference between socialism and communism. The essential distinction between the two concepts lies in the difference between common ownership and state ownership. In socialism, social justice and equality, and thus a better and fairer society, are realized through a social system based on common (i.e., public) ownership of the means of production. Communism aims to consolidate socialism through state ownership of the means of production. Therefore, communism represents a new form of society where human beings overcome material constraints. In that context, communism is the maximum expression of socialism, and in classical Marxist ideology, socialism serves as the transition to communism.

However, the diverse use of the term *socialism* not only has generated a blurred line between socialism and communism but has also caused a division within socialist theories, writings, ideas, and beliefs. The most important of these socialist divisions are utopian socialism, democratic socialism, Leninist socialism, and Marxist socialism. In utopian socialism, there is unity between the individual subject and the collective object. This interpretation of socialism is based on the principle of cooperation. The result of utopian socialism is not only a social system in which the means of production are collectively owned but also a system in which social and economic life is driven by the collective.

On the other hand, democratic socialism tries to find a common ground between revolution and electoral means. Essentially, this interpretation of socialism aims to reform capitalism through state regulations that work to neutralize or remove the social injustices produced by capitalism. In other words, democratic socialism does not seek to completely and radically eradicate capitalism but

rather to reform it and make it more socially sensitive. Social justice can be attained through state welfare policies that incorporate a mixed economy with elements of both socialism and capitalism, as is found in many European welfare states, particularly in Scandinavia.

Leninist socialism, in contrast, rejects all forms of capitalism, reformed or not. This type of socialism argues that social justice, and thus a better and fairer form of society, can only be achieved through social revolutionary consciousness. Such revolutionary consciousness will lead to the overthrow of the capitalist system by force and the seizure of power on behalf of the proletariat. In Leninist socialism, the means of production are controlled by the state; however, the dominant institution is the Communist Party. This party, through democratic centralism or strict and disciplined organization, is the institution where all decisions are made. Therefore, the party uses the powers of the state as an instrument to achieve a new form of society and to help the collective reach the highest level of social justice and equality—that is, communism.

Last, Marxist socialism revolves around the proletariat generated by the capitalist production process. In Marxist socialism, the means of production are collectively owned, and social life is organized through central planning. Socialism, from this perspective, is a necessity to end class struggle and therefore obtain social justice and equality. However, in the case of Marxist socialism, it is believed that socialism will come through a proletarian-led revolution and the implementation of the dictatorship of the proletariat. Such a revolution would eradicate the capitalist system of accumulation and therefore would also eradicate poverty, exploitation, and social injustices. However, the revolution of the proletariat will not come about until society gains a consciousness of class.

Socialism and Geographical Discourse

The bodies of knowledge that deal with socialism have been present throughout the history of the discipline of geography. Geographers have always been interested in understanding how space and society work. In that context, socialist ideas have been used in geography as a framework for understanding spatial phenomena over time and their



social outcomes. These socialist ideas have also been used by geographers to question and challenge the traditionally conservative orientation of geography.

Socialism formally came into geographical discourse with the development of critical human geography and its critique of the positivism introduced to geography by the quantitative revolution. Yet socialism was institutionalized in geography with the emergence, during the 1970s and 1980s, of radical geography. This new school of thought argued that positivism was not useful because it failed to provide alternatives or solutions to the social illness produced by the system of capitalist accumulation. Therefore, radical geographers sought to counter the positivist quantitative methods with techniques drawn from socialist theories.

Radical geography built on concerns for poverty, racism, and segregation. Radical geographers were interested in a proactive discipline capable of shaping society, not just studying it. In other words, geographers saw radical geography not only as a way to understand spatial and socioeconomic phenomena but also as an opportunity to provide alternatives and solutions to current social inequalities. In that context, the socioeconomic inequities associated with spatial inequalities are at the center of the radical geographers' agenda. Therefore, the current developments in radical geography have been focusing on racial and ethnic spatial inequalities with respect to housing, access to services and employment opportunities, and exposure to environmental pollution and related public health outcomes. In that sense, academic work developed from a radical geographical perspective seeks to address current social justice issues. Such academic work has been mainly produced through political geography, urban geography, and economic geography.

As a consequence of the radical turn, geographers developed a Marxist analysis to not only understand but also improve society. This Marxist analysis draws on the concept of historical materialism to illustrate how in the capitalist system the spatial distribution of social subjects is controlled by the means of production. The main objective of this Marxist geographical perspective was to find alternative models to alleviate, if not eradicate, poverty and exploitation in capitalist societies. Therefore, Marxist geographers are

interested in the geographies of social, economic, and political inequalities that they saw around them. In their view, such inequalities are produced by a system of capitalist accumulation and the markets that embody such a system. Consequently, Marxist geographers seek to understand the processes of capitalist accumulation, in order to explain the fundamental factors involved in the dynamics of class, while also examining the processes by which economic landscapes are made.

Marxist geography gained impetus with the current expansion in the scope, volume, and velocity of the flows of goods, services, capital, knowledge, and people across borders. For Marxist geographers, those globalizing forces are intimately tied up with the rise and expansion of the capitalist system. Therefore, such globalizing processes act as the validation of Marxist geography and its analysis of how the capitalist system of accumulation produces poverty and exploitation. In this context, Marxist geographers question the global forces that bring markets and capital together while at the same time increasing the socioeconomic gap between the poorest and richest. Consequently, for the Marxist geographer, globalization reflects the true nature of the capitalist system of accumulation as it fosters increased social, economic, political, and cultural unevenness across space, therefore creating unevenness.

The belief that the global capitalist economic system has divided the globe between rich and poor countries provided the foundation for socialist geographers, especially Marxist geographers, to expand and develop some theories of economic development. From this perspective, socialist geographers argued that unequal capitalist relations not only have prevented poor countries from obtaining proper development but have also generated underdevelopment. Therefore, poverty and inequality are seen as a direct consequence of the exploitation caused by the capitalist economic system. These ideas are based on the Marxist analysis of inequalities, which argues that such underdevelopment is a direct result of the ways in which poor countries are integrated into the world system.

The expansion and development of these theories of economic development follow the proactive nature of socialist geography. Therefore, to not only explain but also provide alternatives and solutions to the social illness produced by the



system of capitalist accumulation, especially the problem of underdevelopment, geographers also make use of theories that explain colonialism and neocolonialism, such as Lenin's theory of imperialism. The Leninist approach saw imperialism as the highest stage of the capitalist economic system, which uses the state machinery to colonize and exploit other countries. Therefore, it is argued, the historical development of the capitalist system has produced underdevelopment in the colonized countries and continues to do so through neocolonization.

Socialism has greatly influenced the development of geography. Socialist theories, writings, ideas, and beliefs were used by geographers seeking a better understanding of the socioeconomic inequities associated with spatial inequalities. Geographers also saw the relationship between socialism and geography as an opportunity to provide alternatives and solutions to such social inequalities. Currently, socialist influences continue to grow in geography as geographers are exploring and developing new methods of analysis to both understand and improve society.

Luis Sánchez

See also Class, Geography and; Colonialism; Communism and Geography; Critical Human Geography; Dependency Theory; Development Theory; Globalization; Harvey, David; Imperialism; Inequality and Geography; Justice, Geography of; Marxism, Geography and; Modernization Theory; Neocolonialism; Poverty; Social Justice; Spatial Inequality; Underdevelopment; Uneven Development

Further Readings

- Harvey, D. (1973). *Social justice and the city*. London: Edward Arnold.
- Harvey, D. (2006). *The limits to capital*. London: Verso.
- Harvey, D. (2006). *Spaces of global capitalism: Towards a theory of uneven geographical development*. London: Verso.
- Hoogvelt, A. (2001). *Globalization and the postcolonial world: The new political economy of development*. Baltimore: Johns Hopkins University Press.

Lenin, V. (1939). *Imperialism, the highest stage of capitalism*. New York: International.

Peet, R. (1999). *Theories of development*. New York: Guilford Press.

Smith, N. (1984). *Uneven development: Nature, capital, and the production of space*. Oxford, UK: Blackwell.



SOCIAL JUSTICE

Social justice is an intellectual and practical response to Cervantes's observation in *Don Quixote* that "there are only two kinds of families in the world . . . The *Haves* and the *Have-Nots*." Of course, a concern for social justice is more than simply acknowledging the inequalities of life. The following three questions outline a discussion about social justice. First, how has social justice been theorized as a moral question? This approach situates social justice as a philosophical ideal. Second, how do we measure social justice? This view positions social justice as a field of scientific inquiry defined in opposition to social inequality and prejudice. Third, what can be done about human suffering? Here, social justice is a call to action. These three questions provide a framework for defining social justice.

Social Justice as a Philosophical Ideal

Human societies depend on social norms and laws to regulate human behavior. When people break laws, they usually face repercussions. Criminal justice is served when punishment is meted out in proportion to the crime that was willfully committed. *Social* justice, on the other hand, questions why people suffer even though they have done nothing wrong. The implication is that we need to abide by universal standards of fairness and basic human rights.

Philosophers have discussed basic human rights for millennia. Plato, writing more than 2,000 years ago, said that Greek citizens should deal with foreigners as Greeks deal with one another. The Roman philosopher Cicero argued that every person should be valued as a citizen of the whole universe. The notion that we should treat others



as we would have them treat us can also be found in many foundational religious texts, including the Bible and the Koran.

Leaping forward to the 18th century, the call for universal human rights was enshrined by Thomas Jefferson in the U.S. Declaration of Independence. Jefferson wrote that all Americans had basic rights to “life, liberty and the pursuit of happiness.” But this represents only a limited “equality of opportunity,” where individual freedoms allow people to succeed in life but provide no guarantee that success will occur. Freedom of opportunity only provides a legal framework for equality before the law. It says nothing about equality of outcomes, where people might expect freedom from hunger, poverty, or violence.

Social Justice as Social Scientific Inquiry

Given the geographical variations in the distribution of natural resources, the randomness of natural disasters, and other factors beyond human control that create social inequality, some philosophers argue that social justice must also focus on equality of outcomes. Social justice is therefore an effort to strike a balance between individual rights and the common good, which we might define as community rights.

To gauge whether equality of outcomes has been achieved, measurements must be taken. One way to compare regional inequalities is to focus on quantitative income or poverty statistics. More sophisticated measures such as the United Nations Human Development Index (HDI) include literacy rates, infant mortality rates, and life expectancy. The HDI recognizes that simply using income or economic output measures, such as the gross national product, to compare regional inequality hides the fact that countries with large economies may have large internal economic disparities or restrictions on human rights.

Social Justice as Call to Action

Marx wrote in *Theses on Feuerbach* that “philosophers have only interpreted the world, the point is to change it.” This call to action, which has been subsequently echoed by many geographers, challenges advocates of social justice to connect philosophical musings with concrete strategies to

reduce social inequality. Two main strategies have been used to reduce inequality of outcomes. The first approach accepts that despite what the Declaration of Independence says, there is no “equality of opportunity.” Long-standing racial and gender prejudices prevent some people from gaining equal access to education and other means of social advancement. To remediate the inequality of opportunity, some countries have implemented “affirmative action” programs, which attempt to increase the chances that minorities and women will gain admission into high-quality schools or get well-paying jobs. This strategy assumes that the inequality of outcomes can be decreased by reducing the inequality of opportunity.

The second approach to achieving social justice attempts to redistribute income away from wealthy social sectors and regions to areas where poverty rates are higher than some benchmark average. The redistribution of wealth is a direct acknowledgment that socioeconomic inequality is an inherently geographical problem. Hence, social justice is an attempt to use universal principles of fairness to address regionally variable problems. Martin Luther King Jr. recognized it as such when he said, “Injustice anywhere is a threat to justice everywhere.”

Because social justice is simultaneously a philosophical ideal, a field of scholarly inquiry, and a call to action, it is more effectively defined as a constellation of lofty ideas and concrete strategies. Social workers at the University of California School for Social Welfare nicely captured this complexity when they defined social justice as a process

which (1) seeks fair (re)distribution of resources, opportunities, and responsibilities; (2) challenges the roots of oppression and injustice; (3) empowers all people to exercise self-determination and realize their full potential; (4) and builds social solidarity and community capacity for collaborative action.

Christopher D. Merrett

See also Bunge, William; *Cosmopolitanism*; *Environmental Justice*; *Ethics, Geography and*; Harvey, David; *Human Rights, Geography and*; *Justice, Geography of*; *Law, Geography of*; *Marxism, Geography and*; Peet, Richard; *Radical Geography*; *Uneven Development*



Further Readings

- Gilmore, R. (2005). Scholar activists in the mix. *Progress in Human Geography*, 29, 177–182.
- Harvey, D. (1973). *Social justice and the city*. Baltimore: Johns Hopkins University Press.
- Ishay, M. (Ed.). (1997). *The human rights reader*. New York: Routledge.
- Merrett, C. (2004). Social justice: What is it? Why teach it? *Journal of Geography*, 103(3), 93–101.
- Smith, D. (1994). *Geography and social justice*. Cambridge, MA: Blackwell.
- Young, I. (1990). *Justice and the politics of difference*. Princeton, NJ: Princeton University Press.



SOCIAL MOVEMENTS

Social movements are sustained, organized forms of collective action that strive to bring about social or political change. Typically originating in civil society, they seek to change the policies and actions of the state, the practices of corporations, or the organization of society generally. Like all social relations, social movements are spatially constituted. Social movements mobilize and operate in a spatial context, are themselves spatially constituted by actors both internal and external to social movement organizations, and seek to alter sociospatial power relations.

There has been an explosion of geographical research on social movements since the late 1980s, incorporating a variety of geographic concepts. Much of the early research focused on the place-based constitution of social movements. John Agnew and R. J. Johnston argued for an understanding of politics that shifts analytical focus away from the nation-state, emphasizing instead the central importance of place-based social relations. Much of the contemporary research is rooted in Agnew's conception of place, consisting of three dimensions: (1) locale—the institutional and informal settings in which social relations are constituted, (2) location—the geographical areas and scales encompassing the settings of social relations, and (3) sense of place—the local structure of feeling. Agnew's tripartite conception underscores the fact that place-based social relations are

always material and meaningful, constituted through processes that may range in scale from the local to the global.

The centrality of the local-global problematic to social struggle is highlighted by David Harvey, who, drawing from Raymond Williams's notion of "militant particularism," argues that "ideals forged out of the affirmative experience of solidarities in one place get generalized and universalized as a model of a new form of society" (p. 32). How, and whether, locally forged ideals and solidarities become generalized has been a matter of some contention among social movement scholars.

Agnew's work suggests two different but complementary ways of thinking about how place-based social struggles relate to broader geographies. On the one hand, Agnew (1987) suggests a network approach focusing on "the 'paths' and 'projects' of everyday life, to use the language of time-geography, [which] provide the practical 'glue' for place in [all] three senses" (p. 28). On the other hand, he finds that "extensive fields of mediated interaction [must be understood as] managed by institutions and organizations" (Agnew, 1996, p. 131) with "hierarchical (and non-hierarchical) 'funneling' of stimuli across geographical scales . . . coming together in places where micro (localized) and macro (wide-ranging) processes of social structuration are jointly mediated" (Agnew, 1996, p. 132). Agnew clearly recognizes the importance of networks and scales, as well as structure and agency, in the constitution of place-based social struggle.

In one of the earliest in-depth geographical analyses of social movement mobilization, Paul Routledge (2003) shows how social movements in South Asia are strongly shaped through place-specific "circumstances, constraints, and opportunities" (p. 21) and how sense of place and place-based network relationships are key to understanding their dynamics. Routledge continues to explore the connection between networks and mobilization in his more recent work, examining the ways in which network strategies can build communication, solidarity, and support across scales and among diverse places. In a similar vein, Featherstone (2003) demonstrates that networked relationships among place-based struggles are to be understood as "generative, as



actively shaping political identities, rather than merely bringing together different movements around ‘common interests’” (p. 405).

While some scholars focus on the construction of the networked relationships of social movement agents, others place greater emphasis on the construction of institutional and state frameworks that both enable and constrain those agents. Andy Herod, for example, examines the scale-shifting strategies labor unions and corporations pursue to gain advantage in regional contract negotiations. Byron Miller, examining the peace movement, analyzes the scalar shifts in the political opportunity structures of the state and the implications of those shifts for mobilization strategy. Kevin Cox addresses the differing degrees of local dependence of political actors and the contingent nature of scales of political engagement. Virtually the entire scale literature conceptualizes scale as dynamic and itself an object of struggle.

Both representational and material notions of space are required to understand the mobilization of social movements. Deborah Martin, for example, addresses representational practices integral to the construction of place-based collective action frames, while Nicholls (2008) shows how material social practices in cities function as incubators of network relationships. The geographic constitution of representational and material social practices shapes relationships of trust, rationalities, and affective bonds, in turn affecting the very ability and propensity of agents to engage in collective action.

While some social movement scholars have tended to focus on particular notions of spatiality, most recognize the significance of multiple forms of spatiality. Indeed, after a period of some debate, it appears that geographically oriented social movement scholars may be moving toward an explicit recognition of multiple spatialities—for example, place, networks, scale—and the ways in which they intertwine.

Byron Miller

See also **Antiglobalization**; **Civil Society**; **Justice**, **Geography of**; **Labor**, **Geography of**; **Neoliberalism**; **Nongovernmental Organizations (NGOs)**; **Resistance**, **Geographies of**; **Scale**, **Social Production of**; **Social Justice**

Further Readings

- Agnew, J. (1987). *Place and politics*. Boston: Allen & Unwin.
- Agnew, J. (1996). Mapping politics: How context counts in electoral geography. *Political Geography*, 15(2), 129–146.
- Bosco, F. (2007). Emotions that build networks: Geographies of human rights movements in Argentina and beyond. *Tijdschrift voor Economische en Sociale Geografie*, 98(5), 545–563.
- Cox, K. (1998). Spaces of dependence, spaces of engagement and the politics of scale, or: Looking for local politics. *Political Geography*, 17(1), 1–23.
- Featherstone, D. (2003). Spatialities of transnational resistance to globalization: The maps of grievance of the inter-continental caravan. *Transactions of the Institute of British Geographers*, 28, 404–421.
- Harvey, D. (1996). *Justice, nature and the geography of difference*. Cambridge, MA: Blackwell.
- Herod, A. (1997). Labor’s spatial praxis and the geography of contract bargaining in the U.S. east coast longshore industry, 1953–89. *Political Geography*, 16(2), 145–169.
- Herod, A. (2001). *Labor geographies: Workers and the landscapes of capitalism*. New York: Guilford Press.
- Johnston, R. (1991). *A question of place*. Cambridge, MA: Blackwell.
- Leitner, H., Sheppard, E., & Sziarto, K. (2008). The spatialities of contentious politics. *Transactions of the Institute of British Geographers*, 33, 157–172.
- Martin, D. (2003). “Place-framing” as place-making: Constituting a neighborhood for organizing and activism. *Annals of the Association of American Geographers*, 93(3), 730–750.
- Miller, B. (1994). Political empowerment, local-central state relations, and geographically shifting political opportunity structures: Strategies of the Cambridge, Massachusetts peace movement. *Political Geography*, 13(5), 393–406.
- Miller, B. (2000). *Geography and social movements: Comparing antinuclear activism in the Boston area*. Minneapolis: University of Minnesota Press.
- Miller, B. (2007). Modes of governance, modes of resistance: Contesting neoliberalism in Calgary.



- In H. Leitner, J. Peck, & E. Sheppard (Eds.), *Contesting neoliberalism: Urban frontiers* (pp. 223–249). New York: Guilford Press.
- Nicholls, W. (2008). The urban question revisited: The importance of cities for social movements. *International Journal of Urban and Regional Research*, 32, 841–859.
- Routledge, P. (1993). *Terrains of resistance: Nonviolent social movements and the contestation of place in India*. Westport, CT: Praeger.
- Routledge, P. (2003). Convergence space: Process geographies of grassroots globalization networks. *Transactions of the Institute of British Geographers*, 28, 333–349.
- Routledge, P., & Cumbers, A. (2009). *Global justice networks: Geographies of transnational solidarity*. Manchester, UK: Manchester University Press.



SOIL CONSERVATION

Soil conservation refers to the actions that humans undertake to ameliorate the effects of accelerated erosion caused by the clearing of vegetation for agriculture or for other types of human activity. Whenever humans clear a new environment of its protective vegetation cover, the soil is exposed to an increase in the erosional effects of rain, flowing water, and wind. If these processes of accelerated soil loss continue

unabated, it can result in decreased soil productivity and diminishment of the soil resource, sometimes to the point of field abandonment. Indirect effects include siltation of streams and water bodies, which can increase the impacts of floods and disrupt waterborne transportation. However, there is much that humans can do to mitigate the impacts of accelerated erosion.

Soil Conservation Systems

Over the centuries, human societies have devised several soil conservation methods, which fall into one of two general categories: (1) mechanical methods or (2) agronomic methods. Mechanical conservation methods involve modifying the slope geometry or making micromodifications within the field. Agronomic conservation methods use plants to protect the soil from the effects of rain splash and runoff or to improve the soil's ability to resist erosive forces. Mechanical and agronomic soil conservation systems are not mutually exclusive, and the two are commonly used in combination (see conservation system photo).

Mechanical Methods

One simple mechanical soil conservation technique involves placing logs behind field stumps, a method that is often used when a field is newly cleared from forest. Another simple means of erosion control involves placing logs or rocks across small gullies or streambeds to trap



Terraces: (A) bench and (B) platform (tree)

Source: Author.

sediments and create workable farm plots. These “check dams” also help harvest rainwater in arid regions or in regions with highly seasonal rainfall patterns.

Terraces involve modifying a sloping surface to reduce the flow of water over the surface, to provide a deeper soil in areas where soils are otherwise too thin for crop production, or to encourage water infiltration. Terraces can take many forms, which include sloping terraces, bench terraces, step terraces, and platform terraces (see terrace photos). Terraces, especially bench terraces, generally involve moving large amounts of materials, and thus, they are only recommended when conditions favor their use over other less labor- and time-intensive methods of soil conservation.

Other mechanical conservation systems involve less initial time and labor inputs than terraces, but they are effective only under the right conditions. One widely used technique is the construction of narrow ridges along the contour. In the United States, this technique is referred to as contour plowing, but Guatemalan farmers construct similar features, called *surcos*, by hand using a short-handled, broad-bladed hoe called an *azadón* (see contour ridges photo).

Ditches can also be constructed to divert water off fields or to collect sediments and encourage infiltration of runoff water. Diversion ditches and storm water drains are designed to divert runoff from field surfaces into open surface drains or grass-lined waterways at field edges. Infiltration ditches trap runoff and allow entrained sediment to settle out, as runoff water infiltrates into the soil rather than running downslope.



Contour ridges planted with wheat and maize

Source: Author.



Beans intercropped with maize (corn)

Source: Author.

Agronomic Methods

Agronomic conservation methods rely on the ability of plant cover to reduce soil erosion. The inclusion of organic matter in the soil enhances the effect of soil aggregation in soils that contain



This conservation system combines both mechanical (diversion ditches and grass-lined waterways) and agronomic methods (contour grass strips) of soil erosion control.

Source: Author.

clays, due to organic matter's tendency to bind with clay particles. These aggregates are more resistant to raindrop impact and splash erosion and help form cloddy surfaces, which serve to improve infiltration rates and to slow runoff velocity. Organic matter also provides soils with increased water storage capacity, which reduces the amount of runoff. Plant remains and leaf litter on the surface help disperse the kinetic energy of raindrop impacts and impede the flow of water over the surface. Living vegetation also reduces erosion by intercepting raindrops, impeding overland flow, and anchoring soil particles. Row crops generally provide the least amount of plant cover, especially during the early stages of crop growth. Grasses and permanent crops such as trees and shrubs generally provide the greatest amount of plant cover.

Cultural soil conservation measures include planting cover crops, intercropping, conservation tillage, and agroforestry. Cover crops are grown during the off-season, often as winter annuals, and then plowed in after harvest to form a green manure. Commonly used cover crops in the United States include rye, oats, hairy vetch, sweet clover, and lucerne. Intercropping (see photo) involves planting more than one crop in

the same field or plot. In Guatemala, farmers usually plant beans and squash in their *milpa* (maize) plots and may also plant several other crops, including beets, radishes, and broad beans, for family use. Intercropping and cover crops help reduce erosion by minimizing the amount of exposed ground surface.

Conservation tillage involves leaving residue from the previous year's crop as surface mulch. The residues help minimize the detachment of soil particles by rain splash, slow overland flow, and improve the organic matter content of the upper topsoil, all of which serve to reduce soil losses. Minimum-tillage and no-till systems also help reduce soil loss by reducing the disturbance of upper soil layers, which can break down soil aggregates over time.

Strip cropping involves growing row crops and protection-effective crops in alternating strips along the contour or perpendicular to the dominant wind direction. This approach lowers the overall erosion on a field by limiting the highest erosion risk to row crops. Soil removed from these strips is usually trapped in the next strip downslope or downwind. The conservation strips are usually planted next to a leguminous or grass crop that provides a high proportion of plant



Ancient stone-faced terraces on Island of the Sun, Lake Titicaca, Andean South America

Source: Author.

cover. These strips can be rotated, although permanent grass strips 2 to 4 meters wide are usually retained on steeper slopes (see conservation system photo).

Strip cropping falls within a larger class of conservation systems that has become known as agroforestry. Agroforestry is not actually forestry but a form of conservation agriculture that involves interplanting of trees or permanent crops with annual crops. Although the term is relatively new, small farmers throughout the world have been practicing some form of agroforestry for centuries. Farmers who practice swidden, or long-fallow slash-and-burn agriculture, in Africa and Latin America have been known to plant as many as 40 different annual and permanent crops in plots as small as one fifth of a hectare. Farmers in the Guatemalan highlands often plant coffee seedlings and bananas among their milpa crops, which they continue to plant until the shade from the tree crops begins to affect the growth of the other crops. Most agroforestry systems promoted by agricultural development agencies follow some variation on strip cropping or intercropping and may combine elements of both.

History and Geography of Soil Conservation

The history of soil conservation is probably as long as the history of accelerated soil erosion. Many societies around the world have used various conservation techniques, especially on hillsides that are prone to high levels of soil erosion. In his travels around the Mediterranean Basin in the late 1930s, Walter Clay Lowdermilk documented terraces that had been used for at least 2,000 yrs. (years) in Israel, Jordan, Lebanon, North Africa, Italy, and France. In the Americas, terraces have been used on hillsides by the Mesoamerican (Central Mexico to Northern Central America) and Andean civilizations for at least 1,500 yrs., perhaps longer (see Lake Titicaca photo). Extensive terrace systems have also been in place for many centuries in China, the Philippines, and the Pacific Island realms.

The United States has long been at the forefront of research on the erosion process and of studies on the effectiveness of various soil conservation practices. The period from 1890 to 1933 is considered the era of the first great conservation movement in the United States, and there is evidence that a less coherent soil conservation



movement was beginning to develop much earlier. Among its proponents were luminaries such as Thomas Jefferson, James Madison, and George Perkins Marsh. Madison lectured on the importance of agricultural improvement, including the benefits of contour plowing in reducing the impacts of soil erosion, and the importance of manures for maintaining soil fertility. Contour plowing is said to have been introduced in Mississippi by a planter friend of Thomas Jefferson at the latter's behest.

From these early beginnings, the practice of soil conservation in the United States increased from the 1850s until the first decade of the 20th century, when the U.S. Department of Agriculture (USDA) declared an official policy of land protection. Over the next three decades, field experiments were established to study the effects of erosion and the effectiveness of various soil conservation techniques, including the importance of plant cover in reducing rain splash erosion, which is a major agent contributing to the detachment of soil particles and their subsequent entrainment in runoff.

Other countries have followed this lead and established national programs designed to test the relevance of work conducted in the United States under other conditions, especially in the tropics, where soil erosion is of major concern. International agencies such as the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), and the United Nations Educational, Scientific and Cultural Organization (UNESCO) have also contributed to the effort to decrease erosion, especially in developing regions. Several international erosion research stations sponsored by institutions such as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, the International Center for Research in Agriculture (ICRAF) in Kenya, and the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in Costa Rica are involved in multinational research on erosion and the effectiveness of soil conservation systems.

Challenges to the Implementation of Soil Conservation

While soil conservation can do much to mitigate the effects of accelerated erosion, widespread

implementation of soil conservation practices faces many challenges. While most farmers are aware of soil erosion's consequences, and of soil conservation's benefits, the effects of both are generally incremental, while labor and capital costs are often incurred at the outset. Certain soil conservation methods, such as terraces and contour grass strips, can have short-term impacts on crop productivity due to decreases in planting surface, shading, or competition for nutrients. Farmers who do not own the land they cultivate or whose landholdings are marginal for supporting their families are less likely to invest capital, labor, or space if there is a high likelihood that they will lose access to the land or that crop production will be adversely affected. Many developing countries lack the capital to invest in national conservation programs. Political instability also hinders farmers' efforts toward agricultural improvement and reduces the interactions between farmers and conservation agents.

Steven James Rainey

See also **Agroforestry; Biota and Soils; Food and Agriculture Organization (FAO); Land Degradation; Population and Land Degradation; Soil Degradation; Soil Depletion; Soil Erosion; Soils; United Nations Environment Programme (UNEP)**

Further Readings

- Hudson, N. (1995). *Soil conservation* (3rd ed.). Ames: Iowa State University Press.
- Moore, J. H. (1958). *Agriculture in ante-bellum Mississippi*. New York: Bookman.
- Morgan, R. P. C. (2005). *Soil erosion & conservation* (3rd ed.). New York: Wiley-Blackwell.
- Rainey, S. J. (2002). Local perspectives on erosion and conservation of soil resources in two highland Guatemalan *municipios*. In M. K. Steinberg & P. F. Hudson (Eds.), *Cultural and physical expositions: Geographic studies in the Southern United States and Latin America*. Baton Rouge, LA: LSU Geoscience.
- Stoll, S. (2003). *Larding the lean Earth: Soil and society in nineteenth-century America*. New York: Hill & Wang.



SOIL DEGRADATION

Soil degradation is the alteration of one or more soil properties due to human or natural causes that results in a lowered performance of a soil for a specific function. The term *soil degradation* is also used to describe alteration of the soil properties associated with a soil's natural or inherent set of physical, chemical, and biological properties. Soil degradation may be a temporary condition or a permanent state, depending on the severity of the degradation and the resilience of the soil to being restored to a functional level for a specific purpose or to its natural inherent state through improved management and/or changes to physical variables (e.g., end of a drought period).

Soil erosion is an example of a soil-degradative process and is often considered to be a temporary

condition (see photo). Erosion may be minimized through alteration of land management practices to slow erosion processes and allow the degraded soil properties associated with soil loss to become restored (e.g., the reestablishment of topsoil).

The U.S. Soil Erosion Service, predecessor to the Soil Conservation Service and now the Natural Resources Conservation Service, identified the degradative effects that the intensive agricultural management practices of the early part of the 20th century were having on the rates of soil erosion in the Great Plains region. High levels of topsoil loss during the preceding years, coupled with drought conditions, resulted in decreased agricultural productivity, leading ultimately to the Dust Bowl. To initiate a new era of soil conservation and restoration, the U.S. government implemented agricultural policies aimed at helping farmers use practices known to decrease



Soil erosion due to water runoff in a grain-producing region of Castilla-La Mancha, Spain, is attributed to a combination of management practices and high-intensity precipitation events typical of Mediterranean winters.

Source: C. Lacasta, Consejo Superior de Investigaciones Científicas, Centro de Ciencias Medioambientales (CSIC-CCMA), Madrid, Spain.



erosion and facilitate restoration of the degraded conditions. These new forms of agricultural land management, such as contour plowing and resting land, mitigated the rates of soil erosion and allowed the reestablishment of topsoil. This change led to sustainability in the form of continued agricultural fertility of the soils of the U.S. Great Plains region.

Soil desertification is another example of a soil-degradative condition. It includes several aspects of soil degradation and is generally a condition not considered to be reversible. Some regions in sub-Saharan Africa experience desertification due to population pressures on soil resources combined with climatic factors. The resulting soil degradation in the form of soil compaction and loss of nutrients is so severe, likened to the spreading of desert conditions, that restoration is not generally considered a possibility.

The processes of soil degradation depend on both human and physical variables that affect a soil region. These human and physical variables can change during timescales as short as a human life and include aspects of land management practices and decisions as well as physical environmental factors such as climate change. Improved understanding of human and physical environmental effects on the processes of soil degradation is helpful in developing ongoing management techniques and policies that specifically address current soil degradation issues characteristic of a particular region, thus improving the sustainability of soil function and resources.

The geographic variation of soil resources, environmental variables, and soil management practices results in wide spatial variability in soil degradation and degradation processes. This results in soil degradation being a location-specific condition that needs to be evaluated for a particular area in reference to a certain performance need of a soil or in reference to the alteration of the soil properties from their inherent or natural state.

Soil degradation processes are categorized as having an effect on the physical, chemical, or biological properties of a soil. The functionality of a soil depends on many interrelated processes that can also be categorized as physical, chemical, and biological. Degradation of one aspect of these general areas usually results in changes in the

other soil property areas as well. Physical degradation of soil includes erosion or loss of topsoil, soil compaction due to animal grazing or use of machinery, and breakdown of the natural soil structure. Compaction or loss of topsoil results in lowered fertility and thus less carbon cycling within the soil. Chemical soil degradation includes changes to the levels of nutrients important to sustain plant growth. Biological soil degradation is the loss of the microbial activity that is important for the breakdown of plant matter, cycling of nutrients, and soil textural properties.

Darcy Boellstorff

See also **Agriculture, Industrialized; Desertification; Land Degradation; Land Use and Cover Change (LUCC); Population and Land Degradation; Soil Conservation; Soil Depletion; Soil Erosion; Soils**

Further Readings

- Lal, R., Blum, W. H., Valentine, C., & Stewart, B. A. (1997). *Methods for assessment of soil degradation*. Boca Raton, FL: CRC Press.
- Lal, R., Sobecki, T. M., Iivari, T., & Kimble, J. M. (2007). *Soil degradation in the United States: Extent, severity, and trends*. Boca Raton, FL: CRC Press.



SOIL DEPLETION

Soil depletion is the loss of soil fertility through a decline in organic matter content, major mineral nutrients, and trace elements. Lowered levels of nutrients lead to poor crops and deficiencies in the diet of grazing animals and, thus, eventually in the human food chain. It is a major handicap in developing sustainable agriculture. The loss of nutrients is the result of both natural and anthropogenic processes. Soils more than 200,000 yrs. (years) old on rocks poor in base elements are particularly prone to nutrient and trace element depletion. In the southeastern United States, in forest soils up to 2 million yrs. old on base-poor igneous and metamorphic rocks, calcium (Ca) in



the rooting zone has been leached out of the soil profile. This means that the potential for replenishment of soil-exchangeable Ca through mineral weathering is low. The natural nutrient cycle maintains sufficient soil fertility for tree growth, but once that cycle is disrupted, through timber harvesting, base elements are rapidly depleted. Exploitative agriculture from 1800 to 1920 in these forests depleted much of the original pre-European Ca in the soil. Mid-20th-century acid deposition (sulfate [SO₄] loading) accelerated soil Ca losses. Such effects are widespread in Europe and the United States. Soil depletion also occurs on younger postglacial soils, for example, in Maine, but less rapidly than in the southeastern United States, because the levels of acid deposition and rates of Ca accumulation in trees are lower. The conifer trees of Maine grow more slowly and require less Ca than the southeastern U.S. hardwoods.

Soil depletion is of concern to most low-latitude countries. All continental African countries, except Libya, experience annual nutrient deficits. Soils in densely populated parts of the semiarid, arid, and Sudano-Sahelian areas lose 60 to 100 kg ha⁻¹ yr⁻¹ (kilograms per hectare per year) of nitrogen, phosphorus, and potassium (NPK). These shallow, highly weathered soils are subjected to intensive cultivation but low levels of fertilizer application. In subhumid and humid African regions, rates of nutrient depletion range from 30–60 kg ha⁻¹ yr⁻¹ NPK in the humid forests and wetlands in Southern Central Africa to more than 60 kg ha⁻¹ yr⁻¹ in the East African highlands.

Globally, in 2000, soil nutrient deficits averaged (in kg ha⁻¹ yr⁻¹) 18.7 for N, 5.1 for P, and 38.8 for K, covering 59%, 85%, and 90% of harvested area in the year 2000, respectively, and annual total nutrient deficit was 5.5 Tg (teragrams, 1 Tg = 1,012 g) for N, 2.3 Tg for P, and 12.2 Tg for K, coupled with a total potential global production loss of 1,136 Tg/yr. Soil depletion is producing fertility problems throughout the world.

Ian Douglas

See also Land Degradation; Land Use and Cover Change (LUCC); Population and Land Degradation; Population, Environment, and Development; Soil Conservation; Soil Degradation; Soil Erosion; Soils

Further Readings

- Huntington, T. G. (2005). Assessment of calcium status in Maine forests: Review and future projection. *Canadian Journal of Forest Research*, 35, 1109–1121.
- Huntington, T. G., Hooper, R. P., Johnson, C. E., Aulenbach, B. T., Cappellato, R., & Blum, A. E. (2000). Calcium depletion in a southeastern United States forest ecosystem. *Soil Science Society of America Journal*, 64, 1845–1858.
- Tan, Z. X., Lal, R., & Wiebe, K. D. (2005). Global soil nutrient depletion and yield reduction. *Journal of Sustainable Agriculture*, 26, 123–146.



SOIL EROSION

Soil erosion refers to the removal of soil materials from their original location and their subsequent transport to another location through the action of wind, water, ice, biotic processes, or human activities. Under most natural conditions, soil-forming processes and soil erosion are in equilibrium. When the balance between these two forces is upset through the removal of the natural cover, soil erosion can accelerate and result in loss of the soil's capacity to support vegetation or in the soil's complete removal.

Factors Affecting Soil Erosion

Factors affecting soil erosion include climate, soil properties, slope gradient and length, vegetation, and soil management practices. Drier climates mean less vegetation and less plant cover to protect the ground surface from raindrop impact and from the flow of water over the surface. Drier soils are also more susceptible to wind erosion than moist soils due to lower particle cohesion. Soils with low clay content and a high content of fine to medium sand tend to be most susceptible to erosion from water and wind. Soils with high clay content tend to be less susceptible due to their ability to form stable aggregates that are resistant to erosive forces. Steeper slopes mean that runoff flows more



Severe soil erosion in a wheat field near Washington State University

Source: Jack Dykinga/Agricultural Research Service, U.S. Department of Agriculture.

rapidly, and with more erosive force, while longer slopes provide greater distances for runoff to build up speed. Vegetation reduces soil erosion by providing cover to protect soil surfaces against erosive forces, while organic matter from the breakdown of plant residues helps produce stable soil aggregates. Management practices that build up soil organic matter, increase groundcover, and incorporate other methods of soil conservation help lower erosion risks.

History of Soil Erosion

Since humans began growing crops and modifying the landscape, accelerated soil erosion has been a major problem facing humankind. Soil erosion has been among the culprits blamed for the decline of civilizations such as the Mesopotamian civilization, the Classical Mayan civilization, and the Roman Empire. Soil erosion is also linked to the mass exodus of migrants in the 1930s from the western Great Plains when drying conditions combined with severe wind erosion set off the series of events that turned the region into a “Dust Bowl.”

Humans have long been aware of the consequences of accelerated soil erosion caused by their activities. Passages in the Old Testament mention threats of streams drying up, while the Greek philosopher Plato referred to the relationship between flood damage and deforestation, and the Roman writer Virgil advocated what amounted to conservation farming. Many early civilizations were not overly concerned with erosion’s impacts because most of these civilizations had developed on irrigated alluvial plains, and thus, they counted on erosion in the headwaters of rivers such as the Nile, the Tigris, and the Euphrates to provide sediments to renew soil fertility.

By the late 18th century, however, more observers began to notice the consequences of accelerated erosion, partly due to the increased impacts of humans on the landscape as populations began to grow at unprecedented rates. In 1818, James Madison lectured on the evils of poor land management. In 1864, George Perkins Marsh wrote about the impacts of forest clearance on river sedimentation and flooding in New England and the Mediterranean Basin.



German soil scientists conducted the first scientific investigations of soil erosion in the 1870s. The U.S. Forest Service first conducted quantitative soil erosion experiments in 1915 in Utah. In 1928, Hugh Bennett of the Soil Conservation Service established a network of field experiment stations that enabled work on the analytical study of the erosion process. In 1954, a national study of soil erosion used modern data analysis techniques to correlate the results of all field experiments to identify and mathematically enumerate the main factors in the erosion process. This allowed for the development of equations that could be used to estimate the soil erosion in an area based on a number of known variables such as rainfall amount and intensity, slope gradient, slope length, soil erosivity, vegetation cover, and the soil management system.

Geographic Extent of Soil Erosion

There are many difficulties involved in estimating soil erosion impacts on a large scale due to the huge variations in soil type, rainfall, management practices, slope, and vegetation that occur over large areas. The use of different assumptions and methods of measurement and analysis also leads to wide variations in erosion estimates. Also, while industrialized countries such as the United States and the United Kingdom have well-funded agencies that produce annual reports on the impacts of soil erosion on croplands under their jurisdiction, similar data are harder to come by in poor countries such as Ethiopia or Guatemala.

In 2003, total annual erosion on all cropland in the United States was estimated at 1.75 billion tons, with 970.6 million tons removed by water and another 776.4 million tons removed by wind. This converts to average per-acre soil losses of 2.6 tons due to water-induced erosion and 2.1 tons due to wind-induced erosion. Although the overall soil loss figures were lower than the overall estimated soil loss rates for 1982, 102 million acres (28% of all cropland) were still losing soil at rates above the soil loss tolerance limits.

One study of the mean water-induced global soil erosion rates between 1979 and 1993 estimated the total annual erosion losses for that period to be around 4.7 tons acre⁻¹ yr.⁻¹ (per acre per year), with the highest overall soil losses

estimated for South America (6.8 tons acre⁻¹ yr.⁻¹) and Asia (6.4 tons acre⁻¹ yr.⁻¹). However, erosion losses in mountainous regions can be as much as 100 tons acre⁻¹ yr.⁻¹ or more.

Steven James Rainey

See also **Land Degradation; Marsh, George Perkins; Population and Land Degradation; Rill Erosion; Soil Conservation; Soil Degradation; Soil Depletion; Soils**

Further Readings

- Hudson, N. (1995). *Soil conservation*. London: B.T. Batsford.
- Kirkby, M. J., & Morgan, R. P. C. (Eds.). (1980). *Soil erosion*. New York: Wiley.
- Pham, T. N., Yang, D., Kanae, S., Oki, T., & Musiake, K. (2003). Global soil loss estimate using RUSLE model: The use of global spatial datasets on estimating erosion parameters. *Geoinformatics*, 14(1), 49–53.
- Stoll, S. (2002). *Larding the lean Earth: Soil and society in nineteenth-century America*. New York: Farrar, Straus & Giroux.



SOILS

A soil is a body of weathered mineral and organic materials that has been altered through time into a series of discrete layers. The movement of water through the materials facilitates the development of layers (horizons) that are distinguished by whether they have lost or accumulated different mineral and organic constituents (Figure 1). A number of strongly interrelated variables contribute to the development of a soil; these are most succinctly summarized by Hans Jenny's *clorpt* equation, which emphasizes the interaction of the five soil-forming factors of climate, organisms, relief, parent material, and time.

Every soil starts from an accumulation of some type of parent material (fractured bedrock, river alluvium, glacial till, wind-blown loess, plant residue, etc.) that is then altered through time by weathering processes that are highly dependent

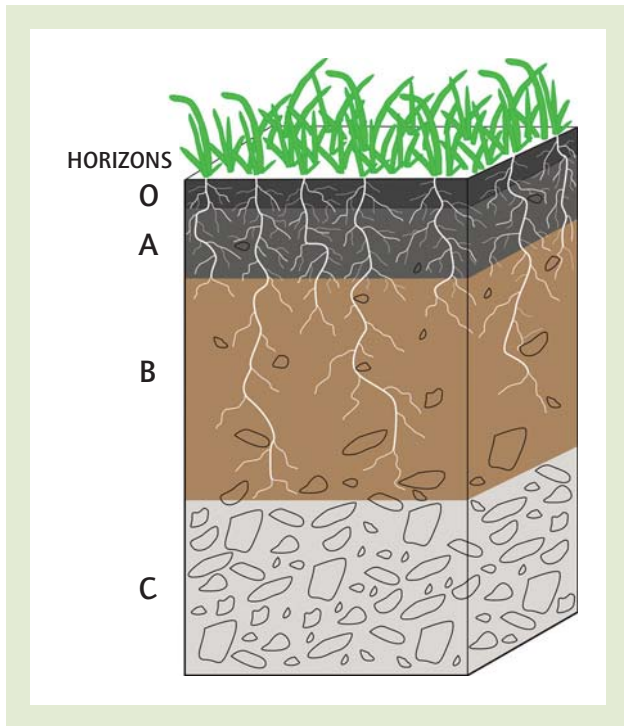


Figure 1 Soil profile illustrating the typical sequence of horizons. O horizons are dominated by decomposing organic material; A horizons are mineral horizons enriched with organic matter; B horizons are most often illuvial horizons, with the illuviated material largely dependent on the interaction of the soil parent material, climate, and time; C horizons represent relatively unaltered parent material. If present, unaltered parent material would be represented by an R horizon.

Source: F. D. Wilkerson.

on the climate (long-term patterns of precipitation and temperature). The organisms (plants and animals of all sizes, including microbes) involved in soil formation are also closely linked with the climate. The landscape position (relief) affects the potential energy for movement of materials into and out of the original parent material. Additions to the parent material can include mineral particles (e.g., dust) and organic materials from decaying plants and animals. These additions and the original parent material are altered by physical and chemical weathering, and through time, the various weathered products are moved (translocated) throughout the parent material, forming what is referred to as a *soil profile*.

Regardless of the dominating soil-forming factor, the presence of water is critical to the formation of a soil profile and its characteristic horizons (layers). A desert soil exhibits very different attributes from a soil developed in a humid environment, but water is a crucial component in both. On the planet Mars, even without what we recognize as plants, the presence of water supports the existence of Martian soils. Water-related soil processes point to its significance in chemical reactions within the soil and its role as a medium for the movement of different materials in solution (leaching) or in suspension. The movement of water is driven by gravity, so the majority of translocation within a soil profile proceeds from the top of the profile downward through time. This movement is facilitated by the presence of soil pores (voids or air spaces), which occur within the profile in a variety of shapes, sizes, and connectivities. As translocations proceed over time, soil components are removed from certain horizons and concentrated in others. Horizons that have lost a certain component are called *eluvial horizons* (soil components have exited that horizon), while horizons with an accumulation of translocated components are *illuvial horizons* (soil components have moved into the horizon).

Weathered parent material contains a variety of minerals characteristic of the chemical composition of the original material. Salts are a common weathering by-product and are the first components to be translocated in solution through the soil profile. In humid environments with adequate water, the majority of salts are easily leached from the soil profile. Tropical soils developed under conditions of plentiful water and warm temperatures are heavily weathered and leached and thus retain little evidence of the original parent material chemistry. When the majority of soluble materials have been removed from tropical profiles, the soils are highly acidic, and they are dominated by iron and aluminum oxides.

In arid environments, salts are not completely leached away but are precipitated from solution within the soil profile, and the climate is actually recorded in the type and amount of salts present and the depth of salt precipitation. The depth of salt deposition within a soil profile marks the maximum depth of water movement, which is the depth at which the salts are chemically



precipitated as they are forced out of the solution. Sodium salts are the most soluble, followed by potassium and calcium. In extreme cases, a soil profile will have deposits of sodium salts at or near the surface of the profile, which results in a physical and chemical environment that is inhospitable to plant growth. As water amounts increase, the sodium and potassium salts will be flushed from the soil profile, and calcium will begin its translocation through the soil. Calcic horizons (soil layers with an accumulation of CaCO_3 [calcium carbonate]) are characteristic of semiarid and arid soils, where the depth-to-carbonate is indicative of the mean annual precipitation.

Once the soluble salts (e.g., sodium, potassium, and calcium) have been leached out of a soil horizon, other soil constituents can begin their translocation process. The movement of clay minerals is one of the more important soil formation processes. Clay minerals are very small particles (<0.002 mm [millimeters]) that have a wide range of chemical composition and either can weather directly out of the parent material or can be secondary minerals formed within the soil profile. Regardless of their source, clay mineral particles are translocated throughout the soil profile by moving water. Soil layers with an accumulation of clay particles tend to take on a reddish color and are known as *argillic horizons*. The presence of high amounts of clay within a horizon can affect both physical and chemical properties of a soil profile.

The mineral-based particles within a soil are referred to as *soil separates* and are categorized by size. Sand-sized particles are 0.05 to 2.0 mm in size and are usually dominated by a resistant quartz (SiO_2) mineralogy. Silt-sized particles range from 0.002 to 0.05 mm and are often described as exhibiting characteristics similar to flour. Clay-sized soil separates are particles <0.002 mm in size and are dominated by plate-like clay mineral particles. The relative proportion of soil separates (expressed as a percentage) defines its texture. Soil textural classes are given descriptive names that define a specific range of soil separates: Loam (7%–27% clay, 28%–50% silt, $<52\%$ sand), silty clay loam (27%–40% clay, $<20\%$ sand), and sandy clay loam (20%–35% clay, $<28\%$ silt, $>45\%$ sand) are a few examples.

There are a total of 12 textural classes defined, and they are most commonly graphically represented on a soil textural triangle (Figure 2).

Soil texture can vary from horizon to horizon and is controlled by the texture of the original parent material in conjunction with the physical and chemical weathering processes occurring within the soil profile. The translocation of clay minerals is a dominant soil formation process and is usually responsible for the abrupt changes in texture within a soil profile. Additions of wind-blown fines (usually silt-sized particles) can enhance the texture of surface horizons, while parent material textures tend to dominate the lower horizons. A granitic parent material will weather into sand-sized particles, shales into clays, limestones into silts, and sandstones into sands. Mixed parent materials such as glacial tills support highly variable soil textures but are usually dominated by the finer components (silts and clays) of the till matrix.

The soil textural class provides clues to a variety of physical and chemical properties. The ability to hold water and plant nutrients is controlled to a large extent by the particle size. Sand grains are large and do not pack closely together, so sandy soils have large pores but a relatively small amount of open pore space compared with the mineral grains. A soil high in sand will tend to be porous and, thus, well drained, with a relatively low water-holding capacity. The very small, plate-like clay particles pack closely together, resulting in small pores but overall a large amount of space between the clay particles. A soil high in clay will tend to be dense and poorly drained but with a high water-holding capacity. High-clay soils can hold two to four times more water than a sandy soil. The surface area of the mineral particles controls their ability to hold nutrients for plant uptake. Sand grains have a relatively small surface area, while the very small clay particles have a high proportion of surface area available for plant nutrient adsorption. Sandy soils are relatively infertile, while high-clay soils have a much greater capacity for storing plant nutrients. Many soil-engineering properties are defined by soil texture and related textural characteristics such as plasticity.

The presence of clays, organic matter, and microbes within a soil profile help to aggregate

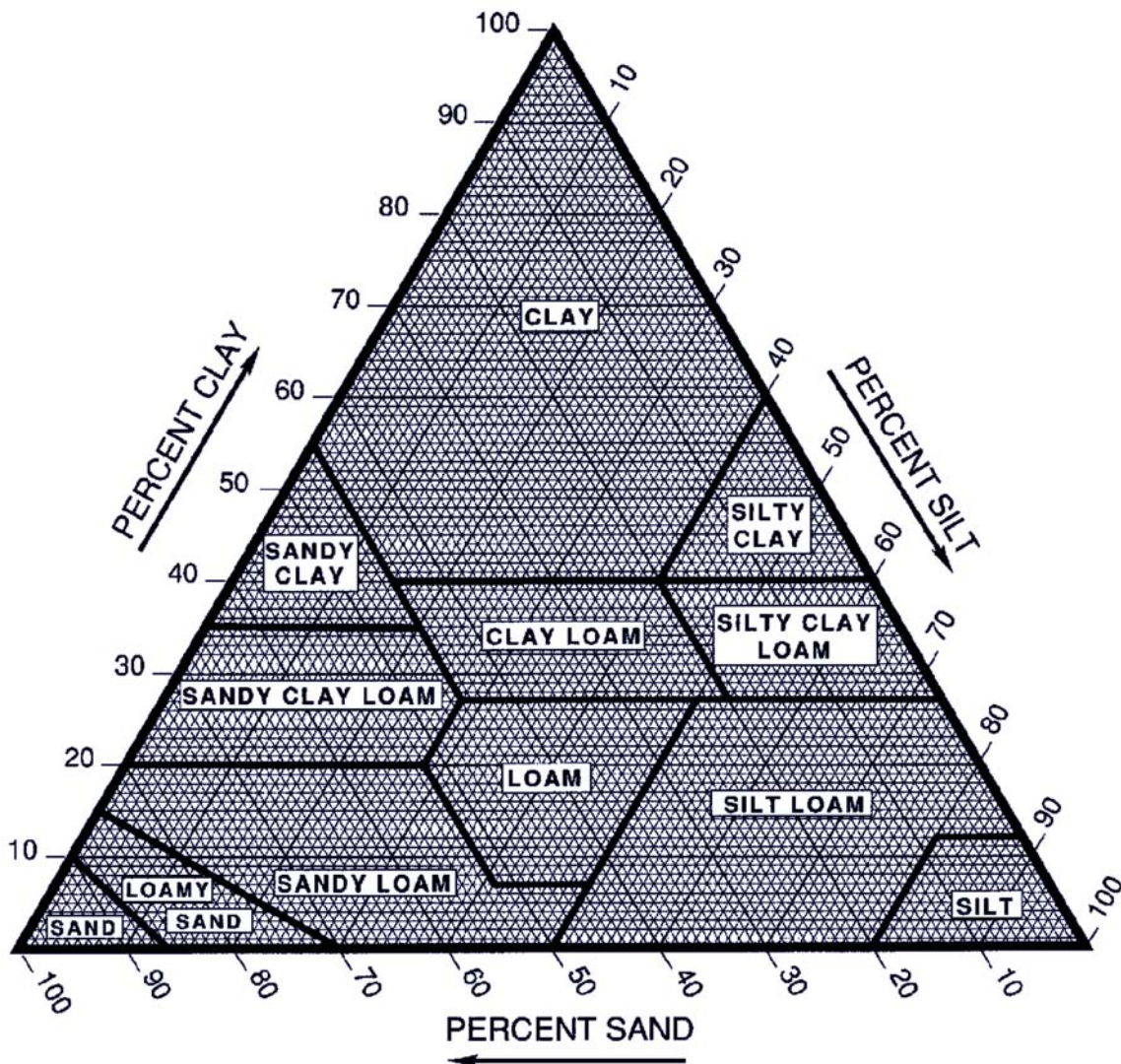


Figure 2 The soil textural triangle provides a graphic representation of the percentage of soil separates in each textural class.

Source: Courtesy of U.S. Department of Agriculture, Natural Resources Conservation Service.

(glue) soil separates into coherent units called *peds* (from the ancient Greek *pedo*, meaning “ground” or “earth”). The soil peds are collectively referred to as the *soil structure*, and like texture, the structure can vary from horizon to horizon within a soil profile. Soil structure is defined by the size, shape, and strength of the aggregated peds, with shape being the most

descriptive characteristic. Ped shapes include granular, blocky, platy, prismatic, and massive. Soil structure plays a role in controlling several physical properties within a soil profile, including drainage, water-holding capacity, aeration, and the environment for root penetration and growth. A massive soil structure acts as a dense, homogeneous unit with restricted pore space and thus



restricted aeration, water movement, and water-holding capacity as well as restricted root access. A massive structure is in direct contrast to a granular structure, which is dominated by an accumulation of small, rounded aggregates that allow for ample aeration, water movement, and storage and an ideal root growth environment.

Like the physical soil properties of texture and structure, soil chemistry is closely tied to the soil parent material and the weathering processes that occur within the profile. Soil chemistry is complex and includes a wide range of chemical reactions across incredibly varied environments. Most chemical weathering reactions that can be replicated in a laboratory occur naturally in soils, including oxidation, reduction, carbonation, dissolution, hydration, hydrolysis, and solution. Soil chemistry is most significant for its role in determining soil fertility and the availability of nutrients for plant growth, but it also plays an important role in controlling certain physical properties. Soil pH and cation exchange capacity (CEC) are two of the more important soil chemistry attributes.

In drier climates, the soil pH is closely tied to that of the original parent material, while in humid climates, chemical weathering processes dominate the profile. Limestone (CaCO_3) has a normal pH of 8, and the resulting soils will maintain that basic pH in drier climates, while granitic soils will be acidic due to the chemistry of the original granite. The accumulation of salts in arid environments also helps support basic pH levels (salts will accumulate when evaporation exceeds the water available for leaching). Humid subtropical to tropical climates are dominated by leaching, and chemical reactions lead to acidic soils with no recognizable chemical ties to the original parent materials.

Soil pH is linked to the availability of nutrients to plants. A neutral pH (pH 7) is preferred by many plants, as pH levels to either extreme (acidic or basic) mean that many nutrients are either not available for plant uptake or are present in high enough levels to be toxic. Some plant communities have naturally adapted to extreme pH levels. Cranberries (*Vaccinium macrocarpon*) prefer acidic soil pH levels between 4.5 and 5.5, and *Rhododendron* spp. prefer a pH level of 5.5. The longest-lived species on Earth, *Pinus longaeva* (bristlecone pine), prefers dolomite ($\text{Ca}\cdot\text{Mg}(\text{CO}_3)_2$)

substrates with a basic pH because the dolomitic soils at this pH level are nutrient-deficient for most plants and the bristlecone are able to out-compete their associated species. Commercial agriculture and horticulture applications often add chemical amendments to adjust the soil pH to the optimum level for the plant species under cultivation.

Soil is often defined as the medium that supports plant growth, but it should be remembered that plants can also grow out of the cracks in bedrock and flourish hydroponically in water. Plants and soils are unquestionably interconnected, as soils supply a physical medium for plant root growth and nutrition and plants supply essential organic material for soil formation, including through recycling of plant nutrients. The interaction between climate, vegetation type, and soil formation is also significant and self-perpetuating.

CEC is the main measurement used to quantify soil fertility. As a whole, a soil will have a neutral charge, with exchange sites on mineral particles and with positive and negative ions in solution. Common ions in the soil solution are the positively charged ions (cations) of calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^{+}), ammonium (NH_4^{+}), sodium (Na^{+}), aluminum (Al^{+3}), and hydrogen (H^{+}). Calcium, magnesium, potassium, and nitrogen are all important plant macronutrients; while sodium is an important plant nutrient, it can be detrimental to a plant's osmotic potential if present in too large quantities (typical of some coastal and arid environments or irrigated settings with inadequate drainage or flushing). Aluminum is toxic to most plants when it is the dominant cation at very low pH levels (exchangeable Al^{+3} ions dominate at levels below pH 4). There are also negatively charged ions (anions) in the soil solution that serve as plant nutrients, including chloride (Cl^{-}), nitrate (NO_3^{-}), sulfate (SO_4^{-2}), and phosphate (PO_4^{-3}).

Organic matter and clay mineral particles are the dominant source of exchange sites within a soil, and both are negatively charged particles with a majority of their exchange sites available for cation exchange (negative sites for holding and exchanging positively charged cations). Both organic matter and clay minerals are relatively small particles with a large proportion of surface area, so a high number of exchange sites are available. Other soil particles, such as sand, have a



relatively small surface area; they are essentially chemically inert (dominated by quartz SiO_2) and offer few if any exchange sites. Plant roots can access the ions held on exchange sites, and while free ions in solution are the most readily available, they are also the most readily leached out of the root zone.

CEC is measured in milli-equivalents (or meq) of negative charge per 100 g (grams) of soil. The CEC of pure clay minerals will vary with their chemical structure, but most are in the upper end of the 5- to 150-meq/100 g range. Soil organic matter CEC is the highest, with an average of 200 meq/100 g. Given the exchange capacity of clays compared with sands, the texture of a soil can be used to estimate CEC. The following textural classes illustrate the role of soil texture in CEC: sandy loam, 2 to 4 meq; loam, 2 to 17 meq; silt loam, 9 to 26 meq; and clay, 5 to 58 meq. Regardless of soil texture, the presence of organic matter has a strong influence on soil CEC, given that the exchange capacity of organic matter is 4 to 50 times larger than that of clay minerals.

Soil organisms are also important for soil fertility through their role in breaking down plant and animal remains into their elemental constituents. Burrowing organisms of all sizes (from badgers, rabbits, gophers, etc., to earthworms and burrowing insects) are important for their role in incorporating organic material into the mineral horizons where the microorganisms (mainly bacteria, but also fungi) can begin the decay process. The organic matter produced from the decomposition of plant and animal remains improves not only a soil's CEC but also its physical properties by increasing its aeration and water-holding capacity. Organic matter is also a key component in improving soil structure.

One of the most significant soil organism processes is the nitrogen cycle. Nitrogen is a major plant macronutrient, and 90% of Earth's nitrogen occurs as a stable gas (N_2) in the atmosphere. The majority of soil nitrogen comes from soil bacteria fixation of the atmospheric N_2 into the inorganic ammonium form (NH_4^+). Other soil bacteria will mineralize lesser amounts of NH_4^+ from decomposing plant and animal remains. Nitrifying bacteria will convert much of the NH_4^+ to the more plant-preferred, but also more readily leached, forms of nitrite (NO_2^-) and nitrate (NO_3^-). And to

complete the nitrogen cycle, other microscopic species will denitrify some of the soil NO_3^- and actually send nitrogen back into the atmosphere.

Larger mammals also play a role in the soil-forming process. Many of the larger wild animals disturb the soil surface through a variety of behaviors, including grazing, hoof impact, digging, and wallowing. Although these behaviors are disruptive to the vegetation and surface horizons, they are also important in establishing seed contact and in some cases even increasing aeration and surface water infiltration. Domestic animals (especially grazers) have some of the same habits, but often their behaviors are artificially restricted, so that instead of increasing seed contact and aeration, the soil becomes compacted, and soil structure is negatively affected.

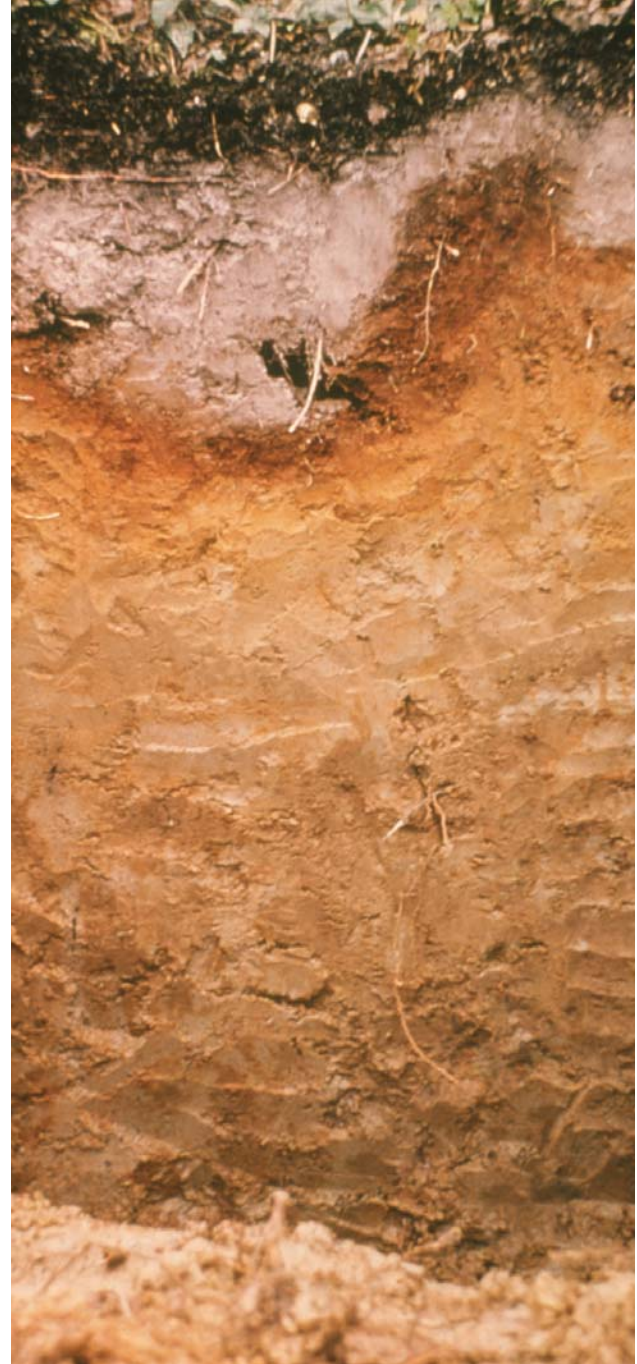
Humans are by far the most influential organism in the soil formation equation. Most impacts from human interaction with the soil are negative. Soil erosion is a natural process, but it has been greatly increased through disturbance by people cultivating, logging, and clearing vegetation for urbanization. We are able to feed large populations through the use of domesticated plants and commercial agriculture, but at a price to soil formation. Decomposing plant remains are a good source of soil organic matter and nutrients, but harvesting of food and animal feed crops removes the majority of plant material before it even gets into the soil cycle. Inorganic chemical amendments (fertilizers, herbicides, pesticides) used to increase crop yields can have negative impacts on soil organisms and physical characteristics such as soil structure. Global movements toward more organic and sustainable methods of agriculture have the potential to reduce, and in some cases even reverse, the negative impacts of humans on soils.

Many different international soil classification (taxonomy) systems exist to help categorize soils into different groups. Most of these are systems developed to fit the needs of specific countries, with more specialized classifications being used by construction engineers and for other technical applications. Countries with well-established agricultural sectors have the most well-known soil taxonomies, including Russia, Canada, the United States, Israel, and Australia. The basis for each taxonomy system varies, but a familiarity with one system usually makes it easier to understand



Typical Mollisol profile. Mollisols (one of 12 soil orders in the U.S. soil taxonomy system) are common under midlatitude grasslands and are defined by their organic-rich A horizons. The whitish areas in the near-surface calcic horizon (Bk) are illuviated deposits of calcium carbonate that are common in these semiarid grassland soils.

Source: Courtesy of U.S. Department of Agriculture, Natural Resources Conservation Service.



Typical Spodosol profile. Spodosols (one of 12 soil orders in the U.S. soil taxonomy system) are most common under coniferous forests on sandy parent materials at latitudes over 40° N/S (cool and relatively wet climates). The horizon is indicative of eluviated horizons dominated by quartz, where the eluviated iron and aluminum compounds have accumulated in the darker horizon underlying the E horizon.

Source: Courtesy of U.S. Department of Agriculture; Natural Resources Conservation Service.



Typical Oxisol profile. Oxisols (one of 12 soil orders in the U.S. soil taxonomy system) are highly weathered tropical and subtropical soils, usually dominated by iron and aluminum oxides. The reddish color is characteristic of intensely weathered mineral soils.

Source: Courtesy of U.S. Department of Agriculture, Natural Resources Conservation Service.

other systems. There are two main international taxonomies developed to help facilitate global soil understanding, the soil classification system of the FAO/UNESCO (Food and Agriculture Organization/United Nations Educational, Scientific and Cultural Organization) and that of the WRB (World Reference Base for Soil Resources).

The current U.S. soil taxonomy system (developed by the U.S. Department of Agriculture's Natural Resources Conservation Service) is a hierarchical classification system based on the presence (or absence) of specific diagnostic horizons. At the most detailed level of classification, there are hundreds of soil series identifiable within the United States, and all can be fit into 12 general soil orders (see photos).

Ginger L. Schmid

See also [Biota and Soils](#); [Desertification](#); [Environmental Impacts of Agriculture](#); [Environmental Management](#); [Environmental Management: Drylands](#); [Geomorphology](#); [GIS in Land Use Management](#); [Impermeable Surfaces](#); [Land Degradation](#); [Nonrenewable Resources](#); [Population and Land Degradation](#); [Rill Erosion](#); [Soil Conservation](#); [Soil Degradation](#); [Soil Depletion](#); [Soil Erosion](#)

Further Readings

- Birkeland, P. (1999). *Soils and geomorphology* (3rd ed.). New York: Oxford University Press.
- Brady, N. C., & Weil, R. (2008). *The nature and property of soils* (14th ed.). Upper Saddle River, NJ: Pearson Higher Education.
- Jenny, H. (1994). *Factors of soil formation: A system of quantitative pedology*. New York: Dover.
Retrieved January 17, 2010, from www.soilandhealth.org/01aglibrary/010159.Jenny.pdf (Original work published 1941)
- Singer, M. J., & Munns, D. N. (2006). *Soils: An introduction* (6th ed.). New York: Prentice Hall.
- Soil Science Society of America Glossary: www.soils.org/publications/soils-glossary
- U.S. Department of Agriculture's *Soil Survey Manual*: http://soils.usda.gov/technical/manual/print_version/complete.html
- U.S. Department of Agriculture's *Twelve Soil Orders*: <http://soils.ag.uidaho.edu/soilorders>



SOJA, EDWARD (1941–)

One of human geography's most passionate and articulate advocates, Edward Soja has long been an aggressive voice for the inclusion of space in contemporary social thought. He is widely regarded as one of the leading theoreticians in urban and political geography. His work has long been characterized by an abiding concern for issues of social justice and inequality as well as for deciphering the ways in which spatial relations are naturalized as well as contested.

From his origins in the Bronx, Soja developed a highly urban-centered geographical imagination. Following a PhD at Syracuse University, he taught briefly at Northwestern University in Chicago, where he briefly pursued a positivist line of thought. His early work concerned Africa, including a dissertation on Kenya and applications of modernization theory. However, soon after, Soja joined the faculty of Urban and Regional Planning at the University of California, Los Angeles, where he has remained since 1972.

Deeply affected by the events of the 1960s, Soja became a committed Marxist and was a major force in encouraging the discipline to see space as a social construction, that is, as made rather than simply given. Soja's works convinced many readers that space was filled with politics and meaning, that its production and reproduction lay at the core of capitalism's survival and expansion, and that spatial transformation was every bit as significant as social transformation. His early work sought out a simultaneous transformation: the "Marxification" of geography and the spatialization of Marxism. In this light, society and space were inseparable, forming a seamless "socio-spatial dialect." He was profoundly influenced by the flowering of spatial thought unleashed in France by Henri Lefebvre and Michel Foucault, playing a major role in introducing their ideas to geographers, and was one of the architects of the "spatial turn."

At the core of Soja's intellectual project lay cities in all their glorious, messy complexity. For Soja, urban life—its everyday rhythms, the division of labor, public policy, struggles over places, and the relations among distant locales—could only be comprehended meaningfully through the

conceptual lens of spatiality. In this regard, he became a firm opponent of historicism, which privileged time over space, arguing that the two dimensions necessarily held equal ontological status. But Soja was also something of an urban *flâneur*, a storyteller seeking to capture the richness of space. Soja's insistence in this regard led him into postmodernism and away from orthodox Marxism's relegation of spatiality to the periphery: A postmodern geography was one that by definition put space on a par with time. In this regard, he faced vociferous objections that he had lapsed into a form of spatial determinism.

His book *Postmodern Geographies*, published in 1989, drew enormous favorable attention worldwide and established him as one of the discipline's leading theoreticians. Rather than simple dichotomies, such as those that pervaded most Enlightenment thought, Soja advocated a "trialectics" consisting of time, space, and meaning. In this reading, the production of spatiality was always open-ended and contingent, never preordained. Empirically, the heart of Soja's agenda lay in Los Angeles, the globalized, post-Fordist, enormously diverse metropolis in which social inequalities are inevitably matched by equally appalling spatial inequalities. He was thus a founding member of the "Los Angeles School" of urban studies, which took as its point of departure that city's experiences in the late 20th century.

In *Postmetropolis*, published in 2000, Soja extended his urban emphasis into a geohistory of spatiality, drawing, for example, on the examples of Jericho and Catal Hüyük to offer a "provocative inversion" that puts early urbanization at the core of the process of domestication. This argument relies heavily on his notion of "synekism," essentially the agglomeration economies and higher rates of creativity induced by face-to-face contact in dense urban environments, including the informal linkages, unstandardized knowledge, and intimate interconnections that are essential for the generation of new ideas, practices, and technologies.

Barney Warf

See also **Historicism; Lefebvre, Henri; Los Angeles School; Marxism, Geography and; Postmodernism; Spatial Turn**



Further Readings

- Classics in human geography revisited (Forum on *Postmodern Geographies*). (2006). *Progress in Human Geography*, 30, 812–820.
- Merrifield, A. (1999). The extraordinary voyages of Ed Soja: Inside the “trialects of spatiality.” *Annals of the Association of American Geographers*, 89, 345–348.
- Soja, E. (1980). The socio-spatial dialectic. *Annals of the Association of American Geographers*, 70, 207–225.
- Soja, E. (1985). Regions in context: Spatiality, periodicity, and the historical geography of the regional question. *Environment and Planning D: Society and Space*, 3, 175–190.
- Soja, E. (1989). *Postmodern geographies: The reassertion of space in critical social theory*. London: Verso.
- Soja, E. (1993). Postmodern geographies and the critique of historicism. In J. Jones, W. Natter, & T. Schatzki (Eds.), *Postmodern contentions* (pp. 113–136). New York: Guilford Press.
- Soja, E. (1996). *Thirdspace: Journeys to Los Angeles and other real-and-imagined places*. Oxford, UK: Blackwell.
- Soja, E. (2000). *Postmetropolis: Critical studies of cities and regions*. Oxford, UK: Blackwell.
- Soja, E. (2008). Taking space personally. In B. Warf & S. Arias (Eds.), *The spatial turn: Interdisciplinary perspectives* (pp. 11–35). London: Routledge.

per year]) at the highest latitudes to a high of 0.25 kW/m^2 ($\sim 2,200 \text{ kWh m}^{-2}/\text{yr.}^{-1}$) in some desert areas of Africa and Australia. Conversion of this potential energy into secondary forms, such as electricity or process heat, depends on technical factors (e.g., efficiency of converters such as photovoltaic cells or thermal collectors), economic constraints (e.g., the absolute and relative costs of technology and fuels), and suitability considerations (e.g., the suitability of land or ocean use for locating the collection infrastructure). Nonetheless, the abundance of solar energy surpasses all other sources of renewable energy. Estimates of the technical potential of solar energy versus wind, biomass, geothermal, and ocean sources of energy show that solar energy represents our largest source of renewable energy supply and a key technology to lower worldwide carbon emissions.

There are several solar energy technologies, which can be arranged along the following continuum: (1) passive and active, (2) thermal and photovoltaic (PV), and (3) concentrating and nonconcentrating. *Passive solar* energy technology collects the energy without converting the heat or light into other forms. In contrast, *active solar energy* technology refers to the harnessing of solar energy to store it or convert it for other applications and can be broadly classified into two groups, namely, PV and solar thermal. Solar PV cells are the “high-tech” option among active solar energy strategies, directly converting solar energy to electricity. Solar thermal applications include two distinct technological streams. The first stream, referred to as *solar thermal nonelectric*, includes applications such as agricultural drying, solar water heaters, solar air heaters, solar cooling systems, and solar cookers. The second stream of solar thermal technology, referred to as *solar thermal electric*, includes technologies that use the sun’s heat to produce steam and generate electricity. The final characteristic in the continuum of solar energy technologies is *concentrating versus nonconcentrating* technologies. Concentrating solar power (CSP) technologies use mirrors or lenses (concentrators) to focus sunlight and thus increase the intensity of light in the focus area. In addition to CSP, concentrators can be applied in PV technologies as well by using a dish collector or optical lenses to concentrate sunlight on a smaller cell area.



SOLAR ENERGY

Solar energy is the most abundant renewable energy source on the planet. The energy influx from solar radiation striking land surfaces is sufficient to meet the present primary commercial energy needs of the world thousands of times over. Usable solar influx is affected by diurnal and geographic variation and weather. Worldwide, the yearly average values of effective solar irradiance reaching Earth’s land surface vary from a low of 0.06 kW/m^2 (kilowatt per square meter; $\sim 500 \text{ kWh m}^{-2} \text{ yr.}^{-1}$ [kilowatt hours per square meter



The solar hot water system at the Adams County Detention Facility, northeast of Denver, Colorado, has been operating since 1988; it exemplifies the benefits users can reap from solar heat. This parabolic trough-based system supplies 46 % of the hot water used in the jail's kitchen, laundry, and showers, which is about 20,000 gallons per day.

Source: Warren Gretz.

In addition to technological differences, solar technologies can be characterized according to their applications. There are broadly three types of solar applications: (1) centralized utility-scale installations, (2) grid-connected distributed installations, and (3) off-grid installations. Centralized utility installations are typically large-scale PV or CSP systems, operating like other conventional power-producing plants, dispatching electricity over thousands of miles to customers. Distributed grid-connected and off-grid applications, in contrast, are smaller in scale and are located on-site, where the energy will be used. These applications can be electric (e.g., PV) as well as nonelectric (e.g., solar hot water). In recent years, distributed solar applications have experienced rapid growth, representing the fastest-growing new energy generation source in the world, with an astonishing

50% global market growth rate in 2007. Its use is primarily concentrated in the industrialized countries, where policy incentives introduced in recent years have spurred its adoption (e.g., “feed in” laws, renewable portfolio standards, tax incentives, rebates, and net metering). The use of urban rooftops to host the technology makes solar systems adaptive to human settlement patterns. Water-heating solar systems are frequently competitive with conventional energy alternatives. Globally, this technology is being rapidly adopted in both industrialized (Germany, the United States, Japan, Israel) and developing countries (China, India, Brazil, Turkey, and South Africa). China currently has more than half of the existing solar hot water and heating applications in the world. Its Renewable Energy Law encourages installation and use of solar thermal systems, and



parts of China already are moving toward solar water heating obligations.

Production of solar technologies is now part of the global economy, with manufacturing and assembly spread over all human-inhabited regions. In contrast, installation of the technology largely draws from the local labor force. The size of the industry is slated to grow rapidly as improvements in cell efficiency occur (analysts project a doubling of efficiency to 24% or more in 5–8 yrs.) and as costs of production continue to fall (grid parity without subsidies is expected to be reached between 2012 and 2015). When these milestones are reached, solar technology will likely become the most important means of energy production for carbon-constrained societies.

John Byrne and Lado Kurdgelashvili

See also **Energy Policy; Energy Resources; Green Building; Green Design and Development; Radiation: Solar and Terrestrial; Renewable Resources**

Further Readings

Bradford, T. (2006). *Solar revolution: The economic transformation of the global energy industry*. Cambridge: MIT Press.

Byrne, J., Kurdgelashvili, L., Barnett, A., Hughes, K., & Thurlow, A. (2005). Beyond oil: A comparison of projections of PV generation and European and U.S. domestic oil production. In D. Y. Goswami (Ed.), *Advances in solar energy: An annual review of research and development* (Vol. 16). Sterling, VA: Earthscan.

Byrne, J., Kurdgelashvili, L., Poconi, D., & Barnett, A. (2004). The potential of solar electric power for meeting future US energy needs: A comparison of projections of solar electric energy generation and Arctic National Wildlife Refuge oil production. *Energy Policy*, 32, 289–297.

Byrne, J., Zhou, A., Shen, B., & Hughes, K. (2007). Evaluating the potential of small-scale renewable energy options to meet rural livelihoods needs: A GIS- and lifecycle cost-based assessment of Western China's options. *Energy Policy*, 35, 4391–4401.

European Photovoltaic Industry Association, & Greenpeace International. (2008). *Solar generation V-2008*. Brussels, Belgium: Authors.

Goldemberg, J. (Ed.). (2000). *World energy assessment: Energy and the challenge of sustainability*. New York: United Nations Development Programme, United Nations Department of Economic and Social Affairs, World Energy Council.

Renewable Energy Policy Network for the 21st Century. (2008). *Renewables 2007 global status report*. Paris: REN21 Secretariat/Washington, DC: Worldwatch Institute.

U.S. Department of Energy. (2008). *Solar energy industry forecast: Perspectives on U.S. solar market trajectory*. Washington, DC: Author.



SOLSTICES

Solstices are points along the path of the sun's apparent orbit (also known as the *ecliptic*) that, when viewed from a point on Earth, mark where the sun is at its farthest from the extension of Earth's equator across the night sky, also known as the celestial equator. The term *solstice* literally means "sun stoppage" due to the apparently long day.

During the summer solstice, in the Northern Hemisphere, the sun appears at its farthest point above the celestial equator; that is, it is at its "highest" in the sky. The exact time of this astronomical phenomenon varies, as the calendar year does not perfectly match the solar year. Hence, although the summer solstice usually falls on June 21 or 22, the specific date does not always correspond to the longest day of the year (for those residing in the Northern Hemisphere). With each year, the solstice drifts 6 hrs. (hours; a fourth of a day, since the solar year is actually 365.25 days long). For those residing in the Southern Hemisphere, the same constraint also applies, although there is the additional confusion that during the Northern summer solstice, the sun is farthest below the celestial equator, and it is thus the Southern winter solstice at this time, during which they have their shortest day, or alternatively, the longest night, of



Stonehenge attracts some 800,000 visitors a year, and on the summer solstice, thousands of people gather to watch the sunrise.

Source: Morguefile.

the year. The exact opposite scenario occurs on December 21 or 22, with the Northern Hemisphere experiencing its longest period of night and the Southern Hemisphere experiencing its longest period of daylight. The effect is amplified with increasing degrees of latitude, with the equator experiencing the least amount of variation in daylight and the poles the greatest during the respective solstices. Within the equatorial astronomical coordinate system, the summer solstice in the Northern Hemisphere corresponds with a right ascension of 6 hrs. and a declination of 23.5° , which places the sun within the Tropic of Cancer during this period. During the winter solstice, the sun is within the Tropic of Capricorn, with a declination of -23.5° and a right ascension of 18 hrs.

In many European cultures of antiquity, the summer solstice was regarded as midsummer and celebrated with festivals. Contemporary Europe still maintains some aspects of midsummer festivals, notably in Ireland and Scandinavia. The primary motive for these celebrations derives from the solstice's relation to the onset of the fall harvest, since it has long been observed as the point

at which day length maximizes and then begins to wane into autumn. (However, in American popular culture, it is commonly regarded as the "beginning of summer.") The solstice is celebrated with festivals by Christian communities throughout the world as "St. John's Day" if celebrated on June 24 or "St. John's Eve" if celebrated the night before; however, neither is this day technically the longest day of the year, nor can it be traced historically to any aspect of the life of John the Baptist. The specific commemoration of John refers to the close association of the opposite solstice, on December 21 or 22, with Christmas, which has been refigured as the birthday of Jesus. The theologically inspired argument is that John the Baptist heralds the coming of Jesus Christ, hence his holiday should come before. In this respect, though the winter solstice is commonly regarded as "the beginning of winter" in most Christian-majority countries (though astronomically, it signals the beginning of increasing amounts of daylight), it is overshadowed by the Christmas holidays that occur several days later. The close association is not coincidental, as early Church officials



deliberately sought ways to incorporate pagan holidays into the Christian belief system.

The solstices' relation to pre-Christian religious traditions in Europe has also been invoked in interpretations of megalithic structures throughout the British Isles, notably at Newgrange in Ireland and Stonehenge in Britain. In both instances, the argument is that the stones were specifically aligned to predict or signal the specific day on which the solstice would occur. In the case of Newgrange, the apparent effect of a beam of sunlight entering the main chamber passage from above and slowly tracing a path along the chamber floor was taken by some as evidence that it was deliberately designed for such an effect. However, since the ruins had to be rebuilt after excavation, it is difficult to establish whether the initial designers had this effect in mind or whether it is simply an unlikely coincidence. In the case of Stonehenge, the argument has been made that on the summer solstice the sun appears to rise just above a specific stone, while on the winter solstice, the moon appears to rise above the same stone. In this case, since the structure is arranged in a circle, it is difficult to rule out that the effect is simply a matter of probability, although it is theoretically possible. Most scholars agree that the stronger case can be made for Newgrange having been originally designed for this effect, since it would have been difficult for the modern reconstruction to deliberately incorporate such a feature, given the short amount of time allotted for reconstruction.

Solstices are also celebrated in non-European cultures. In Chinese culture, the winter solstice is celebrated as "Dong Zhi," which literally means "the arrival of winter." Dong Zhi is celebrated essentially in the same manner as Christmas and Thanksgiving in the Christian world, as a time for families to gather for large feasts. A traditional dish served on Dong Zhi consists of often brightly colored rice dumplings filled with lamb and other ingredients. Furthermore, similarly to pagan European interpretations, Dong Zhi is acknowledged as a midpoint in winter—marking the beginning of more daylight rather than the onset of winter. Within Chinese traditional cosmology, the winter solstice is believed to symbolize the peak of Yin energy (dark, cool, feminine) and the beginning of Yang ascendance (fiery, masculine energy).

Edward Rice

See also *Earth's Coordinate Grid; Equator; Radiation: Solar and Terrestrial; Weather and Climate Controls*

Further Readings

- Brown, P. (2000). *Megaliths, myths and men. An introduction to astro-archaeology*. Mineola, NY: Dover. (Original work published 1977)
- Heinberg, R. (1993). *Celebrate the solstice: Honoring the Earth's seasonal rhythms through festival and ceremony*. Wheaton, IL: Quest Books.



SOVEREIGNTY

As a general term, *sovereignty* can be defined as the absolute authority of a state within its territory. As a theoretical construct, "sovereignty" can be deconstructed into two major components: (1) a state's self-perceived, inalienable right to universal authority, particularly the use of force within its boundaries, and (2) the recognition of such authority and boundaries by the international community. Because sovereignty encompasses the most basic quality of a state—the right to exist—concepts of and conflicts over sovereignty have fundamental implications for international law. Sovereignty is also intrinsically geographic by the nature of its definition; it is contingent on geography not only for determining the literal extent of state power but also for providing the geopolitical context in which states exercise their sovereignty.

However, sovereignty can neither be analyzed nor defined in a contextual vacuum. In 1918, U.S. Supreme Court Justice Oliver Wendell Holmes stated, "A word is not a crystal, transparent and unchanged. It is the skin of a living thought and may vary greatly in color and content according to the circumstances and the time in which it is used" (cited in Reisman, 1990, p. 872). When Holmes's axiom is applied to *sovereignty*, we end up with a theoretical construct that is highly dynamic and context-reflective. In essence, the means by which states claim, enforce, and defend their sovereignty have changed throughout



time, reflecting the geopolitical status quos of different eras.

Etymologically, *sovereignty* is derived from the term *sovereign*, which in turn originates from the absolute monarchies of feudal Europe. In these monarchies, the power of the state, particularly legitimacy over the use of force, was contained within a single person, who often claimed authority through divine providence. While documents such as Magna Carta (1215) limited the power of the absolute monarch in the latter half of the Middle Ages, sovereignty was still limited to a “geography of one.”

Sovereignty arose as a legal/geopolitical phenomenon resulting from the 1648 Peace of Westphalia. The concluding document to the Thirty Years’ War (1618–1648), the Peace of Westphalia (recognized as the first “modern” international treaty), among other territorial compromises, allowed the individual states comprising the Holy Roman Empire to choose their own religion, a power that had been usurped by the Holy Roman Emperor. At the time of the Thirty Years’ War, religious institutions played a significant role in executing state functions, as well as being the largest authoritative presence in the daily lives of the people. Thus, by granting the state sole authority for religious determination, the Peace of Westphalia established the legal precedent for the aforementioned first component of sovereignty: State governments have absolute authority over affairs within their prescribed territories, to the explicit exclusion of external actors. Geography is the crucial contextualizing agent in what scholars have come to call “Westphalian sovereignty.” The concept of Westphalian sovereignty has been the foundation of the international system for more than 360 years.

The ability of a state to have absolute and sole control over its domestic affairs would be functionally nullified without the second component of sovereignty: international recognition. Signatories to the Peace of Westphalia as well as the subsequent international system that embraces Westphalian sovereignty, by electing to operate within that system, implicitly accept the second component. Demanding sovereignty over one’s own territory necessitates recognizing separate geographies of influence under the control of neighboring states/sovereigns.

The functional results of the application of Westphalian sovereignty, embodied in the execution of the Peace of Westphalia via the recognition of other states’ sovereignty, are reflective of the interconnectivity between sovereignty and international law. The International Court of Justice (ICJ), the current de facto governing institution of international law, delineates official sources of international law as “1) international conventions, whether general or particular, establishing rules expressly recognized by the contesting states; 2) international customs as evidence of general practice accepted by law; 3) the principles of law recognized by civilized nations” (United Nations, 1945). As evidenced by the first section of the ICJ’s definition of international law, the principles of sovereignty embodied by the Peace of Westphalia, and the contemporary international system that embraced those principles, are reflective of the “nexus of interaction” that joins sovereignty and international law at the hip.

During the Cold War, concepts of sovereignty were contextualized by the greater geopolitical struggle between East and West. The establishment of NORAD (North American Aerospace Defense Command) is one such example. By allowing the United States to centralize the defense of the North American continent, Canada’s air defense was essentially taken out of the hands of the Canadian government. Thus, the Canadian state’s control over events in its internationally recognized territory was usurped in the name of a greater geopolitical “good,” in violation of the concepts of strict Westphalian sovereignty.

Sovereignty in the 21st century will once again be defined by its geopolitical context. As climate change progresses via anthropogenically augmented global warming, the system of international legal institutions and treaties on which an increasingly globalized humanity relies is being stressed to the breaking point. Treaties such as the United Nations Law of the Sea, which delineates and arbitrates sovereignty over maritime resources, rely on static geographies (e.g., coastlines and permanent ice sheets) to assign sovereignty over increasingly scarce natural resources. When combined with increased access to these resources via the loss of polar ice caps, population pressures on natural resources, and a rise in



“antiglobalization” nationalism, the ambiguous sovereignty created by dynamic geographies creates a geopolitical environment that promotes state-versus-state conflict.

Despite the relative perpetuity of Westphalian sovereignty’s influence on the structure of the modern international system, the theoretical construct of sovereignty remains a hostage to the geopolitical context in which it is applied. In addition, the interconnectivity between the structure and status of the international system of jurisprudence (functional/nonfunctional, the existence of a hegemonic state, etc.) affects how states choose both to enforce their own sovereignty and to respect the sovereignty of other states. More than any other factor, it is the geopolitical context, specifically competition between state actors within the international system, that has defined the role of the concept of sovereignty for three and a half centuries.

Zachary N. Schulman

See also **Borders and Boundaries; Geopolitics; Nation; Nationalism; Political Geography; State; Supranational Integration; Transnationalism**

Further Readings

- Agnew, J. (1998). *Geopolitics: Re-visioning world politics*. New York: Routledge.
- Fowler, M., & Bunck, J. (1995). *Law, power, and the sovereign state: The evolution and application of the concept of sovereignty*. University Park: Pennsylvania State University Press.
- Hathaway, O. (2008). International delegation and state sovereignty. *Law and Contemporary Problems*, 71(2), 115.
- Holmes, S. (2008). Breaking the ice: Emerging legal issues in Arctic sovereignty. *Chicago Journal of International Law*, 9(1), 323–351.
- Reisman, M. (1990). Sovereignty and human rights in international law. *American Journal of International Law*, 84, 872–873.
- United Nations. (1945). *Basic documents*. Retrieved April 20, 2009, from the International Court of Justice Web site at www.icj-cij.org/documents/index.php?p1=4&p2=2&p3=0



SPACE, PRODUCTION OF

See Production of Space



SPACE OF FLOWS

The *space of flows* is a term coined by the sociologist and urban planner Manuel Castells to describe the geographies of the globalized postindustrial informational societies that emerged in the late 20th century, in which productivity is derived primarily from knowledge and information. Concomitant with this transformation, social scientists have searched for new frames of reference to make sense of the emerging geographies of centrality and peripherality unleashed by flexible globalization.

In Castells’s (1996) reading, the time-space compression of postmodern capitalism was manifested in the three “layers” of transportation and communication infrastructure, the cities or nodes that occupy strategic locations within these, and the social spaces occupied by the global managerial class:

Our societies are constructed around flows: flows of capital, flows of information, flows of technology, flows of organizational interactions, flows of images, sounds and symbols. Flows are not just one element of social organization: they are the expression of the processes dominating our economic, political, and symbolic life. . . . Thus, I propose the idea that there is a new spatial form characteristic of social practices that dominate and shape the network society: the space of flows. The space of flows is the material organization of time-sharing social practices that work through flows. By flows I understand purposeful, repetitive, programmable sequences of exchange and interaction between physically disjointed positions held by social actors. (p. 412)

Castells notes, for example, that while people live in places, postmodern power is manifested in the linkages among places, their interconnectedness, as personified by business executives shuttling among global cities and using the Internet to



weave complex geographies of knowledge invisible to almost all ordinary citizens. This process was largely driven by the needs of the transnational class of the powerful employed in information-intensive occupations. Flows thus consist of corporate and political elites crossing international space on transoceanic flights; the movements of capital through telecommunication networks; the diffusion of ideas through organizations stretched across ever-longer distances; the shipments of goods and energy via tankers, container ships, trucks, and railroads; and the growing mobility of workers. In this light, the space of flows is a metaphor for the intense time-space compression of post-Fordist capitalism. Through the space of flows, the global economy is coordinated in real time across vast distances—that is, via horizontally integrated chains rather than vertically integrated corporate hierarchies. In the process, it has given rise to a variety of new political formations, forms of identity, and spatial associations.

Flows by definition involve more than one place; hence, in a networked world, places have little meaning as isolated entities. Places are not locales as much as they are processes in which different types of activities are embedded and different forms of interconnections are established. As they become increasingly connected, the repercussions of actions in one area inevitably spiral out to shape other places, so that discrete boundaries have less and less significance as they are permeated with mounting ease. Decisions made by hedge fund managers in New York, for example, reach out to affect the lives of millions of people in locations as distant as East Asia. The space of flows wraps places into highly unevenly connected chains that center on connections among powerful elites, thus typically benefiting the wealthy at the expense of marginalized social groups. However, the global space of flows is hardly randomly distributed over Earth's surface: Rather, it reflects and reinforces existing geographies of power concentrated within specific nodes and places, such as global cities, trade centers, financial hubs, and headquarter complexes. Thus, far from being abstract networks divorced from history, such systems are only made comprehensible by embedding them in history.

The space of flows is part of a broader conceptual transformation in geography that views space not as discrete places but rather as networks of interconnectiveness. Doreen Massey, for example, promotes a sense of place as embedded within power-geometries that link places to other places, a view in which places constantly change, producing and receiving changes through their interactions with one another. Similarly, Eric Sheppard has argued that globalized power-geometries cut across spatial scales to create “wormholes” that defy the traditional logic of economic geography. Central to such conceptions is the view of space as dynamic, socially produced, and defined by movement. Such arguments point to a relational politics of place that calls into question easy distinctions such as inside/outside, near/far, space/place, and global/local, artificial differentiations that are always embedded in each other and mutually constituted.

Barney Warf

See also Actor-Network Theory; Castells, Manuel; Globalization; Glocalization; Massey, Doreen; Postindustrial Society; Poststructuralism; Relative/Relational Space; Time-Space Compression

Further Readings

- Castells, M. (1996). *The information age: Vol. 1. The rise of the network society*. Oxford, UK: Blackwell.
- Castells, M. (1997). *The information age: Vol. 2. The power of identity*. Cambridge, MA: Blackwell.
- Massey, D. (1993). Power-geometry and a progressive sense of place. In J. Bird (Ed.), *Mapping the futures: Local cultures, global change* (pp. 60–70). New York: Routledge.
- Massey, D. (1999). Imagining globalization: Power-geometries of time-space. In A. Brah, M. Hickman, & M. Mac an Ghail (Eds.), *Global futures: Migration, environment and globalization* (pp. 27–44). Basingstoke, UK: Macmillan.
- Sheppard, E. (2002). The spaces and times of globalization: Place, scale, networks, and positionality. *Economic Geography*, 78, 307–330.



SPACES OF REPRESENTATION/ REPRESENTATIONAL SPACES

The terms *spaces of representation* and *representational spaces* form part of the spatial theorist Henri Lefebvre's conceptual triad used to distinguish between different types of spaces and the different ways in which space is produced. Representational spaces, or spaces of representation, as the original *les espaces de représentation* is more commonly translated, is conceptualized as the everyday space that people produce, inhabit, and act within. Similar to the concept of "place," spaces of representation consist of day-to-day human networks, a diversity of urban aestheticization processes, and the complex symbolisms of the underground and vernacular side of social life. The notion of spaces of representation has been used by cultural geographers in thinking about the production of the urban environment as the manifestation of abstract economic processes as well as the location of social and cultural activities.

Although Lefebvre's triad is a Marxian typology of space, spaces of representation resemble the German phenomenological concept of *Lebenswelt*, or the "life-world." Like the life-world, spaces of representation can be thought of, for example, as a composite of the mental maps people carry of their surroundings, the official street signs and place names that provide orientation, and the local graffiti that act as neighborhood landmarks. The unlikely influence of German phenomenology on Lefebvre may be the result of his having read Ernst Cassirer's own tripartite division of spatial experience into organic, perceptual, and symbolic spaces.

Spaces of representation are also called *lived spaces* (*espaces vécus*), as they are simultaneously produced and enacted through experience, expression, contestation, contemplation, sensation, imagination, and sociocultural and biological reproduction. This is not to suggest that spaces of representation occupy a privileged position within a hierarchy of space; rather, spaces of representation should be thought of in relation to, or in dialectical tension with, the other two parts of Lefebvre's spatial triad:

1. Spatial practice, or perceived space: This concept refers to society's organized spaces, which

at once establish and connect different locations through transportation infrastructure, as well as physically and ideologically separate places in the built environment. It can also be thought of as absolute, fixed, and framed space, as in David Harvey's (2006) spatial matrix, or as a material "firstspace," as in Edward Soja's (1996) trialectics of space.

2. Representations of space, or conceived space:

This notion is the abstract, dominant space of a society as conceptualized by planners, technocrats, politicians, and those who wield both power and creative authority. Such authoritative prescriptions for space dictate how environments should look, function, and support particular types of production and consumption. This most closely matches Soja's notion of an imagined "secondspace."

According to Soja, spaces of representation are the outcome of the first two parts of Lefebvre's triad. Soja sees spaces of representation as a summation of all spatial practices and authoritative representations of space. As part of his explicitly political project, Soja gives analytical priority to spaces of representation, as it is in everyday lived space that society can be investigated, understood, and potentially transformed. This critical "third-space," as he calls it, can be viewed as a postmodern milieu of complexity, diversity, and multiplicity. Because spaces of representation are both "real and imagined," they demand a nuanced analysis of both abstract and social production of space and an understanding of diverse spatialities.

While Lefebvre's work, like Harvey's and Soja's, has focused primarily on the urban, spaces of representation can also be thought of as enacted at the global scale, where the First World/Third World and center-periphery dichotomies are confronted, down to the scale of the body, where identity, personal politics, sexuality, and gender are performed.

The perceived holism of spaces of representation has been challenged, albeit tacitly. Geographers have pointed out that depending largely on one's identified class, race, gender, and nationality, it is within spaces of representation that people congregate through open social networks and mutual feelings of belonging and empowerment; and it is from these spaces that people are excluded given the reality of physical barriers, unequal



access to the flow of resources, the uneven distribution of technologies, and the inconsistent recognition of human rights and social justice.

Stefano Bloch

See also **Absolute Space; Lefebvre, Henri; Marxism, Geography and; Phenomenology; Place; Poststructuralism; Relative/Relational Space; Sense of Place; Soja, Edward; Symbolism and Place**

Further Readings

- Harvey, D. (2006). Space as a keyword. In N. Castree & D. Gregory (Eds.), *David Harvey: A critical reader* (pp. 270–293). Oxford, UK: Blackwell.
- Lefebvre, H. (1992). *The production of space*. Oxford, UK: Blackwell. (Original work published 1974)
- Sheppard, E. (2006). David Harvey and dialectical space-time. In N. Castree & D. Gregory (Eds.), *David Harvey: A critical reader* (pp. 121–141). Oxford, UK: Blackwell.
- Soja, E. (1996). *Thirdspace: Journeys to Los Angeles and other real-and-imagined places*. Oxford, UK: Blackwell.



SPATIAL ANALYSIS

Analysis is “spatial” if the results of an experiment or investigation are likely to depend on how the bounding frame of a representation is delineated. A “representation” can be thought of as any kind of simplification of the seeming infinite complexity of reality—as encapsulated, for example, in the ontologies that structure digital representation in geographic information systems (GIS) and geographic information science (GIScience). The frame may be used to bound any space, at any scale, anywhere—so one can conduct spatial analysis of the organs of the human body, for example, or of the canals of Mars. In definitional terms, the realm of *geographical* analysis is somewhat more restrictive in that it pertains to analysis of Earth’s surface or near surface at scales that range from the architectural to the global.

Today, GIS provides the environment for much of the activity that is described as spatial analysis and makes it possible to harness powerful ideas embodied in software to achieve excellence in visual communication. Spatial analysis helps us understand not only the form but also the functioning of physical, environmental, and human systems at any appropriate spatial and temporal scale. As such, it facilitates generalization while also preserving relevant unique attributes of “places” and particular time periods. Paul Longley and colleagues describe how spatial analysis in GIS helps bring together the idiographic tradition in geography (which emphasizes the uniqueness of places) and the nomothetic (which emphasizes the generality of processes), in a science that is directly relevant to practical problem solving. As such, spatial analysis is of interest and applicability well beyond the realm of academia.

Spatial analysis has roots in many sciences, ranging from geography and the Earth sciences to architecture, urban planning, and ecology. Some of these origins can be traced to the development of quantitative methods in geography, macroeconomics, and the Earth sciences, as well as the discipline of regional science. Spatial statistics and locational analysis dominated the quantitative geography of the 1960s, with the development and application of techniques that together laid the foundations of a new scientific geography. These developments culminated in the reader *Spatial Analysis*, edited by Brian Berry and Duane Marble and published in 1968, and the tradition retains a core following in geography today.

The practice of spatial analysis changed profoundly with the advent of the Internet, in line with broader developments in the practice of environmental and social science. The client-server architectures that developed in the 1990s have been augmented by data inputs and feeds to and from the smallest of handheld devices, and the innovation of “sensor webs” has opened up new prospects for spatial analysis based on measurement and monitoring in real time. It has also developed alongside the drives to interdisciplinary science, multidisciplinary team working, and increasingly problem-centered approaches to scientific practice. Yet despite these far-reaching changes, many of the core themes of spatial analysis and modeling remain fundamentally unchanged



from those addressed by quantitative geographers in the 1960s. Of particular importance are issues of spatial and temporal granularity, representation of human behavior, uncertainty in representation, visualization and user interaction, representation of dynamics and spatial process, and policy application through questions of planning and design. These are core to the various research agendas of GIScience.

Representational Forms and Types of Spatial Analysis

Many of the basic operations of GIS—such as distance measurement, area calculation, and map overlay—are not viewed as spatial analysis per se, although software that provides these functions is now the environment of choice for much spatial analysis. Since its development as a field in the 1970s, GIS can also be thought of as providing a series of parallel, yet more application-centered, developments in spatial statistics and locational analysis. Despite the practical applications focus of GIS, there has been methodological interest in integrating some of the more general spatial analysis techniques into GIS software, as a precursor to adoption by the wider user community. By the mid 1990s, more specialized spatial analysis functions had been incorporated into GIS software, and the research communities in modeling and simulation were developing alongside GIS in a more complementary fashion. It also became much more straightforward to couple non-GIS software (e.g., S-Plus, SAS, or Matlab) to GIS, and it is true to say that the boundaries of what may be described as “GIS” have broken down with the incorporation of low-end spatial analysis functionality into general-purpose software such as Microsoft Office. Today, the cutting edge of GIS extends across many fields of spatial representation in modeling, policy, and design, and spatial analysis permeates the GIScience agenda.

There are two fundamental representational models of GIS, and each lends itself to spatial analysis. The *field* view posits space as a series of continuously varying surfaces, each relating to a different attribute—elevation being the archetypal example. As noted by Longley and colleagues, the *object* view conceptualizes the world

as a desktop, littered with objects that have distinct boundaries and attributes associated with them. Attributes of either fields or objects can be thought of as measured using nominal (presence/absence, e.g., of forest land cover), ordinal (ranked, e.g., residential preference), interval (continuous, arbitrary base scale, e.g., degrees Fahrenheit), ratio (continuous, nonarbitrary base scale, e.g., wind direction), or cyclic (directional, e.g., wind) scales of measurement. The locations for which attributes are measured may be described as points (zero dimensioned, having neither length nor breadth, e.g., the locations of individual animals), lines (one-dimensional, e.g., streets), areas (two-dimensional, e.g., agricultural fields), or volumes (three-dimensional, e.g., watersheds). Spatial analysis is defined by its concern with the associations (or lack of them) between the attributes of different locations—that is, the patterning of points, lines, areas, or surfaces as recorded using nominal, ordinal, interval, or ratio scales of measurement.

In measuring associations, methods of spatial analysis may sometimes seek to ascribe causality using the principles of statistical inference—as in the testing of previously formulated theories by comparison with real data. This is the classic deductive style of spatial analysis, the assumptions of which may be strained by the tendency of nearby observations to be more similar to one another than distant ones. A more tentative approach toward measurement of spatial associations is encapsulated in exploratory spatial analysis, which is used to uncover patterns, anomalies, or relationships that may not be immediately apparent and, subsequently, to suggest and support new hypothesized generalizations about the world as a precursor to new theory. This is the *inductive* approach to spatial analysis.

Michael Goodchild develops the following sevenfold classification of spatial analysis, as commonly practiced using GIS, based on the conceptual complexity of the method.

1. *Simple query*: This is the most rudimentary form of spatial analysis, wherein simple queries typically focus on attribute values or attribute value ranges within predefined areas—such as the calculation of the population size of all areas in a study region with unemployment above 7%.



Queries in GIS are frequently formulated in Standard (or Structured) Query Language (SQL)

2. Measurement: This is the use of simple algorithms to measure the length or extent of geographic features in digital representations, as well as properties such as shape, slope, and aspect.

3. Transformation: This entails operations that *buffer*, or dilate, geographic features (as typically represented by points, lines, or areas) to create new features that include all the area within an investigator-defined distance of the original feature. Buffers may be used to calculate the catchment area of a retail center, for example, or the area vulnerable to aircraft noise around an airport. *Spatial joins* are transformations that provide examples of transformations based on shared properties of containment or adjacency, while *polygon overlay* entails computing the intersections between two areas and concatenating the respective attributes.

4. Descriptive summary: This typically entails summarizing the nature of a collection of points, lines, or areas using appropriate statistics. Such summary measures are analogous to aspatial measures such as means, medians, and modes, with the geographic centroid (center of gravity) being perhaps the archetypal example. The spatial analog of the standard deviation or variance is the *dispersion*, defined as the average distance of a set of points from their mean center. *Spatial autocorrelation* measures quantify how similarity of value is related to similarity of position: Positive spatial autocorrelation is characterized by patterns in which neighboring values are more similar than distant ones, with the opposite relationship described as negative spatial autocorrelation. *Fragmentation statistics* may be used to summarize the degree to which an area is fragmented into different land cover types.

5. Optimization: Spatial optimization methods are used to devise idealized patterns that meet user-specified criteria—as in vehicle routing to minimize the distance traveled or location of a store to maximize patronage by likely customers.

6. Hypothesis testing: Confirmatory spatial analysis typically begins with the statement of a null hypothesis, postulating the irrelevance of the effect of interest, and an alternative hypothesis

that accommodates its effect. These conflicting hypotheses are tested against data, and measures are determined that allow the alternative hypothesis to be accepted or refuted. There are difficulties in adapting the classic strategy of statistical inference to spatial data, because some of the assumptions that underpin inferential statistics assume no spatial autocorrelation and because of problems in differentiating between so-called first-order and second-order effects.

7. Modeling and simulation: This approach to spatial analysis seeks to relate explicit theories about the form of the real world directly to data. Thus, for example, hypotheses about the spatial dynamics of city growth and sprawl might be used to drive digital simulations, or an epidemiologist might use a model of day-to-day population circulation to drive a simulation of the diffusion of an influenza epidemic. There is much interest in devising appropriate measures of whether the resulting outputs “look right” in spatial terms as well as in providing comparative numerical summaries of the outcomes of different simulations. This is the fast-developing realm of cellular automata and agent-based modeling, which have been used to simulate residential development and residential segregation, among a wide range of applications.

Conclusion and Prospects

The range of spatial analysis methods described here extends from straightforward descriptive procedures to customized depictions of the world and critical interpretations of the assumptions that are invoked to represent it. The motivation for spatial analysis is frequently the desire to move beyond “what is?” representations of how the world looks toward “what if?” scenario analyses of how the world works. A hallmark of spatial analysis methods is that they should be transparent and open to scrutiny. In recent years, the proliferation of rich, geographically detailed data sets has had the effect of moving the spatial analysis agenda beyond a preoccupation with technique toward embracing ideas about scenario testing, policy, and application. Today, the standard functionality of GIS provides a framework for data manipulation and visualization that,



when harnessed to spatial analysis techniques, provides powerful ways of creating, analyzing, and evaluating policies and plans designed for both the short and the long term.

Some spatial analysis requires very intensive use of computer processing power, and it is true to say that many of the most recent innovations in spatial analysis techniques are among the most computationally intensive. The sheer volume of digital, geographically referenced data makes spatial pattern detection an increasingly important focus, albeit one tempered by the need to understand the sources and operation of the biases inherent in many rich but nevertheless selective representations. There is a continuing need for research into the ways in which the medium of GIS may overwhelm the message of spatial analysis in the eyes of most users, as well as a need for spatial analysts to understand the importance of good user interface design. Much of spatial analysis software is still used on stand-alone machines, but grid-processing architectures are increasingly providing solutions to problems that require intensive processing of diverse data sets scattered across remote locations and that often require different access protocols. Spatial analysis is also extending into the third dimension, in applications as diverse as Web-enabled photogrammetry and location-based services. The miniaturization of computer devices and the innovation of very low-cost radio frequency identification (RFID) is taking some of academic geography back to its roots in field measurement and environmental cognition, and this poses important new challenges for relaying the inputs to spatial analysis to and from the field in real time. This is all part of an unprecedented decentralization of computing, in which data, software, and applications are being distributed across networks and in which spatial analysis is accommodating real-time feeds from sensor webs and other field observations.

Taken together, the networking of spatial analysis has profound implications for the ways in which we may communicate process and visualize spatial data at a range of spatial scales and across a range of time periods. Michael Batty views these changes as part of a paradigm shift from a “top-down,” centralized control to a much more decentralized, bottom-up approach to organization. This is apparent in the ways in which

we now communicate information and expertise about spatial analysis, which was once the preserve of select institutions but is now readily available from online sources (e.g., www.spatialanalysisonline.com and www.spatial-literacy.org). The consequence is an enhanced ability to use spatial analysis to develop richer, more realistic, and more applicable forms of representation that add value and interpretation to geographic data. This is also leading to rethinking of past practices with regard to the conduct of scientific research and is likely to lead to new theoretical imperatives concerning our approach to science in general and GIScience in particular. The evolving spatial analysis agenda is also likely to encounter new practical problems that will affect the way in which we build applications, and the end users for whom we will build them, and new ethical concerns that will determine the way we respond to problems and influence the GIScience that we wish to pursue.

Paul A. Longley

See also **Analytical Operations in GIS; Bayesian Statistics in Spatial Analysis; Data Querying in GIS; Exploratory Spatial Data Analysis; GIScience; GIS Implementation; Heuristic Methods in Spatial Analysis; Models and Modeling; Ontological Foundations of Geographical Data; Point Pattern Analysis; Quantitative Methods; Quantitative Revolution; Spatial Autocorrelation; Spatial Data Models; Spatial Econometrics; Spatially Integrated Social Science; Spatial Multicriteria Evaluation; Spatial Optimization Methods; Spatial Statistics; Web Service Architectures for GIS**

Further Readings

- Batty, M. (2006). Globalisation, scale and interaction in spatial modelling. *Environment and Planning, B*, 33, 637–638.
- Brimicombe, A., & Li, C. (2008). *Location-based services and geo-information engineering*. Chichester, UK: Wiley.
- De Smith, M., Goodchild, M. F., & Longley, P. A. (2008). *Geospatial analysis: A comprehensive guide to principles, techniques and software tools* (2nd ed.). Leicester, UK: Winchelsea Press.



- Goodchild, M. F. (2007). Spatial analysis. In B. Warf (Ed.), *Encyclopedia of human geography* (pp. 446–450). Thousand Oaks, CA: Sage.
- Longley, P. A., & Batty, M. (Eds.). (2003). *Advanced spatial analysis: The CASA book of GIS*. Redlands, CA: ESRI Press.
- Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic information systems and science* (2nd ed.). Chichester, UK: Wiley.



SPATIAL AUTOCORRELATION

Spatial autocorrelation is a spatial measure that evaluates how dispersed or clustered points are distributed in space and whether or not this distribution has occurred by chance. Unlike other spatial methods for detecting spatial patterns of point distribution without considering their attributes, such as Quadrat analysis and the Nearest Neighbor method, spatial autocorrelation also characterizes how similar these points are with respect to their attribute values. There are two typical spatial autocorrelation statistics: Moran's I and Geary's C . Both Moran's I and Geary's C measure the proximity of locations and evaluate the similarity of attributes.

If the statistics show more positive correlation than would be expected from a randomly distributed pattern, points with similar attribute

values are closely distributed in space (Figure 1A), whereas negative spatial autocorrelation statistics indicate that closely associated points are more dissimilar. A chess board is an example of negative spatial autocorrelation (Figure 1B); every black cell is adjacent to white squares, indicating that the neighbors are not similar. Care should be taken when using spatial autocorrelation, as it is related to the scale of the data.

Moran's I can be computed as

$$I(d) = \frac{\sum_i \sum_j w_{ij}(d)(z_i - \bar{z})(z_j - \bar{z})}{s^2 \sum_i \sum_j w_{ij}(d)},$$

where w_{ij} is the weight at distance d such that $w_{ij} = 1$ if point j is within distance d from point i , otherwise $w_{ij} = 0$; $\bar{z}$ is the mean attribute value; s^2 is the variance of the attribute values and can be calculated as $s^2 = \sum_i (z_i - \bar{z})^2 / n$. Moran's I varies from +1.0 for perfect positive correlation to -1.0 for perfect negative correlation.

Geary's C is calculated from the following:

$$C(d) = \frac{\sum_i \sum_j w_{ij}(d)(z_i - z_j)^2}{2 \sum_i \sum_j w_{ij}(d)s^2},$$

where w_{ij} is the weight; s^2 is the variance of z values and can be computed as $s^2 = \sum_i (z_i - \bar{z})^2 / (n - 1)$. The weight, w_{ij} , only considers the values 0 and 1,

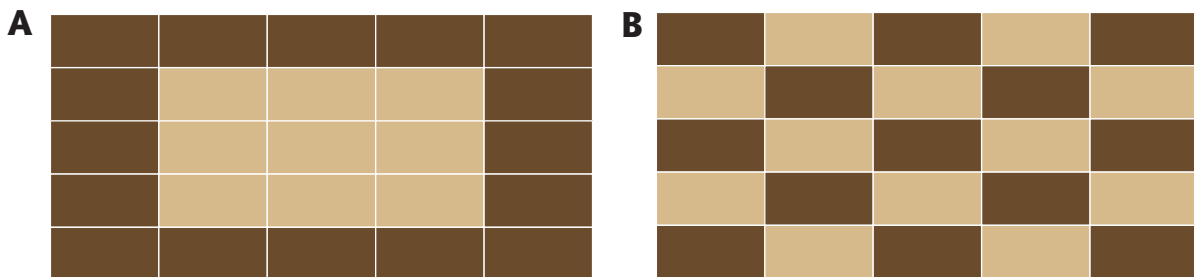


Figure 1 Hypothetical images with (A) positive spatial autocorrelation and (B) negative spatial autocorrelation

Source: Author.

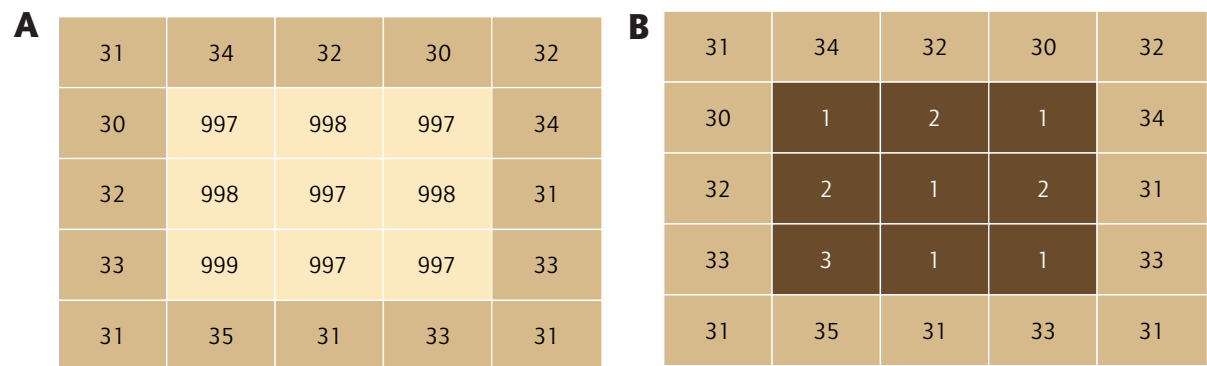


Figure 2 Hypothetical images with (A) hot spots and (B) cold spots
Source: Author.

as mentioned above. A typical Geary C value ranges between 0 and 2. A value of less than 1.0 implies positive autocorrelation, 1.0 implies no autocorrelation, and values of greater than 1.0 imply negative autocorrelation.

Similarly, another spatial autocorrelation approach called the *Getis statistic* (G_i) was developed to characterize the presence of hot spots (Figure 2A) and cold spots (Figure 2B), which are sets of clustered points with large or small attribute values, respectively.

The Getis statistic is computed as

$$G_i(d) = \frac{\sum_i \sum_j^n w_{ij}(d) z_i z_j}{\sum_i \sum_j^n z_i z_j}, \quad \text{for } i \neq j.$$

The G_i is also defined by a distance, d , within which areal units can be regarded as neighbors of i . The weight $w_{ij}(d)$ is 1 if areal unit j is within d and is 0 otherwise. Some of the z_i, z_j pairs will not be considered in the calculation of the numerator if i and j are more than d away from each other.

Soe Win Myint

See also **Bayesian Statistics in Spatial Analysis;**
Exploratory Spatial Data Analysis; Heuristic Methods in

Spatial Analysis; Point Pattern Analysis; Quantitative Methods; Spatial Analysis; Spatial Data Mining; Spatial Data Structures; Spatial Econometrics; Spatial Optimization Methods; Spatial Statistics

Further Readings

Getis, A., & Ord, J. K. (1992). The analysis of spatial association by use of distance statistics. *Geographical Analysis*, 24, 1269–1277.

Goodchild, M. F. (1988). *Spatial autocorrelation* (Concepts and Techniques in Modern Geography [CATMOG], No. 47). Norwich, UK: Geobooks.

Wong, D. W. S., & Lee, J. (2005). *Statistical analysis and modeling of geographic information with ArcView GIS and ArcGIS*. Hoboken, NJ: Wiley.

SPATIAL COGNITION

Spatial cognition concerns the acquisition, management, and application of knowledge about phenomena in the physical world. Humans derive this knowledge from internalized processes within the cognitive system, which is believed to reside within the mind. As such, spatial cognition is intertwined with processes of



thinking, reasoning, memory, abstraction, problem solving, belief formation, perception, sensation, language, and representation related to the spatial properties of objects and events situated in space. The main distinction that can be drawn between cognition and spatial cognition is the focus on the spatial properties of objects and events in spatial cognition.

Geographers interested in spatial cognition mainly focus on the domain of human beings. In other disciplines, spatial cognition also explores cognitive aspects in the context of nonhuman animals. In fact, Tolman's article (1948) on the maze behavior of rats is commonly referred to as the foundation stone of research in spatial cognition. Traditionally, spatial cognition as a field of investigation has been pursued interdisciplinarily by researchers from diverse academic disciplines such as psychology, geography, architecture and planning, anthropology, information science, linguistics, computer science, artificial intelligence, and neuroscience. Theory has been primarily derived within psychology. For instance, one prime example for the psychological tradition in spatial cognition is the work of Jean Piaget and Barbel Inhelder on the acquisition of spatial knowledge by children, published in 1967. Another example is A. W. Siegel and S. H. White's 1975 article on the sequential acquisition of spatial knowledge in adults in terms of landmarks, routes, and survey knowledge. The particular research topics in spatial cognition are just as diverse and include, among others, spatial representations and cognitive maps; orientation, navigation, and wayfinding; learning of familiar and unfamiliar environments; and gender and age differences in spatial abilities.

Cognitive Maps and Cognitive Mapping

At the core of research in spatial cognition lies the urge to understand the internal spatial representations that emerge in animals and humans through interaction with the physical world. That is not to say that spatial representations are merely created through stimulation of the body's senses. Instead, they can also entail derivatives of the imagination that are evoked through activities such as reading novels, listening to songs, and participating in discussions. As noted before, we

observe that geographers focus on humans as the subject of their research (as opposed to animals and intelligent machines) in their drive to understand human decision making in space.

Spatial representations stored in the long-term memory are referred to as *cognitive maps*. First coined as "mental maps" by Peter Gould in 1966, various metaphors have been proposed to describe what a cognitive map is. A noncomprehensive list would consist of Gould's preference surface metaphor, the rubber sheeting metaphor used by Reginald Golledge, the cartographic map or atlas metaphor, and the belief system metaphor.

The expression *cognitive map* often evokes the idea of a cartographic map in people who are not familiar with the meaning of the expression. It is generally accepted, however, that a cognitive map is quite distinct from a cartographic map. Rather than adhering to a single metaphor, it is more likely that a cognitive map incorporates elements of many or all of the aforementioned metaphors. At any given time, a cognitive map entails information about the physical and imagined environments that the individual has experienced. Since the information is dependent on experience and knowledge, both of which are changing over time, a cognitive map can be seen as a dynamic collection of heterogeneous spatial and nonspatial information about the environment that the individual has acquired through interactions with it.

Rather than a homogeneous, indivisible structure, a cognitive map is a set of discrete pieces of knowledge, both explicit and implicit. The pieces show varying levels of distortion, abstraction, and incompleteness. Besides spatial information such as the location of landmarks, the trajectories of routes, and the distance and direction relations between spatial features, a cognitive map also includes individual and subjective components such as emotions, values, and beliefs. The corresponding process of acquiring, storing, manipulating, deriving, and accessing a cognitive map is referred to as *cognitive mapping*.

The first and most prominent application of the concept of the cognitive map can be found in Kevin Lynch's famous book, *The Image of the City* (1960). Lynch elaborated on the externalization of the spatial knowledge of adults with regard to urban environments. In particular, he asked adult residents of Boston, Jersey City, and Los



Angeles to draw sketch maps of their home cities. Out of the individual sketch maps, Lynch created composite maps for each city of the features that were captured by the majority of subjects. He identified five types of elements of a city layout that were evident in the sketch maps: paths, edges, districts, nodes, and landmarks. The term *legibility* was coined to express the importance of the arrangement of these five components for their integration into an encompassing representation of the city. The more legible a city, the easier it is for the individual to understand, memorize, internalize, and organize the city into a cognitive representation, or cognitive map. Lynch's main finding was that the subjects formed cognitive representations that were quite similar for the majority of subjects—an indication that cognitive mapping is a rather universal process that applies to the general population.

Spatial Knowledge Acquisition

Lynch's analysis sparked further interest in the similarities and differences in the development of cognitive maps and the acquisition of spatial knowledge. Research on spatial knowledge acquisition was strongly influenced by Piaget's developmental theory, proposed in 1967 by Piaget and Inhelder. The theory maintains that children acquire spatial knowledge sequentially through four stages of their childhood: (1) the sensorimotor stage (0–2 yrs. [years]), (2) the preoperational stage (2–7 yrs.), (3) the stage of concrete operations (7–11 yrs.), and (4) the stage of formal operations (11 yrs. and above).

Similarly, Siegel and White introduced the theory of *macrogenesis* in 1975. Macrogenesis suggests that adults learn about a new environment in three stages. First, they develop knowledge of salient places or landmarks in the environment. This type of knowledge is commonly referred to as *landmark knowledge*. Subsequently, through further exploration, the individual gains topological and metric knowledge—that is, the distance and direction relations between landmarks—and establishes linear connections, or routes, between landmarks. This type of knowledge is referred to as *route knowledge*. Finally, indicating the greatest familiarity with the environment, the individual gains understanding that allows him or her to

venture away from known routes by detouring and shortcutting. Detours and shortcuts necessitate an integrated, areal type of representation of the environment, or *survey knowledge* as termed by Siegel and White. Significant in this context is the progression from an *egocentric* frame of reference with a primarily nonmetric, topological representation to an *exocentric* frame of reference with a metric, configurational representation of the environment.

Spatial Abilities and Individual Differences

The cognitive maps of the participants in Lynch's analysis showed significant similarities based on the taxonomy that he applied. After all, the subjects were all able to reproduce more or less detailed configurational depictions of their home city. Individual spatial representations and abilities, however, are far from equal. This is not surprising since, as mentioned before, spatial representations, skills, and abilities are informed by spatial knowledge that depends on the individual's experience with the environment. This experience is shaped not just by the specific physical characteristics of the individual but also by sociocultural factors—how we were raised, what our job is, what hobbies we have, and who our friends are. For example, given the same city, the extent of the activity space (i.e., the set of all places that an individual frequents as part of his or her daily life) of low-income, blue-collar workers is generally very different from that of their high-income, white-collar peers.

Vision, considered the spatial sense per excellence, plays a central role in how we experience the world. A single glance around us provides us with a multitude of information that can be used as source for spatial decision making. For navigation purposes, for instance, we can use distant landmarks in combination with feature-matching techniques to determine our location on a map. Salient landmarks can be easily identified and used as directional beacons. A visually impaired individual, however, has only limited or no access to this information. Tasks such as orientation become much more constrained by comparison with sighted individuals. In this context, research has shown clear differences in terms of the performance of the sighted and the visually impaired



in various areas related to spatial cognition, especially with respect to *spatial updating*. Various studies also reported on performance differences between congenitally and adventitiously blind individuals. Having prior visual experience resulted generally in improved performance of the individual in terms of accuracy and the time needed to complete spatial tasks compared with individuals with little or no visual experience.

The aspect of gender has been operationalized in research on the spatial abilities of men and women. In research on mental rotation skills, as one type of spatial skill, men were found to perform better than women. Research on the way-finding abilities (e.g., pointing accuracy) of males and females, on the other hand, has not produced significant differences between the genders. It is generally accepted that gender differences in regard to spatial abilities are specific to the task and testing procedures rather than evidence of the superior physiological disposition of men for all things spatial. It is also unclear to what extent gender differences in spatial abilities are the result of processes of social conditioning that emanated over long periods of time as manifestations of traditional gender roles (e.g., hunters and gatherers). Apart from gender, geographers also explored notions such as race, class, attention, effort, distortions, and bias and their influence on the spatial cognition of the individual.

Recent Research in Spatial Cognition

Over the past few decades, spatial cognition research has gained momentum through the significant proliferation of technology. The Internet, as a prime example, has irreversibly transformed the way we retrieve information and communicate with other people. Cartographic applications such as Google Maps and Google Earth are available free of charge, providing new ways of experiencing and learning about the environment to vast parts of the population. In this context, many interesting research questions emerge: What is the best way to present (spatial) information? How can we improve our user interfaces so that the usability of a spatial technology is maximized? How does the use of spatial technologies influence the user's spatial representations, skills, and abilities?

Clearly, a thorough understanding of the underlying cognitive processes can inform new approaches and practices that are tailored to the expectations and information needs of the user. In addition, such understanding might be used to minimize the cognitive load that is associated with the use of a particular technology—cognitive efficiency as a new design paradigm. A noncomprehensive list of related research topics that are being investigated in geography includes geovisualization, information visualization, and spatializations; pedestrian and car navigation systems; naive cartography, geographic information systems (GIS); and volunteered geographic information; location-based services and mobile computing; ubiquitous computing; artificial intelligence; and robots. It is likely that the importance of spatial cognition will grow with the further dissemination of information technologies in our society.

Little theory exists in regard to the design and evaluation of applications intended as decision-making aids for lay users. Research on public participation GIS (PPGIS), for instance, requires further exploration of the merits of using these tools in participatory planning processes. If our goal is to create inclusive, empowering tools with the intention to offer all users the means to make good decisions, then we need to establish an understanding of the expectations and information needs of each individual user. In addition, we should reflect on the criteria that we use to evaluate such decision-making tools. One common approach is to ask the user for his or her feedback on the tool. Ease of use, the mode and style of the presented information, and the beliefs and emotions of the user in regard to the information and the tool are all aspects that influence the user's assessment of the tool. Research on spatial cognition can provide valuable insight into many of these aspects. As stated earlier, spatial cognition is about understanding how people encode, store, access, and use spatial information. If 80% of all our decisions involve spatial information, then research on spatial cognition is central to understanding and enhancing our decision-making processes—most of which are central to our daily life.

Martin Swobodzinski



See also **Behavioral Geography; Blindness and Geography; Disability, Geography of; Environmental Perception; Golledge, Reginald; Mental Maps; Representations of Space; Spatial Cognitive Engineering; Vision and Geography; Wayfinding**

Further Readings

- Allen, G. (2006). *Applied spatial cognition: From research to cognitive technology*. Philadelphia: Lawrence Erlbaum.
- Dolins, F., & Mitchell, R. (Eds.). (2010). *Spatial perception, spatial cognition*. Cambridge, UK: Cambridge University Press.
- Golledge, R. G., & Stimson, R. J. (1997). *Spatial behavior: A geographic perspective*. New York: Guilford Press.
- Lynch, K. (1960). *The image of the city*. Cambridge: MIT Press.
- Piaget, J., & Inhelder, B. (1967). *A child's conception of space*. New York: W. W. Norton.
- Plumert, J., & Spencer, J. (2007). *The emerging spatial mind*. Oxford, UK: Oxford University Press.
- Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review*, 55, 189–208.



SPATIAL COGNITIVE ENGINEERING

The goal of spatial cognitive engineering is to design spatial information systems and services based on the principles of human communication and reasoning. It is an interdisciplinary endeavor, involving the disciplines of geographic information science, cognitive science, computer science, and engineering. A special focus is human-computer interaction based on the integration and processing of the spatial and temporal aspects of phenomena. The field of spatial cognitive engineering is motivated by the belief that useful and usable solutions to people's geospatial problems can only be found by considering the cognitive abilities and strategies people bring to the problem-solving process.

Roots: Cognitive Engineering

The term *cognitive engineering* was invented by Donald Norman in an effort to integrate cognitive and computer science approaches to the design and construction of machines. According to Norman, cognitive engineering is a type of applied cognitive science. When looking at people's interaction with different everyday things, such as telephones, faucets, and doors, one notices a discrepancy between *psychological user variables* and *physical system variables*. The psychological user variables comprise goals, intentions, concepts, and also spatial and cognitive abilities. During the performance of a task, a user must therefore interpret the physical system variables in the context of his or her psychological goals and translate his or her psychological intentions into physical actions on the system. The goal of cognitive engineering is to bridge the so-called gulf between execution and evaluation (Figure 1), which results from the differences between user and system states in terms of form and content.

This gulf can be bridged from two sides:

1. The system designer can move the system closer to the user in terms of finding better matches to his or her psychological needs.
2. The user can bridge the gap by approximating the description of goals and intentions to the system's language. Such approximation covers different levels of outcomes and intentions.

In his account of cognitive engineering as a new discipline, Norman focused on computer design in general and the design of user interfaces in particular. A major point in the analysis was that different users may require different interfaces, even when performing the same tasks and working with the same system. He therefore advocated a *user-centered* system design, which starts with the user's needs regarding a particular problem.

From Cognitive Engineering to Spatial Cognitive Engineering

Spatial cognitive engineering follows the general ideas of cognitive engineering and applies them to the geospatial domain. Such application highlights important aspects that are integral to and

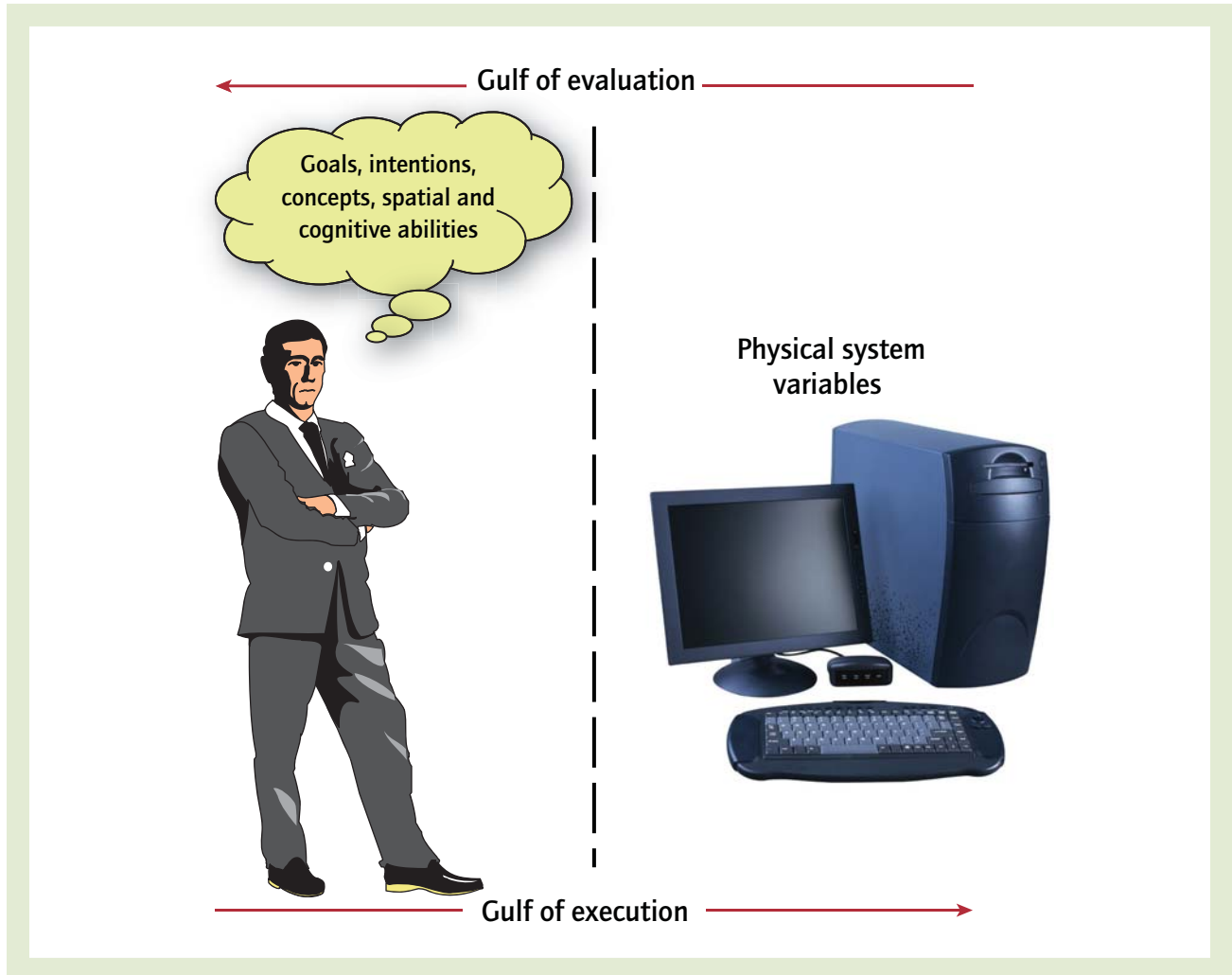


Figure 1 Discrepancy between psychological user variables and physical system variables

Source: Adapted from Norman, D. (1986). Cognitive engineering. In D. Norman & S. Draper (Eds.), *User centered system design* (pp. 31–61). Hillsdale, NJ: Lawrence Erlbaum.

characteristic of geospatial problem solving. Spatial cognitive engineering focuses especially on human-computer interaction regarding the *spatial and temporal aspects* of phenomena in the world. Geospatial services and systems are unique in the way they use data, which are related to locations in space (and time), and in how processing of the data with respect to these spatial locations is possible. The fact that everything is tied to a location in space and time leads to increased complexity regarding reasoning with and analysis of the data. People's questions when using geospatial tools have a spatiotemporal context. One can ask "Where is (a certain object)?" or "Where

are (all objects with certain properties)?" at a given time—for example, when trying to find the nearest kindergarten for a child; or one can ask "What are the properties of (a certain area in space)?" at a given time—for example, when trying to assess the area in which to rent a house.

Resolving the discrepancy between psychological user variables and physical system variables in the geospatial domain goes beyond the user-interface level:

- People use various conceptualizations of space and time, such as "continuous versus discrete" or "absolute versus relative." The particular



spatiotemporal perspective in spatial cognitive engineering implies that spatial and temporal concepts need to be matched between users and systems. Take, for example, the different semantics of spatial concepts, such as location or road, depending on the user and context. Semantic heterogeneity—two contexts leading to different interpretations of the same information—can lead to erroneous decisions made by geospatial services. The results of a spatial analysis may be correct for the data model of the data set but may still not meet the user's expectations and can therefore lead to false decisions.

- Spatial reasoning and decision making in a spatiotemporal context include particularities that need to be accounted for during human-computer interaction. Spatial reasoning is about topology, distance, orientation, and shape with regard to objects and configurations of objects in space and time. Instead of doing exact calculations, people apply qualitative methods of spatial reasoning that rely on magnitudes and relative values—see, for example, the differences between wayfinding instructions as given by humans versus machines. When people perceive space through different channels, they arrive at various kinds of information, which are usually qualitative in nature. People do not move through the environment using rulers or tape measures. Spatial reasoning involves a variety of decision-making methods and choice behavior. In many cases, human decision making is not strictly optimizing in an economical and mathematical sense as proposed by the algorithms of classical decision-making theories. Several of these aspects are accounted for to various degrees during spatial cognitive engineering.

Cognitive User Parameters

When dealing with the problem of considering people's spatiotemporal and cognitive strategies and abilities during their interaction with geospatial services, it is of major importance to account for people's problem-solving requirements. These requirements differ, depending on the category of user. With regard to the acquisition, mental representation, use, and communication of geographic

information, it has been argued that information consumers differ in their cognitive styles, abilities, and preferences. Cognitive research helps understand how individuals and groups of people differ in their cognition of geographic information. Several case studies involving the cognitive aspects of navigation systems demonstrated the importance of taking into account individual differences among navigators, such as different abilities, preferences, and navigational styles. The importance of research on education, experience, culture, gender, and age differences has been emphasized in efforts to design better—in the sense of more *personalized*—geospatial tools.

Users can be categorized into *generic*, *group*, and *individual* with regard to their cognitive parameters, such as strategies, abilities, and concepts. The generic level comprises a general set of cognitive parameters assumed to be applicable to all people. For example, in general, people use landmarks for finding their way and for communicating wayfinding directions to others. The generic category also accounts for the fact that there are numerous cultural universals that people share. User groups are defined by common sets of cognitive parameters. The focus of analysis is on the variation of parameters across different groups. Examples are gender groups, such as all women and all men, and comparatively smaller cultural groups defined, for example, by sharing a common language. These examples demonstrate that user groups occur at different levels expressed through the number of their members. User groups are often defined for user interface design—for example, novice versus expert. Wayfinding services may distinguish between different groups of disabled (e.g., visual or hearing impaired) persons. Wayfinding instructions need to be adapted to these groups to be useful. Dealing with people as individuals puts a focus on individual variation. Every single person is treated differently. Personalization of geospatial services can go a long way; the more parameters there are that need to be adapted, the more complex it becomes.

It is useful to note that this classification forms a hierarchy (Figure 2).

All people share some cognitive parameters, but they also fall into various user groups and have their individual preferences. When using spatial cognitive engineering approaches for the

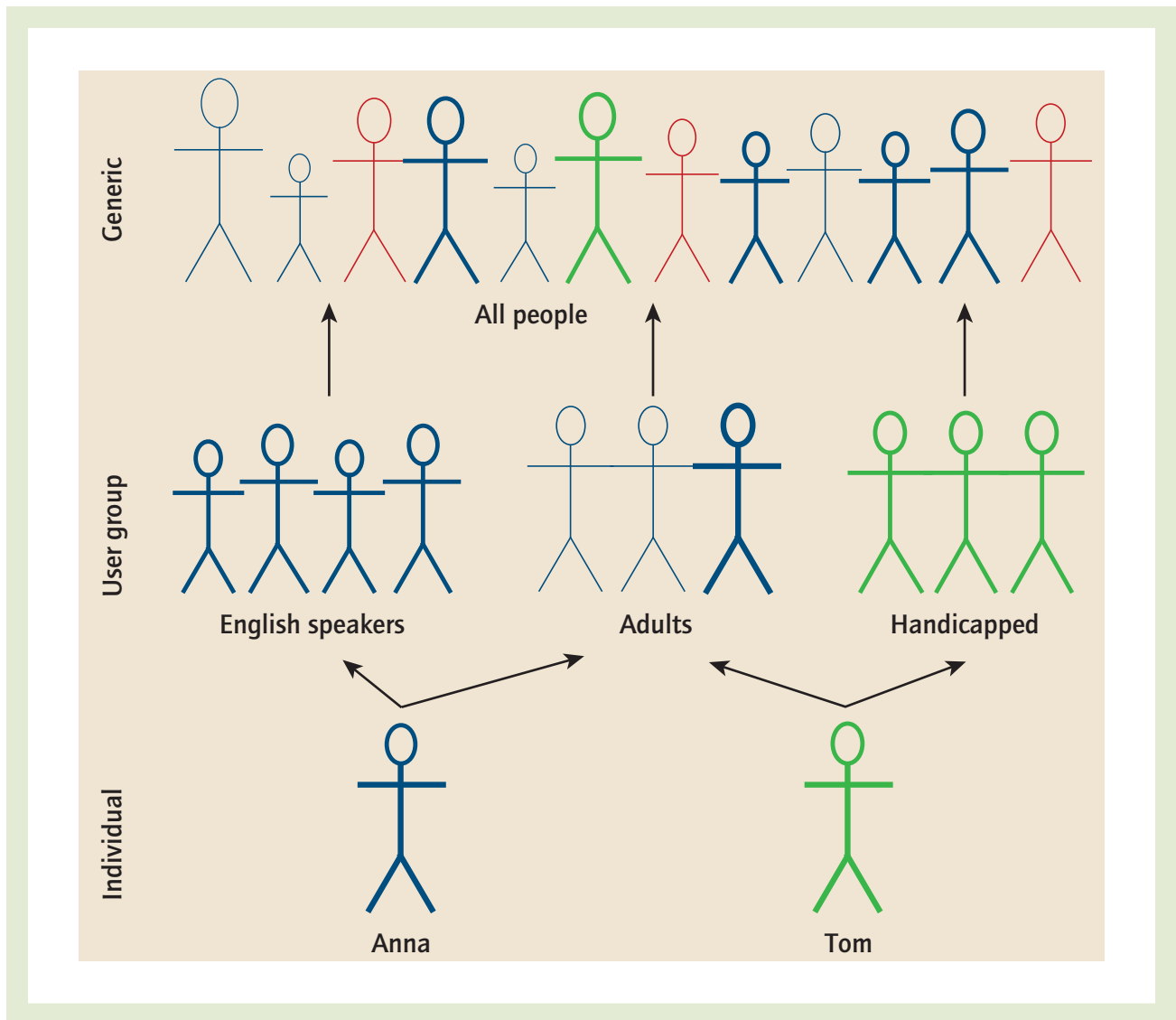


Figure 2 User categorization into generic, group, and individual

Source: From Raubal, M. (2005). *Cognitive engineering for geoinformatics*. Solingen, Germany: Verlag Nature & Wissenschaft.

design of geospatial services, a major question is, therefore, how far one can or wants to move down in this hierarchy.

Applications

Spatial cognitive engineering has been applied in various areas to bring geospatial tools closer to the user, with respect to both monolithic geographic information systems (GIS) and geographic information services. Lately, research has focused on personalizing location-based

services—information services that are sensitive to the location of a (mobile) user—with the goal of creating *location-based decision services*, which support people's everyday spatiotemporal decision making in a mobile context. The following selective list gives some examples of applying spatial cognitive engineering:

- Spatializing user interfaces to map the particular spatial experiences of users to various application domains: Considering how individuals understand and represent space



benefits the design of GIS and facilitates user interaction with these systems.

- Designing natural-language query interfaces for GIS: Such interfaces allow users to pose their spatiotemporal questions in a more natural way.
- Developing personalized navigation services that offer wayfinding directions based on landmarks: These services also consider user preferences for the performance of spatiotemporal tasks.
- Applying cognitive design principles to cartographic maps and geographic visualizations to facilitate people's understanding and knowledge acquisition
- Designing geospatial tools for disabled people, such as global positioning system (GPS)–based navigation systems for the visually impaired

Martin Raubal

See also **Behavioral Geography; Location-Based Services; Spatial Cognition; Spatialization; Usability of Geospatial Information; Wayfinding**

Further Readings

- Allen, G. (Ed.). (2007). *Applied spatial cognition: From research to cognitive technology*. Mahwah, NJ: Lawrence Erlbaum.
- Golledge, R., & Stimson, R. (1997). *Spatial behavior: A geographic perspective*. New York: Guilford Press.
- Montello, D., & Freundschuh, S. (2005). Cognition of geographic information. In R. McMaster & E. Usery (Eds.), *A research agenda for geographic information science* (pp. 61–91). Boca Raton, FL: CRC Press.
- Nielsen, J. (1993). *Usability engineering*. Cambridge, MA: AP Professional.
- Norman, D. (1986). Cognitive engineering. In D. Norman & S. Draper (Eds.), *User centered system design* (pp. 31–61). Hillsdale, NJ: Lawrence Erlbaum.
- Norman, D. (1988). *The design of everyday things*. New York: Doubleday.
- Peuquet, D. (2002). *Representations of space and time*. New York: Guilford Press.
- Raubal, M. (2005). *Cognitive engineering for geoinformatics*. Solingen, Germany: Verlag Natur & Wissenschaft.



SPATIAL DATA INFRASTRUCTURES

A spatial data infrastructure (SDI) is an infrastructure for integration, transportation, and distribution of spatial data via Web services using service-oriented architectures (SOA) and business process patterns. Therefore, it supplies applications with spatial products. A product might be a data set, a service, or a combination of the two.

This entry describes the characteristics of the payload spatial data, gives a historical context, introduces roles and fundamental processes, and illustrates them with technical example architecture, including data, query, and service models.

Characteristics of Spatial Data

Spatial data can be used for many different purposes due to their special characteristics. Like other types of data, spatial data can be encoded digitally and transported via the Internet. But also, in many cases, they can be displayed graphically, making the information easier to interpret and understand. However, there are other characteristics of spatial data that need to be managed before one makes use of them. Many organizations capture spatial data but often in quite different ways and for many purposes. A single organization may capture spatial data for a limited part of the world—for example, a national mapping agency; therefore, spatial data from many organizations must be combined to ensure worldwide coverage. Furthermore, often these spatial data have a short shelf life and therefore will become outdated in a short period.

Due to these special characteristics of spatial data, an efficient integration, transport, and distribution mechanism is crucial to enhance their overall usage. The geospatial information sector identified this potential very early and pushed the development of spatial data infrastructures. SDIs are one of the first large applications of information infrastructures based on Web services.

History

In the early 1990s, these spatial data characteristics resulted in many incompatible solutions.



Early developments focused on the creation of a standard and vendor-neutral data model to encode and exchange spatial data. These efforts were channeled via the founding of the OpenGIS in 1994, which is known today as the Open Geospatial Consortium (OGC). Major milestones since then were the formulation of the U.S. national SDI by the Federal Geographic Data Committee and the first Global SDI conference, GSDI 1, in Bonn, Germany, in 1996. Parallel developments within the World Wide Web and the Internet added a new capability to call remote functions, which are known today as *Web services*. In 2000, the popular Web Mapping Service specification was released by the OGC. As a result, many local, regional, national, and supra-national SDI initiatives were founded. In 2007, the European Union (EU) enacted into law the INSPIRE (Infrastructure for Spatial Data in Europe) directive, together with a long-term roadmap for the implementation of this law running until 2015 and beyond. The law defines 34 spatial data themes, some for geospatial reference data, and other themes needed to support health, agricultural, urban, and environmental applications. It requires public bodies within each of the 27 EU member states to provide data relating to spatial data themes as a set of services for use by institutions and organizations in the EU.

As the development of SDIs is a work in progress, this entry can describe only the current state of the art. Many of the key concepts behind SDIs are stable, while others are evolving.

Roles and Responsibilities

All infrastructures need to support different kinds of users. Different users have different responsibilities, and these can be classified into different roles. Interestingly enough, many infrastructures, for example telecommunication, electronic banking, and public utilities, show very similar roles and responsibilities, even though the actual products that are consumed are physically very different.

A key relationship is between the roles of SDI service customers and SDI service providers. Another key relationship is between SDI service providers and SDI committees. Contracts may be used to formalize these relationships. Some roles

could be assigned to departments within the organizational borders, whereas other roles could be subcontracted to external organizations. Many providers may subcontract roles, with their associated responsibilities, to the same organization, allowing for economies of scale. Users with defined roles are able to interact within a defined process model to find each other and to finally transfer products. Figure 1 shows the role definitions and their relationships. This entry does not describe the secondary roles in detail. The introduction of a new product must involve all the following elements: (1) correspondence to SDI customer requirements, (2) a contract for an information product (IPR) from an IPR owner, (3) setting up of the business network, and (4) setting up of registers (e.g., if unique identifiers [IDs] are required or common data schemas are used). After this initialization process, potential SDI service customers can find, agree on, and bind the new product, serving the final domain end user via the domain service provider.

SDI Committee

The operation of a multiprovider infrastructure network requires a body to handle SDI-wide issues, for example, unique IDs or spatial data application schemas. To balance sensitive interests, this committee should consist of SDI service providers.

SDI Service Provider

A provider is a commercially responsible party, carrying the full business risks. To enlarge a product coverage, a provider may establish an agreement with other providers to share their networks (roaming agreement), without losing any market appearance. A provider may enhance his or her offer by contracting additional resources from IPR owners. A provider also takes care of advertisement, establishment, and maintenance of customer accounts and delivery.

SDI Service Customer

A customer establishes a contract with a provider to use products. A customer may be a public organization or private entity, for example, a for-profit company. In many cases, this role is carried together with the domain service provider's role for a spatially enhanced domain-specific product.

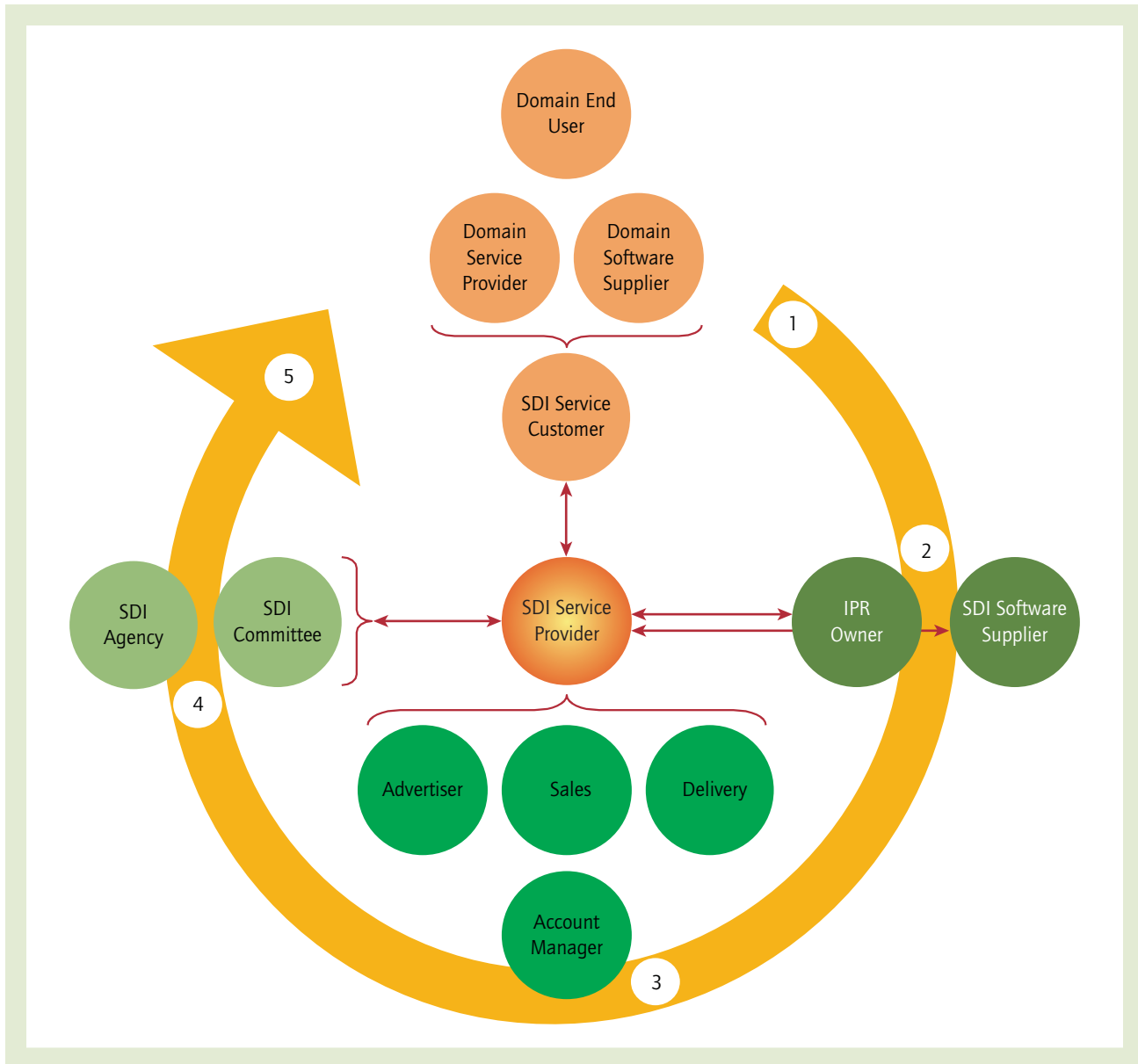


Figure 1 Role model with key relationships and secondary roles

Source: Author.

Process Model

The shift from a closed (desktop) to a distributed (Internet based) environment and therefore from a single- to a multiple-user environment required a process model to allow an ordered interaction between potentially unknown actors. The fundamental business process has four sequential phases. Some phases may be implemented as automated processes, whereas others may be

implemented as manual processes. The process phases and their interactions are shown in Figure 2.

Publish

In the first phase, a new product involving spatial data sets and/or services is published for usage by an SDI service provider. Also, a centrally administered and therefore reliable publication process assigns unique IDs to providers, spatial

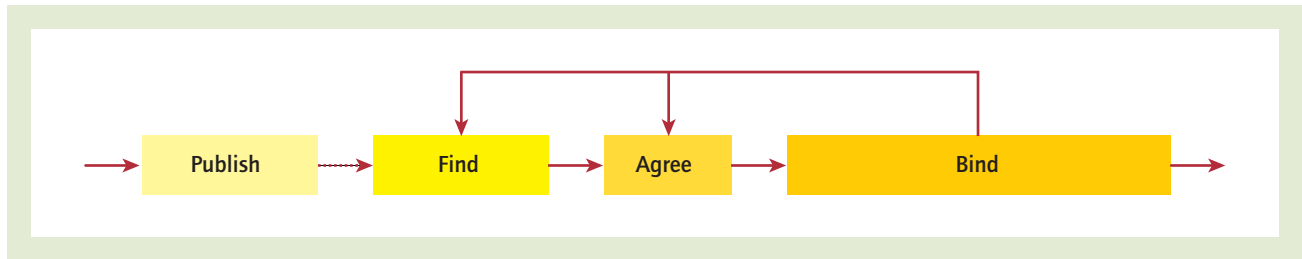


Figure 2 Fundamental SDI process model

Source: Author.

data application profiles, coordinate systems, and license categories. For data sets and services with SDI-wide impact, the registration and maintenance is done by an SDI committee. Otherwise, the publication is done via a product catalog by an advertiser. The result of this process phase is the published product description.

Find

After a product is published, an SDI service customer may find a product by querying the product catalog. In addition, automated applications may search the same product catalog with predefined queries for a given product type—for example, for a specific geographic location. The product description provides some additional information, for example, how to access it, and linking information for the agree-and-bind phase. An advertiser operates a product catalog.

Agree

In general, the establishment and maintenance of contracts between an SDI service customer and an SDI provider is handled in this phase. In a professional SDI, the interest between IPR owners, SDI service providers, and SDI service customers needs to be expressed and agreed via explicit contracts to avoid legal disputes. Alternatively, implicit contracting by declaration of usage rights given in the product description is also possible. In this case, the agree phase might be omitted. This applies also in the case of manually established contracts. Parts of this phase are handled by the sales and account manager roles, acting on behalf of an SDI provider.

Bind

The delivery of spatial products, data, or services is the subject of this phase. There might be contract preconditions prior to access. Therefore, a rights management layer needs to be passed, for example, to check access credentials or to report account usage to the assigned account manager. Different SDI services, for example, for visualization (Web Mapping Services), querying, and downloading (Filter Encoding and Web Feature Service); for transformation; and for process chaining, can be used in this phase. The automated components are described in the following section in detail. This phase is operated by a delivery function acting on behalf of an SDI service provider.

Cascading

Another basic process of integrated distributed services is cascading. A service instance may be implemented on the service side as a collection of multiple services. A received request will be separated according to the distributed services, which are called separately. The responses will be integrated and delivered; that is, two layers will be overlaid and delivered as a single image. Cascading ensures the integration of multiple services within an SDI and also between SDIs. Therefore, it is a fundamental process, which is illustrated in Figure 3.

Architecture Model

The described roles interact via the described business process model. This process may be supported by electronic components. Therefore, a technical architecture shows the derived components. Figure 4 depicts the INSPIRE architecture

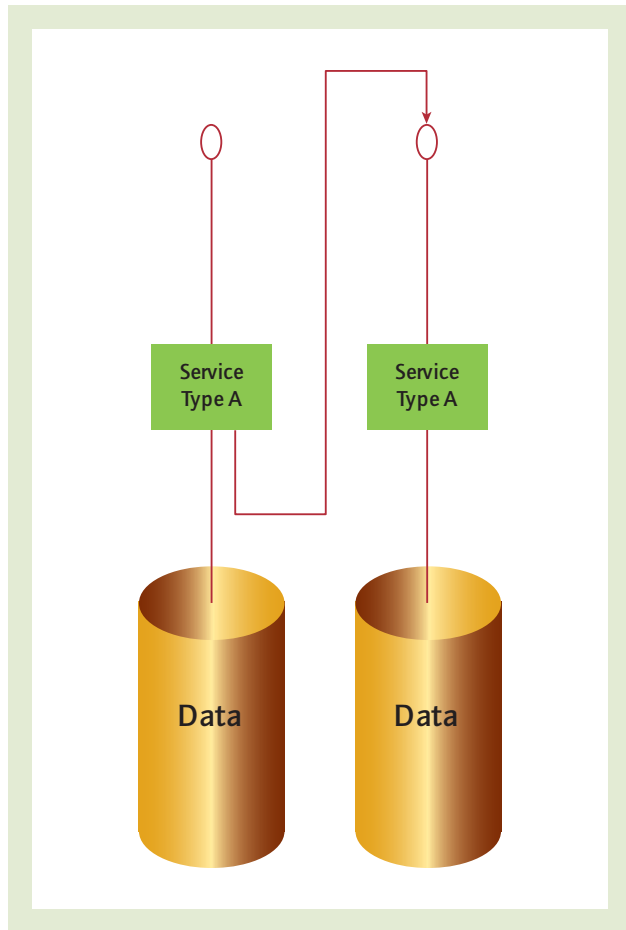


Figure 3 Cascading

Source: Author.

with INSPIRE abstract terms, with the publish phase marked as not finalized yet. Multiple tiers include group service, data, and data schema components. The application tier is undefined because of different domain-specific usage. Geoportals can be used to view spatial data, as with a classic atlas. Between the application and the general service tier, a rights management tier may be used to handle rights issues. The service tier interface is well-defined via standards. The data tier stores data. The thematic spatial data application schema tier defines the structure.

Data Models

Currently, the data models for spatial data and for product description (metadata) have been defined. Most SDIs use the OGC's XML (Extensible

Markup Language) dialect, called *Geographical Markup Language* (GML), although other data schemas, for example, KML (Keyhole Markup Language), might be used. GML aims to offer a set of spatial objects. It separates *model* from *view* and does not offer visualization capabilities. OGC symbology encoding (SE) was specified to define the visualization. Due to this GML characteristic, a GML application schema needs to be derived and named. To enhance exchange capabilities, thematic communities should develop these schemas according to their needs. These schemas should be registered to SDI committees to ensure wide and cross-thematic usage.

The product description is standardized as metadata. ISO 19115/19139 defines the metadata encoding for spatial data. ISO 19119 defines the metadata encoding for services. Due to the wide range of potential descriptions of thematic data and services, the volume of a product description may vary from 18 to 400 elements.

Spatial Operators and Query Language

Spatial information has a spatial reference given by a reference system, which can be described and accessed with mathematical methods. These basic mathematical formulae can be combined into higher-level spatial operators. The following spatial operators representing topological relationships are defined: Equals, Disjoint, Touches, Within, Overlaps, Crosses, Intersects, and Contains. Spatial operators can be combined with logical and relational operators, mathematical expressions, and functions to define a query language. This powerful language is called *OGC Filter Encoding* (FE) and allows spatial and nonspatial analyses of data. It is used to query the product catalog service (discovery service) and the Web feature service.

Service Models

The Internet offers, in addition to digital data transport, remote function calls, which are called operations of Web services. An operation can accept input parameters allowing user-defined on-the-fly production. Web service components are designed to support the business process depicted in Figure 1. Figure 4 shows the service components included in the service tier. These

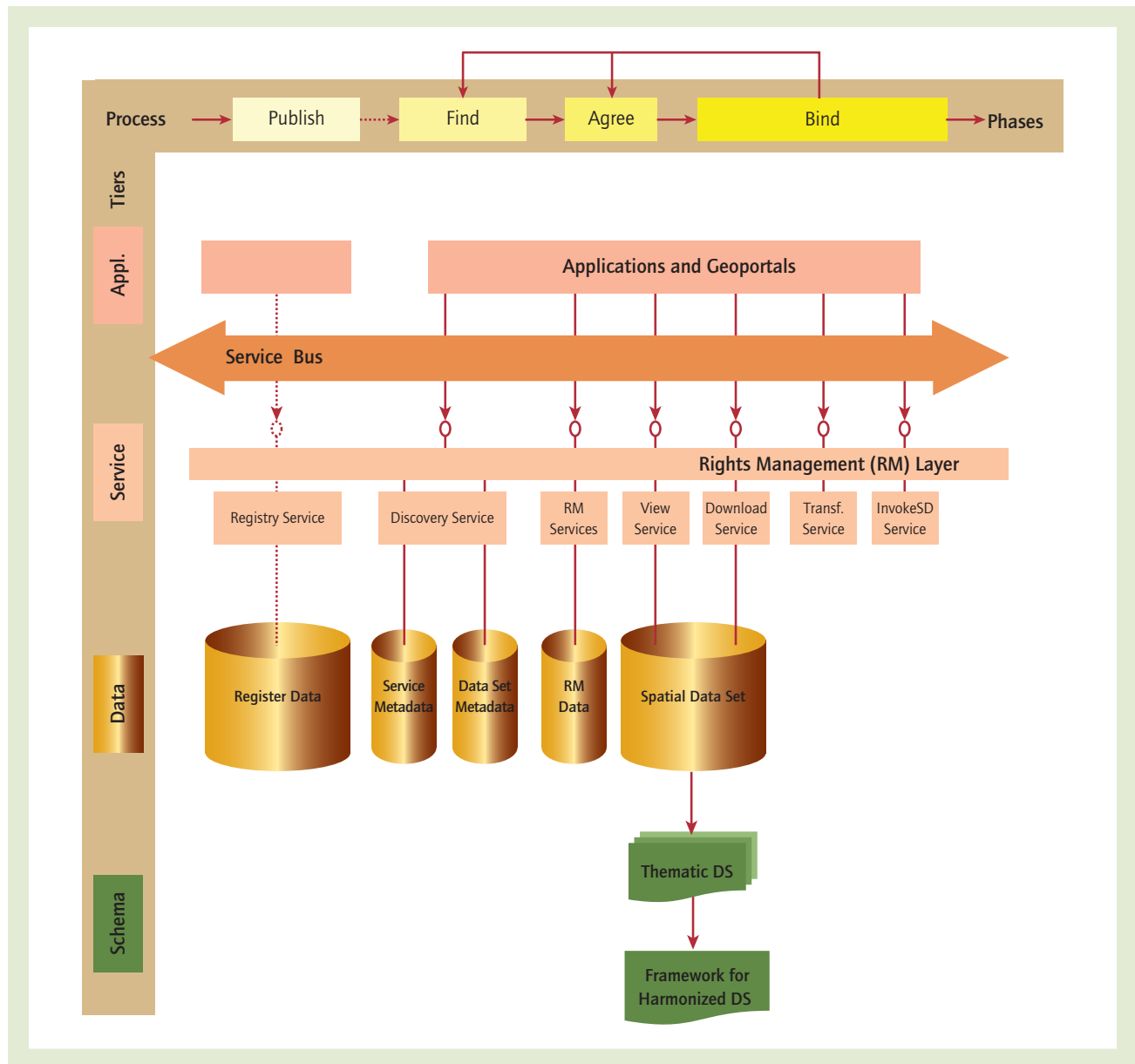


Figure 4 INSPIRE architecture, including “agree” phase

Source: INSPIRE Drafting Team Network Services.

components, which support the process model phases, are described below in detail.

Because the function of register for the publish phase has not yet been defined, no specification for an electronic component is available yet.

The find phase can be supported with a discovery service (catalog service) for search together with the described metadata models and the filter encoding query language. Because of performance

issues and structured search, only a subset of metadata can be queried. A free text search via all data fields is possible, and typical search functions are supported. The results can be listed in a very short, medium, or full set. Also, the results may be limited per request to allow proper visualization. Multiple service profiles are defined to support different thematic domains. Automated search, for example, for the next valid service

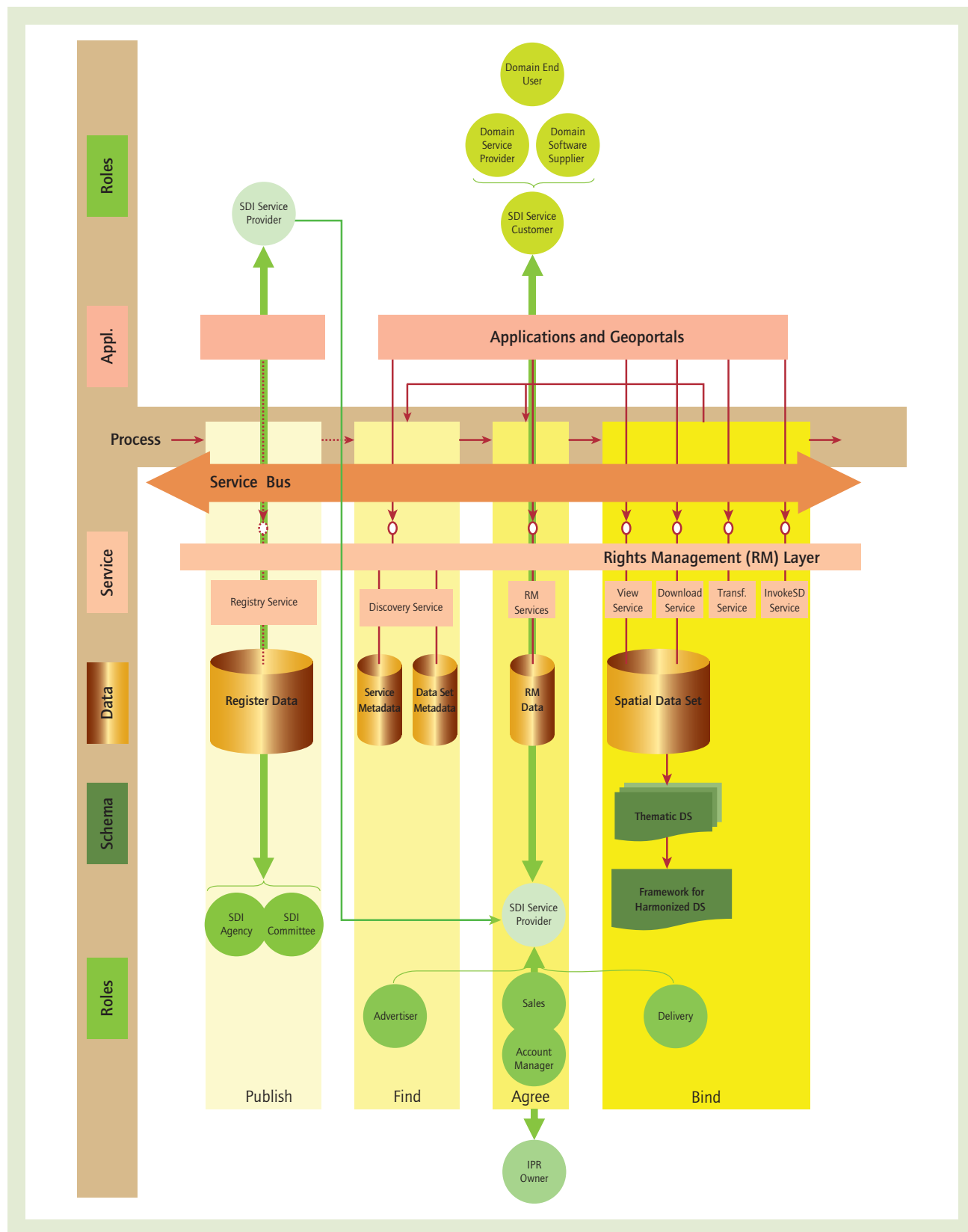


Figure 5 Integrated view of described roles and processes in INSPIRE architecture, including the “agree” phase

Source: Adapted by author from INSPIRE Drafting Team Network Services.



type instance, is also allowed. In the transactional mode, the read and write functions, such as delete, update, and store, are supported.

The agree phase needs services to support the establishment of contracts and management of accounts. Functions for pricing, licensing, and access control are needed. Other business functions, for example, watermarking, might be subjects for future developments.

The delivery phase enfold multiple content and processing services. Specific definitions vary among SDI initiatives and may depend on the providers. INSPIRE defines on an abstract level *view*, *download*, *transformation*, and *invoke* service types. On an applied level, these categories fit the OGC Web Mapping Service (WMS), OGC Web Feature Service (WFS), and other upcoming OGC specifications.

Roles, Process, and Architecture Overview

The described major components of spatial data infrastructures are related to each other. Although many different constellations are possible, Figure 5 illustrates an example of an integrated model of SDI.

Roland M. Wagner

See also **Ground Reference Data; Interoperability and Spatial Data Standards; Metadata; Network Data Model; Ontological Foundations of Geographical Data; Open Geodata Standards; Open Geospatial Consortium (OGC); Point Pattern Analysis; Spatial Analysis; Spatial Data Integration; Spatial Data Mining; Spatial Data Models; Spatial Data Structures; Spatial Decision Support Systems; Spatial Optimization Methods; Spatial Statistics**

Further Readings

- Cox, S., Daisey, P., Lake, R., Portele, C., & Whiteside, A. (2003). *OpenGIS Geography Markup Language (GML) implementation specification* [Computer software and manual]. Wayland, MA: Open Geospatial Consortium.
- Doyle, A. (2000). *OpenGIS Web mapping service implementation specification* [Computer software and manual]. Wayland, MA: Open Geospatial Consortium.

Infrastructure for Spatial Information in Europe (INSPIRE): <http://inspire.jrc.it>

INSPIRE Drafting Team Network Services. (2008).

INSPIRE network service architecture [Computer software and manual]. Brussels, Belgium: Joint Research Center.

Vowles, G. (2006). *OGC GeoDRM Reference Model* [Computer software]. Wayland, MA: Open Geospatial Consortium.

Vretanos, P. (Ed.). (2002). *Web feature service implementation specification* (Version 1.0, Ref. No. OGC 02-058) [Computer software and manual]. Wayland, MA: OpenGIS Consortium.

Vretanos, P. (2005). *OpenGIS filter encoding implementation specification* [Computer software and manual]. Wayland, MA: Open Geospatial Consortium.



SPATIAL DATA INTEGRATION

Spatial data integration is the process of making data from different sources compatible so that they can be used appropriately in an analysis framework. Before spatial data can be viewed, queried, combined, or analyzed, the integration process must address the many ways in which they can differ in terms of the following:

Content: The type of geographic feature or phenomenon represented and the properties used to describe it

Spatial representation: The conceptual model of space (object or field view), spatial data model (vector or raster) and spatial object type (point, line, polygon, cell), or indirect spatial reference (place name or code) used to identify location

Spatial reference: The coordinate system (datum, map projection or coordinate system, and units), geographic extent, and spatial resolution of the data or the source scale of any mapped data inputs

Attributes: The measurement scales, units, terminology, and classification systems

Time frame: The date or data range of acquisition or last update



Data/file format: The format used to encode the data, for example, GML, KML, shapefile, ascii grid, and tiff

Data quality: Attribute and positional accuracy, logical consistency in the geometric and attribute data, and data completeness

Lineage: The means by which the data were acquired, including instruments, calibration, sampling or enumeration strategies, protocols, and processing steps

Purpose: Who collected the data, why, and what, if any, are the restrictions on its use

The three types of spatial data integration tasks are temporal, horizontal, and vertical integration. *Temporal data integration* refers to combining similar data sets collected at different times for the purpose of change detection or to create an updated data set. Horizontal data integration involves the merging of adjacent data sets to create a new data set with a larger geographic extent. Vertical data integration is an essential first step in spatial overlay analysis and has the widest application.

The primary goal of spatial data integration is to use multisource data analysis to support better understanding of existing conditions, relationships, and trends, which in turn should lead to better spatial decision making. Related objectives are to improve the efficiency and quality of information extracted from multiple sources, whether these data are integrated to create new information or to reduce data volume and redundancy. A number of factors are driving the need for sound integration principles and practices. First, because spatial data are often expensive to produce, analysts use a variety of heterogeneous data sets that they did not produce in applications other than those for which the data were intended. Second, technological changes have led to an exponential growth in the type, amount, and availability of spatial data, which in turn has led to an increase in the number of users of and applications for these data. Third, an enormous amount of legacy data exist that could be used for richer temporal analyses. Finally, there is a growing demand for online access to distributed, heterogeneous spatial data; this is often referred to as *interoperability*, due to the need for both data- and systems-level integration.

Two key factors critical to a successful integration process are metadata and spatial data quality

assessment. Metadata, or information about the data, provide information that identifies a data set and documents its characteristics (identified above). Significant problems with spatial metadata include nonstandard metadata, poorly completed metadata, and incomplete or a complete lack of metadata. Assessing the quality of spatial data integration inputs and outputs is critical to maximizing their effectiveness. Spatial data quality is typically discussed in terms of error and uncertainty. Errors are deviations from “true” values in positional or attribute measurement or in category assignment. Since true values are often not known, uncertainty is a broader term used to describe the ways in which a digital representation varies from the real-world geographic object it describes and includes the notion of error, inaccuracy, vagueness, and ambiguity. Measuring errors and uncertainties, determining how they propagate in the spatial data integration process, and assessing the range of quality levels that can be tolerated for specific analysis tasks constitute an important and active research area.

Many of the spatial data integration strategies that have been developed are ad hoc—designed for specific projects and data and performed with little automation. Current efforts to generalize the process include standards and framework data. Agencies such as the U.S. Federal Geographic Data Committee (FGDC), the Open Geospatial Consortium (OGC), and the International Organization for Standards (ISO) are developing standards for spatial data collection, representation, and metadata. FGDC standards include wetlands and vegetation classification systems, content standards for cadastral data, digital orthoimagery, remote sensing swath data, utilities data, metadata, and so on. Standards improve the process of spatial data integration by providing a consistent means for comparing data content and quality. The FGDC is also spearheading the development of the National Spatial Data Infrastructure (NSDI), which includes a framework of the seven most commonly used geographic data themes: geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units, and cadastral information. These data, and related procedures, guidelines, and technology, facilitate integration by providing reference data that spatial analysts



can use to accurately register and compile other data sets or display the locations and the results of their analyses. Additionally, emerging research on geospatial semantics suggests the use of ontologies (domain-specific semantic networks) as a tool for automating spatial data integration.

Spatial data integration is powerful because it allows for more insight than what could be obtained by examining the data separately. However, problems associated with the many ways in which spatial data can differ create major impediments to their appropriate integrated use. Although aspects of spatial data integration are improving and advancing our understanding of underlying issues, current approaches have not kept pace with the increases in spatial data and the applications for their use. The University Consortium for Geographic Information Science (UCGIS) has identified specific research priorities as well as the need for a general theoretical and conceptual framework for spatial data integration.

Patricia Frontiera

See also **Conflation; Error Propagation; Interoperability and Spatial Data Standards; Metadata; Ontological Foundations of Geographic Data; Open Geospatial Consortium (OGC); Spatial Analysis; Spatial Data Infrastructures; Spatial Data Mining; University Consortium for Geographic Information Science**

Further Readings

- Flowerdew, R. (1991). Spatial data integration. In D. J. Maguire, M. F. Goodchild, & D. W. Rhind (Eds.), *Geographical information systems, principles and applications* (Vol. 1, pp. 375–387). New York: Wiley.
- Gong, P. (1994). Integrated analysis of spatial data from multiple sources: An overview. *Canadian Journal of Remote Sensing*, 20(4), 349–359.
- Jensen, J., Saalfeld, A., Broome, F., Cowen, D., Price, K., Ramsey, D., et al. (2004). Spatial data acquisition and integration. In R. E. McMaster & E. L. Usery (Eds.), *A research agenda for geographic information science* (pp. 17–60). Boca Raton, FL: Taylor & Francis/CRC Press.



SPATIAL DATA MINING

Scientific understanding of geographic phenomena often depends on the collection, analysis, and interpretation of observational data. With increasingly powerful and spatially enabled data-gathering techniques, such as remote sensing, census survey, global positioning system (GPS), and sensor networks, large volumes of geographic data are being accumulated at an unprecedented speed in many application domains, including climatology, public health, environmental science, business, and transportation, among many others. These data hold great potential to provide valuable and previously unknown information to understand and solve complex real-world problems. However, it is a great challenge for researchers to discover new knowledge from such large and complex data sets.

During the past decade, knowledge discovery and data mining have quickly become active research areas that span many disciplines, focusing on the development and application of new analysis methods to extract nontrivial and potentially useful information from large amounts of data. Data mining usually involves multiple steps, such as data preprocessing, transformation, analysis, human interaction, and result interpretation. In general, there are two main challenges for data mining research: (1) the discovery of complex, unknown, and even unexpected patterns (which traditional methods cannot find) and (2) efficient extraction of information from very large databases (whereas traditional methods are often computationally expensive and can only deal with small data sets. Common data mining tasks include clustering (unsupervised classification), supervised classification, prediction, association rule mining, temporal trend analysis, outlier detection, and multimedia analysis, among many others. For each task, there are different methods, which can be computational, statistical, or visual.

General-purpose data mining methods, however, cannot fully address the unique challenges related to the analysis of geographic data. Spatial data have a number of characteristics, including spatial autocorrelation, spatial nonstationarity, complex geographical relations and constraints,

high dimensionality, unique spatial pattern types, and various application-specific requirements. General-purpose data mining methods are not able to consider these spatial characteristics and are therefore ineffective in discovering meaningful geographic information. On the other hand, traditional spatial analysis methods, such as spatial statistics, often focus on a specific type of pattern (e.g., spatial autocorrelation) and are only able to analyze small data sets. There is an enormous need for new approaches that are more effective than traditional approaches in turning the wealth of spatial data into valuable information.

Spatial data mining focuses on the development of efficient and effective methods to extract useful information and knowledge from massive spatial databases. Existing methods for spatial data mining span three main groups: *computational*, *statistical*, and *visual approaches*. Computational approaches resort to computer algorithms to search large volumes of data automatically for specific types of patterns, such as spatial clusters, spatial association rules, homogeneous regions, colocation patterns, and spatial outliers. Statistical approaches include spatial scan statistics, geographically weighted regression, multivariate lattice models, and spatial association tests. There are also numerous visualization-based methods for multivariate spatial analysis, such as multivariate mapping, spatiotemporal visualization, and other interactive geovisualization techniques.

Although computational and statistical methods can search for a specific type of pattern very quickly, they have very limited capabilities to support pattern interpretation. In contrast, visualization methods can help humans visually discern complex patterns, propose explanations of the observed patterns, and generate hypotheses for further analysis. To combine the advantages of different approaches, integrated methods have been developed to bring together the computational and visual approaches in order to address complex problems more effectively.

Spatial data mining research is still in its early stage, and its great potential is yet to be fully realized by addressing new challenges, inventing novel methods, and developing successful applications. Following is a brief introduction to several selected major challenges facing spatial data mining research.

Pattern Complexity and Hypothesis Generation

Geographic phenomena by nature are often very complex, involving many known or unknown interrelated factors. The traditional hypothesis-testing approach has very limited capability because there can be numerous hypotheses for a simple geographic problem. A more viable direction that spatial data mining should take is to develop approaches that can search the data and suggest hypotheses.

Spatial Nonstationarity

To make the above problem even more challenging, patterns or relationships may change over a geographic space. For example, the causal factors for a cancer may vary regionally due to differences in living environment, economic status, and health policies.

Computational Efficiency

Because of the massive data volume, the large number of attributes, and the complexity of potential patterns, spatial data mining tasks are computationally demanding. For example, to detect clusters in a large set of spatiotemporal events (e.g., disease incidents) may take hours or even days of computations. This problem becomes much more severe if more factors are to be considered. Every spatial data mining method has to be computationally feasible to handle large amounts of data.

Visual Presentation and Understandability

The understandability of discovered patterns is very important for users to integrate the new information with existing knowledge for scientific inquiry and real-world decision making. Interactive visualization methods are critical to allow users to interactively explore and understand the patterns from different perspectives.

Practical Systems to Address Real-World Problems

One of the ultimate goals of spatial data mining is to help solve real-world problems such as those



related to pandemic control, emergency management, urban planning, business intelligence, global change, and weather forecasts, among many others. It is critical that spatial data mining research be able to produce effective approaches to benefit a broader community, in both scientific and public domains.

Diansheng Guo

See also *Exploratory Spatial Data Analysis; Interoperability and Spatial Data Standards; Spatial Data Infrastructures; Spatial Data Integration; Spatial Data Models; Spatial Data Structures; Spatial Decision Support Systems; Spatial Multicriteria Evaluation; Three-Dimensional Data Models*

Further Readings

- Fayyad, U., Piatetsky-Shapiro, G., Smyth, P., & Uthurusay, R. (1996). *Advances in knowledge discovery*. Cambridge, MA: AAAI Press.
- Guo, D., Chen, J., MacEachren, A. M., & Liao, K. (2006). A visualization system for space-time and multivariate patterns (VIS-STAMP). *IEEE Transactions on Visualization and Computer Graphics*, 12(6), 1461–1474.
- Miller, H. J., & Han, J. (2001). *Geographic data mining and knowledge discovery*. New York: Taylor & Francis.
- Shekhar, S., Zhang, P., Huang, Y., & Vatsavai, R. (2004). Trends in spatial data mining. In H. Kargupta, A. Joshi, K. Sivakumar, & Y. Yesha (Eds.), *Data mining: Next generation challenges and future directions* (pp. 357–381). Cambridge: AAAI Press.



SPATIAL DATA MODELS

Spatial data models, or GIS data models, are the ways of representing spatial information in a geographic information system (GIS) database. Because the world is very complex, choices must be made on how to describe objects and phenomena for research and analysis. Typically, the selection of a particular scale of analysis is made, based

on information needs dictated by the task at hand, where the level of desired detail is portrayed in the model. Sometimes the choice of scale of analysis is constrained by access to data, particularly where satellite data may offer information only at a particular resolution. The categorization of the objects is also a critical decision: What information is to be included or excluded is carefully considered. From these choices, the spatial data collected are generalized (put into categories) and converted into abstract forms (a line represents a road, a point represents a city), and objects are simplified.

Through the choices of spatial representation, information becomes manageable, available for analysis, and straightforward to communicate and share. All spatial data models are spatially referenced: For objects described on Earth's surface, geographic coordinate systems serve as the reference. Spatial references can also be generated for other areas of focus: other planets, the human body, or the human brain, for example. In this entry, raster and vector, the most common spatial data models, are described first. The Triangulated Integrated Network (TIN) model, a variation on the vector data model, and the object data model, as a compilation of vector or raster data models, are also defined. Last, critiques of representation through spatial data models are summarized.

Raster Data Model

A *raster data model* is a two-by-two array, or grid, of spatial information. Analogous to the pixels that make up the image on a computer screen, or images taken with digital cameras, a raster model contains grid cells, spatially referenced and consisting of only one value in each cell. The value may represent temperature, elevation, or even population, estimated for each grid cell. A grid representation forms a surface of information. For raster data models, the choice of scale, categorization, and representation is made by the choice of resolution, or the size of the grid cell.

Vector Data Models

Vector data models use points, lines, and polygons to geometrically represent spatial entities. In contrast to the continuous array of cells in a raster model, spatial objects in vector data models



can be seen as discrete objects: points, representing cities, houses, or trees; lines, representing roads or rivers; and polygons, representing the boundaries of countries or states or the boundaries of buildings.

Spaghetti Data Structure

The simplest vector data model is the spaghetti data structure, where coordinates, or strings of coordinates, for points, lines, or polygons, are stored. The spaghetti structure does not store explicit information on how points, lines, or polygons are described in relation to one another. For example, data on intersections, proximity, and contiguity are not specifically stored.

Topological Data Structure

The topological data structure offers a more advanced data storage technique for vector data models. Information about topology, such as nodes and intersections, lines, and polygons, and about how the spatial entities are related to one another is stored in this structure. The advantage of the topological data structure, though it is more sophisticated, is that it shortens the time that it takes to conduct spatial queries or for users to ask questions about the spatial relationships that exist in the data.

Triangulated Integrated Network (TIN) Model

The Triangulated Integrated Network (TIN) model is a type of vector data model in which for a set of points, each point is connected with its neighbors in all directions by straight lines, forming a cover of triangles over a particular, referenced space. TIN models are commonly used to display differences in elevation. The advantage of the TIN model over the raster model for elevation is that data redundancy is reduced in places where there is not much difference in elevation change.

Object Data Model

In raster and vector data models, the spatial entities that are stored are not hierarchical. When dealing with complex, interrelated spatial information,

it makes sense to lump a series of entities into a larger object, or set. For example, roads, buildings, and important distribution sites may make up a city. With the object data model, multiple layers of entities are included in a more encompassing object. Components of objects may include different types of raster or vector entities: points, lines, or polygons. In some cases, the classification of entities as part of an object is intuitive; however, for other applications, enforcing one object data structure, with distinct and separate entities belonging only to particular objects, may not be the best choice.

Critiques of Spatial Data Models

Criticisms of the choices made regarding representation in a GIS are diverse, adding to an already healthy critical perspective of cartography. Boundary drawing is an exercise in power: power over nature and power over people. As in cartography, spatial data models in a GIS represent information that is necessarily imperfect: generalizing, simplifying, and exclusionary of certain sets of information. Reflecting less on the shortcomings and more on the potential in the burgeoning field of GIS, the way in which time is incorporated into spatial models has been a source of critique and an area of important development for the future of GIS.

Lisa Jordan

See also **Critical GIS; Data Classification Schemes; GIScience; Models and Modeling; Network Data Model; Point Pattern Analysis; Spatial Data Integration; Spatial Data Mining; Spatial Data Structures; Spatial Econometrics; Spatial Optimization Methods; Three-Dimensional Data Models; Triangulated Irregular Network (TIN) Data Model**

Further Readings

- Bolstad, P. (2005). *GIS Fundamentals: A first text on geographic information systems*. White Bear Lake, MN: Eider Press.
- DeMers, M. (2005). *Fundamentals of geographic information systems*. Hoboken, NJ: Wiley.



Longley, P., Goodchild, M., Maguire, D., & Rhind, D. (2005). *Geographic information systems and science*. Hoboken, NJ: Wiley.

Shekhar, S., & Chawla, S. (2003). *Spatial databases: A tour*. Upper Saddle River, NJ: Prentice Hall.

United Nations Department of Economic and Social Affairs Statistics Division. (2000). *Handbook on geographic information systems and digital mapping* (Series F, No. 79). New York: Author.



SPATIAL DATA STRUCTURES

Spatial data structures describe the rules that are used to represent geographic data in geographic information systems (GIS). Geographic data include information about the location, size, and shape of objects or phenomena on or near the surface of Earth, as well as their nonspatial characteristics.

Geographic data in GIS are represented at several different levels of abstraction, each level depending on those beneath it:

Conceptual spatial data models describe how geographic objects (e.g., rivers) or phenomena are represented in GIS.

Logical spatial data models describe how geographic data are represented in a database management system (e.g., as database tables).

Spatial data structures describe the methods and formats for physical storage and processing of geographic information in GIS.

Spatial data structures are the core of a GIS and fundamentally affect its performance and capabilities. Thus, an understanding of spatial data structures is important in the study of geographic data management.

Data structures can be divided into two groups. *Vector* data structures represent geographic objects or phenomena as distinct geometries with specific characteristics and may also include topology. *Raster* data structures represent geographic objects or phenomena as a grid over

which a given characteristic varies continuously. Generally, raster data structures are suitable for continuously varying phenomena, such as temperature, while vector data structures are suitable for the representation of conceptually distinct objects, such as land ownership parcels.

Vector Data Structures: Geometry

Vector data structures explicitly store the geometries that represent geographic objects. They are referred to as *vector data structures* because they represent geometries using a series of points and lines (vectors). In vector data structures, geometries may have different dimensions (Figure 1):

A zero-dimensional (0D) geometry is a point. It is usually represented with x and y coordinates.

A 1D geometry is a line, arc, or string of line segments (sometimes called a *polyline*) connecting point geometries, sometimes requiring additional information about arc properties.

A 2D geometry is a polygon, defined by a sequence of 1D geometries with the same start and end point. Polygons may be simple or complex. Complex polygons may be aggregations of more than one polygon and may have holes, possibly with island geometries inside the holes.

A 3D geometry is a solid, defined by a collection of 2D geometries with a z coordinate (usually representing height relative to a reference point). The solid may also contain holes or be an aggregation of multiple solids.

Geometries may have attributes attached to them. For example, a land ownership parcel may be represented by a 2D geometry (polygon), with attributes for the name of the parcel owner and the land use controls that apply over it.

Vector Data Structures: Topology

Some spatial data structures represent topology as well as geometry. Topology describes how objects are connected to one another.

The topology of a set of objects can be represented by a graph of nodes and links.

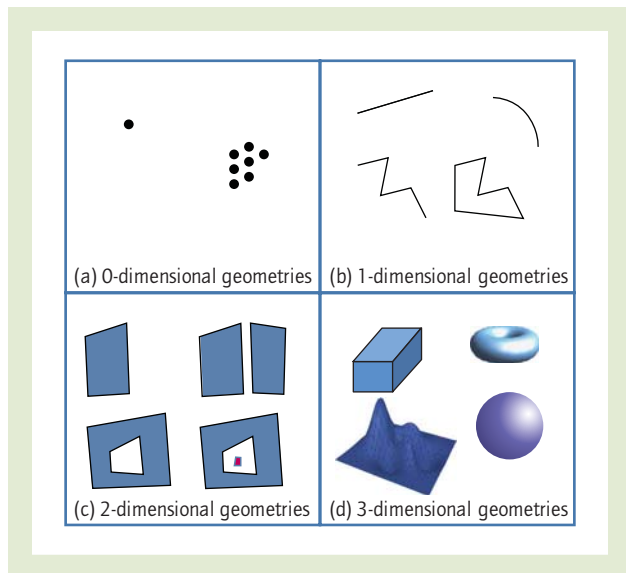


Figure 1 Geometries

Source: Author.

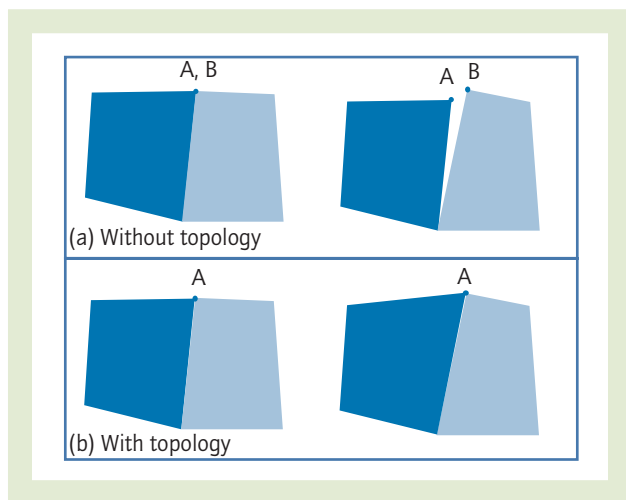


Figure 2 Topology

Source: Author.

Formally, topology describes the set of relationships between objects that are not changed when object geometries are deformed in various ways (twisted, stretched, or resized). In topological spatial data structures, the connections between objects are stored in addition to their geometries, and thus, when there is a change in the geometry of one object, the geometry of a connected object

may also be affected. For example, in Figure 2a, although Points A and B coincide, when B is moved, A is not affected. In Figure 2b, Point A is stored as a node of both polygons, and there is no Point B. When Point A is moved, it affects the geometries of both polygons.

Raster Data Structures

Grid (or raster) data structures represent the world as a grid of cells that have a location and an attribute value or set of values for that cell. There are a number of different ways in which the grid may be physically represented within a GIS.

Most simply, a grid may be represented as a list of coordinates (cell row and column) and an attribute value or set of values. However, such an approach is not usually efficient for data retrieval because adjacent points in the world are not adjacent to each other in the representation and it does not support convenient aggregation of cells to allow a large area to be viewed efficiently. For this reason, hierarchical (or pyramidal if 3D) data structures have been developed that progressively divide the gridded region.

The quad-tree data structure (Figure 3a) is a hierarchical structure with a single cell representing the entire region at the root, which is then progressively subdivided into four blocks (typically northwest, northeast, southwest, and southeast). If a quad-tree block is filled with cells that have the same attribute value, that value is stored. Otherwise the subdivision process is repeated. Irregular quad-tree data structures (Figure 3b) may also be used. In this case, the area is still divided into four blocks successively, but the position of the boundaries between the blocks is determined by the contents of the area.

The r-tree (or rectangle-tree) is similar to the irregular quad-tree but with more flexibility. Any number of rectangles may be formed around features, objects, or clusters; areas that are empty may be ignored, and rectangles may overlap (Figure 3c).

Raster data structures are sometimes used to improve the efficiency of vector data retrieval by not only representing objects as geometries but also referencing the geometries against cells

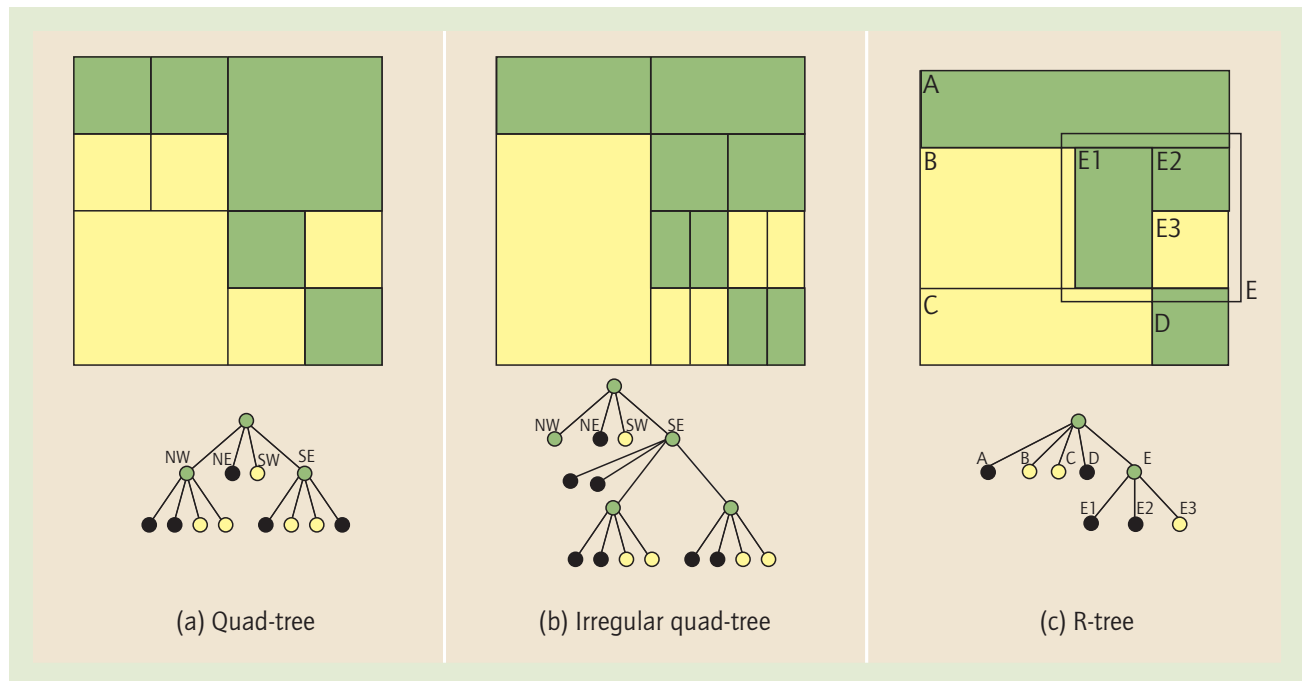


Figure 3 Raster data structures

Source: Author.

in a hierarchy. This approach allows geographically neighboring geometries to be found more efficiently.

Kristin Stock

See also **Coordinate Systems; Data Querying in GIS; Exploratory Spatial Data Analysis; Ontological Foundations of Geographical Data; Semantic Reference Systems; Spatial Data Infrastructures; Spatial Data Integration; Spatial Data Mining; Spatial Data Models; Spatial Econometrics; Spatial Multicriteria Evaluation; Topological Relationships; Vectorization**

Further Readings

- Laurini, R., & Thompson, D. (1992). *Fundamentals of spatial information systems*. London: Academic Press.
- Longley, P., Goodchild, M., Maguire, D., & Rhind, D. (Eds.). (2005). *Geographical information systems: Principles, techniques, management and applications*. New York: Wiley.



SPATIAL DECISION SUPPORT SYSTEMS

Although the concept of spatial decision support systems (SDSS) has been around for approximately 40 years, it was not until the early 1990s that SDSS found a wider recognition in geography and geographic information science (GIScience). The development of SDSS has been associated with the need to expand geographic information system (GIS) capabilities for tackling complex spatial decision problems. Over the past two decades, the SDSS concept has evolved into a field of research, development, and practice that is made up of many different approaches and frameworks, among which are Collaborative SDSS (CSDSS), Group SDSS (GSDSS), Intelligent SDSS (ISDSS), Participatory GIS (PGIS), Public Participation GIS (PPGIS), Spatial Knowledge-Based Systems (SKBS), Spatial Multi-Agent Systems (SMAS), and Spatial Planning Support Systems (SPSS). A broader perspective suggests that all these spatial information systems have a



common aim: to improve the performance of decision makers, managers, and citizens when they confront spatial decision problems.

Defining SDSS

SDSS is an interactive, computer-based system designed to support a user or group of users in achieving higher effectiveness in decision making while solving a semistructured spatial decision problem. The essence of the SDSS concept is captured by the following three terms: (1) semistructured spatial problem, (2) effectiveness of decision making, and (3) decision support.

Any decision-making problem falls on a continuum that ranges from completely structured to unstructured decisions. Most real-life spatial decision problems can be found somewhere between these two extremes. Such decision problems are called *semistructured* (e.g., location-allocation problems, site search and selection problems, land use suitability evaluation, transportation problems, environmental impact assessment, plan/policy evaluation, etc.). The structured part of the semistructured problem may be amenable to automated solution by the use of a computer, while the unstructured aspects are tackled by decision makers. Although SDSS may increase the efficiency of the data-processing operations, the primary aim of the system is to improve the effectiveness of decision making by incorporating decision makers' knowledge and experience into computer-based decision-making procedures. Central to the concept of SDSS is the interaction of the user(s) with a computer-based system containing a set of tools for analyzing spatial and nonspatial data and for modeling spatial decision problems. SDSS integrates previously separate tool sets into a unified whole more valuable than the sum of the parts.

Components of SDSS

A number of frameworks for designing SDSS have been proposed in the past two decades or so. In general, the SDSS concept is based on the DDM (dialogue, data, and model) paradigm. The way the three components are integrated depends on the philosophy behind the design strategy (e.g., a system for supporting a single user vs. that for

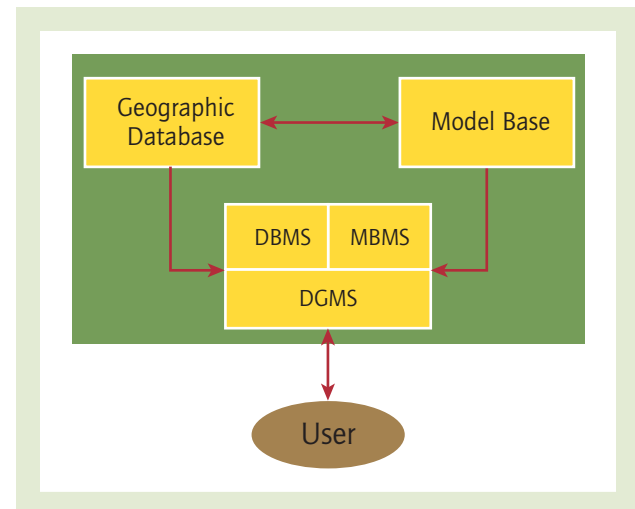


Figure 1 The components of SDSS

Source: Author.

Note: DBMS = database management system; MBMS = model base management system; DGMS = dialogue generation and management system.

group decision making), the types of decision problems (e.g., operational vs. strategic decisions), and the models incorporated into the system (e.g., optimization vs. simulation models). Despite these differences, a well-designed SDSS should have a balance among three sets of capabilities in the areas of data, modeling, and dialogue (Figure 1).

The database management system (DBMS) contains the functions to manage the geographic database. It typically contains a set of tools that are available in full-fledged GIS, such as data acquisition, storage, retrieval, manipulation, queries, integration, and visualization, including techniques and methods for exploratory data analysis that provide decision makers with a better understanding of the decision situation. The model base management system (MBMS) contains the functions to manage the model base. It can include tools for decision analysis (e.g., generic optimization and simulation models as well as domain-specific models such as spatial interaction, spatial choice, location-allocation, resource allocation, land suitability, and hydrological models), statistics and forecasting (e.g., exploratory spatial data analysis, confirmatory spatial data analysis, spatial statistics, and time



series), modeling a decision maker's preferences (e.g., the hierarchical value structure of goals, evaluation criteria, objectives and attributes, multi-attribute value/utility, and consensus modeling techniques), and modeling uncertainty (e.g., "what-if" analyses).

The dialogue generation and management system (DGMS) manages the interface between the user and the computer system. It includes all the mechanisms by which commands, requests, and data are entered into the computer system as well as all the methods by which results and information are output by the system (e.g., cartographic displays, specialized graphics for depicting the results, and tabular reports). In addition, an SDSS may include some kind of artificial intelligence or Expert System (ES) capabilities to improve the accessibility, maintenance, and operation of its major components. The three components constitute the software portion of SDSS. In addition, the decision maker or user is considered to be a part of the system. The unique contributions of SDSS are derived from the interaction between computer and the user.

Changes in computer hardware and software technology over the past decade or so have fundamentally restructured the way in which decision makers, planners, analysts, and citizens interact with computer-based data and models for supporting decision-making processes. The Internet and the World Wide Web (WWW) have added a new dimension to the concept of SDSS. In particular, Web technologies provided new media for sharing information about decision support and a new means for delivering decision support capabilities. The main motivation for making SDSS available online is to stimulate and support group/participatory decision making. Web-based SDSS have reduced technological barriers and made it easier to provide decision-relevant information to users in geographically distributed locations. A Web-SDSS combines several different components, including HTML (Hypertext Markup Language) user interfaces, Internet interface programs, computational models, and geographic databases. It delivers decision support information or decision support tools to user(s) by means of a Web browser, such as Internet Explorer or Netscape Navigator.

Technologies for Developing SDSS

There are three sets of technologies for building an SDSS: (1) SDSS development tools, (2) SDSS generators, and (3) specific SDSS. The tools facilitate the development of specific SDSS, or they can be configured into an SDSS generator, which in turn can be used to build a variety of specific SDSS. Examples of development tools include procedural programming languages and code libraries (e.g., TransCAD—Caliper Script's macrolanguage), interapplication communication software (e.g., dynamic data exchange [DDE]), application-programming interfaces (e.g., TransCAD's API), applets (e.g., GISApplet), visual interfaces, graphics, and color subroutines (e.g., graphical user interfaces, or GUI).

The SDSS generator is a package of related hardware and software that provides a set of capabilities to quickly and easily build a specific SDSS. GIS (e.g., ArcGIS, MapInfo, TransCAD), database packages (e.g., dBase, Oracle Spatial, ArcSDE), decision analysis and optimization software (e.g., LINDO, EXPERT CHOICE), statistical and geostatistical software (e.g., S-PLUS, SPSS), and simulation (e.g., @RISK) can be used as SDSS generators. The specific SDSS is a system devoted to the analysis of a particular set of decision problems. It is the system that actually supports the decision makers in tackling particular spatial decision problems (e.g., CommunityViz, IDRISI).

Examples of SDSS

Theoretically, it is possible to develop specific SDSS in any area of application involving analysis of spatial data for tackling decision problems. Indeed, one of the most remarkable features of SDSS development is the wide range of decision and management situations in which they have been applied. SDSS capabilities are readily available in some GIS. IDRISI's Decision Support and Integrated Land and Water Information System (ILWIS), with its Spatial Multiple Criteria Evaluation feature, provides a good example of a system that has a wide range of GIS capacities, including decision support. IDRISI has been developed in the Clark Labs for Cartographic



Technology and Geographic Analysis at Clark University. It includes a suite of tools for multicriteria decision support that has been applied to support land use planning, risks and vulnerability assessment, sustainable forest management, hazardous material transportation planning, and emergency planning. ILWIS is a GIS and remote sensing software, developed by the International Institute for Geo-Information Science and Earth Observation (Enschede, the Netherlands). Like IDRISI, ILWIS includes a multicriteria decision support module that has been used for land use suitability analyses and water management. CommonGIS (developed by the Spatial Decision Support [SPADE] research team at Fraunhofer AIS, Germany) is an example of a Web-based GIS. It has a suite of visual and computational decision support tools that can be used for tackling spatial decision problems.

A large number of SDSS have been developed using a GIS as the SDSS generator. In particular, the products of the Environmental Systems Research Institute, such as ArcInfo, ArcView, and ArcGIS, have often been used as platforms for developing specific SDSS. For example, CommunityViz (a product of Placeways LLC) is a group of extensions to ArcGIS for urban planning, land use planning, and resource management applications. Spatial Group Choice, developed by a research team at the University of Idaho and the University of Washington, is an ArcView-based spatial decision support system that has been successfully used for habitat site selection, health care resource allocation, and railway transportation planning.

Many government agencies have developed SDSS to support their activities in the area of land use, transportation, and environmental planning and management. For example, the Spatially Explicit Decision Support System (SEDSS) for ecological risk assessment and restoration of the Everglades has been developed by the U.S. Geological Survey. RAISON (Regional Analysis by Intelligent Systems ON microcomputers) is an SDSS developed by Environment Canada. The Australian government, acting through the Bureau of Rural Sciences, has developed the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) to tackle land use and natural resource management problems.

TRAILMAN (Transportation and Inland Logistics Manager) is an SDSS developed for the U.S. Agency for International Development to assist in distribution of food in Africa.

Criticisms of SDSS

The concept of SDSS has been criticized on several grounds. Some critics point out that SDSS practice tends to place too much emphasis on the use of GIS as an SDSS generator and that, therefore, it does not adequately address the issues of system integration, interoperability, user information needs, and the role of context in supporting spatial decision processes. There has been a tendency to adapt the decision-making processes to the existing geographic information technologies rather than to organize the SDSS research and to develop SDSS in the context of the decision-making processes themselves. Neglecting information needs and the socio-organizational contexts of decision processes impedes the widespread use of SDSS. It also diminishes the role of SDSS as a mainstream GIScience methodology. To this end, research addressing GIS from social science/participatory perspectives has contributed to the understanding of the dynamics of spatial decision processes and their socio-organizational contexts. This broadening of the traditional technical base of GIS usage has been supplemented by advances in the area of geocomputation, geovisualization, semantic Web methodologies, and interoperable Web services. These new developments in GIScience have the greatest potential to stimulate future progress in SDSS.

Jacek Malczewski

See also Collaborative GIS; Geocollaboration; Geocomputation; GIS, Environmental Model Integration and; GIScience; GIS Design; GIS Implementation; GIS in Environmental Management; GIS Web Services; Heuristic Methods in Spatial Analysis; Internet GIS; Location-Allocation Modeling; Location-Based Services; Mobile GIS; Public Participation GIS; Resource Management, Decision Models in; Spatial Analysis; Spatial Interaction Models; Spatial Multicriteria Evaluation; Spatial Optimization Methods; Suitability Analysis



Further Readings

- Brail, R., & Klosterman, R. (Eds.). (2001). *Planning support systems*. Redlands, CA: ESRI Press.
- Densham, P. (1991). Spatial decision support systems. In D. Maguire, M. Goodchild, & D. Rhind (Eds.), *Geographical information systems: Principles and applications* (pp. 403–412). London: Longman.
- Geertman, S., & Stillwell, J. (Eds.). (2002). *Planning support systems in practice*. Berlin, Germany: Springer.
- Jankowski, P., & Nyerges, T. (2001). *Geographic information systems for group decision making: Towards a participatory geographic information science*. London: Taylor & Francis.
- Keen, P., & Scott-Morton, M. (1978). *Decision support systems: An organizational perspective*. Reading, MA: Addison-Wesley.
- Leung, Y. (1997). *Intelligent spatial decision support systems*. Berlin, Germany: Springer.
- Malczewski, J. (1999). *GIS and multicriteria decision analysis*. New York: Wiley.
- Sprague, R., & Watson, H. (1996). *Decision support for management*. Upper Saddle River, NJ: Prentice Hall.



SPATIAL ECONOMETRICS

Quantitative geographers, as well as other social scientists, use the methodological techniques of spatial econometrics to analyze data in ways that help understand how humans are interrelated with one another across different geographic areas. More specifically, researchers use spatial econometric techniques to build regression models that attempt to mathematically represent the effects of human interdependence when explaining the factors leading to the geographic distribution of a variable. Spatial econometric techniques have been applied by researchers from a wide variety of fields, such as criminology, archaeology, regional economics, election analysis, international political conflict, and real estate analysis. Common to all these fields is the use of observational data that can be mapped (or geographically

referenced) to infer interesting spatial (or geographic) associations.

Strongly associated with the fields of regional science and quantitative geography, spatial econometrics emerged in the 1970s to deal with the problems social scientists were having in estimating regression models using cross-sectional data in the presence of spatial autocorrelation. The techniques developed out of a concern that it was unrealistic to accept the spatial independence assumption of standard econometric inference, which posits that the values at any one location are unrelated to those at other nearby locations. Like time-series methods, which account for how a data-generating process may be characterized by temporal dependence across lagged time periods, spatial econometric methods were developed to account for spatial dependence across geographically lagged locations, those locations defined as being synchronically within close proximity of one another. A feature distinguishing spatial analysis from time-series analysis is that the causal associations are not unidirectional but are multidirectional.

From a methodological perspective, spatial econometrics comprises a set of techniques to incorporate spatial dependence and heterogeneity into a regression model. Luc Anselin has described the techniques of spatial econometrics as falling into four broad areas: (1) specification of how to represent different forms of spatial dependence and spatial heterogeneity in a regression model, (2) estimation of model parameters, (3) model specification tests and diagnostics of the potential presence of dependence within the data-generating process, and (4) model prediction. A key requirement of the estimation techniques of spatial econometrics is that the data be based on observations that have been geographically referenced at the time they were recorded, often as the centroids of a lattice of regions.

Functional Forms of Interdependence

The field of spatial econometrics has contributed a framework that allows social scientists a rigorous way to communicate their notions of the observed complexities of how humans in different geographic areas may be associated with one another. Spatial econometrics can be used to assess how the value of a variable in one location



depends on attributes in other locations. For example, consider the relationship between government spending and income over a geographical system, $A = \{1, \dots, n\}$.

The functional dependencies between some region i and the other L regions in the geographical system can take a variety of forms that can guide the design of a spatial regression model and, more generally, guide an understanding of differentiating between types of interdependence. Each form of functional dependency below, when estimated as a regression model, results in quantitatively different degrees of interdependence between locations, or, more technically, different spatial covariance structures.

Aspatial Process

An aspatial approach is as follows:

$$\text{Income}[i] = f(\text{Spending}[i]).$$

In this case, we model income (**Income**) in a region as being only a function of government spending (**Spending**) in the same region. If we are interested in understanding the causal relationship between government spending in other regions in spatial proximity to *region i* and income in *region i*, this aspatial model may unrealistically ignore economic externalities. As an example of the potential externalities being ignored, income benefits to *region i* can occur through government spending in neighboring regions, say from new roads or tourist facilities.

Conditional Autoregressive Process

A conditional autoregressive process can be represented as follows:

$$\text{Income}[i] = f(\text{Spending}[i], \text{Spending}[L]).$$

The dependent variable, **Income**[i], depends on both spending region i , **Spending**[i], and spending in other regions, **Spending**[L]. Spatial market externalities can be represented with this functional form. For example, a government investment by one community that helps in attracting tourists to the area will most likely also benefit the tourist industries of neighboring communities.

Spatial Lag Process

A spatial lag process can be represented as follows:

$$\text{Income}[i] = f(\text{Spending}[i], \text{Income}[L]).$$

In this case, income in one region is affected not only by government spending in the same region but also by income in other regions. An example of this process is economic growth spillovers due to interindustry linkages among associated regions.

Spatial Error Process

A spatial error process can be represented as follows:

$$\text{Income}[i] = f(\text{Spending}[i], e[i], e[L]),$$

where e denotes an error or random disturbance, capturing the effects on income that the researcher assumes cannot be empirically accounted for in a systematic way. Here, a region's income depends on the random disturbance in both that region and other regions. As an example, if we assume that e captures random disturbances to an economy such as closed roads from bad weather, then it is reasonable to infer that the shocks to one region's economy may also spill over to affect the economy of surrounding regions.

Space-Time Lag Process

Finally, a space-time lag process can be represented as follows:

$$\text{Income}[i, t] = f(\text{Spending}[L, t - 1]).$$

The term t denotes a time period, and $t - 1$ denotes the previous time period. Here, dependence occurs across both space and time, as the value of **Income** in a region i at time t now depends on spending in other regions from the previous time period.

A common methodological challenge in the specification of spatial structure in a regression is in defining a function of proximity that quantifies the variation in the degrees of influence that regions (or more generally, any set of spatially referenced objects) have on one another. The



problem of what measure to choose to approximate a theoretical concept of spatial proximity in model specification can be considered both positively, as a creative challenge, and negatively, as an unwelcome ambiguous choice. The proximity function needs to be both theoretically relevant to the study at hand and empirically feasible given the available data. For instance, the spatial proximity of two economic regions might be measured in many ways, such as the Euclidean distance between the centroids of two polygonal regional shapes, the length of their shared borders, the time duration of travel between the largest cities of two regions in an automobile, the magnitude of the commuter flows between the regions, the socioeconomic similarity of the regions, or the value of the annual commodity flows between the two regions. Hypothetically, if the objective of the modeling effort is to understand what variables are important for predicting some diffusion process, say political conflict, then using the length of the shared border of two regions may be a relevant way to measure proximity. On the other hand, if we are concerned with predicting the influence of economic growth of one region based on development in neighboring regions, then using a measure of commodity or commuter flows may be a more relevant way to weight the relative importance of the different regions. Such information relating to the spatial structure of interdependence can be represented with a spatial weights matrix, $\mathbf{W}$, whose elements, w_{ij} , can be defined using information on some prior notion of spatial proximity or association between the objects of analysis at locations i and j .

Using this spatial weights matrix, an equation can be written that describes a conditional autoregressive form of the relationship between income and government spending for a multiregional system, which can be estimated using regression:

$$\text{Income}[i] = (b_0 + b_1)\text{Spending}[i] + p\mathbf{w}_i\text{SPENDING} + e[i],$$

with $\mathbf{w}_i$ a row vector of the spatial weights matrix, $\mathbf{W}$, denoting region i 's spatial proximity to the other regions, L , in the geographical system. **SPENDING** is a one-column vector of regional spending variables that when multiplied by $\mathbf{w}_i$ gives a weighted average variable of spending in other

regions. p denotes the estimated parameter that captures the direct effect of this spatial component, $\mathbf{w}_i\text{SPENDING}$, the effect of regional spending on income within each region. The parameters b_0 and b_1 are also estimated in the regression.

Recent Developments

Spatial econometricians are currently extending the field by simultaneously accounting for both spatial and temporal dependence structures, applying spatial probit models, and using Bayesian estimation methods.

In addition, accessibility to spatial econometric techniques has recently been widened by the development of new software. Examples are Roger Bivand's Spdep module for the R open-source statistical package, Luc Anselin's Geoda software, Sergio Rey's open-source STARS package, and Jim LeSage's Spatial econometric toolbox for Matlab. The development of open-source computational tools for the application of spatial econometric methods can be thought of as a way to increase the transparency of such modeling choices for the scientific community.

In recent years, the application of spatial econometric methods has increased. This trend may be attributable to various intellectual and practical factors. There may be a more widespread understanding of the mathematical representations of spatial structure. There may be an increased wave of curiosity, with a broader basis than spatial econometrics, to explore how conventional statistical approaches that ignore human interdependence may be biasing our inferences on aggregate human behavior. In a practical sense, the growing popularity of GIS among social scientists may have also eased the challenge of defining and testing various types of spatial proximity functions, piquing the interest of researchers to explore how spatial effects may play a role in obtaining cross-sectional regression results at a minimal cost.

Criticisms of Spatial Econometrics

In human geography, spatial econometrics can be thought of as being located on the far edge of the quantitative side in the quantitative versus qualitative methodological divide. Spatial econometrics' language of rigorous, formal mathematical logic



may be thought of as a deterrent to the understanding of the results of its research applications by those outside the field. Since a significant portion of the substantive problems that spatial econometrics is applied to deals with social welfare issues such as regional economic growth, urban crime patterns, and international conflict, its models have been criticized as being overly complex to interpret by other geographers. At the same time, such a modeling approach can also be thought of as a new way to complement, rather than compete with, more intuitive approaches, such as visually observing patterns in choropleth maps, which geographers have traditionally used to infer spatial associations and to describe new models.

In a sense, the rejection of the spatial independence assumption, a cornerstone of the field of spatial econometrics, comes at the cost of increased analytical complexity. In another sense, the field of spatial econometrics can be credited with advancing the frontiers of how applied researchers confront empirical problems, attempting new and innovative ways to link regression modeling with theoretical knowledge of spatial processes to model complexities of the human landscape that may have previously been ignored or considered intractable.

Boris Dev

See also Anselin, Luc; Bayesian Statistics in Spatial Analysis; Ecological Fallacy; Error Propagation; Geocomputation; Geographically Weighted Regression; Geostatistics; GIScience; Models and Modeling; Quantitative Methods; Regional Science; Point Pattern Analysis; Spatial Analysis; Spatial Autocorrelation; Spatial Data Models; Spatial Data Structures; Spatial Decision Support Systems; Spatial Optimization Methods; Spatial Statistics

Further Readings

- Anselin, L. (2001). Spatial econometrics. In B. Baltagi (Ed.), *A companion to theoretical econometrics* (pp. 310–330). Oxford, UK: Blackwell.
- Anselin, L. (2002). Under the hood: Issues in the specification and interpretation of spatial regression models. *Agricultural Economics*, 27, 247–267.

- Anselin, L. (2003). Spatial externalities, spatial multipliers and spatial econometrics. *International Regional Science Review*, 26, 153–166.
- Anselin, L. (2007). Spatial econometrics in RSUE: Retrospect and prospect. *Regional Science and Urban Economics*, 37(4), 450–456.
- Anselin, L., & Griffith, D. (1988). Do spatial effects really matter in regression analysis? *Papers, Regional Science Association*, 22, 509–536.
- Anselin, L., & Rey, S. (1997). Introduction to the special issue on spatial econometrics. *International Regional Science Review*, 20, 1–7.
- Cliff, A., & Ord, J. (1981). *Spatial processes: Models and applications*. London: Pion.
- Rey, S., & Anselin, L. (2007). PySAL: A Python library of spatial analytical methods. *Review of Regional Studies*, 37(1), 5–27.



SPATIAL FIX

The term *spatial fix* is embedded in Marxian thinking, which emerged in geography in the early 1970s. It is closely associated with the pioneering work of David Harvey on the historical geography of industrial capitalism. The spatial fix depicts the inherent contradictory nature of capitalism, which has explicit geographical dimensions. First, the spatial fix reflects the intrinsic need of capital to spread out over space in order to overcome its inherent crises of overaccumulation; second, it means securing and deepening a presence in specific locations as a result of built-up investments over time. It has become an important notion within Marxist-influenced human geography and has been applied in a variety of different contexts.

The Spreading Out of Capital

The most acute, persistent problem in industrial capitalism, a falling long-term rate of profit, is linked to overaccumulation crises, a condition in which too much capital is produced relative to opportunities for profitable use for it. In essence, Marxist economics, centered on the labor theory of value, holds that capitalism has a built-in tendency



to produce too much, causing declines in prices and thus profits. In this context, the *spatial fix* has a metaphorical meaning. The term describes capitalism's voracious drive to resolve its inner crisis tendencies through geographical expansion (i.e., finding new markets) and subsequent geographical restructuring. In some sense, it means changing the spatial distribution of factories, investments, and employment by spatial mobility. Spreading out is conceived as a useful mechanism to lessen and delay the negative impacts of economic restructuring by absorbing excess capital.

Integrating additional territories into the circuits of capitalism plays a role in alleviating difficulties. Several spatial scales exist over which capital is spread. At the metropolitan level, suburbanization has been the archetypal spatial fix, as low-cost mortgages and highway systems have propelled the demand for cars and numerous appliances. This process resulted in an increasing tendency for firms and people to move away from declining central cities to emerging new communities. On the global scale, imperialism and colonialism were potential solutions to the internal contradiction of capitalism by spreading out to fresh spaces for accumulation. Recent improvements in communications and transportation make investment flows speedier and cheaper, and globalization is the contemporary version of capitalism's search for a spatial fix to its crisis tendencies. A crisis of overaccumulation in a particular region may lead to the export of capital and labor surpluses to new territories to start up new production there, generating new rounds of uneven development. Surpluses of capital and shortages of labor are swept either by the movement of capital to areas of labor surpluses or by the import of cheap labor into centers of capitalist development. A widespread strategy of many multinational firms has been to relocate factories and production to sites with lower production costs in developing or less developed countries.

The spatial fix was the geographical solution for the inherent problems of capitalism in a loosely connected world. In the long run, however, as global interconnectedness becomes more prevalent, overaccumulation crises are more difficult to postpone on the global scale, so they intensify. By employing the strategy of geographical expansion, capitalism, according to David

Harvey (1985), buys "time for itself out of the space it conquers" (p. 60); nonetheless, this annihilation of space with time cannot go on indefinitely, nor can the spread of conditions for crisis formation over ever-wider spheres be avoided.

Grounded Capital and the Built Environment

Despite a relentless desire to move around the globe, capital investment tends to flow into well-established sites of capital accumulation. The production of urban space and built environment is pursued through switching capital from direct production (primary circuit) to urban infrastructure and technology and human capital (secondary and tertiary circuits). Taking this view, Harvey suggested that in the long run, in the absence of profitable investments in the primary circuit of capital accumulation, capital will flow into the secondary circuit, where it is deployed in the production of the built environment.

Mobility in itself is not sufficient for facilitating capital movement, so ever-growing expansion often depends on the advantages of geographical stability. To function effectively, immovable structures are necessary for the reduction of the cost of moving across space. This type of spatial fix is achieved through securing investment in space in the form of office buildings and communication networks, for example, creating a new environment suitable for capital accumulation. Each form of geographical mobility of capital requires fixed and secure spatial infrastructures. Therefore, a certain portion of capital has to be fixed in place (land and other built forms) for a relatively long period of time; existing urban centers and production capacities serve as the basis for new investments. Eventually, space built for a certain period of time has to be destroyed to make way for a new spatial fix at a later point in time. Profound economic restructuring such as the transition from mass production systems (Fordism) to flexible production (post-Fordism) may result in the obsolescence of the built environment in older industrial cities, forcing capital to seek alternative spatial outlets. In other cases, continuous investment of capital in the built environment strengthens established nodes, which have enjoyed decades of investment in urban infrastructure of all kinds. Despite suburbanization, the central



business district (CBD) is still an important node in the metropolitan area, and this is partially attributed to the entrenched qualities of its built environment. On the global scale, world, or global, cities such as London, New York, Tokyo, and Paris, with their built corporate complexes, stock exchanges, and highly developed telecommunication and transportation networks, are fixed at the top of the global urban hierarchy.

Igal Charney

See also **Built Environment; Business Cycles and Geography; Circuits of Capital; Globalization; Harvey, David; Infrastructure; Marxism, Geography and; Smith, Neil; Space of Flows; Relative/Relational Space; Suburbs and Suburbanization; Time-Space Compression; Uneven Development**

Further Readings

- Brenner, N. (1998). Between fixity and motion: Accumulation, territorial organization, and the historical geography of spatial scales. *Environment and Planning D: Society and Space*, 16, 459–481.
- Glassman, J. (2007). Recovering from crisis: The case of Thailand's spatial fix. *Economic Geography*, 83, 349–370.
- Harvey, D. (1982). *The limits to capital*. Oxford, UK: Blackwell.
- Harvey, D. (1985). *The urbanization of capital*. Oxford, UK: Blackwell.
- Harvey, D. (2001). Globalization and the spatial fix. *Geographische Revue*, 2, 23–30.
- Schoenberger, E. (2004). The spatial fix revisited. *Antipode*, 36, 427–433.

some respects relevant to the human sciences. Inequality is most commonly explained with reference to genetic predisposition, individual action, and social forces, or some combination of the three that leads to disparities between two or more unequal individuals or groups. The means of quantifying inequality are often quite sophisticated and are consistently used to analyze the development of a given group relative to its own past and relative to the situation of others within a specific time frame.

Spatial inequality is a particular form of inequality. Inequality is more generally the study of “who gets what and why.” Adding a spatial characteristic means integrating an element of “where,” enriching the concept by seeking to explain how social, political, economic, and cultural discrepancies relate not only to ideas, structure, and agency but also to the specific attributes of space in the material world. Spatial inequality is a concept that seeks to explain and illustrate discrepancies among populations regarding outcomes, conditions, and/or opportunities across different spaces and spatial scales. It shows inequality in terms of different spatially located demographics and their relationship to a given set of variables.

Spatial inequality occurs for a number of reasons, including the formation and operation of class; racism and/or prejudice toward cultural, ethnic, or minority groups; and other discriminative views and practices (e.g., based on gender, religion, age, or sexuality). Equally important, however, is a clustering among socioeconomic lines, which is a general feature of spatial inequality. Figure 1 shows the level of intra- and intercountry economic disparity among four countries. Economic disparities are a useful and common way of measuring inequality. The graphic shows that while Brazil's richest people are as rich as those of France, its poorest are poorer than the poorest in rural Indonesia. Clearly, this kind of analysis is useful in understanding the massive discrepancies on two different spatial scales, in this case national and global.

Spatial inequality can also be considered in terms of the unequal distribution in goods or services depending on an area or location. Inequality in services, for instance, means that the provision of medical aid or education will differ among spaces. Figure 2 shows the results of a study that found a correlation between nonattendance rates



SPATIAL INEQUALITY

The study of inequality seeks to analyze the causes, contexts, conditions, and outcomes of disparities between two or more groups over a given number of variables. It differs from a study of difference insofar as the former assumes a quantifiable progression from worse off to better off in

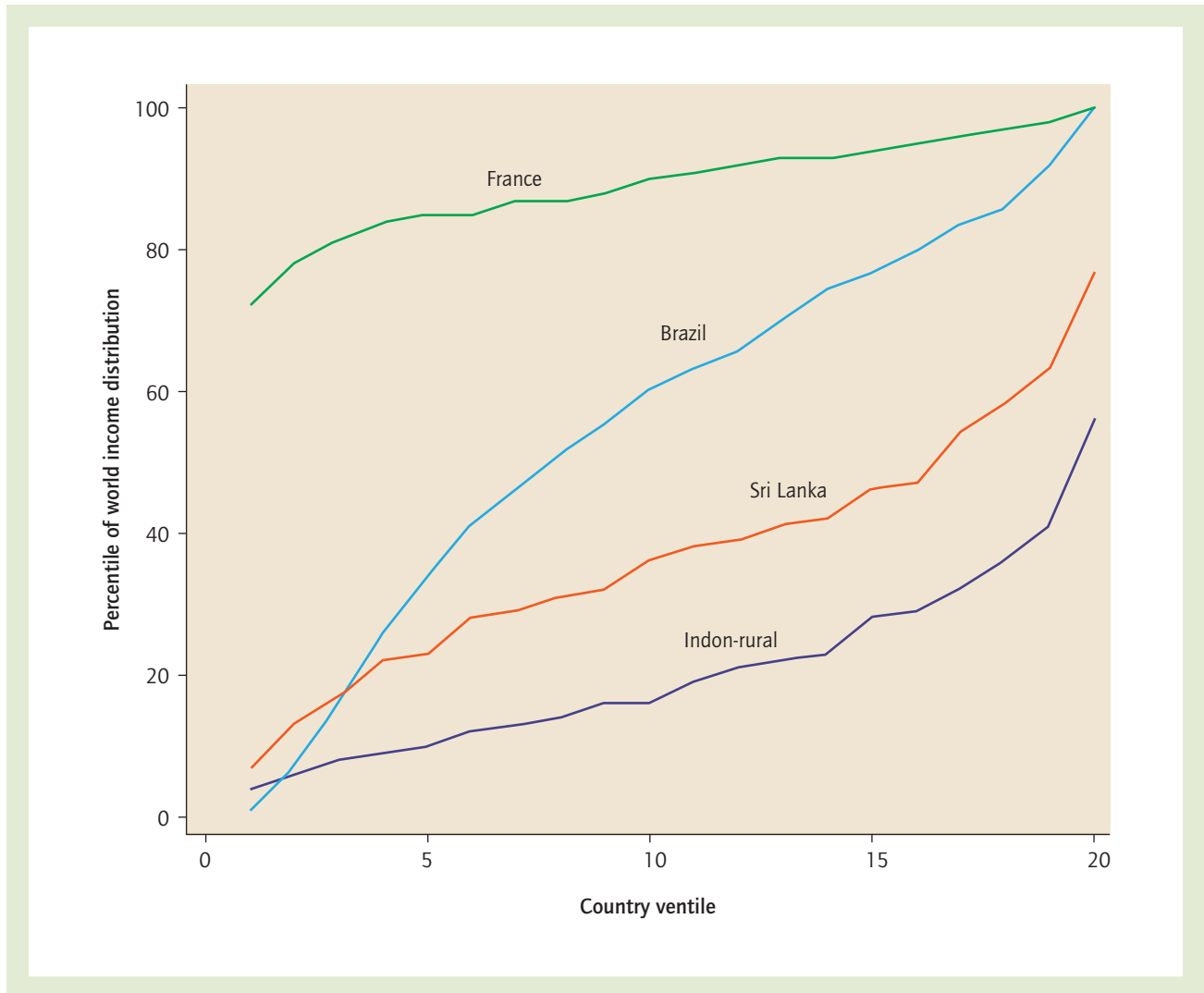


Figure 1 World income distribution by percentile across four countries, 2005

Source: Malanovic, B. (2006). Global income inequality: What it is and why it matters. *World Economics*, 7(1), 19.

and school densities in counties in Gansu province, China. The map shows that counties with a relatively weak density of lower-secondary schools have a higher girls' nonschooling rate than counties with high densities of lower-secondary schools. This study demonstrates that the longer the distance from schools, the higher the opportunity cost of acquiring education and the greater the gender disparities in the school attendance rate.

Spatially, inequality can be examined globally, regionally, nationally, and locally. It can be measured between the global North and the global South, between Asia and North America, between

the United States and China, or between New York and Shanghai. Within countries, spatial inequality studies can evaluate the difference in outcome, condition, and/or opportunity on an interurban scale (e.g., New York vs. San Francisco), an intra-urban scale (e.g., the Lower East Side vs. Harlem), an urban-rural scale (e.g., the Atlantic Northeast vs. the Midwest), and a rural-rural scale (e.g., Appalachia vs. the Midwest). Many other scales are also open to comparison in studies of spatial inequality. Figure 3 shows an example of intraprovincial spatial inequality. We can observe the disparity between per capita

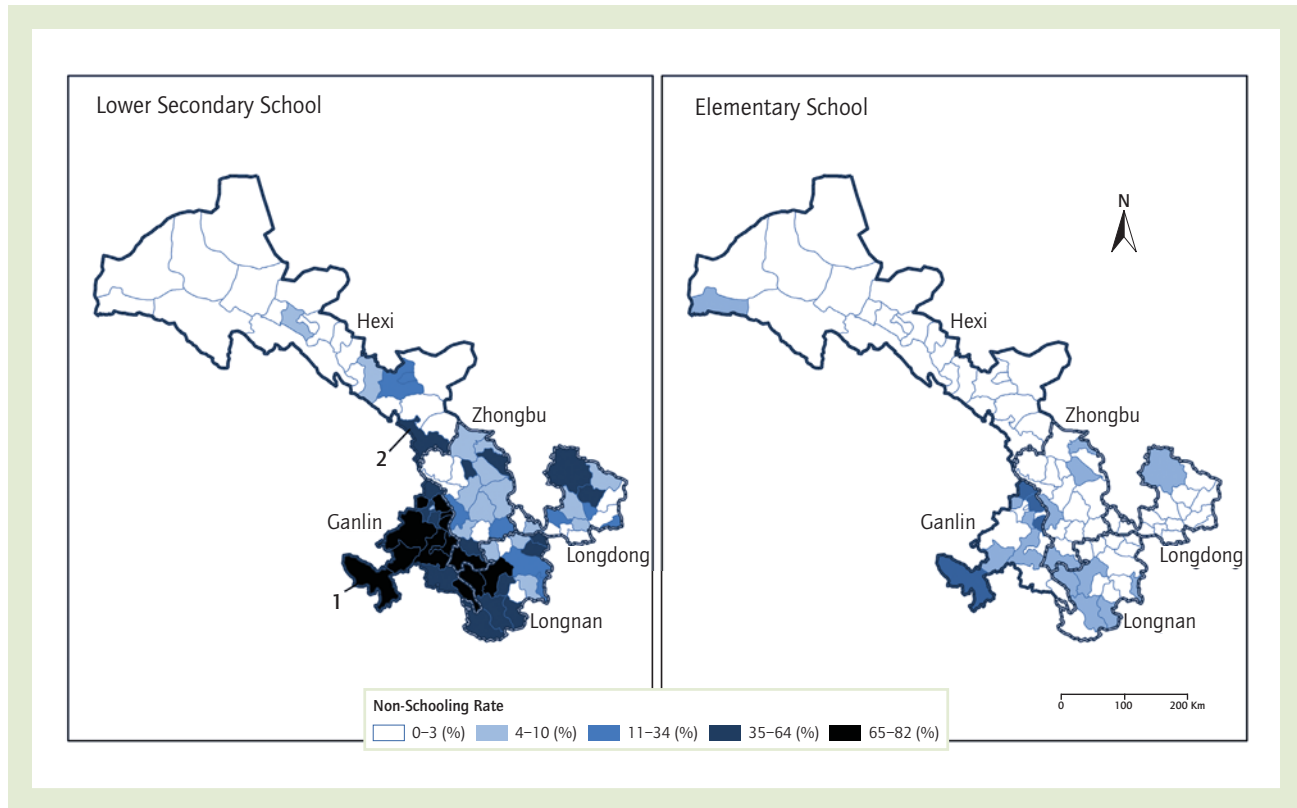


Figure 2 Spatial distribution of girls' nonschooling rates and density of lower-secondary schools in Gansu, China, 2000

Source: Cao, H. (2008). Spatial inequality in children's schooling in Gansu, Western China: Reality and challenges. *Canadian Geographer*, 55(3), 346.

income in Kolkata and in other districts of West Bengal in 2004–2005. No other district in the province had a per capita income that was even half that of Kolkata, not even those that are contiguous to or located near the capital. More than half the districts had per capita incomes of around one third (or less) that of West Bengal's capital. It should also be noted that for almost every district, the per capita income gap with respect to Kolkata has actually widened since 1999–2000, indicating that the recent pattern of economic growth has accentuated spatial inequalities within the state.

Studies of spatial inequality are well suited to representing the dynamic process of change across different spatial scales. They can offer a more nuanced perspective of migratory patterns, remittances, and the impact of global and national flows of capital, goods, and services on local, regional, and national demographics. Spatial inequality is a

useful focus for mapping migrants or the dynamics of slum settlements as they relate to increasing urbanization in the global South and the processes of change of large metropolitan cities such as gentrification and redevelopment. Figure 4 demonstrates the relationship between income discrepancies and slum population in a number of countries in the global South. As an example of spatial inequality, it is successful in demonstrating the linkages between national and local spatial scales through a common pattern of economic outcomes. For instance, Sierra Leone has both the highest income ratio and the highest population of slum dwellers as a proportion of its urban population. The correlation does not hold across all countries, however, as Honduras has high income inequality but a low percentage of slum dwellers.

Studies of the spatial differentiation of outcomes, conditions, and opportunities between

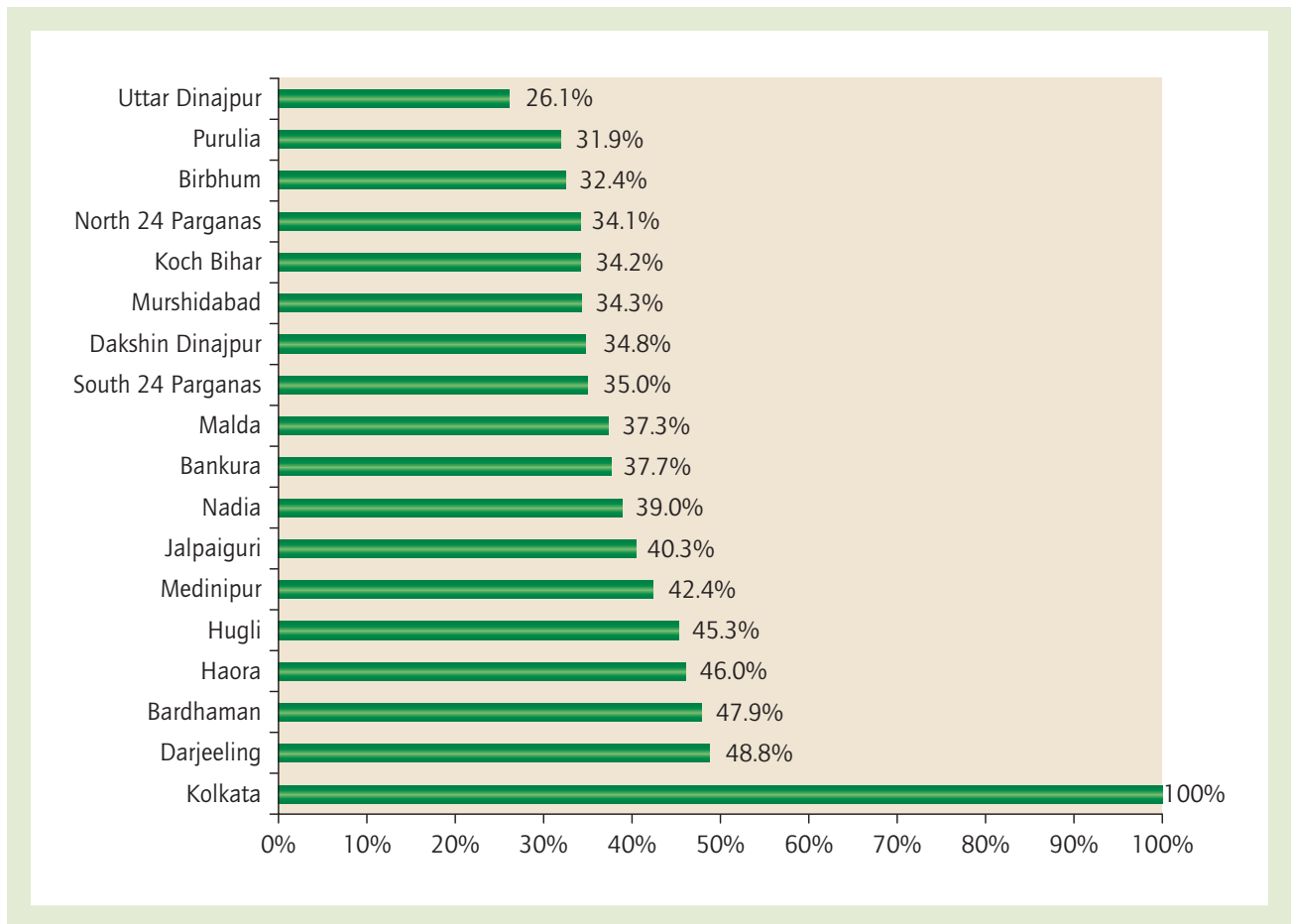


Figure 3 Per capita income in West Bengal districts, India, as a percentage of Kolkata's in 2004–2005

Source: Adapted from Chandrasekhar, C. P., & Ghosh, J. (2008, May 12). Recent growth in West Bengal (Table 2). *MacroScan*. Retrieved January 19, 2010, from www.macrosan.org/fet/may08/fet120508West_Bengal.htm.

different demographics are applicable to every field of study in the human sciences. The use of such a method of study arose out of a need to address the spatial dynamics of change that occur in tandem with economic and political changes and shifts in the cultural and social outlook among populations. Recent spatial inequality research has sought to study spatial inequality for manufacturing wages in five countries in Africa and the process of peri-urbanization in Albania, among others. Table 1 shows some unmet basic needs for urban and rural Albania as well as for the capital, Tirana, demonstrating a clear urban bias, which becomes more pronounced for the capital. Tirana clearly acts as a hub of social and economic activity, to which the provision of social goods is a response.

Studies of spatial inequality have developed rigorous methodologies for mapping the discrepancies of different variables across demographics in different spaces and at differing spatial scales. Methodologically, they are strongly related to quantitative analysis, which has been aided by the development of geographic information systems (GIS).

The study of spatial inequality can be constrained by the ability of the researcher to amass data relevant to both a given spatial scale and the variable(s) being studied. For example, large-scale surveys, particularly in poor countries, are not always a reliable source of information. Moreover, the breadth of studies of spatial inequality risks revolving primarily around studies that relate to economic well-being, when inequality

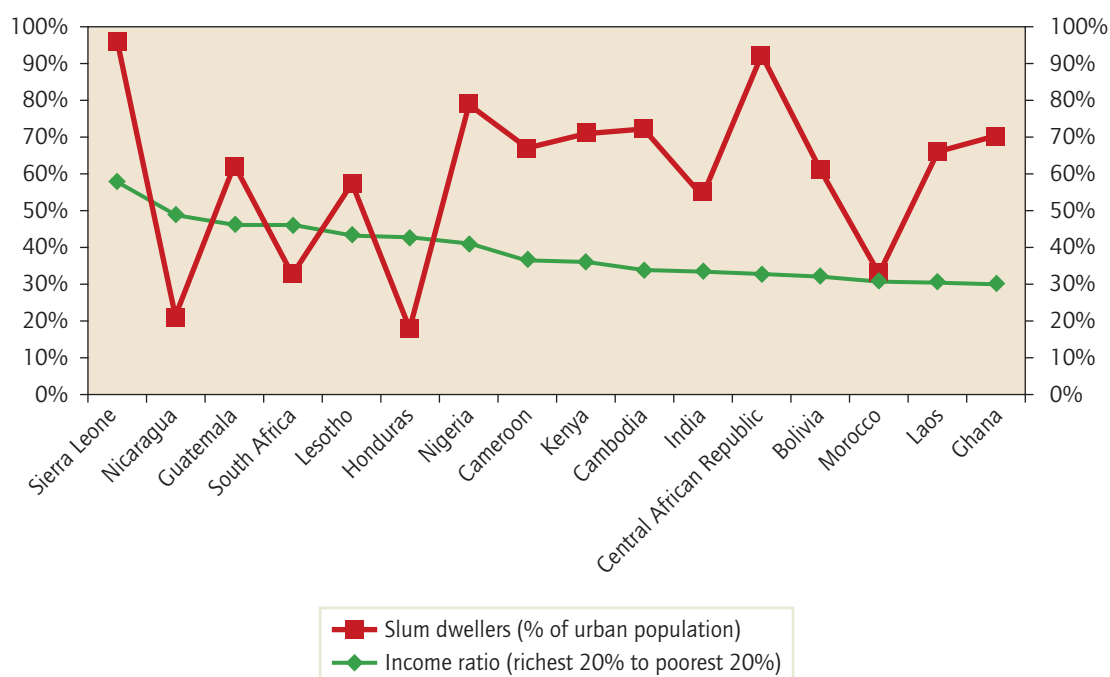


Figure 4 Income ratio relative to slum population in 16 countries in the global South, 2006

Source: Adapted from Hall, P. (2007). Urban land, housing, and transportation: The global challenge. *Global Urban Development*, 3(1), 6, Table 3.

	<i>Tirana</i>	<i>Albania</i>		
		<i>Urban</i>	<i>Rural</i>	<i>Total</i>
1. Inadequate water and sanitation	0.5	2.6	28.6	17.5
2. Inadequate housing	8.5	6.3	16.5	12.5
3. Inadequate energy supply	1.7	9.0	18.1	13.5
4. Crowding (more than three persons/room)	10.3	15.6	18.6	16.7
5. Education (household heads with primary or less education)	34.7	47.0	74.8	61.2
Poor (two or more UBN)	11.5	16.6	47.2	33.8
Extremely poor (three or more UBN)	2.3	3.2	18.3	11.9
Nonpoor (one or no UBN)	88.5	83.4	52.9	66.2

Table 1 Comparative indicators of unmet basic needs (UBN) in Albania, 2003

Source: Deda, L., & Tsenkova, S. (2006). Poverty and inequality in Greater Tirana: The reality of peri-urban areas. In S. Tsenkova & Z. Nedović-Budić (Eds.), *The urban mosaic of post-socialist Europe: Space, institutions and policy* (pp. 151–170). Heidelberg, Germany: Physica.



may reflect an underlying bias that resides more in geographical, social, or cultural predilections than in overt political or economic exclusion or weakness. Thus, qualitative studies of spatial inequality should be used to place the results gleaned from research into a larger context of human activity and geographic space using various theoretical models.

Huhua Cao

See also **Colonialism; Dependency Theory; Development Theory; Ethnic Segregation; Ghetto; Inequality and Geography; Justice, Geography of; Poverty; Race and Racism; Racial Segregation; Segregation and Geography; Social Justice; Underdevelopment; Uneven Development; Urban Underclass; World-Systems Theory**

Further Readings

- Cao, H. (2008). Spatial inequality in children's schooling in Gansu, Western China: Reality and challenges. *Canadian Geographer*, 55(3), 331–350.
- Chakravorty, S. (2005). *Fragments of inequality: Social, spatial, and evolutionary analyses of income distribution*. Oxford, UK: Routledge.
- Chandrasekhar, C. P., & Ghosh, J. (2008). Recent growth in West Bengal. *MacroScan*. Retrieved January 19, 2010, from www.macrosan.org/fet/may08/fet120508West_Bengal.htm
- Deda, L., & Tsenkova, S. (2006). Poverty and inequality in Greater Tirana: The reality of peri-urban areas. In S. Tsenkova & Z. Nedović-Budić (Eds.), *The urban mosaic of post-socialist Europe: Space, institutions and policy* (pp. 151–172). Heidelberg, Germany: Physica.
- Hall, P. (2007). Urban land, housing, and transportation: The global challenge. *Global Urban Development*, 3(1), 1–11.
- Kanbur, R., & Venables, A. (2005). *Spatial inequality and development*. Oxford, UK: Oxford University Press.
- Lobao, L., Hooks, G., & Tickamyer, A. (2007). *The sociology of spatial inequality*. New York: State University of New York Press.
- Lobao, L., & Saenz, R. (2002). Spatial inequality and diversity as an emerging research area. *Rural Sociology*, 67, 497–511.

- Milanovic, B. (2006). Global income inequality: What it is and why it matters. *World Economics*, 7(1), 1–35.
- Tickamyer, A. (2000). Space matters! Spatial inequality in future sociology. *Contemporary Sociology*, 29(6), 805–813.
- Willem te Velde, D., & Morrissey, O. (2005). Spatial inequality for manufacturing wages in five African countries. In R. Kanbur & A. Venables (Eds.), *Spatial inequality and development* (pp. 349–378). Oxford, UK: Oxford University Press.



SPATIAL INTERACTION MODELS

The interest in spatial interaction models is motivated by the need to understand and explain flows of people, commodities, capital, information, or even knowledge across geographic space. By adopting a spatial interaction modeling perspective, attention is focused on interaction patterns at the aggregate rather than the individual level. The basis of modeling is the use of a discrete zone system. Discrete zone systems can obviously take many different forms, in relation to both the level of resolution and the shape of the zones. But quite often, one is forced to use administratively defined regions, such as statistical enumeration areas or the wards of a city. The level of resolution used in the spatial interaction model is in part determined by the discrete zone system.

Spatial interaction models recognize three types of factors to explain the mean interaction frequencies between the origin and destination zones of interaction:

1. Origin-destination variables that characterize the way in which spatial separation of origins from destinations constrains or impedes the interaction
2. (Origin-specific) attributes that characterize the ability of the origins to produce or generate flows
3. (Destination-specific) attributes that represent the attractiveness of destinations



Suppose we have a spatial system consisting of n zones. Let i denote the origin ($i = 1, \dots, n$) and j the destination zone ($j = 1, \dots, n$) of interaction. Then, spatial interaction models may be described as those models that assert a multiplicative relationship between mean interaction frequencies and the effects of origin, destination, and separation variables. The basic form of the spatial interaction model may be expressed—mathematically—as

$$T_{ij} = CA(i)B(j)S(d_{ij}), \quad i, j = 1, \dots, n, \quad (1)$$

where T_{ij} represents the mean interaction frequency from i to j ; C denotes a constant term; $A(\cdot)$ and $B(\cdot)$ are some origin and destination weight functions that involve origin and destination attributes, respectively; $S(\cdot)$ is some distance deterrence function that is hypothesized to summarize all effects of space on interactions; and d_{ij} denotes the spatial separation from i to j . At relatively large scales of geographical inquiry (such as the country scale), this might simply be the straight line (Euclidean) distance separating an origin from a destination. In other cases (such as the regional or urban scales), it might be the travel time, cost of travel, or any other sensible measure of the separation of origins and destinations.

The exact functional form of the three terms on the right-hand side of Equation 1 is subject to varying degrees of conjecture. There is wide agreement that the origin and destination weight functions are generally best given by the power functions

$$A(i) = (a_i)^\alpha \quad (2a)$$

and

$$B(j) = (b_j)^\beta, \quad (2b)$$

where a_i represents an appropriate variable measuring the propulsiveness of i and b_j an appropriate variable measuring the attractiveness of j in a specific spatial interaction context. The exponents α and β are parameters to be estimated.

The distance deterrence function constitutes the very core of spatial interaction models. Hence, a number of alternative specifications of $S(\cdot)$ have been proposed in the literature. But the negative

exponential function is a popular choice (with theoretical relevance from a behavioral viewpoint)

$$S(d_{ij}) = \exp(-\theta d_{ij}), \quad (3)$$

where θ may be interpreted as a distance sensitivity parameter that has to be estimated. As d_{ij} increases, $\exp(-\theta d_{ij})$ decreases. It decreases faster the larger the value of θ becomes.

From a practical viewpoint, it may be convenient to extend the exponential specification (Equation 3) to the multivariate case

$$S(d_{ij}) = \exp \left[\sum_{k=1}^K \theta_k d_{ij}^{(k)} \right], \quad (4)$$

which provides a flexible representational framework for analyzing different types of spatial separation, such as the effects of geographical distance, border, and cultural and language barriers. $d_{ij} = (d_{ij}^{(k)} : k \in K)$ and $\theta = (\theta_k : k \in K)$, where K denotes the number of separation measures. This multivariate exponential specification of the spatial deterrence function leads to the well-known class of exponential spatial interaction models

$$T_{ij} = C(a_i)^\alpha (b_j)^\beta \exp \left[- \sum_{k=1}^K \theta_k d_{ij}^{(k)} \right]. \quad (5)$$

Fitting models of this type to observed data is a question of estimating the unknown parameters α , β , θ_k and the constant term. It is tempting to take logarithms of both sides of Equation 5 and write it in a linear form as

$$\log T_{ij} = \log C + \alpha \log a_i + \beta \log b_j - \sum_{k=1}^K \theta_k d_{ij}^{(k)} \quad (6)$$

and then proceed to estimate parameters by using ordinary least squares regression of the observation, say t_{ij} , on a_i , b_j , and $d_{ij}^{(k)}$ for $k = 1, \dots, K$. But such an approach suffers from two major shortcomings.

First, it cannot be guaranteed that the predicted flows when summed by rows or columns will necessarily have the property to match the observed totals leaving the origins i ($i = 1, \dots, n$) or terminating at destinations j ($j = 1, \dots, n$) in the given spatial interaction system. If the outflow totals for each origin zone and/or the inflow totals into



each destination zone are known a priori, then the log-linear regression model (Equation 6) would need to be modified to incorporate the explicitly required constraints to match the exact totals. Imposing origin and/or destination constraints leads to production-constrained, attraction-constrained, and production/attraction-constrained spatial interaction models that may be convincingly justified using entropy-maximizing methods.

Second, estimating the model parameters by ordinary least squares regression would be only justified statistically if the flows T_{ij} were independent and log-normally distributed about their mean value with a constant variance. This assumption is apparently not valid, since flows are discrete counts whose variance is very likely to be proportional to their mean value. Thus, ordinary least squares regression estimates and their standard errors can be seriously distorted.

For these reasons, spatial interaction models should not be estimated by an unconstrained log-linear regression. Maximum likelihood parameter estimation under more realistic distributional assumptions is generally more suitable. The most common assumption is that the T_{ij} values follow independent Poisson distributions with expected values $E[T_{ij}] = CA(i)B(j)S(d_{ij})$. This assumption is also open to question, since flows are not strictly independent. Moreover, a Poisson distribution may not adequately reflect the degree of variation present in the given data set if, for example, in migration contexts, individuals tend to flow in groups rather than as individuals. Nevertheless, this assumption is generally considered to lead to reasonable parameter estimates (see Bailey & Gatrell, 1995, for more details).

Neural spatial interaction models represent the most recent innovation in the design of spatial interaction models. These models are receiving increasing attention in recent years because of their powerful universal approximation properties. The interested reader may consult Fischer and Reismann (2002), who discuss some major principles of a methodology that enables one to efficiently use neurocomputing techniques for modeling complex spatial interaction phenomena at any level of spatial resolution.

Manfred M. Fischer

See also **Agent-Based Models; Complex Systems Models; Gravity Model; Location-Allocation Modeling; Migration; Mobility; Models and Modeling; Network Data Model; Spatial Data Models; Spatial Optimization Methods; Transportation Geography**

Further Readings

- Bailey, T. C., & Gatrell, A. C. (1995). *Interactive spatial data analysis*. Essex, UK: Addison Wesley Longman.
- Fischer, M. M., & Reggiani, A. (2004). Spatial interaction models: From the gravity to the neural network approach. In R. Cappello & P. Nijkamp (Eds.), *Urban dynamics and growth* (pp. 319–346). Amsterdam: Elsevier.
- Fischer, M. M., & Reismann, M. (2002). A methodology for neural spatial interaction modeling. *Geographical Analysis*, 34(3), 207–228.
- Fotheringham, A. S., & O'Kelly, M. (1989). *Spatial interaction models: Formulations and applications*. Dordrecht, Netherlands: Kluwer Academic.
- Sen, A., & Smith, T. E. (1995). *Gravity models of spatial interaction behavior*. Berlin, Germany: Springer.

SPATIAL INTERPOLATION

Geographic information is collected to support scientific investigations and decision making in a wide variety of domains (e.g., ecology, environmental engineering and science, geography, geosciences, public health, and social sciences). Spatial interpolation, one of the most widely used spatial analysis methods, is often integrated within geographic information systems (GIS) to estimate unknown or unavailable information associated with locations of interest based on collected information. Spatial interpolation is described in most of the textbooks in GIS and spatial analysis. This entry provides a concise but comprehensive review of spatial interpolation methods with a focus on the computation of spatial interpolation.

Taxonomy

Spatial interpolation methods can be developed based on different assumptions, purposes, and



evaluations. These methods exploit Tobler's (1970) famous first law of geography: "Everything is related to everything else, but near things are more related than distant things" (p. 236). For example, local perspectives for interpolation often assume positive spatial autocorrelation, while global perspectives tend to find trend surfaces across the entire space being considered. Spatial interpolation also depends on the type of spatial entities (e.g., point and area) where measurements are made and estimations drawn. The difference between point and area entities contributes to the distinction between point-based and areal interpolation methods, developed for the purposes of different applications such as point-based temperature surface interpolation and the areal interpolation of population characteristics between different areal units (e.g., census tracts and blocks). Consistent with the general concept of interpolation, spatial interpolation is often assessed by whether an interpolated value matches a given sample (i.e., exact interpolation) or not (i.e., approximate interpolation).

Another way to classify spatial interpolation focuses on whether statistical properties are addressed. Deterministic interpolation (e.g., inverse distance weighted, referred to as IDW) does not incorporate consideration of the randomness and probability of spatial variables, while geostatistical interpolation (e.g., kriging) does. A particular spatial interpolation method may take deterministic or geostatistical approaches, hold local or global perspectives, tailor to be point based or areal, and produce approximate or exact outcome. These various aspects of taxonomy are often combined with each other and integrated with additional dimensions (e.g., temporal) based on application requirements and the constraints of computational tractability, leading to many kinds of spatial interpolation techniques and algorithms.

Computation

Computation of spatial interpolation is often intensive for sizable data sets, and thus, high-performance computing environments based on parallel and distributed processing have been employed to enable large-scale interpolation. For example, the IDW interpolation has been extensively studied to improve the performance of computation required to find the nearest neighbors on which calculations

are based. To find nearest neighbors is a well-defined computation problem—formally called *k*-nearest neighbor search—that is notoriously computationally intensive. Various IDW interpolation algorithms have been developed based on parallel and distributed computing architectures. Most of these algorithms exploit the spatial distribution characteristics of data sets to resolve the computational intensity of *k*-nearest neighbor search.

Another example of computationally intensive spatial interpolation is Bayesian kriging, which provides realistic estimation of interpolation error and is able to combine information from disparate sources. However, Bayesian kriging based on Markov chain Monte Carlo (MCMC) methods poses even more significant computational challenges than classical kriging. Both require linear algebra operations that are computationally intensive when the number of measurement locations is large. Because an MCMC sampler typically must be run for thousands of iterations, each requiring numerous operations, the run time for sequential Bayesian kriging algorithms quickly becomes unacceptable. Even with parallel MCMC algorithms running on single high-performance computers, run times may be in the range of several hours, especially for vast geographic data sets. Therefore, the emerging cyberinfrastructure provides an ideal platform to develop parallel MCMC algorithms for Bayesian kriging by taking advantage of dynamically configurable computer resources.

As the size of individual spatial data sets continues to increase, driven by application requirements and enabled by advanced geospatial technologies, the computation of spatial interpolation must be scalable to the sheer size of data sets through the efficient use of cyberinfrastructure. A theoretical approach—spatial computational domain—has been demonstrated to capture the spatial characteristics of an IDW method to satisfy computational requirements for interpolating sizable data sets based on the efficient use of cyberinfrastructure, while the design of this approach is extensible enough to resolve the computational intensity of other spatial interpolation methods.

Shaowen Wang

See also **Analytical Operations in GIS; Bayesian Statistics in Spatial Analysis; Data Querying in GIS;**



Exploratory Spatial Data Analysis; Geographic Information Systems; Geographically Weighted Regression; Point Pattern Analysis; Spatial Autocorrelation; Spatial Data Mining; Spatial Data Models; Spatial Data Structures; Spatial Econometrics; Spatial Optimization Methods; Spatial Statistics; Usability of Geospatial Information

Further Readings

- Armstrong, M. P., & Marciano, R. J. (1997). Massively parallel strategies for local spatial interpolation. *Computers & Geosciences*, 23(8), 859–867.
- Burrough, P. A., & McDonnell, R. A. (1998). *Principles of geographical information systems*. Oxford, UK: Oxford University Press.
- Cowles, M. K., & Zimmerman, D. L. (2003). A Bayesian space-time analysis of acid deposition data combined from two monitoring networks. *Journal of Geophysical Research, Atmospheres*, 108(D24), 9006, STS13.1–STS13.9.
- Hodgson, M. E. (1989). Searching methods for rapid grid interpolation. *The Professional Geographer*, 41(1), 51–61.
- Lam, N. (1983). Spatial interpolation methods: A review. *The American Cartographer*, 10(2), 129–149.
- Tobler, W. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography*, 46(2), 234–240.
- Wang, S., & Armstrong, M. P. (2003). A quadtree approach to domain decomposition for spatial interpolation in Grid computing environments. *Parallel Computing*, 29(10), 1481–1504.
- Wang, S., & Armstrong, M. P. (2009). A theoretical approach to the use of cyberinfrastructure in geographical analysis. *International Journal of Geographical Information Science*, 23(2), 169–193.
- Wang, S., & Liu, Y. (2009). TeraGrid GIScience Gateway: Bridging cyberinfrastructure and GIScience. *International Journal of Geographical Information Science*, 23(5), 631–656.
- Yan, J., Cowles, M. K., Wang, S., & Armstrong, M. P. (2007). Parallelizing MCMC for Bayesian spatiotemporal geostatistical models. *Statistics and Computing*, 17(4), 323–335.



SPATIALIZATION

Spatialization is the transformation of high-dimensional data into lower-dimensional geometric representations on the basis of computational methods and spatial metaphors. Its aim is to enable people to discover patterns and relationships within complex, n -dimensional data while leveraging existing perceptual and cognitive abilities. Spatialization can be applied to various types of data, from numerical attributes to text documents and imagery.

Spatial Metaphors

The main cognitive underpinning of spatialization lies in the extensive use of spatial metaphors, including cartographic and geographic metaphors, such as *map*, *scale*, *distance*, *region*, and so forth, which enable users to “see” n -dimensional relationships within a low-dimensional visualization. Empirical support for this approach is growing. For example, human subject studies have shown that people expect that distances between point symbols representing text documents correspond to the documents’ relative similarity. Such distance-similarity relationships can further be manipulated through the introduction of network links (likened to cities connected by a road network) and through variations in symbology (e.g., the creation of visual groupings based on common symbols). In other words, the combination of the low-dimensional geometry with the set of traditional visual transformations developed largely within cartography can powerfully support the communication and discovery of complex, high-dimensional relationships.

Types of Spatialization Applications and Data

Spatialization can be applied to many different data types in many different application domains. Intelligence and law enforcement agencies need to sift through mountains of text, audio, and video content to extract useful nuggets of information. Research-funding agencies receive thousands of grant applications every year, from which they would like to identify emerging research trends and promising new approaches. In an increasingly



interdisciplinary research arena, both novices and experts find it difficult to stay abreast of the latest advances and are looking for condensed overviews of research results. Environmental scientists are increasingly receiving continuous streams of data from sensor networks, often involving dozens of attributes. Stock market analysts stand to gain from observing unusual market movements, including the relationships between different segments of the economy. Meanwhile, even average computer users find it difficult to keep track of the contents of hard drives containing hundreds of gigabytes of data.

Spatialization has been proposed as one possible approach for all these scenarios. However, we are faced with extremely different data sources, and the methods for turning them into visual form vary accordingly. One way of distinguishing different data sources is according to the degree to which they already consist of a coherent, consistent structure that is supportive of further processing.

Some data are highly structured, with a clear distinction between different elements and consistent attribution, and stored in standard database tables. Population census attributes are a good example, as they are attached to distinct geographic features and have a consistent attribute structure (at least for a given census year). Environmental attributes collected by sensor networks are another example of well-structured data.

On the other hand, there are data exhibiting much less existing structure. Most text, audio, or image contents are good examples. The middle ground is occupied by semistructured data, in which a number of internal structural elements are already distinguished. XML (Extensible Markup Language) is the dominant form of semistructured data today, especially for text documents. Generally speaking, the more structured a data set is, the easier it will be to spatialize it.

Data sets to be spatialized can also be categorized according to how high-dimensional content and relationships are expressed in them. Many data sets are made up of individual elements with a set of n attributes corresponding to dimensions of an n -dimensional space. The notion of *dimensionality reduction* is readily applicable to such data. Examples are census enumeration units and associated attributes. Text documents can likewise be

viewed as existing in an n -dimensional space, with dimensionality determined by the size of the vocabulary.

The second major type of data consists of elements that are explicitly linked to form network structures. Major characteristics of these structures derive from the specific application domain. For example, the files and folders on a hard drive form a hierarchical tree structure. Meanwhile, the networks formed by scientific articles are made up of unidirectional links, with citations always pointing toward past publications. Instead of indicating a specific location in high-dimensional space, network-type data mainly express topological relationships. These are meant to be preserved and conveyed in the low-dimensional display space, and the corresponding methods are known as *spatial layouts*.

Methods of Dimensionality Reduction and Spatial Layout

Broadly interpreted, the term *spatialization* naturally implies turning something that is nonspatial into something that is spatial. To put it more accurately, though, it addresses a transformation *between* different spaces whose main distinction is their dimensionality. People are used to physically navigating and manipulating three-dimensional (3D) space and are likewise able to make sense of visual, geographic representations of that space, which are typically derived from two-dimensional (2D) geometry—sometimes with added elevation values—and stored in GIS databases. The goal of spatialization is to bring the same skills to bear on the complex, high-dimensional data sets that are produced throughout contemporary society. The result is a geometric representation in a low-dimensional, typically 2D or 3D, space that is meant to enable people to detect the patterns, relationships, and trends inherent in high-dimensional data using the perceptual and cognitive abilities that have proven so successful in dealing with geographic space.

Major examples of *dimensionality reduction* techniques commonly used for spatialization include multidimensional scaling (MDS), principal components analysis (PCA), spring models, and the self-organizing map (SOM) method. Among the factors to consider when choosing



among dimensionality reduction methods are scalability (e.g., SOM is applicable to much larger data sets than MDS), performance (e.g., training of large SOMs can take a very long time), and distortion characteristics (e.g., MDS attempts to preserve certain *distance* relationships, while SOM results in the preservation of major *topological* structures).

Among *spatial layout* approaches, the tree map method has enjoyed particular popularity. It takes a tree structure as input and partitions a given rectangular area such that nodes are displayed as areas whose size and color express certain node attributes. Subdivisions are hierarchically stacked in accordance with the tree structure. This method has been popular for visualization of file/folder structures and of the stock market, where the tree structure derives from market sectors (e.g., banking stocks contained in the larger financial sector). There are also a number of graph layout methods, which arrange network nodes and links such that link intersections are largely avoided.

Spatialization Examples

Given the variety of data to which a spatialization strategy may be applied, two different examples are presented here, dealing with text contents and large network structures, respectively.

The first example is based on more than 20,000 abstracts submitted to the annual meetings of the Association of American Geographers (AAG) between 1993 and 2002. This example is quite illustrative of the long series of transformations that is frequently necessary to create a spatialization. In this case, it involved integration of heterogeneous, multitemporal text data; creation of a text index; filtering of the documents and vocabulary; creation of an SOM; storage in a GIS database format; then a series of geometric and attribute manipulations; and finally visualization using GIS software. The result shows major topical subdivisions within this knowledge domain (Figure 1).

The second example is derived from papers published in the *Annals of the Association of American Geographers*. Assume that someone new to geography—the very topic of this encyclopedia—would like to know who the most influential researchers in the field are and how they

connect to form a scholarly research community. The most common approach would be to consult an expert in the field, another would involve going through an introductory textbook on the subject and looking for the names mentioned there. Either way, the results will likely lack objectivity and comprehensiveness. Now, by far the most widely accepted expression of scholarly activity is the publication of original research articles in peer-reviewed journals, which we could presumably consult in our investigation of the geography community. The main impediment to using this resource is the sheer volume of published papers, which makes it impossible to actually survey the field manually. For example, a search of the *ISI Web of Science* database yields 5,956 articles published between 1956 and 2008 in one of the leading geography journals, the *Annals of the Association of American Geographers*. These articles contain 92,000 nonunique references that form a large network of citations (i.e., references from one article to another) as well as a network of cocitations (i.e., articles linked by virtue of being cited together). Spatialization makes it possible to explore the geography knowledge domain through an analysis of such networks. Based on a combination of a spatial layout algorithm with measures of network connectivity, one can derive visualizations of varying types and varying granularity. Apart from the original citations, one could also derive networks of journals or networks of authors. The latter is demonstrated here, with the large co-citation network of authors computationally pruned to contain only the most influential authors and only the most dominant cocitation links (see Figure 2). Node size expresses network centrality, while font size corresponds to the total number of citations of a particular author.

Challenges in Spatialization

There is still a scarcity of spatialization tools that are at the same time easy to use, affordable for most users, and open to modification and integration. Loose coupling of different programs is by far the most common strategy, with relative separation of data preprocessing, dimensionality reduction, geometric transformation, symbolization, and interaction.



Figure 1 Spatialization of the geographic knowledge domain based on 20,000-plus abstracts submitted to the annual meetings of the Association of American Geographers

Source: Author.

When dealing with geographically referenced data, spatialization of n -dimensional attributes should ideally be integrated with other methods of geographic visualization and spatial analysis. However, to date, virtually none of the dimensionality reduction and spatial layout methods mentioned earlier have been integrated into commercial off-the-shelf (COTS) GIS software. Some programming toolkits now include spatialization modules that can be integrated into larger, exploratory visualization environments. The most common roles of COTS GIS in spatialization are the storage of 2D geometry, execution

of various geometric transformations (e.g., surface interpolation), and preparation of visual results.

As spatialization relies heavily on invoking spatial metaphors, much remains to be learned about the specific cognitive mechanisms involved and how to derive from these parameters and guidelines for effective design of spatializations.

Alternative Meanings of Spatialization

Note that *spatialization* is a term that outside of GIScience is sometimes used in different contexts.

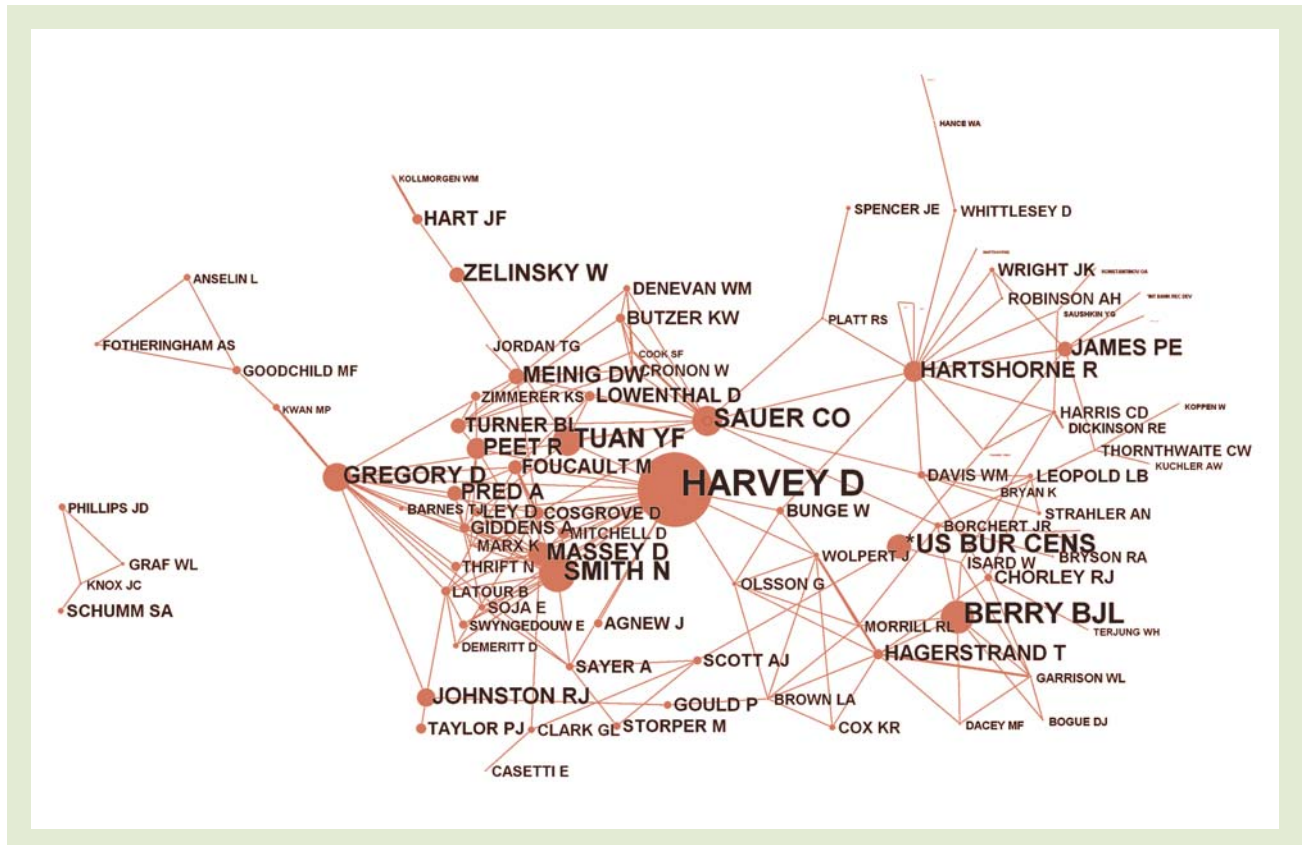


Figure 2 Spatialization of a network of influential authors derived from almost 6,000 articles published in the *Annals of the Association of American Geographers* between 1956 and 2008

Source: Author.

One is the use of sophisticated audio technology to create a spatial impression of the direction from which sound is emanating. This is also known as *sound spatialization*. Another notion of spatialization is encountered in the social sciences, where it refers to the process of uncovering the spatial character of human behavior, relations, and events (e.g., the gendering of space).

André Skupin

See also Exploratory Spatial Data Analysis; Metadata; Network Data Model; Ontological Foundations of Geographical Data; Open Geodata Standards; Point Pattern Analysis; Spatial Data Infrastructures; Spatial Data Integration; Spatial Data Mining; Spatial Data Models; Spatial Data Structures; Spatial Interpolation; Spatial Optimization Methods; Three-Dimensional Data Models; Triangulated Irregular Network (TIN) Data Model; Vagueness in Spatial Data

Further Readings

- Card, S. K., Mackinlay, J. D., & Shneiderman, B. (1999). *Readings in information visualization: Using vision to think*. San Francisco: Morgan Kaufmann.
- Couclelis, H. (1998). Worlds of information: The geographic metaphor in the visualization of complex information. *Cartography and Geographic Information Systems*, 25, 209–220.
- Fabrikant, S., & Skupin, A. (2005). Cognitively plausible information visualization. In J. Dykes, A. MacEachren, & M. J. Kraak (Eds.), *Exploring geovisualization* (pp. 667–690). Amsterdam: Elsevier.
- Skupin, A., & Fabrikant, S. (2003). Spatialization methods: A cartographic research agenda for non-geographic information visualization. *Cartography and Geographic Information Science*, 30(2), 99–119.
- Ware, C. (2004). *Information visualization*. San Francisco: Morgan Kaufmann.



SPATIALLY INTEGRATED SOCIAL SCIENCE

Spatially integrated social science may be defined as the empirical and theoretical practice where space and place are integrating mechanisms across social science disciplines as well as central considerations both as inputs and as outcomes of theories and models. This definition is rooted in the increasingly implemented practice of examining social, political, and economic data and problems in a spatially explicit context using geographic information systems (GIS), geovisualization, and spatial analysis. Space and place serve as input measures in models and analyses, as spatial concepts (e.g., distance, location, connectivity/topology, proximity) and spatial aggregates of place (e.g., neighborhood and region) are incorporated as units of analysis. In addition, processes that are the targets of inference and models are also very often contingent on space or space-time mechanisms such as diffusion, distance-decay effects, or the creation of social spaces as applications of spatial practice.

Human practices are inherently spatial and create social spaces that take on uses determined by the encompassing society. The connections that link people, institutions, economies, and organizations in geographical space pervade a range of different social contexts that may be conceptualized as general network structures embedded within a social and political context that constitutes the social space. The types, functional scales, and ranges of these connections are generated from spatial practice. Thus, social spaces may consist of everything from political and administrative demarcations referenced directly to geography to transport systems, business and interpersonal interactions, flows, and migrations that occur across a variety of distances and scales, and also global trade and transport networks that may extend over a plethora of network infrastructures. Torsten Hägerstrand's conception of time-geography and space-time behavior prisms as well as his idea of the mean information field are all examples of these social spaces.

Development of Spatially Integrated Social Science

The motivation for spatially integrated social science results from the realization of the necessity of space and geographic context in generating explanations of social, economic, and political phenomena: For example, the processes of trade flow interconnection, migration, capital flows, and compression of space-time due to increased efficiencies of movement have led to the realization of the value of the spatial context in social inquiry. Many practitioners place a growing emphasis on the role of space and place in the activities of analysis and theorizing for contemporary social science. The past 20 years have witnessed a revolution in social science, as geography, space-time, and place/locality have become crucial for understanding the complicated relationships in an increasingly interconnected world.

The social sciences have regularly employed statistical analysis to evaluate hypotheses and make inferences since the halcyon days of the quantitative revolution in the 1960s. However, even when data exhibited a spatial attribution or reference, only rarely was any type of quantitative and cartographic cross-tabulation performed. Partially, this was due to the lack of computer-based cartographic tools (until the advent of SYMAP in 1964 and SYMVU and GRID in the late 1960s) as well as the relative lack of user-ready statistical computer instruments, as most statistical software required some programming for implementation. This situation was further aggravated by the lack of a coherent framework for cogently integrating space and social processes. Social scientists had to wait for the development of integrative computer-based tools such as GIS in the 1980s before spatially referenced data could be readily examined in a geographical context.

Analytical Approaches

Spatially integrated methods provide for the integration of a diverse set of data and tools for analysis. Spatial analysis, place/locality-based analysis, and spatially explicit models and theory are tools of analysis and integration that can be implemented using GIS coupled with a variety of



georeferenced data such as remotely sensed imagery and census unit-based sources, for example. Spatial analysis explicitly incorporates space into statistical models not only to avoid specification problems but also to adequately account for measurable spatial effects. Basic spatial hypotheses regarding space as well as space-time dependence can be established using autocorrelation measures, K functions, and a variety of spatially explicit stochastic and permutation methods. These methods can be used to assess the importance and level of effects of spatial contingency. However, all these methods assume that the processes being measured are homogeneous or stationary over the study area(s).

Place- or locality-based analysis relaxes the process homogeneity assumption and permits local contextual influences to drive the process realizations. Methods such as Markov random field segmentation and geographically weighted regression can be used to evaluate specific local effects in a general-process statistical model. Given these methods and approaches, the importance of space can be measured and evaluated for a range of processes. Spatial effects can then be directly incorporated into the social theorizing activity so that predictions will no longer be assumed to be universal. Theories may account sufficiently for spatial variation so as to be able to predict outcomes differently for different locales. As such, policies based on such social theory may become much more effective and provide society with more tailored solutions to different spatial conditions.

Raymond J. Dezzani

See also Accessibility; Agent-Based Models; Analytical Operations in GIS; Bayesian Statistics in Spatial Analysis; Complex Systems Models; Data Indexing; Exploratory Spatial Data Analysis; Fotheringham, A. Stewart; Geodemographics; Geographically Weighted Regression; Geostatistics; GIS, History of; GIScience; GIS in Urban Planning; Hägerstrand, Torsten; Point Pattern Analysis; Quantitative Methods; Quantitative Revolution; Regional Science; Spatial Analysis; Spatial Autocorrelation; Spatial Data Models; Spatial Econometrics; Spatialization; Spatial Optimization Methods; Time-Geography

Further Readings

- Fotheringham, S., Brunsdon, C., & Charlton, M. (2000). *Quantitative geography: Perspectives on spatial data analysis*. London: Sage.
- Goodchild, M., Anselin, L., Applebaum, R., & Harthorn, B. (2000). Toward spatially integrated social science. *International Regional Science Review*, 23, 139–159.
- Goodchild, M., & Janelle, D. (Eds.). (2004). *Spatially integrated social science*. New York: Oxford University Press.
- Goodchild, M., & Janelle, D. (2004). Thinking spatially in the social sciences. In M. Goodchild & D. Janelle (Eds.), *Spatially integrated social science* (pp. 3–17). New York: Oxford University Press.
- Haining, R. (1990). *Spatial data analysis in the social and environmental sciences*. Cambridge, UK: Cambridge University Press.



SPATIAL MULTICRITERIA EVALUATION

Spatial multicriteria evaluation (spatial MCE) is based on an integration of theories, methodologies, and software from geographic information systems (GIS) and multicriteria decision analysis (MCDA). Spatial MCE, also known as GIS-MCA or GIS-MCE (multicriteria analysis or evaluation), is well suited to semistructured problems. These problems often require several individuals (e.g., politicians, citizens) to choose from a set of alternatives (e.g., sites, strategies) despite uncertainties regarding how possible solutions should be generated or evaluated. Spatial MCE approaches augment GIS strengths in data management, spatial analysis, and map-based visualization with MCDA techniques that incorporate user judgment into evaluation processes.

Spatial MCE Methodology

The basic procedure that underlies spatial MCE can be summarized as follows:



1. Identifying a set of feasible alternatives
2. Selecting evaluation criteria and standardizing criteria values
3. Generating criteria weights
4. Selecting a decision rule to rank alternatives
5. Testing the sensitivity of the ranks

Identifying Alternatives

Most spatial MCE procedures begin by identifying a set of alternatives or possible solutions to the problem of interest using standard GIS buffer, overlay, and selection functions. Depending on the problem, an alternative may be considered feasible only if it passes all constraints (conjunctive screening) or if it scores sufficiently well on one or more constraints (disjunctive screening).

Selecting Criteria and Standardizing Data Values

A criterion is a measurable characteristic or attribute that is used to judge the performance of each alternative relative to a normative objective (i.e., statement of what is desired). Criteria are represented in spatial MCE as either raster map layers or database fields associated with vector GIS objects. Criteria should be

- complete and minimal (representing all relevant aspects of the problem with the fewest criteria),
- nonredundant (no “double counting” of a specific variable), and
- independent (no autocorrelation of criteria values).
- Once the criteria have been selected, their data values are standardized to a common scale that ranges from 0 (*worst*) to 1 (*best*) to permit trade-offs between criteria. This scaling can be done relative to a maximum data value, a range, or a more complex nonlinear function.

Generating Criteria Weights

Criteria weights allow stakeholders with dissimilar objectives, interests, or experience to express how important they judge a criterion to be relative to other criteria. Criteria weights are expressed as real numbers that range from 0 (*no importance*) to 1 (*highest possible importance*), subject to all weights summing to 1.

Techniques to derive criteria weights vary considerably in mathematical sophistication, theoretical rigor, and cognitive demands. The procedures used most frequently are as follows:

1. Ranking (ordering criteria from least to most important)
2. Rating (distributing a fixed budget of “points” [usually 100] among criteria)
3. Pairwise comparison (comparing all pairs of criteria and indicating the relative importance of criteria through integer ratios)
4. Trade-off (deriving weights from users’ responses to questions of how many units of change in Criterion A they consider equal to a unit of change in Criterion B, and so on)

Applying a Decision Rule

A decision rule is the mathematical approach used to rank alternatives by combining criteria values and weights. Weighted summation is the most frequently used decision rule. It calculates a score for each alternative by multiplying standardized criterion values by their corresponding weights. The results are summed, and alternatives are ranked from the highest score to the lowest. The analytical hierarchy process (AHP) is also popular. It decomposes a problem into a hierarchy of criteria and subcriteria. Alternatives are evaluated in a pairwise manner for each criterion and assigned a score ranging from 1 (*A and B are equally preferred*) to 9 (*A is very strongly preferred to B*). The criteria-based scores are summed to produce overall scores and ranks for each alternative.

Ideal-point analysis (IPA) is based on the general concept from psychological scaling research that an “ideal” value can be identified for each criterion. Each alternative is scored by summing the weighted deviations from each criterion’s “ideal point.” Alternatives that are closer to the ideal solution (i.e., lower total deviations) are preferred.

Outranking techniques compare pairs of alternatives to determine which alternatives dominate all other alternatives. The relative dominance of Alternative A over Alternative B is calculated as the sum of the weights for all criteria where A is



better than B. This is repeated for all other alternatives to produce a concordance value for A. A similar process is used to derive the opposite discordance index. User-specified thresholds are adjusted incrementally to eliminate outranked alternatives and identify the most preferred alternative(s).

Sensitivity Analysis

Sensitivity analysis allows users to examine how sensitive rankings and specific criteria are to small changes to criterion weights. Most spatial MCE software provides functions that allow users to alter weights interactively to determine if rankings are robust or if criteria weights require further consideration.

Criticisms

Academic interest in integrating GIS and MCDM has grown substantially over the past 20 years; however, this enthusiasm is not apparent in commercial GIS. The MCDA component of spatial MCE has been criticized for its “black box” nature that end users find difficult to understand or trust. Others claim that the subjective processes of criteria selection and particularly weighting undermine objectivity in decision making.

Proponents of spatial MCE note that all analyses are subjective to some degree and representing different individuals’ viewpoints explicitly in spatial MCE is a strength. They also note that the process of using spatial MCE can encourage learning, experimentation, and principled negotiation in difficult problem contexts. Reducing barriers to nonexperts’ use of spatial MCE in practice has proven to be more difficult, although advances in software, theory, and application methodologies offer promise.

Robert Feick

See also Collaborative GIS; Cost-Benefit Analysis; Exploratory Spatial Data Analysis; GIScience; Point Pattern Analysis; Resource Management, Decision Models in; Spatial Decision Support Systems; Spatial Optimization Methods; Usability of Geospatial Information

Further Readings

- Jankowski, P., & Nyerges, T. (2001). *Geographic information systems for group decision making: Towards a participatory, geographic information science*. New York: Taylor & Francis.
- Malczewski, J. (1999). *GIS and multicriteria decision analysis*. Toronto, Ontario, Canada: Wiley.
- Yoon, K. P., & Hwang, C. L. (1995). *Multiple attribute decision making: An introduction*. Thousand Oaks, CA: Sage.



SPATIAL OPTIMIZATION METHODS

Spatial optimization is concerned with maximizing or minimizing an objective related to a problem of a geographic nature, such as route selection, location-allocation modeling, spatial sampling, and land use allocation, among others. Location-allocation analysis is used to determine optimal locations for one or more facilities with respect to the spatial distribution of demand; applications can range from locating a hazardous waste site or siting a landfill as far as possible from existing population, determining optimal bus stop locations to minimize the walking distance from home, and finding a location for a new cell tower to maximize population coverage to determining a biological reserve for habitat recovery or the optimal location for a recreational site in a neighborhood.

Solving a geographic problem translates into the formulation of an objective function subject to some constraints. For example, in locating bus stops, the objective is to maximize potential ridership. But it may not be possible to locate bus stops everywhere, because geographic space is constrained. Additionally, if potential commuters live farther than a critical distance, they will be discouraged from walking to the nearest bus stop. Another example is finding new locations for a cell tower, where potential locations for new towers may be rather limited because it is desirable not only to locate new base stations at higher elevations to minimize obstructions but also to



ensure that they are not too close to residential areas (because of the not-in-my-backyard [NIMBY] effect).

Single and Multiple Objectives

Different approaches exist to solve geographical problems. Depending on the nature of the problem, a single- or multiple-objective approach can be taken. The optimal location of a recreational site may have a single accessibility objective, to minimize the distance from residential units to the site. In locating an obnoxious facility such as a landfill, the objective may be not only to maximize its distance from population centers but also to minimize transportation costs. Some objectives may be conflicting, and it is often desirable to reach a Pareto-optimal solution, in which no changes can be made without making at least one individual worse off.

Heuristics

Once a problem has been formulated with an objective function and constraints, a solver is generally used to find an optimal solution (e.g., CPLEX, LINGO). Exact solution methods such as integer or linear programming, branch and bound approaches, and Lagrangian relaxation often have limited success, given that an increase in the number of variables will cause an exponential increase in the solution time. In some instances, the size of a spatial problem can create a combinatorial explosion, and heuristic search techniques are preferred. Heuristics are algorithms that are able to find a solution (optimal or not) for a given problem in a limited time frame. Some heuristics reach a suboptimal solution rapidly (e.g., myopic or naive strategy), while others can lead to an optimal solution (simulated annealing, genetic algorithms, tabu search) at the cost of a longer running time. Limited research has been devoted to comparing the benefits and drawbacks of several heuristics and metaheuristics (combination of heuristics) in the context of spatial optimization.

Naive or Random Strategy

The naive strategy randomly chooses a number of locations from a set of candidate locations.

This approach does not account for the structure of the solution space and is therefore very inefficient. Nevertheless, the numerical results following the use of this algorithm provide a good lower bound to evaluate other heuristics.

Total Enumeration

This method consists of evaluating which of all candidate locations optimizes the objective function the best. Total enumeration is sensitive to the size of the problem but is optimal in the one-facility location problem as long as the set of candidate solutions is finite (discrete). The method would, however, be inappropriate when the spatial problem calls for the allocation of more than one facility, because of combinatorial explosion.

Greedy Algorithm

The greedy (or myopic) algorithm starts with a feasible solution. The current solution is then exchanged for another one only if the objective function improves. The process continues until no further improvements can be made. The algorithm is easy to implement and returns a good solution, but the solution may be suboptimal. The algorithm can be effective when applied repeatedly as long as the starting feasible solution is changed.

Simulated Annealing

The greedy approach, as well as the total enumeration in the one-facility location, usually gets stuck in a local optimum, while simulated annealing is able to reach optimality. The major advantage of simulated annealing is its ability to avoid becoming trapped at a local maximum. The algorithm employs not only a stochastic search that accepts changes that improve the objective function but also nonimproving moves, which are accepted with a certain probability. The probability of acceptance decreases as the temperature (or system) cools down.

Tabu Search

Simulated annealing allows nonimproving moves. Tabu search, however, deals with cycling the problems of nonimproving moves, in which



the heuristic momentarily forbids swapping of solutions, which would entail a return to a previously visited solution. The so-called tabu list records these forbidden moves.

Metaheuristics

The combination of two heuristic methods—also called a metaheuristic—allows one to improve on a first solution. For instance, because the greedy heuristic may yield a suboptimal solution, an improvement may be desirable; simulated annealing can use the greedy solution at the start of its optimization procedure.

Genetic Algorithm

A genetic algorithm is a metaheuristic that uses techniques from evolutionary biology to find better solutions at each iteration. The algorithm improves feasible or suboptimal solutions by operations that combine individuals of an improving population. The quality of each individual is evaluated, and several of them are randomly selected from the current solution, based on their solution quality. Solutions are then modified using mutation or crossover to form a new basic feasible solution.

Eric Delmelle

See also **Location-Allocation Modeling; Spatial Decision Support Systems; Spatial Econometrics; Spatial Multicriteria Evaluation; Point Pattern Analysis; Triangulated Irregular Network (TIN) Data Model**

Further Readings

- Glover, F. (1989). Tabu search: Part 1. *ORSA Journal on Computing*, 1, 190–206.
- Goldberg, D. E. (1989). *Genetic algorithms in search, optimization, and machine learning*. Reading, MA: Addison-Wesley.
- Hof, J., & Bevers, M. (2002). *Spatial optimization in ecological applications*. New York: Columbia University Press.
- Kirkpatrick, A., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. *Science*, 220(4598), 671–680.

Michalewicz, Z., & Fogel, D. (2000). *How to solve it: Modern heuristics*. Berlin, Germany: Springer-Verlag.

Press, W., Teukolsky S. A., & Vetterling, W. T. (2007). *Numerical recipes: The art of scientific computing* (3rd ed.). Cambridge, UK: Cambridge University Press.

Rardin, L. (1997). *Optimization in operations research*. Englewood Cliffs, NJ: Prentice Hall.

Schietzelt, T. H., & Densham, P. J. (2003). Location-allocation in GIS. In P. Longley & M. Batty (Eds.), *Advanced spatial analysis: The CASA book of GIS* (pp. 345–366). Redlands, CA: ESRI Press.

Xiao, N. (2008). A unified conceptual framework for geographical optimization using evolutionary algorithms. *Annals of the Association of American Geographers*, 98(4), 795–817.



SPATIAL RESOLUTION

Spatial resolution is a measure of the degree of detail in a spatial data set and has been defined variably as the size of the smallest detectable feature, one half the size of the smallest detectable feature, and the minimum angular or linear distance between detectable features. The specific meaning and measurement of spatial resolution varies widely among disciplines and within geography, depending largely on the application area. The key concepts behind spatial resolution are more generally applicable, however, and are important for anyone interested in the study of spatial patterns and processes or mapping. The following sections outline these major concepts, list measures of spatial resolution commonly used by geographers, and discuss briefly the idea of “optimal” spatial resolution.

General Considerations

An increase in spatial resolution (i.e., measurement scale) usually implies a decrease in the geographic extent of the study area (i.e., observational scale). This is primarily due to resource constraints: For example, more time is needed to

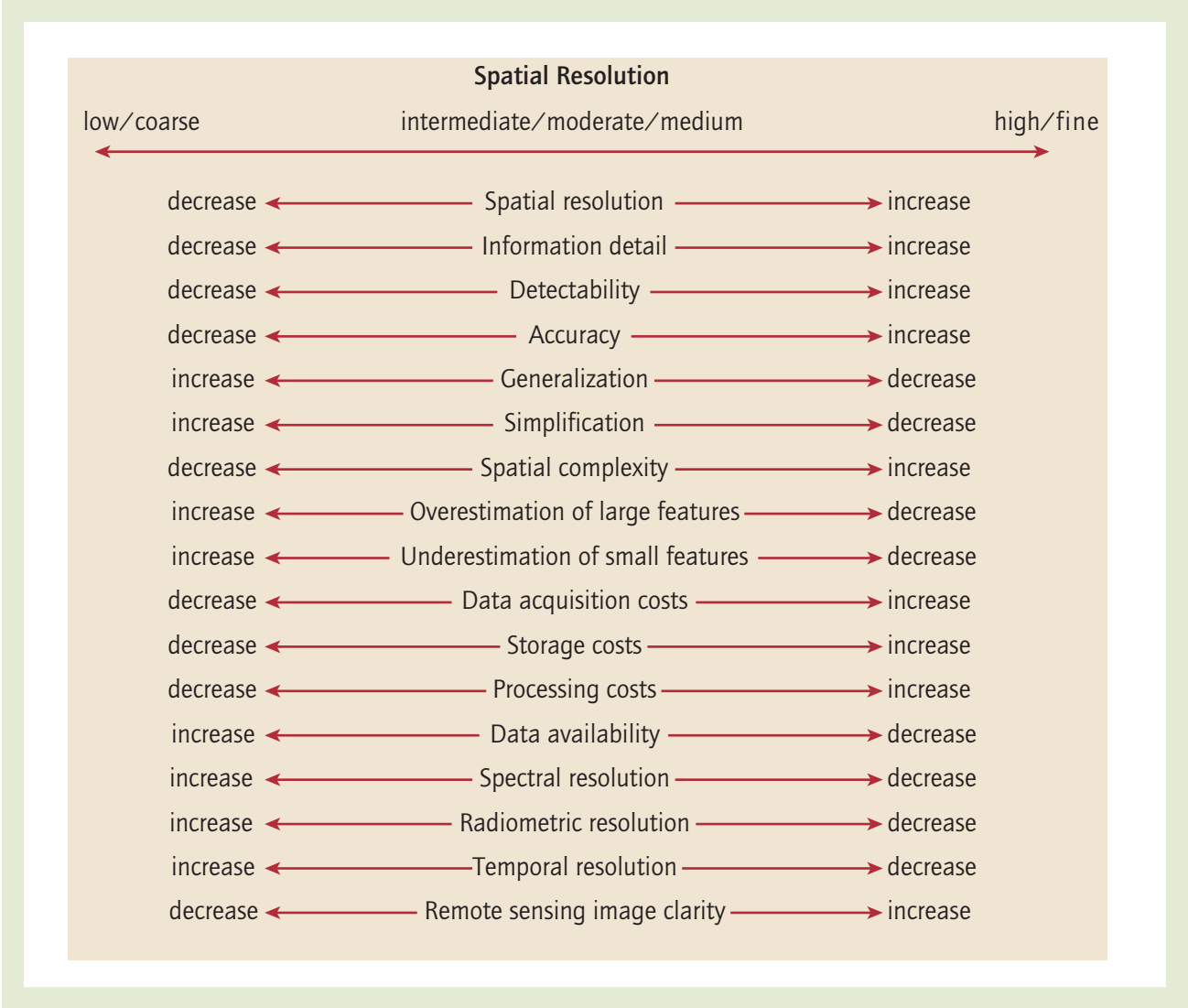


Figure 1 Relationship between spatial resolution and other geographically relevant parameters. As spatial resolution increases, other variables increase or decrease. In remote sensing classifications, for example, a decrease in image spatial resolution tends to lead to an increased overestimation of larger features (e.g., forest land) and underestimation of smaller features (e.g., streams).

Source: Author.

collect many samples across larger areas. An increase in spatial resolution normally also implies an increase in map scale (i.e., cartographic scale), because it is impossible to print a map of a large geographic area with fine spatial thematic detail. If map scale and study area extent are held constant, however, changes in spatial resolution have a number of effects on other geospatial product characteristics as well as data acquisition, storage, and processing (Figure 1). Given these effects,

spatial resolution is an important consideration in study design, analysis, and interpretation.

Measures of Spatial Resolution in Geography

Spatial Resolution and Analog Maps

Assuming that a cartographer cannot make a mark smaller than 0.5 mm (millimeter) in size,

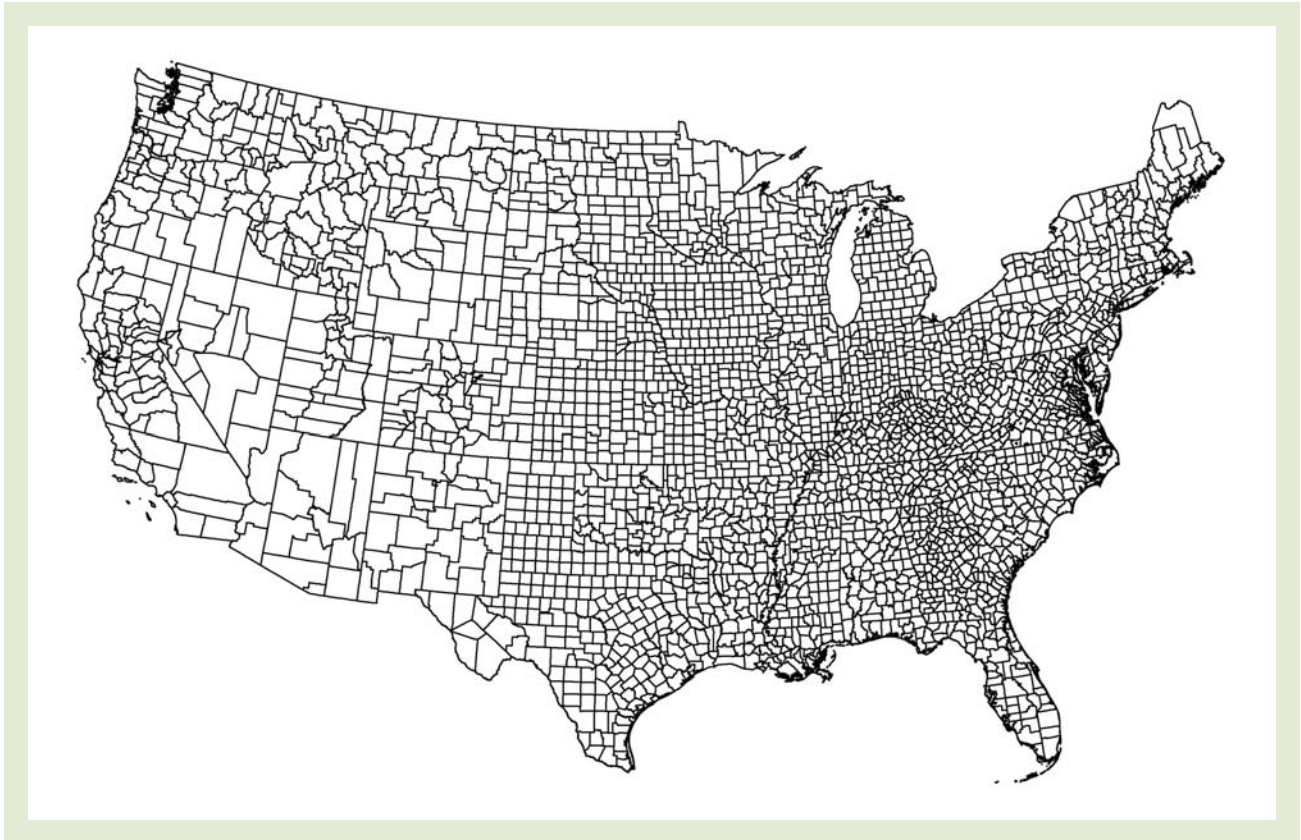


Figure 2 Spatial resolution and vector data. The average spatial resolution of this map of counties in the contiguous United States is 46 km. Spatial resolution is much higher in the Eastern United States, however, and the minimum mapping unit that is contained in the GIS cannot even be detected in the printed version of the map.

Source: Author.

the spatial resolution of a hardcopy map can be calculated by dividing the denominator of the representative fraction (map scale) by 2,000. For maps of 1:24,000, 1:100,000, and 1:250,000 scale, the spatial resolution would thus be 12, 50, and 125 m (meters), respectively (the widths on Earth's surface made by 0.5-mm pen lines on these maps). The size of the smallest detectable feature is twice that of the spatial resolution: 24, 100, and 250 m, respectively. Cartographers are also artists, however, and at times include in an enlarged fashion those features that are too small to be detected but too important to be left out.

Spatial Resolution and Vector Data

The size of the minimum mapping unit (MMU), the smallest detectable feature, is often

used to define the spatial resolution of a vector data set. However, the *average* spatial resolution of a vector data set may also be calculated. For point and polygon vector data sets, it is obtained by dividing the square root of the size of the region of interest by the number of observations. County- and state-level maps of the United States would thus have average spatial resolutions of about 54 and 428 km (kilometers), respectively (3,140 counties and 50 states covering a land area of 9,161,923 km² [square kilometers]; Figure 2). The size of the smallest detectable feature on these maps is twice that of the average spatial resolution: 108 and 856 km, respectively. For line vector data sets, the spatial resolution can be estimated by dividing the size of the region of interest by the total length of the linear features.

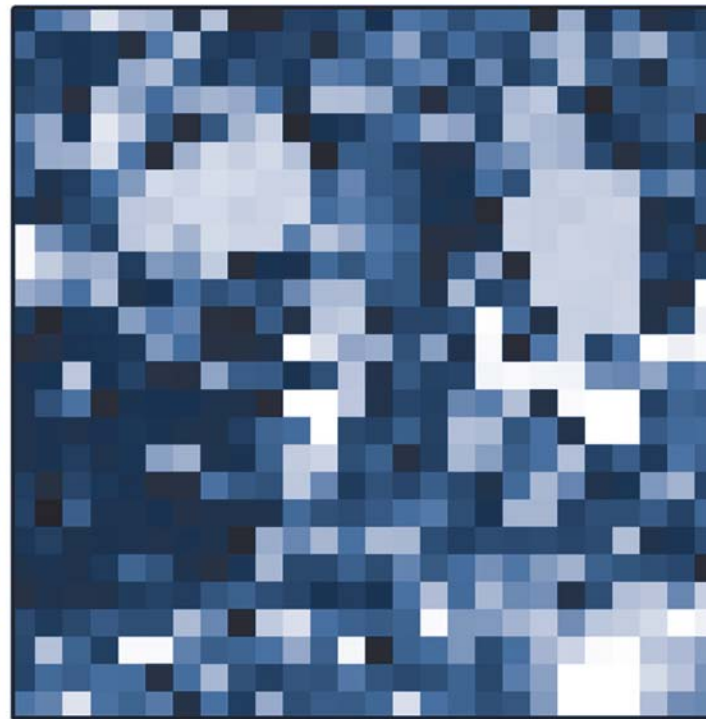
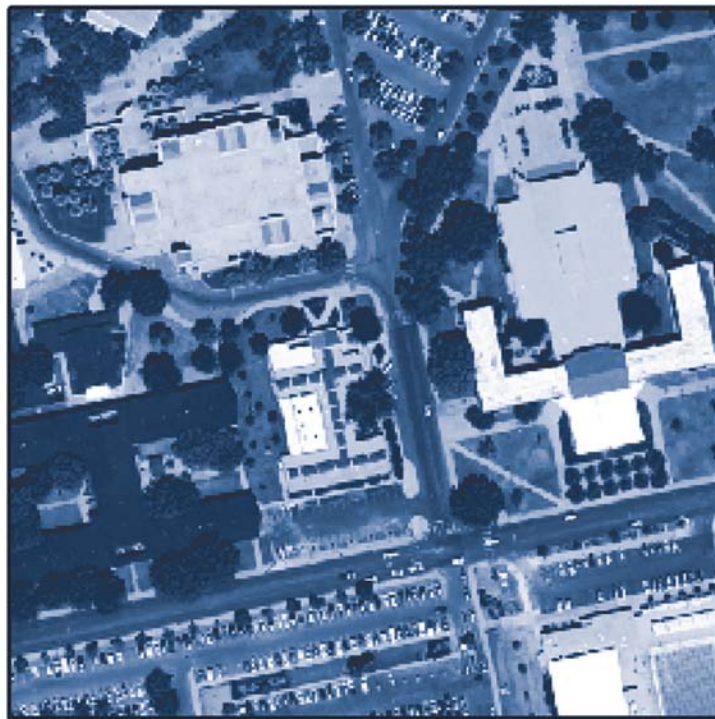


Figure 3 Spatial resolution and raster data. As the spatial resolution of raster data decreases (*left*: 1 m [meter]; *middle*: 10 m; *right*: 30 m), detectability, information detail, and image clarity decrease visibly. Storage and processing costs also decrease because there are fewer pixels to handle at lower spatial resolutions.

Source: Author.

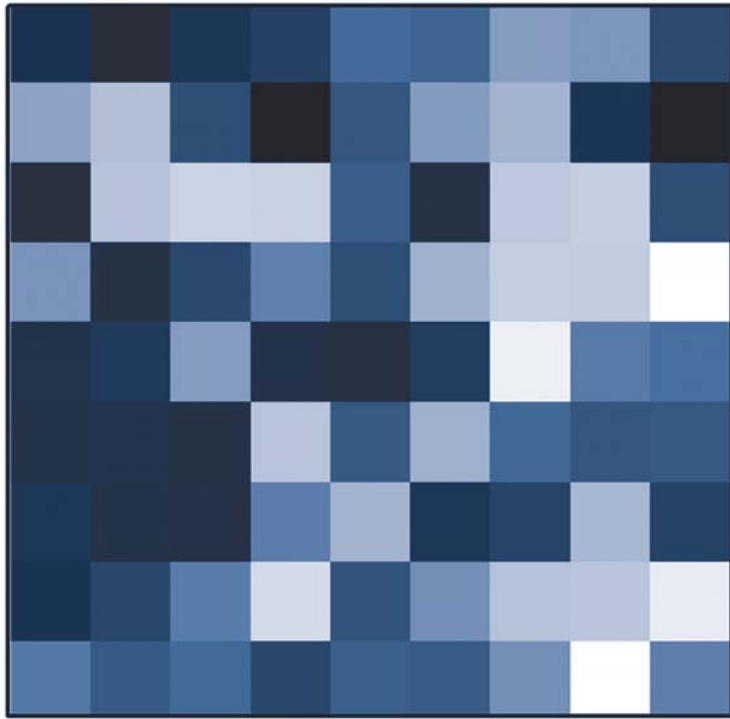
Spatial Resolution and Satellite Images

The spatial resolution of satellite imagery has been measured in many different ways, depending on the user's needs, but most measures fall into one of four categories: (1) measures based on the geometrical properties of the imaging system (e.g., point-spread function), (2) the ability to distinguish between point targets (e.g., Rayleigh criterion), (3) the ability to measure the periodicity of repetitive targets (e.g., modulation transfer function), and (4) the extent of small but finite targets (e.g., effective resolution element). The most commonly used measure falls into the first category and is based on a sensor's instantaneous field of view (IFOV), which determines the area on Earth's surface represented by an individual detector element or pixel at a particular point in time. When measured this way, the spatial resolution

of satellite imagery ranges from about 0.5 m to 1 km (Figure 3). For a feature to be detectable, it should be at least twice as large as the pixel. The quality of a given image for a particular application, however, depends also on many other factors, including but not limited to the spectral resolution, temporal resolution, radiometric resolution, atmospheric conditions, and contrast between features of interest and their surroundings.

Spatial Resolution and Aerial Photography

The spatial resolution of aerial photography is expressed as either sensor system resolution or ground-resolved distance. The sensor system resolution depends primarily on the camera lens and photosensitive material (e.g., the film in an analog camera or charge-coupled device



in a digital camera) and is given in line pairs per millimeter, a measure of the number of resolvable line pairs in the photography. The ground-resolved distance (GR), or smallest resolvable feature on Earth's surface, can be measured as a function of focal length (f), sensor system resolution (RS), and flight altitude above the ground (h): $GR = f \times RS/h$. An air photo acquired from an altitude of 6,000 m with a camera focal length of 150 mm and system resolution of 50 line pairs/mm would thus have a ground-resolved distance of 1.25 line pairs/m. In accordance with the above measures of spatial resolution, the spatial resolution of aerial photography is one half the ground-resolved distance: that is, 0.625 m in the example. It typically ranges from about 10 centimeters to 5 m.

Spatial Resolution and Field Data

In the context of field data, spatial resolution typically refers to the size of the sample unit (e.g., the size of a quadrat in ecological studies). Spatial

resolution may also be calculated from the distance between point samples in a given area (i.e., spatial sampling rate) using the formula for point vector data sets given above.

What Is the Optimal Spatial Resolution?

The optimal spatial resolution is the one that is most suitable to meet a study's objectives. It has to be fine enough to facilitate the detection of features of interest and to capture the patterns caused by processes of interest (i.e., the operational scale, or "scale of action"). Too fine a spatial resolution, however, is wasteful in terms of resource requirements and may convey excessive information (i.e., noise) that does not reveal anything relevant about the subject of interest. Then again, while it is possible to decrease the spatial resolution of a data set, it is impossible to acquire greater information content by increasing the spatial resolution of the original data set: Spatial resolution is finite.

Michaela Buenemann

See also Geographic Information Systems; Image Interpretation; Photogrammetric Methods; Remote Sensing; Radiometric Resolution; Scale in GIS; Spectral Resolution; Temporal Resolution

Further Readings

- Forshaw, M. R. B., Haskell, A., Miller, P. F., Stanley, D. J., & Townshend, J. R. G. (1983). Spatial resolution of remotely sensed imagery: A review paper. *International Journal of Remote Sensing*, 4, 497–520.
- Robinson, J. A., Amsbury, D. L., Little, D. A., & Evans, C. A. (2002). Astronaut-acquired orbital photographs as digital data for remote sensing: Spatial resolution. *International Journal of Remote Sensing*, 23, 4403–4438.
- Tobler, W. R. (1988). Resolution, resampling, and all that. In H. M. Mounsey & R. F. Tomlinson (Eds.), *Building data bases for global science* (pp. 129–137). London: Taylor & Francis.



SPATIAL STATISTICS

The term *spatial statistics* encompasses the statistical processes used to analyze spatial data by incorporating spatial information. It involves the statistical analysis of spatial data. It has been successfully used in various fields for analyzing spatial patterns not evident by merely mapping the distribution over space. Over the years, the importance of incorporating the spatial component in drawing meaningful references for data points distributed over space has become increasingly evident. The long-established methods in classical statistics, though extremely useful for detailed interpretation of large data sets, are not able to account for spatial relationships in the distribution. Typical statistical measures most often do not incorporate the underlying spatial relationships among different variables. As a result, results drawn by classical statistical methods may not provide the actual explanation of the problem under study. With the advent of geographic information system (GIS) tools, it has become possible to compute more complex statistics taking into consideration the spatial relationships among variables. Thus, one of the main objectives of spatial statistics includes the reduction of spatial patterns into concise and clear summaries. Moreover, spatial statistics includes all classical areas of statistics, consisting of design, statistical methods, stochastic modeling, and statistical analysis. The main components of spatial statistics are described briefly in the following sections.

Spatial Data

As mentioned above, spatial statistics includes spatial data analysis. *Spatial data* may be defined as a database that contains information about certain variables and their distribution over space. In other words, a *spatial data set* consists of each record or observation accompanied by its spatial coordinates in the form of latitude and longitude or x and y coordinates as well as topology information. It can also be defined as data pertaining to location, shape, and geographical relationships. Thus, spatial statistics consists of the study of spatially referenced data that can be mapped digitally. Spatial data are represented typically in the form of points,

lines, and polygons (including raster cells), with associated attribute information about each displayed spatial unit. Among the most important and commonly used measures in classical statistics are measures of central tendency, which include mean, median, and mode. However, these measures are not able to take into consideration the spatial locations in the final results. In spatial statistics, these essential statistical measures have been modified to include the individual location information in the final results. For instance, spatial mean can be used to determine the mean center or average center of a set of observations. Similarly, the concept of median has been extended to include the concept of the median center, which is mainly used for determining the spatial median of a set of observations.

Spatial Autocorrelation

In view of one of the main objectives of spatial statistics, which is the analysis of spatial patterns, there are different types of spatial patterns that may exist over space. These patterns include heterogeneous patterns (patterns that vary in a systematic manner from place to place), anisotropy (where there is directional bias in a particular spatial pattern), and clustering effects (where locations with similar attribute values are clustered close together). One of the main components of spatial statistics, as emphasized before, is the study of the underlying spatial relationships between different variables, collectively referred to as *spatial autocorrelation*. It is a function of similarities in both location and attribute values among the different data observations. *Autocorrelation* refers to the pairwise correlation of univariate observations; in more general terms, it can be referred to as self-correlation. Therefore, spatial autocorrelation refers to the spatial distribution of autocorrelation among different observations. This type of autocorrelation arises as a result of some form of ordering in the spatial distribution of variables. Spatial autocorrelation coefficients help in examining the clustering of a given set of observations based on attribute values. It is expressed in the form of positive and negative autocorrelations. Positive autocorrelation occurs when locations with similar attribute values that are clustered have more similar characteristics, while negative

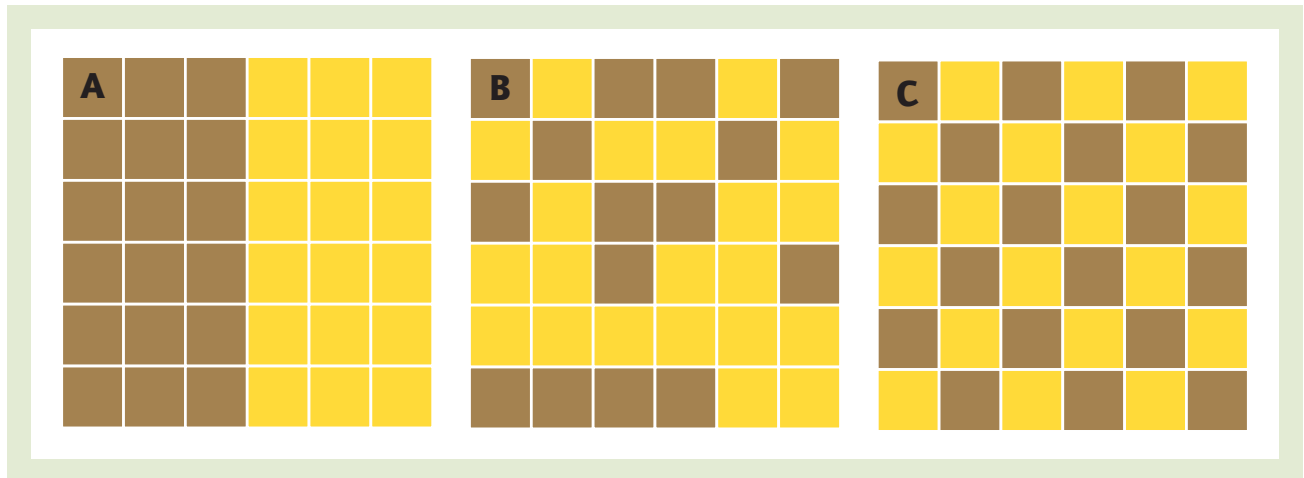


Figure 1 Hypothetical example showing different forms of spatial autocorrelation: (A) significant positive spatial autocorrelation, (B) spatial independence implying no spatial autocorrelation, and (C) significant negative spatial autocorrelation

Source: Goodchild, M. F. (1986). *Spatial autocorrelation (CATMOG)*. Norwich, UK: GeoBooks.

autocorrelation occurs when attribute values of observations located close together are dissimilar. Two of the most effectively used measures of spatial autocorrelation are Geary's ratio and Moran's *I*. Both measures check for spatial autocorrelation by taking into consideration attribute value similarity and location proximity. Furthermore, the concept of spatial autocorrelation does not ignore randomness; rather, it takes into consideration both spatial pattern and error. Figure 1 shows hypothetical examples of different types of spatial autocorrelation.

Geostatistics

Geostatistics is an integral component of spatial statistics. Geostatistics involves the prediction of unknown values at given locations or of aggregation across given regions. Geostatistics has also been defined as a method of taking into consideration the geographic configuration while conducting any statistical analysis. Furthermore, it also involves smoothing and interpolation that enables the prediction and mapping of unknown values at specific locations. The process of making predictions for unknown surfaces includes modeling the spatial relationships among the different locations. To accurately model spatial data,

one needs to carry out extensive exploratory spatial data analysis (ESDA) of the spatial data set under study. ESDA mainly includes viewing a spatial data set in detail to identify the general distribution of the data, for example, plotting frequency distributions of the data set, from which specific details about the spread of the data set can be analyzed. ESDA also enables the identification of spatial outliers among a given set of data measurements. Furthermore, it may also be used to identify any form of global or local trend, as well as any directional bias in the data set. Therefore, the results from ESDA analysis are extremely useful for conducting geostatistical analysis and also in the final selection of the surface analysis model.

Geostatistical analysis of spatial data occurs in two phases. The first phase consists of modeling the semivariogram or covariance to analyze surface properties for a particular spatial data set. The second phase consists of interpolating the data to predict values for unknown locations. Commonly used techniques for spatial interpolation include different forms of kriging, which creates continuous surfaces using the statistical relationships among the known observations—for example, ordinary, simple, universal, probability, indicator, and disjunctive kriging. The

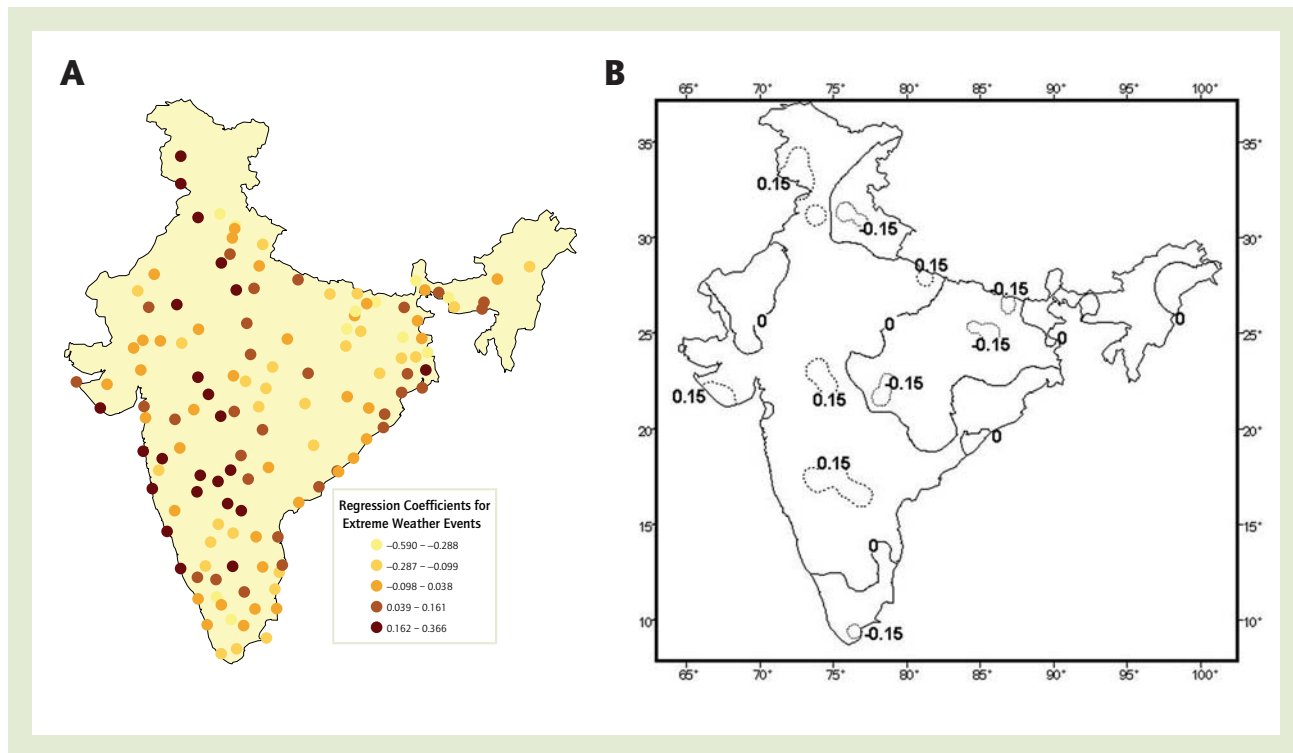


Figure 2 Map of standardized regression coefficients showing (A) trends in the composite extreme events throughout India at the station level and (B) a continuous interpolated surface created by simple kriging

Source: Sen Roy, S., & Balling, R. C., Jr. (2004). Trends in extreme daily precipitation indices in India. *International Journal of Climatology*, 24(4), 457–466.

results of kriging also include the creation of prediction and error surfaces, which enables the researcher to assess the effectiveness of the model used in creating the prediction surfaces. An example of the application of geostatistics in the form of surface interpolation techniques is given in Figure 2.

Shouraseni Sen Roy

See also Bayesian Statistics in Spatial Analysis; Data Querying in GIS; Exploratory Spatial Data Analysis; Geographically Weighted Regression; Geographic Information Systems; Heuristic Methods in Spatial Analysis; Point Pattern Analysis; Quantitative Methods; Spatial Analysis; Spatial Autocorrelation; Spatial Data Mining; Spatial Data Models; Spatial Data Structures; Spatial Decision Support Systems; Spatial Econometrics; Spatial Interaction Models; Spatial Interpolation; Spatial Optimization Methods; Usability of Geospatial Information

Further Readings

- Cressie, N. A. C. (1991). *Statistics for spatial data*. New York: Wiley.
- Goodchild, M. F. (1986). *Spatial autocorrelation (CATMOG)*. Norwich, UK: GeoBooks.
- Griffith, D. A. (1984). Theory of spatial statistics. In G. L. Gaile & C. J. Wilmott (Eds.), *Spatial statistics and models* (pp. 3–16). Boston: D. Reidel.
- Ripley, B. D. (1981). *Spatial statistics* (Wiley Series in Probability and Statistics). New York: Wiley.
- Sen Roy, S., & Balling, R. C., Jr. (2004). Trends in extreme daily precipitation indices in India. *International Journal of Climatology*, 24(4), 457–466.
- Wong, D. W. S., & Lee, J. (2005). *Statistical analysis of geographical information with ArcView GIS and ArcGIS*. Hoboken, NJ: Wiley.



SPATIAL STRATEGIES OF CONSERVATION

Geographers have had plenty to say about the spatial strategies of conservation. Their contributions can be loosely categorized into two main approaches. The first has origins in resource management and draws strongly from biogeography, while the second has origins in critical approaches to the study of human-environment relations (e.g., political ecology). While their differences and distinct contributions are outlined in this entry, it is clear that both groups agree that conservation is an inherently spatial process. The conservation of targeted flora and fauna as well as entire ecosystems is often accomplished through policies that are explicitly spatial: land use zoning, protected areas, buffer areas, and wildlife corridors. These strategies require the delineation of boundaries that separate the protected from the not protected. Furthermore, those conservation mechanisms that are not spatial in origin (e.g., pesticide bans, emissions restrictions, and carbon trading) have spatial outcomes; they take place somewhere (and not somewhere else), and they play a role in shaping the spatiality of related social and economic activities. The treatment of these geographies of conservation, however, differs substantially between the two approaches.

The resource management stream of geography concentrates its effort on how to address already accepted problems of conservation: how to prevent habitat fragmentation, protect biodiversity, and minimize damage to nature by people. To these ends, emphasis is often on how best to characterize the existing fragmentation using geographic information systems and remote sensing, as well as on the location and functionality of protected-area boundaries and buffer zones. For species-specific conservation, the concern is often with the spatial needs of a particular species and the extent and quality of their habitats. It is important to note that the spatial solutions to these conservation problems are largely territorial; that is, they support the creation of territories dedicated to conservation goals such as national parks, wildlife corridors, and ecological zones.

The single large or several small (SLOSS) debate, beginning in the 1970s and persisting in various permutations today, is indicative of this

approach. The debate centers on whether, as a general rule in instances of habitat fragmentation, creation of SLOSS reserves is the best spatial strategy to ensure long-term biodiversity preservation. The answer to this question varies significantly depending on the particular set of circumstances and the ecosystem in question but almost always takes into account the species-area curve from the theory of island biogeography, the diversity of habitats available, and any edge effects that may help or hinder species diversity.

Geographers more closely associated with critical approaches to human-environment relations, such as in political ecology, question the spatial solutions offered by the resource management approach discussed above. They suggest that the delineation of boundaries separating biota that are to be targeted for conservation from biota that are not is a spatial reification of the nature-culture dichotomy and consequently fails to recognize nature as at least a partially social artifact, consistent with social construction of nature arguments. Furthermore, such strategies are deemed to perpetuate unnecessary violence against rural people, particularly indigenous peoples, by separating them from their livelihood. Much research has been conducted, for example, on the impacts of boundary delimitation, protected-area establishment, and conservation policy and their associated voluntary and involuntary displacement. Such critique has focused largely on conservation practices in the developing world, which are seen as coercive and motivated as much by political as by environmental goals.

In addition to exploring the social impacts and political motivations of the boundary demarcation associated with territorial conservation mechanisms, critical approaches have also investigated the spatiality of indigenous, local, and peasant conservation strategies. In contrast to the simple spatial form of parks, protected areas, buffer zones, and corridors, authors have found less managerial forms of conservation to be more spatially complex. Resource use and conservation practices embedded within local social-ecological systems are often species specific and contingent on season, gender, and livelihood group. So, rather than easily legible, impermeably bounded zones of conservation, local conservation management often consists of porously bounded,



overlapping, dynamic zones subject to social relations. The exceptions to this spatial flexibility are sacred groves, cemetery forests, and other areas deemed off limits.

In short, spatial strategies of conservation can and do vary tremendously, and they tend to be consistent with the management goals of the implementing institutions. If conservation goals include limiting or eliminating human use and are managed through a centralized process indicative of state or large nongovernmental organizations, firmly bounded zones separating humans from nature are often the spatial strategy of choice. In cases where conservation goals that see human use of resources as integral, or at least not antithetical, to conservation are implemented through decentralized processes of land management where the managers are present in the landscape, spatially flexible and complex strategies are more likely to be successful.

Most recently, and as a partial reflection of a neoliberal turn in environmental governance, nonterritorial forms of conservation are gaining popularity. These include certification schemes for environmental products and restrictions on agricultural inputs and green development, and they reflect a shift toward sustainability as a primary conservation goal. Such mechanisms are not aspatial but rather tend to de-emphasize the fixed, impermeable boundaries of protected areas in favor of a spatiality produced through the cross-scale articulation of particular target landscapes, livelihoods, and global markets. This trend speaks to a future of conservation governance that makes use of a full range of spatial strategies, combining statically bounded territories of conservation with more diffuse spatial strategies that both limit and encourage particular kinds of activities in particular kinds of spaces.

Robin J. Roth

See also **Biodiversity; Community-Based Conservation; Conservation; Conservation Zoning; Cultural Ecology; Game Ranching; Governmentality and Conservation; Island Biogeography; Landscape and Wildlife Conservation; Landscape Ecology; Parks and Reserves; Patches and Corridors in Wildlife Conservation; Political Ecology; Single Large or Several Small (SLOSS) Debate; Soil Conservation**

Further Readings

- Roth, R. J. (2008). Fixed in the forest: The spatiality of conservation conflict in Thailand. *Annals of the American Association of Geographers*, 98, 373–391.
- Whittaker, R. J., Araújo, M. B., Jepson, P., Ladle, R. J., Watson, J. E. M., & Willis, K. J. (2005). Conservation biogeography: Assessment and prospect. *Diversity and Distributions*, 11, 3–23.
- Zimmerer, K. S. (Ed.). (2006). *Globalization and new geographies of conservation*. Chicago: University of Chicago Press.



SPATIAL TURN

In the late 20th century, human geography underwent a profound conceptual and methodological renaissance that transformed it into one of the most dynamic, innovative, and influential of the social sciences. The discipline, which had long suffered from a negative popular reputation as a trivial, purely empirical field with little analytical substance, moved from being an importer of ideas from other fields to an exporter, and geographers are increasingly being read by scholars in the humanities and other social sciences. As a result of the rebirth in scholarship in geography, other disciplines have increasingly come to regard space as an important dimension of their own areas of inquiry, in what is widely called the spatial turn. Denis Cosgrove (1999), for example, argues that

a widely acknowledged “spatial turn” across arts and sciences corresponds to post-structuralist agnosticism about both naturalistic and universal explanations and about single-voiced historical narratives, and to the concomitant recognition that position and context are centrally and inescapably implicated in all constructions of knowledge. (p. 2)

Recent works in the fields of literary and cultural studies, sociology, political science, anthropology, history, and art history have become increasingly spatial in their orientation.



In some ways, this transformation is expressed in simple semantic terms, that is, in the rising popularity of words such as *space*, *place*, *location*, *positionality*, and *mapping* in denoting a geographic dimension. In other ways, however, the spatial turn is much more substantive, involving a reworking of the very notion and significance of spatiality to offer a perspective in which space is every bit as important as time in the unfolding of human affairs, a view in which geography is not relegated to an afterthought of social relations but is intimately involved in their construction. Geography matters, not for the simplistic and overly used reason that everything happens in space but because *where* things happen is critical to knowing *how* and *why* they happen.

With space and place at the center of the analytical agenda, geographical thought has arguably played a major role in helping facilitate interdisciplinary inquiry that offers a richer, more contextualized understanding of human experience, social relations, and the production of culture. As different disciplines have taken up geography in their own way, they bring to bear their respective assumptions, languages, paradigms, applications, and examples on the meaning of the spatial. Thus, as the spatial turn has unfolded across the social sciences and humanities, it has come to embrace an ever-larger set of uses and implications.

The Historical Fall and Rise of Spatiality

In the 19th century, space became steadily subordinated to time in modern consciousness, a phenomenon that reflected the enormous time-space compression of the Industrial Revolution; intellectually, this phenomenon was manifested through the lens of historicism. Typically, historicist thought linearized time and marginalized space by positing the existence of temporal “stages” of development, a view that portrayed the past as the progressive, inexorable ascent from savagery to civilization, simplicity to complexity, primitiveness to civilization. Historicists such as Georg Hegel, Karl Marx, and Arnold Toynbee offered sweeping teleological accounts that paid little attention to space, human consciousness, or the contingency of social life. In the same vein, social Darwinism usurped the original theory of evolution as contingent and

open ended, substituting it with a simplistic, racist, linear view such as Herbert Spencer’s “survival of the fittest.” Orientalist thought structured the Western geographical imagination such that distance from Europe became equated with increasingly more primitive stages of development, conflating continents with races in terms that were hierarchically organized with respect to their alleged degree of temporal progress. In this way did historicism eclipse space in the service of imperial thought: Beyond Europe was *before* Europe, a theme articulated again in modernization theory and its current neoliberal variants.

The reassertion of space into the modern consciousness was a long, slow, and painful undertaking. In the 1920s, the Chicago School of sociologists and geographers began to inject space into urban analysis, a project that was poignant in its sensitivity to the experience of recent immigrants and the textures of ethnic neighborhoods and simultaneously doomed by its simplistic understanding of class, gender, power, and the world system. In the tumultuous 1960s, the seminal works of Henri Lefebvre and Michel Foucault were critical in suggesting that the organization of space was central to the structure and functioning of capitalism as a coherent whole. Moreover, Lefebvre maintained that space must be understood not simply as a concrete, material object but also as an ideological, lived, and subjective one.

It was social theory—specifically Marxism, initially via the works of David Harvey—that formed the centerpiece for a critical reevaluation of space and spatiality in social thought. Social theory repositioned the understanding of space from given to produced, calling attention to its role in the construction and transformation of social life and its deeply power-laden nature. Harvey’s spatialization of Marxism, and concurrent Marxification of space, centered on the deep structure of commodity production and the conversion of commodities into money, generating a model of production and the labor process that shed light on their transformation of time and space. Landscapes, in this reading, reflected the logic of commodity production at any given historical moment, constituting a “spatial fix” or window of stability that enabled the process of commodity production to unfold unproblematically, at least temporarily.



This line of thought was picked up and advanced by Edward Soja, whose works emphatically insisted that the spatial could not be subordinated to the temporal or the social. Thus, he maintains that social theory should rest on the triangular foundations of time, space, and social structure, each of which contingently structures and is structured by the others. Soja argues that the spatial turn has involved the end of historicism and the reassertion of space into social theory. In a sense, this trend marks a return to Immanuel Kant's position that held the two dimensions to be of equal significance. Similarly, Manuel Castells, noting the pronounced degree to which postmodern capitalism relies on information as its primary resource, distinguished earlier *information societies*, in which productivity was derived from access to energy and the manipulation of materials, from later *informational societies* that emerged in the late 20th century, in which productivity is derived primarily from knowledge and information. In his reading, the spatiality of postmodernism was manifested in the global "space of flows." He notes, for example, that while people live in places, postmodern power is manifested in the linkages among places, their interconnectedness, as personified by business executives shuttling among global cities and using the Internet to weave complex geographies of knowledge invisible to almost all ordinary citizens. This process was largely driven by the needs of the transnational class of the powerful employed in information-intensive occupations.

Why the Spatial Turn?

The spatial turn reflects broader transformations in the economy, politics, and culture of the contemporary world. We cannot understand the production of spatial ideas independently of the production of spatiality—that is, views of geography are only comprehensible by appeal to the social and spatial contexts. Several forces have intersected to elevate space to new levels of material and ideological significance.

Contemporary globalization has undermined commonly held notions of Euclidean space by forming linkages among disparate producers and consumers intimately connected over vast

distances through flows of capital and goods. *Globalization* is an ambiguous term, however, and refers to a variety of processes that play out in different ways, from global cities to international trade to the internationalization of culture and consumption. Unprecedented volumes of immigration across national borders have increasingly confronted residents in many countries, particularly in Europe and North America, with issues of cultural difference. Tourism likewise allows for selective appropriation of distant cultures and places. The global media relay news and events across a global stage. The offshoring of many jobs from the developed world to the developing one has called attention to national differentials in skills and labor costs. International finance, a worldwide space of flows, global deregulation, and the decline in transport costs have all conspired to erode conventional geographic pre-occupations with proximity. Far from annihilating the importance of space, globalization has increased it. Ironically, just as several pundits announced the "death of distance" and the "end of geography," geography acquired a renewed significance in the analysis of international flows of information, culture, capital, and people. As neoliberal capital operates ever more effortlessly on a worldwide stage, small differences among regions become increasingly important. Moreover, as numerous scholars have shown, globalization does not play out identically in different places; rather, context matters, and the incorporation of unique places into the global division of labor changes not only those locales but also the world system as well. Glocalization, therefore, is a two-way street.

The rise of cyberspace and the Internet has also raised issues of spatiality in several fields. The Internet, an unregulated electronic network connecting an estimated 1.5 billion people in more than 200 countries in 2008, allows users to transcend distance virtually instantaneously. Telecommunications systems have become the central technology of postmodern capitalism, vital not only to corporations large and small but also to consumption, personal communication, entertainment, education, politics, and numerous other domains of social life. Indeed, for many people who spend a great deal of time in the digital world, cyberspace has become such an important part of



everyday life that the once solid boundary between the real and the virtual has essentially dissolved: It is difficult today to tell where one ends and the other begins. In allowing people and firms to “jump scale,” to connect effortlessly with others around the world at the click of a mouse, cyberspace has been instrumental in the production of complex, fragmented, jumbled spaces of postmodernity, all of which have called for mounting scrutiny. Similarly, geographic information systems (GIS) offer dramatic new means to analyze spatiality, even if these are often drenched in empiricist and positivist epistemologies. GIS, therefore, is not simply reflective of the new importance of space but also constitutive of it.

Finally, the rapidly rising seriousness of global ecological and environmental problems has played no small role in elevating the significance of space. Issues that once could be understood and contained within relatively localized contexts, such as water pollution, are increasingly viewed as approachable only on a worldwide basis. Acid rain crosses national borders with ease. The enormous crisis of biodiversity unfolding across the world is inseparable from global patterns of habitat destruction, deforestation, and resource consumption. The gradual end of the age of cheap petrochemicals has added new urgency to this issue and threatens to raise the “friction of distance” of commuting fields. Looming over all this is the dark shadow of global warming: As evidence mounts daily of rapidly melting ice caps and glaciers and of ecosystems turned upside down overnight, the location of the sources of greenhouse gases has become a vitally problematic issue. Because environmental issues are unevenly distributed across space and because geography as a discipline has a long history of investigating human-environment interactions, space and spatiality have become crucial dimensions in understanding and tackling these problems.

Barney Warf

See also Chicago School; Critical Human Geography; Globalization; Glocalization; Harvey, David; Historicism; Lefebvre, Henri; Marxism, Geography and; Massey, Doreen; Soja, Edward; Spatialization; Time-Space Compression

Further Readings

- Cosgrove, D. (1999). Introduction: Mapping meaning. In D. Cosgrove (Ed.), *Mappings* (pp. 1–23). London: Reaktion.
- Massey, D. (2005). *For space*. London: Sage.
- Pickles, J. (1999). Social and cultural cartographies and the spatial turn in social theory. *Journal of Historical Geography*, 25(1), 93–98.
- Soja, E. (1993). Postmodern geographies and the critique of historicism. In J. Jones, W. Natter, & T. Schatzki (Eds.), *Postmodern contentions* (pp. 113–136). New York: Guilford Press.
- Warf, B., & Arias, S. (Eds.). (2008). *The spatial turn: Interdisciplinary perspectives*. London: Routledge.



SPECIES-AREA RELATIONSHIP

The species-area relationship is the positive relationship between the number of species and the size of the area in which they live. As the area increases, the number of species that are found within the area of interest also increases. The number of species found in an area is referred to as species richness. The species-area relationship is a general and widely documented pattern of community ecology and biogeography. It has become so well accepted that it is sometimes referred to as a rule or a law. Due to its fundamental importance in describing ecological relationships, the species-area relationship has been prominently incorporated into models of island biogeography and has been used in conservation decisions.

Fundamentally, the species-area relationship is a very simple conceptual relationship between species richness and area. When a small area of a landscape is observed, only a few of the species within the landscape will be included within the boundaries of the area. These species are likely the more common species within the landscape. As the observed area is expanded, it is more likely to include some of the rarer species in the landscape, thus increasing the observed species richness. Once a starting point is defined and the study area is expanded around that point, species richness will never decline. The number of species either increases as the study area increases or



remains the same. Even if the loss of species occurs within an area through time, the relationship between species richness and area within each time snapshot will not be negative.

While the species-area relationship is a positive relationship between species richness and area, the relationship is not linear. As the observed area is expanded and more rare species are observed, the number of unrecorded species in the landscape declines, and fewer additions to the species richness value occur. This relationship was modeled in 1920 by Arrhenius as

$$S = cA^z,$$

where S is the species richness, c is a constant, A is the area, and z is a fitted value that represents the slope of the linear relationship for the log of the equation. This model is better known as the *power model*. Another common model used to describe the relationship between species richness and area is the Gleason model, which was developed in 1922. The equation of the Gleason model is

$$S = d + k \log(A),$$

where S is the species richness, d is the y -intercept, k is the slope of the line, and A is the area. Both equations have been used extensively to describe how species richness increases as area increases, but neither is considered to be applicable in all cases. A major criticism of both equations is that they do not approach a maximum species richness value as area increases. In theory, there are a limited number of species within a landscape, but both the Arrhenius and Gleason models allow species richness to increase without limit as area increases. While in a practical sense, there will be a limit to the area that is being studied, thus making the Arrhenius and Gleason models not completely applicable in most studies, it is important to recognize that the models are just representations of the observed relationship between species richness and area. The inherent flexibility of the equations allows them to be fitted to maximize their representation of a data set. They are tools to quantitatively describe how species richness increases as area increases.

One of the most well-known applications of the species-area relationship is the area effect for the equilibrium model of island biogeography.

This model is also known as the MacArthur-Wilson model, after Robert H. MacArthur and Edward O. Wilson, who popularized the model in the 1960s. The equilibrium model of island biogeography predicts the number of species that should exist on an island that is in equilibrium based on the size of the island, the distance of the island from the mainland, and the turnover of species richness for the island. This model uses the species-area relationship as the area effect to predict that larger islands can support more species than smaller islands. This is used in concert with the distance effect to factor size and location into the equilibrium species richness value for an island. The distance effect is the assumption that islands closer to the mainland have more species than islands that are farther from the mainland.

The distance effect and the area effect have an impact on the number of species on an island at equilibrium through their effects on species immigration and extinction rates. If two islands, one small and one large, are at the same distance from a mainland, the expected immigration rate is the same for both islands, but the larger island is expected to support larger population sizes, which in turn lowers the extinction rate. This results in the larger island having a larger expected species richness value when it is at equilibrium and follows the basic premise of the species-area relationship. If two islands are the same size, but one is closer to the mainland than the other, the immigration rate is expected to be greater for the island closer to the mainland, while the extinction rates for the islands would be the same due to their areas supporting the same population sizes. This results in a higher expected species richness value for the island that is closer to the mainland and is the consequence of the distance effect.

The basic equilibrium model of island biogeography takes area's impact on extinction and distance's impact on immigration into account, but area can also be considered to affect species immigration to an island, just as distance's impact on extinction can also be considered. Larger islands might have greater immigration rates than small islands due to the increased potential for species to find larger islands. This potential impact is known as the target effect. Increased distance, or isolation, of islands might increase the extinction rates for those islands in addition to the predicted



lower immigration rates of the basic equilibrium model of island biogeography. This increase in extinction rates with increasing isolation is known as the rescue effect.

The simplicity of the basic equilibrium model of island biogeography has resulted in numerous criticisms of the model. One of the practical issues with the model is the difficulty in quantifying the immigration and extinction rates for islands. Extensive fieldwork is required to estimate these rates, and they may change with time, which would change the predicted species richness equilibrium. The model also ignores the potential impacts that species may have on each other. Some species may cause the extinction of other species on an island, prevent certain species from immigrating to the island, or interact with species in other ways to influence the species richness of the island. Other scenarios that violate the assumptions of the basic equilibrium model of island biogeography are speciation events on islands that increase species richness without immigration; an uneven distribution of species on the mainland, which would affect immigration rates to islands; and varying habitats on the islands, which would influence both the number of species that could immigrate to the various islands and the rates of extinction on the islands. Despite these criticisms, the basic equilibrium model of island biogeography is regarded as a very useful conceptual tool for understanding how area, distance, and species immigration and extinction affect species richness on islands.

Islands are especially good features with which to examine the species-area relationship because the shores of the islands already define the boundaries of the study areas. It can be problematic to study the species-area relationship on large landmasses because it is more difficult to justify the study areas that are chosen. On large landmasses, the area in which species richness is being counted is likely to be selected from a larger contiguous habitat or to contain multiple habitats that each have their own processes that influence species richness. This makes it very difficult to compare species-area relationships between studies. Islands have inherent boundaries and thus make natural individual units to study and observe relationships. One such relationship for oceanic islands, known as Darlington's rule, states that a 10-fold

increase in the area of an island results in the doubling of the species richness. The studies that have looked at the species-area relationships within large landmasses have focused on areas that are easily distinguished from their surrounding habitat forms. Two examples of these types of areas are mountaintops and lakes. These areas are similar to islands in their readily defined boundaries and their patchy distributions.

Another inland landscape that can use the island model is a fragmented habitat. Habitat fragments can act as islands for species that require the presence of other species that only exist within the fragmented remnants of a formerly continuous habitat. Modern conservation efforts have sometimes used the species-area relationship as a basis for determining what areas to focus on protecting from commercial interests. This is typified by the single large or several small (SLOSS) reserve debate of the 1970s and 1980s. This debate centered on whether a single large nature preserve or several small preserves would maximize the number of conserved species. The rationale for preserving the largest areas of land is that according to the basic equilibrium model of island biogeography, maximizing area also maximizes species richness. This approach has been criticized for not taking into account the inherent differences in species richness between habitats and in species population sizes within habitats and the relative scarcity of different habitats. Selecting a large area of land to conserve over several small areas may not conserve more species if the species in the small areas do not exist in any other locations, if there is a greater species richness inherent in the small areas, or if a number of species in the large land area have small population sizes, which put them in danger of becoming extinct. Ultimately, the optimal spatial design of preserves depends on the characteristics of the species within the communities being conserved. This can include spatial patterns that are not included in the SLOSS debate. The species-area relationship is a widely observed general relationship between area and species richness, but many factors other than area influence species richness and the long-term persistence of species within a habitat, and these need to be considered in conservation and land management decisions.

Matthew Miller



See also **Biodiversity; Biogeography; Conservation; Extinctions; Forest Fragmentation; Island Biogeography; Landscape Biodiversity; Single Large or Several Small (SLOSS) Debate; Spatial Strategies of Conservation**

Further Readings

- Brown, J. H., & Lomolino, M. V. (1998). *Biogeography*. Sunderland, MA: Sinauer.
- Connor, E. F., & McCoy, E. D. (1979). The statistics and biology of the species-area relationship. *The American Naturalist*, 113(6), 791–833.
- Gotelli, N. J. (2001). *A primer of ecology*. Sunderland, MA: Sinauer.
- Lomolino, M. V. (2000). Ecology's most general, yet protean pattern: The species-area relationship. *Journal of Biogeography*, 27(1), 17–26.



SPECTRAL CHARACTERISTICS OF TERRESTRIAL SURFACES

Terrestrial surfaces are composed of a diverse assemblage of human-made materials such as concrete, asphalt, and metal and natural materials such as soils, shrubs, and trees. Scientists observe such features on the surface of the Earth and make measurements to better understand the characteristics associated with them. This entry describes the nature of research using remote sensing and examines the spectral characteristics of vegetation, soil, water, and human-made materials.

Characterizing and monitoring the materials through time is very important for many Earth resource management applications. While the tasks are often conducted by taking detailed field measurements, the process is time and labor intensive and is often difficult to conduct over large geographic areas. Remote sensing, which collects information about a feature without being in direct physical contact with it, has been widely used for conducting the tasks in an efficient way. Spectral remote sensor systems have

matured from simple panchromatic sensors (single band in gray scale) to multispectral sensors (multiple bands, generally between 3 and 15) and further to hyperspectral or ultraspectral sensors, which collect spectral data in up to hundreds and thousands of bands in the electromagnetic spectrum. As the spectral resolution (e.g., 10 nm [nanometers]) of sensor systems improves, we can get a more accurate spectral response for an object under examination. Because each material on the surface of the Earth has a unique spectral pattern in the electromagnetic spectrum, it is important to understand the spectral characteristics of the key materials that are easily found on terrestrial surfaces. It is believed that many of the biophysical and human-made materials under investigation have unique absorption features with 10 to 20 nm width. The following sections will look into the spectral characteristics of selected natural and human-made materials, focusing on the visible, near-infrared, and middle-infrared regions (i.e., 400–2,500 nm) of the electromagnetic spectrum.

Spectral Characteristics of Natural Materials

Three major materials found on the terrestrial surfaces include vegetation, soil, and water. Each of the materials has a distinctive spectral reflectance pattern.

Vegetation

Vegetation is one of the most important components of Earth's ecosystems, since it covers much of the terrestrial surface. Vegetation has various absorption features, such as chlorophyll (430 and 660 nm for chlorophyll *a*; 460 and 640 nm for chlorophyll *b*) and water (around 1,400–1,900 nm) absorption. That is why reflectance is relatively low in those regions. Green energy (around 500–600 nm) between the two chlorophyll absorption bands in the blue and red regions is relatively less absorbed by leaves. Thus, healthy vegetation (i.e., foliage) generally appears to be green to human eyes. Healthy vegetation exhibits dramatic reflectance increase in the near-infrared



region (700–1,200 nm) due to the internal scattering at the cell wall–air interfaces within leaves. Abrupt reflectance increase between the red and near-infrared regions (680–780 nm) is a unique spectral characteristic of vegetation. This region is known as red edge and is highly related to vegetation characteristics such as chlorophyll content and biomass. For example, a shift in the red-edge position may be due to phenological change or vegetation stress. The spectral pattern of vegetation can be influenced by many factors such as nutrient/water stress, disease, and the phenological cycle of vegetation. Thus, the spectral characteristics of vegetation and their change have been widely studied to detect and monitor vegetation health.

Soil

Dry, bare soil generally exhibits a gradual increase in reflectance with increasing wavelength between 400 and 2,500 nm. Many factors determine the spectral characteristics of soil, including particle size, texture, moisture, organic matter content, and surface roughness. For example, as soil moisture increases, incident electromagnetic energy is absorbed by water, resulting in a lower soil reflectance curve. Similarly, the greater the organic matter content of a soil, the lower the spectral reflectance.

Water

Water absorbs most of the incident radiant flux, especially in the near- and middle-infrared regions. Thus, scientists often use near- or middle-infrared bands to delineate water bodies from remote sensing data. If water does not contain organic and inorganic constituents and is relatively deep, it appears very dark throughout the visible, near-infrared, and middle-infrared regions. However, many natural water bodies inherently contain various kinds of organic and inorganic constituents, such as chlorophyll *a* and suspended sediment. These constituents generally result in spectral reflectance increase, particularly in the visible region. Consequently, water color in the visible region (and a portion of the near-infrared region) has been intensively studied to address water quality issues. Light at

the short-wavelength regions (i.e., blue to green) penetrates water bodies to some extent. That is why we can easily identify the bottom topography of water bodies in shallow areas using the blue and green bands. Green light (i.e., centered at 540 nm) is often used to measure water depth because of its ability to penetrate water.

Spectral Characteristics of Human-Made Materials

Human-made materials easily found on terrestrial surfaces are generally impervious. Human-made impervious surfaces such as asphalt pavement have greatly affected environmental resources such as urban air and water. They have also increased the frequency of disaster: for example, flooding due to excessive runoff. In addition, many impervious materials such as asphalt keep rain from infiltrating into the ground and eliminate natural groundwater recharge. Scientists have used spectral remote sensing to identify and manage impervious surfaces in an efficient and timely manner as well as to conserve environmental resources. Typical human-made materials include asphalt, concrete, and steel.

New asphalt pavement has very low reflectance characteristics throughout the visible, near-infrared, and middle-infrared regions. Although asphalt may result in spectral variation in the visible and near-infrared regions with the different deterioration levels over time, it generally appears very dark, even black. Concrete has relatively high reflectance characteristics throughout the visible, near-infrared, and middle-infrared regions. The spectral reflectance of steel is also high, between 400 and 2,500 nm, and it varies by the levels of oxidation and galvanization.

Image pixels with an assemblage of these human-made materials, often found in an urban area, typically appear steel-gray on false color composite images using green, red, and near-infrared bands. Since the spectral reflectance characteristics of these human-made materials are quite different from those of natural (biophysical) materials, scientists have widely used spectral data to identify and classify various land cover features.

Some scientists refer to the spectral pattern of a material as a spectral signature (i.e., a spectral



fingerprint of the material). However, it should be noted that the spectral characteristics of a material, either natural or human-made, vary with many factors, including its condition and data collection date and time. Nonetheless, the spectral characteristics of materials on terrestrial surfaces provide a unique opportunity to efficiently identify and monitor the materials, which allows us to better understand the dynamics of Earth's systems.

Jungho Im

See also Biophysical Remote Sensing; Image Interpretation; Multispectral Imagery; Remote Sensing; Spectral Resolution

Further Readings

- Campbell, J. B. (2008). *Introduction to remote sensing* (4th ed.). New York: Guilford Press.
- Goetz, A. F. H., Vane, G., Solomon, J. E., & Rock, B. N. (1985). Imaging spectrometry for earth remote sensing. *Science*, 228(4704), 1147–1153.
- Jensen, J. R. (2005). *Introductory digital image processing* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
- Jensen, J. R. (2007). *Remote sensing of the environment* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2007). *Remote sensing and image interpretation* (8th ed.). Hoboken, NJ: Wiley.
- Richards, J. A., & Jia, X. (2005). *Remote sensing digital image analysis: An introduction* (4th ed.). New York: Springer.

Earth's surface features is recorded. In broad terms, the narrower the wavelength interval for a particular band or channel, the finer the spectral resolution. The spectral resolution of a remote sensing sensor depends primarily on two factors. The first is the number of bands or channels used and the second is the width or wavelength interval assigned to each band or channel. Higher spectral resolution can be achieved from using a larger number of bands and by assigning a narrower width for each band; however, the spectral position of a band is also important for achieving high spectral resolution. Narrow bandwidth is generally obtained by dispersing the spectrum of incoming radiation on to an array of detectors using prisms or diffraction gratings.

The spectral resolution of a standard black-and-white film is fairly coarse as the spectral sensitivity of the film is restricted to the incident energy in wavelengths extending over the entire visible portion of the spectrum and the various wavelengths of the visible spectrum (i.e., ~0.4–0.7 μm [micrometers]) are not individually distinguishable. That is, black-and-white film records only the overall energy in the entire visible portion of the spectrum. Color film, on the other hand, is sensitive to the incident energy within the blue, green, and red wavelengths of the visible spectrum and therefore has relatively higher spectral resolution. It can discriminate between features of various colors based on their reflectance in each of these distinct wavelength regions.

Most satellite-based as well as airborne remote sensing systems designed for observing Earth's surface features record energy response in several discrete spectral bands at various spectral resolutions (Figure 1). These systems are commonly referred to as multispectral sensors. Landsat's thematic mapper (TM), for example, records electromagnetic energy reflected by and emitted from Earth's surface features in seven discrete bands covering the visible through thermal-infrared portions of the spectrum. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), on the other hand, is designed to provide spectral resolution of Earth's surface features in 14 discrete bands. It has 11 bands to cover the middle-infrared through thermal-infrared portions of the spectrum, compared with only three bands available to cover the same regions on Landsat's TM.



SPECTRAL RESOLUTION

The term *spectral resolution* refers to the number and width of a specific wavelength interval (i.e., band or channel) in the electromagnetic spectrum to which a remote sensing system is sensitive. Spectral resolution describes the ability of a sensor to define the fine wavelength intervals in which electromagnetic energy reflected or emitted from

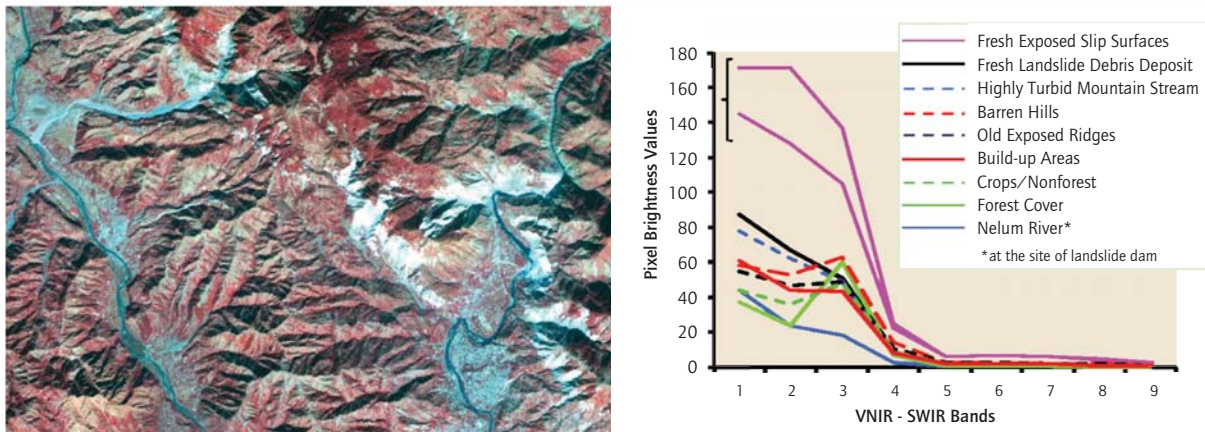
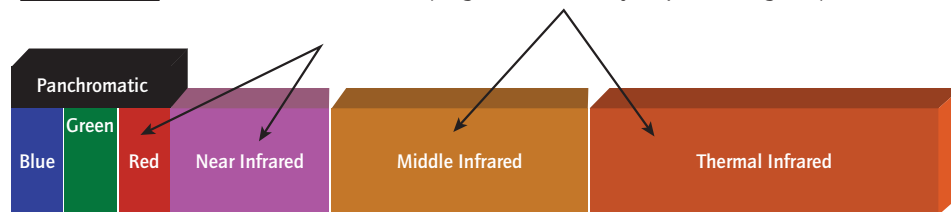


Figure 1 A graph showing the spectral properties of different features in visible through middle-infrared bands of the Advanced Spaceborne Thermal Emission and Reflection Radiometer

Source: Author.

- Multispectral - tens of bands available (large slivers of major spectral regions)



- Hyperspectral - hundreds of bands available (smaller slivers of major regions)

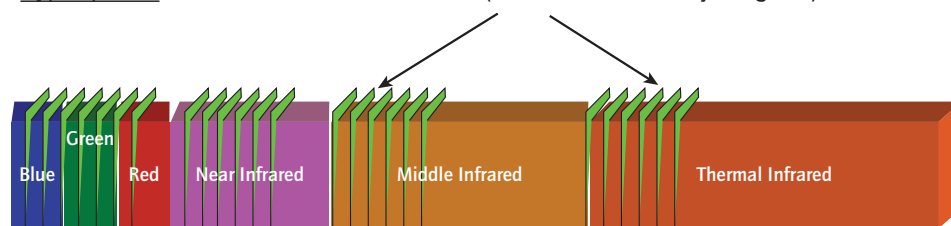


Figure 2 Multispectral sensor versus hyperspectral sensor

Source: Author.

New advanced hyperspectral sensors are designed to detect reflected or emitted energy in hundreds of narrowly defined (i.e., narrow bandwidth) contiguous spectral bands (Figure 2). The Airborne Visible Infrared Imaging Radiometer

(AVIRIS), for example, is designed to record reflected energy in the visible through middle-infrared portions of the spectrum by scanning 224 bands across a very narrow bandwidth. The Hyperion sensor on NASA's EO-1 satellite is



capable of providing spectral resolution of Earth's surface properties in 220 narrow spectral bands. A greater number of spectral bands available on hyperspectral sensors provide more spectral information about Earth's surface properties and are therefore capable of extracting even very subtle spectral information that usually cannot be resolved by multispectral sensors. Through these hundreds of very narrow-wavelength bands, fine spectral discrimination between different features on Earth's surface can be accurately achieved.

Mahtab A. Lodhi

See also **Image Interpretation; Image Processing; Image Texture; Imaging Spectroscopy; Multispectral Imagery; Radiometric Resolution; Remote Sensing; Spatial Resolution; Spectral Characteristics of Terrestrial Surfaces; Spectral Transformations**

Further Readings

- Campbell, J. B. (2007). *Introduction to remote sensing*. New York: Guilford Press.
- Jensen, J. R. (2004). *Introductory digital image processing*. Upper Saddle River, NJ: Prentice Hall.
- Lillsand, T., Kiefer, M., Ralf, W., & Chapman, J. W. (2004). *Remote sensing and image interpretation*. Hoboken, NJ: Wiley.



SPECTRAL TRANSFORMATIONS

Optical Earth remote sensing sensors record the reflected solar radiation in multiple discrete spectral channels, producing a spectral signature for each picture element in a remote sensing image. The amount of reflected energy depends on the physical and chemical nature and status of the object's surface and is a function of the scanned wavelength of the electromagnetic spectrum. The spectral information that is saved in different data layers can be treated separately (e.g., by displaying a single channel on the screen), or it can be combined in different ways, widely referred to as spectral transformations.

Any transformation of a multispectral data set generates a new image or a set of data channels

with the overall aim of maximizing the information content and at the same time minimizing the data load. The general concept of such transformations includes an accentuation of the dichotomies in the multispectral feature space with regard to specific objects (e.g., vegetation, soil, or atmosphere) or processing purposes (e.g., radiometric normalization, image classification, change detection, or estimation of biophysical properties).

Arithmetic Operations/Band Calculations

Arithmetic operations (addition, subtraction, multiplication, division) or band calculations can be carried out on any data set of at least two spectral bands of the same geographical area. They allow the generation of a new image with properties that are more suited to a particular purpose than the original ones. The most widely used arithmetic operation in remote sensing image analysis is the division or rationing of spectral bands with the aim of emphasizing the differences between them. These differences may be quantified to estimate, for example, the biophysical or geochemical properties of the land surface (see next section). Another widely used application of image division is the normalization of spectral response patterns by rationing two spectral bands. This technique makes use of the fact that illuminated surfaces reflect more solar radiation than shaded surfaces of the same nature and that the relation between those two can roughly be described by a multiplicative spectral component.

Many cases of band calculations combine at least two arithmetic operations, for example, image addition and division. For example, the average spectral reflectance in visible light (VIS) is calculated by summing the digital numbers of the respective channels in the blue, green, and red parts of the spectrum and dividing the sum by the number of bands (i.e., $VIS = (B + G + R)/3$).

A special case of band calculations is that of conditional operations that do not make use of the total amount of incoming data for a calculation but use a selection of the data set. An example is the common method of selecting the maximum spectral reflectance value for the same spectral band over the same geographical area out of a collection of n subsequent (e.g., daily)



data takes. This method, known as the maximum value composite method, is widely used in generating coarse-resolution temporal composites of global coverage remote sensing products (e.g., MODIS, Spot-VEGETATION, NOAA-AVHRR).

Spectral Ratios and Vegetation Indices

Spectral ratios describe a group of band calculations that use the spectral reflection in two bands. Modification and extension of ratios to multiple complex band calculations resulted in the emergence of the term (spectral) *vegetation indices* (VIs). This term accounts for the fact that the amount of solar radiation that is reflected from a land surface object is a function of wavelength and object characteristics, especially the type and biophysical properties of the vegetated fraction of the object (e.g., fraction-absorbed photosynthetically active radiation, chlorophyll, leaf area index, or biomass). In particular, VIs parameterize the relation between the absorption maximum in the red (R) region and the reflectance maximum of the near-infrared region (NIR) of the electromagnetic spectrum, which is characteristic of vital vegetation. These circumstances have led to the development of a vast number of VIs that are widely applied in any spatially explicit Earth science application of remote sensing data. Among others, the Normalized Difference Vegetation Index (NDVI) is representative of the group of dual-band VIs. It is the ratio of the difference of NIR and R to their sum:

$$\text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}}.$$

Further development of VIs aimed at optimizing the results from the NDVI but in most cases showed high consistency with simple ratios or the NDVI. A second generation of VIs focused more on the elimination of the external factors influencing reflectance and VIs, such as atmosphere, viewing geometry, and soil background (e.g., SAVI, EVI, GEMI, and many more).

The main problem with the use of VIs in environmental studies is to select an appropriate VI for a specific application. The question of which VI should be used can only be answered based on reliable ground truth information.

Principal Components Transformation

Principal components transformation (PCT), also known as principal components analysis or Karhunen-Loeve analysis, is a technique that transforms the original multispectral remote sensing data set into a new set of uncorrelated variables (components) based on the covariance matrix of the n -dimensional input data set. In general, most of the information content of the original data set is represented by only a few new components, which enables considerable reduction in the dimensionality (i.e., the number of bands) in the data set.

Modified forms of the PCT include the minimum noise fraction procedure, which is more suited for hyperspectral data, and the noise-adjusted PCT.

Color Transformations

Color transformations are used to convert the color coordinate system of an RGB remote sensing data set to a different color space. Such transformations may be useful for printing purposes or for visualization of color composites of remote sensing data but, in most cases, are used for the fusion of remote sensing data of different types, for example, different spatial and spectral resolutions.

Stefan Erasmi

See also **Biophysical Remote Sensing; Environmental Mapping; Image Fusion; Image Interpretation; Image Texture; Radiometric Normalization; Remote Sensing; Spectral Resolution**

Further Readings

- Jensen, J. R. (2005). *Introductory digital image processing: A remote sensing perspective*. Upper Saddle River, NJ: Pearson Prentice Hall.
- Mather, P. M. (2004). *Computer processing of remotely-sensed images: An introduction*. Chichester, UK: Wiley.
- Richards, J. A., & Jia, X. (2006). *Remote sensing digital image analysis: An introduction*. Berlin, Germany: Springer.



SPIT

See Coastal Erosion and Deposition



SPORTS, GEOGRAPHY OF

Sports throughout the world are influenced by both the physical and the human geographies of a given location. Despite this relationship and the wealth of potential research topics, geographers tend not to treat sports as a serious academic theme, although economists, sociologists, anthropologists, historians, and even psychiatrists have done so. This void is evident in the discontinuation of the only journal on sports geography—*Sport Place*—due to the lack of submissions. This intersection of sports and geography has been studied by geographers since the 1960s, first by John Rooney and more recently by John Bale. Today, there continues to be a small group of geographers who study sports.

Topics in the geography of sports cover a wide range of human as well as physical geography themes. The most common topic has dealt with the recruitment of players for sports teams at both the collegiate and the professional levels. Much can be learned from the spatial distribution of athletes in a given sport. Recent trends in North American sports suggest that leagues are globalizing and recruiting players from countries throughout the world. The National Basketball Association and the National Hockey League have long been able to attract players from outside North America, while Latin American players have been a staple in professional baseball for decades. More recently, major league baseball searched for new markets for producing players and exposure. This expansion is best represented by the World Baseball Classic, which began play in 2006. While the tournament includes countries with noted histories of playing baseball—the United States, the Dominican Republic, and Japan—it also includes newcomers to the sport, such as China and South Africa. These new markets serve not only as ways to find new prospects for teams but also as ways to market the leagues and their teams in other countries.

Sports have also played a significant role in geopolitics and nationalism. The Olympics have long been a stage for promoting national pride not only for the host countries but for participants as well. Examples of moments that have stirred patriotic sentiments include the U.S. men's ice hockey team's victory over the Soviet Union in the 1980 winter games and the unexpected fourth-place finish by the Iraqi men's soccer team in the 2004 summer games. The Olympics have also been used as a tool of protest, including the 1976 Montreal summer games, boycotted by numerous African states over apartheid-related issues, and the boycotts of the 1980 Moscow Winter Olympics and the 1984 Los Angeles summer Olympics by the United States and the Soviet Union, respectively. There were also calls to boycott the 2008 Beijing summer Olympics due to human rights concerns in China, although no boycotts took place. The Olympics are also used as a way of seeking legitimacy and recognition by new and aspiring states in the international community. In 2000, athletes from Timor-Leste (East Timor) competed in the Sydney summer Olympics despite not being recognized as a country (Timor-Leste was not independent until 2004). Palestine has also been represented in the summer Olympics since the 1996 Atlanta Olympics.

The political geography of sports goes beyond simply the Olympics. Sports have served as a way to ease political tension, as was the case with the so-called ping-pong diplomacy between the United States and China in 1971, a series of cricket test matches in the 2000s between India and Pakistan, or the 1999 two-game exhibition series played in Havana between Major League Baseball's Baltimore Orioles and the Cuban National Team. But as is the case with the Olympics, sports in general can be used as a way to protest against another country or even an individual. In 2009, the United Arab Emirates denied a visa to the Israeli tennis player Shahar Peer, thereby not allowing her to compete in a World Tennis Association tournament in Dubai.

Sports can also serve as a way of fostering a sense of identity and attachment. Whether it is high school football in Texas, hockey in Canada, baseball in Japan, or rugby in New Zealand, sports help create a common identity at local, regional, and national scales. Furthermore, sports



Japan's catcher Kenji Johjima (*right*) celebrates the final out after South Korea's Keunwoo Jeong (*left*) struck out in their World Baseball Classic game at Dodger Stadium in Los Angeles, March 23, 2009. Japan won 5–3.

Source: AP Photo/Mark J. Terrill.

and the associated teams can serve as a common identity for diasporic peoples, such as the “Red Sox Nation.”

Another important spatial aspect that geographers have researched in terms of sports is the location of sports franchises and their associated playing facilities. While shifts in population play a major role in the diffusion of franchises in North America, other aspects, such as the search for new markets, also serve to drive this expansion. The National Hockey League, for example, has expanded into (or relocated teams to) warm weather locales such as Los Angeles, Phoenix, Dallas, Atlanta, and Miami in recent decades. In terms of urban political economy, the location of sports stadia has reflected central city decline and redevelopment. From the 1960s to the 1980s, North American sports franchises tended to build

or had built for them new stadia and arenas in suburban locations, a reflection of urban population trends. Over the past 20 years, there has been a return to the central city, as sports facilities often serve as anchors to downtown revitalization projects.

Physical geography also plays a role in the performance of sports. High elevations have had a profound impact on sporting events, as they did in the 1968 Mexico City summer Games and the first decade of baseball in Denver. Teams have often taken advantage of their physical settings to create a home-field advantage, a concept that contains many human geographic elements. Examples of this physical advantage include the Bolivian national soccer team hosting World Cup qualifying games at La Paz (more than 3,500 meters above sea level) and the National Football



League's Tampa Bay Buccaneers wearing their white uniforms during home games to combat the relatively high temperatures of Florida. In the case of golf courses and ski resorts, sports can also reshape the physical environment.

While this is not an exhaustive list of the ways in which geography can shed light on various aspects of sports, it is clear that the two are complementary. There is much that geographers can contribute to the growing critical research that sociologists, economists, and historians of sport are already undertaking.

Daniel McGowin

See also **Body, Geography of; Cultural Geography; Popular Culture, Geography and**

Further Readings

- Bale, J. (2003). *Sports geography* (2nd ed.). London: Routledge.
- DeChano, L., & Shelley, F. (Eds.). (2006). *The geography-sports connection: Using sports to teach geography*. Jacksonville, AL: National Council for Geographic Education.
- Foer, F. (2004). *How soccer explains the world: An unlikely theory of globalization*. New York: HarperCollins.
- Raitz, K. (Ed.). (1995). *The theater of sport*. Baltimore: Johns Hopkins University Press.
- Rooney, J. (1974). *A geography of American sport: From Cabin Creek to Anaheim*. Reading, MA: Addison-Wesley.

Squatter settlements are defined as residential areas built on vacant land, either private or public, in an unauthorized fashion. A typical squatter settlement is located on the fringe of a large city; the land is occupied illegally without legal title to it; the houses fail to conform to building codes and regulations; and the settlement lacks or has very limited infrastructure and services such as running water, electricity, sanitation, paved roads, and educational and medical facilities. There are other terms that are used interchangeably, such as *shanty towns* or *informal, spontaneous, irregular, unregulated, unauthorized, unplanned, or self-help settlements*, although each term has its own political implications. Sometimes it is their illegality, sometimes their unplanned nature, and sometimes their substandard qualities that are stressed by the terms used. Countries have their local terms for squatter settlements: *favelas* in Brazil (Portuguese), *barrios* in some other Latin American countries (many Latin American countries have their own terms, e.g., *barriadas* in Peru and *villas miseria* in Argentina), *bustee* in India, *bidonvilles* in Francophone West Africa, *kampong* in Southeast Asia, and *gecekondur* in Turkey.

Usually, a negative view prevails in society about both the place and its people because of the illegal development of squatter settlements: Squatter dwellers are regarded as invaders of land and offenders against private property. They may also be seen as overtaxing public services and causing harm to the city—both to its image as a modern place and to its environment if the houses are built in reservoirs and forests. Furthermore, with their traditional values and way of life, they may be blamed for ruralizing the city. On the other hand, seeing squatter housing as a response of the urban poor to their housing problem may bring some sympathy. The term *squatter housing* implies temporariness, although in fact it has been a continuing presence since its first appearance in the late 1940s and early 1950s.

In most countries, early squatter settlements emerged after World War II in the restructuring of the world economy, although Latin America started capitalist production earlier. In the process of the integration of Third World countries into the capitalist world system, modernization in agriculture disturbed the traditional balance in



SQUATTER SETTLEMENTS

Squatter settlements are basically a Third World phenomenon; they are part of the urban landscape of many Latin American, Asian, Middle Eastern, and African countries. Billions of people live in them. For example, in 2003, 55.5% of the urban population in India, 44.1% in the Philippines, 42.6% in Turkey, 37% in South Korea, 36.6% in Brazil, and 33.1% in Argentina lived in squatter settlements.



Turkish cities such as Istanbul and Ankara are frequently sites of low-income communities called *gecekondu*.

Source: Author.

rural areas, and many peasants, in their search for livelihood, left their villages for the cities. In the face of inadequate housing in the cities, they started building their own houses on land that did not belong to them. The first houses were shanty-like structures; they were built in undesirable locations, such as steep hillsides and riverbanks, close to industrial areas, mostly in old city centers, so that their dwellers could find work and save transportation costs. As these locations disappeared under the migration waves from rural areas, squatter settlements started developing on the peripheries of cities. They were built in faraway areas where no infrastructure and services were available. They were expected to disappear as rural migrants became established in the city and found permanent jobs that would enable them to pay for their housing. However, this expectation proved to be wrong. The level of industrialization in Third World countries lagged behind their level of urbanization, and as a result,

there were not enough jobs in the formal sector to absorb newcomers to the city. Furthermore, the cities lacked affordable housing; Third World states had industrialization as their priority, ignoring other sectors, including housing. Thus, the people themselves had to transform the unoccupied peripheral land into livable environments. They used their meager resources, along with their social networks (mostly kin and fellow villagers) to construct houses and to satisfy basic needs so as to survive in the middle of nowhere. In contrast to the view that squatter settlements destroy nature, they planted trees, as in the case of Turkey, in their endeavor to create environments like the ones back in the villages. Over the years, some squatter settlements developed into established neighborhoods, and their initially shanty-like structures changed into sturdy buildings, while others retained their initial features.

The differences between squatter settlements in different countries should be noted. Several



factors account for the differences. The level of economic development of the country, its political system, its historical background, and the availability of public land are some. As an example, treasury land is abundant in Turkey: The Turkish republic inherited from the Ottoman Empire vast tracts of land that existed outside private ownership. This made it easier for governments, in their pursuit of votes, to legalize squatter settlements. The legalization of squatter settlements has been both a drawback and an advantage. On the one hand, it has aggravated the “squatter problem,” as more and more people began to build squatter houses in the hope of future ownership of their homes; on the other hand, it has contributed to the improvement of squatter settlements, where people, in their expectation that they would own the houses one day, felt free to invest in them, spending money to upgrade them. In Nairobi, Kenya, unlike in Turkey, only temporary structures are permitted on public land; they are rented out, and no improvements are allowed in them. The outcome is decaying houses—mud huts—without basic infrastructure. This situation causes squatter dwellers much inconvenience and resentment and creates health problems. Due to these outcomes, the World Bank maintains that granting residents legal title to their land is key to improving housing standards.

The political system of the country is another factor that affects squatter housing. In those countries where elections are held periodically, political parties are inclined toward populism, promising legalization of squatter settlements during election times. On the other hand, in military regimes, squatter settlements are either strictly prohibited, as they were in Pinochet's Chile, or are rendered invisible, when the state pays no attention to them and to their poor and powerless residents, as in Bolivia when it was under military rule.

Furthermore, if traditional values regarding land tenure prevail, the illegal occupation of land is more easily tolerated. *Usufruct rights*, that is, the right of enjoying the use of property on the condition that one does not cause any harm, can empower squatter builders against the state to claim that they own their houses since they have been living in them for many years. Conflict arises when modern values, such as private property

ownership, compete with traditional ones or render them out of date.

In the initial development of squatter settlements, land invasion is the major issue. In some cases, this process may take the form of an organized mass invasion, as in the case of Lima (Peru) forming housing associations or cooperatives, getting technical advice and support from professionals (architects, engineers, lawyers), occupying the land collectively, and setting up community kitchens while the squatter settlement is under construction. In some other cases, ad hoc invasion prevails, with people hearing from each other about the availability of land, asking their relatives and coworkers to join them, and helping one another in the construction of houses. Solidarity is of central importance in this process. After the invasion of land and the construction of houses, the second issue is to bring infrastructure and services to the settlement; and this is also done collectively. But as the settlement becomes established and the residents settled over the years, the initial tendency of mutual help and cooperation may disappear, and competition and conflict may take their place, especially when families start enjoying some social mobility in their lives in the city. Additionally, although squatter settlements are originally built for providing shelter for the urban poor, this status changes over the years in many instances; commodification of squatter housing becomes the order of the day, and rent concerns largely shape people's relationship with their squatter houses. Squatter settlements turn into dense environments dominated by concrete buildings. Also, as in São Paulo, the formal sector, such as chain stores and banks, may start creeping into squatter settlements to benefit from the consumption desire of their dwellers, which is fueled by the media. Another turn in the development of squatter settlements concerns violence and crime. As in the case of Brazil, portions of many squatter settlements may come under the control of street gangs, and with their own rules and power structure, they may develop into a “parallel society.”

In brief, squatter housing shows a great variety: It differs in different countries and cities, as well as between the past and present. The future of squatter housing is another question to



consider. Squatter settlements are more of a product of modernity, in which nation states and import-substituting industrialization regulated by the state are the main actors in Third World countries. Since the 1990s, this situation has changed following the disintegration of the Soviet Union. The catchword *globalization* is the order of the day, and urban space is gaining much significance under the dynamics of neoliberalism. The private sector, with its transnational partners, is after the profit to be made in city spaces. Regeneration, redevelopment, transformation, and rehabilitation, along with clearance, are spoken of more than ever in the context of squatter settlements. Developers, including large multinational construction companies and municipal governments, want the land occupied by squatter houses, to “develop” it. Populist politics toward squatter dwellers disappears in this case. As squatter settlements are demolished to open up space to the private construction sector for projects that address the affluent classes, such as gated communities and shopping malls, squatter dwellers are displaced. Depending on the democratization of society and the prevalent views about squatter housing and their dwellers, displaced families may be given some rights, such as ownership in an apartment complex built by the municipality, or they may lose their homes and end up in the street. The latter case poses a serious problem for the future of globalizing societies in their relationship with the urban poor. As squatter housing, a compensation for the limited welfare system of Third World societies, disappears, the urban poor face a bleak future and may fall into despair, which may breed violence and illegality. The problem in this case is not squatter housing but the lack of low-cost housing. On the other hand, in those societies and cities that are relatively untouched by the effects of globalization, squatter settlements turn into derelict areas that are outside the attention of the state, while their population is marginalized and excluded more than ever, and in the public view, they are more closely associated with crime and violence: As better-off classes retreat into their own housing and consumption environments, their fear of squatter settlements increases. This fear may be based more on the “talk of crime,” as in the case of Brazil, than on real instances of

crime. This points to the increased tension between squatter dwellers and better-off classes in the city. International agencies, such as the World Bank, attempt to intervene to help the urban poor, for example, by providing credits to squatter dwellers, but this effort remains too limited to change the overall outcome. In brief, the future of squatter settlements and their poor residents looks bleak.

Tahire Erman

See also **Developing World; Housing and Housing Markets; Peasants and Peasantry; Rural-Urban Migration; Urban Geography; Urbanization**

Further Readings

- Davis, M. (2006). *Planet of slums*. London: Verso.
- Drakakis-Smith, D. (2000). *Third world cities* (2nd ed.). New York: Routledge.
- Erman, T. (2001). The politics of gecekondu (squatter) studies in Turkey: The changing representations of rural migrants in the academic discourse. *Urban Studies*, 38, 983–1002.
- Gilbert, A., & Gugler, J. (1992). *Cities, poverty and development: Urbanization in the third world*. Oxford, UK: Oxford University Press.
- Perlman, J. (1976). *The myth of marginality*. Berkeley: University of California Press.



STATE

A state is a politically organized territory with a sovereign government. The concept of the *state* is similar to that of *country*, which is the term used in popular discourse. However, the term *country* has other meanings (e.g., a rural landscape) and is avoided in academic writing and other circumstances where precision in meaning is necessary. At the same time, the term *state* is used synonymously with the term *nation*, which is much different in that the latter refers to a people with a common identity. The meaning of *state* is also obscured because a state's first level of subdivision, commonly called a province, also



is sometimes called a state. The United States is an example where this occurs. However, its states (from Alabama to Wyoming) do not have sovereignty. The United Nations attempts to avoid this confusion by using a capital “S” for those with sovereignty and a lowercase “s” for those without it. This practice helps distinguish the two concepts but has not been widely adopted by others. In any case, the practice works only in some written languages and not in any spoken language.

The world’s political map generally consists of states. Yet among the world’s states are a number of political entities (e.g., colonies, protectorates) that do not completely fulfill the requirements of a state. Similarly, other political entities (e.g., intergovernmental and nongovernmental organizations [IGOs and NGOs]) also are confused with states because they share some characteristics with states. States are distinguished from these other political entities because they have all the required characteristics: government, sovereignty, territory, a permanent resident population, recognition, and organized economic, transportation, communication, and public welfare systems. *Government* refers to an administrative system that oversees the functions of the state. It enacts and enforces laws, manages foreign affairs, regulates the economy, organizes defense, provides some degree of health care and universal education, and designs the transportation and communication systems and ensures their proper functioning. Sovereignty is the ability of a state’s government to perform these functions without interference from other forces, either internally or externally. Some political entities on the world map fail to meet these two criteria and consequently are not considered to be true states. Examples include Greenland (part of Denmark) and Puerto Rico (a territory of the United States with commonwealth status). Similarly, French Guiana (in South America), Guadeloupe, Martinique (both in the Caribbean), and Reunion (in the Indian Ocean) are considered to be among the 26 regions that constitute France as a state, while Clipperton Island, French Polynesia, French Southern and Antarctic Lands, Mayotte, New Caledonia, Saint Barthelemy, Saint Martin, and Wallis and Futuna are France’s dependencies.

Recognition is important for the long-term viability of states. When states have it, other states are expected to treat them according to international norms, most notably to respect their sovereignty and territorial integrity. Those without recognition are vulnerable to infringement on their sovereignty and territorial incursions and claims by other states. Examples of entities on the political map that claim statehood but are not recognized by other states include Nagorno-Karabakh (in Azerbaijan), Somaliland (in Somalia), and Transnistria (in Moldova). Others are only recognized by a very limited number of countries. For example, in early 2010, Abkhazia and South Ossetia were recognized only by Russia, Nicaragua, Venezuela, and Nauru, while Northern Cyprus was recognized only by Turkey. Some have greater recognition. For example, Kosovo and the Sahrawi Arab Democratic Republic (Western Sahara) were recognized by 64 and 49 states, respectively, by early 2010, while the Republic of China (Taiwan) now has fewer than 30 states that recognize it, as many others have shifted their recognition to the People’s Republic of China. Other states are recognized by most other states but still lack full recognition. For example, in early 2010, Israel had diplomatic relations with more than 150 others, and Palestine was recognized by 112, but neither country recognizes the other. Some states have almost complete recognition except by a few states. Examples include Cyprus, which is not recognized by Turkey, and North and South Korea, which do not recognize each other. Though greater recognition brings greater security, these latter cases also illustrate that states still are vulnerable to hostile neighbors that do not recognize them.

States function internally with either a unitary or a federal structure. Unitary states have centralized governments where the power of the state rests and decisions are made. Lower levels of government (e.g., provincial, county, and municipal) are simply nodes that convey and enforce the central government’s decisions and then relay information back to it. Nearly 160 of the approximately 200 states on Earth are unitary states, with France often cited as the best example. Federally structured states are decentralized, meaning that lower levels of government have some degree of



autonomy and frequently levy taxes to perform their separate functions. Federal states are structured either symmetrically or asymmetrically. For the former, all subunits within a layer of the governing structure have the same relationship and degree of autonomy with respect to the central government. The United States, Switzerland, Germany, Canada, and Australia are examples. In asymmetrical states, the relationship between the central government and each other governing unit varies according to what each subunit has negotiated with the central government. The United Kingdom, the Russian Federation, Spain, and Italy are examples. Some academics believe that federal states must be symmetrical and consider asymmetrical states a third type of internal structure: regional.

States can be divided into a number of types: city-states, empires, nation-states, and supra-states. A city-state comprises a single, dominant city that extends its authority over a hinterland, from which it obtains resources. City-states are small in size and trace their origins to the beginning of human civilization. Many of them emerged in fertile river valleys where agricultural surpluses supported sufficient population numbers to form cities. Examples of these river valleys are those found along the Nile, Tigris-Euphrates, Indus, and Huang He (Yellow). Other early city-states were found among the Greeks and in Meso-America and the Andes. Examples of modern city-states are Andorra, Liechtenstein, Monaco, San Marino, and Singapore.

The early city-states were absorbed into empires when they emerged and grew. In contrast to city-states, empires are large in size, with networks of cities. While culturally akin peoples, such as the ancient Greeks, created numerous city-states, empires included many diverse peoples within their boundaries, though they usually were founded by a single people. The early empires were built by peoples such as the Romans, Persians, Mongolians, Chinese, Aztecs, and Incas. The legitimacy of emperors and the expansion of their empires were rooted in the belief that emperors either were divine or ruled by divine right. Empires dominated most of human history, with many lasting into the 20th century, most notably the British, French, Russian, Ottoman, Chinese, and Japanese empires. Some argue that the Soviet

Union was an empire and that contemporary Russia and China retain the characteristics of empires. In addition to their cultural diversity, empires were usually asymmetrical in their governance structures. Empires typically allowed the peoples they conquered and incorporated into them to retain some of their traditional laws and governing practices.

In the 17th century, the modern state began to emerge. Until this time, dynasties typically ruled the states, with the state being treated as a family possession by members of the controlling dynasty. Monarchs usually saw themselves as above the law, which they often applied capriciously, albeit within a cultural context. Consequently, interstate relations, including alliances and the waging of war, were conducted according to familial interests, with states treated as instruments for promoting and protecting dynastic interests. This situation began to change after the Thirty Years' War (1618–1648), which witnessed the excesses of this state system. The resulting Treaty of Westphalia (1648) sought to limit the consequences associated with monarchs' treatment of their states as personal possessions. It established modern international practices such as the use of formal diplomatic connections, alliances, and rules for war and peace. It included the idea of "just war," earlier advocated by Hugo Grotius, who argued that the only valid reasons to initiate war were for defense, inflicting punishment, and obtaining something that rightfully belongs to or is due to the aggrieved party waging war. In curtailing the personal agendas of monarchs, the Treaty of Westphalia forced monarchs to increasingly justify their actions in the interest of their states. These newer views and practices established the modern state system, which is frequently called the Westphalian system.

The modern state crystallized in the 18th century with the Enlightenment, which also marked the rise of the modern nation. The two fused together into the nation-state as the state replaced the concept of monarchy with the concept of nation to justify its existence. Similarly, the nation turned to the state to protect, preserve, and cultivate itself. The 19th century became known as the age of nationalism and is characterized by the reorganization of empires into nation-states. This process continued in the 20th century, which



was marked by notable events leading to the creation of new nation-states: the Paris Peace Conference at the end of World War I, the decolonization that took place after World War II, and the dissolution of the Soviet Union, Czechoslovakia, and Yugoslavia following the end of the Cold War in the 1990s.

In the aftermath of World War II, a new supranational idea emerged that exists alongside the concept of the nation-state and eventually may supplant it. The supranational consists of three or more states working toward some degree of integration of their functions. Because it is a new phenomenon, the degree of integration is still not clear. The European Union (EU), which began with 6 and now has 27 member states, is the most advanced example of a supranational. The initial coordination of economic policies was followed by similar coordination of social and political policies. A clear and recent example of this cooperation was the creation of a common currency, known as the *euro*. Over time, the EU also has created executive, parliamentary, and judicial institutions to manage its shared functions. Supranationals such as the EU may seem little more than transitional entities that only exist while smaller states merge into much larger ones. However, the idea of the supranational is not simply to create giant nation-states. On the contrary, nation-states remain distinctive and autonomous units within supranationals. In the case of the EU, some member nation-states opt out of many practices and policies, including the use of the *euro*. Similarly, national identities are not intended to merge into a new, single, homogeneous supranational identity. At the same time, the ideal level of integration has not yet been determined for supranationals. In the case of the EU, many of its inhabitants fear that integration may erode their distinctive national identities.

George W. White

See also **African Union; Borders and Boundaries; Citizenship; Civil Society; Enlightenment; European Union; Frontiers; Geopolitics; Hegemony; Imperialism; Nation; Nationalism; Political Geography; Ratzel, Friedrich; Sovereignty; Territory; Supranational Integration; Territory; Transnationalism; World-Systems Theory**

Further Readings

- Agnew, J. (1987). *Place and politics: The geographical mediation of state and society*. Boston: Allen & Unwin.
- Agnew, J. (1994). The territorial trap: The geographical assumptions of international relations theory. *Review of International Political Economy*, 1, 53–80.
- Anderson, J. (Ed.). (1986). *The rise of the modern state*. Brighton, UK: Harvester Press.
- Anderson, M. (1996). *Frontiers: Territory and state formation in the modern world*. London: Polity Press.
- Glassner, M., & Fahrer, C. (2004). *Political geography* (3rd ed.). New York: Wiley.
- Held, D. (1989). *Political theory and the modern state: Essays on state, power, and democracy*. Stanford, CA: Stanford University Press.
- Mann, M. (1984). The autonomous power of the state: Its origins, mechanism and results. *European Journal of Sociology*, 25, 185–213.
- Murphy, A. (1990). Historical justifications for territorial claims. *Annals of the Association of American Geographers*, 80, 531–548.
- Storey, D. (2001). *Territory: The claiming of space*. New York: Prentice Hall.
- Vandersluis, S. (2000). *The state and identity construction in international relations*. New York: St. Martin's Press.
- White, G. (2004). *Nation, state, and territory: Origins, evolutions, and relationships*. Lanham, MD: Rowman & Littlefield.



STEEL INDUSTRY, GEOGRAPHY OF

Today, the geography of the steel industry is marked by remarkable internationalization rather than being bound by nationalist industrialization programs for domestic development. The industry's ascent was concomitant with the Industrial Revolution in the 19th century. As the demand for railroads, machinery, and industrial infrastructure emerged, the growth and location of the industry in Britain, and later the United States as



well as other European countries, were dictated by the availability of raw materials. With technological changes and state intervention, the geography of steel production witnessed significant movement away from raw materials and national markets to increasingly global markets and off-shore production. With neoliberal policies, the industry is characterized by more international trade, foreign direct investment, mergers and acquisitions, and, unexpectedly, the predominance of entrepreneurs and firms from developing countries. More recently, as a result of rising energy and raw material costs, the geography of the industry is on the threshold of another round of spatial reorganization.

Raw Materials and Geography

At its core, steelmaking is a relatively simple process. Iron ore, sinter, coal, limestone, and small quantities of scrap are fed into a blast furnace to produce pig iron, which in turn is charged into a basic oxygen furnace to produce molten steel. Liquid steel is then combined with other elements and cast into various shapes, sheets, and sizes, depending on the final application. From the 19th century until the 1950s, most steel plants were located near raw material sources. Historically, coal and/or iron ore regions have hosted steel mills—notably the English Midlands, Western Pennsylvania in the United States, the Ruhr in Germany, Lorraine in France, Minas Gerais in Brazil, Northern and Eastern China, Eastern India, and Eastern Australia. In some cases, national security and regional development concerns have influenced the location of mills away from vulnerable border areas.

However, with technological change, diversified markets, and declining transportation costs, steel mills are no longer tied to the sources of raw materials. With revolutionary changes in transportation and material-handling technologies, a new kind of coast-based steel mill emerged, allowing the efficient sourcing of high-quality coal and ores by massive ocean-faring vessels from far-flung mines in South Africa, Brazil, Australia, India, and so on. In addition to importing raw materials, port-based mills also facilitated competitive exports of steel products, resulting in gains from economies of scale. East Asian

countries, owing to the lack of raw materials, adopted such an investment strategy, which was later followed by other late-industrializing countries. Most Japanese mills, the Pohang Iron and Steel Company (POSCO) in South Korea, China Steel in Taiwan, Companhia Siderúrgica de Tubarão (CST) in Brazil, and Rashtriya Ispat Nigam, Ltd. (RINL) in India are all deepwater-based mills. Integral to the industrialization strategy, these states targeted the steel industry through state ownership (Steel Authority of India, Ltd. [SAIL] in India, SIDERBRAS in Brazil, and POSCO in Korea), investment, and pricing policies for domestic development and exports.

Technology and Geography

The entry barriers to integrated steel production based on coal and iron were high. The main bottleneck was investment, running into roughly US\$10 billion for a 10-million-ton annual capacity state-of-the-art plant. Only enterprises with deep pockets or access to public resources, such as state-owned steel companies, could venture into such large-scale operations. This led to the development of minimill technology, which had a smaller scale of operations and eliminated the expensive coke ovens and blast furnaces used in integrated production. Minimills use steel scrap as raw material, which is converted to purified molten steel using electric arc furnaces (EAFs). Earlier, small quantities of high-value specialty steel products were produced with arc furnaces. The refinement of minimill technology through the use of high-quality (recycled) steel scrap in high-income countries such as the United States, the lower investment barriers due to the small scale of operations, and the advances in casting technologies for minimills to produce high-quality steel sheets for the automotive industry changed the geography of the steel industry, especially in the United States.

As the American South had scrap, low-cost electricity, and land, it became a magnet for many greenfield minimills. In the 1990s, many such mills were constructed, with Nucor, an American firm, leading the pack. Importantly, the rural South allowed the new minimill companies to be geographically removed from major urban centers and the trade union activities common to the



Bethlehem graveyard and steel mill, Pennsylvania

Source: Library of Congress Prints and Photographs Division, LC-USF342-T01-001167-A.

steel and automotive industries in the industrialized North. Weak unions meant more flexibility in shop floor practices, the elimination of strikes, and lower labor costs. The new minimills were instrumental in instituting a flexible work culture, with bonus payments in lieu of the standard fixed employee benefits as part of the total compensation package. Additionally, nontariff barriers, such as the voluntary restraint agreements imposed by the Reagan administration on steel and auto imports from Japan, and the appreciation of the Japanese yen compelled many Japanese auto producers to locate manufacturing facilities in the Southern United States. Not coincidentally, many Japanese steel producers also

formed joint ventures with American steel companies to produce high-quality flat products for both American and Japanese auto transplants. In this sense, the supply response emanating from the American minimill segment and government policy led to a decentralized industry structure.

The geography of the industry was subsequently shaped by breakthroughs in both minimill technology and other small-scale production innovations. Japan and South Korea, best known for energy-efficient, large-scale integrated production, began adopting such technologies. In the 1990s, Tokyo Steel, Hanbo of South Korea (now under new ownership due to bankruptcy), and Essar and Jindal in India entered the fray with



In this astronaut photo from June 12, 2009, the urban fabric of Pohang, South Korea, is strikingly divided by the Hyeongsan River. To the west of the river, residential and commercial development is characterized by small-footprint, gray- and white-roofed buildings. The eastern side of the river is dominated by industrial development associated with the Pohang Iron and Steel Company steelyard. This development (*center*) includes large factory and storage buildings with striking light blue and light red rooftops.

Source: Courtesy of Earth Sciences and Image Analysis Laboratory, National Aeronautics and Space Administration (NASA) Johnson Space Center.

new technologies due to smaller production capacities and thus lower investment costs. As scrap prices increased due to expansion in mini-mills, alternative raw materials were developed. These were directly reduced iron (DRI) and hot briquetted iron (HBI), made feasible by inexpensive natural gas and coal. These inputs are a purer form of iron, which can be fed into blast furnaces and EAFs to produce higher-quality steel. Similarly, the COREX process using noncoking coal (thus doing away with large blast furnaces) permits the direct charge of molten iron into EAFs. These innovations, with their small-scale operations, have been suitable for firms in developing countries with access to natural gas and with

limited markets. In India, Essar Steel, with captive offshore gas sources, has integrated backward to DRI, while Jindal has adopted the COREX process. Other companies from Asia and Latin America have also adopted these small-scale technologies to produce high-quality steel.

Globalization and the New Geography

In the wake of the global economic downturn in the 1970s, the neoliberal ideology of free markets in the 1980s was widely pushed across the global economy. Individual governments, voluntarily and otherwise, internalized deregulation, pursued liberal economic policies, and attempted



privatization of state firms. In this environment, the steel industry witnessed considerable upheaval. Declining steel production associated with the falling significance of heavy industry and a growing services sector led to deindustrialization in the advanced capitalist countries. The simultaneous pursuit of state-led industrialization in select developing countries such as India, China, Brazil, and South Korea had already altered the structure of global steel production. However, many state-owned enterprises, including those in the former Eastern Bloc countries, were plagued by financial and technological inefficiencies, which made them good acquisition targets for investors. The Soviet Union had been the world's largest producer, but its breakup in 1991, combined with the challenges of market transition, reduced steel output in Russia significantly. Furthermore, deregulation, privatization, and new opportunities under global economic integration generated new competitive dynamics in the geographical dispersion of the industry.

Previously, steel industries were seen as national projects, designed to contribute to self-sufficiency in production and targeted at domestic consumption. With deregulation and technological developments, the internationalization of the industry was imminent, leading to a new geography. There are several interrelated forces that led to international investments and increased trade in the industry. First, entrepreneurial firms began to invest in new minimill technology and acquire weak state-owned firms. Second, some of these purchases were integrated backward to raw material production, which was made easier with the discovery of natural gas in certain locations. Third, entrepreneurs and steel firms from developing countries, especially India, have invested and acquired foreign steel and steel-linked raw material production units such as DRI. Fourth, as both China and India continue to grow economically, sustaining the demand for basic steel products, many foreign companies, such as POSCO from South Korea, are investing massively in iron ore as well as steel manufacturing plants in India and elsewhere. Finally, as the demand for raw materials increases due to high economic growth in China and India, these countries have aggressively pursued investments in and alliances with the mineral-rich countries of Africa and Latin America.

The best-known case of internationalization is Mittal Steel. Lakshmi Mittal, hailing from a trading family in India, purchased an old steel mill in Indonesia and built his steel empire in the 1980s and 1990s. He acquired financially strapped, private- and state-owned mills in rich and poor countries such as the United States, Canada, Germany, Ireland, Kazakhstan, Mexico, and Trinidad. He also strategically purchased DRI plants and integrated steel production backward. Perhaps the biggest and the most controversial acquisition has been Arcelor, a large European firm, which itself was the result of earlier mergers. The French, Spanish, and Luxembourg governments strongly opposed the takeover by Mittal, but in the end, the merger went through with a price tag of \$26.5 billion, making the new ArcelorMittal the largest steel company in the world, with nearly 120 million tons of annual capacity and 320,000 employees worldwide. Nippon Steel of Japan, at one time the world's largest steel company, stands at number two, with about 33 million tons production capacity. After this merger, the U.S. government compelled ArcelorMittal to sell off its U.S. plant at Sparrows Point in order to reduce its perceived monopoly.

Other steel companies, such as Essar Group from India, also strategically integrated backward to DRI production. Supported by a captive natural gas supply, DRI-based production expansion made good sense. Essar also pursued a similar global acquisition strategy. It obtained a steel mill in Canada and a mine in Minnesota in the United States, constructing greenfield units in Vietnam and the Caribbean, and has immediate plans for more acquisitions in the United States, Latin America, and Africa, especially in coal and iron ore. The Tata Group, a highly diversified family business, also expanded its steel operations around the world, including Europe, Vietnam, Singapore, and South Africa. But its biggest purchase has been the Dutch-British Corus Group, which was also the final result of earlier mergers, for a price of US\$12 billion. It also acquired Jaguar and Land Rover in the United Kingdom from Ford Motors. These purchases are driven by market access, while the purchases of mines and DRI-producing plants have been strategically aimed at ensuring raw material supplies.



With the high growth in the demand for natural resources due to the growth of China, India, and other emerging market economies, the earlier pessimistic view of “resource curse” has been tempered. Today, extractive industries are enjoying unusual terms of trade gains due to rising prices. Both China and India have begun aggressive and competitive overseas investment in oil and other natural resources in Africa, Central Asia, the Middle East, and Latin America. This development is likely to influence the future geography of the industry. Cash-rich companies from China and India, enjoying massive revenues from exports and inflows of FDI, could continue to purchase mines and steel mills to cater to growing domestic and global demands. This creates a historic opportunity for natural resource-rich economies such as those in Africa and Latin America to reduce their structural dependency and leverage their raw materials for basic industrialization. However, without the necessary institutional changes to mobilize foreign and domestic savings as well as marshal political and administrative capacity, it would be difficult to alter the spatial organization of the steel industry.

Additional macroeconomic factors could continue to shape the geography of the steel industry. While upward movement in the prices of resources can distribute global wealth, it could also have a dampening effect on final demand. The rise in the average price of oil is a case in point, which in early 2008 was close to US\$100 per barrel, rising from about US\$28 per barrel in 2001. With the global credit squeeze resulting from the U.S.-led subprime crisis, the demand for steel-intensive investments could be curtailed and thus their supply constrained. At the same time, nonfossil fuel-based vehicles as well as large-scale public transportation could witness new sources of global demand. However, as environmental concerns mount, rich countries will prefer to locate large-scale mills in raw material-producing, mostly poor countries. Consider the mineral-rich but impoverished state of Orissa in Eastern India, which has been targeted by Korea’s POSCO, India’s Tata, and the Indo-European MittalArcelor for large-scale investments in mining and steel units. The combined estimated value is \$22 billion. If not

checked, such massive investments are likely to have high human costs and ecological consequences. Alternatively, corporate social responsibility, stringent oversight, and new technologies and energy sources could further shape the geography of the global steel industry.

Anthony P. D’Costa

See also **Automobile Industry; Economic Geography; Globalization; Industrialization; Industrial Revolution; Manufacturing Belt; Newly Industrializing Countries; Trade**

Further Readings

- Barnett, D., & Crandall, R. (1986). *Up from the ashes: The rise of the minimill in the United States*. Washington, DC: Brookings Institution Press.
- D’Costa, A. (1999). *The global restructuring of the steel industry: Innovations, institutions, and industrial change*. London: Routledge.
- D’Costa, A. (2002). Korean steel industry. In D. Levinson & K. Christensen (Eds.), *Encyclopedia of modern Asia*. New York: Charles Scribner.
- D’Costa, A. (2007). Steel industry. In W. Darity (Ed.), *International encyclopedia of the social sciences* (2nd ed.). New York: Macmillan.
- Hogan, W. (1994). *Steel in the 21st century: Competition forges a new world order*. New York: Lexington Books.
- International Iron and Steel Institute. (n.d.). *World steel in figures* (various issues). Available from the World Steel Association Web site: www.worldsteel.org



STEREOSCOPY AND ORTHOIMAGERY

If you place your thumb in front of you and then look at it with your left eye and then the right eye, what you will notice is that the thumb is “moving” in relation to the objects behind it. This phenomenon is what helps the human brain see depth and thus perceive which object is in front and

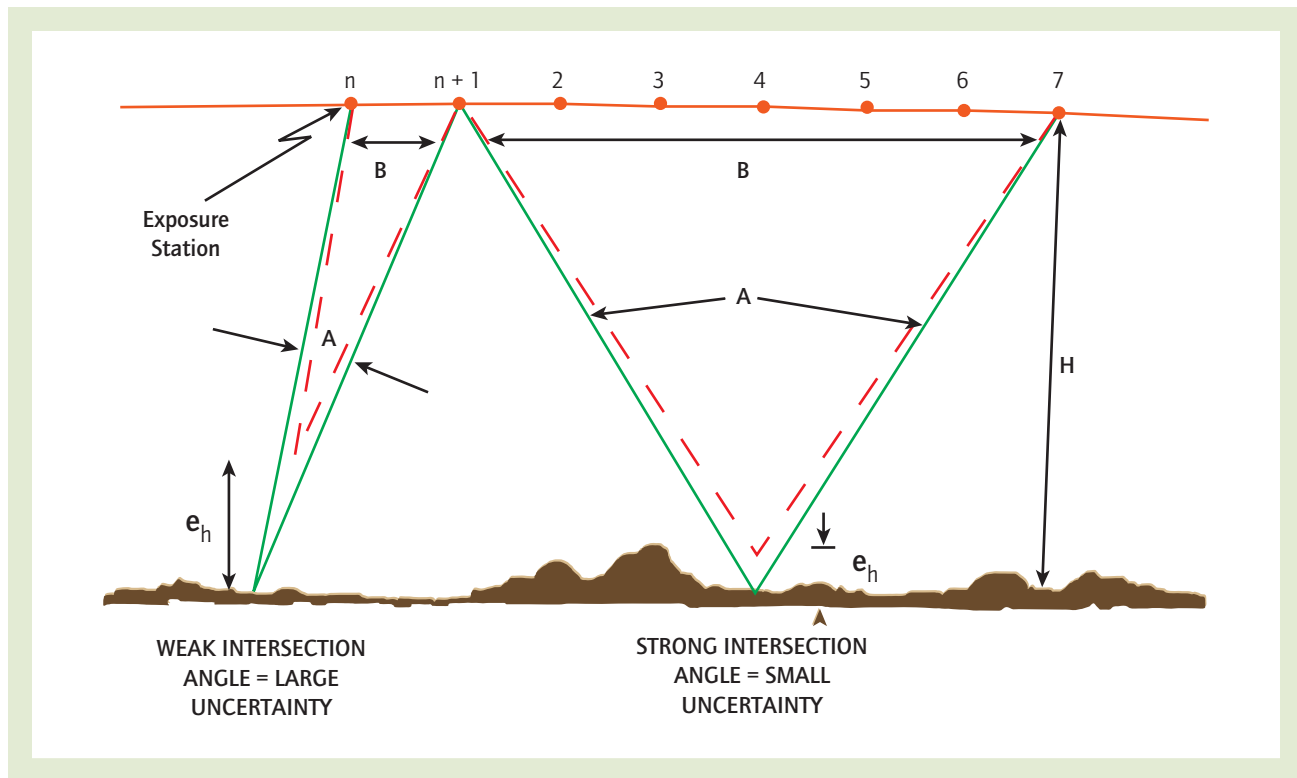


Figure 1 Relative photogrammetric accuracy versus angle of intersection

Source: Light, D. L., Brown, D., Colvocoresses, A., Doyle, F., Davies, M., Ellasal, A., et al. (1980). Satellite photogrammetry. In C. C. Salma, C. Theurer, & S. W. Henriksen (Eds.), *Manual of photogrammetry* (4th ed., pp. 1305–1369). Falls Church, VA: American Society for Photogrammetry. Reprinted by permission of the American Society of Photogrammetry and Remote Sensing.

which one behind. It is called *binocular vision*, and the displacement of your thumb is called *parallax*. The larger the parallax, the further our thumb is from the objects behind it. What we actually perceive is the parallax, and through this we see and appreciate depth. However, it would be wrong to think that all human depth perception comes from the parallax. There are many more cues, such as shading, relative size, precedence, contrast, and haze, that work just fine with *monocular vision*.

This impression of depth can be also realized with the use of images of the same object that are taken from different positions. When each of a pair of such images is separated and viewed by each eye separately, it is possible to perceive depth. This is called *stereoscopic vision* or *stereo-vision*. There are many ways to project the images to each eye, such as through anaglyphs (“filtering” the images with the use of blue-red display and glasses) or polarization (“filtering” the images

with the use of vertical and horizontal polarization display and glasses) or other methods that are used in modern stereomonitor. This pair of images is called a *stereogram* or *stereopair*. The science or art that deals with the use of binocular vision for the observation and production of stereograms is called *stereoscopy*.

The average distance between the human eyes is about 65 millimeters. The human brain can differentiate (perceive parallax) between two objects when they are at a minimum angular distance of about 15 inches. With the use of simple triangulation, we can estimate the minimum depth distance judgment according to the distance of an object from the human eyes. The further the object is from our eyes, the more difficult it gets for us to judge its depth distance. If, however, we can somehow increase the distance between our eyes, then we would get better depth perception, and thus, the distance of the object could be better estimated (Figure 1).



The distance between the two images of the object is called a *baseline*, and the larger it is, the less the error of the object positioning and thus the more accurately the depth distance is calculated (assuming that the other parameters are the same).

As photogrammetry concerns itself with the geometric measurements of objects in analog or digital images, the stereoscopic measurement principle is directly applied. With the production of images of the same object from two different places in space (stereoscopy), one could make measurements of the object's depth distance. This way, the recording and measurement of the object are done in the three-dimensional (3D) world and not just in the 2D world of a piece of paper or a computer monitor.

However, it becomes challenging when we need to represent or display the object. The problem lies in the way the camera is operating. The photograph is captured through a perspective center (single-point perspective view), and the object does not have the same horizontal distance on the plane and on the photograph. In other words, the photograph is not an orthogonal representation of the object. The relief of the object is introducing an error in the measured distances on the photograph. For this, there is a need to use stereoscopy so as to produce a stereopair and thus be able to measure the relief of the object. By knowing the depth distances, it is easy to "project" the object onto a 2D surface, but this time, all different points on the surface have the correct horizontal distances. This photogrammetric product is called *orthoimagery*.

Orthoimagery consists of representing an object in the same way that a map does. This allows us to use orthoimages just as we would maps and thus make direct measurements. But while the map displays selected information that the cartographer chose, the orthoimagery displays all the details of the object that could be captured at the moment. However, it is an artificial product, totally computer generated. Its precision depends greatly on the parameters of image acquisition (orientation of the image, spatial position of the camera) and the relief (acquired by the stereopair).

Nikolaos Galiatsatos

See also Aerial Imagery: Interpretation; Image Interpretation; Imaging Spectroscopy; Vision and Geography

Further Readings

- Kasser, M., & Egels, Y. (2002). *Digital photogrammetry*. London: Taylor & Francis.
- McGlone, C., Mikhail, E., & Bethel, J. (Eds.). (2004). *Manual of photogrammetry* (5th ed.). Bethesda, MD: American Society of Photogrammetry and Remote Sensing (ASPRS).
- Valyus, N. A. (1966). *Spectroscopy*. New York: Focal Press.



STORPER, MICHAEL (1954–)

One of the discipline's leading economic geographers, Michael Storper is well known for his rigorous interrogations of the spatiality of capitalism. His work lies at, and has forged, the intersections of economic development, technological change, innovation and creativity, trade, globalization, and the political economy of regions.

A doctoral student of Richard Walker at the University of California, Berkeley, Storper began his career in the School of Urban and Regional Planning at the University of California, Los Angeles (UCLA) in 1982, and he continues to be affiliated with the School of Public Affairs there. From 1996 to 2002, Storper served as a professor of sociology at the University of Marne-la-Vallée, France, and continues as a professor of economic sociology at the Institut d'Études Politiques de Paris. In 2004, he assumed a Centennial Chair in Economic Geography at the London School of Economics (LSE), but he divides his time between the LSE and UCLA. Storper is thus an important intellectual on both sides of the Atlantic Ocean and writes in both English and French. His papers and books have been noted for their theoretical sophistication and ability to draw together diverse topics and lines of thought,



both traditional and contemporary, into elegant syntheses.

Storper's works have long been important in several subject areas of economic geography. His earlier papers, for example, offered stinging critiques of the product cycle as simplistic and unidimensional. *The Capitalist Imperative*, coauthored with Walker in 1989, marked a foundational summary of economic geography in light of the rising prominence of Marxism and the centrality of the division of labor. In the 1980s, Storper played a key role in the formation of the informal "Los Angeles School" of urban analysis, which paved the way for understandings of economic landscapes in light of the emergence of post-Fordist complexes of flexible production. His work was central, for example, to the emerging conceptions of how and why firms adopted new technologies; their relations to uncertainty, transaction costs, and economies of scale and scope; and how labor markets fluctuated in response. Empirically, he analyzed, among other things, the U.S. film industry and its locational dynamics.

By the 1990s, Storper's career led him toward systematic understandings of the dynamics of regional change more broadly, particularly the contingent trajectories faced by different types of places as they grappled with the changing constraints and opportunities generated by the global division of labor. In *The Regional World*, which appeared in 1997, he sketched a view of a world economy dominated by a necklace of world city-regions, in which agglomeration economies facilitate processes of creativity and innovation. He also took into account issues such as different forms of institutional organization, flows of knowledge, patterns of decision making, regional convergence and divergence, and the spatial scales at which varying social and spatial processes operate to lay out several possible "worlds of production." He offered comparative analyses of regions in Western Europe, the United States, and Brazil. More recently, he has turned to the role of "buzz," or dense webs of face-to-face contact for the exchange of tacit knowledge among key actors as mechanisms of regional competitiveness and innovation.

Barney Warf

See also Economic Geography; Flexible Production; Los Angeles School; Marxism, Geography and; Regional Economic Development; Scott, Allen; Uneven Development; Walker, Richard

Further Readings

- Scott, A., & Storper, M. (1986). *Production, work, territory: The geographical anatomy of industrial capitalism*. Boston: Allen & Unwin.
- Storper, M. (1985). Oligopoly and the product cycle: Essentialism in economic geography. *Economic Geography*, 61, 260–282.
- Storper, M. (1991). *Industrialization, economic development, and the regional question in the Third World: From import substitution to flexible production*. London: Pion.
- Storper, M. (1997). *The regional world: Territorial development in a global economy*. London: Guilford Press.
- Storper, M., & Salais, R. (1997). *Worlds of production: The action frameworks of the economy*. Cambridge, MA: Harvard University Press.
- Storper, M., & Scott, A. (Eds.). (1992). *Pathways to industrialization and regional development*. Boston: Routledge.
- Storper, M., & Venables, A. (2004). "Buzz": Face-to-face contact and the urban economy. *Journal of Economic Geography*, 4, 351–370.
- Walker, R., & Storper, M. (1989). *The capitalist imperative: Territory, technology, and industrial growth*. Oxford, UK: Blackwell.



STRABO

(ca. 58 BC–ca. AD 24)

Strabo, born in Amaseia, was a Greek historian and philosopher and one of the most important ancient geographers. As the author of *Geographica*, a 17-volume treatise that has come down to the present almost complete and is a fundamental source of information on the history of geography and cartography of that period, he



played an important role in the development of early geography.

The treatise offered a historical-anthropological frame and aimed to be a useful cultural instrument for Strabo's rulers. Strabo wrote it not only on the basis of the work of his predecessors (e.g., Anaximander, Eratosthenes, Hipparchus) and taking into account the epic poems attributed to Homer but also incorporating his own ideas and personal observations. Strabo founded his knowledge not only on abstract concepts but also on the concrete experiences gained through his travels and the relations he built with different populations and their cultures, approaching area studies in a sense that could be defined as an early form of "geopolitics" and "human geography."

According to Strabo, geographic studies cannot neglect philosophy, mathematics, geometry, or astronomy and cannot retreat from natural, historical, and economical aspects in the analysis of a region. Explaining the links that exist between a people and their natural environment, he underlined, for instance, the importance of the sea in the evolution of civilization, particularly as can be seen in the case of Greece.

Strabo gives an interesting description of the known world of the time, imagining the inhabited portion of the Earth to be less wide than that considered by Eratosthenes and different from that pictured by the Greek sailor and geographer Pytheas. Strabo set the northernmost edge of the *ecumene* (the world's habitable zones) on the parallel through Ireland, beyond which there was a perpetually frozen region. He set its southern limit at the parallel crossing Ethiopia and its western and eastern limits at the Pillars of Hercules and the mountains of Northern India, respectively. Evocative descriptions are provided regarding the shapes of lands such as the Peloponnese, which he said looked like a leaf, and Mesopotamia, which he compared with a boat seen from its side. Among the many subjects dealt with in his writing are the Mediterranean Sea and the populations living on the lands washed by it, the source and the delta of the Nile River, and the geography of Germania and its tribes.

Susanna Servello

See also **Anaximander; Cartography, History of; Eratosthenes; Geopolitics; Herodotus; Hipparchus; Human Geography, History of**

Further Readings

- Dueck, D., Lindsay, H., & Potheary, S. (Eds.). (2006). *Strabo's cultural geography: The making of a Kolossourgia*. Cambridge, UK: Cambridge University Press.
- Koelsch, W. (2004). Squinting back at Strabo. *Geographical Review*, 94(4), 502–518.
- Strabo. (1960). *The geography of Strabo*. (H. L. Jones, Trans.; 8 vols., Loeb Classical Library, Nos. 49, 50, 182, 196, 211, 223, 241, 267). Cambridge, MA: Harvard University Press.



STRAHLER, ARTHUR (1918–2002)

Arthur N. Strahler earned his doctorate in geomorphology at Columbia University, emerging in 1945 as a classically trained Davisian (read qualitative) geomorphologist. However, his personal dissatisfaction with this kind of geomorphology was soon fueled by exposure to the seminal work of Robert Horton. During the 1950s, Strahler was a great pioneer of quantitative geomorphology founded on physical and chemical principles. His influence was greatly extended by the impact of his doctoral students, including Richard Chorley, Donald Coates, Marie Morisawa, and Stanley Schumm.

Influential Pioneering Papers

Strahler produced a profoundly important series of papers. Initially, he introduced extremely simple statistical measures such as tests of significance, but sophisticated concepts such as dimensionless numbers (e.g., stream order, relief ratio, and the hypsometric curve) quickly followed. Dimensionless numbers were a critical contribution that permitted comparisons across many scales and produced insights previously masked by the shadow cast by scale differences. Perhaps the single most famous concept, among many, is the "Strahler order number."



Within the Strahler stream-ordering system, a stream without tributaries is designated a first-order stream; on meeting another first-order stream, the united streams form a single second-order stream. Beyond this, any stream can absorb those of inferior order, but when meeting a peer, the two unite to become a single stream of the next higher order. In turn, this concept may be applied to drainage basins and associated fluvial concepts. This idea is one of the few to escape geomorphology to become essentially universal throughout science. Appreciation of the role of statistical randomness eventually constrained such research. In short, Strahler introduced a set of “timeless” concepts that did much to redress the then prevailing historical, or time-bound, perspective of geomorphology inherited from Davis.

The Systems Concept

Strahler also made important contributions to the introduction of systems concepts into geomorphology. In particular, he placed a very heavy emphasis on appropriate dimensional analysis in the equations used in a systems approach such that they are always appropriately balanced dimensionally. He also advocated the use of symbols derived from basic electrical circuitry as the most appropriate icons for creating diagrams of system models.

The Earth Science Educator

Strahler spent much of his later career as an independent author, producing innumerable introductory texts in physical geography, geoscience, and environmental science. Within his last publications is a significant attempt to counter the modern challenge to the science of creationism, later renamed creationist science.

Colin Edward Thorn

See also Davis, William Morris; *Geomorphology*; *Physical Geography*, *History of*

Further Readings

Horton, R. E. (1945). Erosional development of streams and their drainage basins: Hydrophysical approach to quantitative morphology. *Geological Society of America Bulletin*, 56, 275–370.

- Schumm, S. A. (2004). Arthur Newell Strahler (1918–2002). *Annals of the Association of American Geographers*, 94, 671–673.
- Strahler, A. N. (1952). Dynamic basis of geomorphology. *Geological Society of America Bulletin*, 63, 923–938.
- Strahler, A. N. (1980). Systems theory in physical geography. *Physical Geography*, 1, 1–27.
- Strahler, A. N. (1992). Quantitative/dynamic geomorphology at Columbia 1945–60: A retrospective. *Physical Geography*, 16, 65–84.



STRATOSPHERIC OZONE DEPLETION

Ozone, denoted chemically as O₃, is a relatively unstable gas with each molecule containing three atoms of oxygen. In a thermally stratified atmosphere, ozone occurs in the lowest two layers, the troposphere and the stratosphere, where it performs different roles. In the stratosphere, ozone occurs in large amounts over a deep vertical extent, forming the *ozone layer*. Stratospheric ozone is sometimes called “good ozone” because it absorbs some of the potentially harmful ultraviolet (UV) radiation from the sun, which can cause skin cancer and can damage vegetation, among other things. Ozone in the troposphere, particularly near the surface, is a secondary air pollutant, which, as a principal component of photochemical smog, is known to have adverse effects on the environment and human health. Stratospheric ozone accounts for about 90% of atmospheric ozone.

The amount of ozone in the stratosphere at any given time largely depends on the balance between the rates of production and destruction of ozone, which are controlled by factors including sunlight intensity, temperature, and the quantity of other gases involved in the ozone formation-destruction process. Ozone forms naturally in the stratosphere whenever UV sunlight is present. When high-energy UV radiation from the sun strikes an oxygen molecule, it causes the molecule to split into two free atoms, each of which combines with an oxygen molecule to produce an ozone molecule. Destruction of ozone in the stratosphere takes place as

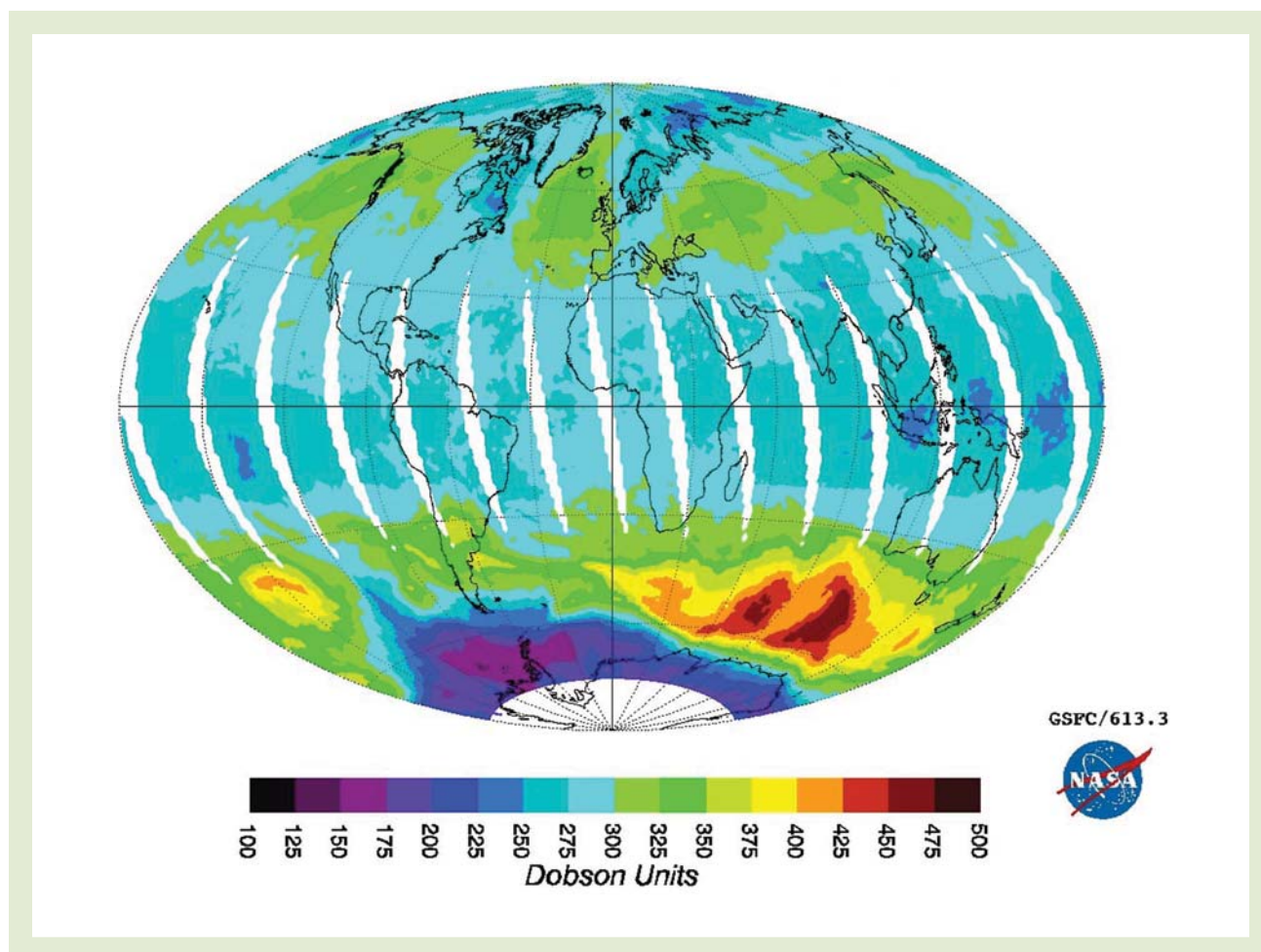


Figure 1 EP/TOMS corrected total ozone for September 1, 2005

Source: National Aeronautics and Space Administration. (2007). *Total ozone mapping spectrometer*. Retrieved December 15, 2008, from http://jwocky.gsfc.nasa.gov/eptoms/ep_v8.html.

quickly as its formation because the chemical is so reactive. As ozone absorbs UV radiation, the molecule splits into one free oxygen atom and one molecule of oxygen. The free oxygen atom then collides with an ozone molecule to form two molecules of oxygen. These reactions occur continually wherever UV sunlight is present in the stratosphere. The net result is a reservoir of ozone that peaks at about 10 parts per million in the midstratosphere, between 12 and 25 kilometers in altitude.

The amount of ozone in a total column of the atmosphere is expressed in Dobson units (DU). A typical value for the ozone column is 300 DU. In the mid 1970s, data collected in the upper atmosphere first showed that the amount of ozone in the stratosphere had diminished. In recent years,

the Ozone Monitoring Instrument (OMI) onboard National Aeronautics and Space Administration's (NASA's) Aura satellite and the EP/TOMS (Earth Probe/Total Ozone Mapping Spectrometer) have been used to get a global picture of ozone levels. Analyses of data from these instruments show that except over tropical latitudes, stratospheric ozone depletion occurs across all latitudes, with the greatest depletion, representing the disappearance of up to 60% of stratospheric ozone, occurring above Antarctica in September, creating what is popularly called the "ozone hole." An example of global ozone data derived from EP/TOMS for September 1, 2005, is shown in Figure 1. Apparent from the image is the ozone hole over Antarctica, represented by a decreased ozone amount

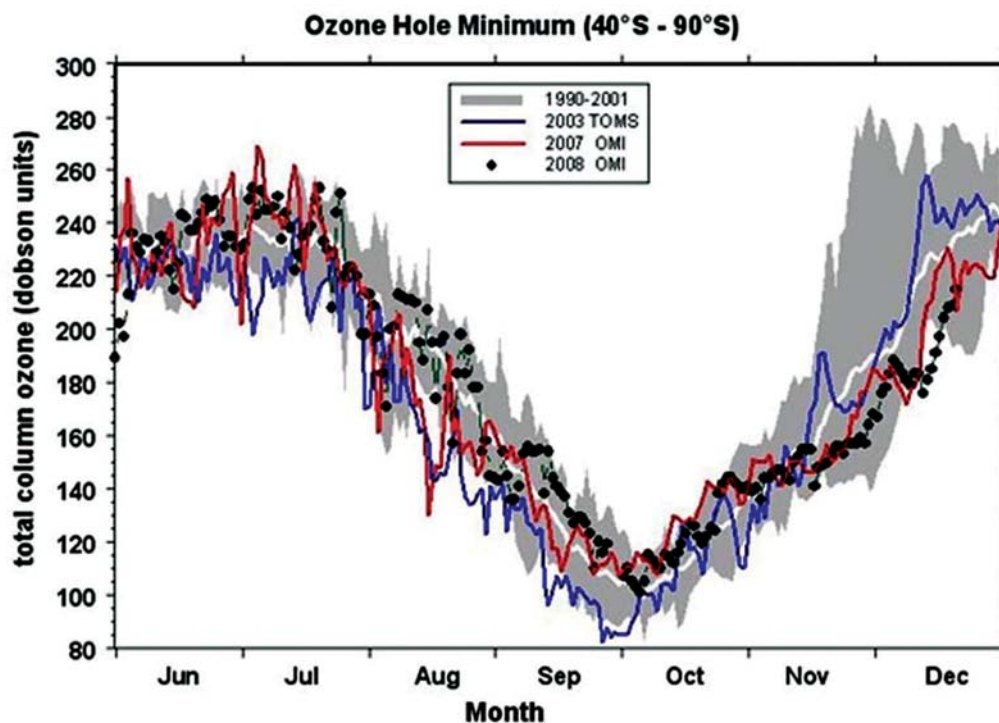


Figure 2 Daily values of total column ozone derived from TOMS and OMI for different years over Antarctica

Source: National Aeronautics and Space Administration. (2007). *Total ozone mapping spectrometer*. Retrieved December 15, 2008, from http://jwocky.gsfc.nasa.gov/ep_toms/ep_v8.html.

ranging from about 250 to <120 DU. More detailed information about the ozone hole can be obtained from Figure 2, which is a plot of the daily values of the total column ozone derived from different instruments for several years over Antarctica (40° S to 90° S).

The loss of stratospheric ozone is attributed to ozone-depleting chemicals (ODCs) that have entered the atmosphere as a result of anthropogenic activities. ODCs are anthropogenic chemicals such as chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, hydrochlorofluorocarbons, and methyl bromide. At one time, CFCs were the most widely used propellants in spray cans. Today, however, they are mainly used as refrigerants, as propellants for the blowing of plastic foam insulation, and as solvents for cleaning electronic microcircuits. Because ODCs are chemically inert, when released into the atmosphere, they do not react easily and

can exist in the troposphere for several decades, entering the stratosphere through the mixing and transport processes of the atmosphere. When CFCs enter the stratosphere, the intense UV radiation breaks them down, releasing chlorine (Cl) atoms that react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer. When other ozone-depleting substances such as methyl bromine and halons are broken apart, they release bromine atoms, which are several times more destructive to ozone molecules than Cl atoms.

One of the frequently asked questions about the ozone hole is “Why does it form in the South Pole, considering the year-round, relatively low sunlight intensity in the region?” This highlights the paramount significance of other factors for the severity of ozone depletion in the southern pole. It has been demonstrated in the past decade that these factors are a combination of conditions



that are unique to the area, such as the presence of the stratospheric polar vortex and the very cold temperatures in the winter months producing polar stratospheric clouds (PSCs). For most of the year, the halogen atoms in the polar stratosphere occur in forms such as hydrogen chloride (HCl) and chlorine nitrate (ClONO₂), which do not react with ozone or each other. However, as PSCs are formed in the polar stratosphere, they provide surfaces for activation of reactions that convert Cl compounds from relatively inert forms to reactive species that destroy ozone in sunlight.

Segun Ogunjemiyo

See also Atmospheric Composition and Structure; Atmospheric Pollution; Chlorofluorocarbons; Poles, North and South

Further Readings

- Fahey, D. W. (Lead author). (2007). *Twenty questions and answers about the ozone layer—Scientific assessment of ozone depletion: 2006 update* (Global Ozone Research and Monitoring Project Report No. 50). Geneva: World Meteorological Organization.
- National Aeronautics and Space Administration. (2005). *Ozone hole: Prospects for recovery*. Retrieved December 5, 2008, from http://earthobservatory.nasa.gov/Features/Ozone/ozone_2.php
- National Aeronautics and Space Administration. (2006). *Ozone resource page*. Retrieved December 5, 2008, from www.nasa.gov/vision/earth/environment/ozone_resource_page.html
- National Aeronautics and Space Administration. (2007). *Total ozone mapping spectrometer*. Retrieved December 15, 2008, from http://jwocj.gsfc.nasa.gov/ep_toms/ep_v8.html
- United Nations Environment Programme. (1998). *Environmental effects of ozone depletion: 1998 assessment*. Nairobi, Kenya: Author.
- World Meteorological Organization. (2007). *Scientific assessment of ozone depletion: 2006* (Global Ozone Research and Monitoring Project Report No. 50). Geneva: Author.

STRIP MINING

Minerals located at or beneath the Earth's surface have long been used for building materials, energy sources, and a wide variety of products to further human development. There are numerous methods for mining these materials. Strip mining is one such method, which has proven to be efficient, economical, and, at the same time, controversial.

Strip mining is part of a broader category of mining techniques known as *surface mining*. These techniques, such as open-pit mining, quarrying, or high wall mining, involve moving massive amounts of earth from above the desired material. The rock, soil, and other material that cover the minerals are known as *overburden*. Each type of surface mining has methods in place to remove the overburden and, in some instances, to reclaim the site after mining operations are complete. Other than surface mining, rock and minerals are extracted from the Earth through underground mining, whereby shafts are dug into the seams, where valuable material is mined and then brought to the surface.

Most societies have engaged in extracting resources from the Earth for hundreds if not thousands of years. However, modern strip mining can trace its roots to the Industrial Revolution and the development of steam-powered, earth-moving equipment capable of removing large amounts of overburden. These early machines have evolved into massive excavators, such as draglines and bucket wheels, which rank among the largest machines ever built. Today, the United States and Germany, two of the most prolific strip-mining nations, lead the way in developing the technology for the machinery and infrastructure to facilitate these macroscale mining operations.

Strip mining occurs in numerous regions other than the United States and Germany. Resources are extracted by strip mining throughout Canada, India, China, Russia, Indonesia, South America, and Africa, among other locales. Energy resources such as coal and oil shale are often extracted through strip mining, as also other resources such as copper and iron ore. Strip-mining techniques are used worldwide for several reasons. Strip mining is highly economical because it requires far fewer workers than underground mining and because it generally is a shorter-term investment,



allowing mining companies to move more quickly onto other operations. Also, strip mining is safer for workers than underground mining because of the hazards associated with the latter, such as cave-ins, explosions, and respiratory problems such as black lung disease.

Traditionally, there have been two types of strip mining. The first is suited for flatter mine sites and is known as *area stripping*. This method places the extracted overburden from the strip currently being mined into the neighboring strip mined previously. The second version is termed *contour stripping* and is applied to areas that are hillier. Both methods are used in extracting coal, the mineral most associated with strip mining. For years, strip mining of coal in the United States was confined to the flatter areas of the Midwest and West, most notably the Powder River Basin of Wyoming. Mining companies in coal-rich Appalachia were not able to take advantage of the economical methods associated with strip mining until the development of a different type of strip mining called *mountaintop removal*.

Mountaintop removal coal mining is an adaptation of strip mining for use in mountainous areas. To gain access to the coal seams in Appalachia, the tops of the mountains must be removed by blasting, creating a flat area suited for strip mining. The use of strip mining in Appalachia has grown significantly since the 1980s due to the adoption of this controversial technique. Coal companies have benefited greatly from mountaintop removal, and it is considerably safer for miners than underground mining.

Mountaintop removal has also been extremely controversial in the region because of its environmental, health, and social effects. This form of strip mining is highly destructive to the local environment, due in large part to the practice of valley filling, where the overburden is pushed into the surrounding valleys as the mountaintop is flattened in preparation for mining. Creating valley fills has led to the contamination of many streams and has been the cause of numerous flash floods in Appalachia. Mountaintop removal sites are often not reclaimed to proper standards, which threatens biodiversity and the growing regional industry of ecotourism. Opponents of the practice also point to increased numbers of respiratory diseases caused by blasting debris, higher than

normal cases of autism and other developmental issues, and contaminated water wells.

Strip mining, including mountaintop removal, is regulated by the U.S. government. Numerous government organizations, such as the Office of Surface Mining Reclamation and Enforcement, the Environmental Protection Agency, and the Mine Safety and Health Administration, regulate mining practices to best ensure the safety of the workers involved as well as the surrounding environment and communities. The Surface Mining Control and Reclamation Act of 1977 is the most well-known policy that oversees strip mining. The policy regulates active mine sites and establishes guidelines for reclaiming abandoned strip mines.

While the U.S. coal industry is dominated by a few very large companies, numerous subsidiaries have been created as a way around regulations such as the 1977 legislation. Instead of reclaiming sites, the smaller subsidiaries file for bankruptcy, and the cost of reclamation gets absorbed by the state. The results of these activities can be seen in the numerous unreclaimed mine sites throughout the United States.

Strip mining remains a highly used but controversial method of resource extraction. In terms of coal, efficient strip mining is seen as a domestic solution to growing energy needs. Strip mining for other minerals remains popular because of the high rate of economic return associated with the practice. However, heated debates rage on, both domestically and internationally, questioning whether or not the benefits of the extraction method outweigh its numerous costs.

Aron Massey

See also **Coal; Energy and Human Ecology; Minerals; Mining and Geography; Open-Pit Mining; Political Economy of Resources**

Further Readings

- Reece, E. (2006). *Lost mountain*. New York: Penguin.
- Stewart Burns, S. (2007). *Bringing down the mountains*. Morgantown: West Virginia University Press.



STRUCTURAL ADJUSTMENT

As an approach to macroeconomic reform in poor and middle-income countries, structural adjustment became a standard in lending programs of the International Monetary Fund (IMF) and World Bank in the mid 1980s. As an idea, it encapsulates the so-called Washington Consensus among these institutions and the relevant departments of the U.S. government (e.g., the Treasury, the Agency for International Development), all based in Washington, D.C. Following major national defaults throughout the developing world in 1982, these lenders implemented stricter conditions for disbursing funds, requiring debtors to “adjust” the “structures” of their economies. Principally, this move entailed scaling back both state regulation of financial markets and subsidies for key industries (e.g., manufacturing) and utilities (e.g., communications, energy). The goal was to make indebted countries—in Latin America, Africa, parts of Asia, and eventually the former Soviet bloc—more economically dynamic and profitable and thus more capable of loan repayment. Such successful metamorphoses, however, have been fleeting (e.g., in The Gambia, Thailand, and Argentina).

Adjustment moved countries away from import-substitution industrialization and similar regimes, which had shielded domestic economies from foreign competition and ensconced state bureaucracies as key providers of extensive public goods, toward a neoliberal model of more globalized markets and a more entrepreneurial role for the state. Despite the aim of “adjusting” poorer economies to converge on an ideal of development, in many cases, this shift intensified the differences between countries, cities, and neighborhoods.

Reforms

Every program of structural adjustment is nationally specific because debtors must negotiate individually, rather than as a cartel, with the key international financial institutions. Each “adjustee” is further distinguished by its own population, resources, political legacy, and cultures. Nonetheless, there are general features of reform that transcend adjustment cases.

In finance and trade, the fundamental prescription has been liberalization: the partial or complete removal of barriers to transnational capital and goods. For financial markets, there is loosening of rules for foreign participation in domestic banks and stock markets. Currencies are also primary targets, typically opened to market fluctuation to create more transparent management but sometimes pegged to another marketized currency (e.g., the Argentine peso, fixed to the U.S. dollar from 1991 to 2001). Trade, on the other hand, is affected by dropping tariffs on imported goods, which had indirectly subsidized domestic producers. Simultaneously, reduction in direct government subsidies to indigenous industries ended the official monopolies or direct ownership by the state. There have been many cases of other curtailed subsidies on basic consumer goods, particularly food—an austerity that, although considered imperative in some adjustment programs, proved an extremely volatile reform across all world regions.

For the state itself, there are usually two major forms of restructuring. The first is privatization of state-owned enterprises, which tend to be concentrated in basic utilities, from the post office to railways to water supply to telephones. There are many cases where privatization brings greater efficiency and some improvements in access to these goods, but it also can lead to steep increases in prices because these companies must operate using market logic, with demand possibly far outstripping supply and competitiveness—not well-being—taking foremost priority. Another drawback of privatization is that it can fail to break effectively with former monopoly conditions; without sufficient oversight, lucrative holdings can be distributed nepotistically at prices far below the market value. This has notably been the case with certain national airlines and phone companies (e.g., Zambia, Argentina). The possibility of extensive foreign ownership of local utilities—often considered strategic resources and part of the national heritage—is a feature of privatization that many critics also lament. The second major transformation to the state is decentralization, which shifts some functional and fiscal responsibilities away from national-level bureaucracies to provincial or urban authorities. Reductions in bloated federal governments



can result from this policy, but it has also backfired: Expensive redundancies can eventuate within state hierarchies, while sometimes local authorities gain new policy purviews and the right to set more independent agendas but without matching finances to realize them.

Repercussions

Beyond the shortcomings of reforms, there are also important unforeseen repercussions resulting from structural adjustment. An original adjustment aim, especially in African cases, was to end the “urban bias” in national development; that is, the curtailment of state subsidies to urban employment sectors and reductions in food subsidies would make nonurban areas more attractive, hypothetically easing the rapid urbanization of the developing world. Instead, several cases show vast increases in unemployment and impoverishment in cities, without ending rural-to-urban migration. Partly, this is because no clear benefits accrued to rural workers in agriculture (as many international commodity prices have been in relative decline), so the pressure to exit the countryside remains. Simultaneously, there was some economic growth in cities as a result of adjustment, but it tended to be limited to certain sectors, especially advanced services and sometimes resource extraction (primarily petroleum related). This growth was insufficient to offset employment losses in industries and public utilities, let alone to absorb urban newcomers, but it did create rather spectacular, circumscribed wealth in the major cities of some countries (e.g., the Philippines, Côte d’Ivoire).

Drastically uneven economies in cities led to stark inequalities across neighborhoods. The developing world has long exhibited extreme gaps in income and quality of life, but structural adjustment greatly exacerbated the polarization and led to the juxtaposition of wealthy and poor areas. Brazil is a famous case in this regard, but examples could be cited from all regions of the developing world. Many observers argue that the sheer obviousness of urban inequality, coupled with the grinding difficulty of making ends meet among the disadvantaged in the wake of adjustment, has contributed to the massive increase in crime and violence across these cities.

The most glaring inequality created by structural adjustment, however, is between poorer and wealthier countries. Although several countries outside the developing world have incurred substantial debt in recent decades (e.g., the United Kingdom, the United States), they can appeal to different sources of financing that do not intervene in domestic agendas as adjustment does. Countries of the developing world do not enjoy the same creditworthiness and therefore fall short of full sovereignty over their development priorities in an age of adjustment. The IMF and the World Bank have made efforts to improve adjustment, especially emphasizing poverty reduction recently. Structural adjustment as an explicit technique has, in fact, incited so much ire from different quarters that it now appears less frequently in loan agreement terminology, though many of its principles remain, particularly in the strong conditions placed on debtors. As such, *adjustment*—under that name or another—still forces the policy options for countries in the developing world into a narrow range of possible actions approved by Washington-based development experts.

Ryan Centner

See also **Developing World; Import Substitution Industrialization; International Monetary Fund; Neoliberalism; World Bank**

Further Readings

- Babb, S. (2005). The social consequences of structural adjustment. *Annual Review of Sociology*, 31, 1–24.
- Mohan, G., Brown, E., Milward, R., & Zack-Williams, A. (Eds.). (2000). *Structural adjustment: Theory, practice, and impacts*. London: Routledge.
- Peet, R. (2003). *Unholy trinity: The IMF, World Bank and WTO*. London: Zed Books.
- Structural Adjustment Participatory Review International Network. (2004). *Structural Adjustment Participatory Review International report: The policy roots of economic crisis, poverty and inequality*. London: Zed Books.
- Walton, J., & Seddon, D. (1994). *Free markets and food riots*. Cambridge, MA: Blackwell.



STRUCTURALISM

Structuralism was at first a theoretical stance and subsequently a movement in the social sciences and humanities, including geography. The origins of structuralism lie mainly in French thought dating from the period between World War I and World War II, although the underlying concepts of structure and system are much older. At first, structuralism was confined to the analysis of (usually nonphysical) social and cultural objects and events that convey meanings and perform functions of communication, and it examined these with a language model designed to analyze and determine their significance. Subsequently, it was also applied to the analysis of political systems, the organization of knowledge, and the structure and evolution of whole societies. Instead of seeking to explain these phenomena one by one, structuralism adopted a systemic approach, concentrating on the underlying structures that made these phenomena possible and gave them meaning. In most disciplines, it subsequently gave way to poststructuralism, with its concentration on deep description and interpretation. The aim of this entry is to outline the evolution of this set of ideas and to consider the ways in which it has had an impact on geography and related disciplines principally in the 1970s and early 1980s.

Tenets and History

A structuralist approach involves the identification of the structural elements of a functioning system and the interrelationships/rules governing the ways in which the elements can be put together to enable the system to function without regard to any specific material content. Any object is interpreted as a product of a combination of structural elements within a system. A simple example is the system of traffic signals, whose function is to manage traffic. In this case the structure is a set of red, yellow, and green lights that are illuminated in repeated sequences and afford the significative content of the system.

Modern structuralism originated in the study of language, where it proved remarkably successful. For structuralists, a language is a self-contained system, each element of which has its

particular place and its own relations to the other elements of the language. In this field, the elements of the system are words or the speech sounds and sign elements of which they are made up. The rules include the grammar governing the way words can be put together. Because a system of language has the functions of signification/meaning and communication, a language is also a system of signs. As a result, expression elements (the signifiers), such as sounds, sound images, and words, cannot be identified independently of their content, their meaning, or the concept to which they refer (the signified). What is more, a language is a system of interdependent elements in which the value of one element depends on the simultaneous presence of the others. A signifier considered on its own has a relation with its signified. In a system, it has multiple relations with other signifiers, of which the most important is the relation of difference: A signifier has a meaning as a result not of its association with a particular signified but of its difference from all other signifiers. This idea of difference is founded on the idea of binary opposites: Finding out what a word or sign is not involves comparing it with some other word or sign.

To these ideas, Noam Chomsky added the examination of the creative role of language. He argued that the structures dealt with in linguistics were for the most part surface structures. Underlying these surface structures were, he suggested, deep grammatical structures from which a vast range of surface structures can be generated. This idea enabled him to explain how speakers of a language can utter sentences they have never heard. It also suggested that the wide variety of surface structures may share the same deep structure and that this deep structure may reflect the workings of the human mind. This view contrasted sharply with empiricist accounts that grounded language in sense perception, although it is important to emphasize that these conclusions were derived from painstaking observation and analysis.

Out of this literature emerged the idea that systems of language have an underlying synchronic structure and that this structure can be studied independently of its sociohistorical context and the consciousness of actors. An additional premise was that this structure governs



diachronic/historical and geographical practices without the awareness of the actors.

The next important step was Claude Levi-Strauss's extension of the concepts of order and the methods of structural linguistics to communication (symbolic) systems in anthropology. Just as comparative studies of languages were composed of fragmented studies until the notion of language as a system was adopted, anthropological studies of communities of peoples were composed of largely separate studies until the idea of society as a system was adopted. At the root of this extension of structuralist ideas to anthropology was the idea that cultural phenomena are socially constructed, are frequently immaterial, are associated with meanings/symbolic values, and can be considered as performing the function of communication, permitting analysis with a language model.

In contrast to interpretative or humanistic social science, which also deals with objects imbued with meaning, structuralism sees itself as an objective science. It insists that explanation (rather than understanding) has specific features that reflect the particular properties of systems of representation (which make possible the specific meanings that enter human conduct and choices). It emphasizes the fact that the manifest phenomena it studies are characterized by variety. For structuralism, the identification of generative structures does not rest on empiricist methods of empirical generalization or correlation. This is because social acts that have observable resemblances can have quite different meanings depending on the social systems of which they are parts. As a science of objects of study whose very nature is to vary, structuralism defines itself in terms of the correlation of differences. In the case of anthropology, the idea was that structural characteristics reveal themselves only through examination of the differences among customs, myths, kinship systems, and so on. And as in the case of Chomsky's approach to language, the aim was to identify the structures (of which human societies may not be conscious) that underpin observed social relations.

Up to this point, the object of study in structuralist approaches consisted of phenomena that are meaningful and that are directly or indirectly a product of human minds. In the 1960s, these ideas were extended to the study of social and political

phenomena to which a communication/language model was not applicable. A case in point was Althusserian Marxism. Other extensions were into the fields of literary and cultural studies (Roland Barthes), psychoanalysis (Jacques Lacan), and intellectual history (Michel Foucault).

Structuralism and Geography

The way in which these ideas entered geography was through a critique of its engagement with empiricism and in particular its encounter with structuralist Marxism. Geography had already passed through a quantitative revolution one of whose aims was to establish geography as a generalizing science, where science was understood in empiricist terms. Structuralism offered an alternative science model that sought to identify not what was common to surface phenomena but generative structures that gave rise to a great variety of surface phenomena: It offered an alternative route to the construction of theories to formulate and make intelligible the workings of the world.

In the 1970s, Marxism swept through the social and human sciences. In geography, many different strands of the Marxist tradition had significant impacts. Within the discipline, some of the most significant figures in this movement were not structuralists, yet strangely, critics of Marxism in geography chose to identify it with structuralism. Geography's engagement with structuralist Marxism was a result of the influence of the work of Louis Althusser, which itself entered geography largely through the early work of Manuel Castells in urban sociology. Castells's main interest was in the way social structures generate spatial structures: The analysis of spatial structures involves, he argued, an analysis of the way in which core elements of the social structure are spatially articulated (Table 1). For Castells, a society is composed of several modes of production, of which one is dominant. A mode of production is a combination of several systems of practices: economic, political, and ideological. In his framework of analysis, Castells identified four concrete spatial expressions (P, C, E, and M; see Table 1) of the fundamental elements of (relatively autonomous) economic, political, and ideological systems and the relations that organize them. In the case of an economic system, for



<i>Instances, Levels, or Systems of Practices of Social Structure</i>	<i>Relations</i>	<i>Spatial Expression</i>
Economic system	• Property (appropriation of product) • Real appropriation (technical labor process)	• P, Production: ensemble of activities producing goods, services, and information • C, Consumption: ensemble of activities relating to individual and collective consumption and reproduction • E, Circulation and exchange
Politico-institutional system	• Domination-regulation • Integration-repression	• I, Institutional segmentation of space • M, Administration and management
Ideological system	• Rationalization and legitimation of particular interests as an expression of general interest	• S, Symbolic space (signs, signifiers, signifieds): urban cultural forms as expressions of ideologies and ideological practices

Table 1 Social practices and spatial organization

Sources: Adapted from Althusser, L., & Balibar, E. (1970). *Reading capital* (B. Brewster, Trans.; pp. 125–127). London: New Left Books; Castells, M. (1977). *The urban question: A Marxist approach* (A. Sheridan, Trans.; pp. 212–216). London: Edward Arnold. (Original work published 1972 in French)

example, the elements are the factors of production (the laborer, the means of production, and the nonlaborer who appropriates surplus labor), and the relations between them (in a capitalist mode of production) are relations of property (the owner appropriates the product) and control (the owner organizes and controls the process of work). I, M, and S (see Table 1) were examined in similar ways.

This structuralist approach had both negative and positive features. On the negative side, it was believed to downplay the role of social action and social agency, although structuralist Marxists insisted that every social order is characterized by social conflicts and struggles. Individuals were, however, conceived as the occupants of positions established by structures, with little scope for effecting structural change. Althusser himself abandoned Marx's claim that the economy determined all other areas of life, arguing instead that the economic structure was determinant only "in the last instance." Although Althusser thereby rejected strict economic determinism, his variant of Marxism was still considered far too deterministic, as it rested on the existence of abstract structures and systems that determine social action

and social phenomena without working through the practical or cognitive understanding of actors. Although social scientists can discover these structures, actors are not necessarily aware of them.

On the positive side, it was clear that an explanation of the characteristics of particular places involves a synthesis of a multiplicity of practices, including economic practices that involve a set of relationships between people and their environment. A further advantage was that it afforded a common set/parallel sets of theoretical ideas (the concept of a system and of structures) that helped reduce the degree of fragmentation of geography, just as it had reduced the degree of fragmentation in other fields (comparative linguistics and comparative ethnology).

For that reason, the equation of Althusserian Marxism with determinism did not lead to a simple abandonment of structuralist ideas. Instead, it gave way to an alternative grammatical account of structures. On this account, structures are sets of rules and principles that govern social life and structure the possibilities of human action and interaction. Structures and systems function, however, because they are captured in the cognitive processes and the practical understanding of



social actors. What is more, these structures do not just govern social action. They themselves are socially constructed and are constantly reaffirmed and re-created in and through social action. Structures condition and result from action.

Michael Dunford

See also **Epistemology; Harvey, David; Human Geography, History of; Marxism, Geography and; Postmodernism; Poststructuralism**

Further Readings

- Althusser, L., & Balibar, E. (1970). *Reading capital* (B. Brewster, Trans.). London: New Left Books.
- Castells, M. (1977). *The urban question: A Marxist approach*. London: Edward Arnold. (Original work published 1972 in French)
- Duncan, J., & Ley, D. (1982). Structural Marxism and human geography. *Annals of the Association of American Geographers*, 72, 30–59.
- Dunford, M. (2007). Textbooks that moved generations. *Progress in Human Geography*, 31(4), 537–549.
- Dunford, M., & Perrons, D. (1984). *The arena of capital*. Basingstoke, UK: Macmillan.
- Massey, D., & Catalano, A. (1978). *Capital and land: Landownership by capital in Great Britain*. London: Arnold.



STRUCTURATION THEORY

Structuration theory has been a popular conceptual framework for studying social and spatial behavior since the 1980s, when it was initiated by the famed British sociologist Anthony Giddens. Geographers and planners with their own substantive theories about human behaviors have been able to think of the structures enabling or constraining those behaviors and, correspondingly, the behaviors that manifest those structures. This entry reviews the geographical and planning applications of the theory, after introducing structurationist thinking with an example.

Essentials

Structuration theory essentially surmounted the long-standing division in the social sciences between “micro” approaches, which focused on the behavior of individual human beings (e.g., the humanistic schools of thought), and “macro” approaches, which emphasized social structures and relations at the expense of an understanding of the human subject (e.g., structural Marxism). Structuration recognizes that human beings are sentient, knowledgeable agents; that is, they always possess consciousness about themselves and their world, however limited. This view depicts culture as the bodies of knowledge that people take for granted—that is, common sense, which allows them to negotiate their way through everyday life. Structures consist of the rules and resources that are drawn on in everyday life, simultaneously enabling and constraining human actions. In everyday life, actors draw on structural rules and resources, and in so doing, they reproduce those structures. Therefore, the socialization of the individual and the reproduction of society and place are two sides of the same coin. In everyday life, people reproduce the world, largely unintentionally, and in turn, their social structures reproduce them through socialization. In forming their individual biographies, people re-create and transform their social worlds. Thus, human beings are both produced by and producers of their worlds in time and space. History and geography are therefore continually produced through the dynamics of everyday life, the routine interactions and transient encounters through which societies are reproduced. For Giddens, the stretching of human activities across time and space is fundamental to the exertion of power. This process Giddens calls time-space distanciation, which geographers have called time-space convergence or time-space compression.

Structurationist Thinking About a School Closure

An example involving closure of a school can be helpful in explaining structuration theory. Begin thinking as a structurationist would by imagining how you would react to an announcement that your neighborhood school is closing, something



that has now happened so often in Western societies that most people have had this experience or know someone who has. Core structuration concepts sensitize a researcher to how people could or did act in general, that is, on an ontological level. In this example, application of structuration theory can help us interpret the effectiveness of residents who attempt to prevent school closures. Note therefore that structuration theory is a “second-order” theory and does not prescribe a specific course(s) of action in this particular situation. Consequently, with this and similar research applications, a supplementary “first-order” substantive theory is required for explaining, for example, why schools close and why residents get upset.

Actors

From the perspective of structuration theory, a neighborhood resident in this example is a social agent or actor who thinks about the closure of a school in his or her neighborhood, and thus, he or she will be reflexive about it. Residents may reflect from within their “practical consciousness” about how they should have reacted earlier to social trends culminating in declining student enrollments. Moreover, they will be able to share their feelings about the closure with friends and neighbors, from within their discursive consciousness. They may be sad or angry about its negating a period of childhood and thus threatening personal “ontological security.” Even an ex-resident who lives many miles away, or, in the lingo of structuration, is “time-space distanciated,” may think as an absent, as opposed to a present, actor about contacting residents or the authorities to fight the closure.

Structures

In structuration theory, social actors who reflect on what they do, and what others do, will activate structures that have entered into their understanding about ways of acting or not acting. These structures not only are the accepted rules of social behavior but also may provide concrete resources for actions. For example, parents and guardians have “authoritative resources” enabling their involvement in their children’s education as a reward for meeting their legal obligation to educate them. Taxpayers have “allocative resources”

through financially supporting their own school district instead of another one. Nonetheless, most residents fighting a school closure will be constrained in their involvement by the procedural rules for a review.

Duality of Structure

Most important in structuration theory, these actors exist in a duality with their rules and resources. It is difficult to know where to break into this duality, but in the school closure example, the previous actions of school administrators and residents will have created and routinized the accepted rules and resources for their respective use in making a closure decision or fighting it. Then, these social actors will internalize, use, and refine what they judge to be the most useful of these rules and resources in their actions. While doing this, they unintentionally reaffirm these rules and resources and therefore reproduce social relationships within the particular situation. For example, residents’ criticisms as well as administrators’ preferences will be behind an evolution in the procedures for closing a school from a committee-based process to a corporate business model. Also, for example, if school closures are progressively construed as only affecting students and their parents and guardians and not other neighborhood residents, then the aforementioned authoritative resources of parents and guardians will be their most powerful ones.

Two Versions of Structuration Theory

Anthony Giddens is the author of the version of structuration theory in the school closure example. During the same period, Pierre Bourdieu, a French sociologist, wrote an independent version of the same theory but with an altered relationship between actors and structures. Recent applications of Bourdieu’s core concept of *habitus* have revitalized explanations of gentrification in older urban neighborhoods. More human geographers have applied Giddens’s structuration theory.

Like other English-speaking social scientists, geographers and planners were probably more exposed to Giddens’s version owing to his prolific publishing in their language, critics’ equally rigorous publishing about him and his theory, and his



unique practice of answering his critics in print. Derek Gregory published an interview with Giddens that explored their mutual interests in understanding behavior in space and time. Giddens was innovative as a sociologist in incorporating spatial and time constraints from Torsten Hagerstrand's time-geography as theoretical structures.

Empirical Applications of Giddens's Structuration Theory

Giddens speculated that application of structuration theory would contribute new interpretations of a wide range of real-world behaviors. He himself only illustrated its application in reinterpretations of earlier research, as two more recent theorists refining his version, John Parker and Rob Stones, have also done. Searches of English language journals, chapters in books, and books found 59 empirical applications of structuration theory published between 1982 and 2008.

Geographers and planners' application of structuration theory has declined. Quite possibly, this decline may simply correspond with possibly temporary changes in the types of spatial behaviors of interest to geographers and planners. The decline may, however, also be due to more permanent reservations about the applicability of core structuration concepts, such as spatiality and duality of structure.

Types of Behaviors in Structuration Theory

Geographers and planners have applied structuration theory to a wide range of topics. For example, Jakub Novak and Ludek Sykora examined how a postcommunist city's spatial organization was being transformed by residents' reduced travel from their new suburban locations into its former core area. Manuel Aalbers inferred an acceleration in the physical and social decline of a neighborhood if disreputable loan sharks and slumlords moved in to cater to disadvantaged residents, including undocumented immigrants. Even so, geographers and planners' applications appear to have confirmed at least two hypothesized practical limitations of structuration theory. First, they have applied it more for interpreting the formal spatial behaviors of individual people and less those of groups or collectivities such as

nation-states and social movements, and they have not applied it to study either emotionally or culturally motivated or sanctioned behaviors. Second, the types of behaviors studied were observable formal social interactions, usually in modern rather than in traditional settings.

Reservations About Spatiality and Duality

Most geographers and planners have avoided engaging with theoretical and methodological reservations about structuration theory's core concept of the duality of structure. Only 3 of 25 applications measured the duality of structure in their analyses, and only 2 of these had a spatial duality of structure. The latter is where an area's geography created by human action becomes a structural enabler or constraint for future action. For example, Michael Dear and Adam Moos illustrated the latter for locations of licensed group homes, where a planned minimum distance between these homes ultimately reinforced clustering in the inner city.

Other researchers were constrained by their data from observing a virtual duality, and their applications confirmed a methodological reservation in the theory. This reservation is that ethnographic data through time or space for individuals are required for observing their instantiation of structural rules and resources, and these structures enable or constrain their or others' behaviors. Similarly, other researchers confirmed a theoretical reservation by measuring an agency-structure dualism, in which structure overpowered agency or vice versa. This reservation is that virtual structures may not apply to all spatial behaviors if the structural contexts for them endure in time and space even if they are not reconstituted by specific individuals in specific encounters.

Conclusion

At the height of structuration theory's popularity, many geographers and planners exploited it more for providing a conceptual framework and less for informing empirical analysis in their application. Moreover, few among others who applied structurationist concepts tested for the core concept of a (spatial) duality of structure. The possibly fewer future applications of structuration theory should therefore be mature ones, with geographers and



planners better appreciating when, and when not, to apply it to spatial behaviors of interest.

Alan G. Phipps

See also **Behavioral Geography**; **Body, Geography of**; **Class, Geography and**; **Critical Human Geography**; **Everyday Life, Geography and**; **Giddens, Anthony**; **Gregory, Derek**; **Humanistic Geography**; **Marxism, Geography and**; **Pred, Allan**; **Structuralism**; **Thrift, Nigel**; **Time-Geography**

Further Readings

- Aalbers, M. (2006). "When the banks withdraw, slum landlords take over": The structuration of neighbourhood decline through redlining, drug dealing, speculation and immigrant exploitation. *Urban Studies*, 43, 1061–1086.
- Bourdieu, P. (1984). *Distinction: A social critique of the judgment of taste*. Cambridge, MA: Harvard University Press.
- Dear, M., & Moos, A. (1986). Structuration theory in urban analysis: 2. Empirical application. *Environment and Planning A*, 18, 351–373.
- Giddens, A. (1984). *The constitution of society: Outline of a theory of structuration*. Cambridge, UK: Polity Press.
- Giddens, A., & Pierson, C. (1998). *Conversations with Anthony Giddens: Making sense of modernity*. Stanford, CA: Stanford University Press.
- Gregory, D. (1984). Space, time, and politics in social theory: An interview with Anthony Giddens. *Environment and Planning D: Society and Space*, 2(2), 123–132.
- Novak, J., & Sykora, L. (2006). A city in motion: Time-space activity and mobility patterns of suburban inhabitants and the structuration of the spatial organization of the Prague metropolitan area. *Geografiska Annaler*, 89B(2), 147–168.
- Parker, J. (2000). *Structuration*. Philadelphia: Open University Press.
- Phipps, A. (2000). A structurationist interpretation of community activism during school closures. *Environment and Planning A*, 32, 1807–1823.
- Phipps, A. (2001). Empirical applications of structuration theory. *Geografiska Annaler*, 83B(4), 189–204.
- Stones, R. (2005). *Structuration theory*. New York: Palgrave Macmillan.



SUBALTERN STUDIES

Subaltern studies is a broadly influential academic movement whose goal is to refocus history on the unique role of subaltern or marginalized people in bringing about large-scale transformations in society. The implications of subaltern studies for geography are especially apparent in the group's exploration of spatialized categories of class, ancestry, and religion.

Subaltern studies began in 1982, when a collective of South Asian scholars in Britain, including Dipesh Chakrabarty and Partha Chatterjee, began publication of a book-length journal titled *Subaltern Studies*, edited by Ranajit Guha. Much of the collective's early work dealt with the politics of peasants who had been involved in the mass movements that ultimately led to India's independence. The journal's inauguration stemmed from a critique both of nationalist historians of India, who tended to focus on the local elites, and of orthodox Marxists, whose restriction of the concept of the working classes to industrial workers alone was, as the members of the subaltern studies collective argued, Eurocentric and badly suited to the varied economy of the Indian subcontinent.

Subaltern studies' turn away from traditional methods of historical research was signaled by ongoing debates over the definition of the term *subaltern*. Although influenced by the Marxist philosopher Antonio Gramsci, who used it to refer primarily to industrial laborers, in the work of the collective the word *subaltern* came to describe any group that is wholly left out of the elite. In this light, the collective's focus also developed in relation to long-standing populist debates in South Asia, from the nationalist writings of N. G. Ranga and L. Natarajan to the variegated Marxism of scholars like A. R. Desai.

Marxism and Subaltern Studies

In recent years, subaltern studies has often been seen as a post-Marxist movement because many of its scholars selectively combine Marxist theory with a variety of other influences. The relationships between cultural Marxism and subaltern studies were particularly close during the 1980s, with the group's focus on material analyses of



subaltern political movements. As such, subaltern studies theories developed in relation to transformations in British Marxism, wherein academics such as E. P. Thompson and Eric Wolf increasingly began to focus on ordinary people as the agents of history in Europe.

However, at that time, the rifts between subaltern studies and orthodox Marxism were also most apparent. Early-subaltern studies research placed particular emphasis on the self-contained autonomy of peasants, whereas some orthodox Marxists portrayed peasants as a byproduct of the particular history of capitalism in South Asia rather than a vibrant political group. Subaltern theorists also critiqued orthodox Marxist views on historical progress, including the assertion that every nation must pass through a transition from feudalism to capitalism. They argued instead that the histories of oppressed peoples needed to be recovered to produce a more accurate picture of major shifts.

Poststructuralism and Subaltern Studies

In the 1990s, the advent of poststructuralist theory was accompanied by a turn to discourse analysis that resonated with the collectives privileging of subaltern voices, voices that are often only minimally available in the historical record. As a result of this mutual influence, over time, subaltern studies research has focused increasingly on texts and textuality, including analyses of the ways elite leaders have defined subaltern groups. Some scholars have seen this move as evidence of greater theoretical sophistication inspired by the work of Jacques Derrida and Michel Foucault. Others, like the former subaltern studies collective member Sumit Sarkar, have seen it as a denial of human agency and therefore simply another form of subaltern disempowerment.

Critiques of Subaltern Studies

Partly due to its inception as a new school that was intentionally positioned between existing paradigms, subaltern studies has been the subject of ongoing debate. Some of the most influential critiques have come from Gayatri Spivak, who has long been associated with the collective. Spivak was one of the first to point out that not

only are fewer writings available by members of subaltern groups, but the conditions were also radically constrained in those instances when subalterns did speak.

Moreover, Spivak and others criticized subaltern studies for supposing that there could ever be a single authentic subaltern consciousness; this assumption originally led to a neglect of gender and other forms of diversity within subaltern groups. She further notes that the British colonizers were the first to consider subalterns as a particular class of subordinated people. As a result, attempts to give voice to the subaltern might only reinforce the unfair distinctions between subalterns and elites. Yet Spivak famously holds open the potential for further research provided that scholars recognize that the concept of the subaltern is simply a *strategic essentialism*, a type of necessary evil used to make practical advances.

Thus, subaltern studies faces four challenges. First, textual records contain few references to subaltern voices. Second, the references that do exist were often written by those in power. Third, even where their words were recorded, subalterns were often speaking in extremely imbalanced circumstances of the type they faced throughout their lives. Fourth, the division of people into elites and subalterns is itself the result of colonial oppression. Despite such obstacles, however, subaltern studies remains a vibrant movement whose scholars continue to use creative and alternative forms of knowledge to overcome the legacies of injustice.

Jess Bier

See also **Critical Human Geography; Discourse and Geography; Gregory, Derek; Orientalism; Peasants and Peasantry; Postcolonialism; Poststructuralism**

Further Readings

- Chaturvedi, V. (Ed.). (2000). *Mapping subaltern studies and the postcolonial*. London: Verso.
- Guha, R. (Ed.). (1997). *A subaltern studies reader: 1986–1995*. Minneapolis: University of Minnesota Press.



Legg, S. (2007). Beyond the European province: Foucault and postcolonialism. In J. Crampton & S. Elden (Eds.), *Space, knowledge and power: Foucault and geography* (pp. 265–290). Williston, VT: Ashgate.

Spivak, G. (1988). Can the subaltern speak? In C. Nelson & L. Grossbert (Eds.), *Marxism and the interpretation of culture* (pp. 271–316). Urbana: University of Illinois Press.

University of Virginia Library. (2008). *Subaltern studies: A bibliography*. Retrieved March 7, 2010, from www.lib.virginia.edu/area-studies/subaltern/ssmap.htm



SUBURBAN LAND USE

Because *suburban* is a relative—and highly subjective—term, suburban land use is best explained with respect to broader patterns of urban and regional development. The word itself carries both positive and negative connotations, depending on the specific context and/or frame of reference. On the one hand, suburbs are often thought of as a low-density alternative to the crowding, congestion, expense, and pollution of built-up urban centers. On the other hand, just as often, they are faulted for being exclusionary, inefficient, monotonous, and resource-intensive environments, and it is not uncommon for them to be described via the pejorative expression *suburban sprawl*. Suburban land use is without question lower in density and more spatially expansive than urban land use, but easy contrasts end there, as the two are increasingly just as complex in terms of the kind of activities they accommodate. This entry summarizes the history, character, and implications of suburban land use in the United States; variations on specific points apply worldwide.

The Three Waves of Suburbanization

Intraregional suburbanization, that is, the outward shift of development from high-density urban centers to low-density outlying areas, occurred via three distinct waves over the course

of the past century or so. The first wave, from the mid to late 1800s through the 1930s, gave rise to the so-called streetcar suburbs and was purely residential in nature. It resulted in a distinct pattern of land use—today called *transit-oriented development* and the cornerstone of the New Urbanism movement—wherein single-family homes were developed in a grid on small lots within easy walking distance of train stations or other public transport hubs.

The second wave, which began in the late 1940s and was both residential and commercial in nature, was fueled by the post–World War II housing boom and expansion of the interstate highway system. It produced an automobile-oriented pattern of land use, wherein homes were developed in various configurations on large lots far from attendant retail and service centers.

The third wave, which began in the 1960s and 1970s and was also both residential and commercial in nature, cemented a radical and more or less permanent transformation of regional structure from a monocentric to a polycentric pattern of spatial organization. Compared with earlier waves of suburbanization, which were essentially population shifts, it involved substantial employment shifts as well. For the first time ever, firms in all sectors of the economy, from manufacturing to high-order services, moved in mass to outlying areas, often clustering in entirely new “edge cities.” The resulting development was just as complex as in built-up urban areas but typically much lower in density and more spatially expansive. Today, most metropolitan areas exhibit a patchwork pattern of suburban land use made up of all three waves of decentralization.

From the Rust Belt to the Sunbelt

At the same time as these intraregional shifts were occurring, an equally important interregional shift also occurred. Specifically, the same personal preferences, advances in communications technology, and expansion of transport networks that led to intraregional suburbanization drew the population to less developed areas in the Sunbelt and elsewhere. Relatively small regions such as Atlanta, Georgia, now one of the nation’s 10 largest metropolitan areas, grew at an unprecedented rate after 1950 and, so, were developed

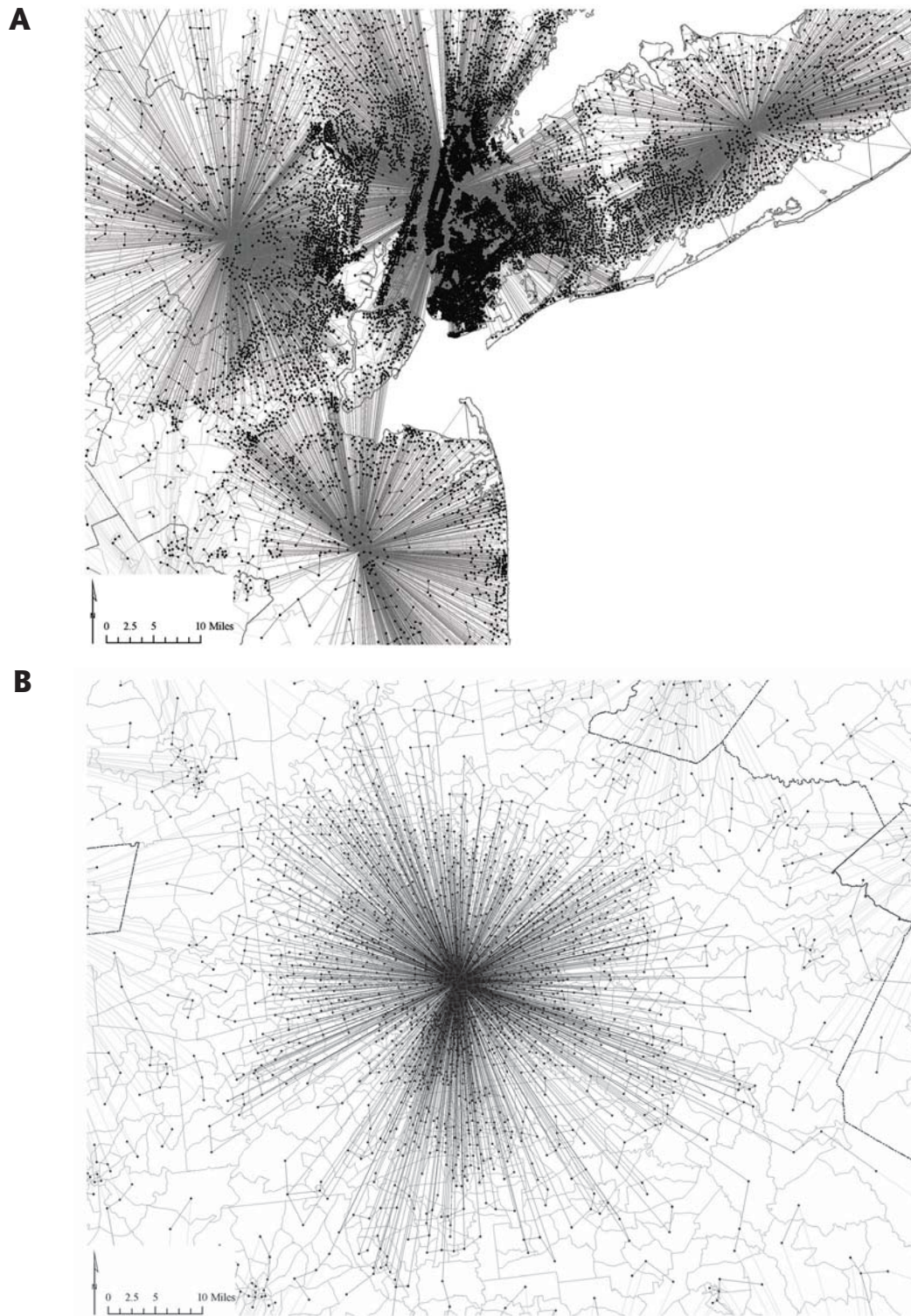


Figure 1 Spatial point patterns in the (A) New York City and (B) Atlanta regions

Source: Authors.



almost entirely in a suburban fashion. That is, they were built in a manner corresponding to the second and third waves of suburbanization and have only limited—or no—high-density urban development. This growth process can be thought of as interregional suburbanization, or the shift of development from older, built-up regions of the country in the Northeast to newer, low-density and automobile-oriented regions in the South and West.

The overall pattern of land use that these shifts produced is shown in Figure 1, which shows the New York City region on the top and the Atlanta region on the bottom. Both maps have the same scale and are identical in their dimensions—about 80 miles east to west and 60 miles north to south. The areas shown in the maps accommodate about 18.7 million and 4.7 million people, respectively. The points, shown in dark gray, are population-weighted centroids of census block group polygons (shown very faintly in the background), and the dark rays connect the points to the population-weighted center of their nearest metropolitan area division and to their nearest neighbor. The New York City region exhibits a very high-density urban core surrounded by suburbs and edge cities that become progressively less dense. The Atlanta region, meanwhile, has almost none of the high-density land use found in the New York City region and almost completely comprises low-density suburban land use. The contrast between the two maps is important because it illustrates not only how suburban land use differs from urban land use but also the relativity of the word *suburban*.

Conclusion

Finally, over the past 50 years, the desirability of suburban land use from a policy standpoint has been the subject of intense debate. At the core, suburbanization is driven by a combination of household preferences, rising incomes, and falling commuting costs—people demonstrably like living in low-density environments and can increasingly afford to do so, in terms of both the housing they purchase and the time they spend commuting. Suburbanization is also accelerated by certain market failures, though, including the failure of development to internalize the benefits of open space, the social costs of traffic congestion, and the cost of the services that it requires. Suburban

environments are also faulted for being exclusionary because they remain financially out of reach of large (poor) segments of the population and for being environmentally destructive and financially inefficient. Recently, suburbs have also been faulted on public health grounds for contributing to obesity because they do not facilitate walking, though this is a matter of some controversy. Environmental concerns cut both ways, because suburbs have simultaneously created a greater “land ethic” and led to the development of cleaner, more fuel-efficient technologies that have greatly reduced the impact of all forms of urbanization, including suburbanization. Going forward, it seems likely that the debate over suburban land use will increasingly turn on whether or not it continues to appeal to household preferences and, more generally, the extent to which it supports the interests of society at large.

*John I. Carruthers, Selma Lewis,
and Robert N. Renner*

See also **Commuting; Exurbs; Housing and Housing Markets; Smart Growth; Suburbs and Suburbanization; Urban Land Use; Urban Sprawl**

Further Readings

- Anas, A., Arnott, R., & Small, K. A. (1998). Urban spatial structure. *Journal of Economic Literature*, 36, 1426–1464.
- Brueckner, J. K. (2000). Urban sprawl: Diagnosis and remedies. *International Regional Science Review*, 23, 160–171.
- Carruthers, J. I., & Ulfarsson, G. F. (2008). Does “smart growth” matter to public finance? *Urban Studies*, 45, 1791–1823.
- Downs, A. (1994). *New visions for metropolitan America*. Washington, DC: Brookings Institution Press.
- Duany, A., Plater-Zyberk, E., & Speck, J. (2000). *Suburban nation: The rise of sprawl and the decline of the American dream*. New York: North Point Press.
- Fischel, W. A. (2001). *The homevoter hypothesis: How home values influence local government taxation, school finance, and land-use policies*. Cambridge, MA: Harvard University Press.



- Garreau, J. (1992). *Edge city: Life on the new frontier*. Norwell, MA: Anchor Press.
- Glaeser, E. L., & Kahn, M. E. (2004). Sprawl and urban growth. In J. V. Henderson & J. F. Thisse (Eds.), *Handbook of urban and regional economics: Vol. 4, Cities and geography* (pp. 2481–2528). Amsterdam: North-Holland.
- Glaeser, E. L., & Shapiro, J. M. (2003). Urban growth in the 1990s: Is city living back? *Journal of Regional Science*, 43, 139–165.
- Kahn, M. E. (2006). *Green cities: Urban growth and the environment*. Washington, DC: Brookings Institution Press.
- Lynch, K. (1981). *Good city form*. Cambridge: MIT Press.
- Mieszkowski, P., & Mills, E. S. (1993). The causes of metropolitan suburbanization. *Journal of Economic Perspectives*, 7, 135–147.
- Orfield, M. W. (1997). *Metropolitics: A regional agenda for community and stability*. Washington, DC: Brookings Institution Press.



SUBURBS AND SUBURBANIZATION

In the sense of the ancient Roman term *suburbium*, which referred to areas outside the city but within a convenient daily traveling distance from it, suburbs have existed as long as there have been cities. *Suburbs* are still commonly defined as the area within commuting distance of a central city, but now they often include more than half the population and jobs of metropolitan areas, and many residents of suburbs no longer commute to or even go to the central city.

Since the 19th century, suburbs have grown to become one of the central facts of modern urban civilization. Processes of suburbanization not only have led to a vast increase in urban area and major changes in transportation and urban form but also have prompted intense and ongoing debates over ideas of good living environments, the appropriate physical setting for a community, the regulation of urban development, and the goals and scope of urban and regional governance. Suburbanization thus involves multiple

processes of population growth and urbanization, technological change in transportation, the transformation of urban form, and dynamic conflicts over ideas of the good city and how to manage urban growth to attain it. Although decentralization and a shift toward automobile-based transport have occurred everywhere, suburbanization processes have produced rather varied outcomes in different places, depending on the timing, economic structure, land ownership patterns, and governance institutions.

Major Stages of Suburbanization

It is possible to identify four broad stages of suburbanization, led by the United States, but with later parallels in the other developed countries. The first stage occurred in the mid 19th century, when new passenger train services allowed the creation of residential suburbs for the wealthy, who could afford daily rail travel to the high-density, compact central city. These early railway suburbs were often beautifully designed experiments in gracious countryside living, in exclusive planned residential estates such as Llewellyn Park in New Jersey, the Main Line communities outside Philadelphia, or Riverside outside Chicago. Described as “bourgeois utopias” by Robert Fishman, these were successful in generating a model of low-density, purely residential suburbs as the ideal in family housing and presented a stark contrast to the gritty and polluted industrial cities of the day. The vast majority of jobs, shops, and housing continued to be located in mixed-use areas in city centers.

Second is the period from the 1860s to the 1930s, when the introduction and rapid spread of horse-drawn trams and then electric streetcars allowed an accelerating expansion of suburban development for the middle and upper classes, creating what are now known as *streetcar suburbs*. Since the area from which inexpensive daily travel to central-city employment and retail areas expanded exponentially, suburban land was cheap, and single-family detached housing became affordable to a much larger share of the population. The house-building industry expanded and began to create a more differentiated range of products for different classes, from self-built prefabricated kits for the lower middle class to the



Suburban sprawl, Las Vegas, Clark County, Nevada

Source: Lynn Betts, U.S. Department of Agriculture, Natural Resources Conservation Service.

rather substantial dwellings for the upper middle class. Some daily retail uses located in strips along major streets carrying streetcar tracks, with residential areas of detached houses on grids of streets up to about a 10-minute walk from the streetcar lines. Most retail and employment remained in the center, except for the growing numbers of suburban factories along the railway lines leading out of the city.

The third period began after World War II, when increasing car ownership, expansion of arterial roads and limited-access highways, and the new availability of government-guaranteed mortgages generated a large-scale house-building industry that built single-family detached homes for all classes, creating vast areas of purely residential development, a trend reinforced by the increasing use of zoning to prevent mixing of

land use. Although some developers attempted to build complete communities, with town centers, parks, and schools, most developments contained only housing and streets to access them and little else. Shopping centers were built in the suburbs from the mid 1950s onward, as retailers followed their customers out of town, but central cities continued as major employment and retail concentrations.

Fourth, since the 1960s, as both factory and then office jobs relocated to suburban and exurban locations, suburbs surpassed central cities in both population and jobs and became increasingly independent of the old central cities. By the mid 1960s, more than half of the population of the United States lived in suburbs. The process of outward expansion accelerated, as job decentralization to what Joel Garreau famously



labeled *edge cities*—large clusters of office, manufacturing, and retail jobs at exurban highway interchanges, frequently associated with airports—allowed a much larger commuting range for their workers. From the 1970s on, many U.S. central cities began a precipitous decline, as those who could afford to leave fled, leaving the poor and the racialized minorities in shrinking and often crumbling core areas with few job prospects and declining schools and services. During the 1990s and later, many central-city areas such as Manhattan and Portland saw population increases, with recolonization by the affluent and gentrification of selected central areas, but the dominant trend has continued to be dispersion of both jobs and population to locations ever more distant from the original centers, giving rise to exurbia and what Robert Lang has called *edgeless cities*.

These patterns were more characteristic of the United States than elsewhere, in part because of earlier and higher rates of automobile ownership and expressway building, large government subsidies for home ownership, and strong property rights that made planning restrictions difficult, and in part as a reflection of differing preferences. For example, in France, the central cities remained the most desirable housing locations for the affluent, and racial minorities found themselves pushed to the suburbs. Even so, in France, issues of urban sprawl became increasingly identified as a policy issue since the 1990s. In most Northern European countries and in Canada, processes of land development were much more tightly regulated, and the kinds of edgeless cities seen in the United States are virtually unknown, as even with increasing automobile use and considerable lower-density development, most development was contiguous with existing urban areas and at higher densities. In Spain, cities such as Barcelona and Madrid revitalized and intensified their central areas and built suburbs at extremely high densities, linked to the expansion of heavy-rail public transit.

In Japan, excellent public transit systems and limited road space and parking in central areas combined to produce highly distinctive suburban development patterns, with much greater reliance on public transit, particularly in metropolitan areas. More significantly, highly fragmented land

ownership, tiny farms, and weak regulation of land development contributed to extensive patterns of metropolitan region growth over huge areas, with plot-by-plot development, highly mixed land uses, much remnant agricultural land, and routine shortages of public infrastructure such as sewers, roads, and parks. Such patterns of suburbanization demonstrate many of the characteristics of the “extended metropolitan regions” identified by T. G. McGee and Ira M. Robinson. In other Asian countries, the high-density, pre-urbanization populations and highly fragmented land ownership were characteristic of wet-paddy rice agriculture. This combined with increasing mobility and urbanization to produce suburban areas with a mix of rural and urban land use and a mix of formal and informal development, with factories and fields incorporating vast areas into growing urban economies. Modes of travel including bicycles and two-stroke motorbikes shifted, with increasing affluence, to automobiles and trucks.

The other major form of suburban development in many developing countries has been large-scale, planned “new towns” and office parks on the urban fringe, often near airports and expressways, often in the form of gated, exclusive developments for the wealthy and for expatriates from developed countries. Gated communities were seen initially in the United States but are now also increasingly seen in developing countries. Although these are diverse, usually they are upscale developments entirely outside municipal jurisdiction. They provide all their own services, often including gates and security guards and sometimes golf courses and other leisure facilities. Instead of paying property taxes to a municipality, residents pay fees to a homeowners’ association or management agency that maintains the shared facilities.

Changing Ideas of the Good City

Worsening environmental conditions in 19th-century industrial cities not only pushed many people out of the city (if they could afford the longer commutes) but also contributed to the birth of powerful and enduring conceptions of the nature of the city as dreadful and corrupting. Similarly, suburbs began to be perceived as its bucolic antidote in the countryside. As the sanitary reform



and city-planning movements gained traction with devastating exposes of the degrading and corrupting slum conditions during the final decades of the 19th century, the idea of the residential suburb as bower of family life was reinforced. The ideal of living in the countryside but with access to the city was firmly established by the early 20th century, just as the countryside began to recede farther away with the accelerating spread of streetcar suburbs.

This analysis of urban pathology was reinforced by the work of the Chicago School of sociology, led by Robert Park and Ernest Burgess, which equated big-city life with the loss of the moral order of the traditional rural community, rising vice and crime rates, and increasing anomie. These ideas were later widely criticized for their environmental determinism—the idea that physical environments rather than social conditions determine culture—but were nonetheless hugely influential. For many, the obvious solution was dispersion of population and the emptying out of the city, arguments that provided powerful ideological support for suburbanization. Such antiurban ideas became dominant, especially in Britain, the United States, Canada, and Australia, and the idea of the detached single-family home in residential-only areas became the prevailing image of a good residential environment.

As mass suburbanization emerged in the 1950s as the dominant pattern, and the newly accessible suburban home ownership was enthusiastically embraced by the working and middle classes, a new, more critical interpretation of suburbanization grew prominent. Critics and social theorists began to identify a new set of social pathologies that they associated with the new suburbs, including isolation, the sorting out of classes into segregated areas, mass conformity and loss of individual identity, and a substitution of consumerism for community. This view of suburbanization as a destructive and failed social experiment was perhaps never better put than by Lewis Mumford in his monumental work *The City in History*:

In the mass movement into suburban areas, a new kind of community was produced, which caricatured both the historic city and the archetypal suburban refuge: a multitude of uniform,

unidentifiable houses, lined up inflexibly, at uniform distances, on uniform roads, in a treeless communal waste, inhabited by people of the same class, the same income, the same age group, witnessing the same television performances, eating the same tasteless pre-fabricated foods, from the same freezers, conforming in every outward and inward respect to a common mold, manufactured in the central metropolis. Thus the ultimate effect of the suburban escape in our time is, ironically, a low-grade uniform environment from which escape is impossible. (p. 486)

In the 1970s, these early indictments were deepened by the work of humanistic geographers, who argued that much of the contemporary suburban landscape was so repetitive that it inspired little sense of place in its residents, or anyone else, and epitomized placelessness. These critiques were amplified by arguments by feminist geographers that suburbs served to trap women in narrow reproductive roles, in places where the physical design served to isolate women from access to paid employment and services. Marxist geographers saw the development of suburbs primarily as a strategy for the deployment of surplus capital, in efforts to stave off an accumulation crisis. Social geographers saw the growing racial divide—between affluent, largely white suburbs, with excellent services, and poor, declining central cities, which were increasingly populated by visible minorities—as a powerful expression of systemic racism. Not everyone agreed, however, with other observers quick to defend the new suburbs as an opportunity for better housing for many and just as likely to generate meaningful places and communities as other urban patterns.

Suburbanization as a Contested Process

Inherent in the process of suburbanization has been a continuously shifting relationship between municipal boundaries and areas of new land development. While early in the 20th century, it was routine for U.S. cities to annex new growth areas by expanding municipal boundaries, in many places, that became much more difficult, usually because adjacent municipalities resisted amalgamation with a central city. The failure to grow urban boundaries to encompass newly



developing suburbs, however, had decisive consequences. First, growth often occurred most rapidly in places with less robust city planning and administrative and fiscal capacity. In the United States, suburbanization produced major conflicts, in the 1970s, between developers and the communities where they were building, over environmental impacts, congestion, and the high costs of suburban growth to existing taxpayers. Some of this was due to the self-interest of those who had found their suburban escape and wanted to slam the door behind them, but it was also a pragmatic response to serious problems of rapid growth and infrastructure shortfalls. This led to growth management efforts by municipalities that sought greater regulatory control over the speed, location, and form of any development and to a large urban politics literature on the political power of progrowth actors in municipal politics. Significant successes in managing growth were few and hard-won, and since 2000, property-rights advocates in several states have successfully challenged growth management approaches as unacceptable restrictions on land ownership (e.g., in Oregon, where long-standing urban growth boundaries were successfully challenged in a referendum in 2006).

Second, metropolitan regions in the United States now show high levels of political fragmentation, with multiple independent municipal governments of various sizes responsible for their own planning, schools, and infrastructure, making larger-scale regional coordination difficult and exacerbating social inequities. Poor and minority populations are concentrated in inner cities, with declining tax bases and substandard schools and services, while the middle-class areas in the suburbs often have excellent services and strong tax bases. Such divisions have also raised concerns about the spatial mismatch between the locations of jobs and housing, as most new jobs at all income levels are located in the suburbs but many workers cannot afford the housing in those suburbs. Fragmentation also positively encourages small municipalities to exclude unwanted land uses such as affordable housing or garbage dumps, leading many to argue that fragmentation has been a major factor behind residential segregation and exclusion and has contributed to the high levels of social polarization in American

metropolitan areas. Such suburban governance problems have prompted repeated attempts to create metropolitan and regional governance structures, which have so far largely failed, apart from Portland, Oregon, and Minneapolis–St. Paul. Other countries such as Canada, Australia, Japan, and Sweden, have been much more active in attempting metropolitan governance schemes for whole urban regions, using tax redistribution to ensure that schools and services are relatively consistent between suburbs and central cities and avoiding the extraordinary collapse of so many central cities seen in the United States.

Since the 1990s, the understanding of suburbanization has again been transformed, as the argument that there are serious dysfunctions associated with low-density suburbanization—commonly labeled “urban sprawl”—on a mass scale became more widely understood. The basic argument was that while it may be possible for a small portion of metropolitan populations to live at very low densities, when the majority do so and when most travel is by private car, then even with massive investments in roads, the resulting traffic creates endemic problems of congestion, pollution, and energy consumption. Low-density, automobile-dependent suburbs are increasingly attacked as the primary obstacle to greater urban environmental sustainability. These accusations have been combined with the ideas of the New Urbanists and of smart-growth advocates in support of stronger attempts to create more compact, mixed, and walkable suburban development forms. These arguments have been influential, particularly among municipal governments that have struggled with the costs of managing extensive development patterns, but suburban and exurban housing has continued to be popular among home buyers, so most attempts at managing growth in the United States have had limited success.

These debates do, however, once again underline the ongoing reality of suburbanization as a dynamic and fundamentally contested process at the intersection of conflicting ideas of desirable residential environments, environmental sustainability, land ownership and property rights, urban governance and citizenship, and social equity.

André Sorensen



See also **Circuits of Capital; Counterurbanization; Exurbs; Gated Community; Gentrification; Land Use Planning; New Urbanism; Smart Growth; Suburban Land Use; Sustainable Cities; Urban Geography; Urbanization; Urban Spatial Structure; Urban Sprawl; Zoning**

Further Readings

- Downs, A. (1994). *New visions for metropolitan America*. Cambridge, MA: Lincoln Institute of Land Policy.
- Duany, A., Speck, J., & Plater-Zyberk, E. (2000). *Suburban nation: The rise of sprawl and the decline of the American dream*. New York: North Point Press.
- Fishman, R. (1987). *Bourgeois utopias: The rise and fall of suburbia*. New York: Basic Books.
- Garreau, J. (1991). *Edge city: Life on the new frontier*. New York: Doubleday.
- Lang, R. (2003). *Edgeless cities: Exploring the elusive metropolis*. Washington, DC: Brookings Institution Press.
- Logan, J., & Molotch, H. (1987). *Urban fortunes: The political economy of place*. Berkeley: University of California Press.
- McGee, T., & Robinson, I. M. (Eds.). (1995). *The mega-urban regions of southeast Asia*. Vancouver, British Columbia, Canada: University of British Columbia Press.
- Mumford, L. (1961). *The city in history: Its origins, its transformations, and its prospects*. London: Secker & Warburg.
- Park, R., Burgess E., & McKenzie, R. (1925). *The city*. Chicago: University of Chicago Press.
- Relf, E. (1976). *Place and placelessness*. London: Pion.
- Rusk, D. (2003). *Cities without suburbs*. Washington, DC: Woodrow Wilson Center Press.
- Teaford, J. (1997). *Post-suburbia: Government and politics in the edge cities*. Baltimore: Johns Hopkins University Press.
- Warner, S. B. J. (1978). *Streetcar suburbs: The process of growth in Boston (1870–1900)*. Cambridge, MA: Harvard University Press. (Original work published 1962)
- Williams, R. (1973). *The country and the city*. New York: Oxford University Press.

SUI, DANIEL (1965–)

One of contemporary geography's leading theoreticians of geographic information science (GIScience), among other topics, Daniel Z. Sui has played an important role in shaping the trajectory of the discipline.

After completing bachelor's and master's degrees in science at Peking University and earning a PhD from the University of Georgia in 1993, Sui taught for 16 years at Texas A&M University, where he held the Reta Haynes Endowed Chair in Geography as well as serving as assistant vice president for research and director of geospatial information science and technology (2004–2008). In 2009, he moved to the Ohio State University as Distinguished Professor of Social and Behavioral Sciences and director of the Center for Urban and Regional Analysis. He was a recipient of a 2009 Guggenheim fellowship. He has also held a variety of visiting fellowships and professorships. Starting in 2007, he served as editor-in-chief of *GeoJournal* and as a regular columnist for *GeoWorld*. His career has also been notable for his extensive publication record, including several books and monographs and countless journal articles, and for millions of dollars in external grant funding. He has also mentored numerous graduate students.

Sui's corpus of work lies largely in the domain of geographic information systems (GIS) theory and applications. His works address, for example, an exceptionally wide array of topics, including neogeography and the "wikification" of GIS, volunteered geographical information, digital cities, location-based services, small-world networks, fuzzy logic, neural networks, fractals, the use of geospatial technologies for surveillance (including geoslavery), the environmental impacts of digital technologies, ecological inference, and empirical applications of GIS to topics as diverse as homeland security, medical geography, binge drinking, traffic accidents, transportation modeling, natural disasters, food insecurity, property value appraisal, water management, floodplain mapping, urban obesity, landscape fragmentation, mental maps, urban modeling, urban heat islands, urban sprawl in Asia and the United States, voter turnout, Internet-based and GIS education, and Tobler's First Law. A consistent



theme throughout these works is the social uses and consequences of digital geospatial technologies, with a critical eye toward the costs as well as the benefits. Sui has also been instrumental in fostering a rapprochement between the GIS and critical human geography communities since the 1990s, when a productive and mutually transformative dialogue began to replace mutual recrimination. His work has become increasingly epistemologically self-conscious, and he helped pioneer the use of poststructuralist concerns such as the social origins and consequences of representations in the GIS literature.

Barney Warf

See also [Geocomputation](#); [Geographic Information Systems](#); [Geospatial Industry](#); [Geostatistics](#); [GIS Implementation](#); [GIScience](#); [GIS Web Services](#); [Humanistic GIScience](#); [Neogeography](#)

Further Readings

- Sui, D. (2000). Visuality, aurality and the shifting metaphors in geographic thought in the late 20th century. *Annals of the Association of American Geographers*, 90(2), 322–343.
- Sui, D. (2003). Musings on the fat city: Are obesity and urban forms linked? *Urban Geography*, 24(1), 75–84.
- Sui, D. (2007). Geospatial technologies for surveillance: Tracking people and commodities in real time. *Geographical Review*, 93(3), 3–9.
- Sui, D. (2008). The wikification of GIS and its consequences, or Angelina Jolie's new tattoo and the future of GIS. *Computers, Environment, and Urban Systems*, 32(1), 1–5.
- Xu, Z., & Sui, D. (2007). Small world characteristics of transportation networks: A perspective from network autocorrelation. *Journal of Geographical Systems*, 9(2), 153–168.

analysis has its roots in the applications of hand-drawn, sieve-mapping overlay techniques used by landscape architects in the late 19th and early 20th centuries. In the 1960s, I. L. McHarg and others refined and advanced the overlay techniques by proposing a procedure that involved mapping data on the natural and human-made attributes of the environment and then presenting this information on individual, transparent maps using light to dark shading (low suitability to high suitability). When the maps were overlaid, the darkest areas then showed the most suitable parcels of land for particular types of land use.

Land suitability methods can be applied for tackling site selection problems or in the context of comprehensive planning. The aim of the site selection analysis is to identify the best site for a specific activity, such as a shopping center, an industrial plant, or a public school, given the set of potential or feasible locations (parcels of land). The problem is to rank or rate alternative sites based on their characteristics so that the best location can be identified. The comprehensive planning aims at identifying the best spatial pattern of land uses such as residential, industrial, commercial, and recreational. The procedure involves developing suitability maps for each land use based on criteria considered as important for the specific activity. The suitability maps are then overlaid to identify areas suitable for more than one land use.

The hand-drawn mapping technique for suitability analysis has been widely recognized as a precursor to the classical overlay procedures in geographic information systems (GIS). There are two fundamental classes of map combination (overlay) operations in GIS: Boolean overlay and weighted linear combination (WLC). Given a set of suitability maps and corresponding threshold values, the Boolean AND operation results in classifying areas as suitable for a particular land use if each suitability map meets its threshold. Conversely, the Boolean OR operation identifies suitable areas as those that meet at least one suitability threshold value. The WLC approach involves standardization of the suitability maps, assigning the weights of relative importance to the suitability maps, and then combining the weights and standardized suitability maps to obtain an overall suitability score. The classical GIS approaches to



SUITABILITY ANALYSIS

Suitability analysis is concerned with determining the most appropriate spatial pattern for future land uses according to specific requirements, preferences, or predictors of some activity. The



suitability analysis have recently been advanced by integrating GIS with multicriteria decision analysis methods.

Jacek Malczewski

See also **GIS, History of; GIScience; Landscape Architecture; Land Use Analysis; Spatial Multicriteria Evaluation**

Further Readings

- Collins, M. G., Steiner, F. R., & Rushman, M. J. (2001). Land-use suitability analysis in the United States: Historical development and promising technological achievements. *Environmental Management*, 28, 611–621.
- Hopkins, L. (1977). Methods for generating land suitability maps: A comparative evaluation. *Journal for American Institute of Planners*, 34, 19–29.
- Malczewski, J. (2004). GIS-based land-use suitability analysis: A critical overview. *Progress in Planning*, 62, 3–65.
- McHarg, I. L. (1969). *Design with nature*. New York: Wiley.
- Murphy, M. D. (2005). *Landscape architecture theory: An evolving body of thought*. Long Grove, IL: Waveland Press.
- Steinitz, C., Parker, P., & Jordan, L. (1976). Hand drawn overlays: Their history and prospective uses. *Landscape Architecture*, 9, 444–455.

SUNBELT

The Sunbelt is an innately geographical idea but one without a clear geographical definition. The term connotes a region (or regions) of the United States characterized by rapid post–World War II economic maturation and growth. In economic terms, two trends stand out. The first of these is the relocation of U.S. manufacturing employment from the Great Lakes region (“Rust Belt” or “Snowbelt”) to new industrial clusters in the warmer climates of the southeastern and

southwestern United States. This shift was fueled in part by the comparative advantages of lower labor costs and proximity to raw materials (especially oil), as well as by the advent of air conditioning, which made tolerable the extreme heat and humidity that characterized much of the southern tier of the United States. The second, more recent, trend is the spectacular growth in producer services jobs in banking, insurance, information, and technology in the urban Sunbelt (metropolitan regions such as Charlotte, Atlanta, Austin, Phoenix, and San Diego; see Figure 1).

The “belt” in *Sunbelt* refers to a southern, balmy arc of the United States, stretching from the Carolinas to California. The origins of the term are commonly attributed to Kevin Phillips in his book *The Emerging Republican Majority*. Phillips argued that the Sunbelt region had evolved into a key geographical focal point for a conservative revolution in American politics, characterized by an unlikely coalition of disaffected Southern whites, Western libertarians, and California cold warriors. This thesis has been complicated by subsequent elections, most notably the 2008 U.S. presidential election, which highlighted how problematic it is to group together states such as Georgia, Florida, California, and Arizona politically.

Population growth in the contemporary Sunbelt has partly resulted from in-migration from northern, particularly Rustbelt, states. A large proportion of these in-migrants are retirees, although the demographic makeup of these new arrivals is by no means homogeneous. Furthermore, the southward shift in manufacturing and service jobs growth has been mirrored by a shift in major immigrant destinations from the traditional immigrant gateways of the major northern cities to places in the Sunbelt. Many of these “New Americans” have adopted the auto-centered, suburban lifestyle that is predominant in the Sunbelt, resulting in remarkably diverse and decentralized immigrant communities in some Sunbelt metropolitan areas. Places such as Chamblee, Doraville, and Norcross in the suburbs of Atlanta and places such as Irving, Garland, and Plano in the Dallas metropolitan area have attracted large non-native-born populations in largely suburban settings. Some observers

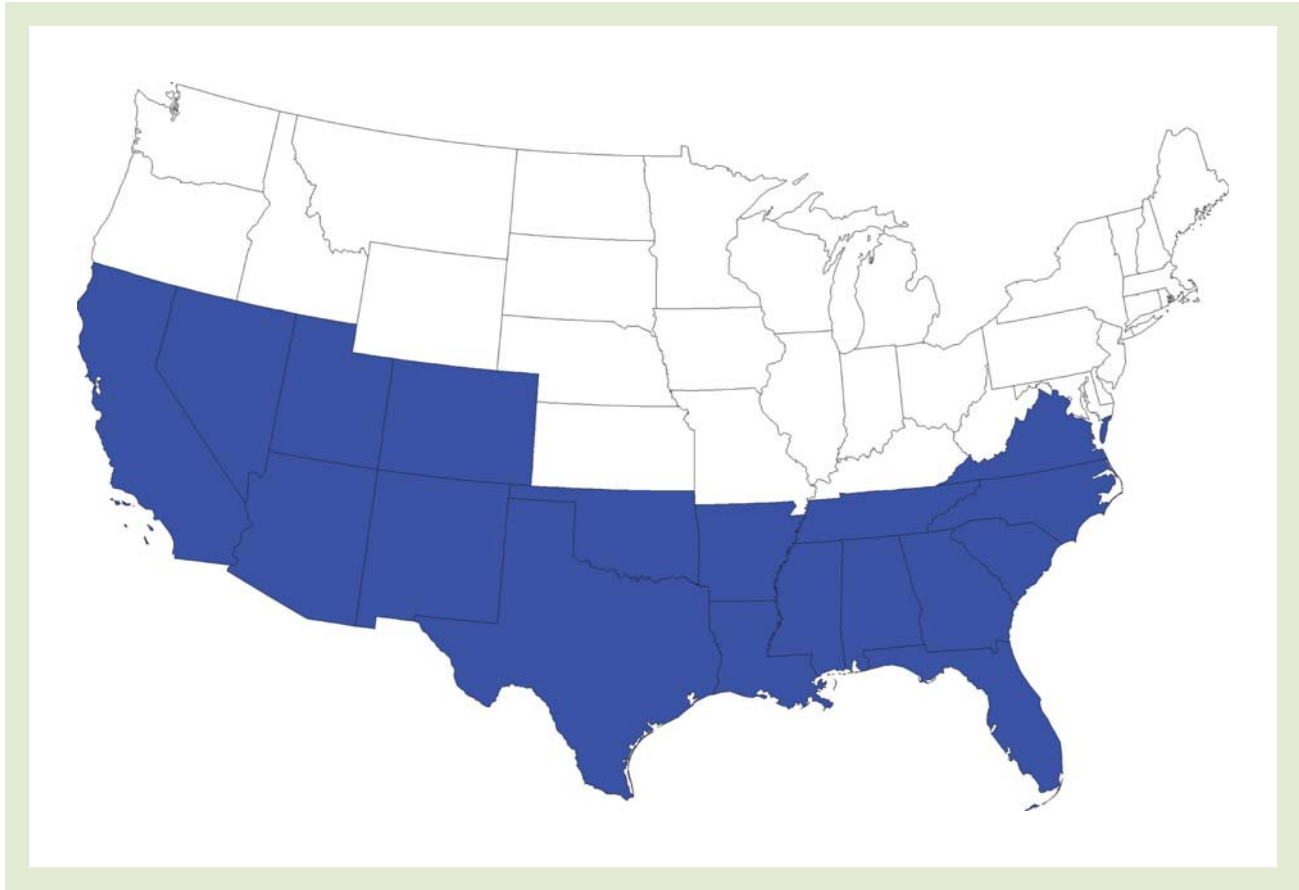


Figure 1 Although its definitions and meanings are often nebulous, the Sunbelt (designated in blue) is generally taken to mean the balmy, southern reaches of the United States.

Source: Barney Warf.

have argued that the essential qualities of a Sunbelt metropolis are that it is young, fast growing, auto centered, and sprawling, but the Sunbelt is also increasingly home to diverse groups of new immigrants.

Is all this enough to make the Sunbelt a coherent region? Attempts at defining the Sunbelt as a coherent geographical region fall short in several respects. First, it is not monolithic. The stereotypical image of the sun-drenched southern tier of the United States transforming from an economic backwater to a large swathe of nouveau riche fails to capture the spatial variability within the Sunbelt. First, much of the Sunbelt continues to struggle with the challenges presented by the pronounced urban-rural split in terms of spatial wealth distribution. Second, the term is relatively imprecise and geographically uncertain. Does

Bend, Oregon, which lies in the high desert region in the rain shadow of the Cascades and has experienced explosive amenity-fueled growth qualify as part of the Sunbelt? What about other Sunbelt regions outside the United States, such as Australia's Gold Coast and England's M-4 corridor? Third, some have argued that the Sunbelt terminology was a construct that had been thrust on those living there. One of the most notable observers of American vernacular regions, Wilbur Zelinsky, noted as much when he wrote in a seminal article that *Sunbelt* was a "deplorable" term, because it was created by elites and handed down to the people rather than the other way around.

Although the term *Sunbelt* is commonly used in both scholarly journals and the popular media and is widely accepted as a regional moniker, it is



less clear where the region begins and ends or what constitutes its key elements. Like other “belts”—Gun Belt, Bible Belt, and Grain Belt—there is something there, but it is difficult to say what or where.

Corey M. Johnson and Keith G. Debbage

See also **Growth Machine; Manufacturing Belt; Migration; Suburbs and Suburbanization**

Further Readings

- Abbott, C. (1990). New West, new South, new region: The discovery of the Sunbelt. In R. A. Mohl (Ed.), *Searching for the Sunbelt: Historical perspectives on a region* (pp. 7–24). Knoxville: University of Tennessee Press.
- Arizona State University Research Team. (2005). Phoenix: Dealing with fast growth. In J. Pack (Ed.), *Sunbelt/Frostbelt: Public policies and market forces in metropolitan development* (pp. 140–181). Washington, DC: Brookings Institution Press.
- Mohl, R. (Ed.). (1990). *Searching for the Sunbelt: Historical perspectives on a region*. Knoxville: University of Tennessee Press.
- Phillips, K. (1969). *The emerging Republican majority*. New Rochelle, NY: Arlington House.
- Zelinsky, W. (1980). North America's vernacular regions. *Annals of the Association of American Geographers*, 70(1), 1–16.

multispectral images) of the known training data are calculated for each class and then used for inputs to the classification algorithm for evaluating and assigning the rest of the data to classes.

Various classification algorithms (or classifiers) may be used in supervised classification to assign a data value to a class. These algorithms can be categorized into parametric and nonparametric approaches. The choice of a particular algorithm depends on the nature of the input data. Parametric classification algorithms assume a normal (or Gaussian) distribution of observed parameters in the training data, while nonparametric algorithms make no such assumption. The most widely used parametric classification algorithm is the maximum likelihood algorithm, in which data are assigned to the class having the highest probability (or likelihood), and the several commonly used nonparametric algorithms include parallelepiped, minimum distance, and neural network-based algorithms.

The quality and quantity of training samples can affect the output of supervised classification. Ideally, each training site should be independent of the others by selecting it through random sampling. However, this is often not possible due to cost and accessibility issues. Training polygons or seeds through automatic growing is often used in the selection of training data to save time and cost. Supervised classification depends heavily on the cognition and skills of the training analyst.

DongMei Chen

See also **Data Classification Schemes; Unsupervised Classification**



SUPERVISED CLASSIFICATION

Supervised classification is the process of automatically grouping data into a set of classes by setting up prototypes using a priori knowledge obtained through training. It often involves selection of training data that can represent homogeneous examples of each class. There are a number of ways to collect training data, including on-site fieldwork, manual interpolation, automatic seeding, and personal experience. The parameters (typically, mean vector and covariance matrix in

Further Readings

- Chen, D., & Stow, D. (2002). The effect of training strategies on supervised classification at different spatial resolutions. *Photogrammetric Engineering & Remote Sensing*, 68(11), 1155–1162.
- Jensen, J. R. (2005). *Introductory digital image processing: A remote sensing perspective*. Upper Saddle River, NJ: Pearson Prentice Hall.

ENCYCLOPEDIA OF
Geography

EDITORIAL BOARD

Editor

Barney Warf
University of Kansas

Associate Editors

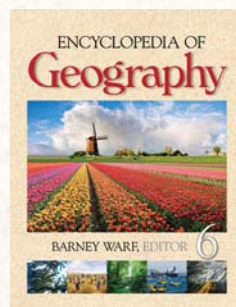
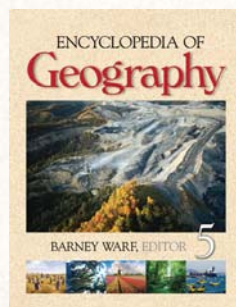
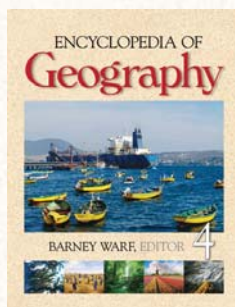
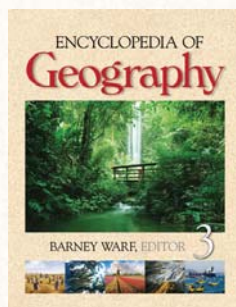
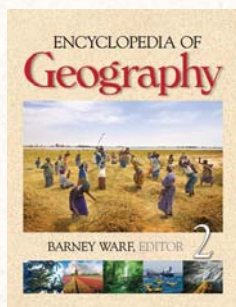
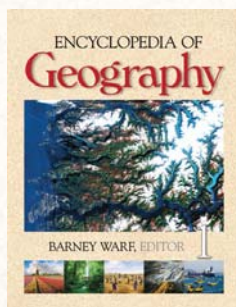
Piotr Jankowski
San Diego State University

Barry D. Solomon
Michigan Technological University

Mark Welford
Georgia Southern University

Managing Editor

Jonathan Leib
Old Dominion University



ENCYCLOPEDIA OF Geography

BARNEY WARF, EDITOR

University of Kansas

6



Los Angeles | London | New Delhi
Singapore | Washington DC

Copyright © 2010 by SAGE Publications, Inc.

All rights reserved. No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

For information:



SAGE Publications, Inc.
2455 Teller Road
Thousand Oaks, California 91320
E-mail: order@sagepub.com

SAGE Publications Ltd.
1 Oliver's Yard
55 City Road
London, EC1Y 1SP
United Kingdom

SAGE Publications India Pvt. Ltd.
B 1/I 1 Mohan Cooperative Industrial Area
Mathura Road, New Delhi 110 044
India

SAGE Publications Asia-Pacific Pte. Ltd.
33 Pekin Street #02-01
Far East Square
Singapore 048763

Printed in Singapore.

Library of Congress Cataloging-in-Publication Data

Encyclopedia of geography, volume I - VI / edited by Barney Warf.

6 v., p. cm.

Includes bibliographical references and index.

ISBN 978-1-4129-5697-0 (cloth)

1. Geography—Encyclopedias. I. Warf, Barney, 1956-

G63.E554 2010

910.3—dc22

2010009453

This book is printed on acid-free paper.

10 11 12 13 14 10 9 8 7 6 5 4 3 2 1

<i>Publisher:</i>	Rolf A. Janke
<i>Assistant to the Publisher:</i>	Michele Thompson
<i>Acquisitions Editor:</i>	Robert Rojek
<i>Developmental Editor:</i>	Diana E. Axelsen
<i>Reference Systems Manager:</i>	Leticia Gutierrez
<i>Reference Systems Coordinator:</i>	Laura Notton
<i>Production Editor:</i>	Tracy Buyan
<i>Copy Editors:</i>	QuADS Prepress (P) Ltd.
<i>Typesetter:</i>	C&M Digitals (P) Ltd.
<i>Proofreaders:</i>	Penelope Sippel, Rae-Ann Goodwin, Annette Van Deusen
<i>Indexer:</i>	Julie Sherman Grayson
<i>Cover Designer:</i>	Ravi Balasuriya
<i>Marketing Manager:</i>	Amberlyn McKay

Volume 6 cover photo: Colorful tulip field in a typical Dutch setting. © iStockphoto.com/JacobH.

CONTENTS

6

List of Entries

vii

Entries

S 2726

T 2775

U 2895

V 3005

W 3041

X 3143

Z 3147

Atlas of the World: A Brief Cartographic Overview

3151

Index

3171

LIST OF ENTRIES

- | | | |
|---|---|--|
| <p> Abler, Ronald
 Absolute Space
 Accessibility
 Acid Rain
 Actor-Network Theory
 Adaptation to Climate Change
 Adaptive Harvest Management
 Adaptive Radiation
 Adiabatic Temperature
 Changes
 Aerial Imagery: Data
 Aerial Imagery: Interpretation
 African Union
 Agamben, Giorgio
 Agent-Based Models
 Agglomeration Economies
 Aging and the Aged,
 Geography of. <i>See</i> Elderly,
 Geography and the
 Agnew, John
 Agricultural Biotechnology
 Agricultural Intensification
 Agricultural Land Use
 Agriculture, Industrialized
 Agriculture, Preindustrial
 Agrobiodiversity
 Agrochemical Pollution
 Agroecology
 Agrofoods
 Agroforestry
 AIDS, Geography of. <i>See</i>
 Disease, Geography of;
 HIV/AIDS, Geography of
 Air Masses </p> | <p> Air Pollution. <i>See</i> Atmospheric
 Pollution
 Albedo
 al-Idrisi
 Altitude
 Ambient Air Quality
 American Geographical Society
 Analytical Operations in GIS
 Anarchism and Geography
 Anaximander
 Animal Geographies
 Annales School
 Anselin, Luc
 Antevs, Ernst
 Anthropogenic Atmospheric
 Change. <i>See</i> Anthropogenic
 Climate Change;
 Stratospheric Ozone
 Depletion
 Anthropogenic Climate Change
 Anthropogeography
 Antiglobalization
 Antipodes
 Antisystemic Movements
 Applied Geography
 Appropriate Technology. <i>See</i>
 Sustainable Development;
 Sustainable Development
 Alternatives; Sustainable
 Production
 Aquaculture
 Archipelago
 Architecture and Geography
 Argumentation Maps </p> | <p> Arid Topography
 Aristotle
 Armstrong, Marc
 Art and Geography
 Asia-Pacific Economic
 Cooperation
 Association of American
 Geographers
 Association of Geographic
 Information Laboratories
 for Europe
 Association of Southeast Asian
 Nations
 Atmospheric Circulation
 Atmospheric Composition and
 Structure
 Atmospheric Energy Transfer
 Atmospheric Moisture
 Atmospheric Particulates
 Across Scales
 Atmospheric Pollution
 Atmospheric Pressure
 Atmospheric Remote Sensing
 Atmospheric Variations
 in Energy
 Atoll
 Automobile Industry
 Automobility
 Avalanches
 Aviation and Geography

 Barrier Islands
 Barrows, Harlan
 Basin and Range Topography </p> |
|---|---|--|

- | | | |
|---|--|---|
| Batty, Michael | Business Models for Geographic Information Systems | Class, Geography and Class, Nature and Client-Server Architecture |
| Bayesian Statistics in Spatial Analysis | Buttimer, Anne | Climate: Dry |
| Behavioral Geography | | Climate: Midlatitude, Mild |
| Berkeley School | | Climate: Midlatitude, Severe |
| Berry, Brian | Cadastral Systems | Climate: Mountain |
| Bhopal, India, Chemical Disaster | CAD Systems | Climate: Polar |
| Biblical Mapping | Câmara, Gilberto | Climate: Tropical Humid |
| Biodiversity | Canadian Association of Geographers | Climate Change |
| Biofuels | Cancer, Geography of | Climate Policy |
| Biogeochemical Cycles | Carbonation | Climate Types |
| Biogeography | Carbon Cycle | Climatic Relict |
| Biome: Boreal Forest | Carbon Trading and Carbon Offsets | Climatology |
| Biome: Desert | Carcinogens | Clouds |
| Biome: Midlatitude Deciduous Forest | Carrying Capacity | Clusters |
| Biome: Midlatitude Grassland | Cartograms | Coal |
| Biome: Tropical Deciduous Forest | Cartography | Coastal Dead Zones |
| Biome: Tropical Rain Forest | Cartography, History of | Coastal Erosion and Deposition |
| Biome: Tropical Savanna | Castells, Manuel | Coastal Hazards |
| Biome: Tropical Scrub | Caverns | Coastal Zone and Marine Pollution |
| Biome: Tundra | Cellular Automata | Cold War, Geography of |
| Biophysical Remote Sensing | Census | Collaborative GIS |
| Bioregionalism | Census Tracts | Colonialism |
| Biosphere Reserves | Centers of Domestication | Color in Map Design |
| Biota and Climate | Central Business District | Columbus, Christopher |
| Biota and Soils | Central Place Theory | Commodity Chains |
| Biota and Topography | Chemical Spills, Environment, and Society | Common Pool Resources |
| Biota Migration and Dispersal | Chernobyl Nuclear Accident | Common Property Resource Management |
| Biotechnology and Ecological Risk | Chicago School | Commons, Tragedy of the Commonwealth of Independent States |
| Biotechnology Industry | Childhood Spatial and Environmental Learning | Communications Geography |
| Biruni | Children, Geography of | Communism and Geography |
| Blaikie, Piers | Chinooks/Foehns | Community-Based Conservation |
| Blaut, James | Chipko Movement | Community-Based Environmental Planning |
| Blindness and Geography | Chlorinated Hydrocarbons | Community-Based Natural Resource Management |
| Body, Geography of | Chlorofluorocarbons | Community Forestry |
| Borderlands | Cholera, Geography of | Commuting |
| Borders and Boundaries | Chorley, Richard | Comparative Advantage |
| Bourghassi, Carmina | Chorology | Competitive Advantage |
| Bowman, Isaiah | Choropleth Maps | Complexity Theory |
| Brownfields | Chrisman, Nicholas | Complex Systems Models |
| Built Environment | Christaller, Walter | Conference of Latin Americanist Geographers |
| Bunge, William | Circuits of Capital | |
| Bush Fallow Farming | Citizenship | |
| Business Cycles and Geography | Civil Society | |
| Business Geography | Clark, Andrew | |
| | Clark, William | |

- Conflation
 Conservation
 Conservation Zoning
 Consumption, Geographies of
 Continental Drift. *See* Plate Tectonics
 Cook, Captain James
 Coordinate Geometry
 Coordinate Systems
 Coordinate Transformations
 Coral Reef
 Coral Reef Geomorphology
 Coriolis Force
 Corporate Voluntary Environmental Initiatives and Self-Regulation
 Cosgrove, Denis
 Cosmopolitanism
 Cost-Benefit Analysis
 Council for Mutual Economic Assistance (COMECON)
 Countermapping
 Counterurbanization
 Coupled Human and Animal Systems
 Coupled Human and Natural Systems
 Creep
 Crime, Geography of
 Crisis
 Critical Geopolitics
 Critical GIS
 Critical Human Geography
 Critical Studies of Nature
 Crop Genetic Diversity
 Crop Rotation
 Cross-Border Cooperation
 Cultural Ecology
 Cultural Geography
 Cultural Landscape
 Cultural Turn
 Cyberspace
 Cyborg Ecologies
 Cyclones: Extratropical
 Cyclones: Occluded
 Dangermond, Jack
 Darby, Henry Clifford
 Darwinism and Geography
 Dasymetric Maps
 Database Management Systems
 Database Versioning
 Data Classification Schemes
 Data Compression Methods
 Data Editing
 Data Format Conversion
 Data Indexing
 Data Querying in GIS
 Datums
 Davis, William Morris
 Dear, Michael
 Debt and Debt Crisis
 Decolonization
 Deep Ecology Movements
 Deforestation
 Deindustrialization
 Delta
 Democracy
 Demographic Transition
 Dendrochronology
 Dependency Theory
 Derechos
 Desertification
 Desert Varnish
 Deterritorialization and Reterritorialization
 Developing World
 Development Theory
 Diamond, Jared
 Diaspora
 Diastrophism
 Difference, Geographies of
 Differential Heating
 Differential Vulnerabilities to Hazards
 Diffusion
 Digital Divide
 Digital Terrain Model
 Digitizing
 Disability, Geography of
 Disaster Prediction and Warning
 Disaster Preparedness
 Discourse and Geography
 Disease, Geography of
 Distance Decay
 Distributed Computing
 Distribution of Resource Access
 Division of Labor
 Domestication Centers. *See* Centers of Domestication
 Domestication of Animals
 Domestication of Plants
 Domino Theory
 Dot Density Maps
 Drought Risk and Hazard
 Drugs, Geography of
 Dunes
 Dynamic and Interactive Displays
 Earle, Carville
 Earthquakes
 Earth's Coordinate Grid
 Eastman, Ronald
 Ecofeminism
 Ecological Economics
 Ecological Fallacy
 Ecological Footprint
 Ecological Imaginaries
 Ecological Justice
 Ecological Mapping
 Ecological Modernization
 Ecological Regimes
 Ecological Risk Analysis
 Ecological Services. *See* Environmental Services
 Ecological Zones
 E-Commerce and Geography
 Economic Base Analysis
 Economic Geography
 Economies of Scale
 Economies of Scope
 Ecoregions
 Ecoshed
 Ecosystem Decay
 Ecosystems
 Ecotone
 Ecotourism
 Education, Geographies of
 Egenhofer, Max
 Elderly, Geography and the
 Electoral Geography
 Electronic Atlases
 Electronics Industry, Geography of
 El Niño
 Emerging Markets

- | | | |
|------------------------------------|-------------------------------------|---------------------------------|
| Emotions, Geography and Empiricism | Environmental Protection | Feminist Environmentalism |
| Endogenous Growth Theory. | Environmental Racism | Feminist Geographies |
| <i>See</i> Knowledge Spillovers; | Environmental Refugees | Feminist Methodologies |
| Learning Regions | Environmental Restoration | Feminist Political Ecology |
| Energy and Human Ecology | Environmental Rights | Fertility Rate |
| Energy Models | Environmental Security | Fieldwork in Human |
| Energy Policy | Environmental Services | Geography |
| Energy Resources | Environmental Social | Fieldwork in Physical |
| Enlightenment | Movements. <i>See</i> International | Geography |
| Enterprise GIS | Environmental Movements | Film and Geography |
| Environmental Certification | Environment and Development | Filtering |
| Environmental Determinism | Epistemology | Filtration |
| Environmental Discourse | Equator | Finance, Geography of |
| Environmental Entitlements | Equinox | Fisher, Peter |
| Environmental Ethics | Eratosthenes | Fish Farming |
| Environmental Footprint. | Error Propagation | Fjords |
| <i>See</i> Ecological Footprint | Ethics, Geography and | Flash Floods |
| Environmental History | Ethnicity | Flexible Production |
| Environmental Imaginaries | Ethnicity and Nature | Flocculation |
| Environmental Impact | Ethnic Segregation | Floodplain |
| Assessment | Ethnocentrism | Floods |
| Environmental Impacts of | Eurocentrism | Flow |
| Agriculture | Euromarket | Flow Maps |
| Environmental Impacts of | European Green Movements | Folding |
| Cities | European Union | Folk Culture and |
| Environmental Impacts of | Everglades Restoration | Geography |
| Manufacturing | Everyday Life, Geography and | Food, Geography of |
| Environmental Impacts of | Existentialism and Geography | Food and Agriculture |
| Mining. <i>See</i> Open-Pit | Exotic Species | Organization (FAO) |
| Mining | Exploration | Footprint Analysis. |
| Environmental Impacts of | Exploratory Spatial Data | <i>See</i> Ecological Footprint |
| Oil Fields | Analysis | Fordism |
| Environmental Impacts of | Export-Led Development | Fordism |
| Pipelines | Export Processing Zones | Foreign Aid |
| Environmental Impacts of | Externalities | Foreign Direct Investment |
| Roads | Extinctions | Forest Degradation |
| Environmental Impacts of | Extractive Reserves | Forest Fragmentation |
| Tourism | Extreme Geography | Forest Land Use |
| Environmental Impacts of War | Exurbs | Forest Restoration |
| Environmental Impact | Factors Affecting Location | Fotheringham, A. Stewart |
| Statement | of Firms | Frank, Andrew |
| Environmental Justice | Fair Trade and Environmental | Frontiers |
| Environmental Law | Certification | Fronts |
| Environmental Management | Famine, Geography of | Gaia Theory |
| Environmental Management: | Faulting | Gama, Vasco da |
| Drylands | Fear, Geographies of | Game Ranching |
| Environmental Mapping | Febvre, Lucien | Gated Community |
| Environmental Perception | Feminist Environmental | Gays and Lesbians, |
| Environmental Planning | Geographies | Geography and/of |
| | | Gazetteers |

- Gender and Environmental Hazards
 Gender and Geography
 Gender and Nature
 General Circulation Model (GCM). *See* Anthropogenic Climate Change; Atmospheric Energy Transfer; Climate Change
 Genetically Modified Organisms (GMOs)
 Genocide, Geographies of
 Gentrification
 Geocoding
 Geocollaboration
 Geocomputation
 Geodemographics
 Geodesy
 Geographical Ignorance
 Geographical Imagination
 Geographically Weighted Regression
 Geographic Information Systems
 Geography Education
 Geolibraries
 Geologic Timescale
 Geomancy
 Geometric Correction
 Geometric Measures
 Geomorphic Cycle
 Geomorphology
 Geophagy
 Geopolitics
 Geosensor Networks
 Geoslavery
 Geospatial Industry
 Geospatial Semantic Web
 Geostatistics
 Geothermal Energy
 Geothermal Features
 Geovisualization. *See* Cartography; Dynamic and Interactive Displays; Three-Dimensional Models
 Getis, Arthur
 Ghetto
 Giddens, Anthony
 Gilbert, Grove Karl
 GIS, Environmental Model Integration and
 GIS, History of
 GIScience
 GIS Design
 GIS Implementation
 GIS in Archaeology
 GIS in Disaster Response
 GIS in Environmental Management
 GIS in Health Research and Health Care
 GIS in Land Use Management
 GIS in Local Government
 GIS in Public Policy
 GIS in Transportation
 GIS in Urban Planning
 GIS in Utilities
 GIS in Water Management
 GIS Software
 GIS Web Services
 Glaciers: Continental
 Glaciers: Mountain
 Global Climate Change. *See* Anthropogenic Climate Change
 Global Environmental Change
 Globalization
 Global Positioning System
 Global Sea-Level Rise
 Global Warming. *See* Anthropogenic Climate Change
 Globes. *See* Cartography; Map Projections
 Glocalization
 Golledge, Reginald
 Goodchild, Michael
 Goode, J. Paul
 Google Earth
 Gottmann, Jean
 Gould, Peter
 Governance
 Governmentality and Conservation
 Gravity Model
 Great American Exchange
 Greenbelts
 Green Building
 Green Design and Development
 Greenhouse Gases
 Green Revolution. *See* Environmental Impacts of Agriculture
 Gregory, Derek
 Gross Domestic Product/Gross National Product
 Ground Reference Data
 Groundwater
 Growth Machine
 Growth Poles
 Gully Erosion
 Guyot, Arnold
 Hadley Cell
 Hägerstrand, Torsten
 Haggett, Peter
 Hanson, Susan
 Harley, Brian
 Hartshorne, Richard
 Harvey, David
 Hate, Geographies of
 Haushofer, Karl
 Hayden, Ferdinand
 Health and Health Care, Geography of
 Heavy Metals as Pollutants
 Hegemony
 Herbicides
 Herodotus
 Hettner, Alfred
 Heuristic Methods in Spatial Analysis
 High-Performance Computing
 High Technology
 Hipparchus
 Historical Geography
 Historicism
 Historic Preservation
 History of Geography. *See* Cartography, History of; GIS, History of; Human Geography, History of; Physical Geography, History of
 HIV/AIDS, Geography of
 Home
 Homelessness
 Hou Renzhi

- Housing and Housing Markets
Housing Policy
Hoyt, Homer
Human Dimensions of Global
Environmental Change
Human Ecology
Human Geography, History of
Human-Induced Invasion of
Species
Humanistic Geography
Humanistic GIScience
Human Rights, Geography and
Humboldt, Alexander von
Humidity
Hunger
Hunting and Gathering
Huntington, Ellsworth
Hurricane Katrina
Hurricanes, Physical
Geography of
Hurricanes, Risk and Hazard
Hybrid Geographies
Hybridization of Plant and
Animal Species
Hydroelectric Power
Hydrological Connectivity
Hydrology
Hydrothermal Energy. *See*
Geothermal Energy
- Ibn Battuta
Ibn Khaldūn
Ice
Identity, Geography and
Idiographic
Image Enhancement
Image Fusion
Image Interpretation
Image Processing
Image Registration
Image Texture
Imaging Spectroscopy
Immigration
Imperialism
Impermeable Surfaces
Import Substitution
Industrialization
Incubator Zones
Indigeneity
Indigenous Agriculture
- Indigenous and Community
Conserved Areas
Indigenous Cartographies
Indigenous Environmental
Knowledge
Indigenous Environmental
Practices
Indigenous Forestry
Indigenous Reserves
Indigenous Water Management
Industrial Districts
Industrial Ecology
Industrialization
Industrial Revolution
Inequality and Geography
Informal Economy
Information Society
Infrastructure
Innovation, Geography of
Input-Output Models
Institute of British Geographers
Interactive Mapping. *See* Map
Animation
Intergovernmental
Environmental
Organizations and Initiatives
International Criminal Court
International Environmental
Movements
International Environmental
NGOs
International Geographical
Union
International Monetary Fund
International Watershed
Management
Internet. *See* Communications,
Geography of; Cyberspace;
Digital Divide;
Telecommunications and
Geography
Internet GIS
Interoperability and Spatial
Data Standards
Interviewing
Invasion and Succession
Isard, Walter
Island Biogeography
Islands, Small
Isopleth Maps
- Jackson, John Brinckerhoff
Jefferson, Thomas
Johnston, R. J.
Journey-to-Work. *See*
Commuting
Justice, Geography of
- Kant, Immanuel
Karst Topography
Kates, Robert
Keystone Species
Knowledge, Geography of
Knowledge Spillovers
Köppen, Wladimir
Köppen-Geiger Climate
Classification
Kropotkin, Peter
Krummholtz
Kuhn, Werner
Kwan, Mei-Po
Kyoto Protocol. *See* Climate
Policy
- Labor, Geography of
Lahar. *See* Volcanoes
Land Degradation
Landfills
Landforms
Land Reform
Landscape and Wildlife
Conservation
Landscape Architecture
Landscape Biodiversity
Landscape Design
Landscape Ecology
Landscape Interpretation
Landscape Quality
Assessment
Landscape Restoration
Landslide
Land Tenure
Land Tenure Reform
Land Use
Land Use Analysis
Land Use and Cover Change
(LUCC)
Land Use and Land Cover
Mapping
Land Use History
Land Use Planning

- Land-Water Breeze
 Languages, Geography of
 La Niña
 Lapse Rate
 Latent Heat
 Latitude
 Law, Geography of
 Learning Regions
 Lefebvre, Henri
 Legal Aspects of Geospatial Information
 Lewis, Peirce
 Lewis and Clark Expedition
 Ley, David
 LiDAR and Airborne Laser Scanning
 Lightning
 Lillesand, Thomas
 Linear Referencing and Dynamic Segmentation
 Literature, Geography and
 Livingstone, David
 Locality
 Locally Unwanted Land Uses (LULUs)
 Location-Allocation Modeling
 Location-Based Services
 Location Quotients
 Location Theory
 Logical Positivism
 Longitude
 Los Angeles School
 Lösch, August
 Love Canal
 Lynch, William
- MacEachren, Alan
 Mackinder, Sir Halford
 Magellan, Ferdinand
 Mahan, Alfred Thayer
 Malaria, Geography of
 Malthusianism
 Manufacturing Belt
 Map Algebra
 Map Animation
 Map Design
 Map Evaluation and Testing
 Map Generalization
 Map Projections
 Map Visualization
- Marcus, Melvin G.
 Marginal Regions
 Marine Aquaculture
 Maritime Spaces. *See* Oceans
 Mark, David M.
 Market-Based Environmental Regulation
 Marsh, George Perkins
 Marxism, Geography and
 Masculinities and Geography
 Massey, Doreen
 Mass Wasting
 Mather, John Russell
 Maury, Matthew Fontaine
 McKnight, Tom L.
 Media and Geography
 Medical Geography
 Meinig, Donald
 Mental Maps
 Mercator, Gerardus
 Metadata
 Metropolitan Area
 Microwave/RADAR Data
 Migration
 Military Geography
 Military Spending
 Miller, Harvey J.
 Minerals
 Mining and Geography
 Mitchell, Don
 Mixed Farming
 Mobile GIS
 Mobility
 Models and Modeling
 Modernity
 Modernization Theory
 Modifiable Areal Unit Problem
 Money, Geographies of
 Monmonier, Mark
 Monsoons
 Morrill, Richard
 Morse, Jedediah
 Mortality Rate
 Most Favored Nation Status
 Movimento Sem Terra
 Multimedia Mapping
 Multispectral Imagery
 Multistakeholder Participation
 Multitemporal Imaging
 Multivariate Analysis Methods
- Multivariate Mapping
 Music and Sound, Geography and
 Nation
 National Aeronautics and Space Administration (NASA)
 National Center for Geographic Information and Analysis
 National Council for Geographic Education
 National Geographic Society
 Nationalism
 Natural Growth Rate
 Natural Hazards and Risk Analysis
 Nature
 Nature-Society Theory
 Neighborhood
 Neocolonialism
 Neogeography
 Neoliberal Environmental Policy
 Neoliberalism
 Neo-Malthusianism
 Network Analysis
 Network Data Model
 New International Division of Labor
 Newly Industrializing Countries
 New Urbanism
 Nitrogen Cycle
 Nomadic Herding
 Nomadism
 Nomothetic
 Nongovernmental Organizations (NGOs)
 Nonpoint Sources of Pollution
 Nonrenewable Resources
 Nonrepresentational Theory
 Nonvisual Geographies
 North American Free Trade Agreement (NAFTA)
 North Atlantic Treaty Organization (NATO)
 Not in My Backyard (NIMBY)
 Nuclear Energy

- | | | |
|---|--|--|
| Nutrient Cycles | Patches and Corridors in Wildlife Conservation | Positionality |
| Nyerges, Timothy | Path Dependence | Positivism. <i>See</i> Logical Positivism |
| Object-Based Image Analysis | Patriarchy, Geography and | Postcolonialism |
| Oceanic Circulation | Peasants and Peasantry | Post-Fordism. <i>See</i> Flexible Production |
| Oceans | Peat | Postindustrial Society |
| Offshore Finance | Pedology. <i>See</i> Soils | Postmodernism |
| Oil Spills | Peet, Richard | Poststructuralism |
| Okabe, Atsuyuki | Penck, Walther | Poverty |
| Olsson, Gunnar | Periglacial Environments | Powell, John Wesley |
| Ontological Foundations of Geographical Data | Permaculture | Prairie Restoration |
| Ontology | Permafrost | Prairies |
| Open Geodata Standards | Pesticides | Precipitation, Global |
| Open Geospatial Consortium (OGC) | Pest Management | Precipitation Formation |
| Open-Pit Mining | Petroleum | Pred, Allan |
| Open Source Geospatial Foundation | Peuquet, Donna | Primate Cities |
| Open Source GIS | Phenomenology | Prime Meridian. <i>See</i> Longitude |
| Open Space | Phosphorus Cycle | Privacy and Security of Geospatial Information |
| Organic Agriculture | Photochemical Smog | Producer Services |
| Organisation for Economic Co-operation and Development (OECD) | Photogrammetric Methods | Product Cycle |
| Organization of the Petroleum Exporting Countries (OPEC) | Photography, Geography and | Production of Space |
| Organophosphates | Physical Geography, History of | Psychoanalysis, Geography and |
| Orientalism | Pickles, John | Ptolemy |
| Ortelius | Pilgrimage | Public Housing |
| Other/Otherness | Place | Public Participation GIS |
| Outsourcing | Place Names | Public Policy, Geography of |
| Overpopulation. <i>See</i> Malthusianism; Neo-Malthusianism | Place Promotion | Public-Private Partnerships |
| | Plantations | Public Space |
| | Plate Tectonics | Public Water Services |
| | Playas | Pyrogeography |
| | Point Pattern Analysis | |
| | Point Sources of Pollution | Qualitative Methods |
| | Poles, North and South | Quantitative Methods |
| | Political Ecology | Quantitative Revolution |
| | Political Economy | Queer Theory |
| | Political Economy of Resources | |
| | Political Geography | |
| | Polychlorinated Biphenyls (PCBs) | |
| | Popular Culture, Geography and | Race and Empire |
| | Population and Land Degradation | Race and Nature |
| | Population and Land Use | Race and Racism |
| | Population Density | Racial Segregation |
| | Population, Environment, and Development | Radiation: Solar and Terrestrial |
| | Population Geography | Radical Geography |
| | Population Pyramid | Radiometric Correction |
| | Portolan Charts | Radiometric Normalization |
| | Ports and Maritime Trade | Radiometric Resolution |
| | | Railroads and Geography |
| | | Raisz, Erwin |

- Rank-Size Rule
 Ratzel, Friedrich
 Real Estate, Geography and
 Realism
 Reclus, Élisée
 Recycling of Municipal Solid
 Waste
 Redistricting
 Refugees
 Regional Economic
 Development
 Regional Environmental
 Planning
 Regional Geography
 Regional Governance
 Regional Science
 Regional Science Association
 International (RSAI)
 Regions and Regionalism
 Regulation Theory
 Relational Space. *See* Relative/
 Relational Space
 Relative/Relational Space
 Religion, Geography and
 Relph, Edward
 Remittances
 Remote Sensing
 Remote Sensing: Platforms and
 Sensors
 Remote Sensing in Disaster
 Response
 Renewable Resources
 Rent-Gap
 Representations of Space
 Research and Development,
 Geographies of
 Resilience
 Resistance, Geographies of
 Resource Economics
 Resource Geography
 Resource Management. *See*
 Environmental Management
 Resource Management,
 Decision Models in
 Resource Mapping
 Resource Tenure
 Restoration Ecology. *See*
 Environmental Restoration
 Restructuring
 Retail Trade, Geography of
 Rill Erosion
 Risk Analysis and Assessment
 Ritter, Carl
 Rivers
 Rock Weathering
 Rose, Gillian
 Royal Geographical Society
 Rural Development
 Rural Geography
 Rural-Urban Migration
 Russian Geographical Society
 Satellites and Geography
 Sauer, Carl
 Scale, Social Production of
 Scale in GIS
 Schaefer, Fred
 Science, Technology, and
 Environment
 Science and Technology Studies
 Scott, Allen
 Sedimentary Rock
 Sedimentation
 Segregation and Geography
 Self-Organizing Maps
 Semantic Interoperability
 Semantic Reference Systems
 Semple, Ellen Churchill
 Sense of Place
 Sequent Occupance
 Services. *See* Producer Services
 Settlement Geography
 Sexuality, Geography and/of
 Shifting Cultivation
 Shortest-Path Problem
 Single Large or Several Small
 (SLOSS) Debate
 Situated Knowledge
 Smart Growth
 Smith, Neil
 Smog. *See* Photochemical Smog
 Social and Economic Impacts
 of Climate Change
 Social Construction of Nature
 Social Darwinism
 Social Forestry
 Social Geography
 Socialism and Geography
 Social Justice
 Social Movements
 Soil Conservation
 Soil Degradation
 Soil Depletion
 Soil Erosion
 Soils
 Soja, Edward
 Solar Energy
 Solstices
 Sovereignty
 Space, Production of. *See*
 Production of Space
 Space of Flows
 Spaces of Representation/
 Representational Spaces
 Spatial Analysis
 Spatial Autocorrelation
 Spatial Cognition
 Spatial Cognitive Engineering
 Spatial Data Infrastructures
 Spatial Data Integration
 Spatial Data Mining
 Spatial Data Models
 Spatial Data Structures
 Spatial Decision Support
 Systems
 Spatial Econometrics
 Spatial Fix
 Spatial Inequality
 Spatial Interaction Models
 Spatial Interpolation
 Spatialization
 Spatially Integrated Social
 Science
 Spatial Multicriteria Evaluation
 Spatial Optimization Methods
 Spatial Resolution
 Spatial Statistics
 Spatial Strategies of
 Conservation
 Spatial Turn
 Species-Area Relationship
 Spectral Characteristics of
 Terrestrial Surfaces
 Spectral Resolution
 Spectral Transformations
 Spit. *See* Coastal Erosion and
 Deposition
 Sports, Geography of
 Squatter Settlements
 State

- | | | |
|-------------------------------|-----------------------------------|------------------------------|
| Steel Industry, Geography of | Textile Industry | United Nations Conference on |
| Stereoscopy and Orthoimagery | Thales | Environment and |
| Storper, Michael | Thermal Imagery | Development |
| Strabo | Thornthwaite, C. Warren | United Nations Environmental |
| Strahler, Arthur | Three-Dimensional Data | Summits |
| Stratospheric Ozone Depletion | Models | United Nations Environment |
| Strip Mining | Three Mile Island Nuclear | Programme (UNEP) |
| Structural Adjustment | Accident | United States Census Bureau |
| Structuralism | Thrift, Nigel | United States Geological |
| Structuration Theory | Thunderstorms | Survey (USGS) |
| Subaltern Studies | Thünen Model | University Consortium for |
| Suburban Land Use | Timber Plantations | Geographic Information |
| Suburbs and Suburbanization | Time, Geographies of | Science |
| Sui, Daniel | Time-Geography | Unsupervised Classification |
| Suitability Analysis | Time-Space Compression | Unwin, David |
| Sunbelt | T-in-O Maps | Urban and Regional |
| Supervised Classification | Tobler, Waldo | Development |
| Supranational Integration | Tomlinson, Roger | Urban and Regional Planning |
| Surface Water | Topological Relationships | Urban Ecology |
| Surveillance | Toponymy | Urban Environmental Studies |
| Surveying | Topophilia | Urban Gardens |
| Sustainability Science | Tornadoes | Urban Geography |
| Sustainable Agriculture | Tourism | Urban Green Space |
| Sustainable Cities | Township and Range System | Urban Heat Island |
| Sustainable Development | Trade | Urban Hierarchy |
| Sustainable Development | Transhumance. <i>See</i> Nomadism | Urbanization |
| Alternatives | Transnational Corporation | Urban Land Use |
| Sustainable Fisheries | Transnationalism | Urban Metabolism |
| Sustainable Forestry | Transportation Geography | Urban Planning and |
| Sustainable Production | Trap Streets | Geography |
| Symbolism and Place | Travel Writing, Geography and | Urban Policy |
| Symptoms and Effects of | Tree Farming | Urban Solid Waste |
| Climate Change | Trewartha, Glenn | Management |
| | Triangulated Irregular | Urban Spatial Structure |
| | Network (TIN) Data Model | Urban Sprawl |
| Taphonomy | Troll, Carl | Urban Storm Water |
| Taylor, Griffith | Tropical Rain Forests. <i>See</i> | Management |
| Taylor, Peter | Biome: Tropical Rain Forest | Urban Sustainability |
| Technological Change, | Tsunami | Urban Underclass |
| Geography of | Tsunami of 2004, Indian | Urban Water Supply |
| Telecommunications and | Ocean | Usability of Geospatial |
| Geography | Tuan, Yi-Fu | Information |
| Teleconnections | Turner, Billie Lee, II | |
| Television and Geography | Typhoons. <i>See</i> Hurricanes, | Vagueness in Spatial Data |
| Temperature Patterns | Physical Geography of | Vance, James |
| Temporal GIS | Typography in Map Design | Varenius |
| Temporal Resolution | | Vectorization |
| Terrain Analysis | Underdevelopment | Vernacular Landscapes |
| Territory | Uneven Development | as Expressions of |
| Terrorism, Geography of | United Nations | Environmental Ideas |
| Text/Textuality | | |

-
- | | | |
|---|------------------------------------|---|
| Via Campesina (International Farmers' Movement) | Water Needs | Wine Terroir |
| Vidal de la Blache, Paul | Water Pollution | Wise Use Movement |
| Video Games, Geography and | Watershed Management | Wittfogel, Karl |
| Viewshed Analysis | Watershed Yield | Wood, Denis |
| Virilio, Paul | Water Supply Siting and Management | Woodfuel |
| Virtual and Immersive Environments | Watts, Michael | Woodlots. <i>See</i> Forest Fragmentation |
| Virtual Geographies | Wayfinding | World Bank |
| Virtual Globes | Weather and Climate Controls | World Cities |
| Vision and Geography | Weber, Alfred | World Court |
| Volcanic Eruptions as Risk and Hazard | Web Geoprocessing Workflows | World Health Organization (WHO) |
| Volcanoes | Web Service Architectures for GIS | World Summit on Sustainable Development |
| Voronoi Diagrams | Wetlands | World-Systems Theory |
| Vulnerability, Risks, and Hazards | White, Gilbert | World Trade Organization (WTO) |
| | Whiteness | Wright, Dawn |
| Waldseemüller, Martin | Whittlesey, Derwent | Wright, John Kirtland |
| Walker, Richard | Wilderness | Writing |
| War, Geography of | Wildfires: Risk and Hazard | |
| Waste Incineration | Wilson, John | |
| Wastewater Management | Wind | Xeriscaping |
| Water Degradation | Wind Energy | |
| Water Management and Treatment | Wind Erosion | Zelinsky, Wilbur |
| | Wine, Geography of | Zoning |



SUPRANATIONAL INTEGRATION

Supranational integration can be described as a process in which two or more nation-states or subnational regions within states come together by themselves or are brought together by a third party to form a new territorial configuration. As a concept, it usually refers to state-level memberships of political coalitions, but it can also be boosted by subnational organizations such as regional councils.

Supranational integration has been a globally important feature of political and economic life, especially since the end of World War II. It has been regarded as important for reducing political tensions and disparities between both nation-states and subnational regions. Apart from its political and economic origins, supranational integration has sometimes taken on a distinctively cultural character. This is the case when regional identity and a shared cultural history, for example, serve to bind administratively separate regions together and trigger the integration process. It can be claimed, however, that the emphasis more recently has been on economic issues, as much supranational integration takes place to increase competitiveness and to better performance in interregional competition. Supranational integration has thus been to a large extent linked with the interconnection and globalization of the world economy, where, among other things, new cross-border regional entities are being established with a view to better economic performance. The boosting of the economy is efficiently supported in this context by a diminishing of the role of borders, which are often regarded as obstacles to growth. Stability, on the other hand, is gained by reducing the regional cross-border imbalances and tensions caused by differences in political and economic structures and thereby evening out development.

The common goals laid down in the process of supranational integration serve to some extent to reduce the sovereignty of the individual state in favor of collective interests, given that both nation-states and subnational actors usually enter into agreements that enhance supranational cooperation by establishing joint institutions that are subject to sets of common rules. Supranational integration has traditionally focused on removal

of barriers to trade and promotion of the free movement of labor, capital, and goods.

As a consequence of the partial transfer of sovereignty to supranational bodies, supranational integration is considered to “hollow out” the nation-state. There has recently been some debate, however, as to whether the state is a passive reactor to these processes or proactive, as devolution of power can equally well be a strategic choice made by the central authorities. Also, only a certain amount of sovereignty is normally given to multinational bodies in connection with supranational integration, as the integration processes are usually controlled by nation-states. If all the sovereignty is given (or taken) away, the process becomes a merger rather than an instance of integration.

The rescaling of nation-states has nevertheless been a part of a broader pattern of regionalist thinking in which devolution of power is regarded as an essential element. Power is, however, said to be delegated not only upward to supranational institutions or downward to regions and cities but also outward to various nonstate bodies such as nongovernmental organizations and businesses. Rescaling has thus led to two-level or even three-level structures in which subnational and regional organizations and institutions implement supranational integration strategies at the practical level (often together with various development agencies and enterprises), but nation-states—and, increasingly, multinational bodies—nevertheless wield the decisive political and administrative power.

As a result of reterritorialization of the state and rescaling of its governance, supranational integration has resulted in the emergence of a number of recently conceived cross-border regional entities. These “nonstandard regions” are constantly being institutionalized by region builders all around the world. Especially in Europe, the idea of “a Europe of the regions” has led to the formation of new cross-border regions. Some of them are truly functional, but in some cases, it is the borders of the nation-states that remain as the lines of division, and no genuine cooperation or uniform supranational regional identity has actually evolved.

All in all, cross-border arrangements, that is, the coalitions and treaties that nation-states, subnational regions, and, to some extent, supranational bodies make to gain economic advantages and improve their stability, are essential for



supranational integration. In supranational integration, politics and business are immanent and usually intertwined to form sometimes fuzzy networks of governance in which several administrative levels are involved. Supranational integration can be either multilateral or bilateral in nature, but the essential point is that it should encompass international decision making and as such enable national boundaries to become more porous.

Supranational Integration as a Process

Supranational integration can also be conceptualized as a process that involves numerous starting points and stages. On the general level, the process of integration contains elements from below and from above, making it characteristically either a top-down or a bottom-up process by nature or something in between. *Functioning from below* means simply that the subnational authorities do not wait for formal procedures from above before initiating cross-border cooperation but use new types of interaction without justification from the formal administration, while *functioning from above* refers to forms of development in which regions are established and are given power and freedom of action by the formal authorities and central governments (nation-states) or by multinational organizations. Supranational integration can evidently take on quite different shapes and paths and aim at quite different things. Sometimes, region building can be quite explicit, as in the case of new competitive regions or “growth corridors,” but occasionally, the construction process is more vague, veiled, and contested. Such is the case when integration takes place against the will of the dominant political forces, being imposed by nongovernmental organizations and private actors, for example.

Although supranational integration is not necessarily anything more than a bilateral cooperation agreement in a defined sector concluded between states or cross-border regions, it is common for the integration process to have several ingredients and aspects. Supranational integration, especially when taking place between subnational regions, is typically a region-building process in which a new region is institutionalized and identified as a distinct unit in the spatial structure of society. There are several mechanisms by

which this can happen, but one key aspect is the increasing of territorial awareness by the creation of regional symbols, including the name of the region. More essential in the case of newly established supranational regions, however, is the emergence of region-based institutions. These exist to a large extent due to the establishment of the region itself, but at the same time they produce and reproduce the region, for example, by constructing regional symbols and representing the borders of the region. Regional development agencies and regional councils that operate at a supranational level are examples of such region-based institutions. As region building is about the discursive production of a region, these actors are also builders of regional identity. This is essential, as a certain amount of regional identity is thought necessary to bind inhabitants to their region and create a regional spirit of initiative. The process of supranational region building is in a sense twofold, however, as, on the one hand, regions are represented as fixed, bounded entities but, on the other hand, they are also networked, porous, and fluid. New regions are thus engaged in competition; but they also, according to the ideas of the new regionalism, which emphasize the significance of linked city-regions, collaborate within various supranational networks and assemblages. New supranational configurations, often created to promote competitiveness, are in direct competition not only with each other but also with administrative regions that have much longer histories.

Cases

An abundance of cases of supranational integration exist, including the regions defined by the North American Free Trade Agreement (NAFTA), the southern Latin American common market (Mercosur), and the Association of Southeast Asian Nations (ASEAN). Perhaps the best-known and most developed case, however, is the European Union (EU), where the shared principles of cohesion and a single market have paved the way for supranational integration covering almost the whole of Europe. European integration has been regarded as an interstate process implemented mainly by central governments. The main bodies that run the EU and approve its legislation include the Council of the European Union, the European



Figure 1 The Barents Euro-Arctic region
Source: Courtesy of the Arctic Centre, University of Lapland.



Commission, and the European Parliament. The aim of this integration has been quite typical of contemporary supranational integration processes in general, that is, to develop freedom and to promote economic and social progress. Although the EU was officially established in 1993, when the Maastricht Treaty was approved by the 12 founding members, its history may be traced back to the 1950s, when the European Coal and Steel Community was established. This developed into the European Economic Community in 1957, with the signing of the Treaty of Rome. The EU currently has 27 member states, which have agreed to maintain and strengthen peace, prosperity, and freedom at a supranational level.

The single market in Europe, with its increasingly porous borders, has also paved the way for supranational regions within the EU, resulting in smaller-scale supranational integration. Good examples of this are the Euroregions, of which there are about 70 at the moment, mostly concentrating on cross-border cooperation in the fields of culture, tourism, and other economic activities. The political power of the Euroregions is limited, however, as they are mostly run by regional and local authorities. Some of the Euroregion initiatives have their roots in the 1950s, but most of them were created in the 1990s, for example, the Cross-Channel and Baltic Euroregions. As inter-regional (and, from the EU's standpoint, intercontinental) competition is considered more or less unavoidable, the institutionalization of internationally competitive supranational regions inside the EU is currently attracting increased support.

Another example of supranational integration, at both the state and the regional level involved, is the establishment of the Barents Euro-Arctic region (BEAR) in the far north of Europe (Figure 1). The official act of establishment took place in Kirkenes, Norway, on January 11, 1993, together with the founding of the intergovernmental Barents Euro-Arctic Council (BEAC) and the interregional Barents Regional Council (BRC). The initiative to establish the region (also known as Barents Cooperation) was actually taken by the Norwegians, and it represented a political strategy for handling the opportunities and also the problems related to the post-Cold War reality of East-West relationships. The original proposal was made by the Norwegian Ministry of Foreign Affairs, and as such, it

is often described as an attempt to widen and restructure ongoing activities in order to promote security. At the moment, the Barents Region includes the 13 subnational territories located in Norway, Sweden, Finland, and Russia that are members of the BRC. Economic issues concerned with energy, natural resources, and business cooperation have been high on the agenda recently, but several projects dealing with security, health, culture, and education have also been implemented by multilateral consortia.

Kaj Zimmerbauer

See also Asia-Pacific Economic Cooperation; Association of Southeast Asian Nations; Borderlands; Cross-Border Cooperation; Deterritorialization and Reterritorialization; European Union; Globalization; North American Free Trade Agreement (NAFTA); North Atlantic Treaty Organization (NATO); Scale, Social Production of; Sovereignty; Transnationalism; United Nations

Further Readings

- Deas, I., & Lord, A. (2006). From a new regionalism to an unusual regionalism? The emergence of non-standard regional spaces and lessons for the reorganisation of the state. *Urban Studies*, 43(10), 1847–1877.
- Jensen, O., & Richardson, T. (2004). *Making European space: Mobility, power and territorial identity*. London: Routledge.



SURFACE WATER

Surface water is intrinsic to global, dynamic human activities: population and urban geography, politics, economics, and culture. As global climate change begins to influence the geography of surface water, the world's population must adapt in concert. Surface water is discussed here as a factor shaping the physical and cultural landscape, which includes the geography of surface water, the different surface water types, its effects on the physical environment, and its importance to the activities of humans.



Approximately 70% of the Earth's surface is water. Surface water is an important part of the hydrologic cycle and is defined as water above the surface that collects in oceans, seas, rivers, streams, lakes, ponds, springs, wetlands, and glaciers. Water found in the atmosphere or contained in rock beneath the surface (groundwater) is part of the hydrosphere but is not categorized as surface water. Because the Earth is a closed system, the total amount of water is constant. However, water is always on the move and is a renewable resource constantly recycled through evaporation, condensation, and precipitation. Through these processes, and over geologic time, surface water will change phase and geography repeatedly to become groundwater, atmospheric water, terrestrial water, and oceanic water. Although not addressed here, it is important to mention the interconnectedness of surface water and groundwater; for instance, some water bodies such as springs and seeps are the visual expression of groundwater at the surface.

The Geography of Surface Water

The majority of surface water is found in the oceans (97.2%) and is saline. Oceans are the largest input to the global hydrologic cycle, where 320,000 cubic kilometers evaporates from their surfaces each year. The world's oceans are highly influential on climate patterns, as these massive water bodies act as a sink for solar energy. Oceanic water circulation moves warm water away from the equator, while cold water is forced toward lower latitudes. These massive transfers of energy drive global temperature and precipitation patterns and explain a great deal about climate and biogeography. For example, the cold current flowing adjacent to the western edge of South America produces dry air and is a factor in the formation of the Atacama Desert climate, while the warm current of the western Atlantic Ocean flows toward Western Europe and keeps annual temperatures mild.

The remaining 2.8% of the Earth's hydrosphere is the nonocean component, and only a tiny 2.5% of this water is fresh. Termed the *cryosphere*, ice sheets and glaciers constitute the frozen fraction of the hydrosphere and are the largest nonocean component of surface water (2.15% of the total hydrosphere). These huge volumes of ice are

concentrated in alpine regions on every continent and at the polar latitudes, specifically the Arctic, the Greenland Ice Sheet, and the continent of Antarctica. Only a fraction of the total global hydrosphere is fresh, liquid surface water: Lakes and reservoirs make up 0.009%, while only 0.0001% is found in rivers and stream channels. The remaining surface water is found in inland seas and saline lakes (0.008%) and in soil moisture (0.005%).

Drainage Basins

The expression of surface water on the landscape is largely controlled by geology and topography. When water flows downhill to collect in a water body, the land surface area that contributes to that collection is termed a *drainage*, or *catchment*, basin. Drainage divides separate drainage basins, where the division of two basins occurs because of higher ground at their shared perimeter. These divisions can be distinct ridges or subtle rises in elevation. A drainage divide may also be called a *watershed*. However, in some cases, *watershed* may also refer to the drainage basin itself. As a classic example of scale in geography, drainage basins can be subdivided into progressively smaller units.

Types of Surface Water

Runoff

Running water is the most important geomorphic factor on Earth. Surface water in the form of runoff is generated when a precipitation event saturates the soil and subsurface to such a degree that it can no longer absorb the moisture and water begins to flow across the land. The volume of runoff is determined by several factors, including the local climate, volume of water generated by the precipitation event, duration of the event, land slope, soil type, geology, and vegetation. Surface runoff can degrade the landscape if the velocity of water is great enough to entrain sediment and erode the soil. Snowmelt runoff is an important contributor to the volume of water in streams and rivers, especially in mountainous regions around the globe.

Streams and Rivers

When surface water flows across the landscape and is concentrated, a stream forms. Streams and



rivers carry surface water and sediments downstream toward a local (lake) or ultimate (ocean) base level. Rivers transport, deposit, and store extensive volumes of sediment that create landforms in fluvial and coastal plain environments, and they are the primary factor involved in terrestrial landscape formation. Over geologic time, surface water deposits materials that form sedimentary rocks. Globally, the longest river is the Nile, while the largest river (in total volume) is the Amazon. Because of the widespread influence of humans, most rivers have been modified in some way.

Lake and Ponds

Lakes are large terrestrial bodies of water that occur where water collects in a depression or basin, and they may or may not have an outlet. Ponds are smaller water bodies than lakes, although debate remains about the definition of each, specifically pertaining to the threshold where a pond is large enough to be deemed a lake. Many sources cite lakes as water bodies large enough to generate waves across their surface. Most lakes on Earth are found in the Northern Hemisphere, where hundreds of thousands of depressions litter the landscape as a result of Pleistocene continental glaciation and are now water filled. The largest lake in the world (in surface area) is the Caspian Sea, while the deepest is Siberia's Lake Baikal (also the largest in volume). Although it is called a sea, the Caspian is a saline lake that lacks a drainage outlet.

Oceans and Seas

The oceans of the world are divided into four main water bodies: Atlantic, Pacific, Indian, and Arctic. There are no distinct geographic divisions defining where one ocean begins and another ends. Seas are smaller, saline water bodies geographically joined with oceans and also lacking definitive boundaries. The nomenclature for seas is not consistent throughout the globe; however, some gulfs are seas, such as the Persian Gulf, while some seas are saline lakes, such as the Caspian Sea, as mentioned above. The International Hydrographic Organization is the agency responsible for classifying the world's water bodies, and this agency should be referenced for specific naming conventions for global water bodies.

Surface Water and Geomorphology

Fluvial Landforms

Surface water acts as a destructive agent, weathering and eroding the landscape by carving river valleys. Sediments are entrained, transported downstream, deposited, and stored in the landscape as a variety of landforms, such as floodplains, deltas, and alluvial fans. Floodplains are formed by the accretion of sediments deposited by river migration or flood processes. Deltas form when a river encounters a body of water, its velocity slows, and its ability to carry sediment diminishes. Deltas can form in dammed lakes, at tributary confluences, or at the mouths of rivers encountering the ocean. In arid regions, alluvial fans are formed when a river draining from a mountain range encounters a change in gradient and its ability to carry sediment is reduced. The transported sediment is deposited as an alluvial landform, which often exhibits a classic fanlike shape.

Glaciers

Surface water in glacial form (alpine and continental) is a significant erosional and depositional force. As glacial ice flows downhill, it abrades, plucks, transports, and deposits glacial sediments into linear ridges, called *moraines*. When alpine glaciers recede, the V-shaped character of previously stream-dominated mountain valleys is replaced by the characteristic U-shape of a glaciated trough, and numerous landforms such as hanging valleys, horns, and paternoster lakes are left behind. Glacial meltwater in both alpine and continental contexts also creates unique landforms: outwash plains, eskers, and kettles, to name just a few.

Coastal Landforms

Oceans create unique shoreline and coastal landforms by reworking and redistributing coastal sediments through wave refraction and longshore currents, producing a variety of depositional and erosional landforms. The former include features such as bars, spits, and barrier islands, while the latter include wave-cut terraces, wave-cut scarps, and arches.



Surface Water and Humans

Surface water is an important factor in human activities. Rivers have led to the colonization of continental interiors, are used in military strategy, and provide the means to transport products to the market. The global economy relies on the presence of surface water to transport large quantities of consumable products. Ocean transportation moves billions of cubic tons of goods and resources throughout the globe each year.

Irrigated Agriculture

Due to the practice of irrigated agriculture, surface water has played a defining role in the diaspora of humans throughout the globe. Cultural groups have arisen around the practice of moving surface water through human-made channels and waterworks, thus furthering the settlement of arid regions otherwise uninhabitable by humans. The earliest origins of irrigated agriculture lie in the Middle East; however, it has also arisen independently in the Far East and in the Americas.

Dams

Dams impound surface water for regulated release downstream and are used for flood control, public water and fire suppression supply, recreation, and electricity generation. Dams fragment watersheds by changing the natural flow of rivers and causing significant changes to upstream and downstream hydrology, riparian ecosystems, water chemistry, and fluvial landforms. The reservoirs created by dams may be sizeable enough to affect the local climate. Although dam construction peaked in the 1970s in the United States, the amount of water currently stored behind dams can spatially cover a surface area the size of France.

The Effects of Global Climate Change on Surface Water

Surface water is a renewable resource and the primary source of global public water supply. Currently, there is sufficient surface water to support the ever-increasing global population, but the geography of that water will continue to be a challenge, as global climate change is altering its distribution

and availability. As glacial ice around the globe melts as a result of climate change, significant effects on surface water are becoming evident. In mountain environments, glaciers, which provide important meltwater for the local ecosystem, public supplies, and irrigation, are diminishing. In many areas, river flows resulting from this melting are volumetrically less than their historic flows. Over one sixth of the world's population depends on this water for its daily needs, and concern about future availability is growing. As the continental glaciers melt, the introduction of freshwater to the saline oceans is predicted to affect global circulation patterns. Sea-level rise in response to global climate change also has the potential to create a variety of hazards, as 10% of the world's population lives within 150 miles of the coast.

Tara M. Plewa

See also **Coastal Erosion and Deposition; Glaciers: Continental; Glaciers: Mountain; Global Sea-Level Rise; Groundwater; Hydrology; Oceans; Public Water Services; Rill Erosion; Rivers; Soil Erosion; Urban Water Supply; Water Degradation; Water Management and Treatment; Watershed Management; Water Needs; Water Pollution**

Further Readings

- Barnett, T. P., Adam, J. C., & Lettenmaier, D. P. (2005, November 17). Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature*, 438, 303–309.
- Bloom, A. L. (1998). *Geomorphology: A systematic analysis of Cenozoic landforms*. Upper Saddle River, NJ: Prentice Hall.
- Graf, W. L. (1999). Dam nation: A geographic census of American dams and their large-scale hydrologic impacts. *Water Resources Research*, 35(4), 1305–1311.
- Knighton, D. (1998). *Fluvial forms and processes*. New York: Oxford University Press.
- Leopold, L. B. (1997). *Water, rivers and creeks*. Sausalito, CA: University Science Books.
- Tarbut, E. J., & Lutgens, F. K. (1996). *Earth: An introduction to physical geography* (5th ed.). Upper Saddle River, NJ: Prentice Hall.



SURVEILLANCE

Surveillance is the practice of watching over a given terrain, its inhabitants, and their relations, commonly for the purpose of exercising instrumental control over that which is being watched. As such, surveillance is central to the establishment and maintenance of “scopic regimes” that enact power to order the world. From its inception as a discipline, and indeed even prior to its attainment of disciplinary status, geography has engaged with surveillance as both participant and observer.

Observing the distribution of human and natural variation across the surface of the Earth, and reporting on that variation, has been a key geographical practice from the times of Strabo through those of Ibn Battuta, John Mandeville, Xu Xiake, and beyond. Such accounts tend to be cartographical exercises conjoined to richly descriptive, and sometimes apocryphal, travelogues. A subset of these, however, serves the additional purpose of providing rulers and their administrative bureaucracies information on the presence and distribution of resources in given territories. Such information, in turn, informs the policies and actions by means of which rule may be imposed on the ground.

But the rise of the European empires, and the corollary entrance into an “age of reconnaissance,” required an unprecedented demarcation of new territories and the cataloguing of their contents. This not only heightened the prominence of expeditionary surveys but was, to no small extent, dependent on them too. Geographers and their explorations, as, for instance, those of Alexander von Humboldt, Richard Francis Burton, and Piotr Kropotkin, were at least initially charged with and supported by the task of seeing for empire building. Empires in turn claimed and asserted, however incompletely in practice, a mastery over all that they saw in no small part through the lenses of such expeditions. This process contributed centrally to both the legitimization and the elaboration of geography as a discipline.

The role of surveillance to fix things in space was complemented by the fixing of attributes to things—the application of categories to that

which was surveyed and the ascription of fixed attributes to these categories. Thus, the expeditionary practice of geography did not merely undertake surveillance but created surveillability, rendering that which was seen recognizable within a disciplined system of spaces understood as both substrate and container. Outgrowths of this process ranged from intricate and intimate catalogs of a given locale’s vegetal and mineral resources to cut-and-dried global mappings of the distribution of the world’s putative races.

Although it was developed and deployed most extensively at and beyond colonized peripheries, intensive geographical surveillance was quickly repatriated back to core territories and, most prominently, to the metropolis. With the rise of the modern state, surveillance was key to the concomitant transformation of subjects into manageable, governable populations. This was accomplished through the innovation of initially geographical sciences, such as demography and its allied statistics, and their implementation through a range of practices, such as the mandatory assignation and stabilization of surnames conjoined to the conduct of increasingly regular censuses. Nor did these innovations remain conceptual abstractions or occasional events. Rather, they were palpably and even immutably materialized on the ground to facilitate state functions such as policing and fire suppression, as with the 19th-century parcelization of Berlin into courtyard apartments or the still extant ward system of Edo (now Tokyo).

Grand expeditionary surveys are now largely a thing of the past. The impetus for intensive and extensive surveillability, however, has continued unabated and, if anything, intensified in recent years. This drive toward *panopticism* (the capacity to readily see into all places) and *synopticism* (the capacity to see everything simultaneously and in relation) has in turn been facilitated by, and spawned, a host of new technologies. Most notable among these, at least from the demonstrated perspective of contemporary geographical research, are those of geographic information systems conjoined to remote sensing (GIS/RS) and closed circuit television (CCTV) monitoring. But equally notable is the shift in the perspectives and roles of many geographers themselves from collaborators in surveillance to critics of it.



A surveillance camera watches operations in the port of Vancouver, Canada.

Source: Volodymyr Kyrlyuk/iStockphoto.

GIS/RS is a relatively novel complex of technologies ranging from satellites to desktop computers. Predominantly a research tool, this complex is targeted and interfaced so as to gather, process, and graphically represent data pertaining to the disposition of selected objects and attributes at discretionarily specified points across the face of the Earth. In contrast, CCTV has emerged predominantly as a tool of law enforcement, consisting of numerous observation cameras dispersed across commonplace landscapes so as to insert an unprecedented reach of centralized observation into the spaces of everyday public life.

Neither technology is necessarily oppressive, and both provide opportunities for creative and even emancipatory use. For example, GIS/RS affords a potential for wide public access to, comprehension of, and intervention in geographical data gathering and the application of such data to

popular decision making. Similarly, the devolution of CCTV's observational capacities into compact and affordable handheld devices permits unprecedented opportunities for popular monitoring of, and reporting on, public malfeasance. But taken together, and fused with innovations such as states' and business corporations' monitoring, databasing, and mining of electronically mediated personal interactions, these technologies work to embody what many geographers caution is becoming a "society of surveillance." Inherent in such a society are radical loss of privacy and the potential for severe new delimitations to permissible ranges of action, expression, and even thought. Furthermore, geographers warn, these ominous possibilities are becoming ever more concrete and rhetorically legitimized realities in the diffusing wake of terrorist activity and the concomitant, putative war on terror. As such, surveillance is



increasingly understood as not just the practice of watching over but as something that itself needs to be carefully watched over.

Steven Flusty

See also **Legal Aspects of Geospatial Information; Panopticon; Vision and Geography**

Further Readings

- Burnett, G. (2000). *Masters of all they surveyed: Exploration, geography, and a British El Dorado*. Chicago: University of Chicago Press.
- Graham, S. (Ed.). (2004). *Cities, war, and terrorism: Towards an urban geopolitics*. London: Blackwell.
- Pickles, J. (Ed.). (1994). *Ground truth: The social implications of geographic information systems*. New York: Guilford Press.

SURVEYING

Surveying is the art, science, and technology of determining or establishing the three-dimensional (3D; x , y , z) position of points on or beneath Earth's surface. Because geographic surveying deals primarily with topography, two other terms, *topographic surveying* and *field surveying*, are interchangeably used. Geographic survey data are used to produce topographic maps, block diagrams, and cross-sectional profiles and to establish vertical and horizontal controls such as spot heights and benchmarks.

Conventional geographic surveying uses theodolites, levels, chains, links, steel (or invar, a steel alloy) tapes, altimeters, compasses, clinometers, tachymeters, stadia rods, plane-table alidades, ranging poles, tripods, and the total station. Three basic sets of readings are taken during a conventional survey: distances, heights, and angles. Horizontal distance can be measured with a tape using slope distance and reducing it to horizontal distance using the cosine of the slope gradient. Elevation (height) is measured using a leveling instrument with a level telescope and a stadia rod or by observing the vertical

angle with a clinometer and deriving height. The horizontal angle is measured with a compass. Direction is expressed relative to a reference line (meridian). A North-South line is the true meridian, although a magnetic meridian may be used if compass azimuths are recorded without adjusting for declination.

The total station is the instrument of choice for many topographic surveyors because it integrates theodolite functions and an electronic distance meter (EDM) with a built-in or external computer for data storage. Its capability to automate and integrate the measurement of distances, heights, and direction greatly improves topographic surveying and mapping.

In any conventional survey, the starting or initial position(s) must be known and must be accessible. Subsequent positions are observed and determined based on preceding point base positions. There are four common approaches used in surveying—namely, triangulation, trilateration, triangulation, and traversing. In triangulation, the location of a point is determined by measuring the angles to it from the initial points at either end of a fixed baseline rather than measuring the distances to the point directly. The point can then be fixed as the third point of a triangle with one known side and two known angles. Triangulation is used in surveying large areas for geodetic purposes. Trilateration is used in conjunction with triangulation to determine the intersections of three sphere surfaces given their centers and radii. Triangulation is a combination of triangulation and trilateration. *Traversing* is the establishment of a series of consecutive lines (legs) and directions whose ends define points (also called *stations*, *hubs*, or *corners*).

There are four main types of traverse: link (azimuth), closed loop (polygonal), closed, and open (free). A link traverse follows along a single direction (azimuth). This method is common for slope profile surveys and is always perpendicular to the contours. Closed-loop traverses begin and end at the same station. In this method, interior and deflection angles can be established. A closed traverse uses a known endpoint, and its exterior angles can be measured. An open traverse ends in an unknown position.

Inaccuracy in surveys is a common problem. Sometimes even closed traverses will not “close”



A road surveyor checks the land on the road construction site in the Dhi Qar Province, Iraq, July 3, 2005. The U.S. Army Corps of Engineers provides quality assurance on the road project.

Source: U.S. Army photo by B. J. Weiner.

because the initial point and the endpoint fail to coincide. This error is called the *closure error* (gap). Closed-loop and closed traverses permit calculation and adjustment for closure error. However, it is more difficult to maintain good accuracy in an open traverse, as it does not enable computational checks for error.

Error is related to the quality of the equipment, the nature of the terrain, and the skill level or experience of the surveyor. The amount of error that can be tolerated (degree of tolerance) is a function of the order of accuracy desired, which in turn depends on the intended use of the survey data. Accuracy is expressed in terms of the proportion of the traverse length, stated as $1/x$: For every x units measured, the survey should be off by 1 unit. First-order

accuracy = $1/25,000$, second-order accuracy = $1/10,000$, and third-order accuracy = $1/5,000$. In a typical topographic survey, the desired level of accuracy is the plottable error—the shortest distance that can be depicted on a map at a given scale. The drafting of lines generally is accurate to within 0.25 mm (millimeters). Survey errors are minimized by conducting quality surveys, repeating measurements in the field, using calibrated instruments, and adjusting and correcting measurements. Several standard survey correction formulae spread the closure error to all angles and legs, especially in closed-loop and closed traverse.

The introduction of the global positioning system (GPS) has revolutionized surveying. GPS is capable of determining positional and navigational information accurately and instantaneously. Two positioning methods can be achieved with the GPS: absolute and differential GPS (DGPS). Absolute positioning uses a single GPS receiver and does not require known survey control points. DGPS uses at least two GPS receivers.

One is the reference receiver (base station), resident at a known location. The other receivers are used in the field to position points of interest. Both absolute positioning and DGPS can be performed in real time or through postprocessing. Real-time positioning is achieved by effecting communication links between the field receiver and an augmentation system. The method of choice depends on the accuracy required, the equipment available, and the logistical requirements. Accuracy in GPS survey is a function of the quality of the equipment and the surveying method employed—absolute positioning or DGPS. DGPS is the more accurate. The use of GPS has added efficiency and productivity to surveying.

Charles Manyara



See also **Cadastral Systems; Geodesy; Global Positioning System; Ground Reference Data; Land Use and Land Cover Mapping**

Further Readings

- Anderson, J., & Mikhail, E. (1997). *Surveying: Theory and practice* (7th ed.). New York: McGraw-Hill.
- Ghilani, C., & Wolf, P. (2008). *Elementary survey: An introduction to geomatics* (12th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Lawson, C. (1990). *Surveying your land: A common sense guide to surveys, deeds, and title searches*. Woodstock, VT: Countryman Press.
- William, R. (1996). *Surveying and mapping for field scientists*. Upper Saddle River, NJ: Prentice Hall.



SUSTAINABILITY SCIENCE

The growing recognition that human activities are transforming Earth systems and having far-reaching implications for society has given rise to the ambitious research field of sustainability science. This area of study is concerned with the most complex challenges that societies face, focusing on the dynamic interaction of nature-society systems in response to stresses emanating from multiple sources. Sustainability science grapples with societal problems that are characterized by multiple viewpoints and a high degree of uncertainty. It evolves from a scientific perspective of critically examining the relationship between nature and society. It addresses tensions among economic, social, technological, and environmental interests among a broad range of stakeholders while focusing on interactions across scales. Though sustainability science has not been clearly defined, in recent years, its central elements have begun to gain clarity; hence, the field has begun to be recognized as an area of inquiry that can point the way toward sustainable development. The field has focused on the nature of a sustainability transition, described by the U.S. National Research Council (NRC) as meeting the needs of

a stabilizing future population while reducing hunger and maintaining Earth's life support systems. This entry synthesizes the emerging scholarship on sustainability science in its quest for a societal transition toward sustainable economic development.

Emergence of Sustainability Science

Sustainability science reflects several decades of scholarship in the fields of natural resource sciences and technology. Indeed, the use of the term *sustainability* can be traced back to a 1712 book, *Sylvicultura Oeconomica*, by the German scientist and forester Hans Carl von Carlowitz. Intellectual contributions on sustainability also come from pioneering scholarship on human-environment interaction by the geographer and anthropologist Peter Glacken in his seminal work *Traces on the Rhodian Shore*, the work of the agricultural economists Yujiro Hayami and Vernon Ruttan on land-saving and yield-enhancing technologies, and the insights from Earth-friendly and user-friendly technology, also termed *appropriate technology*, following the economist E. F. Schumacher's publication of his famous book *Small Is Beautiful*. However, a more academic perspective on sustainability emerged during the environmental movement of the 1970s as well as from the seminal document *The World Conservation Strategy*, published by the International Union for Conservation of Nature in 1980.

Much of today's work on sustainability science is inspired by the landmark Brundtland Commission report on sustainable development, published in 1987 by the World Commission on Environment and Development (WCED). This report argued that the complex challenge of environmental degradation should be integrated with the equally complex challenges of human development and poverty alleviation, suggesting that both challenges need to be resolved simultaneously and in a mutually reinforcing way. Additional impetus to sustainability science was given at the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. The conference's Rio Declaration and Agenda 21 together developed detailed strategies, action plans, and resource needs for attaining sustainable development in the 21st century.



While Agenda 21 exhibited a much needed political and moral appeal, the global community remained divided about the meaning and practice of sustainability. The United Nations Commission on Sustainable Development (UNCSD), established in the wake of the Rio conference to monitor and report on the agreement reached in Rio, provided a sobering appraisal of the first decade of the effort to realize the vision of sustainable development in the 1997 Special Session of the United Nations General Assembly. The report concluded that no significant progress had been made on the sustainable development front despite the limelight that the concept received at the global meeting.

In the ensuing years, the terms *sustainability* and *sustainable development* were revisited and redefined to establish a conceptual basis and to encapsulate various aspects of society and environment relations. In their report *Our Common Journey*, the Board on Sustainable Development of the U.S. National Research Council outlined a scientific agenda and a general strategy for research and development (R&D) in support of the transition to sustainability. Although the report did not describe paths of sustainability science, it concluded that many of the most problematic threats to society and its life support systems come from the multiple stresses resulting from cumulative human activities. This conclusion was significant in that it recognized the value of studying the multiple drivers of environmental and social stressors. More specifically, the report emphasized a move toward a more holistic approach for addressing sustainability challenges by taking into account the dynamic and complex interactions among human-environment systems. The report also laid a much needed foundation for R&D in sustainability science.

During the succeeding years, the discussion about the role of R&D in the sustainability transition, particularly in science and technology (S&T), intensified. This discussion began involving researchers, practitioners, academics, citizen forums, and development and nongovernmental organizations (NGOs) worldwide. When the World Summit on Sustainable Development was held in Johannesburg (2002), consensus was forged on the most important ways in which R&D could contribute to sustainability. The

message emerging from Johannesburg was that the scholarly community must contribute to identifying problems of sustainability with a greater willingness to join the nonacademic communities to work on practical solutions to the challenge of sustainability. While various disciplines and interest groups influenced and contributed to the debate differently, the global challenge of sustainability is now understood to lie in the complex interdependencies of environmental, social, and economic development across scales. Moreover, though threats to sustainability occur more in some regions than in others, the degree and extent of any threat depends largely on the region's social, political, economic, and ecological characteristics. For this reason, the transition to sustainability will often need to happen in local areas first. At the same time, however, it needs to be integrated across geographic scales. Regardless of the spatial scale in question, obtaining insights into events on both global and local scales will continue to be a major challenge facing sustainability science. Thus, a transition to sustainability ultimately rests on the choices that society makes on what to develop versus what to sustain and for how long.

Conceptualizing Sustainability Science

The epistemology of sustainability science draws largely from the study of the Earth and Earth's social and human systems and is characterized by great complexity and uncertainty. Given the nature of such complexity, system thinking has become a way of understanding reality that emphasizes the nonlinear relationships among the different system components. In pursuing sustainability science, it is important to construct a knowledge platform that enables society to replace piecemeal approaches with an approach that can develop and apply more comprehensive solutions to the challenges that society is facing. Structuring knowledge production systems across the global, social, and human systems (discussed below briefly) is therefore an important task of sustainability science.

According to Hiroshi Komiyama and Kazuhiko Takeuchi, the global system constitutes a planetary base for human survival. It is capable of influencing the entire network of Earth systems



and can have severe implications for human existence. Conversely, the rapid expansion of human activities has become a significant driver in altering Earth's systems. Global warming due to increased concentrations of greenhouse gases, destruction of the ozone layer, and biodiversity loss due to land use and land cover change are salient examples of global change that are the outcomes of human and social systems. Given these developments, addressing global systems requires a more integrated approach, for which sustainability science offers a greater potential.

The social system consists of cultural, political, economic, and other institutions that are an important basis for driving economic growth and development. Existing institutions, however, are associated with environmental ills such as degradation of the natural resource base and are also responsible for creating the growing inequality between the rich and the poor. The integrated nature of this situation is responsible for exerting greater stress on global systems. If sustainability science is to be policy relevant, it is important to address both environmental and social issues simultaneously. By incorporating social science into sustainability issues, sustainability science can make major advances in the pursuit of sustainable development.

The healthy functioning of human systems requires the integration of global and social systems in a manner that enables human beings to thrive and sustain their communities. In today's world, people are experiencing emotional distress, inequities, and deterioration of their means of production. Such problems put pressure on social and environmental systems worldwide. As this stress increases and the environment deteriorates, the social system becomes more fragmented, making human society less sustainable—all of which can have a global effect. Emblematic of this trend are the problems of extreme poverty, disease, social exclusion, and conflicts, weakening the sustainability of human systems.

Thus, the emerging field of sustainability science is an ambitious attempt to build a new discipline that seeks to integrate all three systems. Since sustainability science requires integration of multiple and complex systems, system thinking has a special role to play. System thinking helps actors to see the various elements of systems and

cross the boundaries of science in order to create new conceptual frames that highlight interconnectedness and feedback loops. It also offers a powerful perspective and a set of tools to address the most complex challenges facing human society. Efforts to provide useful knowledge for solving the practical but highly complex problems discussed above require advances in the conceptualization and understanding of coupled human-environment systems. While strategies to address the emerging threats of global climate change, governance of emerging technologies, poverty, and hunger are all complex sustainability challenges, the potential exists to galvanize global action to place sustainability science at the forefront of educational, research, and career development agendas. In recent years, rising concerns over global climate change, the conservation of ecosystem services, biodiversity protection, diversification of energy portfolios, improving efficiency and access to water supplies, and enhancing agrobiodiversity and food security have become important priorities of sustainability science.

The conceptual model for sustainability science can be represented as “coevolution,” “coproduction,” and “colearning,” encompassing the three interrelated systems discussed above. This conceptual model is inspired by what researchers call “Mode 2,” or “postnormal,” science. According to Pim Martens, “Mode 1” science is conventional and purely academic and focuses on single disciplines to generate its knowledge base. The researchers who are involved in this process are the major players. In Mode 2 science, researchers are part of a heterogeneous social network focusing on social and anticipatory learning, where everyone contributes to knowledge production and dissemination. In other words, Mode 1, or conventional science, as opposed to Mode 2 science, is predictive and seeks to rationalize certainty, a desirable goal for policy making. Mode 1 science is thus characterized as deterministic and is often disconnected from the challenges facing the real world. Mode 2 science, in contrast, acknowledges that the complete elimination of uncertainty is not possible in decision making and argues that this can be addressed through participatory processes in knowledge production, an idea completely rejected by Mode 1, or rational, science. Postnormal science provides a



well-informed knowledge platform for complex problems, thereby enhancing the interface between science and society. It allows stakeholders to identify and employ strategies that will respond to the transition toward sustainability.

As opposed to Mode 1 science, which generally holds the notion of the community as a passive recipient of knowledge, Mode 2 science leans on the conceptual underpinning of social and anticipatory learning and emphasizes the study of interlocking factors embedded in the socioeconomic and political fabric of communities to understand strategies for sustainability at the local level. It highlights inherent community-based skills, knowledge, strategic responses, and anticipatory capacity to attain sustainability and seeks the cooperation of local institutions and/or individuals in the process. It is through this process of social and anticipatory learning that Mode 2 science fosters a community's capacity to influence its future through iterative planning.

The new research paradigm emerging from Mode 2, or postnormal, science has given impetus to sustainability science, which cuts across multiple scales (time and space) and multiple stakeholders (interest groups). Sustainability science seeks to integrate not only different disciplines but also individual viewpoints and knowledge so that the scientific processes of deliberation and assessment are smoother. And no one set of knowledges or viewpoints is privileged over another. The new frontier of sustainability science also recognizes the value of alternative knowledge systems that have hitherto been neglected by scholarly communities. It differs from normal academic science, which is monodisciplinary in nature and heavily dependent on peer reviews by the scientists themselves.

As an emerging field of study, sustainability science is not yet a discipline. It is the interface of science, practice, and visions of sustainable development. Given the integrated nature of this field of study, the research framework in sustainability science derives its methodological tools from all fields of inquiries, including the social, human, and natural sciences. So the core organizing questions for sustainability science are as follows: How best can global, social, and human systems be integrated and conceptualized so that the goal of sustainable development is attained? How is

the societal relationship with the environment and development reshaped by innovations of science and technology? What contextual factors hinder the path toward sustainable trajectories, and what incentive structures can do that most effectively? How can today's knowledge systems, which are locked in across various cultures and traditions, be harnessed to provide more useful guidance for efforts to navigate a transition toward sustainability? How can today's relatively independent activities of research planning, monitoring, assessments, and decision support be more integrated into systems of social and anticipatory learning?

Sustainability Science: Basic or Applied?

One of the major characteristics of sustainability science is that it seeks the involvement of nonacademic stakeholders in the integration of human and social systems with the global system and aims to integrate different norms and values in order to generate socially acceptable and environmentally just knowledge about sustainability. It challenges traditional concepts and institutions of scientific knowledge generation and serves as an experiment in a new model of science. It recognizes the value of supporting interdisciplinary research and is driven by the goal of creating integrated knowledge that supports decision making for sustainable development. As an integrated science, it seeks to break down the disciplinary boundaries of the traditional sciences and calls for mutual learning, integrated assessment, and coproduction of knowledge. From its core focus of advancing an understanding of coupled human-environment systems, sustainability science has, in a short time period, pursued an ambitious research agenda that challenges academic traditions with respect to fundamental ontological (real-world problem orientation), methodological (participatory research), and epistemological ("linking knowledge to action") issues. In its quest for transition toward sustainability, sustainability science seeks to harness S&T in order to address the sustainability challenges of the human-environment system.

In his seminal treatise on science policy, Vannevar Bush described the conflict between applied and pure research and wrote that applied research



invariably drives out pure research to the detriment of the national capacity for technological innovation. The subsequent separation of applied and basic research shaped the evolution of S&T research and remained a point of departure for the “appropriate technology” movement pioneered by E. F. Schumacher. The rise of pure science research also meant the neglect of what Michael Dove and Daniel Kammen call “mundane science,” which involves the use of location-specific knowledge and small-scale technologies that are problem driven with potential advances to pure science. The inability of pure science research, with its disciplinary focus, to address myriad social concerns led to a growing recognition of the value of interdisciplinary research. This can be seen as a precursor to sustainability science that involved identifying important but neglected fields of research and scholarship.

William Clark has argued that the research framework for sustainability science lies beyond the confines of basic and applied research. Just as sustainability science has reached out to contribute to and learn from the world of applied problem solving, so, too, has it remained closely linked with curiosity-driven research across a range of disciplines. It is an academic endeavor that is geared toward use-inspired basic research and is driven by the integration of knowledge and action across the three systems discussed earlier. By bridging applied and basic research, sustainability science advances the interface between science and policy. Since the issues and problems that sustainability science tackles are interdisciplinary in nature, it involves different stakeholders and actors from different disciplines and requires their collaborative inputs. Thus, interdisciplinarity becomes the hallmark of research orientation in this field. This has meant that scientists seeking to promote a sustainability transition have needed to tap into, and indeed engage in, cutting-edge research in areas ranging from complex systems theory to cultural and political ecology. Sustainability science is an academic enterprise geared toward creating use-inspired research and is therefore neither strictly “basic” nor strictly “applied.” By creating a dynamic bridge between applied and basic research, sustainability science seeks to contribute to the quest for a sustainability transition by increasing the interface between knowledge and policy-based action.

Conclusion

Sustainability science is an integrative science that is interdisciplinary in nature and committed to linking different scientific disciplines such as biology/ecology, the Earth sciences, geography, economics, and other social sciences to provide a guide to science policy for society. Through interdisciplinary research and scholarship, sustainability science helps identify directions for societal actions. The outcomes of sustainability science can bridge the gap between science and policy, which increases the societal value of science and improves decision making through the provision of integrated knowledge about social and environmental problems. Sustainability science must ensure the integration of different styles of knowledge creation to bridge the gulf between science, practice, and politics. Through research, publications, and academic organizations, the field of sustainability science is becoming increasingly prominent in academia. It has the potential to transform research and education and make sustainability an integrated and common theme for scholars, policymakers, and civil society actors alike.

Netra B. Chhetri and Nalini Chhetri

See also Complexity Theory; Coupled Human and Natural Systems; Environment and Development; Political Ecology; Population and Land Degradation; Science and Technology Studies; Sustainable Agriculture; Sustainable Cities; Sustainable Development; Sustainable Development Alternatives; Sustainable Production; United Nations Conference on Environment and Development

Further Readings

- Blackstock, K. L., & Carter, C. E. (2007). Operationalising sustainability science for a sustainability directive? Reflecting on three pilot projects. *Geographical Journal*, 173, 343–357.
- Clark, W. C. (2007). Sustainability science: A room of its own. *Proceedings of the National Academy of Sciences of the United States of America*, 104, 1737–1738.



- Clark, W. C., & Dickson, N. M. (2003). Science and technology for sustainable development. *Proceedings of the National Academy of Sciences of the United States of America*, 100, 8059–8061.
- Glacken, C. J. (1967). *Traces on the Rhodian shore*. Berkeley: University of California Press.
- Kates, R., Clark, W., Corell, R., Hall, J., Jaeger, C., Lowe, I., et al. (2001). Sustainability science. *Science*, 292, 641–642.
- Komiyama, H., & Takeuchi, K. (2006). Sustainability science: Building a new discipline. *Sustainability Science*, 1, 1–6.
- Martens, P. (2006). Sustainability: Science or fiction? *Sustainability: Science, Practice, & Policy*, 2, 36–41.
- National Research Council. (1999). *Our common journey*. Washington, DC: National Academies Press.
- Ravetz, J. R. (2006). Post-normal science and the complexity of transitions towards sustainability. *Ecological Complexity*, 3, 275–284.
- Swart, R. J., Raskin, P., & Robinson, J. (2004). The problem of the future: Sustainability science and scenario analysis. *Global Environmental Change*, 14, 137–146.
- Wilbanks, T. J. (1994). “Sustainable development” in geographic context. *Annals of the Association of American Geographers*, 84, 541–556.
- World Commission on Environment and Development. (1987). *Our common future*. New York: Oxford University Press.

fossil fuels—and politicians, agribusiness leaders, environmentalists, and farmers alike now advocate for “sustainable agriculture.” However, sustainable agriculture is a poorly defined and highly politicized term, and it clearly means different things to different stakeholders. This is because sustainable agriculture is a philosophical approach, rather than a specific production system, that promotes social, ecological, and economic health in food- and fiber-producing lands and communities. A diversity of locally based low-input and knowledge-intensive farm systems exist that follow the principles of sustainable agriculture. As these holistic approaches to cultivation and animal husbandry are further refined and communicated, their legitimacy and widespread adoption is inevitable.

Agriculture's Roots

It is generally understood that agriculture was born around 10,000 to 13,000 years ago, when hunter-gatherers began to domesticate wild plant and animal species for food, predominately along the Fertile Crescent, an event called the Neolithic Revolution. By domesticating plants and animals, these “first farmers” produced food surpluses that supported permanent settlements, which led to rapid population growth, specialized labor, and the development of modern civilization. Agriculture has radically transformed humanity's trajectory as a species and its relationship with and impact on the natural world, creating many opportunities and challenges, especially over the past century.



SUSTAINABLE AGRICULTURE

Agriculture has had a profound impact on the natural world, especially over the course of the 20th century. In many places, agriculture is now increasingly industrialized, leading to monocultures that are reliant on external mechanical, biological, and chemical inputs (e.g., tractors, hybrid seeds, and pesticides). Many geographers and others are beginning to question the sustainability of these conventional systems. Indeed, industrial agriculture has hit a crisis point—especially when considered in combination with the issues of environmental erosion, climate change, and depleting

The Rise of Industrial Agriculture

The rise of industrial agriculture in the 20th century—predicated on mechanical, biological, and chemical technologies—exceeded in magnitude all previous changes in farming. Governments and industry promoted industrial agriculture, as it was their belief that Fordist principles of manufacturing and large-scale production could be applied to agriculture. After World War II, the chemicals developed for military activities were subsequently used in agriculture as synthetic pesticides and fertilizers, and in combination with tractor power, these inputs dramatically increased labor and land productivity.



Farmer-led plant breeding was quickly replaced by expert-based approaches using the new science of genetics, leading to the development of hybrids and other high-yielding and high-input varieties that were distributed worldwide during the Green Revolution. The discovery of antibiotics and vaccines enabled industrial-scale livestock production—often called “factory farming”—in which animals are raised in densely crowded spaces without a significant buildup of disease. Indeed, industrial agriculture increased global food production and helped feed and ultimately increase the world’s human population, now estimated at 6.8 billion people. Despite these significant production benefits, industrial agriculture has caused substantial social, ecological, and genetic erosion worldwide.

Social, Ecological, and Genetic Erosion

The shift toward industrial agriculture has had adverse consequences for farmers, rural communities, and the environment. Many suggest that farmers have become beholden to a “technology treadmill” with the rise of mechanical, biological, and chemical innovations, as increases in production depress prices and require that farmers adopt ever newer technology to stay competitive. Larger farms have generally been able to adopt new technology more easily, which has created fierce competition within rural communities, and many smaller family farms have not been able to stay viable. High input costs remain the number one obstacle to farm profitability. In North America, farmers are facing the worst farm income crisis in history, with the countryside being increasingly depopulated, while agribusiness has garnered record profits. In the global South, reports of farmer suicides are becoming pervasive, as mounting debts tear apart the social fabric of many communities. The environmental costs of industrial agriculture are also placing enormous pressure on human and ecological systems.

Rachel Carson’s publication of the best-selling book *Silent Spring* in 1962 exposed the extent to which chemicals, primarily those used in agriculture, were compromising environmental and human health. Globally, the use of pesticides has grown since World War II, costing billions of dollars annually and causing thousands of human

deaths and adverse health risks due to cancer, acute poisonings, and neurological damage each year. Pesticides also harm a wide variety of wildlife, including microorganisms, fish, birds, and mammals, through direct or secondary environmental exposure. Estimates indicate that this chemical pollution from agriculture costs more than \$100 billion each year in human health and environmental damage worldwide. Soil health, which is critical for food production, has also been damaged by industrial agriculture due to increasing farm specialization, ever-larger farms, and monoculture cropping practices. Because of the use of inorganic fertilizers, the natural organic matter of the soil is not being replenished; thus, despite these chemical substitutes, soil has lost its productivity, resulting in major yield decreases. Some even argue that excessive soil damage has caused the downfall of past civilizations and may cause the downfall of the modern era.

With the increased use of pesticides, some insects, weeds, and fungi evade being controlled and eventually evolve resistance. These “superpests” are often difficult to control, leading some to conclude that chemicals might actually create greater pest problems than they solve. Similarly, the overuse of antibiotics in industrial livestock production is a global concern, given that agricultural pathogens are becoming antibiotic resistant and are being passed to humans via the food chain, which causes health risks and reduces the efficacy of important antimicrobial drugs. These problems are further compounded by the overall loss of genetic diversity in agriculture. To overcome superpests, plant breeders increasingly use genetic materials from locally adapted nonindustrial varieties, as these traditional landraces often have natural pest resistance. However, with the development of scientific breeding programs, many of these landraces were domesticated, and their genetic diversity has been irrevocably lost. As industrial livestock production favors “high-performing” species, many traditional breeds are now becoming endangered and extinct, and this combined loss of livestock and crop agricultural biodiversity is a major global problem. Indeed, agricultural systems that promote social, ecological, and economic sustainability are desperately needed, especially given the environmental and energy challenges of the next decade.



Sustainable Agriculture: From Crisis to Opportunity

In an era of global climate change and depleting fossil fuel, industrial agriculture is increasingly recognized as being very energy inefficient, and this has been deemed its “Achilles’ heel.” Industrial agriculture requires external energy inputs in the form of fossil fuels for tractors and irrigation, petrochemical-derived fertilizers to increase yields, and massive energy requirements to transport food globally. In an era of environmental awareness and concern, industry, governments, farmers, and the public largely agree that sustainable agriculture is desirable. However, sustainability is a contested term, and how it is to be achieved in agriculture remains elusive if not controversial. This is because sustainable agriculture is a philosophical approach, rather than a specific production system, that promotes social, ecological, and economic health in food- and fiber-producing lands and communities. Any agricultural system that is financially and socially prosperous, knowledge intensive, and based on renewable, low-input, and locally based resources is generally considered sustainable. Arguably, the crisis in industrial agriculture has created a necessary opportunity for those countries practicing it to transition to sustainable approaches, and there is no better example of this than Cuba.

The Cuban Experience

The most successful demonstration of the transition to a low-input, self-reliant, and knowledge-based agriculture has taken place in Cuba, which is a world leader in sustainable agriculture. After the fall of the USSR and the continuing U.S. trade embargo, Cuba was largely unable to import either food or the chemicals, fertilizers, fossil fuel, and machines required for the agricultural sector, which at that time was technologically comparable with that of California. Although the crisis initially caused drastic yield reductions in the country, small-scale farmers quickly increased their domestic production, largely by relying on their local knowledge of preindustrial farming techniques such as intercropping, plant breeding, animal traction,

manure spreading, and composting. This success led the government to downsize its industrial-scale state-owned farms, which it gave to farmer cooperatives to manage using their knowledge of low-input and ecology-based agriculture. Technology was developed that supported this transition, and government scientists developed new, ecologically friendly biopesticides and biofertilizers to support the efforts of small-scale farmers. Furthermore, in Havana and in other cities, urban farm and greenhouse initiatives were implemented to create local food security and employment in the most populous regions. Cuba stands as an example of how farmer knowledge, political will, and appropriate technology can be combined to overcome a crisis and create sustainable agriculture and food self-sufficiency.

“Alternative” Agriculture

Sustainable agricultural systems are often referred to as alternative, yet this is a misnomer, as these approaches are actually quite normal and are practiced by millions of farmers worldwide. In Africa, Asia, and Latin America, many farmers have increased their yields, provided for their families, and enriched their communities while being stewards of the land without having adopted high-cost external inputs. Many farmers in North America, Europe, and Australia found that industrial agriculture was making their operations unviable, and they have successfully and sustainably reverted back to older ways of farming that predate the introduction of synthetic pesticides and fertilizers. Indeed, many farm systems around the world exist that subscribe to the philosophy of sustainability.

Approaches that follow the principles of sustainable agriculture include organic farming, biodynamic farming, agroecology, holistic management, urban agriculture, community-supported agriculture, and natural systems agriculture, among others. Diversity is the strength of sustainable agriculture, and many of these systems are used in combination, which allows for a holistic piecing together of the necessary yet complex social, ecological, and economic components of sustainability. The overwhelming similarity among sustainable agricultural systems is that



An Alaska landowner and the district conservationist Phil Naegele discuss management of a sustainable agriculture lingonberry field. Landowners use waste from a local fish cannery as fertilizer.

Source: Ron Nichols, U.S. Department of Agriculture, Agricultural Research Service.

they rely on local knowledge and are ecologically regenerative. Farmers' local knowledge represents a rich and reliable source of information on agroecosystems and helps replace the costly external inputs of industrial agriculture. It is experience based, place specific, and holistic in nature, and it enriches and complements scientific data. In sustainable agricultural systems, farmers' local knowledge often improves and increases nutrient cycling and associated productivity, self-reliance and profitability, and conservation of soil, water, energy, and biological resources. This is achieved in combination with the reduction or elimination of external, nonlocal, and nonrenewable inputs, which often have associated financial and environmental costs. Sustainable agricultural systems are often labor intensive, requiring many skilled and committed

people to contribute to these farms, which in turn leads to populated, vibrant, and socially cohesive rural communities.

Sustainable agricultural approaches are not low technology or "neo-Luddite," as they can incorporate both scientific and farmer knowledge and can be adopted by a diversity of farmers. Farmers, agroecologists, and plant breeders working together at The Land Institute in Salina, Kansas, are developing "natural systems agriculture," which is a model of food production that mimics the prairie ecosystem. They have been breeding perennial versions of major annual grain crops and growing them in polycultures, which reduces the need for tilling, uses few chemicals, and creates a food system that regenerates every year. Importantly, any farmer worldwide—regardless of current practices, motivation, skill,



and knowledge—can incorporate sustainable agricultural approaches into existing operations. Indeed, many people subscribing to the values of sustainable agriculture will be required to participate in future food production.

The Future of Food Production

Worldwide, both farmers and consumers increasingly recognize the importance of sustainable agriculture for society and the environment, especially given the ecological and energy crisis facing humanity and the planet. As the sustainable agricultural movement continues to grow, it will be rooted in values that promote diversity and social, ecological, and economic health and prosperity for the land and its communities.

Ian J. Mauro

See also **Agriculture, Industrialized; Agriculture, Preindustrial; Agrobiodiversity; Agroecology; Crop Rotation; Food, Geography of; Organic Agriculture; Permaculture; Urban Gardens; Via Campesina (International Farmers' Movement)**

Further Readings

- Funes, F., Garcia, L., Bourque, M., Perez, N., & Rosset, P. (Eds.). (2002). *Sustainable agriculture and resistance: Transforming food production in Cuba*. Oakland, CA: Food First Books.
- Pretty, J. (Ed.). (2005). *Sustainable agriculture*. London: Earthscan.

Initially, local governments were considered, from the economic and political points of view, as the most ill suited to resolve major and expensive environmental and social problems. However, in the agreements reached at the United Nations Conference on Environment and Development (the Earth Summit) held in Rio de Janeiro in 1992, it was established that many of the problems and solutions being addressed by *Agenda 21*, have their roots in local activities. Thus, the participation and cooperation of local authorities would be a determining factor in meeting such objectives. In this regard, it was affirmed that local authorities should maintain and promote economic, social, and environmental infrastructure; inspect urban planning projects; develop and implement local environmental policies and laws, and assist other supramunicipal administrations in implementing other environmental policies. As the administration closest to the people, they have to foment citizenship education to promote sustainable development.

The European Conference on Sustainable Cities and Towns, held in Aalborg, Denmark, in 1994 and organized by the International Council of Local Environmental Initiatives (ICLEI), approved the Aalborg Charter. This establishes that the objective of European sustainable cities is to achieve social justice, sustainable economies, and environmental sustainability.

According to the Charter, social justice will necessarily have to be based on economic sustainability and equity, which require environmental sustainability. Socially, cities should create a cooperative environment where unemployment, deprivation, and underachievement are absent and where economic development is compatible with respect for social rights. This will promote an environment where social integration—that is, the compatible cohabitation of racially, culturally, and socially diverse groups—is a reality and where, at the same time, the quality of life for all segments of the population has improved.

Environmentally, cities should use resources ethically, which means that they should minimize their consumption of resource inputs from outside the community and minimize the production of waste outputs. They must also create a society based on renewable energy, complete cycling of resources, no use or release of toxins,



SUSTAINABLE CITIES

A sustainable city is one that while providing a high quality of life to a diversified and plural society in the present, establishes the mechanisms necessary to ensure suitable economic and social growth in the long term while maintaining the natural resources of the environment. This will allow future generations of citizens to satisfy their needs on the same terms.



and development as the restoration and enhancement of the environment's and economy's capacity to support life.

Environmental sustainability requires the maintenance of natural capital, which means that the consumption of renewable resources should not exceed the capacity of natural systems to replace them and that the speed at which we consume nonrenewable resources should not surpass the rhythm of substitution of lasting renewable resources. Environmental sustainability also means that the speed at which pollutants are emitted should not exceed the capability of the resources to absorb and process them.

*Isabel-María García-Sánchez
and José-Manuel Prado-Lorenzo*

See also New Urbanism; Smart Growth; Sustainability Science; Sustainable Development; United Nations Conference on Environment and Development

Further Readings

- Edmondson, S. T. (1999, Summer). APA policy guide on sustainability. *Interplan*, pp. 6–7.
- European Conference on Sustainable Cities & Towns. (1994). *Aalborg charter*. Retrieved February 3, 2010, from the European Union Web site at http://ec.europa.eu/environment/urban/pdf/aalborg_charter.pdf
- McLaren, V. W. (1996). *Developing indicators of urban sustainability: A focus on the Canadian experience*. Toronto, Ontario, Canada: Intergovernmental Committee on Urban and Regional Research Press.
- Portney, K. (2005). Civic engagement and sustainable cities in the United States. *Public Administration Review*, 65, 579–591.
- Stren, R., & Polese, M. (2000). Understanding the new sociocultural dynamics of cities: Comparative urban policy in a global context. In R. Stren & M. Polese (Eds.), *The social sustainability of cities: Diversity and the management of change* (pp. 3–38). Toronto, Ontario, Canada: University of Toronto Press.
- United Nations Environment Programme. (2000). *Agenda 21*. New York: Author.



SUSTAINABLE DEVELOPMENT

Economic and population growth, the availability and depletion of resources, and the absorbing capacity of the Earth and atmosphere are at the core of discussions and concerns about sustainable development. Concerns about sustainable development have a long history, starting with Thomas Malthus, but the use of the term *sustainable development* is of fairly recent origin. The term found its use in the mainstream debate with the Brundtland Report, commissioned by the World Commission on Environment and Development (WCED), and was put on center stage during the United Nations Conference on Environment and Development (UNCED; the Earth Summit), held in Rio de Janeiro in 1992. With the limits-to-growth debate, concerns about finite resources and the carrying capacity of the Earth ecosystem had become a main preoccupation, and computer projections of resource consumption established several critical parameters and demonstrated that human development (and survival on Earth) was ecologically constrained. In other words, the carrying capacity is finite. This entry examines the implications of the Earth Summit and the ongoing debate over the economic and cultural framework needed to achieve sustainable development.

Sustainable Development and the UN Debates

The Earth Summit was called to harmonize the many disparate paths of environmental protection that countries had pursued since the UN Conference on the Human Environment held in Stockholm in 1972, 25 years earlier. Many industrialized countries had incorporated environmental protection into their policymaking, but in the developing world, change had been much slower. Few developing countries had the capacity to respond to environmental threats, and still fewer had any inclination to build the capacity to do so. The major reason for this perceived discrepancy was that for the countries of the global South, environmental protection was inseparable from economic issues. Because of the persistence of severe poverty and perceived injustice in the



global South, environmental protection never attained the level of public concern that it did in the global North. This realization convinced the WCED (which issued the Brundtland Report) that it was futile to attempt to address environmental problems without a broader perspective that encompassed the factors underlying world poverty. When the WCED presented its report to the UN General Assembly in 1987, among its recommendations was a call for the UN to prepare a universal declaration and a convention on environmental protection and sustainable development. The official and stated purpose of the UNCED was to design strategies and measures to halt and reverse the effects of environmental degradation in the context of increased national and international efforts to promote sustainable and environmentally sound development in all countries. As a result, the mandate of the Earth Summit was extremely broad.

The WCED defined *sustainable development* as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. The report called for cooperation between government and business and for the use of technology to address the pressing problems of balancing the social and economic needs of a growing world population with the requirements of a healthy ecosystem. The view prevailed that concerns about sustainability would stimulate society's efforts to become less resource intensive through the use of new technologies and to become more concerned about fulfilling human needs through global environmental management. The Commission was confident that human society would reverse the conflicts between economic growth and the environment, alleviate poverty, and lead the global community to greater cooperation between the global North and the global South.

The UNCED Earth Summit was perhaps the largest, and certainly the most publicized, gathering of heads of state and delegates from national governments, representatives of nongovernmental organizations (NGOs), journalists, youth groups, indigenous people, and other interested parties to discuss environmental and development issues. Maurice Strong—UNCED's Secretary-General—referred to the Earth Summit as a new beginning, but doubts remain about the sincerity

of the negotiating partners in trying to reach an agreement on major global environmental problems, which have since compounded in severity. Several treaties were signed and specific actions agreed to, but how effective the Earth Summit ultimately was remains an issue of debate.

Consensus was reached on the Rio Declaration and Agenda 21, and these agreements, along with the Framework Convention on Climate Change and the Convention on Biological Diversity, were adopted at the Earth Summit. Agenda 21 set out to formulate a blueprint for implementation of the other UN agencies' sector-specific activities regarding environment and development issues and to monitor progress on UNCED's agenda. To finance Agenda 21 and projects related to climate change/global warming and biodiversity, the World Bank's Global Environment Facility (GEF) was approached, and UNCED's Business Council for Sustainable Development—headed by Maurice Strong—was formed to advise UNCED on business issues and to stimulate involvement in specific actions. The developing countries' "Group of 77" wanted to establish an independent green fund in lieu of GEF, which it perceived as beholden to the interests of industrialized countries, the World Bank, and the corporate establishment; however, the idea was defeated by established interest groups from the global North.

Whose Common Future?

Within 1 year of the Earth Summit, the authors of the magazine the *Ecologist* published an edited volume that questioned the success and credibility of the UNCED Earth Summit. From their perspective, it was clear that the corporate sector was the dominant player both in the formulation of the various conventions and in the negotiations. Free market environmentalism was promoted—in their opinion—and corporate sponsors were given special access to the UN Secretariat. The desirability of economic growth, the market economy, and the Western development model were never questioned, and UNCED, thus, never had a chance to address the real problems of the environment and development relationship, according to these critics. The Earth Summit's action plan, Agenda 21, suggested ways to enable poor nations to achieve sustainable development



but never questioned the desirability of the rich nations pursuing the same. So the authors of the *Ecologist* asked the questions “In whose interest are we promoting sustainable development?” and “Who is managing it?” That the stage had been set for conflict between the global North and the global South was confirmed during later climate change negotiations under the UN Framework Convention on Climate Change (UNFCCC).

In a fundamental way, the Western development model is at odds with sustainability of the Earth resource base and carrying capacity, as it denies principles of equity that mandate equal access to resources and the “global commons.” The WCED called for justice toward the next generations but was unable to address the equity demands of the global South in the present time. The call from the developing countries for a more equitable share in wealth and resources was articulated in the Rio Declaration in terms of the “right to development.” At the Earth Summit, many leaders from the global South aligned with the global North in their advocacy of economic growth as the solution to global environmental problems. The prevailing view was that higher levels of economic development would lead to greater care of the environment and more efficient use of energy, thus resulting in lower pollution and greenhouse gas emission levels. Thus, the quest for justice was firmly wedded to the idea of development, and all parties could return to business as usual.

Growth Within Limits or Limits to Growth?

There are essentially two schools of thought on how to proceed toward a more sustainable development path. One—the UNCED approach—recognizes that change is necessary but believes in the power of existing institutions and economic forces to design new directives based on greater consideration for environmental and ecological concerns. Critics of this approach argue that a progrowth economic model must be replaced by an economic system that takes into account the limits of Earth’s ecosystem.

The UNCED’s Global Management Approach

From the UNCED perspective, some reforms and, in particular, new technologies are needed to

confront environmental threats and ecological needs, but no fundamental economic change is necessary. Based on concepts of green development and green technology, supporters of this approach believe that with the application of the right legal, policy, and management tools, nature’s resource base and its ecological services can be maintained and sustained. This approach reflects a commitment to economic growth and global expansion. Business-as-usual policies and proposed solutions are never questioned. As environment and development debates became more mainstream in the 1980s, attempts were made to mold environmental and ecological concerns into market-based models. Following the neoliberal trends in society, a search began for practical ways to incorporate sustainability into existing policies and planning approaches, which led to a whole new cadre of policy and business professionals working on sustainable development issues. The “greening of America” movement was the result. The UN’s warning that global warming threatened the upper and middle classes’ ski resorts in the Alps and the Rockies captured the headlines and brought out more support for climate change policies than any concern about poverty, floods, and food shortages in the developing countries.

Criticism of the UNCED Approach

It is this latter aspect that raised the question of sincerity and true commitment to UNCED’s sustainable development approach. One of the most outspoken critics of the sustainable development as global management approach has been Herman Daly. Daly questions the efficacy of progrowth economics in addressing global environmental problems. He also argues that if the marginal benefits of physical growth decline while marginal costs rise (as elementary economic theory would indicate), then there will be an intersection beyond which further growth would be uneconomical and unsustainable. The application of more advanced technology can (temporarily) expand production, but technological “progress” is usually accompanied by further resource depletion and pollution.

The economy is an open subsystem of Earth’s ecosystem, which is finite, nongrowing, and



materially closed. As the economic subsystem grows, it will incorporate an ever-greater proportion of the total ecosystem. Thus, economic growth is unsustainable, assuming that “natural capital,” or the sum of nature’s resources, is used up faster than it is being replenished. In effect, unsustainable development is intertwined with the loss of carrying capacity and limits to growth. The long-term result of unsustainable development is the inability to sustain human life, and such degradation on a global scale could lead to the extinction of humanity. Daly derides the concept of “sustainable growth” as an oxymoron and maintains that if we truly want to pursue sustainable development and if we value equity and fair share as human values, then the global North must make a commitment to use fewer resources and claim a smaller share of the global commons. It is for this reason that sustainable development has become a very laden political term in mainstream society. Critics of UN policies argue that it is hard to imagine that sustainability through improved environmental management would be achieved by means of greater integration of environmental reforms in the global economy even if the free market were to foster greater efficiency, higher productivity, and improved technology. Thus, the question “Is capitalism sustainable?” needs a serious answer.

Capitalism, Globalization, and Sustainable Development

Those who recognize the bipolar challenges of biophysical limits to growth on the one hand and business-as-usual approaches to development on the other argue that profound transformations of contemporary capitalism are needed sooner rather than later if we are to avoid dramatic disruptions of life on Earth. As the global economy is driven by the profit motive and foreign and corporate investment, and as we possibly approach the limits to growth, a less than equitable distribution of wealth and livelihood security has resulted. The implication of this is that sustainable development efforts require a restructuring of societal relationships, which has made discussions about sustainability and sustainable development highly politicized.

On this view of sustainable development, the Rio Conference has perpetuated a fixation on the

Western development model that fails to acknowledge ecological limits, and this has done a disservice to the global South, since equity concerns were never addressed. At the World Summit on Sustainable Development in Johannesburg in 2002, critics argued that it was time to move beyond Rio, to elevate development and equity concerns on the UN political agenda, and to focus more on the structural inequities in the global economy. This, critics argued, required that the Western development model be abandoned and that the rich reduce their “footprint” to ensure that the poor would be able to protect their livelihood rights.

Arguing that capitalism in its present form is unsustainable has become one of the major points of discussion among the critics of the impacts of globalization, including political ecologists, some of whom charge that sustainable development is an agenda of the global North designed to ensure the dominance of corporate elites. Environmental concerns associated with global production and foreign trade question the validity of the neoliberal economic agenda promoted by the United States, the World Trade Organization, the International Monetary Fund, and the World Bank. Since many negative effects of global production and foreign trade are not confined within national boundaries but spill over to affect other parts of the world (as, e.g., with greenhouse gas emissions) and since negative spillover effects are often more severe in developing countries than in the developed world, some environmentalists and ecologists argue that under the more open international trade regime, the economic growth model associated with capitalism should be abandoned. In its stead, we should pursue a sustainable development course that would promote fair-trade and fair-share principles.

Daly and others have argued that capitalist economic growth is about quantitative expansion and limitless transformation of natural capital into manufactured capital. Sustainable development, on the other hand, is about qualitative improvement in livelihoods, permitting increased economic activity only in so far as it does not exceed the capacity of the ecosystem. Thus, sustainable development requires an emphasis on physical parameters such as resources and carrying capacity, along with an acceptance that economic variables such



as income and profit will have to be adjusted accordingly. To many, it has become abundantly clear that the world's poor will bear the brunt of the damage to ecological systems and will carry most of the costs associated with it, while they are hardly to blame or in a position to make any changes themselves. New core values such as interdependence, empathy, equity, personal responsibility, and intergenerational justice will have to become the guiding principles and the basis for the transformation necessary to meet sustainability challenges.

An Equitable and Sustainable Climate Change Regime

To illustrate, greenhouse gas emissions reduction, necessary to achieve long-term stabilization of emissions concentrations in the atmosphere in order to avert climate change, will require a significantly lower carbon footprint of higher-income countries. If we consider that every person should have equal access to and share equal responsibility for the global atmospheric commons, and if we aim to achieve sustainable levels of greenhouse gas concentrations (450 parts per million) by the year 2050, as projected by the Intergovernmental Panel on Climate Change (IPCC), then we can assign specific carbon budgets for each country. The Stern Report projected the need for cuts of 80% or more in human-induced greenhouse gas emissions worldwide. Using the latest IPCC data, it is estimated that a safe level of emissions per person worldwide would be 2.0 tons of CO₂ (carbon dioxide) in 2050. Whereas most developing countries are currently well below a sustainable per capita limit, residents of the United States emit more than 20 tons of CO₂ per person per year, which means that substantial reductions will have to be made in the United States in order to reach both equitable and sustainable levels worldwide.

The implications of this are far-reaching, and it would seem that the longer we wait to implement the new energy systems, the more difficult it will be to achieve a sustainable level of emissions in an equitable way in the future. An equity- and sustainability-based policy response to global climate change would require that higher-income countries reduce their emissions to the greenhouse

gas stabilization level of 2.0 tons of CO₂ per capita at a rapid rate. Lower-income countries, in contrast, would be allowed to further expand their emissions until about 2040 and then cut back their CO₂ emissions to reach equity and sustainability levels at around 2050. As would seem clear from this example, it is hard to imagine that this can be accomplished under the business-as-usual UNCED approach.

Yda Schreuder

See also Ecological Economics; Ecological Footprint; Global Environmental Change; Globalization; Greenhouse Gases; Neoliberal Environmental Policy; Political Ecology; Political Economy of Resources; Sustainability Science; Sustainable Agriculture; Sustainable Cities; Sustainable Development Alternatives; Sustainable Fisheries; Sustainable Forestry; Sustainable Production; United Nations Conference on Environment and Development; World Bank; World Trade Organization (WTO)

Further Readings

- Byrne, J. B., Kurdgelashvili, L., & Hughes, K. (2008). Undoing atmospheric harm: Civil action to shrink the carbon footprint. In P. Droege (Ed.), *Urban energy transition: From fossil fuels to renewable power* (pp. 27–53). Oxford, UK: Elsevier.
- Daly, H. (1991). *Steady-state economics*. Washington, DC: Island Press.
- Daly, H. (1996). *Beyond growth: The economics of sustainable development*. Boston: Beacon Press.
- The Ecologist*. (1993). *Whose common future?* Philadelphia: New Society.
- Gore, A., Jr. (1992). *Earth in the balance*. New York: Houghton Mifflin.
- Malthus, T. R. (1798). *An essay on the principle of population*. London: J. Johnson.
- Meadows, D. H., Randers, J., Meadows, D. L., & Behrens, W. W. (1972). *The limits to growth*. New York: Universe Books.
- O'Connor, M. (Ed.). (1994). *Is capitalism sustainable?* New York: Guilford Press.
- Pepper, D. (1993). *Eco-socialism: From deep ecology to social justice*. New York: Routledge.
- Porritt, J. (2005). *Capitalism as if the world matters*. Sterling, VA: Earthscan.



- Sachs, W. (1999). *Planet dialectics*. London: Zed Books.
- Sachs, W. (2002). *The Jo'Burg memo: Fairness in a fragile world*. Berlin, Germany: Heinrich Böll Foundation.
- Stern, N. (2006). *The economics of climate change*. Cambridge, UK: Cambridge University Press.
- World Commissions on Environment and Development. (1987). *Our common future*. Oxford, UK: Oxford University Press.



SUSTAINABLE DEVELOPMENT ALTERNATIVES

The literature on sustainable development has long purported to focus on the tripartite relationship between economy, environment, and social justice. While all definitions of sustainability imply this trio of interrelated interests, only two are typically addressed in contemporary analysis: economic sustainability and environmental sustainability. This is true in conceptual and empirical analyses and policy practice. In conceptual terms, sustainability scholarship has focused primarily on normative accounts of sustainable development—the way it *should* be. Sustainability as a policy discourse and an embodied set of practices has yet to live up to its progressive potential to bring together these issues in a holistic way. In response to these forms of analysis, a new body of work on local and regional sustainability, with a more critical and empirical orientation, is emerging. The concepts of “alternative” sustainable development and “critical” sustainability studies sharpen their analytical foci on the relationship between conventional thinking and the “sustainability transition,” how sustainable development looks in practice, and what and who gets overlooked.

This entry has three sections. The first briefly introduces some conventional accounts of the sustainability literature and a critique of these perspectives. The second section summarizes the different perspectives from the critical sustainability studies standpoint. The final section seeks

to ground this point of view further by summarizing the linkages between sustainable development and environmental justice.

Sustaining the “Environment,” Sustaining the “System”?

Concerns for sustainable development made the international scene in the 1980s, when the Brundtland Commission, named after Gro Brundtland, the former Prime Minister of Norway, published its now famous definition of sustainable development. In the decades since, a variety of perspectives have emerged under the Brundtland mantle of sustainable development or have at least gained traction as a result of its popularity. Two key scales of intervention have been proposed by scholars and engaged in by policymakers—systemic and local engagement.

Systemic Intervention

At the systemic level, various perspectives have a key commonality worth noting. These perspectives share a belief in the power of the current economic system and faith in its intrinsic ability to regulate itself to produce progressive outcomes. These accounts are thus tinged with the neoclassical logic of “getting the markets right” and often conclude with appeals to a vague mix of moral imperatives, social conscience, and the threat of looming ecological disaster.

Specifically, these perspectives, which are exemplified by the work of environmental and ecological economists, economic futurists, and ecological modernists, focus on reformulating our current economic systems, especially in terms of redefining how the economic value of the environment is calculated. While these analyses are rigorous, especially those of environmental economists, and may even provide short-term fixes to environmental problems, they return to the same proposition as their neoclassical predecessors: that the market, properly defined, incentivized, and reflecting the real costs of development, is the most desirable institution for delivering human prosperity and ecological integrity. Here, market-produced values are surrogates for the value of “environment.” Wastewater treatment plants, for example, can account for the ecological services of a wetland by



calculating the cost of construction, maintenance, and human resource requirements. Thus, the economic value of a wetland is established by its ability to cleanse impurities from water. Market-oriented values also suggest that prices are triggered solely by signals from the system. Once growth surpasses replacement, for example, disincentives will trigger slower growth.

Ecological modernization theorists share this view, as its progenitors suggest that the ways in which societies value the environment are maturing and taking into account broader concerns than merely simple price triggers and costs. While these developments represent a breakthrough in valuing the environment in ways that traditional economists did not, the analysis falls short of engaging key questions such as the following: What “environment” is being saved? For whom? To what end? How do we measure a contested concept such as “nature’s” services? How do institutions work under conditions of economic change?

Local Engagement

Over the past few years, analyses that bridge the calls for developing a more sustainable society have been taken up by scholars who focus their analyses on the roles of individuals, nongovernmental organizations, and institutions in shaping more sustainable outcomes. In particular, these scholars have not focused on how existing systems can be overhauled to support economic growth per se, nor have they kept an overly narrow focus on the “environment.” These scholars have also called into question the societal implications of sustainable development goals and policies.

Critical Sustainability Studies

Critical commentaries on sustainable development have begun to ask some of the crucial questions raised above. Debates rage on the capacity of local authorities to act in the service of sustainability and the meaning and usefulness of the concept itself. For some, many of the environmental benefits of urban sustainability initiatives accrue to middle-class communities, often at the expense of peripheral local sites as well as those far away. Others have commented on the discursive nature of sustainability. In sustainable

development, there is a central storyline for policy discourses such as ecological modernization. This notion of a “storyline” suggests that sustainable development can be read as a new power/knowledge discourse for organizations seeking to accumulate power. Do the values and institutions of sustainability prioritize the value of capital and the maintenance of existing patterns of social relations? Or can sustainability discourses offer a counterhegemonic opportunity for subaltern groups to reshape urban environments, making them more equitable? Are there complementarities between those actors who focus on social reproduction and sustainability discourses—rather than those solely with environmental concerns—to produce outcomes that have a “red-green” tinge?

Subaltern Sustainability

Scholars are now applying the concept of environmental justice to sustainability practice to reveal that equity and justice are largely divorced from sustainability initiatives. Instead, these authors argue, sustainability is really focused on environmental protection or sustained economic development. They also argue that to be environmentally sustainable, cities must also be socially sustainable. Indeed, a sustainable society is one that looks to issues of social inclusion and welfare, along with economic opportunity and a green environment. The terms *just sustainability*, *actually existing sustainabilities*, and *subaltern sustainability* were coined as an explicit attempt to link issues of social equity to economic and environmental sustainability policy and practice. These concepts are important in critical sustainability theory. By bringing together the sustainability literature and the environmental justice literature, scholars have sought to create a vocabulary for political opportunity and mobilization, both in local government and in the grassroots. Indeed, there remains a critical need to examine how sustainability might be “mapped” onto the current geography of neoliberal capitalism and, more important, where the opportunities for broader, more inclusive political engagement with sustainability might present themselves.

Rob J. Krueger



See also **Ecological Economics; Ecological Modernization; Environmental Justice; Political Ecology; Political Economy; Resource Economics; Sustainability Science; Sustainable Agriculture; Sustainable Cities; Sustainable Development; Sustainable Fisheries; Sustainable Forestry; Sustainable Production**

Further Readings

- Agyeman, J. (2005). *Sustainable communities and the challenge of environmental justice*. New York: New York University Press.
- Desfor, G., & Keil, R. (2004). *Nature and the city*. Tucson: University of Arizona Press.
- Krueger, R. J., & Gibbs, D. (Eds.). (2007). *The sustainable development paradox*. New York: Guilford Press.
- Krueger, R. J., & Savage, L. (2007). City regions and social reproduction: A “place” for sustainable development? *International Journal of Urban and Regional Research*, 31(1), 215–223.
- Polese, M., & Stren, R. (Eds.). (2000). *The social sustainability of cities*. Toronto, Ontario, Canada: University of Toronto Press.



SUSTAINABLE FISHERIES

Until well into the 20th century, ocean resources were believed to be infinite. The “freedom of the seas” paradigm that existed from the 1800s was largely informed by Hugo Grotius, the 17th-century natural rights writer, who argued that the oceans’ resources were inexhaustible and that fishing regulation was unnecessary. However, more modern scientific reports represent a very different state of affairs, making apocalyptic predictions about the state of the planet’s fish stocks. The most alarming forecasts claim that the stocks of all commercial fish and seafood species could collapse by the middle of the 21st century if present trends continue. Indeed, fears have reached such epic proportions that many commentators argue that the current international fisheries situation amounts to a crisis, second only to global warming in significance. Although such forecasts are typically contested by the world’s fishing

industries, there is little doubt that many fish stocks around the world are well below their “maximum sustainable yield”—that is, the largest catch that can be taken continuously from a stock so that it does not deplete it irreparably. This entry reviews the status of fish stocks today and explores the causes of, as well as various government responses to, the problem on national and international levels.

Collapsing Fisheries

A worldwide increase in “fishing effort” (the amount of fishing) since the late 20th century has corresponded with declining stocks and smaller catches. The total fall in global catch between 1994 and 2003 has been estimated at 13%. The explanation most frequently offered for this decline is that there are now too many boats chasing too few fish. Between 1970 and 1990, the Food and Agriculture Organization of the United Nations (FAO) recorded a doubling in the world fishing fleet to more than 1 million large vessels and 3 million smaller boats. Not only are there now more boats at sea, but each of these is likely to be more successful than ever before at catching fish. Fishing underwent vast technological changes over the 20th century, a process known as “technical creep.” The so-called overfishing crisis has its roots in the turn of the 20th century, which saw the capitalization and mechanization of fishing fleets and the widespread use of steam trawlers in the Atlantic. For instance, these technological developments resulted in the collapse of the Great North Whale Fishery in 1880 and the once booming herring and tuna fisheries in the Atlantic in the early part of the 20th century. Despite such crashes, advancements in catching technology continued. Fishing gear such as nets and modern equipment such as sonar and geographic information systems are being constantly improved so that each vessel can catch many more fish than ever before in a single trip.

As a result of this continuous increase in fishing activity, the United Nations (UN) states that 52% of the world’s commercial fish species are fully exploited, 17% are overexploited, and 8% are depleted. And according to the International Council for the Exploration of the Sea, slow-growing and therefore vulnerable deep sea fish,



such as orange roughy, are roughly 90% less numerous than they were in the early 1970s.

These alarming global statistics take on even more significance when considered with respect to particular geographical regions. For example, the collapse of the once abundant Grand Banks cod fishery in Canada in the early 1990s has become emblematic, and many people are familiar with the contemporary decline of the North Sea cod. This has caused widespread concern as the numbers of these fish are well below what is considered sustainable. Europe's fisheries scientists now estimate that cod spawning stock in the North Sea—that is, the section of the population responsible for reproducing—has declined by more than 80% since the early 1970s, and many are concerned that it could follow the Canadian example if radical action is not taken. But such problems are not confined to the Western world. For instance, some tuna stocks in the Pacific have been reduced to 15% of what they once were, and the economically important Patagonian toothfish fisheries in the Southern Pacific Ocean are also considered vulnerable to stock collapse. Similar stories can be told about almost every ocean.

Sustainable management of fish stocks is crucial because as fisheries are an extractive resource, fishing practices such as trawling can harm marine environments more generally. Moreover, these reports of unsustainable fisheries are even more disturbing if seen in the light of the rapidly increasing global demand for fish, which has doubled in less than 30 years, according to the FAO. Fish and seafood provide an important source of nutrition for both humans and animals (in the form of fishmeal, which is often harvested unsustainably), and they provide important employment. The collapse of the Grand Banks fishery, for example, cost that region more than 40,000 jobs. Fishing directly or indirectly sustains the welfare of many coastal regions around the world. However, the dependence on fisheries and related industries varies from country to country. In the United Kingdom, the fishing industry makes up less than 0.5% of gross domestic product, a figure less than the British lawnmower business. But dependence on fishing increases to 10% on the Atlantic coast of Spain and around the shores of Scotland. So while the number of jobs in the fisheries sector represents a low percentage of *overall*

employment in many countries, their socioeconomic importance is still huge.

A “Tragedy of the Commons” and Government Responses

Given that fisheries are so crucial to us as a source of food and means of employment, it is perhaps surprising that we are still facing major problems with their sustainability. One of the reasons for this can be explained with reference to the “tragedy of the commons,” in which the rational, self-interested acts of individuals destroy a common good. This allegory, developed by Garrett Hardin in 1968, is probably the most enduring explanation for resource overexploitation. Many natural resource commentators have used this allegory to exemplify the dilemmas involved in fisheries management. Fisheries are often described as “common-pool resources,” which, because of their nature, are difficult to divide up or fence in. Hence, what one user of the resource does can affect what is available to another user. This situation may lead to a scenario where resource exploitation happens in a way that neglects broader social-environmental responsibilities. The allegory shows how environmental or social externalities arise because self-interest drives economically rational actors to maximize their individual profit, since in a commons, the costs of doing so are shared by all yet the benefits accrue fully to the individual. The ultimate result is resource *overexploitation*, where everyone loses.

With respect to the world's common fisheries, the “external cost” relates to the fact that an individual fisherman's unrestrained profit maximization can damage the sustainability of fish stocks, thus making it harder for other fishermen to catch fish today and in the future. Essentially, it is the “common property” condition of ocean resources that has been blamed for overfishing.

European Union Policy

This conundrum of open access to common fishing grounds affected most 19th- and 20th-century fisheries, and many observers maintained that its solution was beyond the scope of single nation-states acting alone. One of the most notable multilateral solutions to overfishing is the



European Union's (EU's) Common Fisheries Policy. Although fisheries policy in the EU dates back to the early 1970s, the Common Fisheries Policy was not ratified by the member states until 1983. It was designed to give Europe's fishermen equal access to the resources of the EU's "common pond" and to ensure the "economically rational" use of fisheries within the context of a series of social and, later, environmental objectives. That is, the primary purpose of this policy is to ensure the sustainable exploitation of Europe's fisheries.

Notwithstanding this commitment to the goal of sustainable development, stresses remain between the policy's environmental, economic, and social objectives. For instance, tensions still exist between the need to protect vulnerable stocks such as the North Sea cod for environmental reasons and the fishing industry's requirement to make a living and support coastal communities. Indeed, it is generally believed that the Common Fisheries Policy may have compounded the problem of unsustainable fisheries in Europe. Under it, for example, the *limits* on the amounts of fish that fishermen can legally land in a specific time period (fish "quotas") are said to promote *overfishing*, through a practice known as "high grading." This means discarding from the catch "substandard," or unsellable, fish to increase the proportion of valuable fish in the allocated quota. Often, fishermen cannot bring themselves to throw back the already dead fish and so may land them illegally. These fish, caught and landed outside quota limits, are known as "black fish."

Overfishing in the EU has also been blamed on lax enforcement of existing regulations, fishermen's reluctance to comply with them, and the failure of politicians to follow scientific advice on stocks and put in place the measures needed to secure sustainability. But overfishing problems are not confined to Europe. Through access agreements, the EU has actively encouraged deployment of its excess fishing capacity to Africa, South America, and the Indian Ocean. Nongovernmental environment and development organizations have voiced concerns about this export of resource overexploitation to developing countries, arguing that access agreements represent a form of neocolonialism.

For some commentators, the solution to the tragedy of the commons is privatization of

resources that were once open access. As the allegory demonstrates, it appears to be the disjuncture between the universal right of entry to a fishery and the lack of individual responsibility for its overall maintenance that creates the incentive to overfish. Therefore, these commentators argue, externalization of the costs of exploitation onto the whole community of commons users can be remedied by establishing private property rights over the commons. Such rights encourage the internalization of externalities, because if you are legally identified as the owner of the resource (so the argument goes), then you will be more likely to look after it.

Individual Transferable Quotas

Privatizing ocean resources may not be an attractive solution, so long as they are regarded as what the UN calls the "common heritage of mankind." What is more, even if using property rights as a management method were theoretically sound, enforcing them on *mobile* resources might be problematic, for it is not yet feasible to fence off migratory fish species, such as herring or tuna. Consequently, it is only possible to apply a manner of privatization in the form of "individual transferable quotas," or ITQs. These are shares of fishing effort allocated to individual fishers, who can either use that effort themselves or sell it to someone else. ITQs thus approximate a privatized situation, providing the conditions for a market to operate. They are used in Iceland, New Zealand, and elsewhere and have had some success. They are said to afford greater flexibility than standard quotas because fishermen can sell them in hard times, or purchase quotas for valuable fish they could not otherwise land legally, instead of discarding them overboard.

Despite its attractions, there are several significant limitations to this system. For example, ITQs have in some circumstances led to "buyouts" whereby economically thriving operators buy quotas from smaller or less successful fishermen, and as a result, some coastal communities have eventually been altogether deprived of their fishing industries. Hence, the system may not be socially sustainable. What is more, this system does not entirely solve the problem of high grading, and so it is not fully environmentally sustainable either.



International Policy Responses

As well as the quasi privatization of fish resources, some policies have privatized the sea itself. Although much of the ocean is still part of the global commons, some of it is now “territorialized,” or, in effect, privatized, by nation-states. The conditions for this were created by the UN Convention on the Law of the Sea of 1982, which provides the overall legal framework for all ocean activities and establishes general obligations for safeguarding the marine environment. Its key provision is the establishment and extension of exclusive economic zones, or EEZs. These zones allow nations to have territorial and exploitation rights up to 200 nautical miles from the shore, covering all natural resources.

The international fisheries governance regime, however, may fall short. First, coastal countries are not obligated to responsibly manage their fisheries within their EEZs. Second, problems arise when some countries do not wish to collaborate or cannot reach agreement, as there are no binding laws on resolving disputes over resources. Also, introducing EEZs has actually encouraged governments to expand their fleets, thus stimulating overfishing. Yet, paradoxically, the expansion of territorial limits partly stemmed from an “overfishing” crisis in the internationally shared territory beyond them: the “high seas”—a global commons where open-access conditions prevailed and where there was a regulatory free-for-all. Today, the high seas are managed by the UN’s Regional Fisheries Management Organisations. However, they are largely ineffective, principally because they have no means to exclude vessels not abiding by their rules.

International fisheries governance is a mish-mash of codes of conduct and frameworks. Global commitments to sustainable fisheries include the UN’s Convention on Biological Diversity (Article 14) with its Action Plan for Fisheries (1992) and the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks (Article 12, 1995). The most far-reaching is the nonbinding FAO Code of Conduct for Responsible Fisheries (1995). The code explicitly demands participative and transparent decision making by countries and regions. It also calls for “efficiency and effectiveness” to achieve “timely solutions.” At the United

Nations Conference on Environment and Development (the Rio Conference, or Earth Summit) in 1992, countries agreed to ensure “rational and sustainable” fishing. This commitment was reinforced and elaborated at the World Summit on Sustainable Development in Johannesburg in 2002, where it was decided that fish stocks should be maintained or restored by 2015. Given all these codes, it is easy to see why fisheries policy is an expanding area for governance.

One set of mechanisms that is fast gaining purchase in the search for sustainable fisheries consists of market-based instruments targeted to consumers. Eco-labeling and green consumerism now form part of a dominant discourse that might go some way toward eliminating unsustainable fishing practices. Consumer pressure sometimes forces retailers, keen to appear “green,” to source from fisheries certified as “sustainable,” and this encourages fishermen to move to healthier grounds or to use “friendlier” fishing gear. However, as in the ITQ example above, these market mechanisms may be inadequate to achieve and maintain maximum sustainable yield. Among other problems, they rely on consumers having sophisticated information about complex ecological processes and on their being prepared to exercise their spending powers. Second, although eco-labels may tell us that a fishery is “sustainable,” it may not tell us how many miles the fish has travelled in its journey from the ocean to the supermarket shelf and how much atmospheric carbon this has contributed to climate change.

Liza Griffin

See also **Aquaculture; Common Pool Resources; Common Property Resource Management; Commons, Tragedy of the; Environmental Certification; Market-Based Environmental Regulation; Marine Aquaculture; Oceans; Sustainable Production**

Further Readings

- Clover, C. (2005). *The end of the line: How overfishing is changing the world and what we eat*. Berkeley: University of California Press.
- Ellis, R. (2004). *The empty ocean*. New York: Island Press.



SUSTAINABLE FORESTRY

According to the Food and Agriculture Organization of the United Nations (FAO), *sustainable forestry* may be defined as

the stewardship and use of forests and forestlands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and their potential to fulfill, now and in the future, relevant ecological, economic, and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems. (UN Forum on Forests, n.d.)

There are four general goals of sustainable forest management (SFM): (1) to ensure a continuous supply of timber; (2) to ensure local populations' access to a wide range of nontimber forest products; (3) to conserve natural forests for biodiversity, habitat, amenities, and ecosystem services; and (4) to sequester atmospheric carbon in support of climate change remediation. Strategies for pursuing SFM typically make the following assumptions:

- Forests will continue to regenerate naturally over the long term (more than one human generation).
- Forest resource stakeholders (from local communities to transnational timber companies) have sufficient technical knowledge, institutional capacity, and self-interest to manage natural forests for the long term.
- A clear policy framework for SFM exists that is consistent at various intergovernmental levels.
- A politically accountable public entity exists, with the capacity to effectively identify various forest resource stakeholders and consistently monitor their behavior over time.
- Market demand for products and access to markets are relatively stable over the long term.
- Forestland tenure (i.e., property ownership) is clearly delineated, and viable judiciary and police capabilities exist to justly enforce legitimate individual and collective property ownership rights to forest lands.

Despite regional variations, three common themes have emerged among the guidelines for SFM that distinguish it from its predecessor,

sustained yield management: (1) a shift toward a more holistic perspective by changing the unit of analysis from the individual natural resource (e.g., timber or wildlife) to the larger ecosystem with which the resource is entwined; (2) a broadening of scope, from the economics and biology of renewable resource extraction to the social and cultural contexts in which such activities occur; and (3) an expansion in the range of benefits (products and services) provided, from timber for industrial wood production to timber and numerous different nontimber forest products and ecosystem services (carbon sequestration, soil and watershed protection) that SFM claims to provide.

Global Extent of Sustainably Managed Natural Forests

According to the FAO, approximately 30% of Earth's land cover (4 billion ha [hectares]) is forested. From 1990 to 2000, 8.9 million ha of forestland was lost annually to deforestation. In the 21st century, this rate has decreased to 7.3 million ha per year. A global estimate of how much of the remaining forestland is sustainably managed is difficult to determine. More than 200 million ha is currently certified as being sustainably managed by the Programme for the Endorsement of Forest Certification Schemes (PEFC). There are also large areas of land enrolled in programs that promote SFM that are not certified by the PEFC. For example, 440 million ha (11% of the world's total forest cover) is under some form of community-based ownership, and another 12% to 15% of the world's natural forests are managed by timber concession agreements. Another 12% of the world's forests (468 million ha) are in designated protected areas. Therefore, approximately 35% to 37% of the world's forestlands are being managed in some fashion. It is important to note, however, that not all community forests, forests under timber concessions, or protected forests are managed sustainably.

The Montreal Process

The ecological dimensions of SFM are predicated on the first five criteria for SFM, as endorsed by the Montreal Process of 2003, one of nine working groups established to develop SFM guidelines.



The Montreal Process criteria are discussed below because the countries involved in the process account for the majority of the world's forests.

Creation and Maintenance of Biological Diversity.

Ecological research demonstrates that diverse ecosystems are resilient ecosystems. A forest with a wide array of species is less susceptible to potentially catastrophic disturbances such as insect and disease outbreaks, wildfires, and major storm events than a forest with relatively fewer species. Biological diversity is measured in terms of habitat, species, and genetic composition. SFM seeks to create and maintain biodiversity by focusing on management at the landscape level rather than at smaller scales (such as an individual forest).

Forest Health. Maintaining forest health through SFM is essential to ensure that basic ecosystem processes operate within their historic ranges of variation (in terms of frequency, intensity, and scale). Health can be assessed by evaluating the area of forest affected by insects, disease, competition from exotic species, fire, storm, land clearance, permanent flooding, salinization, and domestic animals occurring above and beyond the historic range of variation. Additionally, changes in fundamental ecological processes, such as nutrient cycling and pollination, can affect forest health.

Ecosystem Services. Healthy forests contribute to the protection of adjoining ecosystems, especially the soil and water regimes of those areas, and thereby provide useful environmental services within the larger landscape. Healthy forests act as buffers against soil erosion from both runoff and wind and as a filter, removing pollutants from water before they reach groundwater supplies and streams. Reductions in soil erosion result in less sedimentation in streams and rivers. Additionally, forests help provide clean air by filtering pollutants such as ash, pollen, and smoke in Earth's troposphere.

Forests can also have a significant effect on climate. At the local level, trees provide shade and absorb heat energy, resulting in a cooling effect on both land and water. In the winter, trees can act as a windbreak and can moderate soil temperatures.

And at both local and global levels, forests play an important role in the carbon cycle.

Role of Carbon

Forests are both carbon sources and carbon sinks. A forest is a source when the amount of carbon released through respiration, decomposition, and burning exceeds the amount of carbon taken up (sequestered) through photosynthesis. Conservatively, deforestation and unsustainable forest management account for about one sixth of global carbon dioxide (CO₂) emissions.

A forest is a sink when the amount of carbon sequestered exceeds the amount of carbon released. A global estimate of the total carbon stored annually in forest biomass is 283 Gt (gigatons; 1 Gt = 1,000,000,000 tons). Well-managed forests have the potential to absorb about 10% of global carbon emissions into their biomass and soils. Additionally, solid wood products, such as building materials and furniture, provide long-term carbon storage.

Currently, incentive-based carbon markets are emerging to encourage landowners to engage in forest management practices that increase carbon uptake and storage. Market-based cap-and-trade mechanisms for reducing CO₂ emissions (similar to that currently in place in the United States for sulfur dioxide) would likely have important implications for SFM.

Forest Productivity

Traditionally, forest productivity was measured in direct relation to timber production (i.e., the production of forest land area, the volume of growing stock, the area of planted vs. naturally regenerated forests, and the annual removal of timber products vs. the amount of annual growth). While these indicators are still important, the definition of forest productivity has expanded to include other measures, such as biodiversity, the economic values of nontimber forest products, and ecosystem services.

Forest management practices can have significant impacts on productivity (both positive and negative). Choosing species well suited to a particular area, incorporating genetic improvements such as disease resistance and rapid growth, and



applying management tools (such as prescribed fire, thinning, and control of exotic invasive species) can increase both traditional and nontraditional measures of forest productivity. Other factors that affect productivity include forest species composition, temperature, rainfall, and soil depth and nutrient content.

Social Dimensions

Sustainable forest management explicitly recognizes the importance of the human and social dimensions of forest management, more so than conventional notions of sustained yield harvesting. The emerging interest in the human dimensions and social aspects of forest management correspond with a growing awareness of the significant contribution of deforestation to biodiversity reduction, climate change, and watershed degradation in low-income countries of the global South. As much as 30% of tropical deforestation is caused by small-scale, resource-poor cultivators, many of whom have been economically marginalized by large-scale, Western-style development projects. Accordingly, many proponents of SFM have argued for the inclusion of local communities into SFM programs. These have taken several forms (including biosphere reserves, integrated conservation and development projects, extractive reserves, social forestry, and community forestry), the objectives of which are the following:

- To protect agricultural land from soil and wind erosion, water pollution, and other adverse environmental conditions, thereby improving environmental quality
- To increase the supply of fuelwood, basic construction materials, and nontimber forest products, typically for noncommercial household consumption, thereby improving the quality of life at the household level
- To enhance the natural beauty of the landscape for passive recreational activities
- To provide employment for unskilled rural workers

Challenges in Sustainable Forest Management

Ecologically, the inadvertent and unintentional introduction of exotic invasive species is probably

the most serious challenge to the health and integrity of almost any ecosystem today and also to SFM. Exotic invasive species typically have a negative impact on biodiversity by displacing native species and altering ecosystem functions (e.g., changing the fire regime, nutrient cycling, or hydrology). Genetic biodiversity can also be corrupted as exotics hybridize with native species, altering the native gene pool. Worldwide, upward of 80% of endangered species could suffer losses due to exotic invasives, at a cost of \$1.4 trillion.

Other ecological challenges include soil conservation (minimizing erosion and compaction), water quality and quantity, and wildfires. Policies that encourage the identification and removal of invasion pathways and support public education for recognition and eradication of exotics are needed to fight this particular battle. Forest management practices that minimize soil damage and protect waterways are also needed.

Economic Challenges

The expansion of traditional forest management, based on the principle of maximum sustained yield of a single forest product such as timber, to management for multiple products, environmental services, and cultural values poses troublesome challenges to conventional neoclassical resource economics, with its focus on utility-maximizing, self-interested, rational economic actors operating in a free market context. Most equilibrium models of sustained-yield timber management presume concave utility and production functions, resulting in a single equilibrium point indicating the level of maximum sustainable harvest during a specific production cycle.

In the multiproduct, multiuse definition of SFM, however, where there are many production functions, there will be multiple equilibria, each of which may be affected by different rates of biological reproduction for different species, by their varying degrees of resilience to disturbance, and by the resource use behaviors of various forest stakeholders. Add to this the additional layer of complexity associated with the multiple institutional contexts in which different forest stakeholders operate, and a market-driven model for SFM becomes problematic for effectively balancing the



economic wants of society with the ecological requirements of forests.

Social (Tenorial) Challenges

Land ownership and tenure patterns also pose challenges to SFM. Large forested areas around the world are increasingly being subdivided into smaller parcels as a result of various social processes (e.g., inheritance, in-migration, and household agricultural failure). Parcelization of property ownership often leads to forest fragmentation—the alteration of a continuous forest into isolated forest patches interspersed with land in other, nonforested uses.

From an SFM standpoint, applying traditional forest management practices to smaller parcels can be difficult, particularly when adjacent properties have conflicting uses. Additionally, these smaller parcels of forestland are subject to increasing levels of disturbance along their edges and may not be suitable for species that require interior forest habitat, even as the habitat for edge-adapted species is increased.

Policies that encourage connectivity between fragmented forests, maintenance of structural complexity in forests (i.e., multiple-age classes, snags, and coarse woody debris), and the adoption of varied management practices at multiple scales could offset the negative impacts of forest fragmentation.

Political Challenges

Sustainable forest management can be negatively affected by illegal activities, such as trespassing, timber theft, logging endangered species, and wildlife poaching. In major tropical timber-exporting countries, illegal logging accounts for more than 50% of total timber cutting. The World Bank estimates that illegal logging costs the developing world an estimated \$15 billion annually in lost assets and revenues, in addition to human rights violations and social conflicts. Additionally, up to 10 million ha are annually deforested or degraded as a result of illegal activities.

Other external threats to SFM, especially pertaining to protected areas, in the form of illegal land settlement by migrants and land

speculators pose significant political challenges for governments seeking to balance social problems (e.g., chronic landlessness) with forest conservation commitments. Many of these challenges could be addressed through effective political will and commitment to public policies that support the implementation of forest management plans and the enforcement of existing forestry laws.

Institutional Challenges

Sustainable forest management is also impeded by deficient institutional capacity. Where SFM is a national policy goal, governments often lack the institutional resources to effectively enforce policies that support SFM. At the community level, where SFM is often introduced by outside technical experts, it can be stymied by the lack of a preexisting communal land management tradition or by the domination of individual interests within the community, which may prevent the gains of SFM from being shared broadly.

Forest Concession Challenges

Worldwide, a minimum of 450 million to 500 million ha of natural forest is leased to private timber extraction and/or industrial wood-processing corporations under long-term forest concession agreements. Although the terms of such agreements may contain attributes of SFM (e.g., sustained yield management), many concessions, in practice, have been criticized by conservationists and economists for being overly destructive and economically wasteful, highly susceptible to corruption, harmful to local communities, and unsustainable over even the short term. Logging is believed to account for approximately one third of global deforestation, raising questions as to whether large-scale timber concessions can ever be sustainable.

Recent interest in community-based forest concessions for timber extraction has scaled down forest management areas from large industrial forest concessions (ranging from 50,000 to 25 million ha) to smaller (500–10,000 ha) production units, with strong local (community) participation and management interest in logging and marketing operations.



Innovations in Sustainable Forest Management

Conservation Concessions

Some conservation groups (e.g., Conservation International) have recently proposed to adapt the forest timber concession model to promote forest protection. In the adapted model, forest landowners (private, governmental, and customary) lease forests to investors (e.g., nongovernmental organizations) for a stable rent in exchange for maintaining the intact forest. The rental income from such concessions is allocated to local communities to offset their opportunity cost of income foregone in order to ensure forest conservation. In practice, the effectiveness of conservation concessions is often constrained by the inadequate concession enforcement capacity of forest owners, by questions of national sovereignty, and by external forces over which local concession holders have little control.

Sustainable Urban Forestry (SUF)

As defined by the Sustainable Urban Forests Coalition (SUFC), urban forests are “the aggregate of all vegetation and green spaces that provide a myriad of environmental, health and economic benefits for a community.” Sustainable urban forestry is defined as “the art, science and technology of managing trees, forests and natural systems in and around cities, suburbs and towns for the health and well-being of all people.” Recognizing the positive public health and local watershed and climate benefits of maintaining forests in an urban landscape, several municipalities in the United States and elsewhere have initiated urban forest management plans as part of active land stewardship programs.

Reduced-Impact Logging (RIL)

Reduced-impact logging is the application of scientific and engineering knowledge and techniques, in conjunction with education and training, to improve operating methods for harvesting of industrial timber so as to minimize collateral damage to the residual forest and other elements of the forest ecosystem during a harvesting operation.

Forest Certification

Forest certification is a voluntary process in which a third party evaluates and certifies the management of a forest against a particular set of sustainability standards. Although applied mainly to timber extraction, certification also can be applied to the management of nontimber forest products.

Secondary Forest Management

Forested areas that have regrown through natural regeneration after a major disturbance (e.g., clear-cutting, fire, timber harvest, and/or insect infestation) over time such that the effects of the disturbance are no longer evident are commonly called “secondary forests.” As human pressures reduce the global area in natural forests, the sustainable management of tropical secondary forests will become an increasingly important component of SFM.

Conclusion

The attributes of forests around the globe, and the social and political challenges that shape them, vary widely. As a result, there is no one prescription for SFM for all forest types. Management activities must first be tailored to address the specific needs and challenges of forests at the local level. These local-level management practices must then be integrated at regional, national, and international levels. This is not an easy task. But the continued efforts of the nine international working groups to formulate measurable guidelines for SFM demonstrate a global interest in enhancing forest management strategies and ensuring sustainability of forest resources for future generations.

*John O. Browder and
Jennifer L. Gagnon*

See also Agroforestry; Carbon Cycle; Carbon Trading and Carbon Offsets; Community Forestry; Deforestation; Environmental Services; Forest Degradation; Forest Fragmentation; Forest Land Use; Forest Restoration; Indigenous Forestry; Sustainability Science; Sustainable Development



Further Readings

- Aplet, G. H., Johnson, N., Olson, J. T., & Alaric Sample, V. (Eds.). (1993). *Defining sustainable forestry*. Washington, DC: Island Press.
- Deal, R. L., White, R., & Benson, G. L. (Eds.). (2007). *Sustainable forestry management and wood production in a global economy*. Binghamton, NY: Haworth Food and Agricultural Press.
- Lindenmayer, D. B., & Franklin, J. F. (Eds.). (2003). *Toward forest sustainability*. Washington, DC: Island Press.
- Palo, M., & Mery, G. (Eds.). (1996). *Sustainable forestry challenges for developing countries*. Dordrecht, Netherlands: Kluwer Academic.
- Raison, R. J., Brown, A. J., & Flinn, D. W. (Eds.). (2001). *Criteria and indicators for sustainable forest management*. Wallingford, UK: CAB International.
- Reynolds, K. M., Thomson, A. J., Kohl, M., Shannon, M. A., Ray, D., & Rennolls, K. (Eds.). (2007). *Sustainable forestry*. Wallingford, UK: CAB International.
- UN Forum on Forests. (n.d.). What is sustainable forest management? Retrieved January 31, 2010, from the UN Forum on Forests *Frequently Asked Questions* Web page at www.un.org/esa/forests/faq.html#sfm



SUSTAINABLE PRODUCTION

Sustainable production is the process of creating goods and services that are both environmentally and socially responsible in addition to being economically successful. The geographical effects of sustainable production are ubiquitous, from the transport of goods and the location of facilities to the effects of industry on people and the environment. The motivation for sustainable production, approaches to implementation, frameworks for consideration, and ongoing efforts are all described in this entry.

Motivation for Sustainable Production

Environmental, economic, and social concerns have catalyzed the development of methods, tools,

and techniques for sustainable production. Industry-related environmental disasters, such as the deaths from the release of methyl isocyanate gas in Bhopal, India (1984), and the widespread publicity of the hole in the stratospheric ozone layer in the 1980s caused by ozone-depleting chemicals (e.g., chlorofluorocarbons, or CFCs) have spurred public outcry for better regulation of production practices and emissions. In response, international, regional, and national legislation has been enacted. The Montreal Protocol on Substances That Deplete the Ozone Layer (1987), adopted by many nations, bans the production and use of ozone-depleting chemicals. The 2002 European Union Waste Electrical and Electronic Equipment (WEEE) and the 2003 Restriction of Hazardous Substances (RoHS) directives place responsibility on producers to take actions that reduce environmental impacts. The 1990 U.S. Clean Air Act requires the U.S. Environmental Protection Agency to enforce limits on emissions from production facilities.

Additionally, the economic and social consequences of globalization have created a need for sustainable production. Increases in global competition have prompted the production of goods to move from industrialized to developing nations to avail of the benefits of lower labor costs and less regulation. This shift in industrial activities has changed global patterns of employment and production, with concerns raised about environmental impacts, labor practices, and worker health and safety. These concerns have inspired the development of economies and societies to improve quality of life. This inspiration evolved into the holistic concept of sustainable development.

Toward this aim, sustainability-oriented approaches have been adopted to reduce costs and improve manufacturing productivity and efficiency. The goal is to maintain manufacturing competitiveness while reducing the environmental impacts of production. Such approaches include cleaner production, pollution prevention, and just-in-time, lean, and environmentally responsible manufacturing. Adoption of these approaches by companies starts the institutionalization of sustainable production goals and practices.

Industry has sought to expand transparency and accountability for financial, social, and environmental policies and practices through the



adoption of standards and through communication about performance to stakeholders via sustainability reporting and product labeling. The International Organization for Standardization (ISO) established environmental standards in 1996 (ISO 14000) to complement the existent quality standards of ISO 9000 (1987). The Global Reporting Initiative guidelines (1997) established a systematic way for companies to report sustainability performance that is audited and scored for transparency and credibility. The Social Accountability International (SAI) SA8000 standard (1997) measures corporate performance in protecting workers' rights. AccountAbility's A1000 standards (1999) report on corporate social and ethical performance. Many companies communicate environmental and social responsibility through product labeling about environmental, fair trade, and child labor-free practices.

Sustainable Production of Goods and Services

Sustainable production strives to increase processing efficiency, eliminate waste, and create benign outputs. Increase in processing efficiency is achieved by reducing the use of materials, energy, storage, labor, and time while improving product quality and reducing process variation. Microlevel and macrolevel process planning strategies form the backbone of pollution prevention or cleaner production efforts by improving operational parameters and process flows. The Toyota Production System improves quality by eliminating inefficiencies (*muda*), overloading of equipment or people (*muri*), and variation in processes and products (*mura*). Under a just-in-time manufacturing approach, production is output pulled instead of input pushed—that is, production occurs when demands for products arise rather than when supplies for production are available. A just-in-time philosophy necessitates fast distribution of inputs across the supply chain once a demand is recognized. Lean manufacturing concepts have grown out of these approaches, which started to be widely adopted in the 1980s. Lean manufacturing has a similar goal of eliminating waste by ensuring that each production activity creates the value the customer demands; the catch phrase “lean and green” has emerged to capture this connection.

Eliminating Waste

Quality engineering methods reduce waste by decreasing the number of defective products through continuous improvement efforts such as Statistical Process Control. Guidelines such as design for assembly eliminate waste by reducing labor and the time needed for assembly through optimization of object handling. The concept of eliminating waste is derived from process efficiency efforts but involves thinking beyond traditional processing concerns. Extending the usable life of process consumables can directly eliminate waste, as, for example, in cleaning and reusing metal-cutting fluids. Similarly, finding uses for by-products of processes (often unintentional outputs) eliminates waste while creating market opportunities. Industrial ecology and cradle-to-cradle approaches, developed in the 1990s, seek to establish an ecosystem-like view of production systems, where outputs become inputs to secondary production operations. For example, the eco-industrial park in Kalundborg, Denmark, started sharing waste steam and other by-products between an electric power generator, product manufacturers, and the local community in the 1970s.

Creating Benign Outputs

Sustainable production encourages the creation of benign rather than detrimental outputs for environmental and human health. Green Chemistry, developed in the 1990s, innovated processing alternatives that reduce toxic chemical inputs, outputs, and by-products. Substituting hazardous inputs with more benign, reclaimed, renewable, recycled, or recyclable materials promotes sustainability and can be aided by Design for Environment (DfE), which evolved in the 1990s. Energy efficiency efforts reduce emissions along with using renewable energy; for example, wind turbines power the Ecover factory in Belgium, which makes environmentally friendly cleaning products. Some companies purchase renewable energy credits (RECs) or carbon offsets to offset emissions.

Frameworks of Sustainable Production

The efforts described above mainly affect production processes, but production involves much

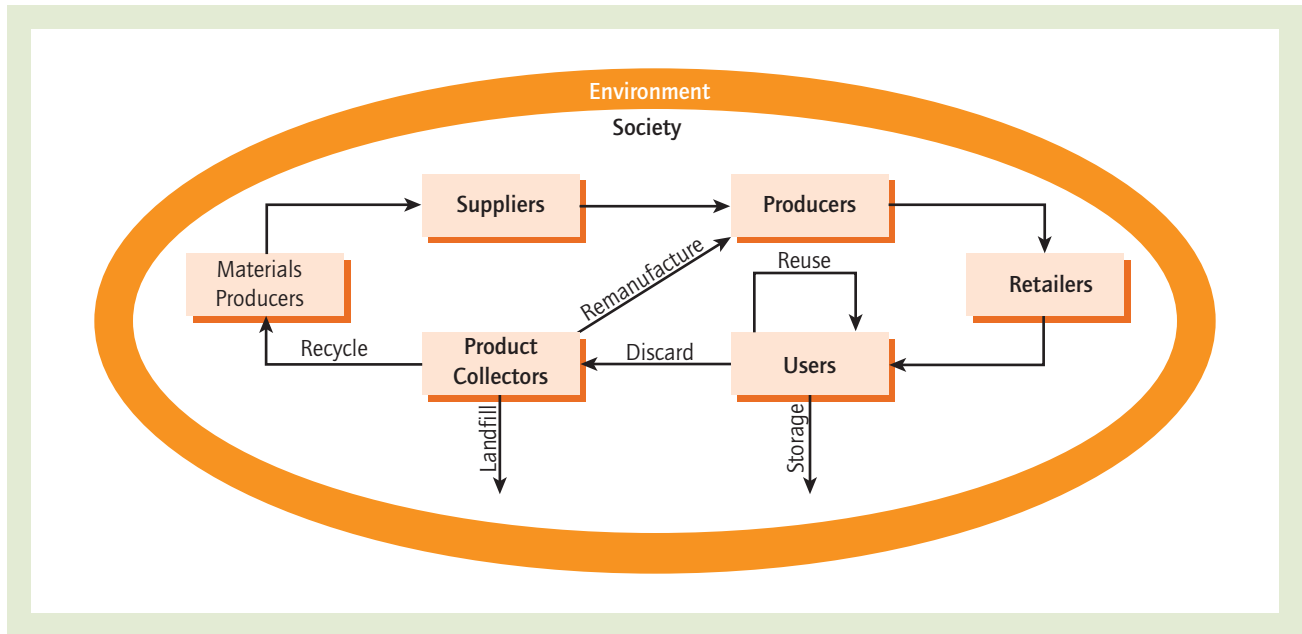


Figure 1 Material and energy flows in a simplified supply chain

Source: Authors.

more than manufacturing. Through the lens of sustainability, production can be viewed as a supply, value, or commodity chain that includes many actors and flows of resources. A life cycle view of production aids the formulation and implementation of policies and practices based on geographical, demographical, and sustainability concerns.

Supply Chains

A supply chain considers the relative location and capabilities of all stakeholders involved in the creation of a product. Typically, a supply chain is thought of as moving linearly forward between material processors, suppliers, manufacturers, distributors, retailers, and consumers. A supply chain may include reverse flows of discarded goods from consumers to collectors that take back, disassemble, and reuse the products. For sustainability, supply chains are considered as closed loops of material and energy flows through society and the environment that ultimately are conserved. Figure 1 depicts a simplified supply chain, where the arrows represent material and energy flows, which are labeled for reuse processes. No matter how processing for production or reuse rearranges materials and energy, by conservation laws, the

sum total of resources remains the same within society and the environment.

Value Chains

The value chain evaluates the remaining value of a product at different points in the supply chain. Product value may not correspond to ownership of the physical artifact but rather to its use, which has led to the development of services and product service systems to deliver value to consumers (e.g., auto leasing).

Commodity Chains

Commodity chain analysis studies the relationships between stakeholders and the steps involved in creating or delivering commodities (e.g., bananas) to consumers. The commodity chain evaluates social relations by financial transactions between actors, steps that increase commodity value, and methods of delivery. Analysis considers details such as commodity origin and destination; cost functions of steps; delivery by load, method, and supplier through particular hubs; regulation of commodities and transport; and value flows.



Life Cycle View

A product life cycle view considers all stages of product life, generally including materials extraction, production, manufacturing, use, and product recovery (or disposal). This final stage is also referred to as product end of life, end of use, or retirement. Product end of use and retirement convey the notion that products should be recovered to conserve materials within society and the environment, supporting sustainability goals. Life cycle assessment can be used to contrast the material and energy flows between products with comparable functions for all life cycle stages.

Each framework's view on material, energy, and monetary flows provides a unique approach to defining production, including a wider range of actors and steps than for processing alone. Additional sustainable production efforts address a wider range of stakeholders affected by production.

Sustainable Production Efforts Throughout the Supply Chain

Improving sustainability across the supply chain involves choices about supplier selection, logistics management, facility construction, and product end of life. Corporate social responsibility (CSR) encourages companies to work for the common good in terms of how products are made and sold and who profits. For example, Timberland, a footwear and apparel producer, established an annually assessed code of conduct for suppliers that requires fair treatment of workers and environmental performance improvement.

Logistics Management

Logistics management improves sustainability by reducing the need for and the impacts of transportation. "Going local" promotes procurement of materials, suppliers, labor, and products in the communities where businesses reside to keep economic flows within those areas and to reduce environmental impacts from transportation. Optimizing logistical networks can reduce transportation distances by locating operations near key supply chain partners (e.g., material processors, distribution hubs, or end consumers) or transporting goods in the largest loads possible. Choosing cleaner

transportation methods, as Peace Coffee, a fair-trade coffee roaster that delivers products to customers by bicycle and biodiesel-fueled vehicles, has done, reduces environmental impacts.

Facility Construction

Factories, warehouses, offices, and other supply chain buildings have impacts. Constructing new facilities on polluted sites, termed *brown-fields*, reduces the social and environmental impacts of production on communities and the environment. The U.S. Green Building Council created the Leadership in Energy and Environmental Design Green Building Rating System (or LEED standards) in 2000 to promote the use of environmentally friendly materials and energy efficiency in the construction, renovation, and operation of buildings.

Product End-of-Use Options

Much attention focuses on product end-of-use and reuse options, which add reverse flows to the supply chain and contribute to sustainable production. Product collectors recover retired products for reuse, repair, remanufacturing, or recycling. Remanufacturing inspects and repairs or replaces components to create a product of comparable quality with newly manufactured products. Recycling creates material inputs for production by separating, breaking down, and processing the materials embodied in discarded products. Discarded products that can be easily disassembled facilitate recovery and reuse. Design for disassembly guidelines assist in defining product structures that allow for nondestructive, efficient separation and reuse of product materials and components. Additionally, reverse logistics pose challenges for product reuse. Take-back systems, such as those in use in Germany, encounter difficulties in reaggregating products, dispersed to customers throughout markets, back to centralized locations. The burden of returning retired products is often placed on users, who may choose to store or discard the products, thus arresting the flow of energy and materials.

*Abigail R. Clarke-Sather, Timothy L. Jenkins,
Karl R. Haapala, and John W. Sutherland*



See also Carbon Trading and Carbon Offsets; Commodity Chains; Environmental Impact Assessment; Fair Trade and Environmental Certification; Green Building; Green Design and Development; Industrial Ecology; Sustainability Science; Sustainable Agriculture; Sustainable Cities; Sustainable Development; Sustainable Development Alternatives; Sustainable Fisheries; Sustainable Forestry

Further Readings

- Allen, D. T., & Shonnard, D. R. (2002). *Green engineering: Environmentally conscious design of chemical processes*. Upper Saddle River, NJ: Prentice Hall.
- Anastas, P. T., & Williamson, J. C. (2000). *Green chemistry: Theory and practice*. New York: Oxford University Press.
- Brezet, H., & van Hemel, C. (1997). *Ecodesign: A promising approach to sustainable production and consumption*. Paris: United Nations Environment Programme.
- DeVor, R. E., Chang, T. H., & Sutherland, J. W. (2007). *Statistical quality design and control: Contemporary concepts and methods* (2nd ed.). Upper Saddle River, NJ: Pearson/Prentice Hall.
- Feld, W. M. (2000). *Lean manufacturing: Tools, techniques, and how to use them*. Boca Raton, FL: St. Lucie Press.
- Hawken, P., Lovins, A. B., & Lovins, L. H. (1999). *Natural capitalism: Creating the next industrial revolution*. Boston: Little, Brown.
- McDonough, W., & Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things*. New York: North Point Press.
- Vogel, D. (2005). *The market for virtue: The potential and limits of corporate social responsibility*. Washington, DC: Brookings Institution Press.

stand-ins for something, whether material (as in the case of places) or not (as in the case of the dove of peace or the Nazi swastika). Indeed, places are intrinsically symbolic, since places are, by their very nature, a part of space with meaning.

Geographers have long been interested in symbolic places and how symbols represent places. The Parthenon represented the birthplace of democracy in ancient Greece as, among U.S. citizens, the Liberty Bell may stand for independence from England. Paris and France may be symbolized by the Eiffel Tower, and St. Louis, Missouri, may be symbolized by its Arch. After the destruction of the World Trade Center, when New York City lost one of its significant symbols, an element in the debate about what would replace it involved the issue of whether to combine the symbolism of New York's dominance with memorialization of the victims of the terrorist attack.

Humans have imbued features of the natural as well as the built environment with symbolism. Ayers Rock in Australia, the San Francisco Peaks of Arizona, and Shaman's Rock in Baikal all have symbolic value to indigenous peoples, sometimes representing the domain of the gods or sacred space. The built environment of most cultures is replete with such sacred symbols—the medieval cathedral, the mosque, pilgrimage sites, and graveyards. Many countries are also imbued with symbols of the state, whether the mega blocks of Soviet communism or the Greco-Roman town hall of many small towns in the United States. Perhaps most pervasive in the newer built environments worldwide are symbols of the power of Mammon. As others have shown, the rich are more able to imprint their symbolism in places than are the poor.

The purposeful construction of buildings intended to be symbols has accelerated since the late 20th century; indeed, the millennium itself was intended to be symbolized in Britain by the eponymous Millennium Dome, a project characterized by cost overruns, delays, and rapid obsolescence. The Renaissance Center was built to symbolize Detroit's emergence from a dark age of urban distress. The world's tallest buildings, including Malaysia's Petronas Towers, Taipei's 101, the Burj Dubai in the United Arab Emirates, Shanghai's World Financial Center, and Seoul's International Business Center, symbolize



SYMBOLISM AND PLACE

Humans have always used symbols, and archeological evidence suggests that in nearly all societies, including prehistoric ones, particular places have held symbolic significance. Symbols are



When New York City lost one of its significant symbols, the World Trade Center, on September 11, 2001, an element in the debate about what would replace it involved the issue of combining the symbolism of New York's dominance with memorialization of the victims.

Source: Markus Seide/iStockphoto.

a never-ending race for superlative height and associated global status. The transformation of Bilbao from working industrial port to leisure destination is symbolized in Frank Gehry's Guggenheim Museum Bilbao, while each symbol of Dubai's conspicuous consumption outdoes its predecessors—from the Burj Arab to the Palm and World Islands. Sydney's Opera House arguably remains the only globally iconic symbol in Australia's built environment. Beijing's "bird's

nest" stadium reflected the aspiration that the 2008 Olympics would be a coming-out party for China as a global superpower. The list of recently built and future projects intended to "put a city on the world map" expands with each mega event and burst of capitalistic optimism.

But, of course, place has many scales, and everyday places are small, domestic, and imbued with meaning and symbolism. The word *place* derives from the Greek word *plateia*, meaning a square or courtyard surrounded by houses—hence, *piazza* and *plaza*. Places can range in size from a garden allotment with a symbolic scarecrow to a village with its green, a shanty town with legible (if transient) territorial markers, or a city replete with symbols (some copyrighted, such as New York's "I ♥ New York"), to countries (Egypt's pyramids) or perhaps even continents. These symbols are a form of shorthand. As examples of synecdoche, they stand in for the larger place of which they are a part. They may also represent a critical event in history (e.g., the Berlin Wall or civil rights monuments).

Symbolic places may be sites of continued strife and controversy, representing alternative interpretations of reality past and present, as in the case of Jerusalem.

Indeed, when symbolic places are consciously designed and constructed, as in the case of the memorial at the crash site of Flight 93 in Pennsylvania, it would probably be impossible to satisfy conflicting preferences. Symbolic representations in places where atrocities and tragedies have occurred, from Buchenwald to Belfast to Salem to Sebastopol, frequently have multiple and conflicting meanings or interpretations to both locals and visitors and to subgroups among them.



Ayers Rock in Australia is sacred to the Aboriginal people of the area.

Source: Morguefile.

Vernacular residential landscapes are encoded with conventional signs of social status and group membership legible to neighbors and outsiders. The landscape of privilege in high-income suburbs brims with the symbolism of class and exclusion. Lot size, architectural type, decorative detail, and even horticultural plantings symbolize the status of residents and broadcast messages of belonging or repulsion. Ethnic neighborhoods of American cities are usually easily recognizable by symbols even in the absence of their inhabitants. A Katrina-devastated small town in Louisiana may symbolize home and hope to some while simultaneously signaling governmental failure and global climate change to others. The symbolism of place is often in the eye of the beholder, as Dolores Hayden convincingly demonstrated, although she also rued the relative paucity of public memory in the urban landscape related to women and other marginalized groups.

Although some argue that symbols cannot be produced intentionally but rather are “organic,” in that they grow and decline as social meaning attaches to them, the contemporary marketing industry disagrees with that assumption, and certainly place marketing takes symbolism very seriously. Places lacking symbolic capital—that is,

that are absent from mental maps or are vague in the public psyche—must build or buy symbols that imprint in the minds of potential tourists, residents, and investors. Places unlucky enough to possess negative mental vibes must invest particular effort in metamorphosing their symbolic imagery. Slough, an industrial town west of London, was unlucky enough to be the target of a poet laureate (John Betjeman’s “Come Friendly Bombs and Fall on Slough”) in 1937 and is still defending itself against the slings and arrows of adverse publicity. Other locations, such as Tiananmen Square in Beijing, undergo refurbishment to fit the newly desired image. Places, of course, gain symbolic freight both from their material landscape and from the events that transpire in them. The government of China hoped that the Olympic celebrations of 2008 would subsume the events of 1989 in its most symbolic public space. But for most locations, changing the physical and/or psychic imagery to attract people and capital is a preoccupation that is generating a new profession—place marketing—and transforming (particularly urban) landscapes into places dressed to impress.

Briavel Holcomb



See also **Architecture and Geography; Art and Geography; Cosgrove, Denis; Cultural Landscape; Folk Culture and Geography; Humanistic Geography; Landscape Architecture; Landscape Interpretation; Literature, Geography and; Mental Maps; Phenomenology; Photography, Geography and; Place; Place Promotion; Representations of Space; Sense of Place; Vernacular Landscapes as Expressions of Environmental Ideas**

Further Readings

- Adams, P., Hoelscher, S., & Till, K. (Eds.). (2001). *Textures of place: Exploring humanist geographies*. Minneapolis: University of Minnesota Press.
- Duncan, J., & Duncan, N. (2004). *Landscapes of privilege: The politics of the aesthetic in an American suburb*. New York: Routledge.
- Foote, K. (2003). *Shadowed ground: America's landscape of violence and terror*. Austin: University of Texas Press.
- Hayden, D. (1995). *The power of place: Urban landscape as public history*. Cambridge: MIT Press.



SYMPTOMS AND EFFECTS OF CLIMATE CHANGE

Long-term changes in the atmospheric concentration of greenhouse gases—notably carbon dioxide (CO₂), methane, and nitrous oxide—due to human activities has altered the radiative forcing of the atmosphere and its energy balance. The physical impacts of these disruptions, known collectively as climate change, are varied but present across the globe. Due to the central importance of the atmosphere in all global environmental cycles, the symptoms and effects of climate change are potentially present anywhere on Earth. Study of these issues requires practitioners to maintain a holistic view of global biogeochemical interactions. The primary feature of climate change effects, as increased energy is expressed in the

atmosphere, is less predictability and greater oscillations in environmental system behavior.

Air Temperatures

Globally measured surface temperatures have increased rapidly since 1979. Generally, the temperature increases are more severe at higher latitudes, as the atmosphere moves excess energy poleward. The warmest years in the instrumental record (extending back to 1850) are 2005, 2007, 1998, 2002, 2003, and 2006. However, temperature increases are not uniform, because of changes in atmospheric circulation and localized effects such as urbanization. These local processes are accounted for in global temperature change calculations and are not the cause of the documented global temperature increase.

Warming air leads to greater occurrence of heat waves; this trend is most pronounced in the polar regions (averaging twice the rate of lower latitudes) and becomes less evident toward the equator. Extreme high temperatures affect older or stressed organisms because the cardiovascular system must work so much harder to regulate temperature. While warmer winter temperatures have led to reduced death rates during the colder months, the increase in summer deaths far outweighs that reduction. These trends have been documented in human populations across the world and in multiple animal species as well. Warmer winter and nighttime average temperatures also mean decreased frost risk, changes in snowfall, and changes in the length of the growing season.

Ocean Changes

Global sea level has risen by more than 3 millimeters per year in the past decade, and it is uncertain if this rate will remain constant or increase. Sea-level rise is caused by oceanic thermal expansion and the melting of the world's ice caps and glaciers. As the majority of the world's surface is covered by water, warmer air temperatures are warming the ocean as well. However, due to the high heat capacity of water and the layered nature of the ocean, with little mixing of surface and deep water, ocean warming is a slow process that will occur over the next century-to-millennia time-frame. If temperatures stabilized today, the ocean



would continue warming for hundreds of years as deep-water mixing slowly occurs. Deep-ocean measurements have measured steady temperature increases throughout the world's ocean basins.

Warmer water is less dense than cold water, and thermal expansion of water has led to increasing sea-level rise. An increase in water temperature also lowers the ability of water to retain dissolved oxygen and carbon dioxide (CO_2), so that biological systems are stressed due to less oxygen for fish and other organisms and warm water releases even more CO_2 into the atmosphere. However, increased freshwater flow from melting glaciers in Greenland and other locations will lower ocean salinity in the high latitudes at areas of ocean multilevel mixing. Lower salinity allows water to absorb more CO_2 . This may be sufficient to offset CO_2 release from ocean warming in other areas but will lead to increased acidification of the oceans.

CO_2 reacts with water to form carbonic acid (used in carbonated beverages), which has a detrimental impact on calcium carbonate (sea shells) as it dissolves them and weakens their structure. Current models estimate pH being lowered to acid levels not seen for millions of years—which will have a catastrophic impact on corals and other calcium carbonate-shelled organisms. Changes in ocean circulation patterns could drastically alter the regional nature of these impacts.

While natural variability makes it difficult to determine trends, the intensity of tropical ocean storms—called hurricanes (Atlantic Ocean), typhoons (Pacific Ocean), and cyclones (Indian Ocean)—has increased, as measured by the Power Dissipation Index (PDI) in recent decades. The PDI is proportional to wind speed cubed and is highly correlated to temperature. While the number of tropical cyclones may or may not be increasing (this is difficult to determine due to the short record of data), the PDI is unequivocally increasing. The number of storms is less critical than the size of the storms because the nonlinear nature of storm damage (damage is correlated to the cubed power of wind speed) means that one severe storm may cause far more damage than several smaller storms put together. Increased El Niño activity has been posited by some studies, but results to date have been inconclusive. However, El Niño events disrupt hurricane formation

because of wind shear effects that do not allow hurricane vortices to form. A better understanding of El Niño and climate change effects is critically needed for long-term planning purposes.

Changes in the Hydrologic Cycle

As climate impacts are expressed throughout the system, changes will be most amplified by extreme events. Increases in moderate to heavy precipitation events in the midlatitudes are the best documented of recent changes. Evaporation and transpiration from plants is accelerated under warmer air temperatures and increasing atmospheric moisture content. Increases in atmospheric water vapor have been observed in recent decades, as every increase in atmospheric temperature of 1 degree Fahrenheit allows air to hold 4% more water vapor. A warming ocean combined with higher evapotranspiration leads to an accelerated hydrologic cycle. These factors interact to paradoxically create both increased drought and increased precipitation. Drought impacts are widespread, as the entire land surface heats and dries, while storm events are local-scale phenomena. Increased frequency of extreme daily rainfall has been documented and is coupled with an overall decline in the number of days with precipitation, so that there is heavier rainfall during a shorter period of time but more rarely than before. A major impact of increased continental drought is an increase in desertification—notably in the Sahel of Africa, in China, and in Australia.

Fires

Forest fires are affected by three major factors—fuel load, ignition agents, and weather. Climate change perturbations to natural systems increase fire risk in all three areas. Warmer temperatures mean longer growing seasons in boreal forests and more fuel production. Frequent storms lead to lightning ignition. Most important, climate change has caused increasing drought and hotter daytime temperatures, which correspond to more violent fires. Increases in fire frequency and extent have been documented in North America, Africa, and Australia. As fires increase in extent, they release the terrestrial stored carbon; this is a



positive feedback cycle, increasing the effects of climate change.

Ice Sheet and Glacier Impacts

The most visible impact of climate change has been changes in the Earth's cryosphere as ice melts globally under warmer temperature—especially in the polar regions. Greenland and Antarctica hold a substantial portion of the Earth's freshwater, and both of these areas have seen unprecedented changes in recent years. Decreases in the Greenland and West Antarctic ice sheets have been accelerating, and these two bodies of ice have sufficient stored-water volumes to raise the sea level by more than 10 m (meters) if both would melt completely. The East Antarctic ice sheet contains far more water and fortunately is currently stable. However, the dynamics of glacier retreat rates are not well understood, as conditions are changing in ways unprecedented in scientific history. A major uncertainty is how the meltwater below glaciers acts to speed their movements. Glacial speeds have dramatically increased in the past few years (especially in Greenland), and the recent Intergovernmental Panel on Climate Change (IPCC) assessment (AR4) noted that calculating future sea-level rise is speculative until these uncertainties can be better parameterized.

Globally, the vast majority of smaller glaciers are retreating, for example, in the high Himalayas, in the Andes, in Patagonia, and in Alaska. Mountain glaciers retreat has multiple additional impacts beyond sea-level rise. The impacts include increases in river volumes, more frequent flash floods, and increased risk of catastrophic floods from high-mountain glacial lakes. Once the upper-elevation glaciers have melted, there will be an increasing collapse in late-summer river volumes, as there is no more glacial melt available to supply rivers (and cities) in the dry season. River flows have also been measured to be peaking earlier in spring due to earlier snowmelt.

Sea ice extent in the Arctic decreases roughly 3% per decade, with higher shrinkage rates (about 7%) during summer, according to the IPCC AR4. This decrease is accelerating and is driven by a positive feedback mechanism that amplifies melting. The white surface of sea ice is highly reflective, and 80% to 90% of the sunlight reaching

the surface can be reflected without warming the system. This energy is thus lost. As sea ice retreats, dark blue water is exposed to sunlight. This dark water captures nearly all this energy, and the warmed water in turn melts more ice. Sea-ice extent and thickness have been decreasing at roughly 10% per decade since the 1970s.

The reduction in global ice volumes, however, is not universal. Ice volume is controlled both by loss due to melting or calving and by deposition from snow. A limited number of glaciers globally have increased in volume due to increased snowfall overwhelming the increased melting rates.

Biogeographical Impacts

Warming temperatures mean milder winters and earlier spring thaws. This results in a longer growing season and favors different plant species. Changes in phenology have been documented across the Earth, and 90% of these changes are consistent with temperature rise, including earlier spring blooming. These factors favor allergenic pollen-producing plants, and pollen counts have increased globally. Overall, it is estimated that Northern Hemisphere plants may rise 500 m or more in elevation and/or shift poleward more than 300 kilometers if dispersal corridors are available.

Cold winter temperatures are a major deterrent to insect population growth, and recent warming has increased the ranges of most insects, including mosquitoes and agricultural pest insects. Tropical infectious disease occurrence has exploded globally as human populations grow and temperatures warm. Disease occurrence is limited to regions where their vectors, such as mosquitoes or ticks, are able to thrive. *Anopheles* spp. and *Aedes aegypti* are two mosquito species responsible for the spread of malaria and other major tropical diseases. They have established temperature thresholds for survival, and the viruses/parasites within them have incubation periods that are also affected by temperature. As disease vector habitat increases because of warmer temperatures, diseases are expanding their range—especially in tropical highland areas that had previously provided refuges for populations from Papua New Guinea to Kenya. According to the World Health Organization, 30 new diseases have emerged worldwide since 1980.



Climate dictates the general range of vectors, while weather affects the timing and intensity of specific disease outbreaks. Climate change is creating more weather events that lead to longer and more sustained disease outbreaks. Moisture availability is also a limiting factor for vector survival, and the changes in the hydrologic cycle noted above have led to more frequent storm events, creating the stagnant water necessary for mosquito propagation.

Warmer winter temperatures are having a similar impact on agricultural and forest pest insects. Millions of acres of timber in Canada have been lost to beetle outbreaks due to the warm winters over the past decade. Agricultural fields have seen major shifts and increases in pest insects globally on account of less frost and fewer cold nights. This is a dynamic process that has had inadequate research, and so the long-term effects are not well understood. Based on reproductive rates, white flies, locusts, and aphids have been found to be especially responsive to rapid changes in weather and climate.

Overall, the IPCC AR4 report cites 29,000 observational data series that show change in environmental and biological systems. Nine out of 10 of these data show an increase in warming consistent with anthropogenic climate change.

Most of these data are from the higher latitudes and more industrialized countries. Further research in the tropics may yield additional symptoms and effects of climate change.

John All

See also [Adaptation to Climate Change](#); [Anthropogenic Climate Change](#); [Biota and Climate](#); [Climate Change](#); [Climate Policy](#); [Desertification](#); [Drought Risk and Hazard](#); [El Niño](#); [Global Sea-Level Rise](#); [Social and Economic Impacts of Climate Change](#); [Urban Heat Island](#)

Further Readings

- Intergovernmental Panel on Climate Change. (2007). *Climate change*. Cambridge, UK: Cambridge University Press.
- National Research Council. (2001). *Climate change science: An analysis of some key questions*. Washington, DC: National Academies Press.
- U.S. Global Change Research Program. (2001). *Climate change impacts on the United States*. Cambridge, UK: Cambridge University Press.



TAPHONOMY

Taphonomy is a multidisciplinary, multitasking body of knowledge that studies the processes affecting organic remains after death—that is, the transition of these remains from the biosphere into the lithosphere. Taphonomic studies are key to paleobiology, paleontology, archaeology, geology, and geography, among other disciplines, as they impinge directly on our capacity to reconstruct paleoenvironments and past biotas. They do so by understanding the postmortem processes on biological materials and how they affect the fossil record—broadly defined as the set of non-living remains and traces of organisms—and the information therein.

The term *taphonomy*, from the Greek *taphos* and *nomos* (the “laws of burial”), was coined by Ivan Efremov in 1940, although such inquiries had been carried out well before, notably by German paleontologists in the late 19th and early 20th centuries. These researchers focused primarily on paleoenvironmental reconstruction, while Efremov and others emphasized information loss and biases introduced in the fossil record. Other researchers, especially after the input by Anna Behrensmeyer, Susan Kidwell, and Diane Gifford, have focused on the “positive” contributions of taphonomy as well. These emphasize the preservation of the fossil record and the paleoecological

and paleobiological information contained in the signatures of the processes that have affected it through time. Moreover, all the recycling pathways of biologically derived materials are informative to taphonomic enquiry.

The processes affecting organic remains from death to final burial, such as carnivore scavenging of vertebrate carcasses, are different from those occurring from final burial until recovery, as is the case with mineral replacement in different organic remains. The former are known as biostratinomy and the latter, as diagenesis, and both constitute taphonomy. On infrequent occasions, as in the case of severe floods and catastrophic death, rapid burial of organisms lead to large concentrations of exceptionally well-preserved fossils, known as fossil *lagerstätten*.

Taphonomists study both direct and indirect evidence—that is, not only the organic remains themselves but also the traces of different organisms, such as the tooth marks of a predator on bones or a leaf imprint on a sedimentary matrix. These traces or signatures of activity by an organism are also known as ichnofossils and commonly inform us of the interactions with its environment. Finally, they study the geological context where the fossils and traces are deposited as well.

To understand and interpret all these lines of evidence, taphonomic principles are needed. As in other historical sciences, the most powerful



strategy for doing so is actualism—that is, the study of contemporary, observable taphonomic processes producing effects analogous to those observed in the fossil record, and their causes. This strategy has been key in taphonomy since the German *Aktuopaläontologie* (invertebrate) program in the early 20th century. Observing present-day processes and their contexts links causes and effects, thereby generating models that can be applied to the fossil record by analogy. In some cases, experiments can help understand the effects of some processes as well. Such studies require assuming that the processes operating in the past are essentially the same as those operating in the present, although their rates and configurations and their interactions may well have changed through time. This methodological assumption is called uniformitarianism.

Another important strategy is the comparative method, namely, the comparison of different fossil records, which allows considering processes at a larger scale of operation. Deductions from general models and strong links among different lines of evidence complement both strategies.

All these approaches allow reconstructing and interpreting the taphonomic histories of different fossils. It should be noted that each specimen—that is, an individual organic remain or trace—has its own history, which can differ from that of other specimens in the same assemblage. Some variables, such as morphological and qualitative ones (e.g., chemical alterations), are monitored on each specimen. Other variables, though, such as the quantitative and contextual ones (e.g., the spatial relationships among different specimens), can only be assessed at the assemblage level. Therefore, analysis always begins at the specimen level, while fossil assemblages, with their specific properties—such as specimen arrangement, statistical trends in specimen properties, and the paleoecological information they bear—turn out to be the main unit of analysis and comparison. The geological context bearing the assemblages provides important, independent evidence as well that helps infer the taphonomic history of the fossil record, for instance, by shedding light on the accumulation processes that concentrated the fossils under study. All these lines of evidence can be

integrated at the landscape level so as to interpret taphonomic patterns and processes at a regional scale.

A more general approach considers taphonomic modes, which encompass fossil records resulting from similar processes (physical, chemical, and biological), involving similar preservational contexts. Hence, different taphonomic modes are characterized by different biases. Changes through time in taphonomic modes would thus generate megabiases.

One particular taphonomic mode is archaeological accumulations, where humans are the main taphonomic agents. These can be isolated or can even modify whole landscapes, as in the case of shellmound concentrations in coastal Brazil and Uruguay. Humans can not only be taphonomic agents but also the subject of taphonomic processes, as has been studied by forensics and paleoanthropology, two disciplines where taphonomy is also central.

It is the multidisciplinary nature of taphonomy, whereby very different questions are posed at varying scales, that contributes to the richness of this research field.

A. Sebastián Muñoz and Mariana Mondini

See also **Biota and Climate; Environmental History**

Further Readings

- Allison, P. A., & Briggs, D. (Eds.). (1991). *Taphonomy: Releasing the data locked in the fossil record*. New York: Plenum Press.
- Behrensmeyer, A. K., Kidwell, S. M., & Gastaldo, R. A. (2001). Taphonomy and paleobiology. In D. G. Erwin & S. L. Wing (Eds.), *Deep time: Paleobiology's perspective*. *Paleobiology*, 26(Suppl. to No. 4), 103–147.
- Gifford, D. P. (1981). Taphonomy and paleoecology: A critical review of archaeology's sister disciplines. In M. B. Schiffer (Ed.), *Advances in archaeological method and theory* (Vol. 4, pp. 365–438). New York: Academic Press.
- Lyman, R. L. (1994). *Vertebrate taphonomy*. Cambridge, UK: Cambridge University Press.



TAYLOR, GRIFFITH (1880–1963)

Thomas Griffith Taylor was an important figure in early-20th-century geography as an advocate of the doctrine of environmental determinism and social Darwinism.

British by birth, his family moved to New South Wales, Australia, when he was a young teenager. He earned a BSc at Sydney and returned to Cambridge for his BA. Trained in engineering, geology, and meteorology, he was selected from 7,000 applicants to serve on Robert Scott's ill-fated Antarctic Terra Nova Expedition in 1911, focusing on that continent's influence on Australia. He led a second expedition there later that year and drew some of the first maps of that continent. On his return to Australia, he assisted with the survey of the site for the new federal capital, even suggesting the name Canberra (of Aboriginal significance). He founded the New South Wales Geographical Society and was the founding editor of the journal *Australian Geographer*. In 1911, he published *Australia in Its Physiographic and Economic Aspects*. He earned a doctorate in geology from the University of Sydney in 1916, using his Antarctic research for his dissertation, and 4 years later, he became the founding head of that institution's geography department, Australia's first, and the McCaughey professor.

Taylor soon became known for his controversial support for environmental determinism, which he liberally laced with racism. He consistently advocated pseudoscientific notions that intelligence was correlated with skin color or the shape of skulls. Justifying the white conquest of the continent as an inevitable result of white racial superiority, he consistently portrayed Australia as too dry and harsh for the large numbers of immigrants seeking entry, in opposition to the boosterist "Australia Unlimited" school of thought. Taylor emphasized the region's limited carrying capacity, arguing that it was essentially a desert capable of supporting no more than 20 to 30 million people, and he was often criticized for an overly pessimistic reading of the continent's economic potential and population limit. His textbook espousing this view was banned in some school districts.

From the specific instance of Australia, he began to generalize to the wider world, theorizing links between race, nationality, migration, and climate. His major work on this topic was *Environment and Race* in 1927, which was widely read and translated into several languages. In *Australia: A Study of Warm Environments and Their Effect on British Settlement*, published in 1940, he put forth the opinion that the optimal course for a country to follow is dictated by the natural environment and that human deviations from this trajectory inevitably led to lower levels of social and economic development.

Frustrated by the university's denial of promotion, he left Australia to become professor of geography at the University of Chicago in 1929, and in 1935, at the initiative of the famed economist Harold Innis, he left for the University of Toronto, where he founded the geography department and remained until 1951. In 1941, he became president of the Association of American Geographers, the first non-American to hold that post; later, he was also elected president of the Canadian Association of Geographers. Over his career, he published 20 books, including his autobiography, *Journeyman Taylor*, and roughly 200 journal articles. After retirement, he returned to Australia, where he became a hero to those opposed to nonwhite immigration, and in 1959, he became president of the Institute of Australian Geographers. He died in 1963 and was cremated.

Barney Warf

See also Environmental Determinism; Race and Racism; Social Darwinism

Further Readings

- Powell, J. (1990). Taylor, Thomas Griffith (1880–1963). In J. Ritchie (Ed.), *Australian dictionary of biography* (Vol. 12, pp. 185–188). Melbourne, Victoria, Australia: Melbourne University Press. Retrieved November 23, 2009, from www.adb.online.anu.edu.au/biogs/A120206b.htm
- Rose, J. (1964). Griffith Taylor, 1880–1963. *Annals of the Association of American Geographers*, 54, 622–629.



- Sanderson, M. (1988). *Griffith Taylor: Antarctic scientist and pioneer geographer*. Ottawa, Ontario, Canada: Carleton University Press.
- Strange, C., & Bashford, A. (2008). *Griffith Taylor: Visionary, environmentalist, explorer*. Melbourne, Victoria, Australia: National Library of Australia.



TAYLOR, PETER (1944–)

Peter J. Taylor is one of the most prominent contemporary human geographers. Born in England in 1944, he earned his BA (1966) and PhD (1970) from the University of Liverpool. His record of scholarship spans more than 40 years and currently includes more than 300 publications, some of which have been translated into as many as 23 different languages. Taylor has contributed to a range of subdisciplines within human geography, most notably in political and urban geography. Indeed, Taylor is recognized as a key figure in the development of political geography as a thriving subdiscipline and is a founding editor of the journal *Political Geography*.

While his contributions to political geography are myriad (indeed, the limited space afforded here cannot adequately do justice to them), he is perhaps best known for integrating world-systems analysis with political geography. His interest in world-systems analysis began as he sought to incorporate political economy into political geography, a subdiscipline he once critiqued as ironically being the most “apolitical” component of human geography. Taylor’s emphasis on world systems opened new spaces for critically assessing and modeling global interstate relations within the context of global cores and peripheries. This project in many ways demystified the development of the modern nation-state as a “container” of social, economic, and cultural forces, on the one hand, and the global liberalization of trade in recent decades known as globalization, on the other. Most recently, Taylor has further used a world-systems approach to investigate global structures of capital flows, contributing to understandings of the rise, and functioning, of “world cities” as command centers of global capital.

These two-tiered thrusts of research—global interstate relations and world cities—coincide with an earlier call by Taylor to reconsider prevailing notions of scale. Taylor proposed that scale be reconceptualized as encompassing three interlocking or interconnected realms: (1) a realm of everyday experience occurring at the level of the “urban,” (2) a realm of ideology encompassing the nation-state, and (3) a universal level of the capitalist world economy in which the previous two are situated. While this scalar hierarchy of realms has come under critical reassessment in recent years, Taylor is credited with launching an important and ongoing debate that has deepened and nuanced a concept of scale that was often akin to cartographic scale and was otherwise taken for granted among human geographers.

Mark de Socio

See also **Political Geography**; **World Cities**; **World-Systems Theory**

Further Readings

- Beaverstock, J., Smith, R., & Taylor, P. (1999). A roster of world cities. *Cities*, 16(6), 445–458.
- Beaverstock, J., Smith, R., & Taylor, P. (2000). World city network: A new metageography? *Annals of the Association of American Geographers*, 90(1), 123–134.
- Taylor, P. (1982). A materialist framework for political geography. *Transactions of the Institute of British Geographers*, 7(1), 15–34.
- Taylor, P. (1994). The state as container: Territoriality in the modern world-system. *Progress in Human Geography*, 18(2), 151–162.
- Taylor, P. (1995). Beyond containers: Internationality, interstateness, interterritoriality. *Progress in Human Geography*, 19(1), 1–15.
- Taylor, P. (2000). World cities and territorial states under conditions of contemporary globalization. *Political Geography*, 19(1), 5–32.
- Taylor, P. (2001). Specification of the world city network. *Geographical Analysis*, 33(2), 181–194.
- Taylor, P. (2002). Measurement of the world city network. *Urban Studies*, 39(13), 2367–2376.



TECHNOLOGICAL CHANGE, GEOGRAPHY OF

Technological change is a direct driver of economic growth. New technologies allow societies to produce existing goods more efficiently and also open up entirely new and previously unimagined possibilities. It was technological change that largely eliminated the persistent cycles of famine and overpopulation that plagued humanity before the Industrial Revolution. Since that time, technology has facilitated an unprecedented expansion of standards of living. Simply put, current incomes as well as levels of health and amounts of leisure time for many people, particularly in the First World, are dramatically better than they were as recently as 150 years ago, and in many ways technological change is largely responsible.

Nonetheless, not everyone has made use of technology as well as today's developed economies. Great disparities in per capita income and other measures of well-being divide developed from developing economies, and technology's uneven geography is central to understanding why this remains so. Moreover, the geography of technological change has important implications for the changing shape of the increasingly interconnected global economy.

Technology: A Unique Component of Production

The word *technology* typically describes a material item, such as an oven or a computer. Academics, however, define technology differently—that is, as the set of rules and ideas that direct the production of an oven, computer, or other economically meaningful products. Under this definition, a technology is like a recipe used in the kitchen. A given technology will call for raw or semifinished materials as ingredients. To carry out the recipe and create a finished product, people apply their skills (human capital), tools (physical capital), and labor. Among these required components, capital, labor, and raw materials are all mostly privately held. Technology, however, bears some resemblance to a public good.

Two characteristics distinguish public from private goods: nonrivalry and nonexcludability.

To grasp technology's quasi-public nature, consider computers, mobile phones, and other electronic devices that contain semiconductors. Semiconductors in turn are the product of a particular set of rules and ideas about electrical conductivity. Like all technologies, the ideas that permit the building of semiconductors are nonrivalrous, meaning that one person's sharing the recipe for semiconductors with another will not diminish the owner's knowledge of it (unlike, say, sharing a private good such as a sandwich, which leaves less for the owner). The technology is also at least partially nonexcludable: It is hard for the owner to prevent another from learning about semiconductors, such that the acquirer might employ them for his or her own gain.

If technologies were "pure" public goods, a new and better semiconductor design created in one location would be immediately, costlessly, and universally available. Entrepreneurs in Paris and Bengaluru could instantly apply the electronic innovations that researchers produced in San Jose. Technology would be without meaningful geographical dimensions because of its perfect nonexcludability. Do we live in that kind of world? One way to answer this question is to compare countries' overall technology levels. Researchers often estimate levels of technology using "total factor productivity" (TFP), which accounts for the efficiency with which an economy or industry combines its factors of production. Simply, an economy with higher TFP can produce more output with less input because its deployment of technology is more sophisticated. TFP is not a perfect measure of technological sophistication, since nontechnological factors might cause these efficiency differences, but it is the most widely accepted indicator available. Table 1 shows TFP levels as ratios to the U.S. level for a handful of economies. Note the large gap between the United Kingdom and India. The United States, Italy, France, and the United Kingdom have productivity levels that are roughly comparable with one another. But each is between four and seven times the level of productivity enjoyed by India, China, Kenya, and Zaire. By this measure, rich countries are much more technologically advanced than poor countries, and these large differences remain even when we control for differences in the kinds of goods that



Country	TFP
United States	1.000
Italy	1.207
France	1.126
United Kingdom	1.011
India	0.267
China	0.106
Kenya	0.165
Zaire	0.160

Table 1 Total factor productivity (TFP; country/U.S. ratio) for selected countries, 1988

Source: Adapted from Hall, R. E., & Jones, C. J. (1999). Why do some countries produce so much more output per worker than others? *Quarterly Journal of Economics*, 114(1), 83–116.

countries make. For example, even if international productivity levels for a particular industry are compared, rich economies tend to be more productive than poor ones. This kind of evidence suggests that we do not live in a world where technology is a pure public good.

Technology Diffusion

If technology is not a pure public good, then how excludable is it? Since the 1950s, economic geographers have sought to measure the spread of technology among people and across space, an idea commonly termed *technology diffusion*, or *knowledge spillovers*. Some researchers traced the proliferation of individual innovations: Zvi Griliches, for example, conducted a pioneering study of American farmers' adoption of hybrid corn seeds in the early 20th century. Others examined patterns of collaboration between scientists and innovators. In general, these studies confirm that technologies diffuse across space but usually do so slowly and unevenly.

One reason why technologies do not circulate freely is that their creators actively seek to contain them. Innovators typically spend a great deal of time, effort, and expense to produce new technologies, and they want to make sure that they reap the rewards. To protect their intellectual property, they might take out a patent that legally mandates that others must pay to use it. They might also engage in secrecy and other less formal means of protection. Hence, an uneven pattern of

technological diffusion might result from a creator's desire to protect his or her technological investment.

Some studies of innovation suggest a more subtle reason that leads to a distinctive spatial pattern of diffusion. Most new technologies are not produced by lone scientists in dustfree laboratories but rather are the result of collective efforts that span organizations. These collaborations can be legally specified joint ventures, but they also frequently arise from casual interactions. Anna-Lee Saxenian discovered this notion in her study of Silicon Valley in the 1980s and 1990s. She learned that local computer engineers and entrepreneurs exchanged vital information at places such as the Mountain View's Wagon Wheel Bar. Silicon Valley's global technological leadership was constituted as much through these informal information-sharing links as by connections to Stanford University. The resulting social system permitted rapid transmission of ideas and generated specific cultural norms of collaboration and competition that helped propel Silicon Valley's firms to the leading edge of computer technology and to keep them there. Moreover, this system of localized, informal, insider knowledge meant that entrepreneurs in Paris and Bengaluru were in an important sense "locked out" of the conversation by their distance. Without the required geographically localized relationships, they were not privy to the exchange of information, and they lacked the cultural norms to participate.

To understand the importance of being in the right place, consider technologies dependent on two different kinds of knowledge or ideas. Codified knowledge is akin to the kind of recipe found in cookbooks, which contain a well-defined list of ingredients in the right proportions and offer careful instructions on how to combine them. Professional chefs, however—those who *create* new recipes and are responsible for culinary innovations—are more likely to employ tacit knowledge. Their procedures may have some loose structure that can be put down on paper, but they depend on their experience and creativity to fill in the blanks and bring it all together. Tacit knowledge is hard to turn into a blueprint that can be shared with anyone, because it depends on practice, trust, and acculturation. But two skilled chefs working in the same restaurant



might quickly and easily convey the needed information so that they could work together to produce a new dish. Tacit knowledge is often associated with innovation and new ideas, while technologies that have been with us for some time find their knowledge becoming increasingly codified. Some tasks, however, such as the job of a professional chef, demand tacit knowledge that can never be fully codified.

What geographical pattern does the distinction between tacit and codified ideas suggest? Codified technologies can be easily exchanged across space. Producers in one part of the world send rigorously specified blueprints for automobile parts to far-flung global suppliers, and they can reasonably expect the suppliers to closely adhere to the requirements. If a supplier fails, myriad competitors are capable of following the recipe. As a result of this intense competition, the production of products whose technology is fully codifiable is likely to occur wherever the cost is lowest. Codified technologies lead to a lowest-cost geographical pattern.

In contrast, tacit knowledge has a high degree of excludability; only individuals with certain shared characteristics can easily exchange it. This common frame of reference is most often born of repeated face-to-face encounters, such as the ones at the Wagon Wheel. As a result, tacit knowledge is typically produced and held in constrained geographical spaces. In addition to Silicon Valley's technology firms, we can see further evidence of this spatial clustering around relationships, complex tasks, and innovations among investment bankers in London, film and television workers in Los Angeles, and fashion designers in Paris. More systematic evidence emerges from examining patent citations. When someone files a patent for a new technology, he or she must cite the patents of other inventors on which the new invention is based. An inventor might cite patents held by scientists working anywhere in the world. But citations indicate strong geographical patterns: Inventors are most influenced by the work of nearby colleagues. In contrast to codified forms of knowledge, technologies dependent on tacit knowledge are therefore likely to lead to highly clustered geographical forms.

Spatial clustering because of tacit knowledge helps explain why cities exist and grow.

Individuals and firms continue to be drawn to dense urban areas to be "in the know." Urban regions are filled with people interacting face-to-face, exchanging ideas, and building social networks. Even in an age of instant messaging and social networking Web sites, engineers and entrepreneurs brave sky-high real estate prices in Silicon Valley to gain access to the social networks and tacit knowledge it contains.

Knowledge-based geographical clustering is also part of the reason for the large differences in economic well-being. Since technology dependent on tacit knowledge is hard to imitate, its producers are to some extent insulated from the kind of lowest-cost competition facing those using recipes that are more easily codified. In aggregate, this means that those regions and nations where new and complex technologies are being produced will typically enjoy high per capita incomes. In this way, technology's uneven geography leads to disparities in people's standards of living.

Globalization and the Geography of Technological Change

Can this uneven pattern of technological change and income continue in the Internet age as international trade ties far-flung economies ever closer together? Is globalization withering technology's excludability, taking it ever closer to the status of a pure public good? With a new generation as comfortable communicating online as off-line, there might come a day when relationships are as easily formed across the world as across a hallway. If this day comes, then technology's geography could conceivably disappear.

But most scholars agree that this situation has not arrived yet. In fact, the world might even be headed in the opposite direction. Greater trade and better communication technologies make it easier for everybody to specialize in what they do best and to farm everything else out to others who can excel in the remaining tasks. Edward Leamer notes that this is leading to a spatial division between "geek work" and "manly work." Advanced economies such as the United States are increasingly dedicated toward skilled "geek work": complex tasks with a high tacit knowledge content. Developing countries are focused on unskilled or semiskilled "manly work," such



as manufacturing and agriculture, which depend more heavily on codified technology. Hence, the emerging geography of technological change might be one in which innovation-oriented tasks and routine production-oriented tasks are increasingly spatially disparate. And proximity to the site of technological change matters for learning and income growth. A more optimistic view is that production and innovation are complementary. Developing economies are exposed to new ideas when they get involved in new forms of production. They might yet learn from these experiences and spawn new, world-changing ideas that shift the geographical center of tacit knowledge.

Thomas Kemeny

See also **Agglomeration Economies; Business Cycles and Geography; Clusters; Diffusion; Economic Geography; Electronics Industry, Geography of; Externalities; Factors Affecting Location of Firms; Flexible Production; Globalization; High Technology; Innovation, Geography of; Knowledge, Geography of; Knowledge Spillovers; Learning Regions; Uneven Development**

Further Readings

- Audretsch, D., & Feldman, M. (2004). Knowledge spillovers and the geography of innovation. In J. Henderson & J. Thisse (Eds.), *Handbook of urban and regional economics* (pp. 713–739). Amsterdam: Elsevier/North-Holland.
- Eaton, J., & Kortum, S. (1999). International technology diffusion: Theory and measurement. *International Economic Review*, 40, 537–570.
- Glaeser, E., Kallal, H., Scheinkman, J., & Shleifer, A. (1992). Growth in cities. *The Journal of Political Economy*, 100, 1126–1152.
- Griliches, Z. (1957). Hybrid corn: An exploration in the economics of technological change. *Econometrica*, 25, 501–522.
- Keller, W. (2004). International technology diffusion. *Journal of Economic Literature*, 42, 752–782.
- Leamer, E. (2007). A flat world, a level playing field, a small world after all, or none of the above? [Review of the book *The world is flat*]. *Journal of Economic Literature*, 45, 83–126.

- Saxenian, A. (1996). *Regional advantage: Culture and competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
- Storper, M., & Venables, A. (2004). Buzz: Face-to-face contact and the urban economy. *Journal of Economic Geography*, 4, 351–370.



TELECOMMUNICATIONS AND GEOGRAPHY

Telecommunications have a long history of folding and reshaping space that extends to the telegraph in the mid 19th century and the telephone in the late 19th and 20th centuries. Today, the collection, transformation, and transmission of large volumes of information constitute a fundamental part of contemporary economies. The majority of jobs in industrialized nations consist of information processing in one form or another. These functions have increased in importance as computing has dramatically declined in cost and risen in power, the production of all goods and services has become more information intensive, technological change accelerated, product cycles shortened, and a deregulated, worldwide market has increased uncertainty and accelerated the competition among places for investment and jobs.

Information systems used to be confined to simple telephone service. For many decades, during which AT&T enjoyed a monopoly over this industry in the United States (and similar monopolies applied in other countries) and there were few incentives for change, the primary focus was on guaranteeing universal access, resulting in 95% penetration rates among U.S. households (second only to the television). During the 1980s and 1990s, as the cost of computing capacity dropped rapidly, communications became the largest bottleneck for information-intensive firms. Simultaneously, the microelectronics revolution unleashed a series of new technologies, including microwave, fiber optics, and satellites, that have increased the power, sophistication, and diversity of telecommunications qualitatively. With the digitization of information, telecommunications



merged with computers to form integrated networks, most spectacularly through the Internet. Technologies such as Electronic Data Interchange (EDI) and wireless services are becoming increasingly popular.

Misconceptions About Telecommunications and Geography

There exists considerable confusion about the real and potential impacts of telecommunications on urban structure, in part due to the long history of exaggerated claims made in the past, particularly by those subscribing to the “postindustrial” theory. Often, such views hinge on a simplistic and utopian technological determinism that ignores the complex, often contradictory relations between telecommunications and local economic, social, and political circumstances.

For example, repeated proclamations that information systems would allow everyone to work at home via telecommuting, dispersing all functions and spelling the obsolescence of cities, have fallen flat in the face of the persistence of growth in dense urbanized places. In fact, advances in videoconferencing notwithstanding, telecommunications are generally a poor substitute for face-to-face meetings, the medium through which most sensitive corporate interactions occurs, particularly when the information involved is irregular and unstandardized in nature. Most managers spend the bulk of their working time engaged in face-to-face contact, and no electronic technology can allow for the subtlety and nuances critical to such encounters. For this reason, a century of technological change, from the telephone to fiber optics, has left most high-value-added, white-collar, and administrative command-and-control functions clustered in downtown areas (despite their high rents), their agglomerative advantages intact if not unchallenged. In contrast, telecommunications are ideally suited for the transmission of routinized, standardized forms of data such as back office clerical functions. In short, contrary to much received opinion, there is no a priori reason to believe that telecommunications inevitably lead to the dispersal or deconcentration of functions; by allowing the decentralization of routinized functions, information technology

may enhance the comparative advantage of inner cities (albeit with jobs generally filled by suburban commuters). Information systems thus allow for the simultaneous concentration and deconcentration of economic activities.

Fiber Optics

The core of the global telecommunications infrastructure is an extensive and seamlessly integrated network of fiber-optic lines—long, thin, flexible, and highly transparent rods of quartz glass (or less commonly, plastic) about the thickness of a human hair that can transmit light signals through a process of internal reflection, which retains light in the core and transforms the cable into a waveguide. They can transmit voice, video, or data traffic at the speed of light; because light oscillates much more rapidly than other wavelengths, such lines can carry much more information than other types of telecommunications. Modern fiber cables contain up to 1,000 fibers each and are ideal for high-capacity, point-to-point transmissions. Indeed, far more than any other technology, such as copper cables, microwaves, or satellites, fiber optics supply the vast bulk of data, voice, and video transmission services around the world. Because of their capacity to deliver high volumes of information rapidly and securely (e.g., via broadband), fiber optics cables form the backbone of the Internet as well as private corporate lines and are widely used in the electronic media for commercial and residential purposes (e.g., cable television).

Today, the world’s fiber system totals more than 25 million km (kilometers) in length, connecting all the world’s continents except Antarctica (Figure 1). The geography of global fiber networks centers primarily on two distinct telecommunications markets across the Atlantic and Pacific Oceans, connecting two of the major engines of the world economy, North America and East Asia. In 1988, AT&T initiated the world’s first transoceanic fiber-optic cable, Trans-Atlantic Telecommunications (TAT-8), which could carry 40,000 telephone calls simultaneously. The Trans-Atlantic line was the first of a much broader series of globe-girdling fiber lines that AT&T erected in conjunction with a variety of local partners. Because large corporate users

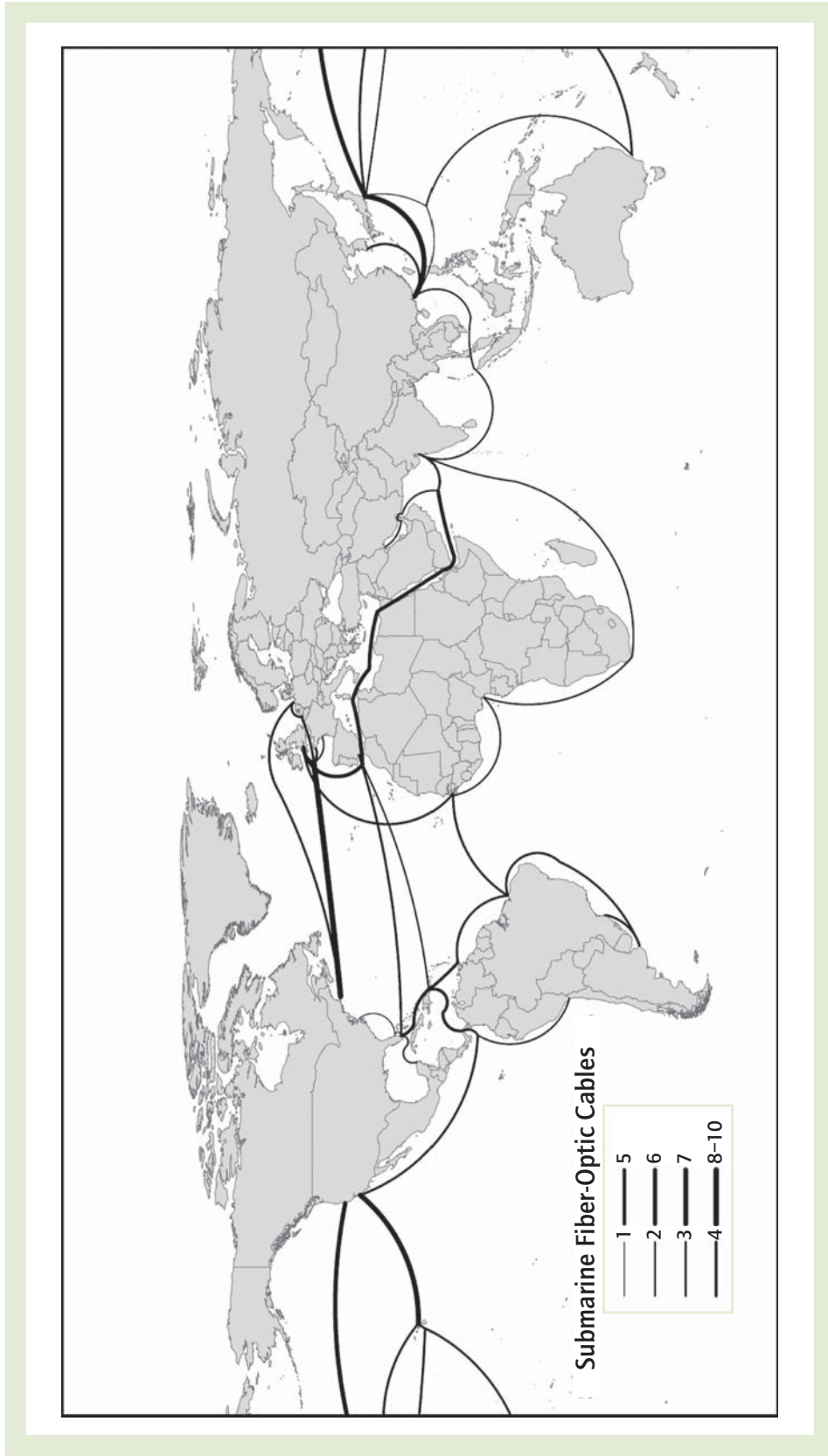


Figure 1 The world's major fiber-optic cables, 2006. Fiber has displaced other forms of telecommunications to become the world's leading method of transmitting information.
Source: Author.



are the primary clients of such networks, it is no accident that the original and densest web of fiber lines connects London and New York, a pattern that extends historically to the telegraph and telephone. The next generation, TAT-9 and TAT-10, which began in 1992, could carry double the volume of traffic of TAT-8. The third generation, TAT-11 to TAT-13, was the first to use the erbium-doped fiber amplifier rather than the older repeaters. Newer generations of cable were even more powerful. Starting with the Trans-Pacific Cable (TPC-3) in 1989, connecting New York and Tokyo, a growing web of Trans-Pacific lines mirrored the rise of East Asian trade with North America, including the surging economies of the newly industrialized countries. The complex interplay of deregulation, globalization, and technological change increased the international transmission capacities and traffic volumes for fiber-optic carriers explosively.

In addition, fiber lines have extended into several newer markets. In 1997, AT&T, NYNEX, and several other firms (including, for the first time, nontelecommunications firms) opened the self-healing Fiberoptic Link Around the Globe (FLAG), a system that eventually expanded to 55,000 km, connecting Europe and southeast Asia. The world's longest submarine telecommunications network, FLAG, the world's longest submarine telecommunications cable, filled a void in undersea cable capacity between Europe, the Middle East, and Asia. In Africa, long marginalized in global telecommunications, AT&T's \$2 billion Africa ONE (Optical NETwork) system circumnavigates the continent with a 39,000-km, high-capacity, self-healing undersea fiber-optic network.

Telecommunications and Finance

Telecommunications have had their most important impacts in the capital markets. Banks, insurance companies, and securities firms, which are generally very information intensive in nature, have been at the forefront of the construction of an extensive network of leased and private communication networks. Electronic funds transfer systems, in particular, which form the nerve center of the international financial economy, allow banks to move capital at a moment's notice, arbitraging interest rate differentials,

taking advantage of favorable exchange rates, and avoiding political unrest. Such networks give banks the ability to move money—by some estimates, more than \$2 trillion daily—around the globe at stupendous rates (the average trade takes less than 25 seconds). Subject to the process of digitization, information and capital become two sides of the same coin.

In the securities markets, global telecommunications systems have facilitated the emergence of 24-hr./d (hour per day) trading, linking stock markets through computerized trading programs. The ascendancy of electronic money has shifted the function of finance from investing to transacting, institutionalizing volatility in the process. Traveling at the speed of light, as nothing but assemblages of zeros and ones, global money performs a syncopated electronic dance around the world's neural networks in astonishing volumes. The world's currency markets, for example, dwarf the funds that change hands daily to cover global trade in goods and services. National boundaries mean little in this context: It is much easier, say, to move \$1 billion from London to New York than a truckload of grapes from California to Nevada.

As large sums of funds flow with mounting ease across countries' borders, national monetary policies became increasingly ineffective, making monetary controls over exchange, interest, and inflation rates progressively difficult to sustain. In the United States, for example, the Federal Reserve, alarmed at the prospect of inflation, changed the reserve ratio of banks numerous times in the 1990s and 2000s, only to find that its control over the national money supply had diminished severely. This is not to say that nation-states enjoy no leverage whatsoever over such factors, but the steady convergence of short-term interest (but not profit) rates globally undoubtedly reflects the mounting ease with which capital transcends national borders.

Another way in which telecommunications have affected the financial industries is through the growth of offshore banking, a reflection of the broader shift from traditional banking services (loans and deposits) to lucrative nontraditional functions, including debt repackaging, foreign exchange transactions, and cash management. Usually introduced in response to favorable tax laws, offshore banking has become important to



many microstates in the Caribbean (e.g., Cayman Islands, Bahamas, Panama), Europe (e.g., Gibraltar, Luxembourg, the Isle of Man, Liechtenstein), the Middle East (e.g., Cyprus, Bahrain), and the South Pacific (e.g., Vanuatu). Thus, as the technological barriers to moving money have fallen, legal and regulatory ones have increased in importance, dispelling simplistic assertions about the “death of geography.”

Other applications of telecommunications in finance include Electronic Data Interchange (EDI) systems, which allow information to move directly among computers, including data, forms, funds, invoices, and text. In insurance, these systems have streamlined underwriting policies, and centralized database management systems have minimized data redundancy and allowed for updates irrespective of the data's physical location. Networks such as the Internet even allow professionals to move into rural areas.

Telecommunications and Global Cities

One of the most significant repercussions of the growth of financial markets has been the growth of “global cities” or “world cities,” notably London, New York, and Tokyo, each of which seems to be as attuned to the rhythms of the global economy as the nation-state in which it is located. At their core, global cities allow the generation of specialized expertise on which so much of the current producer services economy depends. Furthermore, each city is tied through vast tentacles of investment, trade, migration, and telecommunications to clients and markets, suppliers and competitors, and consumers and producers around the world. Each metropolitan area seems to be as attuned, if not more so, to the global economy as the nation-state in which it is located. While several other cities (e.g., Paris, Toronto, Los Angeles, Osaka, Hong Kong, and Singapore) certainly can lay claim to being national cities in a global economy, the trio of New York, London, and Tokyo has played a disproportionate role in the production and transformation of international economic relations in the late 20th century. London, for example, boomed under the impetus of the Euromarket in the 1980s and has become increasingly detached from the rest of Britain. New York rebounded from the crisis

of the mid 1970s with a prolonged bull market on Wall Street facilitated by electronic trading. Tokyo, despite the woes of the Japanese economy, remains an important center of financial activity and home to many of the world's largest banks by asset value. In each city, a large agglomeration of banks and related firms generates well-paying jobs; in each, soaring incomes for a wealthy stratum of traders and professionals has lifted real estate prices to astronomical levels. The primacy of global cities, and their unique niche internationally, hinges largely on their role as producers and conveyors of specialized pools of information. All three metropolises are endowed with enormous telecommunications infrastructures that allow corporate headquarters to stay firmly in touch with global networks of branch plants, back offices, suppliers, clients, subcontractors, subsidiaries, and competitors. This phenomenon illustrates how geographic centralization can be facilitated, not eradicated, by telecommunications.

However, telecommunications simultaneously threaten the agglomerative advantages of dense urban areas, particularly the advantages of face-to-face communications. This trend is particularly evident in finance—the bread and butter of global cities. For example, the National Automated Dealers Quotation System (NASDAQ) has emerged as the world's largest stock market; unlike many other exchanges, NASDAQ lacks a trading floor, connecting millions of traders worldwide through fiber-optic lines in the over-the-counter market. Similarly, Paris, Belgium, Spain, Vancouver, and Toronto all recently abolished their trading floors in favor of screen-based trading.

Back Office and Call Center Relocations

Few domains of economic activity have been as heavily affected by telecommunications as the low-level, routinized back office functions. Back offices perform clerical functions such as data entry of office records, telephone books, library catalogs, stock transfers, payroll or billing information, bank checks, insurance claims, and magazine subscriptions. These tasks involve unskilled or semiskilled labor, primarily women, and frequently operate on a 24-hr./day basis. Back offices have few of the interfirm linkages associated with



headquarters activities and require extensive data-processing facilities, reliable sources of electricity, and sophisticated telecommunications networks.

Historically, back offices have been located adjacent to headquarters activities in downtown areas to ensure close management supervision and rapid turnaround of information. However, under the impetus of rising central-city rents and shortages of sufficiently qualified (i.e., computer-literate) labor, many service firms began to uncouple their headquarters and back office functions, moving the latter out of the downtown to cheaper locations on the urban periphery. Most back office relocations, therefore, have been to suburbs.

Given the increasing locational flexibility afforded by satellites and a growing web of inter-urban fiber-optics systems, back offices have begun to relocate on a much broader, continental scale. Under the impetus of new telecommunications systems, many clerical tasks have become increasingly footloose and susceptible to spatial variations in production costs. New digital call distribution systems have made possible the relocation of phone services that were once confined to centralized locations. Internationally, this trend has taken the form of the offshore office. The primary motivation for offshore relocation is low labor costs, although other considerations include worker productivity, skills, turnover, and benefits. Offshore offices are established not to serve foreign markets but to generate cost savings for U.S. firms by tapping Third World labor pools, where wages are as low as one fifth of those in the United States. Notably, many firms with offshore back offices are in industries facing strong competitive pressure to enhance productivity, including insurance, publishing, and airlines. Offshore back office operations remained insignificant until transoceanic fiber-optic lines made possible geographic flexibility on an international scale. Such functions either may be subsidiaries of multinational firms or they may operate under contract with U.S.-based businesses. Inputs, usually documents or magnetic tapes, are sent by air to offshore processing facilities (e.g., via Federal Express). After processing, generally a few days at most, the results are returned via satellite or dedicated telephone or fiber-optic line. Thus, the capital investments in such operations are minimal, and they possess great flexibility, maximizing

their ability to choose among locations based on slight variations in cost or profitability.

Several New York-based life insurance companies have erected back office facilities in Ireland, with the active encouragement of the Irish Development Authority. Often situated near Shannon Airport, they move documents in by Federal Express and the final product back via satellite or one of the numerous fiber-optic lines that connects New York and London. Likewise, the Caribbean, particularly Anglophone countries such as Jamaica and Barbados, has become a particularly important locus for American back offices. American Airlines paved the way in the Caribbean when it moved its data processing center from Tulsa to Barbados in 1981; through its subsidiary Caribbean Data Services, it expanded operations to Montego Bay, Jamaica, and Santo Domingo, Dominican Republic, in 1987. In Asia, Manila, Philippines, has emerged as a back office center for British firms, with wages 20% of those in the United Kingdom. Such trends indicate that telecommunications may accelerate the offshoring of many low-wage, low-value-added jobs from the United States, with dire consequences for unskilled workers in the home country.

A similar form of low-wage, low-value-added services involves centers of telework, often labeled call centers. Call center functions include telemarketing, customer assistance, and phone orders, often with designated 1-800 numbers. They range greatly in size, from as few as five to as many as several thousand employees. Like back offices, call centers are primarily screen based and do not require proximity to clients. The major cost consideration is labor, although the workforce consists primarily of low-skilled women and high turnover rates are common. They are thus the epitome of a footloose industry, disembedded from their local milieu and highly mobile. There are an estimated 80,000 to 100,000 call centers within the United States, which employ between 3% and 5% of the national labor force, the majority of which are located in urban or suburban locations. Like back offices, call centers have become increasingly globalized. India, for example, has attracted a significant number of customer service centers near its software capital Bengaluru, where workers are trained to speak in the U.S. dialect of English and are able to gossip



with customers about pop culture. Wages there, which average US\$2,000 per year, are higher than average Indian salaries but are only 10% of what equivalent jobs pay in the United States.

Urban Telecommunications Infrastructures

Urban infrastructure investments in communication technologies have by and large remained surprisingly unimportant to policymakers. While many cities and localities are willing to invest in new roads or water control projects, urban planners and economic development officials have often overlooked or ignored altogether the role that telecommunications can play in stimulating economic growth. For example, only 5% of U.S. municipalities have explicit plans for telecommunications. One reason is that there is no statistical correlation between local investment in telecommunications and economic growth. However, while the telecommunications industry *per se* is relatively small and capital intensive, generating few jobs, and while telecommunications by themselves do not guarantee economic development, such systems have become necessities for many firms.

Although large cities typically have much better developed telecommunications infrastructures, the technology has rapidly diffused through the urban hierarchy and is becoming increasingly equalized among regions. In the future, therefore, the marginal returns from investments in this infrastructure are bound to diminish, minimizing competitive advantages based on an information systems infrastructure alone and forcing competition among localities to be based on other factors, such as the cost and quality of labor, taxes, and the regulatory framework. Regions with an advantage in telecommunications generally succeed because they have attracted successful firms for other reasons.

Telecommunications may affect the urban infrastructure in other, less obvious ways. One increasingly important effect of new information systems is “telework” or “telecommuting,” in which workers substitute some or all of their working day at a remote location (almost always home) for time usually spent at the office. The self-employed do not count as teleworkers because they do not substitute it for commuting. Telework

is most appropriate for jobs involving mobile activities or routine information handling, such as data entry or directory assistance. Proponents of telework claim that it enhances productivity and morale, reduces employee turnover and office space, and leads to reduction in traffic congestion (especially at peak hours), air pollution, energy use, and accidents. If this phenomenon grows as expected, it will lead to further decentralization of economic activity in suburban areas.

However, while telecommuting may reduce flows of people, flows of information can never be a substitute for flows of water, electricity, gas, goods, or trash. Indeed, there are countervailing reasons why telecommunications may, in apparent contradictory fashion, increase the demand for transportation rather than decrease it. First, it is not at all clear that telecommuters have shorter weekly commutes overall; indeed, by allowing them to live farther from their workplace, the total distances traveled may actually rise. Second, time freed from commuting may be spent traveling for other purposes, such as shopping or recreation. Telecommuting may alter the reasons for travel but not necessarily the frequency or volume. Third, by reducing congestion, telecommuting may lead to significant induced effects, whereby others formerly inhibited from driving may be induced to do so. In short, the substitutability, rather than complementarity, of telecommunications for commuting is far from clear.

Another potential, and growing, impact of information systems on urban form concerns transportation informatics, including a variety of improvements in surface transportation such as smart metering, electronic road pricing, synchronized traffic lights, automated toll payments and turnpikes, automated road maps, information for trip planning and navigation, travel advisory systems, electronic tourist guides, remote traffic monitoring and displays, and computerized traffic management and control systems, all of which are designed to minimize congestion and optimize traffic flow (particularly at peak hours), enhancing the efficiency, reliability, and attractiveness of travel. Wireless technologies such as cellular phones allow more productive use of time otherwise lost to congestion. Such systems do not so much incorporate new technologies as improve on the existing ones. In-vehicle navigation



systems with inboard computers, such as the Intelligent Vehicle Highway System currently under way in Southern California, represent the next generation of this technology.

Conclusion

The widespread adoption of telecommunications is reflective of a series of broader transformations in the world economy. Economic development officials can adapt their views to these changes by recognizing that economic activity has relatively little to do with the production of tangibles, such as in agriculture and manufacturing, and is dominated by invisible flows of data and capital, which the digital revolution has transformed into twin aspects of the same phenomenon—one that moves at the speed of light—giving firms unprecedented mobility and flexibility. Markets, labor processes, policy planning, and spatial structures have changed accordingly. Cities and regions can search for a competitive advantage in this world in several ways. In large metropolitan areas, buoyed by the historical legacy of dense nucleations of firms interconnected by face-to-face interaction, telecommunications have left agglomeration economies largely intact, albeit not unchallenged, as in the case of electronic screen trading of stocks. In some cases, information systems have contributed to a marked centralization of key activities in a handful of fortunate cities as firms consolidate operations in an attempt to derive economies of scale. Other services, however, that rely primarily on unskilled inputs of routinized information are increasingly vulnerable to substitution by new telecommunications systems, such as back offices. A key theme here, therefore, is that information systems tend to centralize high-wage, high-value-added, white-collar functions while decentralizing low-wage, low-value-added, blue (or pink) collar ones.

Barney Warf

See also Communications Geography; Cyberspace; Digital Divide; E-Commerce and Geography; Globalization; Information Society; Media and Geography; Satellites and Geography; Television and Geography; Virtual Geographies; World Cities

Further Readings

- Akwule, R. (1992). *Global telecommunications: The technology, administration, and policies*. Boston: Focal Press.
- Graham, S. (1999). Global grids of glass: On global cities, telecommunications, and planetary urban networks. *Urban Studies*, 36, 929–949.
- Graham, S., & Marvin, S. (1996). *Telecommunications and the city: Electronic spaces, urban places*. London: Routledge.
- Headrick, D. (1991). *The invisible weapon: Telecommunications and international politics, 1851–1945*. New York: Oxford University Press.
- Hugill, P. (1999). *Global communications since 1844: Geopolitics and technology*. Baltimore: Johns Hopkins University Press.
- Warf, B. (1995). Telecommunications and the changing geographies of knowledge transmission in the late 20th century. *Urban Studies*, 32, 361–378.



TELECONNECTIONS

Teleconnections are hemispheric-scale statistical relationships that result from the spatial interdependencies between the atmosphere and the ocean. In other words, teleconnections describe how atmospheric or oceanic circulation changes occurring at one location are linked to changes at other locations that are widely separated geographically. On the order of weeks to years, these global associations are recognized by an atmospheric circulation disturbance occurring at select locations or “centers of action,” thereby producing oscillations affecting weather patterns downstream. These action centers identify the climatological positions of low- and high-pressure areas associated with particular atmospheric teleconnection patterns or cold and warm sea surface temperature regions with oceanic teleconnection patterns. Frequently, atmospheric oscillations are strongly linked or coupled with oceanic changes. Locations in the vicinity of the action centers shift from characteristic climatologically normal conditions to distinct patterns of climate anomalies that



occur over a range of time periods. The climate anomalies produced by a teleconnection pattern depend on its phase, indicating the prevailing extremes in the action center variable. Teleconnection patterns represent a principal mode of annual large-scale atmospheric circulation variability that produces both short- and long-term regional climate effects.

Teleconnections are identified through statistical techniques demonstrating the degree to which fluctuations in a variable are related to two or more separate areas. Correlation analysis describes the strength and direction of association between paired variables, such as pressure changes in one location compared with all other locations. The El Niño Southern Oscillation (ENSO) is typically identified in this manner. ENSO is an interannual periodic abnormal warming or cooling of the eastern equatorial Pacific SSTs that is regularly accompanied by a shift in the typical surface pressure field between the Australian and Peruvian coasts, the primary action centers that are strongly negatively correlated. Eigenvector-based methods, such as principal component analysis, allow one to detect groups of interrelated variables, simplify the representation of the data field, and recognize similar regional modes of variability. The Pacific/North American pattern is often produced from eigenvector methods that distinguish three primary action centers across North America based on the cold season midtropospheric geopotential height field (i.e., the altitude of the 500- or 700-hectopascal pressure surface). Statistical methods such as these have been used to recognize sets of action centers unique to each teleconnection pattern.

The strength, phase, and location of the teleconnection pattern establish the geographical extent and severity of the climate impacts. For instance, strongly positive ENSO phases (or El Niño) during December to February are typically linked to increased precipitation in northwestern South America and the Southern United States, decreased precipitation in Northern Australia, and higher temperatures in northwestern Canada and South Asia; negative ENSO phases (or La Niña) usually have the reverse effects. The expected climate anomalies associated with a

teleconnection phase suggests a potential for increased long-range climate forecasting. Consequently, teleconnections has been a major component of atmospheric research in recent decades.

Jill S. M. Coleman

See also **Climatology**; **El Niño**; **La Niña**

Further Readings

- Barry, R. G., & Carleton, A. M. (2001). *Synoptic and dynamic climatology*. New York: Routledge.
- Bridgman, H. A., & Oliver, J. T. (2006). *Global climate system: Patterns, processes, and teleconnections*. Cambridge, UK: Cambridge University Press.



TELEVISION AND GEOGRAPHY

Over the past two decades, human geographers have taken an increasing critical interest in the mass media. This development reflects the growing recognition that the media are centrally implicated in both (a) the constitution, experience, and representation of space, place, landscape, and environment (in short, *geography*) and (b) the mechanisms by which geography in its various incarnations, in turn, is implicated in social processes. Of all the mass media, television is seen as perhaps centrally important in these regards; for, despite the rapid growth in penetration and usage of the Internet and notwithstanding the ongoing cultural, economic, and political significance of newspapers, magazines, and radio, it is widely believed that for the bulk of the world's population, television is the most socially *material* mass medium.

Geographers have studied television's social role from a large number of different angles, which can usefully be grouped into three categories, and it is around these three categories that this entry is organized. The first category is geographies *on* television—in other words, the ways in which geography (i.e., space, place, landscape,



and environment) is represented in television programming. The second category is geographies of television: what significant geographical patterns and processes can be identified in the organization of television itself as both an industry (which produces and distributes programming) and a technology (through which people receive and watch such programming). The final category is harder to define but can perhaps best be described as the myriad ways in which television shapes and reshapes the fundamental *experience* of space and place and of spatially mediated identities.

Geographies on Television

There is now a large and rapidly expanding literature dealing with the ways in which geographies are conveyed on screen. The literature shows that it pays to think closely about the representation of both generic and more specific geographies. Generic geographies include the following generalized places: the city, the suburbs, “nature,” the desert, the road, and “home.” By “specific” geographies, we mean actual real-world places situated at all manner of different scales: Africa, the Middle East, the United States, Northern England, Baghdad, Manhattan, and so on.

Just as geographers have been interested in a wide range of different geographies and their materialization in programming, so too have they analyzed these representations from a variety of different vantage points. Some of the analysis has been relatively straightforward—concerned “merely” with understanding how a particular space or place has been conveyed and what that representation tells us about the geography in question that we might not have known before. Increasingly, however, geographers have sought to read “back” from programming to the society that produces it. What can we learn from geography’s representation on television—its structure, form, contents, and even absences—about, for instance, the prevailing social constructions of race, gender, and class? Finally, geographers have sought to more directly link representation and “reality.” A good example of this has been work demonstrating how television’s representation of a particular place can radically alter social consumption (e.g., tourist visits) of that place.

Geographies of Television

The analysis of geographies of television has looked at television as a material *process* through all stages of its life span. These begin with *production*: Where is television programming filmed, and what notable trends can we discern in this respect? Here, for instance, one of the central themes of recent literatures has been to track the emigration of shooting from traditional locations—Hollywood being the archetypal example—to newer and often lower-cost sites, a development referred to as “runaway” productions.

After production, comes *packaging*: the editing and then bundling of programming into, most familiarly, television channels. Where does this activity—arguably the nerve center of the television industry—take place? It has been shown that it typically occurs in large industrial clusters or agglomerations, of which Hollywood is, again, the classic case. Allen Scott’s work has been seminal in demonstrating this idea.

The third link in the chain is *distribution* and its geographies. Once more, the literature on this topic is vast, but its central gist has been to show that on an international scale the main flow of programming has long been from the United States to the rest of the world—sparking, particularly in the 1970s and 1980s, repeated accusations of U.S. cultural imperialism. Since then, it has been shown that while the United States remains overwhelmingly dominant in global television trade, more complex interregional flows from multiple origins do exist and are rapidly proliferating.

The final important geography of television concerns its consumption. Here, especially in the work of David Morley, the emphasis has been on the consumption of television in the home—on family and the social relations of *domestic* space. But it has also been recognized that television long ago breached the boundaries of home—it is consumed in bars, in malls, in airports, and now on mobile phones and similar handheld devices. Discussion of these geographies has been an increasing focal point.

Television, Space, and Identity

Geography is itself produced and reproduced on television; television has its *own* geographies, and



A Turkish Cypriot shopkeeper watches the TV screens that show the Cyprus map and the news in the Northern Turkish part of divided Nicosia, April 22, 2004. The Greek and Turkish Cypriot communities voted in separate referenda on April 24 for the approval or rejection of the United Nations plans for the reunification of their war-divided island.

Source: AFP/Getty Images.

television also shapes and reshapes wider human geographies. This last claim potentially can mean many different things, but two are arguably important. First, watching television can affect how we experience space and place per se—and, moreover, how space interacts with time. Many influential authors have pondered on such themes and have offered arresting phrases to capture these experiential changes. John Thompson, for example, suggests that television and other electronic media have “uncoupled” time and space by breaking down what was traditionally a linear relationship between spatial and temporal distance. Along similar lines, the geographer David Harvey coined the popular phrase “time-space compression” to evoke the way in which the media have shrunk the world and the time taken to electronically navigate it.

Second, by reworking the experience of space and place, television also reshapes social identities that are themselves geographically grounded: identities such as nation, community, or, more broadly, “us” and “them.” Joshua Meyrowitz, for instance, famously argued that our social place and physical place in the world used to mutually reinforce one another but that by familiarizing us with places far away, television ruptured this symbiosis and has left us, literally, with “no sense of place.” Again, there is an enormous literature on such matters. But one example perhaps suffices to demonstrate the complexity of the relationships in question: satellite television. By allowing for single broadcasts that transcend traditional nation-state boundaries, satellite television can arguably lead to the dissolution of narrow, national, place-bounded identities. Equally,



however, satellite television can harden national identities precisely by virtue of its spatial scope—the identities, for example, of diaspora nations spread around the globe and traditionally fractured by space. It is just these types of complexities that geographers of television are increasingly grappling with.

Brett Christophers

See also **Communications Geography; Cyberspace; Identity, Geography and; Information Society; Media and Geography; Representations of Space; Telecommunications and Geography; Virtual Geographies**

Further Readings

- Adams, P. (1992). Television as gathering place. *Annals of the Association of American Geographers*, 82, 117–135.
- Barnett, C. (2003). *Culture and democracy: Media, space and representation*. Edinburgh, UK: Edinburgh University Press.
- Burgess, J., & Gold, J. (Eds.). (1985). *Geography, the media and popular culture*. London: Croom Helm.
- Christophers, B. (2009). *Envisioning media power: Television, capital, space*. Lanham, MD: Lexington Books.



TEMPERATURE PATTERNS

Global temperature patterns are primarily determined by the amount of solar radiation reaching Earth's surface, which in turn is influenced by factors such as latitude, the distribution of land masses and oceans, cloud cover, topography, and the circulation of the atmosphere and oceans. As solar radiation reaches the surface, it is absorbed—resulting in warming, reflected, or converted to latent heat in the evaporation of water. Surface temperature is thus determined by the flux of radiation to the surface and the disposition of this energy as it arrives.

Global temperature patterns are characterized by a latitudinal temperature gradient with colder temperatures toward the poles, greater temperature variability in high-latitude continental interiors as well as in arid regions, and cooler and more variable temperatures at high elevations. The primary controls on these patterns are latitude and land/water contrasts, with cloud cover, humidity, elevation, and large-scale circulation of the atmosphere and oceans contributing. This entry discusses the role played by these factors in determining temperature patterns.

Latitude and Temperature

The average surface temperature of Earth as a whole is 15 °C (59 °F), and the most obvious spatial pattern is a latitudinal gradient: Low-lying tropical regions near the equator typically experience annual average temperatures around 27 °C (81 °F), while high-latitude ice caps in Antarctica and Greenland have annual average temperatures below −40 °C (−40 °F). The seasonal variation in temperature will likewise differ significantly across the planet—low-latitude coasts will have seasonal temperature swings of less than 3 °C (37 °F), while high-latitude continental interiors will experience swings in excess of 40 °C (104 °F).

The latitudinal temperature gradient is due to the variation in the sun angle (the elevation of the sun above the horizon) between the equator and the poles. Earth is an oblate spheroid orbiting the sun at an average distance of 150 million kilometers (93 million miles). Due to the curve of the Earth, the noontime sun will pass directly overhead (the sun angle will be 90°) at a specific latitude, known as the solar declination, with lower sun angles at latitudes away from the solar declination. Due to the constant tilt of Earth's axis relative to the plane of the orbit, the solar declination cycles between the Tropic of Cancer (23.5° N) on the summer solstice to the Tropic of Capricorn (23.5° S) on the winter solstice, passes over the equator twice a year—once on each equinox.

Lower sun angles mainly result in cooler temperatures because the solar radiation is spread over a larger surface area when the sunlight strikes the surface obliquely. When the sunlight is thus diffused, less energy is absorbed per unit of surface and less warming occurs. Two additional



factors also contribute to cooler temperatures at higher latitudes: First, polar surfaces such as ice tend to have higher albedos, so a larger amount of insolation is reflected rather than absorbed. Second, radiation arriving with a low sun angle travels a longer, slanting path through the atmosphere than when the sun is directly overhead, and therefore, more energy is absorbed or scattered before reaching the surface.

Seasonal variability in temperature results from seasonal variations in the sun angle. As Earth orbits the sun, the solar declination latitude moves north and south, producing higher sun angles and warmer temperatures during the summer season. Outside the tropics, there is a 47° swing in noontime sun angle from summer to winter. In addition to sun angle, day length (hours of sunlight) varies from summer to winter, with larger variations at greater distances from the equator. At high latitudes, winters are characterized by short days and low sun angles, while in the summer the days are longer and the sun is higher. As a result, high-latitude locations experience large seasonal variations in temperature, with extremely cold winters and moderate summers. In contrast, at low-latitude locations, the sun remains relatively high above the horizon throughout the year, and seasonal changes in day length are small, resulting in reduced seasonal variation in temperature. Therefore, during winter, the extremely low temperatures at high latitudes result in a significant temperature gradient from the equator to the poles, while high-latitude warming during summer produces a reduced latitudinal gradient.

The Principle of Continentality

Another major factor affecting temperature variations is the difference in heating characteristics of land surfaces versus water surfaces—a set of processes referred to as the principle of continentality. Given the same amount of insolation, a land surface will heat up and cool off more rapidly than an ocean surface, resulting in greater diurnal and seasonal temperature variations in continental interiors compared with coastal locations. There are four key reasons for this difference: (1) the transparency of ocean water, (2) the mobility of ocean water, (3) the differing amounts of latent heat transfer from the two surfaces, and (4) the differences in the specific

heats of the surface materials. Because water is relatively transparent to solar radiation, incoming energy is absorbed throughout the top several meters of the water column. In contrast, insolation striking a land area is entirely absorbed at the surface itself. Because the energy received by the water surface is spread out over a larger volume of the material, the amount of warming experienced directly at the surface is reduced.

In addition to the penetration of solar radiation through the upper layers of the water column, the fluidity of water means that energy can be distributed deeper into the water column once it is absorbed. Thus, energy that might lead to increased warming during periods of high insolation may instead be circulated downward, and heat may circulate upward to moderate episodes of cooling. Land surfaces do experience some conduction of heat downward through the soil column, but the effect is relatively small—in general, energy absorbed at the land surface remains at the surface to produce warming.

A third factor contributing to continentality is the generally higher amount of evaporation that occurs from water surfaces. When water evaporates, energy is used to effect the change in state from liquid to gas. This energy, referred to as the latent heat of evaporation, is used to break the weak bonds between the water molecules and is stored in the higher-energy configuration of the water vapor. When the vapor condenses, the same amount of energy is liberated as the latent heat of condensation. The energy that is used for evaporation does not contribute to any sensible warming at the point of evaporation. Therefore, given the same amount of surplus radiation, a wet surface will experience less warming than a dry surface because a larger amount of energy will be transferred away as latent heat from the wet area. Over a dry surface, most of the surplus radiation will be converted to sensible heat, resulting in warming.

The final factor in the varying temperature responses between land and water surfaces is the difference in specific heat between the surface materials. Specific heat is the physical property of a substance that determines the amount of energy required to raise the temperature of the material. Water has a higher specific heat than land, which means that it takes more energy to produce a given amount of warming in a water surface.



Given the same input of insolation, therefore, a land surface will warm up more quickly than an ocean surface. Conversely, as the surfaces cool by radiating long-wave energy, the land will experience a larger drop in temperature than the water.

Taken together, these four factors produce larger diurnal and seasonal temperature variability in continental interiors compared with coastal locations. Combined with the latitudinal effect on temperature variability discussed above, the largest seasonal swings in temperature will occur at high-latitude continental interiors, for example, Eastern Siberia, and the lowest temperature swings will occur at low-latitude coastal and oceanic locations. Because the prevailing upper-level flow and storm movement in the mid and high latitudes is west to east, the cold dry air masses produced in continental interiors are pushed eastward, and so the most “continental” regions are in the eastern portions of the land masses. Conversely, the maritime effect is more pronounced on west coasts.

Cloud Cover and Water Vapor

A third major control on global- and regional-scale temperature patterns is the amount of cloud cover and water vapor. Clouds are a significant contributor to the planetary albedo and have an overall cooling effect of approximately 5 °C (41 °F) on the global average temperature. Due to the extensive cloud cover associated with the Intertropical Convergence Zone (ITCZ), latitudes near the equator are not the hottest part of the planet, despite the high sun angles. Rather, the hottest temperatures are found in the cloudfree subtropical latitudes (~30° N and S) under the tropospheric subsidence of the subtropical highs. While equatorial temperatures typically average around 27 °C (81 °F) throughout the year, summertime average temperatures in the subtropical deserts will exceed 40 °C (104 °F) in many places.

In addition to reflective cooling, clouds also have a warming effect on the surface as they absorb long-wave radiation leaving the surface and radiate energy back downward in what is referred to as the cloud-greenhouse effect. This effect is most pronounced with high thin clouds, which are effectively opaque to outgoing long-wave radiation but thin enough to pass solar radiation. The warming effect of clouds is particularly

noticeable at night, when only the warming process is operating. Therefore, although the overall impact of cloud cover is one of cooling, the local effect will vary between warming and cooling depending on the time of day and the type of clouds present. In terms of variability, cloud cover tends to reduce the diurnal temperature range as daytime temperatures are reduced by the reflection of insolation and nighttime temperatures are increased by the downward radiation of long-wave energy.

High levels of humidity in the atmosphere play a role similar to the warming effect of clouds, as water vapor is a potent greenhouse gas. In humid environments, long-wave radiation is absorbed as it propagates upward from the surface. The main impact of this is a sharp reduction in diurnal variability—humid and cloudy tropical regions may experience day-to-night temperature ranges as small as 5 °C (41 °F), while diurnal temperature swings of 30 °C (86 °F) are not uncommon in the dry desert areas.

Topography

Topographic features have an impact on temperature at a regional and local scale. Because the main source of heat for the troposphere is Earth’s surface, temperature decreases with altitude, and mountaintops have cooler temperatures than lowlands. In addition, the density and humidity of the atmosphere decrease at higher elevations, reducing the amount of outgoing long-wave radiation absorbed. Thus, high elevations cool rapidly over the nighttime, producing increased diurnal temperature ranges compared with lower regions.

Mountain ranges also affect regional temperature patterns through the production of rain-shadow deserts. Where topographical barriers lie across the prevailing wind flow, orographic uplift leads to cloud formation and precipitation on the windward side of the range. As the now drier air descends on the leeward side of the feature, it is warmed adiabatically, which results in warm arid conditions behind the mountain range.

Circulation of the Atmosphere and Oceans

A final factor that influences global temperature patterns is the large-scale circulation of the



atmosphere and the oceans, which is a product of the latitudinal energy gradient. Surplus energy from the lower latitudes is moved poleward through the atmosphere as well as via the major warm ocean currents, such as the Gulf Stream, found on the western margins of ocean basins in the midlatitudes. This shift of energy produces some warming at the higher latitudes and helps explain why Western Europe has a somewhat more temperate climate than latitude alone would suggest.

Gregory S. Bohr

See also **Adiabatic Temperature Changes; Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure; Atmospheric Variations in Energy; Climatology; Equator; Equinox; Lapse Rate; Solstices; Radiation: Solar and Terrestrial; Weather and Climate Controls**

Further Readings

- Christopherson, R. W. (2009). *Geosystems: An introduction to physical geography*. Upper Saddle River, NJ: Prentice Hall.
- O'Hare, G., Sweeney, J., & Wilby, R. (2005). *Weather, climate, and climate change: Human perspectives*. Harlow, UK: Pearson Education.
- Rohli, R. V., & Vega, A. J. (2008). *Climatology*. Sudbury, MA: Jones & Bartlett.



TEMPORAL GIS

Temporal geographic information systems (GIS) (also known as spatiotemporal GIS) is a concept and an active area of research within geographic information science focusing on representation, management, manipulation, and analysis of spatiotemporal data. Time presents an important component of spatial analysis. However, conventional GIS approaches adopt a static view to model time-dependent processes; thus, they are incapable of representing the changes and dynamics of geographic phenomena. Research efforts to extend GIS with the capabilities of handling spatiotemporal data have been ongoing since the 1980s.

The efforts of augmenting GIS with the capabilities of handling spatiotemporal data have been directed primarily at developing data models for time-dependent processes and phenomena. Similar to the object-based and field-based views of space, a discrete or a continuous view of time can be adopted in a temporal GIS design. The discrete time view uses two types of time objects to describe individually distinguishable events. A *time point* labels the existence of an event or the occurrence of a change, while a *time interval* denotes the duration of a certain status of a geographic entity. On the other hand, the continuous view treats time as a stage where the evolvments of various geographic events occur. This view is particularly important for tracing and studying the process of a geographic phenomenon in which changes take place gradually rather than abruptly.

Time-stamping presents a straightforward approach to adding temporal information to geographic entities. It has been widely used in various temporal GIS applications to integrate the geographic and temporal information of real-world entities. Depending on how a timestamp is applied to an entity, temporal GIS can represent its temporal information at different levels. A timestamp can be attached to a geographic layer (usually stored as a table in a relational database), and all geographic entities in the layer will share the same temporal information. A timestamp can be attached to every single geographic entity in a layer, and each entity will have its own temporal information. Also, multiple timestamps can be applied to different attributes of a geographic entity, and the entity will have attributes with different temporal characteristics. These time-stamping methods have been used in various temporal GIS models to represent changes of geographic entities and support relevant to spatiotemporal queries and analyses.

Another straightforward approach, the *snapshot model*, uses a collection of snapshots to represent the status change of geographic entities in an area. Each snapshot is taken at a specific time point; thus, all geographic entities in one snapshot share the same timestamp. The sequence of the snapshots then presents the change history of geographic entities in a particular area. In the late 1980s, Langran and Chrisman proposed a *space-time composite model* to record accumulated



changes in one single composite layer. A composite layer consists of a set of space-time composites that are derived from combining the geographic entities in multiple snapshots and represent homogeneous features sharing the same history and attributes. Each composite unit in the layer has its own timestamp. A historical state of a geographic entity can be constructed by combining several composite units associated to the entity according to their temporal sequence.

The snapshot model and the space-time composite model are capable of recoding spatiotemporal changes of geographic entities constituting a spatial data layer. However, neither of them can efficiently trace the change history of individual entities. In the 1990s, efforts were made to develop temporal GIS models that could explicitly maintain the lifelines of individual geographic entities. Special links are used to connect different states of entities that are stored in the consecutive snapshots or represented as a collection of space-time composite units. Therefore, a list of such links associated with a particular entity is able to capture the entity's lifeline, which may include various change events such as creation, transformation, disappearance, reappearance, destruction, and so on. As a special case, it is possible to model in temporal GIS the lifelines of moving objects (i.e., geographic entities with continuous motion but without changes of shape, such as human beings, vehicles, and wild animals). Since this type of entities can be simplified as point features, their trajectories, which record the history of their movements, can be conveniently represented as spatiotemporal lines in a temporal GIS environment.

The above approaches are mainly designed to deal with discrete changes. However, a continuous view of time is required for researchers to properly understand the dynamics of many geographic phenomena, such as the development of a weather system and an urban sprawl process. Thus, the ultimate goal of temporal GIS is to represent the dynamic process of geographic phenomena. This implies that a temporal GIS needs to go beyond simply recording the events and tracing the change history of geographic entities to developing the capability of capturing the driving mechanisms behind the displayed changes. Such an approach demands that researchers have a

clear understanding of the dynamic process behind the geographic phenomenon. Given the complexity of this approach, a temporal GIS application of this type usually focuses on a narrowly defined problem domain (e.g., meteorology) and uses mathematical models to simulate the process. Most existing efforts have been concentrating on loosely coupling a GIS framework with a separate system running a simulation model. So far, representing the dynamics of geographic processes remains a major research challenge in temporal GIS.

Temporal GIS also supports spatiotemporal reasoning that provides a theoretical foundation for analyzing the relationships and interactions among geographic entities. Researchers have been working on defining basic temporal relationships. For example, two time intervals can share various relationships such as before, equal, meet, during, overlap, start, and end. These temporal relationships can be combined with spatial relationships to represent rather complex spatiotemporal patterns of geographic entities. Various query and analysis functions have been developed in different temporal GIS applications to support the investigations of spatiotemporal relationships. These functions provide powerful tools for researchers to examine the dynamics and interactions of geographic entities in various research fields.

Hongbo Yu

See also **GIScience; Temporal Resolution**

Further Readings

- Armstrong, M. (1988). Temporality in spatial databases. *Proceedings: GIS/LIS'88*, 2, 880–889.
- Langran, G., & Chrisman, N. (1988). A framework for temporal geographic information. *Cartographic*, 25, 1–14.
- Peuquet, D., & Duan, N. (1995). An event-based spatiotemporal data model (ESTDM) for temporal analysis of geographical data. *International Journal of Geographical Information Systems*, 9, 7–24.
- Yuan, M. (1996). Modeling semantics, temporal, and spatial information in geographic information systems. In M. Craglia & H. Couclelis (Eds.), *Geographic information research: Bridging the Atlantic* (pp. 334–347). London: Taylor & Francis.



TEMPORAL RESOLUTION

Temporal resolution, well defined in the field of remote sensing, is one of four major resolutions that characterize a remote sensing system; the others are spectral, spatial, and radiometric resolutions. Temporal resolution is the length of time that has elapsed between measurements and captures the rate of data collection for a particular area. It can range from seconds to hours to days to years. Temporal resolution defines the minimum length of time over which an event can occur to be discernible in the database. For example, satellite images acquired for a forested landscape every year during the summer season will not capture phenological changes. Temporal resolution also plays an important role in geographic information science (GIScience) because all geographic data are defined with regard to spatial, temporal, and thematic dimensions.

In remote sensing, temporal resolution represents how often a remote sensing system records imagery for the same area. It is a measure of the length of time required for the sensor to pass over and return to exactly the same location, typically referred to as the revisit time. Remote sensing systems often differ with respect to temporal resolution. For example, Landsat 1 was able to acquire imagery of the same location every 18 days. Landsat 7 acquires imagery of the same location every 16 days. Therefore, Landsat 7 has greater temporal resolution. As the temporal resolution of a remote sensing sensor improves and the length of time between image acquisition declines, the number of images that can be acquired for the same area increases.

One of the most important aspects of a remote sensing system is its ability to collect imagery for the same location at multiple points in time. Comparing multitemporal imagery allows researchers to detect changes in spectral properties on the Earth's surface. Temporal resolution plays an important role in our ability to monitor these changes. For example, monitoring the growth of urban development would require a different temporal resolution (months to years) than monitoring the spread of a forest fire (hours to days). The temporal resolution of the remote sensing

system should reflect the changes occurring in the phenomenon under investigation.

In geographic information systems (GIS), temporal resolution refers to the length of time between map updates. For practical reasons, data in a GIS are measured and recorded in discrete temporal units, where each data layer displays the spatial distribution of the variable of interest at one point in time. When a set of data layers are acquired for a variable of interest over the same area at several time steps, the length of the time step between the layers represents the temporal resolution of the GIS database.

Amy C. Burnicki

See also Remote Sensing; Remote Sensing: Platforms and Sensors; Spatial Data Models; Temporal GIS; Topological Relationships; Triangulated Irregular Network (TIN) Data Model

Further Readings

- Jensen, J. R. (2000). *Remote sensing of the environment: An earth resource perspective*. Upper Saddle River, NJ: Prentice Hall.
- Lo, C. P., & Yeung, A. K. W. (2007). *Concepts and techniques of geographic information systems* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Peuquet, D. J. (2002). *Representations of space and time*. New York: Guilford Press.



TERRAIN ANALYSIS

Generically, the term *terrain analysis* covers all processes that extract information from all kinds of terrain surface representation data. Such representations may include contour lines, profile lines, triangulated irregular networks, and square-grid digital elevation models (DEMs). The primary information extracted from terrain surface representations may be about local morphology or the characteristics of the entire catchment/watershed. Based on this primary information, the movements of materials controlled by gravity and the dynamics of energy



controlled by solar radiation over the land surface can be understood and described, and in turn, complex hydrological, geomorphological, pedological, and biological processes can be modeled. For this reason, terrain analysis has found applications in different fields, including geomorphology, soil science, hydrology, ecology, civil engineering, and environmental science.

The relationships between certain components in the natural system and terrain features have long been studied. A typical example of this type of relationship is the appearance of a “chain” of soils at different terrain positions along a slope. “Catena,” a concept proposed to refer to this soil-terrain pattern, became a cornerstone of the contemporary soil survey and mapping. However, only with the development of the contemporary digital technology did terrain analysis grow into a serious research field. Nowadays *terrain analysis* is almost a synonym of *digital terrain analysis* and is a significant aspect of the general spatial analysis that is based on geographical information science and technology. The most widely used terrain surface representation in digital terrain analysis is the square-grid DEM, due to its simplicity of format and easiness of algorithm implementation.

Terrain Attributes Characterizing Local Morphology

In digital terrain analysis, to measure the local morphological features at a given location, including slope gradient, slope aspect, and various types of curvatures, a conceptual procedure is to first represent the actual terrain surface in a mathematical way and then calculate morphological features as the derivatives of the mathematical surface. Specifically, slope gradient and slope aspect are calculated as the first-order derivatives of the surface, and the two most useful curvatures, profile curvature and planform curvature, are modeled as the second-order derivatives of the surface.

With a square-grid DEM, the primary approach to deriving derivatives from a discrete raster representation is the finite difference estimation. The basic idea of this method is to first fit a polynomial to a neighborhood defined by a group of cells (pixels) and then calculate the derivatives of the polynomial surface for the center location

of the neighborhood. The two most widely used polynomials for this purpose are the quadratic polynomial,

$$Z = \frac{1}{2}rx^2 + \frac{1}{2}ty^2 + sxy + px + qy + u,$$

and the Lagrange polynomial,

$$Z = ax^2y^2 + bx^2y + cxy^2 + \frac{1}{2}rx^2 + \frac{1}{2}ty^2 + sxy + px + qy + u.$$

In the above equations, Z is the elevation, x and y are geographical coordinates, and $a, b, \dots, u$ are coefficients whose values need to be derived from the actual terrain surface.

As an example, for a neighborhood typically defined by 3×3 cells, the equation for calculating the slope gradient (in angular degrees) for the center cell is as follows:

$$g = \arctan \sqrt{p^2 + q^2},$$

where p and q are calculated as follows:

$$p = (z_3 + z_6 + z_9 - z_1 - z_4 - z_7)/6w \text{ (under the quadratic polynomial)}$$

$$q = (z_1 + z_2 + z_3 - z_7 - z_8 - z_9)/6w \text{ (under the quadratic polynomial)}$$

$$p = (-z_4 + z_6)/2w \text{ (under the Lagrange polynomial)}$$

$$q = (z_2 - z_8)/2w \text{ (under the Lagrange polynomial)},$$

where $z_1, z_2, \dots, z_9$ are elevation values for the cells in the 3×3 neighborhood illustrated in Figure 1 (w is the length of one side of a cell).

Terrain Attributes Characterizing Catchment/Watershed

From a digital terrain surface representation, one can also derive information that characterizes the entire catchment/watershed. This information typically includes descriptive statistics of the watershed (e.g., minimum and maximum elevations of the watershed) and attributes regarding water flows.

Most attributes regarding water flows are based on the information about local flow direction,

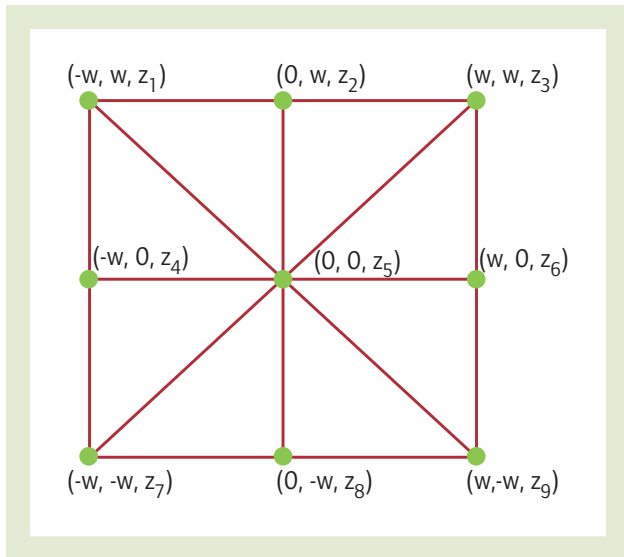


Figure 1 A typical 3×3 neighborhood defined over a square-grid digital elevation model

Source: Author.

which is derived from differences between nearby elevations. The most common method for calculating flow direction is the D8 algorithm, which assumes that the water in the center cell of a neighborhood flows only into one of its eight neighboring cells—that is, in the direction of the steepest descent. Based on the flow direction calculated in this way, information about flow path, slope length, upper-stream drainage area (flow accumulation), and watershed boundary can be derived.

Combining flow accumulation and slope gradient leads to an attribute that effectively characterizes the local moisture condition. This attribute is called wetness index or sometimes compound topographic index, which is calculated as follows:

$$w = \ln\left(\frac{A}{\tan g}\right),$$

where A is the flow accumulation and g is the slope gradient measured in degrees.

Ongoing Research

One challenging issue in terrain analysis is to automatically recognize the predefined terrain positions from a digital terrain surface representation, such as a square-grid DEM. This type of

technique is useful because much of the existing knowledge in a field-based soil survey and mapping is associated with terrain positions. This recognition requires an integration of local morphological information and contextual information. Fuzzy logic has also been introduced to this problem to improve the accuracy and precision of the terrain position representation.

Another major research topic in terrain analysis is the impact of the resolution of the input DEM on the resulting terrain attribute values. This research is driven by the increasing diversity of data sources (particularly from remote sensing) and the increasing availability of high-spatial-resolution data. Understanding the advantages, disadvantages, and uncertainties associated with these data and their suitability for different applications is the prerequisite to the proper and full utilization of the data.

Xun Shi

See also **Hydrology; Landscape Interpretation; Watershed Management; Watershed Yield**

Further Readings

- Beven, K. J., & Kirkby, M. J. (1979). A physically-based, variable contributing area model of basin hydrology. *Hydrological Science Bulletin*, 24, 43–69.
- Burrough, P., & McDonnell, R. A. (1998). *Principles of geographical information systems*. Oxford, UK: Oxford University Press.
- Florinsky, I. (1998). Accuracy of local topographic variables derived from digital elevation models. *International Journal of Geographical Information Science*, 12, 47–61.
- Miline, G. (1935). Some suggested units of classification and mapping particularly for East African soils. *Soil Research*, 4(1), 183–198.
- Moore, I. D., Grayson, R. B., & Ladson, A. R. (1991). Digital terrain modeling: A review of hydrological, geomorphological, and biological applications. *Hydrological Processes*, 5(1), 3–30.
- Shary, P. (1995). Land surface in gravity points classification by complete system of curvatures. *Mathematical Geology*, 27, 373–390.



- Wilson, J., & Gallant, J. (2000). *Terrain analysis: Principles and applications*. New York: Wiley.
- Zevenbergen, L. W., & Thorne, C. R. (1987). Quantitative analysis of land surface topography. *Earth Surface Processes and Landforms*, 12, 47–56.
- Zhou, Q., Lees, B., & Tang, G. (2008). *Advances in digital terrain analysis*. Berlin, Germany: Springer.



TERRITORY

Territory is an important concept for understanding politics and social behavior. Although unsettled etymologically, the term *territory* is usually taken as a derivative of the Latin *terra* (land); however, it has also been suggested that it is derived from the Latin *terrere* (to frighten), indicating that territory is a place that frightens people. This dual meaning is key to understanding territory. Most theories of the state point to territory, in combination with sovereignty and population, as the defining features of the modern state. Yet in a broader context, territory refers to the space occupied, or claimed, by a group of social beings. Essentially, territory indicates a bounded social space of dominance, identity, or jurisdiction.

Territory is a heavily contested concept across the social sciences, where there is little agreement on what territory is or what it means. Therefore, rather than presenting a narrow, unambiguous version of what territory is, this entry describes some basic understandings of territory and presents some of the key considerations surrounding territory, with special emphasis on political territory.

Three Key Functions of Territory

There are three dominant ways of understanding territory:

1. It refers to the natural habitat of a group of people or animals. In zoology, it refers to an area occupied by an animal or a group of animals, which they defend against others of their own kind.

2. It represents a social space that is constituted as a result of the behavior of a group of people, for example, when the supporters of one football team occupy a part of a section of a stadium, they create an area designated for them, where supporters of the other team are not welcome.
3. It denotes an area over which a polity claims dominion. This could be the area surrounding a city-state in early modern Italy or a modern state territory as that of contemporary France. In international law, territory plays an essential role in defining nation-states as legal members of the international community.

Common to these three understandings is the creation of a space from where something, or somebody, else is potentially excluded.

Thing Versus Process

It is impossible to understand territory without a reference to land; however, the physical character of territory is often overestimated. While territory is constituted through the demarcation of a physical space, it is the delimitation and character of this space that give territory its characteristics. The existence of boundaries is never a natural phenomenon; even if mountain ranges or seas can make it impractical for people to move across them, boundaries are always a relational, and hence socially created, phenomenon. One should be careful, therefore, about treating territory simply as a physical object. Rather, territory should be understood in terms of the social relations that produce territory and are affected by territory. For example, it was the development of cartography that provided the spatial knowledge necessary for states to precisely define and agree on the boundaries vis-à-vis each other. This change, in turn, facilitated the development of distinct territorial societies. Without these developments in geographic knowledge and technologies, territory is unlikely to have played the central role that it plays in current affairs. Therefore, to understand what territory is, and how territory is created, we need to look at the historical social processes involved. Such processes are usually described as territoriality or territorial behavior.



Territorial Behavior

As a general concept, territorial behavior describes actions that aim to create a bound social space within which one dominates, and thus excludes others. This can refer to the territory of animals or the erection of a fence to mark off one's property. Understood in this way, territory is a central aspect of any social order referring to the distribution of space, as well as a strategy to create space as one's own. When an urban gang competes with another gang to control a part of a city where it seeks to control drug trade and other illegal activities, it constitutes a territory where members of the gang dominate and from which others are frightened off. In extreme cases, such as the clashes between gangs and paramilitary troops in urban slum areas in Brazil in the early 2000s, the gangs openly challenged the sovereign authority of the state and created territories where authority was disputed. Conflicts between groups of people, such as the divisions in Northern Ireland, can also result in territorial divisions, where sections of the capital, Belfast, have been divided into strict zones for Protestants and Catholics. These zones would not be officially sanctioned by state authority but would be recognized in, and maintained by, the everyday patterns of behavior of the population. Whereas these examples of territoriality produce shifting and maybe vaguely bounded territorial spaces, the political territories of states, appear as more static and settled.

Political History

International politics is based on what is called a sovereign territorial order. This means that the international system is based on sovereign territorial states that recognize each other as legal subjects of international law. Without territory, a state cannot be a legal entity. Territory plays the role of dividing the legal jurisdictions among states into distinct sovereign spheres, and it is, therefore, territory that serves as the foundation of differentiating different sovereign entities as states. Historically, this system is accredited to the peace treaties of Westphalia, officially marking the end of the Thirty Years War in Europe (1618–1648) and initiating a new system in which nation-states rather than feudal empires played the dominant role in continental

(and later, global) politics. These events signaled the spatialization of politics and replaced the system of jurisdictional sovereignty that had characterized medieval politics in Europe. Jurisdictional sovereignty represented a relationship between the sovereign ruler and his or her subjects. As such, it was primarily a hierarchy of personal relationships that decided the extent of the territory over which a ruler could claim dominion. In contrast, the spatialization of politics meant that sovereignty began to refer to a specific area of geographical space; and whoever was living within this area would automatically be considered to be subjects of the sovereign ruler. In sum, the territorialization, or spatialization, of politics points to a transition in the relationship of the sovereignty of a ruler from personal relations to a specifically defined space. This process started in the 15th century and became a defining feature of European politics over the following centuries (Figure 1). Following European colonization of the rest of the world, sovereign territoriality became the dominant way of organizing international relations, and following World War II, sovereign equality based on territoriality was adopted as the main principle of the UN charter.

National Identity

Most theories of national identity and expressions of nationalist ideology stress the link of a nation to a specific territory or homeland. Narratives about the special character of a particular land—its beautiful valleys, forests, and so on—serve to link a particular group of people to a particular land. In theories of national identity, it is common to distinguish between articulations of identity associated with blood lineages (where the collective identity is constituted through kinship-like relations) and articulations of identity associated with territory or the land (where residence within a particular territory is constitutive of the collective identity). The former is associated with the historical example of German national identity, and the latter with France. Regardless of whether territory defines the extent of the collective identity, however, the notion of a homeland is crucial. What is significant is the way in which the territory acquires the role of a home for a particular collective. This discourse of the territory as home is strengthened by the feeling of familiarity that



Figure 1 Cartographic representations, such as Blaeu's map of Europe from the mid 17th century, contributed to the perception of a world divided into neatly bounded territories.

Source: Public domain.

most people have when they return from travel and is associated with being back in a particular territory. In that respect, it is through the discourse on national identity that a population and a territory are tied together into a unit.

Territorial Conflict

Territory has often been a source of conflict and war, caused by competition over natural resources, by a general competition for access to land, or by competing notions of national identity claiming the same area as a core aspect of a particular nation. In legal terms, there is a tension in international politics in that territorial sovereignty is expressed through the norm of territorial integrity

that seeks to maintain the territories of current states intact, but at the same time, territorial sovereignty is legitimized through a claim to national identity. When a recognized state territory contains what is perceived to be more than one nation, it is logically impossible to sustain both the norm of national self-determination and the notion of territorial integrity. This was clear during the 1990s, when the former Yugoslav Republic was split up into smaller states after a series of bloody wars justified with reference to national and ethnic cleavages. Territorial conflict or competition can also take place in a more peaceful way. In recent years, the Arctic region has attracted increasing attention from the Arctic countries, all of which try to claim large areas of the Arctic



seabed. This is done with reference to the UN Convention on the Law of the Sea (UNCLOS) from 1982, which specifies the conditions under which a nation can expand its domain at sea. The countries involved pursue territorial enlargement to get control over the natural resources that might be found there.

Network Versus Territory

In recent years, the significance of territory has been challenged by new approaches to social science. The end of the Cold War and the rise of globalization have led many to believe that territory is becoming less significant. Especially, social constructivist and postcolonial writings have emphasized new “spatialities” coming to play a more significant role and, in doing so, undermining the preeminence of territory. With the advance of communication technology in particular, economic and social transactions can be carried out in an instant across long distances, and it has been highlighted how global networks cut across territorial boundaries and thereby undermine the capacity of the state to exercise sovereign authority within its territory. The main contribution of these writings has been to critically investigate the history and status of territory. By emphasizing the historical development of current territories, and especially contrasting these with non-Western experiences of the territory and spatial behavior, they have shown a range of alternatives to global politics based on a territorial order. For example, poststructuralist studies often stress the existence of alternatives to territorial societies by investigating nomadic traditions and behavior, which they describe as another way of organizing social space. These writings have provided an important contribution by pointing to the limits of viewing the social world from a purely territorial perspective. While it would be a folly to claim, generally, that territory as such no longer matters, it is important to keep in mind that various social practices, such as economic interaction, tend to follow a nonterritorial logic. A useful way to approach this tension is to think about territory and networks as two different social spatialities that often contradict each other while they necessarily coexist.

Jeppe Strandsbjerg

See also **Borders and Boundaries; Cross-Border Cooperation; Deterritorialization and Reterritorialization; Geopolitics; Nation; Nationalism; Political Geography; Sovereignty; State**

Further Readings

- Delaney, D. (2005). *Territory: A short introduction*. Oxford, UK: Blackwell.
- Gottmann, J. (1973). *The significance of territory*. Charlottesville: University Press of Virginia.
- Ruggie, J. (1993). Territoriality and beyond: Problematizing modernity in international relations. *International Organization*, 47(1), 139–174.
- Sack, R. (1986). *Human territoriality: Its theory and history*. Cambridge, UK: Cambridge University Press.
- Shaw, M. (2003). *International law* (5th ed.). Cambridge, UK: Cambridge University Press.



TERRORISM, GEOGRAPHY OF

The geography of terrorism refers to the spatial and locational characteristics of terrorist incidents, including the global and regional patterns of terrorism, the physical places where attacks occur, the location and activities of the human victims of attacks, the spatial and operational characteristics of attack locations, the types of land use commonly subject to terrorist attacks, the ways in which terrorist actors intersect in time and space with the intended victims, and, most generally, the extent to which the characteristics of places and the human activities occurring there interact with political, ethnic, racial, social, religious, or other ideological motivations and attack methods to produce terrorism.

The geography of terrorism is complex and multidimensional. It includes a political geography of the nation-states involved in the sociospatial control of various territories and the official public responses to the incidents of terrorist violence within those territories. Terrorism has a temporal geography, in which tribal or communal hatreds and vengeance propel cycles of reciprocal



political violence within a society over time. Terrorism has an urban and rural human geography, in which the spatial arrangements of ethnic, religious, and racial groups set the stage for terrorist violence. Terrorist violence has a military geography, involving the conquest and control of space and the capture and maintenance of territory.

Definitions of Terrorism

Definitions of terrorism abound. Terrorism is viewed in this entry as the use of violence by individuals, substate groups, agents of the state, and state authority against innocent victims to achieve political, ethnic, racial, religious, or other ideological objectives. Terrorism can be a broad strategy as well as an individualized tactic used in sociopolitical conflict, practiced by nation-states and substate actors alike. The sociologist Donald Black defines pure terrorism as a form of social control and collective self-help among groups addressing perceived problems—one group wages collective violence on others to get something done or to stop something. Terrorism is also considered to be a tactic of asymmetric warfare.

Geographical Components of Terrorism

Every terrorist incident occurs in a physical place in which four necessary elements of terrorism come together: (1) the perpetrator of terroristic violence, (2) the victims of violence, (3) the types of violence (methods and weapons), and (4) the ideological motivations that transform ordinary criminal violence into terrorism. The interactions among terrorists, victims, methods, motivations, and places of attacks produce several geographical dimensions of terrorism.

Spatial Strategy of Terrorist Violence

Terrorist behavior has a spatial component when violence driven by political, ethnic, sectarian, or religious motives is perpetrated to control, change, or eliminate the activities occurring within an area or the people occupying that area. Terrorist violence is instigated to (a) drive out the occupants of a particular place, (b) keep other parties away from an area, or (c) stop certain activities from occurring in an area. Alongside

these motivations is a desire to create a climate of fear through random violence that sends a message that no place is safe and that the innocent will be targeted to accomplish the terrorists' objectives. Ethno-nationalist, state terror, and genocidal campaigns commonly include explicit spatial strategies to stop the performance of human activities in a space, drive people out of certain spaces, or simply eradicate them.

The geography of terrorism involves a broader conception of victimization in which the places of terrorist incidents—as well as the humans in those spaces—are an integral part of attacks and their ideological messages. Assaults on government buildings, diplomatic facilities, public markets, clinics, or pristine natural spaces all send direct and indirect messages to intended audiences, based on the characteristics of the places attacked and the human activities they host. The places attacked are part of an informational strategy of terrorism and often reflect multiple layers of meaning. At a minimum, terroristic violence persuades citizens that the targeted spaces are not safe.

Treatment and Control of Space in Terrorism

Terrorism can have clear geographical motivations. Land control is at the core of the Palestinian-Israeli struggle. The Irish Republican Army (IRA) used terrorism to dislodge Britain's occupation of Northern Ireland. Controlling land was the primary motivation in Sendero Luminoso's violence in Peru, strategically as an example of Maoist guerrilla warfare and tactically as a way of gaining control over coca production. Colombia's terrorist violence stems from the agricultural sources, production locations, and transport of illicit drugs. The Tamil Tigers use terror tactics to capture and control land in Northern Sri Lanka. The ETA (*Euskadi Ta Askatasuna* [Basque Homeland and Freedom]) in Spain uses terror to struggle for sovereign status for the Basque land in the Northern Iberian peninsula. In the past 30 years, radical Islam's interest in the holy sites of Mecca and Medina has produced major terrorist incidents. In Rwanda in 1993 to 1994, the Hutu used mass murder to erase the Tutsi from Rwandan territory. The Sudanese government depopulated



New York City, September 25, 2001: Fragments of the World Trade Center façade that remained after the attacks on the 110-story structures that once dominated the skyline of lower Manhattan.

Source: Mike Rieger/FEMA News Photo.

the indigenous population of Western Darfur using terror tactics between 2003 and 2008. In all these ways, land and spatial control can be the strategic focus of terrorism.

Location of Terrorist Acts Among Political Jurisdictions

The global geography of terrorism begins with the spatial distribution of terrorist incidents among countries. Individualized terrorist attacks occur, and over time, clusters of incidents appear among sovereign states. Spatiotemporal clusters of terrorism among countries are built on the spatial and sociopolitical context of each country, as defined

by its longer histories of political, social, ethnic, or religious conflicts, including not only internal ones but also conflicts with other countries. Terrorism is produced by different actors—it has been executed very effectively by nation-states, by organized and disorganized substate groups, and by grassroots “leaderless” resistance networks. Any of these groups can wage extended campaigns of terror. Furthermore, terrorist groups originate from selected countries and can show specific spatial allegiance to certain areas. Depending on their potency and motivations, groups sometimes wage terror campaigns in other countries or work covertly with public authority when state-sponsored terrorism is involved.



Location and Situational Characteristics of Terrorist Acts

At a more resolved spatial scale, regional differences in terrorist incidence rates are important. Black (2004) suggests that terrorism arises in places where sociodemographic structures result in (a) long social distances between people in terms of their ethnicity, religion, social class, corporate status, or hierarchical authority and (b) short physical distances between people who are socially distant—that is, there is a large social distance between people who live in close proximity to one another. Terrorist violence frequently generates mass casualties, so population density is an important part of terrorist targeting strategies, creating higher urban risk profiles. Within countries, selected cities and localized regions become repeat hosts of terrorist incidents. Acts of terrorism also occur within a set of local operating environments (e.g., an airport, a public park, an office, a government facility). This means that certain land use classifications become more or less attractive targets. For example, land zoned for public transportation corridors has been the scene of devastating terror attacks over time. Countries hosting “mega-events” (e.g., Olympics, Super Bowl, World Cup) have higher risks of terror attacks during such events.

At a basic level, the target of terror attacks sets up the geography of terrorism. Places targeted are rarely random but are chosen for tactical or symbolic reasons. Physical places are often the targets of terrorist attacks because they host some activity. Medical facilities, timber companies, airline counters, dwellings, and places of business have all been sites of terrorist crimes, from minor vandalism through catastrophic destruction. Public markets, restaurants, meeting halls, hotels, office spaces, transport facilities, and resorts are targets of terrorist violence. Sometimes, the place is a more important targeting dimension, while at other times the functions performed in that space are more important. A terrorist incident can target a women’s birth control clinic, the observation deck of a skyscraper, a parking garage, or an airport ticket counter. Terrorism targets locations that have functional or operational characteristics (e.g., a place where abortions are performed, where Hindus worship, where foreign tourists

congregate, or where international business is conducted).

Another geographical component of terrorism comprises the situational aspects of places where terror attacks occur. A detailed analysis of terrorist incidents reveals a wide array of settings. Suicide bombings on public transportation were common in the Israeli-Palestinian conflict and spread to London in 2005. Bombings in restaurants, resorts, and hotels target innocent “occupiers of space” at a particular time. Targeted assassinations occur in residential areas, striking victims in their homes. Firebombings are used in exurban locales by environmental extremists and insurgent groups. Terrorism is often defined based on the characteristics of the attack victims who came together and engaged in routine activities in common places (e.g., a wedding party, a dinner, a shopping center, a station, an airport, or a school).

Terrorist incidents are sometimes designed around the locational and operating characteristics of a target. The Earth Liberation Front firebombs automobile dealers selling Hummers to protest against gas-guzzlers or uses arson to burn partially built houses in undeveloped areas. Mexican narco-terrorists murder an off-duty police official at his residence to demonstrate people’s vulnerability in their homes. The 2006 Mumbai train bombings by a grassroots Islamic group targeted first-class commuters during the evening rush hour.

The targets of terrorism can be comparatively undefended, more accessible to terrorist actors, or difficult to guard and protect. Residential sites and public spaces are relatively undefended. But fortifying the target does not necessarily dissuade attacks. Surprisingly, well-defended places are frequent targets. The multitude of city spaces exhibits higher landscapes of risk. Certain kinds of land use (e.g., public spaces, public transport facilities) are more likely to be the site of terrorism incidents.

At the closest spatial scale where terrorist actors or agents cross paths with victims, terrorism consists of one or more sequential crimes, such as kidnapping, assault, attempted murder, or murder. Each crime is implemented using a method and one or more weapons. The crimes occur together in time and space. The methods and weapons used determine whether the terrorist physically crosses



paths with the victims or instead leaves a device that delivers the attack. The distance from terrorist to victim can be near or far depending on the method-weapon combination. Using a scoped rifle to close the distance between the killer and the victim keeps assassins farther from their victims, as do remotely detonated bombs. At other times, suicide attackers get close to victims. Transportation and communications technologies help create spatial connections between victims and terrorists. Cellular technology and the Internet help coordinate attacks from longer distances. Terrorist groups use technologies (e.g., letter bombs, firearms, computers, airplanes, trains, buses, car bombs, improvised explosive devices) to deliver attacks, which enable terrorist agents to escape, fight it out, or die at the attack site.

When terrorist actors use biological or chemical weapons, or remote detonations of explosives, a slightly different geography develops. Attackers and victims may not come into direct contact, and often the results are not seen until later, after the terrorist actors leave the scene. Letters and parcels bearing viral or biological agents or explosives can use postal systems to reduce the distance between the victims and the terrorists. The U.S. anthrax terrorists in 2001 were probably nowhere near the victims. In contrast, the 1995 Tokyo subway attacks required Aum Shinrikyo members to intermingle with victims in subway cars prior to piercing the bags of sarin and leaving. The 1993 World Trade Center and the 2004 Madrid train bombings used timed detonators that maintained separation between the terrorists and their victims.

Research Questions

The geographical components of terrorism are far-reaching and suggest various avenues for further research. Key questions include the following:

1. What spatial strategies are embedded in terrorist campaigns?
2. Which countries host large rates of terrorist violence, when, and why?
3. Where within a country do terror attacks occur?
4. What land uses and human activities are under way at the places targeted by terrorist violence?

5. How do terrorist actors or agents intersect the personal space of victims?
6. How do terrorists distribute violent incidents across their activity areas?
7. What does the risk profile of a region look like?
8. How do public responses to terror affect people's movement through space?

Samuel Nunn

See also **Antiglobalization; Crime, Geography of; Fear, Geographies of; Hate, Geographies of; Justice, Geography of; Military Geography; Political Geography; Resistance, Geographies of; Risk Analysis and Assessment; War, Geography of**

Further Readings

- Black, D. (2004). The geometry of terrorism. *Sociological Theory*, 22(1), 14–25.
- Cutter, S., Richardson, D., & Wilbanks, T. (Eds.). (2003). *The geographical dimensions of terrorism*. New York: Routledge.
- Drake, C. (1998). *Terrorists' target selection*. New York: St. Martin's Press.
- Flint, C. (2003). Terrorism and counterterrorism: Geographic research questions and agendas. *The Professional Geographer*, 55(2), 161–169.
- Gregory, D., & Pred, A. (Eds.). (2007). *Violent geographies: Fear, terror, and political violence*. New York: Routledge.
- Kent, R. (1993). Geographical dimensions of the Shining Path insurgency in Peru. *Geographical Review*, 83, 441–454.
- Noble, A., & Efrat, E. (1990). Geography of the Intifada. *Geographical Review*, 80(3), 288–307.



TEXT/TEXTUALITY

There is no clear consensus as to what constitutes a text or how the term should be defined. Instead, the term falls victim to a wide array of interpretations and applications across and within



various disciplines; however, it is often associated with the pioneering work of Roland Barthes and other literary theorists and cultural anthropologists such as Paul Ricoeur, Clifford Geertz, James Clifford, George Marcus, and Stephen Tyler. Here, text is regarded as a sociocultural product and/or process and is expanded from its traditionally narrow definition of being a mere printed medium to include things as wide ranging as paintings, photographs, maps, electronic media, landscapes, as well as economic, political, and social institutions.

A text, in the broadest sense of the word, can be regarded as a configuration of signs that is coherently interpretable by some community of users. Implicit in the definition is the view that something can only qualify as a text if it is void of anonymity, randomness, and illogic. Hanks (1989), for instance, distinguishes the senseless cacophony of a crowded street from the sound exchange of words between two mutually oriented interactants, or the noise of rush hour as opposed to the concerted dissonance of a dramatic passage in a musical score. Texts are therefore innately communicative and are part of an ongoing discourse produced, received, and interpreted by various social actors and agents.

The reading of a text occurs through its textuality. A text is replete insofar as it is grounded in a locally defined social context. To understand a text and make it semantically whole, the reader has to draw on a variety of background information or seek to understand the particular context that gave rise to such text. Even the most rigorous of linguists with their emphasis on textual form and content make reference to a text's connection with the sociocultural world. Textuality then refers to the attributes that distinguish the text as an object of enquiry. Texts are produced and understood in terms of the broader sociocultural context in which they arise. If read in isolation from the broader social matrix of which it is inherently a part, a text becomes incomplete and indeterminate.

The term *intertextuality* is also linked to the use of "text" as a concept. Implicit in this is the view that all accounts of the world are highly mediated by preexisting notions and theories. Places are intertextual in that they are shaped by previous texts and practices that are deeply

inscribed in their landscapes and institutions. In short, texts shape, and are in turn shaped by, other texts. Therefore, meaning is produced from text to text rather than in and of the texts themselves.

The Discourse on Text

The discourse as to what constitutes a text, and in extension its textuality, has been a long-standing and ongoing one. There are indeed many approaches to the study of text. Approaches to textual analysis can be differentiated according to the scope and extent to which text is seen as an object of enquiry. For a structuralist, texts are seen as products of an ongoing hegemonic discourse. Much of the initial work on texts in structuralism was carried out by Roland Barthes, who believed that the world was made up of signs. By studying these signs, Barthes believed that one could uncover the complexities and the instability that underlie our everyday life. Accordingly, landscapes were perceived as being produced and shaped consciously to represent a particular set of values and belief systems. Landscapes were therefore found to be unnatural and highly ideological and political. In one of his most famous essays "The Blue Guide," Barthes (1986) critiqued the widely used *Hachette World Travel Guide* as being an instrument of Western cultural manipulation. Barthes illustrated how, by showcasing a limited range of landscape features, the travel guide plays into Western constructions of place, thus ignoring the familiar (Western) and romanticizing that which is deemed as unfamiliar (the Orient). In fact, Barthes described the travel guide as an "agent of blindness," one that conceals non-Western realities.

Poststructuralists, on the other hand, challenge the structuralist notion that texts are coherent and self-contained. Instead, advocates of poststructuralism posit that texts are innately contradictory and indeterminate. Poststructuralists therefore shift their focus away from the text itself (as a bounded linguistic artifact) to the interaction between reader, text, and author. The consequence of this change is the expansion of the notion of text to include even social life.

This expanded notion of texts also has its roots in postmodernism. The postmodern view sees



texts as being constitutive of reality rather than mimicking it. For postmodernists, the world is like a text encoded with meaning. Ricoeur, for instance, posits that social life has characteristics strikingly similar to those of a written discourse. For Ricoeur, social life, like text, is detached from the intentions of its original authors, is inherently unstable, and possesses a certain amount of objective fixity. Additionally, social life has an importance beyond the initial context for which it was constructed—again, like that of a written text. Similarly, Clifford Geertz looks at cultures as texts; for him, culture can be “read” by an ethnographer as one might read a book. He extends his point by claiming that this practice is not only academic in its orientation but also one that everyone practices.

Text, Textuality, and Geography

The bulk of the literature on text and textuality has been confined to a few disciplines—literary studies, linguistics, and anthropology in particular. Most of the initial work focused on issues relating to the organization, production, and interpretation of texts. Throughout the 20th century, competing methods of textual analysis were put forward. Advocates of structuralism have focused on semiotics or text as signs, while post-structuralists have looked at text as being constitutive of larger and more dynamic discourses. The latter mostly adopts a Foucauldian interpretation of text. Here, discourses are seen as connected to knowledge, identity, and power. Society is seen as filled with multiple discourses that are representative of various interest groups. Texts either reflect or shape these multiple and sometimes competing discourses. Over the past few decades, these textual methods of analysis have attracted much attention and interest in the social sciences in general and geography in particular.

It was not until the 1980s and 1990s (during the rise of social and cultural theory in geography) that geographers became interested in textual analysis. This cultural turn saw the promotion of a hermeneutic approach to the study of place and the politics of representation. Most of these studies have focused on landscapes, cultural landscapes in particular. For geographers (new cultural geographers especially), texts represent a

valid way of interpreting landscapes. Implicit in this notion is that landscapes are themselves encoded with messages and can therefore be “read” and decoded as texts. Geographers are interested in the way places themselves encapsulate and communicate cultural identity and how these places in turn shape our own perceptions and identities as social beings. People’s interactions with their surroundings are therefore viewed as interactive and dynamic rather than one-dimensional and static. Landscapes are constantly “written” and inscribed with meanings. These meanings can then be “read” or interpreted as signs about the particular values, identity, beliefs, and practices evocative of that particular landscape, place, space, or era. However, to read these signs, one must understand the language in which it was written—in other words, one has to become familiar with the text’s textuality.

Barnes and Duncan’s (1992) *Writing Worlds* illustrates the many ways geographers have used concepts such as text, discourse, and metaphor to explore the dynamics of power in the representation of landscape. Though the landscape representations explored by the authors in the volume varied considerably (from travelers’ writings to propaganda maps), a common theme running throughout the book was that all sociocultural products and practices, including landscapes, social action, paintings, maps, and even language, are susceptible to textual interpretation. McGreevy (1992) showed how written accounts of the Niagara Falls—dating back to the late 19th century—were informed by the metaphor of death. He went a step further to illustrate how this metaphor of death had crept out of the written texts of the area into the very landscape humans created around the Niagara (evident especially in the many acts of suicide carried out in the area). Likewise, Daniels (1990) used a watercolor depiction of Leeds painted by J. M. W. Turner in 1816 to show how even works of art are themselves inscribed with meaning and can be “read” as text. Daniel showed how the painting addressed both the features of Leeds’ industrialization as well as the intellectual and political psyche of Turner and his time.

Another study worthy of mention is that of Denis Cosgrove (1998), who applied social and cultural theory to the study of landscapes.



According to him, landscapes are constructed and shaped by sociocultural and political processes and thus represent a “way of seeing.” Ways of seeing are ideological and signify the way in which the dominant class in a society represents itself and its property. In short, landscapes are both constituted by and constitutive of social power relations.

Recent research in subjects such as sociology, anthropology, and human geography has built on these past notions of text—though not explicitly—in exploring issues relating to the politics of place, identity and culture, place making, place/destination marketing, transnationalism, and even graffiti. Studies have shown, for instance, how various media texts (including the Internet, travel blogs, online advertisements, and other promotional literature for instance) have helped to either reproduce stereotypes or challenge dominant images of places. Erjavec (2001) showed how the theme and form of news reports worked to reinforce and legitimize discrimination against the Roma in Slovenia during the 1990s. Morgan and Pritchard (2002) also revealed how destination-branding strategies helped shape Wales’s tourism efforts. Based on their analysis of the marketing campaigns and promotional literature of the Wales Tourist Board in particular, the two concluded that the influence of both repressive and liberating historical, political, and cultural discourses was seen in the way Wales marketed itself as a tourist destination. Both examples—though different in their focus—speak to the relationship between texts, identity politics, and place representation.

Even more recently, Mains (2008) has shown how Latin American transnational identities are inscribed in both the cultural and the physical landscapes around the U.S./Mexico border. In looking at the movements or exchange of music and architecture between both sides of the border, she illustrates how cultural identities shape the way places are constructed and represented. For instance, in both Northern Mexico and California, Mexican hip-hop, *ranchero* music, and U.S. rock music dominate. These musical forms are often bilingual, thus indicative of the influence of what can be termed *transnational or border identities*. Similarly, Mains argues that an examination of the built environment of cities

such as Los Angeles or Tijuana will show the influence of Spanish colonial plazas and gardens, indigenous adobe materials, as well as modernist office buildings—again reminiscent of a transnational culture but also indicative of the ways in which cultural identities are sometimes manifested in the physical landscape and in turn mapped onto space. In short, the U.S./Mexico border and its associated cultural and physical landscapes can be read as texts, as they embody the interconnectedness with people and places throughout the Americas and have given rise to, and become increasingly shaped by, a number of distinct and competing discourses on mobility, immigration and legality, and transnational identities to name some.

As mentioned before, even graffiti can be looked at as texts and can be used to understand relations and contestations of power in urban space. Here, graffiti are defined as a sort of text that adopts a historically and culturally grounded interpretation of some aspect of the world, shaped by human personalities and actions. Graffiti not only alter or edit the text of the cityscape but also form an independent body of texts that refer to each other as well as to the “canvas” of the city on which they are literally inscribed. Graffiti thus represent a written and visual aspect of language, with their own semiotics of action, that if read properly can uncover the cultural politics of place, as well as various geographies of power and identity.

There are, however, a number of problems associated with the use of text and, in extension, textuality. A major one relates to the issue of representation. There are important epistemological and ethical issues surrounding the notion of representation and its implications for textual analysis. Duncan (2000) points out two such concerns. The first refers to the issue of the translatability of cultural difference, and the second refers to the ethics of speaking for others. The signs that are embedded in a landscape may have different meanings for those who produce them and for those who interpret them. As such, great care has to be taken when interpreting these meanings. Researchers have to be mindful of their own biases as well.

Kevon Rhiney



See also **Cultural Geography; Cultural Landscape; Discourse and Geography; Identity, Geography and; Place Promotion; Poststructuralism; Representations of Space; Structuralism; Symbolism and Place; Travel Writing, Geography and; Writing**

Further Readings

- Barnes, T., & Duncan, J. (Eds.). (1992). *Writing worlds: Discourse, text & metaphor in the representation of landscape*. London: Routledge.
- Barthes, R. (1986). The blue guide. In *Mythologies* (A. Lavers, Trans., pp. 74–77). New York: Hill & Wang. (Original work published 1957)
- Barthes, R. (1987). From work to text. In *Image, music, text* (S. Heath, Trans., pp. 155–164). New York: Hill & Wang. (Original work published 1971)
- Clifford, J., & Marcus, G. (Eds.). (1986). *Writing culture: The poetics and politics of ethnography*. Berkeley: University of California Press.
- Cosgrove, D. (1998). *Social formation and symbolic landscape*. Madison: University of Wisconsin Press.
- Cosgrove, D., & Daniels, S. (Eds.). (1988). *The iconography of landscape*. Cambridge, UK: Cambridge University Press.
- Daniels, S. (1990). The implications of industry: Turner and Leeds. In S. Pugh (Ed.), *Reading landscape: Country, city, capital* (pp. 66–80). Manchester, UK: Manchester University Press.
- Duncan, J. (1990). *The city as text: The politics of landscape interpretation in the Kandyan kingdom*. Cambridge, UK: Cambridge University Press.
- Duncan, J. (2000). Text. In R. Johnston, D. Gregory, G. Pratt, & M. Watts (Eds.), *The dictionary of human geography* (pp. 824–826). Malden, MA: Blackwell.
- Erjavec, K. (2001). Media representation of the discrimination against the Roma in Eastern Europe: The case of Slovenia. *Discourse and Society*, 12(6), 699–727.
- Geertz, C. (1973). *The interpretation of cultures*. New York: Basic Books.
- Hanks, W. (1989). Text and textuality. *Annual Review of Anthropology*, 18, 95–127.
- Mains, S. (2008). Transnational communities, identities, and moving populations. In

E. Jackiewicz & F. Bosco (Eds.), *Placing Latin America: Contemporary themes in human geography* (pp. 205–234). Lanham, MD: Rowman & Littlefield.

McGreevy, P. (1992). Reading the texts of Niagara Falls: The metaphor of death. In T. Barnes & J. Duncan (Eds.), *Writing worlds: Discourse, text & metaphor in the representation of landscape* (pp. 50–72). London: Routledge.

Morgan, N., & Pritchard, A. (2002). Contextualizing destination branding. In N. Morgan, A. Pritchard, & R. Pride (Eds.), *Destination branding: Creating the unique destination proposition* (pp. 11–41). Oxford, UK: Butterworth-Heinemann.

Ricoeur, P. (1971). The model of the text: Meaningful action considered as a text. *Social Research*, 38, 529–562.

Tyler, S. (1987). *The unspeakable: Discourse, dialogue, and rhetoric in the postmodern world*. Madison: University of Wisconsin Press.



TEXTILE INDUSTRY

The textile industry encompasses a sequence of production processes that transform raw materials into finished textiles and clothing products. Production in these sectors is shaped by two fundamental characteristics. First, cloth is relatively malleable and fragile, so commodity manufacturing in these industries has resisted automation and remained labor-intensive. Second, because the industry's production processes are divisible and able to be separated or vertically disintegrated into sequential stages, firms are able to locate each stage of production at the most advantageous site. As a result, the sector has developed a globalized organizational structure. Figure 1 provides a simplified view of the textiles production sequence.

The raw materials used to make textiles include natural fibers, human-made fibers, and combinations of the two. Natural fibers include cotton, wool, silk, flax, and hemp. Human-made or synthetic fibers can be obtained from processing petrochemicals (nylon and polyester) or made from

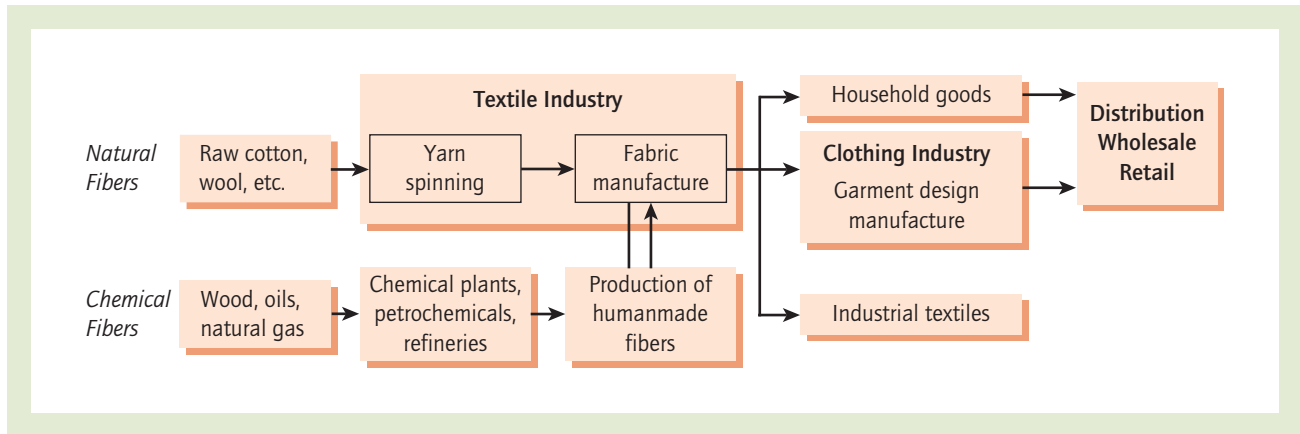


Figure 1 The textile industries

Source: Adapted from Dicken, P. (2004). *Global shift: The internationalization of economic activity* (5th ed., p. 234, fig. 8.1). London: Paul Chapman.

cellulose, which is derived from wood or cotton (rayon and viscose). Although the actual processes differ depending on the type of fiber, textile production involves spinning thread, weaving or knitting it into fabric, and then dyeing and finishing the fabric in different ways, depending on the intended end use. Technological advances in fiber manufacturing have generated a highly automated and capital-intensive subsector. In addition, a vibrant research sector is developing patentable new fibers that combine natural and synthetic materials for a range of high-technology applications (e.g., the carbon-coated textiles used in the aerospace industry).

Textiles have a wide range of industrial, household, and personal uses. They are the principal material in ropes, sacks, canvases, and fiberglass and have a wide range of industry uses (e.g., in filters and the rollers used in printing mills). Textiles are found in home and office furniture, carpets, curtains, bedding, as well as in the interiors of transport vehicles. Nonetheless, about 40% of textiles are used as inputs to clothing production.

Clothing production involves designing garments; making patterns; cutting cloth; sewing the cloth into garments; adding buttons, zippers, and other accessories; and then checking and packaging the final product. Basic clothing production (i.e., cutting and sewing pieces of cloth) does not require advanced skills, complex equipment, advanced technologies, or large capital investments. Clothing

manufacture is therefore characterized by what economists call low barriers to entry and exit, meaning that firms can easily come into or drop out of the industry. As a consequence, the sector has historically been volatile and mobile, changing rapidly in response to the vagaries of the business cycle and shifting its production locations in response to regulatory changes and interregional wage differences.

The sector exemplifies five key theoretical themes in economic geography and development studies: (1) the geopolitics of economic globalization, (2) the tensions between globalized production networks and localized industrial districts, (3) the internationalization of struggles over labor rights, (4) the flexibilization of the labor process, and (5) the contemporary repositioning of “cultural” industries.

Textiles in International Trade and Development

The textiles industries were one of the first sectors to develop globalized production structures and are now the world’s most traded commodities after agricultural goods. Textiles industries are the world’s most regulated industries and are unusually sensitive to policy change.

Textiles have played an important role in international trade and national development. Clothing production’s low entry costs, accessible technologies, and modest skill demands make it



the logical choice of industry to “kick start” national development strategies. Numerous industrializing countries have sought to exploit their comparative advantage in abundant and cheap labor by establishing clothing and textiles production industries. Accordingly, the sector has been the centerpiece of export-oriented industrialization strategies in Japan, Korea, and Hong Kong after World War II, in Asia’s newly industrializing economies (NIEs) in the 1980s, and in China since the 1990s.

Clothing and textiles production in the developing countries often occurs in export processing zones set up to attract foreign direct investment. These zones offer a range of incentives to capital, typically low wages, low infrastructure costs, tax holidays, and cheap and nonunionized labor. In the 1970s and 1980s, the growth of clothing production in less developed countries was fuelled by the relocation of production by Western firms seeking to reduce their labor costs or to escape the unionized workforces of factories in their home economies. Thus, the sector has been the archetypal example of the process of relocation of jobs from the developed to the developing world, a process known as the new international division of labor.

In the post–World War II era, Western governments imposed restrictions on textiles and clothing imports with the aim of protecting jobs in their home economies. The most important of these interventions was the 1974 Multi-Fibre Arrangement (MFA), which was an exception to the General Agreement on Tariffs and Trade (GATT), which allowed high-wage countries to impose import quotas that limited textile imports from low-wage countries. The developing countries viewed the MFA as an impediment to their economic development. At the Uruguay Round of GATT negotiations, member nations agreed to discontinue the MFA and bring clothing trade in line with the rules governing trade in other manufacturing sectors. Between 1995 and 2005, therefore, a transitional Agreement on Textiles and Clothing (ATC) was put in place to gradually phase out the sector’s quota restrictions.

Trade liberalization generated major shifts in the global configurations of textiles and clothing

industries. Figures 2 and 3 show the principal exporting countries’ shares of world textiles and the clothing export trade for the years 2000 and 2006. Both sets of figures highlight the rapid growth of Chinese exports. India, Turkey, and Pakistan have also benefited from recent regulatory reforms. In textiles, the losers in this process have been South Korea, Taipei, Hong Kong, and the United States. In clothing, Mexico, the United States, Hong Kong, and many small countries with low export volumes have lost market share. Hong Kong’s position as a reexport platform is faltering as Western firms increasingly source products directly from China.

Because trade liberalization has removed the advantage previously enjoyed by smaller developing countries (whose textiles exports were not restricted by MFA quotas), production now appears to be concentrating in and around specialized garment production regions. Both the United States and the European Union negotiated new agreements with China in late 2005 to slow the growth of imports into their markets.

The Commodity Chain Perspective

Commodity chain perspectives highlight the institutional relationships that shape trade flows. They view aggregate trends in textile production and exporting as the outcome of transnational subcontracting arrangements between firms. In textiles, these chains of interconnected firms are usually coordinated by large brand-owning core firms based in high-wage nations. Gereffi has called this form of industrial organization a “buyer-led” commodity chain (Figure 4). The commodity chain worldview assumes that power and profit accrues to core firms located close to consumer markets.

In reality, however, the structure of relationships between firms is complexly contingent on a host of factors, including the costs of production in different places; worker productivity relative to wage levels; the uneven landscapes of global and national regulation; the fashion sensitivity of particular products (which determines the “turnaround” time of the product cycle); transport costs; geopolitical conditions; the relative locations of designers, textile inputs,

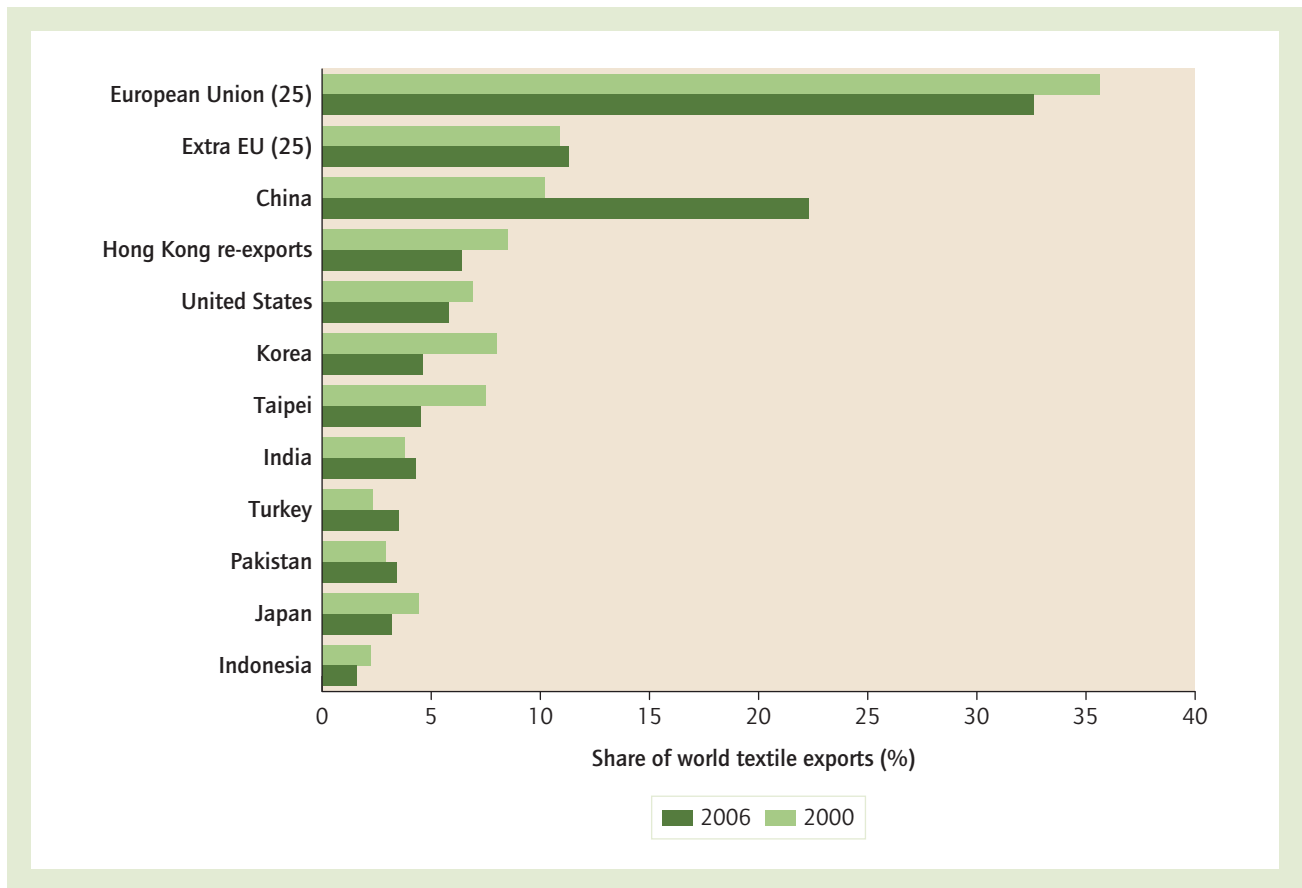


Figure 2 Leading textile-exporting countries

Source: Created from data in World Trade Organization, *International Trade Statistics*, 2007, Table 11.58: “Leading exporters and importers of textiles, 2006.”

accessories, factories, and markets; and, importantly, the power relations among suppliers, intermediaries, and buyer firms. These factors tend to create a product-specific hierarchy in which less complex, high-volume garments are made in low-wage countries while low-volume, fashion-oriented garments are made closer to their final consumption market.

National and global trade regulations are an important influence on the configurations of global production systems. In the 1990s, the growth of regional trade agreements combined with the constraints of the MFA encouraged firms in the United States and European Union to create cross-border production arrangements in nearby low-wage sites. These were usually sites with preferential or unrestricted trade access to Western markets. Mexico’s *maquiladora* exports

to the United States, for example, were facilitated by the North American Free Trade Agreement (NAFTA). This arrangement created markets for American-made fabrics and, thereby, protected American textiles jobs. In Europe, “outward processing” similarly links European brands and European-made textiles to clothing manufacturing sites in Turkey, Eastern Europe, and North Africa.

In recent years, commodity chain analysts have focused attention on the opportunities for less developed countries to upgrade their production capacities and move to higher-value-added activities by learning from their buyers. This view has stimulated research into the nature of the relationships among firms, especially the relationships between core buyer firms and their suppliers. In theory, core firms

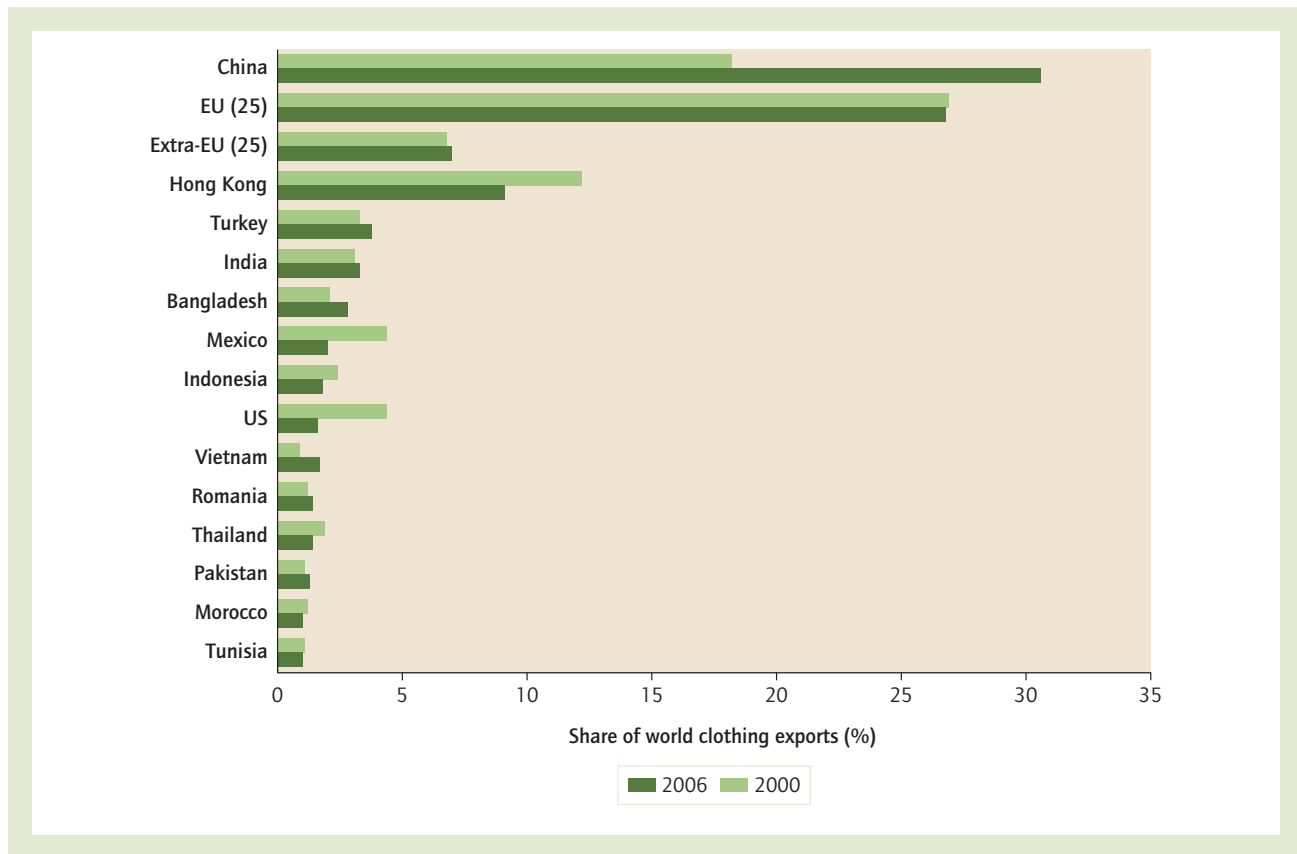


Figure 3 Leading clothing-exporting countries

Source: Created from data in World Trade Organization, *International Trade Statistics*, 2007, Table 11.63: “Leading exporters and importers of clothing, 2006.”

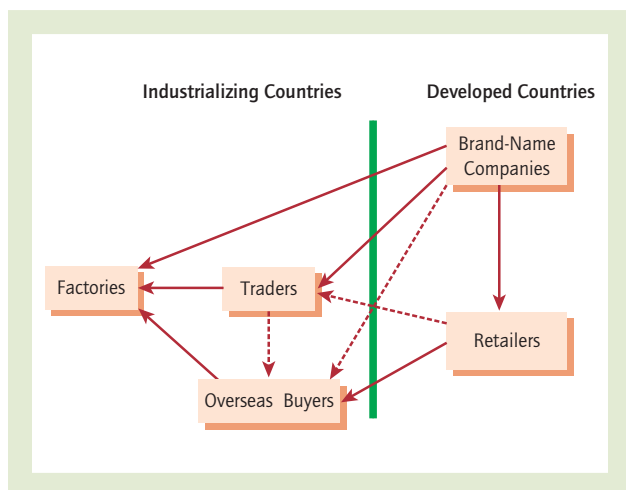


Figure 4 The structure of global commodity chains

Source: Adapted from Gereffi, G. (1994). The organization of buyer-driven global commodity chains: How U.S. retailers shape overseas production networks. In G. Gereffi & M. Korzeniewicz (Eds.), *Commodity chains and global capitalism* (p. 98, fig. 5.1). Westport, CT: Greenwood Press.

in the textiles sector are able to choose where and how different tasks are performed. As buyers in a global industry that is overcrowded with sellers, they enjoy a significant bargaining advantage. In practice, however, firms' options are limited. To ensure the timely supply of garments of the required quality, core firms tend to develop close relationships with reliable “preferred” suppliers. In recent years, the capacity of large retail firms to micromanage their suppliers has been enhanced by the standardization of accounting, auditing, and stock control technologies. These technologies have enabled large global retailers (such as Walmart and the Gap) to consolidate their relationships with their key suppliers and increase the range of tasks required of suppliers. These innovations tend to raise entry barriers and lock the less technically sophisticated producers out of global supply networks.



Labor Rights, Gender, and Business Ethics

The International Labor Office (ILO) has estimated that the sector's worldwide workforce was about 30 million workers in 2000. About three quarters (72%) of these workers live in Asian countries. In high-wage nations, textile employment has fallen relentlessly since the 1970s, but it is still a major contributor to manufacturing employment.

The textiles sector has been an important source of employment for women, who often work in onerous circumstances and are consistently paid 20% to 30% less than men. Home-based work and work in small factories or "sweatshops" is commonplace even in high-wage locations. This work is often insecure or "precarious," reflecting the intermittent nature of intermittent production. The sector has therefore featured prominently in studies of gender and development that highlight the hardships faced by women in these industries, as they negotiate the boundaries between waged and unwaged work and between workplaces and households.

The combination of globalized production structures and low wages place the textiles sector at the forefront of global labor rights campaigns. Activists informed by global commodity chain theories have successfully argued that Western buyer firms should be responsible for the labor conditions in their supplier factories. In response, the core buyer firms have introduced corporate social responsibility, corporate philanthropy and employment, and codes of practice that seek to protect their brand's reputation by ensuring that suppliers comply with minimum labor standards. Activists claim that in practice, these voluntary codes are often ignored. However, in countries such as Australia, the codes of practice have been formally incorporated into clothing industry regulation.

Reworking the Labor Process

In the long distant past, whole garments were crafted by skilled dressmakers and tailors. In the factories that emerged after the popularization of sewing machines in the 1880s, production was segmented so that a worker might perform a single task, such as attaching collars

or making buttonholes. Most of this labor was designed as women's work. The vertical disintegration of the labor process increased the efficiency of production but deskilled the clothing workforce and reinforced its gendered division of labor. Nonetheless, the range of styles, sizes, and colors required in clothing markets meant that clothing production was never standardized in the post-World War II Fordist mass production model.

During the 1970s, increasing competition from garments made in low-wage countries forced manufacturers in high-wage contexts to restructure their operations. Firms shifted toward less price-sensitive, niche markets and targeted higher-income consumers' desire for variety, design excellence, and quality. Firms changed their relationships with the market, investing in brand strategies that sought to capture the interest of a loyal clientele. Firms also aimed to offset the advantage of low-wage producers by increasing labor productivity, focusing on quick-turnaround fashion production and on reducing the time and distance between the conception of designs and the delivery of finished goods.

The inherent uncertainty of fashion-oriented markets encouraged manufacturing firms to adopt strategies variously known as "quick response," "just-in-time," or "lean" manufacturing. These involve a set of related innovations, including increasing the number of stock turns per year (equivalently, accelerating the circuit of capital), minimizing inventories, streamlining production to reduce labor costs, and increasing the productivity of individual workers (i.e., work intensification). New technologies of stock control such as Electronic Data Interchange (EDI, which links factories to retailers), computer-aided design, and computer-controlled laser cutting also increased productivity by eliminating many of the low-skilled jobs that once supported the core activity of sewing cloth. Because of this fragmentation, clothing production has come to be seen as exemplifying the numerical and task flexibility associated with post-Fordist production systems.

Reorienting to fashion production encouraged the development of small, specialized firms and altered the relationships among firms in vertically disintegrated supply chains. Modern



“fast-fashion” systems further accelerate the production cycle as their constant design innovations disconnect fashion from seasonal rhythms. Since fast fashion is organized around time imperatives, it encourages localized production “close” to target markets, brings retailers and manufacturers into close alliances, and promotes the integration of fashion-related manufacturing and service activities across multiple sectors.

In the 1980s, the specialized and flexible clothing production sectors of districts such as Emilio-Romagna in Northern Italy became the prototypes for a new paradigm of industrial production based on specialization, flexibility, and agglomeration. In this model of industrial organization, subcontracting strategies favor small, specialized establishments able to quickly adjust their production profiles to changing market trends. This format generates localized networks of highly specialized small firms with complementary expertise. External economies emerge as firms share innovation-promoting “ways-of-doing” knowledge and develop shared infrastructures, which encourages place-based agglomerations. Because firms gravitate to places that are able to supply their labor requirements—both highly skilled design workers and basic sewing machinists—clothing districts are found in the world’s richest cities, especially places with large immigrant communities such as New York and Los Angeles.

Fashion, Agglomeration, and Place

Because clothing and textiles adorn the body, the textiles sector is deeply linked to the worlds of fashion, consumption, and lifestyle. Rapidly changing fashion styles mean that clothing is increasingly regarded as a perishable commodity. In advanced capitalist economies, anticipating and shaping consumers’ fashion preferences is therefore an increasingly important aspect of clothing and textiles businesses. The crucial role of fashion in structuring the global production system exemplifies the increasing importance of symbolic knowledge in regional economic competitiveness. Within places, the cultural embeddedness and the design intensity of fashion promotes links among fashion-oriented industries,

creating agglomerative tendencies that are increasingly associated with “creative city” and “cultural economy” discourses.

Conclusion

The textiles sector is characterized by international commodity flows but also features extensive spatial agglomeration. It appears that these globalizing and localizing forces are operating together in a mutually reinforcing way so that the industry is concentrating at the nodes in the global networks. As regulatory barriers are relaxed, the sector appears to be increasingly characterized by complexes of competing and cooperating agglomerations.

Sally A. Weller

See also **Commodity Chains; Economic Geography; Export-Led Development; Export Processing Zones; Flexible Production; Globalization; Industrialization; Industrial Revolution; New International Division of Labor; Newly Industrializing Countries; Trade**

Further Readings

- Abernathy, F., Dunlop, J., & Weil, D. (1999). *A stitch in time: Lean retailing and the transformation of manufacturing—Lessons from the apparel and textiles industries*. Oxford, UK: Oxford University Press.
- Breward, C., & Gilbert, D. (2006). *Fashion’s world cities*. London: Berg.
- Dicken, P. (2004). *Global shift: The internationalization of economic activity* (5th ed.). London: Paul Chapman.
- Gereffi, G. (1994). The organization of buyer-driven global commodity chains: How U.S. retailers shape overseas production networks. In G. Gereffi & M. Korzeniewicz (Eds.), *Commodity chains and global capitalism* (pp. 95–123). Westport, CT: Greenwood Press.
- Hale, A. (2005). *Threads of labour: Garment industry supply chains from the workers’ perspective*. Oxford, UK: Blackwell.



Scott, A. (2006). The changing global geography of low-technology, labour intensive industry: Clothing, footwear, and furniture. *World Development*, 34(9), 1517–1536.



THALES

(CA. 626–CA. 548 BC)

Thales, born in Miletus, was a pre-Socratic Greek philosopher, the first natural philosopher who belonged to the Milesian school along with Anaximander and Anaximenes. Unfortunately, we do not have any of his writings; however, his importance in the field of geographic studies is due particularly to his views about the nature of Earth and his search for rational explanations through the observation of natural phenomena and avoidance of mythological beliefs.

According to Herodotus, Thales predicted the solar eclipse that occurred on May 28, 585 BC, but he is also said to have calculated the length of the seasons, the solstices, and the lunar phases; to have learned from sailors how to orient himself thanks to the stars (especially those belonging to the constellation Ursa Minor); to have conceived of diverting the Halys River (now called the Kizilirmak); and to have studied the yearly floods of the Nile, wrongly believing, however, that they were caused by seasonal winds.

In Egypt, Thales studied geometry and then introduced it to Greece. During his journeys through Egypt, where he visited the Nile delta, Thales observed the areas where water encounters land and elaborated a peculiar cosmological theory based on the idea that water is the origin (*arche*) of all things and that Earth rests on this substance. According to Aristotle, he may have found support for his idea in the fact that humidity can be found almost everywhere in the world and that moisture provides living beings with nourishment.

Regarding his idea of the shape of Earth, there are two schools of thought: Some commentators argue that he imagined a circular, flat, and thin world, whereas others support the theory that he believed that the planet was spherical. The explanation that he gave of a natural phenomenon such

as earthquakes is strictly related to the theory of water as the fundamental principle of the world. In his opinion, in fact, lands fluctuate and shake because of the rough motion of the oceanic sprawl on which they float.

Susanna Servello

See also **Anaximander; Aristotle; Herodotus; Human Geography, History of**

Further Readings

- Cohen, S., Curd, P., & Reeve, C. (Eds.). (2005). *Readings in ancient Greek philosophy: From Thales to Aristotle*. Indianapolis, IN: Hackett.
- Panchenko, D. (1994). Thales's prediction of a solar eclipse. *Journal for the History of Astronomy*, 25(4), 275–288.

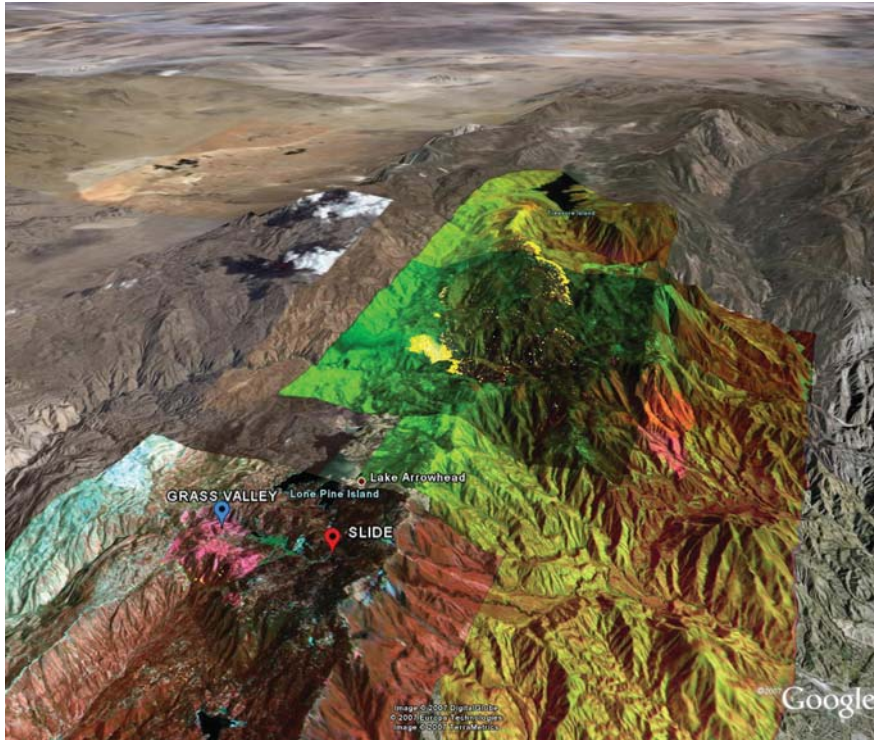


THERMAL IMAGERY

Imagery produced by the sensing of thermal energy emitted or reflected from the objects that are sensed is called thermal imagery. Thermal energy or thermal infrared radiation refers to electromagnetic waves in the 3.5- and 20- μm (micrometer) portion of the spectrum. Most thermal remote sensing applications make use of the 8- to 14- μm range. Earth's surface and atmosphere radiate thermal energy outward owing to heating by solar irradiation and by Earth's internal heat flow. By measuring and recording such emitted radiation in parts of the thermal region of the spectrum, sensors can produce very informative data (as imagery) that provide both distinctive signatures and/or indirect indications of properties of materials, which are sensed, such as vegetation, soil, rock, water, and people. Thermal imagery can be acquired by thermal remote sensing techniques.

Thermal Radiation Principle

Any objects on Earth's surface and in the atmosphere at a temperature above absolute zero in



Thermal-infrared imaging sensors on NASA's *Ikhana* unmanned research aircraft recorded this image of the Grass Valley/Slide Fire near Lake Arrowhead/Running Springs in the San Bernardino Mountains of Southern California just before noon on October 25, 2007. The three-dimensional processed image is a colorized mosaic of images draped over terrain, looking east. Active fire is seen in yellow, while hot and previously burned areas are in shades of dark red and purple. Unburned areas are shown in green hues.

Source: NASA/U.S. Forest Service.

degrees Kelvin can emit thermal radiation due to kinetic energy of molecules within the objects. They are sources of thermal infrared radiation. The thermal radiation obeys Planck's function, which describes the relationship between the object (blackbody) temperature and its spectral radiant exitance. A *blackbody* is an object that is a perfect emitter and absorber. Theoretically, two physical laws can be used to describe the behaviors of thermal radiation: the Stefan-Boltzmann law and Wien's displacement law. The former is related to the Planck's function and is used to calculate the maximum spectral radiant exitance with a known blackbody temperature, and the latter describes the relationship between the true temperature of a blackbody in degrees Kelvin and its peak spectral exitance or dominant wavelength. However, no objects in nature are true

blackbodies, but rather are graybodies such as vegetation, soil, rock, and so on. Therefore, when applying the two physical laws to describe the thermal radiation, an emission efficiency factor called emissivity (ϵ) should be considered. The ϵ is generally a function of wavelength, and it is a factor that describes how efficiently an object radiates energy compared with a blackbody. When $\epsilon = 1$, the object is a true blackbody. So ϵ for all graybodies is less than 1. When sensors record the thermal radiation emitted by objects, thermal infrared atmospheric transmittance has to be considered because of its absorption. Those wavelength regions that allow the major portion of thermal energy to pass through the atmosphere are called atmospheric windows. Currently, there are two major thermal infrared atmospheric windows that can be used for imaging thermal energy: (1) 3 to 5 μm and

(2) 8 to 14 μm ; especially the 8- to 14- μm window is used by most orbital thermal sensors.

Thermal Imagery Acquisition

Thermal imagery can be acquired by two types of remote sensing sensors: (1) across-track thermal scanners and (2) pushbroom linear and area-array charge-coupled device (CCD) detectors.

The thermal scanner became commercially available during the late 1960s. It is an optical-electronic scanning system. Quantum or photo detectors are typically used for this purpose. These detectors are capable of very rapid response. They operate on the principle of direct interaction between photons of radiation incident on them and the energy levels of electrical charge carriers within the detector material. The



earlier models directly recoded thermal energy on the film to form an image. Newer systems record thermal data digitally. Both analog (film) and digital scanners measure and record temperature variation of an object in two dimensions. The modern scanning systems are capable of imaging temperature resolution on the order of 0.1 °C. An across-track thermal scanner image is a pictorial representation of detector response on a line-by-line basis.

So far, most thermal data were collected with a single detector and a scanning mirror as discussed above. It is now possible to make use of both linear and area-array (sometimes referred to as “staring” focal-plane arrays) CCD detectors for acquiring thermal imagery. Detector arrays comprising more than $1,024 \times 1,024$ elements are now available and provide low noise and state-of-the-art sensitivity for extremely low variation of object temperatures. The individual CCD detectors also operate on the same principle as a single detector working for the across-track thermal scanner. But due to the capability of CCD detectors to view the ground resolution element for a longer time, the thermal imagery has improved significantly in terms of both radiometric and geometric resolution.

Thermal Imagery Application

The prominent remote sensing platforms collecting thermal imagery include Landsat Thematic Mapper (TM) band 6 (120-m spatial resolution) and Enhanced TM Plus band 6 (60-m spatial resolution), Terra/Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) bands 31 and 32 (1-km [kilometer] spatial resolution), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) bands 9 to 14 (90-m spatial resolution), and National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) bands 4 and 5 (1-km spatial resolution). The prominent airborne platforms collecting thermal imagery include the Advanced Thermal and Land Applications Sensor (ATLAS) instrument flown on the NASA (National Aeronautics and Space Administration) Stennis Lear jet (ATLAS thermal bands 10–15) and the Itres, Canada, Thermal Airborne Broadband Imager (TABI). Thermal imagery has

been successfully applied in diverse tasks such as determining the rock type and structure, locating geological faults, mapping soil type and moisture, detecting and mapping the extent of active wildfires, studying evapotranspiration from vegetation, detecting and mapping the extent and characteristics of thermal plumes in lakes and rivers, and determining urban heat islands.

Ruiliang Pu

See also Aerial Imagery; Interpretation; Atmospheric Remote Sensing; Image Interpretation; Remote Sensing; Remote Sensing: Platforms and Sensors; Remote Sensing in Disaster Response

Further Readings

- Jensen, J. R. (2007). Thermal infrared remote sensing. In *Remote sensing of the environment: An earth resource perspective* (2nd ed., pp. 249–288). Upper Saddle River, NJ: Pearson Prentice Hall.
- Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2008). *Remote sensing and image interpretation* (6th ed., pp. 352–380). Hoboken, NJ: Wiley.



THORNTHWAITE, C. WARREN (1899–1963)

Charles Warren Thornthwaite was one of the most influential climatologists of the 20th century. His work on the water balance concept remains a legacy today in environmental and scientific disciplines. Scientists used his water balance methods to depict regional climates and to solve environmental and geographical problems specifically related to agriculture and water balance. Thornthwaite realized that a more logical approach to the moisture factor in climate was needed. As a result, he developed the concept of potential evapotranspiration (PE)—evaporation and transpiration from a uniformly covered ground surface of vegetation that would be adequately supplied with water. Empirical relationships were developed to determine PE based on



simple measures of air temperature and a latitude factor to adjust for day length and variables either measured at numerous weather stations worldwide or determined from Earth-sun relationships. Thus, PE, expressed as a depth measure, can be directly compared with precipitation to arrive at estimates of surplus and deficits for the soil-vegetative system and in hydrology to determine runoff.

Thornthwaite had a major impact on the field of climatology through his development of a rational classification of world climates based on water balance principles and the concept of PE. His career spanned several positions, from which he crafted ingenious applied analyses and contributions: Chief of the Climatic and Physiographic Division of the Soil Conservation Service in the Department of Agriculture, a consulting climatologist for Seabrook Farms in New Jersey, and an originator of a consulting company, C. W. Thornthwaite Associates. He also established the Laboratory of Climatology in Centerton, New Jersey. Thornthwaite was elected as the first president of the World Meteorological Organization's Commission on Climatology in 1951. He received the prestigious Cullum Medal of the American Geographical Society and the Outstanding Achievement Award from the Association of American Geographers. In *The Task Ahead*, published in 1961, Thornthwaite provided young scholars with a vision of the task ahead in climatology—a vision valid to this day and one that included scientific grounding in energy and water budget theory and analyses. Last was his contribution to urban geography through his dissertation under Carl Sauer. Thornthwaite's approach was a classic one in what was later to become a strong spatial tradition in the discipline.

Anthony J. Braze

See also **Climatology**; **Physical Geography**, **History of**

Further Readings

Mather, J. R. (2005). Thornthwaite, Charles W. (1899–1963). In J. E. Oliver (Ed.), *Encyclopedia of world climatology* (pp. 717–718). Dordrecht, Netherlands: Springer.

Mather, J. R., & Sanderson, M. (1996). *The genius of C. Warren Thornthwaite, climatologist-geographer*. Norman: University of Oklahoma Press.

Thornthwaite, C. W. (1948). An approach toward a rational classification of climate. *Geographical Review*, 38, 55–94.

Thornthwaite, C. W. (1961). The task ahead. *Annals of the Association of American Geographers*, 51, 345–356.

Wheeler, J. O., & Brunn, S. D. (2002). An urban geographer before his time: C. Warren Thornthwaite's 1930 doctoral dissertation. *Progress in Human Geography*, 26, 463–486.



THREE-DIMENSIONAL DATA MODELS

Three-dimensional (3D) data models focus on portraying the third dimension of physical objects and phenomena through the integration of semantic, geometric, and spatial data relationships. Fundamentally, this is a perspective different from the static, 2D or bird's-eye perspective on the world in traditional spatial data modeling. There are two approaches to modeling the third dimension in geographic information systems (GIS): (1) quasi-3D data modeling and (2) true 3D data modeling.

In the first approach of quasi-3D data modeling, a geographic phenomenon can be constructed as a surface in which a given geographic location is defined by a set of x and y coordinates, and a single value z can be assigned to this location. The value z can be elevation above sea level or any other abstract value associated with the represented phenomenon, for example, population density. In the elevation example, the displayed land surface in a model would be close to what we actually see in the real world (Figure 1). In the population density example, the height of the displayed surface would be the population density at a location at a particular time. This type of approach can efficiently handle 3D visualization through a number of ways, such as generating the surface from value z , draping raster images onto

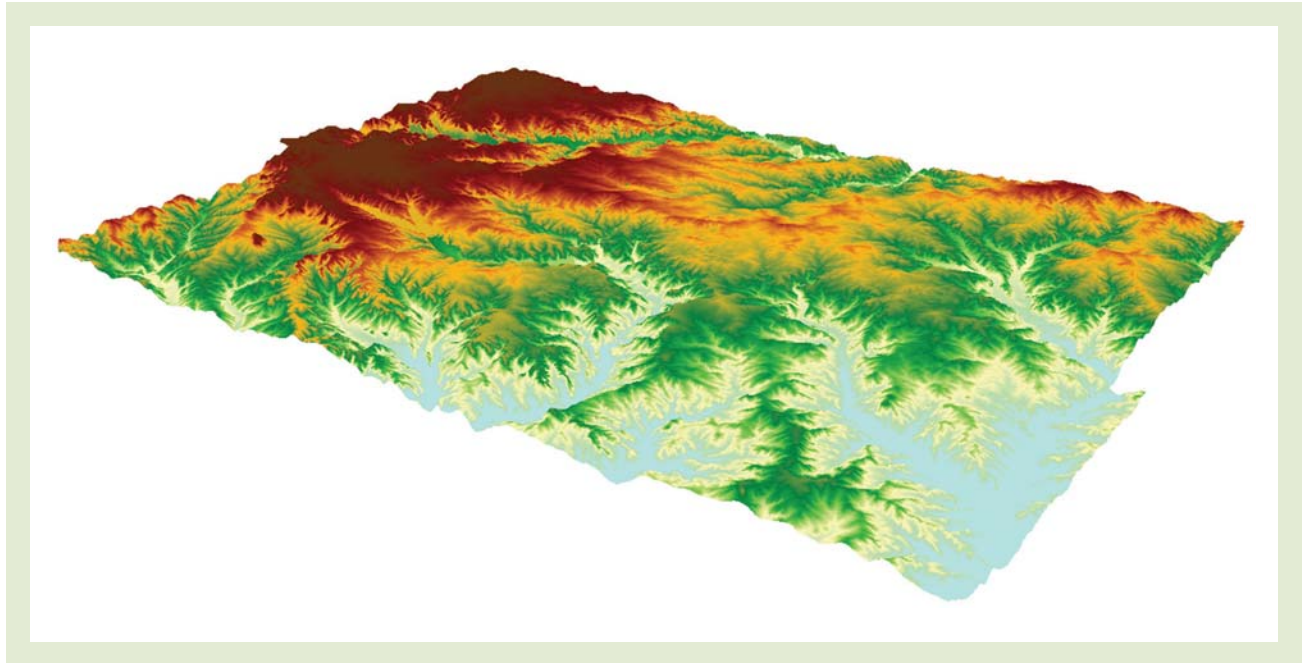


Figure 1 Three-dimensional display of digital elevation model for the county of Greene, Missouri

Source: Author.

the surface (e.g., aerial photos), visualizing terrain from one point to another, and animation (e.g., the function of creating fly-through video). As this type of approach is insufficient to represent data with multiple z values, it cannot be regarded as true 3D data modeling. In addition, this approach is not capable of representing the space above, beneath, and between surfaces in data structure. It is therefore known as quasi-3D data modeling or 2.5D data modeling. Quasi-3D or 2.5D data models are not suitable for 3D solid objects that are continuously distributed in the 3D space, such as ore bodies. From another point of view, quasi-3D or 2.5D data models are mainly used for visualization purposes and cannot support full-3D data querying and analysis, which require geometric and topological relationships.

Given the limitations of conventional 2D and quasi-3D (or 2.5D) data models, a different approach is needed for true 3D data modeling. In true 3D data models, a geographic phenomenon can be constructed as a 3D object, such as a solid cube. Any point in space is specified by three locational values of an x coordinate, a y coordinate, and a z coordinate (e.g., height or depth)

and one or multiple values related to the phenomenon, for example, different geological layers (Figure 2). It should be noted that in true 3D data models every pair of x and y coordinates with multiple z coordinates allows the presentation and manipulation of full information relevant to 3D solid objects.

For 3D data model design, topology is considered the most important concept. Topology can be specified as a set of rules that model how adjacent or neighboring spatial features connect and link to each other in spatial data models. These spatial features can be points, lines, polygons, surfaces, or bodies (volumes). Past studies have reported several 3D data models. For example, Carlson (1987) developed the simplicial complex, including 0-simplex, 1-simplex, and 3-simplex, to describe point, line, surface, and volume. Moleenaar (1990) proposed a model of 3D Formal Data Structure, which contains nodes, arcs, edges, and faces to denote points, lines, surfaces, and bodies. Pilouk (1996) introduced the Tetrahedral Network (TEN) to model 3D objects with vague boundaries based on the 2D Triangular Irregular Network (TIN). Coors (2003) designed the Urban

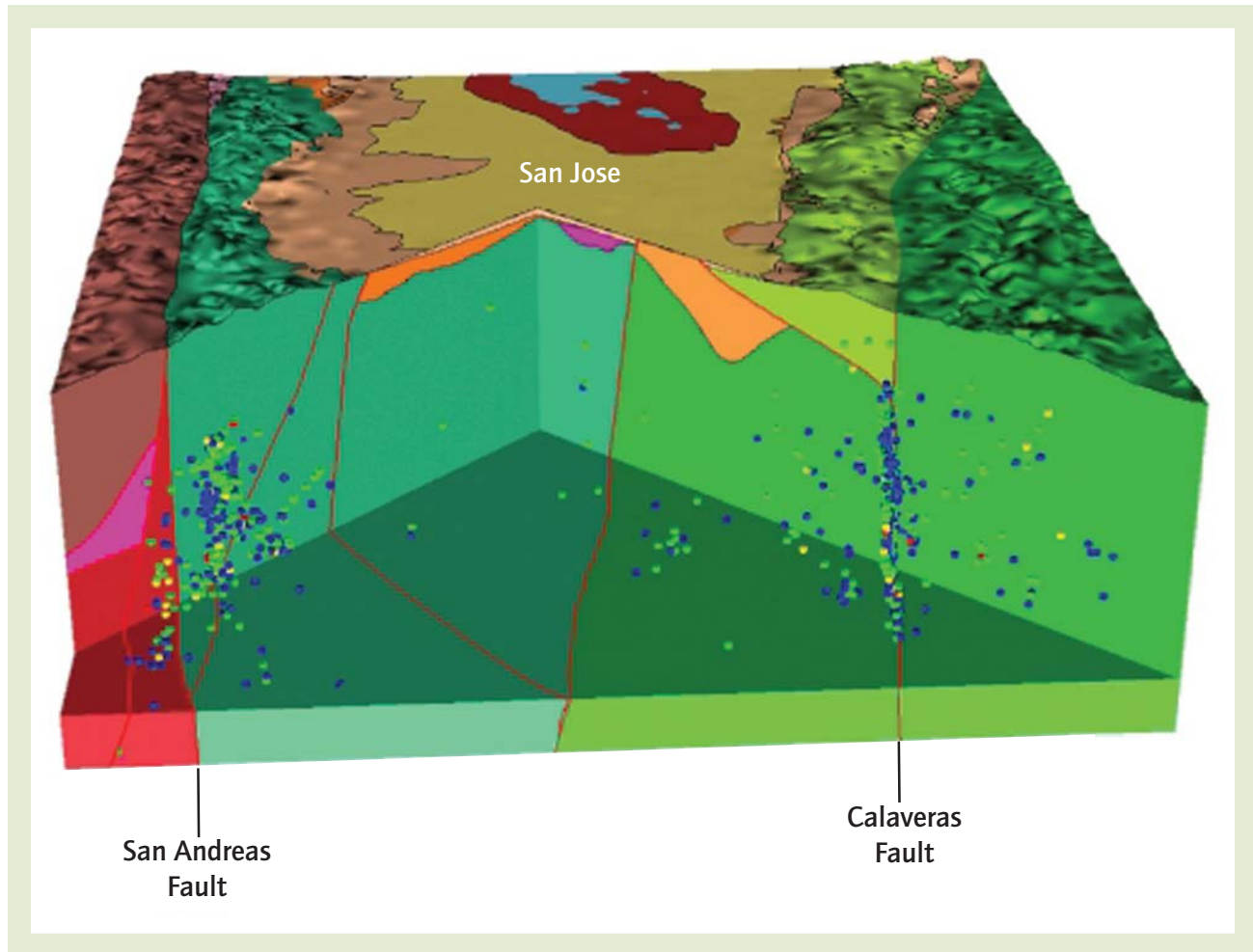


Figure 2 Three-dimensional geologic and seismic velocity model of the Santa Clara Valley area

Source: U.S. Department of Interior, U.S. Geological Survey. Retrieved from <http://earthquake.usgs.gov/regional/nca/3Dgeologic/index.php>.

Data Model, using planar convex faces to represent bodies and surfaces. Lee (2007) proposed the 3D Navigable Data Model, which is a network representation of building factoring pedestrian movements based on a 3D Geometric Network Data Model (GNM) that he developed. In the 3D GNM, a set of nodes denote 3D objects in primal space, and a set of edges denote the spatial relationships between 3D entities in primal space. These models adopted different ways to define topological relationships, that is, spatial relationships between spatial objects, such as intersection, connectivity, direction, containment, and adjacency. The clearly defined spatial relationships enable researchers to describe spatial objects

with either heterogeneous or homogeneous properties, using different basic elements in their specific models. Moreover, the clearly defined spatial relationships provide a basis for data manipulation, data analysis, and other functionalities, such as computation-based queries, editing and examining specific objects, geometric calculation of volume, overlay, and buffering.

The potential application areas of 3D data models include environmental monitoring, geological and mining analysis, 3D urban mapping, disaster management, transportation planning, hydrological analysis, and military operations. For instance, a 3D geologic and seismic model may assist researchers in predicting the shaking



levels of possible earthquakes. It is worth noting that visualization is the most common usage of 3D data models for practical applications.

The development of true-3D data models has been relatively slow. To date very few commercial software packages provide an analytical environment for true-3D data, and 3D functionality is absent. Three-dimensional functionality may include creating 3D objects, editing and organizing 3D data, querying 3D data, processing 3D data, and analyzing 3D data, including 3D data overlay, 3D data buffering, and 3D network routing. Research efforts are needed to extend the uses of 3D data models beyond visualization by resolving issues related to functionality. These issues may include the use of scalable information according to the problem needs instead of aggregated information, designing better data structures, spatial indexing and database management system (DBMS) that are suitable for 3D data representation and analysis, incorporating dynamic or real-time spatial-temporal data into 3D models for decision making and planning, and developing automated approaches to 3D model construction for large areas.

Xiaomin Qiu

See also **Digital Terrain Model; Dynamic and Interactive Displays; Exploratory Spatial Data Analysis; GIS, Environmental Model Integration; GIScience; Land Use and Land Cover Mapping; Map Animation; Models and Modeling; Multitemporal Imaging; Spatial Data Models; Viewshed Analysis; Virtual and Immersive Environments; Virtual Globes**

Further Readings

- Carlson, E. (1987). Three dimensional conceptual modeling of subsurface structures. In N. R. Chrisman (Ed.), *Proceedings of the 8th International Symposium on Computer Assisted Cartography, AutoCarto 8*, Baltimore (pp. 336–345). Bethesda, MD: ASPRS/ACSM.
- Coors, V. (2003). 3D-GIS in networking environments. *Computers, Environment and Urban Systems*, 27, 345–357.

Lee, J. (2007). A three-dimensional navigable data model to support emergency response in microspatial built-environments. *Annals of the Association of American Geographers*, 97, 512–529.

Molenaar, M. (1990, April 10–13). A formal data structure for 3D vector maps. In J. Harts, H. Ottens, & H. Scholten (Eds.), *Proceedings of EGIS'90*, 2, Amsterdam (pp. 770–781). Utrecht, Netherlands: EGIS Foundation.

Pilouk, M. (1996). *Integrated modeling for 3D GIS*. Doctoral dissertation, International Institute for Geo-Information Science and Earth Observation, Enschede, Netherlands.



THREE MILE ISLAND NUCLEAR ACCIDENT

The accident at the Three Mile Island Unit 2 (TMI-2) nuclear power plant near Middletown, Pennsylvania, on March 28, 1979, was the most serious in a commercial nuclear power plant in the United States, even though it led to no deaths or injuries to plant workers or members of adjacent communities. It had major implications for the nuclear industry because it resulted in major changes in the regulatory requirements involving emergency response planning, reactor operator training, radiation monitoring, human factors engineering, radiation protection, and other areas of nuclear plant operations. It also caused the U.S. Nuclear Regulatory Commission (NRC) to tighten and heighten its regulatory oversight.

The accident at TMI-2 was initiated at 4 a.m. by a minor malfunction, or “transient,” in the nonnuclear part of the reactor. The main feed-water pumps stopped running, which prevented the steam generators from removing heat. This event evolved into a series of automated responses in the reactor’s coolant system, and during this time, the relief valve on top of a piece of equipment called “the pressurizer” became stuck in an open position. Misreading of the plant conditions by the operators over a 2¼-hour period before the relief valve was closed and the turning off of an automatic emergency cooling system caused



The Three Mile Island nuclear power plant near Middletown, Pennsylvania, which was the site of a March 28, 1979, power plant accident.

Source: iStockphoto.

the reactor core to become partially uncovered and severely damaged. The major consequences of the accident unfolded over the next week, and it took 1 month to bring the reactor to a cold shutdown.

During the first several days of the accident, communications between the NRC and the site were problematic, which made it extremely difficult for the NRC to obtain up-to-date information from the plant and the utility. The suggestion by the NRC of a possible large-scale evacuation out to 20 mi. (miles) was quite different from the 5-mi. planning requirements imposed by the NRC and Pennsylvania before the accident.

On March 30, midmorning, Pennsylvania Governor Richard Thornburgh's press secretary told reporters that there was no need for evacuation and that people in a 10-mi. vicinity of the plant could remain inside for a while. The only official warning to the public to evacuate came at

approximately 12:30 p.m., when the governor advised pregnant women and preschool children to leave the area within a 5-mi. radius of TMI until further notice. He also ordered schools to close. The advisory to pregnant women and preschool children was lifted on April 9. The governor's warning was the only official warning issued by the government. People in the vicinity of the plant were bombarded by media coverage, which suggested that a major evacuation was imminent. As a result, many people decided to evacuate despite the limited recommendation made by the governor. Approximately 144,000 people within a 15-mi. radius evacuated.

John Sorensen

See also [Chernobyl Nuclear Accident](#); [Natural Hazards and Risk Analysis](#); [Nuclear Energy](#); [Vulnerability, Risks, and Hazards](#)



Further Readings

Sorensen, J., Soderstrom, J., & Copenhaver, E. (1987). *Impacts of hazardous technology: The psycho-social effects of re-starting TMI-1*. Albany: State University of New York Press.

THRIFT, NIGEL (1949–)

Nigel Thrift has long been recognized as one of geography's most imaginative, articulate, and productive scholars. In an exceptionally lengthy series of papers and books, Thrift has made major contributions to the history of geographical thought; introduced a variety of new perspectives ranging from structuration theory to poststructuralist concerns for identity and performativity; advocated a renewed role for regions in geographical analysis; explicated the contingent, contradictory nature of globalization and its implications for regional development; and consistently argued for the centrality of human consciousness, however bounded, in the construction and reproduction of social and spatial relations.

Born in 1949, Thrift earned his PhD from the University of Bristol in 1979. He was stationed briefly in Leeds (1976–1977), spent 4 yrs. (years) (1979–1983) as a research fellow at the Australian National University, and served 3 yrs. (1984–1987) as a lecturer and reader at Saint David's University College, Lampeter, Wales. In 1987, he returned to Bristol, where for more than two decades he was a professor in the School of Geographical Sciences. Between 2003 and 2006, he served as pro-vice chancellor for research at Oxford University. In 2006, he joined the University of Warwick in Coventry as vice chancellor.

Thrift's career both reflected and spurred the enormous intellectual changes in human geography in the late 20th and early 21st centuries. Between 1975 and 2009, he authored or coauthored 110 refereed journal articles and 100 book chapters and wrote, edited, or coedited 39 books. His career began conventionally as an economic geographer with analyses of industrial linkages and markets and multinational corporations,

originally focusing on the specific instance of Australia. This thread has continued in an ongoing form through a sustained interest in organizational theory, which maintained that the specifics of individual corporations were fundamental to the understanding of how markets behaved and changed. Throughout his works runs a nonstructuralist Marxist concern for class, a position that he later extended to a variety of non-class-based forms of social determination. Thrift's worldview takes seriously the complex conditions under which human beings take the world for granted and give meaning to it.

Thrift exhibited a sustained interest in questions of time. No longer could geographers be content with the static geometries of chorology and positivism; social theory had become self-consciously dynamic, portraying every place as a time and integrating into spatial analysis an understanding of how time was socially constructed and, thus, experienced differently under varying historical and spatial circumstances. This work exhibited strong linkages to time-geography, which concerned itself with the movements of individual bodies through the rhythms of everyday life. Thrift also studied the restructuring of time consciousness in contexts ranging from the medieval to the contemporary, including in particular the imperatives of commodity production and capital accumulation. Thrift also played a key role in introducing Giddens's concept of structuration into geography. His paper, "On the Determination of Social Action in Space and Time," published in 1983, was a landmark that both situated structuration theory within the broader intellectual context of "micro-macro" divisions in the social sciences and pointed toward the emerging reconstruction of regional geography.

In the 1990s, Thrift played an influential role in moving geography to new frontiers of poststructuralism, including a variety of concerns with subjectivity, language, representation, discourse, and identity. Although he has never referred to himself as a postmodernist, his theoretical orientations include similar qualities, such as a distrust of broad metatheories, an appreciation for local uniqueness, and an emphasis on social structures and change as inherently open-ended and contingent.



Throughout his career, Thrift has been fascinated by cities as dense nuclei of economic and social transactions, the changing possibilities for economic development afforded by globalization, and the mutations in urban form and life that such transformations entailed. Cities, particularly in the knowledge-driven economies of “soft capitalism,” both reflect and constitute the changing dynamics of social life as contingent constellations of meaning.

If there is any theme that permeates Thrift’s multitudinous works, perhaps it is his sustained interest in connectivity of one sort or another. His papers addressed the relations among bodies and individuals, the diffusion of information, the reciprocal relations between knowledge and power, and the increasingly globalized exchanges of human, symbolic, and financial capital. Thus, he exhibits a consistent concern for the flows of information and knowledge that shape individuals’ conceptions of themselves and one another and that play a major role in the routinized reproduction of social relations. Such linkages reflect and constitute the changing face of capitalism at a variety of spatial scales, ranging from the most intimate and local (e.g., the body) to the international and global.

Thrift’s concern with the differential regional effects of globalization was materialized in a variety of case studies. He has worked extensively on the restructuring of the British space-economy in the face of globalization and mounting social and regional polarization, including the rise of the Greater London region and the nature and impacts of various services such as accounting, property and real estate, and surveying. He also examined other European regions in various contexts, including the rising role of dense human networks in leading innovative regions characteristic of advanced post-Fordist production systems. Thrift also worked extensively on Pacific Asia, particularly Vietnam. These empirical analyses complemented his insistence that regions mattered not only ontologically, that is, as units of empirical analysis, but also epistemologically—that is, no social process was manifested in the same way in different places.

The latter line of thought appealed to geographers who insisted that local uniqueness mattered, many of whom sought to recover regions

from the dustbin of traditional chorology. Throughout the 1980s, the “new regional geography” developed growing linkages to top-down global political economy and to “bottom-up” concerns for living actors and everyday life. Thrift played a key role in articulating this vision of geography, defending it against both positivist and Marxist critics, for whom regional analysis could, by definition, amount to little more than reconstituted empiricism. Unlike chorology, however, the reconstituted regionalism was both theoretically informed and paid great attention to the connections among regions, their linkages to the global division of labor, and the sticky issue of the production of spatial scale. The new regionalism made local uniqueness a valid object of scholarly scrutiny, demonstrating that the local *mattered* in ways that broad models could never discover and that no social process played out exactly in the same way in different time-space contexts. The recovery of regions for social theory obligated the discipline to delve into the intricate dynamics of the local actors who populated them and “made them work”: Thus, the localities school and structuration theory’s focus on everyday life were mutually complementary. This concern with the local extended to his work on the most abstract and globalized of economic sectors, finance.

With Andrew Leyshon, Thrift generated a series of works concerning the international financial system, British financial capital, and banking networks in London. These papers both elucidated the impacts of electronic money and national deregulation and simultaneously demystified money by stressing the key roles played by interpersonal relations predicated on trust and face-to-face contact, including the critical but often overlooked roles played by local milieu, trust, and “institutional thickness,” that is, the cultural context in which financial transactions are always and everywhere embedded. Money, even in its most rarified electronic form, is thus much more than an abstract economic relation, for its real power lies in its symbolic value and links to national and global distributions of social power. Like all social relations, financial systems are inevitably discursively constituted through particular social-cultural practices in different times and places. Such an approach brought a badly needed human quality to a topic dominated



by ethereal understandings devoid of actors and is vital if the new forms of “soft” managerial capitalism are to be understood in all their complexity. Thrift’s writings reveal an understanding that the contemporary forms of capitalism, dominated as they are by finance and information, simultaneously reflect the historic tendency toward increasing commodification of all activities as well as the emergence of a historically unprecedented form of production and consumption, a perspective that eludes the naive optimism and technological determinism of postindustrial theory. The “symbolic economy” calls for new forms of performativity for actors for it to function successfully.

Thrift has exhibited broader concerns for the implications on individual subjectivity of information technology and electronic communications, which are representative of the post-Fordist, digitized “soft capitalism” and its attendant digitized, virtual dimensions. The massive time-space compression unleashed by digital globalization has thus altered the field of possibilities for both nation-states and individual actors in everyday life: The renewed regionalism and reconstituted rhythms of daily life are two sides of one coin. At the level of the corporation and everyday life, Thrift has also taken an interest in the possibilities extended by the widespread use of computational technology and mobile telecommunications. In sum, the contingent, simultaneously determinant interactions between culture and technology form a recurrent theme that runs through his writing.

Thrift has long insisted that geographies are produced by people in prediscursive, practical ways, and he has been one of the discipline’s foremost advocates of theoretical stances that emphasize the contingency of human action. This position stands as a hallmark of the contemporary “cultural turn” in the social sciences, which has led numerous researchers to embed economies in social relations, blurring the artificial distinctions between the “economic,” the “cultural,” the “social,” and the “political.” More broadly, the profound role played by systems of signification, including discourses, language, texts, and representations of all kinds, has led him to forge a nonrepresentational theory of action that stresses performative embodied knowledges; more

recently, he became a leading advocate of nonrepresentational theory. Yet this relational materialist perspective maintains that the global “space of flows” does not float in a disembodied space: Rather, global flows and connections are constructed by human beings who are always embedded in networks of power and knowledge that are themselves part of an ever-changing structural context. Invoking actor-network theory, Thrift effectively abandons the distinction between agents and structures. This view focuses on the exercise of power by actors rather than just the embeddedness of power in networks. Throughout his career, Thrift has worked assiduously to portray geographies as embodied, embedded, contingent, and ever changing, harnessing the fluidity of spatial relations to demonstrate how they are imbricated in changing human relations of power.

Barney Warf

See also Actor-Network Theory; Finance, Geography of; Nonrepresentational Theory; Postmodernism; Pred, Allan; Structuration Theory; Time-Geography

Further Readings

- Amin, A., & Thrift, N. (2002). *Cities: Reimagining the urban*. Cambridge, UK: Polity Press.
- Leyshon, A., & Thrift, N. (Eds.). (1997). *Money/space: Geographies of monetary transformation*. London: Routledge.
- May, J., & Thrift, N. (Eds.). (2001). *TimeSpace: Geographies of temporality*. London: Routledge.
- Pile, S., & Thrift, N. (Eds.). (1995). *Mapping the subject: Geographies of cultural transformation*. New York: Routledge.
- Thrift, N. (1981). Owners’ time and own time: The making of a capitalist time consciousness, 1300–1880. In A. Pred (Ed.), *Space and time in geography: Essays dedicated to Torsten Hagerstrand* (Lund Studies in Human Geography Series B, No. 48; pp. 56–84). Lund, Sweden: Lund University Press.
- Thrift, N. (1983). On the determination of social action in space and time. *Environment and Planning D: Society and Space*, 1, 2357.



- Thrift, N. (1988). Vivos Voco: Ringing the changes in the historical geography of time consciousness. In T. Schuller & M. Young (Eds.), *The rhythms of society*. London: Routledge.
- Thrift, N. (1996). New urban eras and old technological fears: Reconfiguring the goodwill of electronic things. *Urban Studies*, 33, 1463–1493.
- Thrift, N. (1996). *Spatial formations*. Thousand Oaks, CA: Sage.
- Thrift, N. (1999). The place of complexity. *Culture and Society*, 16, 31–70.
- Thrift, N. (2000). Performing cultures in the new economy. *Annals of the Association of American Geographers*, 4, 674–692.
- Thrift, N. (2007). *Non-representational theories: A primer*. London: Routledge.
- Thrift, N., & Leyshon, A. (1994). A phantom state: The de-traditionalization of money, the international financial system and international financial centers. *Political Geography*, 13, 299–327.
- Thrift, N., & Olds, K. (1996). Refiguring the economic in economic geography. *Progress in Human Geography*, 20, 311–337.



THUNDERSTORMS

Thunderstorms are convection storms comprising cumulonimbus clouds that are accompanied by lightning and thunder and moderate to heavy precipitation. Additional attributes may include strong winds, hail, and/or tornadoes. In terms of the hierarchy of atmospheric scales of motion, thunderstorms are classified as *mesoscale* systems, the second smallest after microscale systems. Mesoscale systems have a typical life span of 1 hr. (hour) or more and range in size from a few kilometers to 100 km (kilometers) in diameter. Based on system duration, structure, and formation, thunderstorms are classified as ordinary cell, multicell, or supercell and may or may not be considered severe.

Also known as air mass thunderstorms, ordinary cell thunderstorms have the simplest structure and formation conditions of the three major thunderstorm categories. These storms materialize within warm, humid, and unstable air mass environments amid often weak vertical wind shear

(i.e., wind speed and direction do not change greatly with height). Ordinary cell thunderstorms are usually compact (<1 km in width), nonsevere, and not associated with mechanical lifting mechanisms (e.g., frontal uplift). Ordinary cell thunderstorms typically undergo a three-stage sequence of development: cumulus, mature, and dissipating. The cumulus stage is characterized by rising air parcels or thermals that result from differential surface heating. Updrafts dominate this growth stage, and lightning and thunder are absent. As the cloud particles enlarge and become heavier, the updrafts may not be sufficiently strong enough to sustain their suspension, and the cloud particles begin to fall as precipitation. The manifestation of a precipitation downdraft ushers in the mature stage, the most intense phase typified by strong updrafts and downdrafts, heavy precipitation, lightning and thunder, and gusty surface winds. The air mass thunderstorm begins to dissipate as the warm, humid air source inflow supplying the thunderstorm's energy is suppressed by the precipitation downdraft. The final stage is marked by light precipitation, weak downdrafts, and cloud evaporation. Since the entire development cycle may be completed in less than 1 hr., these scattered storms may be referred to as “popup showers,” for their ability to mature and disperse quickly. Of the approximately 50,000 thunderstorms that occur each day across the world, most are of this ordinary cell variety.

Multicell thunderstorms contain several ordinary thunderstorm cells under various development stages, appearing as a continuous, long-lasting storm. A single thunderstorm cell may initiate new cell development or “daughter cells” along the precipitation outflow boundaries (known as gust fronts) and form a larger cluster of thunderstorms. If the thunderstorms align linearly, this configuration is known as a squall line. Not all squall lines, however, are formed along gust fronts. Frontal and prefrontal squall lines are longer lasting than their ordinary squall line counterparts and are frequently associated with severe weather. Fast-moving squall lines may also produce especially enduring and widespread wind storms called *derechos*, which can produce wind speeds in excess of 100 mph (miles per hour).

Instead of a linear configuration, multicells may also cluster and expand over an extensive



Approaching thunderstorm with lead gust front. Rain-cooled air from the storm moves out ahead of the storm. It ploughs under the warm moist air, forming a flat “shelf cloud.”

Source: National Oceanic and Atmospheric Administration (NOAA) Photo Library, NOAA Central Library; NOAA Office of Oceanic and Atmospheric Research/Environmental Research Laboratories/National Severe Storms Laboratory (NSSL).

region and intensify. Mesoscale Convective Complexes (MCCs) are long-lasting (>12 hrs. or more), nocturnal multicell storm systems that develop in high-moisture environments with weak vertical wind shear, a situation common during the midlatitude summer on the tropics. These slow-moving storms are thousands of times larger than ordinary cell thunderstorms and can produce copious amounts of precipitation. In the maritime tropics, a concentrated thunderstorm cluster around a rotation center may signify the potential for hurricane development.

Supercells are the most intense, most destructive, and rarest thunderstorm type. These storms appear as large isolated cells often ahead of an approaching squall line and can produce large hail, heavy precipitation, and/or tornadoes. In contrast to multicell thunderstorms, supercells are differentiated by a deep, continuously rotating updraft or

mesocyclone tilted away from the primary precipitation downdraft region. This tilted updraft structure enables the continued inflow of moist, humid air into the storm even after precipitation commences, thereby sustaining the latent heat energy supply and enabling the storm to continue for several hours. Supercells may be categorized into three main types, classic, low precipitation, or high precipitation, depending on the updraft and downdraft configuration. Environments with strong contrasts in temperature, moisture, and vertical wind shear support supercell development. These ambient conditions are most commonly found in the North American Great Plains region in spring and early summer; however, supercells are also known to occur occasionally in other midlatitude locations across the world.

The global distribution of thunderstorms is linked to the proximity of maritime tropical air



mass source regions that support prolonged uplift and warmth, conditions largely found in the tropics. In particular, locations in the vicinity of the Intertropical Convergence Zone (ITCZ) are areas repeatedly favored for deep convection. Resulting from the surface convergence of the northeast and southeast trade winds, the ITCZ initiates widespread thunderstorm development in the equatorial region and also in the extratropics depending on its movement relative to the changes in solar intensity. The seasonal migration of the ITCZ creates distinct wet and dry periods in the tropics, but commonly more than 200 days per year are associated with thunderstorm occurrence in regions around Central Africa, Northern South America, and Indonesia/Northern Australia. In East Asia, the ITCZ migration is linked to the monsoonal circulation, referring to a seasonal reversal in wind direction that during summer promotes the inland movement of unstable, warm humid air into the continent.

Thunderstorm activity is also prominent in the midlatitudes, especially in locations that promote air mass interaction. In the conterminous United States, the highest average annual frequency of thunderstorm days (>100 days) occurs in the central Floridian peninsula primarily due to regional sea breeze convergence during the late spring and summer months; a secondary maximum along the Eastern Colorado Rockies occurs as a consequence of summertime convection and leeside cyclogenesis. Although not common, thunderstorms do appear occasionally in high-latitude locations (e.g., Northern Canada) during the warm season if sufficient moisture and an uplifting mechanism are present.

Jill S. M. Coleman

See also **Air Masses; Derechos; Fronts; Lightning; Precipitation Formation; Tornadoes**

Further Readings

Bluestein, H. B. (1993). *Synoptic and dynamic meteorology in midlatitudes: Vol. II. Observations and theory of weather systems*. New York: Oxford University Press.

Doswell, C. A., III. (Ed.). (2001). *Severe convection storms*. Boston: American Meteorological Society.
Kessler, E. (1986). *Thunderstorm morphology and dynamics* (2nd ed.). Norman: University of Oklahoma Press.



THÜNEN MODEL

One of the first and most influential conceptions of relative location was proposed by Johann von Thünen (1780–1850), a German estate owner interested in economic theory and local agricultural conditions. From his experiences as an estate manager, he observed that identical plots of land would be used for different purposes depending on their accessibility to the market. His book *The Isolated State*, published in 1826, proposed one of the very first models in economic geography. von Thünen's aim was to uncover the laws that govern the interactions of agricultural prices, transport costs, and land uses as landlords sought to maximize their profits.

The concept of economic rent, also called location rent, a relative measure of the advantage of one parcel of land over another, is central to von Thünen's model of agricultural land use. Differential rents may result from variances in productivity of different parcels of land and/or variances in the distance from the market. von Thünen demonstrated that rent is the price of accessibility to the market. In other words, rents decline with the distance from a market center because transport costs rise accordingly.

To explain agricultural land use, von Thünen described an idealized agricultural region about which he made certain assumptions. He envisioned an isolated state with a large city serving as the only market. A uniform plain surrounded the city. There were no extraneous disturbances in this idealized landscape; social classes and government intervention were absent. The cost of transport to the central town increased at a rate proportional to the distance. He concluded that near the town will be grown those products that are heavy or bulky in relation to their value and that are consequently so expensive to transport

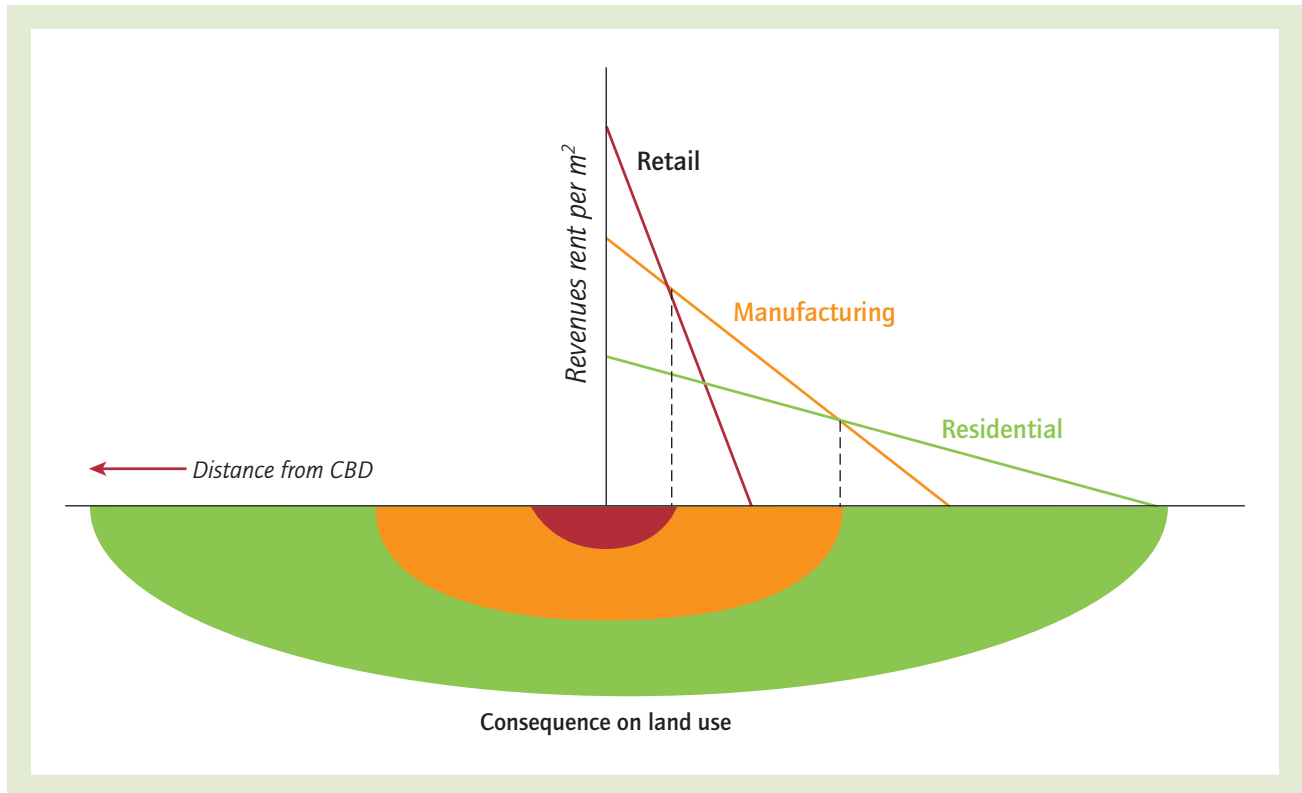


Figure 1 The von Thünen model's bid-rent lines and associated land uses. Given that transport costs erode profits with distance from the market, the Thünen model describes a simplified agricultural system in which land uses change according to prices and transport costs.

Source: Adapted from Wikimedia Commons.

that the remoter districts are unable to supply them. With increasing distance from the town, the land will progressively be given over to products that are cheap to transport in relation to their value. Farmers near the central market pay lower transport costs than farmers at the margin of production. Farmers recognize this condition, and they know that it is in their best interest to bid up the amount that they will pay for agricultural land closer to the market. Bidding continues until bid rent equals location rent. At that price, farmers recover production and transport costs, and landowners receive location rents as payments for their land. Competitive bidding for desirable locations cancels income differentials attributable to accessibility. The bid rent, or the trade-off of rent levels with transport costs, declines just far enough from the market to cover the additional transport costs; hence, farmers are indifferent to their distance from the market.

Location rent for any crop can be calculated by using the following formula:

$$R_k = e(p - a) - efk,$$

where

- R = location rent per unit of land at distance k ,
- e = output per unit of land,
- k = distance to the market,
- p = market price per unit of output,
- a = production cost per unit of product (including labor), and
- f = transport rate per unit of distance per unit of output.

When the rent gradient is rotated around the market town, it becomes a rent cone, the base of which indicates the extensive margin of cultivation for a single crop grown at a single intensity.

Concentric rings or belts will form around the town, each with its own particular staple product. From ring to ring, the staple product will change.

von Thünen was acutely aware that many conflicting factors—physical, technical, cultural, historical, and political—would modify the concentric patterns of agricultural land use. He modified some of his initial assumptions—equal transportation costs in all directions, for example—to approximate actual conditions more closely. Although he retracted the condition of a single-market town, he did not elaborate on the effects of several competing markets and a system of radiating highways. We can presume, however, that the tributary areas of competing markets would have a variety of crop zones enveloped by those of the principal market town and that a radiating highway system would have produced a “starfish” pattern.

Barney Warf

See also [Agricultural Land Use](#); [Economic Geography](#); [Location Theory](#); [Models and Modeling](#); [Transportation Geography](#); [Urban Spatial Structure](#)

Further Readings

- Cromley, R. (1982). The von Thünen model and environmental uncertainty. *Annals of the Association of American Geographers*, 72, 404–410.
- Horvath, J. (1969). von Thünen’s isolated state and the area around Addis Ababa, Ethiopia. *Annals of the Association of American Geographers*, 59(20), 308–323.
- Sinclair, R. (1967). von Thünen and urban sprawl. *Annals of the Association of American Geographers*, 57, 72–87.



TIMBER PLANTATIONS

There are approximately 140 million ha (hectares) of tree plantations worldwide, of which 78% are classified as “productive” and are used primarily for wood and fiber production, while

22% are “protective” and are established primarily for soil and water conservation. The extent of both types of plantations has grown over the past two decades, with productive plantations increasing by approximately 2.2 million ha/yr. (per year) and protective plantations increasing by 380,000 ha/yr. between 1990 and 2005. In both types of plantations, pines are the most commonly planted species. Where tree plantations have been established, they have created both benefits and negative consequences, with the balance varying from one location to another.

Benefits

While tree plantations constitute only 3.5% of the world’s forested area, they are approaching 50% of global wood production. In addition to timber production, tree plantations are an important source of fuelwood in many parts of the world and can provide income from the sale of nontimber forest products (NTFPs) harvested from plantations. While NTFPs account for a much smaller portion of the revenue from plantations than timber, they can be locally important. For example, in the Ecuadorian Andes, an edible mushroom that grows in association with planted pines is harvested and provides an additional source of income. In recent decades, tree plantations have also been valued for their ability to sequester carbon in tree biomass, thereby playing a role in decreasing atmospheric carbon dioxide concentrations. In some cases, tree plantations can also sequester carbon in the soils where they grow. However, this depends largely on the land use prior to plantation: When plantations are established on croplands, soil carbon generally increases, while conversion of pastures or native forests to plantations generally causes a loss of soil carbon.

Costs

Although tree plantations can provide many benefits, there is increasing evidence that they can also cause the deterioration of ecosystem services, in particular water provision. Plantation establishment can decrease stream flow and groundwater recharge, cause acidification of stream



A slash pine plantation in Georgia, United States. Although slash pine has the most limited range of the major Southern pines, more of it has been planted than any other Southern pine, or for that matter any timber species in North America.

Source: Jeff Vanuga, USDA Natural Resources Conservation Service.

water and soils, and produce soil salinization. In many parts of the world, timber plantations have caused additional problems where the exotic species used have become invasive. The invasive spread of commercial plantation species has been recognized as a major threat to native biodiversity in South Africa, New Zealand, Australia, South America, and Hawaii.

Conclusion

The balance between the benefits and costs of tree plantations depends largely on the location in which they are planted. In particular, the type of soils, hydrology, and prior land use, as well as the

condition of the landscape prior to plantation establishment, play an important role, as do the kinds of species used and the way in which the plantations are managed. The degree to which tree plantations can be considered a land use that contributes to environmental sustainability depends on how they influence the provision of ecosystem goods and services, including not only timber and fuelwood but also carbon, water, and biodiversity.

Kathleen A. Farley and Leah Bremer

See also [Carbon Cycle](#); [Environmental Services](#); [Forest Land Use](#); [Plantations](#); [Sustainable Forestry](#); [Tree Farming](#); [Woodfuel](#)



Further Readings

- Farley, K. A., Jobbágy, E. G., & Jackson, R. B. (2005). Effects of afforestation on water yield. *Global Change Biology*, 11, 1565–1576.
- Food and Agricultural Organization. (2006). *Global forest resources assessment 2005* (FAO Forestry Paper 147). Rome, Italy: Author.
- Guo, L. B., & Gifford, R. M. (2002). Soil carbon stocks and land use change. *Global Change Biology*, 8, 345–360.



TIME, GEOGRAPHIES OF

The fast pace of modern life and the complex uncertainties of environmental change have led both human and physical geographers to question their understanding of time. Since the 1960s, there has been a significant shift away from chronological, linear conceptions of time toward understandings that examine it as nonlinear and chaotic, something experienced as dynamic and interconnected with different spaces and places. An increasing range of conceptions and debates is emerging under the heading “geographies of time.” Of particular interest from a human geography perspective are ideas concerning social time, such as geographies of rhythms and lived time, which explore people’s everyday experiences of time. Critically, scholars are increasingly debating whether time should still be conceived independently from space, a dualism prominent throughout geography.

Social Time: The Geographies of Rhythms

Social time essentially focuses on social content, recognizing that the way in which people experience time is dictated by a range of social processes. Jon May and Nigel Thrift provide a comprehensive discussion of social time, identifying four domains that interact to produce people’s experience or sense of time. These domains invoke a way of interpreting experiences through considering the rhythms they generate. Rhythm is used in its widest sense to identify anything from

a repetitive process to a recurrent pattern. Anne Buttimer provides an in-depth discussion of time-space rhythms, emphasizing the complex interactions of people’s sensations and representations of time and space.

The first domain considers the variety of cycles and timetables people are subject to, some of which are fixed, such as tidal movements, while others are relatively applied, for example, a woman’s menstrual cycle. Most, however, are constantly under negotiation; take, for instance, the socially constructed pressure of shift work, which requires people to adjust their circadian rhythms to fit in with factory hours or differing time zones in order to meet the demands of the job.

The second domain relates to the regulation or demarcation of time for specific activities. For example, in many Western societies, the prescribed Monday to Friday working week is closely monitored by time sheets and surveillance mechanisms, while the weekend is often equated with family or leisure time. When either time interferes with the other, for instance, taking work home, these norms are broken, disrupting the regulation of social time and demonstrating the combination of forced and voluntary rhythms that make up daily life.

The third domain involves the increasing array of tools and technologies designed to expressly monitor, inform, or direct how people allocate time. Many of these have been around for millennia, from the calendar to various forms of the clock, both of which reinforce the sensation of time moving forward in a linear fashion. The advent of mass transportation and communications led to what is termed the standardization of time, as clock time became uniform the world over. These technologies are often described as leading to time-space compression, perpetuating the perception of an increased pace of life. They often dictate rhythms of particular representations associated with saving time, or being more productive with the time available.

The final domain relates to the influence of particular texts in demarcating what should be done at particular times of the day, year, and so on. From the Julian calendar of AD 1020, which dictated everything from when to pray to when to plough, to Benjamin Spock’s *Common Sense Book of Baby and Child Care* (1946), which



told mothers when to feed and put their children to bed, there has been a proliferation of texts advising people of a particular geography of rhythms around the appropriate time to perform different tasks.

Lived Time

Modern information and communication technologies are proliferating people's capabilities within the moment through instant real-time interactions. Geography is now turning its attention to understanding this and conceptualizing the present or lived time. Many commentators identify the way time has been turned into a product that can be bought and sold, often called the commodification of time. There is a debate around both how to express the present and to what degree it is influenced by past experiences and future intentions. Attention is turning to how individuals perform or what they choose to do in any particular moment, given a world that is transitory and full of multiple possibilities of action.

Time-Space

Human geographers are increasingly arguing that time and space need to be conceptualized interdependently, raising the question of whether there should be an entry dedicated purely to the geographies of time. Doreen Massey argues that this interdependence does not signal the removal of the differences between the two dimensions and that they still require defining but not in the dualistic sense of space not being time and vice versa. Social time, geographies of rhythms, and lived time are all implicitly spatial, as how time is experienced depends on the spaces and places in which the experience is lived. In today's world, there is a much more complex restructuring occurring than simply the acceleration of life and collapse of space, and geography's constantly evolving dialogue on time and space puts it in a strong position to begin critically analyzing this process.

Phillipa Marlis Mitchell

See also **Everyday Life, Geography and; Thrift, Nigel; Time-Geography; Time-Space Compression**

Further Readings

- Dodgshon, R. (2008). In what way is the world really flat? Debates over geographies of the moment. *Environment and Planning D: Society and Space*, 26, 300–314.
- May, J., & Thrift, N. (Eds.). (2001). *Timespace: Geographies of temporality*. London: Routledge.
- Mels, T. (Ed.). (2004). *Reanimating places: A geography of rhythms*. Aldershot, UK: Ashgate.
- Taylor, P. (2003). Time: From hegemonic change to everyday life. In N. Clifford & G. Valentine (Eds.), *Key methods in geography* (pp. 151–164). London: Sage.



TIME-GEOGRAPHY

Time-geography refers to a set of concepts and a way of thinking that offer a notational system to describe and analyze individuals' and populations' existence, coexistence, constraints, and conflicts in time-space. The time-geographic approach was originally presented in the late 1960s by Torsten Hägerstrand, a well-known professor of human geography at Lund University, Sweden. Time-geography captures complex processes of change on different scales in time and space and is therefore useful for analyzing various topics and problems.

The time-geographic lines of thought are directly linked to Hägerstrand's experiences as the son of an elementary schoolteacher who sought to impart "knowledge about their home district." Hägerstrand found the prevailing academic thinking, which grouped phenomena according to their degree of similarity, to be deficient; his alternative approach was to group phenomena according to their proximity in time and space.

The theoretical roots of time-geography are found in Hägerstrand's thorough empirical fieldwork in Asby parish in Southern Sweden. He and his wife spent several summers biking there searching for houses (or their remains) abandoned by emigrants to the United States during the 19th century. Then, the dominant understanding



among researchers was that each empty house had been the home of an emigrant family. The Asby fieldwork made Hägerstrand question this view, since the resource base surrounding the empty houses was too poor for subsistence—much less for buying a ticket to America. By studying the population in the Asby parish books, individual by individual, he concluded that the emigrant families were those that were relatively well-off but still too poor to find in Asby a place better than their American dream. They sold their houses, and a chain of movements started, with poorer families moving from low-income houses to better ones. As a result, farms that operated under the subsistence level were left empty. Following the individual inhabitants of the houses was the only way to find out who left which house for a better life in America. Houses and people come in many different kinds, but they must be considered together to reevaluate the dominating theory.

In time-geography, the two dimensions of time and space (place, region) are united into a time-space in which processes involving different phenomena can be discerned, irrespective of whether such phenomena are living or nonliving. Each individual is born or created at some point in time, exists during a time period, and dies. This process describes a time-space biography of an individual human being, but since time-geography also includes nonliving phenomena, the more general concept of individual path (trajectory) is introduced. Individuals of the same bounded region (time-space) constitute a population. A bounded region can be defined at different scales: the globe as a whole, a continent, a country, or any locality on the globe. In each region in time-space, individuals (from one or more populations) get in touch with other individuals, and when they move (or are moved), they decouple from one bundle of individuals with whom they were in touch and couple with another bundle. Time-geography facilitates analysis of opportunities for individuals to get in touch with one another and of the constraints on and consequences of such coupling, and it provides tools for dynamic life cycle analysis. For example, environmental problems may be described by the extraction (decoupling) of raw materials in a region and their transportation to a place where they are manufactured (put into new

combinations). Manufacturing is performed at a place by labor, using tools and machines according to procedures that steer the work process, constituting a pocket of local order. Then the product is decoupled from the manufacturing location, transported, and sold. Through the sale, the output is coupled with the customer, who uses the product for reaching the goals of his or her projects. Eventually, the output is worn out, decoupled from the customer, and put in touch with other worn-out individual products at a waste collection center or maybe recycled.

Human individuals performing activities in their projects meet three types of constraints: (1) *coupling constraints* (they must be able to get in touch with another individual at a specific location in time-space in order to fulfill their obligations; e.g., parents have to get their children from day care in the afternoon); (2) *capability constraints* (knowledge, skills, and tools available); and (3) *authority constraints* (regulations, laws, and power relations in social bundles). All these shape the individual's trajectory through time and space in the rhythms of everyday life. Opportunities for individuals to get in touch with one another are revealed by their time-space prisms. Individuals whose time-space constraints prohibit their prisms from intersecting are never afforded the opportunity to meet in person. Geographers such as Alan Pred used this model to describe regional systems of social and economic activity, in which the composite trajectories of individuals reproduce larger social structures in time and space. Time-geography thus became a means of representing and analyzing how social relations were manifested through everyday life in all its temporal and spatial boundedness. Critics of time-geography often argued that it lacked a sufficient account of power and social relations, as well as an adequate theory of human subjectivity.

The time-geographic approach is sometimes taken to be synonymous with its notational system. The notational system is a way of describing the concepts of time-geography, and it is the outcome of Hägerstrand's struggle with the shortcomings of common language to explain his thinking. The notational system is simple and powerful. It can be applied to show how individuals from different populations are born/produced, couple, decouple, move, stay at a

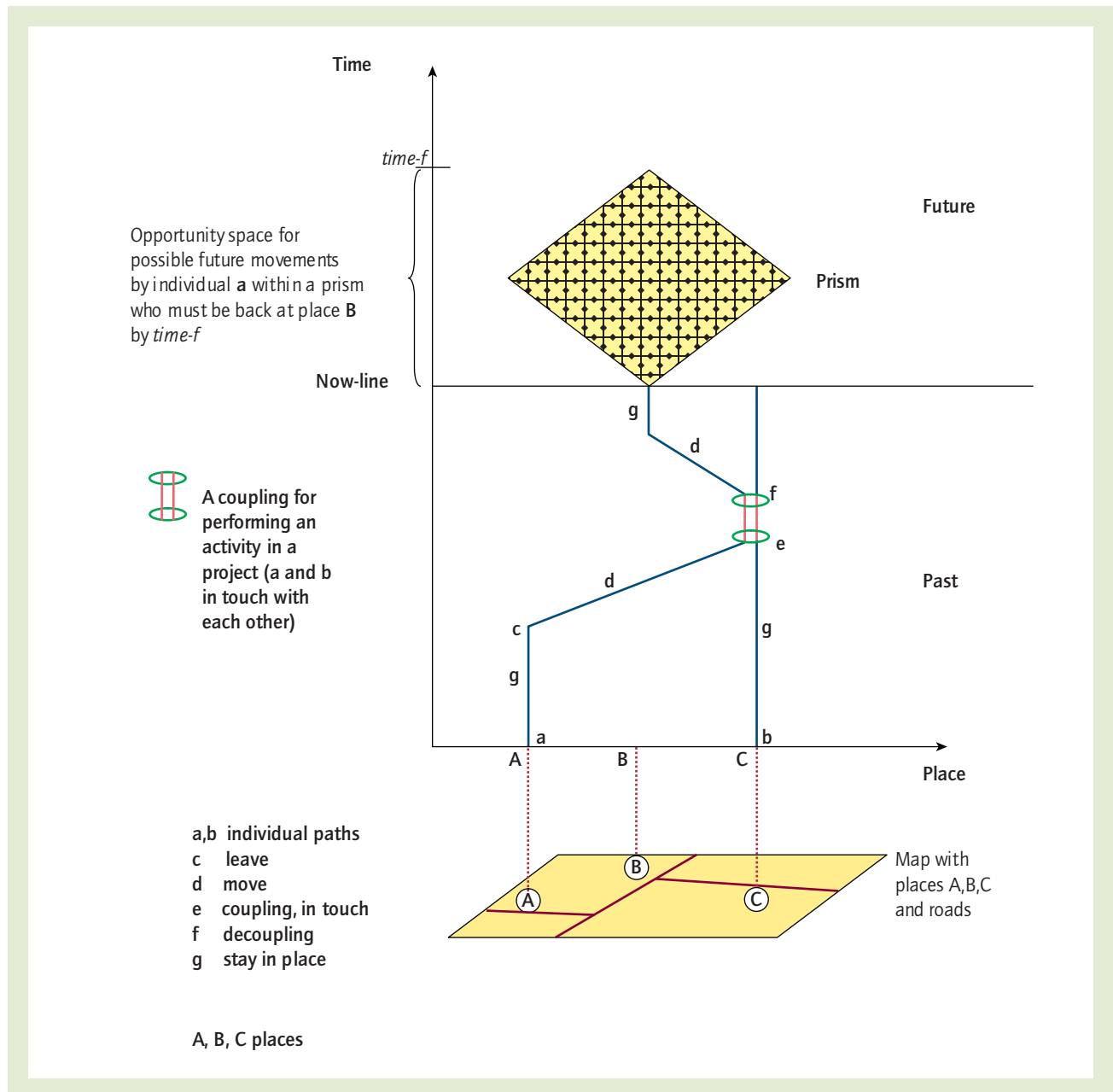


Figure 1 Some time-geographic concepts exemplified by the notational system.

Source: Author.

place, and die/are destroyed—in short, the elementary occurrences in an individual's life.

Time-geography is used for researching environmental problems, energy use, virtual and physical mobility/communication, migration studies, time-use studies, and people's rhythms in daily life. Hägerstrand's time-geography includes the basic principles behind the development of

geographic information systems and was influential in the formulation of structuration theory.

Kajsa Ellegård

See also Behavioral Geography; Everyday Life, Geography and; Hägerstrand, Torsten; Kwan, Mei-Po; Pred, Allan; Structuration Theory; Thrift, Nigel; Time, Geographies of



Further Readings

- Adams, P. (1995). A reconsideration of personal boundaries in space-time. *Annals of the Association of American Geographers*, 85, 267–285.
- Hägerstrand, T. (1970). What about people in regional science? *Regional Science Association Papers*, 24, 7–21.
- Pred, A. (1977). The choreography of existence: Comments on Hägerstrand's time-geography and its usefulness. *Economic Geography*, 53, 207–221.
- Pred, A. (1978). Impact of technological and institutional innovations on life content: Some time-geographic observations. *Geographical Analysis*, 10, 345–372.
- Pred, A. (1981). Production, family, and free-time projects: A time-geographic perspective on the individual and societal change in 19th-century United States cities. *Journal of Historical Geography*, 7, 3–36.
- Pred, A. (1981). Social reproduction and the time-geography of everyday life. *Geografiska Annaler*, 63, 5–22.
- Pred, A. (1984). Place as historically contingent process: Structuration and the time-geography of becoming places. *Annals of the Association of American Geographers*, 74, 279–297.



TIME-SPACE COMPRESSION

If geography is largely concerned with how human beings are differentially located over the Earth's surface, a vital part of that process is how we know and feel about space and time. Although space and time appear as “natural” and outside of society, they are in fact social constructions; every society develops different ways of dealing with and perceiving them. Time and space are thus socially created, plastic, mutable institutions that profoundly shape individual perceptions and social relations. The sociologist Anthony Giddens uses the term *distanciation* to describe how societies are stretched over time and space and how this process itself varies temporally and geographically. Because the economy cannot be detached from other realms of social life, time-space compression is more than simply an economic phenomenon. By changing the time-space

prisms of daily life—how people use their time and space, the constraints they face, the meanings they attach to them—time-space compression is simultaneously cultural, social, political, and psychological in nature. This issue elevates the analytical significance of relative space, in which distances are measured through the changing metrics of time and cost, above that of absolute space, the traditional Cartesian form that characterized most Enlightenment forms of geography, which portrayed distance in fixed, unchanging terms devoid of social roots.

The Concept of Time-Space Compression

Time-space compression involves the myriad ways in which human beings have attempted to conquer space, to cross distances more rapidly, and to exchange goods and information more efficiently. The analysis of time-space compression places emphasis on the connections and interactions among places (and the people who live within them, for connections are always embodied) rather than on individual places per se. For example, in the simplest sense, using the maximum transportation speed at various historical moments as a measure, the world became 60 times smaller between 1500 and 1970, when we compare the speed of airplanes (say, 600 mph [miles per hour]) with that of medieval sailing vessels (10 mph) (Figure 1). By increasing the velocities of people, goods, and information, the world is made to feel smaller even as interactions are stretched over larger physical distances. The term *compression* is therefore misleading: Every round of time-space compression involves an expansion in the geographic scale of social activities. This idea is often taken to mean that space ceases to have relevance. Despite the fashionable use of unfortunate expressions such as the “death of distance” or the “annihilation of space,” the fact remains that geography is a stubbornly persistent feature of human life. Rather than the “annihilation of space,” it is healthier to talk of how one space-time regime displaces another. Far from shrinking the world evenly, successive revolutions in the structure of time and space have left it misshapen, as some places were brought together relationally more than others. Moreover, reducing time-space compression to simple reductions in transport times fails to do justice to its deeply phenomenological dimensions and the complexity with which these two dimensions

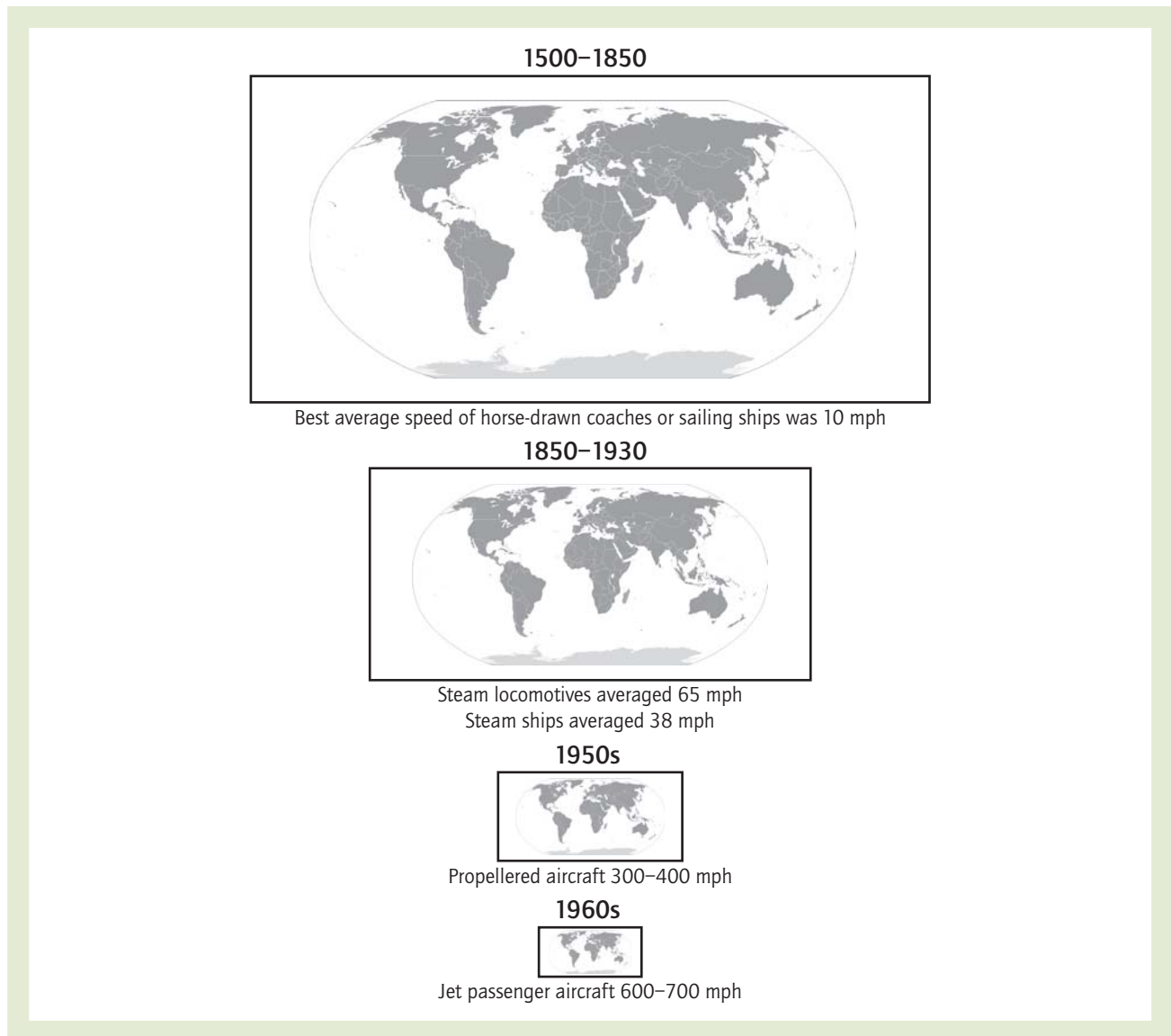


Figure 1 Time-space compression reflects and generates a shrinking world. Historically, rising velocities of transportation have reduced relative distances across the globe.

Source: Author.

are wrapped up in social life and their political and ideological origins and associations.

Time-space compression occurs at multiple spatial and temporal scales, all of which interact with one another, including long-distance networks of trade that historically sutured cities, empires, and, later, nation-states together into interactive wholes; political formations in which the state integrated diverse peoples and places under a single authority, often through tribute, taxes, or conscription; and the ideological and psychological dimensions of how ideologies perceive and represent Others, the

discursive and symbolic representations of foreign or distant places that define community, identity, and the here and now. This process, of course, depends heavily on the relative and differential abilities of social formations to link places together or, in an older nomenclature, to conquer the “friction of distance.” Whenever the consequences of actions in one area spill over into others, time-space compression is at work. Whenever new networks of trade or migration appear, tying together places through flows of commodities and innovation, time-space compression can be detected; whenever a new



medium, communication technology, or widespread ideology, whether it be the book or a religion or the Web, brings together subjects into epistemic communities bound together over vast distances, time-space compression is in the making; whenever the spatial scale of social relations expands, such as from the city to the nation-state or from states to empires, time-space compression is evident; whenever new technologies expand the conceptual horizons of people or social institutions bind them together in a novel manner (such as “citizenship”), time-space compression occurs; whenever the division of labor collapses people into dense wads of humanity, such as the city or the factory, time-space compression can be detected. One way to approach time-space compression is by looking at how external shocks to a society—diseases, invasions, technological innovations, wars—reverberate through local social relations of class, gender, and ethnicity to change inhabitants’ views of time and space and their fabric of daily life. Conversely, locally generated changes may scale-jump to become regional, national, or global in scope. Time-space compression can be studied by examining the changes in daily life that ensued as new technologies, cultures, and forms of social cohesion were introduced and older ones concomitantly annihilated.

The Evolution of Time-Space Compression

Time-space compression is as old as human civilization itself. Early changes in transportation technology, such as the wheel and keel, were instrumental in the development of centralized empires. Many cultures (e.g., the Romans) developed road or canal networks to shuttle people and goods between places. The Mongols and the Incas created messenger systems using horse riders and runners, respectively. The Renaissance and the Enlightenment exemplified the intellectual changes of early modern time-space compression, including the Copernican revolution and perspectival painting. Printing greatly enhanced the distancing of social intercourse, allowing widespread contacts and diffusion of ideas without face-to-face contact. These changes were important moments in the scalar jump from the city-state to the nation-state, the most important social and political unit of the modern era, homogenizing local cultures and economies by

incorporating them within even larger units of social and political control.

The rise of capitalism, and the Industrial Revolution in particular, generated enormous improvements in transportation and communications that significantly reduced travel times between places. For example, the travel time between Edinburgh and London, a distance of 640 kilometers, was roughly 2,000 min. (minutes) by stagecoach in 1658. By the 1850s, with the arrival of the steam locomotive, travel time had been reduced by two thirds, to 800 min. In 1988, the rail journey between Edinburgh and London took 275 min. When the line was electrified in 1995, travel time was reduced to less than 180 min. By airplane, it takes less than 60 min. today. Thus, while the absolute distance between the two places remained the same, the relative distance was reduced by 1,940 min. over 350 yrs. (years), or roughly 5 min./yr.

Air transportation provides spectacular examples of time-space convergence. In the 1930s, it took a plane between 15 and 17 hrs. (hours) to fly over the United States from coast to coast; modern jets now cross the continent in about 5 hrs. In 1934, planes took 12 days to fly between London and Brisbane, Australia; today the Boeing 747 is capable of flying any commercially practicable route nonstop. The result is that any place on Earth is within less than 24 hrs. of any other place, using the most direct route.

Closely related to time-space compression is cost-space compression, the steady reduction in the cost of moving goods, people, or information between places. For example, the opening of the Erie Canal in 1825 reduced the cost of transport between Buffalo and Albany from \$100 to \$10 and, ultimately, to \$3 per ton. Railroad freight rates in the United States dropped 41% between 1882 and 1900. Between the 1870s and 1950s, improvements in the efficiency of ships reduced the real cost of ocean transport by about 60%. Within the discipline of geography, time-space compression was first theorized in terms of the friction of distance imposed by high transportation costs. Closely associated with the friction of distance was its measurement in terms of travel time and cost, which tend to be more useful in explaining travel patterns than are absolute distances.

In the 1960s, Donald Janelle introduced the notion of time-space convergence, the rate at which places drew closer to one another over time in relative space due to rising transport speeds even as



the absolute distance between them remained constant. One example concerned the changing travel time between Lansing and Detroit, Michigan, which was approximately 1,300 min. by stagecoach in 1840. By the 1870s, with the arrival of the steam locomotive, travel time had been reduced by two thirds, to 180 min.; with the introduction of the automobile, the journey was further reduced to only 80 min. Thus, while the absolute distance between the cities remained the same, the relative distance was reduced by 1,220 min. over 120 yrs., or roughly 10 min./yr. Similarly, between 1800 and 1965, travel times between Boston and New York declined from 4,800 to 300 min., or 27 min./yr. Janelle also introduced the notion of time-space divergence, such as when urban infrastructures become so overloaded with traffic that significant delays occur due to congestion.

In the context of late-20th-century globalization and technological changes, falling transport times created a steadily “shrinking world” that changed the suite of opportunities and constraints faced by places, firms, and individuals. Because markets are shaped by the distances beyond which goods and information cannot circulate in a timely manner, transport and communication costs limit their geographic size. For competitive firms, the steadily declining friction of distance was a significant economic benefit. For other firms, the benefits were not so clear: As transport costs dropped and the spatial division of labor became broader, once protected local industries lost their monopoly status and were forced to compete with other producers in neighboring and then in increasingly distant regions. For individuals, the benefits of time-space compression include increasing mobility to a wider horizon of potential destinations. As the transportation literature demonstrates, mobility levels tend to rise proportionate to income; however, transport times remain essentially stable, indicating that the ability to conquer distance is purchased primarily through increasing velocities.

In the 1960s, the shrinking world was a popular theme among technocrats such as Daniel Bell and Alvin Toffler, who approached the topic from the perspective of “postindustrial” society, the decline of manufacturing, and the rise of an information-based service class. Technocratic views of communication were widely promoted by Marshall McLuhan, whose enormously influential

works portrayed a progression from the limited spatiality of preindustrial societies and orality as the dominant form of communication to the influence of printing, to the global networks of modern telecommunications. Each age, he maintained, saw a dramatic increase in the scale of human extensibility. Technocratic theorizations of time-space compression, informed primarily by technological determinism, tended to present space and time as lying outside of social relations; they ignored or minimized the social inequalities and power relations that the process inevitably entails. This rosy, utopian view, with its impoverished sense of politics and inequality, nonetheless spoke to the profound time-space compression that telecommunications unleashed, and it decisively entered popular consciousness on the subject.

Because it is fundamentally an expression of power, time-space compression is always uneven among groups and places. Time-space compression, thus, does not affect all places or peoples equally. Spatially, this process endlessly generates new geographies of centrality and peripherality, bringing some places closer together and others relatively less so. Generally, the elites tend to enjoy the earliest and often the greatest advantages from reduced costs and transmission times of transportation and communications. Time-space compression is intimately associated with the ways in which capitalism generates new geographies over time. Globally, cheaper, more efficient modes of transport widened the range over which goods could be shipped profitably, allowing regions and countries to realize a comparative advantage and stimulating large-scale production and an increasingly internationalized geographic division of labor.

Within countries, transportation improvements contributed to changing patterns of urban accessibility. Cities in the industrialized world grew from compact walking and horsecar cities (pre-1800 to 1890) to electric streetcar cities (1890–1920) and, finally, to dispersed automobile cities in the recreational automobile era (1920–1945), the freeway era (1945–1970), the edge city era (1970–1990), and the exurban era (1990 to present).

Contemporary Time-Space Compression

Telecommunications represent the latest, and perhaps most profound, in the long series of chapters



of time-space compression, effectively reducing the communication time between places to zero. The telegraph in the 19th century, for example, connected the global economy's expanding networks almost instantaneously, allowing news to travel at the speed of light, reducing uncertainty for producers, allowing multi-establishment firms to connect headquarters and branch plants, and allowing markets to expand over ever larger spatial domains. The telephone had similar effects throughout the 20th century, and declines in the cost of telephone service generated considerable cost-space compression, with multiple economic, social, and psychological impacts. Starting in the 1980s with the microelectronics revolution, a worldwide skein of fiber-optic lines has come to form the nervous system of the international financial economy, creating the time-space compression of the flexible, post-Fordist, digitized global economy. Electronic funds transfer systems allow financial institutions to switch vast sums of capital from one place to another instantaneously, in the process arbitraging interest rate differentials, speculating in foreign exchange, and investing or disinvesting in a wide variety of instruments in a diverse array of markets. The Internet represents another dimension of this process. Connecting roughly 1.7 billion people in 2009, the interlinked series of computers that comprise the Internet and the World Wide Web allow almost instantaneous time-space compression. Yet even within the best connected of global cities, for example, there are substantial pockets of "off-line" poverty.

Globally, in a shrinking world, distant strangers become less and less distant or strange. David Harvey attributes the growth of postmodern culture—the fragmented set of discourses emphasizing difference and heterogeneity that flourished in the late 20th century—to the compression unleashed by digitized, globalized time-space compression. It is critical to emphasize that time-space compression is not inherently beneficial to all those affected but results in uneven gains and sometimes losses: For some, it represents a rise in efficiency and an increased ability to master space; for others, it consists of a loss of control as their worlds are enveloped within wider divisions of labor controlled by powerful strangers. Because the structures of time and space are wrapped up with relations of power,

domination, and subordination, the shrinking world does not shrink in the same way or equally for everyone; time-space compressions always simultaneously empower and disempower different social groups. Often the process accentuates existing social inequalities, as when, for example, the wealthy deploy new technologies that leave the poor further behind. Indeed, time-space compression for some may be time-space expansion for others.

Barney Warf

See also **Harvey, David; Relative/Relational Space; Spatial Fix; Telecommunications and Geography; Time, Geographies of; Transportation Geography; Virilio, Paul**

Further Readings

- Agnew, J. (2001). The new global economy: Time-space compression, geopolitics, and global uneven development. *Journal of World-Systems Research*, 7, 133–154.
- Dodgshon, R. (1999). Human geography at the end of time? Some thoughts on the notion of time-space compression. *Environment and Planning D: Society and Space*, 17, 607–620.
- Giddens, A. (1984). *The constitution of society: Outline of the theory of structuration*. Berkeley: University of California Press.
- Harvey, D. (1989). *The condition of postmodernity*. Oxford, UK: Blackwell.
- Janelle, D. (1969). Spatial reorganization: A model and concept. *Annals of the Association of American Geographers*, 59, 348–365.
- Kern, S. (1983). *The culture of time and space 1880–1918*. Cambridge, MA: Harvard University Press.
- Warf, B. (2008). *Time-space compression: Historical geographies*. London: Routledge.



T-IN-O MAPS

The label T-in-O maps, or simply "T-O maps," is the modern name given to a simple world map found in a variety of sources during the Middle Ages. They appear as explicit graphics (i.e., diagrams made with circles and straight lines with



Figure 1 Model of a typical T-in-O map. Common in medieval Europe, T-in-O maps divided the known world into three continents along biblical lines.

Source: Author.

names attached), as the structure underlying far more complex maps (e.g., the Hereford *mappa mundi* has one as its underlying structure for the continental landmasses), and as symbolic representations of the earthly, human, sublunar world (e.g., it inspired the “royal orb” that is or was part of the regalia of European royalty, and in that form, it can be found linked to many Christian statues). In form, the T-O map is a circle with its horizontal diameter marked and with a radius perpendicular to that diameter running down to the lowest point on the circle. The diagram looks like a “T” inscribed in an “O,” hence its modern name. East is at the top of the circle. The upper half represents Asia, the lower quarters Europe (*left*) and Africa (*right*). The outer circle is the Ocean; the left radius represents the Danube (although it is commonly misidentified as the Don); the right radius represents the Nile and the lower radius, the Mediterranean. It portrays the whole of the inhabited world, in the northern temperate zone, as it was known to the Europeans.

Other details are often added to the basic map. There is a more elaborate form showing the Danube’s mouth; often the continents are shown with

the names of the children of Noah (see Genesis 10) from whom the African (from Ham/Cham), Asian (from Shem/Sem), and European (from Japhet) nations were believed to have descended; and often one or two local details (e.g., the Pillars of Hercules [Gibraltar] or the British Isles) are shown.

The map has to be read in conjunction with other geographical diagrams to appreciate it fully. The most important of these other drawings is the zonal map, which has a torrid zone at the equator, frigid zones at the poles (both uninhabitable), and between them a northern temperate zone (which is the area covered by the T-in-O map) and a southern temperate zone, in which it was assumed that there was a corresponding landmass but there was a debate as to whether or not it was inhabited (the antipodes were its putative inhabitants). When this consideration is taken into account, the T-in-O map can be seen not as that of a “flat Earth” but as an attempt to portray lands on a sphere as seen from a great distance. As such, it embodies elements of an orthographic projection; however, insofar as it has the eastern end of the Mediterranean at its center and the ocean as the circumference, it has elements of an oblique azimuthal projection. It was this aspect of this map, when read in conjunction with certain biblical passage (e.g., Ezekiel 5:5) that led to the practice of placing Jerusalem at the center of many medieval maps.

The origins of the map lie in antiquity. In Homer, the shield of Achilles had a depiction of Earth, and around its edge ran the “Ocean river,” while errors in orientation in Roman sources show that they thought of their lands in a way remarkably similar to the way they are laid out in the T-in-O map. Likewise, Luke’s account in the Acts of the Apostles of the travels of St. Paul are far easier to follow on a T-in-O map than on the modern maps now found in bibles. However, the earliest evidence of the map is to be found in the writings of Isidore of Seville (ca. AD 560–636). Evidence points to the copyists having imported the map from Isidore to give clarity to the descriptions. Isidore produced two distinct forms of the map: The simpler one is just the T in the O with the continents’ names found in his encyclopedia, the *Etymologiae*; the more complex map is found in his treatise on the material creation, the *De natura rerum*, which contains additional details of the mouths of the Nile and the Danube, while the linear text mentions other geographical information



that occasionally was depicted on the map (e.g., the cardinal directions placed outside the O). These two forms were subsequently imported into many other texts as distinct items of common knowledge (e.g., Lucretius's textbook *De natura rerum* [*On the Nature of Things*]). Also, the two forms were often merged, or merged and combined with other "facts" of geography, such as that Paradise was in the east.

There is hardly a Western European map from before the 15th century that is not influenced by the T-in-O form. It fitted with the experience and travels of people from that region (e.g., one can travel across Europe using a 12th-century map by Giraldus Cambrensis, which is based on a T-in-O map), it conformed to all their classical authorities (e.g., it helped in reading Sallust), and it supported the image of the world they used in reading the Bible (e.g., the division of the Earth to Noah's sons or the travels of Paul). It finally disappeared from use with the revival of interest in Ptolemy's *Geography* and its very different world map.

Thomas O'Loughlin

See also **Biblical Mapping; Cartography, History of**

Further Readings

- Harvey, P. (1987). Medieval maps: An introduction. In J. Harley & D. Woodward (Eds.), *The history of cartography: Vol. 1. Cartography in prehistoric, ancient, and medieval Europe and the Mediterranean* (pp. 283–285). Chicago: University of Chicago Press.
- Lozovsky, N. (2000). *The Earth is our book: Geographical knowledge in the Latin West ca. 400–1000*. Ann Arbor: University of Michigan Press.
- O'Loughlin, T. (1999). An early thirteenth-century map in Dublin: A window into the world of Giraldus Cambrensis. *Imago Mundi*, 51, 24–39.
- Romm, J. (1992). *The edges of the Earth in ancient thought*. Princeton, NJ: Princeton University Press.
- Woodward, D. (1985). Reality, symbolism, time and space in medieval world maps. *Annals of the Association of American Geographers*, 75, 510–521.
- Woodward, D. (1987). Medieval mappaemundi. In J. Harley & D. Woodward (Eds.), *The history of cartography* (Vol. 1, pp. 286–370). Chicago: University of Chicago Press.



TOBLER, WALDO (1930–)

Waldo R. Tobler is a geographer and a cartographer who has done much to expand ideas about what can be mapped and how. He was closely associated with the quantitative revolution in the 1960s, leading the move to computer mapping, developing new map projections, and applying mathematical techniques to practical questions. His interests led him to consider issues in geographical information science, and he was part of the Santa Barbara team in the National Center for Geographic Information and Analysis.

Tobler was born in 1930 in Portland, Oregon, to a Swiss family. His father was the Swiss consul, with responsibility for the Pacific Northwest. Tobler completed his undergraduate degree at the University of Washington, having drifted into geography because he enjoyed reading maps. He proceeded to a master's degree, specializing in cartography. He left Washington and returned after 2 yrs. (years) to do his doctorate. He was at the University of Washington in the late 1950s, at the same time as many of the future leaders of the quantitative revolution. Geographer William Garrison was a junior faculty member, and the graduate students included Brian Berry, William Bunge, Michael Dacey, Arthur Getis, Duane Marble, and Richard Morrill. Tobler says that he "learned just as much or more from fellow graduate students as from the faculty." Graduate students were encouraged to learn computing as well as to take courses in mathematics and econometrics; ideas from such courses could often be applied in cartography. His PhD dissertation, *Map Transformations of Geographic Space*, developed new ways of mapping based on time or cost distances and investigated the mathematical basis of cartograms.

After leaving the University of Washington, Tobler became a faculty member at the University of Michigan, where he worked for 16 yrs., moving to the University of California, Santa Barbara, in 1977. Although still primarily a cartographer, he kept up his interests in many aspects of spatial analysis. His work on migration is distinctive. While most geographers modeling human behavior do so using statistics, Tobler uses other branches of mathematics, such as vector analysis and partial differential equations. He was also a leader in the development of animated maps, for example, the



film of the spatial development of Detroit. His write-up for this “computer movie,” appearing in 1970, included his most quoted aphorism, now known as Tobler’s first law of geography: “Everything is related to everything else, but near things are more related than distant things.” This claim has attracted much attention. Decades later, the Association of American Geographers held a symposium on Tobler’s first law, the proceedings of which were published in the *Annals of the Association of American Geographers* in 2004.

Robin Flowerdew

See also **Quantitative Revolution**

Further Readings

- Sui, D. (2004). Tobler’s first law of geography: A big idea for a small world? *Annals of the Association of American Geographers*, 94, 269–277.
- Tobler, W. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography*, 46, 234–240.
- Tobler, W. (2002). *Ma vie*. In P. Gould & F. Pitts (Eds.), *Geographical voices: Fourteen autobiographical essays* (pp. 299–323). Syracuse, NY: Syracuse University Press.
- Tobler, W. (2004). Thirty five years of computer cartograms. *Annals of the Association of American Geographers*, 94, 58–73.



TOMLINSON, ROGER (1933–)

Roger Tomlinson played a key role in establishing geographic information systems (GIS) from their earliest years. He is one of the very few who merit the title “father of GIS.”

Born in Cambridge, Britain, Tomlinson was a flying officer in the Royal Air Force before attending Nottingham University. He obtained an honors degree in geography (1957) and then moved to Canada for another BSc in geology at Acadia University in Nova Scotia (1960). He continued with an MSc in geography at McGill (1961), while starting work at Spartan Air Services on various forms of terrain evaluation. This work led him to investigate the use of digital computers to store and analyze geographic information. In the 1960s, he

joined the Canadian government as head of the development program for an information system to be known as the Canada geographic information system (CGIS). While others around the world began to use GIS terminology at about the same time, CGIS was conceived at a continent-spanning scale from the start. His paper on CGIS in 1968, presented in Australia, may have been the first use of the term *GIS* in a reviewed publication. The analytical objectives of CGIS were as challenging as the sheer effort in digitizing four map layers across Canada at a scale of 1:250,000.

He obtained a PhD in 1974, writing a thesis that described CGIS in detail. Tomlinson’s vision of GIS attracted international attention during the 12-year period in which he chaired the Commission on Geographical Data Sensing and Processing of the International Geographical Union. Since the early 1970s, Tomlinson has worked as a consultant to government and industry around the world. His important achievements come largely from the critical appraisal of actual needs and his commitment to pushing the technology forward. At the critical juncture when the commercial software sector was emerging (around 1980), he and his associates rejected all tenders for the Saskatchewan Natural Resources project. This action held the developers to high standards that were not met until a few years later. In this role, as much as at CGIS, he directed the future of what became the GIS industry and practice.

Tomlinson has been a tireless campaigner for geographic awareness and geography as a discipline and a profession. He has received many awards for service to geography and GIS and was appointed to the Order of Canada in 2001.

Nicholas Chrisman

See also **Business Models for Geographic Information Systems; Geographic Information Systems; GIS, History of; GIScience**

Further Readings

- Tomlinson, R. (2003). *Thinking about GIS*. Redlands, CA: ESRI Press.
- Tomlinson, R., & Boyle, A. (1981). The state of development of systems for handling natural resources inventory data. *Cartographica*, 18(4), 66–95.



TOPOLOGICAL RELATIONSHIPS

Topological relationships are the qualitative relationships of geographic objects that are not affected by continuous distortion, such as translation, rotation, scale, or skew. These relationships are said to exhibit a property known as topological invariant. In other words, topological relationships describe the spatial interrelations among geographic objects, and how they are linked together, without reference to their geographic locations, dimensions, or orientations. Some examples of topological relationships are (a) *touch*—a point touches a line (e.g., a bridge on a river); (b) *cross*—a line crosses another line (e.g., a road across a river); and (c) *within*—a region is completely contained by the boundaries of another region (e.g., an island in a lake). In addition to topological relationships, geographic objects can also have projective relationships, such as orientation (left or right), and metric relationships, such as distance, which can be measured quantitatively. These geometric

relationships are fundamental predicates for geographic representation and reasoning.

The definition of topological relationships derives from how geographic objects are understood and represented, or, more broadly, from ontology. One way to define topological relationships is Egenhofer and Herring's nine-intersection scheme, which uses discrete points, lines, and regions to represent the geometries of geographic objects. The scheme uses the interiors, boundaries, and exteriors of two geometric objects to construct a 3×3 matrix, in which every entry denotes whether the intersection of the two object parts is an empty set or not, tested under the topologically invariant condition. Each distinctive set of nine intersections represents a different topological relationship. Out of the 512 (2^9) possible combinations of the 3×3 matrix, the nine-intersection scheme identifies, for example, 8 relationships between two regions with connected boundaries (i.e., no holes or disjointed parts) and 33 relationships between two simple lines (i.e., lines without branches). Some topological relationships are illustrated in Figure 1.

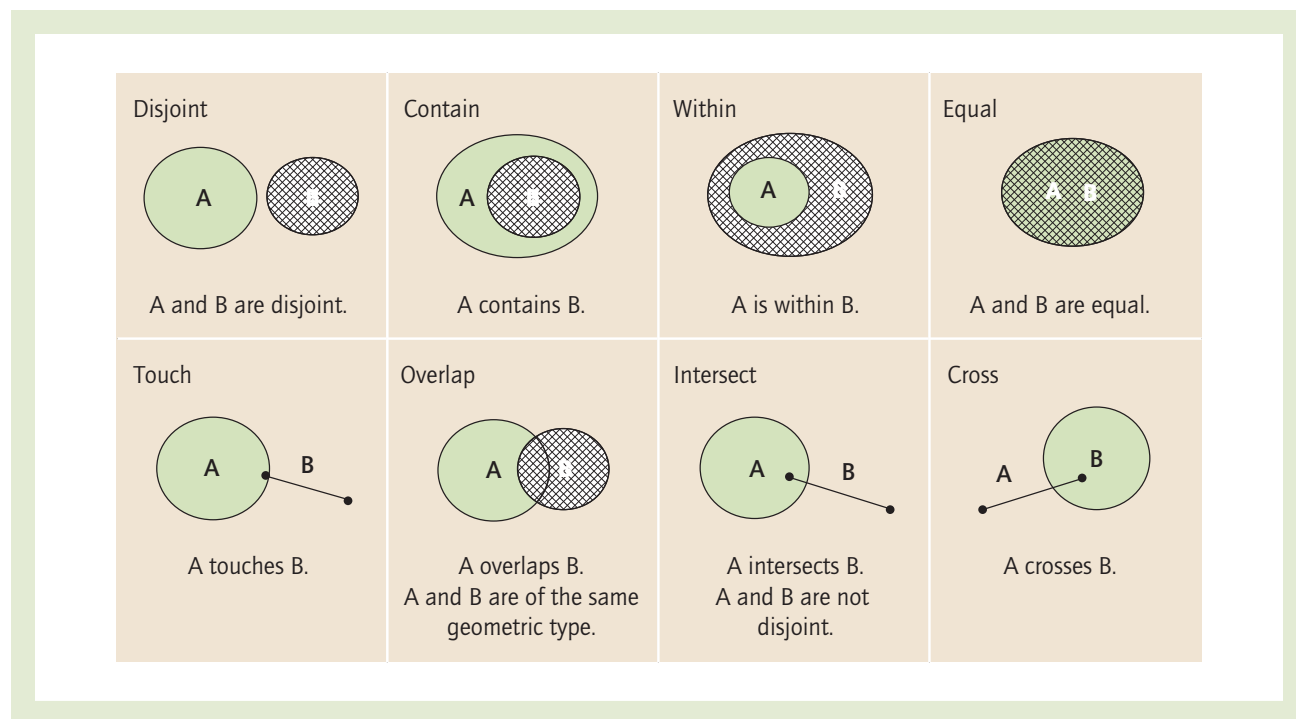


Figure 1 Examples of topological relationships

Source: Adapted from Egenhofer, M. J., & Herring, J. R. (1991). *Categorizing binary topological relations between regions, lines, and points in geographic databases* (Technical Report No. 91-7). Santa Barbara: University of California, National Center for Geographic Information and Analysis.



The nine-intersection scheme provides a formal definition of topological relationships, and as part of the Open Geospatial Consortium specifications and ISO/TC 211 standard, some of the relationships have been implemented in commercial geographic information systems and spatial database systems to formulate qualitative queries about the connection properties of spatial objects. Its reasoning framework facilitates finding new relationships from a set of geographic objects. As the geometric representations of geographic objects become more complex and additional object properties, such as nonplanar geometry, movements of objects, or vagueness of their boundaries, are considered, the task of defining the topological relationships becomes more difficult and sometimes intractable. Many topological relationships identified in the framework have no corresponding natural-language equivalents, making them not applicable in qualitative spatial reasoning that is based on the semantics of natural languages. Given these practical purposes and concerns, topological relationships have become a topic of interdisciplinary research involving the fields of geography, geographic information science, linguistics, artificial intelligence, and cognitive science.

Jiunn-Der Duh

See also GIScience; Network Analysis; Ontological Foundations for Geographical Data; Ontology; Open Geospatial Consortium (OGC); Spatial Cognition; Spatial Data Models

Further Readings

Egenhofer, M. J., & Herring, J. R. (1991). *Categorizing binary topological relations between regions, lines, and points in geographic databases* (Technical Report No. 91-7). Santa Barbara: University of California, National Center for Geographic Information and Analysis.



TOPONYMY

Toponymy is a discipline that developed in the linguistic sciences. It studies the proper names of places from different points of view and according

to different perspectives. This research seeks to find the essence of proper names through their evolution from a single instance of a common name to a final proper name. In the final situation, the proper name is a classically opaque “sign” in which the sound (or the grapheme, in its written form) cannot be directly linked by the user to a meaning, inasmuch as the name has lost its direct link to the designated place. For this reason, the study moves in the direction of etymology, which investigates the semantic origins of names. Research into the etymological origins of a name presupposes that the researcher has knowledge of the language or languages from which the common name emerged and of the forms that this name took in the various stages of its evolution. Historical testimonies are thus fundamental instruments in toponymy research, in particular archival documents for historical names and field research through inquiry with witnesses and direct users of the name.

These characteristics place toponymy at the crossroads of disciplines that are to a greater or lesser degree linked; among these, the most closely linked are the history of populations, ancient languages, and the historical and geographical evolution of languages. The links with geography are strong: Toponymy is a fundamental part of geographic study inasmuch as it studies the names of geographic entities.

Links With Geography

It is important to remember that by its very nature (viz., its focus on the longevity and conservation of original traits), the study of the names of places represents an important part of various aspects of geography inasmuch as the name of a place is testimony to its characteristics and modifications of its territory. Aspects that are particularly enhanced include the spread of different types of flora and the identification of territorial characteristics (physical geography, territorial conformity, spread of fauna, aspects of the territory as interpreted by the population that inhabits it, etc.).

Furthermore, toponymy also sheds light on aspects linked to the economic and social geography of a specific place, for example, the institutional and organizational aspects of territories. From a historical perspective, the analysis of



names can contribute to tracing the history of geographic settlements and migration. Finally, toponymy represents a fundamental part of cartography inasmuch as it can contribute to the identification of names to be written on maps and the most appropriate form of their transcription.

To realize its intentions, toponymy proceeds through the systematic collection of names of places. These names are then analyzed with the intent of making generalizations through observation. Parallel to this approach, other study directions are involved in researching the spread and characteristics of toponymic types in detail.

New Applications

In addition to historical and diachronic investigations, toponymy developed applications that are less strongly linked to its founding discipline. Inherent in this direction is the inquiry into the formal choice of toponyms, the relationships between the name of a place and the community that inhabits it, sociological and legal statutes pertaining to the name, the creation of new names, the replacement of old names, and the links between names of places and people. In this way, toponymy has developed links with disciplines such as sociology, sociolinguistics, cultural history, ethnography, anthropology, philosophy, urban studies, political science, and literary criticism.

Particular attention is given to the definition of a place name inasmuch as it can assume vastly different forms: For example, it can be indicative of a field or a small holding, a settlement, a city, a nation, a continent, water courses, mountain elevations, buildings, and so on. Over time, toponymy has developed research into aspects related to the nomenclature of common geographic names and, in so doing, closely collaborated with geography. In this regard, a recent direction of analysis strives to observe tendencies related to the interlinguistic aspects of a name: translations of names, the use of names in their original form in a different language, and so forth.

Stefano Vassere

See also **Place Names**

Further Readings

- Berg, L., & Vuolteenaho, J. (2009). *Critical toponymies*. London: Ashgate.
- Kadmon, N. (2000). *Toponymy*. New York: Vantage Press.



TOPOPHILIA

Topophilia lies at the intersection of geography and environmental psychology, describing the human emotional experience of the physical environment, including sensory perceptions, attitudes toward nature, and valuations of specific components or composites of the landscape. Topophilia generally implies an affection for specific places, but the term involves a spectrum of responses that may include disaffecting experiences for disliked or less preferred locations. Hence, since its original expression by the geographer Yi-Fu Tuan in the mid 1970s, the meaning of *topophilia* has evolved, and additional related terminologies have emerged. For example, the term *topophobia* has been used to describe the fear of specific geographical features. Furthermore, it is difficult to disentangle topophilia and topophobia—which are often associated with the nonliving components of nature—from the human emotional response to the living components of nature, which is captured separately by the terms *biophilia* and *biophobia*.

When confronted with images or direct experiences of different landscapes such as rain forests, sandy deserts, meadows, ocean fronts, and urban landscapes, most individuals do not find it difficult to declare ranked preferences, although they may not be able to articulate the rationale for such preferences. Attempts to deconstruct responses to specific components of natural or built landscapes are rare, but recent research to elucidate topophilia have revealed four domains within which human emotional attachment or detachment from the physical environment can be categorized: (1) ecological diversity, including the natural composition of vegetation, animals, and insects and the presence of water bodies;



(2) synesthetic tendency, described as the comingling of the senses of sight, smell, texture, and temperature; (3) cognitive challenge, including geometrical shapes, landscape complexity, and opportunities for solitude and contemplation; and (4) familiarity, according to the level of comfort experienced by repeated exposure to the same or similar places.

Understanding the determinants of individual or group preferences for specific components of natural and urban landscapes has been proposed for facilitating the design of restorative environments such as hospital landscapes, where residents hope to recover from diseases, or urban landscapes, where the pressures of daily survival can contribute to subnormal mental health conditions. Additional research may assess variations in individual preferences based on community expressions of toponophilia.

Oladele Ogunseitan

See also Built Environment; Environmental Perception; Everyday Life, Geography and; Home; Humanistic Geography; Phenomenology; Place; Sense of Place; Tuan, Yi-Fu

Further Readings

- Gonzalez, B. (2005). Topophilia and topophobia: The home as an evocative place of contradictory emotions. *Space and Culture*, 8, 193–213.
- Ogunseitan, O. (2005). Topophilia and the quality of life. *Environmental Health Perspectives*, 113, 143–148.
- Ruan, X., & Hogben, P. (Eds.). (2007). *Topophilia and topophobia: Reflections on twentieth-century human habitat*. London: Routledge.
- Tuan, Y.-F. (1974). *Topophilia: A study in environmental perception, attitudes, and values*. Englewood Cliffs, NJ: Prentice Hall.

visible as a condensation funnel or by the dust and other debris incorporated into the rotation. About 1,500 tornadoes are recorded annually around the middle latitudes of Earth, and they typically cause 100 to 300 deaths.

Regional Occurrences and Frequencies

Tornadoes occur in many regions of the world but are most frequent in the middle latitudes, especially in the Central and Southern United States, but with the most loss of life and livelihood occurring in Central Bangladesh. The United States records about 1,100 tornadoes annually. This count has doubled since the 1950s, but the increase is thought to be due to better reporting and recording of tornadoes rather than an actual increase in the number of tornadoes. Canada records about 60 tornadoes annually; the United Kingdom and Australia each about 30; Germany, France, and Italy each about 20; and Argentina and Bangladesh each about 10. A substantial number of tornadoes also occur in other European countries and in India, South Africa, China, Japan, and New Zealand. Tornadoes are undercounted in many countries because small tornadoes are not observed and recorded. The number of tornadoes seems to increase in these regions as reporting efficiency and record keeping improve.

The occurrence of tornadoes is restricted to the regions where conditions are favorable for their formation. Thus, they are most common in the middle latitudes, where a contrast of air masses, vertical wind shear, instability, a strong jet stream, and strong cyclonic storms and fronts most commonly occur. Although tornadoes may occur more frequently over flat terrain, they are known to occur in hilly terrain and to cross large mountain ranges and descend into deep valleys. No terrain is “protected” from tornadoes.

Seasonal patterns of tornado frequency exist, with a spring and summer peak in the United States. The occurrence of tornadoes generally coincides with the annual peak in thunderstorm frequency. On the diurnal scale, tornadoes most often form during the afternoon and evening hours when atmospheric instability is greatest and thunderstorms are most violent.



TORNADOES

A tornado is a violently rotating column of air in contact with the ground. It usually forms under a cumulonimbus (thunderstorm) cloud and is



Conditions for Formation

Tornadoes are classified into two broad categories, supercell tornadoes and nonsupercell tornadoes. A supercell tornado forms within supercell thunderstorms that contain mesocyclones in the middle levels of the atmosphere. Mesocyclones are rotating updrafts that may persist for several hours. They form in a moist, unstable environment with strong vertical wind shear. A supercell thunderstorm may produce several tornadoes, called a “tornado family,” with one tornado forming as the previous one dissipates. Rotation develops in the thunderstorm updraft due to the change of wind speed and wind direction with height above the ground, called vertical wind shear. This wind shear causes horizontal vorticity. Stronger winds aloft cause a tilting and stretching of this horizontal vorticity, and this results in a rotating cloud with vertical vorticity, the mesocyclone.

Not all supercell thunderstorms produce a tornado. The mechanisms that create rotation at ground level, that is, a tornado, are poorly understood. Large vertical vorticity must arise at the ground. This may develop when horizontal vorticity near the ground is tilted into a vertical rotation. Vertical vorticity near the ground may also arise through the transfer of vertical vorticity toward the ground by a rear-flank downdraft from the mesocyclone. The rear-flank downdraft is dry air that descends from midlevels in the atmosphere and wraps around the back of a mesocyclone. The rear-flank downdraft may tilt horizontal vorticity into vertical vorticity, transfer vertical vorticity from the mesocyclone toward the ground, or enhance existing vertical vorticity near the ground, and any of these may lead to a tornado.

Nonsupercell tornadoes occur with the growth stage of a parent cloud and originate from near-ground convergence and rotation, or vertical vorticity, in the lower layers of the atmosphere. Although they are dangerous, they tend to be smaller and weaker than supercell tornadoes. Gustnadoes and landspouts are examples of nonsupercell tornadoes. A gustnado forms along a gust front or other storm outflow boundaries and is visible as a swirl of dust or debris. A landspout appears as a long, narrow rotation, similar to the

waterspouts seen along the Florida coasts, and does not require a preexisting boundary.

A waterspout is a tornado over water. These include supercell tornadoes that form over land and then pass over a body of water. More commonly, however, a waterspout forms over warm waters as a nonsupercell tornado with low-level convergence. They are most common over the waters of the Florida Keys but also occur with cold air advection across the warmer waters of the North American Great Lakes and elsewhere.

Tornadoes may occur over land in association with tropical cyclones (hurricanes). Tornadoes that form in rain bands more than 200 km (kilometers) from the cyclone center are called “outer-region” tornadoes and may touch down near the coast well before landfall of the tropical cyclone. They show a diurnal cycle, with most occurring during the afternoon. Inner-region tornadoes, within 200 km of the center, occur less than 12 hours prior to landfall and tend to be weaker, with no diurnal cycle. About 60% of tornadoes associated with tropical cyclones occur within 100 km of the coast, but the threat persists 2 to 3 days after landfall and extends 400 km inland and 500 km from the cyclone center.

Most tornadoes rotate cyclonically (counterclockwise) due to the direction of rotation in the parent thunderstorm cloud. Some tornadoes have smaller secondary rotations, called suction vortices, within their broader rotation. The suction vortices are cycloidal swaths of stronger winds and create local gradations of wind damage caused by tornadoes.

Damage and Casualties

Damage and casualties result from the strong winds in tornadoes and the impacts of the debris carried in those winds. Damage to buildings and other structures increases with stronger wind speeds but depends also on the strength and quality of the construction and the anchorage of the building to the ground. These characteristics of building quality vary geographically according to traditions, customs, and wealth. Contrary to popular notions, buildings do not “explode” from differences in pressure inside and outside the tornado but from the forces exerted by the winds on the walls and roofs.



The first tornado captured by the NSSL Doppler radar and NSSL chase personnel, Union City, Oklahoma, 1973. The tornado is here in its early stage of formation.

Source: NOAA Photo Library, NOAA Central Library; OAR/ERL/National Severe Storms Laboratory (NSSL).

Wind damage begins with the roofing materials, gutters, windows, awnings, and canopies. These destroyed materials are then carried in the wind and, by their impacts, cause additional damage to structures downwind. With stronger winds, sections of the roof are lifted from the structure, and exterior walls collapse. These building failures can be mitigated by making strong attachments between the roof and the walls that will resist the uplifting forces of the wind. At the higher wind speeds, which are rare, structures are totally destroyed, and all interior walls collapse.

The Enhanced Fujita Scale is used in the United States to rank the intensity of tornadoes and to relate the damage to the estimated wind speeds (e.g., a 3-second gust at 10 m [meters] height) over a range from EF0 (65–85 mph [miles per hour]) to EF5 (more than 200 mph). In Britain, a similar scale for calculating tornado wind speed and damage, the TORRO Scale (Tornado and Storm Research Organisation), is used. Wind

speeds of about 75 mph break large branches from trees, and winds of 100 mph cause trees to snap or be uprooted. A typical family home in the United States will sustain roof damage at about 80 mph, but exterior walls remain intact up to about 130 mph (EF2). Mobile homes, where most tornado-related deaths occur in the United States, are rolled over and destroyed at wind speeds of about 100 mph (EF1). Apartments and condominiums lose roof covering at 100 mph, but walls remain intact to about 155 mph (EF3). Large retail buildings suffer the loss of roof and walls at about 135 mph. About 14% of tropical cyclone tornadoes are ranked EF2 or stronger on the Enhanced Fujita Scale, with maximum winds over 110 mph.

Injuries and deaths occur when people are exposed to the high winds and flying debris of the tornado. Some are injured in collapsed buildings, while others are caught outdoors and struck by debris or carried some distance. The very young



and the elderly suffer more deaths and injuries than youth and middle-aged persons.

Weak structures are easily collapsed by the wind or penetrated by debris and offer little protection to the occupants during a tornado. In the United States, about 45% of deaths due to tornadoes occur among residents of mobile homes, yet only 7% of the population resides in these structures. A stronger building offers more protection, especially if people seek a small interior room for shelter and stay away from windows. An underground shelter or basement is the safest location during a tornado. A vehicle may offer more protection than being outdoors or in a mobile home, but motorists should seek shelter in a sturdy building during a tornado. Death tolls from tornadoes decreased during the 20th century in the United States, from about 300 deaths annually to about 50 per year, due to better warning and communication systems, stronger buildings, and education about the risks and proper shelter.

The deadliest tornadoes in recent decades have occurred in Bangladesh, where 1,300 people were killed by a tornado on April 25, 1989, and 700 were killed on May 13, 1996. The deadliest tornado in the United States was on March 18, 1925, when 695 people were killed in Missouri, Illinois, and Indiana.

Injuries and deaths can be reduced by storm surveillance and early-warning systems. Government weather services can give a warning 5 to 15 minutes before a tornado strikes by receiving a report of a tornado on the ground or by observing strong rotation in a cloud with Doppler radar. The warning and information about the storm are disseminated to the public by radio, television, neighborhood sirens, or other electronic devices. Risks of injury are reduced if persons in the path of the storm become aware of the warning and take immediate action to move to the safest shelter. Where personal shelters, such as a sturdy house, basement, or underground storm shelter, are not available, community shelters can be provided to allow many people to take temporary refuge from the storm. These may be functions of wealth, education, class, race and ethnicity, gender, age, disability, and other social factors.

Thomas W. Schmidlin

See also Climate: Midlatitude, Mild; Climate: Midlatitude, Severe; Cyclones: Extratropical; Disaster Prediction and Warning; Disaster Preparedness; Hurricanes, Risk and Hazard; Natural Hazards and Risk Analysis; Thunderstorms; Vulnerability, Risks, and Hazards; Wind

Further Readings

- Ashley, W. S. (2007). Spatial and temporal analysis of tornado fatalities in the United States: 1880–2005. *Weather and Forecasting*, 22, 1214–1228.
- Bolton, N., Elsom, D. M., & Meaden, G. T. (2003). Forecasting tornadoes in the United Kingdom. *Atmospheric Research*, 67–68, 53–72.
- Church, C., Burgess, D., Doswell, C., & Davies-Jones, R. (Eds.). (1993). *The tornado: Its structure, dynamics, prediction, and hazards* (Geophysical Monograph No. 79). Washington, DC: American Geophysical Union.
- Goliger, A. M., & Milford, R. V. (1998). A review of worldwide occurrences of tornadoes. *Journal of Wind Engineering and Industrial Aerodynamics*, 74–76, 111–121.
- Ono, Y. (1997). Climatology of tornadoes in Bangladesh, 1990–1994. *Journal of Meteorology*, 22, 325–331.
- Schmidlin, T. W., Hammer, B. O., Ono, Y., & King, P. K. (2009). Tornado shelter-seeking behavior and tornado shelter options among mobile home residents in the United States. *Natural Hazards*, 48, 191–201.
- Schultz, L. A., & Cecil, D. J. (2009). Tropical cyclone tornadoes, 1950–2007. *Monthly Weather Review*, 137, 3471–3484.



TOURISM

Tourism is defined as travel to a place outside the usual residential environment, involving a stay of at least one night but no more than 1 year, with varying motivations, such as business, pleasure, visits to friends and relatives (VFR), and education. It is one of the world's largest industries. Tourism has long been of interest to geographers,



Tourism in Switzerland: Hotel Wetterhorn

Source: Barbara Peacock.

given its spatial, temporal, and activity patterns and given its major economic and environmental impacts, ranging from the local to the global.

Geographers have been influential in developing conceptual models for explaining tourism development. Some of the most important models are resort morphology, the tourist-historic city, and the tourist area cycle. Douglas Pearce's work on resort morphology has helped explain the resort's particular urban form and its evolution in response to new recreational demands. Pearce found that many older beach resorts first developed around a traditional waterfront; later, parallel developments, including a road or highway, high-end accommodation and retail, and interior residential zones, were built as one moved inland. Given environmental degradation and traffic hazards with this traditional resort model, newer shore resorts have increasingly integrated accommodations with the sea via yacht moorings. Likewise, modern integrated ski resorts similarly

physically integrate the snow front (slopes and uphill facilities) with concentrated resort buildings. As with new urbanist developments, these new resort models allow for greater integration of accommodations and activities, reduce the amount of land developed, and promote more efficient service provision (e.g., heating, water, sewage). However, equity issues have arisen since integrated development generally favors a single developer, often from distant metropolitan areas and having the needed capital and technical expertise, over smaller local or regional entities.

Another key model in tourism geography is the tourist-historic city model, which represents the fusion of a tourist city with a historic one. The tourist-historic city has attractions, dining services/restaurants, and accommodations in the historic core. Tourists' action spaces and impacts tend to be concentrated within a small portion of the entire city. This model, which was based on medium-sized, older historic cities in Europe, has



Alpine and lake landscapes for tourism, Switzerland

Source: Barbara Peacock.

been modified to explain tourism in other parts of the world. In settlements of the American West, historic and reconstructed tourist attractions and accommodations can be found in the equivalent historic cores, which are the old central business districts containing train stations. However, with the dominance of the automobile, a newer, secondary concentration of lodging and dining services for tourists can be found along interstate highways.

The tourist area cycle model developed by the geographer Richard Butler has influenced and spurred much research, application, and debate. The underlying concept, which is based on the

product cycle, is that tourist areas, their attractions, and the number and type of their tourists evolve over time. Tourist areas move through the following stages: (a) *exploration*, in which there are a small number of tourists who are attracted to unique natural and cultural-historical features, use the local facilities, and have high contact with the local residents; (b) *involvement*, with increasing visitation; (c) *development*, in which the number of tourists during peak seasons exceeds the local population and locally developed infrastructure and original attractions are supplemented and increasingly supplanted by human-made attractions and facilities developed by external entities;

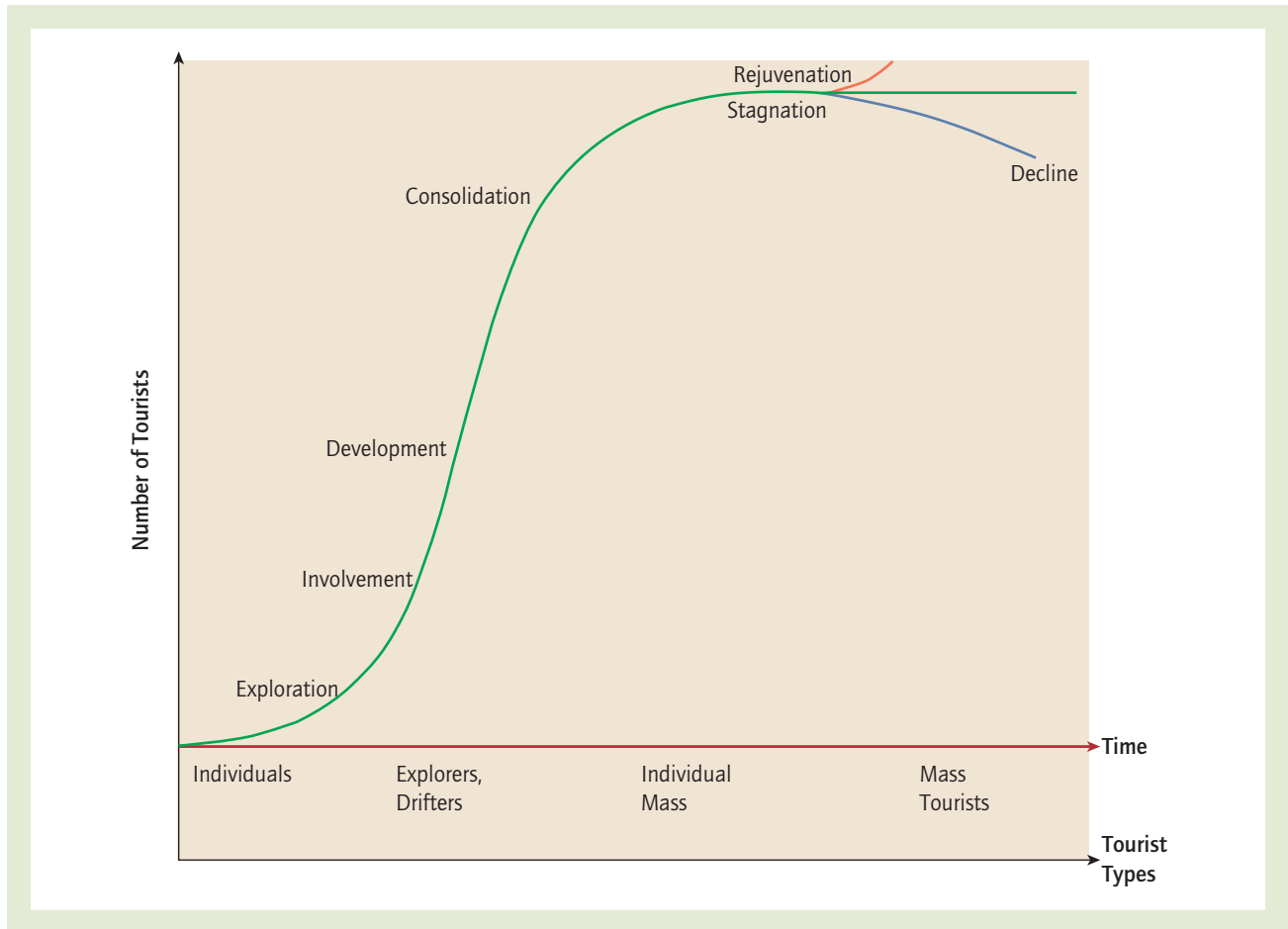


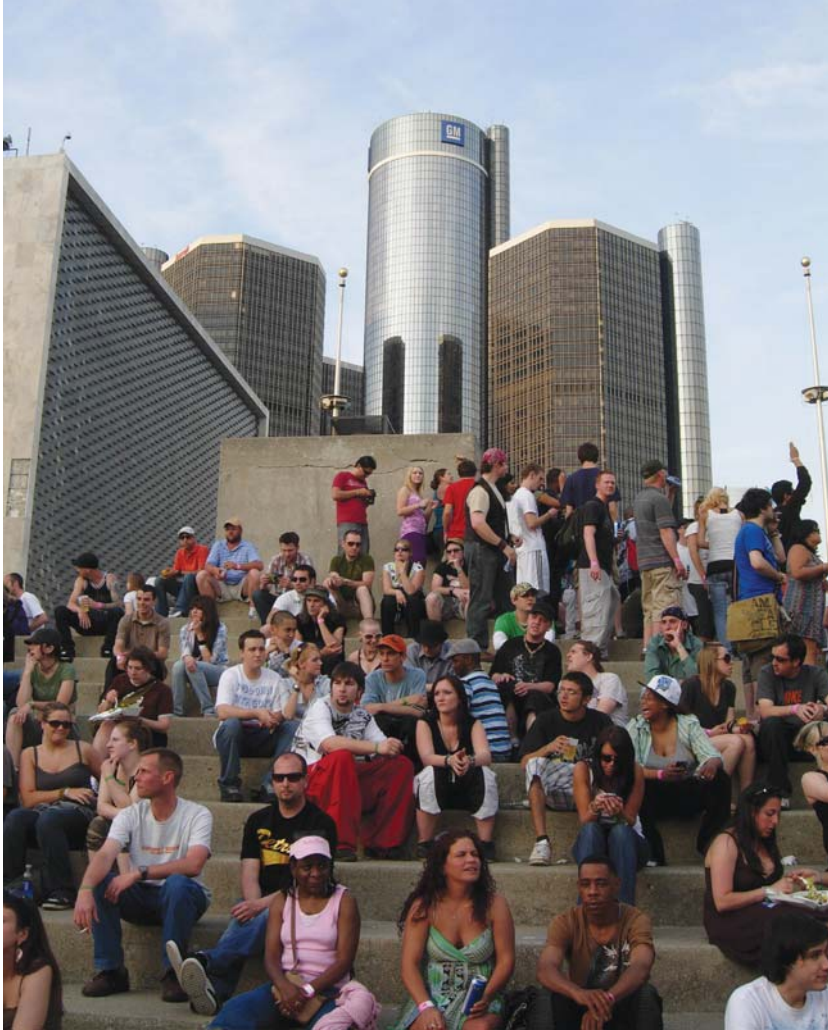
Figure 1 Tourist area cycle model

Source: Drawn by author, based on Butler, R. (1980). The concept of a tourist area cycle of evolution: Implication for management of resources. *Canadian Geographer*, 24(1), 5–12.

(d) *consolidation*, in which tourism is a major component of the economy and thus marketing and advertising efforts increase to expand the visitors' season and market area, particularly as the rate of increase in visitation is declining (while the total number of visitors continues to increase); and (e) *stagnation*, in which the peak number of visitors and carrying capacity levels are reached, natural and cultural attractions are superseded by created ones, and the less fashionable area relies on repeat and convention visitors. At this point, tourist areas can continue to stagnate, or they may move into a stage of *decline*, with reduced visitation and number of tourist facilities but often with increased permanent settlement or retirement. Alternately, they may undergo *rejuvenation* by completely changing the tourist attractions or by

capitalizing on previously untapped resources. While this model has been much examined and debated regarding its fit to real places, it has important implications for planning, as it confronts the assumption that tourist areas are unchanging and will always attract an increasing number of visitors. Butler notes that the competitiveness of tourist areas could be sustained longer if proactive policies were enacted to maintain development within capacity limits.

Geographers have also played an important role in infusing critical perspectives into tourism research. In his seminal 1991 article integrating critical theory and political economy into the study of tourism, "Tourism, Capital, and Place: Towards a Critical Geography," Stephen Britton called attention to the fact that tourism is an



Rejuvenating the city with tourism and entertainment: Movement 2009, Detroit's electronic music festival, with GM headquarters in the background

Source: Author.

important avenue of capitalist accumulation. Places are symbolically marketed as desirable experiences that impart status to those visiting or consuming them. As such, Britton argued that geographic theorization of tourism requires consideration of how social representations and materiality of leisure and touristic experiences and places are incorporated and commodified in the accumulation process. As part of viewing tourism as a mechanism for capital accumulation, geographers have looked at power relations and issues such as social equity, identity, authenticity, and social attachment to space as these are

manifested in travel and tourism. Critical political economy/ecology perspectives on tourism have also been used to examine topics such as imbalances in consumption, impacts on host communities, environmental justice, and sustainable development. The political ecology framework is particularly suited to looking at the impacts of nature protection for economic development and struggles to maintain customary land use, livelihoods, and access to natural resources.

Given economic restructuring and the recent crises in capitalism, Britton also argued that the geographical analysis of tourism could contribute to the analysis of territorial competition and the rejuvenation of depressed regional economies. Britton's call is relevant to the ongoing challenges to reposition deindustrialized downtown areas for consumptive activities such as leisure and tourism and for corporate services. Cities worldwide have developed tourist entertainment districts that typically contain an atrium hotel, a festival mall with restaurants and bars, a convention center, a restored historic neighborhood, a domed stadium, an aquarium, new office towers, a redeveloped waterfront, and casinos, which attract tourists, daytime

professionals, and suburban evening and weekend visitors. When such tourist entertainment districts are developed in areas surrounded by high crime, poverty, or urban decay, they may be secured and isolated "tourist bubbles." Such tourist entertainment districts and bubbles often are sites for festivals and spectacles to attract suburban visitors as well as tourists in the ongoing territorial competition. For instance, Detroit, which has experienced the loss of industrial facilities, jobs, and population since the 1950s, has developed a downtown tourist entertainment district anchored by two new sports stadia, has landed mega sporting events, and has



Urban festivals and tourism; main stage at Movement 2009, Detroit's electronic music festival

Source: Author.

hosted festivals (e.g., Movement, Detroit's electronic music festival, which draws a regional, national, and international audience) to foster its claims of being a world-class city. With the recent bankruptcies of Chrysler and General Motors, Mayor David Bing stressed the city's culture and entertainment (sports, gaming, music) as a means of keeping the city competitive for population, jobs, investment, and industries such as tourism, which are key for its postautomotive future.

In addition to flows of capital, tourism can be investigated in terms of its relation to migration tied to broader economic and social changes. Volatile labor markets since the 1970s in more developed countries, changing income streams (e.g., pensions, capital accumulation through property), and aging of those societies have spurred early retirement and retirement migration to rural areas. Rural lands in advanced industrialized

countries have increasingly shifted from a production orientation to a consumption one. The amenity-based, tourism and housing countryside appeals to those romanticizing nature, the past, and the rural; amenity seekers; second-home owners; and/or entrepreneurs cognizant of the marketable attributes of the rural landscape. In addition to rural, domestic migration, others may choose to migrate overseas to retirement communities or for lifestyle and business prospects (e.g., British immigrants to the Costa del Sol serving travelers from their country of origin). For others, the globalization of labor markets has opened up doors for skilled labor/expatriates in developing countries. Other forms of tourism-related migration include VFR and seasonal labor flows differentiated by ethnicity, race, and gender.

While tourism has been a way to address the challenges resulting from the shift from Fordism



to post-Fordism and from production to consumption, tourism production itself has remained remarkably varied. The travel industry has provided post-Fordist, individually tailored experiences (e.g., specialized luxury ecotourism excursions). However, in neo-Fordist tourism, which is marked by industrial concentration of airlines, transnational hotels, cruise companies, tour operators, and computerized booking systems and by high sales volume, standardized vacation packages appealing to a mass audience continue to be provided. Neo-Fordist tourism employment consists of both highly skilled, well-paid permanent professionals and flexible, low-wage seasonal labor. At the same time, the travel and tourism industry also includes pre-Fordist or artisanal businesses such as bed and breakfasts. Thus, given the coexistence of different production systems in both time and space, there has not been a clear shift from Fordism to post-Fordism in the tourism industry.

Tourism can benefit the discipline of geography. Tourism geography education can increase course enrollments and majors in departments that develop tourism majors or concentrations. It can raise the discipline's visibility as geographers bring content on sustainability, cultures, heritage, and geospatial analysis to interdisciplinary tourism and hospitality programs. Research on tourism can contribute to applied and theoretical developments in geography. For instance, tourism provides an ideal lens for investigating transnational spaces, as it highlights multiple ties and interactions linking people or institutions across borders of nation-states (i.e., migration of tourism workers, transnational business structures, and tourists and local residents reshaping identity, landscape, and social networks). Tourism can aid in conceptualizing the flexibility and fluidity of capital, complex ownership, and globalization. Likewise, tourism can help in the theorization of border spaces, which can be deterrents or attractions but also can be "non-places" or "in-between spaces." Cross-border cooperation, which ties into geopolitics, peace, and international treaties, is important to tourism and can be investigated in terms of how it varies by scale (i.e., being greater at the interlocal and international scales than at the larger global, regional, and bilateral scales). One major research outlet has been the journal *Tourism Geographies*. Given the

geographical aspects of tourism, including how it transforms the environments of destinations, entails movement over space, and provides a distinctive way for people to relate to the world, *Tourism Geographies* would incorporate these aspects through geography's unique synthesis of the social and physical sciences in understanding places, regions, and the world. Geographers continue to contribute to research on topics as varied as indigenous tourism, amenity/retirement migration, mountain tourism, mobilities, protected areas, tourism and climate change, heritage tourism, tourism landscapes, and tourism planning. Geography and tourism will continue to be mutually enhancing in the future.

Deborah Che

See also **Consumption, Geographies of; Globalization; Mobility; Place Promotion; Travel Writing, Geography and**

Further Readings

- Ashworth, G., & Tunbridge, J. (2000). *The tourist-historic city: Retrospect and prospect of managing the heritage city*. Amsterdam: Pergamon Elsevier.
- Britton, S. (1991). Tourism, capital and place: Towards a critical geography of tourism. *Environment and Planning D*, 9, 451–478.
- Butler, R. (1980). The concept of a tourist area cycle of evolution: Implication for management of resources. *Canadian Geographer*, 24(1), 5–12.
- Ioannides, D., & Debbage, K. (Eds.). (1998). *The economic geography of the tourist industry: A supply-side analysis*. London: Routledge.
- Judd, D., & Fainstein, S. (Eds.). (1999). *The tourist city*. New Haven, CT: Yale University Press.
- Pearce, D. (1978). Form and function in French resorts. *Annals of Tourism Research*, 5, 143–156.
- Timothy, D. (2001). *Tourism and political boundaries*. London: Routledge.
- Torres, R., & Momsen, J. (2005). Gringolandia: The construction of a new tourist space in Mexico. *Annals of the Association of American Geographers*, 95(2), 314–335.
- Williams, A., & Hall, C. (2000). Tourism and migration: New relationships between production and consumption. *Tourism Geographies*, 2(1), 5–27.



TOWNSHIP AND RANGE SYSTEM

The U.S. Public Land Survey System is a township and range pattern of land division that was imposed across the United States west of Pennsylvania's western boundary in territory deemed "public domain" as the early nation expanded to the Pacific Ocean. It is the foundation of a cadastral survey that defines boundaries for land ownership. It forms a gargantuan checkerboard of surveyed grid-squares defining millions of parcels of land that served literally as the framework for colonizing and developing the vast new country. Reminiscent of Roman land centuriation, at least in its geometry, the American system was first proposed by Thomas Jefferson, who saw it as the most democratic way to create a great agrarian commonwealth of independent farmers based on freehold land ownership. Neither he nor anyone else at the time foresaw the rugged Western terrain that the system would confront.

The system had its origin in the Land Ordinance of 1785, which provided for the systematic survey and monumentation of public domain lands, and the Northwest Ordinance of 1787, which established a rectangular survey system designed to sell and grant federal lands to private owners. From a modest beginning in the Seven Ranges area of Eastern Ohio, the system grew to encompass most of the nation's territory and to stamp the American landscape with its unique, mechanistic imprint of seeming dominance over the continent's natural environment. The chief exclusions from this federal system of land division are portions of Ohio that were surveyed and alienated from the public domain before the system was fully institutionalized; land in Texas, which remained under state control as a condition of annexation; lands granted to private interests under Spanish, French, and Mexican dominion prior to American sovereignty; Native American reservations; and certain high-mountain areas in the Far West that have never been officially subdivided.

Earth's curvature required that the extension of the system be tied to periodic benchmarks of longitude and latitude, known as prime meridians, and baselines defined for specific regions, so that the theoretically flat two-dimensional grid

pattern could be laid out on the spherical surface with necessary corrections made at intervals. The basic areal unit is the survey *township*, a square 6 miles on each side, comprising 36 square miles, each square-mile subunit (640 acres in area) being called a *section*. Within townships, sections are numbered sequentially from the northeast corner to the southeast corner. Townships have distinctive locational identities, expressed as so many *townships* north or south of a particular baseline and so many *ranges* east or west of a particular prime meridian—downtown Chicago, for example, lies in T39N.R14E, that is, the 39th township north of the Centralia Base Line and the 14th range east of the third principal meridian.

Each section of land may be further subdivided into quarter sections (160 acres) and quarter-quarter sections (40 acres), the latter being one of the smallest standard land units sold or granted to private interests, apart from the irregular fractional sections formed by intersecting watercourses, coastlines, survey correction lines, or, in the rare cases of government townsites, townsites lots. Recipients of land in the township and range system have generally been free to select land parcels in almost any geometrical combination of subunits within the checkerboard consistent with purchase and payment requirements that have varied with federal land policy over time. Every discrete land unit within this national survey system is described by a unique geographical reference system, expressible in alphanumeric shorthand. Land descriptions are read from the smallest division to the largest (e.g., the NW1/4 of the NW1/4 of Sec. 9 of T39N.R14E). Such geometrically simple description facilitated land reconnaissance and purchase by intending pioneers and distant purchasers alike; it has greatly simplified the registration of billions of land parcels in this continental-scale nation and constitutes the basis of most land transfers and ownership today. Since 1785, almost 1.5 billion acres have been surveyed into townships and sections.

The spatial regularity of the township and range system at every geographic scale—whether viewed locally on the ground or synoptically from the air—is extraordinary. This order is especially remarkable considering the relatively crude surveying instruments available and the sometimes

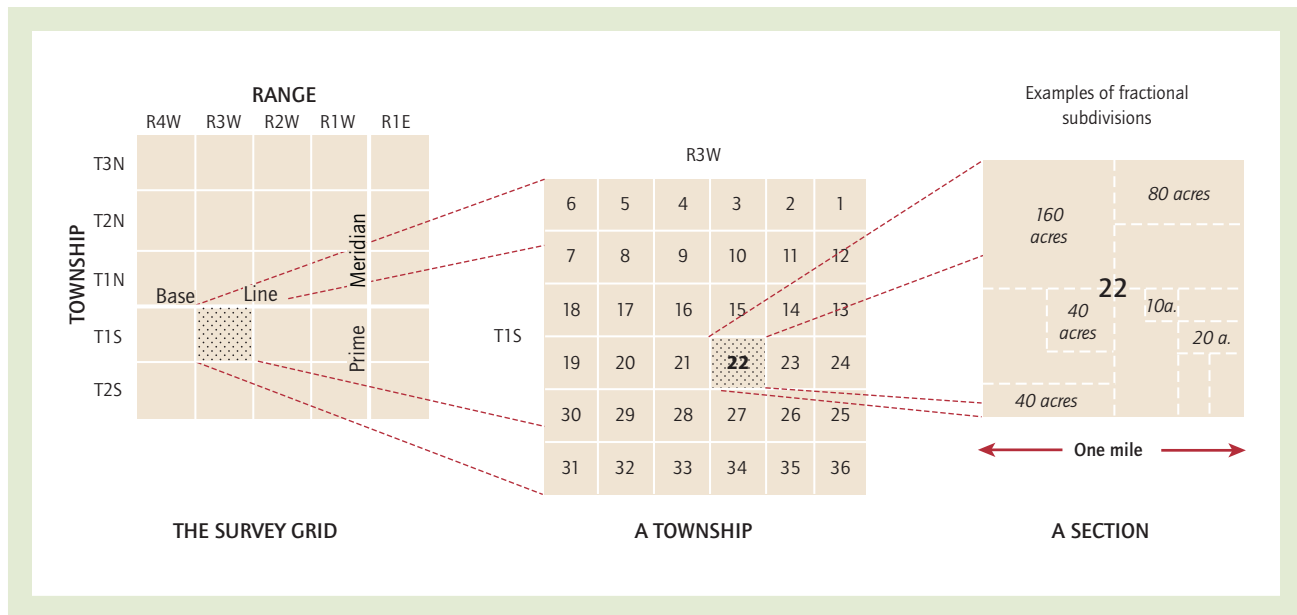


Figure 1 Essential elements of the township and range system

Source: Author.

severe environmental conditions under which much of the original surveying was done, most of it accomplished during the 19th century across terrain regarded as utter wilderness. In many localities, small departures from cardinal orientation of lines and from strict acreage results occurred due to errors caused by these circumstances and also by other factors, including, for example, the presence of ferrous metals in mountainous locations that threw off surveyors' compass readings. Other departures from the strict checkerboard occur when the surveyed lands border prior land grants that, if recognized by the U.S. Congress, were left intact, embedded within the U.S. surveys that wrapped around them.

The influence of the township and range system on the settlement geography and cultural development of the United States has been profound. It created the largest gridded landscape in the world, and its rigid imposition on the land, regardless of relief, drainage, soils, and other natural features bearing on sustainability, produced a sometimes awkward fit with the natural environment. Its very layout, coupled with the federal government's policies of acquisition, encouraged the wide spatial dispersion of individual farm settlements across the land rather than community-based,

group settlements focused on village life. The inherent physical isolation this built into the pattern of rural colonization had deep, enduring consequences for the development of the American social character, even after the balance of the nation's population shifted largely from rural to urban environments.

Michael P. Conzen

See also **Cadastral Systems; Coordinate Systems; Cultural Landscape; Environmental History; Environmental Impacts of Agriculture; Environmental Management; Jefferson, Thomas; Landscape Design; Land Tenure; Public Space; Settlement Geography; Surveying**

Further Readings

- Johnson, H. (1976). *Order upon the land: The U.S. rectangular land survey and the upper Mississippi Valley*. New York: Oxford University Press.
- Johnson, H. (2009). Gridding a national landscape. In M. Conzen (Ed.), *The making of the American landscape* (2nd ed.). Boston: Routledge.



TRADE

Trade is usually defined as the exchange of goods and services among countries. That exchange is a type of spatial interaction, or movement, that has long been a fundamental component of the study of geography. The analysis of trade is often split into two basic parts. One part, largely the interest of economists, concerns the structure of trade or the selection of goods and services that a country produces for exchange with other countries. The second part concerns the pattern of trade, or the geography of the exchange of those goods and services. It is the pattern of trade that is of primary interest to geographers, who have long studied the flows between countries. In studying those flows, geographers have also considered their institutional context, including government policy, and their effects at both the national and subnational regional scales.

What Is Traded?

The spatial pattern of trade is of primary interest to geographers, but flows among countries are often viewed as the result of their relative efficiencies in production. In the 1770s, Adam Smith argued for the economic benefits of trade based on specialization of production between countries. That specialization argument was advanced further by a contemporary of Smith's, David Ricardo, in what is called the law of comparative advantage. That law is derived from an analysis of two countries in which each is able to produce the same two commodities. Even a slight difference in the relative costs of production between the two countries can be shown to be the foundation for trade between them that will result in an overall increase in production and, by implication, lower costs for producers. The law of comparative advantage is a common foundation for many arguments in favor of free (or liberal) trade and of neoliberalism in general. Working in the early to mid 20th century, economists described the sources of comparative advantage in terms of the factor endowments of places and the factor intensities of industries. According to their requirement, factors of production such as labor or capital are unevenly distributed from place to

place; some industries are labor intensive, and some are capital intensive in production. When factor intensities of production and factor endowments of places are matched, then comparative advantage arises, and trade can produce benefits. For example, one country well endowed with labor would produce labor-intensive goods to trade for capital-intensive goods produced in a country well endowed with that factor.

Comparative advantage/factor endowment theory is focused on differences in supply conditions between countries as the basis for trade, but more recently, market similarities between countries have been theorized as trade inducing as well. If consumers in different countries have similar incomes and tastes, according to this approach, then producers in those countries will find ready markets for their goods in trade because they produce goods that are attractive in each other's market in terms of their basic characteristics and also because consumers will enjoy the variety that such trade affords. Even if goods are produced for other industries, and not for consumers, the argument holds. Different countries will have producers of specialized goods that can be sold in other countries with similar industrial composition. Similarities in consumption preferences seem easily applicable to trade in services, such as those provided in professional and financial markets and in transportation. Another major component of service trade, however, is tourism, which may conform to differences in "factor" endowments such as good weather, beaches, and cultural attractions.

Geographical Patterns

Actual geographical patterns of trade are likely the inspiration of trade theory. Comparative advantage and /factor endowment theory suggests that trade will most likely occur between countries that are economically very different from each other, which was the most noticeable pattern of trade during the colonial and late imperial eras. European countries imported raw materials from their colonial possessions, which were well endowed with natural resources, or they imported other primary products such as sugar and cotton produced by large numbers of slaves or, later, by very low-cost labor. In turn, the Europeans sold



Stacked shipping containers, lighters, and cranes at a container terminal on Victoria Harbor, Hong Kong

Source: Linda and Colin McKie/iStockphoto.

manufactured goods in their colonial monopolies. More recently, the flows of trade between countries that are similar in their high incomes are easily observed, which is why trade theory has focused on market similarities between countries rather than on differences in production costs. In fact, trade among similarly wealthy countries is so prominent that trade is often described using a gravity model, which typically ignores production costs in its specification.

The typical gravity model is specified as $T_{ij} = f(G, I_i \dots I_j, 1/D_{ij})$, where T_{ij} is trade between two countries i and j , G is a constant defined with respect to what is being traded, I is income, and D is some cost of transporting G . Such gravity models have been used frequently to describe trade, indicating that the major factors promoting trade are the incomes of trade partners, not differences in production cost, while a factor in reducing trade is the cost of transportation. In short, the gravity model describes a pattern of trade that is most readily observed between wealthy countries

located in close proximity to each other. It also describes trade as least likely between poor countries that are distant from each other. In general, the gravity model is correct. Measured by value or volume, trade in both goods and services tends to be greatest among the world's wealthier countries, followed by trade between wealthy countries and poorer countries, while trade among low-income countries is a distant third. That general pattern has been roughly stable for a long time, but the place of individual countries changes. A notable example of changing trade is that between China and Brazil. Both have experienced significant income growth recently, and the trade between them has increased significantly as well.

Policy and Customs Unions

Trade theory assumes that trade is liberal, that is, devoid of government restrictions, and at the same time is the justification for liberal trade policies. Actual trade, however, occurs in an institutional



framework in which government-directed commercial policy plays an important role. Common instruments used by governments to inhibit imports, for example, are tariffs and quotas. *Tariffs* are taxes on imported goods that governments have used both to raise revenues and to protect domestic producers from trade competition by offsetting other countries' advantages in production costs. *Quotas* are limitations on the physical quantity of imports; only so many square meters of cloth can be imported, for example, or so many automobiles. Such a physical limitation not only raises the price of the imported good by inducing its scarcity, it also allows for domestic monopolies to form among a country's own producers. Recent multilateral trade agreements have had the general trend of reducing tariffs and quotas in the interest of promoting more trade, under a neoliberal mindset. Such agreements have also encouraged the reduction of other means of limiting imports, such as the requirement that they meet certain environmental or safety standards in their production.

While much commercial policy is focused on limiting imports, some of it is aimed at promoting exports or supporting high prices for export goods in other countries' markets. Export processing zones have been established by many countries as geographical areas in which producers enjoy special tax rates and other benefits as long as they are engaged in producing goods for export. Governments also try to manipulate exchange rates in such a way that the goods produced in their own country are relatively inexpensive in other countries, while imported goods remain highly priced. Export prices in some markets are encouraged to remain high if demand can still be sustained. The Organization of Petroleum Exporting Countries, for example, is a cartel of suppliers that uses internal production quotas to target prices in the global oil market.

More general trade agreements among several countries are referred to generically as customs unions, but those agreements can take many forms. Some countries combine into free-trade areas, in which goods and services may pass across common borders (nearly) without restriction as long as the member countries are the places of production. The North American Free Trade Agreement establishes a free-trade area that includes Canada, Mexico, and the United

States. Actual customs unions act as free-trade areas with the additional characteristic that the member countries have common trade policies, including tariff rates, toward nonmember countries. The European Union that emerged in 1993 was developed from a customs union called the European Common Market, which was completed in 1968. There are many variants of customs unions in places around the world, including Mercosur in South America and the Economic Community of West African States.

Geographical Effects of Trade

Trade policies are developed and customs unions are formed because trade has economic effects on countries that are of interest to governments. Going back to the theory of comparative advantage, there is a strong argument that trade can lead to economic growth. Most governments, however, are not usually encouraging of trade in general but rather of exports in particular. Several East Asian countries are often used as examples of export-led economic growth, including Japan, South Korea, Taiwan, and, especially, China. Policies that promoted exporting have been employed in each of those countries over time, and each of those countries has experienced very high growth rates from very low starting points in recent history. At the same time that governments usually encourage exports, however, they also tend to discourage imports. Increases in imports can often lead to problems for domestic producers of the same good or service. While the law of comparative advantage indicates benefits of trade in aggregate, it also indicates that any country should expect both winners and losers as industrial specialization among countries develops along with increased trade. Wage and profit declines or even significant loss of employment and income can occur in some industries as their country opens its doors to more imports, and governments are often petitioned by the injured parties for protection. Protection is also sought by groups before imports are allowed to increase by groups that anticipate injury.

The effects of trade can also vary geographically within countries. Some geographical effects are felt in those parts of a country in which an



industry injured by trade is concentrated, while positive effects typically arise in those parts in which more highly competitive industries are located. Policy often has geographical effects. China's economic liberalization, for example, especially targeted export production along its coast. That strategy has led to an uneven distribution of the benefits of trade, with much higher incomes on the coast than those that prevail in the interior. Many parts of a country, regardless of policy, seem to have a locational benefit with respect to trade—border regions, for example, with respect to lowering transport costs—while less accessible parts of countries are often less favored by positive trade impacts or more inclined to have a disproportionate share of the costs of trade.

Dean M. Hanink

See also **Antiglobalization; Aviation and Geography; Comparative Advantage; Competitive Advantage; Development Theory; European Union; Export-Led Development; Fair Trade and Environmental Certification; Foreign Direct Investment; Globalization; Gravity Model; Neoliberalism; North American Free Trade Agreement (NAFTA); Organization of the Petroleum Exporting Countries; Ports and Maritime Trade; Supranational Integration; Transnational Corporation; World Trade Organization (WTO)**

Further Readings

- Anderson, K., Martin, W., & van der Mensbrugge, D. (2006). Doha merchandise trade reform: What is at stake for developing countries? *The World Bank Economic Review*, 20, 169–195.
- Bowen, J., Jr. (2006). The geography of certified trade-induced manufacturing job loss in New England. *The Professional Geographer*, 58, 249–265.
- Dicken, P. (2007). *Global shift: Mapping the changing contours of the world economy* (5th ed.). London: Sage.
- Grant, R. (2000). The economic geography of global trade. In E. Sheppard & T. Barnes (Eds.), *A companion to economic geography* (pp. 411–431). Oxford, UK: Blackwell.

Poon, J., Thompson, E., & Kelly, P. (2000). Myth of the triad? The geography of trade and investment “blocs.” *Transactions of the Institute of British Geographers*, NS 25, 427–444.

Silva, J. (2007). Trade and income inequality in a less developed country: The case of Mozambique. *Economic Geography*, 83, 111–136.



TRANSHUMANCE

See Nomadism



TRANSNATIONAL CORPORATION

The term *transnational corporation* (TNC) is used to describe firms with overseas operations and is often used interchangeably with other terms such as *multinational corporation* or *global firm*. TNCs play a significant role in processes of globalization and are collectively a key actor in the global economy. A qualitative shift in the nature of the global economy since the 1970s has seen processes of globalization accelerate, and transnational firms are both a cause and an outcome of increased global economic integration. The unevenness of global economic activity is in part a result of the investment decisions made by the world's largest firms. Interest in TNCs—from academics, policymakers, and governments—focuses on their growth, geographies, investment decisions, and impacts on national economies.

Definition and Measurement

There are many definitions of TNCs, ranging from the simple notion of firms that have operations in more than one country to more sophisticated conceptualizations that acknowledge the complexity of firm internationalization. The most widely used definition in geography is by Dicken (2007), who defines a TNC as “a firm that has the power to coordinate and control



operations in more than one country, even if it does not own them” (p. 106). This definition offers an important qualification that transnational corporations are not simply “present” in more than one country. Their transnationality results from the nature of their presence in different markets and their organizational structure. TNCs are engaged in a wide range of different industrial sectors ranging from resource extraction to services such as banking. They share three basic characteristics:

1. Operations within and between different countries, coordinated and controlled through transnational production networks
2. The ability to use such networks to exploit global geographical differences in the distribution of resources
3. Flexibility to shift their geographical locations

Transnational firms can be measured in a variety of ways, for example, overseas revenues, number of employees, transnationality, geographical spread, overseas profitability, and many more. In 2005, the biggest company in the world (as measured by total revenues) was ExxonMobil, the world’s largest employer was Walmart, the firm with the greatest foreign assets was General Electric, and the United Nations Conference on Trade and Development ranked Canadian media firm Thomson Corporation as the most transnational and Deutsche Post as having the greatest geographical spread. The total number of TNCs is growing yearly. Between 1970 and 1998, the number of TNCs worldwide grew from 7,000 to an estimated 53,600, with some 449,000 foreign subsidiaries.

Evolution of TNCs

The geographical expansion of firms outside their home territories is not a new phenomenon. Historically, companies such as the East India Company and Hudson’s Bay Company developed extensive geographical networks to trade over large distances. However, the modern transnational firm emerged in the second half of the 19th century as part of a dramatic increase in international economic activity. Processes of

globalization accelerated after 1945, and increased internationalization and integration were enabled by two interrelated processes: first, the rapid development of technologies of time-space compression—travel was quicker, cheaper, and possible over greater distances, and developments in telecommunications facilitated transnational communication—and second, the introduction and development of flexible systems of production and organization in firms. By the 1970s, firms were increasingly investing in overseas markets and integrating production and distribution across a range of different territories.

There are two main types of international production. *Market-oriented production* sees foreign direct investment (FDI) in production facilities inside a new market. Firms are attracted to particular markets for a number of reasons, but the most common are market size (such as the large markets of the United States and China) and/or markets with particular demands for products based on national income levels (e.g., the increased demand for consumer goods in the newly emerging economies). *Supply or cost-oriented production* sees TNCs locating production at the site of supplies of particular commodities. These commodities could be raw materials (such as timber, minerals, energy resources) or labor (to exploit geographical differences in labor costs, productivity, and skill levels).

As business firms began exploiting the new global opportunities offered through technological advancement, they reorganized and restructured in response to the challenges faced by their internationalization strategies. Organizational structures are forced to change as traditional models are unable to respond effectively, or quickly, enough to the demands of operating not only in more locations but with greater links between each location. Barlett and Ghosal (1989) suggested four major ideal types of TNCs that help trace the development of a firm’s organization as it internationalizes. First is the “multinational” organizational model, in which, as a firm internationalizes, it establishes offices in new national markets. These branches are fairly autonomous, and headquarters maintain control over finance. Second is the “international” organizational



model, in which overseas operations are more integrated into the domestic corporation. Third is the “classic global” organizational model, in which the headquarters act as a centralized hub and coordinate most decision making. Overseas operations are treated as input and output points feeding the firm’s global market. Fourth is the “transnational” organizational model, in which headquarters oversee a complex integrated network, coordinating components, products, resources, people, and information. This model is an outcome of the dilemma facing TNCs in today’s turbulent, competitive global economy. Firms need the best features of each of the four types at the same time: They need to be globally efficient, flexible over a number of geographical territories, and capable of transferring knowledge across their global networks.

A key part of TNC restructuring has been a shift in the coordination of supply chain inputs to gain cost and time efficiencies. Firms continue to review the degree to which certain functions are retained within the firm or outsourced to other companies. Recent decades have seen a substantial increase in externalized supply relationships, with firms outsourcing functions such as information technology, back offices, logistics, human resource management, and production. For example, Dell, the world’s second largest maker of personal computers, outsources customer service functions to India and Latin America and manufacturing to contractors predominately based in Asia. Such examples of outsourcing often occur over large geographical distances. However, the adoption of “just-in-time” production techniques and technologies has encouraged the colocation of firms and their suppliers as closer geographical proximity aids flexibility and responsiveness to demand. In the automotive sector, for example, large production plants include the original equipment manufacturer (e.g., General Motors), a large number of supplier firms producing components (e.g., car seats, windshield wipers), and even branch offices supplying temporary labor to work on the production line (e.g., Adecco). Therefore, as a result of the realignment of supply relationships, the scale at which firms coordinate their production chains has shifted to the regional or global scale. However, the resulting geographical “footprint”

of the firm (i.e., where it actually conducts production, final assembly, and delivery to customers) is highly dependent on the management and strategies of the firm and, crucially, on the sector in which it operates.

Factors Influencing the Geography of TNCs

While TNCs share many characteristics, there is great variety in the shape and size of TNCs, both within and across different industry sectors. No two firms are the same, and even closely competing firms make (sometimes radically) different strategic and locational decisions. TNCs should be understood as inherently complex, constantly evolving, and unique. The sector in which the firm operates, the national context, and the ownership structure are among the key factors that shape the TNC.

Sector

First, the sector of which the firm is part plays a decisive role in determining its geography. For example, British Petroleum’s production sites are dictated by the source of raw materials and extraction technologies. Many of these sites are located in lower-income nations such as Kazakhstan, Botswana, and Bolivia. In comparison, in labor-intensive industries such as garment manufacturing or call-center operations, firms seek sources of cost-effective labor. The majority of the world’s garment manufacturers have production sites in Asian economies, including China and Cambodia.

National Context

Second, the “nationality” of the firm shapes and influences the geographical contexts in which they are situated, and this is especially true of their country of origin. The national context in which a TNC is headquartered influences the firm culture, the nature of supplier relationships, and the regulation of finances. In addition, the size of a firm’s home market determines the drive to internationalize as firms in large markets such as the United States may expand overseas later than a firm based in Belgium.



Ownership Structure

Third, the ownership structure of a TNC can affect its management and corporate strategies, particularly internationalization and sourcing decisions. The majority of TNCs answer to shareholders, which may result in short-term demands for return on investments. However, some TNCs are privately or government owned, which can have a significant impact on competitive decision making, imposing limitations on accessing finance for expansion and, in the case of government-owned enterprises, regulatory restrictions on operations.

Impacts of TNCs

Much rhetoric surrounding TNCs credits the firms with immense powers and omnipotence. TNCs are viewed by some, particularly in the popular media, as renegade entities scouring the globe for investment and exploitation opportunities to generate vast profits. While such views are often overstated, they reveal two key debates surrounding TNCs: their “placelessness” and the impacts of their location decisions. First, the suggestion that TNCs operate completely freely across the global economy is refuted by geographers. In many ways, the importance of place is confirmed by the location decisions of TNCs—the global economy is not an even playing field. Huge differences in the distribution of raw materials, labor, and transport infrastructure result in a complex, shifting, and uneven mosaic of local and national economic spaces, and it is these disparities that TNCs seek to exploit through their internationalization strategies. While nation-states are attracted by FDI from TNCs, the scale and extent of TNC activity does pose some problems for national economies. For some, TNCs have surpassed nation-states as the key actors in the global economy. This status raises concerns for nations regarding their ability to shape and guide their economies and compete internationally. However, the relationship between TNCs and national governments is not as one-sided as it may seem at first glance. The nation-state creates the geographical contexts in which TNCs operate. With the exception of some supranational regulation (e.g., through the European Union or

trade agreements), the conditions in which TNCs are embedded in any context are regulated by the national government. This covers aspects of business such as labor regulation (wages, terms, and conditions) and finances (taxation, investment incentives).

Second, the impacts of TNCs in host economies are contested. Some suggest that TNC investment in lower income countries keeps economies relatively backward and dependent on advanced capitalist nations for investment, jobs, and technology, while others argue that FDI by TNCs is an instrument for dispersing the production of goods and services to those locations where they can be most efficiently produced. Many geographers are situated in between these dichotomous viewpoints and suggest that FDI has both benefits and costs to host economies. Benefits can accrue through a number of mechanisms. For many countries, FDI by TNCs is an important source of capital and employment. The TNC may use local suppliers, thereby increasing benefits as employment increases and knowledge is transferred from the TNC to the local firms. The costs of FDI include the financial incentives offered to the TNC (such as tax incentives and/or the provision of infrastructure), the degree of revenues generated as the foreign operation remits earnings and profits back to its parent company, and the quality of jobs created. A key concern is whether the host economy is able to capitalize on the benefits of FDI to “upgrade” local industry, skills, and work standards and connect further into the global economy. If the costs outweigh the benefits, the host economy may find itself as a temporary low-cost location for the TNC in which low-skilled labor is provided without tangible benefits accruing. Not all FDI impacts are related to the economy, as TNCs are also important transmitters of social, cultural, and political change, particularly in developing countries. Again, these changes can be both positive and negative and vary depending on the TNC and the host economy in which it is located.

Jennifer Johns

See also **Economic Geography; Foreign Direct Investment; Globalization; Neocolonialism; Neoliberalism; Trade**



Further Readings

- Bartlett, C., & Ghoshal, S. (1989). *Managing across borders: The transnational solution*. Cambridge, MA: Harvard Business School Press.
- Coe, N., Kelly, P., & Yeung, H. (2007). *Economic geography: A contemporary introduction*. London: Blackwell.
- Dicken, P. (2003). "Placing" firms: Grounding the debate on the "global" corporation. In J. Peck & H. Yeung (Eds.), *Remaking the global economy* (pp. 27–44). London: Sage.
- Dicken, P. (2007). *Global shift: Mapping the changing contours of the world economy* (5th ed.). London: Sage.



TRANSNATIONALISM

Transnationalism denotes processes and practices through which contemporary international migrants forge and maintain ties across national borders to their countries and places of origin. The acceleration of economic globalization has enabled these migrants to create new transnational social and cultural spaces that span multiple polities and societies. Migrants create these new social spaces by, among others, sending money home to family members in the form of remittances; they influence the political lives and well-being of their home places through hometown associations, contribute to economic development projects in their countries of origin, or participate in religious and cultural organizations that span national borders. While these new social spaces are similarly facilitated by innovations in transportation and communication technologies, migrants' "transnationalism from below" differs from globalization from above in that it is individual migrants' and groups' social practices rather than the economic power of transnational corporations that create new ties between places.

The terms *transnational migrant* or *migrant transnationalism* were made popular by Nina Glick Schiller, Linda Basch, and Christina Blanc-Szanton, whose observation of migrants' continued engagement across borders through multiple

practices led them to suggest that contemporary migrants differ from previous waves of immigrants in that they no longer need to give up ties to their home places and face less pressure to assimilate to the host nation. Glick Schiller, Basch, and Blanc-Szanton initially suggested abandoning the term *immigrant* in favor of *transmigrant* to reflect that migrants live their lives across borders and in multiple nation-states. Emphasizing migrants' resistance to changing political and economic conditions in a globalized economy, they proposed rethinking conceptions of ethnicity, race, and nation. Such assumptions were echoed in postcolonial and cultural studies that suggested that transnationalism, aided by new mass media such as satellite television, was fostering new cultural identities that stretched beyond national and local contexts and undermined nation-state and nationalist projects.

This initial enthusiasm seemed to overshoot the conceptual and explanatory power of transnationalism and prompted criticism from scholarship in the social sciences that has since sought to refine several aspects of the initial conception proposed by Glick Schiller and colleagues. Some of these extensions and refinements constitute attempts at creating types and taxonomies of transnationalism aimed at better defining what does and does not constitute transnational processes and practices. These taxonomies distinguish economic, sociocultural, and political practices with low and high levels of institutionalization. In a taxonomy proposed by Portes, Guarnizo, and Landolt, hometown associations are considered political transnational practices with a low level of institutionalization, whereas cultural events organized by foreign embassies are considered highly institutionalized sociocultural practices. The frequency and regularity of transnational practices in question receive additional consideration in such typologies. There is debate about the usefulness of such typologies, and more recent work has instead sought to examine migrant transnationalism in relation to multiple axes of difference.

The extent and intensity of transnational practices vary according to the socioeconomic positionality of migrants and the conditions in sending and receiving societies that limit or enable transnational mobility. Among the factors facilitating and constraining transnational mobility are gender,



class, and migration status. So-called hypermobile migrants, or “astronauts,” travel with ease across borders, for example, the Hong Kong Chinese business executives who bought property on the Pacific Coast of Canada. These “transnational elites” are able to take advantage of the globalizing economy by maintaining investments and economic interests in Hong Kong while raising their families in Vancouver. In contrast, poorer migrants’ transnational practices often remain limited to sending remittances to family members or making phone calls, especially if these migrants’ mobility is constrained due to their insecure status as refugees and asylum seekers. Undocumented migrants face even more restrictions because they lack the proper papers that would allow them to travel across borders with ease.

Rather than juxtaposing the home and host countries, geographic research instead shows how migrants forge complementary local, national, and transnational ties. This research questions claims that assimilation is no longer necessary for contemporary migrants. Geographers have examined the complex spatialities of migrant transnationalism as they emphasize how identities are constructed in relation to both home and host places, as migrants negotiate the contexts of both. The analysis of the daily practices of Salvadoran migrants under Temporary Protected Status in the United States demonstrates the difficulty of migrants’ struggles to create and maintain transnational (social) spaces in efforts to connect to their places of origin while coping with status insecurity in the United States. This research grounds migrants’ transnational ties in the lived experiences of their everyday lives and shows that transnational spaces are created, in part, through place-making practices and the creation of local ties.

Migrant transnationalism presents new challenges and opportunities for sending and receiving states. Restrictions imposed on refugees and other migrants demonstrate that transnational mobility is facilitated, regulated, and limited by sending and receiving states. Because migrant remittances form an important revenue source for them, sending states have increasingly been creating provisions for extraterritorial voting, dual nationality, or dual citizenship to bind their citizens abroad to the state of origin. These legal changes also affect receiving states, which

increasingly allow dual citizenship. Such changes in citizenship law prompted by the transnational realities of contemporary migrants are frequently accompanied by fierce public and political debates. The attacks of September 11, 2001, in particular, have prompted debate about migrants’ transnational practices, citing security and border control issues while highlighting the potential for terrorism among migrant populations. This is particularly salient for Muslim migrants, whose religious faith is portrayed as undermining liberal democratic values. More generally, the political attachments, loyalties, and activism of contemporary migrant populations have moved to the center of public debate and of researchers’ attention. As numerous migrants remain citizens of their country of origin and engage multiple polities across national borders, hosting states and societies question their loyalty to the receiving polity. Migrants’ collective political identities, activism, and practices of citizenship are thus part of the study of transnationalism as they challenge and change a state-centered approach to politics.

Patricia Ehrkamp

See also **Citizenship; Cross-Border Cooperation; Globalization; Immigration; Migration; Mobility; Remittances; Transnational Corporation**

Further Readings

- Bailey, A., Wright, R., Miyares, I., & Mountz, A. (2002). (Re)producing Salvadoran transnational geographies. *Annals of the Association of American Geographers*, 92, 125–144.
- Bauböck, R. (2003). Towards a political theory of migrant transnationalism. *International Migration Review*, 37, 700–723.
- Ehrkamp, P., & Leitner, H. (Eds.). (2006). Theme issue: Rethinking immigration and citizenship: New spaces of migrant transnationalism and belonging. *Environment and Planning A*, 38.
- Glick Schiller, N., Basch, L., & Blanc-Szanton, C. (1992). Transnationalism: A new analytic framework for understanding migration. In N. Glick Schiller, L. Basch, & C. Blanc-Szanton (Eds.), *Towards a transnational perspective on*



migration: Race, class, ethnicity, and nationalism reconsidered (pp. 1–24). New York: New York Academy of Sciences.

Guarnizo, L., & Smith, M. (1998). The locations of transnationalism. In M. Smith & L. Guarnizo (Eds.), *Transnationalism from below* (pp. 3–34). New Brunswick, NJ: Transaction.

Mitchell, K. (2004). *Crossing the neoliberal line. Pacific Rim migration in the metropolis*. Philadelphia: Temple University Press.

Portes, A., Guarnizo, L., & Landolt, P. (1999). The study of transnationalism: Pitfalls and promise of an emergent research field. *Ethnic and Racial Studies*, 22, 217–237.



TRANSPORTATION GEOGRAPHY

Transportation geography is the subfield that deals with the movement of people and goods across space, as well as the social and material infrastructures that enable or constrain those movements. More than most subfields of geography, transportation geography has strong connections with outside disciplines, including economics, engineering, planning, and landscape architecture. On the one hand, these linkages have led to a greater engagement with policy making than in most areas of geography. On the other hand, the subfield has also come under criticism for its somewhat narrow focus and isolation within geography. That said, transportation geography has made significant contributions to the discipline in demonstrating the importance of gender, the integration of economic and environmental concerns, and the need to engage with policymakers, among other areas. Particularly in the current era of globalization, connections between distant peoples and places are of growing importance, and transportation geography is key to understanding how those connections happen (or fail to happen). In terms of researchers, practitioners, and productivity, this is a subfield that is on a positive growth trajectory.

This entry is organized according to a series of categories into which most transportation geography research can be sorted. However,

many of these categories have begun to merge as the transportation industry and the study of it have become more integrated across modes and places. Significant opportunity exists to draw from emerging areas within geography and related disciplines to further strengthen this subfield and for other geographers to incorporate insights from the study of transportation nodes and networks.

Passengers and Freight

At its most basic level, transportation geography is concerned with the movement of people and goods. With respect to the former, this includes the travel choices and constraints of individuals over long and short distances: how mode choice, trip length, and destination are constrained or enabled by the available networks. With respect to the latter, the movement of people and goods includes the choice of mode and route with an eye toward minimizing cost. With respect to both, it includes the broader social and economic contexts, including cost as a decision factor, as well as the impacts on land use.

The main focus of transportation geography is on the movement of people, ranging across modes and scales. Much early work focused on the policy implications of suburbanizing metropolises, later evolving into a significant literature on excess commuting that tried to explain the long average distances between home and work. Long-distance and international travel have also been key areas of study, from tourism and migration to more recent work that uses flights or passengers as a proxy for connections between world cities in a global network. New cultural and social approaches explore the consumption of transportation in terms of the symbolic meanings of vehicles and of motion itself.

Research on the geography of freight transportation has evolved along with the industry. The early focus was on freight rates, linear programming, and the “transportation problem” from economics, in keeping with the regulated nature of freight transportation in the mid 20th century. Connections between freight transportation and land use focused on cities as historical break-of-bulk points, with general conceptual models describing evolving relations between colonial

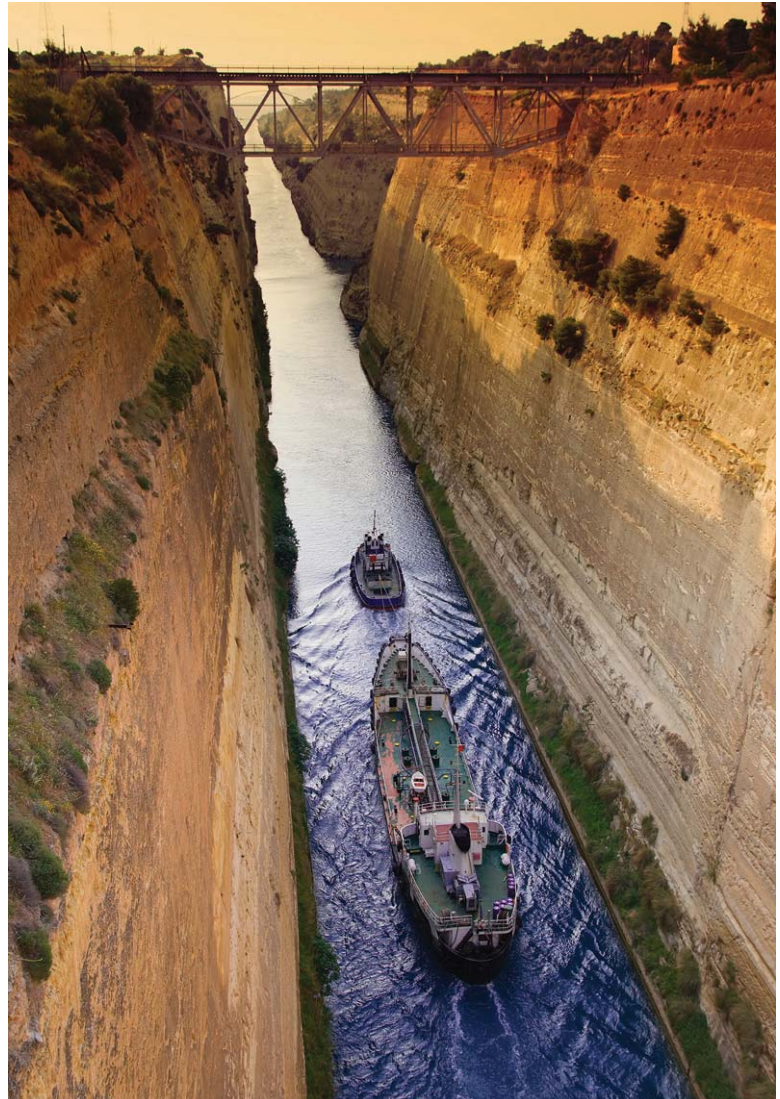


cities and their home ports, the relations among colonial cities, and the relations between ports and their surrounding cities. As the industry deregulated and became more entwined with globalizing economic activity, the research focus shifted to containerization, logistics, and the ensuing changes in all transport modes. More recent approaches include global commodity chains, logistics and supply chain management, and the new landscapes of distribution centers and intermodal terminals.

Accessibility/Mobility

One of the most basic distinctions drawn within transportation geography is between the concepts of accessibility and mobility. Generally speaking, accessibility refers to the presence and extent of infrastructure networks, while mobility refers to the movements of people and goods along those networks. Both have important implications for social equity and economic impact.

von Thünen's classic model of economic activity as concentric rings around the city is based on accessibility, measured as proximity to the city center. Accessibility is also at the core of models of the evolution of North American urban form at the regional and metropolitan scales, respectively, as the predominant modes of long-distance and commuting travel changed over time. More recent models of urban form take into account the polycentric form of the modern North American city and the need to access multiple locations for work, shopping, and so on. Accessibility can also be measured through network analysis, as has been done for airports to show changes across time due to deregulation, airline mergers, and political change. It can also be studied in terms of the effects it has on land use. For example, the impact on urban land prices of introducing fixed mass transit (such as a light rail line) is a subject of much debate.



A tugboat pulls a freight ship through the Corinth Canal, Greece.

Source: David H. Seymour/iStockphoto.

However, the simple fact that infrastructure exists does not mean that all people have access to it. The classic example is the limited-access highway, with the evacuation of New Orleans after Hurricane Katrina as a more recent demonstration. The mobility aspect of transportation geography focuses on how easily people can get to and use transportation infrastructure: proximity to a highway or bus stop, vehicle ownership, or wheelchair access, for example. Of particular interest is the “spatial mismatch” problem, where locations with a surplus of jobs (often in the suburbs) may not be easily accessible to the unemployed (often in central-city neighborhoods).



because of poor transit connections and low vehicle ownership.

The concept of “mobility” is not to be confused with the recent work coming out of sociology and related disciplines on “mobilities.” The most prominent work in this regard has been the concept of automobility, describing how modern society is inextricably intertwined with the production and consumption of automobiles and the mobility they provide (and followed more recently by aeromobility, velomobility, and other modes). Much of this work focuses on the need to examine everyday spaces and journeys to understand how people, places, and mobility construct each other. Geographers are just beginning to incorporate this theoretical approach into research on the construction of space, place, and policy.

Aggregate/Disaggregate Approaches

Planners and geographers alike generally approach transportation systems from one of two ways: (1) in the aggregate, based on territories such as census tracts or counties, (2) or in the disaggregate, focused on individuals or households. In particular, planners tend to take the former approach, looking at flows of commuters or travelers at a large scale. However, while a disaggregate approach may be more time-consuming in terms of data collection and analysis, it offers a better understanding of the opportunities and constraints individual travelers experience, as well as the reasons behind their travel decisions.

Aggregate flows are generally broken down into five categories of study: trip purpose, trip time, modal split, trip length, and spatial patterns. Within the United States, trip purpose has experienced a major shift in recent decades, with the majority of trips now being made for non-work purposes and with a concomitant shift in spatial patterns. Trip time and length have increased on average, with both contributing to the worldwide increase in vehicle miles traveled (VMT) at a much faster rate than population growth. Modal split continues to be heavily biased toward the automobile in developed countries, and increasingly in developing countries as well. The spatial pattern of trips can be used to characterize different urban areas, from the strong bidirectional flow of traditional commuters that

enables a mass transit system such as New York City’s to capture a majority of commuting trips to a multinodal space such as Los Angeles, with automobile congestion in all directions.

The disaggregate approach to transportation is exemplified by Hanson’s work on the different transportation experiences of men and women, which led not only transportation geography but the discipline as a whole to consider the role that gender plays in the production of space. This work has since been expanded to include differences based on class, race, age, disability, and other markers of social differentiation. Travel diaries and interviews are the most common methods for disaggregate analysis. More recently, Kwan and Miller have revived time-space maps with the use of geographic information systems to visually represent the daily travels of individuals throughout a city or region. While data collection is often a limitation of the disaggregate approach, it involves fewer simplifying assumptions than aggregated studies and can lead to richer results.

Public/Private Dimensions

Public versus private financing of transportation is one of the major distinctions among modes and places. A significant contribution of transportation geography has been close examination of the impacts of deregulation and privatization since the late 20th century. For example, Goetz’s study of U.S. airline deregulation clearly demonstrates the importance of a geographical approach, as the average decrease in airfares following deregulation is more properly described as a price savings in places benefiting from competition as against a price increase in cities where one airline holds a monopoly or near monopoly. Similarly, the ongoing privatization of airlines and airports in Europe and Asia is changing air travel patterns in those regions, most notably by increasing accessibility for the average traveler. The deregulation and privatization of railroads, trucking, and buses, however, have received less attention.

On the public side, a considerable amount of work has examined the economic impact of public investment in transit and other transportation infrastructure. As North American cities have inaugurated or revived light rail in the past few decades, geographers have studied the impact on



land values, ridership, and residential and other types of development. The results demonstrate weak or strong spatial connections between public investment in transportation and economic and social outcomes, depending on the scale of analysis. This follows a long tradition of examining the impact of public financing of highway systems in both rural and urban locations. The role of investment in transportation infrastructure in promoting economic development is the central concern of transportation geography in the context of developing countries.

In recent years, transportation funding worldwide has shifted to a model of public-private partnerships and joint ventures. Transportation geographers have explored the broader impacts of projects such as the Channel Tunnel in terms of the economic development implications at multiple scales for the cities and regions along the route. They are also beginning to study the spatial impacts of mechanisms such as congestion pricing on metropolitan equity and traffic congestion.

Economy, Environment, and Sustainability

Because of transportation geography's origins within economic geography, transportation geographers have long had an interest in the connections between mobility and economic development. This connection has been explored, for example, in terms of the timing of development relative to highway improvements in both urban and rural areas, teasing apart the chicken-and-egg question to show that the type and location of development matters in answering the question. The connection between transportation and land use is also relevant here, with geographers modeling the interactions between multiple transportation users and land uses, from the neighborhood scale to the national. The economic impact of terminals (including ports, airports, and intermodal facilities) has also been studied, including the broader regional and national impacts.

On the other hand, transportation can have serious environmental impacts, and geographers have contributed by analyzing the impacts on both human and biosphere health in terms of waste generation and pollution, resource use, and the physical presence of transportation infrastructure. The widespread impacts of transportation

are clear, from individuals suffering from asthma to the worldwide effects of global climate change, to which transportation contributes as the source of one fifth to one third of global carbon dioxide emissions. Road building in developing areas of the Amazon has been shown to reduce biodiversity and increase deforestation, while runoff from roads has negative effects on ecosystems all over the world. On a different note, recent U.S. research has shown a possible connection between living in a low-density suburb and being overweight among both children and adults. This connection between the built environment and human health is an important topic of current debate within both geography and planning.

These two areas of economy and environment are slowly being brought together through the concept of sustainable transportation. Incorporating the larger definition of sustainability as having economic, environmental, and social components (in roughly that order), sustainable transportation is one of the fastest-growing areas of study within transportation geography. International collaboration on ways to reduce vehicle emissions and energy consumption (including alternative fuels), to alter land use patterns in order to reduce vehicle miles traveled, and to move people rather than cars is currently one of the most exciting frontiers of this subfield. As automobile ownership and per capita vehicle miles traveled continue to rise around the world, this is also one of the most important areas of study.

Modes and Intermodalism

Traditionally, transportation geographers have tended to focus on one mode at a time, whether road, rail, water, air, or (occasionally) pipelines. Because of the different economic, social, and financial contexts of each of these modes, work on one mode has tended to remain largely separate from others. However, recent trends within the freight industry in policy and planning indicate that multiple modes and intermodalism are becoming more important topics of study.

While the transportation system itself remains dominated by the automobile, transportation geography is more equivocal. Significant work exists on the causes and consequences of automobile use for commuting and recreation, particularly



within the history of suburbanization. As the consequences of exclusive reliance on the private auto become more and more clear, researchers have tried to identify alternatives, explain why individuals make the choices they do, and demonstrate how current policies promote unsustainable outcomes. For example, while telecommuting and e-commerce were expected to reduce the need for travel, studies have shown that telecommuters do not necessarily make fewer trips and goods still need to be delivered to the consumer whether or not they pass through a store first.

Although research on rail in North America has declined in tandem with the decreasing use of this mode in the 20th century, the recent increase in freight traffic may signal an upsurge in academic work as well. Passenger rail has been well studied in Europe, particularly as competition for air travel on short-distance trips. Rail in the form of public transit is also well studied, particularly with regard to the land use implications of new and expanded metropolitan networks both historically and in the present (such as property values, job attraction, and residential density).

Maritime studies have generally focused on changes in the shipping industry as a result of containerization. An early period of centralization among North American port cities is being supplanted by some decentralization in response to port congestion. While books in the popular press have emphasized the importance of containerization to globalization, transportation geographers have focused on shipping lines and terminals and only recently looked at inland ports and connections to industrialization in places such as the Pearl River delta. As inland waterways become more important in Europe and elsewhere, attention is turning to that mode as well.

Similarly, studies of air transportation have tended to focus on the vehicles and terminals themselves rather than the broader environmental, social, and economic impacts of air transportation. Nevertheless, there have been significant contributions in terms of the impact of deregulation and low-cost carriers on air transportation networks around the world. Additionally, recent work has studied the diffusion of SARS (severe acute respiratory syndrome) across airline networks and the consequent health implications. The growing mobilities literature has placed

special emphasis on aeromobility in defining and constructing the modern era. However, of the four main modes, air transportation's connections to land use remain the least understood.

Finally, as the freight industry has become intermodal, thanks to containers that can travel by land, sea, or air, geographers' attention has turned toward intermodal facilities as well. Metropolitan areas face challenges in terms of retrofitting or adding infrastructure to accommodate the growth in freight traffic and its intermodal requirements, and geographers are well positioned to explain the importance of context in shaping logistics networks. Research is also examining the rail-airport connections that are growing across Europe, where intermodalism is relevant to passenger travel as well.

Conclusion

In keeping with general trends in the social sciences, geography has become more oriented toward networks and flows rather than places and territories. Transportation geography has always had this orientation, based on its subjects of study. The incorporation of places *with* networks, territories *with* flows, has long been a strength of this subfield, positioning it well within the discipline as a whole. On the other hand, while it was at the forefront of the quantitative revolution, transportation geography has been criticized in recent years for not having moved beyond that point in terms of methodology and subject matter. While it is true that transportation geography remains one of the most quantitative areas of geography, it has used that to its advantage in terms of close connections with related disciplines and with policymakers. Nevertheless, there is considerable room as well as opportunity for transportation geographers to incorporate broader processes and discourses, such as globalization, neoliberalization, and the cultural turn of its parent, economic geography. Because transportation enables most economic activity and social activity, it is of vital importance for geographers and others to be aware of and incorporate the work being done in this subfield. The processes of globalization have only strengthened the importance of transportation geography, and the ever-increasing movement of people and goods,



combined with a growing concern over energy and environmental costs, ensure that it will continue to be key for many years to come.

Julie Cidell

See also **Accessibility; Automobile Industry; Automobility; Aviation and Geography; Commuting; Economic Geography; GIS in Transportation; Gravity Model; Hanson, Susan; Infrastructure; Kwan, Mei-Po; Location Theory; Miller, Harvey J.; Mobility; Ports and Maritime Trade; Railroads and Geography; Time-Space Compression; Trade**

Further Readings

- Black, W. (2001). An unpopular essay on transportation. *Journal of Transport Geography*, 9, 1–11.
- Black, W. (2003). *Transportation: A geographical analysis*. New York: Guilford Press.
- Garrison, W., & Levinson, D. (2006). *The transportation experience: Policy, planning, and deployment*. New York: Oxford University Press.
- Goetz, A. (2006). Transport geography: Reflecting on a subdiscipline and identifying future research trajectories. *Journal of Transport Geography*, 14, 230–231.
- Hanson, S. (2003). Transportation: Hooked on speed, eyeing sustainability. In E. Sheppard & T. Barnes (Eds.), *A companion to economic geography* (pp. 468–483). Malden, MA: Blackwell.
- Hanson, S., & Giuliano, G. (Eds.). (2004). *The geography of urban transportation* (3rd ed.). New York: Guilford Press.
- Hilling, D. (1996). *Transport and developing countries*. London: Routledge.
- Knowles, R., Shaw, J., & Docherty, I. (Eds.). (2008). *Transport geographies: Mobilities, flows and spaces*. Malden, MA: Blackwell.
- Rodrigue, J.-P., Comtois, C., & Slack, B. (2006). *The geography of transport systems*. London: Routledge.
- Sheller, M., & Urry, J. (2006). The new mobilities paradigm. *Environment and Planning A*, 38, 207–226.
- Whitelegg, J. (1997). *Critical mass: Transport, environment and society in the twenty-first century*. London: Pluto Press.



TRAP STREETS

Trap streets is a term used to refer to the cartographic convention whereby mapmakers deliberately insert fake places (such as streets and street names) into their maps so as to later be able to demonstrate plagiarism by other cartographers.

For well over a century, the U.S. court system has dealt with copyright infringement lawsuits brought when a cartographer or publishing company believes that their maps have been directly copied by a competitor. Because maps are widely assumed to be depictions of reality, it is difficult to determine whether mapmakers have compiled original research or copied directly from another cartographer in creating their maps (what the cartographer Mark Monmonier has referred to as “editing the competition”). Hence, map companies will at times add streets, street names, towns, or other features, often in out-of-the-way places, so as to later detect copying by competitors. Such deliberate errors are not confined to cartographers. Similar copyright traps have been found in dictionaries and encyclopedias as ways to detect later plagiarism.

While map companies are hesitant to point out their trap streets, such “errors” have been reported in the media in both the United States and the United Kingdom. A detailed discussion of the use of trap streets is found in a 1997 U.S. District Court decision, *Alexandria Drafting Co. v. Amsterdam*, in which Alexandria Drafting Company sued Franklin Maps for copyright infringement alleging that Franklin plagiarized Alexandria Drafting Company’s maps in Franklin Maps’ Philadelphia-area road atlases. One way that lawyers for Alexandria Drafting Company demonstrated this plagiarism was that numerous trap streets that Alexandria Drafting Company had earlier inserted into their maps subsequently appeared in Franklin’s maps. However, the use of trap streets to legally demonstrate copyright infringement was called into question in the court’s ruling in this case, which found that “false facts,” such as trap streets, are not copyrightable elements.

Jonathan Leib

See also **Cartography**



Further Readings

- Alexandria Drafting Co. v. Amsterdam, 43 U.S. P.Q.2d (BNA) 1247 (E.D. Pa. 1997).
 Alford, H. (2005, August 9). Not a word. *The New Yorker*, p. 32.
 Monmonier, M. (1996). *How to lie with maps* (2nd ed.). Chicago: University of Chicago Press.



TRAVEL WRITING, GEOGRAPHY AND

Travel writing, by definition, is geographic. It narrates the experiences of observing places and moving through space and links travel with representation. A translation of what is seen into what is read, travel writing is of interest to geographers for its description and representation of different parts of the world. This entry discusses what constitutes travel writing, how human geographers have studied it, and what role travel writing has played in both the history of geography and the historical geographies of colonialism and imperialism. Although travel itself—whether long or short distance, temporary or permanent—is a nearly universal human experience, studies of travel writing have focused primarily on 18th- and 19th-century European and North American travelers, leaving much room for future work.

As a genre, travel writing ranges from books and serialized accounts published by well-known authors to unpublished diaries and journals kept by ordinary travelers, from texts by explorers and scientists traveling under the auspices of governments and crowns to letters by men and women traveling for pleasure. Over time, travel writing's meaning has changed. In the early 16th century, travel writings were considered forms of art and education, while in the late 17th century, they were central to the production of scientific knowledge about the “New World.” By the late 18th century, being well versed in travel writing was a sign of good taste among the European public. Across these shifts, travel writing's popularity grew, and by the 19th century, travel narratives were bestsellers.



Page from Chapters CXXIII and CXXIV of the book *Il Milione* (*The Travels of Marco Polo*), originally published in 1298–1299 but frequently reprinted and translated

Source: Public domain.

As transportation technologies reduced the costs and difficulties of travel throughout the 18th and 19th centuries, travel writers tried to distance their work from the growing number of tourism publications. Pointing to tourism's supposed crassness, travel writers went to great lengths to show their commitment to uncovering the “authentic” character of the sites they visited and to demonstrate the value of their own first-hand experience of places. In doing so, however, travel writers did not simply “uncover” the places discussed but, instead, actively constituted them, often through comparison with familiar landscapes. In comparing, for example, the American

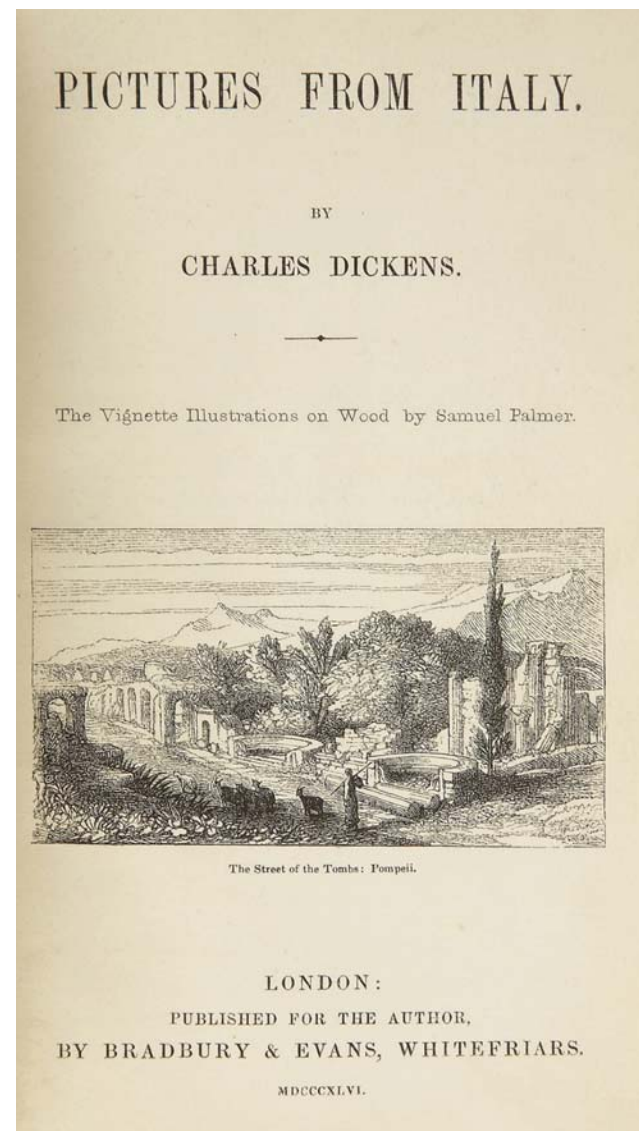


West with an English landscape, British travelers textually produced the new through images of the old, even as they faced the challenge of ensuring that the unfamiliar, whether Egypt or the Amazon, remained different enough to maintain travel's exotic allure.

Within human geography, travel writings have been used in various ways. In some cases, they have been treated as valuable firsthand accounts of places, such as colonial South America, or events, such as the U.S. Civil War. In other instances, travel writings have been analyzed as literary texts; and geographers have interrogated the discursive and intertextual strategies through which travelers both represented places and peoples and were in dialogue with genres from scientific and military writings to novels and political texts. More recently, geographers have used travel writings to examine how travel writers' own senses of self were differently affected by the acts of traveling and writing.

Across these approaches, geographers have studied travel writing most intensely in two areas. First, travel writing has played an important role in the history of geography as both a formal academic discipline and a broader interest in the human and physical world. Through geography's role in European colonial expansion and the impulse to map colonial territories, travel accounts of European explorers and geographers helped bring "science" and the New World to a reading public. Narratives by travelers such as Alexander von Humboldt provided detailed geographic information about the physical, social, and cultural features of colonized holdings and peoples, helping translate unfamiliar lands into territories ripe for commercial exploitation and settlement and bringing rich descriptions of these "new" places to eager readers.

In their writings, European and North American travelers often discursively erased humans from colonial landscapes, presenting lands across Africa, South America, and elsewhere as "empty" spaces awaiting European investment and definition. Such descriptions, it is important to note, frequently had material consequences, as their representations of colonial lands as latent resources fed into and justified subsequent European exploitation of these sites. Through their depictions of "native" peoples, colonial travel



Title page from the first edition of *Pictures From Italy*, a travelog by Charles Dickens, 1846

Source: Public domain.

narratives also illustrated what Mary Louise Pratt calls "contact zones," where groups and cultures met and interacted. In many cases, these interactions were deeply asymmetrical, and travel writers not only relied on native knowledge to maneuver and understand the places they observed but also were complicit with an "othering" that rendered colonial subjects both different from and inferior to European subjects.

Travel writings have also been central to geographic studies of colonialism and imperialism, particularly vis-à-vis gender. Through studies of



travel narratives by European white women in various colonial settings, feminist historical geographers have shown how gendered analyses of travel writings blur the lines between imperial, public spaces and domestic, private spaces. As they demonstrate, the inclusion of women travelers often calls into question monolithic narratives or understandings of colonialism and highlights the complexity of interactions among European and native women and men.

As this last example shows, the specifics of the social, economic, and political relations of colonialism and imperialism can be most effectively seen when travel writings by men and women, by known and obscure writers, are analyzed alongside one another. This comparative approach enriches understandings not only of the geographies and practices of colonialism but also of the transformative nature of travel itself. In the process, it offers an exciting model for subsequent work on travel writings from other historical and geographic contexts.

Jamie Winders

See also **Colonialism; Discourse and Geography; Gender and Geography; Geographical Imagination; Gregory, Derek; Historical Geography; Orientalism; Representations of Space; Text/Textuality; Writing**

Further Readings

- Blunt, A. (1994). *Travel, gender, and imperialism: Mary Kingsley and West Africa*. New York: Guilford Press.
- Gregory, D. (1995). Between the book and the lamp: Imaginative geographies of Egypt, 1849–50. *Transactions of the Institute of British Geographers*, 20, 29–57.
- Morin, K. (1998). British women travellers and constructions of racial difference across the nineteenth-century American West. *Transactions of the Institute of British Geographers*, 23, 311–330.
- Pratt, M. (1992). *Imperial eyes: Travel writing and transculturation*. London: Routledge.
- Winders, J. (2005). Imperfectly imperial: Northern travel writers in the postbellum U.S. South, 1865–1880. *Annals of the Association of American Geographers*, 95, 391–410.



TREE FARMING

Tree farming, or plantation forestry, is a system of cultivated forests established by planting or seeding in the process of afforestation (converting bare or fallow land into forests) and reforestation (planting once forested land with trees or other woody plants). Tree farms are established for several reasons, for example, to produce wood biomass, especially where natural timber stands are depleted; to meet the demand for high-quality species (e.g., mahogany, cedar); to develop export markets; to conserve or restore soil and water; to protect biodiversity; and to supply potential markets for carbon sequestration. While tree farms provide numerous benefits, critics note a number of ecological and socioeconomic defects; these are summarized below.

While tree farms existed throughout the world for centuries, their incidence increased dramatically in the mid 20th century. This is largely due to the expansion of commercial timber harvesting, the growing strategic importance of the pulp and paper industry, and the depletion of merchantable natural timber stands. Tree farms are relatively inexpensive to implement and maintain, produce cash crops in greater volumes and shorter periods of time than natural forests, require little infrastructural investment, and can provide jobs in underdeveloped regions. Tree farms are intensively managed, which simplifies production and reduces silviculture and harvesting costs as well as loss of time and resources due to inclement natural phenomena. According to Roger Clapp, the shift from natural to plantation-based systems of forestry is conceptually equivalent to the agricultural revolution. Most large-scale tree farms rely on species that grow rapidly and are resistant to drought. The most common are pine, which mature in between 15 and 30 yrs. (years), and eucalyptus, which mature in as few as 7 yrs. (see photo). Acacia is also commercially grown in southeast Asia.

The inception of large-scale plantation forests occurred in the 1960s, primarily on easily accessible fallow agricultural lands in Spain, Portugal, the southeastern United States, and the Canadian province of Ontario's St. Lawrence Valley. The Weyerhaeuser Corporation also



Casuarinas growing in dunes, Zululand, South Africa. Casuarinas are planted in coastal sand dunes for the stability they provide to the ground and for their timber.

Source: © Anthony Bannister; Gallo Images/Corbis.

played a leading role in developing successful tree farms in the northwestern United States during this era. Brazil and Chile developed large-scale plantations in the 1980s that demonstrated the economic viability of commercial tree farming. Many of South America's first large-scale tree farms were established by Japanese pulp and paper firms in response to elevated North American fiber prices and the depletion of timber stocks in and the ensuing ban on log exports from southeast Asian countries. More recently, Indonesia, Malaysia, Thailand, China, India, Russia, South Africa, Australia, and New Zealand have developed large-scale plantations. According to a recent report by the Food and Agriculture Organization of the United Nations, commercial tree farms account for roughly one half of the global total while nonindustrial plantations and unspecified plantations each account for approximately one quarter of the global total. Four countries

house more than 60% of the world's tree farms: China, India, Russia, and the United States.

Commercial tree farms can alleviate pressures on natural timber stocks and reconcile the interests of environmental advocacy groups and proponents of timber-based economic development. In fact, some major timber-producing countries or regions—most notably New Zealand and the southeastern United States—derive the majority of their commercial wood fiber from tree farms, while natural forests are set aside for conservation or preservation. The spatial consolidation of timber supplies through tree farming also reduces the financial and environmental burden of transportation, which has historically been a major impediment to profitability, rationalized production, and ecological sustainability in forest-based industries. Additionally, the environmental benefits gained through tree farming are often used as a justification to access public funding for such endeavors.



Recent Debates and Controversies

Tree farms are a valuable ecological and socioeconomic component of the world's forest resources. However, recent debates and controversies highlight the shortcomings of commercial plantation forests. These shortcomings are classified as either ecological defects or socioeconomic defects, but there is often notable overlap.

The absence of multilayered canopies, the depleted water tables, the inability to protect soils, the lack of habitat for wildlife and livestock, and microclimates altered by nonnative tree species are some of the most pressing ecological defects associated with tree farming. The lack of biodiversity on tree farms also draws criticism. Because the primary objective of most tree farms is to maximize the output of timber, monoculture crops are common. Critics, however, are skeptical that such crops are sustainable in the long run and claim that the aforementioned ecological defects are the result of monoculture plantations. Additionally, monoculture plantations are disproportionately susceptible to damage by invasive or parasitic insects and flora. Many point to small-scale and nonindustrial tree farms as the best means of balancing the need for long-term ecological sustainability with the need for efficient and profitable timber production.

The socioeconomic defects of commercial tree farming are most prevalent in underdeveloped nations or regions, particularly southeast Asia and South America. Three predominant defects exist. First, commercial tree farms rarely provide high economic multipliers to local or regional economies. This is especially the case where work systems are highly mechanized and capital intensive or where production is export oriented and devoid of value-adding processing facilities such as pulp or lumber mills. Second, profits are often distributed unevenly and fall into the hands of multinational firms, corrupt governments, or military juntas. Third, the conversion of land into plantations displaces peasants and indigenous cultivators from common lands that supply pasture and fuel.

Brendan Sweeney

See also **Agroforestry; Community Forestry; Deforestation; Forest Restoration; Indigenous Forestry; Plantations; Social Forestry; Sustainable Forestry; Timber Plantations**

Further Readings

- Carnus, J.-M., Parotta, J., Brockerhoff, E., Arbez, M., Jactel, H., Kremer, A., et al. (2006). Planted forests and biodiversity. *Journal of Forestry*, 104(2), 65–88.
- Clapp, R. A. (2001). Tree farming and forest conservation in Chile: Do replacement forests leave any originals behind? *Society and Natural Resources*, 14(4), 341–356.
- Food and Agriculture Organization of the United Nations. (2001). *The state of the world's forests*. Rome, Italy: Author.
- Marchak, P. (1997). A changing global context for British Columbia's forest industry. In T. J. Barnes & R. Hayter (Eds.), *Troubles in the rainforest: British Columbia's forest industry in transition* (pp. 149–166). Victoria, British Columbia, Canada: Western Geographical Press.



TREWARTHA, GLENN (1896–1984)

Born in southwestern Wisconsin in 1896, Glenn Trewartha was an influential 20th-century American geographer. Trewartha's academic career was impressive in both its length and scope. His publication career covers seven decades, from his first publication in 1923 to his last in 1982 (just 2 yrs. [years] before his death in 1984). Most impressively, Trewartha was a recognized leader in three distinct areas of geography: (1) weather and climate, (2) the geography of Japan, and (3) population geography.

Trewartha was hired as an instructor at the University of Wisconsin, Madison, in 1922, and received his PhD there in 1925. After receiving his doctorate, Trewartha was promoted to assistant professor at Wisconsin in 1926 (and later to associate professor and professor). He spent the next 40 yrs. at Madison before retiring in 1965 as the Finch Research Chair in Geography.

First and foremost, Trewartha was a leading expert on weather and climate. He published the very influential textbook *An Introduction to Weather and Climate* in 1937. The book went through five editions over the next 40 yrs., the



last edition being published in 1980. Trewartha is best known for his introduction of and modifications to the Koppen climate classification system. Also, Trewartha is credited with coining the term *greenhouse effect* in 1937.

In addition to his work on climate, Trewartha was also a leading American scholar on Japan. One of the first American geographers to specialize in the regional geography of Japan, Trewartha published his first book on the country in 1934, with subsequent editions published in 1945 and 1965. As a leading American scholar on Japan during World War II, Trewartha served as a consultant to the U.S. government during the war and afterward during the Allied occupation government's reconstruction efforts.

Trewartha is also remembered as the founder of the subdiscipline of population geography. As president of the Association of American Geographers, Trewartha used his 1953 presidential address to advocate for population geography as a distinct and prominent subdiscipline. He believed that population geography had long been ignored by geographers and argued that the study of population should be central to the discipline. He proposed that geography had three main elements: (1) the "physical earth," (2) the "cultural earth," and (3) population. Trewartha saw the study of population as a central organizing principle of geography and as the key linkage between the human and physical sides of the discipline.

Jonathan Leib

See also **Population Geography**

Further Readings

- Hartshorne, R., & Borchert, J. (1988). In memoriam: Glenn T. Trewartha, 1896–1984. *Annals of the Association of American Geographers*, 78, 728–735.
- Pandit, K., Weeks, J., Plane, D., Graham, E., Conway, D., & Silvey, R. (2004). Fifty years since Trewartha. *Population, Space and Place*, 10, 277–309.
- Trewartha, G. (1934). *Japan: A physical, cultural and regional geography*. Madison: University of Wisconsin Press.

Trewartha, G. (1937). *An introduction to climate* (3rd ed.). New York: McGraw-Hill.

Trewartha, G. (1953). A case for population geography. *Annals of the Association of American Geographers*, 43, 71–97.



TRIANGULATED IRREGULAR NETWORK (TIN) DATA MODEL

The Triangulated Irregular Network (TIN) is a data model that describes surfaces, especially terrain. It has been developed as an alternative to the two other data models for surfaces, the Regular (Rectangular) Grid and the Contour Model. The summary term is *digital terrain model* (DTM).

The philosophy that underlies TIN is that triangles are a good approximation of terrain that is less than smooth (i.e., has breaks such as ridges). TIN needs a fraction of the units of regular grids and is computationally faster than contour modeling.

A triangle has three components: (1) one area, (2) three edges, and (3) three vertices. It shares each edge with one other triangle and each vertex (node) with an average of five other triangles. This sharing allows the linkage of the triangles into a network. The resulting relationships are usually identified under the term *topology*.

All structures have topology. For the regular grid, topology is implicit; that is, each vertex in the network is given by its numbered location, the northwest corner usually being the position 0,0. The neighbors of vertex (i, j) are $(i \pm 1, j \pm 1)$. For the contour structure, contours often have with them stored the labels of the contours above and below (the "contour tree"). This we could call a "partially explicit" topology.

The implementation of the TIN model into a data structure can happen in different ways.

- The first structure stores in one array the triangles together with their edges and, in a second array, the edges with their limiting vertices. A third array would have the vertices



with their coordinates. All topological relations are stored explicitly.

- The second structure is based on the edge as the main carrier. With each edge are stored the labels of the two endpoints and the labels of the two triangles that are bordering the edge, leading, again, to an explicit topology. A separate array holds the coordinates of each vertex.
- A third structure has the edges as the basis. Each record stores the label of the “leading vertex” or node and the labels of all vertices that are linked to the node. The edges are arranged in clockwise order around the node, starting due north. There is a record for every node in the network. Another array stores the coordinates of all nodes. This structure is different from the other two in that the node records are of variable length and the topology is partially given implicitly through the sequence of neighboring edges. This is likely the structure that needs the smallest amount of storage and is fastest for searches across the network.

So what is a data structure such as TIN good for? First of all, to enter a set of data points into a structure with all the topological attributes gives the points accuracy and solidity. Second, a structure allows for the production of a variety of applications. Most operations that involve surface networks are searches across the surface with one or two of the dimensions (x , y , and height, or z) kept constant. The most frequent application is likely the creation of regular, rectangular grids, because a number of geographic information systems use TIN only for storage purposes, and as soon as something is done with the data, they are converted into the regular grid. These grids are the result of searches across the network with first the y dimension kept constant (horizontal lines) and then the x dimension (vertical lines). The drawing of contours means searching the network with the z dimension kept constant.

TIN is a structure on the way to a better understanding of terrain. Terrain is given by its rivers (channels) and ridges, and TIN is a very good approximation. “TIN is the thinking man’s DTM.”

Thomas K. Poiker

See also **Digital Terrain Model; Landscape Interpretation; Terrain Analysis; Topological Relationships**

Further Readings

Poiker, T. K. (1997). *Unit 39: The TIN model*.

Retrieved November 12, 2009, from www.geog.ubc.ca/courses/klink/gis.notes/ncgia/u39.html

Tchoukanski, I. (n.d.). *Triangular irregular network*.

Retrieved November 12, 2009, from www.ian-ko.com/resources/triangulated_irregular_network.htm



TROLL, CARL (1899–1975)

Carl Troll was a German geographer who developed the concept of landscape ecology and made significant contributions to the study of high-mountain geography. He also served as president of the International Geographical Union from 1960 to 1964.

Troll was born in Bavaria, Germany, on December 24, 1899. He studied at the University of Munich, obtaining a doctorate in botany (1921) and another in geography (1925). Between 1926 and 1929, he undertook an extensive research journey through the Andes, during which he expanded on the concepts and research of his famous countryman, Alexander von Humboldt. His mountain studies were extended to Eastern and Southern Africa in the 1930s, and he was a member of the disastrous German expedition to Nanga Parbat in 1937. In 1930, he was appointed professor of colonial and overseas geography in Berlin. He moved to Bonn University in 1938.

His major achievements prior to the outbreak of World War II include the application of air photography to the analysis of landscape and formalization and adaptation of the concept of *Landschaftsökologie* (landscape ecology) to the study of *Hochgebirge* (high mountains); he applied the theory of altitudinal zonation to both the physical and the human and cultural aspects of mountains. However, his numerous publications in German made little impact on the English-speaking world until after the war. Yet



his treatise on patterned ground and frozen/periglacial phenomena at high altitude (1944) attracted U.S. military intelligence. It was republished in English translation (1948), thereby introducing his work to a worldwide readership.

At enormous personal risk, Troll protected his Jewish colleague, Professor Alfred Philippson, and his family from death in a concentration camp, through his contact with the pro-Nazi Swede Sven Hedin, a confidant of Hitler. After the war, Troll played a crucial role in reintegrating German geography into the international community, which was recognized by his election as president of the International Geographical Union in 1960. This led to acceptance of his proposal for an IGU Commission on High-Altitude Geocology in 1968, which he chaired until 1972, when ill health forced him to resign.

Troll used the vehicle of what developed as the “Mountain Commission” to interest international scholars in working together to expand mountain research worldwide. He attracted to the commission younger scholars, many of whom became leaders in the field, from Poland, Russia, Switzerland, Kenya, Japan, Canada, New Zealand, and the United States, as well as his own students and colleagues throughout Germany. Thus, he created a powerful research network. While he did not live to see this infectious concept and effective teamwork develop as a force for creating worldwide awareness about mountains, his life’s contribution provided the vital catalyst.

One of Troll’s special interests centered on the explanation of the factors affecting the position of the upper timberline worldwide. He also exuded an enthusiasm for terminology. His pre-war development of climate diagrams was outstanding for its time. In 1947, he founded and edited the quarterly journal *Erdkunde* (Earth Study). Many of his students became leaders in mountain research, including Olov Hedberg, Masatoshi Yoshino, and Frederich-Karl Holtmeier. His enthusiasm and charisma were overriding personality characteristics that did much to extend his influence. He died in Bonn in 1975.

Jack D. Ives

See also **Landscape Ecology; Physical Geography, History of**

Further Readings

Geographical Journal. (1976). Carl Troll [Obituary]. 142, 193.



TROPICAL RAIN FORESTS

See Biome: Tropical Rain Forest



TSUNAMI

The devastating tsunami in the Indian Ocean of December 26, 2004, alerted the world to one of the most terrifying natural phenomena on Earth. Few will forget the scenes of carnage and destruction wrought by the floodwaters as they swept across coastal areas. In fact, tsunamis have been known about for generations. The word *tsunami* is derived from the Japanese word meaning “harbor wave.” Tsunamis are frequently described as tidal waves; however, this view is erroneous, since they have nothing to do with tides. Tsunamis are generated by offshore earthquakes, submarine slides, and, occasionally, subaerial landslides that enter water bodies. Asteroid impact is an additional but much rarer mechanism. With the exception of asteroid impacts, the displacement of mass, whether through submarine sediment slides, the collapse of a volcanic edifice, or an earthquake that induces faulting of the seabed, leads to a large-scale displacement of water. Although most tsunamis are phenomena associated with the open ocean, some tsunamis can be generated within lakes and/or fjords due to rockslide failures. An attempt is made here to explain the processes of tsunami generation and propagation as well as what happens when tsunamis strike coastlines. A description is also given of how societies have responded to the perception of tsunami risk.

Tsunami Mechanics

When a tsunami is generated, the initial water movement is generally characterized by a rapid



drawdown and a lowering of the sea surface at the coast as the water moves into the area of seabed displacement. Thereafter, due to the build up of momentum, large kinematic waves are propagated outward from the zone of seabed disturbance. The waves travel across the ocean at very high velocities, often in excess of 280 mph (miles per hour), and possess very long wavelengths and periods. Tsunami velocity is mostly a function of water depth. Thus, as the waves approach shallow water, the wave velocity decreases, and the wave starts to break. At the coast, the tsunami flood level (run-up) is partly a function of the dimensions of the propagated waves but is also greatly influenced by the topography and bathymetry of the coastal zone, and as such, the waves can reach considerable elevations, causing widespread destruction and loss of life.

It is a mistake to think of a tsunami as a single wave. All tsunamis consist of a train of waves that can strike a coastline over time periods ranging from a few minutes to several hours. Often, a large incoming wave can be followed by a much smaller one. However, the backwash from the first wave can interfere with the wave motion of the second incoming wave. In many cases, this interference can act to amplify the dimensions of the second wave, causing it to increase in size beyond the first. From this description, it can be easily appreciated that the dimensions of individual tsunami waves striking a coastline are greatly influenced by wave resonance, refraction and diffraction effects, and local near-shore bathymetry.

Geography of Tsunamis and Warning Systems

The majority of tsunamis occur around the Pacific Ocean, but many are also known from other areas. The frequency of Pacific tsunamis is due to the high occurrence of severe earthquakes under or close to the seabed as a result of the subduction of oceanic crust adjacent to continental margins. Such geological processes are a characteristic feature of Japan, where there is a long history of devastating earthquakes and tsunamis. Between 1596 and 1938, the Japanese islands were struck by 15 major tsunamis. One of the worst of these took place on June 15, 1896, as a result of a large submarine earthquake centered under the ocean floor 93 mi. (miles) offshore. Since the epicenter of the earthquake was

located beneath the ocean floor, the inhabitants on nearby coasts, although they knew that an earthquake had taken place, were unaware that a dangerous tsunami had been generated.

Long before the tsunami of December 2004, the long history of tsunamis known to have affected coastlines bordering the Pacific Ocean led to the development of warning systems designed to alert the public in advance of the arrival of individual tsunamis. Following the Aleutian Trench earthquake and tsunami of April 1, 1946, together with the destruction of the Scotch Cape Lighthouse on Uminak Island and the devastation of Hilo, Hawaii, a case was made for the establishment of a tsunami warning system designed to protect life and property.

The Pacific Tsunami Warning System was developed by the U.S. Coast and Geodetic Survey (since 1970, the National Geodetic Survey) and has its center of operations on the Island of Oahu, Hawaii. The center, known as the Pacific Tsunami Warning Center (PTWC), became operational in 1948 and is linked to seismographic stations throughout the Pacific Basin. These provide data on Pacific earthquakes whose magnitude and epicenters make them tsunamigenic (capable of producing tsunamis). When an earthquake has taken place, the PTWC issues a tsunami watch to all receiving stations. The PTWC is also linked to more than 50 tide-gauge stations located throughout the Pacific. Any tsunami that has been generated by an earthquake is automatically recorded in the tide-gauges closest to the epicenter. If a tsunami has been detected, then the tsunami watch is upgraded to a tsunami warning. At this stage, the estimated times of arrival of the first waves are computed for all stations across the Pacific. Once the PTWC has issued a tsunami warning and has provided information on the times of arrival of the first waves, it is the responsibility of the local police, military, and civil defense agencies to decide on whether or not particular areas should be evacuated.

The accuracy of PTWC tsunami warnings is well illustrated by the famous Chilean earthquake and tsunami of May 21, 1960. Once the earthquake epicenter had been calculated and a brief study of local tide-gauge data had been completed, it was estimated that the velocity of the tsunami was 440 mph and that the tsunami would reach



the Hawaiian islands 14 hours and 56 min. (minutes) after its generation off the Chilean coast. The prediction was that the first wave would strike Hilo at 9:57 p.m.—it arrived 1 min. late.

In areas where the coast is located close to the epicenter of a tsunamigenic earthquake, the time that elapses between the generation of the tsunami and its arrival on the coast is often frighteningly short. For example, the first tsunami waves that struck the Chilean coast on May 21, 1960, arrived only 15 min. after the main earthquake shock. Similarly, there was only a relatively short time interval between the March 27, 1964, earthquake in Alaska and the arrival of tsunami waves at the coast. In both cases, loss of life occurred because the tsunami struck coastlines long before any PTWC warning could be given. In the case of the 2004 Indian Ocean tsunami, since the Pacific tsunami warning system did not extend as far afield as Indonesia, it was not possible to generate an instant warning to countries bordering the Indian Ocean. Instead, the first indications that a tsunami was likely to be generated came from the global array of seismic monitoring stations that were recording the occurrence of a huge earthquake beneath the Indian Ocean.

The presence of a tsunami warning system is essential for the Pacific region due to the large number of tsunamis that are known to have occurred. However, large tsunamis are also known to have taken place in other parts of the world, albeit less frequently. The Indian Ocean tsunami of 2004 is a good example of this, but there have been many other catastrophic events. In Europe, for example, the most destructive historical tsunamis were those that accompanied the Lisbon earthquake of November 1, 1755; the earthquakes in Sicily and Calabria on February 5, 1783, and December 8, 1908, respectively; and the Aegean Sea earthquake of July 9, 1956. Of these, the most destructive event was the Lisbon earthquake in 1755.

Prehistoric Tsunamis

In recent years, it has become increasingly clear that many large prehistoric tsunamis can be recognized in coastal sediment sequences, since such tsunamis frequently result in extensive coastal erosion and sediment deposition. The recognition that specific prehistoric tsunamis can be identified

using geological methods has provided the scientific community with very valuable information on the long-term frequency of tsunamis in particular areas of the world. For example, it is now known from geological studies along the Pacific coastline of the United States and Canada that a large, severe, destructive tsunami took place about 300 yrs. (years) ago. The geological evidence for this tsunami, associated with a large offshore earthquake, is supported by historical data from Japan, which suggests that this particular tsunami caused severe flooding throughout the North Pacific region. The recognition that such destructive floods associated with former earthquakes have taken place in the relatively recent geological past has alerted governmental organizations that if a similar event were to occur in the future, there would be widespread destruction in many of the cities that border the Pacific coastline of the United States and Canada.

Geological investigations have similarly shown that one of the most destructive tsunamis to have affected northwest Europe took place as a result of one of the world's largest submarine slides, which occurred in the Storegga area on the continental slope west of Norway. The second Storegga slide is believed to have occurred around 8,000 yrs. ago and involved the movement of about 400 mi.³ (cubic miles) of sediment and rock across the seafloor over a distance in excess of 300 mi. The magnitude of this slide is demonstrated by the movement of two blocks, 500 to 650 ft. (feet) thick and up to 6 to 20 mi. wide, that were transported as far as 125 mi. downslope, over seabed surfaces with average slopes of no greater than 1° to 2°. The tsunami generated by this landslide caused extensive flooding of coastlines bordering the Norwegian Sea and northeast Atlantic Ocean. For example, in the North Sea, flood levels reached up to 13 to 20 ft. above the contemporary high-water mark, while along the coastline of Western Norway and the Shetland Isles, the tsunami locally reached up to 30 meters (about 90 ft.) above former sea level (see photo).

Conclusion

The occurrence of this giant tsunami in prehistory teaches us an important lesson. It tells us



Section showing tsunami deposits at Maggie Kettle's loch, Sullom Voe, Shetland Isles. The tsunami deposits, exposed at the base of the section, consist of coarse sand deposits within which are balls (intraclasts) of peat caught up in the deposit during the passage of the tsunami wave. The tsunami that produced this deposit took place around 8,000 yrs. ago, when sea level in Shetland was approximately 65 ft. below present. The occurrence here of tsunami deposits at 33 ft. above sea level therefore implies a former tsunami run-up of around 100 ft. in this area.

Source: Author.

that there are few coastlines of the world that are not at risk from tsunamis. With this realization comes the need to be able to quantify tsunami risk. It highlights the need for tsunami scientists to be able to inform planners and politicians of the probability of occurrence of future destructive event in specific areas. This task is exceptionally difficult, since the database of

past events in history and in prehistory is always bound to be incomplete. Sadly, it has taken a catastrophic event such as that which occurred in 2004 to accelerate the pace of tsunami research to help find answers to these questions.

Alastair Dawson

See also Coastal Erosion and Deposition; Coastal Hazards; Earthquakes; Natural Hazards and Risk Analysis; Oceanic Circulation; Tsunami of 2004, Indian Ocean

Further Readings

- Bondevik, S., Mangerud, J., Dawson, S., Dawson, A. G., & Lohne, Ø. (2003). Record-breaking height for 8000-year-old tsunami in the North Atlantic. *Eos (American Geophysical Union)*, 84(31), 289–300.
- Bryant, E. (2001). *Tsunami: The underrated hazard*. Cambridge, UK: Cambridge University Press.
- Dawson, A. G., & Stewart, I. (2007). Tsunami deposits in the geological record. *Sedimentary Geology*, 200, 166–183.
- Dudley, W. C., & Lee, M. (1998). *Tsunami!* Honolulu: University of Hawaii Press.
- Murty, T. S. (1977). *Seismic sea waves: tsunamis*. Ottawa, Ontario, Canada: Department of Fisheries and Environment, Fisheries and Marine Service, Canada.



TSUNAMI OF 2004, INDIAN OCEAN

A major tsunami took place on December 26, 2004, which was the deadliest tsunami in recent history. On that fateful day, the tsunami left more than 225,000 people dead or missing, with many millions made homeless in a total of 11 countries. Indonesia, Sri Lanka, India, and Thailand were the hardest hit.

Regional Map of Tsunami-Affected Areas

28 December 2004

This map illustrates coastal areas under 20 meters in elevation, as shown in bright yellow. This low-lying coastal zone is not a direct indication of areas affected by the 26 December 04 Tsunami—only those areas which may have suffered damage. For example, although Bangladesh is almost entirely under 20m in elevation, extensive swamps and limited settlements along the coast resulted in few casualties.

- Capital
- Large Town
- Epicenter
- Nuclear Power Plant
- International Border
- Elevation under 20m

Disaster Type: Tsunami
Disaster Date: 26 December 2004
Data Source: GLCF, NASA, USGS
Sensors: Modis-Terra mosaic
Elevation Data: SRTM30/ETOPO2
Resolution: 1km
Scale: 1:12,000,000 for A3 Prints
Datum: WGS-84
Projection: Geographic coordinates
Map Produced: 28 December 2004

The depiction and use of boundaries, geographic names and related data shown here are not warranted to be error-free nor do they necessarily imply official endorsement or acceptance by the United Nations.

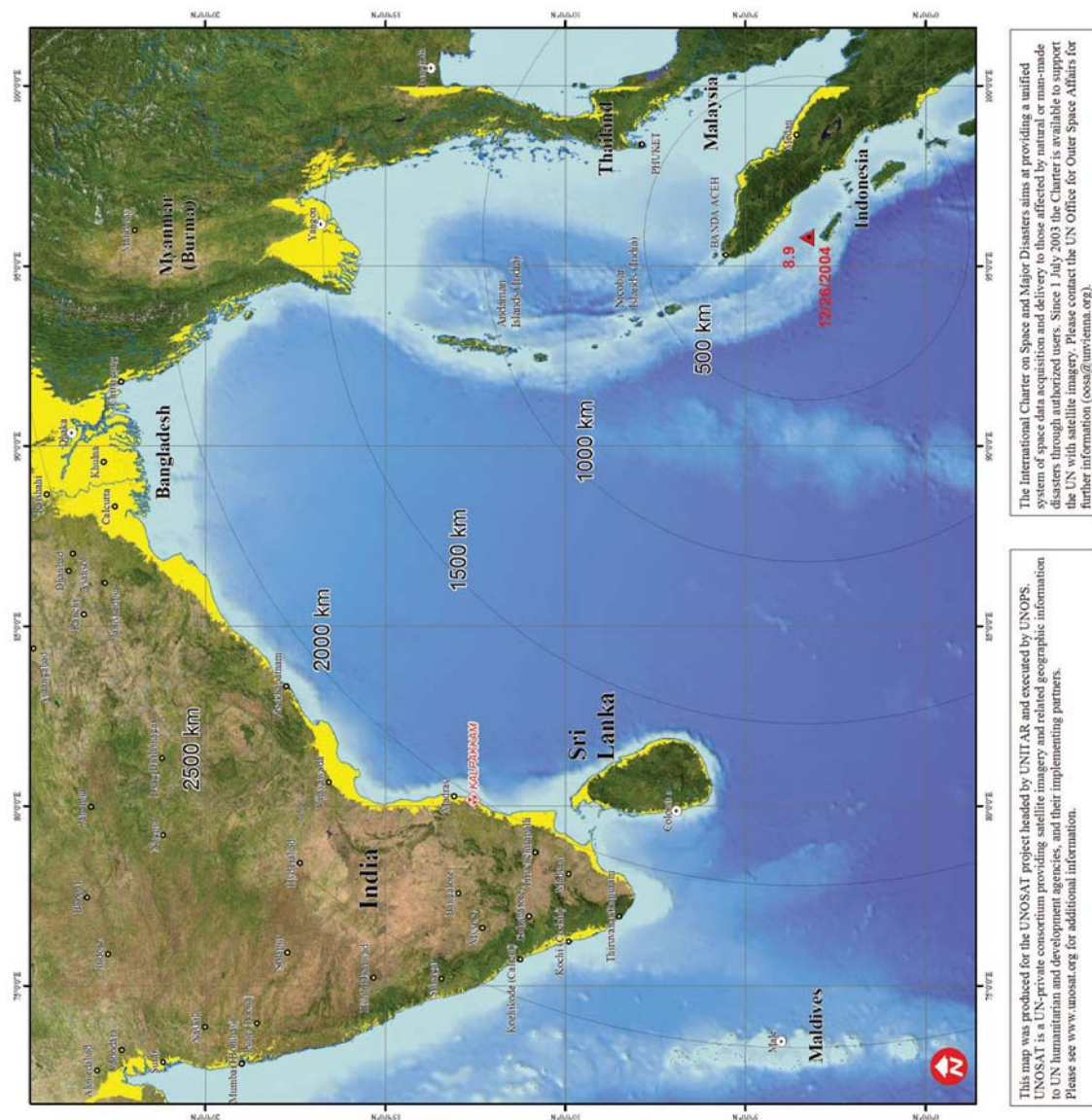


Figure 1 A regional map of those countries most affected by the tsunami. This map also illustrates the approximate land coverage under 20 m in elevation as a zone of potential tsunami damage.

Source: Courtesy of UNOSAT, the UN Institute for Training and Research (UNITAR) Operational Satellite Applications Programme, implemented in cooperation with the European Organization for Nuclear Research (CERN). Map based on data provided by International Charter Space and Major Disasters.



The tsunami was caused by an offshore (undersea) earthquake of magnitude 9.2 that was triggered along an area of plate collision where the India Plate, an oceanic plate, is being subducted beneath the Burma-Sunda plate across a subduction zone in the area of the Sunda Trench. The epicenter of the 9.0-magnitude quake was under the Indian Ocean off the western coast of Sumatra, Indonesia. The earthquake was associated with the rupture of the seafloor along a length of 1,000 km (kilometers; 620 mi. [miles]). Along this zone, the land surface was displaced both laterally and vertically by several meters. This event led to the sudden displacement of the overlying ocean water and the production of the tsunami.

Along the coast of Northern Sumatra, tsunami waves up to 30 m (meters; 100 ft. [feet]) in height destroyed everything in their path. The tsunami traveled across the Indian Ocean, causing devastation along coastlines as far as away as Somalia, Kenya, and the Maldives. Some of the most destructive flooding took place along the coasts of Thailand, Sri Lanka, and India, where many thousands of people lost their lives and many more lost their livelihoods.

Alastair Dawson

See also Coastal Hazards; Natural Hazards and Risk Analysis; Tsunami; Vulnerability, Risks, and Hazards

Further Readings

- Chini, M., Bignami, C., Stramondo, S., & Pierdicca, N. (2008). Uplift and subsidence due to the 26 December 2004 Indonesian earthquake detected by SAR data. *International Journal of Remote Sensing*, 29, 3891–3910.
- Klein, N. (2007). Blanking the beach: The second tsunami. In N. Klein, *The shock doctrine: The rise of disaster capitalism* (pp. 385–405). London: Penguin.
- Srinivas, H., & Nakagawa, Y. (2008). Environmental implications for disaster preparedness: Lessons learnt from the Indian Ocean tsunami [Special issue]. *Journal of Environmental Management*, 89, 4–13.



TUAN, YI-FU (1930–)

The works of the Chinese American geographer Yi-Fu Tuan represent a major contribution to geographical scholarship. His huge corpus of writings reflects a humanistic-geographical approach that in the 1960s and 1970s went against the grain of positivistic studies that were reflected in the so-called quantitative revolution.

Tuan was born in Tanjin, China. The work of his father, a diplomat, required the family to move frequently between continents, and Tuan was educated in China, Australia, Britain, and the United States. For much of his early life, therefore, his “home” was rarely static; he never lived in one place for more than 5 yrs. (years) until he was 38 yrs. of age, when he became based at the University of Minnesota. He completed his academic career at the University of Wisconsin but has continued writing and researching. Tuan sees himself as a “cosmopolite” and, on balance, feels that such a life is better than the “safeness of the hearth.”

Tuan’s post-high school education commenced at Oxford University. He gained his undergraduate degree at the age of 20, and at Oxford, he developed a penchant for physical geography, a field that he developed further in his postgraduate studies at the University of California, Berkeley. His studies focused on pediments in southeastern Arizona, with his fieldwork undertaken between 1953 and 1955.

The bulk of Tuan’s work may be described as humanistic or phenomenological geography. His writing has been inspired by the studies of the American scholar John Kirkland Wright and his notion of “geopietry” (meaning the relationship between humans and nature) and those of the conservationist Aldo Leopold. Carl Sauer and J. B. Jackson were other inspirations. Tuan is well-known for his use of an eclectic range of authors, and he is willing to draw on literary as well as academic sources, both of which have influenced his intellectual development.

It can be argued that Tuan’s reputation was built on two key books that have been used and applied over the past 30 years or more. The first of these is *Topophilia* (1974), a path-making work that focused on the links between human beings and place. It is regarded by his peers as a “classic



in human geography,” though it is erroneously believed that he coined the neologism *topophilia* (W. H. Auden and Gaston Bachelard used the word before him). However, there is no doubt that he popularized a concept that has been subsequently applied to a wide range of themes that deal with the “sense of place,” or the cognate idea of *genius loci*. A study of “negative” senses of place (“topophobia”), *Landscapes of Fear* (1979), is less well-known. He returned to the power of place in *Space and Place* (1977), another definitive work that sees place as inhabited space.

Although Tuan is considered by some as an academic “outsider,” it is possible to see in his work illuminations of writing by Michel Foucault and other eminent scholars. For example, Tuan’s *Segmented Worlds and Self* (1982) stresses the changing spatial structures in society in relation to society’s varied forms of control. Later work saw Tuan define geography as a “moral science”; for example, in *Dominance and Affection* (1984), perhaps his most pessimistic book, his foci are pets and gardens. In this fascinating work, he wrestles with the possibility that affection—indeed, love—may be seen as an extreme form of domination.

Two terms characterize Tuan’s oeuvre: *humility* and *vitality*. He continually seeks to explore the “good life.” As he seeks it in many of his works, he draws extensively on literature and self-reflection. To be sure, he has had his critics (though they are few and far between), yet he returns and modifies his examples by testing and editing his findings.

Tuan is a scholar who wishes to engage with his readers. Hence, in *Dominance and Affection*, facts and ideas are carefully, but with responsibility, displayed and explored, and the author necessarily focuses further on a specific problem and its detailed examination. Additionally, for many years, he has disseminated weekly letters to his colleagues and students that provide a “verbal outlet” to his thoughts.

Tuan has published a large number of papers and books, most of which have been acclaimed. His works *Escapism* (1998) and *The Good Life* (1986) are examples where taken-for-granted subjects are explored through Tuan’s philosophical lens, through which he seeks understanding and appreciation without being seduced by surface phenomena. Indeed, he regards a humanistic

approach as seeing ordinary objects afresh, delighting in them for what they are and, as they appear, excavating hidden relations and meanings and then, in conclusion, presenting surfaces and depths—the seen and the unseen.

Tuan’s work has been appreciated in a wide variety of disciplines, including geography, history, architecture, psychology, philosophy, and sports studies. He has received many honors, including the Callum Geographical Medal from the Association of American Geographers and the Laurat d’Honneur of the International Geographical Union.

John Bale

See also **Existentialism and Geography; Humanistic Geography; Phenomenology; Sense of Place; Topophilia**

Further Readings

- Rodaway, P. (2004). Yi-Fu Tuan. In P. Hubbard, R. Kitchin, & G. Valentine (Eds.), *Key thinkers in geography*. London: Sage.
- Tuan, Y.-F. (1974). *Topophilia: A study of environmental perception, attitudes and values*. Englewood Cliffs, NJ: Prentice Hall.
- Tuan, Y.-F. (1977). *Space and place: The perspective of experience*. Minneapolis: University of Minnesota Press.
- Tuan, Y.-F. (1979). *Landscapes of fear*. New York: Pantheon Books.
- Tuan, Y.-F. (1984). *Dominance and affection: The making of pets*. New Haven, CT: Yale University Press.
- Tuan, Y.-F. (1999). *Who am I? An autobiography of emotion, mind, and spirit*. Madison: University of Wisconsin Press.

TURNER, BILLIE LEE, II (1945–)

Billie Lee Turner II helped reinvigorate a science orientation to human-environment relationships, initially by steering cultural and historical geographical topics shared with anthropology into the

subfield of cultural ecology and subsequently by leading the development of land change and sustainability science. Of his scholarly contributions, including the role of geography as a human-environment research endeavor, three deserve special consideration. First, his field research in Mexico and Middle America paved the way for a new understanding of ancient Mayan human-environment relationships by demonstrating the various cultivation and landscape practices employed by this civilization. His work provides the basis by which questions on the rise and fall of the Mayan civilization must be set. Second, he and his students helped develop the induced intensification thesis of smallholder cultivation in the contemporary tropics, demonstrating how outcomes linked to both Boserup and Malthus are possible. This thesis demonstrates how the ambient environment alters the outcomes of different levels of pressures on land use and how household response to these pressures is predicated on a fusion of market and subsistence factors. Third, he has been an international leader in the development of global environmental change and sustainability research, through the lens of what has become land change science. His team of researchers has advanced remote sensing and modeling assessments of tropical deforestation, demonstrating that vulnerability must address a coupled human-environment system and pointing the way toward the research challenge of discovering sustainable land architectures.

Turner earned his PhD from the University of Wisconsin–Madison in 1974. In 1980, he joined the Graduate School of Geography, Clark University, where he remained for the next 28 years, mentoring 40 PhD students and serving as the Higgins Professor of Environment and Society. For several years, he was director of Clark's Graduate School of Geography and the George Perkins Marsh Institute. He served as a fellow at the Center for Advanced Studies in the Behavioral Sciences (Stanford) and was elected to the National Academy of Sciences (1995), American Academy of Arts and Sciences (1998), and Massachusetts Academy of Sciences (2008). In 2008, he became the Gilbert F. White Professor of Environment and Society, School of Geographical Sciences, Arizona State University.

Robert Gilmore Pontius Jr.

See also [Agricultural Intensification](#); [Agriculture](#), [Preindustrial](#); [Cultural Ecology](#); [Human Dimensions of Global Environmental Change](#); [Land Use and Cover Change \(LUCC\)](#); [Malthusianism](#); [Political Ecology](#); [Shifting Cultivation](#); [Sustainability Science](#)

Further Readings

- Turner, B. L., II, & Brush, S. B. (Eds.). (1987). *Comparative farming systems*. New York: Guilford Press.
- Turner, B. L., II, Clark, W. C., Kates, R. W., Richards, J. F., Mathews, J. T., & Meyer, W. B. (Eds.). (1993). *The Earth as transformed by human action: Global and regional change in the biosphere over the past 300 years*. Cambridge, UK: Cambridge University Press.
- Whitmore, T. M., & Turner, B. L., II. (2001). *Cultivated landscapes of native Middle America on the eve of conquest*. Oxford, UK: Oxford University Press.



TYPHOONS

See [Hurricanes](#), [Physical Geography of](#)



TYPGRAPHY IN MAP DESIGN

Typography in maps refers to symbols and signs in maps. Since maps are graphical representation of spatial relationships that essentially reduce the permutations of space into a two-dimensional topological construct, the role of typography is limited to labeling points, arcs, and polygons (referred to as features) with appropriate and efficient form, style, and weight factors.

In 1990, John B. Harley redefined maps as more than mere efficient representations of physical surfaces. Through a postmodernist reinterpretation of map typography, Harley viewed maps as representations of power. Thus, maps have joined the ranks of other graphical pursuits, such as architecture and design, that encounter such ontological



issues. The impact on typography has been evident ever since the stability of ideas, as Plato imagined it, was challenged in the past two centuries with concepts such as semiotics and deconstruction. Ferdinand de Saussure (1857–1913), a Swiss professor of linguistics and a contemporary of Sigmund Freud, Émile Durkheim, Charles Darwin, and Karl Marx, revolutionized the field by introducing the concept of semiotics. The broader epistemological basis for semiotics is contained in structural and poststructural philosophy.

The history of symbols and signs since antiquity has evolved separately in the fields of art, architecture, and cartography, but there are signs of convergence, at least epistemologically.

Since all relevant information cannot be printed on maps, the field of cartography developed a sophisticated ontology. The way the cartographer represented symbols and signs depended on what was viewed as important and appropriately signified the signifier (semiotics). Therefore, the symbol for “north” is interpreted as the direction north, but the orientation of north (up, in most maps) is historically a result of maps mostly constructed as a cultural legacy of the Northern Hemisphere. Therefore, the semiotics of typography is in what it implies and is more complex than functional issues such as what it represents.

With the advent of computer cartography and the possibility of dynamic labeling (through artificial intelligence and haptic manipulations such as “zoom” and “mouse over”), a strict cartographic hierarchy need not be followed; instead, map

typography can be dynamically “programmed” to satisfy a large community of map users. The resulting flexibility does not eliminate the complex power structure that Harvey implied earlier but allows for improved efficiency. With artificial intelligence algorithms, the complex demands on map typography can now be better handled than was possible in the earlier era of analog maps.

Since traditionally, map making and mapping software have usually represented feature-based maps (i.e., maps that contain discrete and finite elements that can be represented by points, arcs, and polygons), the representation of “fields,” or continuous objects, has been neglected. However, the dynamic representation of time and space through digital technology now allows for field-based typography. Examples include traffic and weather simulation, as seen in some geographic information software such as Transmodeler.

Aniruddha Banerjee

See also **Cartography; Harley, Brian; Map Design; Map Visualization**

Further Readings

- de Saussure, F. (1960). *Course in general linguistics* (C. Bally & A. Sechehaye, with A. Reidlinger, Eds.; W. Baskin, Trans.). London: Owen. (Original work published 1916)
- Harley, J. B. (1990). Cartography, ethics and social theory. *Cartographica*, 27(2), 1–23.

U



UNDERDEVELOPMENT

Underdevelopment refers to not only a theory but also an economic process and a condition described by radical views of development. The theory is rooted in structuralist Marxist ideas and is associated with the dependency school of development, which is critical of North-South relations. This entry first gives a description of underdevelopment. It then traces the historical evolution of thinking concerning radical underdevelopment theory, highlighting important thinkers, and offering descriptions of the various iterations of theories of underdevelopment. Finally, important critiques of underdevelopment and the dependency school are discussed, concluding with the state of ideas of underdevelopment today.

The dependency school of thought is commonly understood to be a response to the failure of modernization theories of development in the 1950s and 1960s, notably in Latin America, particularly the agenda of the United Nations Economic Commission for Latin America (ECLA), as well as the crisis of orthodox Marxism. ECLA intellectuals argued that development and underdevelopment are the result of the same process. In contrast to modernization theory of development through comparative advantage in international trade, these scholars argued that the colonial integration of Latin American, African, and Asian economies into the global capitalist

system had led to outward-oriented development dependent on the export of primary sector commodities. This process created a center and a periphery in the global economy; a system in which peripheral economies are systematically disadvantaged not only by the geographic divide in production and trade but also by the lack of technology transfer that would normally occur with the development of a capital goods or value-added industrial sector, where the difference between the value of the factors of production, including labor and capital goods, and the final sale price of a good, accrues to the contributor. Developed largely by Third World intellectuals, it challenged the ideas of modernization theory dominant in the 1950s and 1960s, offering a counternarrative to First World narratives of history, economics, and development.

Origins and Evolution

Underdevelopment refers to an economic condition characterized by undiversified primary sector production for export (usually agriculture), wide income disparities typified by a small upper class where wealth is concentrated, and a small internal market. The state of underdevelopment, in which poorer nations have market relations with industrialized countries, must be distinguished from those without development, which do not have market relations with industrialized countries. Discussions of underdevelopment typically



The Crocodile River flows through the biggest slum of Freetown, Sierra Leone: Kroo Bay.

Source: Ines Gesell/iStockphoto.

focus on the spatial scale of the individual state and its trade relations with developed economies. Two categories of underdeveloped states are distinguished: (1) those that were nation-states before they were integrated into the world economy and (2) those that transitioned from colonies into states at independence but without any change in their social or economic relationships with their ex-colonial administrators. In either case, underdevelopment is a historical legacy of colonialism and a process directly attributed to the historical spread of capitalist structures: The center-periphery (or metropolis-satellite) relations that were forged during colonialism resulted in formal colonies depending on developed countries to purchase their raw materials. Thus, any growth or development in countries dependent

on raw materials depends on expansion of the market in developed countries.

Radical underdevelopment theory and the dependency school of development have their origins in the early 1950s. As early as 1950, the Argentine economist Raúl Prebisch, head of ECLA, recognized the inadequacy of the conventional global division of labor, in which regions such as Latin America produced raw materials and commodities for export to developed regions such as North America and in turn received manufactured goods from these regions. Prebisch argued that the dependence on commodities and raw materials exports was at the root of the poor economies' problems and that capital accumulation was impossible under those conditions because it was inhibited by disadvantageous terms



of trade, that is, exports of low-priced foods and raw materials and imports of expensive manufactured goods. In response to this realization, Prebisch promoted a new strategy for Latin American economies. The strategy was based largely on protectionism and import substitution industrialization, but it also retained a focus on the export of raw materials and food commodities. Even as integration into the world economy was seen as detrimental to the development of Latin American economies by ECLA, the argument for continued focus on raw materials export was that it would finance the importing of capital goods, supporting economic growth through technology transfer. Governments would play an active role in implementing the ECLA strategy.

After a period of growth in Latin America in the 1950s, nation-states participating in the ECLA program faced economic stagnation attributed to the failure of the ECLA strategy. It essentially proved overly ambitious and inadequate for the problems facing Latin America and other poor regions, as it did not attack structural disadvantages but, instead, worked from the assumption that industrialization would fix other obstacles of development in the developing economies. In fact, import substitution industrialization fell short of producing a favorable balance of trade for underdeveloped countries because it neglected the diversification of the export sector from raw materials and commodities.

The failure of the moderate ECLA strategy prompted more radical thinking on development in the 1960s among Latin American intellectuals. At the same time, Latin America was experiencing a crisis of orthodox Marxism. The Cuban and Chinese revolutions inspired the theory that societies did not have to pass through the requisite stages of bourgeois revolution and then socialist revolution, as Marxist theory asserted; instead, they could proceed directly to socialist revolution without the evolution of the bourgeoisie. This neo-Marxism also provided the basis for the radical critiques of the ECLA program and shifted the thinking of Latin American development theorists in the 1960s from economic structures to inclusion of the social implications of the center-periphery division of labor.

Andrew Gunder Frank developed key critiques of the modernization school of development that

significantly contributed to the development of dependency theory and thinking about the processes and implications of underdevelopment. First, modernization theory is based on the experiences of First World countries, which never experienced colonization—a process that effectively set in place the structures of Third World economies. Instead, modernization theory attributes underdevelopment to internal factors such as culture or a lack of investment. Frank offered an external explanation in place of the internal one, with the reasoning that societies such as China were advanced before experiencing colonization, which effectively reversed these societies' development. Frank further theorized the mechanisms of underdevelopment, proposing a metropolis-satellite model in which complex systems of economic surplus extraction and transfer span the globe, flowing from Third World economies to First World countries. These critiques led Frank to a series of hypotheses that theorize “the development of underdevelopment”—a famous term coined by Frank that signifies underdevelopment as a historical process rather than a normal or inevitable condition of Third World societies. Essentially, Frank hypothesized that satellites that had the closest historical relationships to metropolises are the most underdeveloped and that there is a direct correlation between their relationship with the metropolis and the extent of their underdevelopment. Furthermore, reintegration of satellites into the economic system after a crisis reverses any previous industrial development those countries might have achieved. Frank also played a key role in communicating and disseminating the ideas of radical underdevelopment theory and the dependency school to the English-speaking world, where it resonated with the ideas of radical young researchers who were in the midst of overturning their own establishment.

Cardoso and Faletto added nuances to the radical underdevelopment theory in the early 1970s, further critiquing modernization theory's modern-backward dichotomy and adding internal factors such as national-scale class relations to the external explanation. They argued that the dominant socioeconomic class imposes through political action a set of social relations that is most in its own economic interests and that elites' relationship to international metropolises



facilitates the flow of wealth toward the metropolises. In other words, the internal economic relations between the classes, as well as elites' ties to the core economies, actually limit political action and thus restrict social change. Hence, polarization between the classes can occur internationally, regionally, as well as nationally—the result of the historic evolution of capitalism; however, how it has played out in each country depends on the economic and class structure of the specific country and the elites' relationships. The evolution of oppositional ideas and theories of development was not restricted to Latin America; scholars such as Samir Amin in the early 1970s drew from the experience of African societies and their struggles for sovereignty, creating further iterations of theory under the rubric of neocolonialism.

Critiques of Underdevelopment and the Dependency School

Critiques of the radical underdevelopment theory and the dependency theory (often considered synonymous) address a variety of issues. First, the primary unit of analysis used by *dependistas* (early proponents of the dependency theory) is the nation-state, which was not the sole actor and is arguably no longer the primary actor in economic globalization. Instead, transnational corporations and international institutions bring with them distinct dynamics of domination, even as they continue the work of extracting economic surplus from underdeveloped countries. Second, the dependency school cannot explain Third World capitalist development; in fact, it effectively ignores it. A third critique of the underdevelopment and dependency theory is its strict developmentalist approach, arguing that societies had to go through some kind of socialist revolution followed by a process of autonomous development. Another important critique of underdevelopment spoke to its oversimplification of metropolis-periphery relations: It did not acknowledge that even as the core economies extracted surplus from Third World countries during the process of underdevelopment, the situation was often much more complex in that capital often flows in the other direction as well, that is, from the metropolis to the periphery. For example, transnational corporations invest in

industrialization and production infrastructure since they have an interest in promoting development as it opens new markets for their goods and services. The problem of dependency persists, however, since developing countries depend on developed countries for technology and investment. Put in other terms, development and dependence exist simultaneously, and the exact manifestations are varied and complex, in contrast to the simple scenario presented by dependency theorists.

Current State of Underdevelopment and the Dependency School

Although theories of underdevelopment and dependency are often considered today to be defunct or obsolete, it must be recognized that the evolution of thinking on underdevelopment took place in the context of the Cold War. The Cold War was a period of instability and turmoil in which intellectual opposition was part of wider political and social opposition movements that fed into the development of oppositional thinking that is still relevant today as underdeveloped societies continue to struggle against foreign economic, social, and cultural domination. Contemporary issues, including the foreign debt crisis, only reinforce the argument that the basic precepts of underdevelopment still hold and can be further developed to integrate new developments and phenomena of contemporary globalization. Furthermore, scholars such as Milton Dos Santos in the late 1990s pointed out that underdevelopment and dependency theories are still given much scholarly attention and underdevelopment discourses are still widely used, especially in Third World intellectual circles. Others argued that the ideas proposed by scholars of oppositional theories in the 1960s and 1970s are still relevant to today's world as part of a larger movement to revitalize the inclusion of oppositional narratives of economics and history, especially in light of the contemporary dominance of neoliberal ideas.

Heather R. Putnam

See also Colonialism; Dependency Theory; Developing World; Development Theory; Import Substitution



**Industrialization; Marxism, Geography and;
Modernization Theory; Neocolonialism; Uneven
Development; World-Systems Theory**

Further Readings

- Cardoso, F., & Faletto, E. (1979). *Dependency and development in Latin America*. Berkeley: University of California Press.
- Frank, A. (1967). *Capitalism and underdevelopment in Latin America: Historical studies of Chile and Brazil*. New York: Monthly Review Press.
- Slater, D. (2004). *Geopolitics and the post-colonial: Rethinking North-South relations*. Oxford, UK: Blackwell.
- So, A. (1990). *Social change and development: Modernization, dependency and world system theories*. Newbury Park, CA: Sage.



UNEVEN DEVELOPMENT

Uneven development is a general term for the measurement and explanation of spatial patterns of variation in the quality of life among human beings, or in a more restricted sense within Marxist theories, the concept is a fundamental and inescapable part of capitalism. The definitions of *development* are varied and contentious. Even given a particular definition, the patterns observed will vary widely depending on the chosen spatial scale. It is more challenging still to uncover the causes of any pattern and to situate these causes within a theory with explanatory power for larger areas and longer time periods. This entry discusses the definition and measurement of uneven development, the problem of scale, neo-Marxism and neoliberalism within the context of uneven development, and the subaltern and current trends.

Geographers and other social scientists have tended to approach uneven development through the lens of theories that, despite their varied emphases, overlap considerably: world-systems theory, dependency theory, neoliberalism, and, especially, neo-Marxism. Each approach grapples

with the question “To what degree is uneven development an inevitable, even desirable, consequence of the spatially unequal comparative advantages inherent in a global capitalist system?” Another question is, “To what degree is uneven development a consequence of physical geographic endowment, and to what degree is it due to the chance contingencies of history?” Since the refutation of environmental determinism in the 1920s, this second question is asked less often; it is now generally taken for granted that uneven development is a complex intertwining of both factors. The subfield of cultural ecology, influenced by anthropologists such as Eric Wolf, has continued to examine the particulars of this intertwining, as have geographers such as Philip Porter and Eric Sheppard and, for a broader audience, Jared Diamond.

Work since the 1990s has tended to question assumptions regarding structure and agency and has inquired how spatial disparities may be mitigated, or redefined, by individuals or groups often considered its passive victims—the so-called subaltern. Postcolonial and Marxist geographers observe how neoliberal experiments have played out in various regions of the world and have reworked some Marxist ideas to better explain uneven development in the rapidly globalizing 21st century.

Defining and Measuring Uneven Development

Except with case studies for the smallest areas, much geographic analysis depends on the availability of spatial data. The most commonly used measure is gross national product (GNP)—the total final output of goods and services produced by an economy—and its derivatives, especially GNP per capita. While in some cases, this may be quantified for subnational regions or supranational blocs, by definition GNP privileges the nation-state scale. GNP may be considered as a static measure (e.g., to compare “more developed” and “less developed” nation-states) or as a dynamic rate of change (e.g., to identify “rapidly developing” nation-states).

Even if we accept “income” as an appropriate proxy for “development,” there are many practical problems with this measure, such as its failure



to capture the informal economy, which is often considerable in developing nations. Another option is the Human Development Index (HDI), popularized by the United Nations Development Program, which combines life expectancy at birth, adult literacy, mean years of schooling, and income sufficiency for an adequate quality of life.

Some studies use other variables such as human right indices to analyze development. Most, however, assume that income is a fairly reliable proxy. This assumption may be explicit, as in studies based on world-systems theory, or implicit, as in studies based on capital flows and in most feminist work. While they may agree on little else, Marxist geographers and neoliberal advocates both tend to rely on income as a useful indicator. The few who contend it directly are those, often postcolonialists, who question the entire idea of development.

On occasion, “development” has been examined as a sort of industry unto itself. The Colombian anthropologist Arturo Escobar has shown how the identification, professionalizing, and institutionalizing of development “problems” by rich nations and their allies in poorer ones increase the power of both at the expense of those they claim to serve. Escobar advocated indigenous, autonomous social movements and localized, place-based strategies of development, a strategy compatible with certain geographic methods such as participatory research mapping.

The Problem of Scale

In one way or another, analyses of development study human beings, individually or grouped at various spatial scales. It could be argued that ever-increasing mobility makes it less important to map and analyze people, and groups of people, as if they were fixed points in space. However, three facts work against this argument. First, labor and, to a lesser degree, capital and ideas are less mobile than is often assumed; nation-state boundaries are still generally strong barriers, and those who do migrate are often considered “temporary” workers without full rights in their host nations. Second, many geographers analyze “space” in a sense that goes beyond mere coordinates on the Earth’s surface; for example, Ashraf Ghani sees space as an

“arena of represented practices,” where social constructions of gender may underscore less apparent inequalities of development. Third, some geographers (often “transnationalists”) study mobility itself as a vector for both amelioration and worsening of uneven development at different scales.

At the scale of nation-state blocs, the groundwork for much geographic study of uneven development was laid by world-systems theory, formulated in the 1970s by the sociologist Immanuel Wallerstein. World-systems theory examines the economic conditions of nation-states within the global system, which in its most basic form is seen as having a core (the most developed nations, with 20% of the world’s population but 80% of its GDP), a semiperiphery (Mexico, the Newly Industrializing Countries, and the “BRICs,” i.e., Brazil, Russia, India, and China), and a periphery (including Africa, the poorer parts of Asia, Oceania, Latin America except for Mexico and Brazil, and the Caribbean). This world system originated in 16th-century Europe, when the core was England, Northern France, and the Netherlands, although its membership has changed over time. A global labor pool is linked through commodity chains, and in the periphery, labor is generated through some threat of force. Even if shirts are made in the Honduras of cotton from India, the patent holders, the designers, the marketers, and the ultimate controllers of labor and capital investment are mainly in the core. In these and other ways, world-systems theory supports Marxist assertions.

World-systems theory is well suited for examining supranational political-economic entities in the core (such as the European Union), as well as international trading blocs, such as the North American Free Trade Agreement (NAFTA), which facilitate the flow of goods and capital in and out of the core. It helps explain why the nation-state is becoming less important in the core (e.g., the United States now shares economic dominance with countries such as Japan) and in the periphery (where ethnic ties often dominate, reinforced through 19th- and 20th-century European colonial practices), while the nation-state continues to be strong in the semiperiphery (in large-population “emerging markets” such as Mexico).



Geographic studies directed toward other scales are consequently less top-down or Eurocentric than world-systems theory. Some multiscale studies have their roots in dependency theory, which acknowledges relationships between local elites and dependents—even between village leaders and other villagers—up to and including global nation-state blocs. At each level, unequal terms of trade lead to self-perpetuating unequal exchange, another basic tenet of Marxism.

Subnational regional patterns of uneven development have been examined throughout the world, including in Mexico (the indigenous south vs. the developed north), England (the richer southeast vs. the poorer north), and China (the industrialized coast vs. the impoverished interior). The Brazilian economist (and later president) Fernando Cardoso has influenced many such studies. Often, more developed regions are centered on urban centers of finance, academic research, or government, themselves often located in former or current places of commercial trade (e.g., ports or important international borders) or colonial loci of centralized bureaucracy.

The Marxist geographer Neil Smith (2008) wrote that “city building has become a motive geographical force of capital accumulation, a source of massive surplus value production” (p. 263), especially in Asia, in part fueled by massive rural-to-urban migration. Recent urban geography work builds on earlier studies of uneven development (many contrasting inner cities and suburbs) to focus on alternative models in developing nations as well as on gentrification.

Neo-Marxism, Neoliberalism, and Uneven Development

The writings of Marx contain little about the spatial implications of the theories he espoused, but throughout the 20th century and into the 21st, Marxist geographers developed a large body of literature on the subject. To explain uneven patterns of development, these writers have departed from the teleological predictability that infuses orthodox Marxism. Instead, they emphasized how Marxism regards the global capitalist system as a zero-sum game, and consequently, we should expect to find entrenched spatial concentrations

of “winners” and “losers.” This idea is paralleled in world-systems theory, which argues that increasing linkages tend to perpetuate inequalities rather than ameliorate them, as neoliberalist thinkers contend. Also, as in world-systems theory, the nation-state is seen as having played a key role in protecting and expanding systems of surplus extraction.

Since the 1980s, Neil Smith and David Harvey have been the most prominent neo-Marxist geographers. In their works, capitalism seeks to equalize the conditions of production over space while simultaneously taking advantage of, and so accentuating, those differences—as capital “seesaws” between the developing world (the source of cheap raw materials and cheap labor) and the developed world. This view helps explain recent phenomena such as the global rise in remittances and the decrease in food security in the late 2000s, as once self-sufficient countries such as Mexico and Nigeria devote ever-increasing amounts of land and labor to the production of foodstuffs for export.

Spatial patterns of uneven development are perpetuated because capital, even in the era of instantaneous global financial transactions, still seeks to “park” itself somewhere; capital can only circulate if some part of it does not. This process can be analyzed at many scales. The geographer Don Mitchell analyzes specific small landscapes as loci of regional and global inequalities. A strawberry farm in California, for example, is a fixed node in space where capital is invested; the products of that landscape, and the landscape itself, hide the unjust labor conditions that allow it to exist. Others examine subnational regions, showing how, for example, the continued importance of face-to-face contacts influences corporate decisions. At the world-system scale, Federal Reserve Chair Ben Bernanke suggested that money generated during the real estate bubble in Japan in the 1990s (during a downturn in southeast Asia) eventually found its way into the U.S. debt market, thus helping set the stage for the economic collapse of 2008.

The global slowdown of the early 1970s, along with the expanded foreign debt of semiperipheral countries such as Mexico and Thailand in the 1980s, set the stage for neoliberal experiments in the 1990s. Neoliberal theory contends that uneven



development can be ameliorated by removing state regulation and barriers to free flow of goods, capital, and (sometimes) labor. Marxist geographers such as David Harvey argue that this has made some countries more internally uneven than before, while separating the semiperiphery into two groups: (1) those that have generally benefited (e.g., China and India) and (2) those that have not (e.g., Mexico).

The neoliberal experiment has faced practical difficulties, including the following: (a) it may be perceived as a disguise for accelerated capitalist accumulation to benefit developed nation-states and local elites, (b) the nation-state bureaucracy and power structure often remain as strong as before, and (c) the “temporary” hardships produced by “structural adjustments” have led to many rightist governments of the 1990s being replaced by leftist ones in the 2000s. In the 2000s, most neoliberal advocates have recognized these deficiencies while remaining optimistic that the underlying principles are sound.

The Subaltern and Current Trends

To what degree do the causes of uneven development come from privileged, centralized decision makers (e.g., supranational organizations such as the World Bank, rich nation-states, and transnational corporations), and to what degree can they be mitigated by the less transparently powerful “subaltern” entities (e.g., poor nation-states, “progressive” nongovernment organizations, and individuals)? As Marxism is rooted in the potential for dynamic disequilibrium and revolt in human societies, neo-Marxist thought on uneven development has found commonalities with postcolonialist and post-structuralist thinkers such as Homi Bhaba, who criticize both world-systems theory and dependency theory for their failure to acknowledge the power of the subaltern in intellectual, cultural, and sometimes political realms.

In part, such criticism is a reaction to the assumptions of modernization theory, which in geography grew out of Eurocentric studies of innovation diffusion in the 1960s. Many geographers now recognize how the Internet, for example, permits relatively low-cost links to be formed between people in the global periphery

and global NGOs; others, however, point out that even Internet access is spatially uneven.

One implication of this turn from Eurocentric attitudes is a revised understanding of history. Eric Wolf showed how, well before the 16th-century European global expansion, multiscale spatial inequalities in development existed in Asia, Africa, and the Americas through the buildup of hegemonic political and military systems and long-distance trade linkages.

“Development” can be thought of as an unfolding of something that was in some sense there to begin with (this is its etymological root meaning) or instead as the intervention of an outside force on a region and its people. Geographers today consider local actions and global processes as mutually constitutive. While flexible accumulation and globalized commodity chains and capital flows allow development to happen in some places where it had not occurred before (e.g., Ireland and parts of India and China), it still must happen in some places and not in others.

Discussion of uneven development continues among neo-Marxist geographers, as well as others who explore the complexities and contradictions of postcolonial globalization. At the nation-state scale, these complexities include the incomplete adoption of neoliberal tenets by countries such as Mexico (where deregulation of land and water markets has been contested) and the perpetuation of extractive and elite-benefiting practices by some postcolonial governments (e.g., Indonesia) with roots both in European colonialism and before it. Geographers of uneven development are well positioned to analyze the global economic downturn of the late 2000s, wherever it tends to reduce spatial inequality, so as to “lower all boats” equally while maintaining patterns, or to exacerbate inequalities as capital flees from a periphery now with reduced options for local and regional development.

John Kelly

See also **Dependency Theory; Development Theory; Gross Domestic Product/Gross National Product; Harvey, David; Justice, Geography of; Marxism, Geography and; Modernization Theory; Neoliberalism; Peet, Richard; Radical Geography; Smith, Neil; Social Justice; Transnational Corporation; Underdevelopment; World-Systems Theory**



Further Readings

- Harvey, D. (2006). *Spaces of global capitalism: Towards a theory of uneven development*. London: Verso.
- Klak, T. (2004). Geographies of power in the post-cold war world system. In D. Janelle, B. Warf, & K. Hansen (Eds.), *WorldMinds: Geographical perspectives on 100 problems* (pp. 9–14). Dordrecht, Netherlands: Kluwer.
- Peet, R., & Hartwick, E. (1999). *Theories of development*. New York: Guilford Press.
- Smith, N. (2008). *Uneven development: Nature, capital, and the production of space* (3rd ed.). Athens: University of Georgia Press.
- Wolf, E. (1982). *Europe and the people without history*. Berkeley: University of California Press.



UNITED NATIONS

The United Nations (UN) is an international organization created in the aftermath of World War II to promote peace and prosperity among and within nations and states. Its formal existence began on October 24, 1945, with the ratification of the UN Charter by China, France, the Soviet Union, the United Kingdom, the United States of America, and other signatories.

The UN is generally considered to be the successor to the League of Nations, which was established in 1919 to promote international cooperation, peace, and security. As the league's international role faded in the 1930s and 1940s, various national governments agreed to form a new organization. They met in San Francisco in 1945 to draw up the UN Charter. As of December 2009, the UN had 192 member states; Montenegro (which joined in 2006) is its newest member.

The charter is the constitution of the UN, detailing rights and obligations of member states and establishing and describing UN organs and procedures. According to its charter, the purposes of the UN are the following:

- (1) to maintain international peace and security . . .
- (2) to develop friendly relations among nations based on respect for the principle of equal rights and self-determination of peoples . . .

(3) to achieve international cooperation in solving international problems of an economic, social, cultural, or humanitarian character, and in promoting and encouraging respect for human rights and for fundamental freedoms . . .

(4) to be a centre for harmonizing the actions of nations in attaining these common ends. (UN, 2005, p. 5)

The following principles guide the work of the UN (2004, p. 5):

1. All its members have sovereign equality.
2. All members are to fulfill in good faith their Charter obligations.
3. They are to settle their international disputes by peaceful means.
4. They are to refrain from threat or use of force against any other state.
5. They are to give the UN every assistance in any action it takes in accordance with the Charter.
6. Nothing in the Charter is to authorize the UN to intervene in matters that are essentially within the domestic jurisdiction of any state.

Countries that accept the obligations and responsibilities entailed in the UN Charter may apply for membership; the General Assembly admits new members on the recommendation of the Security Council. The charter also allows for expulsion of a member, but this has never occurred.

The UN has six principal organs: (1) General Assembly, (2) Security Council, (3) Economic and Social Council, (4) Trusteeship Council, (5) International Court of Justice, and (6) Secretariat. There are also numerous UN programs and funds (e.g., UNICEF [United Nations Children's Fund], UN-Habitat, UNDP [United Nations Development Programme]), specialized agencies (e.g., UNESCO [United Nations Educational, Scientific, and Cultural Organization], WHO [World Health Organization]), and thousands of nongovernmental organizations associated with the UN in a variety of ways.

These UN organs are heavily dependent on data, methods, theories, topics and practices, many of them specific to the field of geography.



United Nations headquarters in New York City

Source: Steve Cadman/Wikimedia Commons.

Like the discipline of geography, the work of the UN is broad in scope but integrative in nature, with an emphasis on education and capacity building. The work requires definition and understanding of place and its dimensions.

Since the UN is run for and by the people of the world, data come from all over the world, are qualitative and quantitative in nature, and are subject to technological change. For example, originally, country tabulations of censuses used to be collected in filing cabinets, but today sophisticated

databases, ETL (extract, transform, and load) processes, and Web-based exchange with statistical offices are common. The demographic data collected by the UN, for example, are used for global population projections—the only such projections in the world still regularly produced based on a consistent set of methods, tools, and data. These data are used for a worldwide demographic assessment of past, current, and future demographic trends.

Cartography is also crucial to the work of the UN and has undergone significant technological changes. For example, maps are essential to peacekeeping missions as well as to aid organizations, which need to know where to distribute food for the needy or where to vaccinate sick children. Often, the UN itself is the principal authority over the definition, collection, and distribution of worldwide data on various topics (see, e.g., the Principles and Recommendations for Population Housing Censuses [UN, 2008] or the Technical Reference Manual for the Standardization of Geographical

Names [UN, 2007]). Several UN entities provide technical expertise, logistical support, and material aid intended to strengthen the capabilities of member nations in these fields.

The UN Charter lists maintaining international peace and security as its primary goal. The UN monitors and assesses global political developments and actively engages in peace-making and preventive diplomacy. The charter also entails work on economic and social development and humanitarian affairs, all of which



involve geographical matters. Sustainable development, climate change, urbanization, and HIV/AIDS are among the core issues on the UN's current agenda. At the 2000 Millennium Summit, member states reaffirmed their support for the UN and declared it as the focal point through which all governments should seek to realize common goals of peace, security, and development. The eight Millennium Development Goals, supported by a number of specific and attainable targets, were agreed on as the framework to achieve common development goals: (1) the eradication of poverty; (2) universal primary education; (3) the promotion of gender equality; (4) reductions in child mortality; (5) improvements in maternal health; (6) combating HIV/AIDS, malaria, and other diseases; (7) ensuring environmental sustainability; and (8) developing a global partnership for development.

The work of the UN is ultimately defined by the world's people. Their governments vote on resolutions, in the General Assembly or the Security Council, affecting lives all over the world. Over the years, nongovernmental organizations have also become partners in the day-to-day activities of the UN, forming a "valuable link to civil society" (UN, 2004, p. 13). The staff of the UN (generally referred to as the UN Secretariat) come from all over the world. Personnel are recruited to meet certain region- and country-specific quotas; they speak at least one of the official six UN languages and have taken an oath to be solely responsible to the UN and not to any government or other authority external to the organization. Although much of the work of the UN is political, the critical inputs are often scientific, based on common data, methods, theories, and topics, many of which are intimately related to the field of geography.

Sabine Henning

Author's note: The views and opinions expressed in this paper are those of the author and do not necessarily represent those of the United Nations.

See also [United Nations Conference on Environment and Development](#); [United Nations Environmental](#)

Summits; United Nations Environment Programme (UNEP)

Further Readings

- Fasulo, L. (2004). *An insider's guide to the UN*. New Haven, CT: Yale University Press.
- United Nations. (2004). *Basic facts about the United Nations*. New York: Author.
- United Nations. (2005). *Charter of the United Nations and status of the International Court of Justice*. New York: Author.
- United Nations. (2007). *Technical reference manual of the standardization of geographical names* (Sales No. E.07.XVII.5). New York: Author.
- United Nations. (2008). *Principles and recommendations for population and housing censuses* (Rev. 2; Sales No. E.07.XVII.8). New York: Author.

UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT

The United Nations (UN) Conference on Environment and Development was convened between June 3 and 14, 1992, in Rio de Janeiro, Brazil, 20 years after the first global environmental conference in Stockholm. The primary focus of the Rio conference was to reconceptualize the global development agenda to include the sustainable use of natural resources. World leaders attempted to ameliorate the world's most pressing environmental issues by agreeing on a comprehensive strategy. This strategy aimed to meet current socio-environmental needs while ensuring a healthy and viable world for future generations. The Rio Summit boasted unparalleled representations from 172 governments, including 108 heads of state, and the participation of 1,400 nongovernment organizations (NGOs).

The 1984 Brundtland Commission (named after the chair, Norwegian Prime Minister Gro Harlem Brundtland) laid the foundations of the



Rio Summit. The commission published a provocative and widely circulated document titled *Our Common Future*. Lauded by the international environmental community, it derogated the world's failure to achieve development goals sustainably and outlined visionary actions for reversing anticipated environmental catastrophes. This document helped propel international support among world leaders for the Rio Summit and generally outlined the topics for discussion.

The main plan of action developed and adopted by the 178 governments at the Rio Summit is known as Agenda 21. It is a comprehensive blueprint for global, national, and local actions by UN organizations, governments, and major environment and development stakeholders. Ten years later, the World Summit on Sustainable Development (WSSD), held in Johannesburg, attempted to affirm UN commitments to the "full implementation" of Agenda 21, alongside the achievement of the Millennium Development Goals and other international agreements.

One of several other important achievements of the conference was agreement on the UN Framework Convention on Climate Change (FCCC), which aimed at stabilizing greenhouse gas concentrations at a level that would prevent dangerous interference in Earth's atmosphere. The FCCC later led to the Kyoto Protocol, a legally binding agreement among countries to reduce carbon emissions. Another key agreement adopted at Rio was the Convention on Biological Diversity. It established three principal goals: (1) conservation of biological diversity, (2) sustainable use of its components, and (3) fair and equitable sharing of the benefits from the use of genetic resources.

The Rio Summit was sharply criticized for its failure to include the regulation of businesses, financial institutions, and transnational corporations in Agenda 21 despite their central role as carbon emitters. Furthermore, several accords were left unmet after Rio, largely due to the United States' unwillingness to sign key treaties.

Presaging a growing civil society influence in UN covenants, 18,000 representatives attended a parallel summit specifically for NGO participants (a number that has swelled at consecutive UN summits). However, civil representation remained

geographically unbalanced, and civil society organizations remained ancillary collaborators to states and largely remained distant from the central politics shaping Agenda 21.

*Anna Carla Lopez, Emma Norman,
and David L. Carr*

See also [Climate Policy; Environment and Development; Sustainable Development; United Nations; United Nations Environmental Summits; United Nations Environment Programme \(UNEP\); World Summit on Sustainable Development](#)

Further Readings

Carr, D., & Norman, E. S. (2008). Global civil society? The Johannesburg World Summit on Sustainable Development. *Geoforum*, 39, 358–371.

World Commission on Environment and Development. (1987). *Our common future*. Oxford, UK: Oxford University Press.



UNITED NATIONS ENVIRONMENTAL SUMMITS

The United Nations (UN) has laid the foundation for heightened global environmental awareness since the 1970s. A central approach to address these wide-ranging issues, and bring them to the forefront of the international agenda, is through high-level environmental conferences of national leaders. These summits have provided space for critical dialogue among world leaders, government representatives, and civil society. They have become the arena in which environmental objectives are set and plans of action written and adopted. Three major summits have convened since the 1970s.

The first of the global summits was held from June 5 to 15, 1972, in Stockholm, Sweden. It was the progenitor of the Rio Summit and the Johannesburg Summit and marked a historical turning point in terms of political and public recognition of environment and development issues at a global scale. The Stockholm Summit laid the basis



for international environmental cooperation and led to the creation of the United Nations Environment Programme and related global and regional environmental-monitoring networks. It also paved the way for civic engagement in the global arena. However, the actual number of civilian participants was low by contemporary standards, with fewer than 300 nongovernmental organizations (NGOs) attending.

Following Stockholm, the Brundtland Commission published a provocative and widely circulated document in 1984 titled *Our Common Future*. Lauded by the international community, it railed against the world's inability to achieve development goals sustainably and outlined visionary actions for preventing environmental catastrophes. It rallied international support among world leaders for another global environmental conference and generally outlined the topics for discussion.

The subsequent global conference was the 1992 United Nations Conference on Environment and Development (Earth Summit), held in Rio de Janeiro. By the time of the Rio Conference, the global environmental movement had gained momentum, and political will on behalf of governments to address environmental issues had grown substantially. Fourteen hundred NGOs were officially registered, and 18,000 representatives attended a parallel summit for NGOs. The main plan of action developed at the Rio Earth Summit is known as Agenda 21. It was adopted by 178 nations and is an all-inclusive outline of actions to be taken at all scales by UN organizations, governments, and key groups in all areas in which humans affect the environment.

The most recent of the UN global environmental summits was the World Summit on Sustainable Development (WSSD), held from August 26 to September 4, 2002, in Johannesburg, South Africa. Its main objective was to reinforce an intergovernmental commitment to sustainable development and natural resource use. It also took stock of developments since Rio. More than 20,000 participants from governments and NGOs, the private sector, and the scientific community participated. The large number of unmet accords inherited from the 1992 Rio Summit called for a novel approach to include civil society in global agreements and action plans:

the UN Stakeholder Forum Implementation Conference (IC). The IC was designed to mobilize stakeholder participation and facilitate the implementation of commitments established in Rio as embodied in Agenda 21.

While the UN summits have received increasing attendance and media recognition, concrete results have consistently fallen short of international agreements. Consistent summit shortcomings, leading to a sense of “summit fatigue,” shifting geopolitical coalitions, and struggling financial markets, will continue to challenge the accomplishment of summit accords.

*David L. Carr, Emma S. Norman,
and Anna Carla Lopez*

See also Civil Society; Environment and Development; Sustainable Development; United Nations Conference on Environment and Development; United Nations; United Nations Environment Programme (UNEP); World Summit on Sustainable Development

Further Readings

- Carr, D. L., & Norman, E. S. (2008). Global civil society? The Johannesburg World Summit on Sustainable Development. *Geoforum*, 39, 358–371.
- Morphet, S. (1996). NGOs and the environment. In P. Willetts (Ed.), *The conscience of the world: The influence of non-governmental organizations in the UN system* (Vol. 35, pp. 116–147). Washington, DC: Brookings Institution Press.
- Willetts, P. (1996). From Stockholm to Rio and beyond. *Review of International Studies*, 22, 57–80.



UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP)

The United Nations (UN) Environment Programme (UNEP) was created by UN General Assembly resolution 2997 (XXVII) on December 15, 1972, to act as the global and regional voice



for environmental policy within the UN system. This action followed the recommendation of the June 1972 UN Conference on the Human Environment, held in Stockholm, Sweden. The UNEP Secretariat was established in Nairobi, Kenya, and is headed by an executive director, who also serves as UN Under-Secretary-General. The executive directors included Maurice Strong (1973–1975), Mostafa Tolba (1975–1992), Elizabeth Dowdeswell (1993–1998), Klaus Toepfer (1998–2006), and, most recently, Achim Steiner (2006–present). The UNEP is funded by trust funds and funds allocated by the UN regular budget, by special earmarks, and by a voluntary Environment Fund. The largest contributors to the Environment Fund are the United Kingdom, Germany, the United States, and the Netherlands. There is a professional staff of around 500 working at the UNEP and a total of almost 1,000 employees. Several of the professional staff members are nationals from the United Kingdom, the United States, Germany, France, the Netherlands, Canada, and Japan, as well as Kenya. In addition to its Nairobi headquarters, the UNEP has regional offices in Washington, D.C., New York, Mexico City, Brasilia, Geneva, Brussels, Vienna, Moscow, Bangkok, Beijing, Cairo, Addis Ababa, and Manama (Bahrain). There are several additional liaison offices, division offices, and outposted offices around the world.

The UNEP's mandate is to coordinate the development of environmental policy consensus by keeping the global environment under review and bringing emerging environmental issues to the attention of governments and the international community for action. Its mission and objectives have been strengthened by several actions taken since the early 1990s. These include Agenda 21, adopted by the 1992 UN Conference on Environment and Development; the 1997 Nairobi Declaration on the Role and Mandate of the UNEP; the 2000 Malmo Ministerial Declaration and the UN Millennium Declaration; and the recommendations related to international environmental governance approved by the 2002 World Summit on Sustainable Development and the 2005 World Summit of the UN. The UNEP has five priority work areas: (1) environmental assessment and early warning, (2) development and implementation

of policy instruments, (3) enhanced coordination with environmental conventions (treaties), (4) technology and knowledge transfer, and (5) special support for Africa.

The UNEP is also one of three implementing agencies of the Global Environment Facility (GEF), along with the UN Development Programme and the World Bank. The GEF was set up to assist developing countries and those with economies in transition to pay for the incremental costs of measures and technologies designed to achieve global environmental benefits in six areas: (1) climate change, (2) ozone layer protection, (3) biological diversity, (4) international waters, (5) land degradation, and (6) persistent organic pollutants. This program, based in Washington, D.C., has provided more than \$7.5 billion in grants from donor countries for more than 2,000 projects in more than 165 countries since 1991 and has leveraged more than \$30 billion in cofinancing. It is also the financing mechanism for a few of the environmental conventions that are listed below.

The UNEP hosts several environmental convention secretariats, most of which are located outside Kenya. Among these are the Ozone Secretariat and the Montreal Protocol's Multilateral Fund; the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); the Convention on Biological Diversity; the Convention on the Conservation of Migratory Species; the Basel Convention on the Transboundary Movement of Hazardous Wastes; the Rotterdam Convention on Prior Informed Consent (for international trade in banned or severely restricted chemical products); the Stockholm Convention on Persistent Organic Pollutants; and six Regional Seas Conventions and Action Plans. It also established the Intergovernmental Panel on Climate Change (IPCC), along with the World Meteorological Organization (another UN agency based in Geneva). The IPCC publishes special reports on topics relevant to the implementation of the UN Framework Convention on Climate Change. In 2007, the IPCC won the Nobel Peace Prize, which was shared with the former U.S. Vice President Al Gore Jr., for its work over the past two decades to build up and disseminate greater knowledge about anthropogenic climate change and to lay the foundations for the measures that



are needed to counteract such change. The UNEP first called for the negotiation of a climate change convention in 1985, which led to international agreements in 1992 and 1997.

Important accomplishments of the UNEP have been achieved in six areas. First, and most fundamental, are stronger international arrangements to enhance global environmental protection and security. Second, it has conducted periodic assessments and made forecasts to support decision making and international consensus on the main environmental risks and the responses to them. Third, it has provided support for more effective national and international responses to environmental risks, including policy advice to governments, multilateral organizations, and others to strengthen environmental protection and incorporate environmental considerations into the sustainable development process. Fourth, it has enabled a more effective coordination of environmental affairs within the UN system. Fifth, it has promoted greater awareness and institutional capacity for environmental management among governments, the private sector, and civil society. Last, the UNEP has promoted better understanding of the connection between the natural environment and human security, poverty eradication, and prevention and mitigation of natural disasters.

Barry D. Solomon

See also **Climate Policy; United Nations Environmental Summits**

Further Readings

- Axelrod, R. S., Downie, D. L., & Vig, N. J. (Eds.). (2005). *The global environment: Institutions, law, and policy*. Washington, DC: CQ Press.
- Speth, J. G., & Haas, P. (2006). *Global environmental governance: Foundations of contemporary environmental studies*. Washington, DC: Island Press.
- United Nations Environment Programme. (2008). *UNEP 2007 annual report*. Nairobi, Kenya: Author.



UNITED STATES CENSUS BUREAU

The Census Bureau is an agency of the U.S. federal government that produces a wide variety of statistical information for the public and private sectors. It has done so since the first federal census of population in 1790, in accordance with the provision in Article I of the Constitution that an “actual Enumeration shall be made within three years after the first Meeting of the Congress of the United States, and within every subsequent Term of ten years, in such Manner as they shall by Law direct.” This constitutional requirement has served as the basis for conducting a census of population at 10-year intervals ever since. In response to increased governmental and private sector demands for statistical information, the Census Bureau has become the federal government’s largest statistical agency and now produces many statistical series in addition to those derived from decennial censuses.

Regulations governing the collection of statistics by the Census Bureau, formally codified in the U.S. Code, Title 13, Census, require that statistical information remain confidential, meaning that the identity of individuals, households, or organizations that have provided information must not be revealed to any user. Important consequences for the geographic presentation of statistics derive from these regulations, particularly when the capabilities of modern geographic information systems (GIS) are taken into consideration. Data confidentiality safeguards often result in the loss of place-specific geographic detail; nonetheless, statistical information from the Census Bureau provides one of the primary empirical bases for understanding the nation’s human geographies, especially with regard to settlement, the characteristics of residents, and a wide range of economic topics.

A variety of geographic requirements are associated with each phase of collecting, processing, and presenting statistics. In the data collection phase, generally referred to as enumeration, one must locate and then obtain information from a person, household, business firm, or other unit of observation at a specific location, usually a street address. In the processing phase, geographic



The U.S. Census Bureau began updating its address list of the nation's approximately 130 million housing units in spring 2009. Census workers used confidential and secure GPS-equipped handheld computers to verify, add, and delete addresses. An accurate address list ensures that every household receives a census questionnaire in 2010.

Source: U.S. Census Bureau, Public Information Office (PIO).

identifiers are added to responses obtained in the collection phase that will be used to report the tabulated statistics. These requirements have remained essentially unchanged since the first census of 1790, but the manner in which they are operationalized has altered radically since then. The transformation of the nation from 4 million residents situated along the Atlantic Seaboard in 1790 to 305 million residents spread over a continent-scale country of 3.5 million mi.² (square miles) today has dramatically increased the geographic operational demands. Changing societal demands have brought about increased types of

statistical information, with more thematic type-of-area identifiers, for ever more specific locales. Still more dramatic, in terms of their impacts on geographic operations within the Census Bureau, are the technological transformations wrought by modern high-speed computers and the electronic processing of information during the latter 20th and early 21st centuries.

Geographic operations in the data collection stage have always included the necessity for producing innumerable local-area maps for in-the-field data collection. In the data-processing stage, enumeration areas—the basic spatial unit for



internal geographic operations—are created. They enable all subsequent spatial bookkeeping operations to occur. From the census of 1790 through 1870, the administrative districts of federal marshals served this purpose. With the 1880 census, Henry Gannett (1846–1914), the bureau's first professional geographer, established a geography program to produce field maps and enumeration areas that took into account both the physical features of the environment and the existing patterns of human settlement. These enumeration areas were then aggregated into geographic units for tabulating statistics. By the 2000 census, the number of these enumeration areas—the basic spatial units from which all geographic units for tabulating statistics are formed—had increased to 8 million.

Geographic operations for acquiring and processing responses always present formidable challenges in terms of maintaining the accuracy of place-specific geographic information associated with each response. Prior to high-speed computers, the Census Bureau produced detailed local-area maps from the best available sources, including local governments and topographic quadrangles, for such operations—a series of exceedingly tedious paper-based tasks. Beginning with the 1970 census, detailed geographic information was digitized to create reference maps to display geographic tabulation units in the Metropolitan Map Series, which covered 100,000 mi.² of the most intensively settled portions of the country. With the 1990 census, the Census Bureau introduced the TIGER® (Topologically Integrated Geographic Encoding and Referencing) database for managing its internal geographic operations and for creating reference maps that display the geographic units in which statistics are tabulated. This GIS has served as the basis of geographic operations of the Census Bureau ever since.

The historic evolution of geographic units that have served to report statistical information mirrors American society's increased expectations for data, which demand an ever-increasing variety of units with ever-greater geographic specificity. In 1790, the states themselves were the only formal geographic units required for reporting statistics, as the census was conducted explicitly to allocate seats in the U.S. House of Representatives and apportion the Revolutionary War debt

among the states. Since then, the number of geographic units provided by the Census Bureau for presenting statistics has increased dramatically, coming to include, among many others, various subnational regionalizations, units representing residential settings as small as city blocks (with at least 300 residents), units representing forms of settlement that range from urban and rural locales to metropolitan areas, and units that represent school districts and voting districts for state legislatures and the U.S. Congress. Today, users can create their own customized geographic units of analysis and have statistics tabulated online in real time via the Internet.

The Census Bureau has collected statistics, which were then made publicly available, from the initial decade of the federal government's existence. Today, the topics covered by this agency's statistics range from geographical mobility, foreign trade, and housing to hundreds of other topics. Frequency of issuance ranges from monthly to once per decade. The operational challenges faced by the Census Bureau to produce national-scale statistical data sets have resulted in countless innovations in geographic operations and in the tabular and the geographic/cartographic representation of statistics. Once instituted by the Census Bureau, these innovations have readily crossed over into the private and public sectors outside the federal government. They not only underlie the statistical base of knowledge provided by the federal government but also enable users of Census Bureau products to statistically analyze the processes that transform the nation's human geographies and how they relate to its physical environment.

Donald C. Dahmann

See also **Census**; **Census Tracts**; **Metropolitan Area**

Further Readings

Adams, J. S., Van Drasek, B. J., & Phillips, E. G. (1999). Metropolitan area definition in the United States. *Urban Geography*, 20, 695–726.
U.S. Census Bureau: www.census.gov



UNITED STATES GEOLOGICAL SURVEY (USGS)

The United States Geological Survey (USGS) is a nonregulatory scientific research agency housed in the U.S. Department of the Interior employing scientists in five scientific disciplines—geology, hydrology, geography, biology, and geospatial information science—at more than 400 U.S. locations. USGS scientists provide decision makers with timely and relevant information on the nation's landscape, natural resources, and hazards. The USGS is the country's largest civilian mapping agency, providing online access to base data, map products, and geospatial Web services derived from satellite imagery, aerial photographs, and the 7.5-min. (minute) topographic maps of the United States.

The USGS was established by Congress on March 3, 1879. John Wesley Powell, its director from 1881 to 1894, initiated a plan for the topographic mapping of the entire United States. USGS

scientists contributed to the war efforts during World Wars I and II, trained the astronauts who landed on the moon in 1969 in geology, and helped launch the first civilian Earth-observing satellite in 1972, which evolved into the Landsat program that provides a continuous historical record of medium-resolution satellite imagery to the public.

USGS geologists study the causes and effects of geologic hazards such as earthquakes, volcanoes, and landslides; map the basic geology of the United States; investigate coastal change; provide assessments of energy and mineral resources; and contribute to an understanding of global climate change.

USGS hydrologists pioneered techniques for gauging the discharge in rivers and streams and modeling the flow of complex groundwater systems. USGS hydrologists provide information to minimize loss of life and property from water-related hazards such as floods, to manage groundwater and surface water resources, and to protect water quality.



USGS survey crew measuring mudflow damage, Upper Muddy River, with Mount St. Helens and the May 18, 1980, mudflow in the background. Skamania County, Washington, October 24, 1980.

Source: U.S. Geological Survey/Photo by Lyn Topinka.



USGS geographers and cartographers developed topographic mapping techniques using aerial photography during the 1930s, and they led the revolution in automated cartography and geographic information systems in the 1970s and 1980s. The 7.5-min. topographic map series of 55,000 quadrangles covering the United States was completed in 1992, and geographic data from these maps are the basis for *The National Map*, which provides online access to data from the USGS and its partners in federal, state, and local governments. Researchers in geography study the causes and consequences of land use and land cover change and hazard vulnerability, and they provide land use and land cover data through the Multi-Resolution Land Characteristics Consortium.

Biologists in the USGS provide scientific understanding and technologies to support the management and conservation of the nation's biological resources. Biologists study ecosystems, contaminants, aquatic resources, genetics, and endangered and invasive species. The USGS has developed the National Biological Information Infrastructure, a collaborative online system providing access to data and information on the nation's biological resources.

Barbara S. Poore

See also **Aerial Imagery: Data; Cartography, History of; GIS, History of; Land Use and Land Cover Mapping; Powell, John Wesley**

Further Readings

Rabbitt, M. C. (1989). *The United States Geological Survey: 1879–1989* (U.S. Geological Survey Circular 1050). Reston, VA: U.S. Geological Survey.

U.S. Department of the Interior, U.S. Geological Survey. (2007). *Facing tomorrow's challenges: U.S. Geological Survey in the decade 2007–2017* (U.S. Geological Survey Circular 1309). Reston, VA: U.S. Geological Survey.

U.S. Geological Survey. *About USGS home*. Retrieved December 1, 2008, from www.usgs.gov/aboutusgs



UNIVERSITY CONSORTIUM FOR GEOGRAPHIC INFORMATION SCIENCE

The University Consortium for Geographic Information Science (UCGIS) is an organization of universities and colleges, federal agencies, industry partners, and international affiliates whose purpose is to foster research and education in the field of Geographic Information Science (GIScience). UCGIS was founded in the early 1990s based on the recognition that a diverse and broad-based organization was needed to sustain growth in GIScience within the United States.

As described on the UCGIS Web site, the UCGIS mission and its associated goals are organized in three main thrusts:

Unify:

1. Provide ongoing research priorities for advancing theory and methods in GIScience.
2. Assess the current and potential contributions of GIScience to national scientific and public policy issues.

Facilitate:

1. Expand and strengthen GIScience education at all levels.
2. Provide the organizational infrastructure to foster collaborative interdisciplinary research in GIScience.

Benefit Society:

1. Promote the ethical use of and access to geographic information.
2. Foster GIScience and analysis in support of national needs.

Governance of UCGIS is conducted by an executive committee (made up of the president, the president elect, the past president, and the executive director) and a board of directors. The activities of the UCGIS are performed by the chairs of committees (research, education, policy and legislation, communications, and membership), who organize the work of the delegates. Delegates from the UCGIS 75-plus institutional members are scholars representing disciplines, including



cartography, cognitive science, computer science, engineering and land surveying, environmental sciences, geodesy, geography, landscape architecture, law and public policy, remote sensing and photogrammetry, and statistics. Each year, delegates and partners participate in a summer assembly and a winter meeting to coordinate research and education activities of national need.

Special workshops create significant products to advance GIScience research and/or education. Recent UCGIS products include the following:

- A GIScience research agenda developed from convening a 10-year diverse representation of delegates (McMaster & Usery, 2005)
- A monograph describing a GIScience and technology body of knowledge for education and research (DiBiase et al., 2007)
- A research agenda (Yuan & Stewart Hornsby, 2007)
- A research monograph (Stewart Hornsby & Yuan, 2008) about the topic of geographic dynamics

Each year, UCGIS conducts a search for a published research contribution that is worthy of national recognition and for an educator who has made outstanding contributions to GIScience education worthy of national recognition.

Current information about UCGIS activities can be found on the organization's Web site at www.ucgis.org.

Timothy Nyerges

See also **Geographic Information Systems; GIS, History of; GIScience**

Further Readings

- DiBiase, D., DeMers, M., Johnson, A., Kemp, K., Taylor Luck, A., Plewe, B., et al. (2007). *Geographic information science and technology body of knowledge*. Washington, DC: Association of American Geographers.
- McMaster, R., & Usery, E. (2005). *A research agenda for geographic information science*. Boca Raton, FL: CRC Press.

Stewart Hornsby, K., & Yuan, M. (Eds.). (2008). *Understanding dynamics of geographic domains*. Boca Raton, FL: CRC Press.

Yuan, M., & Stewart Hornsby, K. (2007). *Computation and visualization for the understanding of dynamics in geographic domains: A research agenda*. Boca Raton, FL: CRC Press.



UNSUPERVISED CLASSIFICATION

Unsupervised classification is one of the two basic approaches to digital image classification with the goal of producing land cover maps from remotely sensed data. The other is supervised classification. Unsupervised algorithms evaluate the spectral properties of image pixels and segregate them into naturally occurring statistical groups with little or no guidance from the analyst. The underlying assumption is that a remotely sensed landscape comprises a mosaic of land cover classes, each of which is relatively uniform in terms of spectral pattern. Following image classification, a significant challenge for the analyst is to apply meaningful land cover labels to the spectral classes identified. This entry summarizes the unsupervised classification logic, briefly examines two commonly used algorithms, and discusses the primary advantage and disadvantage of the approach.

Unsupervised classifiers are based on the multi-spectral data space location of spectral class means, the measurement of distance between class means and individual pixel locations, and the establishment of boundaries delineating the individuality of spectral classes. The amount of analyst-supplied input at the onset of the unsupervised classification varies by algorithm. In general, though, the algorithms work by assigning a number of image pixels, either systematically or at random, as initial class means. The distance between individual image pixel locations and the class means is calculated, and pixels are assigned to the nearest class mean. Once the entire image has been evaluated, new class means are calculated based on the addition of pixels to the initial mean value. The process then repeats, or iterates,



until there is a statistically insignificant change in the location of class means or in the number of pixels that switch class membership or until a maximum number of iterations is reached.

The two most commonly used unsupervised classification algorithms are K-means and the Iterative Self-Organizing Data Analysis Technique, or ISODATA. Both are iterative processes that, in general, operate as described above. K-means, however, requires the analyst to specify a fixed number of desired classes and then minimizes the within-class variability by optimizing the sum-of-squares error between individual class means and member pixels. ISODATA is more flexible, in that spectral classes can be merged or split. Classes are merged when two or more class means are located in close proximity. A class is split when its standard deviation exceeds a threshold value.

Relative to supervised approaches, a primary advantage of unsupervised classification is that the potential for human error is reduced. That is because there is less input required from the analyst and because of the high likelihood that each unique spectral class in an image will be identified. Unlike supervised classification, no prior knowledge of the study area is required to initiate an unsupervised process. However, detailed knowledge of the study area is needed to accurately label the resultant spectral classes. The primary disadvantage is that matching spectral classes to the desired set of land cover classes can be difficult.

Bradley C. Rundquist

See also **Image Processing; Land Use and Land Cover Mapping; Multispectral Imagery; Remote Sensing; Supervised Classification**

Further Readings

- Campbell, J. (2007). *Introduction to remote sensing* (4th ed.). New York: Guilford Press.
- Jensen, J. (2005). *Introductory digital image processing: A remote sensing perspective* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

UNWIN, DAVID (1943–)

Born in Chesterfield, Derbyshire, United Kingdom, David J. Unwin was among the first generation of students trained in quantitative geography. With the recognition of geographical information science (GIScience) as a research domain, he became a leading member of that community, having published his landmark text *Introductory Spatial Analysis*, which formed the precursor for *Geographic Information Analysis*, which he coauthored with David O'Sullivan.

Unwin graduated in geography from University College London in 1965 and received his MPhil degree in 1970. By then, he was a lecturer of geography at the University College of Wales at Aberystwyth. In 1973, he moved to the University of Leicester, where he worked until he moved to Birkbeck College, London, in 1992 as professor of geography. He was pro-vice master of the college (2000–2002), before moving to serve as director for learning programmes at UK eUniversities Worldwide Limited. He retired in 2004.

Two principal themes characterized Unwin's research: (1) teaching and (2) computing/geographical information. He was concerned with improving the quality of teaching in British higher education, especially computer-assisted education, and he served on various geography curriculum committees in both British schools (A levels) and universities. His contributions to research on teaching are also illustrated by his work on the *Journal of Geography in Higher Education*; he was a member of its founding editorial board from 1977 to 1986, and he served as coeditor from 1986 to 1989.

Unwin's research in the area of computing led to the writing of key books, titled *Computing for Geographers* in 1976 and *Computer Programming for Geographers*, in 1985 and leadership of a number of research grants for computer-based thematic mapping. In GIScience, his principal research contributions have been in cross-area estimation (with Mitchel Langford, University of Glamorgan) and in visualization and virtual reality, which led to coedited books.

The two interests came together in a string of grants such as the Leicester Image Processing



Suite, Computers in Teaching Initiative Centre for Geography (codirected with David Maguire), Visualisation for the Social Sciences (a Leicester-Birkbeck collaboration), and the Virtual Field Course Project (a Leicester-Birkbeck collaboration). Outside geography, his administrative responsibilities at Birkbeck and UK eUniversities were related to both teaching and technology.

Unwin's most notable service to the research community was for the Quantitative Methods Study Group of the Institute of British Geographers as the secretary/treasurer (1974–1976), as chair (1976–1979), and as editor of the CATMOG series (Concepts and Techniques of Modern Geography, 1979–1982). He also participated in establishing the first European Colloquium on Theoretical and Quantitative Geography in 1978.

Unwin's MPhil research was in climatology, and he maintained interest in this area throughout his career. Merging this with a lifelong interest in fell running and mountaineering, in 1978, Unwin authored *Mountain Weather for Climbers*.

Peter Fisher

See also **Geography Education; GIScience; Spatial Analysis; Spatial Statistics**

Further Readings

- Dawson, J. A., & Unwin, D. (1976). *Computing for geographers*. New Abbot, UK: David & Charles.
- Dawson, J. A., & Unwin, D. (1985). *Computer programming for geographers*. Harlow, UK: Longman.
- Fisher, P., & Unwin, D. (2001). *Virtual reality in geography*. London: Taylor & Francis.
- Hearnshaw, H., & Unwin, D. (Eds.). (1994). *Visualisation and GIS*. Chichester, UK: Wiley.
- O'Sullivan, D., & Unwin, D. (2002). *Geographic information analysis*. New York: Wiley.
- Unwin, D. (1978). *Mountain weather for climbers*. Leicester, UK: Cordee.
- Unwin, D. (1981). *Introductory spatial analysis*. London: Methuen.



URBAN AND REGIONAL DEVELOPMENT

Students of urban and regional development consider the social, economic, and political forces that shape, and are shaped by, the physical and social landscapes of metropolitan areas. Urban and regional development is a multidisciplinary subject of study that draws interest from scholars affiliated with a broad range of social and physical sciences, including planning, sociology, geography, political science, anthropology, and health and environmental sciences. The multidisciplinary nature of urban and regional development should not be surprising given the significance of the city, and more recently the concept of the region, in each of these disciplines. Placing a boundary around the term *urban and regional development* is, consequently, a difficult task. Indeed, given the disciplinary intersections inherent in urban and regional development, any effort at delimiting the literature would unfortunately result in omissions that some may find problematic. Nevertheless, what follows is an attempt to be as inclusive as possible concerning urban and regional development and its theoretical evolution.

Origins of Urban and Regional Development

Like most academic concepts, the origins of urban and regional development can be traced to broader intellectual pursuits combined with changes in wider economic, cultural, and political conditions. In geography, students of urban and regional development emerged from the sub-disciplines of urban and economic geography. Early geographical models of urban development were often econometric. Walter Christaller's central place theory, for example, focused on the placing and spacing of urban settlements by examining the geographical draw of hierarchies of economic goods that, in turn, produced hierarchies of settlements spaced equidistant from each other by virtue of the mix of goods and services found in them. Brian Berry used central place theory to understand distributions of urban settlements and economic activities in the Midwest of the United States.



Early contributions from sociology include Ernest Burgess's studies of Chicago, in which he viewed the city as a laboratory for the study of urban form and urban social problems. Cities were seen as organic, expanding and changing in social and physical form in a process similar to the succession of plant life. The structure of urban form and growth appeared to be in concentric zones, with the central business district (CBD) at the center and surrounded by a transition from the CBD to more residential areas, which in turn were structured into concentric zones by levels of affluence. The mobility of citizens, measured in journey-to-work commutes, use of telephones, and land values at strategic locations (and change in the number and spatiality of strategic locations), is couched in terms of a city's "metabolism" and reflects the "vitality" and "health" of a city's economic and social life. Additionally, "disorganization" of urban life in the form of vice, poverty, concentrations of minority populations, and disinvestment in the built environment is attributed to the "excess" of actual population growth over natural increase (i.e., immigration). Disorganization along with the demand for labor are seen as natural to urban life and appear to act as "stimulants" for the mobility of citizens, creating pressures for urban expansion and succession of land uses.

Anthropological contributions to urban and regional development focus on the cultural and social life of cities. Urban cultures and subcultures are examined within the context of specific groups navigating and shaping the built environment through everyday life practices, providing "the city" with vibrancy—different smells, ethnic cuisines, cultural and religious activities, markets, tempo, entertainment, and family and social gatherings. Particular groups, whether ethnic enclaves in specific neighborhoods or organizational units such as corporations and civic institutions, are examined to identify the cultural practices that collectively provide individual cities with their unique sense of place.

Planning and health and environmental science concerns arose largely in response to the rapid urban growth associated with industrialization in the 19th century. The need to regulate and spatially segregate various kinds of urban development and provide for infrastructural

requirements arose from the rapid and haphazard development of thickly settled tenement housing in cities such as New York in the 1800s. Health and environment concerns drove the creation of infrastructure such as sewage, water supply, and ordinances for the designing and spacing of buildings to allow sunlight to penetrate densely constructed urban areas. The need for such planning became evident after the outbreaks of diseases such as cholera, typhoid, yellow fever, and dysentery in the crowded and unsanitary quarters of industrializing cities such as New York and London.

Following World War II, planning practices shifted toward accommodating the fast-growing suburban populations. Planned private suburban communities such as the Levittowns of New York, New Jersey, and Pennsylvania—along with others scattered about the United States—were aimed at accommodating the high demand for housing for a burgeoning middle class in the postwar United States. In the latter part of the 20th century, public planning became more prevalent in the United States as environmental concerns emerged in the 1970s and 1980s against the backdrop of increasing pollution and other negative externalities associated with rampant leapfrog suburban development. In Europe, where national governments are generally more centralized than in the United States, planning practices largely focused on decreasing densities around public transportation nodes and expanding the public transportation infrastructure. It should be evident here that the United States and Europe diverged in developing their respective transportation infrastructures. The United States focused primarily on constructing and maintaining its interstate highway system to accommodate the growth of privately owned automobiles. Suburbanization, including leapfrog development, generally follows the contours of the interstate highway system. Europe's preindustrial and pre-automobile cities with narrow streets and high densities were not easily malleable to the kinds of urban structural change required to accommodate limited-access highway systems. Consequently, the major focus in Europe was largely on public transportation such as high-speed trains, subway systems, and light rail systems, which are less intrusive on the built environment. The planning professions in the



United States and Europe thus reflect the social and cultural implications associated with these differing transportation infrastructures.

Urban Governance

The 1950s and 1960s saw the publication of a series of works that broadened the scope of urban and regional development to include urban governance. The publication of Floyd Hunter's book *Community Power Structure* in 1953—a Marxist analysis of a “Regional City’s” (largely understood to represent the city of Atlanta) close ties between the city’s business class and the city government—launched a new theoretical framework for studies of urban and regional development. Rather than viewing the social and built environment as “natural” or organic, the new focus was on how class dynamics (re)produces the social and economic landscape in modern capitalist cities. The business community, for example, was recognized as pivotal in a city’s social and political structure. The leaders of the business community are seen as more than representatives of their particular company or industry; rather, they are seen as representatives of a *class* of capitalists who police and act on behalf of class interests in addition to the interests of their particular businesses. This is done through the establishment of business policy organizations in which local firms offer their expertise and resources to local government officials to help shape urban policies. In addition, business leaders financially back pro-business candidates for office and tend to head local community foundations, arts councils, and other eleemosynary organizations to merge the resources they command, including social and political networks, for the purpose of fund-raising and/or mobilizing the kinds of support that such organizations require to function.

The publication of C. Wright Mills’s *The Power Elite* in 1956 and G. William Domhoff’s *Who Rules America?* in 1967 broadened the scope of the community power structure literature beyond the confines of “the city” to include national governance. Much of this broadened literature considers the socialization mechanisms of preparatory schools, elite universities, and exclusive social clubs as components of a social structure organized for the inculcation and maintenance

of class awareness for new generations of business and social leaders at the national scale.

The political scientist Robert Dahl’s *Who Governs?* (published in 1961) refocused on the urban scale and challenged the burgeoning school of community power structure. Dahl’s book was a long-term study of the governance of the city of New Haven in Connecticut. Rather than finding a small class of business or social elites who overly influence urban policy making in New Haven, Dahl described a tumultuous process of negotiations and quid pro quos among myriad social and business interests. Additionally, Dahl found a very dynamic set of actors whose composition changes dramatically with the rise of the industrial revolution, rapid immigration, and the subsequent changes in urban form and structure. The process of urban governance over time that Dahl describes is one of transition from an era of elite leadership in the early days of British colonialism and then U.S. independence to a steady rise of interest groups that increasingly diminishes the power of any one group to overly influence urban government. In other words, urban governments must be responsive to a widening array of interests. The result, then, is a process of municipal governance and urban development that appears to be chaotic but in actuality represents “a miracle of democracy” in the sense that political influence is effectively diluted by the need for urban governments to be responsive to a widening, pluralistic range of voters.

The work of Robert Dahl effectively launched what in political science is known as the “pluralist school,” which remains a powerful framework for contemporary studies. Indeed, throughout the 1970s and 1980s, urban scholars generally worked within the framework of either the “elite school” of community power structure or the “pluralist school,” with little overlap between the two. The two models are largely separated by epistemology—that is, they differed in their expectations of what can be researched. Pluralists, for example, take a “decisional” approach and analyze actual decisions (e.g., legislation and the decision-making processes behind them) regarding urban policies. They generally conclude that political influence is decentralized but imbalanced among a range of competing interests. Meanwhile, anything beyond concrete decision



making is, according to the pluralists, beyond the confines of scientific inquiry. Elite theorists, on the other hand, assume that the desires of local elites (usually business elites) guide the political process behind the scenes and limit the scope of the political process to only those issues that are comparatively innocuous to local elites. Methodological approaches in the elite theory tradition—popularized by Floyd Hunter—involve reputational analyses in which decision makers are interviewed to gauge their assessment of the involvement of people who, by the nature of their perceived high social or economic status, possess the potential to tacitly influence the decision-making process. The split between the elite theorists and the pluralists continued into the mid 1970s, until Harvey Molotch's seminal article on urban growth machines, published in 1976, changed the terms of the debate.

Growth Machine, Urban Regimes, and Regulation Theory

The growth machine hypothesis broadens the scope of urban politics in urban and regional development to include more than political decision making. The sociologist Harvey Molotch's growth machine hypothesis was laid out in greater detail with the publication of *Urban Fortunes* in 1987, a book that he coauthored with John Logan. The growth machine hypothesis conceptualizes cities as battlegrounds of competing interests between what they refer to as "rentiers"—a class of people who, as property owners, earn their living from rent—and "users." Elites are recast as those with a variety of interests favoring economic growth: They include, for example, property owners who seek to maximize the "exchange" values of their properties; newspaper executives who seek to increase readership, which, in turn, increases the demand for advertisements; city government officials who would prefer to see tax revenues increase; local businesses and utility companies desiring more industrial customers; universities seeking increased enrollments; unions seeking to increase the pool of local jobs for their constituents (and increase membership); and the arts, sports franchises, and philanthropy institutions, seeking increased audiences and contributions. These disparate groups

of interests ostensibly act as a unified business class that collectively influences urban and regional political decision making by virtue of the myriad financial and social resources at their command.

With growth machines at the heart of political coalitions across a range of U.S. cities, what emerges is a "battle of the growth machines"—that is, competition among cities and places for various forms of inward investment. The geographer David Harvey, for example, observed that city governments had largely transformed during the 1980s from concerning themselves primarily with effective and efficient municipal service provision to, instead, participating as agents of speculative investment making in local land uses with the aim of laying the groundwork for private inward investments. Cities by and large were faced with broader changes in global economic structure with the emergence of data processing and communications technologies in the developed world, which, in turn, intensified global competition and prompted a dramatic shift of the manufacturing sector to the emerging economies. The economies of the developed world, meanwhile, largely transformed into flexible high-technology production and services. In short, as the geographer Kevin Cox details, "capital" has become increasingly mobile across space as a consequence of globalization, prompting a "new urban politics" in which localities must respond by becoming more "entrepreneurial." This entails investing public revenues into speculative ventures, such as the provision of location and tax incentives to firms that would locate new production or other facilities nearby or to existing locally based firms to prevent them from relocating out of a particular jurisdiction. Furthermore, speculative ventures include the building of new stadiums, convention centers, and arts facilities and developing restaurant-and-bar districts or other "places of consumption" that aim to be a draw for the "creative-class" workers of the new high-technology manufacturing and service-based economy.

The publication of the political scientist Clarence Stone's book *Regime Politics* in 1989 brought together the elite and pluralist schools more so than the growth machine concept. Stone's book was another long-term study of the



city of Atlanta, Georgia, largely covering the years since the publication of Hunter's work in 1953. The urban regime concept's breakthrough in bridging the gap between community power structure and pluralism lies in its situating of political leaders within the constraints of the democratic process; that is, regime theory recognizes that urban politicians must be responsive to myriad interests as the pluralists contend. At the same time, however, regime theory also recognizes that business interests appear to wield more influence than others over the formulation of urban policies. In capitalism, business leaders—through no action of their own—are seen as possessing “systemic power” by virtue of their private ownership over the productive assets of society. Particularly in the United States, urban governments are reliant on their business communities for fiscal solvency because of the vital resources they command—namely, jobs and capital. Municipal governments, therefore, have traditionally been more responsive to the long-term needs of business community leaders over the needs of other constituents and have actively engaged with business leaders through informal networks to develop various political platforms. In short, *governance* is a more apt description of urban management and development given that urban governments alone lack the resources required to effectively develop and implement policies. Therefore, political leaders must reach out to the broader community—typically the business community—to mobilize the necessary resources for effective governance.

The regime concept proved to be problematic when applied to British or other European cities, where governments are more centralized and generally less dependent on local resources for effective governance. In Britain, regulation theory found more fertile academic ground than the concept of urban regimes. Led by the geographer Bob Jessop, regulationists explore the modes of “social regulation” and their roles in urban and regional development. Social relations—labor markets, capitalist competition, consumption, social movements, and so on—are seen as being mediated through governmental, social, and civic institutions at varying and interlocking scales of interaction. How these relations are mediated and directed help shape and direct the forms that

urban and regional development takes. Agglomeration economies, deindustrialization, the rise of “cultural” economies, and the like are attributed to specific locally based arrangements of regulatory institutions and social relations. Ash Amin and Nigel Thrift have referred to these arrangements as “institutional thickness” and attribute a locality's capacity to secure inward investments and “embed” global forces of production in particular places as contingent on a locality's level of institutional thickness.

Regulation theory brought to the fore the issue of scale that was hitherto undeveloped and largely absent from studies of urban and regional development. The concept of institutional thickness is cognizant and inclusive of various institutions—governmental, economic, social, and otherwise—operating at a range of scales. The “region” as opposed to the “city” is seen as particularly important for harnessing and directing the powers of regulation and social interaction toward embedding global processes in particular places. Authors have drawn from the works of others in the broader discipline of economic geography, including the concept of the “city-region,” for a better framework for understanding institutional thickness across scales. Others have called for a new politics of the “region” as opposed to the “city” so that cities and regions are better equipped to respond to the changing scales of global production and exchange.

Conclusion and Future Directions

The multidisciplinary field of urban and regional development is a rich and dynamic field of study. Although much of the work has been presented somewhat in a linear fashion, it should be noted that the various approaches to urban and regional development outlined above continue to flourish both independently and with much cross-fertilization of concepts, insights, and methodologies. Each approach offers promising insights for future directions of inquiry.

One particularly promising approach to urban and regional development has emerged from the broader discipline of human geography. The attention to issues of scale as outlined above has permeated much of social inquiry in human geography and other social sciences. The concept



of scale as networks and the “return” of graph theory in broader social science, along with new software technologies created specifically for network analyses, offer interesting methods for isolating specific interests identified in models such as urban regime theory, regulation theory, and “institutional thickness” in urban and regional development. Recent work, for example, seeks to identify specific business interests that enjoy centrality in urban regime coalitions through social network analysis. Others demonstrate the utility of viewing previously “amorphous” concepts such as globalization as economic transactions mediated through specific social relations and networks across space, linking regions and localities to “global” capital. Social networks and relations take the form of potential suppliers and business partners bridging global capital with local or regional markets and of customers representing forward and backward linkages up and down the production chain. This new thrust of inquiry promises to situate urban and regional development amid specific social, economic, and political actors that, collectively, constitute “coalitions,” “institutional thickness,” and other structures of social relations. By teasing out specific actors from these broader social forms, new possibilities emerge, with implications for human agency, urban social movements, and political action.

Mark de Socio

See also Agglomeration Economies; Central Business District; Chicago School; Circuits of Capital; Deindustrialization; Economic Base Analysis; Economic Geography; Environmental Impacts of Cities; Environmental Planning; Growth Machine; Growth Poles; Housing and Housing Markets; Industrial Districts; Infrastructure; Innovation, Geography of; Knowledge, Geography of; New Urbanism; Postindustrial Society; Public Policy, Geography of; Public-Private Partnerships; Regional Economic Development; Regional Environmental Planning; Rent-Gap; Rural-Urban Migration; Squatter Settlements; Suburbs and Suburbanization; Transportation Geography; Uneven Development; Urban and Regional Planning; Urban Geography; Urban Hierarchy; Urbanization; Urban Spatial Structure; Urban Sprawl; World Cities; Zoning

Further Readings

- Amin, A., & Thrift, N. (1995). *Globalization, institutions, and regional development in Europe*. Oxford, UK: Oxford University Press.
- Cox, K. (1995). Globalization, competition and the politics of local economic development. *Urban Studies*, 32(2), 213–224.
- Cox, K., & Mair, A. (1988). Locality and community in the politics of local economic development. *Annals of the Association of American Geographers*, 78(2), 307–325.
- Cox, K., & Wood, A. (1997). Competition and cooperation in mediating the global: The case of local economic development. *Competition and Change*, 2, 65–94.
- Dahl, R. (1961). *Who governs? Democracy and power in an American city*. New Haven, CT: Yale University Press.
- Domhoff, G. (1967). *Who rules America?* Englewood Cliffs, NJ: Prentice Hall.
- Florida, R. (2003). Cities and the creative class. *City & Community*, 2(1), 3–19.
- Harvey, D. (1989). From managerialism to entrepreneurialism: The transformation in urban governance in late capitalism, *Geografiska Annaler B*, 71(1), 3–17.
- Hunter, F. (1953). *Community power structure: A study of decision makers*. Chapel Hill: University of North Carolina Press.
- Logan, J., & Molotch, H. (1987). *Urban fortunes: The political economy of place*. Berkeley: University of California Press.
- Mills, C. (1956). *The power elite*. New York: Oxford University Press.
- Peck, J. (2005). Struggling with the creative class. *International Journal of Urban and Regional Research*, 29(4), 740–770.
- Scott, A. (2001). Globalization and the rise of city-regions. *European Planning Studies*, 9(7), 813–826.
- Stone, C. (1989). *Regime politics: Governing Atlanta, 1946–1988*. Lawrence: University of Kansas Press.
- Wood, A. (1996). Analysing the politics of local economic development: Making sense of cross-national convergence. *Urban Studies*, 33(8), 1281–1295.
- Wood, A. (2005). Comparative urban politics and the question of scale. *Space and Polity*, 9(3), 201–215.
- Wood, A., & Valler, D. (Eds.). (2004). *Governing local and regional economies Institutions, politics and economic development*. Burlington, VT: Ashgate.



URBAN AND REGIONAL PLANNING

Think of the things one sees in a city or region that everyone wishes were otherwise. They might have been otherwise if there had been careful planning in the past. The periodic confrontations over the building of new shopping centers, high-rise apartments, airports, landfills, and highways; the demolition of historic buildings; or the failure to conserve open space are a measure of the regard with which planning is held. In these contentious situations, the subject under debate is not the need for planning but rather the need for better planning, not *whether* but *how* it should be done.

Planning is a systematic process of thought and action intended to contribute to effective decision making for the welfare and integrity of communities and the sustainability of the natural environment. It involves forethought and the judicious or systematic use of scarce resources to attain a desired goal. The primary objective of planning is to make an informed decision. This entry reviews the history of planning, its development in the areas of both urban and regional planning, and the characteristics of the planning process itself.

History

Planning has been going on throughout history, and it is tempting to explain it away by merely stating that humans have a natural urge to plan; it is part of humans' organizational makeup. Historians and anthropologists have uncovered evidence of planning from the classical civilizations of Greece and Rome to the nation-states and mercantile empires of the 19th century; in America, from the Iroquois confederation to the Inca and Aztec empires in Mexico; in Africa, from the tribal empires of the Ashanti and Mali in West Africa to the Zulu Empire and the kingdom of Zimbabwe in Southern Africa; and in the East, from the early cultures of Japan and China to the Persian Empire. The roots of planning extend to the first emergence of structured societies at the dawn of human history. Indeed, the planning of common activities, in the sense of deliberate anticipation, and the development

of strategies for action are evident in all primitive human societies.

Planned cities were at the core of all great pre-classical civilizations. Evidence lies in the layout of early Roman and Greek cities and in the civilizations that developed in the Indus River valley. Greek cities were based on a grid system layout, and they included standard elements such as a temple complex or Acropolis, a marketplace or Agora, and a recreational complex made up of an amphitheater (for theater and performances) and a hippodrome (for sports events and chariot races). Such was the plan for the city of Miletus, which was planned by Hippodamus, the father of town planning, in 480 BC. In North America, early urban settlements were generally preplanned in Europe before the settlers set off for the New World. For instance, Savannah, Georgia, planned in 1733 by James Oglethorpe, was inspired by the layout of London's residential squares. Each square contained 40 residential lots laid out on a modified grid around a central square.

In addition to the traditional role of designing a city's physical form, planning expanded in the 19th century to include slum clearance, urban renewal, suburban development, transportation planning, urban growth management, and environmental planning. Today, planning has become so complex that it is useful to categorize it into three forms: (1) substantive planning, (2) contextual planning, and (3) spatial planning. Substantive planning refers to the functional areas of planning interest, and specific types include environmental planning, health planning, transportation planning, and physical or land use planning. Contextual planning refers to the context of planning, and specific examples include comprehensive planning, regulatory planning, policy planning, and strategic or long-range planning. Finally, spatial planning refers to the spatial aspect of planning, such as rural, urban, and regional planning.

Urban Planning

Urban planning is also referred to as city, town, or community planning. In Britain, the term *town planning* has been used since the late 19th century. "Community planning" entered the Canadian lexicon not long after World War II, when



the Community Planning Association of Canada was formed. In the United States, the comparable term is *city planning*, and it emerged shortly after 1900. However, in both Canada and the United States, “urban planning” has also become the accepted term since 1960. Urban planning is defined as a systematic process of identifying community goals and specific land use objectives, exploring and assessing the options available to the community, and choosing and implementing the best option. Its purposes are to fulfill the following:

1. Minimize or avoid an unsatisfactory state of affairs such as urban sprawl, traffic congestion, and environmental degradation
2. Protect the health, safety, and welfare of the urban society
3. Ensure efficient allocation of scarce public resources

Most of the urban planning activities involved reconciling private and public preferences to solve problems caused by growth and development. The planning profession has evolved over the past century.

Urban planning in the decades following World War II was concerned with how to accommodate vast population increases by providing housing, public utilities, parks, schools, and public transportation. Cities and towns in this era were often subject to epidemics of diseases and prone to extensive fire hazards. Their new populations needed adequate housing, water, and sewage systems. The 1960s began with major concerns over the physical deterioration in communities. Hence, urban renewal became the focus of planning efforts until the “bulldozer approach” used to achieve it was called into question by Jane Jacobs in her famous book *The Death and Life of a Great American City*. In the 1970s, urban planning concerns focused on the effects that large-scale projects such as airports, shopping centers, and apartment complexes might have on the existing community environments.

Another response to urban problems in the early 1960s was the emergence of a cadre of professionals who gradually codified their ideas and experience about solving urban planning problems. The urban planning profession emerged

during this period and has since generated a rich array of planning concepts, theories, and processes that continue to be drawn on heavily in contemporary planning practice. Modern planners have mastered the techniques for preparing plans and are able to involve a wide range of people in the planning process. Besides, today’s planners understand the legal foundations and techniques for plan implementation and are able to articulate planning issues to a wide range of audience.

Regional Planning

Few planning problems are confined within individual communities. The reasons stem from the interrelationships of various socioeconomic and natural processes in a community and the ways in which the effects of development are transmitted through space. For instance, the drainage of storm water from a subdivision located on a watercourse has the potential of causing pollution to areas downstream. Hence, it is often necessary to undertake planning for areas larger than a single community and large enough to encompass the major effects of a single development project. When large areas are distinguished by identifiable unifying characteristics, they are called “regions.” Regional planning is concerned with many different facets of the physical and human environment over large areas that may or may not have well-defined political boundaries. Regional planners attempt to visualize a better future for a region and recommend steps to achieving a desired vision.

One of the first planners to advocate the need for larger-area planning was Patrick Geddes. After observing a rapid spread of urban development in 19th-century Britain, Geddes coined the term *conurbation* to capture the interdependent nature of linked cities. He drew attention to the independence of all activities within a geographic unit such as a watershed to emphasize the need for regional planning. Ebenezer Howard also deserves credit for the emergence and development of regional planning. His publication titled *Garden Cities of Tomorrow* (1902) helped initiate the Garden City movement. The movement was not only concerned with planning single new towns but was also based on the concept of



organizing a territory around large cities to minimize sprawl and conserve natural resources far beyond the city.

The trend toward regional planning is buttressed by the following developments: (a) urban space has become a series of interconnected districts that stretch across a vast geographical area, (b) economic relationships exist between residents in towns and those in the country, and (c) there is a need to avoid wasteful duplication of planning efforts or facilities in several local jurisdictions. Regional planning recognizes the need to take a synoptic approach to areawide problems and the planning of each jurisdiction in coordination with adjoining areas. A successful example is the river-basin-planning activities of the Tennessee Valley Authority (TVA). The TVA is a regional planning authority that transcends the jurisdictions of seven states, including Virginia, Georgia, Mississippi, Kentucky, Virginia, North Carolina, and Alabama. In establishing the TVA in 1933, the U.S. Congress showed its awareness of a growing trend toward regional planning and an understanding that many of the problems of the Tennessee Valley could hardly be solved by individual states acting alone.

Regional planning is also done at a metropolitan level. Metropolitan regions often have a core city and hinterlands that have noticeable economic and social links. A typical metropolitan region in the United States contains multiple local governments—an average of 104 jurisdictions, which include (a) general-purpose governments in counties, municipalities, and townships and (b) special-purpose governments such as school districts, fire districts, and industrial districts. Regional planning minimizes duplication of public services and development efforts by forging partnerships with local governments as well as the business and nonprofit sectors. Given the autonomy accorded to local government units, regional planning blends their competing aims for development in the interest of all citizens of a metropolitan region. This requires special organizational arrangements, such as the Regional Council of Governments, Regional Planning Commissions, or the Metropolitan Planning Organization (MPO) in the United States. For instance, MPOs serve as the decision-making body for federally funded transportation projects

within a metropolitan area. They also prepare and maintain long-range transportation plans with input from the general public.

Process

A traditional planning process is used in urban and regional planning practice. The process begins with problem diagnosis or dissatisfaction with a status quo situation. Planners work with the general public to articulate a common goal or vision. Next, the vision or goal is refined into a set of objectives that are specific, quantifiable, and measurable. The objectives serve as milestones toward the desired goal. A study is undertaken to assemble facts and figures that enable planners to develop alternative courses of action consistent with the stated goal and objectives. The study may involve the survey, analysis, prediction, and projection of future needs or a future state of affairs. The best course of action is chosen, implemented, and monitored for consistency or unintended consequences. Public participation is essential at each stage of the planning process because it helps (a) incorporate public concerns and values in the planning process, (b) minimize opposition by developing a consensus among stakeholders, and (c) build credibility between planners and the general public. Overall, the traditional planning process is seen as a systematic, rational, and comprehensive decision-making tool.

Seth Appiah-Opoku

See also [Community-Based Environmental Planning](#); [Environmental Planning](#); [GIS in Urban Planning](#); [Land Use Planning](#); [Participatory Planning](#); [Regional Environmental Planning](#); [Urban and Regional Development](#); [Urban Geography](#); [Urban Land Use](#); [Urban Planning and Geography](#); [Urban Policy](#); [Urban Solid Waste Management](#); [Zoning](#)

Further Readings

Alexander, E. (1992). *Approaches to planning: Introducing current planning theories, concepts and issues* (2nd ed.). Philadelphia: Gordon & Breach Science.



- Calthorpe, P., & William, F. (2001). *Planning for the end of sprawl: The regional city*. Washington, DC: Island Press.
- Glasson, J. (1974). *An introduction to regional planning: Concepts, theory and practice*. London: Hutchinson.
- Hodge, G. (1991). *Planning Canadian communities*. New York: Methuen.
- Howard, E. (1902). *Garden cities of tomorrow*. Whitefish, MT: Kessinger.
- Jacobs, J. (1961). *The death and life of a great American city*. New York: Random House.
- Kelly, S. (2004). *Community planning: How to solve urban and environmental problems*. Lanham, MD: Rowman & Littlefield.
- Levy, J. M. (1991). *Contemporary urban planning*. Englewood Cliffs, NJ: Prentice Hall.
- Terrence, J. (2003). *The metropolitan chase: Politics and policies in urban America*. Upper Saddle, NJ: Prentice Hall.



URBAN ECOLOGY

Urban ecology has traditionally been considered a field of inquiry emphasizing ecological processes and organization under the conditions of industrial urbanization. There is a growing interest in interdisciplinary, urban theoretical and scholarly research among the natural, social, and planning sciences, especially within the context of rapid global urbanization, population concentration, and industrial and environmental change. As a field of academic inquiry, urban ecology reflects and embodies changes and transitions in both urban theory and ecological theory over the past half-century.

Early Developments

Early urban ecological exploration and explanation in the mid 20th century reflected contemporary ecological thinking and theory involving the supposed linearity and directionality of ecological change (or succession) and the relative stability, efficiency, and coherence of ecological structure and organization. To this end, early academic interest in the effects of urban industrial growth

on natural environments and ecological processes emphasized the degrading character of cities, with urban form and function critiqued and characterized as anathema to the form and function of “healthy” environmental systems. Industrial pollution, human waste, landscape fragmentation, and the growing and spatially concentrated demand for natural resources by industry and urban consumers were—and to a large degree still are—implicated in declines of air, water, and soil quality at local and regional scales, with broad environmental, social, and economic implications. Similarly, the replacement of native local and regional fauna and flora with nonnative, or invasive, species of plants and animals was implicated in the overall and generalized diminishment of urban landscapes, where local and regional biodiversities were being replaced by more homogeneous, weed-based ecological communities.

Because “nature” was, from this perspective, abolished by the city, then—by implication—its study, in the form of ecology, was antiurban, both in theory and in practice. The nonurban, or rural, remained the principal domain of “true” nature and, thus, of ecological inquiry throughout most of the 20th century. The implications for subsequent constructions of and distinctions between *urban* and *rural*—that is, the city (and urban society) as degrading and degraded and the hinterland (and rural society) as a more ecologically uncontaminated place—have been the topic of sustained critique and debate.

The Role of Human Ecology

By the late 20th century, urban ecology had emerged as a key object of explanation and academic inquiry among an interdisciplinary population of, principally, North American scholars. Equipped with a new set of ecological principles and concepts, and integrated theories of human-environment interaction, these *human ecologists*—ecologists, anthropologists, sociologists, and resource managers, many trained in rural or developing regions of the world—brought to the study of urban ecology a more sophisticated and nuanced appreciation of human-environment relationships in cities, whereby urban society and urban environments were understood as coregulated and codependent systems whose



interaction was nondeterministic, dialectical, and involving dynamics of feedback and change along multiple axes and gradients, from the purely physical to the socioeconomic. Anthropogenic environmental change, it was theorized, resulted in new sets of material and spatial conditions to which urban society responded and adjusted, which, in turn, resulted in further environmental change, future adjustments, and so forth.

This new systems approach of urban human ecology (not to be confused with the Chicago School of Human Ecology, developed in the 1920s, which focused on social and cultural relations within cities) replaced the ecological principles of balance, linearity, and stability (i.e., those concepts that fed accusations of environmental degradation) of earlier critiques with new models emphasizing the impacts of change, nonlinearity, and chaos on ecological structure, form, and function. The result was a new emphasis on the *humanized* urban ecosystem, one in which urban society was a fundamental organizational component and agent of nonnormative and nonlinear environmental change at various spatial and temporal scales. Urbanization, from this perspective, amounts to a form of environmental disturbance to which the natural system and, subsequently, human systems respond in dialectical fashion. This model of urban human ecology thus disposed of earlier nature-society, urban-rural dualisms to argue that cities are, in fact, fully functioning and viable ecosystems and that the politically charged “degradation” is better understood and explained as a form of systemic change to which urban societies respond and adapt. The 1997 emergence of the flagship journal *Urban Ecosystems* and the parallel development of the, traditionally nonurban, Long-Term Ecological Research (LTER) Project sites (funded by the U.S. National Science Foundation) in Baltimore, Maryland, and Phoenix, Arizona, signaled the legitimacy and success of this new, more interdisciplinary model of systems-based urban human ecological thinking and scholarship.

Urban Environmental Services

Parallel to the emergence of urban human ecology in the 1990s was a growing interest in the economics and social value of ecosystem services,

sometimes called environmental services. The services perspective argues that healthy urban ecological communities provide myriad unintentional benefits that justify environmental protection, management, and/or restoration. These services include the removal of pollutants and toxins from air (via photosynthetic activity and soil respiration) and water (via root uptake, soil filtration, and plant transpiration), soil stabilization (via root structure), and temperature regulation (via shade from trees and forests or heat absorption by urban water sources). On the one hand, scholarship in the area of ecosystem services argues that “healthy” and intact urban ecological systems, if protected and managed properly, have the capacity to absorb much of the effluent and wastes of industrial production and social consumption. This perspective calls attention to the—largely unaccounted for and unappreciated—economic benefits of healthy urban ecosystems that accrue at multiple scales, from the household to the municipality to the region. Urban ecological degradation, thus, does not simply represent a future expenditure (i.e., through technological investment, environmental remediation, restoration, or containment) but entails an opportunity cost of likely significant magnitude. On the other hand, the services perspective advances the argument that the benefits provided by “healthy” urban ecosystems fall under the category of quality-of-life indicators demanded by urban residents, whereby healthy ecosystems promote urban social and economic health and a healthy, happy, and productive urban citizenry.

To this end, insofar as they meet certain quality-of-life criteria and satisfy public demand, healthy urban ecosystems are said to help produce the conditions of economic development, including the attraction of tourists, jobs, and full-time residents. Borrowing principles that are reminiscent of Frederick Law Olmsted’s ideas a century ago, this language of urban sustainability and the sustainable city has its origins in the fields of urban landscape architecture and design. In doing so, and in recognizing and representing the city as the container of (potentially) viable and healthy ecosystems, the services perspective strongly refutes earlier arguments and perspectives that alluded to cities as a priori environmental abominations.



Critical Urban Ecology

Apolitical and ahistorical urban ecological thinking and analysis generally characterized both the human ecology and the ecosystem services perspectives of the late 20th century. A response to this has been a more critical inquiry into the structural underpinnings of urban ecological change, the unequal distribution of ecosystem services and their quality-of-life and economic benefits, and the unequal distribution of degraded urban ecological landscapes and their potential risks. This emerging critical urban ecology, or *urban political ecology*, is based largely in the discipline of geography and is a nascent, if growing, area of interest among, especially, urban theorists and scholars, rather than ecologists, per se. Closely allied with urban environmental justice, urban political ecology emphasizes the modern urban environment as a historical construct of industrial urbanism and fragmentation, one whose patterns and rights of access, use, distribution, and change are contested and (re)negotiated along myriad axes of political and economic power. A hybrid of Third World political ecology and critical urban theory, urban political ecology reframes urban human-environment relations as the product or a reflection of unequal social relations and seeks opportunities for urban ecological inclusion, the right to urban nature, and thus the right to the city.

Alec Brownlow

See also Energy and Human Ecology; Environmental Services; Greenbelts; Green Building; Green Design and Development; Human Ecology; Political Ecology; Suburban Land Use; Urban and Regional Planning; Urban Environmental Studies; Urban Green Space; Urban Metabolism; Urban Solid Waste Management; Urban Water Supply

Further Readings

- Botkin, D. B., & Beveridge, C. E. (1997). Cities as environments. *Urban Ecosystems*, 1, 3–19.
- Brownlow, A. (2006). An archaeology of fear and environmental change in Philadelphia. *Geoforum*, 37, 227–245.

- Collins, J. P., Kinzing, A., Grimm, N. B., Fagan, W. F., Hope, D., Wu, J., et al. (2000). A new urban ecology. *American Scientist*, 88, 416–425.
- Grimm, N. B., & Redman, C. L. (2004). Approaches to the study of urban ecosystems: The case of Central Arizona—Phoenix. *Urban Ecosystems*, 7, 199–213.
- Grove, J. M., & Burch, W. R. (1997). A social ecology approach and applications of urban ecosystem and landscape analyses: A case study of Baltimore, Maryland. *Urban Ecosystems*, 1, 259–275.
- Heynen, N. C. (2003). The scalar production of injustice within the urban forest. *Antipode*, 35, 980–998.
- Heynen, N., Kaika, M., & Swyngedouw, E. (Eds.). (2006). *In the nature of cities: Urban political ecology and the politics of metabolism*. New York: Routledge.
- Hough, M. (2004). *Cities & natural process: A basis for sustainability* (2nd ed.). New York: Routledge.
- Mumford, L. (1956). The natural history of urbanization. In W. L. Thomas (Ed.), *Man's role in changing the face of the Earth* (Vol. 1, pp. 382–400). Chicago: University of Chicago Press.
- Pickett, S., Burch, W., Dalton, S., Foreman, T., Grove, J., & Rowntree, R. (1997). A conceptual framework for the study of human ecosystems in urban areas. *Urban Ecosystems*, 1, 185–199.
- Rowntree, R. A., Platt, R. H., & Muick, P. C. (Eds.). (1994). *The ecological city: Preserving and restoring urban biodiversity*. Amherst: University of Massachusetts Press.
- Williams, R. (1975). *The country and the city*. New York: Oxford University Press.



URBAN ENVIRONMENTAL STUDIES

Urban environmental studies are emerging as an integrated science aiming to understand extended urban areas that include not only biological and physical features but also economic and social components. These studies improve our



understanding of urban climate, hydrology, ecosystems, and environmental conditions and help us gain critical knowledge of how human and natural environments have interacted to motivate past urban environmental changes. The crux of science in urban environmental studies concerns the fluxes of energy, water, and carbon, how these fluxes are related to one another, and how they have changed over space and time. A better understanding of these science questions contributes to building a conceptual framework for sustaining the urban environment and thus enhancing the quality of life of its residents. The complexity of urban environmental issues calls for a systematic approach by interdisciplinary teams. This introduction reviews most important concepts and research methods in urban landscape, climate, water, vegetation, and sustainability.

Urban Landscapes

Urban landscapes are typically a complex combination of buildings, roads, parking lots, sidewalks, garden, cemetery, soil, water, and so on. Each of the urban component surfaces exhibits unique radiative, thermal, moisture, and aerodynamic properties and relates to its surrounding site environment to create the spatial complexity of ecological systems. To understand the dynamics of patterns and processes and their interactions in heterogeneous landscapes such as urban areas, one must be able to quantify accurately the spatial pattern of the landscape and its temporal changes. It is necessary to have a standardized method to define these component surfaces and to detect and map them in repetitive and consistent ways.

Various approaches have been developed in the studies of landscapes in general and urban landscapes in particular in the fields of geography, planning, landscape ecology, natural resources, environmental science, and so on. The land use and land cover approach is a predominant one, especially in geography, planning, and landscape ecology. Land cover can be defined as the biophysical state of Earth's surface and immediate subsurface, including biota, soil, topography, surface water and groundwater, and human structures. In other words, it describes both natural and human-made landscapes of Earth's

surface. Land use can be defined as the human use of the land. Land use involves both the manner in which the biophysical attributes of the land are manipulated and the purpose for which the land is used. However, the relationship between land use and land cover is not always direct and obvious. A single class of land cover may support multiple uses, while a single land use may involve the maintenance of several distinct land covers.

Urban areas are composed of a variety of materials, including different types of artificial materials (concrete, asphalt, metal, plastic, glasses, etc.), soils, rocks, minerals, and green and nonphotosynthetic vegetation. Remote sensing technology has often been applied to map land use or land cover. Each type of land cover may possess unique surface properties (material); however, mapping land covers and materials have different requirements. Land cover mapping needs to consider characteristics in addition to those coming from the material. The surface structure (roughness) may influence the spectral response as much as the intraclass variability. Two different land covers, for example, asphalt roads and composite shingle/tar roofs, may have very similar materials (hydrocarbons) and thus are difficult to discern, although from a material perspective, these surfaces can be mapped accurately with hyperspectral remote sensing techniques. Therefore, land cover mapping requires taking into account the intraclass variability and spectral separability. On the other hand, analysis of land use classes would nearly be impossible with spectral information alone. Additional information, such as spatial, textural, and contextual information, is usually required for a successful land use classification in urban areas.

Traditional methods of land use/cover classification based on detailed fieldwork suffered two major common drawbacks, (1) confusion between land use and land cover and (2) lack of uniformity or comparability in classification schemes, resulting in difficulty in comparing land use patterns over time or between areas. The use of aerial photographs and satellite images since the late 1960s does not solve these problems, since these techniques are based on the formal expression of land use rather than on the actual activities that gave rise to land use patterns. In fact, many land use types cannot be identified



from the air. As a result, mapping of the Earth's surface tends to present a mixture of land use and land cover data, with an emphasis on the latter. Another major problem in urban land use/land cover classification is related to so-called mixed pixels. It is rare that urban land classification can yield an accuracy of greater than 80% by using per-pixel classification (i.e., "hard classification") algorithms. The low accuracy of land use/cover classification in urban areas is largely attributed to the mixed-pixel problem, where several types of land use/cover are contained in one pixel. The mixed-pixel problem results from the fact that the scale of observation fails to correspond to the spatial characteristics of the target. Therefore, the "soft"/fuzzy approach of land use/cover classifications has been applied, in which each pixel is assigned a class membership of each land use/cover type rather than a single label. It has been suggested that characterization and quantification, rather than classification, should be applied to provide a better understanding of the compositions and processes of heterogeneous landscapes such as urban areas. Merrill Ridd proposed a conceptual model for remote sensing analysis of urban landscapes, that is, the vegetation/impervious surface/soil model. It assumes that land cover in urban environments is a linear combination of three components—namely, (1) vegetation, (2) impervious surface, and (3) soil. It has been suggested that this model can be applied to spatial-temporal analyses of urban morphological, biophysical, and human systems. While urban land use information may be more useful in socioeconomic and planning applications, biophysical information that can be directly derived from satellite data is more suitable for describing and quantifying urban structures and processes.

Impervious surfaces are anthropogenic features through which water cannot infiltrate into the soil, such as roads, driveways, sidewalks, parking lots, rooftops, and so on. In recent years, impervious surface has emerged not only as an indicator of the degree of urbanization but also as a major indicator of environmental quality. Impervious surface is found to be inversely related to vegetation cover in urban areas. In other words, as impervious cover increases within a watershed/administrative unit, vegetation cover would

decrease. The percentage of land covered by impervious surfaces varies significantly with land use categories and subcategories. Detecting, monitoring, and analyzing impervious surface is valuable not only for environmental management, for example, water quality assessment and storm water taxation, but also for urban planning, for example, building infrastructure and sustainable urban growth.

Urban Climate and Air Quality

The most remarkable feature of urban climate is the urban heat island (UHI) effect. Urban climatologists have long been interested in the phenomenon that observed ambient air temperature differs between cities and their surrounding rural regions, to which the UHI effect refers. The urban-rural temperature differences are usually modest, averaging less than 1 °C, but they occasionally rise by several degrees when urban, topographical, and meteorological conditions are favorable for the UHI to develop.

Two types of UHI can be distinguished pertinent to the methods of temperature measurement: (1) the urban canopy layer heat island and (2) the urban boundary layer heat island. The former consists of air between the roughness elements, for example, buildings and tree canopies, with an upper boundary just below roof level. The latter is situated above the former, with a lower boundary subject to the influence of urban surface. The spatial pattern of the canopy layer heat island corresponds closely to the distribution of surface cover characteristics. The myriad component surfaces and the spatial complexity when they are mosaicked create a limitless array of energy balance and microclimate systems, preventing urban meteorologists from drawing any generalization. Most of the previous UHI studies have been conducted at the mesoscale using an energy budget approach, which separates the energy flow into measurable interrelated components for simulation modeling. Because the morphological characteristics of urban landscapes that modify urban climate occur at the microscale, it is imperative to have a good understanding of urban morphology.

Knowledge of urban surface energy balance is fundamental to the understanding of UHIs and



urban thermal behavior. If the net horizontal heat advection is not considered, the surface energy balance of a city can be expressed as

$$R_n + A = H + LE + G \text{ (W/m}^2\text{)},$$

where R_n is the net all-wave radiation, A the anthropogenic heat flux, H the sensible heat flux, LE the latent heat flux, and G the net storage heat flux. To quantify the urban surface energy balance, in situ measurements (largely tower based) can be obtained to estimate accurate heat fluxes at the roof level. However, because of the diversity in size, shape, height, composition, and spatial arrangement of the urban “canopy” components, it is difficult to define a surface datum for such measurements, especially for an entire city. Moreover, the sites of the measurements are frequently not associated with meteorological stations. To date, most of the urban heat flux observations have been conducted in a limited number of residential areas. Several experimental studies were conducted in European cities but did not analyze specifically the different components of surface energy balance. Because direct observation of heat fluxes is rare, many efforts have been made to parameterize the terms by using more routinely measured data.

A fundamental problem with the in situ measurements of energy fluxes lies in the great difficulty of selecting a representative site for a larger adjacent region due to the complexity of urban material composition. Sue Grimmond and Catherine South outlined the method to extract surface cover information for the Multi-City Urban Hydrometeorological Database (MUHD). The most noticeable recent advance in terms of instrumentation relates to the use of stand-alone sensors, with which observational data can be recorded for a network in a city. Even with the MUHD and the new sensor technology, siting criteria for urban locations are still hard to define for documenting local-scale heat flux variability. It is extremely difficult and expensive to investigate the detailed spatial pattern of energy fluxes in a city, if cost, time, instrument, and data calibrations are considered all together. Furthermore, the surface energy balance approach has met with mixed success in documenting the temporal variability of energy

fluxes in urban areas. Most of the in situ measurements are used to determine the diurnal variability, but they are less used for evaluating the seasonal and the interyear variability.

Remote sensing studies of urban thermal landscapes and UHIs have been conducted mostly by using NOAA AVHRR data. However, in all these studies, the 1.1-kilometer spatial resolution AVHRR data were found suitable only for large-area urban temperature mapping, not for establishing accurate and meaningful relationships between image-derived values and those measured on the ground. The 120-m (meter)-resolution Landsat Thematic Mapper's (and later the Enhanced Thematic Mapper Plus [ETM+] data of 60 m) thermal infrared data, as well as Terra's ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) images (with spatial resolution of 90 m in thermal infrared bands), have also been extensively used to derive land surface temperature and to study UHIs. Most recent advances include the development and use of quantitative surface descriptors for assessing the interplay between urban material fabric and urban thermal behavior and the use of the landscape ecology approach to assess this interplay across various spatial scales and identify the operational scale of an urban thermal landscape. Because the ASTER sensor collects both daytime and nighttime thermal infrared images, analysis of land surface temperatures has also been conducted for a diurnal contrast. Studies using satellite-derived surface temperatures have identified surface temperature heat islands, which are believed to correspond more closely with the canopy layer heat islands, although a precise transfer function between land surface temperature and the near-ground air temperature is not yet available.

In addition to the UHI phenomenon, rainfall is often higher in the urban area by a margin of 5% to 10%. This increase is attributable to the thermal-induced upward movement of air, increased vertical motions from mechanically induced turbulence, increased cloud and raindrop nuclei, and industrial increases in water vapor. Urban wind speeds tend to be lower because of the rougher surfaces, frequently higher temperatures of the urban fabric, and reduced duration of sunshine due to air pollution.



Urban Air Pollution

Urban areas are associated with sources of a variety of air pollutants and regional pollution problems such as acid rain and photochemical smog. Cities are also major contributors to global air pollution related to ozone depletion and carbon dioxide warming. Within an urban area, the level of pollution varies with the distance to pollution sources, including both stationary and mobile sources (e.g., vehicles). Local pollution patterns in cities are mainly related to the distribution of different land use and land cover categories, the occurrence of water bodies and parks, building and population densities, the division of functional districts, the layout of transportation network, and air flushing rates. Pollution levels tend to rise with land use density, which usually increases toward a city center. Therefore, there is generally an urban-rural gradient in the concentrations of air pollutants. For example, the concentrations of particulates, carbon dioxide, and nitrate ion (an oxide, as in acid rain) in the inner city are typically two to three times higher than in the suburban areas and five times higher than in the rural areas.

Furthermore, urban areas experience another type of pollution—heat pollution. Because of the construction of tall and closely spaced buildings, the flushing capability of the air at the ground level is largely reduced. However, the relationship between air pollution and urban heat has not been fully understood, although both relate to the pattern of urban land uses. UHIs favor the development of air pollution problems but are not indicators of air pollution. Higher urban temperatures generally result in higher ozone levels due to increased ground-level ozone production. Moreover, higher urban temperatures result in increased energy use, mostly due to the greater demand for air conditioning. As power plants burn more fossil fuels, the pollution level is driven up. A few studies have so far examined the correlation between land surface temperature and air pollution measurements.

Urban Water

The process of urbanization has a considerable hydrological impact in terms of influencing the

nature of runoff and other hydrological characteristics, delivering pollutants to rivers, and controlling rates of erosion. One of the most notable impacts is the way in which urbanization affects flood runoff. Because urbanization replaces land surface with nonevaporating and nonporous materials, there is a trend for flood runoff to increase in comparison with rural areas. Urban drainage densities may be greater than the rural densities, and the installation of sewers and storm drains accelerates runoff. As a result, the rainfall-runoff process in an urban area tends to be quite different from that in natural conditions depicted in classical hydrological cycles. Peak discharges are higher and occur sooner after runoff starts in basins. It should be noted that this effect of urbanization varies according to the size of flood. As the size of flood becomes larger and its recurrence interval increases, the effect of urbanization tends to decrease.

Urban warming changes the moisture characteristics, precipitation amount, and storm characteristics in the urban areas. Higher air temperatures hold more moisture, and warmer water increases the moisture content of storms. Urban warming often increases precipitation amount and storm frequency and intensity. Global warming relocates precipitation globally, so that some places may experience unusually wet and others unusually dry conditions. Moreover, watersheds with large amounts of impervious cover may experience an overall decrease in groundwater recharge and baseflow and an increase in storm flow and flood frequency. Imperviousness is also related to the water quality of a drainage basin and its receiving streams, lakes, and ponds. Increase in impervious cover and runoff directly affects the transport of nonpoint source pollutants, including pathogens, nutrients, toxic contaminants, and sediment. Increases in runoff volume and discharge rates, in conjunction with nonpoint source pollution, will inevitably alter in-stream and riparian habitats, resulting in the loss of some critical aquatic habitats. Some measures for mitigation have been suggested, including the construction of porous pavements and neighborhood detention ponds and wetlands to collect storm water. To increase evapotranspiration, various types and shapes of green spaces, green roofs, and green walls are advocated. In sum, urban areas have a unique feature in water balance.



Urban Vegetation

In the process of urbanization, natural vegetation cover is largely replaced by paved surfaces. Open spaces are maintained for recreational or ornamental purposes rather than for the production of food or timber, so that the ecosystem dynamics of the remaining “green” areas of the city are usually quite different from those of the open countryside. The use of exotic species in urban areas seems to suggest an increase in species diversity, but many of these exotic species are very rare and restricted to certain locations. Moreover, the levels of use of fertilizers and pesticides per unit area in cities are usually much higher than on agricultural land, with corresponding environmental effects. Species diversity is kept low by the ruthless pursuit of weeds and pests. The contribution of exotic species to urban ecological complexity is thus insignificant. Furthermore, urban vegetation grows in an environment remarkably different from natural vegetation. Impervious surfaces prevent rainwater from recharging the groundwater, making less water resources available for urban vegetation. In the meantime, impervious surfaces are easy to heat up due to low specific heat capacity. Recent studies based on satellite observation found that the UHI effect changes vegetation phenology. Intensive management can significantly enhance carbon storage by urban vegetation.

Urban Environmental Sustainability

To define various strategies for urban sustainable development in the context of accelerated urbanization and global climate change, urban planning, resources, and environmental management and governance strategies need to be examined and evaluated. Among the key challenges of the current era are the range, complexity, and intertwining nature of environmental problems in the urban areas and the limited response capacity and capability of cities, in developed countries as well as in developing ones. It is imperative to understand fully the science, technology, and policy issues in urban environmental studies and how they interplay in a particular social, economic, political, and cultural context. Policies, regulations, impact adaptation, mitigation, and remediation can intervene in the urban environmental

system by reducing or enhancing the negative feedbacks. Technologies such as modeling, statistical analyses, geospatial techniques, and digital cities have effects on both the science and the governance. The interdisciplinary nature of urban environmental problems often requires an interdisciplinary team approach to address them.

Qihao Weng

See also [Energy and Human Ecology](#); [Environmental Footprint](#); [Environmental Services](#); [Greenbelts](#); [Green Building](#); [Green Design and Development](#); [Human Ecology](#); [Political Ecology](#); [Suburban Land Use](#); [Urban and Regional Planning](#); [Urban Ecology](#); [Urban Gardens](#); [Urban Green Space](#); [Urban Heat Island](#); [Urban Metabolism](#); [Urban Solid Waste Management](#); [Urban Water Supply](#)

Further Readings

- Arnold, C. L., Jr., & Gibbons, C. J. (1996). Impervious surface coverage: The emergence of a key environmental indicator. *Journal of the American Planning Association*, 62, 243–258.
- Cadenasso, M. L., Pickett, S., & Grove, J. M. (2006). Dimensions of ecosystem complexity: Heterogeneity, connectivity, and history. *Ecological Complexity*, 3, 1–12.
- Goudie, A. (1990). *The human impact on the natural environment* (3rd ed.). Cambridge: MIT Press.
- Grimmond, C. S. B. (2006). Progress in measuring and observing the urban atmosphere. *Theoretical and Applied Climatology*, 84, 3–22.
- Grimmond, C. S. B., & Souch, C. (1994). Surface description for urban climate studies: A GIS based methodology. *Geocarto International*, 9, 47–59.
- Landsberg, H. E. (1981). *The urban climate*. New York: Academic Press.
- Oke, T. R. (1988). The urban energy balance. *Progress in Physical Geography*, 12, 471–508.
- Pickett, S. T. A., Cadenasso, M. L., Grove, J. M., Groffman, P. M., Band, L. E., Boone, C. G., et al. (2008). Beyond urban legends: An emerging framework of urban ecology, as illustrated by the



- Baltimore ecosystem study. *BioScience*, 58, 139–150.
- Ridd, M. K. (1995). Exploring a V-I-S (Vegetation-Impervious Surface-Soil) model for urban ecosystem analysis through remote sensing: Comparative anatomy for cities. *International Journal of Remote Sensing*, 16, 2165–2185.
- Weng, Q., & Lu, D. (2009). Landscape as a continuum: An examination of the urban landscape structures and dynamics of Indianapolis city, 1991–2000. *International Journal of Remote Sensing*, 30, 2547–2577.
- Weng, Q., Lu, D., & Liang, B. (2006). Urban surface biophysical descriptors and land surface temperature variations. *Photogrammetric Engineering & Remote Sensing*, 72, 1275–1286.
- Weng, Q., & Yang, S. (2006). Urban air pollution patterns, land use, and thermal landscape: An examination of the linkage using GIS. *Environmental Monitoring and Assessment*, 117, 463–489.
- White, M. A., Nemami, R. R., Thornton, P. E., & Running, S. W. (2002). Satellite evidence of phenological differences between urbanized and rural areas of the Eastern United States deciduous broadleaf forest. *Ecosystems*, 5, 260–277.



URBAN GARDENS

Urban gardens can be described as private green spaces belonging to a property within towns and cities. They vary in size from a relatively small patch of green space situated in front of a domestic property, often found in inner-city areas to large spaces surrounding an individual property, exceeding several hundred square meters. Urban gardens provide a haven for a wide range of flora and fauna within urban areas. The urban garden is generally not believed to be exceptional in its species richness, yet it has higher plant diversity than is found in the Amazon rain forest. Many bird species also frequent urban gardens, adding a sense of character to a neighborhood, especially during the summer months.

To understand the benefits of urban gardens, it is useful to explore some of their significant characteristics. These include the following:

1. High plant diversity
2. Large number of food chains
3. Large number of unique habitat zones
4. Constant state of succession
5. Disturbed state

The relatively high plant diversity reflects that fact that many gardeners plant as many species as possible. This phenomenon has a knock-on effect, since the numerous varieties of plant species provide the basis for a different food chain. Gardeners are usually keen to create several zones within a garden, such as a water feature, a flowerbed, lawns and hedges, and so on, each of which supports different types of flora and fauna. A constant state of succession is ensured by not allowing a particular plant species to dominate. This has the added advantage of preventing a garden from supporting only a specific plant species such as woodland. Finally, because the garden is continuously subjected to disturbance, it is generally welcoming of foreign species, thus ensuring diversity.

Urban gardens provide a range of benefits to an urban area that are not widely acknowledged. Vegetation is known to have a substantial effect on the temperature, moisture, and precipitation regimes of urban areas. For instance, plants can reduce temperatures by as much as several degrees Celsius in large urban green spaces by increasing the relative humidity of the air, causing it to cool, and counteracting the urban heat island effect. Indeed, a large tree, well supplied with water, has the ability to provide local cooling equivalent to several air conditioners running over much of a day.

Urban gardens have the potential to provide significant benefits to human well-being. In the United States, for example, a study found gardeners consistently reporting the importance of urban gardens in providing an opportunity for exercise and reduction in stress levels. In a U.K. survey, gardeners cited the creation of a pleasant environment and the promotion of relaxation as the two most important aspects of gardens. Other benefits noted were personal satisfaction gained through maintenance and in producing a tidy piece of green space, the health benefits of fresh air and



Bird's-eye view of a park six stories above the ground in downtown Tokyo

Source: Lawrence Karn/iStockphoto.

exercise, a sense of peace and tranquility, and the opportunity to meet and talk with neighbors.

Despite their crucial role in urban society, there is generally a lack of information on the extent of urban garden space because local government is not required to monitor or manage such spaces, yet it is apparent from aerial photography and other sources that they constitute a significant portion of many urban properties and must therefore constitute a sizable proportion of urban areas. This relatively large aggregated green space has the advantage of another very significant feature, namely, flood alleviation. As climate change begins to produce more extreme events such as floods, urban gardens have the distinct advantage of attenuating flood peaks.

Urban gardens form a large part of the public face of a household and its owners and may display a “neighbor mimicry effect,” whereby proximal gardens share significantly more characteristics than distal gardens. Urban front gardens, in particular those that look similar, in terms of their form and the types of vegetation present, may be found close to each other along street sections. This apparent mimicry effect could be very important in deciding important landscape changes in areas where planning authorities have little influence.

Given the numerous benefits of urban gardens, it is surprising to find that they are facing increased threat for several reasons. These include increased car ownership, difficulty of on-street parking,



poor public transport, and a fashion for low-maintenance minimalist landscape. Fear of car crime or robbery while walking from the car to the house has also been cited as a reason to park on front gardens.

Rizwan Nawaz

See also **Environmental Services; Greenbelts; Green Design and Development; Urban Ecology; Urban Green Space**

Further Readings

- Dunnett, N., & Qasim, M. (2000). Perceived benefits to human well-being of urban gardens. *Hort Technology*, 10, 40–45.
- Gaston, K. J., Warren, P. H., Thompson, K., & Smith, R. M. (2005). Urban domestic gardens (IV): The extent of the resource and its associated features. *Biodiversity and Conservation*, 14, 3327–3349.
- Gomez, K. J., Jabaloyes, J., & Vano, E. (2004). Green zones in the future of urban planning. *Journal of Urban Planning and Development*, 130, 94–100.
- Kellet, J. E. (1982). The private garden in England and Wales. *Landscape and Urban Planning*, 9, 105–123.
- London Assembly Environment Committee. (2005). *Crazy paving: The environmental importance of London's front gardens*. London: Greater London Authority.
- Owen, J. (2005). *The ecology of a garden: The first fifteen years*. Cambridge, UK: Cambridge University Press.
- Sanders, R. A. (1986). Urban vegetation impacts on the hydrology of Dayton, Ohio. *Urban Ecology*, 9, 361–376.
- Thompson, K., Austin, K. C., Smith, R. M., Warren, P. H., Angold, P. G., & Gaston, K. J. (2003). Urban domestic gardens I: Putting small-scale plant diversity in context. *Journal of Vegetation Science*, 14, 71–78.
- Zmyslony, J., & Gagnon, D. (1998). Residential management of urban front-yard landscape: A random process? *Landscape and Urban Planning*, 40, 295–307.

URBAN GEOGRAPHY

The dawn of the 21st century ushered in an era when, for the first time in the history of humanity, the majority of people on the planet live in urban areas. More than ever before, cities are now at the core of defining the human experience, for better or for worse. In this context, urban geography is eminently positioned as a field that can enhance our understanding of the structure, form, and function of cities, explain the process of urbanization and the dynamics of urbanism, and offer valuable insights into an equitable and sustainable urban future.

Indeed, more than ever before, urban geography is one of the most vibrant and productive areas of inquiry in the discipline. The volume of scholarly work that focuses on the multitude of urban-related topics that have attracted the attention of geographers has shown an unabated trajectory of quantitative growth and qualitative sophistication. At the end of the first decade of the 21st century, the momentum not only seems to have carried the subfield to the center of attention of geography as a whole but, in many ways, has been instrumental in the recognition of the contributions of geographers to the broader field of urban studies and affine disciplines such as sociology, urban planning, political science, anthropology, and so on. To take stock of where urban geography stands today and where it might go in the future, it is useful to briefly retrace whence it came, if only in very broad strokes.

Origins and Growth of Urban Geography

The emergence of urban geography can be traced back to 19th-century discussions of urban origins and growth. The early emphasis on the site and situation of settlements and their role as centers of civilization was linked to geographers' overarching interest in the relation of humans to their physical environment. This abiding concern with excavating the rise of cities and the role of environmental conditions—whether physiographic or climatic—in shaping society reflected the broader disciplinary concerns of early geographers in arriving at scientific explanations that bridged the gap between the physical sciences



and the incipient social sciences. It also hinged on an ultimately flawed reliance on assumptions that the natural environment exerted a determining influence on human society and behavior, as well as on the structure, form, and function of its spatial arrangements. In effect, such geographers would argue that the site of a city determines—not merely influences—the prospects of its social development and economic growth. Two of the more prominent figures in this particular perspective were the American geographers Ellen Churchill Semple and Ellsworth Huntington. Their work and that of their colleagues was challenged in the 1920s as overly simplistic and deterministic. The debunking of environmental determinism acted as a dead end for the sort of human-environment work that had emerged in the early decades of geography's disciplinary development and that had definitively moved urban geography into a different direction altogether.

Early on, the environmental-determinist paradigm was matched in popularity by a growing interest in the regional patterns of settlement and in the classification of urban structure, form, and function. Early works such as Frederick Emerson's 1907 study, *A Geographical Interpretation of New York*, or Almon E. Parkins's 1918 volume, *The Historical Geography of Detroit*, were among the founding texts of this particular tradition in urban geography. In most cases, copious descriptive information was compiled with little attempt made to offer anything more analytical. This empiricist paradigm, too, was ultimately inadequate in providing a sustained analytical framework because of its inherent limitations as an almost exclusively descriptive approach. Nevertheless, the regional description paradigm served the discipline well in preparing the way for more analytically refined approaches that shifted the focus of geographical inquiry from the environment alone to socioeconomic conditions and their spatial patterns.

Key in this regard was the influence of the Chicago School, which became a catalyst in promoting both the growing interest in analyzing cities and the emerging concern with understanding the links between socioeconomic conditions and spatial patterns. This approach was pioneered by researchers in the sociology department at the University of Chicago in the 1920s and 1930s, using

the city of Chicago as an urban "laboratory." A seminal text of this tradition was the famous volume by Robert Park and Ernest Burgess, *The City*, first published in 1925. A core element of the Chicago School approach was the axiomatic acceptance of the proposition that human society reflects natural processes and, as such, is conditioned by "natural laws" that apply to it just as much as they apply to plant communities, for example. Nevertheless, despite the reluctance of the Chicago School to irrevocably sever the threads to the organismic analogy between society and nature, its development signaled the transition to more positivist methodologies, with their emphasis on the "scientific method," as well as a more nomothetic inclination that sought to determine universal laws. Of special interest is the use of ethnography as a tool in discovering the links between social relations and their spatial arrangements, a method that would gain renewed currency several decades later. Most important, at the time, the focus of the Chicago School on mapping groups and institutions in the urban landscape was well suited to the interests of geographers, who were heartened by this spatial turn in the social sciences and embraced the work of their sociologist colleagues.

In particular, the keen interest of the Chicago School to abstract the spatial patterns of the city into models that captured salient aspects of the social order and urban structure fueled the growth of interest in urban geography. Ernest Burgess's concentric zone model and Homer Hoyt's sector model became clarion calls for visualizing the interplay of social and spatial processes. Many young geographers, eager to solidify the credentials of their discipline as a scientific enterprise, immersed themselves with relish in modeling. Chauncy Harris and Edward Ullman's multiple-nuclei model represented just one of the more sophisticated refinements that geographers contributed to the study of cities. Of special significance is that the work of social scientists—not the least geographers—in this vein of research eventually led to the development of factorial ecology in the 1970s that used multivariate statistical techniques to examine residential differentiation in urban areas. In this sense, the Chicago School was an important antecedent for the robust urban geography that spread across Anglo-American geography departments in the 1950s and 1960s.



An aerial view of Chicago. Chicago played a key role in the rise of urban studies, including urban geography.

Source: Morguefile.

The parallel—albeit discrete—development of central place theory in interwar Germany, in the work of the geographer Walter Christaller and the economist August Lösch, was to influence a great number of geographers in the post-World War II period and directly contribute to the rapid expansion of Anglo-American urban geography. The focus of their work, and that of their successors outside Germany, was on modeling the optimal spatial distribution of settlements and, especially, to explain the size, spacing, and function of smaller settlements in the urban hierarchy. The four basic concepts were (1) centrality, (2) range, (3) threshold, and (4) hexagonal trade areas. These were based on assumptions that consumers behave rationally and that they operate on an isotropic plane—a uniform landscape devoid of physical or human-made obstacles or hazards.

The effect of these general tendencies to abstraction and theory development was the inevitable emergence of an urban geography as a full-fledged spatial science by the 1950s and 1960s. With the whirlwind of spatial science unleashed, urban geographers immersed themselves in a matrix of spatial variables and spatial systems. Whereas previous generations of geographers had looked at geology or biology for inspiration, this generation was more focused on mathematical statistics and physics, or “social physics” to use the moniker of the day. The intensive quantification of the work that urban geographers were performing mirrored similar developments in other social sciences, to one extent or another. This particular paradigm culminated, perhaps, with the publication of David Harvey’s *Explanation in Geography* of 1969, widely hailed as a landmark text for the field. Nevertheless, a sustained reaction had



already been mobilized in an effort to counter the abstraction inherent in spatial science and to ground urban geography in a less abstract, albeit still positivist, approach that had human behavior at its core.

Behavioral and Humanist Perspectives on Urban Geography

Starting in the mid 1960s, the behavioral thread of urban geography focused on the cognitive processes by which human subjects made decisions. This was less a rejection of urban geography as spatial science than a rescaling of the research conducted to a human dimension rather than the aggregate dimension necessary for work in spatial science. Behavioralism retained much of the positivism of the previous approaches, but the guiding principle was that the analysis of the daily spatial behavior of individuals and the exploration of how individuals experienced and responded to places would provide a deeper understanding of urbanism and urbanization. Some of the core statements of this approach can be found in Julian Wolpert's 1964 article in the *Annals of the Association of American Geographers*, "The Decision Process in Spatial Context," and Allan Pred's 1967 monograph, *Behavior and Location: Foundations for a Geographic and Dynamic Location Theory*.

The behavioral turn was a significant development in urban geography, primarily because it initiated a thread that rejected the aggregate scale of spatial science for a more human orientation. Nevertheless, as would be expected of such a dynamic discipline, right away there were plenty of geographers who argued that the behavioralists were too timid in their critiques of spatial science and that they were not really going far enough to explore the human dimensions of urban life. Inspired by the philosophical currents of phenomenology/existentialism that were quite popular in continental Europe in the post-World War II period, humanist urban geographers sought to break away from the positivist methodologies that dominated the discipline. They favored, instead, methods such as textual analysis and ethnography, the latter having an antecedent in the work of the Chicago School a few decades earlier. Humanistic urban geography embraced the individual as an agent and sought to understand the

subjectivities of his or her lived experiences in the city. The notion of space yielded its role as an organizing concept for the discipline to a more subjective notion of place. What mattered to the humanists was to extract the significance that individuals attach to places as the sites of their lived experiences. To do so, the humanist urban geographer must enter the "life-world" of the subject to glean the meanings attached to the places experienced by the human consciousness. Just as important, the humanist seeks to understand the ways by which that human consciousness actively reconfigures places in the lives of human subjects through intersubjectivity. Edward Relph's 1976 classic *Place and Placelessness* and Yi-Fu Tuan's 1976 work *Topophilia* became the essential texts of this turn in geography, influencing a generation of urban geographers.

The Radical Turn

Parallel to the behavioralist/humanist rejection of spatial science in the mid 1960s was a growing concern with the relevance of the work done by urban geographers. In the spirit of the times, a growing number of young geographers were influenced by the antiwar movement, the civil rights struggles, and the realization that large populations in the inner cities were socially marginalized and spatially segregated. The political upheavals and social struggles of the 1960s were a catalyst for the formation of radical tendencies, especially among urban geographers, that moved more and more to the left, identifying with the emancipatory aspirations and theoretical positions of Marxism. These urban geographers reached back to the work of Friedrich Engels's 1844 *The Condition of the Working Class in England in 1844* and the voluminous opus of Karl Marx to reject the academic abstractions of spatial science that were increasingly seen as amoral at best or complicit in oppression at worst. Motivated, in part, by the rediscovery of Marx, especially through the interpretive lens of Western Marxism, young radicals took to heart the dictum that philosophers have only interpreted the world in various ways and that the point was to change it.

An important development in the United States was the inauguration, in 1969, of the radical journal *Antipode*, which provided a venue for



radical urban geographers to publish their heterodox work. Another seminal event in the radicalization of urban geography in those early days was the publication of David Harvey's 1973 *Social Justice and the City*. Confronted with images of crushing urban poverty, racial segregation, widespread public and private disinvestment in the city, clashes in the streets with the police, burning city neighborhoods, and a host of other jarring urban phenomena in the most advanced capitalist economy in the world, it became an urgent preoccupation for radical urban geographers to explain and address what they were witnessing. They rejected what they perceived to be the voluntarism of the behavioralists and humanists with their emphasis on the individual as an agent. They sought, instead, to make use of radical political economy as a method to expose the profligate economic, political, and social structures that underpinned the injustices at the core of the capitalist system, oppressing the working class, women, and minorities, especially in the cities of the United States and other "First World" countries. In 1980, Edward Soja introduced the concept of the "sociospatial dialectic" in an article by that title in the pages of the *Annals of the Association of American Geographers*. The self-evident notion that the social and the spatial are inextricably intertwined and that one cannot be properly understood without the other became an organizing principle for radical urban geographers such as Harvey, Neil Smith, and Soja. Influenced, in part, by the work of the French philosopher Henri Lefebvre, who argued that space is a social product and who asserted the centrality of space in organizing and sustaining capitalism, these radical urban geographers embraced a more nuanced and subjective perspective relative to earlier Marxist analyses. In their work, Marxism was spatialized, and the social relations and spatial practices that constitute the city were subjected to a relentless scrutiny.

In the early 1970s, the terms *structuralist* and *Marxist* were used to describe radical urban geographers who engaged with the voluntarists/humanists in a set of protracted disputations that defined the general theoretical and methodological contours of urban geography. Over the years, there have been several refinements and

restatements of the respective arguments in a dialectical exchange that has been quite productive and has propelled urban geography to a place of prominence in the discipline and in the broader social sciences. One illustrative example has been the way in which the two camps have engaged the question of gentrification in North American cities during the 1980s and 1990s. On the one hand, the geographer Neil Smith authored a series of articles starting in 1979 and culminating with the publication, in 1996, of his book *The New Urban Frontier: Gentrification and the Revanchist City*. Smith's arguments were unabashedly of Marxist provenance and emphasized the role of structural forces, including real estate speculation and land prices, as the prime impetus behind gentrification. On the other hand, the geographer David Ley approached the same question with a humanist's sensibility, insisting on human agency as the driving force behind gentrification. His contributions to the heated discussions through the 1980s culminated in 1996 with the book *The New Middle Class and the Remaking of the Central City*. Geographers were joined by researchers from other disciplines in this academic melee throughout the 1980s and into the next decade, signaling a new currency for urban geography.

"Post-al" Encounters in Urban Geography

A seminal development during the late 20th century was the emergence of a poststructuralist position that would lead to a number of *post-al* approaches to the study of cities: postmodernism, post-Marxism, postfeminism, postcolonialism, and so on. Building on humanist disaffection with structural explanations—and heavily influenced by the development in literary criticism of a derivative, Anglophonic reading of translations of what the French called *la pensée* 1968—some urban geographers challenged what they saw as the totalizing, deterministic straightjacket of the Marxist analysis of cities. Part of a "cultural turn" in geography, *post-al* urban geographers in the 1980s and 1990s delved into the study of culture in the city. Gender, race, ethnicity, and sexuality were very much on the agenda, rectifying the considerable degree of neglect that the silences of earlier urban geographies had bequeathed the field. What emerged was a definitive rejection of



even the hint of positivism, a diligent abjuring of structural explanations, an embrace of multiple perspectives, and a preoccupation with discourse and ideology. Citing French authors became fashionable, with the names of Foucault, de Certeau, Bourdieu, Lyotard, Baudrillard, Deleuze, Guattari, Irigaray, Cixous, and others used liberally in the writings and speeches of a new brood of urban geographers. This change coincided with the “spatial turn” across the social sciences and the humanities, where space and the geographical imaginary were discovered and embraced. This step brought scholars from other disciplines in contact with the work of geographers, creating a vibrant interdisciplinary exchange that focused on urban space and spatiality. All of a sudden, literary theorists, sociologists, anthropologists, and other scholars were assiduously quoting urban geographers, while urban geographers picked up where their humanist predecessors had left off and merrily sauntered further afield into literatures hitherto beyond their range. Literary criticism and psychoanalysis, for example, were no longer distant precincts but, rather, fruitful fields for cross-pollination for work on urban space and spatiality in the post-modern era. This development has coincided with the announcement of the existence of a Los Angeles School of urbanism to replace the void left by the Chicago School decades ago. According to the geographer Michael Dear’s 2001 edited volume *From Chicago to L.A.: Making Sense of Urban Theory*, the Los Angeles School is characterized by a move away from the modernism of the Chicago approach to a more postmodern vision that draws its inspiration from the fragmented and decentered nature of the sprawling metropolis in Southern California.

The infusion of post-al attitude and latitude invigorated both Marxist and non-Marxist urban geographers and contributed to the further development of the boisterous critical urban geography that one encounters today. What makes urban geography “critical” is a skeptical posture that interrogates what is taken for granted about the social relations and spatial practices in urban areas. It is a big tent under which are accommodated epigones of radical and humanistic geography alike, in a collegial conviviality that bears similarities to a marriage of convenience. Nevertheless,

despite the constant spats, the palpable suspicion, and the unmitigated irreconcilability that seems to mark critical urban geography, it has produced an important body of work that has secured, to a substantial degree, its bona fides within the academy. Global city regions, transnational urbanism, the right to the city, spaces of consumption, the embodiment of the urban experience, virtual urbanities, urban surveillance, and the mobilities and materialities of urban space are all common threads of inquiry for critical urban geographers alongside more persistent themes such as urbanization, segregation, governance and urban politics, or the effects of neoliberal economic policies on metropolitan areas.

More recently, the environment reentered the picture after decades of exile, in the form of urban political ecology. Drawing from critical urban geography as much as from political ecology, geographers have rediscovered nature in the city. Unlike the earlier environmental turns of the determinists or human ecologists, however, today’s urban political ecologists do not fasten onto ontological assumptions about nature, nor are they preoccupied with organismic analogies. Rather, they posit nature as the hybrid of human and nonhuman processes that are both physical and cognitive. As such, what emerges is a rigorous analysis that examines the social production of urban environments and the complex articulation of nature and the city, in a project that harkens back to the egalitarian and emancipatory intentions of radical urban geographers. In Nik Heynen, Erick Swyngedouw, and Maria Kaika’s edited volume *In the Nature of Cities: Urban Political Ecology and the Politics of Urban Metabolism*, one can glimpse the sprawling and ambitious agenda of this paradigm that combines the concerns of a socialized ecology with a spatialized political economy in an era of inexorable urbanization.

Finally, the perennially gnawing question of relevancy has led urban geographers to another seemingly atavistic turn. Just like nature and the environment have found a place in 21st-century urban geography, increasingly a more empirical geography has emerged to reclaim currency and credibility in the discipline. Advances in geographical information technology have fueled an interest in an applied urban geography that, in a way, harkens back to spatial science. This time,



however, the byword is *mixed methods*, diligently integrating quantitative and qualitative approaches. Thus, geographic information systems (GIS) and statistical methods have joined ethnography and other qualitative methodologies to create integrated analyses of urban phenomena that affect the lives of real people in real communities. It is generally thought that this new applied urban geography is better positioned to effect change and affect the lives of urban communities in a progressive direction because it provides needed analysis that can influence policy making. One recent example of this sort of work has been the research on the effects of subprime mortgages and foreclosures on the working class and people of color done by Elvin Wyly, Dan Hammel, Kathe Newman, and others.

In conclusion, today urban geography is more diverse and spirited than ever. In the Association of American Geographers, and its equivalent professional organizations in Canada and the United Kingdom, urban geography's preeminence as a popular subfield or specialty is rivaled only by the number of geographers engaged in GIS work. The "spatial turn" in the social sciences and the humanities has clearly given geographers currency among other scholars studying urbanization and urbanism. At the same time, urban geographers have drawn on the rich and varied history of their discipline to forge a dynamic field of inquiry that rightfully claims a central role in the development of geography and its engagement with other disciplines.

Dennis Grammenos

See also Built Environment; Central Business District; Central Place Theory; Chicago School; Commuting; Counterurbanization; Economic Base Analysis; Economic Geography; Environmental Impacts of Cities; Ethnic Segregation; Exurbs; Gated Community; Gentrification; Ghetto; GIS in Urban Planning; Growth Machine; Homelessness; Housing and Housing Markets; Housing Policy; Infrastructure; Landfills; Los Angeles School; Metropolitan Area; New Urbanism; Primate Cities; Public Housing; Racial Segregation; Rank-Size Rule; Real Estate, Geography and; Rent-Gap; Rural-Urban Migration; Settlement Geography; Squatter Settlements; Suburban Land Use; Suburbs and Suburbanization; Sustainable Cities; Transportation

Geography; Uneven Development; Urban and Regional Development; Urban and Regional Planning; Urban Ecology; Urban Environmental Studies; Urban Gardens; Urban Green Space; Urban Hierarchy; Urbanization; Urban Land Use; Urban Metabolism; Urban Planning and Geography; Urban Policy; Urban Spatial Structure; Urban Sprawl; Urban Sustainability; Urban Underclass; World Cities; Zoning

Further Readings

- Atkinson, R., & Bridge, G. (Eds.). (2005). *Gentrification in a global context: The new urban colonialism*. London: Routledge.
- Cassis, Y. (2007). *Capitals of capital: A history of international financial centres, 1780–2005*. Cambridge, UK: Cambridge University Press.
- Davis, M. (2006). *Planet of slums*. London: Verso.
- Dear, M., & Flusty, S. (1998). Postmodern urbanism. *Annals of the Association of American Geographers*, 88(1), 50–72.
- Dear, M., & Wolch, J. (1993). *Malign neglect: Homelessness in an American city*. San Francisco: Jossey-Bass.
- Drakakis-Smith, D. (2000). *Third world cities* (2nd ed.). New York: Routledge.
- Duany, A., Platter-Zyberk, E., & Speck, J. (2000). *Suburban nation. The rise of sprawl and the decline of the American dream*. New York: North Point Press.
- Florida, R. (2002). *The rise of the creative class: And how it's transforming work, leisure, community and everyday life*. New York: Basic Books.
- Ford, L. (1994). *Cities and buildings: Skyscrapers, skid rows, and suburbs*. Baltimore: Johns Hopkins University Press.
- Garreau, J. (1991). *Edge cities: Life on the new frontier*. New York: Doubleday.
- Harvey, D. (1976). Labor, capital, and class struggle around the built environment in advanced capitalist societies. *Politics and Society*, 6, 265–295.
- Harvey, D. (1978). The urban process under capitalism: A framework for analysis. *International Journal of Urban and Regional Research*, 2, 101–131.
- Harvey, D. (1982). *The limits to capital*. Oxford, UK: Blackwell.



- Lees, L., Slater, T., & Wyly, E. (2008). *Gentrification*. London: Routledge.
- Ley, D. (1996). *The new middle class and the remaking of the central city*. Oxford, UK: Oxford University Press.
- Pred, A. (1977). *City systems in advanced economies*. New York: Wiley.
- Pred, A. (1990). *Lost words and lost worlds: Modernity and the language of everyday life in late nineteenth century Stockholm*. Cambridge, UK: Cambridge University Press.
- Relph, E. (1976). *Place and placelessness*. London: Pion.
- Sassen, S. (2001). *The global city*. Princeton, NJ: Princeton University Press.
- Scott, A. (1986). Industrialization and urbanization: A geographical agenda. *Annals of the Association of American Geographers*, 76, 25–37.
- Scott, A. (1988). *Metropolis: From the division of labor to urban form*. Berkeley: University of California Press.
- Scott, A., & Soja, E. (1996). *The city: Los Angeles and urban theory at the end of the twentieth century*. Berkeley: University of California Press.
- Smith, N. (1982). Gentrification and uneven development. *Economic Geography*, 58, 139–155.
- Smith, N. (1996). *The new urban frontier: Gentrification and the revanchist city*. London: Routledge.
- Smith, N. (2008). *Uneven development: Nature, capital, and the production of space* (3rd ed.). Athens: University of Georgia Press.

being colonized by pioneer plant species. The definition might reasonably be expanded to include freshwater and marine environments. Thus, urban green space includes iconic sites such as London's Hyde Park and New York's Central Park, large expanses of seminatural vegetation such as Perth's Kings Park and Botanic Garden, and abandoned sites such as can be found in all cities. Irrespective of their form, urban green spaces are perceived in many ways by those who encounter and use them. For many people urban green spaces are places that enhance physical and psychological well-being by providing contact with the "natural" world, yet for others they are places of fear or spaces that serve to reinforce social boundaries. This entry first defines ecology *in* cities and the ecology *of* cities and examines the contributions urban green spaces can make in terms of environmental services, engineered urban green space, social and cultural services, and health and well-being. Negative outcomes and perceptions of urban green space are then examined. The entry concludes with a look at the future of the many forms of urban green space.

Homo sapiens is rapidly becoming a predominantly urban(ized) species. At the beginning of the 20th century, only 10% of the world's people lived in urban areas; that number now stands at more than 50% and continues to grow. Ongoing urbanization and the growth of megacities pose threats to biodiversity, dramatically alter climatic and hydrologic processes in urban environments and the surrounding landscapes, and threaten to isolate humans living in cities from "nature" as urban green spaces are lost to development and infilling. Nevertheless, many urban areas contain a surprising amount of green space. These "urban green spaces," in their many forms, provide a wide range of environmental and sociocultural services to city dwellers, including those related to health, education, and recreation. Such spaces are playing an increasingly central role in integrated regional and urban planning and design.



URBAN GREEN SPACE

Urban green space, which is related to, but not necessarily the same as, an urban ecosystem and green infrastructure, comes in a variety of forms and serves a variety of purposes in the urban landscape (see the first set of photos). Various types of urban green space are recognized in the literature: planned or unplanned remnant intact patches of vegetation embedded in the urban matrix, planned spaces such as parks or restored areas, and abandoned or derelict sites that are slowly

Ecology in and of Cities

There is a long tradition of studying and documenting the ecology of urban green spaces in cities, such as the descriptions of the plant species that colonized bombed sites in the aftermath of



Examples of urban green space in Auckland, New Zealand: (A) Albert Park in the inner city; (B) restored Waiatarua wetland, Meadowbank; (C) recreational space, Dunkirk Reserve, Point England; and (D) the author's back garden. Note that all these spaces are multifunctional and provide both environmental and sociocultural services.

Source: Author.

World War II. In the early 1990s, however, urban ecology rose to prominence as a subdiscipline of ecology. Urban ecology has taken two broad approaches: (1) the study of ecology *in* cities and (2) the study of the ecology *of* cities. The former is concerned with understanding the composition, structure, and function of the populations of organisms and the habitats in which they live in cities; the latter uses the tools and concepts of ecology, such as the quantification of biogeochemical fluxes and ecological footprints, to study cities as ecological systems.

Ecology in cities faces several challenges, including the loss of habitat; air, soil, and water pollution; the direct and indirect threats of invasive species; and climate change. Despite such threats to biodiversity, many cities are surprisingly

“green” and are often extremely spatially heterogeneous. For instance, two thirds of the Greater London area (158,000 ha [hectares]) comprises green space of some type, 20% of the total area is considered to be valuable wildlife habitat, and 16% is protected in some way; many threatened and iconic species can be found within this area, including the stag beetle (*Lucanus cervus*). Similarly, urban waterways, including artificial structures, in Northern New Zealand (e.g., Hamilton and Auckland) contain significant populations of native fish, such as the endemic banded kokopu (*Galaxias fasciatus*). The common view of urban expanses as “biological deserts” does not sustain scrutiny; indeed, per unit area, domestic gardens may have levels of species richness approaching those of tropical rain forests.



Wildlife corridors in the urban environment: (A) wildlife corridor alongside railway in Wandsworth, southwest London (with Wandsworth Common in the background) and (B) habitat corridor in Central Park, New York (with inset photo of a sign requesting that visitors stay on the walkways and reduce impact on the area).

Source: Author.

Environmental Services

Urban green spaces are not simply refugia for rare (or other) plant and animal species. They can also modify and ameliorate biophysical processes and so have become useful tools for urban planning (in which context they are sometimes called *green infrastructure*). In terms of the physical environment, urban green space can improve local air and water quality, filter wind and sound, and counteract the elevated temperatures produced by the urban heat island. Significant temperature differences between parks and built-up areas have been recorded, with these differences extending over hundreds of meters; bodies of water in the urban landscape provide similar cooling effects. Urban green spaces can also provide environmental services to nonurban parts of the landscape (see wildlife corridor photos). For example, populations of the bird species Tui (*Prosthemadera novaeseelandiae*) in the Waikato (Northern New Zealand) use urban plants to supplement their food supply. This is particularly important during times of the year when native plants are not flowering. Tui living in remnant patches of native forest outside urban areas commute into urban areas to exploit these nectar sources. Thus, urban green space provides a wide range of valuable environmental services both within and beyond the urban environments within which they are located.

Engineered Urban Green Space

As the environmental services that urban green spaces provide have become increasingly valued, there has been growing consideration of how green spaces can and should be included in urban design and planning. Low impact urban development and design (LIUDD) emphasizes the utility of green infrastructure, with a focus on the amelioration and management of the urban water cycle. The retention of urban green space can reduce the amount of impervious surfaces in urban catchments; these surfaces are associated with (a) dramatic shifts in storm hydrographs (especially increased “flashiness”) and (b) the flux of sediments and undesirable contaminants into waterways. As an example, New Zealand’s largest urban wetland restoration project, Waia-tarua wetland in Meadowbank, Auckland, was restored in the 1990s in an effort to trap sediments in storm water runoff from the surrounding catchments; of the 130 metric tons of contaminants and sediment flowing through this system prerestoration, a significant fraction is now retained in the wetland. The project has had other positive effects, such as providing a recreational resource and an increasing habitat for waterfowl (including kotuku, *Egretta alba modesta*) (see first set of photos). LIUDD also encourages the implementation of microlevel urban



green spaces such as green roofs and rain gardens (both designed for increased water retention and/or biofiltration).

Wildlife corridors provide another example of engineered urban green spaces, with their primary purpose being improving ecological connectivity in urban environments but with the added benefit of increasing the quantity of urban green space (see wildlife corridors photo). Wildlife corridors are designed to link isolated populations together, with the goal of facilitating the flow of individuals and genes between isolated local populations, and to allow mobile species to move through fragmented landscapes.

Social and Cultural Services

Urban green spaces are places where ecological and human-social systems come together. Besides their environmental benefits, urban green spaces provide social and cultural services. As well as being associated with improved physical and psychological health and even increased longevity, they also provide valuable resources for recreation and learning. Furthermore, urban green space can also have benefits in the wider community by developing social ties and attachment to the community by promoting individual interactions—this is an indirect benefit of, for instance, community-driven urban restoration projects. Recent studies have even suggested that vegetation may reduce crime levels, despite the fear that urban green spaces are often centers of antisocial behavior.

Health and Well-Being

Urban green space provides many health services, both physical and psychological. Konstantinos Tzoulas and colleagues have suggested that urban green space provides health benefits in two ways: (1) by improving the local environment, they promote physical activity and so physical health and well-being and (2) passive viewing of green space after negative experiences (e.g., hospitalization) can boost psychological health and well-being. The use of urban green spaces for physical exercise and recreation is a visible example of the health benefits such environments provide. Studies (controlled for age

and sex) associate the availability of green space with increased exercise levels, although the evidence for the quality and proximity of urban green space alone being directly related to physical activity among local populations is equivocal.

The second mechanism by which urban green spaces provide sociocultural benefits is more subtle. Roger Ulrich reported in 1984 that hospital patients who could see natural environments recovered significantly faster from surgery than those with more limited views. Subsequent research has reinforced the links between exposure to urban green space and psychological health across a broad section of society. Exposure to and interaction with “nature,” which for those living in cities will often be limited to urban green spaces, has been argued by child psychologists as playing a crucial role in children’s cognitive, emotional, and social well-being. There is some concern, therefore, over the diminishing access to nature (as urban green space declines) and the increasingly sporadic (in time) interactions children have with it. As one example of the benefits associated with providing children access to nature, there is a growing awareness that there are links between “attention” and children’s access to and use of green space. The engagement of children who have attention deficit hyperactivity disorder with green space has been associated with the reduction of symptoms.

A Downside?

Despite the many benefits associated with urban green spaces, they are also associated with some negative outcomes and perceptions. In particular, people may see urban green spaces as dangerous places where crimes are likely to occur. In this context, the nature of the green space is particularly important; derelict and/or poorly maintained green spaces are perceived very differently than well-maintained ones.

Rather than strengthening links between different members of the community, urban green spaces can sometimes serve to act as boundaries that reinforce socioeconomic division and segregation. Some authors have argued that the poor park conditions in Roxbury and North Dorchester near Boston imply low levels of local interest and little pressure on local municipalities to maintain



parks and that low levels of local interest are associated with disenfranchisement and segregation.

In terms of human interaction with urban green spaces and the wildlife that use them, problem issues include increased human-wildlife conflict and the potential for urban green space, especially in peri-urban environments, to act as reservoirs for disease. For example, links between suburban expansion, tick abundance, and the growing incidence of Lyme disease in North America are well documented. Interactions between humans and green space in urban environments are complicated, and understanding them is not just a case of “the more, the better.”

The Future

Urban green space encompasses many forms, including remnants of “natural” vegetation, restored environments, and human-made or engineered spaces. These spaces provide important environmental and sociocultural services to organisms, including humans, using and living in urban environments. A growing body of research considers ecology in and the ecology of cities and the many services that urban green spaces provide. Despite the considerable environmental and sociocultural services provided by urban green spaces, how best to integrate such areas into urban planning and design remains an open question. Urban environments are experiencing, at an accelerated rate, many of the environmental changes facing the planet as a whole—elevated temperatures; dramatically altered hydrological systems; air, water, and soil pollution; and habitat loss. We have much to learn from how urban green spaces respond to such pressures and how they can be used to respond to the social and environmental changes such pressures will bring.

George L. W. Perry

See also [Energy and Human Ecology](#); [Environmental Services](#); [Greenbelts](#); [Green Building](#); [Green Design and Development](#); [Human Ecology](#); [Suburban Land Use](#); [Urban Ecology](#); [Urban Environmental Studies](#); [Urban Gardens](#); [Urban Heat Island](#); [Urban Land Use](#); [Urban Metabolism](#); [Urban Planning and Geography](#); [Urban Solid Waste Management](#); [Urban Water Supply](#)

Further Readings

- Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., et al. (2008). Global change and the ecology of cities. *Science*, 319, 756–760.
- Pickett, S. T. A., Cadenasso, M. L., Grove, J. M., Nilon, C. H., Pouyat, R. V., Zipperer, W. C., et al. (2001). Urban ecological systems: Linking terrestrial, ecological, physical, and socioeconomic components of metropolitan areas. *Annual Review of Ecology and Systematics*, 32, 127–157.
- Solecki, W. D., & Welch, J. L. (1995). Urban parks: Green spaces or green walls? *Landscape and Urban Planning*, 32, 93–106.
- Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., et al. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, 81, 167–178.
- Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, 224, 420–421.
- van Roon, M. (2005). Emerging approaches to urban ecosystem management: The potential of low impact urban design and development principles. *Journal of Environmental Assessment Policy and Management*, 7, 125–148.



URBAN HEAT ISLAND

Urban areas often experience warmer temperatures than their surrounding rural areas. This phenomenon, called the urban heat island (UHI) effect, has been observed in numerous settlements around the world, making it one of best-documented examples of inadvertent climate modification. Heat islands occur in the air, at the surface, and in the ground beneath cities. Atmospheric heat islands may extend to considerable distances aloft, although UHIs occurring below roof level in the urban canopy layer have received the most attention in the literature. As an increasing proportion of the world’s population lives in urban areas, cities grow, and their impact on environmental, biophysical, and atmospheric processes increases. This entry provides a brief overview of UHI impacts, describes the physical causes of UHIs, and closes with a brief synopsis of urban climate research.



May 19, 1998: Hot rooftops shine brightly in a fresh, false-color image of Baton Rouge, Louisiana, taken as part of the Urban Heat Island Pilot Project (UHIPP) conducted by NASA and other agencies. It clearly demonstrates the principle behind UHIPP—that the differences in cooling and heating between the natural and humanmade surfaces can affect city temperatures.

Source: NASA/Marshall Space Flight Center.

Urban heat islands directly affect a number of human and natural systems. UHIs also generate indirect impacts through altering mesoscale circulations such as thunderstorms and urban/country breezes. Urban gardeners are well aware that

the UHI alters flowering dates and extends the growing season in cities. Urban warmth can be favorable for many species of plants and animals, particularly during the cool seasons. Conversely, elevated urban temperatures often negatively



affect human comfort and health during warm seasons. Sensitive demographic cohorts such as the elderly and infirm are at particularly high risk of heat-related illnesses and mortality. Energy demands are also affected by the UHI. In warm climates, the higher number of cooling degree days occurring within cities further increases cooling costs. In cool climates, however, energy savings from reduced heating degree days may offset or surpass the increased cooling bills. Even climate science is affected by the UHI since artificially high temperatures can introduce bias into long-term temperature records. If land use/land cover is changed in the vicinity of a weather station, localized climatic changes could appear in the station's record and be misinterpreted as a regional or even global signal of climate change. Removing this urban bias requires sophisticated statistical techniques. The influence of urban areas on large-scale temperature trends continues to attract attention among climatologists.

UHIs are not limited to large cities; small towns generate heat islands too. In fact, any place where artificial land cover has replaced natural land cover could have a climate that is different from its surroundings. Replacing natural land covers, such as trees and grass, with artificial land covers, such as concrete and asphalt, alters the local energy balance. First of all, more incoming energy is retained in urban areas than in rural areas. Many urban surfaces have a low albedo (reflectivity) and often absorb more solar energy than the natural land covers they have replaced. In addition, the geometry of street canyons causes multiple reflections within the canyon, allowing multiple opportunities for building materials to absorb energy. Along with the aforementioned characteristics, the physical and thermal properties of construction materials are also different from those natural materials. Many building materials are very effective at retaining absorbed solar energy and radiating heat into the surrounding environment for hours after sunset. By comparison, rural areas generally cool much more quickly. Therefore, differences in urban and rural cooling rates after sunset often generate the UHI. Additionally, maximum nocturnal UHI development typically occurs on calm, clear nights. Calm winds limit the mixing of urban and rural air, and clear skies promote rapid nocturnal cooling through the loss of longwave radiation.

Another alteration of the energy balance in urban areas involves latent heat exchange. Impervious surfaces combined with a low amount of vegetation in urban areas result in little water being available at the surface to absorb latent heat through evapotranspiration. The result is that much of the excess available net energy goes to sensible heat, often making urban areas warmer than the surrounding, unmodified rural areas.

Urban climatology has experienced tremendous growth since Luke Howard's original study of London's UHI in the early 1800s. Through documenting the UHI of numerous individual cities, scientists better understand the causes of the UHI. We have also learned that cities having similar populations can experience very different UHI characteristics due to the lifestyles of their inhabitants, the geographic setting, and physical characteristics such as land use patterns and choice of building materials. Field-based studies have become increasingly more complex as observational instrumentation has improved. Remotely sensed data have also been used extensively in UHI research to analyze surface temperature patterns and to track land use and land cover changes over time. Data from field research and remote platforms provide information for computer models that has greatly advanced our understanding of UHI dynamics. Despite the vast increase in our knowledge, numerous questions remain about the relationships between UHI and global climate change. Global warming will likely affect cities primarily by altering regional-scale processes such as wind and precipitation patterns. What is far less understood, however, is how urban climates affect larger-scale processes that create uncertainty when trying to model atmosphere processes.

The number of publications about urban climate in both physical science and non-physical-science journals has increased over the past decade. The recognition of urban climate's importance and relevance to other disciplines indicates the health and vitality of the discipline. This is encouraging since urban sustainability efforts must involve numerous scientists, professionals, and stakeholders working together to achieve common goals.

Donald M. Yow



See also **Anthropogenic Atmospheric Change; Anthropogenic Climate Change; Built Environment; Climatology; Environmental Impacts of Cities; Land Use and Cover Change (LUCC); Sustainable Cities; Urbanization**

Further Readings

Arnfield, A. J. (2003). Two decades of urban climate research: A review of turbulence, exchanges of energy and water, and the urban heat island. *International Journal of Climatology*, 23, 1–26.

International Association for Urban Climate:
www.urban-climate.org

Yow, D. M. (2007). Urban heat islands: Observations, impacts, and adaptation *Geography Compass*, 1(6), 1227–1251.



URBAN HIERARCHY

Urban areas exhibit a large range of population sizes—from hamlets to global cities—each having a corresponding economic role within the urban system. Settlements with larger populations that provide more and diverse services are higher up the urban hierarchy. Settlements with smaller populations and a limited number and type of services are further down the urban hierarchy. The size and distribution of urban areas within this system have important implications for economic development.

The urban hierarchy may be illustrated by a pyramid where the smallest settlements (hamlets) are at the bottom of the pyramid and global cities are at the top (Figure 1). Settlements at the bottom of the pyramid have small, rural populations and

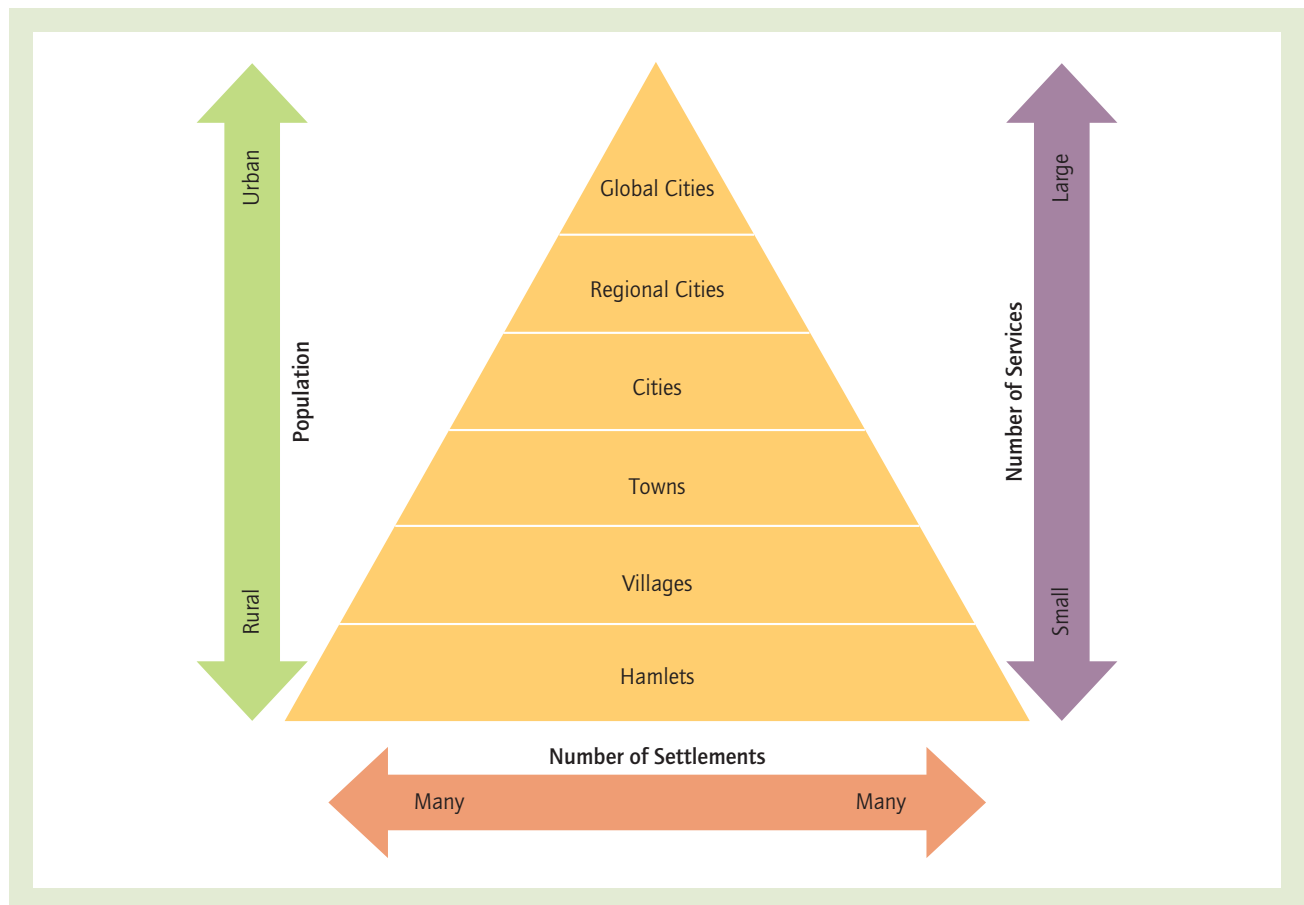


Figure 1 Population, settlements, and services in the urban hierarchy

Source: Author.

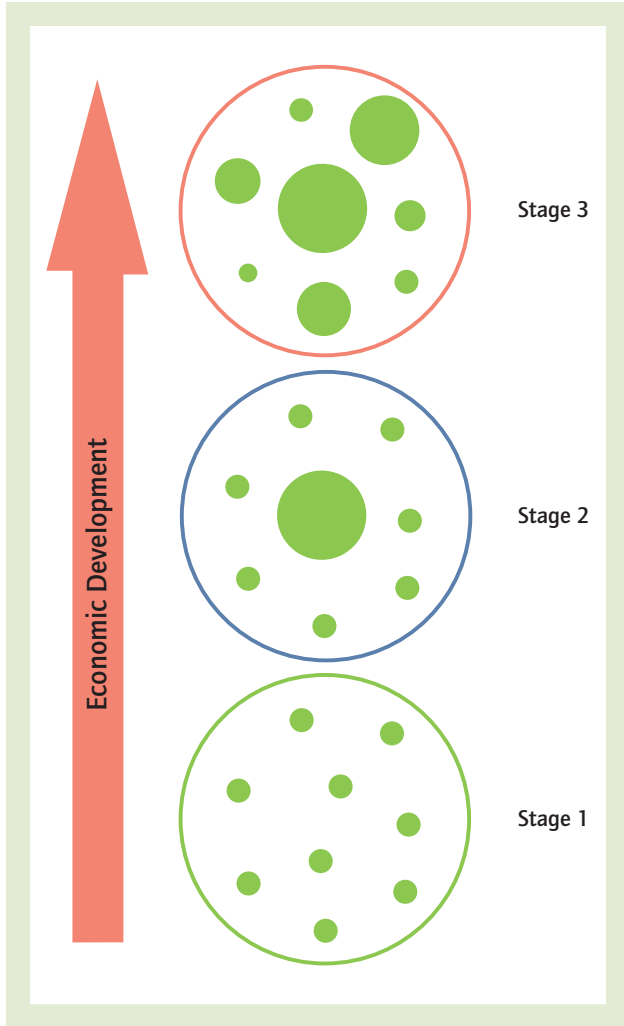


Figure 2 Urban hierarchy and economic development

Source: Author.

contain a small number and limited variety of economic services within the system. This type of settlement is the most dominant and widespread. Settlements at the top of the pyramid have large, urban populations and contain a large number and wide array of economic services. Usually, there is one settlement at the top of the urban system. As you move up the urban hierarchy, the number of settlements in each category declines as the populations and the number and diversity of services expand. For example, in the United States, the city at the top of the urban hierarchy is New York, which has the country's largest population;

is a major global financial, transportation, and cultural center; and offers a wide variety of social and economic services. Just below this level would be cities such as Los Angeles and Chicago, both of which have large, urban populations and offer numerous retail, financial, medical, education, and cultural services. One step below on the urban hierarchy, we will find cities such as Atlanta, Denver, Seattle, and Miami. Each has large urban populations, but they are smaller in size than the populations of New York City, Chicago, and Los Angeles. They also offer a somewhat smaller number of services. Below this level, we find cities that might be the largest cities within a state and/or state capitals. These cities serve an important economic and administrative role at a statewide or perhaps regional level. Smaller cities that are not state capitals or are not the largest cities within a state are found at the next level. They supply services to a portion or region of the state and have a significantly smaller population. Towns with smaller populations and a smaller array of services depend on nearby cities for more diverse services. Hamlets have small populations and very limited services, such as gas stations, convenience and/or grocery stores, and restaurants.

In the early stages of development and in agriculturally based economic systems, settlements typically are of similar size and are evenly distributed across the landscape (Figure 2, Stage 1). This pattern minimizes transportation costs and competition. Over time, one city or settlement (the core) gains dominance or power over other settlements in the system (Figure 2, Stage 2). This core or primate city may be centrally located compared with the other cities, or it may have an ideal location as a port city for access to water transportation. Primate cities are the largest and most dominant cities within a system of cities. Primate cities have populations many times greater than the second largest and subsequent cities. Usually, primate cities were once centers of much larger systems (e.g., empires). Over time, city systems tend to move toward a rank size distribution (Figure 2, Stage 3).

When a primate city size distribution exists within a system of cities, negative economic consequences can occur. During Stage 1, settlements are of comparable size and economic well-being

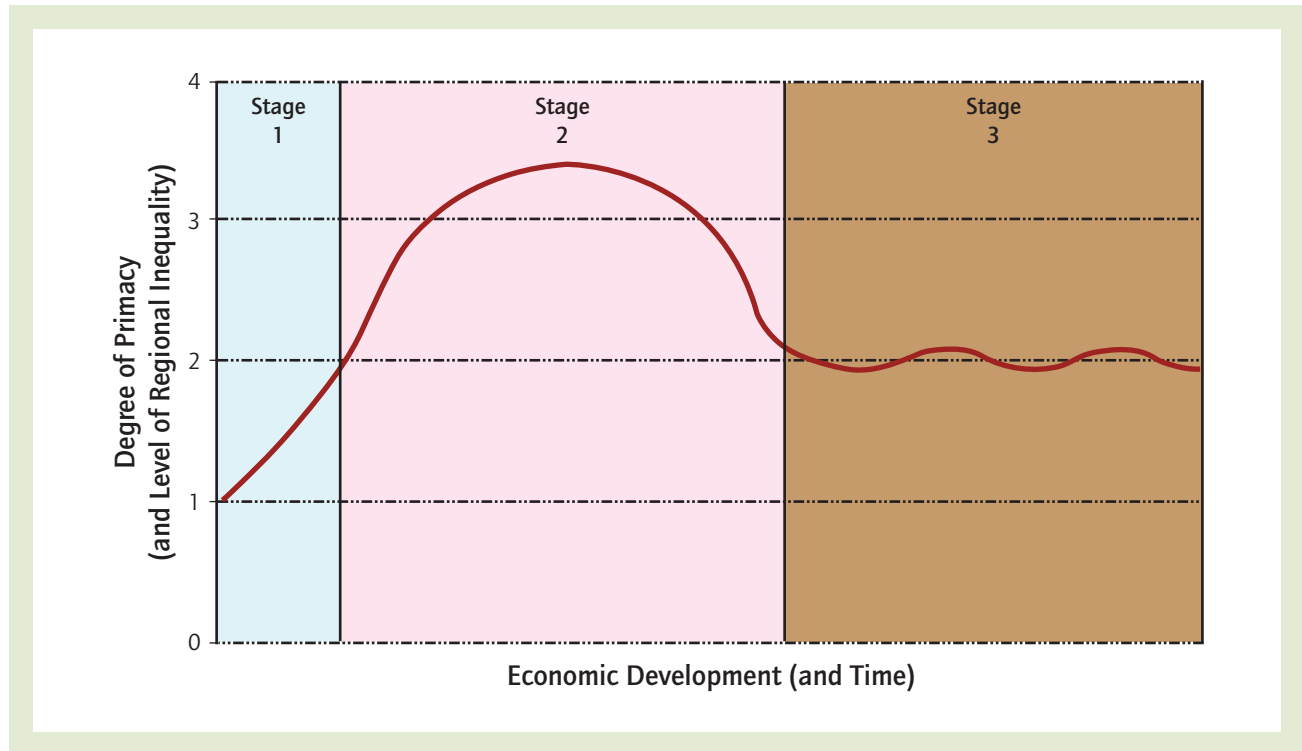


Figure 3 Urban hierarchy and degree of primacy

Source: Author.

(Figure 3). As economic development occurs and/or time passes, one city or settlement dominates the region or has a high degree of primacy—now referred to as the core (Stage 2). The core has a high capacity for generating and absorbing change. The core is technology rich and economically rich and depends on inputs from the periphery (the smaller settlements in the systems). Development in the periphery is determined by the core region institutions and tends to be resource rich but economically poor. The periphery is based on outputs to the core. As economic development increases and/or time passes, the system approaches a rank size distribution, and there is a more equitable distribution of wealth across the region (Stage 3).

The world faces comparable challenges of core and periphery regions as globalization occurs. Developed regions (the core) rely on undeveloped regions (the periphery) for resources and labor. Undeveloped regions must deal with rapid population growth in urbanized areas as an agrarian-based populace seeks the promise of higher-paying

factory jobs. As these peripheral regions reach higher levels of economic development, they will become less dependent on the developed world for technology and investment, and the global economic system will likely have a more equitable wealth distribution.

Lisa Theo

See also **Central Place Theory; Primate Cities; Rank-Size Rule; Urban Geography; Urbanization; World Cities**

Further Readings

- Berry, B. (1964). Cities as systems within systems of cities. *Papers in Regional Science*, 13(1), 146–163.
- Pred, A. (1977). *City systems in advanced economies*. New York: Wiley.
- Taylor, P. (2003). *World city network: A global urban analysis*. London: Routledge.



URBANIZATION

The urban world at the dawn of the 21st century has assumed special importance for two principal reasons. First, the world's population has recently crossed the threshold from being more rural to being more urban. In absolute terms and according to UN estimates, this means that of the world's population of approximately 6.8 billion, approximately 3.5 billion people (or 51%) are living in urban settings. To put this notion in historical context, consider that 58 yrs. (years) earlier only 29% of the world population lived in cities. The projection for 2050 is 70%. Second, a dramatic change in the urban hierarchy is taking place as the large cities—variously termed *global cities*, *world cities*, *megacities*, and so on—are beginning to dominate the urban landscape. This entry first reviews the historical development of the urban world, from the earliest settlements in Mesopotamia to the present, and the types of explanations researchers have used to describe this process. Problems in measuring the degree of urbanization are then discussed, including the concept of *urban degree* (the level of a country's urban concentration, expressed in percentage at a point of time). Although urbanization is occurring around the globe, there are significant differences in this process; some of the global trends are noted here. The entry concludes with a look at the future of urbanization.

Along with urbanization, other changes are taking place concomitantly: The rural-urban and interurban mobility of population is accelerating, the traditional rural-urban dichotomy is blurring, and research and technological innovations in economic development and transportation—along with the relaxation of political-institutional barriers—are growing. Consequently, a diversified and unprecedented mix of urban phenomena, urbanization processes, and urban patterns in global and regional scales is emerging, giving rise to complex issues, problems, and prospects. The concentration of urban populations is manifested in many forms and functions—both historically, through cyclical changes (e.g., urbanization, de-urbanization, and re-urbanization), and spatially, from the monocentric, core-oriented settlements to the polycentric, peripherally focused patterns.

Urban fringe, urban cluster, urban sprawl, “rurban,” and extended urban areas are among the terms frequently used to identify and characterize the spatial patterns of the emerging urban landscapes. Urbanization is linked with social and demographic changes such as smaller family sizes, occupational specialization, and increased population densities. Ideally and typically, urbanization is tied with increasing wealth and improved quality of life. While an urbanizing world has the potential to impart extraordinary benefits—including an enhancement of the quality of life—to its citizens, it also faces significant problems that include the degradation of environment and a challenge to urban sustainability. Urbanists seek to analyze these diverse urban issues from a variety of perspectives and scales in order to understand the spatial processes and patterns.

Urban Evolution

Early urban settlements were small but iconic representations or symbols of civilization, extensively written about in a number of regional contexts. Even though the concentration of population in settlements can be traced historically, the evidence of urban origin—the where, when, and how of urban concentrations and their subsequent spread—remains uncertain. Scholarly disagreements on the genesis, traits, settlement patterns, and modes of dispersal of urbanization notwithstanding, we know that urbanization has been a nearly continual process throughout human history. The earliest cities, or urban settlements, first developed approximately 6,000 yrs. ago in Mesopotamia. These were followed by cities developing independently in the Nile Valley in Egypt, the Indus Valley in South Asia, the Yellow or Huang He River valley in China, parts of Africa, and Mesoamerica and South America over the next several millennia. These regions are widely cited as the early “urban hearths.”

Of the theories offered to explain urban origin, four broad theories—hydraulic, economic, military, and religious—provide the dominant views. Briefly, a surplus in agricultural production was a critical notion underlying the hydraulic theory, and the notion of cities as the locations for trade was central to the economic theory. In the military theory, the need for concentration was



attributed to the communal defense, while the role of religious leaders in the organization and control of territories for ensuring the safety and security of community dwellers was the basis of the religious theory. Clearly these explanations are not mutually exclusive.

Historically, urbanization has been linked with the progress of society from agrarian to industrial. Most societies before the 16th century were only marginally urban, as the vast bulk of the populations consisted of peasants and farmers. The mode of agricultural production, extraction of natural resources, and trading activities of urban dwellers had distinctive geographical and locational advantages. Subsequently, the progress of the agrarian economy, increased trade in the 16th century, and the onset of the Industrial Revolution in the 18th century laid the foundation of large-scale urbanization. Cities grew in number and population and became interlinked in trade and commerce.

Urbanization as a global phenomenon accelerated markedly with the advent and expansion of European colonialism. This diffusion of urbanization may be broadly depicted in several phases: The earliest phase grew incrementally and most apparently in Latin America, subsequently appearing in South Asia, Southeast Asia, and Africa. Other parts of Asia, such as China, were affected too, though later and not to the same degree. This first phase, lasting until the mid 1800s, was rooted in city-based mercantile colonial activities. During this period, city growth occurred mostly in colonial trading centers.

A second, industrial colonial phase was evident from the mid 1800s through the 1920s. During this phase, urbanization was increasingly tied to the extraction of raw materials for industrial activities and for growing food consumed in the rapidly expanding industrial centers. States were more directly involved in territorial control of their colonies. Colonial urbanization became more complex and more pervasive. Cities grew rapidly, became denser and increasingly segregated, and came to bear the hallmarks of European colonial planning.

The emergence of diversified urban economies and the development of a variety of transportation modes in the 19th century provided the stimulus for urbanization to accelerate, while

distinctive patterns of urbanization became evident during the second half of the 20th century, especially during the post-World War II period. Several factors can be attributed to this distinctive pattern. First, many of the so-called less developed countries gained independence from colonial rule and initiated socioeconomic developmental planning emphasizing large-scale industrialization. Second, some of the more developed industrial countries shifted their industrial base from traditional manufacturing to a wide range of tertiary activities. This shift altered the location of activities by prompting regional redistributions of population within countries while spreading industries to new sites outside the core cities and countries. Third, the revolutions in finance, trade, and commercial activities involving both the developed and the developing countries, particularly during the past 25 yrs., gave rise to the process of globalization, which is intrinsically linked to the accelerated growth and development of many larger cities. One prominent outcome of the globalization process is seen in the emergence of the current global city or world city.

Throughout world history, urbanization, industrialization, and societal changes have been closely interrelated. Two key factors, broadly speaking, have shaped the pattern of urbanization over the centuries: the demographic (population base and growth rates) and the economic (resource base, growth rates, and development), making the socioeconomic development path key to understanding urbanization. This intricate relationship makes it imperative to understand, measure, and monitor urbanization, primarily by means of assessing the urban concentrations of population in space and over time.

Measuring Urbanization

In general, urbanization is described as the process of concentration of a population in space designated as urban—a process that encompasses the migration of populations from rural to urban areas, a natural increase in the urban population, and a reclassification of rural areas to urban. Although the idea of spatial concentrations of population might appear to be simple, it is well recognized that a variety of its correlates manifest



themselves in urban space, reflecting the complexities of the process. Virtually all the countries of the world have designated their urban places or areas, although the conceptual definition of the term *urban* remains variable. Broadly, the following are among the key criteria that have general global acceptance:

- A minimum threshold of population size, built-up area, or density
- Occupational traits of the labor force (primarily nonagricultural)
- Administrative status
- Spatial structure and organizational pattern

In spite of the general agreement on the key criteria, the study of urbanization is fraught with two problems, namely, that the urban concept is not uniformly defined across the globe and that the data on the criteria for urbanization lack uniform definition, stringency, accuracy, or availability. These problems make it difficult to adequately assess and compare the urban status or patterns of individual countries or regions, not to mention the difficulties involving intracountry or cross-country comparability. Traditionally, easily computable demographic data, such as a minimum threshold of population size, are used for determining the urban status of a designated place. This simple approach reflects one of the many urban traits that arise out of population concentration. Wide variations in urban concentrations are apparent across nations, usually related to the countries' levels of development and industrialization. In this respect, measurement of urbanization becomes a key indicator in assessing the developmental status.

The change in the degree of urbanization (urban degree) can be measured in two ways: (1) urban growth—the difference in the level over a period of time and (2) the relative difference between urban and rural growth rates. If the urban growth rate exceeds the rural growth rate over a specified time period, an urbanizing process sets in, indicating change in the societal status of the country. The measure of concentration and change in a population, as noted in its urban degree, growth, and urban-rural differentials, is related to a host of underlying demographics (e.g., birth rates, death rates), economic

(e.g., migration of labor force), and/or administrative (e.g., urban designation policy) factors.

Global Trends: An Overview

The difficulty in generalizing about global urbanization primarily arises from the complex geographies of countries and regions. First, the geographic patterns of the level of urbanization vary substantially across the globe. By world region, the world's most urbanized areas are North America (the United States and Canada; 81%), Latin America (78%), Europe (72%), and Oceania (71%). Less urbanized areas are Africa (39%) and Asia (41%). Given their demographic magnitude, it is wise to single out the urbanization levels of China (47%) and India (29%). Notable countries at the extremes are Singapore (100%) and Uganda (13%). Next, the pattern of change across the developed and less developed regions, both in the number of urban populations and in the rate of urbanization, are noticeably uneven (Figure 1). Irrespective of their level of urbanization, during the 25 yrs. following World War II, the urban population steadily increased in both the developed countries and the less developed countries. However, during the next 25 yrs. (1975–2000) both the size and the growth rates of the urban population in the less developed countries significantly exceeded the same in the more developed countries.

The urban structure, depicting the proportion of population distributed in a variety of size groups of places within given geographical and/or administrative territorial boundaries, can indicate important attributes of spatial development as observed in many regions in less developed countries. During the period from 1975 to 2000 (Table 1), the pattern of change in three selected hierarchical size groups of urban population showed a steady rise in the number of urban settlements in the smallest (<1 million population) size group, while they declined in their share of the total urban population. For the intermediate (1–5 million) and the largest (>5 million) size groups, the number of settlements increased, while their proportion of total urban population either increased or remained steady during these years. The structural patterns did not show much variation between the more developed countries and the less developed countries. However, compared

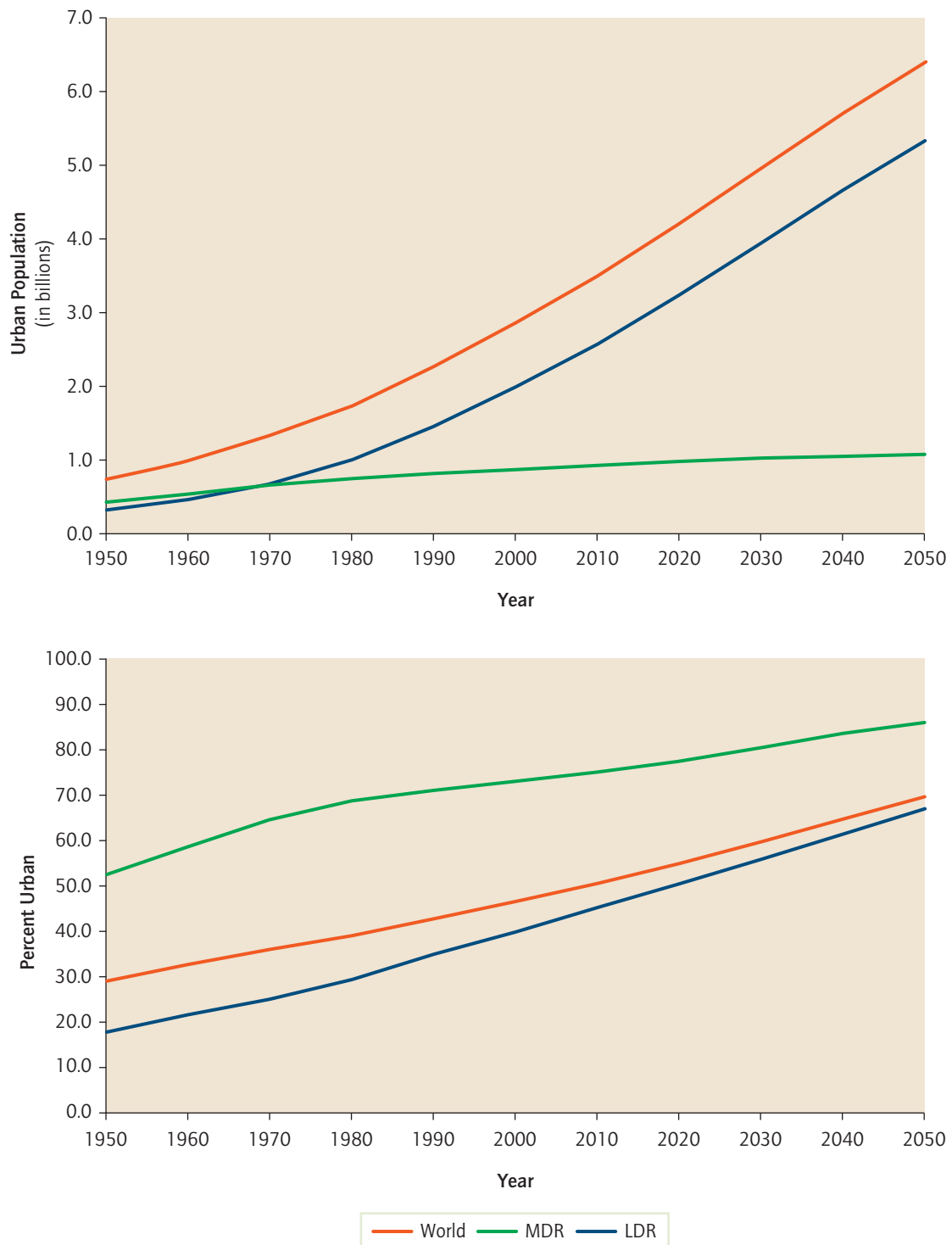


Figure 1 Urban population: uneven growth of MDRs (more developed regions) and LDRs (less developed regions)

Source: Adapted from United Nations. (2008). *World urbanization prospects: The 2007 revision* (pp. 74–83; Table A2). New York: Author.



Region/Year	Urban Population by Size Groups, 1975–2025			Number of Cities		
	<1 million	1–5 million	>5 million	<1 million	1–5 million	>5 million
World						
1975	67.9	20.9	11.2	237	163	18
2000	62.8	22.3	14.9	399	334	44
2025	59.8	23.1	17.0	551	524	75
MDRs						
1975	67.3	19.6	13.2	102	71	8
2000	63.6	22.4	14.0	116	98	10
2025	62.4	20.4	17.2	132	103	17
LDRs						
1975	68.3	22.1	9.6	135	92	10
2000	62.5	22.2	15.2	283	236	34
2025	59.2	23.8	17.1	419	421	58

Table 1 Urban population: selected size group of cities

Source: Adapted from United Nations. (2008). *World urbanization prospects: The 2007 revision* (pp. 220–230; Table A17). New York: Author.

Note: MDRs = more developed regions, LDRs = less developed regions.

with the smallest (<1 million) size group, a rather dramatic growth in the number of settlements for the two larger-size classes in the less developed countries depicts significant changes in the urban system (Table 1).

The emergence of megacities—those with 10 million or more people—marks a milestone in the 20th-century urbanization of the less developed countries. Out of a total of 19, there were only 5 megacities in the developed regions in 2007 (Table 2). It is estimated that by the year 2025, only one more city will be added to the megacity list in the developed region, while the rest, accounting for nearly 80% of the total number of cities, will be in the less developed countries. Over the past two decades, megacities in the less developed countries have experienced significant growth. Some, such as Dhaka in Bangladesh and New Delhi in India, recorded a huge increase of 11.3 million and 11.5 million people, respectively, during the period from 1975 to 2007. The average population of the world's largest 100 cities now stands at more than 7 million, compared with only 700,000 in 1900. The observed trends are attributed, broadly, to the forces generated from

within (e.g., development policies) and/or outside (e.g., economic globalization) the more developed countries and the less developed countries.

The Urban Future

Urbanization is a universal process. No matter how its evolutionary path is traced or interpreted, the certainty of its steady pace can hardly be disputed. Much social progress and development and economic prosperities are derived from urbanization. The continuity of the pattern of growth and pace, however, also clearly indicated the vulnerability of the urban environment. The basic issue for the future, then, is simple: How should the urban world grow?

While discussing the pros and cons of urbanization in the context of the global urban revolution, there are two major differing views on the state of urbanization. The “urban optimists” are motivated by the notion that the societal benefits of urbanization generate an overall improvement in the quality of life of the individuals as well as in the developmental levels of nations. The “urban pessimists,” on the other hand, worry



Urban Agglomeration	Population in Millions		
	1975	2007	2025
Tokyo, Japan	26.6	35.7	36.4
New York–Newark, USA	15.9	19.0	20.6
Mexico City, Mexico	10.7	19.0	21.0
Mumbai, India	7.1	19.0	26.4
Sao Paulo, Brazil	9.6	18.8	21.4
Delhi, India	4.4	15.9	22.5
Shanghai, China	7.3	15.0	19.4
Kolkata, India	7.9	14.8	20.6
Dhaka, Bangladesh	2.2	13.5	22.0
Buenos Aires, Argentina	8.7	12.8	13.8
Los Angeles–Long Beach–Santa Ana, USA	8.9	12.5	13.7
Karachi, Pakistan	4.0	12.1	19.1
Cairo, Egypt	6.4	11.9	15.6
Rio de Janeiro, Brazil	7.6	11.7	13.4
Osaka-Kobe, Japan	9.8	11.3	11.4
Beijing, China	6.0	11.1	14.5
Manila, Philippines	5.0	11.1	14.8
Moscow, Russia	7.6	10.5	10.5
Istanbul, Turkey	3.6	10.1	12.1
Kinshasa, Democratic Republic of the Congo			16.8
Lagos, Nigeria			15.8
Jakarta, Indonesia			12.4
Guangzhou, Guangdong, China			11.8
Lahore, Pakistan			10.5
Shenzhen, China			10.2
Chennai, India			10.1
Paris, France			10.0

Table 2 Urban population: megacities

Source: Adapted from United Nations. (2008). *World urbanization prospects: The 2007 revision* (pp. 164–167; Table A11). New York: Author.

about the adverse effects of urbanization, especially in the context of the developing countries, where socioeconomic unrest and urban pathologies such as poverty and slums continue to plague society. People across the globe perhaps see their individual and collective urban futures somewhere along the continuum.

To optimize the benefits of urbanization for societal development while minimizing, or at least coping with, its adverse consequences, it is imperative that research be focused on the global, national, and regional or local scales to understand the divergent paths of the complex urbanization phenomenon. In charting the future course of urbanization, the needs and wants of the people

for a desirable urban living environment in a variety of contexts must be incorporated. Just as it is essential that the stakeholders—the citizens, the private and the public bodies—participate in envisioning the urban culture for shaping the future, it is equally crucial to collect, store, and distribute accurate and comparable urban data for ongoing research that would serve as the foundation for effective planning strategies and policies.

Debnath Mookherjee and George Pomeroy

See also Counterurbanization; Gentrification; Rural-Urban Migration; Suburbs and Suburbanization;



Uneven Development; Urban and Regional Development; Urban and Regional Planning; Urban Environmental Studies; Urban Geography; Urban Hierarchy; Urban Land Use; Urban Planning and Geography; Urban Policy; Urban Spatial Structure; Urban Sprawl; Urban Sustainability; Urban Underclass; World Cities; Zoning

Further Readings

- Bloom, D., & Khanna, T. (2007). The urban revolution. *Finance & Development*, 44(3), 9–14.
- Carter, H. (1983). *An introduction to urban historical geography*. London: Edward Arnold.
- United Nations. (2008). *World urbanization prospects*. New York: Author.
- Zlotnik, H. (2004). World urbanization: Trends and prospects. In T. Champion & G. Hugo (Eds.), *New forms of urbanization: Beyond the urban-rural dichotomy* (pp. 43–65). Aldershot, UK: Ashgate.



URBAN LAND USE

Cities across the world are complex mosaics of economic, social, political, and recreational land uses. How and where these land use activities are organizationally patterned reflect not only a city's primary function (e.g., an "economic engine" in an industrial economy or a "cultural/administrative" center in an agrarian economy) but also at least two other overarching forces—accessibility and territoriality/congregation/segregation. In general, the utility of a designated place or location within a city is defined by its potential usefulness, which, in turn, is often a function of its accessibility. Activities that tend to be land intensive have a propensity for high levels of interaction and serve a necessary and functional purpose that requires accessible locations. Alternatively, low-accessible locations are occupied by those land use activities that are characteristically land extensive (activities that require the use of large tracts of land) and functionally peripheral and independent (Figure 1).

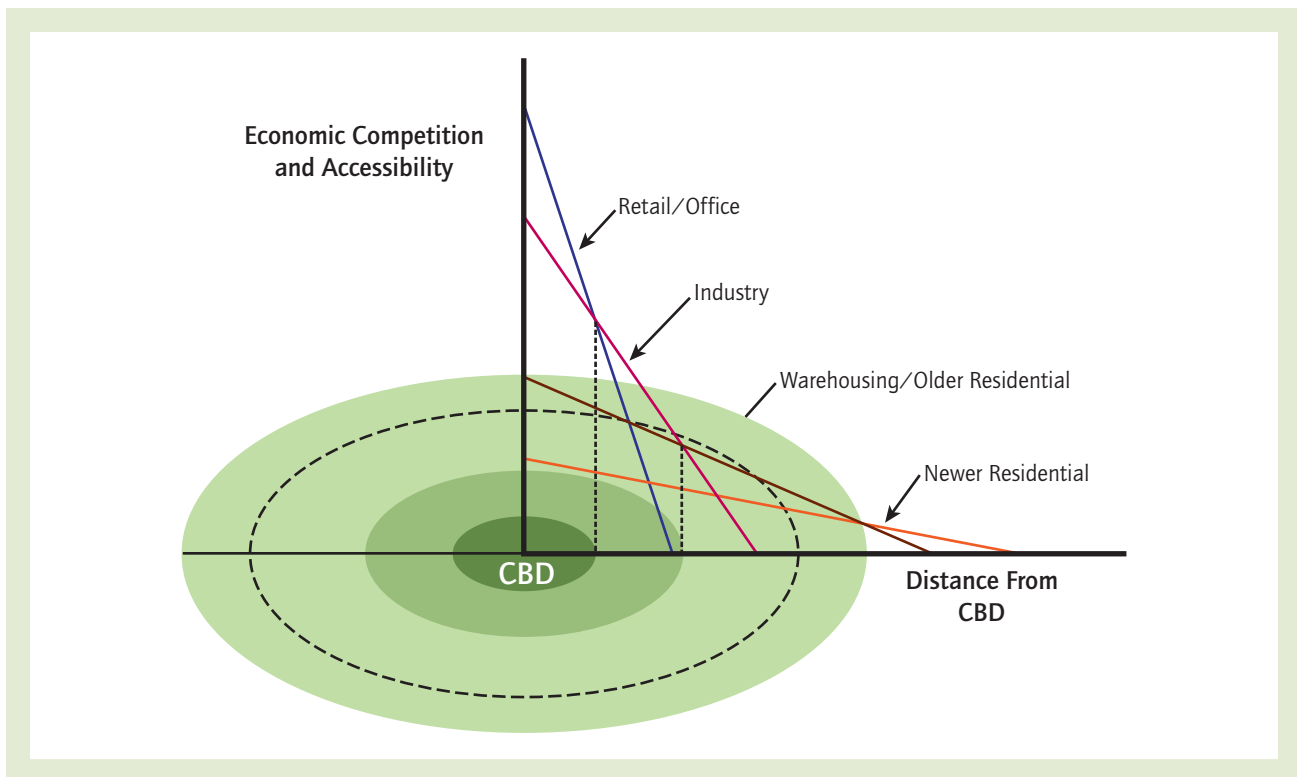


Figure 1 Economic competition, accessibility, and the resultant urban land use patterns in relationship to the central business district (CBD)

Source: Author.



At the same time, land use activities are often organized in clearly demarcated geographic *territories* so as to define and preserve “group” membership and identity. Typically, this involves the use of both inclusionary and exclusionary practices in an effort to create homogeneous groupings by housing, retail/commercial establishments, professional services, and industry. Of particular significance is the occurrence of *congregation*—a voluntary territorial and residential clustering of specific groups of people (i.e., language, religion, race, lifestyle, among others) that engenders a sense of place unity as defined by a common electoral power base, a system of reciprocal support, and cultural preservation. However, there also exists an involuntary form of congregation (*segregation*) that results in territorial and residential clustering involving discrimination and the spatial separation of specific groups of people. In this way, both accessibility and territoriality/congregation/segregation are important place-defining forces that shape the internal structure of cities worldwide and their urban land use patterns. This entry discusses four urban land use models: (1) the concentric zone model, (2) the sector model, (3) the multiple-nuclei model, and (4) the peripheral model, as well as the application of these models.

Urban Land Use Models

Whereas economic competition, accessibility, and the propensity toward social and ethnic discrimination/segregation/congregation are evidenced in many of the cities across the globe, the resultant urban land use varies considerably due to the influences of culture, history, and particularly the functional roles cities have played in the world economy. Since the 1920s, geographers, sociologists, and economists have attempted to identify and examine the ever-evolving geographic placement of people, economic activities, and administrative functions in cities. Within the North American context, four models describing the internal structure of cities have been developed: (1) the concentric zone model, developed by Ernest W. Burgess in 1923; (2) the sector model, developed by Homer Hoyt in 1939; (3) the multiple-nuclei model, developed by Chauncy Harris and Edward Ullman in 1945 (Figures 2A, B, and

C); and (4) the peripheral model, developed by Truman Hartshorn and Peter Muller in 1989 (Figure 3).

Traditionally, the city’s center, commonly known as the central business district, or CBD, has served as the principal “hub” for retail, office, and significant administrative/institutional land use activities. In particular, the CBD has not only contained the highest density of all these land use activities but has also been positioned at the nodal point of transportation systems and is visually characterized by an impressive vertical skyline. Typically, the CBD is surrounded by a zone of mixed land uses, including older residential neighborhoods, small factories, warehousing, and multifamily residential complexes, and is often collectively referred to as an urban land use “zone in transition.” Geographically, beyond this zone is a mosaic of residential neighborhoods and suburban territories of various age, social, and ethnic compositions.

Concentric Zone Model

The concentric zone model was the first attempt to explain the distribution of different social groups within cities. Fueled by streams of migrants and immigrants from diverse cultural backgrounds to the North American industrial cities throughout the late 1800s and early 1900s, residential territories of congregation were established to provide a sense of security, communication, and familiarity. On average, these original ethnic communities persisted over one to three generations, after which an increasing number of individuals from these groups were able to obtain better employment and therefore relocated to newer, higher-income housing that was being built at greater distances from the CBD. In this way, the concentric zone model proposed a continual outward expansion of the city (in the form of concentric rings or zones), with the development of ever newer, more spacious and expensive residential neighborhoods (Figure 2A).

Sector Model

In 1939, a second urban land use model was developed by H. Hoyt. Because the key component influencing the geographic placement of land use activities in this model was accessibility,

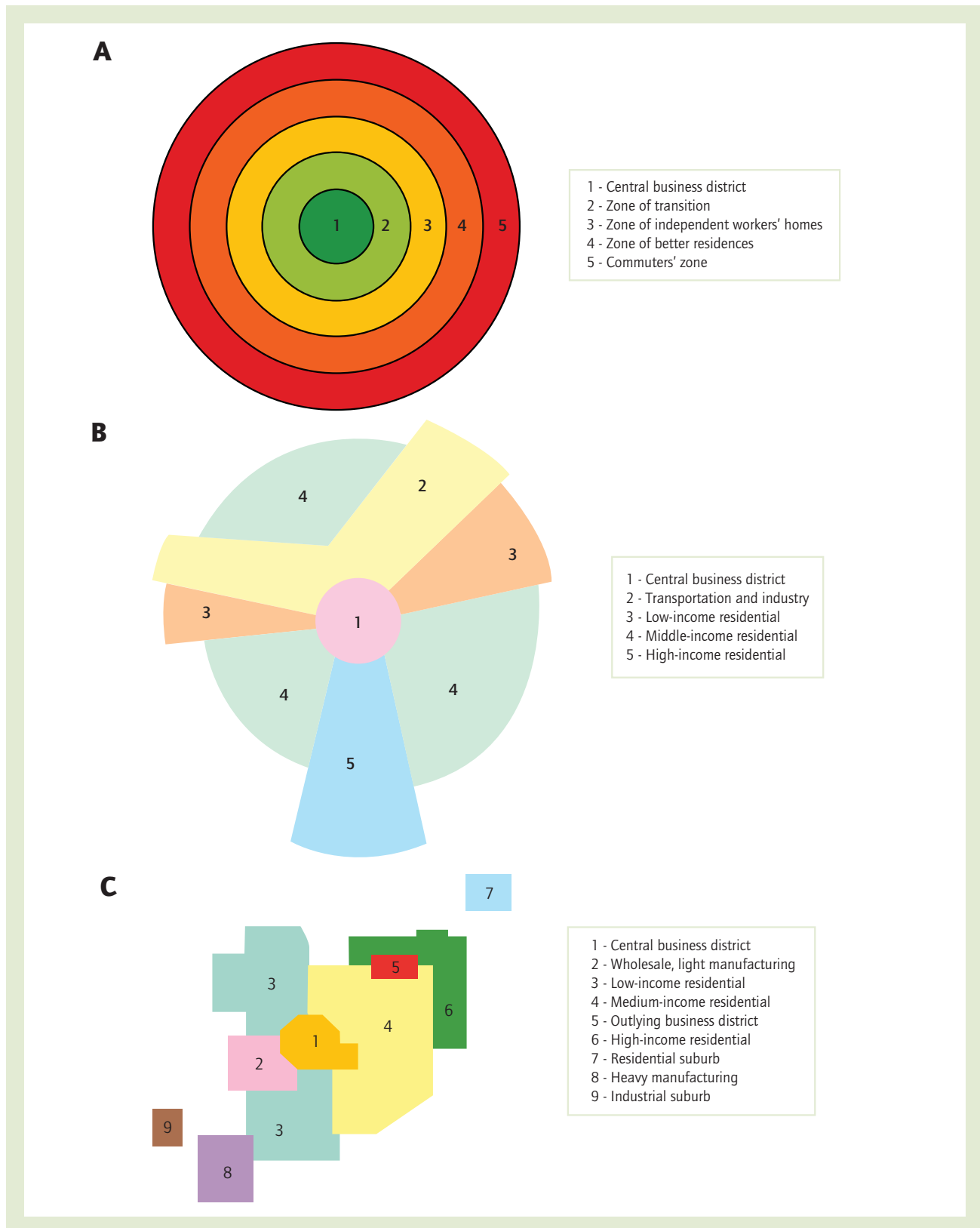


Figure 2 The three urban land use models: concentric zonal, sector, and multiple nuclei

Source: Author.



Hoyt argued that cities developed in a series of sectors (aligned along transportation “corridors”), not concentric rings (Figure 2B). As a city expanded geographically outward radial, as opposed to circumferential, transportation systems were built (e.g., suburban commuter roads and streetcar and elevated rail lines) to facilitate and channelize growth. And due to economic competition and the compelling demand for accessibility, land use activities located and geographically sorted themselves into clusters or sectors that were congruent with the transportation arteries radiating outward from the CBD. In this way, Hoyt suggested that high-rent residential areas grew outward from the CBD, along major transportation routes, surrounded by middle-income housing, and low-income housing settled in districts adjacent to the CBD near industry. Finally, the dynamism of the sector model is characterized by a “filtering-down process,” as older residential neighborhoods were abandoned by the outward movement of their original high-income occupants and were replaced by households of the next lower-income strata.

Multiple-Nuclei/Peripheral Model

In contrast to the concentric zone and sector models, the multiple-nuclei model views urban land use in cities as being shaped by several nodes of growth, as opposed to the single-CBD assumption (Figure 2C). In 1945, Harris and Ullman suggested that different land use activities have uniquely specific locational requirements; for example, retailing needs accessibility, heavy manufacturing relies on horizontal production spaces near railroads, port functions are best served by waterfront activities, and other nodes, including universities, airports, and parks, may serve as the focal point for other types of land use activities. And basically, both territorial segmentation and segregation were hallmark characteristics for understanding the resultant spatial pattern of urban areas.

While these three urban land use models are somewhat dated for explaining present-day urban land use patterns, they nevertheless continue to provide a historical baseline to the structural underpinnings of land use in contemporary metropolitan complexes. As an extension, Hartshorn

and Muller have proposed a peripheral land use model that accounted for the pervasive suburbanization of a multiplicity of CBD functions between 1970 and 1990 (Figure 3).

The peripheral model focuses on the circumferential outer beltway that has redefined the role of suburban nodes, not by their relationship with the traditional CBD but rather with other outlying suburban nodes. Contained within the peripheral model is the notion that households are highly segregated into relatively homogeneous suburban territories, whereby suburban nodes are highly developed and self-supporting employment, retail, and recreation centers. Finally, peripheral models legitimize the occurrence of exurbanization—a “residential appendage”—as the outermost land use activity connected to an urban area.

Application of Models

None of the four models individually and completely explain urban land use patterns. Partly due to their simplistic assumptions as well as the time period in which they were developed, the models do not encompass all the changing forces that geographically shape today’s urban communities. Nevertheless, the four urban land use models collectively provide the structural basis for understanding the social, economic, and political geographies of the contemporary city. While the four models may be particularly useful to describe urban land use patterns in North American cities, adjustments are needed for their application in both European and less developed country (LDC) contexts.

In particular, wealthier people in European cities not only cluster along specific sectors extending outward from the CBD but more prominently occupy places of residence in and adjacent to the CBD. Historical preservation combined with the numerous cultural amenities found in European CBDs, along with high transportation costs (fuel), make living and functioning in or near the CBD in high demand. As such, the poorer European urbanites tend to dominate the outer “suburban” tracts of land. Moreover, there exists an important distinction between Western and Eastern European cities. Namely, Western European cities and their resultant land use patterns are deeply

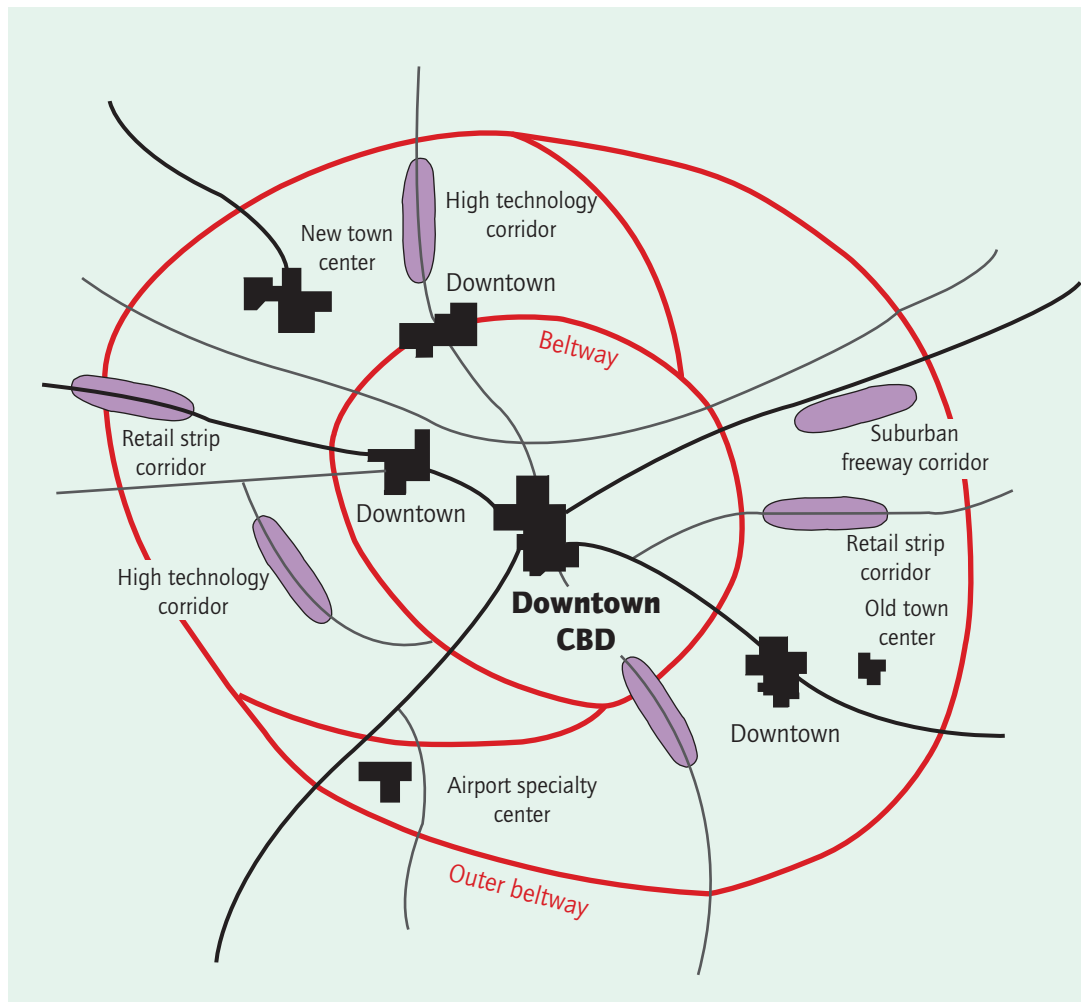


Figure 3 The peripheral urban land use model

Source: Author.

rooted in their medieval origins, Renaissance restructuring, and level of industrial capitalism. Their geographic compactness, high population densities, and pervasive “apartment”-style residences have fostered the continued reliance on public forms of transportation. Cities in Western Europe often combine places of residence with places of employment; for example, retail/business establishments occupy street-level space, while subsequent upper levels are occupied by households for living space. In many of these cities, the historic core is gentrified, where the middle-income groups, the elderly skilled artisans,

and the young entrepreneurs share space and intermingle with preserved historical buildings, monuments, and tourist attractions.

In contrast, Eastern European cities and their resultant land use patterns reflect a different ideological base—centrally administered planning principles. In particular, explicit segregated land use, “intra” neighborhood equality and autonomy, and restrictions on the geographical size of a city were adopted during the communist period, from 1945 to 1990. While none of these objectives ever became fully implemented, they have served as the cornerstones for the geographic



layout of Eastern European cities. Slowly but steadily, as the former Eastern Bloc countries, along with the former Soviet Socialist Republics that are now part of Eastern Europe, increasingly incorporate market principles of land allocation, the land use pattern of Eastern European cities may begin to resemble that of their western counterparts.

By comparison, the fastest-growing cities and the most rapidly growing populations are found in the developing world. Despite the variety of urban structure that abounds in culturally diverse regions such as Latin America, the Middle East, and Africa, there exist at least three common planning principles that underlie their urban land use. First, the lowest-income individuals have and continue to increasingly situate themselves in the outlying areas of the city, away from city services, often occupying the land illegally and forming squatter settlements. Second, there is an absence of adequate urban infrastructure to support the growing population—sanitation, drinking water, roads, electricity, and so on. Third, many of these cities have a colonial heritage that, over an extended period of time, left indelible architectural, religious, political, and cultural imprints on the geography of the city. In much of the developing world, urbanization is driven by massive rural-to-urban migration. In short, urban land use in less developed countries is primarily a culmination of historical origin, colonial imprint, and functional role within its current cultural setting.

Conclusion

Urban land use of cities across the world, whether in North America, Europe, or the developing world, is reflective of underlying antecedents for the design and planning of urban space. Whether land use is based on “grid systems” (the remnants of Greek and Roman settlements), position of power or celebrated glory (e.g., the Renaissance), religious edifices (e.g., the mosque, cathedral), military ordinance, or cities that should be designed and function like “machines” (e.g., the modern movement and industrial capitalism), geographical principles play a significant role in all urban landscapes.

Jeffrey P. Richetto

See also Chicago School; Exurbs; Hoyt, Homer; New Urbanism; Rural-Urban Migration; Suburban Land Use; Suburbs and Suburbanization; Urban and Regional Development; Urban and Regional Planning; Urban Ecology; Urban Environmental Studies; Urban Geography; Urban Spatial Structure; Urbanization; Urban Sprawl

Further Readings

- Berke, P. R., Godschall, D. R., & Kaiser, E. J. (2006). *Urban land use planning*. Urbana-Champaign: University of Illinois Press.
- Greene, R. P., & Pick, J. B. (2006). *Exploring the urban community: A GIS approach*. Upper Saddle River, NJ: Pearson Prentice Hall.
- Hartshorn, T., & Muller, P. (1989). Suburban downtowns and the transformation of metropolitan Atlanta's business landscape. *Urban Geography*, 10, 375–395.
- Knox, P., & Pinch, S. (2006). *Urban social geography: An introduction*. New York: Pearson Prentice Hall.



URBAN METABOLISM

The concept of urban metabolism provides a framework for examining natural resource flows and use in urban areas. Urban metabolism studies draw an analogy with the metabolic requirements and processes of an organism. Like an organism, a city requires water, energy, food, and other resources to fuel, grow, and reproduce itself. It also produces wastes and residuals that must be disposed of with minimal hazard. Urban metabolism studies can be used to provide insight into the sustainability of the relationships between a city and its supporting physical environments and have recently begun to include social and economic relationships as well.

The first formal urban metabolism study was prepared in 1965 by Abel Wolman for a hypothetical North American city of 1 million inhabitants to highlight key urban environmental issues of modern industrialized cities: the



Material Flow		10 ⁶ Tons/Year			Kilograms Capita ⁻¹ Year ⁻¹		
		1971	1997	% Change	1971	1997	% Change
Inputs	Food	2.4	5.0	+108	570	680	+20
	Fossil fuel	4.0	13.0	+225	1,000	2,000	+100
	Construction materials	4.0	25.0	+525	1,000	3,800	+280
	Other goods	1.0	3.5	+250	250	530	+112
	Freshwater	390	913	+134	99,010	137,976	+39
Outputs	Total solid waste	3	13.8	+245	762	2,086	+174
	Sewage	288	677	+153	73,115	102,311	+40
	CO ₂	9	31.6	+250	2,285	4,776	+119
	Air pollutants	0.26	0.33	+27	65	50	-23
Hong Kong population: 393,900 (1971); 6,617,100 (1997)							

Table 1 Urban metabolism of Hong Kong, 1971 and 1997

Sources: Data compiled from Newcombe, K., Kalma, J. D., & Aston, A. R. (1978). The metabolism of a city: The case of Hong Kong. *Ambio*, 7, 3–15; Warren-Rhodes, K., & Koenig, A. (2001). Escalating trends in the urban metabolism of Hong Kong: 1971–1997. *Ambio*, 30, 429–438.

provision of a safe and adequate urban water supply, the effective disposal of sewage, and the control of air pollution. Since then, approximately 10 urban metabolism studies of actual cities have been conducted, including Hong Kong, Vienna, Toronto, Tokyo, London, and Sydney. Analysis using urban metabolism as a framework metaphor typically takes the form of a material flow analysis, where researchers take stock of the inputs, storage, transformation, and output of different materials and their residuals across a defined urban system and over time. While some studies look specifically at the flow of a single material such as water or nitrogen, most provide a comprehensive accounting of inputs and wastes.

Taking stock of material flows across an urban system and over time helps draw attention to the need to examine the systemwide impacts of the consumption of natural resources and provides valuable information for decision making and planning for the future of cities. An urban metabolism study may reveal inefficiencies in resource use, opportunities for policy intervention to slow or prevent the exhaustion of resource supplies, and the sources of potential problems from the buildup of potentially hazardous materials and emissions within the urban system and its surrounding environment.

Urban Metabolism as Indicator of Sustainability

Different indicators describing the metabolic flow of resources can be used to draw conclusions about the sustainability of a city's urban metabolism and therefore of the city itself. These include the magnitude of and changes in the total and per capita resource use and waste generation and the degree of circularity in resource use.

Most urban metabolism studies indicate that in general the magnitude of the per capita resource use in cities is large and increasing. For example, a comparison of the comprehensive studies of the urban metabolism of Hong Kong in 1971 and 1997 (Table 1) demonstrates increases of 20%, 100%, and 280% in the per capita consumption of food, fossil fuels, and construction materials, respectively. In addition to increased resource use, Hong Kong's total waste and residual outputs of municipal solid waste, carbon dioxide (CO₂), and sewage discharges have also risen by 245%, 250%, and 153%, but per capita air pollutants emissions have decreased by 23%. A review of urban metabolism studies from eight metropolitan regions across five continents suggests that the trend of increasing total and per capita urban metabolisms is prevalent worldwide, fueled in part by increasing urbanization and material wealth.

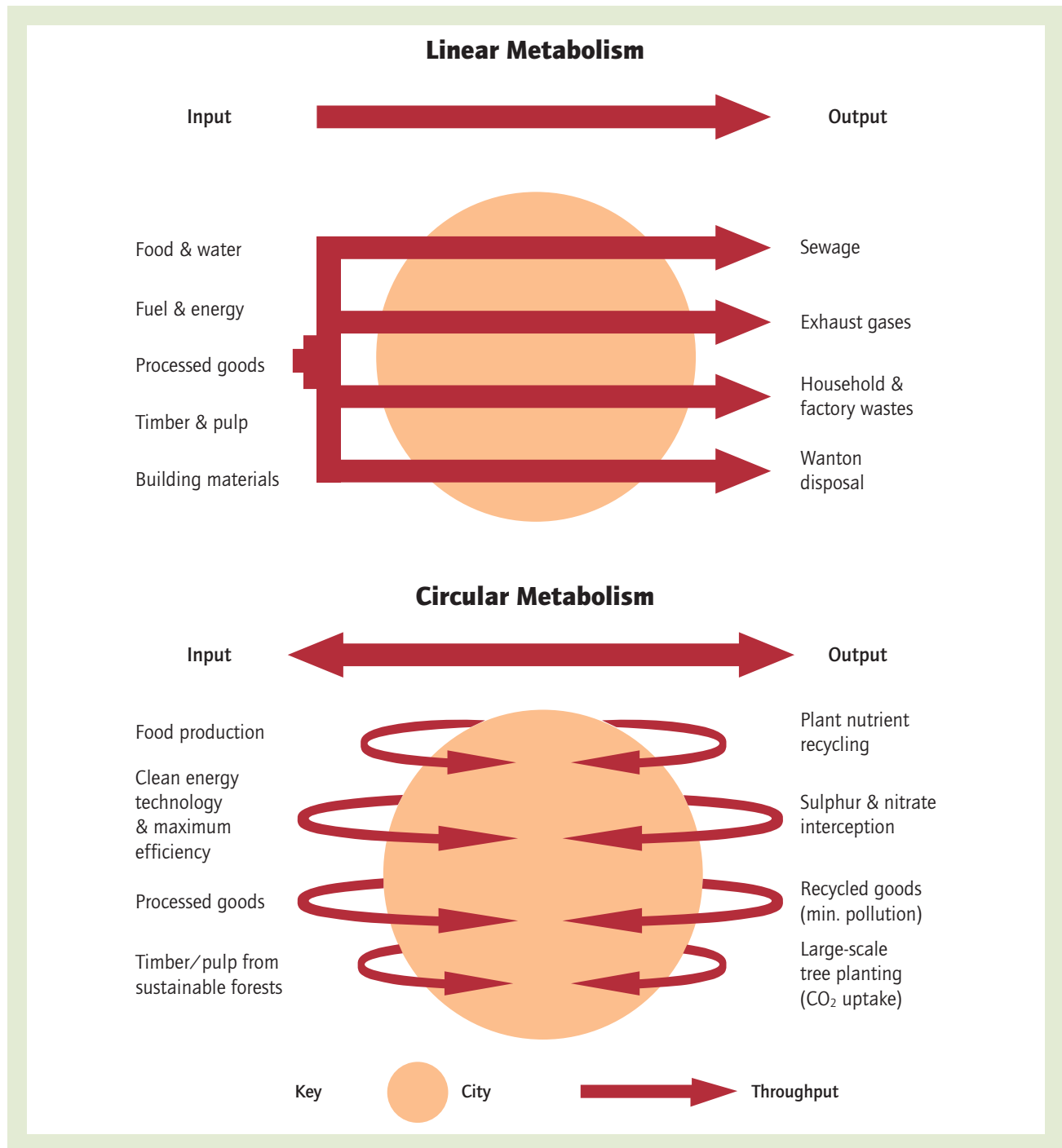


Figure 1 Linear and circular urban metabolism

Source: Girardet, H. (1992). *The GAIA atlas of cities: New directions for sustainable urban living* (pp. 22–23). London: Gaia Books.

Herbert Girardet, a long-time scholar of the urban metabolism of cities, highlights the shape of a city's urban metabolism as another key indicator of sustainability (Figure 1). A city's urban

metabolism may be linear, where input is unrelated to output. A city has a linear urban metabolism when it acquires, concentrates, and consumes ecosystem resources and disposes of its



waste products in a manner such that they cannot be reused or may potentially cause harm to other systems or the city itself. In most cities, the use of fossil fuels is a prime example of a linear urban metabolic process. Fossil fuel resources from beyond urban system boundaries are stored and then consumed as sources of energy, and the waste products of heat such as particulate emissions, nitrogen oxides (NO_x), sulfur dioxide (SO_2), CO_2 , and other greenhouse gases are released and contribute to the creation of the urban heat island effect, climate change, acid rain, and air pollution.

On the other hand, a city's metabolism may be circular, whereby it is able to reuse or recycle its waste products or return them as a source of inputs for other systems. In many North American and European cities, the flow of food and the embodied organic matter, nutrients, and energy within is becoming a more circular urban metabolic process. Food products are brought into or grown within the urban system and consumed by its inhabitants. The waste products of garbage and sewage are increasingly collected and treated by the city. In some cities, innovative waste management practices are used to produce compost and other soil amendments from food wastes that can be reused as inputs for agriculture and horticulture or to capture methane and heat to serve as new sources of energy. A narrowly focused study of food nitrogen flows in Toronto, Canada, from 1990 to 2004, suggests that the degree of circularity in the urban nitrogen metabolism is between 2.3% and 4.7%. This circularity appears quite low, given the number of municipal programs aimed at collecting and composting household food wastes. The accounting revealed that major sources of the linearity of the nitrogen metabolism were in sewage treatment and commercial food waste disposal. This finding emphasizes the ability of an urban metabolism study to identify processes at which to target interventions to increase the sustainability of a city's relationship with its surrounding environment.

Factors Influencing City Metabolism

There are several factors that influence the magnitude and shape of the urban metabolism of

cities. The natural and physical built form characteristics of an urban area, such as climate and surface and groundwater resources, as well as urban form and transportation technology, are key determinants of total and per capita energy and water use. For example, a low-density sprawling city in an interior continental climate is likely to have a larger metabolic energy requirement for transportation, heating and cooling, and water distribution than a compact city of the same population size in a temperate climate.

Municipal policies and practices such as building codes and waste and water management technology, as well as urban residents' attitudes and behavior, will also influence a city's urban metabolism, in terms of both its magnitude and its degree of circularity. For example, the degree of circularity of a city's urban metabolism can be increased through composting and recycling, grey water separation and reuse, and district heating and cogeneration facilities. The success of municipal policies aimed at reducing the magnitude of urban metabolism will require targeting inefficiencies in resource use and reuse and significant participation by urban residents, who also must be supported by appropriate changes in infrastructure and urban form. By taking stock of resource flows, urban metabolism studies can help identify both current and future trends in resource use and track progress toward greater sustainability between cities and their surrounding environments.

Jennifer Forkes

See also [Anthropogenic Climate Change](#); [Ecological Footprint](#); [Greenhouse Gases](#); [Industrial Ecology](#); [Urban Ecology](#); [Urban Green Space](#); [Urban Heat Island](#); [Urban Water Supply](#)

Further Readings

- Girardet, H. (1992). *The Gaia atlas of cities: New directions for sustainable urban living*. London: Gaia Books.
- Kennedy, C. A., Cuddihy, J., & Engel-Yan, J. (2007). The changing metabolism of cities. *Journal of Industrial Ecology*, 11, 43–59.



- Newcombe, K., Kalma, J. D., & Aston, A. R. (1978). The metabolism of a city: The case of Hong Kong. *Ambio*, 7, 3–15.
- Warren-Rhodes, K., & Koenig, A. (2001). Escalating trends in the urban metabolism of Hong Kong: 1971–1997. *Ambio*, 30, 429–438.
- Wolman, A. (1965). The metabolism of cities. *Scientific American*, 213(3), 179–190.

URBAN PLANNING AND GEOGRAPHY

Although the world population has historically been rural, there are now more people in urban areas than in the rural hinterlands for the first time in history. According to UN estimates, in 2010 more than 3.5 billion people (50.6%) will inhabit urban centers around the world, with the highest concentration of large urban centers in Asia (Table 1, Figure 1). Typical of this concentration is the metropolitan complex of Tokyo and Yokohama, Japan, with the largest urban population of approximately 36 million people (Figure 2). The growing urban areas need to provide for citizens' demands for housing, employment, transportation, infrastructure, and the vast array of services and facilities. To meet these demands, it is essential to understand the environmental, social, economic, and political characteristics of the ever-growing urban realm. Urban geography has contributed significantly to this knowledge and continues to expand its role by providing theoretical, technological, and analytical advancements to assist in this effort. Correspondingly, the integration of this knowledge and its implementation into strategies, policies, and programs to meet the needs of the urban population is a task planners have undertaken. The implementation of their plans is a key component to ensure the health, safety, and well-being of urban citizens. The spatial dynamics of the urban area and its growth management create the interaction between urban geography and urban planning and are the focus of this discussion.

Year	Total	Urban	%
1990	5.290	2.275	43.0
1995	5.713	2.554	44.7
2000	6.115	2.850	46.6
2005	6.512	3.165	48.6
2010	6.909	3.496	50.6
2015	7.302	3.848	52.7
2020	7.675	4.213	54.9
2025	8.012	4.583	57.2
2030	8.309	4.960	59.7

Table 1 World total and urban population (billions), 1990–2030

Source: UN Department of Economic and Social Affairs, 2008.

Urban Geography

The description and analysis of urban areas has been a subject of study for geographers since the earliest settlements. The distribution and location of urban centers and the factors that influence their spatial patterns provide for the understanding of urban development and, in some cases, their demise. Figure 3 illustrates the multidimensional approach that geography has taken in the study of urban areas. There are four dimensions to the geographical analysis of urban areas: (1) the spatial, (2) thematic, (3) analytic, and (4) chronological. The overall thrust of this research has been through a spatial dimension or lens focusing on a thematic factor or some combination of factors, such as the environmental, social, economic, or political characteristics. The spatial lens changes with scale, so that by zooming in a theme can be investigated at the local level or microscale—a neighborhood or a smaller portion of the city—and by zooming out the global interrelationships (macroscale) between cities or metropolitan areas can be examined. The spatial dimension establishes the context in which the theme can be described and analyzed. Urban areas consist of only a tiny portion of Earth's land surface (.5%); however, they are home to currently more than 50% of the population. Urban geography has to be able to analyze this landscape at various scales because of the interrelationships and connections within an urban area and between urban areas across the globe.

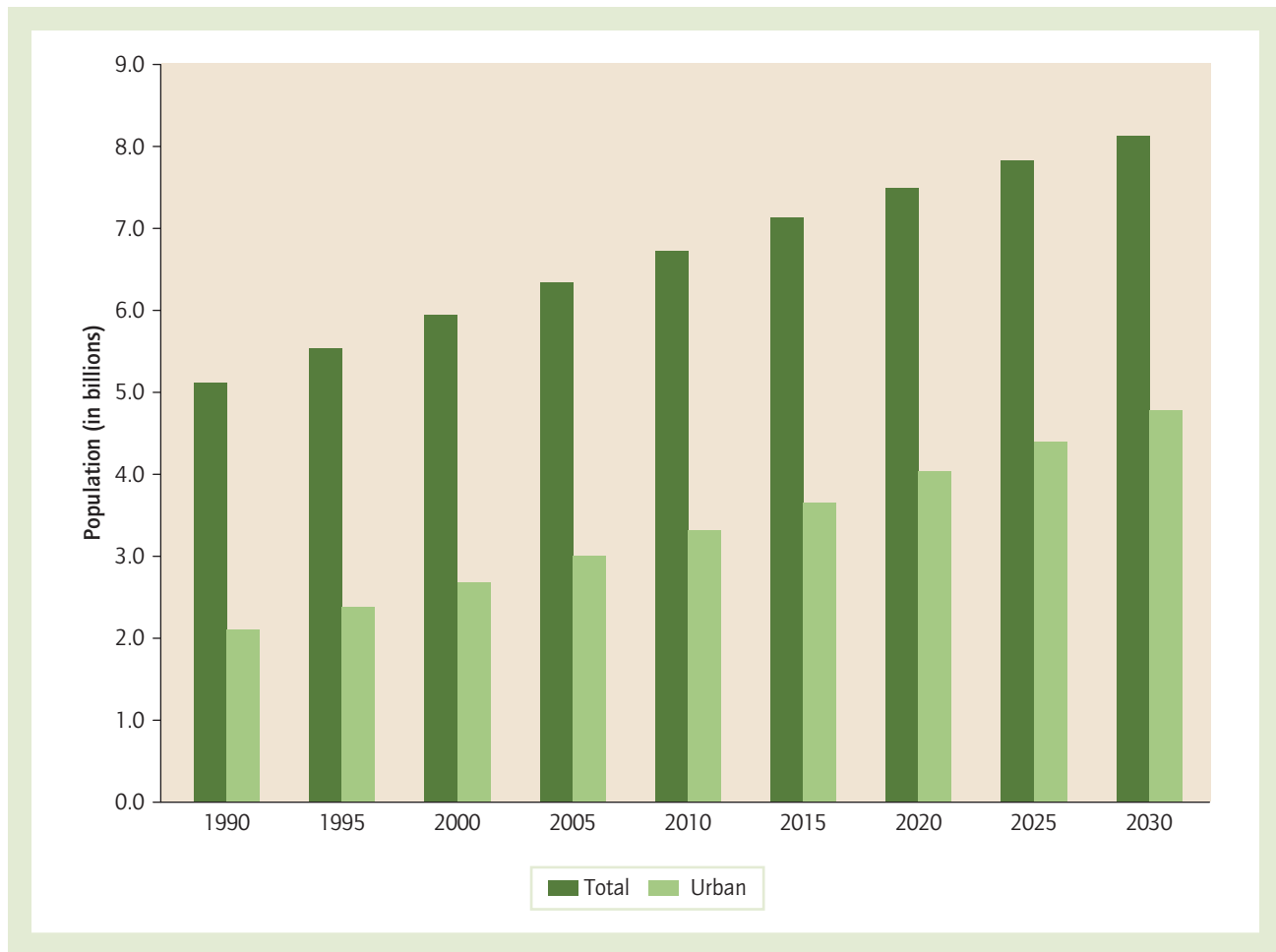


Figure 1 World total and urban population, 1990–2030

Source: UN Department of Economic and Social Affairs, 2008.

The thematic dimension of urban research provides the elements of an urban area that are linked together to establish its character. The city is a system either within its own area or as a part of the interconnection between cities, and it is imperative to know the elements of the city or cities to understand how the system works together. The general environmental, social, economic, and political dimensions are the broad characteristics of any city. However, there are many subthemes that are more specific; for example, the social dimension can be subdivided into families, race, ethnicity, or medical history. The number of subthemes can be limitless depending on the specificity of the researchers and their characteristic interest. This notion is made more complex by the investigation

of multiple subthemes spanning several major elements. The spatial distribution of environmental quality and its impacts on health and living conditions for the underprivileged of a specific ethnic background are an illustration of this point. Thus, many different subthemes of several elements can be examined at different spatial scales.

Urban research's analytical dimension has four main components: form, function, process, and structure. Each component represents a different aspect of the urban area that broadens our understanding of the city system or system of cities. The form is generally the arrangement of the urban elements or subthemes and is represented by their spatial distribution at a local, regional, national, or global scale. The functional component of an

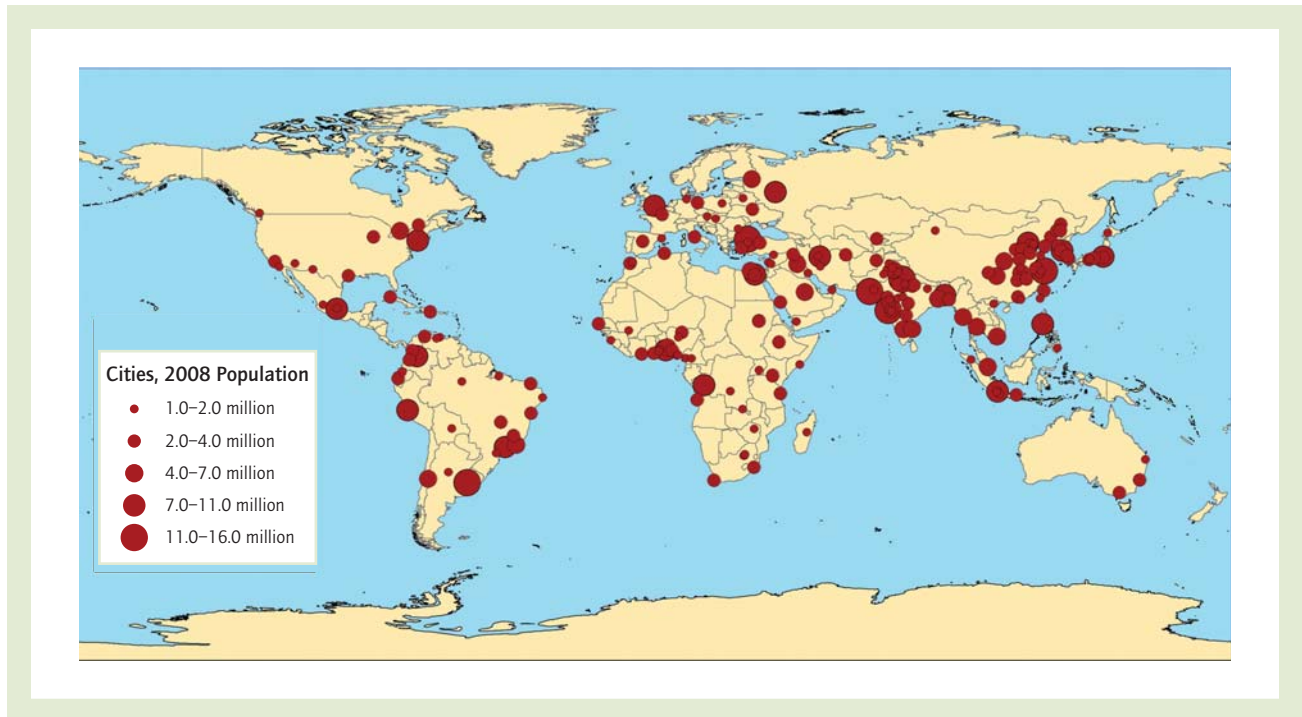


Figure 2 Major world cities. Most of the world's large cities and most urban growth are found in economically developing countries.

Source: Author.

investigation explores the purpose, role, or meaning that the subtheme has within the city system or system of cities. A city may have an economic base on which to focus, and the investigation may be concerned with what role that city has within the broader economy of the region, nation, or international system. The process component of this dimension is examined using many different methods based on the subtheme being researched. The importance of process is that it reveals the interrelationships, linkages, and connections between the subthemes. The strengths or weaknesses can be examined, which can provide the cause-and-effect relationships between the social, economic, and environmental issues within the urban area. Finally, the structural component of the analytical dimension is the foundation on which the urban form, functions, and processes are built. The structure provides the rules of urban operation, whether it is the capitalist-driven international system of manufacturing cities or the socially conscious neighborhood that has formed a cooperative for housing, employment, and food distribution. The structure

presents the assumptions that are the bases on which the urban system operates. Without knowing the underlying rules or assumptions, it is difficult to understand the relationships, linkages, or connections between the subthemes. Urban geography investigates urban areas using all the different analytical components for a better understanding of the overall city system or system of cities depending on the spatial scale and the intent of the research undertaken.

The final dimension of urban geography is the chronological. There are four approaches that urban geography has taken in this dimension—(1) historic time, (2) a progression or sequence in time, (3) the present time, and (4) the future or predictive time. The historic time approach is an investigation of an urban area at a specific date or time span in the past. A study of the spatial distribution of Spanish Moorish cities in the 12th century and their function for western expansion would be an example. The intent is to understand a component of the analytical dimension using the thematic dimension. The progression or

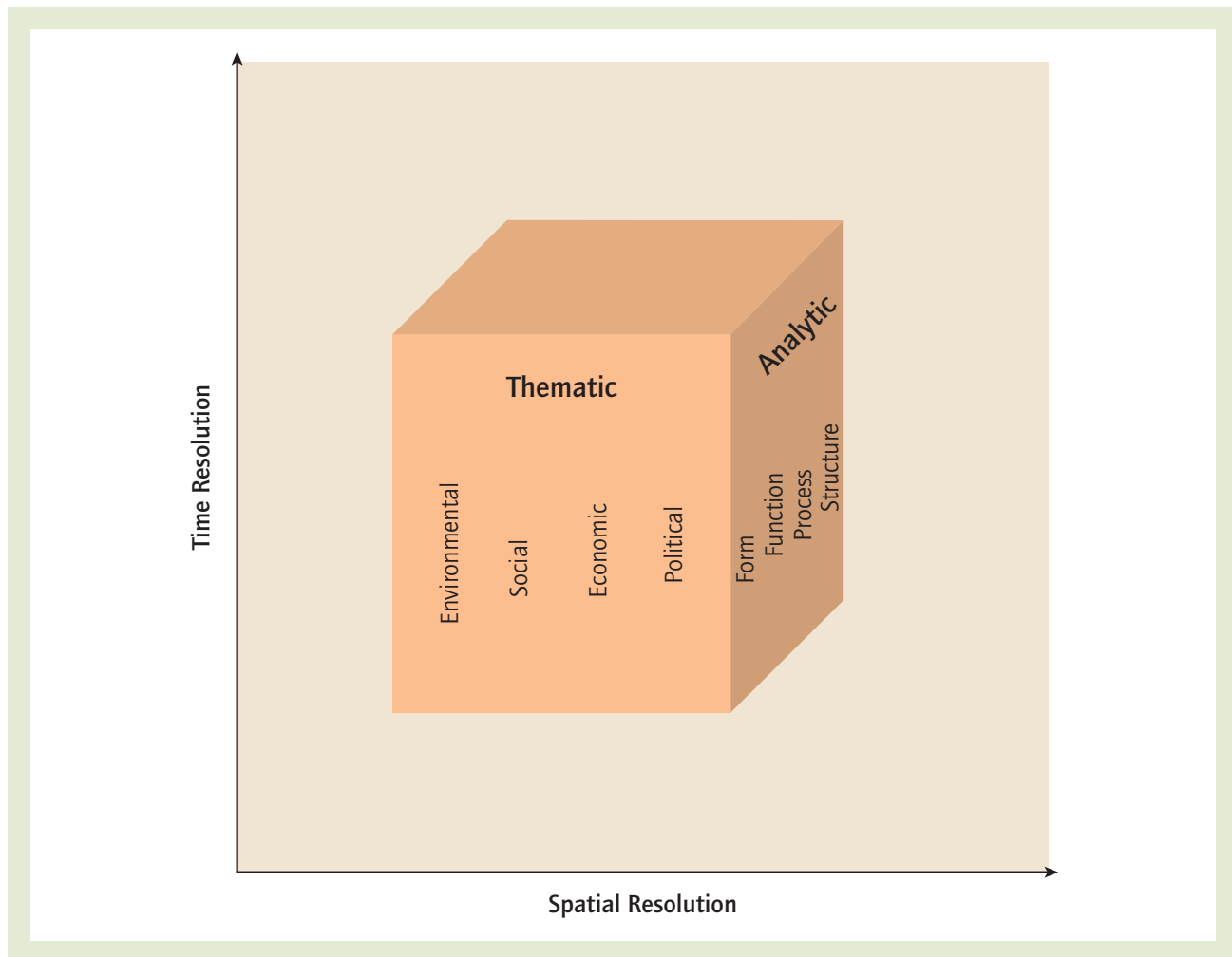


Figure 3 Multiple dimensions of urban geography

Source: Author.

sequence-in-time approach to historic urban geography examines the change over time within or between urban areas. This approach may use several of the analytical components to investigate a specific urban area in order to understand what processes create a change in form or how structural changes manifest themselves in the urban area. The majority of urban geography, however, is concerned with the present or current time dimension. The intent is to know the current factors, situations, and results of contemporary urban society. Data and information are collected and analyzed with the purpose of strengthening the relevance of solving today's city issues. Finally, the ability to project into the future through analytical and scenario-based computer programs

allows urban geography to envision what may be the result of contemporary urban activities based on structural assumptions. The ability to model future urban areas may have great significance to world society because the United Nations has predicted that the proportion of the world population in urban areas will increase to 80% by 2050, totaling almost 7.4 billion people.

Planning

Urban areas are generally the result of the landscape's characteristics, social and economic activities, and infrastructure of historic urban development. To meet the ever-expanding needs of the urban population, urban planners and



engineers incorporate modern design and technologies into this historic context. However, they do not work alone; multiple agencies work together to maintain existing facilities and services and identify, predict, and construct new facilities and expand services for the future population. Local and regional planners apply either reactionary or visionary planning tools and techniques to construct strategies, policies, and programs designed to address the identified issues and needs. The local planner generally works with citizens at the neighborhood or community level to identify problems and examine different policy options to solve both immediate and long-term problems. Citywide or regional planners address the broader issues, incorporating input from multiple areas of the city or its jurisdictions, with the same purpose of examining different strategy and policy options to solve these broad issues and meet the citizens' needs. Urban planners examine the urban form, functions, processes, and structures that combine to create the urban area. The different scales of the problems are addressed by different levels of planning, local to regional, with coordinated and cooperative goals to assist in making the city a better place for living, working, and recreation.

Planning entails different approaches and techniques based on the scale of the project. Generally, urban plans will be comprehensive in their approach or will address a specific topic or urban area. The most common is the comprehensive plan that is constructed to identify the overall community vision and develop goals, objectives, and policies for specific topics, for example, environmental protection, land use, economic development, and so on, to lead the community in the direction of their choice. The plan then becomes a guiding document for decision makers because it has identified and prioritized those topics that the community believes are important. Policies and programs are then implemented to obtain the goals and objectives stated in the plan. Another type of plan is a more detailed analysis of a topic area, for example, environmental protection or neighborhood, and this type of plan establishes more specific sets of strategies, programs, and policies that will be implemented to reach the plan's stated goals and objectives. Because they are more specific in either the topic or the scale of

the plan, different techniques for obtaining data and information along with the analysis are employed by the planners to reflect the finer detail of the plan. Both types of plans, however, have the same purpose: to address the issues of the urban community and provide for the citizens' health, safety, and welfare.

Integration

Urban geography and planning are not separate activities; they each rely on the results of the other to create a livable, sustainable urban environment. The incorporation of the different urban geography dimensions into the analysis of urban issues is part of the task of the planner, so that they can determine the most feasible strategies, programs, and policies to address the problems. In particular, geographic information systems (GIS) have been of particular usefulness to both activities because they are multidimensional and have the capability to predict future results or scenarios based on differing sets of assumptions. A GIS is designed to analyze georeferenced data at different spatial scales and the complexities of multivariate analysis. GIS have been used at the neighborhood level to organize and provide current information to community organizers for housing and employment problems. At the city level, a GIS is used daily for transportation routing, maintenance, and problem solving. Even at the global scale, GIS is assisting with issues of global warming and pollution control by monitoring environmental conditions and simultaneously evaluating alternative strategies to mitigate the impacts of the increasing urban population. Urban geography and planning provide the theory, applications, and policies that are needed to address the ever-expanding urban world.

William J. Gribb

See also GIS in Urban Planning; Public Participation GIS; Suburbs and Suburbanization; Urban and Regional Development; Urban and Regional Planning; Urban Environmental Studies; Urban Geography; Urban Hierarchy; Urbanization; Urban Land Use; Urban Policy; Urban Solid Waste Management; Urban Spatial Structure; Urban Sprawl; Urban Storm Water Management; Urban Sustainability; Zoning



Further Readings

- Campbell, S., & Fainstein, S. (Eds.). (1999). *Readings in planning theory*. Malden, MA: Blackwell.
- Green, R., & Pick, J. (2006). *Exploring the urban community: A GIS approach*. Upper Saddle River, NJ: Pearson Prentice Hall.
- Kaplan, D., Wheeler, J., & Holloway, S. (2008). *Urban geography* (2nd ed.). New York: Wiley.
- United Nations. (2008). *World urbanization prospects: The 2007 revision*. Department of Economic and Social Affairs, Population Division. New York: Author.



URBAN POLICY

Urban policy refers, broadly, to the numerous ways in which national or federal governments implement programs that affect the nature of cities, including modes and priorities of financing municipalities, strategic planning to stimulate urban economic growth, attempts to combat uneven regional development or encourage cooperation among local governments, control over negative externalities such as destruction of the natural environment, targeted subsidies for specific problems (e.g., homelessness), and political restrictions on the autonomy of the local state. As such, urban policy is closely related—but not identical—to urban and regional planning efforts. There is typically no single national urban policy, but aggregations of many different policies, some of which may work at cross-purposes, with varying effects over space and time. Because the capitalist city is not simply the product of market forces, but also of the state, urban policy plays a critically important role in shaping urban space and the quality of life within it.

Most “urban” policies are not specifically called urban; rather, they affect cities indirectly, such as when they address issues such as infrastructure, transportation, urban labor and housing markets, environmental problems (e.g., water supplies, air pollution), energy use and availability, and so forth. Policies aimed at specific economic sectors, such as protectionism for manufacturing firms,

have uneven urban impacts; similarly, immigration controls differentially affect the supply of labor in urban space. Indeed, virtually all government policies have implicit, if not explicit, urban consequences, such as tax laws, land use controls, and anti-poverty programs.

Urban policy is both deeply political and geographical in nature. Far from being politically neutral, urban policies reflect the interests of multiple constituencies and stake-holders, including corporate interests, different social classes, various groups in civil society, and different factions within the state. Although urban policy often caters to hegemonic interests, it is important to view it as a contested arena in which different political interests and discourses jockey for influence. Additionally, because urban policy varies among and within countries, because it shapes urban space in different ways, urban policy is also profoundly spatial in nature.

This entry begins by noting variations in urban policy among countries; next, it briefly summarizes Keynesian urban policy that dominated in the early to mid 20th century; then, it focuses on neoliberalism and its impacts concerning how governments treated urban areas. Next, the entry discusses the implications of these trends for local planning efforts. It concludes with comments concerning urban policy in the developing world.

National Urban Policy Differences

Urban policies vary widely in time and among countries, depending on the global political and economic system, the structure and health of the national economy, their respective degrees of urbanization, national political dynamics (e.g., unitary vs. federal government structures), the relative degree of political autonomy enjoyed by local governments, modes of tax collection and disbursement of public moneys, national and local administrative priorities, the nature and severity of social problems, and popular historical and cultural climates that facilitate or inhibit government intervention.

Compared to Europe, Japan, or Canada, the political culture in the United States is markedly more favorably disposed to presumptions about the primacy and efficacy of the “free market” and exhibits a widespread mistrust of government



intervention. As a result, with most governance effectuated at the local level, urban policy in the United States has always been relatively anemic compared to European states. In the United States, the bulk of tax revenues are generated and most public services are provided at the state and local levels rather than the federal one, and the country lacks national planning systems regulating land use, population, or other policy measures. Thus, despite the importance of the federal government in financing many local measures, American urban policy tends to be relatively ineffectual. In Canada, Germany, and the United States, provincial, Länder, and state governments, respectively, play important policy roles, a dimension lacking in Britain and many European countries.

European urban policy, in contrast, is typified by significantly stronger national governments, stricter controls over local policy implementation and land use (e.g., historic preservation), and more widespread popular acceptance of such measures. In France, for example, a long tradition of a powerful national government has tended to resist many recent initiatives toward privatization and deregulation common in the United States or Britain. In contrast to the United States, where corporate interests tend to figure prominently in federal and local policies regarding urban space, European policy measures tend to leave more room for the interests of the working class and popular political will. Uneven development and attempts to alleviate it via regional development strategies have long been more important to European countries than in the United States. There are wide variations among European states: Germany, for example, retains a much stronger tradition of social democracy and centralized policy making than does Britain, which more closely resembles the United States in this regard. Sweden and Greece both lack explicit national urban policies; however, while Sweden allows almost complete local autonomy for its cities, such independence is almost nonexistent in Greece. However, recent initiatives of the European Union have fostered a gradual, if halting, policy convergence among countries.

In Japan, urban policy has long focused on attempting to encourage growth outside of the major metropolitan regions, in which the bulk of the nation's population and productive capacity are concentrated. Traditional policy measures in

Japan were exceptionally heavy handed, dictated by fiat from the national government to local ones with little opportunity for feedback. Recent economic stagnation and gradual population decline have forced a more relaxed departure from this rigid top-down system of governance. Lax regulatory controls are often widely perceived as diminishing the aesthetic quality of Japanese urban landscapes, and recent legislation has encouraged local governments to address this issue.

Keynesian Urban Policy

As the economies of many Western countries became focused on Fordist mass production in the late 19th and early 20th centuries, urban policy began to assume a focus on regulating growth and minimizing social inequalities that could prove to be disruptive. Although its origins may be traced back to the Progressive Era at the turn of the 20th century, Keynesian urban policy began to be implemented emphatically in the Western world during the Great Depression of the 1930s as a result of that crisis. In part, this set of initiatives included attempts to stimulate aggregate demand, particularly in sectors such as housing. For example, in the United States, the Federal Home Loan Bank was erected in 1932 to subsidize credit for mortgage providers. In 1934, the National Housing Act established the Federal Housing Administration, through which the federal government insured numerous mortgages. It also initiated the policy that allowed deductions of interest paid on mortgages from federal income tax, which subsidized the middle class, encouraged suburban expansion, and persists to this day. Public housing projects also emerged, eventually comprising 20% of the British housing stock but only 2% of that in the United States, where it was pioneered under the Public Works Administration but later passed to the U.S. Housing Authority. In Britain, local authority housing programs witnessed the construction of millions of working class housing units, a system extended by the Building Societies of the late 20th century. Other measures include national government attempts to assist fiscally distressed local governments, stimulation of employment, and massive infrastructure expenditures, all of which powerfully affected urban spaces and social life.



Keynesian urban policies in Western Europe, the United States, Canada, and elsewhere persisted well after World War II throughout the long post-war boom, although they assumed different forms in different countries. Many governments provided assistance to veterans in the purchase of houses, and their policies amplified a long-standing trend toward urban decentralization and sprawl. Their impacts were largely confined to combating poverty and unemployment, taming the effects of business cycles, mitigating social inequality, and controlling negative externalities (e.g., traffic congestion and environmental destruction).

Keynesian urban policy in the United States traditionally focused largely on the problems of inner cities, including the urban renewal programs of the 1950s, the Model Cities Program of the 1960s, and the Housing and Community Development Act of 1974, the centerpiece of urban policy under the Nixon administration. President Johnson's Great Society programs, including the War on Poverty legislation, were largely concerned with the dire straights faced by the urban underclass, in part responding to the urban riots of the 1960s. In the 1950s and 1960s, under the guise of urban renewal, federal efforts were also aimed at enhancing the commercial viability of downtown areas (e.g., via highway on-ramps and off-ramps), often involving massive displacement of low-income minorities and the obliteration of their neighborhoods. The Urban Mass Transportation Act of 1964 provided federal funds to finance mass transit facilities, which favored low-income areas, and the 1968 Federal Housing Act increased the supply of low-income housing. Under the Carter Administration, the Comprehensive Employment and Training Act in 1978 offered cities fiscal aid, subsidies and public service employment programs and instigated the Urban Development Action Grant program to subsidize the rehabilitation of older industrial and commercial spaces. These programs were augmented by a host of other programs, including Targeted Job Tax Credits and community development block grants.

Neoliberal Urban Policy

Beginning in the United States and the United Kingdom in the 1980s, and subsequently expanding to

encompass many other countries, urban policy underwent a pronounced turnabout with the hegemony of neoliberalism. Typically, this shift was characterized by widespread deregulation and privatization, and by the state's withdrawal from the broad domain of social reproduction (i.e., government financing for public services, especially those aimed at the poor). National governments in many countries altered their funding priorities, eliminated many programs of their predecessors, initiated new ones in keeping with the ideological imperatives of the "free market," and transformed the national policy matrix within which cities are governed.

The transition from national to global markets, and associated internationalization of economic linkages within many countries, made the viability of nationally based state welfarism increasingly questionable. Even in the bastions of state welfarism such as Scandinavia, where social programs have long been regarded as sacrosanct, neoliberalism has induced attempts to reduce social spending. With the neoliberal demise of the welfare state, urban policy in many countries became increasingly less concerned with the provision of social benefits to the poor and needy and more concerned with budget reductions in such expenditures.

In the United States under the Reagan administration, federal subsidies to localities for mass transit, education, water treatment, medical care, and public housing were sharply reduced. This assault on the welfare state had mixed results: While some domestic programs suffered sharp contractions, others, including social security, Medicaid, Medicare, food stamps, and Aid to Families with Dependent Children were sufficiently popular to escape relatively unscathed. Urban Development Action Grants, initiated by the Nixon administration in 1974 and earmarked for specific purposes, were folded into block grants. This shift in funding strategies gave local political authorities considerably more control over the allocation of federal funds during a period in which interurban competition rose sharply. To a considerable extent, block grants subsidized downtown developments without regulating them, contributing to the surge of gentrification in central city areas. Additionally, the "workfare" reforms of the Clinton administration in the 1990s,



which continued under the presidency of George W. Bush, removed tens of millions of people from the “welfare rolls” of public relief, a burden disproportionately felt by cities. Opposition to such measures was frequently labeled as “anti-growth,” and the costs of such projects in terms of residential displacement rarely entered into discourse about their contribution to a broadly inclusive “public good.” Post-Keynesian urban policy thus successively subordinated social needs to the prerequisites of real estate firms, bankers, the construction industry, and related interests.

Neoliberal urban policy also witnessed a sustained devolution of powers from national to local governments. In the United States, this took the form of Reagan’s New Federalism, which shifted financing for many programs to the states. In the U.K., the collapse of Keynesian policy was apparent in the ascendancy of Thatcherism, which centralized many responsibilities formerly controlled by the local state (including the abolition of the Greater London Council in 1985), in contrast to the devolution of governance underway in the United States. However, the U.K.’s City Challenge program spurred competition among the states. Similarly, the Major City Policy in the Netherlands was designed to stimulate local urban economic rejuvenation.

Perhaps the most geographically obvious neoliberal strategy that combined elements of deregulation, privatization, and public-private partnerships was the Enterprise Zone. Originally proposed as a means of unleashing market forces in distressed inner cities through the simple removal of government controls, enterprise zones soon evolved into more complex attempts to generate private investment through active public subsidies (income and capital gains tax breaks, depreciation allowances, labor training programs) in selected urban areas. Enterprise zones, first implemented in the U.K. in 1981, began as an experiment to give inner cities tax relief and freedom from planning restrictions. The British government also created Urban Development Corporations to stimulate property investment, map land uses, and make sites available to developers; in the United States, these assumed the form of Urban Redevelopment Authorities.

A central neoliberal tool in urban policy has been the institution of public-private partnerships.

Advocates of this strategy justify it on the grounds that it illustrates an unproblematic mutual interest between the two sectors: Involvement by the public sector allows for supervision and oversight of projects in which private developers would otherwise enjoy autonomy. Public promotion and facilitation of private development are assumed to produce a general public benefit, that is, positive externalities that include improving a city’s economic base and raising real estate values, thereby generating additional tax revenues that in turn permit greater resources for social redistribution. Moreover, the long-term gains outweigh the ostensibly short-term public subsidies deployed. Corporate interests are attracted to cities that deploy powers of eminent domain, assemble and package land parcels, erect new infrastructures, and offer various subsidies. Private interests are held to contribute expertise, experience, financial resources, and technological and managerial efficiency frequently inaccessible to those in the public domain. The involvement of the public sector in such ventures often allow private interests to claim that they have made contributions to civic welfare. The opportunity costs of government spending on such ventures were rarely acknowledged, including funding that might otherwise have been extended to distressed urban areas.

It should be noted that neoliberal urban policy was not implemented to the same extent everywhere. In Japan, for example, privatization and reductions in social expenditures were considerably less prevalent than in the United States or Western Europe. In France and Southern Europe, too, neoliberal urban policies found much less purchase than in other parts of the continent.

Finally, neoliberal urban policy was influential in the rise of world cities, large metropolitan areas that play powerful roles in the global economy. As national regulations were portrayed as inhibiting competitiveness in a worldwide market, deregulation tended to accelerate the explosive rise of financial and producer services in cities such as London, New York, Los Angeles, Tokyo, Toronto, and, increasingly, Singapore and Shanghai. The health of many such centers has become increasingly more linked to the global economy than to their national ones, rendering them problematic from the point of view of national urban policy makers.



Local Urban Policy Under Neoliberalism

At the local level, the transition to neoliberalism induced a switch from “managerial” to “entrepreneurial” planning, in which local authorities became increasingly preoccupied with attracting capital and generating economic growth at the expense of long-standing priorities such as social equality, protection of the poor and socially marginalized, and environmental protection. In many countries, bereft public authorities became susceptible to the aggressive overtures of private capital, raising the political leverage of investors over local public authorities. Frequently, interurban and inter-regional competition sharply accelerated, forcing public authorities to partake in zero-sum auctions to woo increasingly footloose capital. Typically, older industrial cities suffered while service-based urban areas flourished. Levels of inequality rose accordingly. The broad shift in the priorities of local governments led them to become less concerned with issues of social redistribution, compensation for negative externalities, provision of public services, and environmental management and more absorbed with questions of economic competitiveness, attracting investment capital, and the production of a favorable “business climate.” Long-term capital budgeting, master planning, and infrastructure investments have given way to short-term concerns of job generation, looser regulations, and tax relief. Planning is hence concerned more with promoting economic development and less with regulating its aftermath. In the United States, a common result was widespread commercial sprawl, often in the form of ugly strip malls, in which public land use controls are so relaxed as to be negligible.

In this context, neighborhoods assume importance either through their economic significance or through political power. Frequently, planning resources are allocated toward economically influential areas (e.g., the central business district) or politically powerful neighborhoods (including suburbs and gated communities), but not toward the ghettos populated by the urban underclass that command little attention from urban policy makers. In this way, urban policy reproduces and deepens difficulties endured by the poor, ethnic

minorities, and the politically disenfranchised. Therefore, despite neoliberal rhetoric about how consumer sovereignty depoliticizes urban development, it has in fact politicized planning to an unprecedented degree.

Urban Policy in the Developing World

Societies, governments, and cities in that vast swath of the planet commonly known as the developing world generally face circumstances that differ substantially from those in the economically advanced countries, and hence urban policies differ accordingly. Levels of urbanization range markedly among developing countries, ranging from the minuscule (e.g., much of sub-Saharan Africa) to predominantly urbanized (as in much of Latin America). Rapid demographic growth, rural-to-urban migration, housing shortages, inadequate public services, and widespread poverty tend to be the norm, although the severity and frequency of such problems vary enormously. Moreover, depending on the country, urban policy initiatives may be hampered by lack of adequate funding mechanisms, foreign interference, widespread corruption, shortages of human capital, or inadequate effective leadership. Some developing countries face political divisions, including ethnic conflicts, or widespread distrust of the state based on long histories of oppression, as in post-apartheid South Africa, that hamper effective urban policy implementation. Finally, in countries in which military expenditures have the highest priority, urban policy may fall well behind in terms of planning efforts and implementation.

Many developing countries feature urban hierarchies characterized by primate cities (e.g., Mexico City, Seoul, Buenos Aires, Lagos), in which both public and private investments, and hence employment opportunities, are overconcentrated within a single megacity. (Notably, France also faces this issue.) Urban policies in such a context may attempt to decentralize some government functions to smaller cities (e.g., in Argentina), although such efforts are typically met with stiff resistance.

In many developing countries, housing shortages and problems of accessibility to clean water and air are important obstacles to development.



Because more people rely upon public transportation and public medical and educational services in the developing world than in economically developed ones, much urban policy is concerned with the provision of such services. In countries with rapid growth in population and/or incomes, rising numbers of automobiles can lead to severe traffic congestion, often a centerpiece of urban policy initiatives. Thus, urban sustainability is often a priority in urban policy measures, although its successful achievement via policy initiatives is questionable.

Rapid rural-to-urban migration, and the consequent swelling of urban shantytowns and squatter settlements, present formidable challenges to the provision of public services and control of crime. In such cases, urban and rural policies are inextricably intertwined. Many governments have attempted to meet such challenges by encouraging rural development, including infrastructure development, as a means of reducing the influx to urban areas; others respond with forcible destruction of such communities. Some governments in the developing world enforce price limitations on essential foodstuffs, a policy that critics hold discourages local farmers but reduces the reproduction costs of urban labor, particularly for transnational corporations.

To some extent, Western neoliberal urban policy initiatives have been replicated in the developing world. In China, for example, most urban areas now enjoy greater autonomy in decision making and revenue collection than they did in the past. Structural adjustment programs implemented by the International Monetary Fund may also limit national or municipal authorities' ability to assist low-income populations, as with subsidies for mass transit.

Barney Warf

See also **Growth Machine; Growth Poles; Housing and Housing Markets; Housing Policy; Infrastructure; Neoliberalism; New Urbanism; Public Housing; Public Policy, Geography of; Regional Governance; Regulation Theory; Rural-Urban Migration; Squatter Settlements; Urban and Regional Development; Urban and Regional Planning; Urban Geography; Urban Hierarchy; Urbanization; Urban Land Use; Urban Planning and**

Geography; Urban Spatial Structure; Urban Sprawl; Urban Underclass; Urban Water Supply; World Cities; Zoning

Further Readings

- Bourne, L., & Simmons, J. (2003). New fault lines? Recent trends in the Canadian urban system and their implications for planning and public policy. *Canadian Journal of Urban Research*, 12, 1–27.
- Brenner, N. (2004). *New state spaces: Urban governance and the rescaling of statehood*. Oxford, UK: Oxford University Press.
- Cochrane, A. (2006). *Understanding urban policy: A critical introduction*. Oxford, UK: Blackwell.
- Dikeç, M. (2006). Two decades of French urban policy: From social development of neighbourhoods to the Republican penal state. *Antipode*, 38, 59–81.
- Fainstein, N., & Fainstein, S. (Eds.). (1982). *Urban policy under capitalism*. London: Sage.
- Florida, R., & Jonas, A. (1991). U.S. urban policy: The postwar state and capitalist regulation. *Antipode*, 23, 349–384.
- Fowler, E., & Siegel, D. (Eds.). (2001). *Urban policy issues: Canadian perspectives*. New York: Oxford University Press.
- Gaffikin, F., & Warf, B. (1993). Urban policy and the post-Keynesian state in the United Kingdom and the United States. *International Journal of Urban and Regional Research*, 17, 67–84.
- Hill, D. (2000). *Urban policy and politics in Britain*. New York: Palgrave Macmillan.
- Hill, R., & Fujita, K. (2000). State restructuring and local power in Japan. *Urban Studies*, 37(4), 673–690.
- Jones, M., & Ward, K. (2002). Excavating the logic of British urban policy: Neoliberalism as the “crisis of crisis-management.” *Antipode*, 34, 473–494.
- Raco, M. (2009). From expectations to aspirations: State modernisation, urban policy, and the existential politics of welfare in the UK. *Political Geography*, 28(7), 436–444.
- Wolman, H. (Ed.). (2008). *Urban and regional policy and its effects*. Washington, DC: Brookings Institution Press.

URBAN SOLID WASTE MANAGEMENT

Urban solid waste refers to industrial, commercial, institutional (collectively known as ICI waste), residential, and construction/demolition waste generated in urban areas. Current waste management practices emphasize approaches such as recycling that attempt to divert waste from landfills as much as possible. This is a significant reversal from practices that existed during most of the 20th century, when the main role of the waste management professional was to collect and dispose of waste as efficiently as possible by burning or burying it. Waste diversion has been increasing at a steady pace since the mid 1980s, when governments in most industrialized countries responded to landfill shortages and growing environmental concerns about excessive waste production by introducing municipal recycling programs.

Another significant change in urban waste management since the late 20th century is that it is no longer just a local issue. Because of economies of scale at large waste management facilities, the consolidation of private sector waste management companies, and the lack of local facility capacity, waste disposal and treatment can occur hundreds of miles from the point of generation and even in adjacent countries. Recyclables, particularly waste electrical and electronic equipment (WEEE) and recyclables found in the residues from mechanized material recovery facilities, can be shipped even further for processing. These may end up in lower-income countries, where the labor-intensive separation of different types of recyclables from one another, the removal of contaminants, and the breakdown of recyclable items into their component parts are considerably less expensive but often more environmentally hazardous than in industrialized countries. This entry discusses the waste hierarchy, waste generation, and composition; integrated waste management; the informal sector composed of self-employed individuals who participate in waste collection, separation, and recycling; urban waste management facility siting; and policy tools.

Although recycling is probably the most common waste diversion technique in use today,

nearly all urban waste management policies subscribe to the waste management hierarchy, of which recycling is only one element. The ordering of elements in the hierarchy is seen as problematic by some, but most governments have adopted the following ranking, in order of environmental performance from best to worst: (a) waste prevention activities (also referred to as source reduction or waste minimization) that reduce the mass, volume, or toxicity of a product or material at source; (b) reuse; (c) recycling and biological treatment; (d) thermal treatment (typically with energy recovery); and (e) disposal. Despite the enormous effort being put into diversion of wastes by governments, a disappointing aspect of current urban waste management practice is the lack of attention paid to the root cause of waste production, namely, consumption.

Waste Generation and Composition

Within the broader category of urban waste, waste generated by households, municipal governments, and small commercial and retail generators is known as municipal solid waste. Municipal waste excludes industrial waste—waste generated by large commercial and retail generators and construction and demolition wastes—because these categories are usually managed by the generators rather than by municipalities. Much of the data on waste generation in various countries or cities refer to municipal waste because these data are publicly available and well tracked by municipal governments. However, the data may sometimes include ICI waste, so caution should be taken when comparing data across jurisdictions.

The amount of urban waste generated per capita varies considerably around the world. Because of their wealth, industrialized countries produce considerably more urban waste than lower-income countries, generally on the order of two to three times as much per capita. About one third of the urban waste from higher-income countries is paper, one third is organic, and the remainder consists of plastics, metals, glass, wood, rubber, leather, textiles, and miscellaneous materials. In lower-income countries, a much larger portion of the waste stream is organic, typically from half to three quarters, while paper and plastic waste



constitute 5% to 15%. Lower-income countries have a higher percentage of organic waste because residents consume fewer processed foods (much of the organic waste is produced at the point of processing rather than in the home) and have fewer sources of other types of waste, such as packaging and wastepaper from offices. Inert materials, such as ash residues from cooking fuels, can make up a large portion of the urban waste stream in countries where householders lack access to reliable electricity or natural gas distribution networks and rely on coal briquettes for cooking and heating.

The Waste Hierarchy and Integrated Waste Management

Understanding the composition of urban waste is the first step in managing that waste. A waste stream that is high in organics means that biological treatment, such as composting, should be an essential component of waste management. The energy content of the waste stream is also important in determining waste management approaches. Paper and plastics, for example, have high calorific values, while organics, which are high in moisture, have low calorific values. Burning waste to recover energy is not an effective management technique for lower-income countries, where the waste stream has a large percentage of organics.

One way to assess the environmental impacts of alternative waste management options is through life cycle analysis (LCA). LCA enumerates the energy, water, and material inputs and the outputs of airborne emissions, water effluents, and solid wastes at each stage of a waste material or waste product's life cycle, from the "cradle" to the "grave." The cradle in LCAs of waste management systems is typically the point at which municipal solid waste is set out for collection, and the grave is disposal in a landfill. Recycling, biological treatment, and thermal treatment occur in between. LCA studies confirm that recycling is better for the environment overall than incineration with energy recovery, and that incineration with energy recovery is better than landfilling. These results are generally consistent across all types of materials. In other words, LCA tends to confirm that the waste

management hierarchy is valid in terms of environmental performance, at least in industrialized countries, where most of these studies have been conducted. The one exception is plastics, which a few studies have shown to have higher acidification effects and energy use when they are recycled rather than burned. Another cautionary note in the use of the waste management hierarchy is that it does not consider the social or financial impacts of each option. For example, although incineration with energy recovery may be better for the environment than landfilling, it may also be far more costly and therefore unattractive to municipal governments. An approach known as integrated waste management (IWM) has emerged to address this problem. IWM recognizes the interrelationship of environmental, economic, and social factors in designing waste management systems. It also recognizes that the best system for one location may differ from that in other locations because of geographic variations in, for example, the composition of waste, the availability of markets for recyclables, and the availability of suitable sites for waste management facilities.

The Informal Sector

Almost all countries, regardless of their level of income, have what is called the "informal" waste sector, where waste is collected, separated, recycled, and sometimes reused by self-employed individuals. The sector is unregulated, and individuals do not report their incomes for taxation purposes. Cities in lower-income countries have no formal municipal recycling programs, yet many of these cities divert just as much or more waste from landfills as cities in the industrialized North because of the informal sector. The value of recyclables in the waste stream relative to incomes is much higher in lower-income countries than in the industrialized ones. Householders and other waste generators receive payments at depots or from itinerant buyers, who go from door to door collecting the most valuable recyclable and reusable items. Waste pickers on the street and at open dumps or landfills sort through valuable items remaining in the waste stream. Many people in the informal sector are rural migrants, and most start collecting recyclables because it provides a source of income with few barriers to



entry. Even so, the job is hazardous. Those who pick through waste for recyclables at dumps and on the streets risk exposure to broken glass, pathogens, dust, and other pollutants. It is also a stigmatized profession, whose workers are regularly harassed by police and the public. The informal recycling sector is present in industrialized countries as well. Although much smaller in size, it plays an important role in recycling beverage containers (where deposits exist), scrap metal, and sometimes paper—all collected by picking through garbage and recycling bins or bags. Reuse that occurs at yard sales and car boot (trunk) sales and flea markets are also examples of waste diversion through the informal sector.

In the industrialized world, almost all waste generators receive collection services, but in developing countries, cities often don't have the financial resources to provide collection services, leaving anywhere from 25% to 50% of the city without service. In the absence of municipal collection services, residents burn their waste, bury it, dispose of it in lakes and streams, or leave it in open dumps. Some communities have responded to this problem by creating community-based collection programs, frequently with the assistance of nongovernmental groups. Community organizers gather fees from residents and pay informal workers to collect waste and deliver it to a centralized municipal collection point.

Urban Waste Management Facilities

The infrastructure for managing waste includes a range of facilities, from landfills to incineration or energy-from-waste facilities, to biological treatment facilities (for composting and bio-gasification) and transfer stations (where waste is compacted for long-haul transport). Opposition to the siting of waste management facilities is widespread. Some refer to this opposition as NIMBYism (not in my backyard), a contested term that implies that opposition is about self-interest rather than real concerns. Opponents cite many concerns, including odors, groundwater pollution, air pollution, noise, traffic, dust, and property value impacts. Opposition is present not only in industrialized countries. There are many examples of civil disobedience against the siting and operation of disposal facilities in lower-income countries, where

weak environmental regulations and lax enforcement can produce severe pollution problems.

Policy Tools

A wide array of policy tools is being used to divert waste from landfills. They include regulatory instruments, such as landfill bans on recyclable materials; economic instruments, such as landfill taxes; and voluntary instruments, such as agreements by industry to minimize production wastes. One of the most effective policy tools for encouraging waste diversion in the residential sector is a collection, or user fee. Under a user fee scheme, householders pay for collection of their waste by weight, or more commonly by volume, rather than paying a flat fee or hidden fee in general taxes. Householders can reduce their fees by recycling more, by using home composters, and by purchasing products with less packaging or more durability.

Another increasingly popular policy tool for waste management in industrialized countries is extended producer responsibility (EPR). EPR places partial or full responsibility for the postconsumer stage of a product's life cycle on the producer of that product. A basic principle of EPR is to shift the burden of paying for waste management costs from municipalities and the general taxpayer to the producers and consumers of particular products. Europe has been a leader in EPR, starting with Germany's 1991 packaging ordinance, in which producers were required to take back and either recycle or recover energy from specified percentages of postconsumer packaging. In 1994, the European Union's Packaging and Packaging Waste Directive introduced targets for the recovery, recycling, and heavy metal content of packaging waste and stimulated a wave of EPR packaging policies among its member countries. WEEE, waste batteries, and end-of-life vehicles are also subject to EPR policy in the European Union. By placing responsibility for postconsumer products and materials on the producer, EPR is meant to encourage producers to make design changes to their products that will reduce waste management costs. Such changes could include making a product easier to recycle or reuse, reducing packaging, and a variety of similar changes collectively known as design for environment (DfE). Although EPR



has been successful in transferring waste management costs to producers, it has not been as successful in encouraging DfE. There are many reasons for this lack of success, prime among them being that many EPR policies allow producers to meet diversion targets collectively, for the industry as a whole, rather than ensuring that individual producers meet waste diversion targets for their own products. Future generations of EPR policy may be more effective in achieving the DfE goal and at reducing waste at source.

Virginia W. Maclaren

See also **Consumption, Geographies of; Informal Economy; Not in My Backyard (NIMBY); Recycling of Municipal Solid Waste; Waste Incineration**

Further Readings

- Davies, A. R. (2008). *The geographies of garbage governance*. Aldershot, UK: Ashgate.
- Mayers, C. K. (2007). Strategic, financial and design implications of extended producer responsibility in Europe. *Journal of Industrial Ecology*, 11, 113–131.
- McDougall, F. R., White, P. R., Franke, M., & Hindle, P. (2001). *Integrated solid waste management* (2nd ed.). Oxford, UK: Wiley-Blackwell.
- Nas, P. J. M., & Jaffe, R. (2004). Informal waste management: Shifting the focus from problem to potential. *Environment, Development and Sustainability*, 6, 337–353.



URBAN SPATIAL STRUCTURE

In economically advanced, postindustrial countries such as the United States, the proportion of people living in towns, cities, and metropolitan areas reached 75% or more by the late 20th century in developed countries. In the world as a whole, the proportion of urban population rose from less than 5% in 1800 to slightly more than 50% of a much larger aggregate world population by the early 21st century. Numerically, world urban residents expanded from perhaps 30 million

in 1800 to about 3 billion in 2000. Matters of urban spatial structure, which pertain to the geographical patterns and characteristics of urban places, thus concern a very large and expanding share of the world's people. This entry examines the factors that influence urban spatial structure and how they contributed to growth in urbanization in the United States. It then discusses the ways in which geographers have conceptualized urban spatial structure through the concentric zone, sector, and multiple-nuclei models and also considers the limitations of these models. The entry concludes with a look at how urban spatial structure may evolve in the future.

One major facet of urban spatial structure involves the overall geographical patterns of urban settlements at regional, national, and global scales, especially in terms of the sizes and locations of towns, cities, and metropolitan areas. Another major facet involves the internal spatial arrangements of activities and land uses within urban settlements. Indeed, one of the most common analytical distinctions made in urban geography reflects a division according to geographical scale into matters that involve, first, “interurban” features of “systems of cities” for cartographically smaller map scales, at which towns, cities, or metropolitan areas are most reasonably represented using point symbols, and, second, “intra-urban” characteristics of city systems for cartographically larger map scales, at which the internal features of towns, cities, or metropolitan areas are most reasonably represented using line or area symbols. In between these are intermediate geographical scales, at which urban land use and activity patterns can be examined for metropolitan regions, which are conventionally subdivided into central city, suburban, and fringe subareas.

Patterns of Interurban Spatial Structure

Economic and environmental considerations usually predominate when one tries to understand the spatial structure of an overall interurban system of cities.

Economic Functions

While differences in the social, cultural, political, or demographic characteristics of cities create

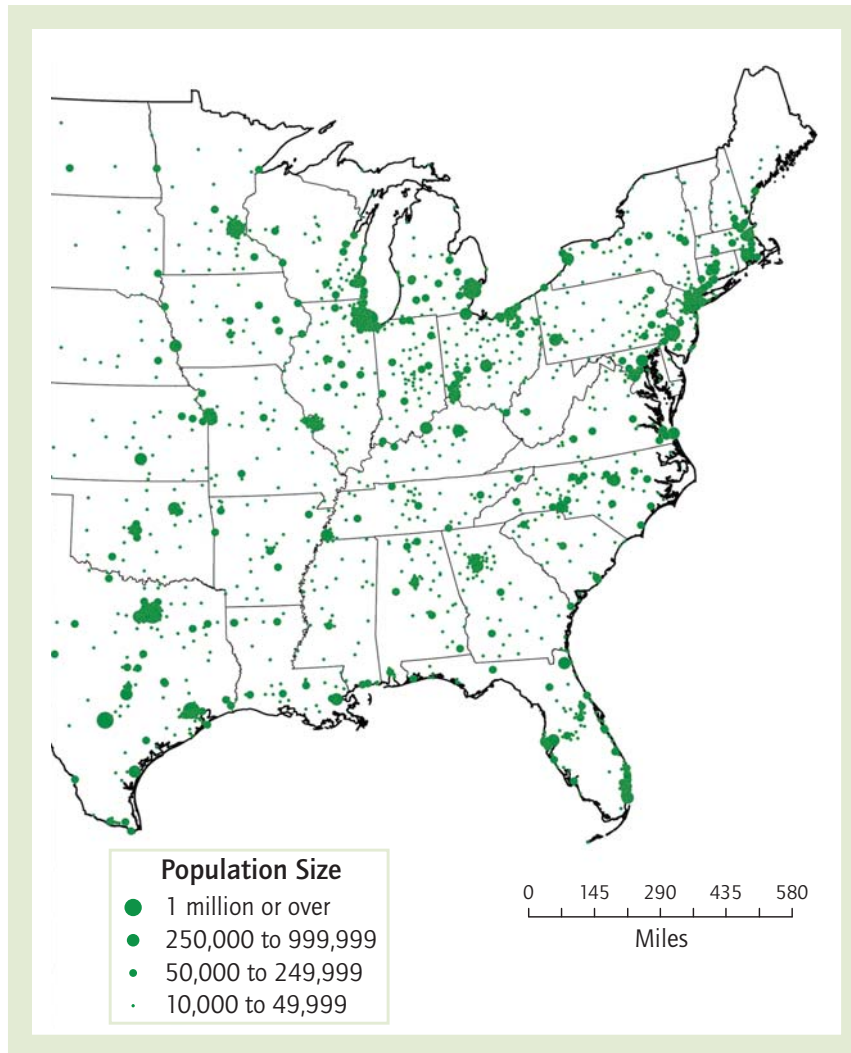


Figure 1 Population sizes of Eastern U.S. cities, 2000. The intra-urban morphology of cities is closely bound up with the evolving interurban system of cities.

Source: Author.

an enormous diversity of urban lifestyles, it is the differences in their economic functions that largely account for geographical variations in their rates of economic growth and levels of economic well-being. Some cities are mainly mining centers, known for their mineral, petroleum, or natural gas industries. Others are mainly manufacturing centers, known for the production of nondurable goods, such as chemicals, textiles, or food products, or durable goods, such as electronic or transportation equipment. Most cities perform trade or service functions, which include the collection and wholesaling of agricultural products,

warehousing, retail trade, and the provision of diverse educational, medical, governmental, and other services. Industrial location theory, central place theory, and regional growth theory all help improve understanding of how cities with different economic bases function within a larger system of cities. Cities mainly specialized in goods production or handling have generally grown more slowly than cities mainly specialized in services, especially consumer or producer services. Indeed, at the very top of the world urban system are “global” or “world” cities, such as New York, London, and Tokyo, which owe their elevated status and success to the provision of a wide range of financial and producer services. Major transnational corporations generally have their headquarters located in world cities, even though their production facilities are often dispersed among many smaller urban and rural settlements.

Environmental Settings

Even in the modern postindustrial era, the environmental settings of cities remain important. For example, many of the largest cities in the Eastern United States are located along or near a seacoast or lake front, including New York, Chicago, Philadelphia, Washington, and Miami (Figure 1). Other major cities can be found along interior waterways, such as Minneapolis, St. Louis, New Orleans, and Pittsburgh, which originated and continue to function as Mississippi or Ohio River ports. The surrounding fertile agricultural lands, as in the Corn Belt or Great Plains; the nearby deposits of minerals or fossil fuels, including iron ore, coal, oil, or natural gas; or adjacent forest or mountain amenities are of importance to cities



such as Kansas City, Dallas–Fort Worth, Birmingham, or Houston. Changes in technology and in consumer tastes create continual reassessments of natural resources, causing some cities to experience booms while others lag behind. More leisure time has made amenity-rich locations especially attractive in recent years.

Patterns of Intra-Urban Spatial Structure

While economics and environment usually feature prominently in geographical discussions of systems of cities, much more varied terminologies can be encountered in geographical discourses focused at the intra-urban city system scale of daily urban experience. At this scale, an urban or metropolitan settlement represents the geographical context in which most people live and work. Refined land use specialization usually is regarded as one of the defining characteristics of urban existence in a postindustrial society, such as that of the United States. Nearly two thirds of Americans now live in owner-occupied, single-family detached homes, which increasingly are located in suburban settings. Most other Americans live at higher residential densities in duplexes, apartments, or high-rise condominiums, which mainly are located in inner-city settings. Less than 7% of Americans lived outside the “core-based” Metropolitan or Micropolitan Statistical Areas in 2006, and less than 5% lived on farms or ranches in rural settings.

The Emergence of Urbanization in the United States

In any thoughtful consideration of the spatial structure of urban settlement, it is worth keeping in mind that barely two centuries ago, at the time of the first U.S. Census in 1790, about 95% of Americans lived on farms, and the largest city, New York, had a resident population of only about 49,000 people. In comparison, in 2006, there were 363 urban settlements in the United States, which exceeded the 50,000 population threshold for Metropolitan Statistical Area status, and the New York Consolidated Metropolitan Statistical Area alone contained an estimated population of more than 18.8 million people. These enormous changes in urban

demography have been paralleled by equally impressive changes in urban transportation, communications, and construction technologies, which make it possible to move people, goods, and ideas much faster and higher in the modern, machine-powered city than was possible in the earlier, muscle-powered city. The 19th-century city was transformed by electric trams, commuter railroads, landline telephones, and electrically powered elevators just as much as the 20th-century city was transformed by private automobiles, television, wireless cell phones, and high-speed Internet connections. In New York City, in 1790, virtually everyone had to walk to school, workplace, or shop; in New York City, in 2006, there were so many transport choices among so many modes of surface or subway and steel-wheeled or rubber-tired conveyances that some residents regarded walking as a recreational exercise.

Most modern urban geography texts devote at least two thirds of their contents to matters that involve intra-urban spatial structure. When urban geography first supplanted rural settlement geography as a realm of excitedly expanding geographical discourse about the middle of the 20th century, the split between interurban and intra-urban topics was usually about even. But intra-urban topics now predominate to such an extent that their page coverage in a typical urban geography textbook echoes the proportion of the U.S. population that lives in metropolitan areas with populations of 1 million or more, a proportion that noncoincidentally is about 60%. When Metropolitan Statistical Areas of all population sizes are considered, it is found that their areal extent spans about 20% of the total U.S. land area, although Urbanized Areas, which comprise the more densely populated built-up portions of urban clusters, cover only about 5% of all U.S. land.

Models of Intra-Urban Spatial Structure

The question of whether broad geographical generalizations can legitimately be drawn about the myriad, complex, and subtle urban spatial structures to be found within these urban settings is generating tension between urban geographers who tend to view the city from a positivist,



model-building perspective and those who tend to view the city from a softer and more nuanced, postmodern perspective. These poles can be represented, on the one hand, by computer-based quantitative factorial ecologies that mathematically summarize vast arrays of hard areal statistics and, on the other hand, by eloquent and sometimes adamant descriptions of “street-level participant observations” made in inner-city settings. In between these two perspectives, there are perhaps some commonalities of view among interested urban geographers regarding at least some of the basic features of intra-urban spatial structure.

Virtually every recent urban geography textbook includes a section dealing with the “three classic models” of urban spatial structure (Figure 2). In a way, these three classic intra-urban models are rather like the three “essential” filters that an aspiring photographer should have handy to photograph through atmospheric haze (haze filter), to avoid reflections (polarizing filter), or to focus on small subjects (close-up filter). These simplified abstractions scarcely guarantee a “perfect picture” of the city, but they can direct attention to revealing and worthwhile vistas.

Concentric Zone Model

The concentric zone model can be thought of as presenting a view that enables a city or metropolitan area to be visualized as if from a high altitude. Google Earth is a handy Web-based source for high-altitude views of most cities in the United States, as well as elsewhere. Details merge into very broad patterns if a city is viewed from high above, but a dominant geographical core central business district (CBD) usually can be identified by finding the tallest buildings and by observing the convergence of major transportation lines. Dense workday populations, traffic congestion, and high land values also usually characterize the CBD. According to urban “bid rent” theory, commercial or institutional activities are more likely to be able to profit from and hence pay for scarce and expensive sites near a city’s Peak Land Value Intersection. Commercial and institutional activities therefore tend to dominate within the CBD. Outward from the CBD, competition for space among activities with differing capacities to profit

from accessibility leads to an overall pattern of concentric zones. As distance from the CBD increases, this pattern can be physically manifested by lower building height and perhaps larger lot size, demographically manifested by lower population density and perhaps by different population characteristics in terms of age structure or ethnic composition, and economically manifested by lower land value. With notable exceptions such as New York’s Central Park or Boston’s Common, there usually is very limited green space in most CBDs, but open land becomes more common and finally predominates as the urban periphery is reached.

According to the concentric zone model, most famously articulated by the urban ecologist Ernest W. Burgess for Chicago in the mid 1920s, the CBD is usually surrounded by a zone in transition, within which anticipated land use change discourages maintenance, leading to physically decaying structures occupied by wholesaling or light manufacturing activities unable to afford the high rents of the CBD, followed in succession by “lower-status,” “medium-status,” and finally “higher-status” residential zones. In Burgess’s era, only members of the wealthy elite could afford large peripheral estates and indulge in fashionable midmorning work trips on a comfortable commuter railway line. Economic necessity forced everyone else to live closer to their place of work and to travel by crowded public buses, trolleys, and subway or elevated trains.

Sector Model

The sector model can be thought of as presenting a view that allows pronounced directional biases to be detected in urban spatial patterns. The dominance of the CBD remains apparent, but distance decay effects are no longer so uniform as to create perfectly symmetrical zones in any direction outward from the CBD. Instead, transport corridors, water fronts, historical attachments, and other directionally biased influences lead to radial variations in land values, land uses, and neighborhood characteristics in different directions outward from the CBD. Homer Hoyt’s Depression era research on residential patterns in many American cities showed that appealingly comfortable and highly valued residential properties

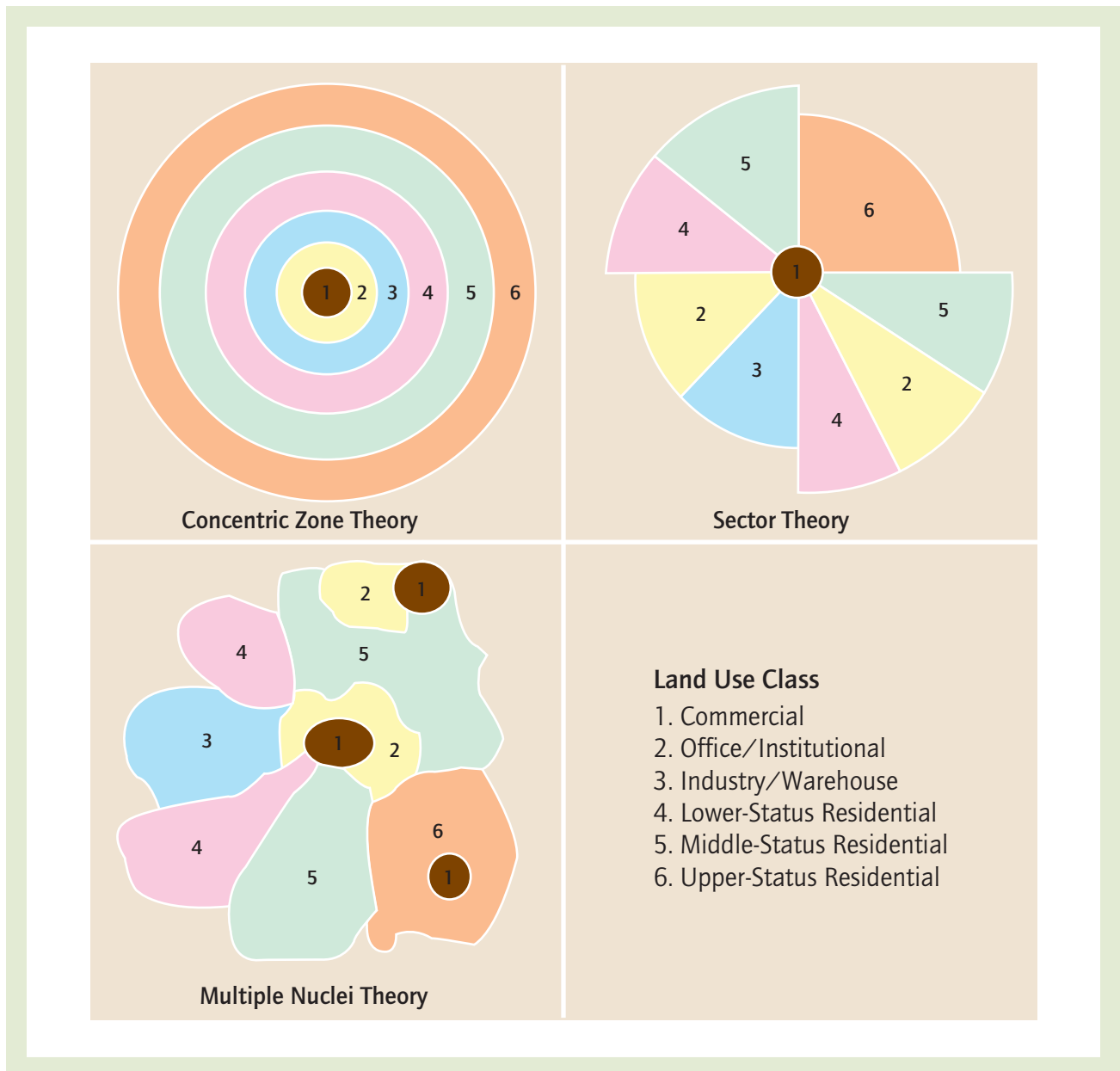


Figure 2 Models of urban spatial structure. The Chicago School models greatly influenced the subsequent trajectory of thought about the structure of cities.

Sources: Adapted from Mayer, H. M., & Kohn, C. F. (Eds.). (1959). *Readings in urban geography* (p. 281). Chicago: University of Chicago Press; Rugg, D. S. (1979). *Spatial foundation of urbanism* (2nd ed., p. 216). Dubuque, IA: Wm. C. Brown; Greene, R. P., & Pick, J. B. (2006). *Exploring the urban community: A GIS approach* (pp. 124–129). Upper Saddle River, NJ: Prentice Hall; Kaplan, D., Wheeler, J., & Holloway, S. (2009). *Urban geography* (2nd ed., pp. 198–199). Hoboken, NJ: Wiley.

often dominate along high-status corridors from near city centers outward, as northward from the Loop along Lakeshore Drive in Chicago or north-westward from Capitol Hill toward Georgetown and beyond to Chevy Chase and Bethesda in the

Washington, D.C., metropolitan area. Although Hoyt's generalizations were asserted during the heyday of the streetcar, many continued to be applicable during the late-20th-century freeway automobile era, though at a much expanded



geographical scale. In the greater Washington, D.C., metropolitan area, for example, the fashionable Northwestern Corridor now extends much further outward along Interstate 270, beyond Rockville toward Frederick, Maryland.

Multiple-Nuclei Model

The multiple-nuclei model can be thought of as presenting a view that reveals distinctive and usually rather homogeneous districts of many varieties. On the commercial side, financial districts group banks, stock brokerage firms, and related services near one another; entertainment districts are formed by geographical clusters of theaters, restaurants, and perhaps sports arenas; automobile districts cluster new and used car dealerships and automobile repair shops; warehouse and light manufacturing districts feature clusters of often functionally linked production facilities; airport districts cluster around airfields; port districts line waterfronts; and so on. On the residential side, there are high-rent clusters of luxury townhouses and high-rise condominiums; “zones of dependence,” with geographical concentrations of decaying multifamily private and perhaps public housing units; and so on. On the institutional side, college or university districts cluster academic classroom and research facilities near student housing and college-oriented businesses such as bookstores and bars; medical districts group nearby general and specialty hospitals and physicians’ offices; and so on. As a rule, districts tend to be larger, more highly specialized, and more distinctive in larger metropolitan areas and less distinctive in smaller cities and towns, though a tendency to geographically cluster similar or functionally linked land uses exists throughout the urban hierarchy, as evidenced, for example, by the clusters of feed, fertilizer, and farm equipment suppliers in small rural service communities in the Midwest.

Diversity, Spatial Specialization, and Urban Futures

Three final points about urban spatial structure remain.

First, towns, cities, and metropolitan areas are extraordinarily diverse in their geographical

patterns, especially when considered at local or neighborhood scales. In any urban settlement, if one were to walk down a street, ride a bus, or look out from an upper-story window, he or she is likely to see a colorful variety of people, land uses, and activities. The three simple classic models described here, and even their more complex and sophisticated counterparts, are abstractions that may generalize but cannot entirely capture the on-the-ground character of a real city.

Second, spatial specialization at an urban or metropolitan scale can have Janus-like implications. Janus, the Roman god of doors, gates, and beginnings, is represented artistically with two opposite faces. On the one side, spatial segregation of people and activities can increase well-being by giving urban residents utility-maximizing choices of geographical settings that most appeal to them, in terms of architectures, public services, shops, neighbors, lifestyles, and so on. But on the other side, service needs and the fiscal capacities to meet these needs can become severely geographically mismatched. This problem is especially conspicuous in larger and older metropolitan settings, where the richer suburban municipalities are politically, administratively, and legally quite separate from the seriously underbounded central cities. In such settings, gated communities quite literally wall service demands out and fiscal resources in.

Third, urban spatial structure is very dynamic through time. The degree of dynamism is especially conspicuous in North America, where small towns grew into giant metropolises in a historical blink of an eye. But in the early-21st-century period of steeply rising energy costs, the future of urban spatial structure seems uncertain. The second half of the 20th century witnessed rural-to-urban land conversion at a prodigious rate, as expanding freeway systems pushed further and further outward from city centers. But expensive gasoline is likely to diminish the appeal of distant suburban commuter zones, affecting building trends and home values throughout the metropolitan regions. Big sedans and SUVs (sport-utility vehicles) with gas-guzzling engines are beginning to filter down through the used car market to congest the parking lots of inner-city public housing projects. Pedestrian-friendly New Urbanism developments are likely to become increasingly fashionable. Privately planned New



Urbanism communities feature mixed land uses, narrow residential lots, and small-town-like neighborhoods with schools, churches, shops, or offices within easy walking distance of homes. Imagine a gaslight-illuminated Victorian-era streetcar suburb but with a small, fuel-stingy hybrid gas-electric car parked in front of each bungalow, and one just might be looking back into the North American urban future.

J. Clark Archer

See also Built Environment; Central Business District; Central Place Theory; Chicago School; Gated Community; Gentrification; GIS in Urban Planning; Housing and Housing Markets; Hoyt, Homer; Los Angeles School; New Urbanism; Public Housing; Rural-Urban Migration; Segregation and Geography; Smart Growth; Suburban Land Use; Suburbs and Suburbanization; United States Census Bureau; Urban and Regional Development; Urban and Regional Planning; Urban Ecology; Urban Environmental Studies; Urban Geography; Urban Hierarchy; Urbanization; Urban Land Use; Urban Planning and Geography; Urban Policy; Urban Sprawl; Urban Sustainability; Urban Underclass; World Cities; Zoning

Further Readings

- Berry, B., & Horton, F. (1970). *Geographic perspectives on urban systems*. Englewood Cliffs, NJ: Prentice Hall.
- Greene, R., & Pick, J. (2006). *Exploring the urban community: A GIS approach*. Upper Saddle River, NJ: Prentice Hall.
- Hartshorn, T. (1992). *Interpreting the city: An urban geography* (2nd ed.). New York: Wiley.
- Kaplan, D., Wheeler, J., & Holloway, S. (2009). *Urban geography* (2nd ed.). Hoboken, NJ: Wiley.
- Knox, P., & McCarthy, L. (2005). *Urbanization: An introduction to urban geography* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.
- Mayer, H. M., & Kohn, C. F. (Eds.). (1959). *Readings in urban geography*. Chicago: University of Chicago Press.
- Pacione, M. (2001). *Urban geography: A global perspective*. New York: Routledge.
- Rugg, D. S. (1979). *Spatial foundation of urbanism* (2nd ed.). Dubuque, IA: Wm. C. Brown.



URBAN SPRAWL

The term *urban sprawl* should be understood in the context of a deep-seated and ongoing conflict over differing visions of and priorities for the development of urban regions, between those who see contemporary suburban land development patterns as a good thing and those who see them as a major social and environmental problem. The meaning and image of urban sprawl are contested and are thus continually evolving, but most discussions of urban sprawl identify a number of common characteristics, including low-density residential development on the urban fringe, segregated land uses that give rise to long-distance travel and dependence on automobiles for mobility, and leapfrogging of development over undeveloped areas.

Although critiques of urban sprawl have become increasingly prominent during the past three decades, concern about patterns of urban expansion was a major issue for planning advocates in Western Europe and North America in the early 20th century. Their argument was that planned suburban growth offered a chance to prevent the problems of overcrowding, disease, pollution, and congestion that plagued 19th-century industrial cities and that unplanned urbanization would merely produce more of the same. A major goal of the early planners was therefore to be able to regulate and plan for development on the fringe, to ensure that housing areas were separated from industry; road patterns were well designed; water, sewer, and public transit facilities were built; and parks and natural areas set aside. Although most developed countries had enacted some elements of city planning legislation before World War II, powers were limited, and most development continued to be unplanned.

After the war, increased city-planning powers, rapid economic growth, and a spurt in house building led to the development of expansive new suburban areas with single-family, detached homes. Zoning regulations designed to avoid the problem of mixed housing and industrial areas encouraged the creation of purely residential developments, while the mobility offered by widespread automobile use meant that land was cheap



Aerial view of San Jose, California. The intersection of Interstate 280 and California State Route 87 (Guadalupe Parkway) is visible at the bottom of the photograph.

Source: Robert Campbell/U.S. Army Corps of Engineers Digital Visual Library.

and housing could be built for all classes at relatively low densities. Early in this postwar residential boom, the term *urban sprawl* was coined to describe the new patterns of suburban residential development. Early critiques were in part aesthetic, as observers reacted with shock to the enormous scale of the transformation of rural landscapes into homogeneous tracts of single-family homes that were widely seen as ugly.

Over time, however, as the scale of suburbanization accelerated, with ever-larger and more dispersed patterns of development during the past 50 years, the critiques of urban sprawl became more sophisticated and were supported by a growing range of actors. These include many municipal governments and planners, who must deal with the high infrastructure costs of low-density and leapfrog development patterns that leave tracts of land undeveloped; environmentalists, who show

that sprawl consumes far more land than necessary and threatens wildlife because scattered development leads to habitat fragmentation; transport planners, who see low-density, segregated land uses as the major cause of traffic congestion even with high levels of investment in roads, because virtually every trip must be made by car; health advocates, who argue that automobile-dependent suburbs contribute to ill health and obesity by making walking and bicycling difficult; those concerned with social equity, who see the high levels of racial and economic segregation of American society as in large part a product of the white flight to affluent suburbs, which left the poor and racialized minorities to reside in the crumbling inner cities; and those concerned with global warming and environmental sustainability, who see automobile-dependent suburbs as unnecessarily wasteful of fossil fuels.



Sprawl hits the wall (but then goes around it): the Golden State and Antelope Valley freeways in the San Gabriel Mountains in the northern part of Los Angeles County

Source: Michael Dear. Used with permission.

Although some observers dismiss critics of sprawl as elites who merely wish to impose their own aesthetic preferences on the rest of the population, there do appear to be substantive reasons to question the long-term viability of contemporary patterns of extensive suburban growth. And although all developed countries have struggled with the implications of the mobility offered by widespread car ownership, similar conflicts over suburban development played out quite differently in different countries. For example, many Northern European nations have created relatively powerful public controls over suburban development and design, while among the developed countries, the United States and Japan have taken the opposite approach with much weaker regulation and greater freedom for private property developers.

Critiques of sprawl have led to the elaboration of at least three main programs for a different

pattern of urban development: (1) new urbanism, (2) smart growth, and (3) sustainable cities, each of which are premised on the idea that sprawl is a major urban problem and that alternative and more compact urban forms should be a major policy priority. It has not proven easy, however, to stop the growth of sprawl, because existing development patterns have a great deal of momentum and are strongly supported by those with vested interests in continued development, such as urban fringe landowners, developers, construction and building material interests, realtors, and the myriad other actors who profit directly from land development and have powerful incentives to resist new regulatory controls and infrastructure obligations. Also resistant of greater regulation, however, are others, including some affordable housing advocates, who fear that increased regulation will drive up housing prices,



and advocates of free markets, who see any state intervention as an infringement on private property rights. Another major obstacle to attempts to limit urban sprawl is the fragmentation of local government in most metropolitan regions, which makes coordination difficult and can promote competition between jurisdictions for desirable development and the exclusion of unwanted land uses, each of which can contribute to further sprawl. It seems highly likely that urban sprawl will continue to provoke controversy.

André Sorensen

See also **Counterurbanization; Exurbs; Gentrification; New Urbanism; Smart Growth; Suburban Land Use; Suburbs and Suburbanization; Sustainable Cities; Urban Land Use; Zoning**

Further Readings

- Bruegmann, R. (2005). *Sprawl: A compact history*. Chicago: University of Chicago Press.
- Clawson, M., Hall, P., & Resources for the Future. (1973). *Planning and urban growth: An Anglo-American comparison*. Baltimore: Johns Hopkins University Press.
- Gillham, O. (2002). *The limitless city: A primer on the urban sprawl debate*. New York: Island Press.
- Sorensen, A. (2001). Building suburbs in Japan: Continuous unplanned change on the urban fringe. *Town Planning Review*, 72(3), 247–273.
- Soule, D. C. (2006). *Urban sprawl: A comprehensive reference guide*. Westport, CT: Greenwood Press.



URBAN STORM WATER MANAGEMENT

Urban storm water management is concerned with the draining of urban areas during and following precipitation as well as dry weather flows. Historically, urban storm water management has focused on managing flood risk through the transit of precipitation within drainage systems, with either combined (sewage and surface water, e.g., the United Kingdom) or separate (surface waters

only, e.g., Australia) systems. The aim of separate systems has been to channel the water rapidly, and often invisibly, to the nearest watercourse, while combined systems use the runoff to flush the system, reducing the likelihood of blockages but often requiring water treatment prior to release. Early examples of urban storm water management exist from the Minoan (e.g., Crete) and Greek (e.g., Pirene, Turkey; see first photo) civilizations. One of the longest-maintained systems is the Cloaca maxima in Ancient Rome, which provides an early example of urban storm water management, with drains collecting rainfall, draining marshlands, and transporting effluent to the river Tiber. London and Paris developed extensive sewer systems in the mid 19th century to remove the bad odors, believed at that time to be the cause of cholera. These systems were indeed responsible for significantly reducing the incidence of cholera, although this was because they led to a significant reduction in the contamination of local drinking waters. The expansion of urban areas during the past century has seen many new challenges within urban water management. As the proportion of catchments covered with impervious surfaces has increased, the quantity and quality of the runoff have changed. These challenges have been particularly acute in the rapidly urbanizing parts of the developing world.

Surface water flows are relatively unpredictable and exceedingly difficult to control, as the source—precipitation—is inherently stochastic. The amount of water discharged into drains varies depending on the duration and intensity of precipitation and the extent to which it can infiltrate into pervious surfaces.

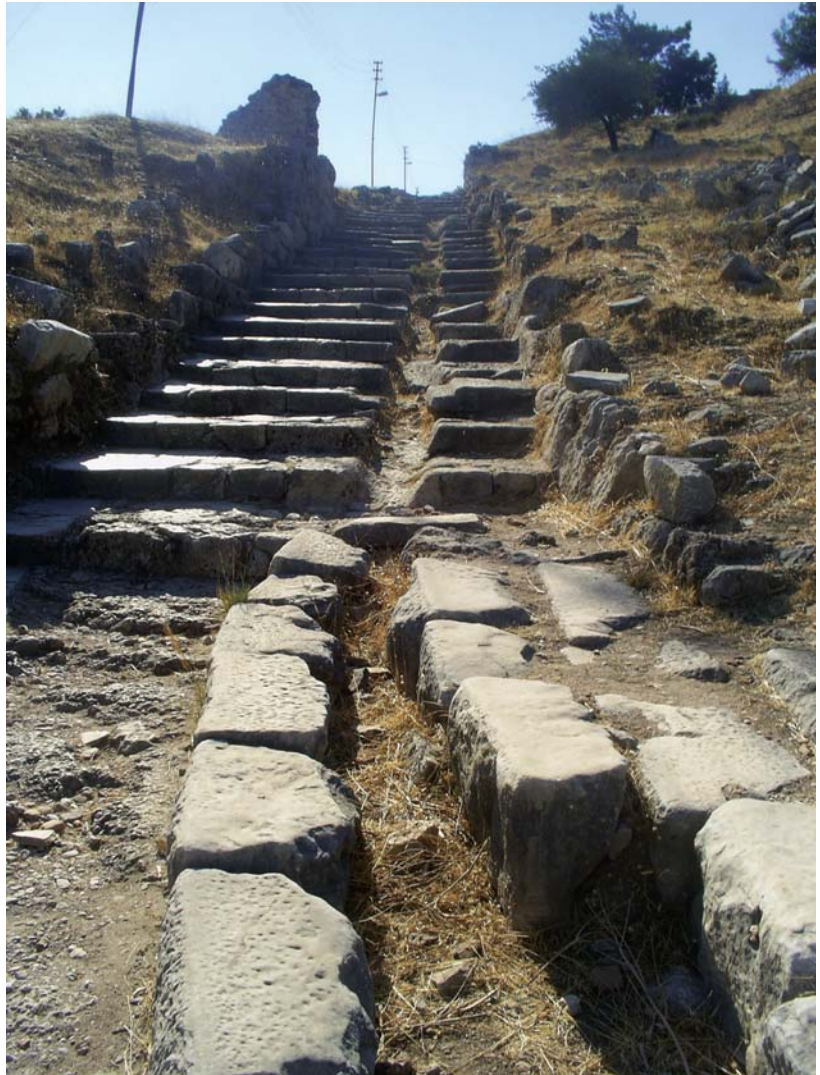
Sewers fail when the infrastructure fails, such as when a blockage occurs or when the sheer volume of precipitation entering them exceeds their design capacity. The design of a piped infrastructure capable of providing drainage for all precipitation magnitudes is unfeasible on economic grounds; as a result, there is always the risk of system failure due to incapacity. Flooding risk is normally expressed as a statistical measure (probability ratio), based on a return frequency, such as a 1-in-100-year storm event.

Varying precipitation levels mean that combined sewers have to convey varying quantities of wastewater at varying concentrations. When



these systems are overloaded during heavy precipitation events, in an attempt to reduce the pressure on the system, untreated waste may be discharged into the nearest watercourse via a combined sewer overflow (CSO), with an obviously negative impact on the environment. On rare occasions when CSOs do not function properly, wastewater can circumvent the constraints of the system, potentially flooding streets, homes, and businesses.

Developers and water system managers are increasingly under pressure from environmental agencies and local authorities to implement approaches to mitigate the risk of flooding. The management of urban drainage in a sustainable manner has increased in importance in recent years. In North America, these approaches are often considered as *best management practices* (BMPs); in Europe, they are known as *sustainable drainage systems* (SuDS); and in Australasia, they are called *water-sensitive urban design* (WSUD). The aim of these systems is to reduce the impact of storm water runoff on receiving rivers, as storm water runoff adversely affects the flow regimes, causing river hydrographs to peak sooner, often at higher levels; the runoff may also wash contaminants into the watercourses, such as organic litter, soil/dust, salt, metals, fertilizers, pesticides, chemicals, oils, hydrocarbons, and a range of other substances that may accumulate on surfaces. The approaches applied depend on the specific issues presented at each site: the duration and intensity of precipitation events; the proportional area covered by impervious surfaces; catchment relief; the drainage system, both natural and anthropogenic, and the level of integration between the two; and land use, with urban areas often including residential, retail, and industrial developments and car parks.



Drains run along the surface of a street in Pirene, Turkey, but a drain also runs beneath the road surface.

Source: Author.

Current water management approaches focus on the sources of runoff and pollution and the tools used to contain and reuse the water within parkland, urban housing, and commercial and industrial areas, with the ecological status of the area and the receiving water bodies of particular importance. The water management approaches used increasingly attempt to reproduce the natural processes of infiltration, which do not operate when using impervious surfaces. Examples of this include the wider use of “green roofs” (see Prague photo), which retain the precipitation within planted beds, or replacing impervious surfaces with systems such as porous paving, which



Green roof on a superstore in Prague, Czech Republic

Source: Author.

permits the water to drain through. These approaches, although successful in many areas, are costly and difficult to retrofit, particularly within urban areas, though increasingly these are being seen as key at the planning stage in gaining planning permission, particularly for large developments. Storm water is increasingly treated as a resource that can bring environmental, economic, and social benefits to urban areas; with capture, treatment, and reuse, storm water can provide an important contribution to water use within urban communities.

Urban storm water management in developing countries is of particular importance with these areas currently facing the greatest challenges to public health resulting from the meager provision of potable (drinking) water, inadequate drainage, and rapid urban expansion. The greatest challenge within developing countries is balancing the demands to provide sanitation and water supply with financial constraints and environmental management. In developing countries, specific challenges exist, with relatively few resources

given to infrastructure development and often relatively poor planning of new developments. Rapid growth often takes the form of informal settlements, with little management of basic infrastructure, as a consequence of which developments are often constructed in unsuitable areas, such as the floodplain or on high gradient slopes. Often, the administrative requirements for successful storm water management are not present, with limited coordination between bodies and across administrative boundaries, leading to poorly integrated drainage systems. The challenges faced by developing urban centers are not new, but the opportunities are also challenges, particularly from a financial and resources perspective.

Historically, drainage has been perceived to be the domain of the civil engineer, but the successful implementation of modern-day urban storm water management requires an integrated approach involving an interdisciplinary team of groups and individuals, including engineers, hydrologists, urban planners, environmental scientists, economists, social scientists, and



developers, who engage with communities and local bodies.

Neil Macdonald

See also Floods; GIS in Water Management; Public Water Services; Surface Water; Urban Water Supply; Wastewater Management; Water Management and Treatment; Water Needs; Water Pollution; Watershed Yield; Water Supply Siting and Management

Further Readings

- Butler, D., & Davies, J. W. (2004). *Urban drainage*. London: Taylor & Francis.
- Davis, A. P., & McCuen, R. H. (2005). *Stormwater management for smart growth*. London: Springer.
- Ferguson, B. K. (1998). *Introduction to stormwater: Concept, purpose, design*. London: Wiley.
- Parkinson, J., & Mark, O. (2005). *Urban stormwater management in developing countries*. London: International Water Association.



URBAN SUSTAINABILITY

As a concept and a field of study, urban sustainability emerged out of the sustainable development movement that took off in 1987 with the publication of the Brundtland report, *Our Common Future*. Via the Brundtland report and the subsequent 1992 United Nations Conference on Environment and Development (Earth Summit), held in Rio de Janeiro, sustainable development brought together the international priorities of poverty alleviation and environmental conservation, creating an agenda for simultaneous improvement in both situations worldwide. Sustainable development has since been defined in terms of the quest for a balance between economic, social, and environmental conditions and, in the form of “sustainability,” as the achievement of a state of living that can be continued long into the future without deterioration of any of these three. The field of urban sustainability can be viewed from the perspective of international development and prescriptions for global

and intergenerational equity and from the perspective of specific urban development and design tools and techniques, realizing the efficiencies of urbanization and building on case studies. Urban sustainability has a different significance for urban developers, city managers, social justice advocates, and urban dwellers. This entry discusses the diverse agendas and practices of urban sustainability, as well as research perspectives on the topic.

The Urban Sustainability Agenda

The emergence of urban sustainability as an important concept in international development corresponds with the tipping of the balance of the world's population toward a majority of urban, rather than rural, dwellers. This balance was tipped sometime in the first decade of the 21st century, depending on which population estimate is used. Correspondingly, UN-HABITAT, the United Nations agency responsible for local settlements, has taken on urban sustainability as a key challenge. Thinking about urban sustainability in the context of the less developed world brings the human dimensions of sustainable development into focus—that is, the part of the original Brundtland definition that emphasizes poverty alleviation and meeting the needs of the current generation. In the developed world, where the means exist to provide for these needs, the other component of the definition, its focus on intergenerational and environmental equity, is more aptly tackled. Coordinated action by developed and developing nations alike would, of course, be ideal. Some point to significant opportunities for “leapfrog” development, by which the developing world might draw on the experience and expertise of the developed world to bypass the most unsustainable stages of development and create green, sustainable cities before many developed world cities are able to make this transition. This ideal is complicated in practice by the higher up-front costs of green development, the fact that many new technologies are unproven, and the sentiment throughout the developing world that those primarily responsible for the unsustainable state of our cities should be the ones to incur the costs of the sustainability transition.



A common framework for urban development is needed that incorporates the impacts of decisions well into the future as well as around the world. However, initiatives in governing cities with an eye further into the past and the future—such as Portland’s attempts to meet the Kyoto Protocol carbon emissions reduction target or the goal of Masdar City, Abu Dhabi, to generate zero carbon and zero waste by 2016—paradoxically can decrease accountability and action. The politicians and professionals of today will rarely be affected personally by the failure of their projects and goals beyond the horizon of the immediate future, and comparisons with past conditions can be manipulated in any number of ways. The public attention that flows to cities that make grand plans and targets is rarely, if ever, sustained long enough to track their progress, as the standard metrics for evaluating concepts such as carbon neutrality and zero waste do not exist and public and political preferences and pressures are certain to change significantly over time.

Initial studies in urban sustainability were concerned with the impact of cities on sustainable development globally. Coming from an ecological perspective, many sustainability advocates were ambivalent toward or openly derided cities, with scholars such as William Rees going so far as to label cities as ecological black holes. This characterization is justified by the fact that cities develop via the destruction of their local ecologies and their replacement with paved surfaces, biologically unproductive land uses, and the consumption of natural resources far beyond their actual footprint on the landscape (what Mathis Wackernagel and William Rees call the ecological footprint). To most ecologists, cities represent artificial landscapes, in contrast to those composed of mostly nonhuman elements. Furthermore, cities are centers of finance and politics, where many of the most environmentally destructive decisions are made; centers of education, where people are taught the lessons and skills that lead to widespread discounting of natural wealth and productivity; and centers of culture, where these decisions, lessons, and skills are normalized and reproduced. According to this thinking, the surest path to sustainability would be large-scale deurbanization and a return to small, “human-scale” settlements; reliance on “appropriate”

rather than high technology; and primarily local rather than global trade patterns. There are some cases in which this theory can be considered to hold: A number of Rust Belt cities in North America, for instance, are more sustainable settlements following their decline than when they were prosperous, and experimental sustainable communities such as Findhorn, Scotland, and Arcosanti, Arizona, have been established quite consciously apart from the city. Still, the implications of this strain of thinking about sustainability, when applied globally, are troubling in that cities are home to an increasing majority of the world’s people and high rates of urbanization are associated with greater levels of freedom and human rights around the world.

The embodiment of sustainability in the urban realm was raised as an issue by scholars who noticed what Andrew Light called the “urban blindspot” in sustainability and related fields. They noted that, despite the currently destructive state of urbanism, the potential for cities to be beacons of sustainability is great. Efficiencies exist in nearly every realm of urban development: energy efficiencies through shared walls in apartment buildings compared with single-family homes; economic efficiencies through multisectoral industrial clustering, as in the case of eco-industrial networking; and efficiencies in social marketing and rapid changes to social norms toward more sustainable values through, for example, large-scale public demonstrations for climate action; international gatherings such as Earth Summits; and personal lifestyle change efforts such as Earth Day pledges and reusable shopping bag campaigns. Here, the primary notion is to work with the urban advantage that stems from high population density in contrast to the unsustainable resource use and lifestyle patterns found in the suburbs. Positive action in this realm has been pursued primarily by those who study and practice urban design. The designer’s sustainability toolbox consists of ideas such as smart growth, cradle-to-cradle design, zero waste, carbon neutrality, one-planet living, new urbanism, green building, transit-oriented development, and life cycle analysis. Working examples of sustainable design exist as neighborhoods within cities, such as Freiberg, Germany, and Fremantle, Australia.



On July 22, 2009, the U.S. Postal Service dedicated its first “green” roof, the largest in New York City and one of the largest in the country. This photo shows detail and a cross section of the roof, which is on the Morgan mail facility in midtown Manhattan. Built in 1933, the 2.2-million-ft.² facility became a historic landmark in 1986. Its roof was constructed originally to serve as an additional mail processing location, supporting 200 lb./ft.² When the roof was scheduled for replacement in 2007, it was deemed strong enough to support the weight of the soil, vegetation, and other requirements of a green roof. The roof will last up to 50 years, twice as long as the roof it replaced. It will also reduce the amount of contaminants in storm water runoff flowing into New York’s municipal water system. The agency projects the reduction of polluted runoff to be as much as 75 % in summer and up to 35 % during winter.

Source: © James Leynse/Corbis.

Urban Sustainability in Practice

In professional practice, urban sustainability presents new challenges for the processes of developing, redeveloping, and managing cities. In theory and to some leading-edge cities, urban sustainability represents a new holistic management framework more than any particular process or policy. In this way, urban sustainability is being applied within a small but growing number of city halls to issues of immigration and integration, poverty alleviation and slum upgrading, improving environmental management and environmental impacts, urban design, regional planning and combating

sprawl, downtown revitalization, housing, transportation, and risk management—the full gamut. Often, these considerations are grouped in terms of the “brown agenda” of urban sanitation and infrastructure; the “green agenda” of environmental services and resource and energy conservation; and the social agenda of developing just and fair institutions and opportunities in the arenas of economics, education, health, governance and so on. As the social agenda remains the least well understood and least well addressed of the urban sustainability domains and given that its scope is so broad, this domain is often broken down into subgroups such as culture, governance, and education.



Research Perspectives on Urban Sustainability

In the early 21st century, while increasing numbers of cities are establishing sustainability branches and functions, the majority of cities with sustainability policies do not clearly differentiate these from environmental policies, offices, and functions. What specifically makes an urban policy oriented toward sustainability as well as what makes a sustainability policy specifically urban are both questions under examination and experimentation. In line with the sustainable development mantra to “think globally, act locally,” different local conditions make different policy approaches suitable. Developing world cities may adopt a sustainability approach to find better, long-term solutions to the state of slums and life conditions of slum dwellers, while a developed world city in decline might pursue a shift to a new economic base, and a thriving developed world city might leverage a building boom or mega event toward sustainability principles.

From an ethical perspective, inquiry into urban sustainability needs to ask, “What is it we are interested in sustaining?” The answer depends on one’s perspective. For city managers, planners, and elected officials, their particular cities need to be sustained over the long term, and a comprehensive approach to maintaining or enhancing its economic, social, and environmental conditions is the preferred strategy. In this context, we need to ask whether a sustainability agenda can be reconciled with pressures for global economic competitiveness, in which most if not all cities are engaged. It is also important to investigate where the responsibility for achieving urban sustainability lies and the opportunities and limitations for action at the scale of particular cities, by urban governments and their citizens, compared with those of higher orders of government, international bodies, and global civil society.

For social justice advocates, it is the lives of urban dwellers worldwide that need to be made sustainable. With an estimated 30% of the world’s poor living in cities, Sudhir Anand and Amartya Sen ask how sustainable development can be a meaningful concept when the living conditions of so many are too deplorable to be worth sustaining. In this context, urban sustainability demands

a narrowing of social and economic disparities, which are often exaggerated in cities. This means correcting long-standing imbalances and relieving poverty and other inequities through social policies and redistributive economic programs that are informed by a holistic approach. The alignment of urban sustainability and democratic agendas becomes apparent here, bringing into focus research questions relating to the relative role of the public and of experts, of social capital and urban citizenship, and of various forms of public participation in urban sustainability.

For urbanists, it is the city, as the dominant kind of human settlement, and the global urban system that need to be brought into balance with the nonurban world. On this point, some researchers point to the value of increasing the resilience of cities for a future sure to be filled with intense shocks and threats, from climate change and economic and social upheavals. Others, such as David Satterthwaite, are primarily concerned with the role that moving cities toward sustainability can play in achieving sustainable development at the global scale. This would mean planning for resilient cities, not just in terms of their own long-term needs and contributions but also in terms of building and maintaining equitable long-term relationships with all other cities in the global network, and thinking about flows of immigration, trade, tourism, ideas, and environmental goods and services around the world. Satterthwaite poses this distinction between inward- and outward-looking sustainable cities in terms of the following question: Sustainable cities or cities that contribute to sustainable development? It is at best disingenuous to talk about sustainability at a local scale if it is achieved by transferring costs, inequities, or waste products elsewhere; at worst, it is the active perpetuation of environmental injustice. The pursuit and study of urban sustainability entail a perspective that moves from the local scale of a single city, down to the individual neighborhoods, businesses, parks, and natural areas within it, and up to the global scale of the world system of cities. The quest is for more effective integration of the diversity of needs and interests operating within and among cities. It is a challenge to consider the impacts and implications of actions for the very long term, respecting the vast diversity of



conditions and aspirations for the future that may emerge.

Meg Holden

See also **Environment and Development; Environmental Justice; Footprint Analysis; Green Building; Green Design and Development; Sustainable Cities; Sustainable Development; United Nations Conference on Environment and Development; United Nations Environmental Summits; Urban and Regional Planning; Urban Ecology; Urban Environmental Studies; Urban Green Space; Urban Land Use; Urban Metabolism**

Further Readings

- Anand, S., & Sen, A. (2000). Human development and environmental sustainability. *World Development*, 28(12), 2029–2049.
- Campbell, S. (1996). Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development. *Journal of the American Planning Association*, 62(3), 296–312.
- Light, A. (2000). The urban blind spot in environmental ethics. *Environmental Politics*, 10(1), 7–35.
- Newman, P., & Kenworthy, J. (1999). *Sustainability and cities: Overcoming automobile dependence*. Washington, DC: Island Press.
- Satterthwaite, D. (1997). Sustainable cities or cities that contribute to sustainable development? *Urban Studies*, 34, 1667–1691.
- Wackernagel, M., & Rees, W. (1996). *Our ecological footprint*. Gabriola Island, British Columbia, Canada: New Society.
- World Commission on Environment and Development. (1987). *Our common future*. New York: Oxford University Press.



URBAN UNDERCLASS

The term *urban underclass* has been extremely controversial in the social sciences since its ascendancy in the early 1980s. The term, coined by Gunner Myrdal in 1962 to describe a stratum of the long-term unemployed population in American

cities, tenaciously persists in academic and policy circles. At the core of all dominant definitions, the term references an urban population that is persistently low income and has difficulty obtaining suitable waged work to ensure a decent quality of life. Most also agree that there is a strong racial and class association that corresponds to this population—that is, they are disproportionately African American, Latino, and workers at the lowest end of the new postindustrial service economy. At the same time, this population is recognized as having relatively poor access to key goods and services, such as decent jobs and housing, well-funded schools, and suitable parks and open space.

But much disagreement persists about the urban underclass concept. First, scholars clash over the reasons behind the deployment and resonance of the notion. On the one hand, it is suggested that the term *urban underclass* is a simple, objective, and neutral descriptor for a stratum of the impoverished urban population. It supposedly helps clarify the specifics of a particular needy, service-dependent population. Analysts here dispassionately put truth and reality into an accurate, descriptive term. On the other hand, others explain the term's origin and longevity in its ability to target and stigmatize a population. Analysts here are said to contribute to a complex societal process whereby the poor (and particularly impoverished ethnic minorities) become singled out and differentiated as culturally problematic beings in need of social rehabilitation. Analysts, in the process, wittingly and unwittingly validate a pejorative “classing” and “racing” of society that pervades public thought. In the debate over the use and resonance of the urban underclass concept, these two contrasting positions dominate.

Scholars also differ on the causes for the rise and persistence of this population. Staking out a widely accepted notion, William Julius Wilson explains this phenomenon by reference to a changed city, national, and international economy. Wilson and adherents identify the rise of a service-based economy (supplanting a manufacturing economy) that has afflicted the poor, particularly impoverished minorities. This rise of service jobs, concentrating in two areas—low-wage, “McDonald's-type” jobs and high-wage,



education-intensive jobs—fails to provide meaningful employment opportunities for this population. Concomitant with the loss of decent-paying manufacturing jobs, the working-class and poor populations get devastated. Unlike Wilson and his adherents, a group of Marxist scholars have sought to explain the reasons for this economic transformation. David Harvey traces this economic transformation to the rise of two forces, neoliberalization and globalization. First, new labor-punishing rules and regulations and corporate labor-cutting practices across America have allowed unskilled, low-wage, dead-end jobs to proliferate. Second, a new global reality has dramatically shrunk the globe. In the process, a hypermobility allows production units to close or move an accelerated number of manufacturing plants out of America to lower-wage world regions.

This position contrasts with the still entrenched notion of the culture of poverty. This alternative, coalescing around the ideas of Ken Auletta, George Gilder, and Charles Murray attributes the origin of the urban underclass to the emergence of an antisocietal culture in inner cities. The rise of counternormative values, manifest in “underclass behavior,” purportedly send inner-city mothers, fathers, and children down paths of social dysfunction, with an inability to integrate into mainstream America. One structural factor is seen by many in this camp to shape this population: the individually damaging effects of a dysfunctional welfare state apparatus that ran roughshod over this population, beginning in the 1960s. Government programs inadvertently killed individual initiative to work and sacrifice, creating a service-dependent population now enslaved to government largesse.

Scholars also disagree on the duration of existence of this population. To some, a distinctive, new urban underclass is less than 30 years old. Its roots are in the post-1980 ascendancy of the postindustrial economy, which has dramatically polarized the rich and poor in urban America. This position notes a long history of poverty, underemployment, and unemployment in U.S. cities. However, they point to a relatively new reality of long-term poverty populations having grown more hopeless, despairing, and socially removed from society’s mainstream. In contrast, others see the contemporary urban underclass

population as simply the most recent manifestation of a long-term urban poverty population. There roots have been variously traced to the supposed afflicting effects of the Great Society in the 1960s, the Keynesian economic stimulus apparatus beginning in the 1930s, and the “reality” that the poor have always been with us and will always be with us as long as people have different wills and initiatives to succeed.

Finally, scholars disagree on the level and intensity of the constraints that impinge on the daily lives of this population. Two dominant positions have arisen. The first contends that the black urban underclass reflects a legacy of historical discrimination that pervasively persists today. Some writers fervently argue that African Americans have faced discrimination in housing markets, labor markets, and common social life that superseded that of other previous ethnic populations in cities. In this context, they suggest that blacks today continue to be held back in labor hiring practices, job promotion opportunities, obtaining better housing, and securing government services. Paraphrasing Cornel West, hiring, firing, and everyday life in cities today is still profoundly colored. But other voices proclaim such discrimination as essentially dead. Racism is said to persist in withered, subtle ways, but the reality of an urban underclass now must be explained by other factors, namely, human choices embedded in a ghetto cultural formation. Poverty and isolation are supposedly now normative, the end products of human decision flowing out of the structure of poor black communities. Poor blacks have absorbed and re-created an oppositional culture—that is, a set of behaviors, attitudes, and expectations that fundamentally conflict with those of the broader society.

The urban underclass concept today takes on more salience as poverty has deepened and really expanded across American cities. Yet scholars are no closer to resolving their differences of opinion about this notion’s *raison d’être*, the rise and causes of this referenced population, and the duration of its existence. After years of national silence regarding urban poverty, the controversy over the notion of urban underclass is likely to intensify.

David Wilson



See also **Ethnic Segregation; Filtering; Housing Policy; Inequality and Geography; Poverty; Public Policy, Geography of; Race and Racism; Racial Segregation; Social Justice; Urban Geography; Urban Policy**

Further Readings

- Auletta, K. (1982). *The underclass*. Woodstock, NY: Overlook.
- Gans, H. (1996). *War against the poor: The underclass and antipoverty policy*. New York: Basic Books.
- Gilder, G. (1981). *Wealth and poverty*. New York: Basic Books.
- Jencks, C., & Peterson, P. (1991). *The urban underclass*. Washington, DC: Brookings Institution Press.
- Katz, M. (1990). *The undeserving poor: From the war on poverty to the war on welfare*. New York: Pantheon.
- Marks, C. (1991). The urban underclass. *Annual Review of Sociology*, 17, 445–456.
- Murray, C. (1983). *Losing ground: American social policy, 1950–1980*. New York: Basic Books.
- Myrdal, G. (1962). *An American dilemma: The Negro problem and modern democracy*. New York: Harper & Row.
- Rickets, E., & Sawhill, I. (1988). Defining and measuring the underclass. *Journal of Policy Analysis and Management*, 7, 316–325.
- Wacquant, L. (2008). *Urban outcasts*. New York: Polity Press.
- West, C. (2004). *Democracy matters*. New York: Penguin.
- Wilson, D. (2007). *Cities and race: America's new Black ghetto*. London: Routledge.
- Wilson, W. (1987). *The truly disadvantaged*. Chicago: University of Chicago Press.
- Wilson, W. (1996). *When work disappears*. Chicago: University of Chicago Press.

providing water of sufficient quantity and quality to urban populations is significant. Demand for water is driven by population growth and changes in the ways in which societies demand water for domestic, industrial, and commercial uses. Providing water to urban settlements has involved technological and engineering innovation. Deeper, and often controversial, struggles over access to and control of water are also important. These institutional and political questions are rarely resolved in a consistent manner and reveal deep contradictions. Many of these involve conditions of scarcity. This scarcity, even though it may have origins in physical conditions, is often not natural. Instead, scarcity is the result of power relations that have evolved in particular places and times. Rapid urbanization, whatever the timing or cause, lays bare the complexities of urban water supply. Opening with a brief examination of the technical aspects of supplying water to urban areas, this entry provides a consideration of systematic inequities in access to water in both historical and contemporary contexts.

Technology, Engineering, and Urbanization

Ancient engineering techniques for moving water for domestic purposes displayed keen engineering skill in using gravity. Innovations included the use of natural and manufactured pipes, containers, and taps and the use of various simple machines. The Roman aqueducts, for example, moved large quantities of water over long distances and efficiently and elegantly stored and distributed water within cities. Other ancient and medieval societies similarly mastered the use of gravity, with varying degrees of precision.

Bringing water to a city allowed both private and public uses. In addition to meeting practical needs, many of these uses were symbolic and served to reinforce or legitimate sets of power relations. Even in medieval Europe, regarded as a period of technological reversal and stagnation, the exploitation of water sources outside cities and the construction of water conduits continued. In this case, it was often through the exercise of the ecclesiastical power of the Church rather than the secular power of government. Expertise in gravity-based techniques diffused from city to city or from monastery to monastery. Adoption,

URBAN WATER SUPPLY

Water and cities have a complex relationship influenced by natural conditions and by the abilities of human societies to adapt and reshape them to meet their needs and desires. The challenge of



however, was uneven, and even with adoption, place-based particularities influenced access to water and the types of uses made of it—for example, open fountains in Italy or spigots in England.

Cities and towns with ample local water supplies or proven long-distance access to them sometimes enjoyed a comparative advantage as manufacturing and later industrialization took hold. In cities that experienced rapid population growth in the manufacturing era, adequate potable water supplies became a necessity. Demands for potable water supplies in the largest cities were driven by concerns over public health, as human and industrial waste had compromised available local supplies. It had become clear that piecemeal private provision of water was insufficient to protect the rich and powerful against the threats of waterborne diseases. Responding to both elite demands and the pressure of broader political movements, collective and most often public ownership and operation of urban water emerged. Success in the development of water and sewerage services dramatically reduced the impact of waterborne diseases. Rapid growth required significant additions to the water resources of cities, particularly if the available local resources were limited or too polluted for use.

In the North American context, New York City extended its influence (using state authority) into a widening hydrological hinterland. As in ancient times, the city and the countryside became linked through this hydrological connection—faster growth and greater water demands led to the expansion of what some have called the “water frontier.” For modern-day New York, this means a network of reservoirs outside the city, with city influence on land use and environmental change. More than 1 billion gallons of water is delivered daily.

Similar stories can be told about most major cities in the core of the world economy as they added publicly provided water supplies. In areas of extreme water scarcity, limits on water supply could constrain population and economic growth and required more aggressive and long-distance appropriation. These, in turn, have prompted conflict as rural demands for water, especially for agriculture, have been displaced by thirsty cities and the perceived inevitability of urban and suburban growth.

Water treatment to achieve an aesthetically acceptable or healthier product has similarly evolved. Techniques have grown from rudimentary settling chambers and sand filters designed to improve the smell and appearance of water to the addition of chemicals and more advanced purification techniques targeted at bacteria, viruses, and parasites. Cities increasingly have come to rely on a complex combination of engineering and chemistry to meet everyday water needs. A failure of these technologies can quickly lead to public health threats.

Geographical and technological fixes for urban water problems require tremendous commitments of resources. In the modern setting, water infrastructure requires significant initial financial investment as well as a commitment to maintenance over the longer term. In the United States, water borrowing by cities to provide for water and sanitation needs grew exponentially in the late 19th century. Urban areas outside the core of the world economy, particularly capital cities and those with an industrial base, also added public water systems. Sometimes, improvements were seen to have significant symbolic value, providing the appearance of modernity as well as health benefits—even if only for a fraction of the city and its population.

Organizing Water Delivery

The construction and operation of urban water systems does not mean that all residents of a city receive water of consistent quality and quantity. Indeed, inequities in water delivery and pricing were and are commonplace and remain a structural feature of many urban landscapes. This is partly because of the reactive nature of water supply provision (supply capacity lags behind demand), but systemic inequity is also an outcome of place-based power relations and, therefore, is of special interest to geographers. These inequities were present in ancient societies and remain visible today. The formal architecture of political power in a state plays a significant role in the development of urban water supplies by influencing the geographical scale for responsibility. Countries with strong central governments have different planning and implementation processes than those where power may be devolved



to the regional or local scale. Rigorously enforced national environmental or drinking water standards with strong fiscal support will bring results that are vastly different from those where local decision making is coupled with limited access to capital.

In many cities, increases in population outstrip existing or planned capacity. This is true whether population increases are caused by 19th-century industrialization and urbanization or 21st-century migration from the countryside into shantytowns or informal neighborhoods in countries in the periphery of the world economy. Individual areas within a city may have water service as a consequence of local political movements or simply because of political patronage. On the other hand, they may *not* be served because of lack of political power, to prevent temporary settlements becoming permanent, or to avoid unacceptable compromises of service to other, “more deserving” areas. Residents of areas that lack a reliable supply of good-quality piped water, even at the scale of shared public standpipes, are forced to rely on their own wells or surface water or other methods of provision. Lack of sanitation and the presence of industrial pollution may make wells or surface water unhealthy, leading to higher child and infant mortality rates and shortened life expectancies. Those with no other choices may also be subject to the market relations of vendors, who may get water from a public system only to sell the water under exploitive and monopolistic conditions. This situation, sometimes facilitated and supported by urban politics, can lead to egregious exploitation through the regressive pricing of urban water. Poor and marginalized populations often get less water at lower quality and yet pay significantly more for it. Water provided by public systems may be influenced by collective ideals, public subsidies, and the regulation of a “natural monopoly.” Those excluded from the public supply experience no such protection.

The keystone status of clean water in public health and economic development has drawn consistent attention in international development policy. The 1980s, for example, was declared the International Drinking Water Supply and Sanitation Decade by the United Nations (UN). Water and sanitation feature prominently in Earth Summit (United Nations Conference on Environment

and Development, 1992, Rio de Janeiro) documents such as Agenda 21 and in the UN Millennium Development Goals. The 2006 report of the United Nations Development Programme specifically focused on water and sanitation, providing further compelling analysis of water problems.

The practicalities of meeting the water needs of millions of people have involved shifting institutional and organizational arrangements. While there may be limited room for optimism, the situation is complex and laden with contradiction.

Contemporary Political Economies of Water

Recent conflicts have stemmed from the impact of globalization. Here, a neoliberal agenda of commodification and privatization runs head-on into visions of water as a collective human right. In the context of globalization, policy-based lending from the World Bank and International Monetary Fund has brought the realities of global capitalism and corporate control into the arena of urban water supply. Defining water as an economic good (as well as a necessity) became fused with a vision of private expertise as the best solution for urban water supply woes in the developing world. This expertise was to be provided by global corporations—with attractive, and often guaranteed, returns on their investments—themselves funded with loans from the World Bank or other multilateral lenders. The privatization message took on an almost magical allure and was backed by the financial power and dominance of global institutions and corporate interests. This showed itself in different ways in different settings, with impacts in all world regions. In England and Wales, for example, privatization was a response to a domestic policy agenda (deregulation and privatization of government enterprises) and the financial pressures of compliance with European Union environmental directives. In France, private companies, which have played a significant role in water services for decades, became global-scale operators through mergers and acquisitions. In the United States, where municipalities with aging infrastructure and underinvestment faced massive financial commitments, international corporations offered the promise of better service for lower costs as well as a reduction and “disciplining” of the



public sector workforce. In the cities of the developing world, policy-based loans, often as part of national-scale structural adjustment packages, have transformed the provision of urban water by requiring privatization. Global-scale water corporations have received lucrative concessions and contracts with promises not only to meet ambitious collective water supply goals but also to fully recover their costs (and profits). Global privatization has been paralleled by the development of global-scale governance. This has occurred not only through existing international institutions but also through the creation of new organizational forms, which are not state based but part of the development of a new international regime for water.

While privatization and commodification have been part of this international regime, there has also been resistance to privatization from international nongovernmental advocacy organizations, localized and global social movements, and public sector labor unions—a broader and globalized civil society. While outcomes have varied, there is one clear finding: Privatization and commodification have not been panaceas and have, in fact, moved the inequities of urban water provision into the public limelight. Urban water is no longer the domain of engineers and bureaucrats. It has become the focus of the mainline international environmental organizations, global corporations, global capital investment funds, national and international economic and social development organizations, investigative media, and an array of vocal advocates and activists for democracy and transparency. Place-based stories of protest and resistance, in print and on video, are not confined to the streets of cities in the developing world; they also feature in the city council chambers of North America. The details of each story may be different, but underlying each is a deep and enduring concern over access to and control of water.

As the 21st century unfolds, urban water provision promises to be at the cutting edge of local and global conflict. Conflict over the broader availability of water will be supplemented by struggles over the ways in which the provision of water is organized. Concerns over efficiency of urban water consumption as well as the risks of terrorist threats to the integrity of urban water

supplies have joined the list of controversies. Against a backdrop of climate change and evolving forms of global capitalism and civil society, urban water supply will continue to be a focus of examination.

Richard Kujawa

See also **Civil Society; Environmental Rights; GIS in Water Management; Public Water Services; Wastewater Management; Water Management and Treatment; Water Needs; Watershed Yield; Water Supply Siting and Management**

Further Readings

- Barlowe, M., & Clarke, T. (2003). *Blue gold: The fight to stop the corporate theft of the world's water*. New York: New Press.
- Bennett, V. (1995). *The politics of water*. Pittsburgh, PA: University of Pittsburgh Press.
- Gleick, P. (2008). *The world's water 2008–2009*. Washington, DC: Island Press.
- Magnuson, R. J. (2001). *Water technology in the Middle Ages*. Baltimore: Johns Hopkins University Press.
- Olivera, O. (2004). *¡Cochabamba! Water war in Bolivia*. Cambridge, UK: South End Press.
- Snitow, A., Kaufman, D., & Fox, M. (2007). *Thirst: Fighting the corporate theft of our water*. San Francisco: Jossey-Bass.
- Swyngedouw, E. (2004). *Social power and the urbanization of water*. New York: Oxford University Press.
- Watkins, K. (2006). *Beyond scarcity: Power, poverty and the global water crisis*. New York: United Nations Development Programme.



USABILITY OF GEOSPATIAL INFORMATION

A number of possible definitions of usability are available in the literature of geospatial information, and the needs of spatial data usability have been compared and contrasted with the broader data-related activities of providers and users of



geoinformation. For example, one official definition of usability is given by the ISO 9241-11 standard on Display Screen Regulations, Use of Ergonomics for Procurement and Design. In this definition, system usability consists of the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use, where

- effectiveness measures the accuracy and completeness with which users achieve specified goals,
- efficiency measures the resources expended in relation to the accuracy and completeness with which users achieve goals, and
- satisfaction measures the freedom from discomfort and the positive attitudes toward the use of the product.

Usability elements outline the features and characteristics of the product that influence the learnability, effectiveness, efficiency, and satisfaction with which users can achieve specified goals in a particular environment. The context of use determines the types of users, tasks, and equipment and the physical and social environments in which a product is used. Therefore, a system consists of users (the people who interact with the products), equipment (hardware, software, and materials), tasks (activities required to achieve a goal), and a physical and social environment for the purpose of achieving particular goals.

Usability has also been defined as a set of attributes that bear on the effort needed for use, and on the individual assessment of such use, by a stated or implied set of users (see ISO 9126). This definition differs from the ergonomics-based definition in that characteristics other than efficiency and effectiveness are also seen as elements of usability.

Nielsen, concerned with software usability, sketches a broader context he calls system acceptability. One aspect of it is usefulness, which pertains to whether the system can be used to achieve a desired goal. Therefore, it is possible to break usefulness down into utility and usability—utility denoting the question of whether the functionality of the system in principle can do what is needed and usability denoting the question of how well users can use this functionality.

It is hard to isolate a core set of fundamental techniques that clearly distinguish data usability from any single-component discipline; in some ways, it is a uniquely powerful combination of individual techniques that characterizes the field. In summary, data usability might be identified as an umbrella term consisting of several elements aggregated into several groups:

- *Marketing*: added value, benefits, costs, novelty, services provided, and satisfaction
- *Quality*: authoritativeness, guarantee against error, integrity, metadata, reliability, validity, and utility
- *Software and tools*: human computer interaction, standardization, integration, searchable, and interface
- *Human perception/cognition*: authoritativeness, decision type, interestingness, novelty, popularity, satisfaction, trust, user skill levels, familiarity, interpretation, and visualization
- *Applications*: aggregation levels, type, exclusiveness, visualization, integration, decision type, use with models and algorithms, availability, and accessibility

Each individual category can be discussed in light of specific user groups and/or applications. For example, in the marketing category, cost is a very common and often a very important element and plays a large part in usability. In the applications group, availability and accessibility also determine the use of data. Moreover, it is important to realize that elements such as accessibility and cost of spatial data can vary among different countries and cultures. Another example is the update frequency. To decide on the desired update frequency, users should be asked to define the tolerable difference between decisions made and the time frame for future decisions.

There is also a dynamic component in the definition of usability. As time goes by, some data sets will be more useful than others. This is a consequence of the nature of the elements being depicted and the temporal and spatial scale of the representations. Accordingly, consideration will have to be given to the best way of improving the use of the database. Again, a usability framework should provide milestones for the application of objective methods aiming to extend the lifespan



of a database within reasonable limits. This methodology will affect the way data sets are produced, maintained, and used. There is also considerable scope for the implementation of data-modeling techniques such as rule-based classifications and data mining.

Finally, there is an important element linked to the way users perceive and use existing data sets. The same data presented in an unfamiliar way to the user become ineffective. The human interface is an important area for constant improvement. Visualizations such as three-dimensional representations, virtual reality, and animations seem to bridge the gap between data producers and data consumers. Therefore, these techniques improve the likelihood of data being fully understood and used.

Monica Wachowicz

See also **Legal Aspects of Geospatial Information; Privacy and Security of Geospatial Information**

Further Readings

International standards for HCI and usability:
www.usabilitynet.org/tools/r_international.htm

Journal of Usability Studies: www.upassoc.org/upa_publications/jus

Nielsen, J. (1993). *Usability engineering*. Boston: AP Professional.

Wachowicz, M., & Hunter, G. J. (2002). Special Issue on Spatial Data Usability. *Data Science Journal*, CODATA. Retrieved December 14, 2009, from www.jstage.jst.go.jp/browse/dsj/_vols



VAGUENESS IN SPATIAL DATA

This entry examines aspects of vagueness in spatial data from the perspective of a spatial database used to support a geographic information system (GIS). A spatial database is a collection of data concerning objects located in some reference space that attempts to model some enterprise in the real world. The real world abounds in uncertainty, and any attempt to model aspects of the world should include some mechanism for incorporating uncertainty. There may be uncertainty in the understanding of the enterprise or in the quality or meaning of the data. There may be uncertainty in the model, which leads to uncertainty in entities or the attributes describing them. And at a higher level, there may be uncertainty about the level of uncertainty prevalent in the various aspects of a database.

Many operations are applied to spatial data under the assumption that features, attributes, and their relationships have been specified a priori in a precise and exact manner. However, inexactness often exists in the positions of features and the assignment of attribute values and may be introduced at various stages of data compilation and database development. Models of uncertainty have been proposed for spatial information that incorporate ideas from natural-language processing, the value-of-information concept, non-monotonic logic and fuzzy set, and evidential and

probability theory. Thus, in the modern GIS, there is a need to more precisely model and represent the underlying uncertain spatial data. The major aspects of spatial data description to focus on for uncertainty considerations include spatial region descriptions, spatially related attributes, and spatial relationships.

Spatial Region Descriptions: Fuzzy Sets

In contrast to an ordinary set for which a set element is either in or out of the set (set membership of only 0 or 1), a fuzzy set is one in which the membership of an element may have a value between 0 and 1, representing the degree to which the element belongs to the fuzzy set. Within a fuzzy set, we may have objects comprising the *core* (full membership of 1.0 in the set in question), and we may have a *boundary* (the area beyond which they have no or negligible membership in the set). A classic spatial example of the core and boundary problem is determining where a forest begins. Is it determined based on a hard threshold of trees per hectare? This may be the boundary set by management policy, but it is likely not the natural definition. There are several ways to manage these uncertain boundaries. If a spatial database can represent the outlying trees as being partial members of the forest, then a decision maker will see these features as being partial members if the database is queried.



Spatially Related Properties

Next, consider spatially related properties such as soil types, which might be described in linguistic terms such as

{sandy, loamy, . . . }.

Such linguistic terms are commonly modeled as *fuzzy sets*. So soil classification might be assessed as belonging to the fuzzy set “sandy” with a membership value of 0.8. It is also possible to allow numeric as well as scalar values. For example, a fuzzy number such as “about 3 cm” of rainfall at a location could be used.

To use minimum bounding rectangles in a spatial database for vague regions, a fuzzy minimum bounding rectangle (FMBR) can be defined as consisting of nested rectangles. The innermost rectangle is the MBR over the core of the vague region (certain region or membership = 1). The outer rectangle is an MBR over the outer boundary of the vague region. This approach allows the consideration of common indexing approaches such as grid files or *R*-trees.

Spatial Relationships

The major types of spatial relationships that can be considered are geometrical orientation and topological relationships. An approach to uncertainty in such spatial relations can be based on determining configuration similarity for spatial constraints involving topology, direction, and distance. This approach uses extended objects for direction and topology, and centroids for distance; it handles uncertainty in fuzzy relations, for example, an object that satisfies more than one directional constraint, as well as fuzziness related to linguistic relationship terms. Another approach is based on MBR and spatial extensions of Allen’s temporal relationships. The basic relationship definitions, and their use in defining relevant directional and qualitative topological relationships, provide a framework for the abstract spatial graph, a spatial data structure specifically designed to retain orientation and topological information with respect to two-dimensional objects and to provide information to support fuzzy querying capabilities on these relationships. The weights

computed from the abstract spatial graphs directly support fuzzy queries regarding qualitative topological and directional information. These techniques permit queries such as “Does ‘some of Object A overlap most of Object B?’” or to determine that while Object A is *slightly southwest* of Object B, it is at the same time *mostly west* of Object B.

Another approach to representing uncertainty that can be used is the theory of rough sets. Rough sets involve a universe, U , and the indiscernibility relation, R upon U . Then, a rough set X is defined by

Lower approximation of
 $X: RX = \{x \in U \mid [x]_R \subseteq X\},$

Upper approximation of
 $X: \bar{R}X = \{x \in U \mid [x]_R \cap X \neq \emptyset\},$

where $[x]_R$ denotes the equivalence class of R containing x .

Consider the spatial concepts, $U = \{\text{tower, stream, creek, river, forest, woodland, pasture, meadow}\}$, and let R be as follows:

$R^* = \{[\text{tower}], [\text{stream, creek, river}], [\text{forest, woodland}], [\text{pasture, meadow}]\}.$

Given some set $X = \{\text{medium, small, little, tiny, big, huge}\}$, we would like to define it in terms of its lower and upper approximations:

$RX = \{\text{tower, stream, creek, river}\}$

and

$\bar{R}X = \{\text{tower, stream, creek, river, forest, woodland, pasture, meadow}\}.$

A *rough set in A* is the group of subsets of U with the same upper and lower approximations. In the example given, the rough set consists of the following subsets:

{tower, stream, creek, river, forest, pasture}

{tower, stream, creek, river, forest, meadow}

{tower, stream, creek, river, woodland, pasture}

{tower, stream, creek, river, woodland, meadow}.



The major rough set concepts of interest are the use of an indiscernibility relation to partition domains into equivalence classes and the concept of lower- and upper-approximation regions to allow the distinction between certain and possible, or partial, inclusion in a rough set.

The indiscernibility relation allows us to group items based on some definition of “equivalence” as it relates to the application domain. We may use this partitioning to increase or decrease the granularity of a domain, to group items together that are considered indiscernible for a given purpose, or to “bin” ordered domains into range groups. To allow *possible* results, in addition to the obvious, certain results encountered in querying an ordinary spatial database system, we may employ the use of the boundary region information in addition to that of the lower-approximation region. The results in the lower-approximation region are certain. These correspond to exact matches. The boundary region of the upper approximation contains those results that are possible, but not certain.

Frederick E. Petry

See also **Analytical Operations in GIS; GIS Design; Ontological Foundations of Geographical Data; Topological Relationships; Usability of Geospatial Information**

Further Readings

- Bordogna, G., DeCaulwe, R., & DeTre, G. (Eds.). (2004). *Spatio-temporal databases: Flexible querying and reasoning*. New York: Springer-Verlag.
- Burrough, P. A., & Frank, A. (Eds.). (1996). *Geographic objects with indeterminate boundaries*. London: Taylor & Francis.
- Petry, F., Robinson, V., & Cobb, M. (Eds.). (2005). *Fuzzy modeling with spatial information for geographic problems*. New York: Springer-Verlag.
- Zhang, J., & Goodchild, M. (2002). *Uncertainty in geographical information*. London: Taylor & Francis.

VANCE, JAMES (1925–1999)

James E. Vance Jr. is known for his scholarship on urban, historical, and transportation geography. These interests became apparent in his doctoral dissertation on *The Growth of Suburbanism West of Boston*, supervised by Raymond Murphy and completed at Clark University in 1952. After holding appointments at the Universities of Arkansas, Wyoming, and Nebraska, he taught from 1958 to 1991 at the University of California, Berkeley, where he directed 28 successful doctoral dissertations. His work emphasized the evolution and structure of cities; the roles of transportation and trade in shaping regional settlement; and the social processes that internally differentiate urban areas. Vance (1990) focused especially on “urban morphogenesis—the creation and subsequent transformation of city form” (p. 38).

The popularity of Vance’s courses on urban geography and transportation geography led him to write monumental textbooks on these subjects. *This Scene of Man* (1977) surveyed the evolving role and structure of the city in Western history. A revised edition, *The Continuing City* (1990), added two chapters on the modern metropolis and transportation innovations since 1850. In *Capturing the Horizon* (1986), Vance traced the emergence of modern transportation systems: canals, railroads, urban transport, maritime navigation, and aviation. His final book, *The North American Railroad* (1995), interpreted development of the railway networks of the United States and Canada, where, he argued, geographical factors dictated significant variations from British antecedents.

Vance made several influential contributions to geographic theory. First, in his work on the functional organization of the North American downtown, he argued that abstract economic forces such as land rent were insufficient to understand the structure of the central business district (CBD); instead, he stressed historic origins, functional requirements, and social factors. Vance summed up the historical-geographical processes of CBD evolution as “the seven lives of downtown: inception, exclusion, segregation, extension, replication and readjustment, redevelopment, and the city of realms.”



A second geographical contribution was the “mercantile model,” which highlighted the role of long-distance trading ties in locating early settlements around the port, transportation facilities, warehouses, markets, and so on. Intended as a critique of and alternative to Walter Christaller’s central place theory, Vance’s (1970, 1990) mercantile model argued that wholesale trade resulted in the formation of new settlements or “points of attachment,” which if successful became regional centers with their own hinterlands. This emphasis on commercial forces external to the local urban system, confirmed by empirical studies in North America, provided a missing link in central place theory.

A third contribution was the concept of “the city of realms,” an influential spatial model for the contemporary North American metropolis. Vance’s view of the urban-realm model recognized a decentralized metropolis split into a series of daily activity areas no longer dependent for their existence on the traditional CBD. The criteria of urban realms included topography and physical geography, the overall size of the metropolis, economic functions of the realms, and the regional geography of transportation. Vance’s (1977, 1990) “city of realms” predicted the contemporary dispersed metropolis a quarter century before notions of “edge cities” came into vogue.

Brian J. Godfrey

See also **Berkeley School; Railroads and Geography; Transportation Geography; Urban Geography; Urban Spatial Structure**

Further Readings

- Vance, J. (1970). *The merchant’s world: The geography of wholesaling*. Englewood Cliffs, NJ: Prentice Hall.
- Vance, J. (1977). *This scene of man: The role and structure of the city in the geography of Western civilization*. New York: Harper’s College Press.
- Vance, J. (1986). *Capturing the horizon: The historical geography of transportation since the transportation revolution of the sixteenth century*. New York: Harper & Row.

Vance, J. (1990). *The continuing city: Urban morphology in Western civilization*. Baltimore: Johns Hopkins University Press.

Vance, J. (1995). *The North American railroad: Its origin, evolution, and geography*. Baltimore: Johns Hopkins University Press.



VARENIUS (1622–1650)

Bernhard Varen (latinized to Varenius) was born near Lünenburg, Germany, in 1622. Through studies at the gymnasium of Hamburg and the University of Königsberg, he excelled in mathematics, natural science, and philosophy, leading to the completion of a degree in medicine at the University of Leiden in 1649. There is no evidence of his having practiced medicine. Rather, he settled in Amsterdam, working as a tutor and taking interest in the discoveries of contemporary Dutch navigators, the work of geographers, and the achievements of Willem Blaeu and other cartographers. Varenius contributed to regional understanding with *Descriptio Regni Japoniae* in 1649 and to studies of religion. However, he is best known for *Geographia Generalis*, published in the 28th and final year of his life by Elsevier Press in 1650.

Geographia Generalis is a milestone in the history of science, staking a position for a formal discipline of geography, aligning it with the rationalist perspective of the early Enlightenment (represented in the philosophies of René Descartes and Francis Bacon) and with the commitment to empirical documentation. Residing in Amsterdam, Varenius had access to the wealth of new information made available through seafaring voyages of discovery and trade. Documenting and systematizing that knowledge was one of his central objectives. He recorded quantitative information about the shape, size, and motions of Earth, documented findings about the distributions of land and water, and systematized notes on the characteristics of mountains, woods, deserts, and the atmosphere in different locations, seeking where possible to identify trends and general spatial patterns.

Geographia Generalis identifies two branches of geography—special and general. Whereas



special geography is focused on the description of countries and regions (referred to today as regional geography), general geography was seen by Varenius as a systematic science, focused on understanding the features at the surface of Earth and on relationships between Earth and other celestial bodies. He saw value in basing regional description on a foundation of general understanding and proceeded to outline three different aspects of general geography. These included absolute geography, to measure the size, shape, and motions of Earth; relative geography, to draw associations to climatic patterns and the measurement of time; and comparative geography, to describe geographical variations in the characteristics of different parts of Earth and to identify appropriate principles of mapping and navigation.

Historians of geography characterize the successive translations and revisions of *Geographia Generalis* (by Isaac Newton in 1672 and 1681 and by others well into the mid 1700s) as helping establish a foothold for teaching systematic geography in many of the leading academic institutions of Britain, America, and Europe. It provided a foundation for thinking about the practices of geography and its role in science. The work of Varenius was invoked in 17th- and 18th-century debates over the merits of Cartesian and the Newtonian scientific systems, lauded by Alexander von Humboldt in his *Cosmos*, and although it no longer garners such central attention, it is seen as a foundation for good scientific practice by 21st-century scholars who seek to advance the science of geographic information.

Donald G. Janelle

See also **Chorology**; **Human Geography**, **History of**

Further Readings

- Baker, J. (1955). The geography of Bernhard Varenius. *Transactions, Institute of British Geographers*, 21, 51–60.
- Warntz, W. (1989). Newton, the Newtonians and the *Geographia Generalis Varenii*. *Annals of the Association of American Geographers*, 79, 165–191.



VECTORIZATION

Vectorization is the process of converting or transforming a scanned image or raster file by digitizing features into sets of X,Y coordinates and then using software to create a vector file or layers of points, lines, and polygons that represent corresponding features from the parent raster image. After vectorization, attribute data can be assigned to the points, lines, and polygons.

Vectorization is part of a larger set of tools within geographic information systems (GIS) software programs. Vectorized data can be used to study, learn, and make decisions about how humans interact with their surroundings, resources, other living things, or the larger environment.

In the early days of GIS, the process of vectorization was known by terms such as *raster-vector restructuring*, *line extraction*, and *line modeling*. Line modeling was also known as *spaghetti modeling*. This modeling represented line data in a very unstructured way, with the end result being a set of intertwined and disconnected lines that looked like a plate of spaghetti. As attribute data were added, lines with similar attributes were given the same symbology, and the lines began to fall into categories that had structure. These categories were then separated into different layers.

Vectorization is a basic component of GIS used in processing raster data to create various vector layers that make up the components of a GIS database. For example, if roads were traced or digitized using GIS software from an aerial photograph, the individual segments that make up the road, both curves and straight segments, would be turned into a series of X,Y coordinates to form corresponding line segments that represent the image of the road on the aerial photograph. These segments are then grouped together into a vector layer. The layer then represents the road in the GIS. This process is repeated for all other graphic elements from the air photo, which may include ponds, fields, parking lots, house locations, intersections, power poles, and so on and are then converted to vector point, line, and polygon layers. From these layers, attribute data can be attached describing all possible characteristics of the points, lines, and polygons that have been created. These vector layers can then be



used together with other geospatial data sets and layers in a GIS to perform spatial analysis.

John A. Olson

See also **Data Format Conversion**; **Digitizing**

Further Readings

Bolstad, P. (2002). *GIS fundamental: A first text on geographic information systems*. White Bear Lake, MN: Eider Press.

Hohl, P. (1993). *GIS data conversion: Strategies, techniques, and management*. Albany, NY: OnWord Press.



VERNACULAR LANDSCAPES AS EXPRESSIONS OF ENVIRONMENTAL IDEAS

Vernacular landscapes, sometimes termed *ordinary landscapes*, are the surfaces of everyday life that we see all around us and that are created and re-created daily. Cultural geographers study vernacular landscapes to understand the lives of ordinary people who live in those landscapes. Ordinary landscapes take the form of everyday places such as parking lots, tree-shaded suburbs, trailer parks, or a patchwork of fields in Midwestern U.S. farmlands. They are lived in and are continuously changing.

Geographers agree that there are many layers of meanings embedded in any landscape and that multiple cultural landscapes exist in the same place. These vernacular landscapes can be studied to illuminate ideas about the human environment. However, the term *landscape* is somewhat ambiguous. Its meanings can be understood and even expressed differently by different social groups and at different times. It is used by many professionals, among them architects, artists, Earth scientists, geographers, and historians, with myriad meanings. Differences in meaning between disciplines and even within a discipline present challenges in understanding and translating the term. The landscape is all around us; it is related to

nature but is not identical with nature. Landscape is also related to the environment. It is less organic than the everyday environment that sustains and surrounds people, and also less inclusive. There is scenery in every landscape, but landscape is not identical with scenery. Geographers have described landscape as the intermingling of physical, biological, and cultural features.

Cultural geographers observe landscapes with their eyes but interpret them with their minds. Peirce Lewis has argued that landscapes are the products of impressions of our senses rather than the logic of sciences. Landscapes are expressions of cultural values, social behaviors, and individual actions worked into a particular locale over a span of time. Lewis has further maintained that the human landscape reflects human values and aspirations, tastes, and fears, combining them into a tangible, visible form. The landscape holds a fairly accurate cultural record, one that many cultural geographers agree is an unintended autobiography where glories are embedded and cultural warts and blemishes are also included. Grady Clay has said that there are no secrets in the landscape. The ordinary day-to-day qualities of people are exhibited for anyone who wants to find them and knows how to look for them.

Contemporary cultural geographers have created different categories of landscape types. The differences in the categories have to do with the elements contained in those landscapes. In addition to vernacular landscapes, there are symbolic landscapes, which are representations of specific virtues, values, ideas, or memories. For instance, a builder, artist, politician, and/or a financier can aspire to impart a particular idea to the larger public. The Lincoln Memorial and other public buildings and monuments around the Mall in Washington, D.C., were built in the neoclassical architectural style and were deliberately designed to communicate the grandeur and a sense of power. The Lincoln Memorial itself imitates the style of the Greek city-state and communicates the authority and power of democratic principles.

Ordinary landscapes influence and change the perceptions, values, and behaviors of the people who live and work in them. Since they are continuously changing and geographers cannot study everything, they study selected items in the ordinary, everyday landscapes; however, scholars



Tulip field in a typical Dutch setting, Berkmeer, the Netherlands

Source: Jaap Hart/iStockphoto.

must put them in context, where they are a part of a larger thing that is undergoing continuous modification and change as a result of both conscious as well as unconscious processes.

Two Examples of Vernacular Landscapes

Two examples illustrate vernacular landscapes. The first is the historic beginning of vernacular landscapes as described by John Brinckerhoff Jackson. The second example uses elements in the vernacular landscape of a community in southwest Uganda.

The term *vernacular* suggests something traditional, homemade, or countrified; historically, the term was associated with buildings. Identifying dwellings as vernacular alluded to the work of a

craftsman who used local materials and techniques, but the buildings also reflected local environmental and economic conditions. Jackson was one of the early geographers who traced the historical development of vernacular dwellings from their beginnings in European architecture of the 16th, 17th, and early 18th centuries. According to Jackson, the term *vernacular dwellings* was mostly used by architects and architectural historians to emphasize form and building techniques. Vernacular dwellings were seen as loyal to local forms and rarely incorporated external innovations; they were even considered timeless. A shift occurred in the mid 19th century as signaled by the exploration of rural life by antiquarians and others who sought a life beyond the urban, industrial one.



Later studies of the vernacular landscape involved archaeologists, geographers, and social historians, who brought to light the fact that the vernacular building was not timeless but had a history of its own, different from formal architecture yet shaped by ancient archetypes. The vernacular building, they argued, had undergone a long and complex evolution. During colonial times, the American vernacular dwelling, in both rural and urban locations, was movable or even temporary and focused on the child-centered family. This vernacular dwelling has evolved over time to include utilities and other conveniences and an increased number of rooms. Jackson suggested that the American vernacular dwelling, although designed as a micro-environment, greatly depends on the community. The vernacular dwelling is a source of services rather than a political entity. It has evolved in the suburbs, company or college towns, trailer parks, resort areas, and condominium complexes.

This second example describes two elements of the vernacular landscape of the Chiga community of southwest Uganda. The Chiga are mostly subsistence farmers who are increasingly focusing their energies on producing food for sale in produce markets surrounding their locale.

The Chiga landscape is characterized by rugged hills and steep-sided valleys cut deep by occasional streams and swamps. During the rainy season, the swamps flood and cut off entire areas from access to produce markets for extended periods of time. Individual villages build bridges, which provide access across the swamp at its shallowest points. The bridges are unlike conventional bridges as commonly understood. Instead, they appear like an unsurfaced or dirt road with concrete pillars on either side. The pillars are about 3 ft. (feet) wide, erected upright to about waist height and about 12 to 15 ft. apart. Beyond the concrete pillars are deep trenches designed to drain the water away from the bridge surface. At one end of the bridge is a barricade designed to stop vehicular traffic while allowing foot traffic across. The community collects a small bridge toll to help with maintenance costs. A sign just before the bridge proudly declares the “floating bridge” open to traffic and includes the name of the community that built it and sometimes the date the bridge was opened for use. The concept of the floating bridge reflects the

fact that during the wet season, the swamp swells and covers the surface of the bridge, although one is always able to see the concrete pillars. Their portions above water appear to be floating and mark the limits of the hard surface of the bridge.

The hilly terrain with the steep-sided valleys makes it impossible to use mechanized farming techniques. Much of the land is cultivated by hand. The Chiga community is densely populated, and land parcels come in relatively small sizes. At a glance, the terrain has a terraced appearance, although terracing is not a technique that the Chiga employ. Instead, the land parcels are divided into horizontal layers as one travels downhill. The land has a patchwork appearance that comes from the various landowners making different land use decisions. Some fields lie fallow; some have crops that are browning as they near harvest season; and some have newly planted rows of sweet potato vines. Still other parcels appear forested as a result of having lost the fertile top soil to persistent soil erosion.

These two examples illustrate the ordinary nature of vernacular landscapes. They are lived in and created through a combination of conscious and unconscious processes. Vernacular landscapes are all around us and are undergoing transformation continuously. Studying them enables us to say something about the values, aspirations, tastes, fears, glories, and blemishes of the people who lived and continue to live in these vernacular landscapes.

Christine W. Mathenge

See also [Architecture and Geography](#); [Berkeley School](#); [Cultural Geography](#); [Cultural Landscape](#); [Everyday Life](#), [Geography and](#); [Folk Culture and Geography](#); [Jackson, John Brinckerhoff](#); [Landscape Architecture](#); [Landscape Interpretation](#); [Meinig, Donald](#); [Sauer, Carl](#)

Further Readings

- Jackson, J. B. (1984). *Discovering the vernacular landscape*. New Haven, CT: Yale University Press.
- Meinig, D. (Ed.). (1979). *The interpretation of ordinary landscapes: Geographical essays*. New York: Oxford University Press.



VIA CAMPESINA (INTERNATIONAL FARMERS' MOVEMENT)

La Via Campesina has evolved as an international movement of poor peasants and small farmers from the global South and North. Initiated by Central, South, and North American peasant and farmers' movements and European farmer's groups, Via Campesina was formally launched in 1993 in Mons, Belgium. Existing transnational networks of activists located in peasant movements and nongovernmental funding agencies in the North facilitated the earlier contacts between key national peasant movements, most of which had emerged already in the 1980s. By 2008, Via Campesina represents more than 150 (sub)national rural social movement organizations from 56 countries in Latin America and the Caribbean, North America, (Western) Europe, Asia, and Africa. Since its birth, Via Campesina's main agenda has been to defeat the forces of neoliberalism.

Transnational regional coalitions of agrarian movements have played a critical role in linking (sub)national movements together. The most organizationally robust and politically coherent regional alliances are those in Latin America and Europe. The most uneven, thin, and organizationally and politically fragile regional alliance is the one in Africa. There are no regional networks of Via Campesina in the Middle East and North African region, Central Asia, the USSR, or China. One of the earliest regional pillars of Via Campesina was the Central American peasant alliance ASOCODE (Asociación de Organizaciones Campesinas Centro Americanas para la Cooperación y el Desarrollo), which was at its peak in the 1990s.

The entry of Via Campesina into the global governance scene has altered the international civil society terrain in many significant ways. For one, it has ended the monopoly of the International Federation of Agricultural Producers (IFAP) in terms of representing the farming sector in international governance processes. Founded in 1946, IFAP is an international farmer's federation of generally medium to rich farmers. Via

Campesina's entry provided a distinct representation for poor peasants and small farmers. Moreover, Via Campesina's entry into the global scene ended the monopoly of nongovernmental organizations (NGOs) in representing "civil society" in various state and nonstate fora. Via Campesina is distinct in the sense that it is a movement that directly represents (sub)national organizations of poor peasants and small farmers in contrast to the intermediary role of NGOs.

Many of the national movements that are leading members of Via Campesina have engaged in dramatic anticorporate actions, such as bulldozing a McDonald's fast-food shop in France, burning a Kentucky Fried Chicken outlet in Bengaluru, India, and uprooting a genetically modified (GM) soya farm and a eucalyptus nursery in Brazil, among others. The protest suicide of Lee Kyang Hae, a South Korean farmer, during the Cancún World Trade Organization (WTO) negotiations was another form of dramatic action.

Via Campesina's political work focuses on seven issues:

1. Agrarian reform
2. Biodiversity and genetic resources
3. Food sovereignty and trade
4. Women
5. Human rights
6. Migrations and rural workers
7. Sustainable peasant agriculture

However, actual global campaigns have been highly uneven between these issues.

The campaigns against GM crops and the WTO are perhaps the most high profile among all Via Campesina's campaigns. Their campaign against GM crops is anchored by several high-profile national initiatives, especially in France (by the Confederation of French Farmers, led by José Bové), India (by the Karnataka State Farmers' Association, led by M. S. Nanjundaswamy, who died in early 2004), and Brazil (by the Movimento dos Trabalhadores Rurais sem Terra or MST, led by Joao Stedile). This campaign is framed within anticorporate monopoly and anti-monocropping practice perspectives. Meanwhile,



the anti-WTO campaign put Via Campesina in the global media spotlight from Seattle to Cancún to Hong Kong. Via Campesina was perhaps the most consistent and organized transnational agrarian movement that opposed the WTO.

The global campaign on agrarian reform by Via Campesina perhaps comes far behind in terms of global projection and impact. This campaign was launched in 1999, together with two other transnational civil society networks—Foodfirst Information and Action Network and the Land Research and Action Network. It was primarily a campaign against the neoliberal land reform framed and promoted by the World Bank. This policy promotes a land reform that is voluntary and based on the willing seller/willing buyer principle. It has been carried out in various countries, including Colombia, Brazil, South Africa, and the Philippines. While Via Campesina has been able to push the World Bank to a defensive political position on this issue, the general impact of the campaign at the national level has been marginal; the same policy was expanded in Brazil, and it remains the main national legal framework for South African land reform.

Meanwhile, campaigns on human rights have been intermittent. It has been limited to occasional global “action alert” calls for specific human rights violations in different countries. However, the Via Campesina campaign for a universal “Peasants’ Charter” can also be located within human rights, especially since this issue is being addressed before the United Nations Commission on Human Rights. There are no significant initiatives in the other areas listed earlier. Finally, since the Bali conference on climate change in December 2007, Via Campesina has identified climate change as a key transnational campaign issue. The group has attempted to address agrofuels and the food price crisis that erupted in 2008 as part of its broader campaign. Whether or not Via Campesina will be able to develop the climate change issue as a master frame in its transnational political campaign remains to be seen.

Moreover, Via Campesina is a transnational movement that goes beyond engagement in “expose and oppose,” agitation-propaganda types of campaigns alone. Via Campesina is seriously engaged in developing concrete alternatives and proposals. The main framework for its “catch-all”

alternative is the notion of food sovereignty—the right to produce, trade, and consume food within and near one’s territory. This alternative framework brings in several new key development issues that are related to geography, including the question of place or territory as well as scale. But it has also brought in old development questions, including rural-versus-urban, as well as industrial-versus-agricultural paradigms.

Saturnino M. Borras Jr.

See also **Agricultural Biotechnology; International Environmental Movements; Movimento Sem Terra; Neoliberalism; Nongovernmental Organizations (NGOs); Peasants and Peasantry; World Trade Organization (WTO)**

Further Readings

- Borras, S., Jr. (2008). La Via Campesina and its global campaign for agrarian reform. *Journal of Agrarian Change*, 8, 258–289.
- Borras, S., Edelman, M., & Kay, C. (2008). *Transnational agrarian movements confronting globalization*. Oxford, UK: Wiley-Blackwell.
- Desmarais, A. (2007). *La Via Campesina: Globalization and the power of peasants*. London: Pluto.
- Edelman, M. (2008). Transnational organizing in agrarian Central America: Histories, challenges, prospects. *Journal of Agrarian Change*, 8, 229–257.



VIDAL DE LA BLACHE, PAUL (1845–1918)

Paul Vidal de la Blache is an important figure in the history of geography. Born in the village of Pezenas in the south of France in 1845, educated at the Lycée Charlemagne and the prestigious École Normale Supérieure in Paris, Vidal took the lead in establishing a French school of geography at the turn of the 20th century that became world renowned for its holistic study of landscape. Vidal held positions at the University of Nancy (1872–1877) and the École Normale



Supérieure (1877–1898), and was chair of geography at the Université de Paris, Sorbonne, from 1898 until his retirement in 1909.

Throughout his career, Vidal sought to establish geography as an explanatory science instead of the descriptive, almanac-style fact-finding exercise that most geographers of his time practiced. Having been thoroughly schooled in history, he also emphasized the human aspects of geographical study at a time when geographers usually paid singular attention to the physical environment. Vidal emphasized that existing geographical landscapes are the result of a combination of human and natural processes. As he put it, landscapes should be considered like “medallions,” forged with the image of the social ways of life they include. Nature does not determine social behavior, and social behavior does not fully dominate nature. Rather, social behavior adapts to nature’s constraints and opportunities in the production of what some now call *social-nature*. In geography, this became known as *possibilism*.

The scientific task of geography is thus to explain how the various landscapes that geographers observe actually evolved as a result of the different ways in which humans adapted to nature in different times and places. To study these various modes of life (*genres de vie*) in turn necessitates a holistic approach, including both social and natural science. To Vidal, this was precisely the synthesis that geography as a discipline should achieve, thereby distinguishing it from the more analytic disciplines of either society or nature.

To establish this new scientific geography, Vidal helped found a new research journal, *Annales de Géographie*, in 1891. This journal promoted holistic, interdisciplinary research on geographical landscapes and was dominated by the Vidalian approach, as was French geography until World War I. While critics questioned whether the notion of *genres de vie* could be used in the study of more urban, industrialized landscapes, Vidal’s approach was instrumental in the formation of the now famous French Annales School of History, influential for its equally holistic emphasis on the *longue durée* of human-environmental adaptation in the course of history. Indeed, because most French geographers refused to engage in the disciplinary turf battles at the turn of the 20th century, *la tradition vidalienne* was largely relinquished to historians (as well as Durkheimian

sociologists). As a result, soon after Vidal, French geography largely lost its focus and prominence both in France and elsewhere, and his role in the formation of these more successful disciplines is largely ignored.

Kevin Archer

See also **Annales School; Cultural Geography; Febvre, Lucien**

Further Readings

Andrews, H. (1986). The early life of Paul Vidal de la Blache and the makings of modern geography.

Transactions of the Institute of British Geographers, 11(2), 174–182.

Baker, S. (1988). Paul Vidal de la Blache. *Geographers Biobibliographical Studies*, 12, 189–201.



VIDEO GAMES, GEOGRAPHY AND

Video games have only recently attracted attention from human geographers. Unlike other forms of popular media such as cinema, literature, or television, video games offer a highly interactive and experiential virtual world. It is this “worldhood” or “spatiality” that is an attractive and fertile research ground for geographers. Embedded within each video game is a particular world that the player is able to manipulate and explore. These worlds can be realistic or a complete fantasy, as in many role-playing games. A virtual world or space is often necessary to limit and frame the activities possible within a game. For example, it would be difficult to program or code for a game in which absolutely anything were possible. In this sense, video games are particular milieus of activity, often highly repetitive. A productive engagement with video games would elicit not only important textual, social, and political themes but also how the virtual worlds within video games are constructed, including the types of freedoms and choices they offer to the player, as well as the “perspective” used (such as third person or first person).



The history of video games goes back to the flight simulators widely used during World War II. In 1962, the very first video game, “Spacewar,” appeared. When Atari released the classic coin-operated *Pong* in 1972, video games started to become enormously popular. The introduction of the personal computer in the 1980s greatly enlarged the market for games played on machines such as the Atari 400 and the Commodore 64 and, later, Nintendo and Sega. Sony’s PlayStation took this industry to a new level. By the late 1990s, Web-based games allowed for the creation of massively multiplayer online role-playing games, such as “World of Warcraft,” connecting millions of players worldwide via the Internet.

The video games industry is lucrative and expanding at an unprecedented rate. Two thirds of U.S. households play them regularly. In terms of annual sales, it now rivals the Hollywood film industry. Indeed, in recent years the mainstream status of video games has been confirmed with huge releases such as the highly anticipated and critically acclaimed “Grand Theft Auto IV.” During the first week of its April 2008 launch, the game grossed more than \$500 million, smashing all previous video game and Hollywood records. Competitive video game events, once limited to a few networked computers in a basement, are now international events, such as the World Cyber Games. More surprising is that the average age of a video game player is currently 35 years, and she or he has been playing for more than 12 years according to the Entertainment Software Association.

The geography of the video game industry is an interesting and hybrid one, with the main centers of design and programming situated in North America, Japan, and Western Europe. This tri-regional structuring of the industry often leads to hegemonic representations but can also lead to blurred cultural and national identities. In the case of the former, video games that depict “wars” often do so from a narrow and single perspective. Games such as the hugely popular “Call of Duty” can be criticized for depicting simplified and racist enemies and allies. The hypersexual and hyper-violent content of video games is also a perennial source of controversy, although there is no clear consensus in the psychology literature on the impact that video games have on players. In this sense, video games are sites of ongoing culture

wars. Yet despite these overcoded representations, there is always the possibility of experimentation within video games. Online games such as “World of Warcraft” allow users to “perform” alternate gender identities. In summary then, video games allow players to interact in virtual worlds that “spatialize” the social, political, and sexual dimensions we find in everyday life.

Ian Graham Ronald Shaw

See also **Cyberspace; Media and Geography; Virtual and Immersive Environments; Virtual Geographies**

Further Readings

- Balkin, J., & Noveck, S. (Eds.). (2006). *The state of play: Laws, games and virtual worlds*. New York: New York University Press.
- Boellstorff, T. (2008). *Coming of age in Second Life: An anthropologist explores the virtually human*. Princeton, NJ: Princeton University Press.
- Castronova, E. (2007). *Exodus to the virtual world: How online fun is changing reality*. London: Palgrave Macmillan.
- Dyer-Witheford, N., & de Peuter, G. (2009). *Game of empire: Global capitalism and video games*. Minneapolis: University of Minnesota Press.
- Halter, E. (2006). *From Sun Tzu to Xbox: War and video games*. New York: Thunder’s Mouth Press.
- Shaw, I., & Warf, B. (2009). Worlds of affect: Virtual geographies of video games. *Environment and Planning A*, 41(6), 1332–1343.
- Wolf, M. (1997). Inventing space: Toward a taxonomy of on and off screen space in video games. *Film Quarterly*, 51(1), 11–23.



VIEWSHED ANALYSIS

Viewshed analysis, a form of visibility analysis that identifies visibility between points in a landscape, emerged as a geographic field several decades ago. Recent advances in software and computing power enabled viewshed analysis to become a common form of geographical analysis, and it is now a standard tool in many geographic

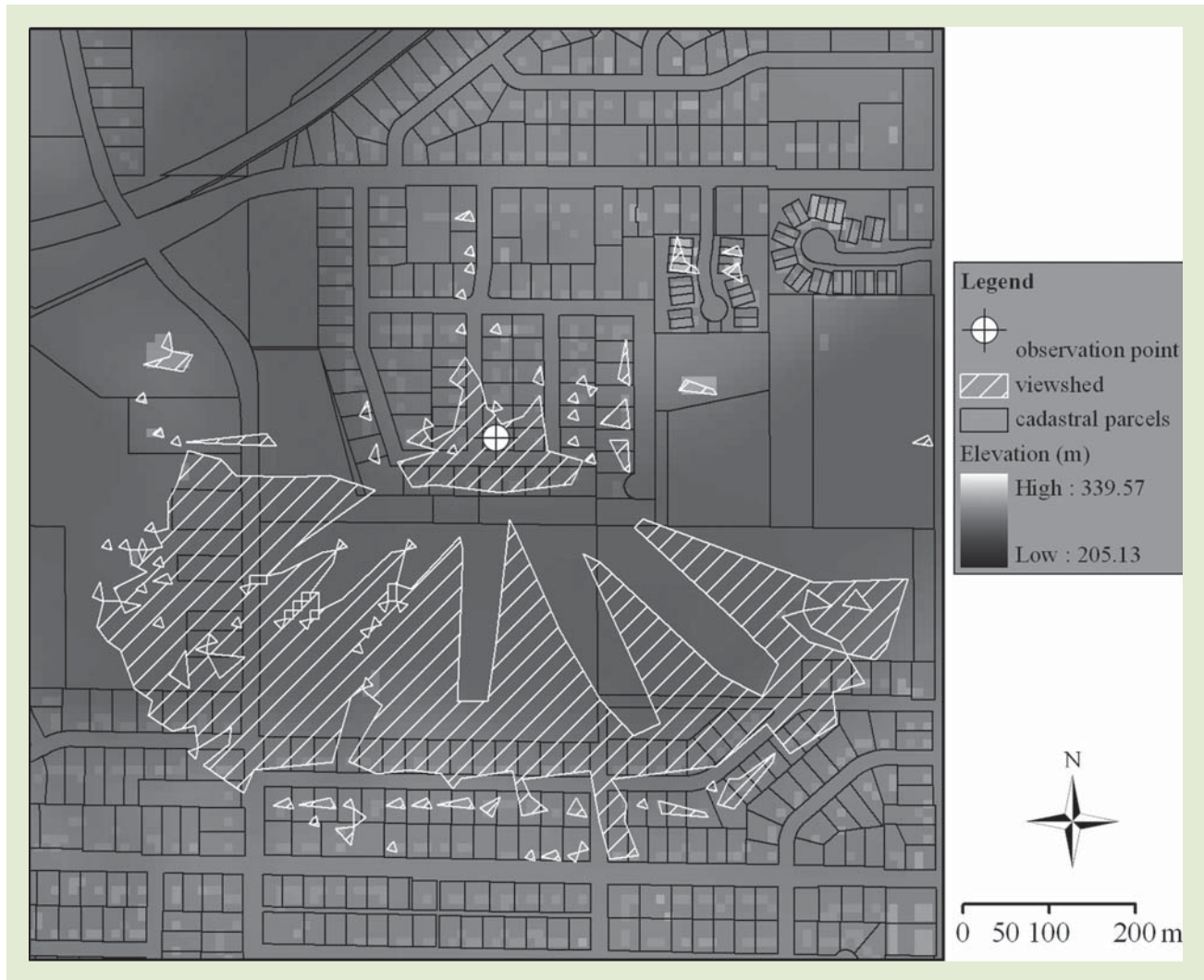


Figure 1 Sample viewshed

Source: Author.

information systems, enabling viewshed analysis to be used in a range of fields. The following entry discusses the techniques used to calculate and analyze viewsheds as well as the applications of viewshed analysis.

Viewshed analysis is typically conducted as a raster-based operation in a GIS. It begins with the calculation of a viewshed, a two-dimensional (2D) projection of a view, using one of many algorithms (see DeFloriani & Magillo, 2003). The viewshed procedure identifies landscape areas that are visible from a given location based on elevations from a digital terrain model (e.g., digital elevation model, triangulated irregular network) and accounting for that location's height and position,

the view angle, and, frequently, a viewer height offset or maximum-view radius. Locations that connect to the observation location by a line-of-sight are identified as visible and part of the observation location's viewshed, while all other locations are not. The resulting viewshed thus approximates the view from a given location (Figure 1).

The structure of calculated viewsheds is analyzed using metrics that quantify viewshed characteristics. Numerous viewshed metrics exist and include measures of size, complexity, and relief as well as the visual prominence of landscape features of interest. Viewsheds for an observation point may be calculated under different land use scenarios and their metrics compared to assess



the impacts of proposed land use changes on scenic quality. Viewsheds may also be visualized and compared in three dimensions using 3D modeling techniques.

A variety of fields use viewshed analysis. In planning, it is often used to identify the potential scenic impact of proposed landscape changes (e.g., van der Horst, 2006). Viewshed analysis is also used to identify the economic values of different view types using economic valuation techniques (e.g., Bastian, Reiners, Blasko, McLeod, & Germino, 2002). Additionally, archaeologists employ viewshed analysis to reconstruct past landscapes or cultural interactions (e.g., Lake & Woodman, 2003).

Heather Sander

See also [Digital Terrain Model; GIS in Archaeology; GIS in Urban Planning; Land Use Planning; Terrain Analysis; Three-Dimensional Data Models; Triangulated Irregular Network \(TIN\) Data Model](#)

Further Readings

- Bastian, C. T., Reiners, W., Blasko, B., McLeod, D., & Germino, M. (2002). Environmental amenities and agricultural land values: A hedonic model using geographic information systems data. *Ecological Economics*, 30, 337–349.
- DeFloriani, L., & Magillo, P. (2003). Algorithms for visibility computation on terrains: A survey. *Environment and Planning B*, 30, 709–728.
- Lake, M., & Woodman, P. (2003). Visibility studies in archaeology: A review and case study. *Environment and Planning B*, 30, 689–707.
- van der Horst, D. (2006). A prototype method to map the potential visual-amenity benefits of new farm woodlands. *Environment and Planning B*, 33(2), 221–238.



VIRILIO, PAUL (1932–)

An important, if little understood, theorist of social and spatial change is Paul Virilio—the so-called high priest of speed, a planner, a historian of technology, a photographer, and a philosopher of architecture and cinema. Other than military

service, his formal education included the study of art at the École des Métiers d'Art as well as phenomenology at the Sorbonne.

Impressed by the events of World War II, Virilio's work is grounded in the practices of the military, and he regards the culture of speed as driven primarily by its needs, whose conquest of the tyranny of distance extends repeatedly into civilian life. Virilio takes as his point of departure the intersections of military technology and the experience of speed, underscoring the machinic qualities of time and space as they are produced and conceptualized through his central concern, war. Thus, the state is essentially a machine to wage war, exhibiting a logic quite different from the Marxist emphasis on capital accumulation; in Virilio's reading, the state is a “means of destruction,” not a means of production. For him, geography is a product of warfare because the preparation for and engagement in military conflict, including things such as logistics, intelligence, and the speeds of military machinery and rockets, are the fundamental bases of territorial organization. Space here is reduced to little more than a theater of war, and the state is simply a machine for waging it. Steady improvements in the ability to wage war are thus instrumental in developing the ability to bind together ever-larger units of space and time. Not capital accumulation but the dynamics of military conquest are the driving force behind the historical rounds of time-space compression. Space and time are the products of speed as it emanates from the prerequisites of warfare. Thus, Virilio asserts that

War and the preparation for it produce the space-time of human experience as a function of projectile speeds, logistical rates of transport, or intelligence insight gathering. The territorial organization of space into human settlements and political units of authority, from the earliest human village settlements to medieval city-states, modern nation-states and world-wide empires, reveals a constant tendency: they express different orders of military power, knowledge and technological organization. (1995, p. 365)

Telecommunications also figure centrally in Virilio's worldview, in which digital technologies



produced a world in which information is speed and duration is nonexistent. Virilio maintains,

Speed enables you to see. It does not simply allow you to arrive at your destination more quickly, rather it enables you to see and foresee. . . . Speed changes the world vision. In the nineteenth century, with photography and cinema, world vision became “objective.” . . . It can be said that today, vision is becoming “teleobjective.” That is to say that television and multimedia are collapsing the close shots of time and space as a photograph collapses the horizon in the telephotographic lens. (qtd. in Redhead, 2004, p. 45)

The tyranny of constant speed leads to alienated, stressed-out, exhausted citizens who populate the virtual geographies of the space of flows; distorts human perception; sterilizes communications; forces a colonialism of daily life by machines; and generates a mindless automation that robs people of their humanity in a hypermotorized, digitized world. Virilio asserts that time-space compression has become sufficiently complete so that the struggle for space—geopolitics—has been displaced by chronopolitics, the struggle for time. In Virilio’s view, postmodern capitalism has created such enormous time-space compression that “distinctions of here and there no longer mean anything” (1991, p. 13). Despite the hyperbole, Virilio’s insights are useful in understanding that speed and velocity are not simply technical issues but profoundly cultural and political ones as well.

Barney Warf

See also **Telecommunications and Geography; Time-Space Compression**

Further Readings

- Bartram, R. (2004). Virilio, dromology and time compression. Paul Virilio’s new ocularcentrism. *Time and Society*, 13, 285–300.
- Luke, T., & Ó Tuathail, G. (2000). Thinking geopolitical space: The spatiality of war, speed and vision in the work of Paul Virilio. In M. Crang & N. Thrift (Eds.), *Thinking space* (pp. 360–379). London: Routledge.

- Redhead, S. (2004). *Paul Virilio: Theorist for an accelerated culture*. Toronto, Ontario, Canada: University of Toronto Press.
- Virilio, P. (1986). *Speed and politics*. New York: Semiotext(e).
- Virilio, P. (1991). *The lost dimension*. New York: Semiotext(e).
- Virilio, P. (1995). *The art of the motor*. Minneapolis: University of Minnesota Press.



VIRTUAL AND IMMERSIVE ENVIRONMENTS

A virtual environment is a setting that is not real but includes real traits with which people can identify. The contents may reflect pure imagination or may model the real world. The environment becomes immersive when users are no longer observers but participants in the setting that is depicted, in some cases becoming actors in a larger drama. This entry describes the nature of some of the most popular virtual environments, such as *Second Life*, and explores their significance for geography.

Virtual settings or environments have long been a part of the human experience, as exemplified by prehistoric cave paintings, the utopic “Garden of Eden” and “New Jerusalem,” Homer’s *Odyssey*, and the Greek and Roman “Golden Age” myths. Today, people lose themselves in the elaborate landscapes of movies, plays, and novels. And of course, there is the ever-present video game—the ultimate “out-of-body” experience for devotees. Geographers create their own virtual settings in the forms of maps, geographic information systems, and three-dimensional (3D) flythroughs.

Perhaps the most elaborate virtual environment is the virtual world, which emphasizes participant immersion and community engagement. While that books, movies, and plays invite the reader or viewer to step into imagined worlds, as do 3D renderings of landscapes, these types of immersion lack the “authenticity” of the virtual worlds that began to appear in the mid 1990s. Thanks to improving computer technologies (particularly in



gaming), and to the development of social networking and 3D Internet technologies, 21st-century virtual worlds are fully contained immersive environments in which participants not only imagine their involvement but are actually involved. Modern virtual worlds contain communities of people who interact in settings that are networked, persistent, synchronous, immersive, and, above all, 3D. Participants enter these worlds as extensions of, or alternatives to, the real worlds that they inhabit and the real lives that they lead.

The new virtual worlds are here to stay. The Gartner research group predicted in 2007 that by the end of 2011, 80% of active Internet users (and Fortune 500 companies) will have some sort of 3D presence. Other observers have commented that virtual worlds will soon be pervasive interfaces for the Internet, using multiple entry and exit points, and that “metaverse browsers” will connect participants to multiple worlds. According to Wade Roush, the user may encounter an “interverse” connecting various “intraverses.” In brief, virtual worlds offer the potential of redefining the communications landscape very much like the World Wide Web did in the mid 1990s.

The Nature of Virtual Worlds

The casual observer can be forgiven for his or her confusion over the multiplicity of terms associated with virtual worlds—for example, “synthetic” worlds, MMORPGs (massively multiplayer online role-playing game), MUGs (multi-user game), and, direct from Neal Stephenson’s 1992 Cyberpunk classic *Snow Crash*, the “Metaverse.” To some degree, they all refer to the same phenomenon. The commercial manifestations of these worlds include *There.com*, *Entropia*, *Active Worlds*, *Sims Online*, *Kaneva*, *Google Lively*, *Wonderland*, *Croquet*, and the increasingly popular (and occasionally infamous) *Second Life*. These platforms are not intended as games. There are no contest rules and no winners or losers. Instead, participants enter these worlds in search of friendships, to interact with professional colleagues, to establish businesses, to create organizations, and, in some rare cases, to earn large amounts of real money.

Second Life has monopolized recent press coverage and is the industry leader in terms of money

generated, number of “residents” (more than 14.6 million as of this writing), and graphics sophistication. At the heart of *Second Life* is the resident or character, called an *avatar*. Avatars can be modified in an almost infinite number of ways, including by race, gender, age, hairstyle, body mass, and even fashion sense. Some participants create avatars that are extensions of themselves—that is, to augment their true lives—while others construct new and (sometimes radically) different identities. Many participants generate multiple avatars to adopt different identity profiles for different occasions. In some cases, avatar creation is an attempt at therapy, as with the person confined to a wheelchair in real life who creates a walking character. Once in *Second Life*, residents may convert dollars into lindens, the *Second Life* currency, to buy clothing, new skins and shapes for their avatars, real estate, furnishings, and entertainment. Participants inside this virtual world interact with each other very much like they do in the real world, except that knowing who is really behind the wheel may be a mystery.

The geography of *Second Life* is complex and at times chaotic. The basic unit is the island or “sim” (as in “simulation”), which is a 256-m (meter) by 256-m grid embracing about 16 acres. Some of these units have been clustered to create corporate-controlled continents, of which there are perhaps half a dozen. The 21,973 islands (as of July 2008) are normally privately controlled. Islands and continents are placed to accommodate computer server needs, rather than natural processes, and are spaced in a very predictable gridlike sequence. This lack of regard for natural landform creation processes will cause consternation among geographers and geologists who look at the systemwide map. At the local level, however, terrain can be shaped to create mountains, shorelines, water courses, and so on, which, if done correctly, creates greater authenticity. Residents buy or rent real estate on these lands. Since there are no meaningful land use controls on the continents, they tend to be cluttered with garish builds that give the landscape a cartoonish quality. Private island covenants, on the other hand, prevent some of these excesses.

Three-dimensional social worlds such as *Second Life* are not without problems. Some users lament the complexity involved in learning how to



engage a virtual world, and almost everybody complains about platform stability. Avatars, as of this writing, do not show meaningful human expressions unless complex scripting is used. The social side of *Second Life* can be X-rated and off-putting to residents who stumble into the wrong location. *Second Life* is a user-created world with few rules.

Virtual worlds, and particularly *Second Life*, are increasingly being used by universities as meeting places and as a way of extending the university's global reach. In addition, some of the most beautifully constructed settings in *Second Life* are campuses, as illustrated by the University of Ohio and Vassar College sites. At Vassar, part of the Sistine Chapel has been meticulously re-created.

The Meaning of Geography

Virtual environments have long been the subjects of geographical inquiry, although relatively little work has been done on modern virtual worlds. It has been understood for some time, however, that once the technology matures, virtual worlds will become very much a part of the geographer's milieu (see the special edition on cyberspace of *The Geographical Review*, 1997).

Virtual worlds will not lead to the "collapse" of geography, as observers such as Cory Ondrejka have argued. They may, however, lead to the collapse of distance. In most virtual worlds, people can teleport from one location to another; in *Second Life*, residents can fly as well as teleport. Traditional distance-related location factors may no longer pertain, except at the local level, as people no longer need to accommodate the friction of distance in a world of instant transport.

Place, on the other hand, still exists. Indeed, the central purpose of the virtual world is to construct a place in which participants can create a shared sense of presence (albeit in avatar form). Participants may be scattered across the world, but they can be within speaking distance of each other to join in a meeting, to engage in friendly chatter, or to have a night out on the town. Furthermore, as in the real world, places may be distinguishable by culture group, nationality, lifestyle choice, and personal interests—note, for example, the Amsterdam, Copenhagen, and Zurich locations. Other

places provide nonthreatening and anonymous spaces for groups that may have relatively few such options in the real world; this advantage has been noted by some members of the gay community. Finally, a virtual world offers nearly unlimited opportunities for geographers (and others) who want to provide 3D physical and social modeling of places.

Merrill Johnson

See also **Cyberspace**; **Video Games**, **Geography and**; **Virtual Geographies**

Further Readings

- Bainbridge, W. (2007). The scientific research potential of virtual worlds. *Science*, 317, 472–476.
- Bell, M. (2008). Toward a definition of virtual worlds. *Journal of Virtual Worlds Research*, 1, 1–5. Retrieved July 17, 2008, from <http://jvwresearch.org>
- Bittarello, M. (2008). Another time, another space: Virtual worlds, myths and imagination. *Journal of Virtual Worlds Research*, 1, 2–18. Retrieved July 17, 2008, from <http://jvwresearch.org>
- Boellstorff, T. (2008). *Coming of age in Second Life*. Princeton, NJ: Princeton University Press.
- Castronova, E. (2007). *Exodus to the virtual world: How online fun is changing reality*. New York: Macmillan.
- Cyberspace [Special issue]. (1997). *Geographical Review*, 87(2), 139–208.
- Jennings, N., & Collins, C. (2008). Virtual or virtually U: Educational institutions in *Second Life*. *International Journal of Social Sciences*, 2, 180–186.
- Ondrejka, C. (2007, Summer). Collapsing geography: *Second Life*, innovation, and the future of national power [Electronic version]. *Innovations*, pp. 27–54.
- Roush, W. (2007, July/August). Second Earth [Electronic version]. *Technology Review*, pp. 39–48.
- Stephenson, N. (1992). *Snow crash*. New York: Bantam Books.
- Taylor, J. (1997). The emerging geographies of virtual worlds. *The Geographical Review*, 87, 172–193.



VIRTUAL GEOGRAPHIES

Virtual geographies are a broad area of research within geography and geographic information science that seeks to understand how new digital technologies and modes of communication are creating new notions of space and place. Among those areas of interest are the creation and exploration of virtual environments, including virtual worlds, cyberspace, and cybergeographies, and notions of other invisible social spaces. As the Internet, the World Wide Web, and other communication technologies continue to expand their roles in everyday lives, the study of the virtual geographies of evolving digital society will become an even more important component of the discipline. Understanding the virtual geographies they create, whether they be virtual worlds we inhabit through our avatars, the rapidly changing invisible landscape of cyberspace, or the virtual spaces of social interaction, will become an increasingly important aspect of understanding geography itself.

Perhaps the most recognizable of virtual geographies are digital reconstructions of landscapes, whether real or imagined. Recent advances in affordable graphics technologies are now moving far beyond the static two-dimensional paper map and providing researchers with the tools to not only generate nearly photo-realistic three-dimensional virtual landscape environments but also incorporate realistic light and textures as well as replicate physical systems such as cloud and water movement, fog, and weather. Computer and video games now routinely feature extensive virtual worlds with recognizable geography and real-world behaviors, and the ability to achieve a high level of realism is a key element in the commercial success of such games.

Creating a sense of immersion through the generation of such lifelike virtual landscape features, combined with camera perspectives and navigation that mimic human perceptions of movement through space, is a key element in generating the sense of immersion and interaction that allows users to feel as if they are experiencing a virtual landscape. To further enhance the sense of immersion within the virtual world, many researchers are turning their attention to developing tools

and mechanisms for conveying other sensory aspects that imbue a location with a sense of place, such as sound and even smell.

Until recently, much of the work in the development of virtual landscape reconstructions was focused on individual virtual-world projects, but the rapid adoption of Internet technology has spurred the development of online virtual worlds such as Linden Lab's *Second Life* (<http://secondlife.com>). These new collaborative virtual worlds are beginning to demonstrate the power of such environments for the generation and shared exploration of digitally re-created spaces and places. These virtual worlds, based on either real-world or fantasy landscapes, provide users a familiar way in which to interact with a digital landscape, as they move and interact with virtual elements through an avatar, a virtual self. In addition, activities in many virtual worlds such as *Second Life* are centered on building spaces and places within the virtual platform, creating new virtual geographies that do not necessarily have direct analogs within the real physical world. However, the geographic principles that seek to explain how humans shape and interact with space and place are clearly visible within these virtual geographies.

In addition to the virtual geographies represented within virtual worlds, the development of networks to connect computers has also led to the development of virtual geographies that represent the spatial structures of those networks. Often referred to as *cyberspace*, a term coined by William Gibson to describe the invisible spaces that represent the connectivity among computers, the virtual spaces of the Internet and the World Wide Web have their own spatial relationships and structures. Several geographers interested in attempting to identify and understand how these spaces are formed and evolve began a research initiative in 1996 with an emphasis on mapping and measuring the spatial aspects of cyberspaces, which was dubbed *cybergeography*. These efforts have focused on attempting to graphically illustrate the invisible structure of the Internet and the World Wide Web, from maps of Internet traffic to data flows and even the paths navigated through individual Web sites. The rapid rise in popularity of Web-mapping applications such as Google Maps, which allow users to map their



own data onto free base geographic data layers, has also spurred the development of new spatially oriented virtual communities and social networking sites that are creating their own virtual geographies. As these technologies migrate to mobile platforms, they are changing the ways in which people inhabit physical and virtual spaces and redefining how they form a sense of place.

The increasing focus on the exploration of virtual spaces created by these new technologies has also broadened to include other notions of invisible spaces, such as the virtual geographies of human social behavior and how they are being shaped by new communication technologies. For example, recent work has looked at wide-ranging topics such as the virtual geographies of Internet commerce (e-commerce) and virtual geographies of the body and self.

Susan Bergeron

See also **Cyberspace; Neogeography; Video Games, Geography and; Virtual and Immersive Environments**

Further Readings

Batty, M. (1997). Virtual geography. *Futures*, 29(4/5), 337–352.

Crang, M., Crang, P., & May, J. (Eds.). (1999). *Virtual geographies: Bodies, space, and relations*. New York: Routledge.

Fisher, P., & Unwin, D. (Eds.). (2002). *Virtual reality in geography*. London: Taylor & Francis.

Kitchin, R., & Dodge, M. (2001). *Atlas of cyberspace*. London: Pearson Education.



VIRTUAL GLOBES

A virtual globe is a computer software that allows interaction with a three-dimensional (3D) representation of Earth or another world. Virtual globes belong to a group of applications collectively termed *geobrowsers*, which include modern Web-based dynamic maps. Geobrowsers are a key component in the development of “neogeography” as they provide a medium through which

users can organize, search, and visualize information according to geospatial parameters. Virtual-globe technology has been available for over a decade but entered mainstream consciousness only with the release of Google Earth in 2005. The subsequent popularity of this software has inspired a rapid evolution in the features and capabilities of many virtual globes. This entry provides an overview of their history and popularization, describes the different types of virtual globes, and discusses their evolving capacity to create and display geospatial data.

History and Popularization

The creation of virtual globes is the result of 3D software, virtual reality and hypermedia, and remote-sensing technology developments that have been ongoing since the 1970s. It was Neal Stephenson’s 1992 novel, *Snow Crash*, that popularized the concept of a computerized globe showing dynamic imagery and inspired the initial real-life development of such programs. In *Snow Crash*, the primary protagonist accesses a software program called “Earth” that was created by the Central Intelligence Corporation as a user interface to their geospatial information, including weather data and real-time satellite surveillance. This “live” virtual globe presents greater capabilities than current real-world programs; however, virtual-globe technologies are developing increasing abilities to display dynamic data.

Inspired by *Snow Crash*, Mark Pesce, a cocreator of Virtual Reality Modeling Language (VRML), developed WebEarth, an open-source VRML application that builds a model of the Earth from composite satellite images. The first commercially available virtual globe to display dynamically updated earth data (clouds) was EarthBrowser. It was originally released in 1998 as a Macintosh shareware product called *Planet Earth* and continues to be developed by its creator, Matt Giger, for both Macintosh and Windows platforms.

An explosion of virtual-globe technologies occurred in 2001 with the development of Keyhole’s Earth Viewer (acquired by Google in 2004 and released in 2005 as Google Earth), Skyline-Globe, SINTEF (Norwegian: Stiftelsen for industriell og teknisk forskning [The Foundation for



Scientific and Industrial Research]) (Norkart since 2006) virtual globe, and Geofusion's GeoPlayer. However, it was the release of the open-source project NASA World Wind (2004), followed by Google Earth (2005), that brought virtual globes to the attention of a wider audience. In 2005, the use of these tools to aid rescue and relief efforts related to Hurricane Katrina received media coverage demonstrating the abilities offered by virtual globes, and their day-to-day use entered the public consciousness. By June 2008, downloads of Google Earth, the most widely used virtual globe, had topped 400 million.

Both NASA World Wind and Google Earth were developed as stand-alone applications. In contrast, Microsoft leveraged existing server and mapping technologies to create its Virtual Earth platform. It powers Live Search Maps inside an Internet browser. Released in 2005 as a 2D mapping product, it evolved into a globe application when 3D viewing capability was added in 2006. Unique to Virtual Earth is the inclusion of high-resolution aerial photography captured from a bird's-eye perspective view.

Similar to Microsoft, ESRI (Environmental Systems Research Institute) developed globe technologies that complemented existing products. In 2003, they released ArcGlobe, a 3D analyst extension to ArcGIS 9. This was followed in 2006 by ESRI's stand-alone globe, ArcGIS Explorer. Similar to most virtual globes, this is a free-to-download product, but its capabilities are greatly expanded when used in conjunction with ArcGIS server.

Currently, Google and Microsoft represent the leaders in virtual-globe technology with hundreds of millions of users, with World Wind and ESRI garnering tens of millions of users. Developments in mobile and multitouch technologies are leading to the next developments in virtual globes. New applications (e.g., Earthscape, developed using the iPhone Software Developer Kit), are making virtual globes accessible anywhere cell phone coverage can be found.

Types of Virtual Globes

There are two primary types of virtual globes. One attempts to create a realistic mirror of the real world, while the other type is based on graphical

representations of global information data sets. "Real-world" globes, such as NASA World Wind, Google Earth, ESRI ArcGIS Explorer Microsoft Virtual Earth, and SkylineGlobe, create a representation of Earth by tiling high-resolution satellite imagery and aerial photography over a digital elevation model of the underlying terrain. Both Google and Microsoft invest considerable time and effort into acquiring, processing, and serving high-resolution imagery. World Wind, an open-source community project, uses mostly public domain data sets such as Landsat 7 imagery and Shuttle Radar Topographic Mapping (SRTM) project terrain. Other real globes built on open-source virtual globes, for example, Ping's 3Map (based on WebEarth), Dapple, and Punt (based on World Wind), also leverage the same data sources. Similarly, small development projects (e.g., Earth-Browser, Norkart Virtual Globe, and Poly9 Free-Earth) rely on public data sets and have a limited coverage of high-resolution imagery.

The second type of virtual globe provides a global representation of data sets with limited or no land cover imagery. These "specialized" globes are representations of social, economic, infrastructure, or environmental data (e.g., Global-i). A common application for these globes is weather visualization (e.g., Software MacKiev's 3-D Weather Globe & Atlas). The key requirement for these globes is the ability to update data dynamically—a feature that is also used within integrated data layers in "real-world" globes, for example, the Google Earth weather layer.

Geospatial Content

The ability of virtual globes to display dynamic content makes them more than just a Web-based map or simple satellite image representation of the world. Most virtual globes provide integrated "layers" of content both static (e.g., political borders) and dynamic (e.g., clouds) in nature. They also allow users to add their own geospatial data. The standard that emerged to create content for virtual globes is an object-oriented extensible markup language, Keyhole Markup Language (KML). Originally developed by Keyhole and then Google, after their purchase of Keyhole, Inc., in 2007, KML was submitted to the Open Geospatial Consortium to become an



open standard. It was officially accepted as an international standard on April 14, 2008. Through KML, developers, scientists, educators, and anyone with georeferenced information have the ability to create informative visualizations and display them within a range of virtual globes and other geobrowsers.

John E. Bailey

See also **GIS Software; Google Earth; Neogeography; Open Geospatial Consortium (OGC); Three-Dimensional Data Models; Virtual and Immersive Environments**

Further Readings

- Aurambout, J.-P., Pettit, C., & Lewis, H. (2008). Virtual globes: The next GIS? In C. Pettit, W. Cartwright, I. Bishop, K. Lowell, D. Pullar, & D. Duncan (Eds.), *Landscape analysis and visualisation* (pp. 509–532). Berlin, Germany: Springer-Verlag.
- Butler, D. (2006). The Web-wide world. *Nature*, 439, 776–778.
- Open Geospatial Consortium. (2008). *KML* (reference document OGC 07-147r2). Retrieved November 9, 2009, from www.opengeospatial.org/standards/kml
- Simonite, T. (2007, May 2). Virtual Earths let researchers “mash up” data. *NewScientist*. Retrieved October 7, 2009, from www.newscientist.com/article/dn11773#



VISION AND GEOGRAPHY

Vision has been a topic of much interest not only for geographers but also for philosophers, painters, photographers, filmmakers, art historians, and cultural theorists. Since vision is studied and understood differently by a variety of people, it should not be expected that its theoretical and material impacts could be experienced in a similar vein. Vision has long been a concern for ontology (the study of existence), epistemology (the theory of knowledge and its production), and methodology.

Modern Western society has held vision as the paramount sense called on to produce knowledge, suggesting that seeing means knowing. Geography has a long-standing relationship with visual culture and has often been called a *visual discipline*. The link between vision and order, classification, and description has heavily influenced geographic thought. Throughout the late 19th and part of the 20th centuries, geographers were expected to describe, understand, and represent the world through maps or words completely and objectively. Geographers relied heavily on their senses, predominantly vision, to draw empirical or experience-based conclusions. Today, vision continues to dominate contemporary geographic research. However, in the past few decades, much work has been done by geographers and others concerned with the visual to recognize that vision cannot be taken as given. Ways of seeing, imagining, and representing what is seen are now understood to be the effect of specific social and technological circumstances.

Geographers approach the spatiality of vision in exciting and innovative ways. Contemporary human geographers have explored social practices that construct visibility, examined images that give shape to geographical imaginations, and engaged with various technologies of vision that design ways of seeing. They examine and produce meaning through map making and geographic information systems imagery by reading landscapes as visual texts and by investigating representations of space in a variety of media, such as painting, photography, and film. In the past 30 years, geographers have become increasingly concerned with representations of space within the visual field. Denis Cosgrove greatly influenced the way geography approaches the visual. He engaged with cultural landscapes not as passive objects but as sites where power relations, gender roles, national identity, political ideologies, and other social processes are actively produced. His scholarship pursued a new line of inquiry and methodology within human geography. Stephen Daniels and Denis Cosgrove, among others, began to apply iconography (a critical reading of imagery to explore cultural values) to interpret images as socially, historically, and spatially contingent texts. Images are now understood not simply as mimetic evidence of objective, stable, and complete realities



but as powerful tools that actively construct the geographic imagination.

Technology plays a critical role in producing new ways of seeing. Technological advances in image capture, such as photography and film, engineer space and reality in meaningful ways. For example, with the advancement of aerospace engineering, images of Earth were taken that captured our planet in its entirety, representing Earth as being within the control of humans and our technologies and thus playing a powerful role in furthering political imaginations and geocultural agendas.

To address questions related to the ontologically stable world images present, many geographers have drawn on poststructuralist thought. Poststructuralist theory advocates that what is understood as material reality is a pieced-together fiction that is fragmented, partial, and multiple. Theorists such as Michel Foucault and Jacques Lacan have been instrumental in conceptualizing vision, visibility, and the function of the gaze for the modern subject. Vision is understood as what the human eye is capable of seeing within the visible portion of the electromagnetic spectrum. Visibility is broadly understood as socially produced and perspectival. Visibility is a process that is historically, spatially, and technologically contingent. The concept of the gaze is integrally connected to vision and visibility. Michel Foucault's understanding of the relationship between the gaze and subjectivity has been highly influential in geography and the social sciences more broadly. Foucault argues that the modern subject internalizes the panoptic gaze and is under perpetual surveillance both by himself or herself and by others. This understanding of the gaze renders the modern subject as fully visible, trackable, and governable. The psychoanalytic theorist Jacques Lacan's notion of the gaze is distinct from the act of looking—the eye and the gaze are split from one another. The gaze itself is the object of looking and does not belong to the subject but rather to the object, such as a painting or a film. Lacan's theorizations of the gaze were taken up by psychoanalytic film criticism in the 1970s. The so-called Lacanian film theory is the site of much theoretical confusion and is being rearticulated by many scholars advancing a more rigorous understanding of the Lacanian gaze.

Geographers are engaged with the visual in a variety of contexts. Gillian Rose dedicated much attention to the relationship between geography and the visual. She examined how geographical knowledge within academia is constructed, packaged, and presented through visual tools such as PowerPoint slides, questioning a neat presentation of images on a slide that portrays knowledge as being spatially captured, stable, and whole. Marcus Doel and David Clarke have written on the ways by which the visual is constructed in film by film and in particular how montage, the assemblage of parts, is central to the relationship of human geographers to the visual. Increased research has been initiated on how to produce new ways of seeing through geographic information systems (GIS) and what representational practices are embedded in this powerful visual technology. Chris Lukinbeal is advancing research on analyzing the visual products generated by GIS. He explores how these technologies are put to work in the academy and in broader social contexts. Also, through critical map reading, geographers have produced insightful scholarship on how maps play a role in the construction of tourist spaces and consumer identities. Many geographers are moving toward a geography that does not rely so heavily on the visual and accesses other senses for knowledge production. However, because of geography's deep roots within the visual field, it is still robust terrain for geographical inquiry.

Nazanin Naraghi

See also Cosgrove, Denis; *Media and Geography*; *Photography, Geography and*; Rose, Gillian; *Television and Geography*

Further Readings

- Cosgrove, D. (2008). *Geography and vision: Seeing, imagining and representing the world*. London: I. B. Tauris.
- Dubbini, R. (2002). *Geography of the gaze: Urban and rural vision in early modern Europe*. Chicago: University of Chicago Press.
- Goin, P. (2001). Visual literacy. *Geographical Review*, 91(1/2), 363–369.



- Jay, M. (1994). *Downcast eyes: The denigration of vision in twentieth-century French thought*. Berkeley: University of California Press.
- Levin, D. (Ed.). (1993). *Modernity and the hegemony of vision*. Berkeley: University of California Press.
- Rogoff, I. (2000). *Terra infirma: Geography's visual culture*. London: Routledge.
- Rose, G. (2007). *Visual methodologies: An introduction to the interpretation of visual methods*. London: Sage.



VOLCANIC ERUPTIONS AS RISK AND HAZARD

Volcanoes are a principal agent of degassing of the interior of the Earth and other planets. They are thought to be the main source of the Earth's atmosphere and hydrosphere, and thus they are a vital part of the sustainable Earth system. Volcanic activity has provided the air we breathe and the water that makes up most of our body mass. Volcanism also provides vital enrichment to the Earth's soils, particularly in tropical areas. In spite of the long-term benefits, the effects of eruptions can be seriously negative in the short run, so volcanoes can be considered a type of natural hazard that threatens life and property.

Among natural hazards, volcanoes have caused far fewer deaths and damage to property historically than have floods, coastal hazards, and earthquakes and so are considered hazards of local or minor rank by some people. The historic record may be misleading because it is brief compared with geologic time and because large eruptions occur too rarely to have been accurately assessed and understood. There are at least 1,500 volcanoes that are considered active in the world, and about 400 have erupted in the past century. Eruptions span at least eight orders of magnitude, ranging from erupted magma volumes of less than 10,000 m³ (cubic meters) to more than 1,000 km³ (cubic kilometers). But most eruptions are quite small in scale, and their hazards are generally quite localized to areas near the volcano. Larger eruptions are known to have global impact, but because of their statistical rarity, the

scientific understanding of these events is very limited. Understanding of the largest eruptions (super-eruptions) is the most limited, but these possibly include worldwide loss of multiple growing seasons and huge global loss of life (volcanic winter).

The assessment of volcanic hazards begins with geologic maps, which record the distribution of past volcanic deposits that reflect past activity and the locations where hazardous events occurred, leading to hazard maps that cover the volcano environs, especially in areas downslope from active vents. Volcanic deposits are dated to assess the frequency and probability of hazards, and vulnerability is assessed through geographic information system population density maps and social science surveys. The topography of areas near volcanoes provides an important key to hazard zonations, because many types of volcanic hazards are governed by gravity and the damaging volcanic agents (lava flows, pyroclastic flows, mudflows, avalanches, debris flows) descend from high to low elevation following valleys. A useful tool in hazard work has been the development of numerical models of hazards, which can be applied to the individual topography to derive "objective" hazard maps. Completed hazard maps exist for only a small fraction of Earth's active volcanoes. To accompany hazard maps, hazard reports are written in plain language for the public to explain the nature of hazards that occur during eruptions. These reports are used in local communities and especially schools. Where risk is high, additional measures for public education and outreach are undertaken, and zoning measures may be implemented.

Atmospheric hazards that result from eruptions are of special interest, because they typically extend farther from the volcano and may thus affect a broader area. Explosive eruptions create finely divided magma that transfers its heat rapidly to the air and rises to stratospheric height. Since many particles are so fine that they do not fall, they can be carried hundreds to thousands of kilometers before fallout. Ice nucleates on this fine ash and helps it grow and fall out. Stratospheric ash is a severe aircraft hazard, while fine ash fallout can occur on a continental scale in super-eruptions and is a deadly hazard to lungs. Ash fallout masses and particle sizes decrease



A blanket of ash covers Subic Bay Naval Base in the Philippines in the aftermath of Mount Pinatubo's eruption, June 1991. The volcano, which erupted for the first time in more than 600 years, forced the U.S. military to coordinate Operation Fiery Vigil evacuation efforts to remove more than 20,000 evacuees from the area.

Source: Sgt. Paul Bishop.

with distance for the first 100 kilometers or more, but distal fallout is governed by meteorological processes and may result in heavy fallout far from the volcano. Sulfur dioxide is a second hazardous material contributed by eruptions to the stratosphere. It reacts with the atmosphere and forms sulfuric acid, which exists as a liquid aerosol particle that stays in the stratosphere much longer (a few years) than ash (a few days) and can create stratospheric warming and surface cooling.

Although monitoring of volcanoes is likely to lead to successful forecasting of most eruptions, many volcanoes remain completely unmonitored because of insufficient funds. Many more have only very limited monitoring. New holistic assessments of volcanic threat that measure population distributions and hazards beyond the immediate vicinity of the volcano (especially those to aircraft) are now being employed to guide decisions about which volcanoes should have priority for monitoring in the public interest. Remote satellites are used to measure thermal anomalies,

surface deformation, gas emission rates, and vegetation changes at volcanoes around the world to provide direct field information at unmonitored volcanoes. A worldwide alert system exists to integrate ground monitoring data and satellite observations in order to provide volcanic cloud hazard warnings to aircraft, which are especially vulnerable at night.

Many volcanoes are far from human population centers, but there are especially important volcanic hazard sites where active volcanoes occur near large cities (e.g., San Salvador, El Salvador; Guatemala City, Guatemala; Mexico City, Mexico; Quito, Ecuador; Naples, Italy; Auckland, New Zealand; San José, Costa Rica; Shimabara, Japan). The realization of the vulnerability of these cities to volcanic hazards has led to multidisciplinary hazard studies aimed at mitigation, which employ monitoring, public communication, and outreach.

William I. Rose



See also **Acid Rain; Natural Hazards and Risk Analysis; Volcanoes**

Further Readings

- Blong, R. J. (1984). *Volcanic hazards*. Orlando, FL: Academic Press.
- Ewert, J., Guffanti, M., & Murray, T. (2005). *An assessment of volcanic threat and monitoring capabilities in the United States (NVEWS)* (USGS Open-File Report 2005-1164). Reston, VA: U.S. Geological Survey.
- Iverson, R., Schilling, S., & Vallance, J. (1998). Objective delineation of lahar-inundation hazard zones. *Geological Society of America Bulletin*, 110, 972–984.
- Keller, E., & Blodgett, R. (2007). *Natural hazards* (2nd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Newhall, C., & Self, S. (1982). The volcanic explosivity index (VECI): An estimate of explosive magnitude for historical volcanism. *Journal of Geophysical Research*, 87(C2), 1231–1238.



VOLCANOES

The spatial and temporal distribution of volcanism on Earth's surface is associated with geodynamics. Volcanic morphology is related to physical properties and chemical composition of the magma governed by the tectonic setting as well as exogenous processes over geological time. Eruptive activity comprises phenomena that are potentially dangerous to humans and infrastructure. The negative effects of those phenomena, however, can be minimized with hazard evaluation studies and volcanic monitoring. In contrast, eruptive activity has generated some of the most fertile soils of our planet, geothermal energy is produced from the internal heat of volcanic systems, volcanic materials have constructive and industrial uses, and volcanic landscapes are tourist sites.

Volcanism

Volcanism is directly related to the internal structure of Earth and interaction among tectonic plates. Volcanism occurs in divergent and convergent boundaries. Divergent boundaries occur within ocean basins and continents marked by midocean ridges and rift valleys, such as the Icelandic volcanism and Great Rift Valley of East Africa, respectively. Convergent boundaries are complex according to the kind of plate's interaction: oceanic plate/oceanic plate, oceanic plate/continental plate, or continental plate/continental plate. Intraplate volcanism occurs less frequently, either undersea as in the Hawaiian Islands or in continents such as the Yellowstone Volcanic Field. Geodynamic settings determine the physical and chemical characteristics of the magmas.

Magma is molten rock of silicate composition. Magma is generated by the partial melting at the asthenosphere or within the lithosphere. There rocks are under high pressure and temperature, and just slight changes due to increase in temperature, decompression, or addition of fluid phases can cause rocks to melt to generate magma. The lower density of the magma compared with the surrounding rock favors the ascent. During the ascent, processes such as fractional crystallization, magma mixing, assimilation, and contamination modify the original chemical magma composition and determine their temperature, viscosity, and gas contents and consequently the type of eruption.

The classification of igneous rocks is based on texture and chemical and mineralogical composition. Texture reflects the conditions of cooling. Coarse-grained textures with large crystals result when magma cools slowly beneath the surface. Fine-grained textures occur when lava cools rapidly at the surface. Basalt, andesite, dacite, and rhyolite are the common extrusive igneous rocks. Gabbro, diorite, granodiorite, and granite are their intrusive equivalents. Petrologic studies elucidate the origin and evolution of magma that generates igneous rocks.

Types of Eruptions

Eruptions occur when the magma reaches the surface through a vent or crater. However, magma



also erupts through fissures on the flanks of a volcano or in flat areas. An initial classification of eruptions differentiates between effusive and explosive eruptions.

Effusive eruptions are characterized by emissions of lava. Eruptions of low-viscosity and high-temperature lavas produce *pahoehoe* morphological features. In contrast, *aa* lavas present a fragmented and rough morphology due to a relatively higher viscosity. With the increase in viscosity of lavas and decrease of temperature, domes may form. The accumulation of lavas over geological time generated shields, composite, and stratovolcanoes. The eruptions of Hawaiian volcanoes are typically effusive.

Explosive eruptions are produced by the sudden separation of volatiles from magma, fragmenting it and the surrounding rocks inside volcanic edifices. Volcanic explosions eject fragmented material known as *tephra* into the atmosphere by eruptive columns or produce pyroclastic flows sweeping the volcanoes' flanks. Tephra includes various sizes of particles: block (>64 mm [millimeters]), lapilli (2–64 mm), and ash (<2 mm). Due to temperature contrasts with the atmosphere, it rises until it loses buoyancy and then travels under the influence of the wind and falls, mantling the landscape with a thickness from millimeters to meters. These deposits are called *fall deposits*. Based on the analysis of distribution, thickness, and chronostratigraphic studies of fall deposits, volcanologists infer the magnitude and development of an eruption. When an eruptive column collapses due to its high density, dense clouds of tephra flow down over the volcanoes slopes, forming pyroclastic flows. A pyroclastic flow consists of a hot mixture of fine and coarse fragments of rock, pumice, and gas, and its flow is controlled by the topography, moving fast along canyons or ravines until it stops and the material is deposited. According to the components, ash flows, pumice or scoria flows, and block and ash flows can be distinguished.

In some volcanoes, magma intrusion may produce partial collapse and a blast. Magma intrusions increase the pressure on the volcano's flanks, provoking the partial collapse of the edifice and a sudden release of the lithostatic pressure over the magma body, producing a lateral

blast. The sector collapse generates a debris avalanche whose distribution is not governed by the topography, covering large areas and traveling considerable distances. Its morphological features are characterized by conic mounds called *hummocks*.

The Volcanic Explosivity Index (VEI) describes the magnitude of explosive eruptions. VEI ranges from 0 to 8; each increase represents a factor of 10 in the volume of erupted material. Determination of an eruption's VEI depends on the volume of erupted material, height of the column, and duration. The AD 79 eruption of Vesuvius (Italy), which destroyed Pompeii and Herculaneum, had a VEI of 5.

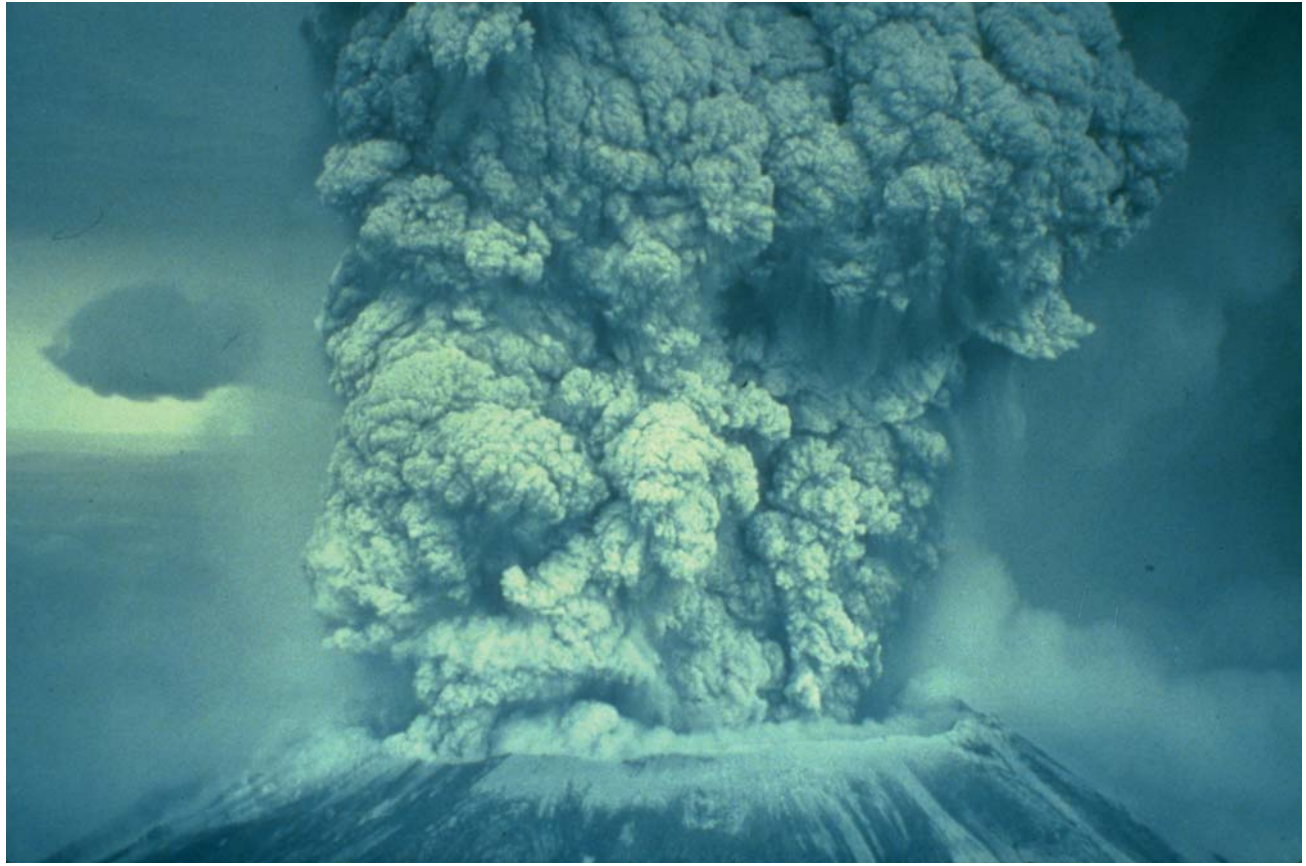
Volcanic Morphology

Volcanoes are endogenous features. Their shape and dimensions depend on geodynamic settings, magma production, and emission rates. According to morphology, they can be scoria (cinder) cones, domes, shield volcanoes, composite volcanoes, calderas, maar, tuff rings, and tuff cones.

Cinder cones are made of tephra falls that accumulate around the vent. They may grow on the flanks of shield volcanoes, composite volcanoes, and calderas. Cinder cones are born to constitute volcanic fields with eruptions lasting from days to years. An example is the birth of Parícutín volcano in Western Mexico in 1943; its eruption lasted 9 years, with social, economic, and ecological effects on the region.

The morphology of lava domes varies from dome shapes to pinnacles or spines. The domes may grow on the slopes or within the crater of composite volcanoes. As a dome grows, its surface cools, and partial collapses of it can generate pyroclastic flows. Domes can seal the conduit system, provoking the pressurization of the volcanic system and triggering explosive eruptions. The eruption of Mt. Pelée (Martinica Island) in 1902 resulted from dome growth.

Shield volcanoes owe their name to their similarity in shape with the old European warrior shields. They are built by the piling of successive lava flows erupted from a central vent or fissures on volcano's flanks and are slightly convex, with gentle slopes and sometimes with a caldera or cinder cones on top. Mauna Loa (Hawaii) is



The May 18, 1980, eruption of Mt. St. Helens, an active volcano in Washington State, had a VEI of 5.

Source: National Oceanic and Atmospheric Association News Photo.

considered the largest and one of the most active volcanoes of Earth; its height from the ocean floor is approximately 10 km (kilometers). According to their basal diameter and height, shield volcanoes are classified as Hawaiian (Mauna Loa, Mauna Kea), Galapagos (Alcedo and Cerro Azul), Icelandic (Skjaldebreidur and Skalarfell), or Mexican (Cerro Grande and Santa Clara).

Lavas and pyroclastic material make up composite or stratovolcanoes during their complex and large evolution. Symmetrical cones, steep slopes, and a crater at the summit are their morphological features. The magma rises from magmatic reservoirs through conduit systems to reach Earth's surface. Eruptions at composite volcanoes generate lava domes, eruptive columns, and pyroclastic flows or undergo partial collapses. Mt. Fuji (Japan), Mt. Rainier (United States),

Popocatepetl (Mexico), and Arenal (Costa Rica) are examples of active composite volcanoes. High-altitude or high-latitude volcanoes host glaciers at their summits. Interaction between volcanic activity and the presence of ice bodies may produce the debris flows or lahars that sweep the volcanoes slopes. Also, rainfall may remobilize loose tephra to form lahars.

A caldera is a negative morphological element with a circular to elongated concave shape of several kilometers. The origin of calderas is associated with major eruptions. Magma is erupted through vents and as the magmatic chamber is emptied, subsidence occurs and a depression is formed and lavas and pyroclastic flows are distributed over a considerable area. Voluminous pyroclastic flow deposits with a variable degree of consolidation are generated. Crater Lake (United States) with a diameter of 9 km was produced by



Mt. Mazama's eruption in 6800 BC. Other calderas are Taupo (New Zealand), Santorini (Greece), and La Primavera (Mexico).

When magma encounters water bodies such as the sea, lakes, rivers, or aquifers during its ascent to the surface, explosive eruptions are generated. The temperature differences between magma and water suddenly produce steam. The resulting increase in volume fragments the magma and the surrounding rocks. Ejected material deposited in the proximity of the vent builds up tuff cones. A greater dispersion of ejected material forms tuff rings. A maar is a low-relief form, like a crater produced when explosions fragment the surrounding rock, leaving no deposits around. Maars are often filled with water and form small lakes.

Volcanic Hazards

Volcanic phenomena such as lava flows, tephra falls, pyroclastic flows, debris avalanches, lahars, gas emissions, earthquakes, and tsunamis are potentially dangerous to humans and the environment. Hazard evaluation and monitoring of active volcanoes or volcanic fields can reduce volcanic risk. Hazard evaluation includes the study of historical eruptions, characterization of eruptive activity through time, and analysis of volcanic deposits using stratigraphic, geochemical, geochronological, and geophysical criteria, allowing determination, with an acceptable degree of uncertainty, of the type, extent, and spatial distribution of volcanic products.

Monitoring networks for follow-up of volcanic seismicity, deformation, gas emission, and geochemical and hydrological changes, among others, provide valuable data for the forecast of eruptive processes and associated hazards over the course of an eruption.

Hazard evaluations and monitoring data are of great importance to decision makers for land use planning and protection of people who live under the threat of volcanic hazards.

Volcanic Areas as a Source of Natural Resources

Volcanic soils cover extensive areas around the Pacific, East African Rift Valley, the Canary

Islands, and Azores and are considered among the world's most fertile soils. Most areas covered by volcanic soils are at the same time exposed to volcanic hazards; however, hazards evaluation studies can reduce the potential risks to population and infrastructure. Ore deposits are associated with magmatic processes. Crushed lava, pumice, and scoria are the source for construction and industrial raw materials.

At some places, close-to-the-surface stagnant magma bodies heat groundwater, generating geothermal systems, which are used as hot mineral springs for bathing, cooking, or heating. Geothermal energy provides heat for 90% of the housing in Reykjavik (Iceland), and geothermal power plants generate electricity. The United States is the world's largest producer of electricity from geothermal energy.

Volcanoes are among the most scenic landscapes around the world; these include Thínvellir (Iceland), Teide Volcano (Canary Islands), Mt. Fuji, Unzen Volcano (Japan), Arenal Volcano (Costa Rica), Pacaya Volcano (Guatemala), Vesuvius Volcano and Pompeii (Italy), Villarica Volcano (Chile), Hawaii (United States), and so on. These tourist sites attract millions of visitors each year. The United Nations Educational, Scientific and Cultural Organization considers some volcanic areas as "geoheritage" sites. In addition, other geological or geomorphologic elements of nature are often worthy of being preserved, and they form part of geoparks, which are sites with geological, archaeological, ecological, and cultural significance. Geotourism, education, and sustainable development are the main components of the geoparks. Kawaninka Geopark in southwest Australia comprises volcanic cave systems, offshore volcanic island, dormant volcanoes, craters, lakes, and wetlands. Magma Geopark in southwest Norway consists of intrusive igneous rocks that crystallized 930 million years ago. Cultural history related to mineral exploitation and the rounded outcrops characterizes the landscape.

Patricia Julio-Miranda

See also **Geothermal Energy; Geothermal Features; Plate Tectonics; Volcanic Eruptions as Risk and Hazard**



Further Readings

- Blong, R. J. (1984). *Volcanic hazards: A source book on the effects of eruptions*. Sydney, New South Wales, Australia: Academic Press.
- Chester, D. (1993). *Volcanoes and society*. New York: Chapman & Hall.
- Francis, P., & Oppenheimer, C. (2004). *Volcanoes*. New York: Oxford University Press.
- Luhr, J. F., & Simkin, T. (Eds.). (1993). *Paricutin: The volcano born in a Mexican cornfield*. Phoenix, AZ: Geoscience Press.
- Scarpa, R., & Tilling, R. (1996). *Monitoring and mitigation of volcano hazards*. New York: Springer.
- Schmincke, H.-U. (2006). *Volcanism*. New York: Springer.
- Sgurdsson, H., Houghton, B., McNutt, S., Rymer, H., & Stix, J. (Eds.). (2000). *Encyclopedia of volcanology*. San Diego, CA: Academic Press.
- Wilson, B. (1989). *Igneous petrogenesis: A global tectonic approach*. Dordrecht, Netherlands: Springer.



VORONOI DIAGRAMS

The Voronoi diagram (also called a *Dirichlet tessellation* or a set of *Thiessen polygons*) is a partition of a metric space such that we associate all locations in that space with the closest object in that space, based on the specified metric. Thus, each object is the generator of a cell or tile, and the set of tiles covers the space or map.

In the simplest case, we are given a set of points S in the Euclidean plane, which are the Voronoi generators. Each generator, s , has a Voronoi cell, $V(s)$, consisting of all points closer to s than to any other generator. The cell boundaries of the Voronoi diagram are all the points in the plane that are equidistant to two generators, and the Voronoi nodes are the points equidistant to three (or more) generators. Voronoi cells can be defined for metrics other than Euclidean, such as the Manhattan distance, and for other surfaces than the plane, such as the sphere. Voronoi cells can also be defined by measuring distances to objects that are not points. The dual graph of the Voronoi

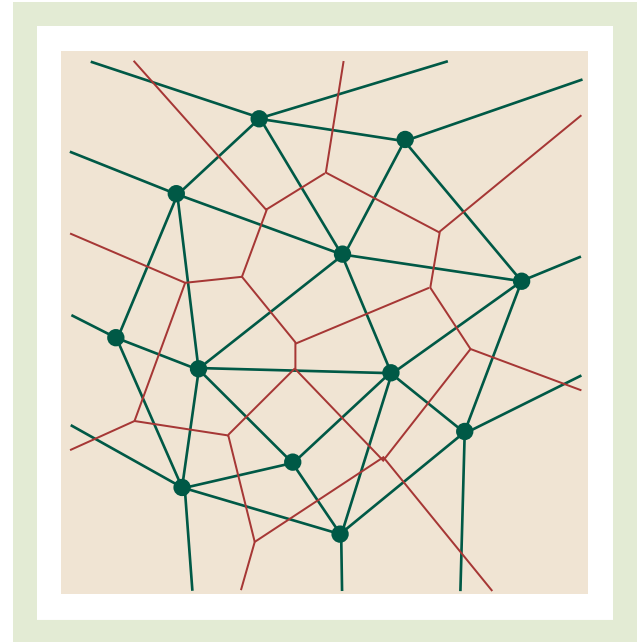


Figure 1 The Voronoi diagram of a set of points, together with the dual Delaunay triangulation

Source: Author.

diagram of S corresponds to the Delaunay triangulation (DT) of S (Figure 1). Here, all Voronoi cells have generators that form the vertices of the DT, all Voronoi edges have perpendicular Delaunay edges, and all Voronoi vertices are the centers of the circumcircles of the DT.

The idea of the Voronoi diagram is relevant in many spatial sciences, giving descriptions of proximity, adjacency, clustering, territoriality, and others. The DT is widely used as a stable and well-defined triangulation for terrain modeling. Informal use of Voronoi diagrams can be traced back to Descartes in 1644. The Voronoi diagram was used in 1854 by the British physician John Snow to show that the majority of people who died during the cholera epidemic in the Soho district of London lived closer to the contaminated pump at Broad Street than to any other source of water.

Properties

Given a set of service locations (e.g., post offices), the Voronoi diagram identifies the closest service to any particular location. The location furthest

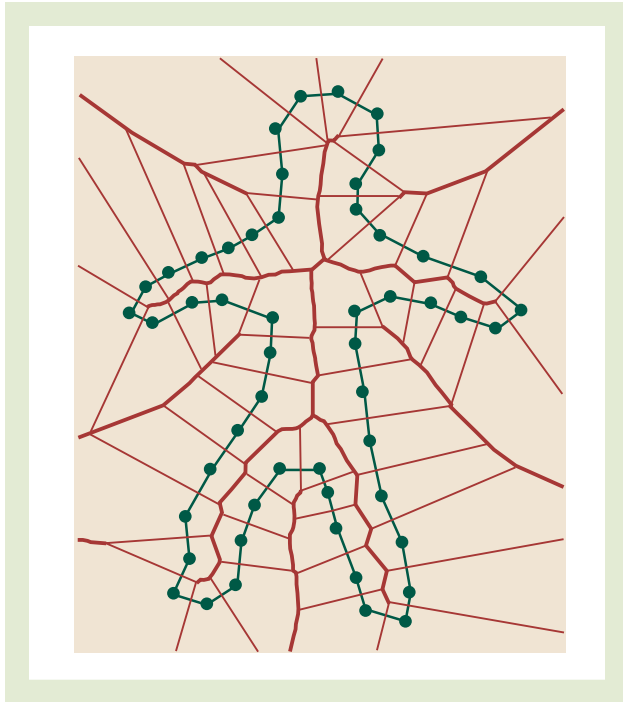


Figure 2 The crust (boundary) and skeleton (medial axis) of points along the boundary of a closed shape are formed from subsets of the Voronoi diagram and the Delaunay triangulation.

Source: Author.

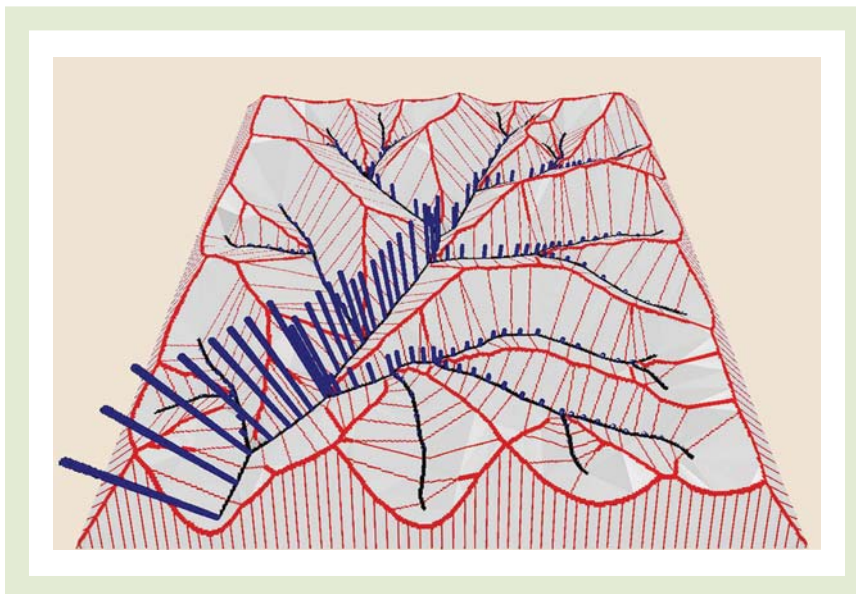


Figure 3 Approximate catchment analysis. Points on the rivers are digitized and the Voronoi diagram/Delaunay triangulation constructed. Voronoi vertex circle radii are interpreted as heights, giving a simple terrain model. The local runoff area of the river points is given by their Voro.

Source: Author.

from any point in S is one of the vertices of the Voronoi diagram of S . This has the largest possible empty circle within the map. This is equivalent to the triangle in the DT of S with the largest circumcircle. Every triangle in the DT has an empty circumcircle. Equivalently, every edge in a DT has an empty circle touching the two ends. Given a set of n points in S , the closest pair of points will be on an edge of the DT of S . Similarly, the nearest neighbor to each of a set of points will be defined by an edge of the DT of S . The Euclidean minimum spanning tree of a set of points S is a graph without any cycles that connects all points in S with a minimum total edge length. It is a subset of the edges of the DT of S . The DT is a planar graph. By Euler's formula, it has at most $3n - 6$ edges and at most $2n - 5$ triangles. The convex hull of S is a subset of the edges of the DT. The DT maximizes the minimum angle of each triangle by comparing it with its neighbors. This approach gives the fattest triangles possible for the set S (Figure 2).

Voronoi diagram construction is "local": Inserting a generator adds a new cell that was "stolen" from its neighbors. Thus, the Voronoi diagram and the resulting DT may be updated locally. If the set of points S are on the boundary of a closed shape, then the medial axis transform (MAT), or skeleton, is a subset of the Voronoi edges (the Voronoi vertices have empty circumcircles). In three dimensions, many of the properties described above for two dimensions still apply.

Applications

Apart from geography, many disciplines use Voronoi diagrams, including: cosmology (e.g., galaxy clustering); biology, ecology, forestry, and zoology (e.g., plant and animal competition, tree crown areas); geology (e.g., ore reserves and simple mapping based on a Voronoi cell around each drill hole or outcrop, surface and



volume interpolation, fluid flow); meteorology (e.g., rain-fall based on a Voronoi cell around each rain gauge); robotics (e.g., path planning from the medial axis); and pattern recognition (e.g., crust/boundary and skeleton/MAT for points representing an object boundary).

In geography, the Voronoi diagram is used for cluster analysis, point pattern analysis, location optimization, surface and volume interpolation, surface modeling from contour maps, growth models, adjacency analysis, buffer zone calculation, collision detection in dynamic systems, fluid flow simulation rapid digitizing of polygon maps, reconstruction of scanned maps, merging of field and object data in a geographic information system, runoff modeling, watershed estimation, catchment analysis, and region detection in remote sensing, to name a few (Figures 3 and 4).

The primary value of the Voronoi diagram is that it provides a mathematically defined and consistent allocation of space to the nearest generator. This property leads directly to the idea that the Voronoi boundaries are equidistant between generators and hence may be used for path planning and medial axis generation. Similarly, as all spatial locations are assigned, the resulting tessellation provides a functional definition of adjacency between discrete objects, based on geometry alone, which provides useful techniques for cluster analysis, interpolation based on the immediate neighbors to the unknown point, and collision detection for moving vehicles or interactive map construction. The dual DT, based on the Voronoi diagram, is valuable both because it minimizes splinter triangles and because individual updates only change local portions of the map.

Christopher Malcolm Gold

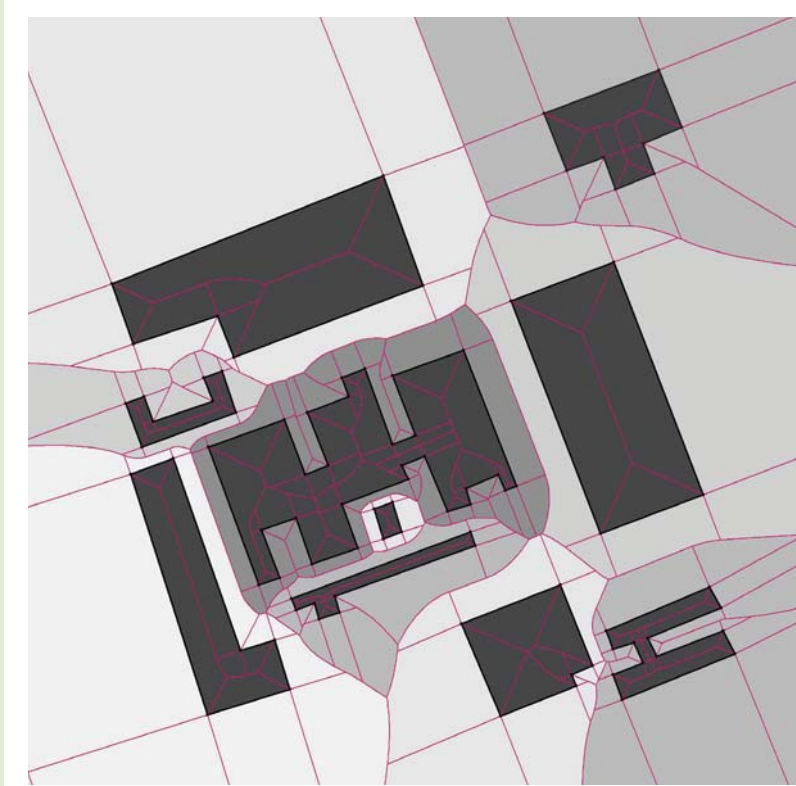


Figure 4 The Voronoi diagram of line segments allows proximity and navigation analysis of urban areas.

Source: Author.

See also Geometric Measures; Geostatistics; GIScience; Spatial Statistics; Triangulated Irregular Network (TIN) Data Model

Further Readings

- Aurenhammer, F. (1991). Voronoi diagrams: A survey of a fundamental geometric structure. *ACM Computing Surveys*, 23, 345–405.
- Berg, M. de, van Kreveld, M., Overmars, M., & Schwartzkopf, O. (2000). *Computational geometry* (2nd rev. ed.). Berlin, Germany: Springer-Verlag.
- Okabe, A., Boots, B., Sugihara, K., & Chiu, S.-N. (2000). *Spatial tessellations: Concepts and applications of Voronoi diagrams* (2nd ed.). New York: Wiley.



VULNERABILITY, RISKS, AND HAZARDS

Study of hazards involves the concepts of vulnerability, risks, and hazards, with hazards research evolving to include considerations of social vulnerability and resilience. Although public use of the words *vulnerability*, *risk*, *hazard*, and *threat* has sometimes been interchangeable, each word has its own distinct definition within the field of hazards geography.

Hazards

Hazards represent threats of potential damage or destruction to individuals and society. The actual hazard event, such as a flood, earthquake, wildfire, blizzard, or nuclear reactor accident, may result in a disaster if the incident results in substantial human disruption, whether measured by property damage, injury, or loss of life. An event must have the potential to be sufficiently disruptive of human activities to be considered a hazard, thus the physical magnitude of the event that is considered a hazard varies geographically and temporally. For example, several centimeters of winter snow would be considered routine in the northern Midwest, while it would pose a significant hazard in Southern Florida. Likewise, routine moderate precipitation is not considered a hazard but a valuable resource. However, too little or too much rain results in drought and flood hazards, respectively. Indeed, hazards are sometimes termed *negative resources*.

Geographic study of natural hazards grew out of the pioneering work of Gilbert White, nearly three quarters of a century ago, dealing with river flooding. Because flood losses were increasing even though substantial investments had been made in the construction of dams and levees, White saw the need to fully explore how human activity was related to flooding. To appropriately understand flood hazards, the complex interrelationships between the natural environmental systems that led to flooding and the web of human activity that resulted in lives and property being placed at risk needed to be thoroughly understood.

Natural and Technological Hazards

Building on these studies of flood hazards, the hazards field expanded to include not only a wide variety of geological, hydrological, and meteorological events but also many technological hazards, including those related to industrial and transportation accidents, releases of toxic chemicals and radiation, and pollution. At the same time, the study of hazards spread from American or European settings to less industrialized non-Western societies—although such studies remain in the minority. Hazards related to global warming are increasingly being considered, and studies have considered the consequences of such warming on drought, wildfire, and hurricane hazards, among other hazard threats. Furthermore, growing world populations have led to both overgrazing and deforestation, both events that may increase the likelihood of flood, drought, and landslide hazards. Thus, hazards may have either natural or human causes.

Recent research has included *Natech* hazards, those in which natural hazard events trigger technological disasters. Natech hazards include events such as flooding or seismic activity that spills toxic chemicals. The definition has expanded to include disruption of critical infrastructure, such as water supply lines, electrical transmission systems, or transportation networks, resulting from natural hazards.

Geographers have also studied the risk and distribution of various diseases from a hazards perspective, yet diseases and pollution have often been studied from other perspectives. Furthermore, geographic study and teaching about hazards often excludes disease and pollution hazards. While Ken Hewitt has proposed the geographic study of hazards of war, and others have studied terrorism hazards, these topics are ignored by the majority of hazards geographers. Nevertheless, urban violence, poverty, and street crime can all be studied from a hazards perspective.

Geographic study has tended to concentrate on the hazard itself, or the spatial patterns of disaster, while societal response and disruptions resulting from disasters are typically studied by sociologists. In studying hazards, geographers consider both the physical event and the human response or adjustment to it, as it is the complex



interactions of the physical and human systems that create and determine the intensity of the hazard. Changes in technology, human occupancy, and timing provide the context that can either accentuate or ameliorate hazards. While some geographers have emphasized hazards resulting from specific physical threats, others have focused on human responses, including perception, hazard mapping, land use planning, evacuation, and reconstruction, among other mitigation topics.

Human perceptions of hazards were viewed by Robert Kates as the first step in his Adjustment Process Control Model. Once the awareness of and concern about a hazard reached a critical threshold, an individual or group initiated a search for ways to reduce or mitigate that hazard threat. This search for adjustments was constrained not only by the searcher's knowledge of possibilities but also by economic, environmental, social, political, and technological factors. While the connections between hazard perception and adjustment behavior are often considered in hazard studies, the linkages are far from being direct. Many cultural and contextual issues influence and constrain perceptions of both hazards and potential adjustments, and much remains to be done to develop better models that explain human response to hazards.



NASA satellites capture remarkable images of the wildfires that raged in Southern California on October 22, 2007. This image shows the thick, billowing smoke coming off the numerous large fires and spreading over the Pacific Ocean. Fire activity is outlined in red. Dry, drought-stricken vegetation and Santa Ana winds, which can reach hurricane speeds, have contributed to the devastating effect of these blazes.

Source: NASA/MODIS Rapid Response.

Risks

Risks have been loosely described as *environmental threats*, but risk can be viewed as a function of hazard and vulnerability. Risk is often defined as a measurement of the probability of experiencing an extreme event or an event of a particular magnitude. Although the public often misconstrues probability information, much geographic study of and societal response to floods has dealt with the concept of the 100-year flood, or a flood with a 1% probability of occurrence in any given year.

Flood Insurance Rate Maps display those areas of the United States with this flood risk, in which flood insurance and land use regulation are required. Other maps displaying the probabilities of experiencing a wide variety of hazards, including both river and coastal flooding, coastal storm surges, landslides, volcanic ash deposits and lahars, and seismic shaking and liquefaction, have been widely published. The consequences of this risk—the disaster potential—are related to both the physical hazard and the vulnerability of the population.



Vulnerability

Vulnerability to hazards varies depending on both the physical and the social setting of a community. Because vulnerability can be defined as the potential for and consequences of casualty or economic losses, it is not necessarily directly related to hazard risk or probability. For example, a playing field occupying a floodplain that is inundated every year or two is less likely to sustain property damage significantly disrupting human activities than a residential area located nearer the fringe of the floodplain that may be flooded every other decade. Thus, vulnerability is related to the physical probability that an area will be flooded and to the type of human usage of the site. While physical conditions determine the nature and frequency of the hazard event, social conditions control the land use and occupancy decisions regarding hazardous sites.

Social Vulnerability

Social vulnerability is strongly influenced by the income, racial or ethnic status, age, education, and political standing of a population. The poor are disproportionately more likely to occupy lands that are subject to frequent flooding or landslides and sites that are in close proximity to toxic waste dumps and industrial polluters. Wealthier individuals have the economic resources to avoid physically vulnerable sites and often have control of political institutions that may influence siting of such developments. Furthermore, the poor are most likely to occupy dwellings that provide minimal resistance to seismic shaking or offer little protection against high winds or floodwaters. Regardless of their residence, individuals who are elderly or disabled are more vulnerable to hazard occurrences and present challenges during both the evacuation and the disaster recovery periods. Polarization and spatial segregation of different socioeconomic groups result in their different vulnerabilities to hazards.

A “progression of vulnerability” has been identified by Ben Wisner and Piers Blaikie in their Disaster Pressure and Release Model to demonstrate how unsafe conditions interact with hazards to produce disasters. Root causes that are related to poverty and social marginalization lead to dynamic pressures that result in unsafe

conditions. These are manifested by populations living in dangerous locations, with inadequate incomes, and lacking public institutions that might mitigate or warn about the hazard threat. Economic vulnerability is enhanced when meager incomes are threatened by disaster-induced job losses. Certain types of employment are far more vulnerable to specific hazards than others. For example, peasant farmers are far more vulnerable to drought than urban workers.

Resilience

Resilience to hazard losses refers to individual and community attributes that enhance both loss avoidance and disaster recovery. Resilience can also be viewed as the ability to absorb or tolerate hazard consequences, both physically and socially. Resilient communities have greater abilities to recover from a disaster. Financial resources are key, inasmuch as wealthy groups can draw on existing resources to rebuild and restore homes, businesses, and damaged infrastructure. Likewise, wealthier individuals and groups are more likely to have incorporated hazard mitigation into the design and construction of their houses and businesses, thus reducing their vulnerability to hazard losses and increasing the likelihood that a hazard event will not result in an interruption of business activities. Resilient communities are less likely to suffer long-term losses of employment or public services, inasmuch as pre-event planning provides mechanisms to both avoid or minimize losses and to appropriately respond to changing conditions.

Hazards and Vulnerabilities of Megacities

The unique hazardousness of megacities has been described by geographers, most notably J. Kenneth Mitchell. Given their huge populations, which may be defined as exceeding 10 million residents, a disaster could potentially involve so many casualties and so much destruction of property and infrastructure that it would cause social and economic disruptions of entire nations. Megacities, which are disproportionately located in less developed countries, are also frequently located in low-lying coastal settings that are vulnerable to both coastal storms and sea level rise, both which could be exacerbated by global warming. Yet for many



hazard threats, such as tornadoes, landslides, and even some river flooding, only a portion of the megacity would be physically vulnerable to destruction from a particular event. In contrast, because of their much smaller geographic area, the entirety of a rural village or small town might suffer the consequences of such events. While the nature of the physical vulnerabilities of megacities and small communities varies for many threats, certain events, such as earthquakes or tropical cyclones can result in widespread destruction in megacities.

Megacities have greater resilience to hazards than smaller rural communities. Not only is the national wealth and political power typically concentrated within megacities, but also these cities have a disproportionate share of their nation's emergency response capabilities, including physicians and hospitals, firefighting equipment and personnel, and transportation links with the outside world. Nevertheless, the truly megadisaster does have the potential to overwhelm this response capacity, justifying the attention given to the hazard vulnerability of megacities.

Hazards and Vulnerability of Place

Geographic information science (GIScience) provides a powerful tool to analyze spatial variations in hazard vulnerability. While Ken Hewitt and Ian Burton promoted the concept of “hazardousness of a place” three decades ago by discussing all physical and technological hazards within a Canadian city, recent development of the “hazardousness of a specific place” concept by Susan Cutter involves spatial analysis tools that integrate physical vulnerability data and land use information with multiple measures of social and economic vulnerability. This work enables geographers and emergency planners not only to identify the specific locales within a community that have the greatest physical vulnerability to a particular hazard or group of hazards but also to input the character of the built environment (density and quality of construction, type of land use), the social characteristics of the population, and

the location of highways and other key infrastructure, to evaluate both the need for evacuation and the efficacy of particular evacuation routes. By combining risk and vulnerability data, GIScience permits the pre-event determination of those locales most and least likely to suffer destruction from multiple scenarios of different hazard events, enabling the better staging of disaster recovery resources. High levels of physical vulnerability—such as along coastal beaches—often do not correspond with high levels of socioeconomic vulnerability, thus detailed GIScience analysis may determine that residents occupying areas of medium physical vulnerability to one or more hazards may actually be the most vulnerable to disaster losses given their social vulnerabilities and lower levels of resiliency.

John A. Cross

See also Disaster Prediction and Warning; Drought Risk and Hazard; Ecological Risk Analysis; Hurricanes, Risk and Hazard; Natural Hazards and Risk Analysis; Resilience; Risk Analysis and Assessment; Volcanic Eruptions as Risk and Hazard; White, Gilbert; Wildfires: Risk and Hazard

Further Readings

- Alexander, D. (2000). *Confronting catastrophe: New perspectives on natural disasters*. New York: Oxford University Press.
- Burton, I., Kates, R., & White, G. (1993). *The environment as hazard* (2nd ed.). New York: Guilford Press.
- Cutter, S. (Ed.). (2001). *American hazardscapes: The regionalization of hazards and disasters*. Washington, DC: Joseph Henry Press.
- Hewitt, K. (1997). *Regions of risk: A geographical introduction to disasters*. Essex, UK: Longman.
- Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). *At risk: Natural hazards, people's vulnerability and disasters* (2nd ed.). London: Routledge.

W

WALDSEEMÜLLER, MARTIN (CA. 1470–CA. 1522)

In 1507, on two maps of the world developed to accompany his *Cosmographiae Introductio*, Martin Waldseemüller included the name “America.” These maps were the first to use the name “America” for the southern part of the newly discovered Western Hemisphere, located in the middle of a land mass that would metamorphose during the 16th century into what we recognize today as South America.

The complete title of the first map, “Universalis cosmographia secundum Ptholomaei traditionem et Americi Vespucii alioru[m]que lustrations,” recognizes the work of the ancient Greek cartographer Claudius Ptolemy, as well as the reports of “discoveries” from 1497 to 1504 by the Italian navigator Amerigo Vespucci. It is not clear how much of the South American continent Vespucci actually visited, but his name was clearly placed in the center of the land area. Most significant in this recognition of Vespucci’s discoveries is the fact that he concluded that the land was not a part of Asia. Unlike Columbus, who was certain that he had reached Asia, Vespucci was convinced that this land was something else. Vespucci transmitted this view in a series of letters, and Waldseemüller mapped this perspective on the new maps. Within the context of the *Cosmographiae*

Introductio, this was a dramatic shift in the European worldview.

Waldseemüller’s partner in this work was Matthias Ringmann, who edited and amended the text of Claudius Ptolemy’s *Geographia* (the core of the *Cosmographiae Introductio*), a compilation of what was known about the geography of the world in about AD 150. Using the versions of *Geographia* published in Rome in 1478 and Ulm in 1482, as well as a Greek manuscript, Ringmann and Waldseemüller followed the modified text and original Ptolemaic maps with 20 new maps describing areas of the world not known 13 centuries earlier.

The first map was a modification of one of Ptolemy’s conic projections, extending the coverage of the Eastern Hemisphere to include all of Earth’s surface, except for the area in the Southern Hemisphere from 40° S latitude to the pole; however, the southern tip of Africa is carefully defined. As the knowledge base grew, maps created throughout the 16th century changed, with additions and modifications intended to make each one the most accurate and up-to-date representation. As new data emerged from the exploratory ventures to the New World (as well as eastward from the southern tip of Africa across the Indian Ocean), the maps of the world changed drastically (e.g., Mercator’s maps of 1538 and 1569).

The title of the map, “World Description According to Ptolemy and the Travels of Americus



Figure 1 The world according to Ptolemy and the travels of Americus Vesputius and others

Source: Original map in the collection of the Library of Congress, Geography and Maps Division. Hand-colored version reprinted with permission of the author from Whitfield, P. (1994). *The image of the world: 20 centuries of world maps* (pp. 48–49). San Francisco: Pomegranate Artbooks.



Vespucius and Others,” makes clear the cartographer’s intention: to create a new world map from the most up-to-date resources (see Figure 1). Waldseemüller’s second world map, composed of 12 globe gores, also includes “America.”

In subsequent maps, Waldseemüller replaced the name “America” with “Terra Nova.” Relying on the latest and most substantive information available, he did not employ the name “America” in his revised edition of the map in 1513. This revision provides little explanation about the resources that were used. In the *Carta Marina* of 1516, however, there are extensive explanations of the map content. It is important to note that the *Carta Marina* employed a cylindrical projection with a format like that of the portolan style navigation charts employed during this period.

While Waldseemüller did not use the name “America” on his later maps, and others acted similarly, enough world maps from the period continued to use it (e.g., Peter Apian’s map of 1520, which looks very much like Waldseemüller’s map of 1507). German and Dutch cartographers were instrumental in firmly establishing the use of the term. Waldseemüller produced other maps, all developed on the principle of obtaining and organizing the most reliable and up-to-date information.

As for the “Universalis cosmographia secundum Ptholomaei traditionem et Americi Vespucii alioru[m]que lustrations,” of the 1,000 copies that were printed, only one remains. It is on permanent exhibit at the Library of Congress in Washington, D.C.

George F. McCleary Jr. and Karen S. Cook

See also **Cartography, History of; Mercator, Gerardus; Portolan Charts; Ptolemy**

Further Readings

- Johnson, C. (2006). Renaissance German cosmographers and the naming of America. *Past and Present*, 191(1), 3–43.
- Woodward, D. (Ed.). (2007). *Cartography in the European Renaissance* (The History of Cartography, Vol. 3). Chicago: University of Chicago Press.



WALKER, RICHARD (1947–)

A longtime professor of geography at the University of California, Berkeley, Richard Walker has played a significant role in Marxist theorizations of economic geography, agriculture, water and the social construction of the environment, and urban change. A student of David Harvey, Walker completed his PhD at Johns Hopkins University in 1977. With more than 80 refereed articles and four books, his work has been influential in several domains of human geography. He has long insisted eloquently on the centrality of the production process, the division of labor, and the politics of the state as driving forces behind numerous social and spatial phenomena under capitalism. He has also written on geographic pedagogy, particularly the challenges of teaching political economy. He has been actively involved with the journal *Antipode*, serving as its editor from 1991 to 1999. In addition to his research, Walker has mentored a number of successful PhD students, including Michael Storper.

Walker’s early works centered on the dynamics of American suburbanization, which he recast in light of the changing urban division of labor in the late 19th century rather than as an accumulation of individual residential location decisions. A series of papers and book chapters embellished this theme so often framed in empiricist and idealist terms. Thus, he maintained that suburbanization was not a “crabgrass frontier” but, rather, the reflection of long-standing industrial decentralization, real estate speculation, and the active promotion of business and government elites.

His other works in economic geography include powerful critiques of technological determinism; analyses of the relations between class, space, value, price, and profit; theorizations of uneven spatial development; assaults on behavioral perspectives of the firm; and an analysis of services as part of the broader logic of commodity production rather than a postindustrial utopia with their own, independent dynamics. *The Capitalist Imperative*, coauthored with Michael Storper in 1989, is widely heralded as one of the discipline’s most concise explications of the national division of labor and its consequences. Similarly, Walker and Sayer’s *The New Social Economy* in 1992



aptly summarized structuralist accounts of changing job patterns, technological change, and state policy.

He has also spent decades studying the historical development of California. Specific lines of thought within this topic include the geopolitics of water in the state, particularly the powerful role played by agribusiness. Walker also wrote extensively about the development of the greater San Francisco Bay area, its historical transformations, its changing social and spatial features, its struggles over green spaces, and its ongoing globalization.

Barney Warf

See also **Harvey, David; Marxism, Geography and;**
Smith, Neil; Storper, Michael; Suburbs and
Suburbanization

Further Readings

- Walker, R. (1995). California rages against the dying of the light. *New Left Review*, 209, 42–74.
- Walker, R. (2001). California's golden road to riches: Natural resources and regional capitalism, 1848–1940. *Annals of the Association of American Geographers*, 91(1), 167–199.
- Walker, R. (2004). *The conquest of bread: 150 years of California agribusiness*. New York: New Press.
- Walker, R. (2007). *The country in the city: The greening of the San Francisco Bay area*. Seattle: University of Washington Press.
- Walker, R., & Sayer, A. (1992). *The new social economy: Reworking the division of labor*. Cambridge, MA: Blackwell.
- Walker, R., & Storper, M. (1989). *The capitalist imperative: Territory, technology and industrial growth*. Oxford, UK: Blackwell.



WAR, GEOGRAPHY OF

History and contemporary events have demonstrated that there is a ubiquitous and fundamental link between geography and military operations of all types (i.e., peacekeeping through war). The relationship between warfare and factors of

geography such as terrain, weather, climate, and elements of the human landscape has always been evident. Likewise, the essential geographic concepts of location, time, space, and distance have a profound influence on military operations. Thus, military geography is defined as the application of the geographic discipline—its information, principles, tools, methodologies, and technologies—to the organization and implementation of the full spectrum of military operations.

Analytical Framework

Its publications, theory, and practice of war suggest that, at its core, military geography examines the characteristics of the environment within which military operations take place and that operations are influenced by the uniqueness of the natural and human landscape within diverse regions. The sum total of the geographic characteristics of a place is called a military operating environment. This is important because the development of a military strategy involves the selection of objectives, the deployment of forces, a method and sequence of employment, and the movement of military power to an area. Consequently, every phase of a military operation is subject to the effects of terrain and the elements of the natural landscape, the pervasive influence of weather and climate, and the elements of the human landscape. Hence, specific characteristics of places can be linked systematically with their effects on military activities, and the characteristics and effects can be correlated to regions. These effects are to some extent predictable, manageable, and can be useful in planning military operations.

Military Operating Environments

The study of geography demonstrates powerfully that places matter and that each place has unique characteristics. Military geographers think of places as operating environments, each exclusively influenced by the interrelationship of a discrete set of geographic variables. Karl von Clausewitz called the operating environment “terrain” in his famous 1832 treatise *On War*. In von Clausewitz's view, the environment is composed of the sum of the land and its inhabitants. Like von



Clausewitz, other strategists indicate that the operational significance of the environment varies with the mission, technology, and current circumstances. So too, then, must a geographic assessment of a military operating environment. Consequently, military geographers link geography and military operations by asking three fundamental questions: (1) What is the environment like? (2) Why is it like this here? (3) How will it shape the operation?

Thus, the *military operating environment* is the aggregate of all factors of the landscape that shape and control the ebb and flow of military operations, and in the final analysis, an examination of the operating environment typically results in an assessment of the following:

- Key terrain: strategic areas and selected critical objectives
- Surface structure: movement corridors and terrain compartments
- Weather and climate: effects on humans, machines, and operations
- Transportation networks and nodes
- Resources
- Logistical requirements
- Human landscapes: population, ethnic groups, urban zones, and cultural considerations

The Environmental Matrix

Military plans must be considered based on the advantages and limitations afforded by the geographic characteristics of the operating environment. In a wartime context, the purpose of any strategy is to weaken or destroy the enemy's ability to resist and to enable the fulfillment of stated objectives. To this end, distinctly different strategies have been pursued throughout history. The fundamental military strategy is the employment of military force to cause an enemy to capitulate completely. At the other end of the spectrum, people may employ a more limited approach, in which destruction of the enemy is thought to be impossible because political aims are restricted or because military power is inadequate. Insurgent forces use this form of strategy to prosecute their objectives: They employ military force at selected times and places with the objective of wearing down their opponent. Nonetheless, regardless of

the strategy, the success of a military operation depends on a reliable plan that takes into account a cogent analysis of extant geographic factors in a military operating environment.

Hence, the foundation of a geographic analysis of the operational significance of a region and its characteristics is called the *environmental matrix*. The environmental matrix is defined as the sum of all factors that operate at a place and that can have an effect on the successful implementation of any operation. The environmental matrix includes both natural and human components and assumes that the operating environment is the manifestation of their combined effects. The matrix, however, is only a methodology for analysis and is *not* predictive. Furthermore, because the landscape is not static and the context and objectives of military operations vary over time, care must be taken to reevaluate significant elements of the matrix continuously. An example of an environmental matrix is given in Figure 1.

Scales of Analysis

Variations in the size and scope of military problems demonstrate the need for military geographic analyses to be conducted at different spatial scales. In a military sense, scale is translated into military operations at the strategic, operational, and tactical levels—or for simplicity, macro- and microgeographic scales.

At the macro scale, military strategy is the method of employing military power to secure a national objective: Consequently, strategic military geography narrows down to the collection, compilation, analysis, and interpretation of geographic data for use in the preparation of war plans or plans to support national-level military operations other than war. Within this context, the principal concerns of strategic military geography include strategic mobility, accessibility, networks, resources, and vulnerability.

At the microgeographic scale, tactical military geography is the translation of geographic information as it relates to the employment and movement of military units during battle. Therefore, military geography at this scale is highly detailed and is typically directed toward the study of military characteristics of discrete types of terrain and geographic conditions and the development

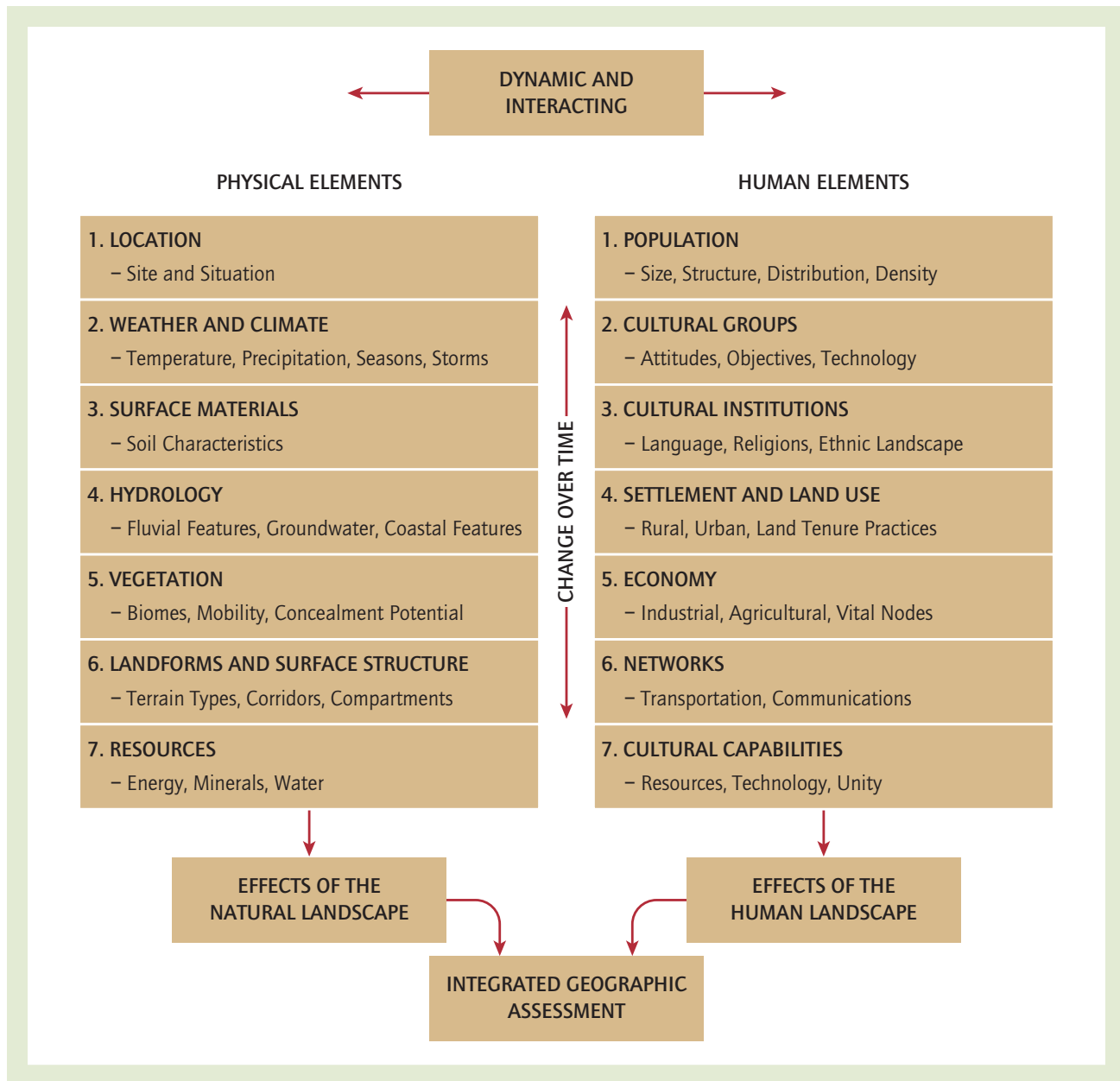


Figure 1 Sample environmental matrix

Source: Author.

of plans to exploit those conditions. Tactical military geography includes the structure of terrain, elements of the natural landscape, conditions in the atmosphere, and the direct influence of the human landscape on operations. The manifestations of the military operating environment at the micro scale can generally be expressed as (a) observation, (b) cover and concealment, (c) mobility, (d) communications, (e) navigation,

and (f) human imprints on the battlefield and rules of engagement.

Approaches to Military Geographic Analyses

The existence of interactions between military environments and operations clearly requires methodologies and approaches that enable cogent



analyses of their potential influence on success or failure. Hence, military geography analyses can be grouped into three formal categories: systematic, topical, and regional.

In a military context, systematic geography engenders the application of systematic sciences such as geomorphology, climatology, and meteorology to the accomplishment of military operations or solving military problems. The full scope of systematic sciences that support military geography ranges between social and physical sciences, with widely divergent geographic subjects such as oceanography, meteorology, demography, biogeography, medical geography, and pedology, to name a few. Topical military geography serves to link systematic sciences to military science and focuses on the application of scientific knowledge to solve basic military problems. For example, data developed by geomorphologists, climatologists, biogeographers, and pedologists can be examined in the context of cross-country mobility to demonstrate the effects of slope, vegetation, and soil conditions on the ability of various military vehicles to cross a given landscape. Thus, topical military geography accounts for the differences imposed by diverse environmental conditions (e.g., deserts, forests, weather) on various types of military operations.

Similar to its role in academic geography, regional military geography assimilates the various characteristics of discrete formal or functional regions into an integrated study. Thus, the examination of military geography from a regional perspective should provide an integrated assessment of a formal region, such as a theater of operations, or a functional region, such as a terrorist network. Military geographers have developed regional study into a highly specialized and detailed methodology called *area analysis*. Area analyses stand out as mission-oriented studies in that they form the basis for a systematic interpretation of geographic conditions on a proposed course of action.

The Evolution of Military Geography

Linkages between geography and war and the exploitation of geographic information to support military affairs have likely existed for many millennia. Accordingly, military geography has

evolved since its formal beginnings in the 19th century, with developments in theory and methods of warfare, technological innovations, changes in the global strategic situation, and extension of areas of military interest. Early military geographies (e.g., Theophile Lavallee, *Géographie Physique, Historique et Militaire*, 1836, and Albrecht von Roon, *Militarische Landerbeschreibung von Europa*, 1837) were highly descriptive regional catalogs of data and chorographic descriptions of terrain, but they typically lacked incisive analyses. As an academic discipline, military geography essentially reached a contemporary zenith during World War II and the Cold War as a great deal of research was focused on supporting a global war and the important geostrategic conditions of the postwar world. During this era, military geographers not only included traditional assessments of military environments and regions but also saw the introduction of sophisticated analyses of the technologic requirements to support military operations and the geopolitics of global conflict. The Vietnam War and the period immediately following that conflict represent the nadir of academic military geography in the United States. This demise was caused largely by the social and political upheaval that occurred in its aftermath, which found its way onto American campuses.

Military geography, however, has experienced a renaissance and has perhaps achieved a new acme during the period following the Cold War, especially among academic geographers. The de facto strategic partitioning of the world by the two major superpowers effectively ensured that conflicts between client states were limited and that the bipolar strategic scenario was essentially stagnant for many years, thus restricting the nature of military geography. The new global situation has triggered a series of widespread developments in military affairs, and this expansion of areas of military interest has revitalized military geography. An examination of recent publications indicates that the discipline has expanded its scope well beyond traditional analyses of the terrain, weather, climate, and elements of human landscape as they pertain to warfare and violent conflict. Indeed, as the scope of military operations has expanded because of formerly nontraditional uses of military forces, such as humanitarian support operations, so too has the scope of military



geography evolved. Contemporary events such as ethnic warfare, environmental change, and global terrorism have forced an expansion of military geography as well. Today, research efforts have been extended to areas such as environmental security, security landscapes, the geography of ungoverned space, strategic chokepoints and piracy, energy and water resources, disaster relief, global-warming scenarios, and more effective analyses of latent ethnic divisions that have erupted into violent conflict following the end of the Cold War.

Francis A. Galgano

See also Cold War, Geography of; Environmental Security; Fear, Geographies of; Geopolitics; Military Geography; Political Geography; State; Terrorism, Geography of; World-Systems Theory

Further Readings

- Clausewitz, C. von. (1976). *On war* (P. Paret, Trans.). Oxford, UK: Oxford University Press.
- Flint, C. (2005). *The geography of war and peace*. New York: Oxford University Press.
- Palka, E., & Galgano, F. (2005). *Military geography from peace to war*. New York: McGraw-Hill.
- Stephenson, M. (2003). *Battlegrounds, geography and the history of warfare*. Washington, DC: National Geographic Society.
- Winters, H. (1998). *Battling the elements*. Baltimore: Johns Hopkins University Press.



WASTE INCINERATION

Waste incineration is a waste disposal method that can be used to combust a range of materials classified as municipal solid wastes and hazardous wastes. Incinerators, sometimes referred to as thermal treatment plants, convert wastes into steam, gas, heat, or ash (those that produce a source of energy are often known as waste-to-energy plants). Waste incineration is a contentious and emotional issue. Geographers and other social scientists have explored many conflicts associated with waste incineration. Following a brief review of the history of waste incineration,

some of the key conflicting issues are highlighted in this entry.

Waste incineration, or the systematic burning of waste, has been taking place for a little over a century. It is recorded that the first incinerator was established in the United Kingdom in 1874 and the first waste-to-energy plant was developed in the mid 1890s. The United States had more than 600 municipal waste incinerators in operation during the 1930s. Incinerators at that time employed low-level technology, and they functioned with limited control over the waste mix that entered the facility or the emissions that were produced by the combustion process. Mounting scientific evidence about the issue of human health hazards and environmental contamination led to growing public concern about the practice in Europe and North America from the 1950s onward.

Since the 1970s, tough national and transnational levels of emission controls have encouraged improvements in incinerator technology. Indeed, the 1980s and 1990s have seen a resurgence of interest in incineration as a waste management option because of enhanced levels of profitability, improved design, and a growing consensus for the need for energy supplied from non-fossil-fuel sources.

Some of the key arguments proffered by the proponents of incineration include the following:

- Incineration emissions are insignificant relative to total air pollution in developed economies, and any emission problems can be solved technologically.
- The generation of energy from incineration preserves nonrenewable fuels and therefore contributes to a net reduction in greenhouse gas emissions.
- Energy recovered from incinerators can serve as a revenue source.
- The volume of waste is reduced by as much as 90% and may extend the available landfill space.
- Incinerators offer geographical concentration of waste in comparison with other, more dispersed options such as landfills.
- No significant alterations to waste collection practices are required, and the construction, management, and operation of incineration plants can be carried out by the private sector, reducing potential tax burdens.



However, incinerator facilities and proposals for such plants have faced opposition from local communities in most countries in Europe and in the United States for at least the past 25 years. Some of the main arguments put forward by the anti-incinerator lobby include the following:

- The incineration process releases dioxins and furans into the air, resulting in possible risks to human health as well as to the environment.
- Incineration simply transfers contaminants from one medium to another (from the ground to the atmosphere).
- The release of contaminants into the atmosphere cannot be controlled in comparison with containment in a landfill.
- Incinerator plants are costly to construct relative to other waste management options.
- Ash produced from the incineration process still needs to be disposed of.
- The incineration process requires paper and other combustibles, competing with and detracting from recycling and waste minimization programs.

Geographers and a range of social scientists have produced a large body of research exploring contentious issues such as community responses to waste incinerator facilities, risk communication for incinerator siting, the technical processes of risk analysis and public perception of risk associated with incinerators, and the impact of waste disposal facilities on housing prices. One of the most important areas of research to emerge in relation to incineration conflicts has been the social and environmental justice movement. The uneven spatial location of waste infrastructure has been well documented. Often waste facilities tend to be located in areas that are characterized by remoteness, areas with peripheral communities, areas with economic marginality, areas with political powerlessness whose people have a culture of acceptance, and areas of existing environmental degradation. Community opposition to waste management infrastructure, such as incinerators, has given rise to many phrases, including “not in my backyard” (NIMBY) and “locally unwanted land uses” (LULUs). A key extension of this opposition has moved from NIMBY to NIABY (“not in anyone’s backyard”) as the objection is often based

not only on self-interest but also on wider social and political issues. These include general environmental concern, dissatisfaction with the consultation process, and distrust of decision makers.

It has been argued that while older incinerators were responsible for air pollution, more modern waste-to-energy plants claim to have rectified this problem by incorporating better pollution control technology and improved combustion processes. The common goal of all modern waste-to-energy plants is the production of an essential product—energy.

Many people consider incinerators a better waste disposal method than the traditional dumping of wastes in sanitary landfills, and they are commonly used in countries such as Japan, where land available for landfills is scarce. Despite the controversial image of incinerators, current research generally concludes that there is a place for incineration provided that it is part of an integrated waste management plan and that it incorporates strong waste prevention, waste minimization, and recycling programs.

Frances Fahy

See also **Environmental Justice; Landfills; Locally Unwanted Land Uses (LULUs); Not in My Backyard (NIMBY); Recycling of Municipal Solid Waste; Urban Solid Waste Management**

Further Readings

- Blowers, A., & Leroy, P. (1994). Power politics and environmental inequality: A theoretical analysis of the process of peripheralization. *Environmental Politics*, 3, 197–228.
- Davies, A. (2005). Incinerator politics and the geographies of waste governance. *Environment and Planning C: Government and Policy*, 23, 375–397.



WASTEWATER MANAGEMENT

Any water whose quality has been affected after being used by human-related activities is considered to be wastewater. Therefore, wastewater management is intrinsically related to water quality



management. Its definition can be broadly summarized as the activities that a person or a group of individuals or entities carries out to protect public and environmental health from the adverse effects of contaminants found in wastewater. Managing wastewater encompasses several important areas that can be summarized as follows:

- The collection and transportation of the wastewater away from highly populated or environmentally sensitive areas via sewerage networks (sewerage is the infrastructure used to collect and transport wastewater, including pipes, pumps, screens, channels, and combined sewer overflows, used to move sewage from its origin to the point of eventual treatment or disposal)
- Treatment prior to discharge
- Releasing wastewater again into the environment (land, rivers, lakes, and oceans) or reusing the treated wastewater for beneficial purposes (e.g., cooling of power-generating facilities, groundwater recharge augmentation)
- Ensuring that the concentrations of contaminants found in the receiving water bodies or land do not harm people and the environment

Sources of Wastewater

Wastewater is collected in sewerage networks (if available) or in small decentralized systems such as privy houses, pit latrines, septic tanks, and so on. Most cities throughout the world have sewerage systems that allow for the collection of both wastewater and runoff resulting from rain. Runoff carries a mixture of water, sediments, oil, and grease from streets that is combined with wastewater from human-related activities that produce liquid wastes. Sources of wastewater from human-related activities are classified as point source or direct, and nonpoint source or diffuse. Examples of direct sources are the discharges from domestic residences, public properties such as governmental buildings, private commercial properties, industrial and mining facilities, and livestock farms. Examples of diffuse sources are agricultural areas. Each of these

sources can add different types and concentrations of contaminants to water.

Wastewater Constituents

Wastewater is composed primarily of water. Alongside water, there are high concentrations of chemicals, toxic compounds, and organic and inorganic matter. When wastewater is accumulated and is left untreated, the decomposition of the organic matter that it contains leads to nuisance conditions, including the production of malodorous gases. Untreated wastewater contains a large number of pathogenic organisms (bacteria, viruses, parasitic worms, etc.) that come from human and animal intestinal tracts. These organisms are the leading causes of epidemics such as typhoid, cholera, hepatitis A, dengue fever, among others and bacteriological and viral diseases. Wastewater also contains nutrients, such as nitrogen and phosphorus, that exist naturally in the environment. However, the high concentrations of these nutrients in wastewater can stimulate unwanted growth of algae and other aquatic invasive species. Wastewater may also contain heavy metals and different types of toxic compounds that are known carcinogens. Because of these reasons, the highest priority of wastewater management has been to adequately remove potential nuisance conditions that can severely affect public and environmental health.

Brief History

Wastewater problems are very old. But it was not until the mid to late 18th century that management of water quality and wastewater began. Events such as the Broad Street cholera epidemic in London led to the enactment of the first regulations to protect public health and drinking water from wastewater discharges. The “sanitary idea” of Edwin Chadwick in London proposed that wastewater must be collected via sewerage networks away from the highly populated centers and the community water supply sources. The collected untreated wastewater was then discharged untreated into water bodies further downstream of communities. Engineers during these times favored the construction of drinking water treatment plants instead of having to



spend money in treating wastewater prior to its being discharged.

Concern for the pollution of rivers resulted in the creation of the first type of surface water quality standards, the “dilution standards,” which are still used today in combination with what are known as “end of pipe” effluent standards (for wastewater treatment plants, or WWTPs), and ambient water quality standards for the protection of river basins.

Broad irrigation and intermittent filtration of wastewater on land were the first known types of treatment other than discharging untreated wastewater into water bodies. Intermittent filtration was the first step in the development of sewage treatment techniques that involved the biochemical oxidation of the organic matter. In the late 19th century, several methods of sewage treatment were developed and tested. Examples of the new technologies developed in that period were the contact and trickling filters developed by Joseph Dabdin and the septic tank developed by Donald Cameron. Modifications to the Cameron septic tank later followed (Travis tank, Imhoff tank, etc.). Modern technologies evolved from these simple but effective wastewater treatment systems.

Modern Approaches

Countries throughout the world have followed similar approaches in establishing policies and regulations for the management of wastewater, each with different levels of success. For example, the United States and Mexico have almost identical regulations for managing wastewater, but due to heavy financial burdens for operation and maintenance costs, as well as costs of monitoring and control of wastewater discharges, Mexico’s wastewater treatment coverage is much less than in the United States. Other countries in Latin America such as Brazil and Argentina have wastewater management programs similar to those of the United States and European countries such as Germany, the United Kingdom, and France.

Many of these less developed countries have enacted regulations that emulate those of the more industrialized and developed nations. Examples of some of the wastewater management regulations include the application of point source standards or end-of-pipe regulations, requiring

discharge permits, wastewater quotas, incentive programs to reduce nonpoint sources of pollution, and also the application of ambient water quality standards. Figure 1 summarizes the wastewater management process. Within each section, there are major issues to be addressed. For instance, the collection and transportation of sewerage is an important topic of hydraulics in the field of civil engineering.

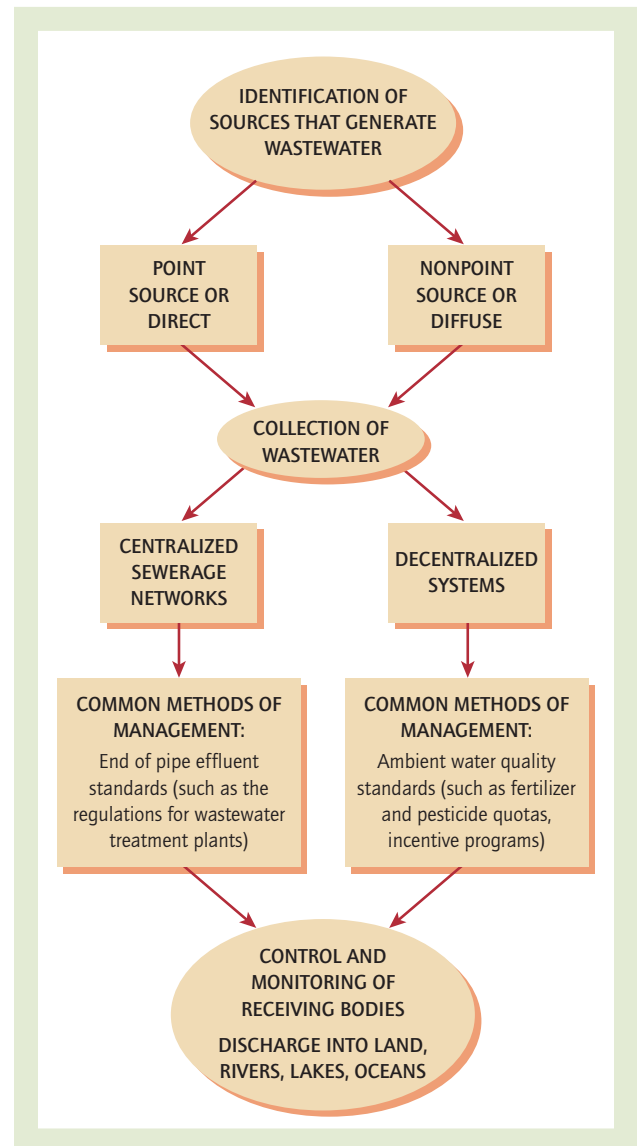


Figure 1 Simple diagram of the wastewater management process

Source: Author.



Wastewater Treatment

Wastewater collected in sewerage systems is commonly treated at large-scale WWTPs. However, for many communities, this practice is not cost-effective or practical. These latter communities rely on what are known as onsite wastewater treatment systems (OWWTS). All treatment methods have been classified into two categories. Methods in which the applications of physical forces are used to remove pollutants are known as “unit operations.” Methods of treatment in which chemicals or biological reactions are applied are known as “unit processes.” These two groups of methods are often applied simultaneously. Several levels of treatment can be attained, depending on the target goals desired. The levels of treatment are preliminary, primary, secondary, and tertiary (or advanced).

The most common treatment is an aerobic system called the activated sludge process. This wastewater treatment process is based on the recirculation of a biomass composed of microorganisms that are able to absorb and adsorb the organic matter carried in the wastewater. Other types of treatment may include ecological approaches using reed bed systems such as constructed wetlands. Modern systems include tertiary treatment by microfiltration or synthetic membranes. These advanced treatment systems, however, are very expensive, and their use has been limited. As the membranes required for advanced treatment become less expensive, these methods will become more popular.

Agustin Robles-Morua

See also **Cholera**; **Geography of**; **Nonpoint Sources of Pollution**; **Point Sources of Pollution**; **Water Degradation**; **Water Management and Treatment**; **Water Pollution**

Further Readings

- Biswas, A. K., Tortajada, C., Braga, B., & Rodriguez, D. J. (Eds.). (2006). *Water quality management in the Americas*. Berlin, Germany: Springer.
- Melosi, M. V. (2008). *The sanitary city* (Abridged ed.). Pittsburgh, PA: University of Pittsburgh Press.

Metcalf & Eddy, Inc. (2002). *Wastewater engineering: Treatment and reuse* (4th ed.). New York: McGraw-Hill Higher Education.

Montgomery Watson Harza, Inc. (2005). *Water treatment: Principles and design* (2nd ed., revised by J. Crittenden, R. Trussell, D. Hand, K. Howe, & G. Tchobanoglous). Hoboken, NJ: Wiley.



WATER DEGRADATION

Water is a “renewable” resource that provides essential services, is constantly restored by the hydrologic cycle, and can be degraded when used or altered faster than it can be replenished. Freshwater degradation occurs when the physical, chemical, or biological characteristics of water become harmful to the environment or organisms, including humans, by which the usefulness of the water resource is in some way reduced. The quality of water as a resource, and therefore the acceptable level of degradation, depends on the intended use of the water and consequently also depends on the desires of multiple, often conflicting stakeholders. The globally variable distribution of water resources, the burgeoning human population with increasing consumptive uses, and increasing waste production and pollution make water degradation an important societal and ecological concern. This entry discusses the sources, distribution, and use of freshwater; water stresses, causes, and drivers; indicators and assessment of water degradation; and water degradation prevention measures.

Sources, Distribution, and Uses of Freshwater

Water covers about 70% of Earth's surface area; 97.5% of this is saltwater, contained mostly in oceans and seas, and 2.5% is freshwater. Most freshwater, about 68.7%, is frozen in ice caps and glaciers, 30.1% is stored as groundwater, and the remaining small fraction (<1%) is found as surface water in lakes and rivers, as soil moisture, and in the atmosphere and biota. At any time, usable freshwater amounts to about 0.01% of the world's total water. The world's continents receive an estimated annual precipitation of



Plastic and trash pollution in Bicz Lake, Romania

Source: Stéphane Bidouze/iStockphoto.

110,000 km³ (cubic kilometers), which is variably distributed by ecological region.

Although we have enough water at a global scale, the distribution of freshwater has been a problem. P. Gleick indicated in 1993 that two thirds of the world's population lives in areas receiving only one quarter of the world's annual rainfall. The global freshwater demand per capita is rising substantially as a result of economic development and population growth. Agriculture represents 70% of the global annual freshwater use (FAO-AQUASTAT). Meeting the rising water demands and the increasing reliance on irrigation to produce food will be a challenge for the growing population and for economic activity in the face of the decline in the finite freshwater resources and increases in pollution.

Water use can be classified as consumptive when water is physically removed for a specific purpose, such as public potable water supply,

irrigation, livestock, mining, and others. Non-consumptive uses include hydroelectric power generation, fisheries, navigation, environmental flow, and others that require a certain amount of water at a given point and time but that do not necessarily remove water from its source.

Water Stresses, Causes, and Drivers

The degrading factors that influence water quality can be chemical, biological, or physical, often with compounding interactions among these three causes.

Chemical Water Pollution

Chemical water pollution is the reduction of the usefulness of water by contamination with one or more degrading substances, such as sediments, organic wastes, nutrients, metals, salts, and many



other natural and synthetic chemicals that can be caused by both anthropogenic (human caused) and natural processes. Humans have a great impact on water quality through their consumptive uses and also in the generation of pollution. Several components of the hydrologic cycle can also affect the quality of water; for example, evaporation from surface pools can concentrate salts and other chemicals by reducing the overall water volume, and runoff and infiltration can leach harmful levels of metals into groundwater. Degradation of water quality due to processes in the hydrologic cycle is referred to as background pollution or natural contamination to distinguish it from degradation from anthropogenic causes.

Sources of pollutants can be classified as either point or nonpoint sources. Point sources are generally categorized as contamination coming from a discrete source, such as a discharge pipe. Point sources are generally easy to identify, have quantifiable discharges, and have readily evident environmental impacts; examples include industrial effluents, wastewater treatment plants, landfills, and abandoned mines. Nonpoint sources are generated from broad and diffuse sources that can be difficult to identify and quantify. Examples include agricultural and urban runoff. The pollutants from nonpoint sources enter water bodies by surface and groundwater movement and from the atmosphere in the form of precipitation (e.g., acid rain). Nonpoint source pollution accounts for the major sources and causes of water degradation globally.

Biological Pollution

Biological pollution of water resources has mostly been identified with waterborne diseases that include infectious hepatitis, cholera, bacterial dysentery, and microscopic parasites such as *Giardia* and *Cryptosporidium*. Many of these diseases are associated with the presence of raw or improperly treated sewage or animal wastes that get into a drinking water resource. Improvements in wastewater treatment have reduced or eliminated most cases of waterborne infectious diseases in developed countries, but these diseases continue to be widespread in undeveloped nations. Discharges of organic matter, such as sewage, pulp mill effluents, and animal processing wastes, can affect water quality by creating an oxygen demand. Aerobic

(oxygen using) waterborne bacteria consume the available dissolved oxygen (DO) during the decomposition of organic matter, reducing DO to a level insufficient to support other oxygen-breathing aquatic organisms (e.g., fish) and making the water unfit for human consumption. The measurement of the oxygen demand needed to satisfy the decomposition of organic matter is called the biological oxygen demand (BOD).

Eutrophication

Eutrophication is a widespread problem and exemplifies the interactions between chemical pollutants and biological processes to degrade water quality. Eutrophication is the process whereby a water body accumulates nutrients (mostly nitrates and phosphates) that are essential for, and often limit, the growth and proliferation of algae and other aquatic plants. Eutrophication is a natural process (natural eutrophication) that occurs when nutrients leach from soils or erode from rocks. However, anthropogenic activities, mostly associated with the use of agricultural fertilizers, have greatly increased the rate at which water bodies are becoming eutrophied (cultural eutrophication). Algae proliferate (bloom) and use the excess nutrients, fixing atmospheric carbon dioxide (CO_2) into organic matter in the form of new algal cells. As these cells die and decompose, they create a BOD that leaves little DO to support other aerobic aquatic organisms (e.g., fish).

Physical Factors

Water control and supply projects have been in use since ancient times and have led to numerous human-benefitting results, including economic growth and food production. Structures such as dams, reservoirs, and distribution systems can support urban and agricultural development but often have severe ecological consequences. Dams and reservoirs can degrade the ecological usefulness of the water by reducing stream flows, halting nutrient and sediment delivery, blocking fish migrations, and destroying habitats.

Water Stress

Water stress is mainly caused by overtapping of available water resources without considering



sustainability or following few or no water and soil conservation practices to augment groundwater recharge and reduce runoff. Overpumping of groundwater is often associated with salinization of groundwater in coastal areas. Salinization is the increase in soluble salts in the water due to various factors. The increased use of chloride salts in roads during winter and overpumping of groundwater in coastal areas, which leads to the lowering of the piezometric surface (saltwater intrusion), are the major sources of salinization. Some surface irrigation practices in arid regions can also increase salt accumulation on the surface of irrigation fields and hence increase the salinity of the receiving water bodies during runoff.

Thermal Pollution

Thermal pollution is water degradation due to the alteration of the temperature of the water and is also a common problem, especially for aquatic organisms. Currently, the main source of thermal pollution is using water as a coolant in electrical power generation and other industrial manufacturing plants. These processes increase the temperature of the receiving water bodies, reducing the available dissolved oxygen, and stressing aquatic organisms. In some instances, such as the release of deep cold water from a dam, the temperature of water bodies decreases, which can also stress warm-water organisms.

Indicators and Assessment of Water Degradation

It would often be difficult and expensive to conduct complete analysis of the numerous factors that can potentially degrade water quality. Often, water quality indicators are used to assess if water is fit for a desired use. These assessments range from simple field measurements to complex laboratory analysis requiring standardized protocols. The extent of water degradation often does not become apparent until water quality indicators fall below set standards. Standards are developed for the intended purpose or use of the water resource—such as drinking water, safety of human contact, fishing, navigation, and ecosystem health. Water bodies that

fall below standard values are classified as polluted or degraded for that purpose.

The most commonly used water degradation indicators for domestic use of water are taste and odor, alkalinity, pH, dissolved metals, dissolved organic substances, salts, metalloids, microorganisms, heavy metals, and others. Chemical indicators of water degradation for environmental use include alkalinity, pH, dissolved oxygen, chemical oxygen demand, biochemical oxygen demand, nitrate, phosphates, and pesticides, while physical assessments include temperature, turbidity, and total suspended solids. Biological assessments, often using indicator organisms (e.g., total coliform as an assay for many pathogenic bacteria), are also commonly used to characterize water bodies intended for domestic or environmental use.

Water Degradation Prevention Measures

The hydrologic cycle and the environment through which water travels contain many chemical, physical, and biological processes that assist in decreasing the mass and concentration of harmful materials. Examples include the biodegradation of organic and synthetic wastes and the sedimentation of metals. This natural attenuation capacity depends on the form and residence time of the water; that is, flowing water generally has a greater ability to self-cleanse than does groundwater. However, water quality suffers when the rate of degradation exceeds this attenuation capacity. The most effective methods of reducing water degradation are to identify and lessen or eliminate the causes if possible. This often involves land management procedures termed *best management practices* (BMPs). BMPs include practices such as replacing water-demanding crops with dry-land (xeriphytic) crops to reduce water consumption and decreasing excess nutrient runoff from agriculture by using less fertilizer and more conservative cropping systems.

Assefa M. Melesse and Leonard J. Scinto

See also Agrochemical Pollution; Climate Change; Groundwater; Nonpoint Sources of Pollution; Pesticides; Point Sources of Pollution; Wastewater Management; Water Management and Treatment; Water Pollution



Further Readings

- Cech, T. V. (2003). *Principles of water resources: History, development, management, and policy*. New York: Wiley.
- Food and Agriculture Organization of the United Nations. (2000). *Water quality management and control of water pollution* (Water Reports 21). Retrieved November 20, 2009, from <ftp://ftp.fao.org/agl/aglw/docs/wr21.pdf>
- Gleick, P. (1993). An introduction to global fresh water issues. In P. Gleick (Ed.), *Water in crisis* (pp. 3–12). New York: Oxford University Press.
- Madramootoo, C. A., Johnston, W. R., & Willardson, L. S. (1997). *Management of agricultural drainage water quality* (Water Reports 13). Retrieved November 20, 2009, from www.fao.org/docrep/w7224e/w7224e00.htm
- Seelig, B., & Nowatzki, J. (2001). *Working to avoid nitrogen contamination*. Retrieved November 20, 2009, from www.ext.nodak.edu/extpubs/watnut.htm



WATER MANAGEMENT AND TREATMENT

Scientific water management is a relatively new branch of science. Yet proper use of water resources and their management and treatment (widely understood as preparing the water for various purposes) are inherently connected to development and civilizing societies on Earth. This field has recently come into prominence because of the increased water demand related to global population growth and more intense use among almost all social and industrial sectors. Compounding this, global warming and climate change scenarios on Earth forecast that water resources will diminish in many places, while intensified extreme phenomena (e.g., floods or droughts) will render the proper distribution of water resources more difficult. The diminishing quantity and quality of available water resources generate the need for their better treatment. This requires new investigation of alternate treatments such as new methods for collection precipitation or improved methods for the desalinization of seawater.

Water Management

Water management is usually supervised by governments through designated governmental agencies. Their main task is to ensure an adequate quantity and quality of water for the use of people, society, and the economy. In many countries, the institutions that are set up to supervise water management also deal with the protection of water against pollution and the protection of a country's territory against floods. Because the issues of water management are of vital global importance, many have broader implications and must be dealt with at the international level. For example, European Union member states act collectively under the "Water Framework Directive" or the "Flood Directive." International cooperation in this field is also carried out by the United Nations Educational, Scientific and Cultural Organization (UNESCO). Specialized nongovernmental organizations have also been playing a vital role recently in influencing the decisions taken in the field of water management.

Water Resources

Water belongs to the category of "depletable natural resources"; at the same time, it is also considered one of the "renewable resources." There are three basic groups of resources for meeting water needs (Table 1):

1. Atmospheric precipitation and deposits
2. Underground waters at deep water-bearing layers (with no direct recharge of surface waters)
3. Surface waters (river runoff comprising surface and shallow ground runoff)

Water Needs

Water needs are determined by the quantity of water necessary for the human population and for the functioning of those sectors of the economy that are active in a given area (region, country, continent): agriculture and forestry, industry, electrical power generation (especially hydroelectric power generation), municipal economy, and inland ship and cargo transport.

Continent	Area (million km ²)	Population (millions)		Water Resources (km ³ /yr.)				Potential Water Availability (1,000 m ³ /yr.)		
		2007	2050	Average	Maximum	Minimum	Coefficient of Variation	Per 1 km ²	Per Capita in 2007	Per Capita in 2050
Africa	30.1	944	1,953	4,050	5,082	3,073	0.10	134	4.29	2.07
Asia	43.5	4,010	5,378	13,510	15,008	11,800	0.06	311	3.37	2.51
Australia and Oceania	8.95	35	49	2,404	2,880	1,891	0.10	269	68.69	49.06
Europe	10.46	733	669	2,900	3,410	2,254	0.08	277	3.96	4.33
North America	24.3	523	718	7,890	8,917	6,895	0.06	324	15.09	10.99
South America	17.9	381	528	12,030	14,350	10,320	0.07	672	31.57	22.78
The World	135	6,625	9,294	42,785	44,751	39,775	0.02	317	6.46	4.60

Table 1 Renewable water resources and water availability by continents

Sources: Water resources data are from *World Water Resources and Their Use* (a joint State Hydrological Institute/UNESCO product). Retrieved December 1, 2009, from <http://webworld.unesco.org/water/ihp/db/shiklomanov>. Population data are from Population Reference Bureau's 2007 *World Population Data Sheet*. Retrieved December 1, 2009, from www.prb.org/pdf07/07WPDS_Eng.pdf. Potential water availability per capita calculation is by the author.

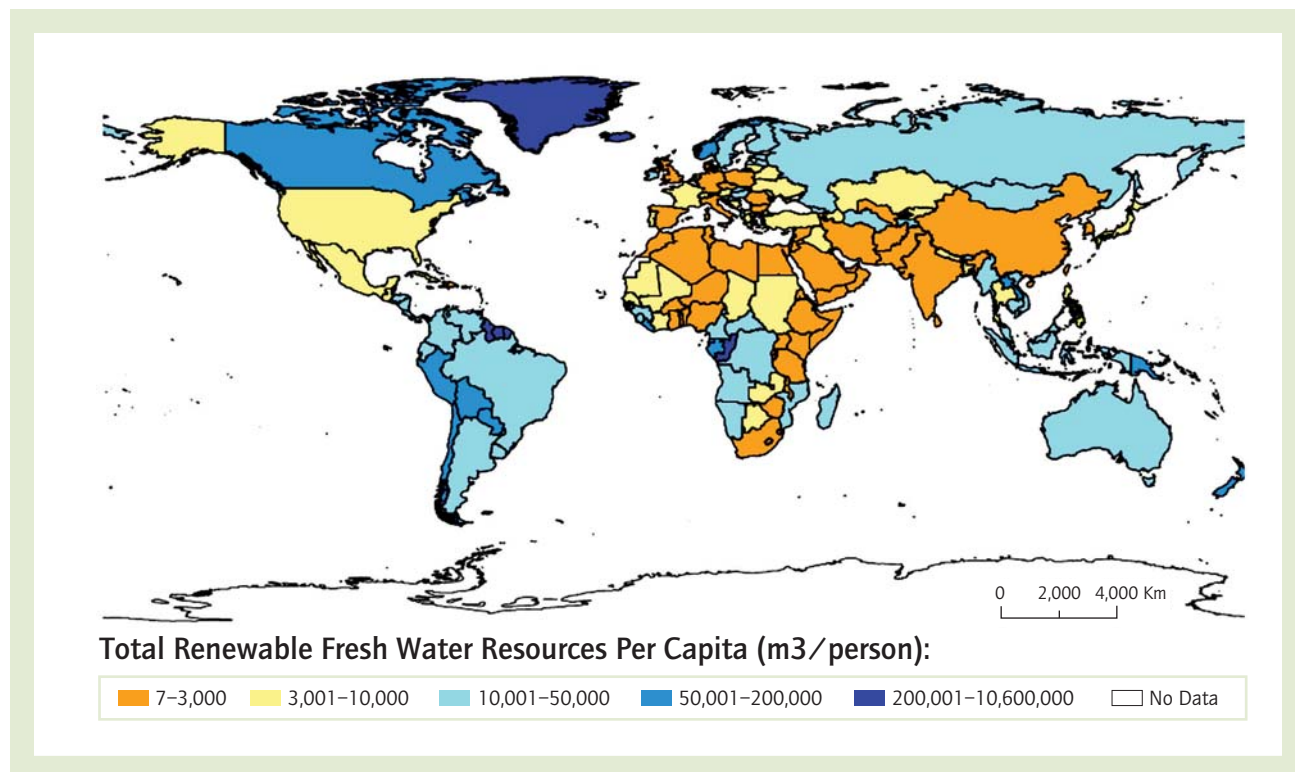


Figure 1 Total renewable freshwater resources per capita (cubic meters per person): long-term annual average

Sources: Data from EUROSTAT (Statistical Office of the European Communities), FAO (Food and Agriculture Organization), OECD (Organisation for Economic Co-operation and Development), and UNSD (United Nations Statistics Division). Map from UNSD Environmental Indicators, “Water Resources: Long-Term Annual Average.” Retrieved December 8, 2009, from <http://unstats.un.org/unsd/environment/waterresources.htm>.

It is estimated that the minimum quantity of water required for a person to drink, to use for sanitary (hygienic) purposes, and to support agricultural cultivation is 1,000 cubic meters (m³) per year (Figure 1). Existing world water resources are estimated to be sufficient to cover the minimum needs of 42.8 billion people, a figure more than six times the world population in 2007. The world's population is estimated to grow to 9.3 billion people in 2050, at which time there will still be 4,600 m³ of water available for each inhabitant of Earth (Figure 2). However, it has to be borne in mind that these figures only deal with quantity and that at present a considerable fraction of available water resources requires costly treatment.

In the future, water quality may be expected to deteriorate significantly (especially in many densely populated areas of our planet), so the actual availability of pure water may become limited. Moreover, water resources are very unevenly distributed across Earth. There are large

differences in supply and demand even within a given country or continent.

Water can be used by water *consumers* (who use it up, e.g., for agriculture and forestry, industry and heat engineering, or the general municipal economy) and also by water *users* (who take advantage of water resources without using them up, e.g., for hydroelectric power generation, inland ship transport, and water tourism and recreation). According to different estimates, around 67% of world water is used by agriculture, 20% to 25% by industry, and the rest by the municipal economy. Of course, the distribution in a particular country depends on the environmental conditions and the degree of economic and social development in that country.

Water Treatment

Chemically pure water is never found in nature. Being one of the best solvents, water contains

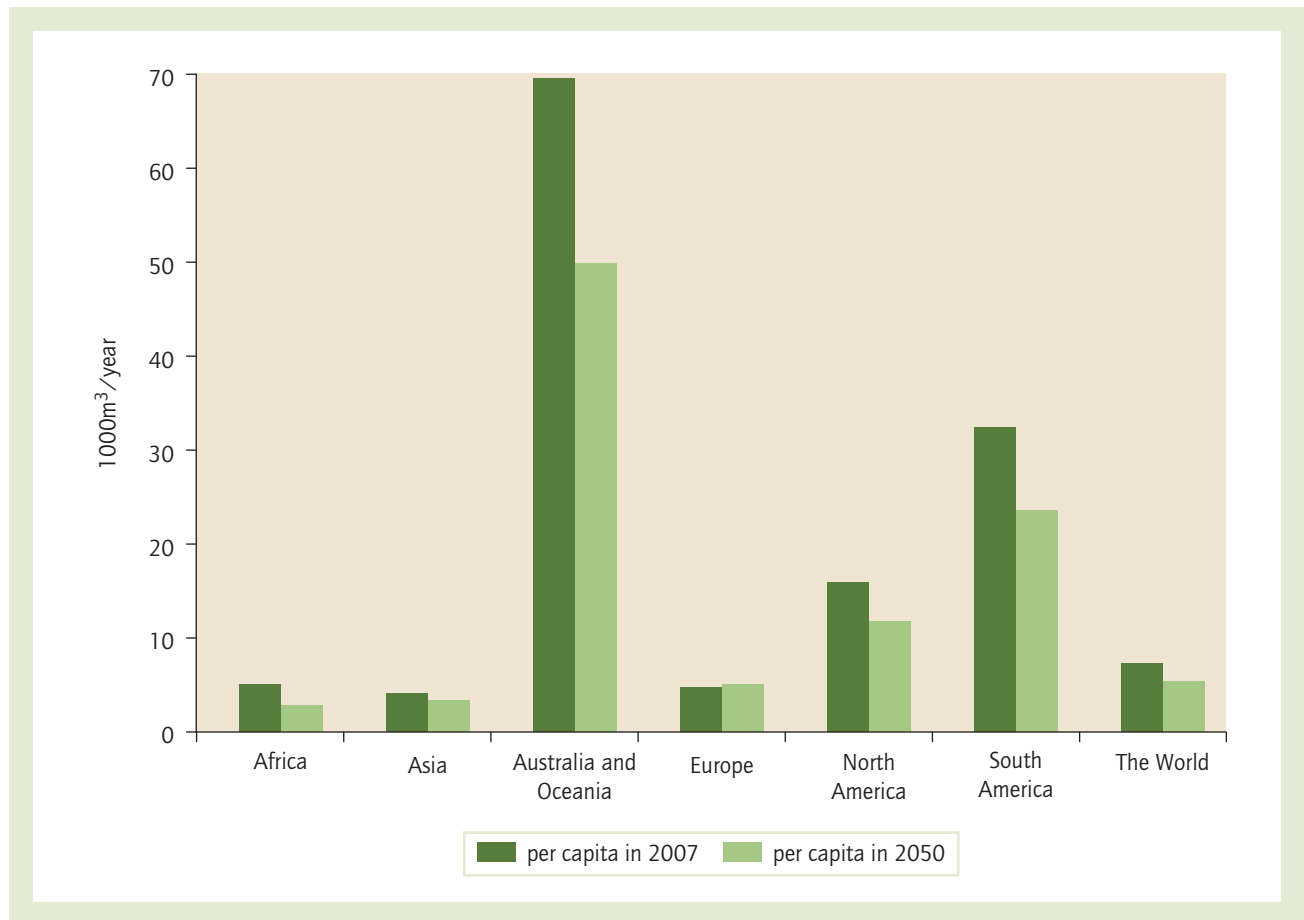


Figure 2 Potential water availability in 2007 and 2050

Source: Author.

not only hydrogen and nitrogen but also a large variety of contaminants, both chemical and bacteriological. These substances may be dissolved in water or form suspensions. Because water is a perfect habitat, it can also contain microorganisms. The products of human activities, such as agricultural and industrial waste and sewer water discharge, cause a number of pollutants to enter the water. Some contaminants can be determined organoleptically by evaluating the color, turbidity, and density of particulate matter. The most widespread chemical contaminants are metals, including manganese, aluminum, lead, zinc, and copper. The nonmetals, such as nitrate, fluoride, and phenols, appear less frequently. However, agriculture and municipal economic reasons are the cause of increasing contamination of water resources by nitrates, pesticides, herbicides, and

polychlorinated biphenyls. Microorganisms can be primarily found in water in the form of bacteria and viruses.

All these reasons explain why it is necessary to purify water. Water treatment is the process of bringing water to the state required for a specific purpose. Different processes are used depending on the end use; some processes adjust underground or surface water to make it suitable for drinking purposes, while other processes are used to adjust contaminated water (e.g., from underground mine workings) to satisfy cooling needs in conventional power plants.

Some water purification processes employ physical methods, such as sedimentation or adsorption, while others use chemical and biological methods. In addition, potable water is disinfected by chlorination, ozonation, or UV radiation (Figure 3). Potable water has to meet

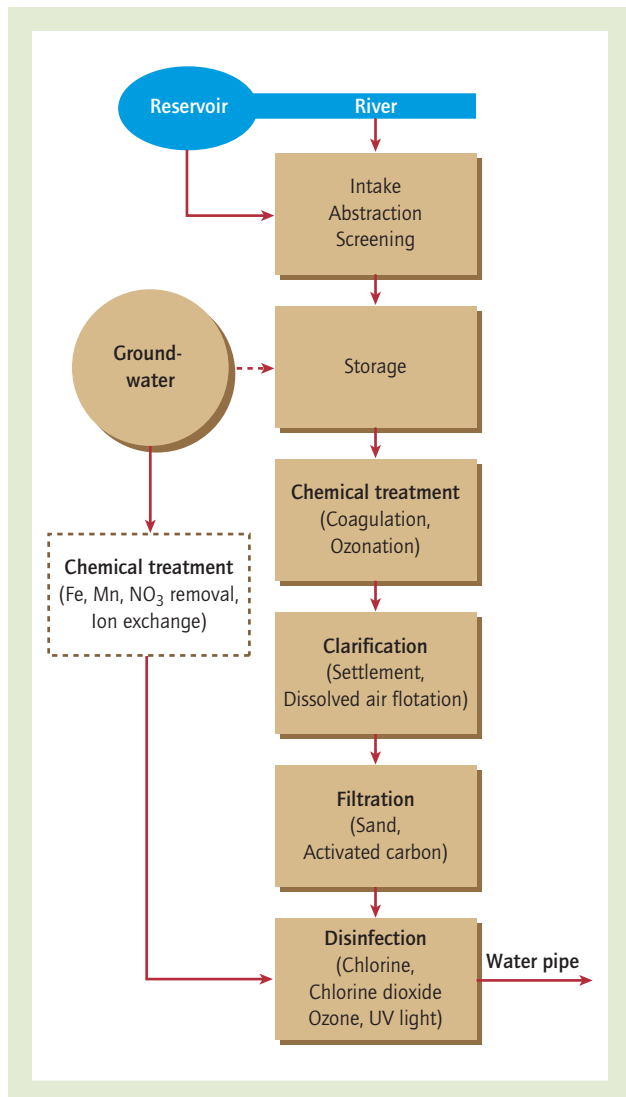


Figure 3 Potable water treatment process

Source: Author.

the requirements stipulated by state law. The World Health Organization, the U.S. Environmental Protection Agency, and the European Union provide guidelines stipulating the recommended (maximum and minimum) values of the various substances that drinking water should contain.

Water Management Problems

The principal challenges that water management agencies will have to face in the coming years include the following:

- Shortage of good-quality water (the lack of potable water and sanitary facilities is already an acute problem)
- Changes in the distribution of water resources connected with global climate change
- Natural disasters directly connected to water (floods) or causing damage to the existing natural or human-made water management infrastructure
- Conflicts caused by unequal access to water resources
- Deteriorating quality of water resources leading to higher treatment costs

Timeline of International Water Management Efforts

Today, water is considered one of the most important factors for sustainable development. The most important timeline of events that led to treating water as such is presented as follows. The majority of the documents supporting the timeline events are available through the United Nations Organization agencies.

1965–1974. The world's attention was first drawn to water issues during the International Hydrological Decade (1965–1974), initiated by the UNESCO. This program led to an unprecedented advance in the field of water science knowledge and cooperation.

1972. In this period, another important event took place—the United Nations Conference on the Human Environment—which produced an important declaration stating, “A point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental consequences” (Declaration of the UN Conference on the Human Environment). The declaration made environmental issues a priority and set the stage for further investigation into water resources.

1977. The first intergovernmental conference focusing on water issues was held in Mar del Plata, Argentina. This “UN Conference on Water” resulted in the “Mar del Plata Action Plan” with recommendations covering all the essential components of water management.



Twelve resolutions covering a wide range of specific subject areas were also adopted, making it one of the most effective and productive meetings thus far assembled concerning the subject of water resources.

1987. Ten years later, the World Commission on Environment and Development (also known as the Brundtland Commission) published a report titled *Our Common Future*. This report shaped the guiding principles for sustainable development. Although the report does not expressly address water, it contains the most commonly quoted definition of sustainable development, which is also applied to water resources: “Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.”

1992. Another advance on the sustainability path was the “Dublin Statement,” adopted by the International Conference on Water and the Environment. Its four principles are often quoted as the guiding principles of water resource management.

1992. The most comprehensive plan for global, national, and local actions in every area of human impact on the environment is Agenda 21, adopted by the UN Conference on Environment and Development meeting held in Rio de Janeiro, Brazil. Chapter 18 of the document is devoted to freshwater resources.

1996. On the initiative of water specialists and international organizations and in response to increasing concerns about world water issues among the global community, the World Water Council was established. Every third year, it organizes the World Water Forum, which is the largest periodic international event in the field of water.

2000. The UN General Assembly in New York created the Millennium Development Goals, aimed at ensuring environmental sustainability. The specific goals were to integrate the principles of sustainable development into country policies and programs, to reverse the loss of environmental resources, and to reduce by half the proportion

of people without sustainable access to safe drinking water by the year 2015.

2001. The Freshwater Consultation held in Berlin, Germany, produced two important documents: (1) the “Bonn Recommendations for Action,” focused on sustainable management of water resources, and (2) the “Bonn Charter for Safe Drinking Water.”

2002. The goal of the World Summit on Sustainable Development held in Johannesburg, South Africa, was to reinforce and fully adopt the Millennium Development Goals set out 2 yrs. (years) before. The “Plan of Implementation” of this summit includes actions related to water sustainability for the eradication of poverty and protection and management of natural resources for economic and social development. The conference also called for governments to develop integrated water resource management and water efficiency plans by 2005.

2003. In an effort to increase awareness of the importance of sustainable freshwater use, protection, and management, 2003 was designated the International Year of Freshwater. This coincided with the publication of the second *UN World Water Report*—a comprehensive review giving an overall picture of the state of the world’s freshwater resources and aiming to provide decision makers with the tools to implement sustainable use of water. This report is published every 3 yrs. and brings together the efforts of 24 UN agencies.

2005–2015. Today, we are in what has been proclaimed the Decade of Water for Life (2005–2015) by the United Nations. The primary goal of the decade is to promote efforts to fulfill international commitments on water-related issues, such as the Millennium Development Goals.

Damian Absalon

See also **GIS in Water Management; International Watershed Management; Public Water Services; Urban Storm Water Management; Urban Water Supply; Wastewater Management; Water Degradation; Water Needs; Water Pollution; Water Supply Siting and Management**



Further Readings

- Biswas, A. (Ed.). (1997). *Water resources: Environmental planning, management, and development*. New York: McGraw-Hill.
- Herschy R. W., & Fairbridge R. W. (Eds.). (1998). *Encyclopedia of hydrology and water resources*. Dordrecht, Netherlands: Kluwer Academic.
- Stewart, B. A., & Howell, T. A. (Eds.). (2003). *Encyclopedia of water sciences*. New York: Marcel Dekker.
- United Nations Educational, Scientific and Cultural Organization. (2009). *United Nations world water development report* (3rd ed.). Retrieved November 20, 2009, from www.unesco.org/water/wwap/wwdr/index.shtml
- United Nations Educational, Scientific and Cultural Organization. (n.d.). *World Water Assessment Programme: Milestones 1972–2003*. Retrieved November 20, 2009, from www.unesco.org/water/wwap/milestones/index.shtml



WATER NEEDS

Water needs are defined for the purposes of this entry as the requirements of Earth systems for water, and the entry specifically explores the interactions between humans and the environment in the use of water and the impacts of those uses on the functioning of Earth's ecosystems. The needs of Earth's ecosystems (including humans as a part of these ecosystems) for water are relevant both because water is an important aspect of human-environment interactions and also because water features, water availability, and water use are defining elements of place. Geography has a rich tradition of research on water and wetland ecosystems and human use of water resources. This entry addresses several aspects of water needs: the need of Earth's ecosystems for water, human uses of water, the impact of various human uses on water quantity and water quality, and the linkages between water and energy. In addition, it discusses the need for information and tools to better manage the world's water resources and the need for development of informed, effective water governance institutions to help alleviate potential

conflicts over this precious and increasingly scarce resource.

Water Needs of Earth's Ecosystems

The primary and most critical water need is the need for sufficient water at the appropriate time and in the required amount to sustain Earth's ecosystems, of which humans are a part and on which all life depends. As water moves through the hydrologic cycle, not only is water itself transported but also energy and materials are moved through their own biogeochemical cycles, habitat is provided for aquatic organisms, and terrestrial systems are sustained. Water and freshwater ecosystems provide numerous ecosystem services to people worldwide. Ecosystem services are the wide range of benefits provided to people through the functioning of Earth's ecosystems. This includes many types of services such as provisioning services that provide food, water, and fiber; supporting services such as transportation and cycling of materials; preservation services such as preserving plant and animal species; and cultural and aesthetic services that include social, economic, spiritual, and recreational benefits.

The allocation and management of water resources, especially in international river basins, are becoming more difficult. Increasing demands are being placed on human and environmental systems by competing water uses that include hydropower generation; flood control; agricultural, industrial, municipal, and industrial water use; flows for water quality; fish habitat and fish passage; and recreational and cultural uses. Competing interests for water are taxing the limited water supplies. The water needs of agriculture, industry, and urban areas compete with environmental claims for in-stream water or the water rights of indigenous people. Traditional water governance structures are not well suited to address the complex issues and needs of competing agents to resolve the emerging problems over water quantity and quality, nor are they flexible enough to address the projected rapid changes in the timing and delivery of water as the world's climate changes.

As part of the Pilot Analysis of Global Ecosystems, the World Resources Institute (WRI) assessed the condition, status, and trends in the world's freshwater ecosystems. WRI selected and



analyzed both quantitative and qualitative information and developed five indicators of the condition of the world's freshwater systems:

1. Human modifications of water bodies and watersheds
2. Water quantity
3. Water quality
4. Food (fish in particular)
5. Aquatic biodiversity

A major finding of this project was that the world's freshwater systems are so degraded that their ability to support human, plant, and animal life is greatly in peril.

Freshwater systems in general and wetland ecosystems in particular have been subject to serious degradation worldwide. Among the key findings of the Millennium Ecosystem Assessment (MEA) conducted by the WRI, United Nations Environment Programme, World Bank, and others were that wetland and freshwater systems have suffered greater and more rapid loss and degradation than other ecosystems worldwide and the condition of both freshwater and coastal wetland species is deteriorating faster than in other ecosystems. The authors of the MEA, which was released in 2005, identified population growth and increasing economic development as the primary indirect drivers of degradation and loss, and the primary direct drivers as infrastructure development, land conversion, water withdrawal, eutrophication, and pollution, as well as overharvesting and overexploitation of fisheries and other resources and the introduction of invasive alien species. Further key findings included the expectation for population growth and global climate change to increase the rate and extent of wetland loss, the incidence of waterborne diseases, and nutrient loading to freshwater and coastal systems. These impacts are expected to be severe and may result in the loss of many of the functions that we rely on wetlands and freshwater systems to provide, but they have been largely taken for granted until now.

Protection of these ecosystems and the services they provide is thus a critical element to consider as the world plans for the water needs of the next millennium.

Water Use

About 4,000 km³ (cubic kilometers) of water each year are withdrawn from freshwater systems for human use, an amount equivalent to about 20% of the base flow of the world's rivers. Groundwater withdrawals are estimated at approximately 600 to 700 km³/yr. (per year)—or about 20% of global water withdrawals. On a worldwide basis, agriculture withdraws the most water from surface and groundwater systems, with about 70% of water withdrawals worldwide used for irrigation. In the United States, the U.S. Geological Survey (USGS) has estimated that water withdrawals for energy production are responsible for the greatest amount of water used, with the quantities of water used for thermoelectric and thermonuclear power generation slightly higher than those withdrawn for agriculture. Human use of freshwater has altered both the amount of water delivered to rivers, streams, and wetlands and the timing of its delivery. These changes have resulted in the decline and even the extinction of freshwater plant and animal species and may impair the ability of freshwater ecosystems to sustain themselves.

Water scarcity now affects much of the world, according to the United Nations Comprehensive Assessment of the Freshwater Resources of the World. About 40% of the world's population—roughly 2.3 billion people—live in regions with a per capita water supply of less than 1,700 m³/yr. About 1.7 billion people live in river basins where water supply is less than 1,000 m³/yr., and nearly 10% of the world's population suffers from serious water shortages.

Water Quality

Water quality appears to have degraded worldwide with the growth of intensive agriculture and large urban/industrial areas. Water pollution is a major cause of death and disease in the developing world, although surface water quality has improved in North America and Western Europe with respect to some pollutants such as phosphorus and some pesticides. Nonpoint source pollution from agricultural runoff is still a concern, however, even in the richest nations of the developed world. The delivery of nitrogen to coastal



regions worldwide is expected to increase by 10% to 20% in the next two decades.

Water for Agriculture

In the late 1990s, irrigated agriculture accounted for 40% of the global food production, even though just 17% of the global cropland is irrigated. This reflects the disparity between the productivity of rain-fed systems versus irrigated systems. Agriculture is society's major user of water, withdrawing 70% of all water worldwide, according to the World Meteorological Organization.

Water and Energy

Water and energy are highly linked throughout the world. Water is both a source of electric power and a resource that requires energy to obtain or distribute to places where it is needed. The production of many forms of energy, not only hydropower but also thermoelectric and thermonuclear power, requires the use of water for cooling. Often, when people remove water from a river or stream for use, the water returns to that stream at a warmer temperature. In the United States, there has been a growing recognition of an "energy-water nexus," or an interaction between water and energy. Of the total electricity generated in the world, hydropower generated approximately 18% of the electricity used worldwide in 2006 and accounted for about 5% to 6% of overall energy use. There are 19 countries that rely almost entirely (90% or more of electricity generated) on hydropower for generation of electricity, including Brazil, Norway, Burundi, and Laos.

Water and Wetlands at the Land-Sea Margin

Nutrient pollution and the resulting algal blooms are more frequently observed in both inland and coastal systems around the world. At least 415 coastal areas have been identified by the WRI as experiencing some degree of nutrient enrichment; more than one third of the areas identified have been affected so severely that the oxygen concentrations in the coastal waters have become low enough (<2 parts per million) to be lethal to

marine organisms for a portion of the year. As a result of this nutrient pollution, primarily from agricultural runoff, more and more coastal regions are being affected by the zones of low oxygen concentration, threatening coastal and marine life and the associated fish and shellfish production from nearby fisheries.

The loss of coastal wetlands and the protection they provide to coastal ecosystems has been blamed for both the increased impact of eutrophication and the increase in damage resulting from the unmitigated wave and wind energy of hurricanes and tropical storms.

Restoration of coastal wetlands would protect valuable coastal regions that are presently vulnerable to damage from hurricanes, tropical storms, and tsunamis. Restoration of riverine wetlands could help lower the delivery of nutrients to coastal waters, decreasing problems with hypoxia and preventing the loss of economic benefits from the harvest of shellfish and fin fish. In addition, land management practices that reduce nutrient pollution and sediment export from cropland would benefit both the aquatic systems within agricultural watersheds and the coastal environments downstream.

Water and Society

The human and cultural dimensions of our relationship with water are perhaps the most difficult to assess, describe, and quantify; yet our cultural, aesthetic, and spiritual relationships with water are among the most powerful forces spurring society to action. Connection to place, and often to places that are characterized by the presence of water, has been recognized as an important aspect of the development of a conservation ethic. Water is an integral part of religious ceremonies in many cultures, and specific water bodies (such as the Ganges River for Hindus) are sites of holy pilgrimage.

Reliable Information on Water Use

Current efforts toward global assessments of the condition and trends of freshwater ecosystems worldwide are hampered by the lack of standardized, comprehensive data collection and by the transboundary nature of many of the world's



watersheds and river basins. Hydrologic stations around the world have been declining over the past three decades, and some important data (such as the location of small dams 15 meters in height or less) have not been collected. In the United States, annual threats to the budget of federal agencies charged with monitoring stream flow and water quality (i.e., the USGS and the U.S. Environmental Protection Agency [EPA]) have affected water-monitoring programs such as EPA's Index of Watershed Indicators (IWI) program (26% of U.S. watersheds have insufficient data for classification with this index) and the USGS National Water-Quality Assessment (NAWQA) program. In addition, funding for the 50 state Water Resources Research Institutes has been threatened annually throughout the early part of this millennium. Scientists who rely on such programs for critical data on the nation's water resources must expend substantial energy each year in attempting to reinstate funding for these programs. Consistent underfunding of NAWQA has required the USGS to prioritize watersheds for monitoring, shifting focus from region to region every few years rather than maintaining long-term, continuous monitoring programs in the 60 basins identified as a representative sample of watersheds nationwide.

The collection of comprehensive, basic hydrological and geochemical data worldwide would significantly enhance the ability to monitor the status and condition of the world's freshwater resources and to anticipate and address threats to freshwater ecosystems. To manage water resources effectively, water scientists need to develop a global database that will allow the monitoring of precipitation, runoff, stream discharge, withdrawals for various uses, and water quality data collected, using the standard methodology. Key water quality variables that need to be measured include sediment and dissolved organic carbon, temperature, nutrients (especially compounds containing nitrogen and phosphorus), bacteria, and the occurrence and abundance of organisms that cause waterborne diseases.

Data concerning groundwater withdrawals are even more difficult to obtain than data on surface water withdrawals, compounding the difficulty in understanding current uses or forecasting the sustainability of the world's water supplies. The WRI

recommends the compilation of a global data set on groundwater resources (including their distribution, capacity, and use) and has encouraged national governments to establish water-quality-monitoring programs that combine chemical and biological measures of water quality for both surface water and groundwater.

Finally, information concerning the value of ecosystem services provided by freshwater ecosystems, including wetlands, lakes, rivers, and streams, should be placed in the hands of decision makers. Decision makers at many levels are often uninformed concerning the value of the many ecosystem services provided by freshwater ecosystems and the benefits these systems provide to people. As a result, their decisions are seldom informed by even semiquantitative estimates of the economic value of both the marketed and the nonmarketed services provided by freshwater ecosystems, leading to an undervaluing of those services in decision making.

Conclusion

Freshwater is one of the world's most precious as well as most threatened resources. Conservation of existing freshwater resources, protection of surface and groundwater from pollution and overuse, and distribution of clean water for drinking and household use to regions where water is scarce will be among the greatest challenges to the national governments of the world in the next century, as population increases and clean water becomes increasingly scarce. Strengthening and informing the institutions responsible for water governance will also be critically important in ensuring that the water needs of the future are met.

Mary V. Santelmann

See also **Agrochemical Pollution; Anthropogenic Climate Change; Coastal Dead Zones; Environmental Services; Groundwater; International Watershed Management; Nonpoint Sources of Pollution; Urban Water Supply; Wastewater Management and Treatment; Water Degradation; Water Management and Treatment; Water Needs; Water Pollution; Water Supply Siting and Management; Watershed Management; Watershed Yield; Wetlands**



Further Readings

- Fekete, B., Vörösmarty, C. J., & Grabs, W. (1999). *Global, composite runoff fields based on observed river discharge and simulated water balance* (Report No. 22). Koblenz, Germany: World Meteorological Organization, Global Runoff Data Center.
- Kjellen, M., & McGranahan, G. (1997). *Comprehensive assessment of the freshwater resources of the world*. Stockholm, Sweden: Stockholm Environment Institute.
- Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Wetlands and water synthesis*. Washington, DC: World Resources Institute.
- Nassauer, J. I., Santelmann, M. V., & Scavia, D. (Eds.). (2007). *From the corn belt to the Gulf: Societal and environmental implications of alternative agricultural futures*. Washington, DC: Resources for the Future Press.
- Revenga, C., Brunner, J., Henninger, N., Payne, R., & Kassem, K. (2000). *Pilot analysis of global ecosystems (PAGE): Freshwater systems*. Washington, DC: World Resources Institute.
- Selman, M., Greenhalgh, S., Diaz, R., & Sugg, Z. (2008). *Eutrophication and hypoxia in coastal areas: A global assessment of the state of knowledge*. Washington, DC: World Resources Institute.
- World Resources Institute. (2008). *EPA partners with WRI to heighten awareness of ecosystem services*. Retrieved December 1, 2008, from www.wri.org/press/2008/10/epa-partners-with-wri-heighten-awareness-ecosystem-services

in aquatic ecosystems. Pathogens serving as typical microbiological pollutants cause many illnesses ranging from typhoid and dysentery to minor respiratory and skin diseases. Chemical pollutants are poisonous to aquatic life, birds, animals, and people. Excess inputs of nutrients from agricultural management lead to eutrophication—the excessive growth of algae, periphyton, and weeds, which can deplete dissolved oxygen to the detriment of fish, reduce potability, and preclude recreational uses of water. Suspended sediment threatens aquatic ecosystems directly and indirectly. Reduction of light penetration due to the presence of suspended sediment directly reduces photosynthesis. In addition, sediment smothers bottom-dwelling organisms and clogs fish gills, prevents successful development of fish eggs and larvae, and modifies fish movement and migration. Indirectly, suspended sediment serves as a carrier for the nutrients, metals, and organic biocides that adsorb to the sediment.

Because of the complex interaction between groundwater and surface water, groundwater pollution, sometimes referred to as groundwater contamination, is not included here. Surface water pollution is generally classified by sources into point and nonpoint source pollutions. Point source pollution refers to the process by which harmful substances enter a waterway through a discrete conveyance, such as a pipe or a ditch. Examples of point sources include discharges from a sewage treatment plant or a factory, or a tributary that transports pollutant loads into the main stream. Nonpoint source pollution refers to diffuse contamination that does not originate from a single discrete source. It is often a cumulative effect of small amounts of contaminants gathered from a large area. Nutrient runoff in storm water from “sheet flow” over an agricultural field or metals and hydrocarbons from an area with highly impervious surfaces and vehicular traffic are sometimes cited as examples of nonpoint source pollution. Different types of nonpoint source pollutants derive from different types of sources. Suspended sediment is largely originated from cultivated agricultural lands, deforested areas, urban construction sites, dirt roads, and even eroded channel banks. Phosphorus inputs mainly come from fertilizer applied to agricultural soils and



WATER POLLUTION

Water pollution occurs when harmful materials are introduced into the lakes, rivers, oceans, and groundwater. These harmful materials are referred to as pollutants. There are a variety of pollutants ranging from biological (e.g., bacteria and viruses) to chemical (e.g., metals, solvents, pesticides, and floating detergents and oils) forms, and from nutrients (e.g., phosphorus and nitrogen) to suspended sediment. They cause diverse problems



manure supplied from concentrated livestock operations. Although, part of it (about 30% of the total input in the United States and Europe) can be sequestered by crops, the majority of applied phosphorus remains in the upper 10 centimeters of soils in the agricultural fields or exports to surface waters by erosion or leaching. In the United States and Europe, only 18% of the nitrogen input in fertilizer is removed from farms in produce. The surplus of nitrogen may accumulate in soils, erode, or leach to surface water and groundwater. Some may enter the atmosphere through volatilization of NH_3 (ammonia) and microbial generation of N_2O (nitrous oxide). Much of the nitrogen volatilized to the atmosphere is subsequently redeposited on land or water and eventually returns to aquatic ecosystems.

The degree of water pollution can be quantified by water quality, the physical, chemical, and biological characteristics of water in relationship to a set of standards. The most commonly used criterion for measuring water quality is the total maximum daily load (TMDL), which is a calculation of the maximum amount of a pollutant type that a water body can receive and still safely meet the water quality standards. The TMDL is the sum of the individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, and a margin of safety (MOS)—that is,

$$\text{TMDL} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}.$$

According to the U.S. Clean Water Act Section 303 implemented in 1972, each state is required to identify and list the impaired water bodies based on its TMDL standards.

Pollutant loads from point sources such as municipal sewage treatment plants tend to be continuous, with little variability over time. Often they can be monitored by measuring water discharge and pollutant concentrations periodically at a single place. Consequently, point sources are relatively simple to measure and regulate and can often be controlled by treatment at the sources. The primary focus of legislation and efforts to curb water pollution for the past several decades was on point sources. However, it is well-known that nonpoint sources are now the

dominant inputs of both sediment and nutrient pollutants in most U.S. surface waters. Therefore, greater attention has been placed on the contributions from nonpoint sources, especially in rapidly urbanizing or developing areas. Nonpoint source pollutants often derive from extensive areas of land and are transported via overland and underground or through the atmosphere to receiving waters. Therefore, estimation of nonpoint source pollution loads is much more difficult because the diffusive nature of the sources means that the affected area is extensive and hard to identify due to the complicated processes of pollutant movement.

Physical processes relevant to nonpoint source pollution are easier to understand from the perspective of the watershed, which refers to the area of land where all the water that is under it or drains off it goes into the same place, termed the *outlet*. A watershed is a basic geomorphic unit that can be appropriately divided into two components: hillslope lands and the stream network connected to them. Nonpoint sources of pollution are typically located in hillslope areas, but the associated pollutants can affect a large portion of the downstream area by their movement with surface and subsurface flow. The processes of pollutant transport may be described as solid particulate transport and dissolved substance movement, respectively. The former includes suspended sediment and particulate phosphorus and other compounds that can be absorbed on sediment, whereas the latter mainly contains dissolved phosphorus and nitrogen. Suspended sediment is transported by surface runoff. A large proportion of phosphorus is transported with suspended sediment. Therefore, the concentration of phosphorus in water bodies is normally positively related to that of suspended sediment if management practices for phosphorus are not implemented. Nitrogen is primarily transported in dissolved form through surface runoff and subsurface or groundwater through infiltration and leaching.

The processes of pollutant transport are complex. Soils eroded from nonpoint sources such as agricultural fields and construction sites in hillslope areas of a watershed are transported by surface runoff due to rainfall or snowmelt in the form of rill or interrill flow (collectively termed *overland flow*) into the connected branches of the stream

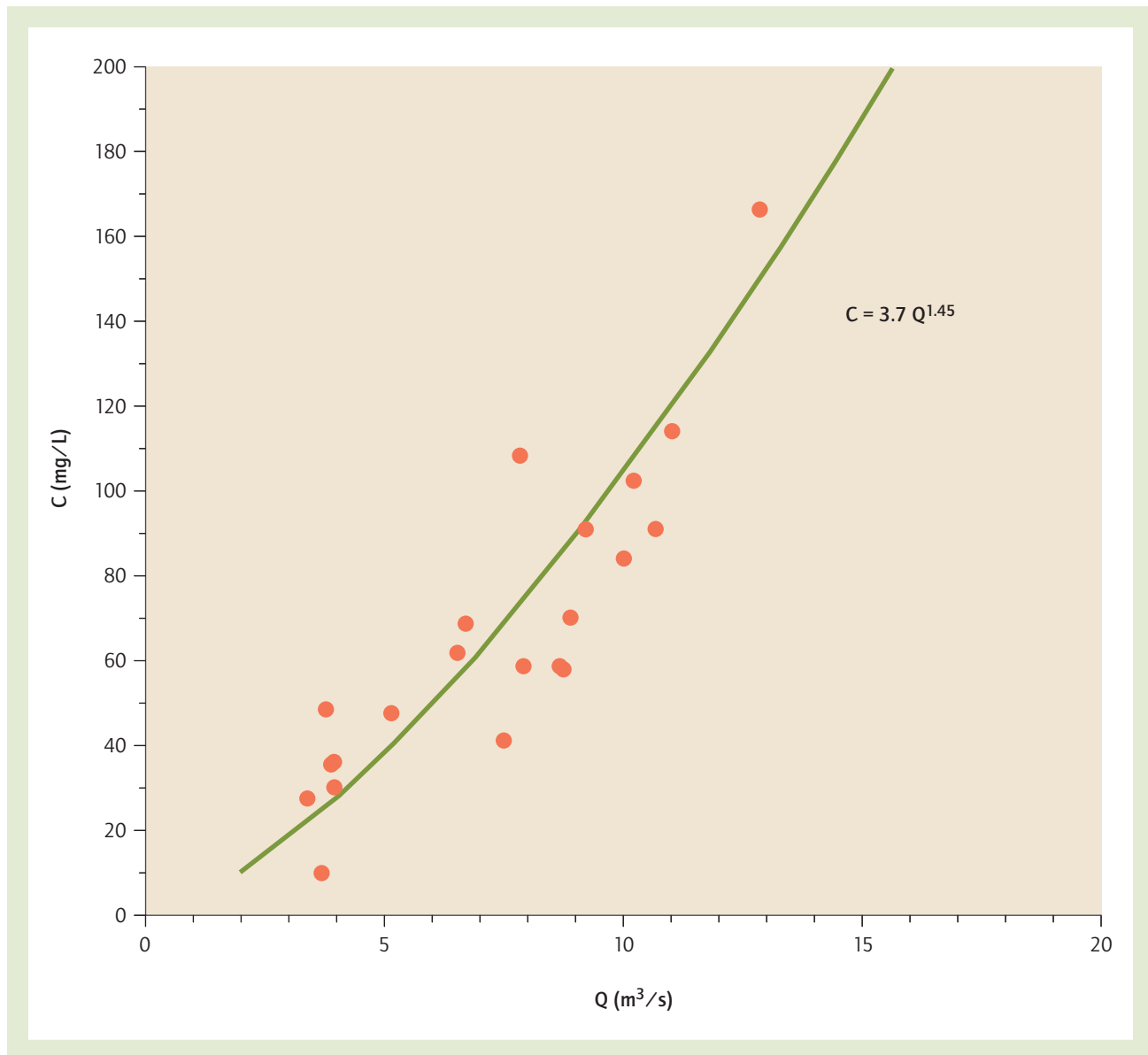


Figure 1 A sediment-rating curve

Source: Author.

network. Part of the transported suspended sediment may be deposited in the stream bed and resuspended later. Therefore, the processes of suspended sediment transport are controlled by the intensity and duration of rainfall or snowmelt events, hillslope topography, land use and land cover, and in-channel hydraulic dynamics. These processes typically vary with both space and time.

Suspended sediment transport has been extensively studied for decades. Usually, suspended

sediment load Q_s is determined by establishing a sediment-rating curve (SRC) (Figure 1), which is a mathematical relationship between Q_s (or sediment concentration C) and Q

$$M = aQ^b,$$

where M is either Q_s or C , and a and b are rating curve parameters determined by regression analysis using data obtained via in situ sediment



sampling. Different values of a and b may be caused by factors such as different rainfall events or different extents of new sediment sources. The SRC method significantly reduces the sampling number required for estimating Q_s , compared with the traditional sampling method. It has been widely used to determine Q_s for a stream reach or an entire watershed for a single hydrological event, a year, or more than a decade. However, many watersheds do not have a functional relationship between the two variables, suggesting that Q may not be the only independent variable that controls Q_s . This is mainly because sediment transport is essentially not at capacity. Consequently, Q only reflects the available hydraulic capacity of transporting sediment. The actual in-channel sediment load can also be limited by sediment supply, which is related to many other environmental variables, such as topographic conditions, soil types, land use, and land cover. In these watersheds, if data for a hydrological cycle (e.g., a rainfall event) are plotted in the diagram of C against Q , the peak value of C is not in phase with that of Q . Instead of following an SRC curve, the data form a loop termed a *hysteresis loop*. The dynamic link between nonpoint sources and in-channel sediment transport may be revealed by analyzing the orientation of the loop, termed *hysteresis analysis*. For example, a clockwise loop may indicate that the upstream channel is the main sediment source or sediment depletion occurs on a hillslope, whereas an anticlockwise loop may suggest that sediment is directly derived from hillslope agricultural lands or there exists an additional sediment source due to bank erosion or sediment supply from upstream tributaries (see Figure 2).

The dynamics of phosphorus and nitrogen transport during a single hydrological event may be characterized by both the SCR method and the hysteresis analysis. The latter can be typically associated with the method of establishing a pollutogram, expressed as

$$F = X^\beta,$$

where F and X are the cumulative percentage of the total amount of a pollutant and water for a single hydrological event, respectively, and β is the coefficient, whose values of greater or less

than 1 indicate that the pollutant arrived predominantly toward the beginning or end of the event, respectively. The value of 1 for β signifies that the pollutant concentration is constant during the event.

In addition to temporal variation, pollutant transport also varies in space. The spatial distribution of pollutant loads has been conventionally characterized using various process-based watershed models, which use various mathematical equations to describe the hydrological, sediment, and chemical processes involved and automatically link the solutions of the equations among spatial elements in terms of physical principles such as mass balance and wave propagation. According to their different spatial arrangements, watershed models may be generally categorized as lumped and distributed models. In the former, such as the Dynamic Watershed Simulation Model and the Soil and Water Assessment Tool, a watershed is divided into limited, relatively coarser areas assuming that variations of various physical processes controlling pollutant transport within each area are negligible. In the latter, such as the Annualized Agricultural Nonpoint Source Pollution model and the Better Assessment Science Integrating Point and Nonpoint Sources model, however, a watershed is dissected by a grid with regular sizes, and each cell has values representing its physiographic conditions. The lumped models are relatively simple and easy to use, but they may inappropriately ignore the process variations within the spatial elements used in the models. The distributed models can accurately characterize the processes involved in pollutant transport at very small spatial scales, but often their input files are very complicated, and some of the required input parameters are not known and have to be artificially created. With respect to predicting pollutant load for the entire watershed, both types of models behave similarly.

Peng Gao

See also Agrochemical Pollution; Coastal Zone and Marine Pollution; Nonpoint Sources of Pollution; Point Sources of Pollution; Wastewater Management; Water Degradation; Water Management and Treatment; Water Supply Siting and Management

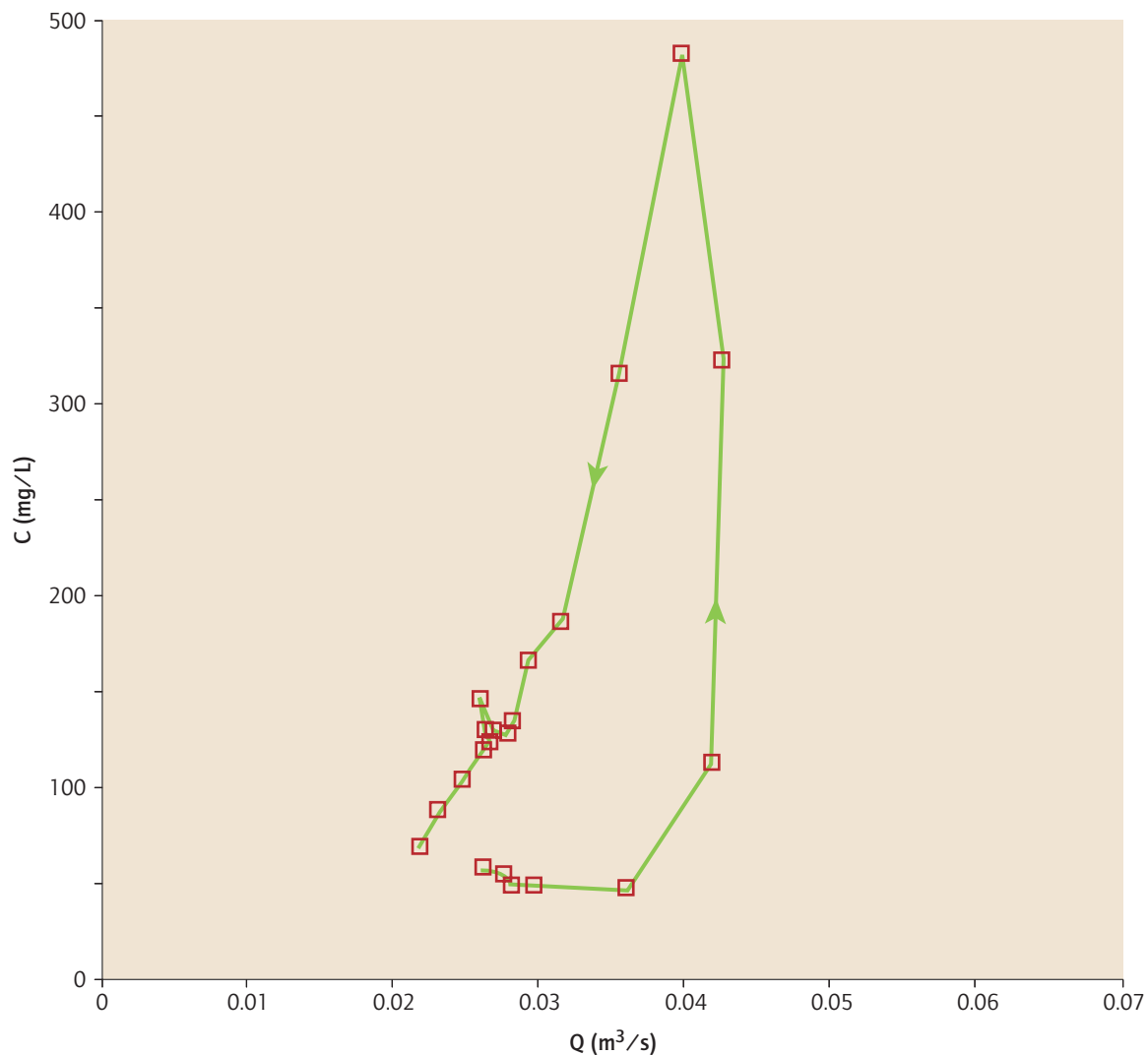


Figure 2 An anticlockwise loop

Source: Author.

Further Readings

Carpenter, S. R., Caraco, N. F., Correll, D. L., Howarth, R. W., Sharpley, A. N., & Smith, V. H. (1998). Nonpoint pollution of surface waters with phosphorus and nitrogen. *Ecological Applications*, 8(3), 559–568.

Gao, P. (2008). Understanding watershed suspended sediment transport. *Progress in Physical Geography*, 32(3), 243–263.



WATERSHED MANAGEMENT

Water management is a very broad term that pertains to the design and deployment of planning approaches to access and supply water. The term encompasses the planning and provision of water quantity (adequate volume of supply), water quality (safety of source), and also flood protection. Originally the term implied provision of water only for people, but more recently it has begun to



incorporate adequate supply and quality for the natural environment—namely, wildlife and its habitat. Water is essential for all life, and an increasing number of locations encounter either water quantity or quality concerns. This entry discusses water quantity, the philosophies of managing water quantity in the United States, water quality, flood protection, and water management through good governance.

While more of Earth's surface is covered by water (approximately 70%) than land, because of the vast size of the oceans, the majority of the planet's water is saltwater (97.5%). Of the 2.5% of water that is *freshwater*, approximately 70% is frozen in the Arctic and the Antarctic or is effectively inaccessible to humans as soil moisture or deep groundwater. Of the world's total water, only about 0.007% is freshwater available for human use. Freshwater is a globally scarce resource, and it also has a highly variable distribution depending on location and climate. Water management is a core topic of geography as it links both natural systems and human action. A watershed is geographically defined in hydrology as consisting of all areas that drain to a common waterway. While watershed-based management is the logical approach to benefit hydrology, watersheds often transcend political boundaries, making watershed management more challenging.

Water Quantity

Provision of an adequate volume of freshwater supply, or water quantity, is a primary concern of hydrologists, planners, and other individuals responsible for water management. While freshwater is globally scarce, its distribution is highly variable, which means that different locations encounter distinctive challenges to provide freshwater supply for human and industrial use. For example, arid regions in the southwestern United States have severe water shortages, while water-rich areas along the Great Lakes (the United States and Canada) have plentiful supply.

In general, management of water quantity is best approached at the drainage basin or watershed scale, which is the extent of land (the catchment area) that channels snowmelt and rain drainage into a waterway. However, water, particularly

lakes and rivers, has been traditionally used as a convenient geographic feature of the landscape to divide land into different political boundaries. This means that many watersheds cross political boundaries at different scales. Some examples of transboundary rivers include the Colorado River, which forms part of the boundary of Arizona with Nevada and California, and the Ohio River, which forms the southern boundary of Ohio, Indiana, and Illinois and the northern boundary of West Virginia and Kentucky. Some national boundaries are also formed by rivers, such as the Jordan River, which flows along Syria, Israel, Palestine, and Jordan, or by lakes, such as the Caspian Sea, which borders Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan.

Even if water is not the actual boundary, water also flows through different political boundaries, making the management of water politically challenging. Consider, for example, the Tigris and the Euphrates rivers, which have headwaters in Turkey and flow through Syria and then into Iraq. Depending on their position within the watershed, nations often adopt different views as to how water management should be approached. Turkey views the Tigris and Euphrates system, which is sourced in that country, as a resource that it has the right to contain and has built the Ataturk dam and other smaller dams to manage the flow of water from Turkey into Syria. Downstream, Syria and Iraq argue that they have a right to the water that traditionally flowed through the rivers' water course and contest Turkey's right to restrict the rivers' flow north of their borders. In a world with a growing population and an increasing demand for limited water, water management is a real source of conflict, particularly where watersheds cross political boundaries. Indeed, several books have explored the issue of wars over access to water. Even within nations, there can be conflict over how water should be allocated. One recent example in the United States is the dispute between Virginia and Maryland about the right of a growing suburban county in Virginia to access additional water from the Potomac River. That this dispute had to be settled by the U.S. Supreme Court in 2003 demonstrates the intensity of conflict surrounding access to water.



Philosophies of Managing Water Quantity in the United States

Within the United States, water allocation is within the purview of individual states, and there are two philosophies about how water allocation should be managed. The Mississippi River geographically divides the two different philosophies, with the *right-to-use* riparian doctrine to the east and the *prior appropriation* doctrine to the west. The demarcation of these is linked to both the biogeography of the regions and the historical uses of the water.

Right to Use

The right-to-use doctrine means that property owners along rivers and lakes have a right to reasonable use of the water as it flows past their property. Use is considered reasonable if the quantity and quality of flow are not diminished, preventing other riparian users from making reasonable use of the water. The right-to-use doctrine is used in states with moister climates and more plentiful water sources, though as with the example of Virginia and Maryland above, even locations that traditionally had larger volumes of water are encountering water management conflict with the rising population and increased use of water resources. Increasingly, the right to use depends on governmental regulation to monitor the reasonableness of use. This regulated riparian system is administered by state agencies that apply the principles of reasonable use to issue permits for the use of or discharge into water.

Prior Appropriation

Prior appropriation became the method for water allocation in the western states because of their drier climate. Historically in the west, fewer people sought the rights to use water in association with mining claims and, later, for agricultural irrigation. With the higher annual variability in rainfall in the region, there was greater uncertainty about availability of water. Moreover, in the western states, where water is limited, limiting the use of water to only adjacent landowners would also limit the number

of settlements because nonriparian lands would have significantly diminished productivity. Hence, unlike the right-to-use doctrine, the prior appropriation doctrine separates water rights from land ownership. The principle of the prior appropriation doctrine is commonly explained as “first in time, first in right,” because it is a system where the earliest water users have rights to water that take precedence over subsequent claims. Through the prior appropriation doctrine, water rights entail the diversion of water from its source for a beneficial use. If appropriated water is no longer put to beneficial use, that right is lost as the right passes to the next user with a claim; this “use it or lose it” attribute of the prior appropriation system is not conducive to water conservation by users with early rights.

The growing population of the western states, high rainfall variability, and increasing demand for water mean that in years of low rainfall some rivers would effectively run dry. For example, the transboundary Colorado River, whose allocation was determined in the years following particularly high rainfall, has been so depleted that only a trickle enters Mexico, and in some years, the river no longer consistently reaches the sea, with devastating effects on wildlife and habitats in former wetlands and coastal areas.

Minimum Flows and Levels

The potential for devastation of the environment through overappropriation of water, particularly in low-rainfall years, in the 1990s led to an effort to devise a system to protect the environment, working in concert with the prior appropriation doctrine, in the watersheds of the western states. The western states now have instituted laws that ensure *minimum flows and levels* within watercourses to provide for the needs of habitat and wildlife. Rising demands for water in the eastern states under the right-to-use doctrine have also led to the formulation of water management regulations to protect minimum flows and levels for wildlife. One example is within the South Florida Water Management District. Here, the water management system has been significantly modified to incorporate



An upstream small dam, terraces, buffer strips, grass plantings, and other conservation measures are part of a project designed to improve the quality of water entering Union Grove Lake in Tama County, Iowa.

Source: Lynn Betts, USDA Natural Resources Conservation Service.

the needs of wildlife and its habitat for water of adequate quantity and quality.

Water Quality

While conflicts surrounding water allocation relate to the ability of competing interests to access sufficient quantities of water, water quality issues largely pertain to concerns over the deterioration of water as a result of pollutants entering waterways. Water quality issues tend to manifest more in downstream portions of rivers, which experience accumulation of pollution from upstream. Two types of pollution can occur: (1) from *point sources*, that is, single identifiable sources such as factory pipes discharging effluent into a river, and (2) from *nonpoint sources*, which consist of many diffuse sources, including water runoff moving over or through the

ground transporting urban pollutants, fertilizers, contaminated sediments, or biological waste.

Point source pollution is easier to regulate than nonpoint source pollution. One of the key challenges of managing nonpoint source pollution is that while the individual activities may fall within environmental safety guidelines, the cumulative effect in the watershed is the creation of unsafe levels of pollution. While, at an additional expense, water can be treated to improve water quality before distribution for human consumption, poor water quality also has a deleterious effect on the natural environment. For example, in the Florida Everglades, elevated levels of naturally occurring phosphorus have resulted in a shift from natural to invasive vegetation, resulting in a negative effect on wildlife, including endangered species.

Flood Protection

Flood protection is a high-profile aspect of water management. Flood protection largely entails protecting homes, roads, and other aspects of the built environment from inundation during high-water events. In many locations, flooding is part of the natural cycle of a watershed. For example, until the Aswan Dam was constructed, the Nile River annually overflowed its banks, depositing soil sediments and making the area fertile for agriculture. Throughout the world, many dams and levees have been built in an attempt to prevent flooding of property. While these water management structures offer some stabilization of water levels and flood protection, they may be unable to provide protection from extreme high-water events and also may have deleterious effects on the environment.

In addition to protection from flooding of rivers, flood protection encompasses protection of coastal areas from hurricanes, typhoons, and storm surges. Recent events have demonstrated the devastating effects of inadequate coastal defenses, such as the 2004 tsunami and the breaking of the New Orleans levees by Hurricane Katrina in 2005. Beyond surface inundation, flood protection is also important for preventing saltwater intrusion of freshwater aquifers, which once contaminated may take many years to be usable again for human's freshwater needs.

Managing Water Through Good Governance

Water management concerns in the 19th and 20th centuries were understood as technical issues to be solved by hydrologists and engineers. Since the end of the 20th century, there has been a shift toward understanding water management concerns not only as engineering challenges but also as highly contested, often politicized, issues that require the engagement of wider stakeholders toward designing sustainable and equitable water management strategies. Good governance of watershed-based management requires the inclusion of wider-ranging nongovernmental interests in shaping water management policy for a given watershed, which

is important in light of increasing demands for limited water. One example where water management practices were significantly modified through the integration of wider stakeholder groups in a watershed-scale planning process was in South Florida. Through the involvement of competing stakeholders, a common vision emerged for improving water management. This perspective included a shift in focus from primarily water supply and flood protection to provision for the environment toward securing the long-term sustainability of the water supply to meet an anticipated growth in both human demands and environmental needs.

Mary Dengler

See also **Everglades Restoration; Hurricane Katrina; Indigenous Water Management; International Watershed Management; Nonpoint Sources of Pollution; Participatory Planning; Point Sources of Pollution; Wastewater Management; Water Management and Treatment; Water Needs; Water Supply Siting and Management; Watershed Yield**

Further Readings

- Dengler, M. (2007). Spaces of power for action: governance of the Everglades restudy process (1992–2000). *Political Geography*, 26, 423–454.
- De Villiers, M. (2001). *Water: The fate of our most precious resource*. New York: Houghton Mifflin.
- Gleick, P. H. (Ed.). (2006). *The world's water 2006–2007*. Washington, DC: Island Press.
- Pearce, F. (2006). *When rivers run dry*. Boston: Beacon Press.
- Postel, S. (2003). *Rivers for life*. Washington, DC: Island Press.



WATERSHED YIELD

The ebb and flow of sediment movement in a watershed is spatially and temporally complex and difficult to quantify. However, attempting to quantify and understand sediment dynamics in a watershed is important for the successful management of aquatic and terrestrial ecology and



the associated health of the watershed. Soil erosion is a worldwide problem that has degraded small and large watersheds. Estimating the sediment yield of a watershed helps resource managers understand the amount of soil erosion that exists and how much sediment is stored in the watershed. Within the fluvial hierarchy, watersheds provide a spatial framework by which the physical and environmental metrics influencing sediment movement can be evaluated. A watershed is defined as the contributing area of land that captures and drains precipitation to an outlet point, which does not have to be a stream or lake confluence. Rather, the outlet can be a point on a stream reach, and the contributing area of the watershed would be delineated from the predefined point.

Sediment yield in a watershed is quantified using the amount of sediment passing a point in the watershed per some unit of volume per time (i.e., cubic meters per kilometer per year) or mass per time (kilograms per square meter per year). Sediment yield can be estimated by coring reservoirs and lakes, performing suspended sediment sampling at the outlet, direct site observation and calculation of erosion, and computer modeling. Reservoirs and lakes act as sediment traps and through coring or bathymetric surveys can provide an insight into temporal and spatial changes of sediment routing through the watershed. Suspended sediment is measured at the outlet and plotted against discharge. A rating curve can be established if the duration of sampling spans multiple high- and low-discharge events. The source of suspended sediment (mostly silt and clay) is mainly from surface and subsurface erosion, which includes roads, culverts, tile lines, rills, gullies, overland flow, and stream banks. One of the concerns of only measuring suspended sediment is that bed load transport is not accounted for. However, bed load normally comprises a small amount of the sediment transport in large river systems. Direct site observations are difficult and time-consuming. In turn, soil erosion models have become a popular means of establishing the erosion estimates. These include, but are not limited to, the universal soil loss equation, revised universal soil loss equation, water erosion prediction project (WEPP) model, and geographic information systems (GIS).

Sediment is mobilized and transported in a watershed by physical and chemical weathering and erosion. Only a small portion of the sediment eroded in a watershed is quantified as the sediment yield of the watershed. This is because sediment is deposited and stored throughout the watershed. Temporary and permanent storage exists on the bed of the channel, bars, floodplains, wetlands, impoundments, and hillslopes. Watersheds of contrasting size route sediment differently. Watersheds draining a small area will generally have sediment yields greater than watersheds draining a larger area. Where relief and hillslope gradient are higher, sediment has a greater opportunity to reach the stream. Watersheds draining a larger area have streams that parallel floodplains and terraces, which store flood deposits and hillslope-generated sediments.

Besides watershed size, variables that influence sediment yield include climate and precipitation, vegetation, soils, topography, and land use. Rainfall has the ability to intensify erosion, especially on high-gradient slopes with sparse vegetation. Vegetation captures rainfall, and through the process of stem flow and the interception of falling droplets, infiltration occurs and rain splash erosion is decreased. In addition, roots of the vegetation (on hillslopes and floodplains) hold the soil in place, which increases cohesion and decreases surface erosion. Coarse-textured soils with low infiltration capacity, hydrophobic soils, and soils with low organic matter or weak structure tend to be the most susceptible to erosion. Generally, particle size decreases downstream, and because larger streams are inset into their own deposits, bank cohesion increases while sediment yield decreases. However, it is important to recognize that this oversimplified fining hypothesis is spatially complex. Under the influence of gravity, slopes with higher gradient and longer slope length cause increased soil erosion. Changes in land use affect the sediment yield in a watershed. Anthropogenic changes, including mining, deforestation, urbanization, fire, and agriculture, have altered sediment yield worldwide.

Researchers have attempted to portray sediment yield in a regional context, but high spatial variability has limited the results. When sediment yield is plotted as a function of precipitation, three sediment yield peaks exist at (1) ~450 mm (millimeters; continental semiarid climate), (2) 1,250



to 1,350 mm (Mediterranean climate), and (3) >2,500 mm (tropical monsoon climate). The peak at ~450 mm corresponds to a transitional zone between desert shrub vegetation and grasslands. Precipitation slightly greater than ~500 mm is associated with grasslands and forests, with a decrease in the erosion potential. Sediment yield peaks at 1,250 to 1,350 mm and >2,500 mm are associated with seasonal precipitation amounts. Concerns about relating sediment yield to precipitation are that (a) seasonal precipitation affects the vegetation, which determines the erosion potential, and (b) anthropogenic alteration to the environment will mask the role of precipitation. Sediment yield should be determined on a watershed-by-watershed basis because of the inherent variability that exists in sediment transport and storage throughout the watershed.

Dale Splinter

See also **International Watershed Management; Surface Water; Water Needs; Water Supply Siting and Management; Watershed Management**

Further Readings

- Graf, W. L. (1988). *Fluvial processes in dryland rivers*. Berlin, Germany: Springer-Verlag.
- Knighton, D. (1998). *Fluvial forms and processes*. London: Arnold.
- Langbein, W. B., & Schumm, S. A. (1958). Yield of sediment in relation to mean annual precipitation. *Transactions of the American Geophysical Union*, 39, 1076–1084.
- Reid, L. M., & Dunne, T. (2003). Sediment budgets as an organizing framework in fluvial geomorphology. In G. M. Kondolf & H. Piegay (Eds.), *Tools in fluvial geomorphology*. New York: Wiley.
- Renwick, W. H., Smith, S. V., Bartley, J. D., & Buddemier, R. W. (2005). The role of impoundments in the sediment budget of the conterminous United States. *Geomorphology*, 71, 99–101.
- Walling, D. E., & Webb, B. W. (1983). Patterns of sediment yield. In K. J. Gregor (Ed.), *Background to paleohydrology* (pp. 69–100). New York: Wiley.



WATER SUPPLY SITING AND MANAGEMENT

Water is a critical resource for the health of ecosystems and the reproduction of society. Water siting refers to the process of transformation of this basic component of the biosphere into a resource able to satisfy human needs. Siting includes, therefore, both the places where water is captured for human activities and the technologies and institutional arrangements that make this transformation possible. Water management refers to the institutional, legal, and technological arrangements by which water is allocated temporally and spatially to the different users (agriculture, industry, urban, environmental flows).

Surface water and groundwater are the two main conventional sources of freshwater, and their use entails different technologies of capture and also different institutions to regulate its use. Surface water of rivers and lakes can be directly captured from the source by means of ditches, especially for agricultural use. However, for thousands of years, dams, reservoirs, and channels have been developed to guarantee water availability where and when needed. Interbasin water transfers are justified on the ground that they contribute to redress the balance between “surplus” and “deficit” basins. Dams, reservoirs, and water transfers are important human interventions to mobilize and transform nature and have important consequences on the environment and society. While these interventions allow population and crop growth where water is scarce, they also modify the physical environment and affect the living condition of local populations and environments.

Aquifers are underground geological formations formed by layers of porous and permeable materials containing water. By means of wells or pumps, water can be brought to the surface. In this case, the use and consumption of water tends to be more local. Overextraction of water from aquifers can cause depletion and pollution, often irreversibly damaging the source.

Other nonconventional sources of water supply may be also relevant in some contexts. Desalination technologies involve several methods to



Aerial view of the spillway at Broken Bow Dam on Broken Bow Reservoir on the Mountain Fork River in McCurtain County, Oklahoma. This photograph shows only the spillway. The U.S. Army Corps of Engineers constructed the dams in 1968 for flood control, water supply, and hydroelectric power generation.

Source: U.S. Army Corps of Engineers.

turn seawater or brackish water into freshwater. Currently, the most efficient of such methods is called reverse osmosis. However, large amounts of energy are consumed in the process, with subsequent emissions of carbon dioxide (if the primary energy sources are fossil fuels). In turn, this process is reflected in the economic costs and subsequently limits such technology to urban (including tourist related) and industrial uses in the developed world.

Water harvesting is another technology traditionally practiced in the developing countries. It consists of the capture and storage of rainwater and has the advantage of not requiring a large infrastructure. Its usefulness at the local scale makes it an interesting resource that is being rediscovered in Western societies. Equally, the treatment and reutilization of wastewater (gray water) by means of small-scale or centralized utilities can

be a resource for agriculture, industry, and even household outdoor uses. This practice is common in California.

Water management requires the existence of a series of formal and informal institutions, practices, and regulations that determine how water is to be allocated across space and time among different users. Agriculture accounts for most of the water consumption worldwide. However, urban water consumption is dramatically increasing due to the processes of urbanization of rural land in the developing world and the increase of water consumption in Western urban areas because of changes in urban patterns and the widespread use of water-consuming appliances. Tourism also accounts for an important share of urban water consumption in some regions of the world, especially in the coastal temperate areas. Eventually, industry



could be a heavy and intensive user of water depending on the activity, and it especially affects water quality.

The special characteristics of water differentiate it from other raw materials such as oil, minerals, or food in transportation at the international level. Water sources tend to be acquired locally or regionally. Although water use is geographically bounded to place, international trade of commodities, from garments to vegetables to computers, implies a very significant flow of “virtual water,” that is, the water that has been used locally to produce each item. Increasingly, trade strategies are considered by water-stressed countries to alleviate water scarcity.

During the 20th century, engineering perspectives on water supply have reigned supreme, and policymakers have tended to centralize and increase supply by building new infrastructure to capture water. Although much of this philosophy still persists, there is an ongoing transition from a supply-side approach to water resources toward demand management, which tends to make the most of available resources while downsizing the scale of the infrastructure of supply. Demand-side management includes both economic and noneconomic tools, such as educational campaigns, restrictions, and so on. Price mechanisms are the main instruments for regulating demand and promoting the efficient use of resources. Efficiency in the management and use of water is deemed essential. Institutional changes become materialized in new water legislation that—for example, in Europe—tends to establish the river basin as the unit of policy action and integrated water resources management and for incorporating environmental costs into the price of water for full cost recovery of water supply. Water markets represent an important institutional arrangement to allocate water to the highest economic value (e.g., in Chile, Australia, South Africa, and the Western United States).

To sum up, water siting and management comprise both supply- and demand-side management strategies, encompassing a series of technological and political arrangements. As long as climate variations enhance water stress in some parts of the world, technology, productive activities, and urbanization may either alleviate this

situation or contribute further to the social scarcity of water.

Hug March Corbella and David Saurí

See also [International Watershed Management](#); [Urban Water Supply](#); [Water Management and Treatment](#); [Water Needs](#); [Watershed Management](#)

Further Readings

- Brooks, D. B. (2006). An operational definition of water demand management. *International Journal of Water Resources Development*, 22, 521–528.
- Dinar, A. (2000). *The political economy of water pricing reforms*. Oxford, UK: World Bank.
- European Commission. (2000). *The EU water framework directive* (Directive 2000/60/EC). Retrieved November 20, 2009, from http://ec.europa.eu/environment/water/water-framework/index_en.html
- Hoekstra, A. Y., & Hung, P. Q. (2005). Globalisation of water resources: International virtual water flows in relation to crop trade. *Global Environmental Change: Part A*, 15, 45–56.
- Organisation for Economic Co-operation and Development. (2003). *Social issues in the provision and pricing of water services*. Paris: Author.
- Renzetti, S. (2002). *The economics of water demands*. Boston: Kluwer Academic.
- The World Commission on Dams. (2000). *Dams and development*. London: Earthscan.
- World Health Organization. (2003). *The right to water*. Geneva: Author.



WATTS, MICHAEL (1951–)

Michael J. Watts is a Marxist geographer specializing in political ecology and economic geography. Born in England, Watts has published more than 200 scholarly articles, books, and essays that have appeared in leading journals in geography and anthropology. His work focuses on the politics of oil, agrarian political economy, and development. Much of that work is based on field research in Nigeria and West Africa and related work in India, Vietnam, and the United



States. He is the Class of 1963 Professor of Geography at the University of California, Berkeley, where he has taught since 1979. Watts's scholarly work combines his commitments to social change with his formidable intellect, yielding a wide-ranging body of work whose influence extends far beyond geography.

Watts is widely regarded as a founding figure in the field of political ecology for his initial research on the politics of famine in Nigeria during the 1970s. Drawing from his training in cultural ecology and anthropology at the University of Michigan under Roy Rappaport, Bernard Nietschmann, Eric Wolf, and Michael Taussig, Watts brought Marxist political economy to bear on questions of nature and society. He argued that famines were crises of distribution that laid bare the structural inequalities of capitalist markets as means of distribution, challenging the prevailing neo-Malthusian accounts of famine as instances of scarcity created by the demands placed by a growing population on natural resources. Watts's arguments also challenged Nobel laureate Amartya Sen's critical explanation of famine as an outcome of the social curtailment of freedom.

One of the last students to receive a doctorate in geography at the University of Michigan, Watts's approach contrasted sharply with the lingering influences of Carl Sauer's "Berkeley School" of geography that he encountered as a new professor. At Berkeley, Watts developed his approach to political ecology through engagement with questions of culture, power, and political economy through participation in critical efforts to rethink Marxist political economy. In particular, Watts drew on the works of Raymond Williams and E. P. Thompson to address the importance of culture to questions of nature, resource struggles, and society, engaging with poststructuralism and the cultural turn in the social sciences. Together with Alan Pred, he developed a critical approach to studying capitalism in terms of its historically and geographically specific patterns of accumulation and forms of resistance. Watts continues to develop these themes through research on the politics of oil in the Niger Delta, bringing Foucaultian-inspired analytics to bear on questions of governance and natural resources.

A geographer unburdened by the disciplinary bounds of the field, Watts has helped influence a range of research as a collaborator, colleague, and advisor. At Berkeley, Watts served as director for the Institute for International Studies from 1994 to 2004, founding a series of seminars and colloquia that shaped a generation of scholarship. In particular, the Berkeley Workshop on Environmental Politics, which he cofounded with Nancy Peluso and Donald Moore, has become a critical locale for debates on environment, cultural politics, and political economy. He has also worked with Gillian Hart to build Berkeley's programs in development studies and African studies. He has directed more than 60 doctoral dissertations, and many of his students are now prominent scholars in geography. He is also one of the more highly regarded lecturers on the Berkeley campus. Watts has received numerous awards and accolades during his career, including a Guggenheim fellowship in 2003 for his work on oil in Nigeria. He delivered the first talk in the Hettner Lecture series at the University of Heidelberg in 1999.

Joe Bryan

See also **Cultural Ecology; Development Theory; Famine, Geography of; Marxism, Geography and; Political Ecology**

Further Readings

- Peet, R., & Watts, M. J. (Eds.). (2004). *Liberation ecologies: Environment, development, social movements* (2nd ed.). London: Routledge.
- Pred, A. R., & Watts, M. J. (1992). *Reworking modernity: Capitalisms and symbolic discontent*. New Brunswick, NJ: Rutgers University Press.
- Watts, M. J. (1983). *Silent violence: Food, famine and peasantry in Northern Nigeria*. Berkeley: University of California Press.



WAYFINDING

Wayfinding is the cognitive-conceptual process of finding and planning a route from an origin to a destination through a known, partially known, or



unknown environment. Travel from an origin to a destination is a fundamental human activity that nearly everyone completes on a daily basis. The centrality of wayfinding to humans is made evident by the expanding knowledge domain specific to wayfinding and related concepts as well as the booming, multimillion-dollar industry providing services and support for wayfinding and navigation technologies.

Wayfinding should be distinguished from locomotion (movement) and navigation. Wayfinding is the cognitive-conceptual aspect of route finding and planning, locomotion refers to the actual physical movement of a cognitive agent in an environment, and navigation is a stylized form of wayfinding that typically includes guiding a vehicle such as a ship or an aircraft. Wayfinding's cognitive-conceptual nature is stressed as it synthesizes complex cognitive processes (e.g., landmark recognition, route retracing, route planning, route selection, path integration) with conceptual primitives of spatial knowledge (location, direction, distance, connectivity, and spatiotemporal sequence).

The basis for wayfinding is knowledge about one's environment, or if knowledge (internal/mental or external) is not available, the administration of a wayfinding strategy to uncover such knowledge. In addition to the primitives of spatial knowledge mentioned above, successful wayfinding also requires knowledge about landmarks (salient objects located in an environment), knowledge about routes (how landmarks and other salient locations are connected), and survey knowledge (how landmarks and routes are spatially arranged).

Research on landmarks has undergone a renaissance in recent years because of the increased availability of navigation devices and improved analysis functions for identifying landmarks for use in navigation services. Mimicking the extensive human emphasis on landmarks when wayfinding, several technological developments now allow for the automatic identification and selection of landmarks in databases, three-dimensional city models, and the Internet. Across all proposed landmark taxonomies, two orthogonal approaches can be distinguished: (1) reference to the landmarks themselves, identifying three kinds of landmark salience (visual, semantic, and structural), and (2) focus on the geometric conceptualization

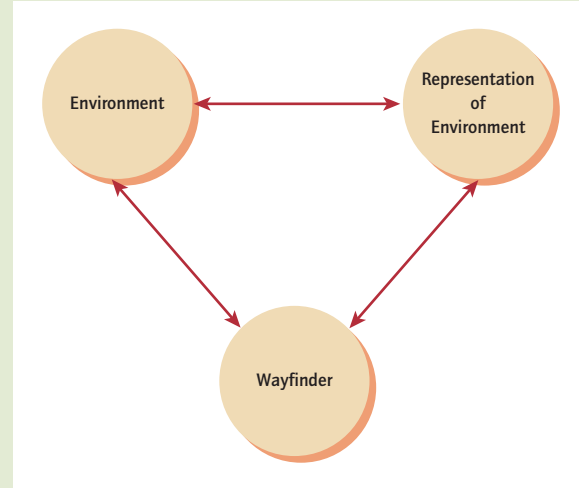


Figure 1 The interaction among wayfinder, environment, and representations of the environment

Source: Author.

of the landmark when used in wayfinding and navigation, indentifying three geometric dimensions (pointlike, linear, or area-like).

The first step in every wayfinding activity is to determine one's location in the environment. This location information, from a cognitive point of view, is not the exact coordinate pair at which a wayfinder is located but an alignment of the wayfinder's mental representation of the environment and the information the wayfinder is accessing either directly (through perceiving his or her surroundings) or indirectly (e.g., through a map). Figure 1 shows this triangular relationship schematically with relations among the wayfinder, the environment, and an external knowledge source such as a map.

Some wayfinding strategies are employed when one's current location or possible wayfinding routes are partially or completely unknown. In these cases, the term *wayfinding* is used in its most literal sense: to find one's way. Other wayfinding strategies are specific to route choice behavior; that is, from a given set of known alternatives a specific route is chosen. Examples are choosing the shortest or longest route segment first or choosing the route segments with the smallest deviating angle from the destination.

Most wayfinding activities take place along constraining artifacts such as street or public



transportation networks. Even most natural environments offer superimposed artificial structures such as trails. It is of crucial importance to understand the influences that specific environments have on wayfinding and on wayfinding success. This point becomes particularly apparent when the environment, either cultural (e.g., a city layout of streets and buildings) or natural (e.g., mountain ranges), is misaligned from our mental preconceptions. Examples include the northwest to southeast orientation of the mountains located outside Santa Barbara, California, or the southwest to northeast isthmus on which Madison, Wisconsin, is built. The naming of features within these landscapes, based on the traditional gridded city block convention of the United States, often contrasts with the true characteristics of the feature.

Other examples that stress the importance of the environment on wayfinding become apparent when we look at different wayfinding strategies. How is wayfinding in street networks different from wayfinding in deserts? While in relatively unstructured environments, such as open oceans or deserts, information about one's location and especially direction (i.e., bearing) is of utmost importance, the constraining nature of structured environments deemphasizes these spatial primitives and places a greater emphasis on connectivity. For example, when wayfinders are moving through a road network, choices about where to turn are very limited and the actual turning angle is of secondary importance. The initial physical turn (e.g., at a highway interchange) may even be in a direction opposite the planned direction change.

The importance of understanding and using the knowledge that an environment offers is recognized in several research communities and is gaining particular importance for researchers interested in supporting wayfinding through cognitively ergonomic navigation devices. For example, an understanding of the environment can lead to a tremendous reduction in the amount of information that a wayfinder must remember during the process of wayfinding. If this inherent environmental knowledge can be formally characterized through a cognitively guided analysis of an environment, these principles of understanding and organizing an environment can be used to communicate environmental knowledge and/or help wayfinders better understand their surroundings.

Wayfinding, especially in large cities but also on a geographic scale, often takes place in a multimodal environment that offers various forms of transportation. Pedestrian walks are combined with public transportation, which in itself can be a combination of, for example, buses and subways. Taxicab rides to an airport are combined with indoor wayfinding in airport buildings, flying to another airport, and so forth. The challenges of multimodal wayfinding are manifold and often involve tasks such as temporal sequencing of events, switching between different signage systems (indoor vs. outdoor), and switching from constrained travels (e.g., a cab ride) to semistructured wayfinding in large airport spaces.

In summary, wayfinding is a cognitive process that synthesizes a variety of cognitive subprocesses and combines different kinds of spatial knowledge. Wayfinding and wayfinding strategies are deeply interwoven with the characteristics of an environment in which the wayfinding process takes place. Current developments in technology support wayfinding services by providing tailored, cognitively ergonomic information solutions. Wayfinding, as an everyday process, is central to a modern understanding of spatial cognition.

Alexander Klippel

See also **Behavioral Geography; Mental Maps; Spatial Cognition**

Further Readings

- Golledge, R. (Ed.). (1999). *Wayfinding behavior: Cognitive mapping and other spatial processes*. Baltimore: Johns Hopkins University Press.
- Liben, L., & Downs, R. (1993). Understanding person-space-map relations: Cartographic and developmental perspectives. *Developmental Psychology*, 29(4), 739–752.
- Passini, R. (1984). *Wayfinding in architecture*. New York: Van Nostrand Reinhold.
- Sorrows, M., & Hirtle, S. (1999). The nature of landmarks for real and electronic spaces. In C. Freksa & D. Mark (Eds.), *Spatial information theory. Cognitive and computational foundations of geographic information science* (pp. 37–50). Berlin, Germany: Springer.



WEATHER AND CLIMATE CONTROLS

Climate, which consists of observations of meteorological parameters (i.e., weather) over a specified period of time, is shaped by many environmental factors. Although weather conditions at any particular time can be ephemeral and deviate from expectations, over a long period of time, certain characteristics are associated with any given location on Earth. The longer the period of record, the more likely that climate regimes will be identifiable with recognizable temperature and precipitation characteristics. This entry discusses seasonal changes in climate as well as major controls and localized controls on weather and climate.

Seasonal Changes in Climate

The seasons are among the most well-known environmental parameters that affect long-term climate and shorter periods of time associated with weather. Seasonal changes in climate for a given locale are imprinted on the daily lives of the biology in these locales, in everything from the smallest plants to the local human inhabitants. For example, anyone reading this passage may be able to picture the environmental conditions in their own hometown during each of the four astronomical seasons and may also imagine the likely climate conditions present during these seasons. These “memory maps” of climate changes due to the seasons can be found in anyone inhabiting a particular area for a long enough period; in fact, with enough living experience, nearly all biological life forms appear to incorporate temperature and/or moisture into their evolutionary adaptations, associated with particular sites on Earth.

It is important to note that the effect of seasons on weather and climate is solely due to changes in solar insolation (incoming sunlight) during the year, and this is reflected in the latitude of an individual location above or below the equator—all places along a given latitude will receive these changes in incoming solar energy. The general patterns of incoming energy are reflected in the seasonality, as discussed above. Although we have four seasons in the United States, other regions of the world do not have such distinct divisions in

yearly climate. For example, areas located within 23.5° of the equator have very minor changes in temperature throughout the year—these latitudes are commonly known as the tropics, as they lie between the maximum latitudinal extents of vertical solar declination. We refer to the annual range in temperatures in the tropics as very minor. In areas far to the north, such as Alaska and above the Arctic Circle, the annual range can be very great—these areas can receive lengthy periods of dim to no sunlight during winter, contrasted with lengthy periods of daylight through summer. Therefore, latitude plays a significant role in seasonal-scale climate trends. However, many other geographic parameters control the actual weather that occurs at any selected location, and these other controls on weather are the focus of this entry.

Major Controls on Weather and Climate

A general discussion of the controls on climate typically begins with the assessment of the thermal properties of land or soil versus those of water, typically referring to the oceans and their enormous heat storage capacity. Land absorbs the solar energy that is received during the day and rapidly heats up due to a low specific heat (a physical property referring to the energy a substance must absorb to raise the temperature of a 1-gram mass of water by 1°C). The reverse is also true: At night, when the sun is no longer providing incoming energy to the surface of Earth, the land cools down rapidly due to the same characteristic of low specific heat. The opposite is true of water, which has a very high specific heat. It takes a long time, therefore, for water to heat up and cool down. This is reflected in the long lag times between peak solar insolation and peak water temperatures. For example, if one were to visit one of the Great Lakes (such as Lake Huron or Superior) in May, one might find the water to be too cold to swim even on a 100°F day. However, visiting in August on a day with a maximum temperature of 85°F , one would likely experience water temperatures 10° to 15° higher. This is because even though the sun reaches its seasonal declination zenith on the summer solstice (June 21), it takes about another 30 days for this peak in incoming energy to translate into a peak in water temperatures. The end result in these differences



in specific heat between land and water is a greater range in temperatures in locations that are far removed from large bodies of water (called *continental climates*), with a smaller annual range of temperatures at locations located near such bodies of water due to the moderating effects of proximity to these features. Furthermore, these properties are reflected in the differences in climates between locations in the Northern Hemisphere versus those in the Southern Hemisphere. In general, Northern Hemisphere climates are more variable and have a higher annual temperature range than Southern Hemisphere climates. Once these more rapid swings in temperature over large land masses are considered, it is logical that the majority of severe weather events such as tornadoes, mesoscale convective complexes, and derechos occur in the Northern Hemisphere.

When one considers the differential heating between water and land, another factor must be considered—that of oceanic currents. Just because two cities at a given latitude are within a certain distance from an ocean does not imply that the weather at both places will be the same. In fact, ocean currents play a large role in the actual climatic conditions at these coastal locales. Typically, western coasts in the Northern Hemisphere are associated with cool currents, as colder water circulates toward the equator from the polar regions. This is reflected in the cool oceanic water off of the northwest coast of the United States—taking a dip in the waters off Seattle even in August can be quite a chilly experience. Surfers in California often have to wear wetsuits to prevent hypothermia, even as far south as Los Angeles or San Diego. The opposite is true of most east coast locales. For example, the water in Miami may be cool in winter, but it is still much warmer than water at the same latitude along the western coast of the North American continent. This is due to the Gulf Stream, an enormous current of warm water that travels up the eastern coastline of the United States before curving out into the Atlantic and flowing toward Europe. In fact, given the latitude of the United Kingdom and Northern Europe, winters would be much more severe if not for the modifying effects of the warm Gulf Stream flowing just offshore. Thus, in the Northern Hemisphere, cities near western coastal boundaries often experience cool marine climates, whereas

cities near eastern coastal boundaries often experience more continental climates, with a warming influence from northerly bound currents. These trends are reversed in the Southern Hemisphere.

A final observation on the differences in climate between two coastal cities located on opposite coasts includes an examination of the wind patterns at western versus eastern continental margins. For example, San Francisco, on the Pacific (western) coastline of the United States, experiences prevailing winds from the westerly direction, which drive the air situated above the cool California current ashore, producing cool sea breezes and late-afternoon advection fog. In contrast, Charleston, South Carolina, located on an eastern coastline, receives westerly prevailing winds also, but these flow from land toward the ocean (hence, a continental climate). Charleston's weather would be influenced by the warm oceanic current just offshore, resulting in milder wintertime temperatures. Therefore, the environment over which the prevailing wind travels helps control the climate patterns that subsequently occur, even at two coastal locations. These are collectively referred to as continental versus maritime climate controls.

Another major climate control is the altitude of any location. Since Earth's atmosphere is significantly denser at the surface than at increasing altitude, higher locations experience greater temperature ranges and are generally cooler than locations with lower altitudes. However, it is important to note an important caveat with the assumption that a linear decrease in temperature takes place with increasing elevation: The soil or material composing the majority of the exposed surface plays a large role in the true climatic conditions experienced at locations with high elevations. The concept of greater or lesser energy absorption based on differing reflectance properties of surface material is known as albedo. The end result, however, is that locations that are at similar elevations and similar latitudes may have different temperature ranges based on the underlying material that is exposed to sunlight. Darker rock or heavily built urban environments will be more likely to absorb and slowly release heat energy than environments containing lighter colored material or less built structure, which would tend to reflect more sunlight than the darker



material (higher albedo). This could result in the former possessing generally warmer temperatures and the latter exhibiting colder temperatures.

Localized Controls on Weather and Climate

Albedo can be associated with any feature covering Earth's surface. This includes not only snow, water, rock, vegetation, and human-made objects but also atmospheric features such as clouds. Therefore, excessively cloudy locations are likely to have lower daytime temperatures as much of the incoming sunlight is reflected out to space. One can often see this taking place when looking at large thunderstorms at a distance—the base of the cloud may appear dark, because most of the sunlight has been reflected off the top of the clouds, which may appear bright white. This relates to weather in that incoming sunlight that is not reflected is absorbed by Earth's surface, which slowly warms. Most of the heat energy in a location actually occurs from the ground up; therefore, the more sunlight absorbed, the higher the temperatures will be in general. Therefore, places with greater cloud cover are likely to have lower daytime high temperatures.

Water vapor in the atmosphere and in clouds actually acts as a greenhouse gas, absorbing heat energy and then reemitting it back toward Earth's surface. Therefore, water vapor and, in effect, cloud layers act as electric blankets—absorbing the energy released by Earth's surface at night and releasing it to the atmosphere. The end result is that while cloud cover lowers daytime high temperatures, it actually prevents nighttime temperatures from dropping very much. Very cloudy locations will show little variation in temperatures between night and day, assuming all other weather parameters are unchanged. One of the best examples of this would be the monsoon climate of southeast Asia, caused by a seasonal shift in wind direction. When the monsoon shifts to the rainy season, temperature variations between days and nights are miniscule.

Large-scale weather features, such as the subtropical high-pressure systems situated at about 30° north and south of the equator, the Inter-Tropical Convergence Zone, and climate teleconnections such as the El Niño–Southern Oscillation, can affect weather conditions on

climate timescales. As an example, the Bermuda High Pressure System, a strong anticyclone that commonly occurs during the Northern Hemisphere summer over the central Atlantic, can serve to both bring drought conditions to the southeastern United States and, at the same time, act as a steering mechanism for southerly-tracking hurricanes, funneling their tracks across Florida and into the Gulf of Mexico. The effects of El Niño, in particular, are known to vary geographically over relatively regional geographic scales.

Another relatively local control on weather conditions is orography, or the presence of mountain ranges. The orientation of the mountain range to the prevailing winds is essential in determining long-term climate patterns. North-south-oriented mountain ranges such as the Rocky Mountain Cordillera in the Northern Hemisphere or the Andes in the Southern Hemisphere are associated with a distinct climate boundary depending on which side of the mountain range experiences the prevailing winds. The side that experiences these winds will also experience rising air, which cools adiabatically, and a large amount of precipitation and cloudiness—this is known as the windward side of the mountain range. Descending air that has then crossed the mountain range sinks on the leeward side and warms adiabatically, essentially drying out. In these areas, deserts called rain shadows are commonly formed. Much of the arid southwestern United States is associated with this rain shadow phenomenon. Much of the effect of the monsoon in southeast Asia is associated with wind flow toward or away from the Himalayan mountain belt. It should be noted, however, that mountain ranges parallel to the prevailing wind direction have a lesser impact on local climates—the Alps of Western Europe, which are situated in a primarily east-west orientation, have much less of a windward-leeward relationship than the aforementioned North and South American Cordillera.

Other rarer and more localized weather controls include lake effect snows, lake breezes, mountain and valley breezes, and katabatic winds.

Brian H. Bossak



See also **Adiabatic Temperature Changes; Air Masses; Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Moisture; Atmospheric Pressure; Climatology; Climate Types; El Niño; Land-Water Breeze; La Niña**

Further Readings

- Lutgens, F. K., & Tarbuck, E. J. (2007). *The atmosphere* (10th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.
- Wallace, J. M., & Hobbs, P. V. (2006). *Atmospheric science* (2nd ed.). London: Academic Press.

WEBER, ALFRED (1868–1958)

The younger brother of the famed German sociologist Max Weber, Alfred Weber developed an enormously influential model of corporate location based on the minimization of transportation costs that powerfully shaped economic geography, particularly location theory, spatial science, and regional science, for decades to come. Weber's famous model was originally developed for the analysis of manufacturing, although it can be applied to other sectors such as services as well. It was very useful to the exploration of the influence of transportation costs in a rigorous way, and many economic geographers still work in this tradition.

Alfred Weber taught at the University of Heidelberg from 1907 to 1933, when he was dismissed by the Nazis. Although he stayed in the country

during World War II, he played a significant role in the resistance movement of the German intelligentsia. Following the Nazi defeat in 1945, he was reinstated at his old university, where he remained until his death.

Weber's approach emphasizes the role of transportation costs in the location decisions of individual companies. He attempted to determine the patterns that would develop in a world of numerous, competitive, single-plant firms. Weber began by assuming that transportation costs are a linear function of distance, that producers face neither risk nor uncertainty, and that the demand for a product is infinite at a given price—that is, producers could sell as many units as they produced at a fixed price. Firms encountered costs of moving inputs, or backward linkages from suppliers and raw materials, as well as outputs, or forward linkages to clients in the market (Figure 1). The best location for a manufacturing plant is the point at which total transportation costs, that is, costs of transporting inputs plus outputs, are minimized.

The costs of moving supplies and materials vary according to their weight and the degree to which they are used in the production of each good, leading firms to be either resource or market oriented. Thus, firms for which the costs of moving inputs are greatest (weight-losing industries) tend to locate near the site of raw materials, such as mining companies, while those for which the costs of transporting goods to market (weight-gaining industries) are greatest tend to be market oriented, such as bottled-drink manufacturers (Figure 2). Weber modeled this process both mathematically and using physical weights and drew lines of equal

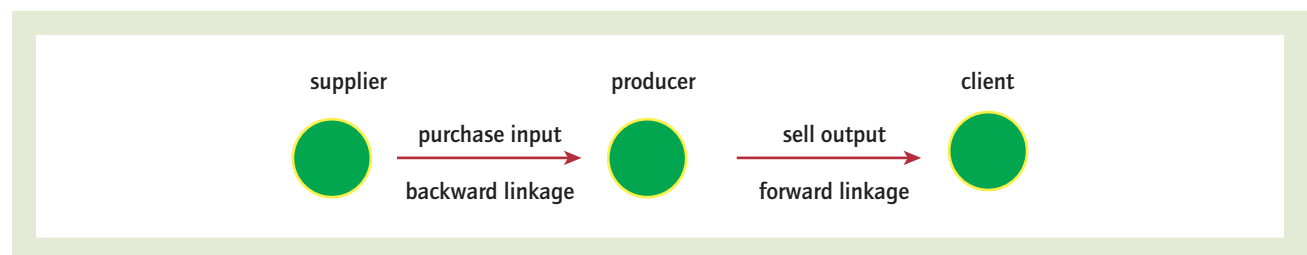


Figure 1 All firms must confront purchases of inputs (backward linkages) and sales of output (forward linkages), which are mediated over space by transport costs.

Source: Author.

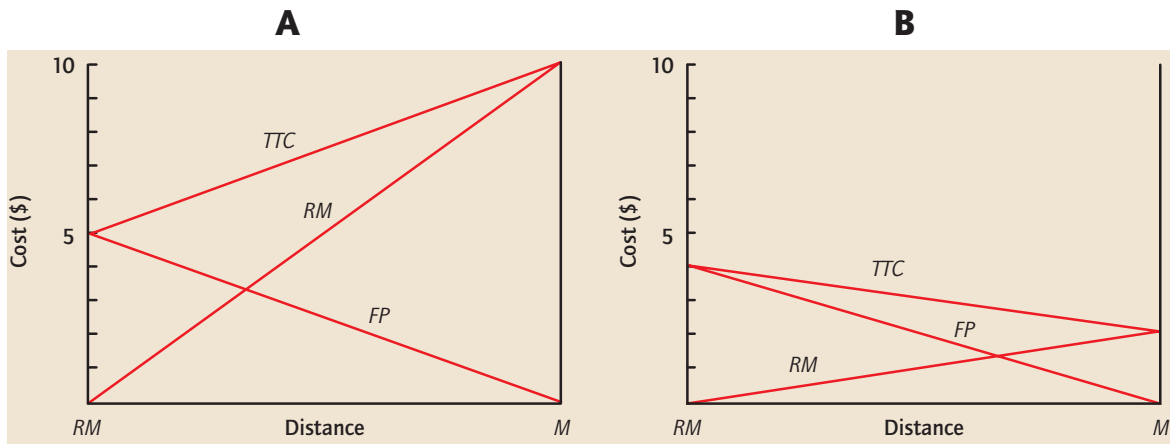


Figure 2 Transport cost structure of raw material and market-oriented firms. Firms face the costs of moving raw materials (RM) and final products (FP), which when combined create total transport costs (TTC) that are minimized either at the site of inputs (A) or at the market (B).

Source: Author.

total transport costs called *isodapanes*. The optimal location, he further maintained, would also be influenced by spatial variations in labor costs and by agglomeration economies.

Despite its broad appeal, there are several developments that limit its applicability. First, not all firms need to minimize transport costs; given the rent-transport trade-off that all firms must make, some firms will accept higher transport costs and locate on the urban periphery to minimize rents. Second, the production process is much more complex than it was in the early 20th century, when Weber developed his model. Many plants begin with semifinished items and components rather than with raw materials. Producers' goods seldom lose large amounts of weight; therefore, there is not much tendency toward material orientation. Weber's model has also been criticized for its unrealistic view of transportation costs as a linear function of distance. Because of fixed costs, especially terminal costs, long hauls cost less per unit of weight than short hauls do. Plants tend to locate at material or market points rather than at intermediate points, unless there is an enforced change in the transportation mode, such as at a port. However, with the expansion of the modern trucking

industry and its flexibility in short hauls, the disadvantages of intermediate locations have been reduced.

Finally, other developments have a bearing on how industrial location choices have changed. Transportation costs have been declining in the long run and now constitute a relatively small share of the final costs of most goods. This decline increases the importance of other locational factors, particularly labor costs and productivity. This trend is most obvious in firms producing high-value products. Yet for firms that distribute consumer goods (e.g., soft drinks) to dispersed markets, transportation costs remain a significant factor. Second, natural resources are no longer as important in the growth of economies as they were historically. Instead, there has occurred a widespread trans-materialization of resources as smaller, lighter products are made from resources to which high technology and brainpower have been added. Finally, real-world patterns are evolutionary, not the result of decisions made by optimizers at one moment in time. Most real-world decisions do not result in the best (the most profitable) locations, and locational decisions, once made, often lead to industrial inertia, the tendency to



continue investing in a nonoptimal site even if more optimal locations exist.

Barney Warf

See also **Economic Geography; Factors Affecting Location of Firms; Location Theory; Regional Science; Transportation Geography**

Further Readings

- Cooper, L. (1968). An extension of the generalized Weber problem. *Journal of Regional Science*, 8(2), 181–198.
- Gregory, D. (1981). Alfred Weber and location theory. In D. Stoddart (Ed.), *Geography, ideology and social concern* (pp. 165–185). Oxford, UK: Blackwell.
- Weber, A. (1929). *Theory of the location of industry*. Chicago: University of Chicago Press.



WEB GEOPROCESSING WORKFLOWS

The rapid evolution from monolithic desktop geographic information system (GIS) applications with tightly coupled geodata to spatial data infrastructures (SDIs) with independent, interoperable, and distributed Web services has changed the GIS world fundamentally. Nevertheless, the existing SDIs are focused on data retrieval and visualization. To generate information out of data, it becomes necessary to process the data. However, the complexity of spatial data often requires the functionality of several geoprocesses and has led to Web-based geoprocessing workflows. The Web-based geoprocessing workflows can be viewed as a combination of two fundamental concepts: geoprocessing and workflow in a service-oriented and Web-based context.

Geoprocessing

In the absence of a general definition, the term *geoprocessing* can be seen as a specialization of

the term processing in a spatial context. In other words, geoprocessing is the processing of spatially related data. In classical desktop GIS applications such as GRASS or ArcGIS, geoprocessing represents the core GIS analysis functionality and thus is one of the key concepts. In contrast to monolithic desktop GIS, distributed GIS are based on loosely coupled services organized in SDIs. According to the ISO 19119 specification, there are four different types of geoprocessing services:

1. Spatial processing, such as coordinate transformation services, feature manipulation services, or route determination services
2. Thematic processing, such as thematic classification services, geographic information extraction services, or image processing services
3. Temporal processing, such as temporal reference system transformation services, subsetting services, or temporal proximity analysis services
4. Metadata processing, such as statistical calculation services and geographic annotation services

From the work of the Open Geospatial Consortium, the Web Processing Service specification evolved as a standardized but generic service approach to perform geoprocesses in an SDI on distributed data. These processes can be as simple as the sum of two numbers (e.g., population) or as complex as a global climate model. The data required by the service can be delivered across a network or made available on a server. Image data formats or data exchange standards such as geography markup language or KML can be used to encode the data. The Geoprocessing Web Services form the building blocks for Web-based geoprocessing workflows.

Web-Based Workflows

The term *workflow* was defined by ISO 19119 as “the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules.”



This concept of a workflow has been extensively researched in the information technology (IT) and business fields for several decades. With the advent of the service-oriented architecture paradigm and the increasing data-processing power of network computing, Web-service-based workflows are currently a prominent workflow type. By integrating several Web services from different partners into a single workflow, it becomes possible to form virtual enterprises. These concepts of Web-based workflows rely heavily on service chains to exchange information between workflow participants. There are three different architectural patterns defined for service chains according to ISO 19119:

1. User transparent chaining
2. Translucent chaining
3. Opaque chaining

Especially the opaque chaining pattern is applied by the “mainstream” IT workflow management systems, which mostly use the idea of Web service orchestration (WSO). This concept is defined as a description of how composed Web services interact on the message level. The description includes the business logic and execution order. Based on the predefined message exchange protocol, the interaction is controlled by a central orchestration engine that enables the Web services to be held loosely coupled. This common central orchestration approach is widely supported by several major IT WSO frameworks. The frameworks allow the visual composition of workflows instead of programming and hence enable flexible and rapid workflow modeling and execution. The Business Process Execution Language is mainly used by these frameworks since it is the de facto standard.

Web-Based Geoprocessing Workflows

Web-based geoprocessing workflow brings both terms together. It can be seen as an automation of a spatial process/model, in whole or in part, during which geoinformation is passed from one distributed geoprocessing Web service

to another according to a set of procedural rules and standardized interfaces. In other words, Web-based geoprocessing workflows integrate loosely coupled spatial data and services in an interoperable way, where each part of the workflow is responsible for only a specific task, without being aware of the broader purpose of the workflow. Especially in highly specialized environments such as the GI domain, not every processing step can be potentially handled by a single entity, and therefore, geoprocessing workflows have to be formed. Therefore, outsourcing specialized tasks to highly specialized Web services becomes necessary. As a result, workflows become flexible and are able to quickly adapt to changing market conditions thus leading to higher flexibility and scalability of geoprocesses.

The idea that geoprocessing workflows should be flexible and scalable reflects the general transition from a supply-driven economy to an on-demand economy in the geodomain. Therefore, Web-based cross-enterprise geoprocessing workflows as virtual business processes can be formed by integrating several processes from different partners while still being regarded as a single process from an external point of view.

Due to the distributed nature of geographic data, geoprocessing workflows provide a flexible means for the processing of highly distributed and complex data for a wide variety of applications. The aggregation of existing geoprocessing workflows, exposed as Web services or wrapped by Web services, into a single workflow uses the powerful and flexible capabilities of Web-based geoprocessing workflows.

The full potential of Web-based geoprocessing workflows as an integration platform has already been demonstrated by several research communities. However, further progress of this technology and its broader adoption require that advances be made in the areas of semantic geodata interoperability and in the legal aspects of geospatial information.

Bastian Schaeffer

See also Internet GIS; Legal Aspects of Geospatial Information; Semantic Interoperability



Further Readings

- Groot, R., & McLaughlin, J. (2000). *Geospatial data infrastructure: Concepts, cases, and good practice*. Oxford, UK: Oxford University Press.
- International Organization for Standardization. (2005). *ISO 19119: Geographic information services*. Retrieved January 15, 2008, from http://portal.opengeospatial.org/files/?artifact_id=1221
- Krafzig, D., Banke, K., & Slama, D. (2006). *Enterprise SOA: Service-oriented architecture best practices* (The Coad Series). Upper Saddle River, NJ: Prentice Hall.
- Masser, I. (2005). *GIS worlds: Creating spatial data infrastructures* (1st ed.). Redlands, CA: ESRI Press.
- van der Aalst, W., & van Hee, K. (2004). *Workflow management: Models, methods and systems*. Cambridge: MIT Press.
- Weerawarana, S. (2006). *Web services platform architecture: SOAP, WSDL, WS-policy, WS-addressing, WS-BPEL, WS-reliable messaging and more*. Upper Saddle River, NJ: Prentice Hall/PTR.



WEB SERVICE ARCHITECTURES FOR GIS

There have been many successful developments of geographic information systems (GIS) serving different purposes and different organizations and using different GIS software packages. However, geospatial information sharing and acquisition remains a challenge due to the heterogeneity of existing systems in terms of proprietary system designs, data models, and database storage structures. The emergence and use of Web services and Web-service-oriented architecture (SOA) technologies offer the potential to overcome barriers to interoperability among heterogeneous GIS.

Service-Oriented Architecture

The SOA was developed by IBM, Microsoft, and other leading IT industry organizations to support the development of applications that integrate existing computing technologies into

solution-based systems. A pure architectural definition of SOA presents it as a design within which all functions are defined as independent services with well-defined and invokable interfaces. An SOA is essentially a collection of Web services that communicate with each other by passing simple data or coordinating some activities. IBM has created a model for an SOA that describes three roles—(1) service provider, (2) service requester, and (3) service broker—and three basic operations—(1) publish, (2) find, and (3) bind. Service providers publish services to a service broker. Service requesters find required services using a service broker and bind to them. The binding from the service requester to the service provider should loosely couple the service. This means that the service requester has no knowledge of the technical details of the provider's implementation, such as the programming language, deployment platform, and so forth. Because Web services in SOA are based on open standards, they are able to work together and understand each other even though they don't use the same language or share the same application platform. For example, the data service "Wisconsin land use map"—residing on a Microsoft Windows server in Wisconsin—can be invoked by the service "display Wisconsin land use map" written in Java code and residing on a Linux server in Los Angeles.

To implement an SOA, the open-standard specifications—WSDL (Web Service Description Language), SOAP (Simple Object Access Protocol), and UDDI (Universal Description, Discovery and Integration Service)—are developed to support the interaction of Web services. The WSDL is an Extensible Markup Language (XML)-based language used to describe the services that a business offers and to provide a way for individuals and other businesses to access those services electronically. A complete WSDL definition contains all the information necessary to invoke a Web service, such as what a Web service can do, where it resides, and how to invoke it. It provides a way for service providers to describe the basic format of Web service requests over different protocols or encodings and thus helps improve interoperability between applications. The SOAP is a



communication protocol for communication between applications running on different operating systems with different technologies and programming languages. It defines a format for sending messages between communicating applications via the Internet and specifically using Hypertext Transfer Protocol (HTTP). SOAP consists of three parts: (1) an envelope that defines a framework for describing what is in a message and how to process it, (2) a set of encoding rules for expressing instances of application-defined data types, and (3) a convention for representing remote procedure calls and responses. UDDI provides a mechanism for clients to dynamically find other Web services. Using a UDDI interface, users can dynamically connect to services provided by external providers. The provider typically publishes a WSDL description of its Web service, and the requester accesses the description using a UDDI or other type of registry and requests the execution of the provider's service by sending a SOAP message to it. Since all data in SOA are tagged in XML, communication between applications doesn't depend on any particular operating system or programming language.

Web Service Architectures for GIS

A Web service architecture for sharing geospatial data and geoprocessing models over the Web is illustrated in Figure 1. The main objectives of the Web service architecture for GIS are to (a) maximize productivity and efficiency with geospatial data and online geoprocessing sharing, (b) overcome spatial data and GIS model duplication and maintenance problems, and (c) make it easy to integrate different GIS applications.

The Web service architecture for GIS is based on independent OGC Web services. It is composed of three elements: (1) service provider, (2) service broker, and (3) service client. The service provider supplies geospatial data and geoprocessing models, the service client allows users to search and integrate geospatial data and geoprocessing models from providers, and the service broker provides a registry for available services. The service provider uses OGC data services such as WFS (Web Feature Services), WMS (Web Map Services), and

WCS (Web Coverage Services) to publish geospatial data and WPS (Web Processing Services) to publish geoprocessing models connected to existing heterogeneous GIS such as GIS1 and GIS2 (Figure 1). The service broker uses OGC WRS/CS (Web Registry Services/Catalog Services) instead of using a UDDI to register and manage the OGC data and processing services and allow users to search for these Web services over the Web. Service clients search the contents of catalog services to find the data sets and services of interest, and they also can combine the OGC Web services found through catalog Web services.

A catalog service can publish and search for collections of the resource-based metadata information, and it has two main functions—discovery and publication. Discovery means that the service requester seeks to find resources of interest through simple browsing or by sophisticated query-driven discovery that specifies simple or advanced search criteria. The catalog performs the search and returns a result set that contains all registry objects that satisfy the search criteria. The requester may then choose to retrieve representations of result set items according to some specified schema and element set. The OGC catalog service supports distributed search. That means that a catalog service can interwork with other affiliated catalogs to enlarge the total search space. When a catalog is linked to a peer catalog, it makes the resource descriptions managed by the peer implicitly available to its own clients. The propagation of request messages to the affiliated catalog is invisible to the client—it is not necessary to know where the metadata repositories are located or how they are accessed. A catalog service allows Web services to publish resources in two ways: (1) harvest operation and (2) transaction operation. Harvest operation is the basic publication, and in this operation the catalog itself attempts to harvest a resource from a specified network location, thereby realizing a “pull” model for publishing registry objects. If the catalog successfully retrieves the resource and can handle it, then one or more corresponding registry objects are created or updated. The second way of publication is transaction operation, which is enhanced publication. Transaction operation supports modifying catalog content through a public interface that allows a

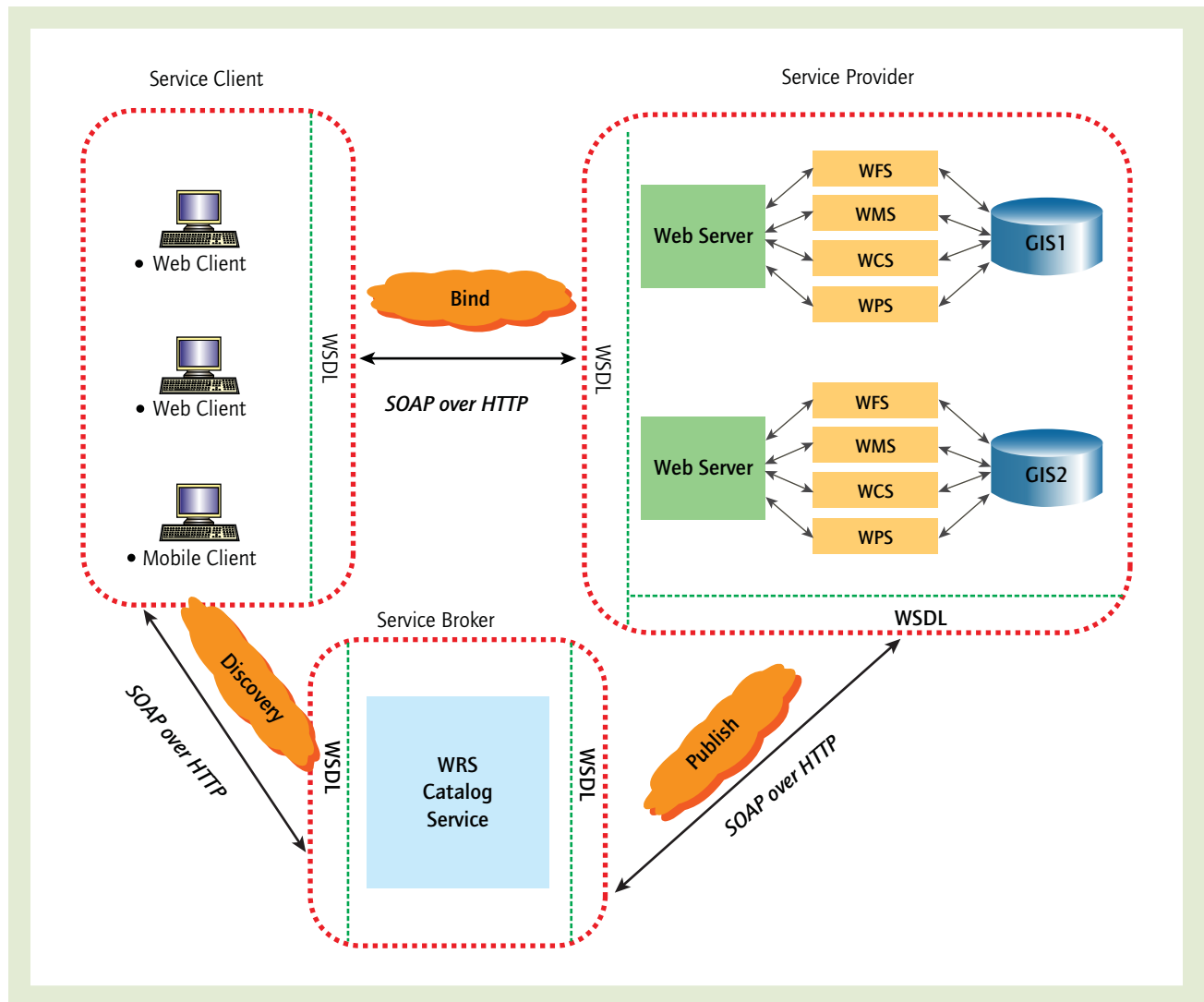


Figure 1 Web service architecture for GIS

Source: Author.

“push” style of publication. A user may insert, update, or delete catalog entries according to criteria specified in the request message. Typically, this operation is subject to some kind of access control such that only authorized users may perform such actions.

As illustrated in Figure 1, the Web services in the SOA for GIS are achieved via WSDL by connecting service providers, service brokers, and service clients. The SOAP binding over HTTP is employed for communication between Web services via the Internet. The SOA ensures data interoperability through the standard exchange

mechanism between diverse GIS sources connected over the Web.

The main benefit of the SOA is that it allows the sharing and integration of spatial data and geoprocessing models from diverse sources transparently across the Web. That is, the SOA allows geospatial data and GIS models to be shared and reused across applications, enterprises, and community boundaries. Thus, many existing proprietary GIS legacy databases and models may be reused and shared. With a ubiquitous set of standards in the SOA, users are capable of creating applications that can be built on top of existing



applications. In addition, the SOA allows geoprocessing to be carried out by chaining (linking) several services representing relatively independent, distributed applications. With its loosely coupled structure, the SOA permits smart and fast updating of the system's obsolete data and models and quick integration of new data and models into the application system, thus enhancing the flexibility and reuse of spatial data and GIS models. Therefore, it may reduce the cost of developing new application programs and leverage an organization's existing investment in data and applications.

Although the Web SOA offers the aforementioned advantages, it presently only resolves technical interoperability through Web services and standard interfaces, and it stops short of resolving the semantic heterogeneity problem in existing GIS. One possible approach to overcoming the problem of semantic heterogeneity is developing domain-specific ontologies and semantic interoperability systems. The concept of Geospatial Semantic Web has been suggested recently to address the vexing challenges of semantic interoperability.

Chuanrong Zhang

See also **GIS Web Services; Internet GIS; Interoperability and Spatial Data Standards; Ontological Foundations of Geographical Data; Open Geodata Standards; Open Geospatial Consortium (OGC); Semantic Interoperability**

Further Readings

- IBM. (2000). *Web services architecture overview*. Retrieved November 19, 2008, from www-128.ibm.com/developerworks/web/library/w-ovr/index.html
- OpenGIS catalogue service implementation specification. (2004). Retrieved November 19, 2008, from www.opengeospatial.org/standards/cat
- OWS 2 common architecture: WSDL SOAP UDDI. (2004). Retrieved November 19, 2008, from http://portal.opengeospatial.org/files/?artifact_id=8348
- Peng, Z.-R., & Tsou, M. S. (2003). *Internet GIS: Distributed geographic information services for the Internet and wireless networks*. New York: Wiley.



WETLANDS

Wetlands are lands that are significantly influenced by the presence of water. Although relatively rare, these fragile ecosystems, which occupy approximately 6% of Earth's surface, are found on every continent except Antarctica. Wetlands are found in most of the world's climatic zones, ranging from warm tropical climates to frigid arctic climates. They are present across a wide range of elevations around the world, from below sea level to mountaintops.

Wetlands are broadly classified according to topography and water salinity. Topographically, they may be present in either coastal areas or inland. When subdivided according to water salinity, they may range from saline (salinity ≥ 30.0 parts per 1,000) to brackish (salinity 29–0.6 part per 1,000) to fresh (salinity ≤ 0.5 part per 1,000). The salinity of coastal wetlands is influenced by distance from the ocean, tides, topography, and the presence and discharge of various sources of freshwater, such as rivers and groundwater. Examples of coastal wetlands include cord grass (*Spartina* sp.)–dominated tidal marshes and mangrove (*Rhizophora mangle*, *Avicennia* sp., *Laguncularia racemosa*, *Sonneratia* sp.) swamps.

The vast majority of interior wetlands are freshwater; however, saltwater interior wetlands may occur in arid regions. Interior wetlands are subdivided according to the environment in which they occur. Major classes of interior wetlands include riverine (river environment), palustrine (pond, pothole environment), and lacustrine (lake environment). Cattails (*Typha* sp.) and rushes (*Juncus* sp.) are plants commonly found in interior wetlands.

Regardless of the environment where a wetland is located, all wetlands share three characteristics: (1) wetland hydrology, (2) hydric (i.e., wetland soil), and (3) hydrophytic vegetation. Water within a wetland may be permanent, inundating the area year-round, or it may be seasonal or ephemeral, flooding an area only a few weeks or months of the year. Prolonged flooding, particularly during the growing period, significantly affects the soil and the vegetation of wetlands.

Given time, continued soil saturation dramatically influences the chemical and physical



Canada geese, common egret, and shore birds in a pothole wetland in South Dakota. Wetlands provide a haven for migrating ducks, geese, and other waterfowl.

Source: Dennis Larson, USDA Natural Resources Conservation Service.

composition of the soil. The upper portions of soil become anaerobic (i.e., without oxygen). Hydric soils have either an organic or a mineral texture. Organic hydric soils are composed mainly of vegetation with varying degrees of decomposition. Muck and peat are common examples of an organic wetland soil. Mineral hydric soil contains little organic matter. This type of soil develops readily identifiable characteristics, such as gleying and mottling. Gleying is a process that occurs in anaerobic, waterlogged soils where iron present in the soil is chemically reduced to iron oxide because of the lack of oxygen. This results in a soil that has a distinctive blue-gray or greenish color. Mottles may also develop from the reduction of iron. Mottles are small, generally

pea-sized or less, reddish-brown or yellowish specks/spots found in dark wetland soil.

Saturated anaerobic conditions influence the type of vegetation that occurs within wetlands. Wetlands vegetation may develop morphological adaptations, which allow the vegetation to thrive in saturated conditions. Common adaptations include shallow root systems, adventitious roots, pneumatophores, multiple trunks, and buttress trunks. Adventitious roots and pneumatophores are some of the more interesting adaptations. Adventitious roots are roots that may develop from the stem or branches of a plant at points above the soil. Pneumatophores are roots that protrude through soil and surface water, thus allowing plants to obtain oxygen in an otherwise



anaerobic environment. Both mangroves and bald cypress (*Taxodium distichum*) develop extensive networks of pneumatophores.

Wetlands are extremely important habitats for humans and wildlife. Coastal wetlands are some of the most productive ecosystems in the world, serving as nursery grounds for much of the world's commercial fisheries. Coastal wetlands also serve as storm buffers, absorbing storm surges and waves associated with tropical and extratropical weather systems. Both coastal and inland wetlands store excess rainfall and floodwater and act as sinks and filters for waterborne contaminants such as heavy metals, and pathogens such as *Escherichia coli*. Many interior wetlands serve as recharge zones for groundwater aquifers. Wetlands are also critical habitats for myriad wildlife, especially waterfowl (see photo).

Even though wetlands are critical to the survival of many species of plants and animals, they are being destroyed at a very rapid rate. Globally, approximately half of all wetlands have been destroyed since 1900. Wetlands are under intense pressure from humans, who drain them for urban, industrial, and agricultural purposes. Coastal zones are under constant threat from global warming and associated sea level rise. Rising seas are inundating and destroying coastal wetlands.

Several international organizations promote wetland research, conservation, and restoration. Two of the most notable organizations are the Society of Wetland Scientists, which supports scientific wetland research, and Wetlands International, which advocates conservation and restoration. In 1971, an international convention on wetlands was held in Ramsar, Iran. The convention, known as the Ramsar Convention (Ramsar), developed an international treaty, titled the Convention on Wetlands of International Importance Especially as Waterfowl Habitat, to conserve wetlands worldwide. To date, 158 countries have signed this treaty. Ramsar also created and maintains a list of threatened wetlands. The list, called "Wetlands of International Importance," includes more than 1,800 wetlands located throughout the world that are considered critical to wildlife. New wetlands are added to the list annually.

Wetlands are important ecosystems that protect humans from storm surges, filter contaminants

from water, and provide habitat for economically viable wildlife. These fragile environments are under increasing pressure from humans, who drain and destroy wetlands, and from changing climates. More research, conservation, and restoration are needed to protect this valuable resource for future generations.

Molly McGraw

See also **Biota and Topography; Ecosystems; Groundwater; Hydrological Connectivity; Surface Water**

Further Readings

- Mitsch, W. J., & Gosselink, J. G. (2007). *Wetlands* (4th ed.). Hoboken, NJ: Wiley.
- Reed, D. J. (1993). Hydrology of temperate wetlands. *Progress in Physical Geography*, 17, 20–31.
- Williams, M. (Ed.). (1993). *Wetlands: A threatened landscape*. Oxford, UK: Wiley-Blackwell.
- Zedler, J. B., & Kercher, S. (2005). Wetlands resources: Status, trends, ecosystem services, and restorability. *Annual Review of Environment and Resources*, 30, 39–74.



WHITE, GILBERT (1911–2006)

Gilbert Fowler White was a prominent and influential American geographer, known as the father of floodplain management in the United States, although his environmental research and policy influences extended to water resources and global environmental issues. He was an advocate of practical applied research to improve the human condition. White was born in Chicago, grew up near the University of Chicago campus, and spent summers working on a ranch in Wyoming. He credited both environments with helping shape his research interests and perspectives.

Having satisfied all the requirements for a doctorate except the dissertation at Chicago, White accompanied his PhD advisor, Harlan Barrows, to Washington, D.C., in 1934 to work for the Mississippi Valley Committee of the Public Works Administration. The tenure in Washington was



anticipated to last 6 months, but 8 years later, White was still there. He worked as a staff member for a number of committees and commissions related to natural resources and flood control. The government service helped provide White with a research agenda and skills to implement the policy implications of research.

His Quaker convictions precluded his working for the federal government during World War II, so he left to complete his doctoral dissertation prior to performing relief work in France and then being interned in Germany. His dissertation, *Human Adjustment to Floods*, is seen by many as the seminal work leading to the widespread adoption of nonstructural alternatives to dams and levees to cope with flood hazards in the United States. White himself characterized his dissertation as a call to consider a broad range of possible adjustments to floods and to fully evaluate all the consequences of each adjustment. *Human Adjustment to Floods* led to the field of floodplain management.

After World War II, White became president of Haverford College, before returning to the University of Chicago in 1955 as a professor of geography. At Chicago, he initiated a program of research on natural hazards, much of which evolved from ideas put forth in his dissertation. He mentored numerous students who made their own contributions to natural hazards research, education, and policy, effectively establishing the foundations of the hazards research paradigm still practiced in geography. In 1970, White moved to the University of Colorado, where he continued his hazards research activities, became director of the Institute of Behavioral Science, and eventually founded the interdisciplinary Natural Hazards Research and Applications Information Center. The center continues to serve as a clearinghouse for hazards research and policy, helping provide a bridge between hazards researchers and practitioners.

Although best known in the United States for his contribution to natural hazards research, White was active in many other environmental spheres. His research conducted with the epidemiologist David Bradley and White's wife, Anne U. White on domestic water use in East Africa served as a model for other researchers in other locations. White felt that international cooperation

on river basin development could facilitate other forms of peaceful relations among nations and chaired an advisory group to the United Nations on the Lower Mekong River. White published prolifically throughout his career, until a few years before his death. He served on many national and international committees, commissions, and advisory groups dealing with a wide range of environmental issues, including climate change, water supply, human-made lakes, pollution, the environmental effects of nuclear war, nuclear waste storage, and hazards other than floods.

He served as president of the Association of American Geographers (1961–1962), was elected to the National Academy of Sciences (1973), and received the National Medal of Science (2000) from the U.S. president. Although White was modest about his influence on public policy, others felt that his impacts were significant, often through the actions of his students and followers or because of the way of thinking he brought to many environmental issues. White passed away in Boulder, Colorado.

Earl J. Baker

See also **Applied Geography; Barrows, Harlan; Environmental Management; Floodplain; Floods; Natural Hazards and Risk Analysis; Sustainability Science**

Further Readings

- Cohen, M. J. (2006). The roots of sustainability science: A tribute to Gilbert F. White. *Sustainability*, 2(2), 1–3. Retrieved November 20, 2009, from <http://ejournal.nbii.org>
- Kates, R. W., & Burton, I. (2008). Gilbert F. White, 1911–2006: Local legacies, national achievements, and global visions. *Annals of the Association of American Geographers*, 98, 479–486.
- White, G. F. (1945). *Human adjustment to floods* (Department of Geography Research Paper No. 29). Chicago: University of Chicago Press.
- White, G. F., Bradley, D. J., & White, A. U. (1972). *Drawers of water: Domestic water use in East Africa*. Chicago: University of Chicago Press.



WHITENESS

Associated with archaic terms such as *Aryan*, *Teutonic*, *Anglo-Saxon*, and *Caucasian* and often assumed to be an inherited biological reality, whiteness is in fact a socially, historically, and geographically constructed understanding of racial identity. Usually constructed against a perceived nonwhite other, there are multiple lived experiences of whiteness, varying across time and space and differing by scale. Understandings of whiteness shape both sparsely populated rural areas and multiracial urban locations, albeit in different ways, and there is no singular, essential white identity.

Whiteness is most commonly associated with pale, pinkish-colored skin and people of Northern European descent. European colonial and U.S. expansionist practices were central to the construction of modern racial whiteness. In the 19th century, U.S. national identities such as Irish and Italian were often envisaged by the elites of Northern European descent as a stepping stone between the inferior African black race and the superior white Anglo-Saxon. Strategies such as employers hiring European immigrants rather than African Americans, and the subsequent benefits of unionization, saw associations develop between whiteness and working-class identities in the United States. As a result, people of these formerly disparaged European nationalities achieved whiteness, so to speak, and gained the benefits of a white racial identity in a racially segregated society. In the 20th century, throughout the United States, associations between whiteness, wealth, and power were strengthened by the construction and maintenance of racialized landscapes such as sundown towns and whites-only suburbs.

In industrialized Western societies, a myth of color blindness developed in the late 20th and early 21st centuries, rendering whiteness largely unexamined. Consequently, discussing whiteness is, to some extent, a taboo subject, except among explicit racists whose appeals to white identities are often linked with hate groups such as neo-Nazis or the Ku Klux Klan. Recognizing the negative associations of overt appeals to whiteness, many white people avoid using the term *white*, instead articulating whiteness through discourses of normality, nature, nationality, culture, and

landscape. For example, some espouse the need to preserve the “European” heritage or to protect specific cultures. In this manner, demands that whiteness be politically recognized are made using the language of multiculturalism and cultural pluralism and through rhetorical appeals to heritage, tradition, ethnicity, and genealogy.

An associated concept is that of white privilege. This refers to the everyday unearned structural advantages that accrue to people whom others identify as white. Often unconscious and unrecognized by the beneficiaries, arguably because of the taboo surrounding articulations of whiteness, white privilege structures Western societies in a manner that positions the values and beliefs of the white (and usually middle class) population as the norm against which the behaviors and practices of others are contrasted. Commonly associated with the practices of institutionalized racism, white privilege reconfigures understandings of racism to explain the advantages gained from whiteness. These advantages, however, vary with the shifting boundaries of whiteness and are reconfigured by class, gender, sexuality, age, and other demographic characteristics.

Euan Hague

See also **Critical Human Geography; Ethnicity; Race and Racism**

Further Readings

- Bonnett, A. (2000). *White identities: Historical and international perspectives*. New York: Prentice Hall.
- Kobayashi, A., & Peake, L. (2000). Racism out of place: Thoughts on whiteness and antiracist geography in the new millennium. *Annals of the Association of American Geographers*, 90, 392–403.
- Loewen, J. (2005). *Sundown towns: A hidden dimension of American racism*. New York: Touchstone.
- McCarthy, J., & Hague, E. (2004). Race, nation and nature: The cultural politics of “Celtic” identification in the American West. *Annals of the Association of American Geographers*, 94, 377–408.



- Pulido, L. (2000). Rethinking environmental racism: White privilege and urban development in Southern California. *Annals of the Association of American Geographers*, 90, 12–40.
- Roediger, D. (1999). *Wages of whiteness: Race and the making of the American working class*. London: Verso.
- Schein, R. (Ed.). (2006). *Landscape and race in the United States*. New York: Routledge.

WHITTLESEY, DERWENT (1890–1956)

One of the more important figures of cultural geography in the early to mid 20th century, Derwent Stainthorpe Whittlesey is best known for advocating the notion of sequent occupance. He served as president of the Association of American Geographers (AAG) in 1944 and was editor of the *Annals of the Association of American Geographers* for 12 years.

Born in the farming community of Pecatonica, Illinois, Whittlesey studied at the University of Chicago, where he completed a degree in history in 1915; he then attended the School of Geography, where he studied under Ellen Churchill Semple and Harlan Barrows. After graduation, he taught at Chicago from 1920 to 1928, when he moved to Harvard to become its first human geographer; for the remainder of his career, he was professor of cultural and political geography at Harvard. He served as a consultant for the U.S. state, war, and navy departments during World War II. His interest in political affairs led him to publish *The Earth and the State* in 1939 and, with two coauthors, *German Strategy for World Conquest* in 1942. Whittlesey delved into several other topics, including agricultural development and the nature of regions and regionalism. He also studied Africa for 35 years, particularly Rhodesia (now Zimbabwe). His work historicized cultural and political issues in an era when much of geography viewed the world in static, ahistorical terms.

In 1929, Whittlesey introduced the term for which he is best known, *sequent occupance*—a technique for analyzing landscapes as the product

of successive groups over time, each of which uses it in its own way and leaves a lasting imprint. Landscapes are thus created by the number of groups that occupied an area at different moments, and comprise a palimpsest. To understand the landscape was to understand the history and practices of its various groups of inhabitants, each of which created a spatiality that both reflected that of its predecessor and subsequently influenced that of its successor. Each group, he argued, carried the seeds of its own transformation; culture was thus never a frozen set of ideas or objects but was continually in motion. In framing this issue, Whittlesey drew selectively from human ecology, but he forcefully offered a social dynamic at odds with the deterministic erosional cycle of William Morris Davis, which was then the dominant means of interpreting landscapes. In this respect, Whittlesey shared much in common with Carl Sauer, that is, a view of cultural landscapes as ever changing and historically generated, as produced rather than given; both played a vital role in combating environmental determinism. Sequent occupance would later find its way into the resurrection of localities research in the late 20th century.

As president of the AAG in 1944–1945, Whittlesey published his presidential address when the annual conference was canceled to curtail wartime travel. His essay “The Horizon of Geography,” published in 1945, deftly summarized the changing scale of spatial consciousness that accompanied humanity’s ascent from hunting and gathering to the modern age: “By scrutinizing successive space-horizons from the most primitive known down to the present, it should be possible to determine the character and limits of geographic space in the present world of revolutionary technology and social adaptation” (p. 3).

One of the most famous events concerning Whittlesey was the closure of the Harvard geography department in 1948, of which he was the chair. In a period in which the discipline, dominated by empiricist chorology, was not known for intellectual vitality, the closure marked the first of a long series. The department fell under sustained attack from geologists and from Harvard’s president, who felt that geography did not qualify as a university discipline. Isaiah Bowman, the then president of Johns Hopkins University,



could have helped in this situation but chose not to do so, in part because he felt that the Harvard department overemphasized human geography and in part due to his homophobic feelings about Whittlesey, who was widely presumed to be gay. Whittlesey, however, continued to teach at Harvard until his death.

Barney Warf

See also Bowman, Isaiah; Chorology; Cultural Geography; Hartshorne, Richard; Human Geography, History of; Palimpsest; Sauer, Carl; Sequent Occupance

Further Readings

- Martin, G. (1988). On Whittlesey, Bowman and Harvard. *Annals of the Association of American Geographers*, 78, 152–158.
- Smith, N. (1988). “Academic war over the field of geography”: The elimination of geography at Harvard, 1947–1951. *Annals of the Association of American Geographers*, 77, 155–172.
- Whittlesey, D. (1929). Sequent occupance. *Annals of the Association of American Geographers*, 19, 162–165.
- Whittlesey, D. (1939). *The Earth and the state: A study of political geography*. New York: Henry Holt.
- Whittlesey, D. (1945). The horizon of geography. *Annals of the Association of American Geographers*, 35, 1–36.
- Whittlesey, D., Colby, C., & Hartshorne, R. (1942). *German strategy of world conquest*. New York: Farrar & Rinehart.

in the North American context. As its definitions have changed, wilderness areas have become contested sites.

During the settlement era, Euro-Americans often feared the wilderness, as it was home to dangerous creatures and seemingly dangerous “others,” the indigenous peoples of the continent. In the 19th century, several influences reworked the meaning of wilderness. The aesthetic and spiritual ideas of Romanticism and Transcendentalism for some transformed the wilderness from a devilish place to a location where one might more easily commune with God. The perceived loss of the frontier, growth of cities, and polluting impacts of industrialization made others look to wilderness as symbolic of a rugged, independent American character that was threatened by urbanization. Wilderness became a therapeutic space.

As these definitions of wilderness took hold, arguments over the purpose of wilderness entered public discourse. In the 20th century, the preservationists, who sought to protect the ecological and aesthetic integrity of the wilderness by leaving areas untouched by development, fought against the conservationists, who strove to extract valuable natural resources using methods that would ensure their continued supply into the future. Around the world, international organizations; federal, state, and provincial governments; and nongovernmental organizations have officially protected lands as wilderness areas. In many instances, the act of drawing boundaries around wilderness areas and, furthermore, defining who and what belongs within such spaces has raised considerable controversy.

In recent years, human geographers have argued that the evolving definition of wilderness is evidence that it is a social construct. This does not mean that wild places do not exist or that their ecological, aesthetic, and spiritual qualities are insignificant but, instead, that notions of wilderness are products of human cultures. Some scholars assert that few designated wilderness areas extant today were ever uninhabited; in many cases, indigenous peoples were removed from their lands to create a wilderness that fits a narrow definition. Others point out that wilderness has class, gendered, and racial dimensions. These ideas are vigorously contested, especially by those who are concerned that resource extraction, pollution,



WILDERNESS

Wilderness is understood as a region that exists in its original, natural state with few or no human inhabitants. It may contain distinctive geographic features, rare ecosystems, or plant and animal species that require vast expanses of land for habitat. Since the 1970s, geographers and environmental historians have closely examined the definition of wilderness. They found that its meaning has changed significantly over time, especially



The Arctic National Wildlife Refuge, pictured here, is home to some of the most diverse and spectacular wildlife in the Arctic. The refuge's rich pageant of wildlife includes 36 fish species, 36 land mammals, 9 marine mammals, and more than 160 migratory and resident bird species.

Source: U.S. Fish & Wildlife Service.

and land development are threatening to permanently damage or even end fragile, irreplaceable, and ecologically important natural areas. For these advocates, the scientific community cannot afford scholarly debates over definitions that might further a political agenda to tamper with wilderness.

Cheryl Morse Dunkley

See also [Class, Nature and; Critical Studies of Nature; Environmental History; Ethnicity and Nature; Gender and Nature; Nature; Nature-Society Theory; Social Construction of Nature](#)

Further Readings

Cronon, W. (1995). The trouble with wilderness; or, getting back to the wrong nature. In W. Cronon (Ed.), *Uncommon ground: Rethinking the human*

place in nature (pp. 69–90). New York: W. W. Norton.

Nash, R. (2001). *Wilderness and the American mind* (4th ed.). New Haven, CT: Yale University Press.



WILDFIRES: RISK AND HAZARD

Analysis of the threat, hazard, and risk relative to wildfire is a spatial problem: Where does a wildfire occur relative to resources valued by humans? In the natural or built environment? Wildfires burn uncultivated vegetation in natural environments, whether mountainous forests, rural woodlands, brush lands, or prairie grasslands. In common usage, the terms *threat*, *hazard*, and *risk* are often interchanged and confound understanding of the important distinctions between them.



Any wildfire may be considered to pose a *threat*, to present the potential to do harm. *Threat* refers to the source that could cause damage. A wildfire threat exists where heat from burning vegetation could ignite other combustible material regardless of whether burning that material would constitute a loss. Whether a wildfire poses *hazard* or *risk* depends on whether any valued resources, natural or human-made, that could be damaged by fire are potentially in a path of fire spread. Unless some resource determined to be of value is in harm's way, no hazard or risk is associated with a wildfire.

The term *hazard* may be most effectively used when planning to mitigate potential losses in some future, nonspecified time. Efforts to thin forest fuels around homes well in advance of the wildfire season constitute hazard reduction. This action is taken in the absence of an immediate threat. Fuel reduction usually occurs where it is recognized that the potential for loss would be high if a wildfire were to occur some time in the coming years.

Analysis of risk explicitly requires assessment of the probability that a loss will occur as a result of wildfire. What is the chance or likelihood that a fire will reach and damage or destroy a valued resource? The probability statement may be qualitative, based on some form of actuarial analysis, or derived from quantitative techniques such as numerical fire spread modeling. Strictly applied, *risk analysis* is the calculation of expected loss, the value of the threatened resource multiplied by the expected value change to that resource.

For example, if a fire is ignited on a heavily forested mountain, the mere presence of an active flame is commonly considered to present a threat. If a communications tower is downwind or otherwise in the vicinity of the flames, the fire presents a hazardous condition relative to the tower. This statement of hazard does not assume one way or the other that the fire will actually reach and damage the tower. If the tower is valued at \$250,000 and there is a 50% chance that the fire will reach and destroy the tower, the tower is *at risk*. The expected loss is calculated at \$125,000. This calculation could be extended to loss of services if a value for the loss could be clearly defined.

Analysis of hazard and risk posed by wildfire is fundamentally a two-part spatial problem. It

starts with threat analysis: Where is the fire currently located, and where is it headed? The second part analyzes hazard and risk. Hazard assessment identifies the valued resources that wildfire may intersect as it spreads. Risk assessment considers the probability that valued resources will be damaged or destroyed so that the value will be changed. This spatial intersection of the potential area of wildfire spread with valued resources may be implied by observation and judgment or explicitly determined through rigorous geospatial analysis commonly conducted within geographic information systems.

Fire behavior models predict fire spread, and fundamental spatial analysis evaluates geospatial databases of values potentially at risk (Figure 1). Spatially explicit numerical models calculate the direction and rate of spread of wildfire based on the characteristics of weather, topography, and vegetation. These factors influencing and controlling fire behavior have been determined through observation and experiment. Weather characteristics include the direction and speed of prevailing winds and the influence of temperature, precipitation, and relative humidity on fuel moistures. Topographic or terrain factors include elevation, hillslope gradient or steepness, and aspect, the direction a hillslope is facing. The vegetation or the fuels that may feed a wildfire are defined by surface fuels, the distance between the ground surface and the lowest limbs, the spacing of the crowns of overstory trees, the vegetation bulk density, and the height of the dominant forest or shrub canopy. The current fire location and where the fire will probably spread are mapped with geospatial data of values potentially at risk. Many data sets are available that represent critical infrastructure such as electric power lines, oil and gas pipelines, and locations of public buildings and recreational facilities on public lands. These data sets are improving and expanding, driven by commercial and national security needs.

Assigning a value to the resources at risk may be very simple or complicated. Clear dollar values may be assigned to objects in the built environment. Dollar amounts typically represent the cost of repairing or replacing any items damaged or destroyed by a wildfire. Often, no clear market value exists for the valued natural resources. For example, what is the value of an isolated

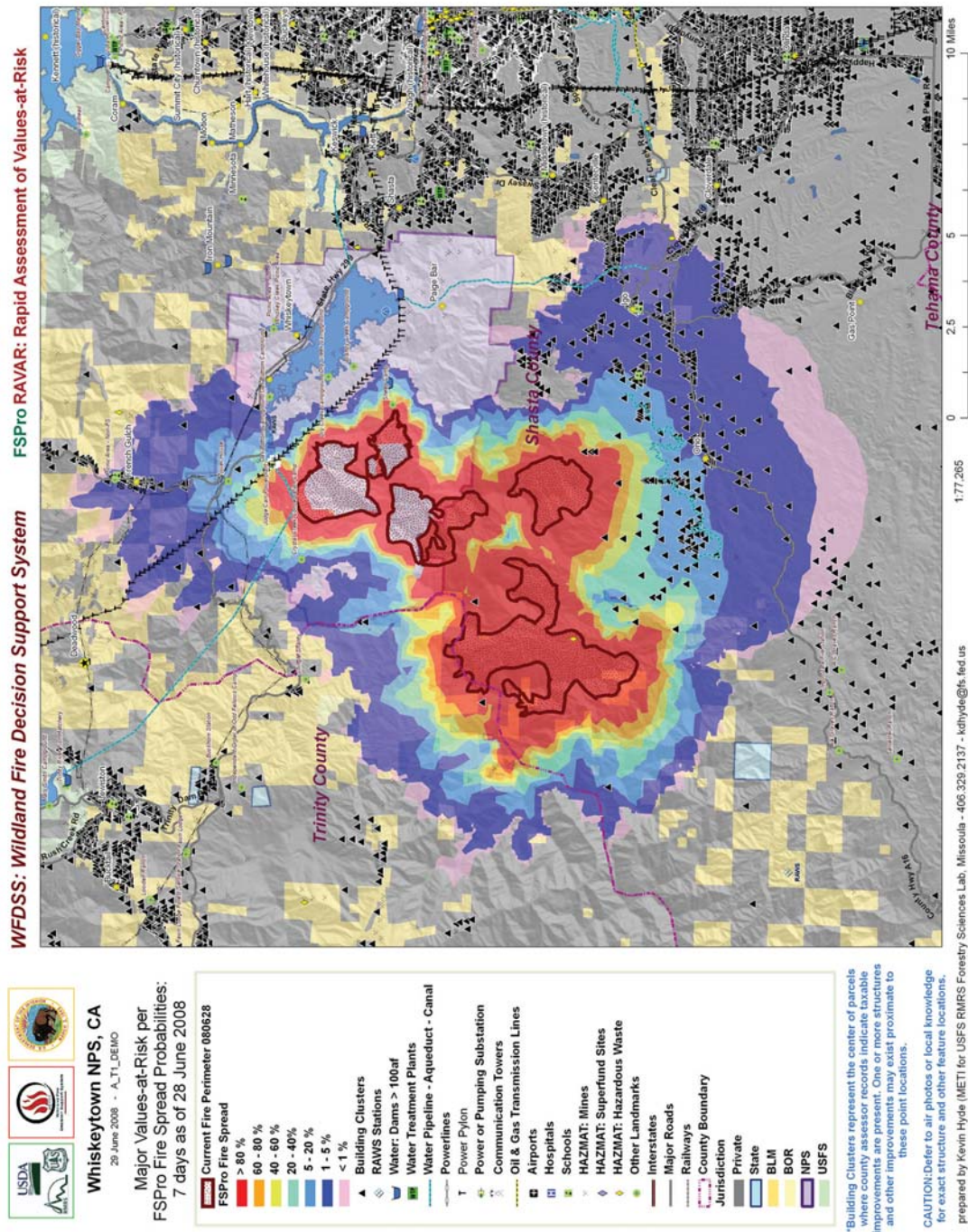


Figure 1 Risk assessment map for the Whiskeytown Fire near Redding, California, 2008. The rainbow array represents the area of probable fire spread predicted by the Fire Spread Probability (FSPRO) model of the USDA Forest Service. Fire spread is mapped relative to threat.

Source: Author.



population of an endangered plant or the value of clean water? Two problems commonly arise while assessing the hazard or risk to such resources. The first problem is what economists refer to as the valuation of nonmarket resources—a highly controversial area of economic theory. One nonmonetary, indirect solution to this is to simply summarize the amount of nonmarket resources by area, linear distance, or item count within the area into which a fire may spread. Another difficulty comes where the wildfire might ultimately benefit ecosystem health. Wildfire is a natural process within forests, grasslands, and shrub ecosystems, a process to which many species are adapted and without which they fail to thrive. Wildfire may be necessary to maintain or restore ecosystem health and functionality. This problem is compounded by the source of ignition: Is the fire caused by a “natural” lightning strike or by humans? When a fire is caused by humans, it may be considered unnatural even if the possible outcome could be beneficial to the ecosystem.

Given the conflict between the potential benefit of wildfire and the potential for loss of valued resources, the analysis of trade-off is inherent in the assessment of hazard and risk presented by wildfire. In the short-term, a wildfire may destroy a lookout tower atop a mountain. However, the same fire could lead to the regeneration of fire-dependent tree species and improve ecosystem health through trophic cascading benefits. For example, a wildfire could ultimately spur regeneration of whitebark pine, which produces seeds that provide highly enriched hibernation food for the endangered grizzly bear.

Kevin Hyde

See also **Forest Degradation; Forest Land Use; Indigenous Forestry; Natural Hazards and Risk Analysis; Pyrogeography; Social Forestry; Sustainable Forestry**

Further Readings

Andrews, P., Finney, M. A., & Fischetti, M. (2007, August). Predicting wildfires. *Scientific American*, pp. 47–55.

- Calkin, D. E., Jones, J. G., & Hyde, K. (2008). Non-market resource valuation in the post-fire environment. *Journal of Forestry*, 106, 305–310.
- Finney, M. A. (2005). The challenge of quantitative risk analysis for wildfire. *Forest Ecology and Management*, 211, 97–108.
- National Research Council. (2007). *Successful response starts with a map: Improving geospatial support for disaster management*. Washington, DC: National Academies of Science.
- Williams, R. J., & Bradstock, R. A. (2008). Large fires and their ecological consequences: Introduction to the special issue. *International Journal of Wildland Fire*, 1, 685–687.



WILSON, JOHN (1955–)

John Wilson is one of geography's leading practitioners of geographical information systems (GIS), particularly in the context of environmental concerns. He is a professor of geography at the University of Southern California, where he chairs the department of geography, directs the geographic information science and technology graduate programs as well as the GIS research laboratory, and also holds adjunct appointments as professor in the departments of computer science and civil and environmental engineering. He received his PhD in geography from the University of Toronto, Canada, in 1986. He also holds an LLB honors law degree from the University of Canterbury, New Zealand.

From 1992 to 1997, he was a professor of geography in the department of Earth sciences, an adjunct professor of soil science in the department of plant and soil science, and the director of the Geographic Information and Analysis Center at Montana State University. His early career included positions as assistant professor (1984–1990) and associate professor (1990–1994) of geography, with corresponding adjunct appointments in soil science at Montana State University. He founded the Geographic Information and Analysis Center at Montana State University in 1989 and the GIS Research Laboratory at the University of Southern California in 1997. He has held several visiting appointments in environmental



studies, geography, and planning at the Australian National University, the University of Utrecht in the Netherlands, and the University of Waikato in New Zealand.

Wilson's research builds on physical, human, and quantitative emphases in geography. His master's research investigated internal migration in the Gilbert and Ellice Islands Colony using the 1973 census data, and his doctoral dissertation analyzed environmental change in the Lake Simcoe Basin. Nevertheless, his research culminates in GIS tool development, spatial analysis, and environmental modeling. He has published numerous books and articles on these topics, including two edited volumes, *Terrain Analysis: Principles and Applications* in 2000 and the *Handbook of Geographic Information Science* in 2007. He is one of the leading geographers actively involved in collaborative, multidisciplinary research with the goal of improving knowledge and understanding of the human impact on both the natural and the built environment. Many of his research projects (see www.uscgislab.net) not only contribute to geography but also broaden geographic perspectives to a wide range of academic communities. He has received numerous honors for his research and teaching, the most recent being a Mellon Award for Excellence in Mentoring from the Center for Excellence in Teaching in 2005 and an Albert S. Raubenheimer Outstanding Faculty Award for his research, teaching, and service contributions in 2004, both at the University of Southern California. He has received accolades outside academia with the Special Achievement in GIS Award for Leadership With Geospatial Technology from the Environmental Systems and Research Institute in 2006 and 2008.

Wilson has also led national and international efforts to strengthen academic communities in GIS. He founded the journal *Transactions in GIS* in 1996 and has served as its editor-in-chief since its inception. He has served on the editorial boards of *Applied Geography* and *Annals of the Association of American Geographers*. He chaired the Applied Geography Specialty Group of the Association of American Geographers (1989–1991) and the Research Committee of the University Consortium for Geographic Information Science (2002–2005). He served as president of the University Consortium of Geographic Information

Science in 2006–2007 and is an active participant in the UNIGIS International Network—a worldwide consortium of more than 20 institutions that collaborate on the development and delivery of online geographic information science academic programs.

May Yuan

See also **Geographic Information Systems; GIScience; GIS in Environmental Management; University Consortium for Geographic Information Science**

Further Readings

- Deng, Y.-X., & Wilson, J. (2008). Multi-scale and multi-criteria mapping of mountain peaks as fuzzy entities. *International Journal of Geographical Information Science*, 22(2), 205–218.
- Wilson, J., & Burrough, P. (1999). Dynamic modeling, geostatistics, and fuzzy classification: New sneakers for a new geography? *Annals of the Association of American Geographers*, 89(4), 736–746.
- Wilson, J., & Fotheringham, S. (Eds.). (2007). *Handbook of geographic information science*. Oxford, UK: Blackwell.
- Wilson, J., & Gallant, J. (Eds.). (2000). *Terrain analysis: Principles and applications*. New York: Wiley.



WIND

Wind is a fluid motion in an atmosphere. All wind is caused by pressure differences. Wind is ubiquitous but varies considerably in its spatial and temporal scales and has a significant impact on the human and physical components of Earth.

Humans have long been fascinated by the wind. For example, several references to wind are found in the Bible. In Greek mythology, Aeolus was the custodian of the four winds. Evangelista Torricelli, who invented the barometer, provided the first scientific description of wind formation in the mid 17th century. We now have the capability of measuring wind from space and have garnered enough information about wind patterns to



predict weather and generate power from wind, for example. This discussion of wind is organized around four themes: formation, types, measurement, and importance.

Formation

Horizontal differences in pressure can cause air movement, or wind. Atmospheric pressure, air density, and air temperature are interrelated. Warm air temperatures increase the air's molecular velocity, decrease air density, and cause air pressure aloft to rise. Cold temperatures increase air density and cause air to sink, thus lowering the air pressure. Generally, airflow is from high to low pressure, compared across uniform height above the surface, with wind velocity increasing with increasing pressure differences. The difference in pressure between two places divided by the horizontal distance between two places is called the pressure gradient. Tightly spaced isobars (lines indicating equal pressure) on a weather map indicate increased pressure gradients. Larger pressure gradients are associated with larger pressure gradient forces. Newton's second law of motion predicates that the relationship between pressure gradient force and wind speed is positively linear.

In addition to pressure gradient force, several other forces influence wind speed and direction. Coriolis force (after Gaspard Coriolis), or effect, is an apparent force resultant from Earth's rotation. Coriolis force opposes pressure gradient force, causes wind deflection, and does not affect wind speed. Deflection is toward the right and left in the Northern and Southern hemispheres, respectively. Deflection magnitude depends on wind velocity and latitude. Increasing latitude corresponds with increasing deflection, with no deflection at the equator. Centripetal acceleration affects airflow around circulation centers and influences wind direction but not speed. Centripetal acceleration steers winds at right angles to the rotational center of the low pressure. The fourth force is friction, which opposes the dominant wind direction and causes a deceleration. Frictional effects are only found close (less than 1 kilometer) to Earth's surface.

Global and upper-level wind circulation can be conceptualized using Hadley's (after George

Hadley) three-cell model in which the Hadley (0° – 30°), Ferrel (30° – 60°), and Polar (60° – 90°) cells are found in both the hemispheres (Figure 1). The Hadley cell is a convection loop; warm equatorial air rises and moves aloft, laterally to the poles, cooling as it approaches the middle latitudes (30°). The rising equatorial air produces the equatorial trough, and surface air converges. The region of convergence is the intertropical convergence zone (ITCZ), its exact location fluctuating throughout the year between approximately 25° N and 20° S. ITCZ controls monsoons, a phenomenon primarily influencing the northeast Indian Ocean region. The region between 0° and 30° is the doldrums, and warm air and weak horizontal pressure gradients dominate. The poleward extreme of the Hadley cell at 30° N/S is dominated by convergent air aloft descending to the surface, thus increasing surface air pressure (the subtropical highs). The resultant generalized weather around 30° is warm surface temperatures and relatively cloudfree skies. Earth's major deserts (e.g., Sahara) are found here. The horse latitudes are an informal name for 30° N/S. Ships traveling to the New World were greatly slowed from the weak pressure gradients and winds. Legend indicates that as travel time increased, food decreased and horses were eaten or evacuated overboard. Winds divert poleward and toward the equator from the subtropical high-pressure systems. The equatorward winds are the northeast (Northern Hemisphere) and southeast (Southern Hemisphere) trades; these relatively steady winds were named so because they provided sailing ships with routes during merchant trading.

The pressure and wind patterns of the Ferrel cell (after William Ferrel) are more complex than those of the Hadley cell. The poleward winds originating around the subtropical highs at 30° are the westerlies; wind deflects to the east in both hemispheres. The westerlies converge with the polar easterlies around 60° . The converging air at 60° does not readily mix, mainly because of contrasting temperatures. The boundary between the two air masses is the polar front, a low-pressure zone. The weak polar cell circulates poleward aloft, descends at the poles, and moves horizontally toward 60° on the surface (westerlies) where air rises. The latitudinal extents described in the Hadley three-cell model are

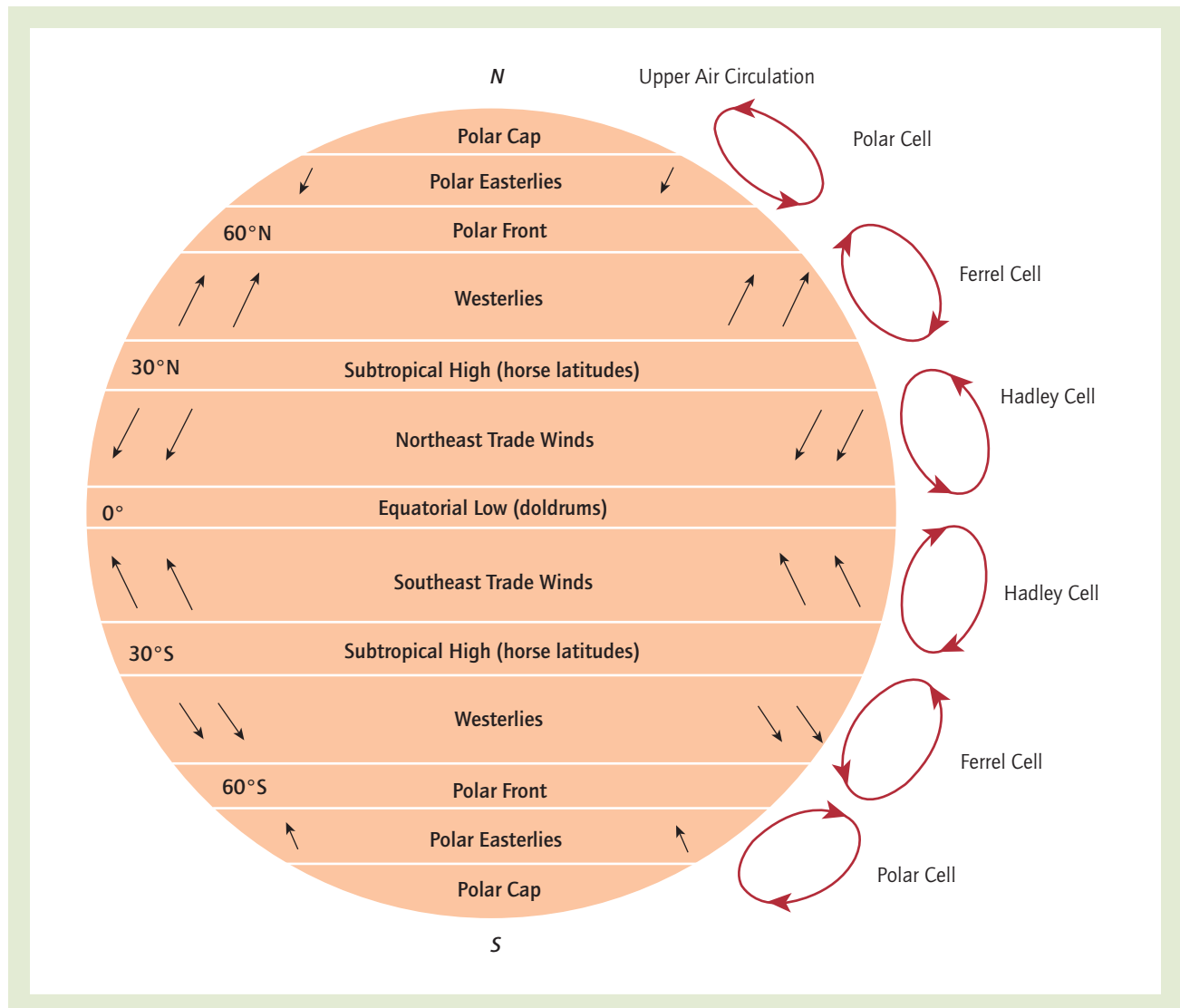


Figure 1 Idealized global circulation according to Hadley's three-cell model, disregarding the effect of landmasses

Source: Author.

idealized. Actual locations are influenced strongly by seasons and the different heating and cooling characteristics of land and water.

Types

Jet streams are fast-flowing air currents that are thousands of kilometers long, a couple of hundred kilometers wide, and a few kilometers thick; they are found between 10 and 15 km above the surface. There are two jet streams: (1) subtropical,

fluctuating about 30°, and (2) polar, fluctuating about 60° and influenced by the Rossby waves.

Surface winds range in scale from meters to thousands of kilometers, and their air temperature differences have different causes. Land-sea breezes typically direct wind from the land to the water in the evenings, when lower temperatures and higher pressure are observed on the land, compared with higher temperatures and lower pressure observed over the water. These winds are strongly influenced by the high thermal holding



capacity of water. Various regional names (e.g., *mistral* in Southern France and *taku* in Alaska) are used to describe katabatic drainage-type winds; cold dense air accumulates in high valleys or plateaus and descends (in altitude) due to gravity. “Snow-eating” winds are specific to mountain ranges in which cold, moist air ascends the windward slope, condenses, and adiabatically descends the lee slope as a warm, dry wind. Regional names include foehn in the Alps, Santa Ana in Southern California, and chinook in the Rocky Mountains.

Measurement

Wind is typically characterized by its speed and direction. Surface wind speed is frequently measured with anemometers that are colocated with other meteorological instruments at 10 m above the bed. Four-cup anemometers were invented in 1846 by John Thomas Romney Robinson. Modern-day cup anemometers have three cups, as the reduction in cup number allows the instrument to respond faster to changing wind speeds. If fine spatial and temporal resolution is required, hot wire and thermal anemometers are used to sample at rates in excess of 25 hertz, with minimal disruption to the wind field. Sonic anemometers measure the horizontal, vertical, and lateral flow components and are needed to study turbulence. During fine-scale and/or turbulence studies, wind velocity is often measured at multiple elevations above the ground. Wind velocity logarithmically increases from the surface, according to the “law of the wall” equation developed by Theodore von Kármán in the early 20th century. Since the 1990s, global ocean surface wind speeds have been measured from space using radar scatterometers. Jet streams and other upper-level winds are measured with weather balloons.

Units frequently used to represent wind speeds are meters per second (m/s), kilometers per hour (km/hr.), nautical miles per hour (knot), miles per hour (mph), and feet per second (ft./s). One m/s is equivalent to 3.6 km/hr., 1.9 knot, 2.2 mph, and 3.3 ft./s. The windiest place on Earth is George V, Antarctica, where speeds typically exceed 325 km/hr. Dodge City, Kansas, is the windiest city in the United States (22 km/hr.)—the “windy city,” Chicago, Illinois, only averages 16 km/hr. Jet

stream velocities accelerate during winter, averaging approximately 150 km/hr., compared with summer averages of about 75 km/hr.

The Beaufort wind scale (after Sir Francis Beaufort) originated as a method for mariners to estimate wind speed from observations of the sea and is still used to categorize wind speeds. The modern scale has 12 classes; the upper extent classifies all winds greater than 73 mph (117 km/hr.).

Wind direction is most frequently measured 10 m above the surface with a wind vane. Winds are named according to the source direction, employing the 16-principle compass bearings.

The wind chill factor, or a measurement of the effect of cold temperature and wind velocity on humans, is predicted and reported by the U.S. Weather Service. It is an estimate of how the temperature “feels” to humans.

Importance

Wind is one example of a geomorphic agent of change. Aeolian-formed landforms are estimated to cover 20% to 25% of Earth’s land surface. Wind speed and duration and fetch length influence the formation of wind, or gravity, waves (1- to 30-s periods). Wind-generated waves are created from the tangential forces created when wind travels over water. Gravitational forces act in a restorative capacity and oppose wave growth. Present-day wind on Mars is evidenced by aeolian ripples superimposed on dunes, sediment accumulation on the lee side of protruding rocks, and yardangs.

High-velocity winds may have a significant impact on human life and the environment. Mid-latitude storms form when warm tropical and cold polar air masses interact. The warm air jet-tions vertically and cyclonically. During their most organized stage (cyclogenesis), these storms typically comprise two fronts—warm and cold—rotating counterclockwise (Northern Hemisphere) and clockwise (Southern Hemisphere) about a low-pressure system. Cold fronts produce various types of precipitation, including rain, hail, snow, and sleet.

Tropical cyclones comprise a low-pressure center with winds rotating around the eye in the same direction as observed with midlatitude



cyclones and have sustained winds exceeding 115 km/hr. The storms are hurricanes in the northern Atlantic and eastern North Pacific, typhoons in the western North Pacific, cyclones in India and Australia, and buguios in the Philippines. Storms are hundreds of kilometers wide; the eye is approximately tens of kilometers in diameter. Tropical cyclones form when upper-level winds diverge and the air aloft is leaving faster than the surface air is entering. Storms are fueled by the transfer of sensible and latent heat from tropical ocean waters to the atmosphere; therefore, storms dramatically lose strength at landfall. The Saffir-Simpson Scale ranks hurricane wind intensity from 1 to 5 and is used to estimate potential property damage and coastal flooding. Since hurricanes began to be categorized using this scale, three Category 5 tropical cyclones have made landfall in the United States: Labor Day Hurricane (1935, Florida Keys), Hurricane Camille (1969, Mississippi coast), and Hurricane Andrew (1992, Homestead, Florida); however, Hurricane Katrina (2005, Mississippi and Louisiana coasts) is the most devastating storm to date and affected the land as a Category 3 cyclone. It is believed that the changing climate will increase the frequency of intense tropical storms.

Tornadoes and “dust devils” are vertical columns of circulating air. The latter is smaller spatially, ranging from 1- to 10-m wide and from 1- to 1,000-m high, and is formed when hot surface air rises, giving way to cooler, lower-pressure air. Tornadoes vary dramatically in size; however, in the United States, a conservative average surface width is hundreds of meters, with an average ground path length of approximately 10 km. Tornadoes are classified according to the Enhanced Fujita Scale (since 2007), ranging from EF0 to EF5. EF1 and EF2 make up approximately 85% of all U.S. tornadoes, with wind speeds less than 178 km/hr. Tornadoes with wind speeds exceeding 322 km/hr. (EF5) are rare; only two have been reported—in Greensburg, Kansas (May 4, 2007) and concentrated around Parkersburg, Iowa (May 25, 2008). There has been a dramatic increase in reported tornado activity since the 1940s; however, much of that increase is due to improved detection capabilities.

Average wind speeds can severely affect the human and natural environment. The Dust Bowl

in the Western United States was caused from seasonal winds eroding the agriculturally damaged soil, turned into dust. The airborne particulates had a significant impact on the respiratory systems of humans and animals across the United States.

Wind influenced global ship-borne expeditions, and thus the colonization of the New World. Modern-day transportation is still influenced by wind, including shipping vessels, commercial and private air traffic, and space flight. Airports, for example, are designed to accommodate the regional prevailing wind direction because aircraft always depart and land into the wind.

Wind-generated power is an alternative to fossil fuels. Power is generated from a turbine or a wind farm, comprising a group of turbines. Consistent wind speeds exceeding 16 km/hr. are ideal. Wind turbines are typically located on land in mountainous regions, near the coast, or offshore, the latter presently exclusive to Europe. Wind farms have relatively minor environmental impacts but are damaging to migratory species and local aesthetics, and they increase noise and light pollution.

Jean T. Ellis

See also Atmospheric Circulation; Atmospheric Energy Transfer; Atmospheric Pressure; Chinooks/Foehns; Dunes; Fronts; Hurricanes, Physical Geography of; Tornadoes; Wind Energy; Wind Erosion

Further Readings

- Ahrens, C. D. (2008). *Meteorology today: An introduction to weather, climate, and the environment*. Pacific Grove, CA: Brooks/Cole.
- DeBlieu, J. (2006). *Wind: How the flow of air has shaped life, myth, and the land*. Emeryville, CA: Shoemaker & Hoard.
- Livingstone, I., & Warren, A. (1996). *Aeolian geomorphology: An introduction*. Essex, UK: Addison Wesley Longman.
- Oke, T. R. (1987). *Boundary layer climates*. London: Methuen.
- Righter, R. W. (1996). *Wind energy in America: A history*. Norman: University of Oklahoma Press.



WIND ENERGY

The wind is a natural energy resource that has been used by humans on a modest scale for hundreds of years. Recently, however, concerns about climate change and diminishing reserves of fossil fuels have resulted in an increasing interest in wind as a major contributor to future energy needs. This renewed interest has not been without controversy, and major obstacles remain to realizing the full potential of wind as a modern energy resource. Doing so will require significant modifications to our energy infrastructure. It may also require some unpleasant compromises and difficult decisions about how we value Earth's resources.

The Natural Phenomenon

Earth's winds are generated by seasonal and geographic variations in planetary heating, resulting in the formation of weather systems that redistribute heat around the globe. Wind can be used to perform work because air has mass, and thus, as it moves it has kinetic energy. The amount of kinetic energy (KE) possessed by a given volume of air with mass (M) and velocity (V) is described by the relationship $KE = 0.5MV^2$.

Earth's winds are dissipated by their interaction with the planet's surface, which acts as a source of friction. Because of friction, winds on our planet are typically stronger and more consistent the higher one travels into the atmosphere. For the same reason, near-surface winds are typically higher in areas where there are few surface obstructions, such as on the ocean, treeless plains, and glacial plateaus. The twin influences of altitude and terrain can sometimes result in dramatic spatial variations in average wind speed over short distances. In addition, the wind speed varies considerably over time, so wind is considered an *intermittent* energy resource.

Generating Electricity From Wind

Although in the past wind energy was used to propel sailing ships, pump water, and grind grain,

it is currently used almost exclusively to generate electric power. Turbines used to generate electricity come in many shapes and sizes. The most common modern design uses three vertically oriented blades to drive a shaft oriented in the horizontal direction, usually termed a *three-blade, horizontal-axis turbine*. Other varieties exist (e.g., different types of vertical-axis turbines) but are comparatively rare. Modern wind turbines are typically measured by their ability to generate electric power, termed *rated capacity*. The rated capacity is the maximum amount of power that the turbine can instantaneously produce under ideal conditions. Modern turbines range in power output from several hundred watts (W) to several megawatts (MW). One MW of electricity-generating capacity can serve 200 to 300 average homes. Today, the nation with the largest installation and rated capacity of wind turbines, or "wind farms," is Germany, with the United States and Spain a distant second and third.

The capacity of a wind turbine is determined to a large degree by the length of its blades and the area they sweep, termed the *swept area* (A). The power (P) in the area swept by the blades is determined by the relationship $P = 0.5\rho AV^3$, where ρ equals the density of air (in kilograms per cubic meter, kg/m^3) at sea level. To arrive at the actual rated capacity of a wind turbine, additional coefficients must be added to describe the efficiency of the turbine. Turbines used for commercial power generation often top 400 feet from the base of the tower to the tip of the blades, allowing for longer blades and a larger swept area as well as giving them access to stronger, less turbulent winds away from the ground.

Advantages

The theoretical potential of wind energy is one reason why it is seen as an attractive energy resource. The amount of energy contained in Earth's winds is enormous on the human scale. Some estimates indicate that in theory there is enough wind energy potential in the United States to serve *all* the country's current energy consumption, not just electricity usage. Areas of high wind energy potential are widespread throughout the world, although areas of high potential



Wind turbines on Royd Moor above Penistone in South Yorkshire, England. Completed in 1993, the wind farm has 13 turbines that incorporate features intended to reduce noise.

Source: © Can Stock Photo Inc.

are frequently concentrated in certain regions such as the U.S. Great Plains.

Complementing its widespread availability and potential, wind energy is attractive because it is a renewable resource and because it does not produce any of the harmful emissions associated with fossil fuel electricity generation, including carbon dioxide associated with climate change. A more recently realized benefit is that the cost of wind-generated electricity is generally lower than the cost of other renewable alternatives. In fact, wind even compares well with some types of fossil fuel in electricity generation, particularly natural gas.

Drawbacks

A chief drawback of using wind to generate electricity is that it is an uncontrollable, intermittent resource. Electricity cannot be effectively stored for long, so supply must balance demand at all times to keep the electric grid functioning. In some cases, wind power may not be available when it is needed, creating the need for expensive

backup generation. Compounding this problem, electricity demand is typically highest on hot summer afternoons, which often does not coincide with peaks in wind power.

A further disadvantage of wind power is that wind farms must be sited in areas with good wind resources to be effective. Unfortunately, more often than not such areas are long distances away from the population centers where the electricity is needed. Developing electricity transmission infrastructure to transport wind power is a long and expensive process. An additional drawback is that utility-scale wind turbines are large, highly visible, and intrusive. Some people consider them ugly and argue that they destroy the beauty of treasured landscapes. Others believe that they pose a threat to wildlife, particularly birds and bats. Both these issues are often hotly debated in areas where wind farms are proposed.

Justin R. Barnes

See also **Anthropogenic Climate Change; Energy Policy; Energy Resources; Renewable Resources; Wind**



Further Readings

- Elliott, D. L., Wendell, L. L., & Gower, G. L. (1991). *An assessment of the available windy land area and wind energy potential in the contiguous United States* (PNL-7789). Richland, WA: Pacific Northwest Laboratory.
- Johnson, G. L. (2006, October). *Wind energy systems, electronic addition*. Retrieved August 13, 2008, from www.eece.ksu.edu/~gjohnson
- Pasqualetti, M. J. (2004). Wind power: Obstacles and opportunities. *Environment*, 46(7), 22–38.
- Pasqualetti, M. J., Gipe, P., & Richter, R. W. (Eds.). (2002). *Wind power in view: Energy landscapes in a crowded world*. San Diego, CA: Academic Press.



WIND EROSION

From the sand seas of the Sahara to the loess plateau of China, to the yardang fields of Iraq and the dune fields of the Lençóis Maranhenses in Brazil, wind erosion has led to the development of distinctive and often dramatic landscapes. Many of the most recognizable of these landscapes, the sand seas and dunes, for example, are the product of the deposition of wind-eroded material. Wind erosion has also shaped landforms on Mars. Although wind does not have the erosive power of flowing water or ice, its pervasiveness compensates for that lack of force. It has been estimated that as much as a third of the land area of the Earth is susceptible to wind erosion (with the continents of Asia and Africa most at risk). Catastrophic wind erosion of soils in the Great Plains of the United States during the Dust Bowl era of the 1930s caused the infamous “black blizzard” dust storms and also led to the creation of the U.S. Department of Agriculture and the (then) Soil Conservation Service. This discussion of wind erosion is organized around four central themes: (1) erosion processes, (2) transport processes, (3) erosional landforms, and (4) wind erosion hazards.

Erosion Processes

Wind causes erosion mainly through two mechanisms: deflation and abrasion. Deflation is the

direct removal of unconsolidated sediments from a surface. Abrasion occurs when the wind is carrying a sediment load that can work on and reshape an otherwise resistant surface. Once materials have been eroded, they are then subject to transportation by the wind and deposition in another location.

Deflation

The wind is able to deflate materials when the force it exerts on a surface exceeds the resisting forces acting to stabilize the particles. For a dry sand surface, there is a physics-based relationship that balances the resisting force of gravity against the driving force of the wind. The state where the resisting and driving forces are in balance is termed the *threshold condition*. Quantification of the threshold state is fundamental to predicting wind erosion and is simplest when sediments are cohesion-less. When they are not, the process becomes much more complicated. If the sand is wet, for example, then there is an added resisting force caused by surface tension binding the grains. The presence of salt crusts or algae will also increase the necessary threshold wind speed.

For dust particles (i.e., silts and clays), establishing the threshold condition is more complicated. Such particles may be bound to each other by electrostatic forces, for example. For soils, the initiation of motion also depends on the characteristics of clods, such as size, organic content, and moisture content. For agricultural soils, there are also larger-scale controls such as cultivation practices or the presence of wind shelter belts. The Wind Erosion Prediction System is a model developed to account for these and other factors, based on simulation of field conditions such as particle size, clod processes, moisture, and organic content; wind speed and threshold conditions; and management practices, among other things.

Abrasion

Aeolian abrasion is caused by the impact of wind-borne sand or dust particles on a lithified or cohesive surface. Abrasion occurs when the resisting force, in this case, the strength of the surface material, is less than that imparted by the impact of grains. Saltating sand grains may affect igneous



or metamorphic rocks with enough force to generate microscopic fractures so that small pieces of the parent rock become susceptible to chipping away—a natural sand-blasting process. Abrasion of sedimentary rocks is more apt to occur as a result of wearing away of the cementing materials that bond individual grains, thus releasing those grains from their matrix. The rate of abrasion is a function of the cube of wind speed and the size and availability of grains for transport. Abrasion is most common in dry windy climates, where there is minimal vegetation to stabilize surfaces and reduce surface wind speeds. For these reasons, abrasion is an exceptionally active process on Mars, where wind speeds are quite high and there is an abundance of unconsolidated sediment and no vegetation.

Transport Processes

Once particles begin to move, their transport rate, Q , is a function of the cube of wind speed, the threshold condition, and the size and density of the grains. Once the shear velocity exceeds the threshold value, transport increases rapidly with additional increases in wind speed. The blowing sediments move in four ways: creep, reptation, saltation, or suspension. Creep refers to the movement of particles while in almost constant contact with the surface—by rolling, for example. Reptation is the sporadic movement of grains in short hops close to the surface caused by the impacts of other grains. Grains saltate by bouncing across the surface in trajectories that are long compared with their height and with heights that are great compared with those of reptation. Saltating particles are only occasionally in contact with the surface. Most aeolian sand transport is via the mode of saltation. Suspension occurs when particles travel mainly without contacting the surface, supported in the air by turbulent motions that exceed the gravity force. Most fine particles (dust) are transported via suspension.

For a given location on a sediment surface, erosion will occur if the quantity of sediments being removed downwind exceeds the quantity being received from upwind, regardless of the wind speed. Variations in transport rates are caused by changes in sediment availability or changes in wind speed. Changes in sediment availability are

associated with surface conditions. If the surface upwind of a location has no sediments or the transport potential of sediments is limited by cohesion, then the entire transport demand must be fed by localized erosion. More subtle changes in sediment supply are caused by variations in grain size (because of their influence on threshold shear velocity) or changes in surface slope—it is harder to move grains uphill than downhill.

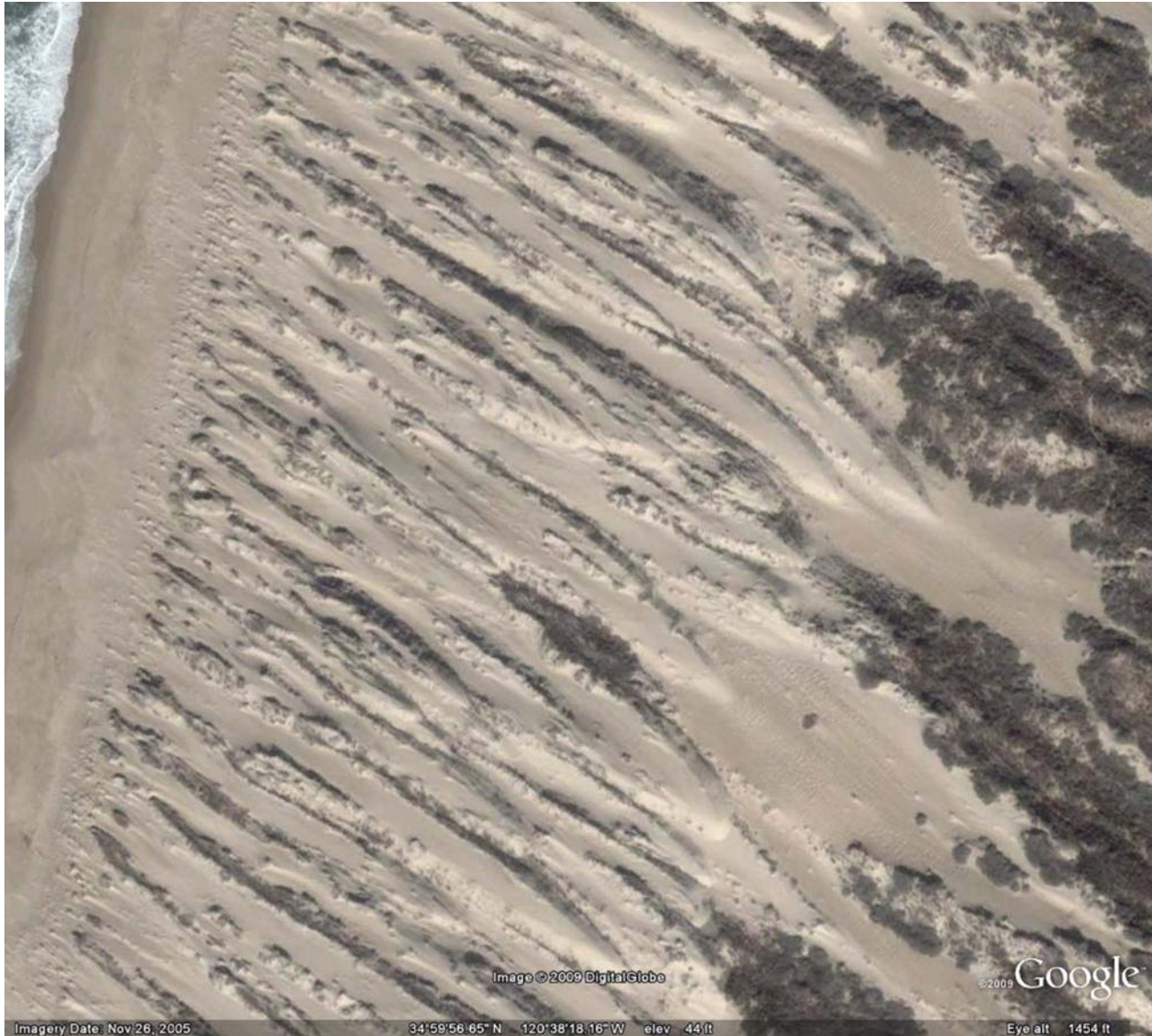
Changes in the near-surface wind speed are caused by changes in surface roughness, such as those caused by the development of ripples, or by the presence of obstructions such as vegetation. Dense stands of dune grasses can stop sand transport because local wind speeds can be reduced to zero. At larger scales, changes in the wind regime may result from topographical control of wind speeds and directions or changing weather patterns. Winds are accelerated, decelerated, and steered around mountain ranges and through valleys, for example. These controls may effect the movement of either sand or dust.

Landforms of Erosion

Erosional landforms are of two general types: (1) those associated with deflation and (2) those associated with abrasion. In the former case the resulting forms are depressions, whereas in the latter case the resulting forms may stand above the surrounding landscape.

Deflation Forms

Blowouts and pans are the two most common erosional forms caused by deflation. Blowouts are scour forms that occur in vegetated coastal dune systems, usually in trough or saucer configurations. Trough blowouts occur in foredunes when the wind erodes a gap through the dune (see foredune system photo). Trough blowouts are frequently associated with the development of parabolic dunes, as the blowout becomes a pathway for windblown sand to pass through the dune. Such blowouts may deflate until erosion is prevented because the sand surface becomes armored by lag deposits of coarse sediments or shells or because the water table is reached. Saucer blowouts occur in back dune systems where there is localized failure of vegetation, which



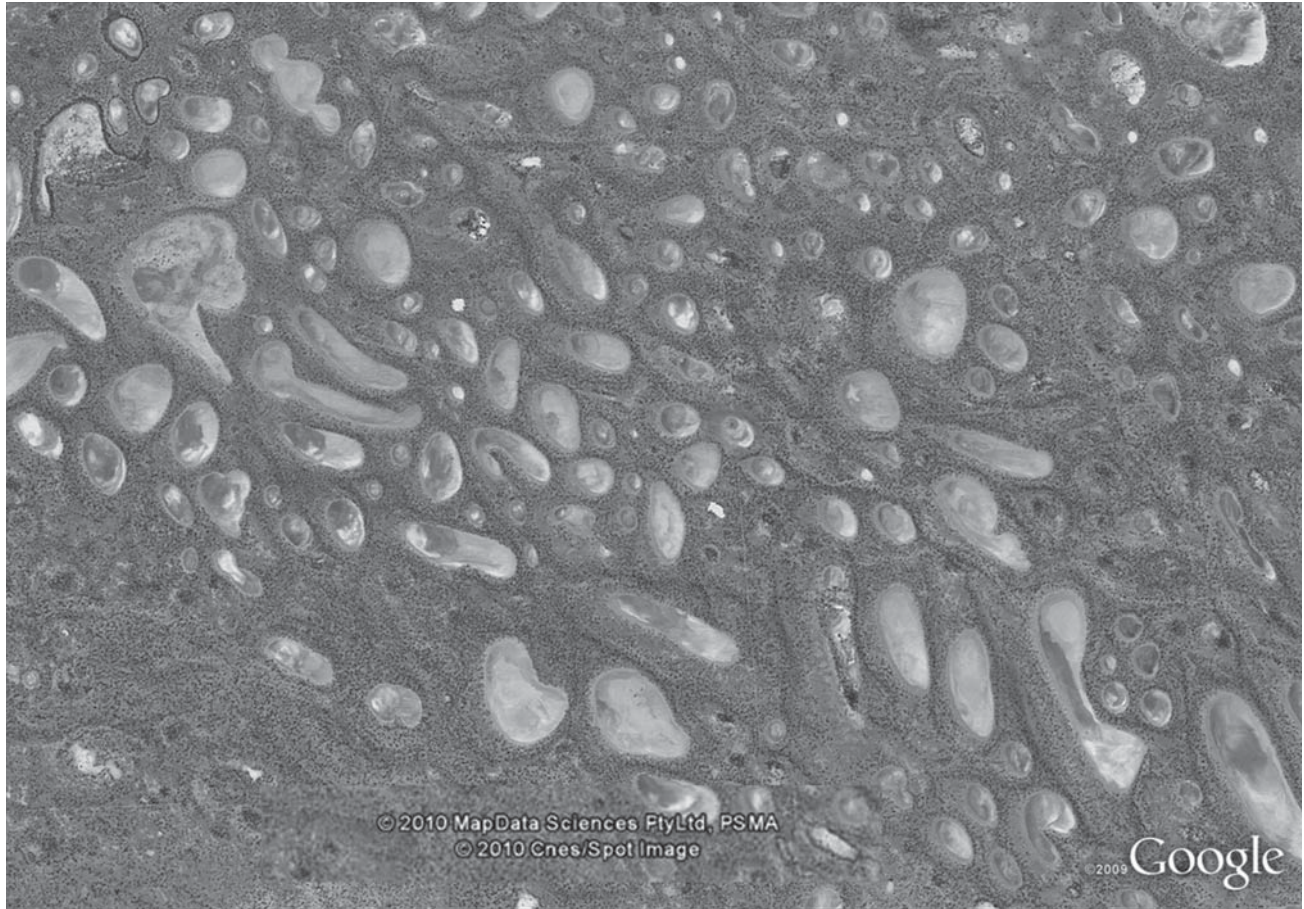
The foredune system at Guadalupe, California, is densely dissected by trough blowouts. The area depicted is approximately 0.2 square km.

Source: Google Earth.

exposes the underlying sand to the wind. Saucer blowouts are depressions that are elongated along the axis of the dominant wind transport direction, but where winds are highly variable, these blowouts become nearly circular in outline. Erosion of these blowouts is also limited by armored surfaces or the water table.

Pans are shallow, wind-eroded depressions with maximum dimensions of tens of meters to

tens of kilometers. They occur in arid to semi-arid environments, where the sparse vegetation leaves much of the surface exposed to erosional winds. Large pans tend to form in the bottom of enclosed drainage basins. Their origins are often complex, involving the interplay among geological structure, internal drainage patterns, weathering, pedogenesis, climate, and wind. In cases where the role of wind is central to pan formation,



A pan field from Western Australia. The area depicted is approximately 40 square km.

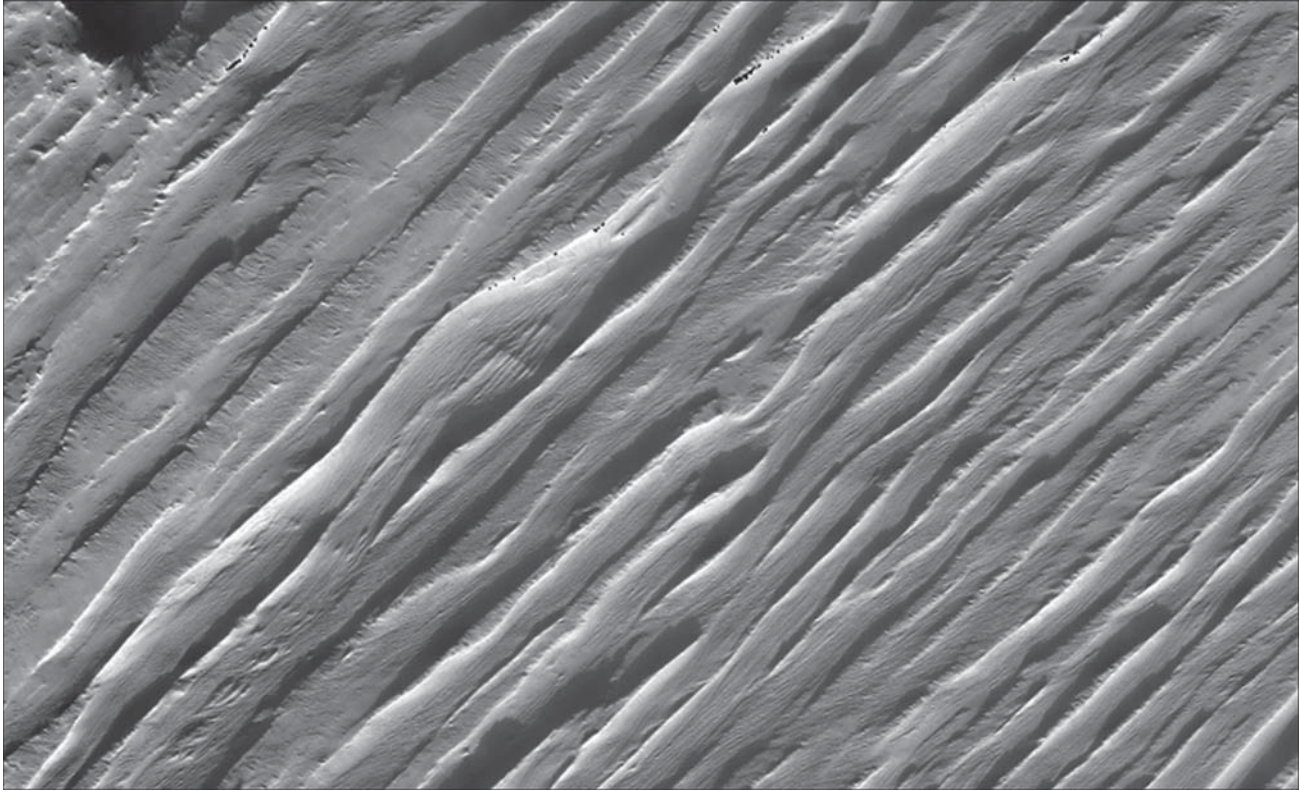
Source: Google Earth.

there are usually downwind sand dunes or lunettes (dunes where the clay content of the sediments exceeds 20%). Pans of this type are found in the Basin and Range provinces of the Western United States; Western Australia and New South Wales, Australia; Northern and Southern Africa; Manchuria; the pampas of Argentina; and Mongolia, for example. Many pans are seasonally flooded, and if they are large enough, their shorelines are subject to erosion and reworking by wind waves. Where wind waves modify pans substantially, the long axis of the pan tends to be perpendicular to the dominant wind direction.

Small pans are formed by deflation, usually of soils. Deflation pans occur in sets, often in large numbers densely distributed on the surface,

where they may be the most conspicuous landscape element—especially when they are flooded or lined with saline soils (see Western Australia photo). Fields of small pans occur in Australia, the U.S. Great Plains, Botswana, South Africa, and China, for example.

Deflation surfaces develop when wind removes fine grains from a particle size distribution, leaving behind a lag deposit, or armoring, of sediments that are too large to be blown away, or where crusting, as by salts, occurs to stabilize a surface. In coastal environments, deflation surfaces form on washover fans. Such surfaces may form on exposed glacial till surfaces, on or adjacent to dry lake beds or streams. Some desert pavements may be caused by deflation, although other processes may be active as well. Extensive



Yardang field on Mars: part of the *Medusae Fossae* formation. The area depicted is approximately 600 square kilometers.

Source: Courtesy of NASA/JPL/Arizona State University.

armored surfaces are called hammada or reg, especially in North Africa, Australia, and Asia.

Abrasion Forms

Erosion of cohesive or lithified surfaces creates forms of two general types: ventifacts or yardangs. Ventifacts (“wind made”) are any of several characteristic wind abrasion features formed on bedrock outcrops or on individual stones. The main shapes associated with ventifacts are facets and flutes, and there are several minor forms, including pits and sills. The classic ventifact shape is the dreikanter—a stone with three facets. Each facet is believed to have formed at right angles to the dominant wind direction, with multifaceted ventifacts resulting from the rotation of the stones, the occurrence of abrading winds from more than one direction, or abrasion caused by secondary flows. Flutes are channelized scours that develop in parallel sets oriented parallel to

the dominant wind direction. Their formation is attributed to abrasive (probably dust-carrying) vortices. Ventifact characteristics such as orientation are used in the reconstruction and interpretation of paleowind climates. Ventifacts have been used to reconstruct wind regimes on Mars.

Yardangs (see Mars photo) are streamlined, wind-sculpted forms that vary in length from less than a meter (m) to tens of kilometers (km) and are 4 to 10 times as long as they are wide. They are oriented parallel to the dominant wind direction. Sculpting of yardangs by wind action is usually confined to the lowest 1 or 2 m of the exposed surfaces, whereas a suite of other subaerial processes may operate on the higher slopes of the landform. Most yardangs are eroded from cohesive sediments such as silts, clays, or chalks, but they may also form in sandstone or limestone. The local relief increases as material is weathered, abraded, and blown away from the depressions that separate individual yardangs.



Yardangs usually occur in sets, or fields, because their development is controlled by regional wind conditions and local geology. Fields of megayardangs (with individual lengths exceeding 1 km) may cover thousands of square kilometers and are found mainly in hyperarid climate regions such as Namibia, Chile and Peru, interior China, Chad, the Middle East, and North Africa. Megayardang fields are also common on Mars.

Wind Erosion Hazards

Hazards as a direct result of wind erosion include loss of agricultural soils, migration of sands over infrastructure or valued resources, increased respiratory disease, and poor visibility, to name a few. The loss of agricultural soils is a global problem affecting food security, especially in marginal, semiarid environments such as the Sahel. Problems may arise because of the direct loss of agricultural productivity caused by erosion of topsoil or at downwind locations because of the indirect impact of deposition of sediments on crops or in waterways, for example, or by the transport of toxic materials such as pesticides and herbicides. It has been estimated that the magnitude of the offsite costs of blowing dust may exceed 40 times that of the onsite costs.

Blowing sand and migrating dunes have buried or threatened settlements in environments as disparate as Ireland, Denmark, the Western United States, Brazil, and North and South Africa. In some cases, this led to complete abandonment of sites. There is a similar threat to roads, railroads, and agricultural lands in many of these places and also in others, such as the Takla Makan of China, Australia, and New Zealand. Atmospheric dust can produce human and animal health hazards at a great distance from its source, especially respiratory diseases such as asthma, emphysema, and lung cancer. Blowing dust can reduce visibility catastrophically, leading to traffic accidents. In less dramatic cases, the reduced visibility requires daytime illumination of street light systems.

Douglas J. Sherman

See also **Desertification; Desert Varnish; Dunes; Prairies; Soil Erosion; Wind**

Further Readings

- Cooke, R., Warren, A., & Goudie, A. (1993). *Desert geomorphology*. London: University of London Press.
- Greeley, R., Kuzmin, R. O., & Haberle, R. M. (2001). Aeolian processes and their effects on understanding the chronology of Mars. *Space Science Reviews*, 96, 393–404.
- Griffin, D. W., Kellogg, C. A., & Shinn, E. A. (2001). Dust in the wind: Long range transport of dust in the atmosphere and its implications for global public and ecosystem health. *Global Change and Human Health*, 2, 20–33.
- Hagen, L. J. (2004). Evaluation of the Wind Erosion Prediction Systems (WEPS) erosion submodel on cropland fields. *Environmental Modeling & Software*, 19, 171–176.
- Nickling, W. G. (1994). Aeolian sediment transport and deposition. In K. Pye (Ed.), *Sediment transport and depositional processes* (pp. 293–350). London: Blackwell Science.
- Nordstrom, K. F., & Hotta, S. (2004). Wind erosion from croplands in the USA: A review of problems, solutions and prospects. *Geoderma*, 121, 157–167.



WINE, GEOGRAPHY OF

An excellent way to comprehend a region's geography is to study its wine. Wine production is inextricably intertwined with the physical, cultural, and economic geography of a region; in essence, to drink a wine is to taste its geography. So widespread is the influence of wine in geography that a review of the geographical literature and an inspection of papers at professional meetings show that most subfields of geography are represented. Up-to-date references are available at the Association of American Geographers' Wine Specialty Group Web site www.geographyofwine.org.

Wine has been a research topic in geography since the ancient Greek and Roman geographers. Historical geographers pinpoint the home of the wine grape, *Vitis vinifera*, as southwest Asia, and its diffusion and history have been documented in works by Sauer, Unwin, and McGovern. *Vitis*



Vineyards in the Chianti region of Tuscany, Italy

Source: John Menard.

vinifera is a remarkably adaptable plant with many subvarieties, each with a preferred environment, providing geographers with a fertile research opportunity.

The geographical nature of wine can be appreciated by looking at wine labels. The most prominent identifier is the source region of the wine—for example, Bordeaux, Burgundy, Champagne, Barolo, Rioja, Chianti, Brunello di Montalcino, and Valpolicella. European wines are named by the geographic region of production and not by the grape variety. Most Americans recognize the name Champagne, but few know that their favorite bubbly can only be produced in one small region of France or that it is made from Pinot Noir, Pinot Munier, and/or Chardonnay grapes. Over hundreds of years of experimentation, European winemakers have identified the best grapes in a particular region. The grape variety is not mentioned on the label; they just assume that one knows the contents by the geographical name. Red wine from Burgundy is made from Pinot Noir, Chianti from Sangiovese, and Barolo from Nebbiolo. New World wineries have little history and are still experimenting; therefore, the grape variety is prominently displayed.

The French belief that geography has a great impact on wine is epitomized by their use of the word *terroir* to define the sum total of all physical and cultural aspects that give a wine its characteristics. The concept of *terroir* dictates that geography gives wine a sense of place and that the wine is unique from wine produced elsewhere. *Terroir* is a powerful geographical concept because it synthesizes the spatial elements of the natural environment with the socioeconomic ones.

There are many variables influencing *terroir* or the geography of wine. Of prime importance are the physical variables, including climate, microclimate, air drainage, solar prospect, water drainage, geology, topography, altitude, and soil conditions. There are also socioeconomic factors, including grape-growing methods, wine-producing techniques, group pressure for a specific style, the local yeast influence, the type of wood used in barrels, and even how wine pairs with local food.

The sum total of all these factors is what makes a red Burgundy unique. The same Pinot Noir grape grown in California, New York, New Zealand, or Washington will produce a wine with a different style, aroma, and taste. Not only do



the French think that a Pinot Noir from Burgundy tastes different from one produced in California, but they also believe that wines produced from different parts of a vineyard will vary because of the microgeographical conditions.

Many excellent books and articles are available on terroir. Not only does the environment influence the wine, but the wine can influence the cultural geography of an area, resulting in a wine landscape as described by geographers including Peters and Sommers. Terroir is the true essence of the geography of wine for it brings together the physical and cultural aspects that form the geographical imprint of a wine region. The idea of terroir is so accepted that several countries have a legally binding set of rules defining specific regions. The French have the Appellation d'origine contrôlée, the Italians the Denominazione di Origine Controllata, and the Americans the American Viticultural Area (AVA). There were 190 AVAs in the United States as of May 2008. Theoretically, one can taste the difference between a Cabernet Sauvignon produced in the Napa Valley and one made in the Sonoma Valley because of the uniqueness of the terroir.

Books and journal articles on the geography of wine abound. The classics are by de Blij and Unwin. Other excellent books by geographers include Peters's work on wine landscapes and several regional books by Baxevanis and Sommers. Many books are written in a geographical format by nongeographers, with the *Wine Atlas of the World* (2007) by Johnson and Robinson being an excellent reference. An especially useful geographically organized collection of books is the *Wine for Dummies* series by Ed McCarthy and Mary Ewing-Mulligan.

Geographical journals have a good selection of articles on the geography of wine. Although not a geographical journal per se, the *Journal of Wine Research* has many articles on geography and terroir. Several recent articles highlight weather and climate (e.g., the Niagara Peninsula lake effect, global warming). Other articles highlight the use of remote sensing and using geographic information systems (GIS) to analyze the best places to plant vineyards, how to protect vineyards from insect pests, and how to assess their productivity.

In conclusion, whether it is regional analysis, comparative studies, terroir, climate, GIS analysis,

diffusion studies, economic analysis, or studying cultural winescapes, the geographer is uniquely equipped to study the geography of wine.

Percy H. Dougherty

See also **Wine Terroir**

Further Readings

- Baxevanis, J. (1987). *The wines of Bordeaux and Western France*. Totowa, NJ: Rowman & Littlefield.
- de Blij, H. (1983). *Wine: A geographic appreciation*. Totowa, NJ: Rowman & Allanheld.
- Gade, D. (2004). Tradition, territory and terroir in French vitaculture: Cassis, France, and Appellation Controlee. *Annals of the Association of American Geographers*, 94, 848–867.
- Johnson, H., & Robinson, J. (2007). *The world atlas of wine*. London: Mitchell Beazley.
- Peters, G. (1997). *American winescapes: The cultural landscapes of America's wine country*. Boulder, CO: Westview Press.
- Sommers, B. J. (2008). *The geography of wine: How landscapes, cultures, terroir, and the weather make a good drop*. New York: Plume.
- Swinchatt, J., & Howell, D. (2004). *Terroir: The role of geology, climate, and culture in the making of French wines*. Berkeley: University of California Press.
- Unwin, T. (1996). *Wine and the vine: An historical geography of viticulture and the wine trade*. London: Routledge.
- Wilson, J. (1998). *Terroir: The role of geology, climate, and culture in the making of French wines*. Berkeley: University of California Press.



WINE TERROIR

Terroir is a concept introduced by French wine-makers to portray the characteristics of the place where grapes are grown that help define a wine's aroma, flavor, and other components sensed by the consumer. A wine that reflects its geographic origin thus expresses its terroir. The terroir is essentially the physical geography of the vineyard



Vineyard in the Constantia region of Cape Winelands in South Africa

Source: Don Bayley/iStockphoto.

as a function of the ecological and physiological response of the grapevine to its site, including the climate, geology, soil, and topographic factors that may influence vine growth, rooting, crop load, and fruit ripening. Wine growers around the world understand the importance of terroir and how it is expressed in the wines, choosing to cultivate specific wine varieties on sites that will produce the best wines. Through careful wine tasting, consumers learn to recognize wines by their origin and detect this sense of place or appellation of origin in tastings. Many winemakers choose to let the essence of terroir shine through in their wines versus masking these characteristics through winemaking practices.

Physical Geography and Wine Growing

The physical geography of an agricultural field, and in this case a vineyard in reference to wine grapes, exerts important controls on viticulture, with subtle differences in climate, geology, soil, and topography reflected in the wines produced from grapes grown at different sites. These site characteristics may act in a singular fashion or in tandem, such that grapes produced in adjacent vineyards on different soils, but with the

same climate, produce wines with different characteristics, or soil and climate may act mutually to change the character of wine grapes along a gradient up valley, where both climates and soils change.

Terroir is a concept introduced by the French in their Appellation d'origine contrôlée (AOC) system and is now used by winemakers worldwide to explain the essence of place as a function of the physical geography of the vineyard where the grapes for any particular wine are grown. French viticulturalists have shown that distinct differences in wine-growing districts and vineyards in Bordeaux, for example, produce very different wines as one proceeds inland up the Garonne and Dordogne rivers across river and glaciofluvial landforms and soils of different types and ages. Winegrowers in other regions of the world, including California, New Zealand, South Africa, and Germany, have used this same concept of vineyard geography to develop vineyards and produce wines best suited to the site. Agencies that regulate the naming of agricultural regions and the labeling of wines have established similar geographically based appellation of origin systems in various countries, such as the American Viticultural Areas program in the United States.



Because of the impact of vineyard geography on fruit composition, and subsequently on the flavor and other characteristics of the wine, vintners have long been interested in the effects of climate and soils on wine. Researchers have shown that climate, that is, the surface environment of the vine (canopy zone), is an important factor that affects fruit composition and wine quality and is intimately tied to the concept of the vintage (e.g., wine quality in a given year or harvest). The length of the growing season, the intensity and duration of solar radiation, temperature extremes, growing degree-day totals, precipitation events, wind speeds, and other aspects of the vineyard climate affect vine flowering, leaf canopy development, fruit set, crop load, and grape maturation. Viticulturalists can manipulate the vine canopy (through trellising, pulling leaves and shoots, cluster thinning, and other practices) to influence the microclimate of each plant, yet the regional climate effects cannot be changed (such as excessive summer heat or late-growing-season rainfall).

The soil—that is, the subsurface environment of the vine (rooting zone)—is also a primary factor affecting vine vigor and fruit composition, and the chemistry, quality, flavor, and aroma of the wine. Since it is the underground environment of the vine, it is more difficult for the viticulturalist to manipulate this part of the ecosystem, with even tillage of the soil and the addition of soil amendments not penetrating nearly to the depth that most vines root to. The fruit of the vine thus very much reflects the nature of the soil where it is grown and any related characteristics of the geology and geomorphology of that site that may influence soil texture, nutrients, water-holding capacity, and other parameters. The soil system interacts with the plant's root system to control the water, gas, and nutrient flux in the root zone to the shoots, leaves, and fruit in the grapevine's canopy. Many of the metabolic and biosynthetic processes remain poorly understood for grapevines and most other woody plants (including agricultural crop plants), thus the physiological impact of the soil on the vine remains largely unknown in a mechanistic sense.

It is encouraging that both chemical and descriptive (i.e., human sensory) evaluation of wines often allows discrimination of wines by

geographic origin, implying that the climate, geology, and soils are significant controls of grape and wine composition, even overriding whatever techniques the winemakers use in making the wine. Research has shown that unusual soils produce unusual wines and that an area that has uniform climate, geology, and soils across it (such as a single alluvial fan in a small valley or a mountain top surface) has very similar wines that can be discriminated through both descriptive analyses and multivariate ordination techniques. Doing controlled experiments, researchers have shown that *terroir* is a valid scientific concept that determines the flavor, aroma, and other characteristics of wines. In other words, place matters, and geography matters.

Deborah L. Elliott-Fisk

See also **Agroecology; Climatology; Soils; Wine, Geography of**

Further Readings

- de Blij, H. J. (1983). *Wine: A geographic appreciation*. New York: Rowman & Allanheld.
- Sommers, B. J. (2008). *The geography of wine*. New York: PLUME, Penguin Group.
- Trubek, A. B. (2008). *The taste of place: A cultural journey into terroir*. Berkeley: University of California Press.
- Unwin, T. (1996). *Wine and the vine*. London: Routledge.
- Wilson, J. E. (1998). *Terroir: The role of geology, climate and culture in the making of French wines*. Berkeley: University of California Press.



WISE USE MOVEMENT

The Wise Use movement was a coalition of broadly antienvironmental and antifederal organizations and political movements active in the United States from roughly the late 1980s through the late 1990s. The term *wise use* was strategically borrowed from Progressive-era conservationists, for whom it functioned very much like *sustainable development*, in both its ambiguity



and its emphasis. The Wise Use movement had three wings. The first, based in the rural West, centered on efforts by rural commodity producers to maintain their historical, privileged access to many public lands in the region for production. The second, the property rights movement, argued that governmental regulations affecting private property constituted a legal “taking” of a portion of that property, for which owners should be compensated. The third, centered in Washington, D.C., was a coordinated effort by regulated industries to repeal, weaken, or prevent many major national and international environmental laws and treaties. Each of these wings existed before and after the Wise Use movement *per se*; what distinguished the movement was their temporary alliance and commitment to a united agenda.

Wise Use was strongest in the rural West, where it was in part a cultural and political response to regional restructuring. Since 1980 or so, the rural West had seen dramatic declines in primary production industries and the concurrent growth of a service economy, rapidly increasing environmental priorities on public lands, and major demographic and political shifts. In reaction, Wise Use claimed to be a grassroots social movement, rooted in a regional culture, responding to overly intrusive outsiders. It defined itself mainly in opposition to the environmental movement and federal agencies governing land uses, which it portrayed as outsiders infringing on local rights to livelihoods and self-determination. Wise Use had a surprising amount in common with many social movements in the global South centered on resource access and control, examined in the literature of political ecology: For example, it emphasized cultural identity, local knowledge as an alternative to expert science, reinventions of community and tradition, and defenses of local claims against state authority. It was also part of a broader trend toward the neoliberalization of environmental governance.

The Wise Use movement lost cohesion in the late 1990s for three reasons. First, its three wings diverged as it became clear that pursuing their respective goals demanded different sorts of actions in different arenas. Second, groups focused on public lands realized that confrontational approaches were proving counterproductive,

and many began to seek the same ends via participation in collaborative management instead. Third, the two presidential administrations of George W. Bush (2001–2009) were highly sympathetic to Wise Use’s goals, and indeed were staffed in part by individuals with connections to it, removing participants’ motivations for an anti-federal stance.

James McCarthy

See also **Common Property Resource Management; Environmental Management; Environmental Management: Drylands; Environmental Social Movements; Neoliberal Environmental Policy; Political Ecology; Resource Management**

Further Readings

Heynen, N., McCarthy, J., Robbins, P., & Prudham, S. (Eds.). (2007). *Neoliberal environments: False promises and unnatural consequences*. New York: Routledge.

McCarthy, J. (2002). First World political ecology: Lessons from the Wise Use movement. *Environment and Planning A*, 34, 1281–1302.



WITTFOGEL, KARL (1896–1988)

Karl August Wittfogel was a well-known German American historian and a sinologist. Concerned primarily with humanity’s relationship with nature, his work influenced geography, anthropology, and urban studies. The environmental historian Donald Worster credits Wittfogel with pointing out that nature was not passive but formed a strong force in shaping the history of humanity. Wittfogel is also known for his early Marxist thought and his later critique of Marxism.

Wittfogel was born in Woltersdorf, Germany, and received his PhD from the University of Frankfurt in 1928. In the 1920s and 1930s, he was an active communist and an avid critic of fascism. When Hitler gained power in Germany in



1933, Wittfogel became a target of the Nazis. He was imprisoned in a concentration camp until international support prompted his release. Wittfogel moved to the United States and acquired U.S. citizenship in 1939. He taught first at Columbia University and then at the University of Washington until he retired from teaching in 1966.

Wittfogel is primarily known for his view that water played a critical role in early civilizations, states, and cities. He was especially concerned with Asian civilizations. Wittfogel explains these views in his 1956 essay "The Hydraulic Civilizations" and in his most famous work, *Oriental Despotism: A Comparative Study of Total Power*, published in 1957. One central point of Wittfogel's hydraulic civilization thesis is that arid and semiarid societies required tremendous amounts of control and stern management of water resources. Wittfogel believed that water was a key resource for civilizations. Water was needed for irrigation and was vital for agriculture in arid and semiarid regions and often required large engineering projects that were built with forced labor. Wittfogel believed that this factor was especially important in the early development of Asian civilizations. He notes that other resources, such as soil and air, are as important to agriculture as water, but water differs in one principal way. Water can be stored. In Wittfogel's opinion, the control of water resources was such an important factor in the survival and development of Asian civilizations that he refers to them as hydraulic civilizations. Wittfogel believed that the control over water gave governments enormous power over people. According to Wittfogel, the rulers of civilizations in arid and semiarid areas eventually acquired a tremendous amount of control. Governments ruled strictly and monopolized their economies through "hydraulic government." The word *despotism* in the title of his well-known work refers to this harsh control over the lives of masses of people. Some, such as Neil Smith, view his concern with Asian despotism as a slightly veiled critique of communism.

Jessey Gilley

See also **Environmental Determinism; Environmental Perception; Hydrology; Marxism, Geography and; Orientalism**

Further Readings

- Smith, N. (1987). Rehabilitating a renegade? The geography and politics of Karl August Wittfogel. *Dialectical Anthropology*, 12, 127–136.
- Wittfogel, K. (1956). The hydraulic civilizations. In W. Thomas (Ed.), *Man's role in changing the face of the earth* (pp. 152–164). Chicago: University of Chicago Press.
- Wittfogel, K. (1957). *Oriental despotism: A comparative study of total power*. New Haven, CT: Yale University Press.
- Worster, D. (1993). *The wealth of nature: Environmental history and the ecological imagination*. New York: Oxford University Press.



WOOD, DENIS (1945–)

Denis Wood is an artist, writer, cartographer, psychogeographer, and independent scholar. A former professor of design at North Carolina State University, Wood writes extensively on the nature of maps, mapping, and mapmaking processes. He has helped establish the subdisciplinary field of critical cartography, refining and extending J. B. (Brian) Harley's questioning of the objective neutrality of maps. Wood explores the social and political implications of mapmaking through playfully antagonistic prose, polemically undermining the authority of Western scientific cartography. He develops a theoretically rigorous critique of the power of maps, drawing on poststructural thinkers Michel Foucault and Jacques Derrida, the linguist Ferdinand de Saussure, the literary theorist and semiotician Roland Barthes, and the developmental theorist Jean Piaget. Wood is responsible for broadening the definition of maps as cultural products inherently imbued with power.

Eschewing the criterion of accuracy, Wood reads maps as narrative texts and members of a broad family of representations alongside landscape portraits and detective stories. After early research studying experimental maps, mental maps, and map literacy acquisition, Wood turned to semiotics to cast maps as sign systems coproduced with specific sociohistorical contexts. Maps are inherently subjective propositions that work



within a discursive system of coded representations to link an imagined territory with associated phenomena. A false distinction between maps and other forms of representation limits the creative, emotional potential of maps gained through a narrative understanding.

Wood relentlessly attacks cartographers for their legitimization of scientific maps. The professionalization of mapping masks political interests under pretenses of unbiased, distanced neutrality. Through claims to objectivity, maps portend to represent a world of facts as they really are rather than as purposively selective fictions that create the world as much as they closely resemble it. The presupposition of accuracy obscures the politics embedded within maps and empowers them as weapons of domination, reproducing society and legitimizing the status quo.

While modern cartography has served the interests of the State and the dominant elite, counter-mapping practices also employ the power of maps for resistance. Wood calls for the death of cartography and the return of mapping to the status of a universal birthright of humanity. His recent collaborative work with John Krygier assists nonprofessionals with map design through visually rich narratives, graphical guides, and a Web site dedicated to do-it-yourself (DIY) cartography.

Richard Donohue

See also **Cartography; Countermapping; Critical GIS; Critical Human Geography; Harley, Brian; Monmonier, Mark; Pickles, John**

Further Readings

- Crampton, J., & Krygier, J. (2006). An introduction to critical cartography. *ACME: An International E-Journal for Critical Geographies*, 4(1), 11–33. Retrieved November 23, 2009, from www.acme-journal.org
- Krygier, J. (2009). *Making maps: DIY cartography—Resources and ideas for making maps*. Retrieved November 23, 2009, from <http://makingmaps.net>
- Krygier, J., & Wood, D. (2005). *Making maps: A visual guide to map design for GIS*. New York: Guilford Press.

Wood, D. (1992). *The power of maps*. New York: Guilford Press.

Wood, D. (2003). Cartography is dead (thank God!). *Cartographic Perspectives*, 45, 4–7.

Wood, D., & Felds, J. (2008). *The nature of maps*. Chicago: University of Chicago Press.



WOODFUEL

Wood and charcoal provide the major energy resources for most residents of developing countries, especially for cooking and heating. To these people, the real energy crisis is the disappearing sources of inexpensive or free wood for fuel, along with deforestation. The persistence of mass poverty in regions such as sub-Saharan Africa limits access to these resources. Pitfalls in energy sustainability erode gains in the potential for human development and environmental sustenance.

Access to adequate and appropriate energy resources has implications for the economic, social, and ecological dimensions of both local and global development. Energy is a necessary requirement for sustainable development. The commercial energy sector has powered recent gains in global economic growth and has been the main driver in the globalization of the world economy. Nations with a high proportion of modern and conventional fuels in their energy mix, such as those in the global North, tend to have highly advanced economies. Conversely, nations in the South, with a high proportion of traditional fuels, have generally faced complex human development challenges in providing livelihoods and environmental quality. The relationship between energy and economic development is not necessarily direct; however, energy is a critical input in the development framework.

To sustain the existing expanding economies and to accommodate new and potentially high-demand entrants from the developing world, energy supplies need to expand. While global energy supplies are experiencing relatively low or even flattening growth rates, demand levels are escalating. Recent aggressive participation in global energy markets by giant economies with hitherto low demand streams, such as China and India, could



exacerbate this situation. Conservation measures have not made up for the gaps in energy supply. This trend could make many other countries less competitive in global markets for reasonably priced energy resources. While international markets have a robust capacity to balance energy supply and demand levels, adverse supply constraints could stretch the resilience of the system beyond the normal efficient allocation mechanisms. The looming threat of global climate change adds a new urgency for policymakers to broaden the range of energy strategies to include sources that were previously discounted, including woodfuel.

Woodfuel has been perceived to play a minimal role in models of modern socioeconomic development, but this is simply a world economic view. Regionally, wood caters to the needs of the majority of the rural population in developing nations. The sizable urban population there also depends on woodfuel, especially charcoal; and electric power supplies are erratic, overpriced, and nonexistent in large sections of the ever-expanding spontaneous settlements. Furthermore, cheap alternatives such as liquefied petroleum gas are not easily accessible, and substandard equipment and inadequate safeguards make them potential hazards in the cramped living spaces of slums.

In the developed world, only a relatively small amount of both value-added and raw wood is used to generate electricity. It is still used for limited-space heating in the northern regions and may even provide fuel for gourmet cooking. Wood is by no means the primary source of energy, and the vast majority of the population does not use it directly since cheap commercial fuels are readily available.

For the majority of the world's rural population, especially in sub-Saharan Africa, wood of all types and forms is the primary fuel source. This



Three women in a village in Maharashtra, India, carry wood logs to use as fuel for cooking.

Source: iStockphoto.

includes high-oil-producing countries such as Nigeria, Angola, and Gabon. Rural sub-Saharan Africa has an estimated electrification rate of only 7.5%, and therefore, an estimated 70% to 90% of the population depends on biomass fuels, principally wood. South Asia, with the next lowest rate, had an electrification rate of 30.1% in 2005. The World Energy Council noted that while Africa has nearly 13% of the world's population, its share of the world's primary energy consumption is only 3%. These facts and similar others demonstrate a real need for expanded access to the commercial energy sector through development, as well as policy, research, and technological



attention to woodfuel, which is often readily available.

Considered inefficient and often unsustainable, woodfuel has nonetheless enabled the poor countries of the world to survive socioeconomically and ecologically. The energy budgets of most developing countries confirm this. In effect, woodfuel has saved these cash-starved economies trillions of dollars in deferred energy imports over the years. Such savings have benefited other areas of national needs such as education, health care, and general infrastructure. Meanwhile, the low participation of these developing countries allowed many of the energy-intensive economies to buy fossil fuels at reasonable prices. The principal use of woodfuel may have prevented millions of tons of greenhouse gas emissions, compared with the dominant use of fossil fuels. This idea is supported by the fact that in the relatively sparsely populated moist forests and woodland regions, deadwood, rather than green standing biomass, is harvested for fuel. Fuel impacts on direct forest loss, in this context, is also negligible.

In all policy considerations, wood has limitations in economic growth. Inappropriate wood harvests, of course, may also trigger ecological problems such as deforestation. For all practical purposes, no modern economy can compete successfully in the global economy as it is now with raw woodfuel as its energy base.

In spite of inherent limitations, wood should be one of the alternative mainstream fuels. As global attention is drawn to the impacts of the biofuels on food prices, wood cellulose and other wood derivatives should receive scientific and technological attention. The routine use of wood in rural areas of the developing world is generally for household purposes. Research policy should focus on its calorific value, profitability for long-distance transport, smoke emissions reduction, and incentives for fuelwood farms. It is imperative that the private sector be encouraged as a necessary partner.

William Y. Osei

See also Agroforestry; Community Forestry; Deforestation; Forest Degradation; Forest Fragmentation; Forest Land Use; Renewable Resources; Sustainable Development

Further Readings

- Hosier, R. H. (1988). The economics of deforestation in Eastern Africa. *Economic Geography*, 64, 121–136.
- Osei, W. Y. (1993). Woodfuel and deforestation. *Journal of Environmental Management*, 37, 51–62.
- Osei, W. Y. (1996). Rural energy technology: Issues and options for sustainable development in Ghana. *Geoforum*, 27, 63–74.
- World Energy Council. (2005). *Regional energy integration in Africa*. London: Author.



WOODLOTS

See Forest Fragmentation



WORLD BANK

The World Bank (often called simply “the Bank”) is one of the Bretton Woods institutions, including the International Monetary Fund (IMF), that have their roots in the post–World War II meeting of eminent economists in Bretton Woods (New Hampshire) to discuss the rebuilding of Europe. While the Bank was to provide longer-term funds for investment in productive endeavors, the IMF was to provide short-term balance-of-payments relief.

What is often referred to as the World Bank is part of the World Bank Group, which is made up of the following five development institutions: (1) International Bank for Reconstruction and Development (IBRD), (2) International Development Association (IDA), (3) International Finance Corporation (IFC), (4) Multilateral Investment Guarantee Agency (MIGA), and (5) International Centre for Settlement of Investment Disputes (ICSID). The World Bank comprises only the IBRD and the IDA. Although the IBRD and IDA share the same staff and headquarters in Washington, D.C., each has a different focus: The IBRD assists middle-income and creditworthy poor countries, while the IDA focuses on the world’s



poorest countries (i.e., those with per capita income of less than US\$1,065 in 2008). The IBRD also has a much larger country membership and a broader mission than the IDA. It provides its client countries with loans, guarantees, and analytical and advisory services. The IBRD's financial strength enables it to borrow in capital markets at low cost and to offer clients favorable borrowing terms. The IDA provides interest-free, long-term loans, called credits, and grants to governments of the world's 82 poorest countries, which have little or no capacity to borrow on market terms. The IDA's lending is financed by contributions to the IDA from donor countries, the IBRD's net income transfers, grants from the IFC, and IDA loan repayments. IDA funds are used to finance poverty reduction programs and are allocated to countries based on anticipated "development effectiveness," and the Country Assistance Strategy is used for distributing the money within the country (Table 1).

Each of the World Bank Group institutions is owned by its member countries, which are shareholders. The Bank is supervised and directed by a 24-member Board of Governors. The voting power of the individual executive director is based on the shares of the countries they represent. The United States, Japan, Germany, France, and United Kingdom each appoint one executive director, and collectively, these five countries control 37.4% of the total votes. The president of the World Bank Group has a 5-year term and is selected by the executive directors. While this formal structure gives the impression of balance in the relative power of owner nations, in reality the United States has the greatest influence because,

as the largest contributor, it selects the president (who by tradition has always been a U.S. citizen), who is then approved by the Bank's executive directors (the managing director of the IMF has also traditionally been European). The Bank's leadership has been a source of criticism by those who argue that the developing country clients have no say in selecting its leader.

Since the establishment of the Bank in 1944, its development philosophy has gone through several transformations. The first major transformation, following the implementation of the US\$12 billion Marshall Plan for the postwar reconstruction of Western Europe, was a shift in focus to the development needs of developing countries. The second transformation, which occurred under Bank President Robert McNamara (1968–1981), shifted the focus of the Bank's loans from investments in infrastructure to broader support for development projects involving human development and economic transformation, paving the way for the Bank's initiation of structural adjustments programs (SAPs) during President Alden Clausen's (1981–1986) tenure. Implemented in the 1980s and 1990s, SAPs sought to promote economic development through trade liberalization and free market enterprise. The Bank's development philosophy was heavily criticized during its 50th anniversary, in 1994, under the slogan "50 years is enough." Moreover, the Bank was criticized for promoting and financing inequitable and unsustainable development that creates (rather than reduces) poverty and destroys the environment and for being undemocratic because it denied citizens of poor countries a role in making the major development decisions affecting their societies. These

	<i>IBRD</i>	<i>IDA</i>
Year established	1944	1960
No. of member countries	185	167
Fiscal 2008 lending/commitments	\$13.5 billion for 99 new operations in 34 countries	\$11.2 billion for 199 new operations in 72 countries
Cumulative lending/commitments	\$446 billion	\$193 billion

Table 1 Some basic facts (as of June 30, 2008) about the IBRD and IDA, two of the largest development agencies in the world

Source: Compiled from The World Bank. (2008). *The World Bank annual report 2008*. Retrieved December 1, 2009, from <http://go.worldbank.org/JP57KOICX0>.



criticisms led to a final transformation under James Wolfensohn's presidency (1995–2005), marked by the emergence of the “Comprehensive Development Framework” approach based on four principles: (1) a holistic long-term strategy; (2) domestic ownership, both “owning” and directing the development agenda; (3) a stronger partnership among governments, donors, civil society, the private sector, and other development stakeholders; and (4) a transparent focus on development results to ensure better poverty reduction. Today, the Bank virtually sets the global development agenda, which is currently focused on reducing poverty in developing and transition countries.

These transformations have been accompanied by a change in the composition of the Bank's staff. From a once homogeneous staff of engineers and financial analysts based only in Washington, D.C., the Bank now has a multidisciplinary and globally diverse staff, nearly 36% of whom are based in 120 offices around the world.

The Bank's dominance in setting the international development agenda stems from its enormous financial power. As the largest bank of its type, the Bank had, for instance, an administrative budget of \$2.1 billion and a combined IBRD and IDA funding commitment of \$24.7 billion in Fiscal Year 2008, easily exceeding the resources of any other international development agency. Moreover, as convener of almost all the existing consortia or consultative groups, such as the “donor” clubs, it coordinates the overall aid programs of bilateral donors as well as IMF lending to individual countries.

Francis Owusu

See also **Development Theory; International Monetary Fund; Neoliberalism; Structural Adjustment; World Trade Organization (WTO)**

Further Readings

Kapur, D., Lewis, J., & Webb, R. (1997). *The World Bank: Its first half century*. Washington, DC: Brookings Institution Press.

Peet, R. (2007). *Geography of power: The making of global economic policy*. London: Zed.

Ritzen, J. (2005). *A chance for the World Bank*.

London: Anthem Press.

World Bank. (2007). *A guide to the World Bank* (2nd ed.). Washington, DC: Author.



WORLD CITIES

A world city is a dominant place in the global economy with a disproportionately large share of the world's business functions, especially capital commanding functions, but the term dates back to at least the beginning of the 19th century, when Goethe used it to describe cities of overwhelming political and cultural importance. Within the contemporary study of geography, however, world cities are usually defined as centers with a very large proportion of command-and-control functions within the global economy (Figure 1). These are most commonly measured as large concentrations of producer services, including banking and financial services, insurance, real estate, legal services, accounting, and professional associations. World cities are also highly dependent on each other for investment and other business activities, creating a world city network. Due to increased global competition in place marketing, world city status is a desirable achievement for local planners, trying to attract outside investment or a share of the global tourism. More recently, the concept of the world city has been criticized for focusing too strongly on urban hierarchies and economic aspects and for being West-centric.

Historical Development of the Term

Although the term *world city* was used by Goethe, its meaning differed from today's conception of a world city, as it then signified a place of political and cultural importance. World city research in the contemporary study of geography focuses strongly on economic processes, although political, cultural, and social processes inform some aspects of the research. Moreover, the research is strongly shaped by disciplines other than geography, especially urban planning and sociology.

In the 20th century, Patrick Geddes also used the term *world city* in his book *Cities in Evolution*, which was published in 1915. However, the

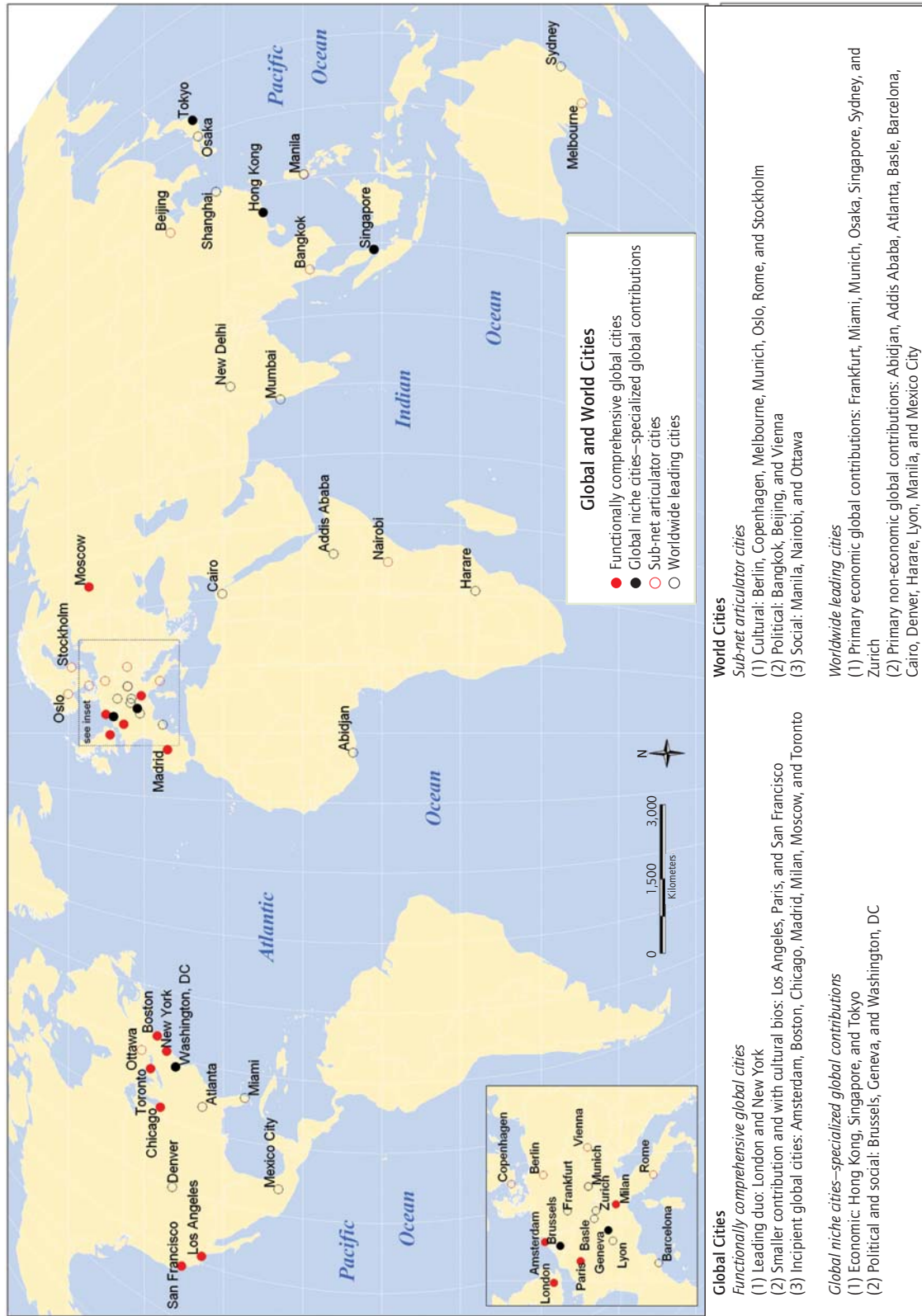


Figure 1 Global and world cities

Source: Map created by the author. Taxonomy based on Taylor, P. J. (2005). Leading world cities: Empirical evaluations of urban nodes in multiple networks. *Urban Studies*, 42(9), 1593–1608.



British urban planner Peter Hall provided the first systematic analysis of world cities in 1966, when he published his book *The World Cities*. Hall analyzed seven cities, which were of overwhelming economic importance in the world economy at the time, but he focused on their internal structures and organization as well as national and regional roles, with relatively little attention to linkages between these world cities. Understanding world cities as part of a network of world cities did not happen until the 1980s, when researchers at the University of California, Los Angeles, among them the urban planner John Friedmann, published their hypothesis of a world city network. This reorientation in world city research was a direct response to changes in the world economy since roughly the 1970s, which saw a shift from Fordist production methods to more decentralized and flexible methods as well as a reduction in trade barriers and increased economic globalization.

A further major development in world city research came in the early 1990s, when the sociologist Saskia Sassen published *The Global City: New York, London, Tokyo*. One of the major contributions of that book was the identification of producer services as command-and-control functions in the world economy. Producer services have subsequently become and continue to be a core analytical component of world city research. The label “global city” was intended to mark a conceptual difference from “world city,” in that a global city is not merely a dominant city in the world but the processes articulated in it are truly global intercity linkages. Various rankings of a world city network were produced using producer services as an analytical cornerstone. This work was significantly advanced by the geographer Peter Taylor and the Globalization and World City (GaWC) Research Group founded in the late 1990s at Loughborough University in the United Kingdom.

World City Network

World cities are the command-and-control centers of the global economy but are not individually in a position to fulfill these command-and-control functions. Instead, they are also highly dependent on each other—that is, they not only compete for

the same business but also rely on each other in fulfilling the capital commanding functions in the global economy and thus constitute a system. The geographic distribution of cities remains of central importance for this system regardless of considerable improvements in telecommunications over the past two or three decades. The most regularly mentioned world cities at the top of the urban hierarchy, New York, London, and Tokyo, for example, are located in three distinct world regions and time zones and are thus in a position to collectively influence business in the Americas, Europe-Africa, and the Asia Pacific Region at any time, whereas one individual city could not do so. Los Angeles, Chicago, Toronto, Paris, Frankfurt, Amsterdam, Hong Kong, Singapore, and Sydney, among others, are often cited as other major world cities.

These world cities have in common that they host the largest stock exchanges and the headquarters of the world’s largest banks and other transnational producer services firms. Through these producer services or command-and-control functions, world cities fulfill core functions within the world economy. Strong links thus exist between world-systems theory, which conceptually divides countries into core, periphery and semiperiphery economies, and world city research, although the former focuses on the nation-state as the main unit of analysis and the latter on cities. World cities are often ranked into alpha, beta, gamma, and delta groups, based on the concentrations of producer services in them. Depending on changes in these concentrations, cities retain both upward and downward mobility within the system.

The Internal Structure of World Cities

The internal structure of world cities is characterized by an advanced telecommunication infrastructure, a large stock of high-end office space, a large proportion of urban amenities, spectacular architecture, and signature buildings as well as highly polarized labor markets. Moreover, the hosting of cultural festivals, sports events, and other mega events, such as the Olympics or Expos (world exhibitions), are means for cities to attract business and tourists and thus attain (or maintain) world city status.



Office space and infrastructure are essential prerequisites in attracting the offices, especially regional or global headquarters, of large transnational corporations, which give a city the status of a world city. However, cultural amenities, such as theaters, museums, concert halls, and sports arenas, are of similar importance in attracting global managerial staff and professionals to work in a city. Similarly, mega events, with their substantial global media reach, are tools for promoting a city and showcasing its attractiveness and achievements. Spectacular architecture provides an image of a city to promote it through the global media.

Partly as a result of this economic structure, world cities are characterized by a highly polarized labor market. On the one hand, a large number of professionals and managerial staff in transnational corporations receive high incomes with additional benefits, enabling them to enjoy many of the cultural amenities, while on the other hand many low-income workers struggle to find adequate housing, schooling for children, and often food. These workers often earn a minimum wage (or in case of illegal employment, below minimum wage) and find employment in low-end service jobs, such as cleaning, food services, or domestic labor. Both labor markets, high and low income, are highly international and depend on migrant workers—transnational professionals on the one hand and economic migrants on the other. The process of social polarization is also a result of post-1970s state restructuring and the reduction of social redistribution by nation-states.

Critique of the Concept

The concept of the world city has been critiqued as being West-centric and too focused on economic processes of globalization rather than on a broad cross-section of different processes, including cultural, political, and social ones. The focus on producer services privileges a narrowly defined subsection of the global economy, resulting in a focus on a small number of cities, while other important global or regional economic circuits are excluded from the analysis. Few cities that are routinely included in world city rankings are in the global South. Moreover, critics charge that through rankings of world cities, it is implicitly suggested that the cities at the top of the urban

hierarchy are the examples or standards, while other cities are the followers that should attempt to develop in the same way. Supporters of world city research point to its theoretical tradition in world-systems theory and stress that the rankings are an expression of power and influence in the world urban system rather than an indication of which cities have developed “correctly.”

Björn Surborg

See also Globalization; Producer Services; Taylor, Peter; Urban Geography; Urban Hierarchy; Urbanization; World-Systems Theory

Further Readings

- Beaverstock, J., Smith, R., & Taylor, P. (1999). A roster of world cities. *Cities*, 16(6), 445–458.
- Beaverstock, J., Smith, R., & Taylor, P. (2000). World city network: A new metageography? *Annals of the Association of American Geographers*, 90(1), 123–134.
- Friedmann, J. (1986). The world city hypothesis. *Development and Change*, 17, 69–83.
- Friedmann, J., & Wolff, G. (1982). World city formation: An agenda for research and action. *International Journal of Urban and Regional Research*, 6(3), 309–344.
- Hall, P. (1966). *The world cities*. London: Weidenfeld & Nicolson.
- Robinson, J. (2002). Global and world cities: A view from off the map. *International Journal of Urban and Regional Research*, 26(3), 531–554.
- Sassen, S. (1991). *The global city: New York, London, Tokyo*. Princeton, NJ: Princeton University Press.
- Taylor, P. (2004). *World city network: A global urban analysis*. London: Routledge.



WORLD COURT

The World Court is the common name for the International Court of Justice (ICJ). It is the main judicial organ of the United Nations (UN) and is headquartered at the Peace Palace in The Hague (the Netherlands). It began functioning in 1946.



The Peace Palace, also known as Vredespalais, in The Hague, the Netherlands. It houses the principal judicial body of the United Nations, the International Court of Justice, and the Permanent Court of Arbitration.

Source: Arjan de Jager/iStockphoto.

Its predecessor was the Permanent Court of International Justice (PCIJ), established in 1920 by the League of Nations. The Court's earlier roots can be traced back through The Hague Peace Conference of 1899, the Alabama Claims arbitration in 1872, and the Jay Treaty of 1794 between Britain and the United States.

Fifteen judges serve on the World Court. They are elected for 9-yr. (year) terms by the UN General Assembly and the Security Council and are eligible for reelection. Candidates must receive an absolute majority of votes in both bodies. For continuity, one third of the Court is elected every 3 yrs. Once elected, the Court's judges then elect a president and vice president. The Court's official languages are English and French.

The judges must represent the world's main forms of civilization and legal systems. No more

than one person of a single state (i.e., country) may serve concurrently as a judge. Presently, three judges are from Africa, two are from Latin American and the Caribbean, three are from Asia, five are from Western Europe and other states, and two are from Eastern Europe. Judges are not delegates of their respective countries but instead are obligated to act impartially and conscientiously. For Court cases concerning a country that does not have a judge on the Court, a country may request that an ad hoc judge from it or another country be added for such cases. Ad hoc judges also must agree to be impartial in their decision making.

The World Court has two main functions: (1) issuing advisory opinions and (2) settling contentious cases. The first centers on legal questions submitted to it by the UN's five organs and



16 specialized agencies. The second is an application of international law to settle legal disputes brought to it by countries' governments. The Court only accepts contentious cases from countries that are members of the UN and parties to the Statute of the Court or countries that accept the Court's jurisdiction. Its judgment is delivered publically and is considered final, binding, and not subject to appeal. Advisory opinions are also delivered publically but are not considered binding.

Between 1946 and mid 2008, the Court delivered 25 advisory opinions, 97 judgments, and had 12 pending contentious cases. Judgments have concerned issues such as political boundary disputes, territorial sovereignty, noninterference in the internal affairs of states, rights of passage, diplomatic relations, and human rights.

George W. White

See also **Borders and Boundaries; Human Rights, Geography and; Identity, Geography and; International Criminal Court; Justice, Geography of; Law, Geography of; Sovereignty; State**

Further Readings

International Court of Justice: www.icj-cij.org/homepage/index.php?p1=0

Shabtai, R. (2006). *The law and practice of the International Court, 1920–2005* (4th ed.). With the assistance of Yaël Ronen. Boston: M. Nijhoff.



WORLD HEALTH ORGANIZATION (WHO)

The World Health Organization (WHO) was one of the earliest bodies created by the United Nations. The WHO effectively began in 1948, when its constitution came into force, and to this day it continues to spearhead global public health initiatives. Over the years, the WHO has played a key role in the organization and promotion of global programs to eradicate infectious diseases, including small pox, polio, and measles; in helping developing countries, in particular, to build

their public health care systems; and in the development of surveillance systems for and responses to highly infectious emergent diseases (e.g., Ebola).

Arguably, the WHO's greatest contribution to date is the role it has played in transforming the thinking on the development of primary health care. In 1978, the WHO organized the Primary Health Conference in Alma Ata, where WHO member countries declared,

The Conference strongly reaffirms that health, which is a state of complete physical, mental and social wellbeing, and not merely the absence of disease or infirmity, is a fundamental human right and that the attainment of the highest possible level of health is a most important worldwide social goal whose realization requires the action of many other social and economic sectors in addition to the health sector. (Alma Ata Declaration, first principle)

These words shifted the focus of research and practice away from a narrow concept of health as the absence of disease to a much broader focus on physical, mental, and social well-being; acknowledged that to understand health, research and practice must address the social and economic determinants of health; and raised health status to the level of other fundamental human rights. In other clauses, the Alma Ata Declaration sets out the responsibilities of governments to attain the goal of health and declared that the elimination of health inequalities within and between countries needed to be attained.

The WHO definition of health, its focus on the social and economic determinants of health, its advocacy of health as a right, and its goal of reducing health inequalities all found their way into the writing, research agendas, and critical debates of the 1990s among medical geographers. While medical geography continues to exist as a subfield of geography, it can be argued that the ideas that came out of the Alma Ata Conference help set the stage for the development of health geography in the latter part of the 1990s, with the take-up of key concepts from critical geography and an emphasis on place, gender, disability, population health, and the use of qualitative methods. Today, both medical and health geographers



continue to look to the WHO for its leading role in the global efforts to eradicate disease and promote health.

Mark W. Rosenberg

See also **Health and Health Care, Geography of; Medical Geography; United Nations**

Further Readings

- Gatrell, A. (2002). *Geographies of health. An introduction*. Oxford, UK: Blackwell.
- Gesler, W. M., & Kearns, R. A. (2002). *Culture/place/health*. London: Routledge.
- World Health Organization: www.who.int/en



WORLD SUMMIT ON SUSTAINABLE DEVELOPMENT

The World Summit on Sustainable Development (WSSD), which convened in Johannesburg, South Africa, from August 26 to September 4, 2002, aimed to reaffirm and assess the progress of the multilateral commitments launched at the Rio Conference 10 years earlier. Specifically, the WSSD was designed to evaluate the progress of the Millennium Goals and Agenda 21 and to set new priorities and goals to counter global poverty and environmental degradation in the coming years. United Nations (UN) Secretary General Kofi Annan identified five priority areas for action at the Summit: (1) water and sanitation, (2) energy, (3) health, (4) agriculture, and (5) biodiversity.

The United Nations Commission on Sustainable Development served as the central organizing body of the WSSD. A 10-member steering committee (representing each region of the world) guided the process and attempted to raise political support for the summit. Four preparatory meetings were also held prior to the WSSD, three in New York City and one in Bali, Indonesia.

The WSSD is one of a series of UN global earth summits popularized since the Stockholm Summit in 1972. It was the largest summit to date, with more than 100 heads of state and an

estimated 25,000 participants (from 180 countries) representing governmental, business, and activist organizations. The WSSD differed from the previous summits in two important ways: (1) it adopted a sustainable development approach, which widened the environmental goals to include poverty alleviation, and (2) it created opportunities for greater civic engagement through the organization of a parallel stakeholder's forum conference. Stakeholders included businesses, women and children, trade unions, indigenous leaders, local representatives, farmers, and the scientific community.

Despite this new approach and the unprecedented number of attendees, the WSSD was widely criticized for failing to devise a specific time frame and funding provision for the implementation of their goals. Many blame summit fatigue for the lack of results. Others blame the increasingly neoliberal approach to global governance and the subsequent weakening of the sustainable development ideology. Furthermore, the events of September 11, 2001, and the subsequent War on Terror, along with the credit crisis of 2008, have contributed to widespread unilateral policies that prioritize military and financial security over global environmental conservation and sustainable development.

Emma S. Norman and David L. Carr

See also **Civil Society; Environment and Development; Neoliberal Environmental Policy; Sustainable Development; United Nations Conference on Environment and Development**

Further Readings

- Carr, D., & Norman, E. S. (2008). Global civil society? The Johannesburg World Summit on Sustainable Development. *Geoforum*, 39, 358–371.
- Death, C. (2008). No WSSD + 5? Global environmental diplomacy in the twenty-first century. *Environmental Politics*, 17, 121–125.
- Frantzius, I. V. (2004). World Summit on Sustainable Development Johannesburg 2002: A critical analysis and assessment of the outcomes. *Environmental Politics*, 13, 467–473.



- Gutman, P. (2003). What did WSSD accomplish? An NGO perspective. *Environment*, 45, 20–26.
- Taylor, R. (Ed.). (2004). *Creating a better world: Interpreting global civil society*. Bloomfield, CT: Kumarian Press.
- Wapner, P. (2003). World Summit on Sustainable Development: Toward a post-Jo'burg environmentalism. *Global Environmental Politics*, 3, 1–10.



WORLD-SYSTEMS THEORY

One of the major models of how the global system of states and markets operates, world-systems theory, introduced by the sociologist Immanuel Wallerstein in the 1970s, is an enormously influential perspective on the changing structure and dynamics of the world economy. In many respects, it retains a fundamentally Marxist version of the world, one that puts production, class, uneven development, and historical context at the center.

The focus of world-systems theory is on the entire world rather than on individual nation-states. This view maintains that one cannot study the internal dynamics of countries without also examining their external ones; thus, the boundary between foreign and domestic effectively disappears. This stance notes that all regions are interconnected; that is, they never exist in isolation. Moreover, this focus notes that the growth of the West occurred *in interaction with* other parts of the world, not through its inherent internal dynamism, thus serving to oppose the widespread Eurocentrism of much of social science.

World-systems theory distinguishes between large-scale, precapitalist *world empires*, such as the Romans, Mongols, or Ottomans, all centralized political systems that appropriated the social surplus from their peripheries through the state, and the capitalist world *system*, in which there is no single political entity to rule the world but a multiplicity of entities of varying sizes and degrees of sovereignty; that is, there is a single market but multiple political centers, meaning that there is no effective control over the market. With the rise of capitalism, the primary political units shifted from

empires and city-states to nation-states. The political geography of capitalism is thus not the nation-state but the interstate system. Occasional attempts to reassert a world empire included the Hapsburgs, Napoleon, and Germany in World Wars I and II, each of which represented a temporary contraction in the world system but a permanent reconfiguration in its hierarchy of states.

Wallerstein held that the world system arose in the “long 16th century” (1450–1650) and gradually enveloped all other parts of the globe. Until the 19th century, various parts of the world *affected* one another; as they become locked into a single, worldwide division of labor, however, they became increasingly *reliant* on each other. However, recent variations of world-systems theory have extended the concept “backward” in time to include increasingly earlier social formations. For example, Andre Gunder Frank held that even Neolithic mini systems constituted a world system of sorts. Janet Abu-Lughod offered a celebrated concept of a late-13th- and early-14th-century system, which connected China, India, the Arab world, and medieval Europe via the Silk Road routes and maritime trade across the Indian Ocean but was ended by the bubonic plague. Indeed, many world-systems theorists argue that prior to the 19th century, the world economy was primarily Asian in nature.

World-systems theorists maintain that capitalism takes many forms and uses labor in different ways in different regions. In the global core, labor is predominantly waged (i.e., organized through labor markets), while in developing countries there is considerable use of nonfree labor, ranging from slavery to indentured workers to landless peasants working on plantations. Some critics of Wallerstein, particularly Robert Brenner, argue that his view prioritizes trade over the commodification of labor, leading to allegations that he is “neo-Smithian” in his worldview. World-systems theorists counter that the world economy structures places in such a way that high-valued goods are produced in the core and low-valued ones in the periphery. The search for profits through low-cost labor drives the world system forward to expand into uncharted territories.

Unlike the bifurcation between developed and less developed countries that both modernization and dependency theories advocate, in world-systems



theory there is a tripartite division among core, periphery, and semiperiphery. The core and periphery are the developed and undeveloped countries, or First and Third worlds, respectively: One is wealthy, urbanized, industrialized, and democratic, the other rural, impoverished, agriculturally based, and dominated by authoritarian governments. The semiperiphery has characteristics of both core and periphery and includes states in the upper tier of the less developed world, such as the newly industrializing countries in East Asia, Brazil, and Mexico. Core processes generate high wages, high levels of urbanization, industrialism and postindustrialism, advanced technology, and a diversified product mix. In the world periphery, the world system creates low wages, low levels of urbanization, preindustrial and industrial technology, and a simple production mix. In between are states that are part of the semiperiphery, where both sets of processes coexist to a greater or lesser degree. The theory suggests that semiperipheral countries are exploited by the core countries with regard to raw material and product flows while at the same time the peripheral regions are also exploited. However, unlike dependency theory, world-systems theory allows for some degree of mobility within the global economy: Thus, capitalism does not inevitably breed poverty; rather, its effects are contingent and historically and geographically specific. However, the possibilities of development are limited, and the development of one country via industrialization is likely to coincide with the underdevelopment of another.

World-systems theory pays particular attention to the role of a single hegemonic state that dominates the global political and economic system. The hegemon sets the rules of the game, so to speak. Hegemony exists when one core power enjoys supremacy in production, commerce, and finance and occupies a position of political leadership. The hegemonic power is the leading trading and investment country, its currency is the universal medium of exchange, and its city of primacy is generally the financial center of the world. Because of its political and military superiority, the dominant core country maintains order in the world system and imposes solutions to international conflicts that serve its self-interests. During the period of Spanish dominance in the 16th and

17th centuries, for example, mercantilism was the dominant ideology. In the 17th century, the Dutch enjoyed a brief window in which they controlled Indonesia, South Africa, Curacao, and New Amsterdam (later New York). Under the Pax Britannica of the 19th century, when Britain controlled one quarter of the Earth's surface, free trade was the norm. And since the rise to dominance of the United States, especially since World War II, neocolonialism has been the typical pattern (although during the Cold War there were two superpowers and a bifurcated world system). Consequently, hegemonic situations are characterized by periods of relative peace (e.g., the 19th century). During a power's decline from hegemony, rival core states, which can focus on capital accumulation without the burden of maintaining the political and military apparatus of supremacy, catch up and challenge the hegemonic power. Thus, in the early 20th century, Germany challenged Britain for global leadership, with catastrophically violent results.

The rise and fall of hegemonic powers is sometimes tied by world-systems theorists to long-term cycles or Konratief waves, a view that attempts to correlate upswings and downswings with changes in hegemonic status. Moreover, hegemonic powers may overextend themselves militarily, leading to an erosion of their economic base. When powers in the core have conflicts among themselves, they open opportunities both for new hegemonies and for countries on the periphery: the Napoleonic Wars of the early 19th century and World War II in the 20th century were thus openings for nationalist anticolonial movements worldwide, first in Latin America and later in Asia and Africa. World-systems theory thus allows for resistance and decolonization and notes that hegemonic power is always contested.

Geographers have been attracted to world-systems theory because of its sensitivity to spatial differences in historical experience and the ways in which it allows regions to be contextualized within a global setting. The view offers significant insights into the possibilities of development (or lack thereof), the constraints to individual actors such as nation-states or transnational corporations, the origins of war, and phenomena such as trade and economic crises. World-systems theory in various forms thus forms an integral part of



human geography and has become woven into most of the discipline's conceptualization of how the global economy and geopolitical apparatus function.

Barney Warf

See also Colonialism; Dependency Theory; Development Theory; Geopolitics; Globalization; Imperialism; Marxism, Geography and; Modernization Theory; Nation; Nationalism; Newly Industrializing Countries; Trade; Uneven Development; World Cities

Further Readings

- Abu-Lughod, J. (1989). *Before European hegemony: The world system A.D. 1250–1350*. New York: Oxford University Press.
- Chase-Dunn, C. (1998). *Global formation: Structures of the world-economy* (2nd ed.). Lanham, MD: Rowman & Littlefield.
- Chase-Dunn, C., & Hall, T. (1997). *Rise and demise: Comparing world-systems*. Boulder, CO: Westview Press.
- Denemark, R., & Thomas, K. (1988). The Brenner-Wallerstein debate. *International Studies Quarterly*, 32, 47–65.
- Frank, A. (1996). *The world system: Five hundred years or five thousand?* London: Routledge.
- Frank, A. (1998). *ReOrient: Global economy in the Asian age*. Berkeley: University of California Press.
- Journal of World Systems Research*: <http://jwsr.ucr.edu/index.php>
- Skocpol, T. (1977). Wallerstein's world capitalist system: A theoretical and historical critique. *American Journal of Sociology*, 82, 1075–1090.
- So, A. (1990). *Social change and development: Modernization, dependency, and world-system theories*. Newbury Park, CA: Sage.
- Straussfogel, D. (1997). World systems theory: Toward a heuristic and pedagogic conceptual tool. *Economic Geography*, 73, 118–130.
- Wallerstein, I. (1974). *The modern world system: Capitalist agriculture and the origins of the European world economy in the sixteenth century*. London: Academic Press.
- Wallerstein, I. (1979). *The capitalist world-economy*. Cambridge, UK: Cambridge University Press.

Wallerstein, I. (1980). *The modern world system II: Mercantilism and the consolidation of the European world-economy, 1600–1750*. New York: Academic Press.

Wallerstein, I. (1993). The time space of world systems analysis: A philosophical essay. *Historical Geography*, 23, 5–22.



WORLD TRADE ORGANIZATION (WTO)

The World Trade Organization (WTO) is a multistate organization formed to administer a set of interlocking international agreements, which are concerned primarily with trade regulation. It also functions as a forum to negotiate changes and additions to these agreements. It officially came into existence on January 1, 1995. As of July 2008, there were 153 members, including most but not all of the world's sovereign governments. The WTO is explicitly committed to lowering trade barriers and to general economic liberalization. It plays a key role in international political economy and in contemporary geopolitics.

Most of the constituent agreements of the WTO took their present form during a series of multilateral negotiations known as the Uruguay Round, taking place from 1986 to 1994. These built on and incorporated an older set of international agreements known as GATT (General Agreement on Tariffs and Trade), dating from 1947. The Uruguay Round agreements regulate a vast sweep of international economic policy, including tariff levels, the use of nontariff trade barriers, subsidies, copyright law, trade in services, and foreign investment. In addition, trade in agriculture and textiles were deemed exceptional and were subject to separate agreements. The foundational WTO agreements also included provisions for their own alteration and augmentation in expected future negotiations. Ministerial meetings of the WTO are held about once every 2 years in different locations around the world to conduct these negotiations, the most recent being held in Hong Kong in 2005. Thus far, few changes have been made to the original agreement other than time-dependent clauses from the Uruguay



Round kicking in (e.g., the expiration of the Agreement on Textiles and Clothing in 2005).

In addition to the biannual ministerial meetings, most WTO members maintain permanent missions in Geneva, where they meet as the General Council of the WTO and staff various subcommittees. WTO headquarters in Geneva also house a permanent bureaucracy known as the Secretariat, which arranges meeting logistics, handles the circulation of documents, and dispenses implementation advice to developing country members. The highest office in the WTO is that of director general, a post currently held by Pascal Lamy, a French citizen.

In the event of a formal trade dispute between members, the General Assembly meets as the Dispute Settlement Body (DSB). The dispute settlement procedure involves an expert panel constituted specifically to evaluate and issue recommendations on each case and a permanent standing seven-member Appellate Body to hear appeals. The DSB itself has the final say as to whether or not to adopt the recommendations of the panel and the Appellate Body. In the case of a guilty verdict, the country at fault must render compensation to the winning country; if no compensation can be agreed to, then the winner of the dispute is authorized to level limited trade sanctions against the offending country. The General Assembly also meets as the Trade Review Body to conduct periodic evaluations of each member country's current economic policies.

Members of the WTO incorporate most of the world's population and economic wealth. About 40 of the world's recognized countries are not members of the WTO, notably Russia. The accession of China to the WTO in 2001 was considered a pivotal event in the growth of the WTO. Members of the WTO generally constitute sovereign states. The major exception is the European Union (EU), which is recognized as a member in itself, separate from its own member states, which also hold individual membership in the WTO. For most purposes, the 27 members of the EU choose to negotiate as a bloc. Other informal groupings of countries exist within the WTO, which often meet among themselves prior to Ministerial Meetings to hammer out a common position on specific issues. Some of the most important of these blocs include the Quad, consisting of the most powerful economies: the EU, the United

States, Japan, and Canada; the G20, consisting of about 20 (membership tends to fluctuate) of the larger developing economies, formed mainly to advocate for stronger rules against agricultural subsidies; and the G33, another coalition of developing countries formed to advocate for special and differential treatment for developing economies in the application of WTO rules.

WTO negotiations have often been contentious. Two ministerial meetings (Seattle 1999 and Cancun 2003) are notable for having broken down without producing a consensus agreement. Since Seattle, ministerial meetings have attracted large, organized protests from labor, environmental, and antineoliberal groups, among others. Since at least 2001, when the series of negotiations known as the Doha Round began, talks have been repeatedly deadlocked over the issue of agricultural subsidies, which many (mostly developing) states see as blocking their access to markets in the EU and the United States. This is part of a wider issue involving the widespread sentiment that WTO rules are biased against developing economies. Other controversial issues include the inclusion or noninclusion of labor and environmental standards in WTO rules, procedural transparency in WTO meetings, the copyrighting of genetic materials, pharmaceutical patents and the availability of life-saving drugs, special and differential treatment for developing countries, and the rights of governments to discriminate against foreign-owned companies.

Chris Blackden

See also **Antiglobalization; Globalization; International Monetary Fund; Neoliberalism; Structural Adjustment; Trade; World Bank**

Further Readings

- Jawara, F., & Kwa, A. (2004). *Behind the scenes at the WTO: The real world of international trade negotiations/the lessons of Cancun* (Updated ed.). London: Zed Books.
- Peet, R. (2003). *Unholy trinity*. London: Zed Books.
- Wallach, L., & Woodall, P. (2004). *Whose trade organization? A comprehensive guide to the WTO*. New York: New Press.



WRIGHT, DAWN (1961–)

Dawn Wright is a professor in the department of geosciences and an adjunct professor in the College of Oceanic and Atmospheric Sciences at Oregon State University (OSU). Wright is a dedicated researcher, educator, and proponent of geographic concepts and spatial thinking who has made significant contributions in the fields of geographic information science (GIScience) and the coastal and marine sciences, as well as in the broader field of geography.

Wright's research includes issues of application and analysis in the use of geographic information systems (GIS) with oceanographic data, particularly data modeling, spatial analysis, and data conversion; the processing, production, visualization, and interpretation of seafloor maps; marine data modeling, metadata, ontologies, and vocabularies; and cyberinfrastructure, particularly geographic/geospatial semantic Web issues and the related use of tools such as Web portals and Web services. She is highly regarded worldwide for her work in the areas of GIScience and coastal and marine GIS.

Wright received her bachelor's degree in geology from Wheaton College (1983), master's degree in oceanography from Texas A&M (1986), and PhD in physical geography and marine geology from University of California, Santa Barbara (UCSB) (1994) under the advisement of Raymond Smith. Her research has been funded by the National Science Foundation, the National Oceanographic and Atmospheric Administration, and the U.S. Department of Agriculture and has been published in multiple books and peer-reviewed journals. One of her best-known works was as lead author of the 1997 article "Demystifying the Persistent Ambiguity of GIS as 'Tool' Versus 'Science,'" a discussion and analysis of the perception of GIS among geographers in the early 1990s. She also helped develop the ArcGIS Marine Data Model, published in 2007.

Wright teaches introductory and advanced courses in GIS, as well as seminars in geography, GIScience, and marine-related topics, and has served on many graduate student committees at OSU. In addition to research, her work is also largely defined by her service to the broader

research community. She currently serves as chair of the University Consortium on Geographic Information Science Research Committee, as an Association of American Geographers National Councillor, on the National Academies Ocean Studies Board, on the editorial boards of several journals, including *Transactions in GIS* and the *International Journal of Geographic Information Science*, and as director of the Geographic Information Science Certificate Program at OSU.

Numerous awards have recognized Wright's academic work and her contributions to science and the community. She received a 1995 National Science Foundation Faculty Early Career Development Award, was awarded a 2004 Fulbright grant to Ireland as a Senior Specialist in Information Technology, was given the Raymond C. Smith Distinguished Alumni Award in 2007 by the UCSB Department of Geography, and was selected as the 2007 U.S. Professor of the Year for the state of Oregon by the Carnegie Foundation for the Advancement of Teaching, among others. She has given invited seminars, talks, and keynote addresses at diverse conferences such as GeoTech; GIScience; Technology, Entertainment, and Design; and the Environmental Systems Research Institute Education User Conference and has published many invited articles and book chapters.

Dylan Keon

See also **GIScience; Oceans; University Consortium for Geographic Information Science**

Further Readings

- Wright, D., Blongewicz, M., Halpin, P., & Breman, J. (2007). *Arc Marine: GIS for a blue planet*. Redlands, CA: ESRI Press.
- Wright, D., & Goodchild, M. (1997). Data from the deep: Implications for the GIS community. *International Journal of Geographic Information Science*, 11(6), 523–528.
- Wright, D., Goodchild, M., & Proctor, J. (1997). Demystifying the persistent ambiguity of GIS as "tool" versus "science." *Annals of the Association of American Geographers*, 87(2), 346–362.



WRIGHT, JOHN KIRTLAND (1891–1969)

John Kirtland Wright, historian and geographer, spent most of his career as a professional geographer with the American Geographical Society. In his many roles at the society (including research associate, director, and, more important, editor of the society's journal, *Geographical Review*), he published more than 500 documents. Many of these were book reviews and "Notes" of one or two pages, a regular feature in the *Geographical Review*. These notes and reviews covered a diverse array of topics, including many aspects of physical, human, and regional geography, as well as geographical methods and techniques. No area in geography was omitted: Topics ranged from Ancien Régime, Antarctica, and Eratosthenes to linguistics, migration, the Pyrenees, and the Zuider Zee. It has been pointed out that his ideas and contributions are interwoven into the entire fabric of geography, into the canvas, not just splashes of paint on the surface.

Operating outside academia, many of his ideas emerged late in his career as mainstream concepts in geography, and their diversity and foresight laid foundations for intellectual structures throughout the discipline. *Aids to Geographical Research*, with Elizabeth Platt (first published in 1923, with a second edition in 1947) and other bibliographically focused resources, including the *Research Catalogue* of the AGS, were facilitators for research in the discipline. Many of his conceptual innovations deal with exploiting the relationship between history and geography. Beginning in 1925, "The History of Geography: A Point of View" was followed by "A Plea for the History of Geography" and *The Geographical Basis of European History*. This theme continued in his publications and presentations while he worked with the effective organization and presentation of statistical data; in 1937, he examined "Some Measures of Distributions." Works that followed were nonstatistical forerunners of the quantitative revolution. His 1944 paper on the "Terminology of Map Symbols" became the basis for the organization and symbolization of data on maps in academic cartography.

Cartographic concepts and processes were examined from the organization of data for mapping to the perceptual and cognitive processes of the map reader. Decades of consideration of the statistical and graphic organization of geographical information resulted in work on human nature and the impact of aesthetic feeling, imagination, and subjectivity in geography.

At the outset, given the opportunity as he began his graduate studies at Harvard, he chose not to specialize in geography, which at the time involved the study of "nature-minus-man." He decided to make his study of history geographical, which he did for half a century. He looked from a variety of perspectives at *terrae incognitae* (unknown lands), which made the use of imagination critical to geographical exploration and mapping. The results of exploration involve interpretations, modifications, and inventions, all involving aspects of the imagination. His ideas were seminal in the movement that has been called the "cognitive reformation" of American geography, involving environmental perception, cognition, and behavior. One can turn to the 1966 series of essays in *Human Nature in Geography* and find that he was ahead of the developments that would occur throughout the discipline during the 20th century.

The breadth of his perspective not only of the discipline but also of geography as a whole is embodied in geosophy, the study of geographical knowledge from any or all points of view.

George F. McCleary Jr.

See also **American Geographical Society; Cartography; Cartography, History of**

Further Readings

- Bowden, M. (1970). John Kirtland Wright, 1891–1969. *Annals of the Association of American Geographers*, 60, 394–403.
- Koelsch, W. (2003). William H. Tillinghast, John K. Wright, and some antecedents of American humanistic geography. *Journal of Historical Geography*, 29, 618–630.
- Lowenthal, D. (1969). John Kirtland Wright, 1891–1969. *Geographical Review*, 59, 598–604.



- Lowenthal, D., & Bowden, M. (Eds.). (1976). *Geographies of the mind: Essays in historical geosophy in honor of John Kirtland Wright*. New York: Oxford University Press.
- Wright, J. (1943). The terminology of certain map symbols. *Geographical Review*, 34, 653–654.
- Wright, J. (1952). *Geography in the making: The American Geographical Society, 1851–1951*. New York: American Geographical Society.
- Wright, J. (1966). *Human nature in geography: Fourteen papers, 1925–1965*. Cambridge, MA: Harvard University Press.



WRITING

Writing is the means by which geographers have traditionally represented the physical, cultural, and social worlds as they perceive, measure, and understand them. It is a conventional tool, the use of which entails uncertainty and perceptual bias. The contingent nature of understanding conveyed through the written word is a bedrock tenet of poststructural academics, but the idea that all language is fundamentally metaphoric or “figural” is an old one, with roots in the writings of both Plato and Friedrich Nietzsche. The recognition of writing’s fraught nature in geography dates back to Immanuel Kant. Writing today is undertheorized by geographers and is largely used either unreflectively or to predictable political ends.

As Jacques Derrida indicated, writing as a tool is intrinsically imbricated in power-creating systems. Every system of symbols to represent concepts entails the embrace of a dialectical and recursive methodology that works to obscure its own mechanisms and the power relations that underlie them. While contemporary social scientists tend not to focus on the embedded nature of written understandings, the roots of the modern discipline of geography lie in a nuanced grasp of the necessarily metaphoric nature of description and depiction in conveying both measurable and perceptual aspects of particular places. Geography is crucially the expression and transmittal of understandings of places and spaces as much as it is those understandings per se.

Ralph Hall Brown played a central role in conveying the centrality to geography of not simply the physical realities of a given location but also the evolving human understanding of a place’s significance and structure. That is, he was concerned with the context of knowledge about places and how it develops over time. Recognizing that character and culture were significant influences on both knowledge and action, Brown used fiction as a lens through which to assess the state of geographical knowledge in a particular time and place. His best-known work, *Mirror for Americans*, published in 1943, is an analysis of a fictional colonial-era protagonist, whom Brown used to both humanize colonial conceptions of American geography and stress their contingent and contextual nature.

With the quantitative turn, the literary and discursive treatment of geographic perception was often considered to be insufficiently rigorous. Geography began to purport to be one of the sciences that measured rather than one of the arts that perceived. Yet many geographers—including Brown, J. Wreford Watson, Douglas Pocock, Marwyn Samuels, and especially Yi-Fu Tuan and Donald Meinig—remained committed to a conception of geographic perception that required nothing short of a literary sensibility. Tuan particularly stressed the need for geographers to cultivate, among other qualities, the empathy and insight that any good writing exhibits. Similarly, Meinig held that geographic writing had to become overtly novelistic in order to cultivate relevance and an audience.

Tuan and others promoted a focus on experiential knowledge that had linguistic implications. Just as geography moved into the social world, writing itself came to be recognized as something that entails more than just transcription and analysis of books, maps, and surveys. Both the built environment and language are vectors for individual expression and emotion and can define and shape consciousness and sensibility. Neither is merely the by-product of macroeconomic priorities or microeconomic decisions. Geography’s focus on “being in the world” led to its embrace of a necessary incompleteness—an eternally deferred final understanding that is intrinsic to writing as well. Language itself is an important power in constructing places (and, by implication,



in constructing the power that those places then exert). Spatial patterns can therefore be seen as not dependent on actual geography alone but rather as a product of the metaphors used to describe their parts.

This foregrounding of writer qualities and self-awareness found particular expression in the impressionistic works of Gunnar Olsson and the self-conscious typographic experiments of Allan Pred, which attempted to convey the feel of a place through placement and treatment of words on a page as much as through their content. A utilitarian backlash against the “New Mandarin” style was in large measure successful, as geographic writing has subsequently become essentially indistinguishable from generic social science prose.

Nevertheless, many recent conceptions of academic writing do take it as given that “objective” discourse itself has lost validity and that all expressions are socially constructed. The modernist voice that presumed a reader who was basically nonexistent as an individual, requiring only rationalist demonstration rather than any appeal to social or personal interests, has been discredited, and books or articles themselves are seen as unavoidably contingent in both content and form. Any theoretical construction is then simply spatially embedded practice, which implies that perspective is directly reliant on position, which itself is a product of social discourse.

Such an incomplete perspective is doubly endemic to geographic discourse in that it comes to grips with the relations between the structural and the experiential, or between what a place “is” and what it “is like.” Academic prose may be a useful medium through which to cogently lay out the structural aspects of social situations, but social experience itself is a distinctive phenomenon whose transmittal requires a medium that forthrightly encompasses subjectivity. Such writing is the cognitive nexus between what happens and how geographers begin to make sense of it, and “higher” thinking itself is premised on the metaphoric understanding of the world that we reflexively apply to the world’s stimuli. Moreover, contingent experience, circulated images, and stories about places are all central in comprehending the meaning of complex environments,

and they all require interpretation in addition to generalization.

Recent geographic scholarship has tended to emphasize the quality of writing, confusing it with reporting and using it as source material for interrogating social structures. Geographical approaches to literature, for example, often tend to treat it as symptomatic of society’s ills, as if it were simply another tool of a broader social hegemony or a “cultural product.” From this perspective, writers are blind to the social forces they depict, and their work as a whole is merely what the literary scholar Robert Alter refers to as a reflex of ideology. Such a perspective confuses the contents of a book and its function as literature, misreading representations of experience as experience itself.

This approach creates an impoverished discourse wherein only a certain privileged language, such as social scientific tropes, attains status as legitimate geographic argument. The limited geographic linguistic palette of the present moment is a barrier to the discipline’s ability to effect broad change. The language spoken by geographers often does not speak to common experience or to structural engagements as they are broadly understood. For example, we need only contrast the ease with which nongeographers speak of the weather to the difficulty that many geographers have in speaking with precision about place and its complications. We can speak, for example, of it “raining cats and dogs,” but similar metaphors to describe complicated landscapes (whether physical, social, or economic) do not hold the same currency. The embrace of metaphor in popular meteorology has helped foster the illusion of popular understanding and thus of popular engagement—simply put, many people feel that they have an intuitive understanding of the weather, while far fewer would claim such an understanding of any geography beyond the local.

Timothy Mennel

See also **Discourse and Geography; Humanistic Geography; Literature, Geography and; Postmodernism; Pred, Allan; Representations of Space; Symbolism and Place; Text/Textuality; Tuan, Yi-Fu**



Further Readings

- Alter, R. (2005). *Imagined cities: Urban experience and the language of the novel*. New Haven, CT: Yale University Press.
- Billinge, M. (1983). The Mandarin dialect: An essay on style in contemporary geographical writing. *Transactions of the Institute of British Geography*, 8, 400–420.
- Brown, R. (1943). *Mirror for Americans*. New York: American Geographical Society.
- Curry, M. (1996). *The work in the world: Geographical practice and the written word*. Minneapolis: University of Minnesota Press.
- Meinig, D. (1983). Geography as an art. *Transactions of the Institute of British Geographers*, 8(3), 314–328.
- Olsson, G. (2007). *Abysmal: A critique of cartographic reason*. Chicago: University of Chicago Press.
- Pocock, D. (Ed.). (1981). *Humanistic geography and literature: Essays on the experience of place*. Totowa, NJ: Barnes & Noble.
- Tuan, Y.-F. (1978). Literature and geography: Implications for geographical research. In D. Ley & M. Samuels (Eds.), *Humanistic geography: Prospects and problems* (pp. 194–206). Chicago: Maaroufa Press.
- White, H. (1980). The value of narrativity in the representation of reality. *Critical Inquiry*, 7(1), 5–27.



XERISCAPING

Xeriscaping is an approach to landscape design that integrates the resource conservation objectives of communities in dry environments and water-stressed urban areas. The principal management objective of xeriscaping is to create a landscape that is water conserving and requires little or no irrigation. The term was coined by the Denver Water Department in 1981 and has been widely adopted by state, county, and city governments that promote alternatives to the common water-intensive turfgrass landscapes of North America. Xeriscaping has gained in popularity as an environmentally friendly and aesthetically pleasing alternative to such conventional landscaping. As the term has entered popular discourse, xeriscaping is increasingly used as an umbrella term for landscaping that encompasses a range of environmental objectives. These objectives extend beyond water conservation and include the reduction of chemical pesticide and fertilizer runoff, the restoration of indigenous plant communities, and the development of wildlife habitat to increase urban biodiversity. Furthermore, the term is often used to refer to water conserving landscapes within nonxeric environments. Given the importance of the residential lawn as an agent of environmental change and a cultural icon, the diffusion of xeriscaping is important as a harbinger of environmental attitudes,

environmental consciousness, and resource management practices of urban and suburban North Americans.

Landscape Management Practices

Xeriscaping encompasses a range of landscape management practices selectively adopted to conserve water. The precise selection of particular combinations of landscape elements and management practices is adapted to local and site conditions but typically integrates soil management, composting, mulching, and the planting of drought-tolerant plants with deep root systems. Xeriscaping practices vary by region depending on climate, native vegetation, soil types, land use, and other environmental factors. Landscape plans are typically developed to suit particular characteristics of a residential yard, such as soil types, exposure, slope, and grade, in order to maximize water retention. Xeriscaping often requires conversion of an existing turfgrass lawn to new ground covers that typically include native and drought-resistant grasses, shrubs, trees, and non-living surfaces. Mulches are often used to retain water and control weeds. Retention of areas of turfgrass is compatible with xeriscaping principals if located in appropriate water-use zones. Those who adopt xeriscaping often integrate personal aesthetic preferences into landscape design. Xeriscaping advocates often emphasize



Funded in part by a grant from the Arizona Department of Water Resources, the Tempe Women's Club Park was converted to a Xeriscape Demonstration Garden in 1995 to promote low-water-use plants and desert landscaping practices.

Source: Richard Bond, City of Tempe Water Conservation Program.

the individuality of landscape design that can be incorporated into landscape plans, in contrast to the relatively uniform conventional lawn.

Other Environmental Benefits

Although the term suggests management for reduced water consumption, xeriscaping is commonly associated with a range of environmental objectives that residents seek to realize through their landscape choices. Due to health concerns, especially for children and pets, eliminating or reducing applications of chemical pesticides has

been highlighted as a benefit of xeriscaping. Regional environmental impacts of landscaping choices are also highlighted by xeriscaping proponents. For example, in coastal Florida, environmental scientists believe that the incorporation of native vegetation into residential landscaping practices will reduce the impact of nonpoint source pollution on coastal ecosystems. However, additional environmental amenities, such as the restoration of wildlife habitat and increased urban biodiversity, can be problematic for residents who fear that wildlife may interfere with their enjoyment of their yards.



Geography of Xeriscaping in North America

The popularity of xeriscaping—as well as the particular forms xeriscaped landscapes have taken—is partly a reflection of efforts by state, county, and city governments to promote resource conservation in residential landscaping. Initially, such efforts were primarily concentrated in the mountain west, southwest, and southeast portions of the United States. In these states, recent migrants from the Midwest and the Northeast have often reproduced landscape patterns similar to those in their home regions without recognition of the limitations of available water resources. Currently, most U.S. states sponsor public education or extension programs that promote xeriscaping as a means of reducing water consumption and addressing other local and regional environmental problems.

Social Dimensions of Xeriscaping

Land area under turfgrass lawn in urban and suburban North America has expanded greatly over the past three decades and unquestionably dominates the American residential landscape. The more recent and more modest trend toward adoption of xeriscaping thus represents an important alternative to the turfgrass lawn. Xeriscaping might thus be seen as a reaction to the uneasy relationship that North Americans have with their lawns, including their concerns about domestic water consumption and health and safety concerns associated with chemical-intensive turfgrass landscaping. Moreover, the growth of xeriscaping raises important questions about the environmental aesthetics of North American residential landscapes and the values and perceptions of socio-environmental spaces as reflected in landscaping decisions.

Despite its growing popularity, the continued diffusion of xeriscaping practices faces legal, cultural, and financial obstacles. Although many states have gone so far as to develop county extension programs to assist homeowners in integrating xeriscaping principles into their landscaping practices, city ordinances and deed community regulations may restrict the conversion of conventional landscapes into xeriscaped landscapes.

Cultural values are often at stake in such landscape conversions, and resistance by neighbors is

common. Cultural obstacles are often created by pressure from neighbors who fear a break with the uniformity of neighborhood lawns. Additional concerns cited by neighbors of those who adopt xeriscaping include fear of declining property values as a result of unkempt yards and fears of unwanted wildlife.

The transformation of turfgrass lawns into xeriscaped yards often requires that homeowners make significant time and financial investment in their yards. Even established xeriscaped landscapes may require substantial maintenance. Many residents rely on private landscaping firms that specialize in environmentally friendly landscaping for advice and guidance. Such expenses represent a financial barrier to the adoption of xeriscaping by low-income households. Thus, the diffusion of xeriscaping and the above obstacles to wider adoption reflect the cultural, political, and economic complexities that accompany shifts toward urban environmental sustainability.

Thomas A. Smucker

See also **Environmental Management: Drylands; Landscape Design; Land Use; Water Needs**

Further Readings

- Beck, T., Heimlich, J., & Quigley, M. (2002). Gardeners' perceptions of the aesthetics, manageability, and sustainability of residential landscapes. *Applied Environmental Education and Communication*, 1, 163–172.
- Cheng, Z., Richmond, D., Salminen, S., & Grewal, P. (2008). Ecology of urban lawns under three common management programs. *Urban Ecosystems*, 11(2), 177–195.
- Johns, R., Smucker, T., Mustafa, D., Dorsey, J., & Connely, S. (2007). Xeriscaping as coastal amelioration: Using “Florida Friendly Landscaping” to reduce pollutant runoff and water consumption in Pinellas County, Florida. *Interdisciplinary Environmental Review*, 10(2), 113–141.
- Robbins, P. (2007). *Lawn people: How grasses, weeds, and chemicals make us who we are*. Philadelphia: Temple University Press.



ZELINSKY, WILBUR (1921–)

Wilbur Zelinsky is an iconic cultural and population geographer who focuses on finding big-picture geographical manifestations of human meaning in every detail and facet of American life. He is an expert in field-based exploration, archival research, quantitative and qualitative analyses, cartographic representation, and clear and direct writing. His work reflects an unusual originality and continues to inform scholars in many disciplines.

Zelinsky was born in Chicago and began his academic career at Wright Junior College. He completed his baccalaureate at the University of California at Berkeley in 1944, earned a master's degree from the University of Wisconsin in 1946, and returned to Berkeley for his PhD, which he completed in 1953. His early work experiences trained him for observation and analysis. He was a map draftsman in various firms during World War II, a terrain analyst for the Army Corps of Engineers in Occupied Germany in 1946, and an industrial location analyst for the Chesapeake & Ohio Railway from 1954 to 1959. His academic appointments include the University of Georgia from 1948 to 1952, the University of Wisconsin as a researcher from 1952 to 1954, Wayne State University as an adjunct professor from 1954 to 1959, and Southern Illinois University from 1959 to 1963. He joined the geography department at

Pennsylvania State University in 1963, where he has remained ever since. He was department head from 1970 to 1976, assumed emeritus status in 1987, and continues as an active scholar.

Zelinsky's publication record includes more than 200 books, atlases, chapters, articles, reviews, and reports, not counting reprints and second editions. Topics he has studied include cemeteries and cemetery names, energy consumption, food ways, log houses, migration, nationalism, personal names, place names, rural population distribution, settlement patterns, town forms, and vernacular regions. His first published article in 1948 was perhaps the first by any geographer on African Americans. His hypothesis of the mobility transition (an increase in rural to urban migration followed by an increase in intra- and interurban migration with modernization) is a significant complement to the concept of demographic transition (a decrease in death rates and, subsequently, birth rates occurring with modernization) both operationally and intellectually. He was the first geographer to write about the place of women in the profession. His 1974 presidential address to the Association of American Geographers (AAG), "The Demigod's Dilemma," was an important early humanistic call to rethink overly scientific premises in the social sciences. His scholarly focus in recent years has been the landscape effects of religion and the meaning of ethnicity.

Zelinsky was president of the AAG from 1972 to 1973, and honors include the AAG's 1966



Award for Meritorious Contributions to Geography, a Guggenheim Fellowship from 1981 to 1982, and the 1993 Jackson Prize for the revised edition of his best-known work, a slim book titled *The Cultural Geography of the United States*. He received the American Geographical Society's Cullum Medal in 2001 and the AAG Presidential Achievement Award in 2006.

Joseph S. Wood

See also **Cultural Geography; Ethnicity; Fieldwork in Human Geography; Population Geography; Religion, Geography and**

Further Readings

- Zelinsky, W. (1961). An approach to the religious geography of the United States: Patterns of church membership in 1952. *Annals of the Association of American Geographers*, 51, 139–193.
- Zelinsky, W. (1975). The demigod's dilemma. *Annals of the Association of American Geographers*, 75, 123–143.
- Zelinsky, W. (1992). *The cultural geography of the United States*. Englewood Cliffs, NJ: Prentice Hall.
- Zelinsky, W. (2001). The uniqueness of the American religious landscape. *Geographical Review*, 91, 565–585.

be used for. Zoning has been studied by political geographers interested in the exercise of governance and by economic geographers interested in the consequences of these laws on land values and economic activity. Zoning has also been extended to classifying and preserving the physical attributes of land on flood plains, steep slopes, and wetlands, and other characteristics. The idea of zoning has also been expanded to consider more generally the spatial isolation of populations or activities by local governments and policing activities.

Discursively, zoning is often tied to the idea of social disorganization and the apparent need to reconstitute order in cities. Such arguments hinge on the assumption that an increasingly complex urban life necessitated the need for “order” and the separation of private dwellings from buildings for commercial and industrial use. Historians of zoning regulations have diverging arguments about the original function of these laws. Some argue that zoning was meant to prevent the encroachment by the lower classes and people of other ethnicities on high-land-value neighborhoods, such as garment workers in New York and Chinese laundries in California. Conversely, other scholars argue that zoning laws were meant to protect the lower classes from the deleterious health effects of industrial production and overcrowding. Whether the original crafters of the American zoning law had socially progressive intentions in mind or not, the discourse of “order” and the desirability of “separation” have been enormously important in shaping public understanding of zoning. “Order” has turned out to mean many things in zoning, from regulating new development to redirecting nearly all capital production to licensed, commercially zoned districts. This discourse continues to inform and justify daily practices of zoning and can be evidenced in much of the research on zoning.

Political geographers have couched zoning in the larger context of governance and used it to reveal power relations and social inequities. Such geographers consider the wider political processes that allow counties and municipalities to use zoning laws to manage behavior through enforcement practices, to enforce state power over privately held property, and to generate spatial data on property. These articulations produce a

ZONING

Initially introduced in New York in 1916 and quickly spreading to nearly all large American urban areas, zoning is a practice of municipal or county government land segregation according to use, density, building height, and lot size. Zoning is a police power permitting governments the right to refuse permission to use land in ways differing from the zoning code. Zoning is often equated with city and county planning processes but functions differently in reality. Zoning is considered a “negative” tool in that cities only have a right to deny a land use application rather than designating exactly what the property can

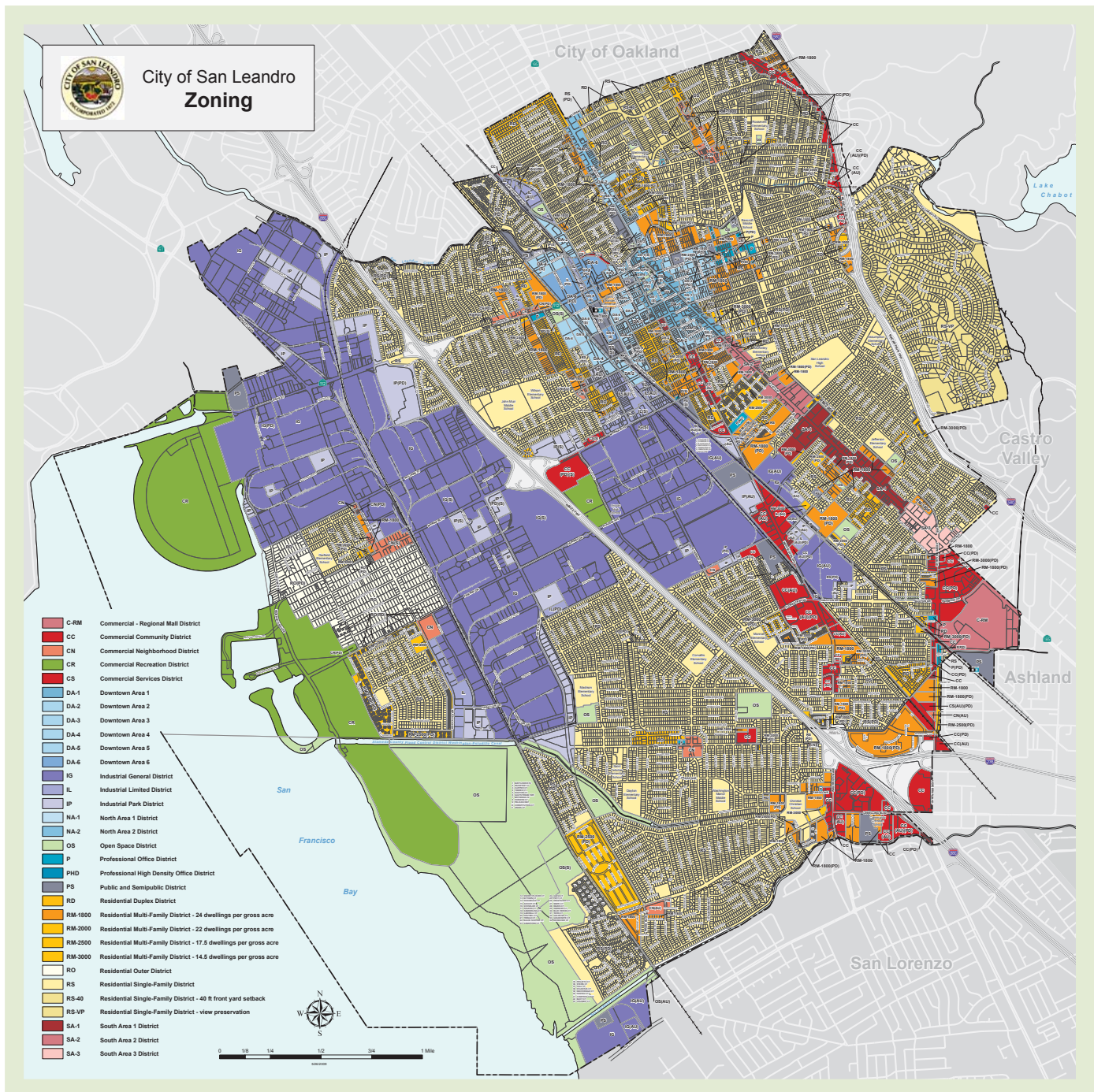


Figure 1 Map of zoning districts within the city of San Leandro, California

Source: City of San Leandro, California. Retrieved August 26, 2009, from www.ci.san-leandro.ca.us/develop/zonemap.pdf. Used with permission.



legalized and enforceable landscape, dictating what activities citizens can perform and where. Political geographers regard regulatory agencies generally, and zoning particularly, as a way to produce a regulated urban landscape, cultivate legitimacy, and produce governable populations. Some zoning literature focuses on the regulatory enforcement, that is, the multiple ways the state shapes society through local enforcement, ideologies, and policies.

Economic geographers have focused on the effects of zoning laws on land values and optimal zoning designations for wealth accumulation. Such analysis of zoning has frequently taken the form of large-scale quantitative studies, often with Houston, the only major American city without zoning laws, serving as a foil.

The legal geographies literature has provided important groundwork to consider the ways law generally is spatially produced at different scales. Scholars of property have looked to zoning regulations to better understand the relationship between property, citizens, and the state. Geographies of social control have taken the zoning concept of separation and isolation and used it in different ways to explore social exclusions. Social control literature has focused on the “zoning” of people, applying the logic of land use law and exclusion to individuals or classes of people. Researchers of social control have emphasized the way particular groups or behavior have been legally defined, isolated, and located by the law. Geography and social control literature has focused on the exceptions built into the law by focusing on marginal populations such as the homeless, sex workers and adult businesses, political activists, and drug culture participants.

Criticisms of Zoning

Zoning has been tied to exclusionary practices intended to limit affordable housing and housing plurality. This constraint often takes the form of inflated property size restrictions and low-density requirements, presenting obstacles to mixed-income housing and, effectively, achieving some degree of racial segregation. Such results arguably reinforce class divisions and limit opportunities to attain housing equity. More recently, inclusionary zoning practices have attempted to

provide more affordable housing options and grant incentives for developers to produce a range of affordable to moderately priced properties. Inclusionary zoning establishes municipal and county ordinances that mandate a certain percentage of affordable housing be developed among otherwise market-rate housing. Such practices are an attempt to bypass the economically exclusive practices of zoning laws. Inclusionary zoning has been criticized by developers for adding onerous regulations and by affordable housing advocates for placing unrealistic expectations given the powers afforded to zoning. Furthermore, criticism has been lodged about the ways such laws are administered. Zoning laws are non-retroactive, producing an uneven landscape of conforming and nonconforming properties.

Globally, cities and countries frequently have land use regulations and reviews of new development projects, though the police-power based zoning seen in American cities is infrequently implemented. The American model of zoning was initially imported from Germany. Zoning regulations were adopted in Canadian cities subsequent to their adoption in the United States.

Elizabeth Underwood-Bultmann

See also [Land Use Planning](#); [Suburban Land Use](#); [Urban Land Use](#); [Urban Planning and Geography](#); [Urban Policy](#); [Urban Sprawl](#)

Further Readings

- Anderson, K. (1987). The idea of Chinatown: The power of place and institutional practice in the making of a racial category. *Annals of the Association of American Geographers*, 77(4), 580–598.
- Dubber, M. (2005). *The police power: Patriarchy and the foundations of the American government*. New York: Columbia University Press
- Platt, R. (2004). *Land use and society: Geography, law, and public policy*. New York: Island Press.
- Schweiterman, J., & Caspall, D. (2006). *The politics of place: A history of zoning in Chicago*. Chicago: Lake Claremont Press.

ATLAS OF THE WORLD: A BRIEF CARTOGRAPHIC OVERVIEW

The *Encyclopedia of Geography* includes the following 18-page atlas as a convenient source for political maps of the world. This section also includes a global topographical map of the world and examples of some of the principal map projections used in depicting the world. In addition, the A–Z entries include numerous world maps relevant to both physical geography (e.g., angiosperm family richness, global distribution of deserts, ecoregions, the Köppen-Geiger climate classification) and human geography (e.g., colonial migrations, human development, famine-prone regions, Internet penetration rate). See the entries under “World maps” in the index at the end of this volume for a complete listing.

The maps included here offer a basic overview; however, space limitations do not allow for detailed depictions of countries and major cities. The *College Atlas of the World* published by Wiley and National Geographic is a useful source not only for more extensive political maps and other information in human geography but also for a global view of many aspects of physical geography.

For more detailed maps in human and physical geography:

de Blig, H. J., & Downs, R. M. (Eds.). (2007). *College atlas of the world*. Washington, DC: National Geography Society with Wiley.

For a detailed description of the government, political parties, legislature, and communications in each nation:

Banks, A. S., Muller, T. C., Overstreet, W. R., & Isacoff, J. R. (2010). *Political handbook of the world 2010*. Washington, DC: CQ Press.

For updated information on the global population:

The International Data Base of the U.S. Census Bureau, available online at www.census.gov/ipc/www/idb. Click on the Data Access tab on this Web site to view a variety of demographic indicators for each country, including past, present, and estimated population from 1950 to

2050. Country data can be viewed both as a table and as a population pyramid. The U.S. and World Population Clocks, which are constantly updated, can be found at www.census.gov/main/www/popclock.html.

Contents of the Atlas

Political Maps:

World Map, Mollweide Projection	3152–3153
Africa	3154
Antarctica	3155
Arctic Region	3156
Australia, New Zealand, and Oceania	3157
Asia	3158
Southeast Asia	3159
Western Europe	3160
Eastern Europe	3161
Caribbean	3162
North America: United States and Canada	3163
North America: Mexico and Central America	3164
South America	3165
Topographical Map of the World	3166–3167
Map Projections	3168–3169

Map Sources

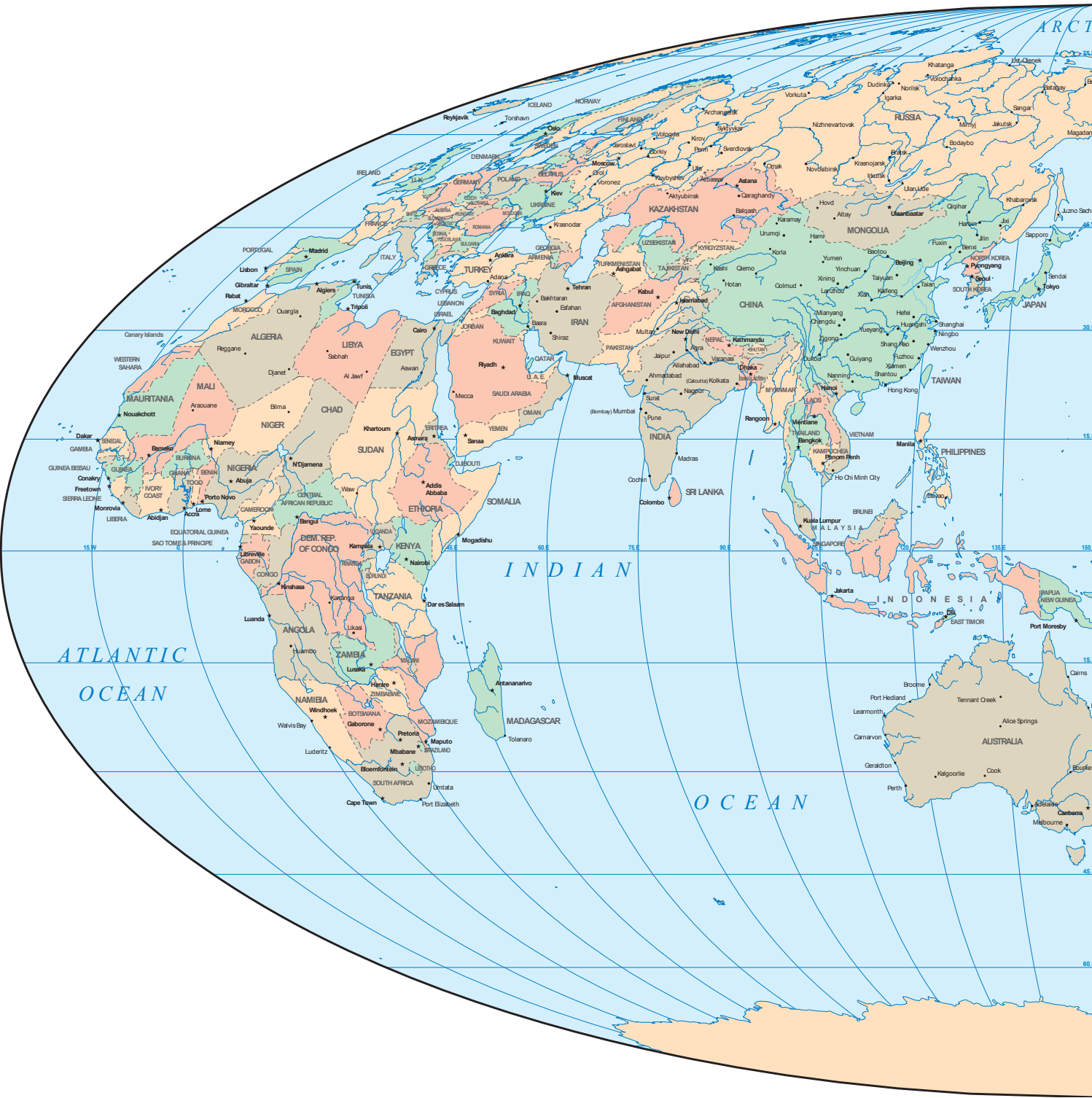
Political map of the world, Mollweide projection:
© Map Resources.

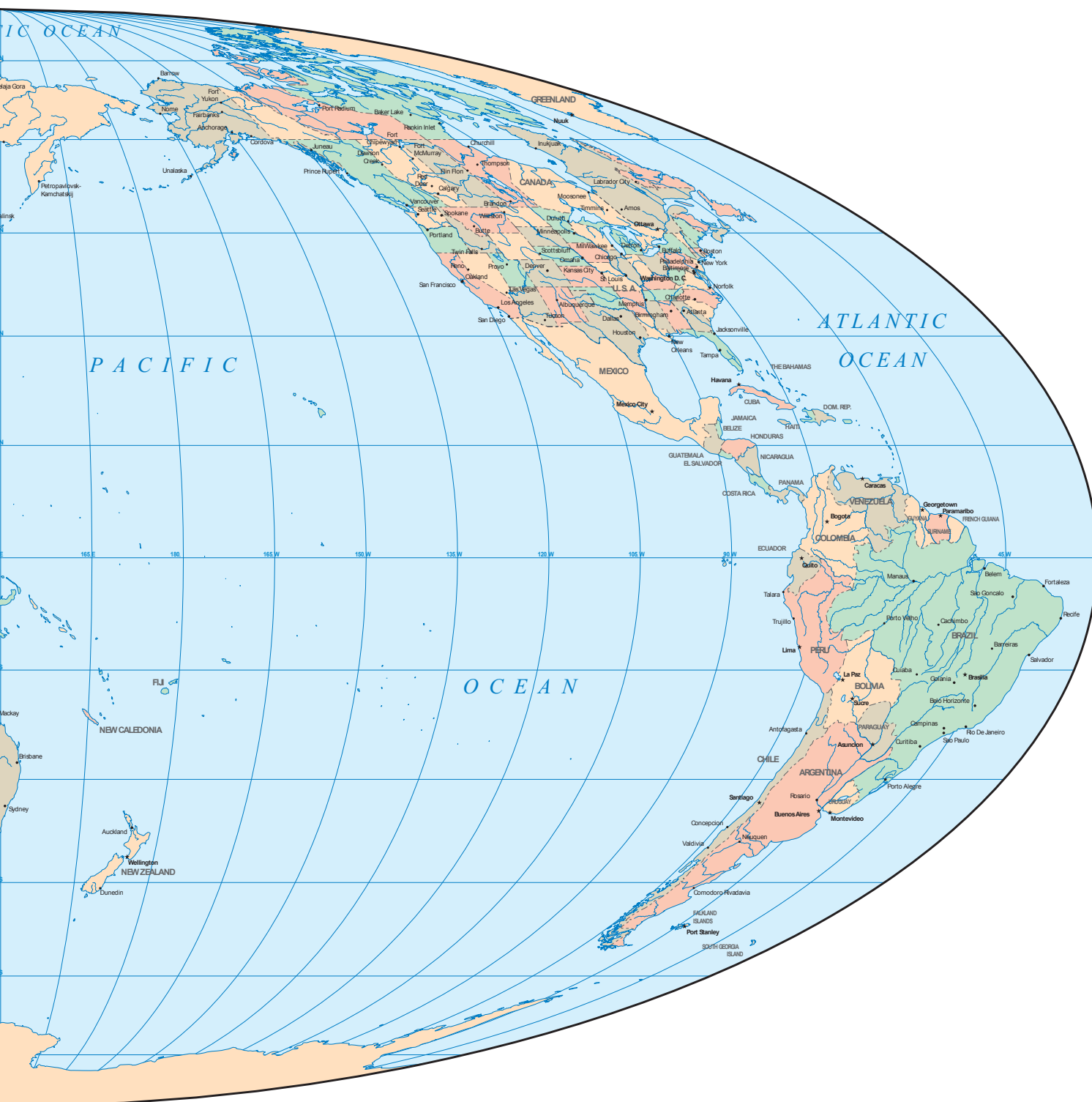
Political maps of Africa, Antarctica, Australia, Asia, Southeast Asia, Oceania, Western Europe, Eastern Europe, Oceania, North America, the Caribbean, Mexico, Central America, and South America: Adapted by Sandra Sauvajot from Maps for Graphic Design, © Map Resources.

Political map of the Arctic: Perry-Casteñada Library Map Collection, University of Texas Libraries.

Global topographical map: © Map Resources.

World Map, Mollweide Projection





1000 Kilometers
Parallel scale at
0 north 0 east

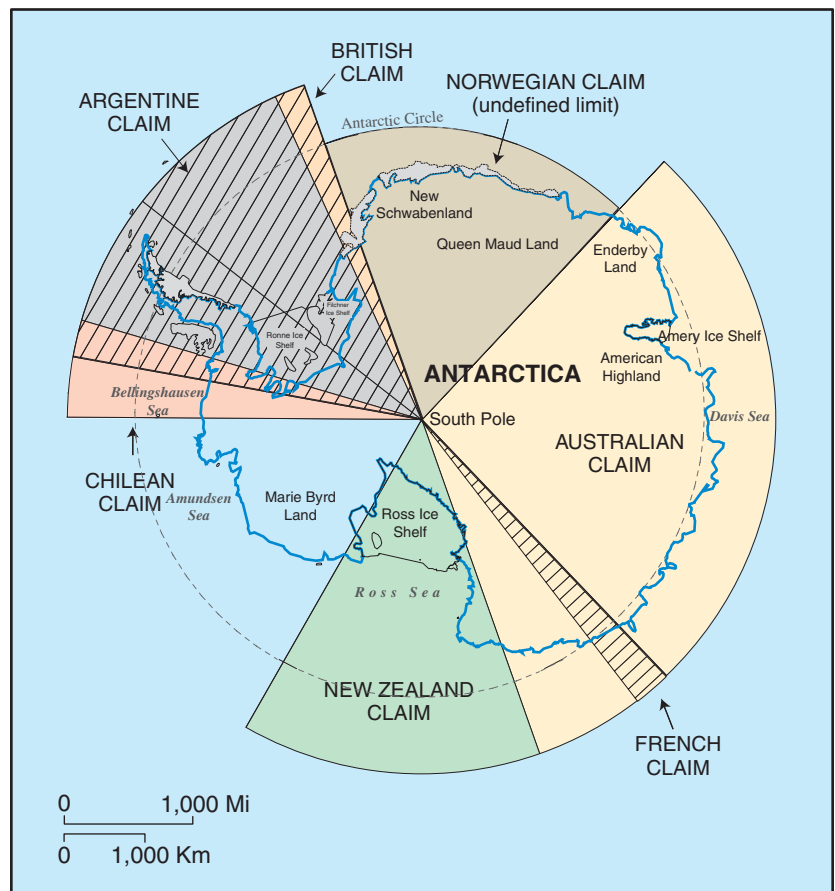
1000 Kilometers
Parallel scale at
30 north 0 east

1000 Kilometers
Parallel scale at
60 north 0 east

Africa



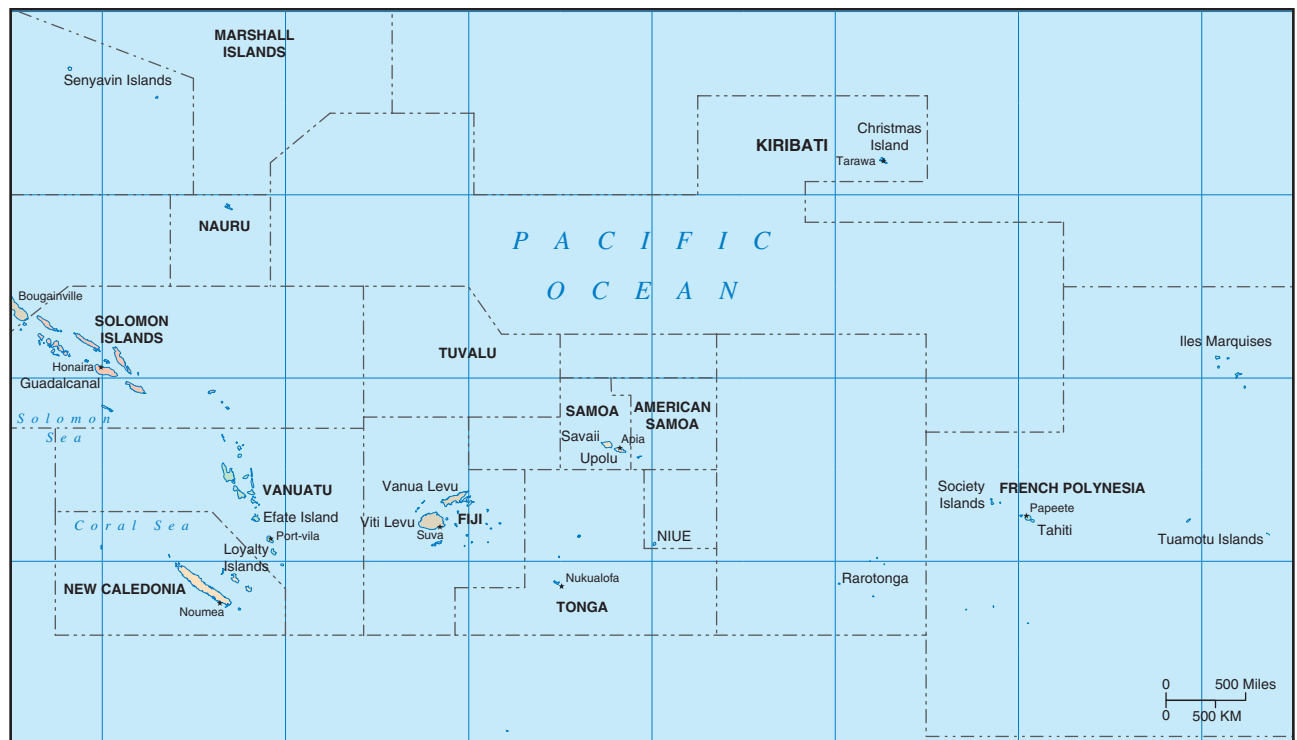
Antarctica



Arctic Region



Australia, New Zealand, and Oceania



Asia



Southeast Asia



Western Europe



Eastern Europe



Caribbean



North America: United States and Canada



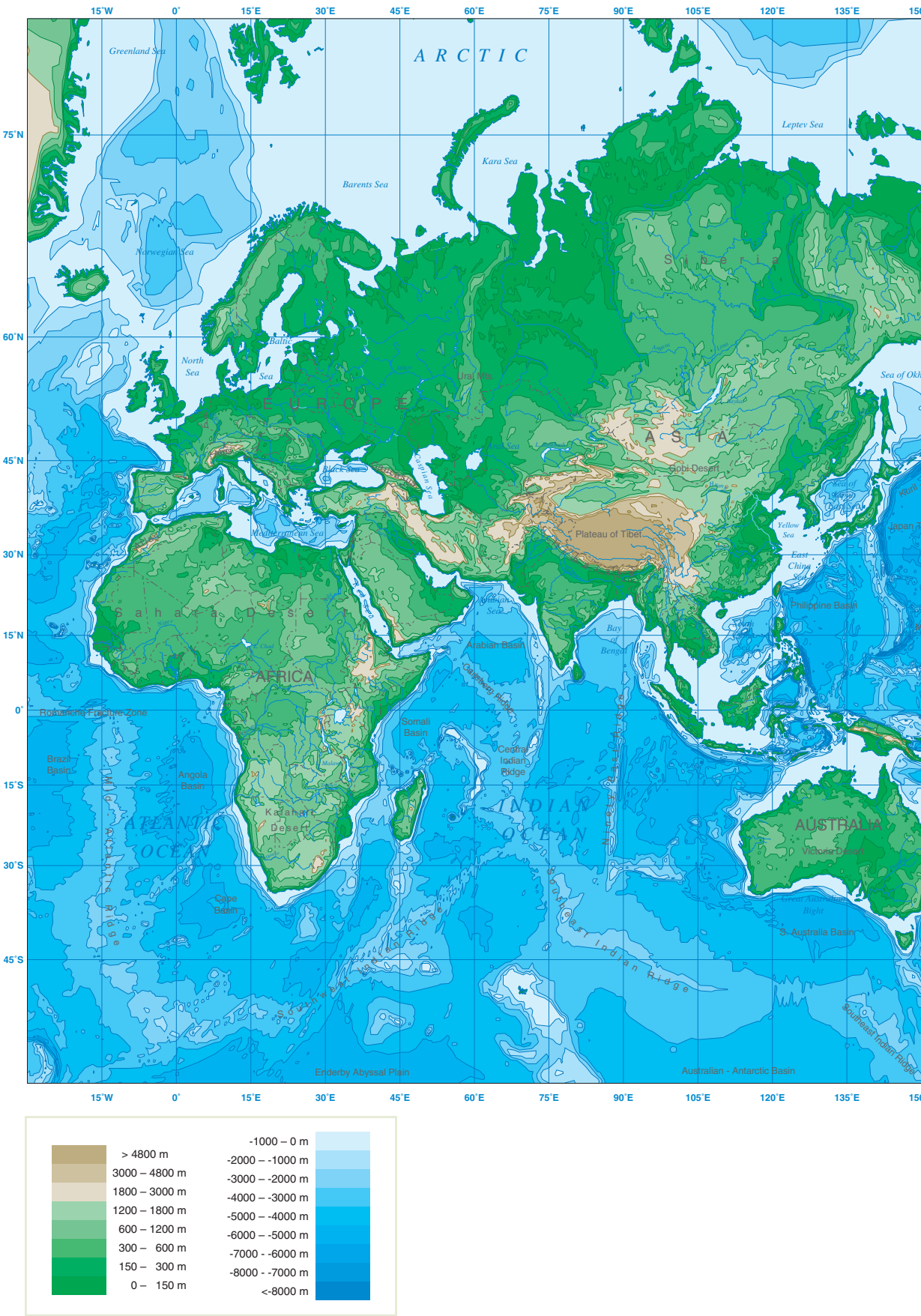
North America: Mexico and Central America



South America



Topographical Map of the World





1000 Kilometers
Parallel scale at
0 north 0 east

1000 Kilometers
Parallel scale at
30 north 0 east

1000 Kilometers
Parallel scale at
60 north 0 east

Map Projections

Cartographers use a variety of projections to represent the spherical surface of Earth on a flat map. Because it is mathematically impossible to render a globe on a plane without changing the spatial configuration of the data involved, all such mapping involves some degree of distortion, so in choosing a projection, the cartographer will consider what properties are most important to preserve, at the cost of some other properties. For example, projections may accurately represent or distort the area (equivalence), shape (conformality), direction, distance, and scale of Earth's features, but not all of these simultaneously. Projections are important because maps shape how we view the world, and their distortions often enter into our geographical imaginations. Different types of projections are useful for different cartographic purposes. See the Map Projections entry in this encyclopedia for a detailed description of different types of projections.

The majority of the maps in this encyclopedia use the Mercator projection, developed in the 16th century by Gerardus Mercator, a Flemish cartographer. Intended for navigation, it uses a rectangular grid that shows constant bearings as straight lines, and hence became popular among navigators. It remains the most commonly

used map projection today, reproduced in countless classrooms, atlases, and textbooks. However, the Mercator projection greatly exaggerates the size of areas at higher latitudes (for example, Greenland is only as eighth as large as South America, but its area appears much greater on a Mercator map). In 1989, several North American geographical organizations passed a resolution urging the use of alternative projections.

The Mollweide projection, created in 1805 by the German mathematician Carl B. Mollweide, is a more accurate representation of the size of areas, but distances and shapes are distorted.

The Fuller dymaxion projection, created by R. Buckminster Fuller in the mid 20th century, is useful in showing the interconnectedness of Earth's landmasses and has less distortion of areas than the Mercator projection. It is used in this encyclopedia to show Earth's cryosphere (see Ice entry).

Developed in 1923 by John Paul Goode, the interrupted Goode homosoline projection presents the world in discrete regions in order to minimize distortions of size and shape. It is useful for showing raster data, in which a geographical area is divided into cells identified by row and column.



Mercator projection: This projection distorts the size of regions far from the equator. For example, Greenland appears to be larger than South America, but in fact, South America is eight times larger.

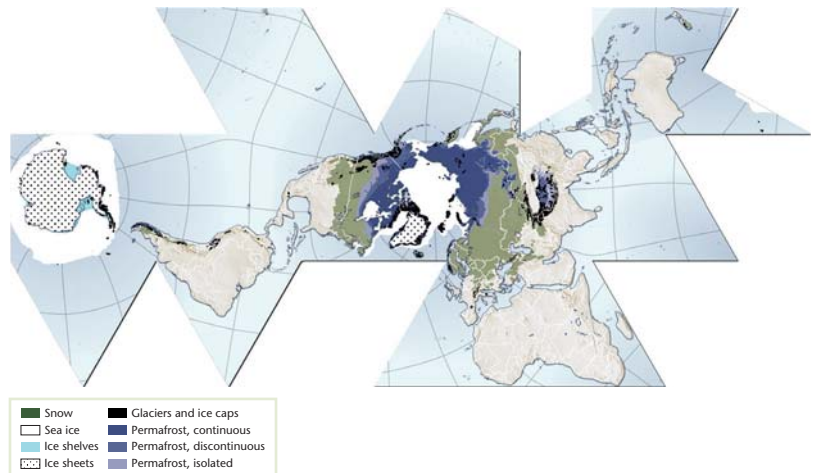
Source: Barney Warf.



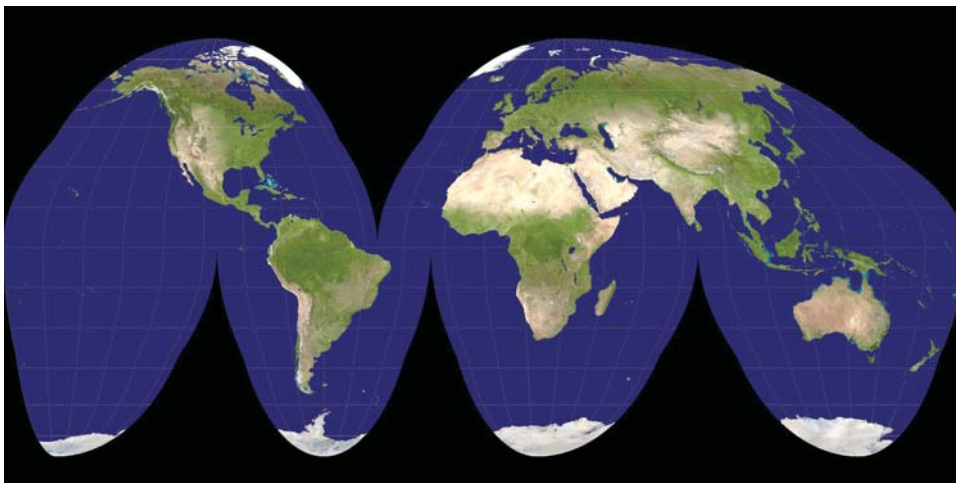
Mollweide projection: A Visible Earth image collected by the Earth Observatory experiment of the U.S. government's NASA space agency. The reticle is 15 degrees in latitude and longitude.

Source: National Aeronautics and Space Administration.

Buckminster Fuller or "Dymaxion map" projection: Earth's cryosphere. Snow cover extent for Northern Hemisphere is represented by the 1966–2005 February average, for Southern Hemisphere by the 1987–2003 August average. Sea ice extent for Northern Hemisphere is represented by the 1979–2003 March average, for Southern Hemisphere by the 1979–2002 September average. Permafrost data for mountain areas and for the Southern Hemisphere are not represented in this map; neither are river and lake ice.



Source: UNEP/GRID-Arendal Maps and Graphics Library. June 2007. UNEP/GRID-Arendal. Cartography by Hugo Ahlenius. Retrieved February 27, 2009, from <http://maps.grida.no/go/graphic/the-cryosphere-world-map>.



Interrupted Goode homolosine projection: A Goode projection of a Visible Earth image collected by the Earth Observatory experiment of the U.S. government's NASA space agency.

Source: National Aeronautics and Space Administration.

INDEX

Entry titles and their page numbers are in **bold**.

AAG. See Association of American Geographers (AAG)

Aalbers, Manuel, 5:2710

Abercrombie, Patrick, 3:1363

Abler, Ronald, 1:1–2

academic career of, 1:1

communication work of, 1:1

governance work of, 3:1357

professional affiliations and service of, 1:1, 4:1975

ABMs. See **Agent-based models (ABMs)**

Absolute space, 1:2–4

Cartesian/Euclidean notion of space and, 1:3

René Descartes, Cartesian rationalism and, 1:3

Euclidean geometry and, 1:2

Hipparchus, Earth's 360° circumference and, 1:2

Newton and Leibniz debate, 1:2–3

Plato's views, 1:2

relative space *vs.*, 1:2, 5:2402

Academics for Justice, 1:96

Accessibility, 1:4–5

accessibility in geographic information systems and, 1:5

accessibility studies and, 1:4–5

aggregate accessibility measures (Garrison) and, 1:4

aviation and, 1:179–182

before-and-after studies of, 1:4

GIS in transportation and, 3:1311–1312

individual (space-time or disaggregate) measures of, 1:3

proximity (zonal or aggregate) measures of, 1:3

time-space accessibility measures of, 1:5

Acemoglu, Daron, 5:2218

Acid rain, 1:5–7

ambient air quality and, 1:69

coal-fired power plants, copper smelters and, 1:6

definition of, 1:5

ecosystems disturbed by, 1:7

emissions trading program (U.S.) and, 1:7

freshwater aquatic environments affected by, 1:7

greenhouse gas trading and, 1:7

hydrogen and oxygen biogeochemical cycle and, 1:205–206

long-range control programs and, 1:7

monitors of, 1:6–7

natural sources as precursors of, 1:6

sulfur dioxide and, 1:153

trees damaged by, 1:6 (photo)

Ackerman, Edward, 4:1897, 5:2238

Actor-network theory, 1:8

agency views of, 1:8

commodity chains and, 1:524

critical human geography and, 1:8

critical studies of nature, post-humanism and, 2:623–624

deep-green, deep-ecology philosophies and, 2:624

gay and lesbian geographies and, 3:1185

gender and nature and, 3:1196

human and nonhuman actors focus of, 1:8

hybrid geographies and, 3:1503

Bruno Latour and, 1:8, 2:649, 5:2272

physical applications of, 1:8

poststructuralism and, 5:2272–2273

proponents of, 1:8

relational view of spatiality of, 1:8

rural development and, 5:2490–2491

We Have Never Been Modern (Latour) and, 2:649

Adams, John, 3:1357

Adaptation to climate change, 1:9–12

adaptation targets and, 1:10–11

agricultural irrigation and, 1:10

autonomous *vs.* planned adaptations and, 1:9–10

avoidance of disaster-prone areas, 1:10

Bali Action Plan and, 1:9

biodiversity adaptations and, 1:11

climatologically sensitive systems and, 1:9

crop insurance and, 1:11

crop replacements and, 1:10

drought early warning systems and, 1:11

drought risk and hazard and, 2:790–794

ecosystem services and, 1:11

education about, 1:10

environmental management goals and, 1:9–10

extreme events, 1:10–11

greenhouse gas levels increase and, 1:9, 1:11

human migration barriers and, 1:11

- human population growth issue and, 1:11
- new pest species and, 1:10
- no-regrets policies and, 1:9, 1:10, 1:11
- policy-level adaptations and, 1:10–11
- public health infrastructure element of, 1:10
- regional case studies and, 1:9
- shoreline protection tactic and, 1:10
- species level adaptation and, 1:11
- strategies of, 1:9
- tillage practices changes and, 1:10–11
- United Nations Millennium Ecosystem Assessment and, 1:11, 2:862–863
- water crises measures and, 1:11
- See also* **Adaptive harvest management; Climate change; Climate policy**
- Adaptive harvest management, 1:12–14**
 - active *vs.* passive management and, 1:13
 - commercially harvested resources focus of, 1:12
 - community-based natural resource management and, 2:549–551
 - criticisms and challenges, 1:13
 - ecological data analysis and, 1:13
 - harvested populations and, 1:13
 - learning process feature of, 1:12–13
 - positive *vs.* negative feedback loops and, 1:12–13
 - social processes measurement and, 1:13
 - species and resource sustainability and, 1:12
- Adaptive radiation, 1:14–15**
 - archipelagoes, island-like systems and, 1:14, 1:106
 - Burgess Shale, Canadian Rocky Mountains fossil evidence and, 1:14
 - cichlid fishes in East African lakes and, 1:15
 - colonization of isolated ecosystems and, 1:14
 - evolution *vs.*, 1:14
 - extinction rates and, 1:14
 - Galapagos Islands example of, 1:14–15
 - horses, evolution of, 1:14
 - mass extinctions, 1:15
 - rapid speciation element of, 1:14
- Aden, 2:1054
- Adiabatic temperature changes, 1:15–17**
 - adiabatic heating and cooling conditions and, 1:15
 - air temperature and relative humidity relationship, 1:16
 - atmospheric energy variations and, 1:162
 - atmospheric pressure and, 1:155–157
 - chinook/foehn winds and, 1:394–395
 - cloud formation and, 1:15
 - condensation and evaporates rates and, 1:15
 - dew point, condensation and, 1:16
 - dry adiabatic lapse (DALR) rate and, 1:15–16
 - dry climate and, 1:430
 - explanation of, 1:15
 - lapse rates and, 4:1757–1761
 - latent heat and, 1:15, 4:1761–1762
 - mountain climate and, 1:443–449
 - moving *vs.* still air and, 1:16
 - rising and subsiding air and, 1:15
 - saturated adiabatic lapse rate and, 1:16–17, 1:17 (fig.)
 - temperature and pressure changes elements of, 1:15
 - temperature changes in air passing over mountain and, 1:17 (fig.)
 - temperature drop, atmospheric pressure drop and, 1:15
 - See also* **Atmospheric composition and structure; Atmospheric energy transfer**
- Adorno, Theodor, 4:1862, 5:2230
- Aerial imagery: data, 1:17–22**
 - Airborne Real-Time Cueing Hyperspectral Enhanced Reconnaissance (ARCHER) and, 1:18
 - airborne remote sensing and, 1:17
 - aircraft photography and, 1:15
 - American Society of Photogrammetry and, 1:15
 - Amnesty International, Eyes on Darfur project (satellite image), 3:1200
 - applications of, 1:21–22
 - atmospheric remote sensing and, 1:157–161
 - black-and-white film uses and, 1:18
 - collection and distribution agencies and, 1:19–20
 - color film development and, 1:18
 - color infrared photography and, 1:15
 - data sources and, 1:19–20
 - data types and, 1:19
 - Deepwater Horizon oil spill (satellite image), 4:2074
 - digital imagery advantages and, 1:19
 - dust storm in Sahara Desert and, 1:21 (photo)
 - early aerial photographs and, 1:15
 - hyperspectral remote sensing (aerial imaging spectroscopy) and, 1:18
 - image texture and, 3:1540–1541
 - innovations in, 1:18–19
 - land use and cover change, 4:1737
 - LiDAR-intensity imagery and, 1:19, 4:1778–1779
 - light detection and ranging (LiDAR) and, 1:18, 1:19
 - multispectral aerial imagery and, 1:15
 - oblique *vs.* vertical images and, 1:19
 - orthophotography and, 1:19
 - panchromatic imagery and, 4:2112–2115
 - paper, film, and digital data sources of, 1:19
 - photogrammetric methods and, 4:2173–2175
 - side-looking airborne radar (SLAR) and, 1:18, 1:19
 - social impacts of, 1:22
 - traditional cameras and, 1:18
 - typhoons in western Pacific Ocean and, 1:20 (photo)
 - See also* **Aerial imagery: interpretation; Image specific subject; Remote sensing**
- Aerial imagery: interpretation, 1:22–25**
 - atmospheric remote sensing and, 1:157–161
 - context of site and association elements in, 1:24
 - detection, identification, measurement, and problem solving tasks of, 1:23
 - false color digital ortho quarter quad, Del Mar, California, 1:24 (fig.)
 - human *vs.* computer interpretation and, 1:25
 - image interpretation and, 3:1534–1536
 - image texture and, 3:1540–1541
 - intensity, hue, and saturation elements in, 1:23
 - interpretive elements of, 1:23–25
 - LiDAR and airborne laser scanning and, 4:1778–1779
 - oblique views and, 1:23
 - pattern, height, and shadow elements in, 1:24
 - photogrammetric methods and, 4:2173–2175
 - remotely sensed information linkage to ground information function of, 1:23
 - size, shape, and texture elements of, 1:23–24
 - spatial resolution element in, 1:23
 - spectral wavelength variations element of, 1:23
 - tone and color elements of, 1:23
 - types of, 1:23
 - See also* **Aerial imagery: data; Remote sensing**
- Afghanistan
 - antiglobalization, anti-U.S. sentiment in, 1:97
 - basin and range topography in, 1:186

- Cold War and, 1:504
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 human rights atrocities in, 3:1481
 nation-state after colonialism in, 1:517
 NATO actions in, 4:2048
 opium and heroin production in, 2:797
- Africa**
- AAG specialty groups focus on, 1:122
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
African AIDS Epidemic (Iliffe) and, 3:1437
 African Charter of Human and Peoples Rights, 3:1480
 African monsoon and, 4:1941
 Afro-Asiatic languages and, 4:1750 (fig.)
 Amnesty International, Eyes on Darfur project (satellite image), 3:1200
 Animal domestication, 2:783
 aquaculture in, 1:103
 Association for Promoting the Discovery of the Interior Parts of Africa, 2:1057
 basin and range topography in, 1:186
 borderlands in, 1:292
 bush fallow farming in, 1:301, 1:302
 “calabash chalk,” (geophagy) and, 3:1248–1249
 cholera in, 1:401, 1:402
 climate change adaptation research in, 1:9, 1:464
 coastal zone and marine pollution and, 1:501
 Cold War and, 1:504
 colonial migrations, 1500–1914, 3:1542, 3:1543 (fig.)
 colonial public water systems in, 5:2317
 colonization of, 1:512–513, 1:516, 2:1027, 5:2216–2217
 Congo River basin, tropical rain forests of, 1:132
 Convention Governing the Specific Aspects of Refugee Problems in Africa, 5:2378
 decolonization in, 2:691, 2:692
 deforestation in, 2:696, 2:698
 democratization in, 2:702
 desertification in, 2:717, 2:972–973
 developing countries in, 2:725 (fig.)
 drought in, 2:727, 2:787
 dry climates in, 1:429, 1:430 (fig.)
 ecological footprint and biocapacity of, 2:827 (table)
 environmental history studies in, 2:929
 exploration of, 2:1057
 export processing zones in, 2:1067
 Vasco da Gama’s circumnavigation of, 2:1054, 3:1178–1179
 gender inequalities in, 3:1589
 geothermal energy use in, 3:1267 (fig.), 3:1269
 German colonies in, 1:509
Heart of Darkness (Conrad) and, 4:1787
 HIV/AIDS epidemic in, 2:727, 3:1437–1438, 3:1437 (fig.)
 hunting and gathering tribes in, 3:1492
 import substitution industrialism (IAI) in, 3:1550
 indigenous forestry in, 3:1569
 installed generating capacity values since 1950 in, 3:1511, 3:1511 (table)
 land degradation in, 4:1680, 4:1680 (table), 4:1682 (photo)
 land inequalities in, 4:1693
 landlocked countries in, 2:726
 land privatization in, 5:2494
 life expectancy in, 3:1410
 midlatitude grasslands in, 1:228, 1:228 (fig.)
 military expenditures in, 4:1899 (table)
 minerals mined in, 1:512
 mining frontier in, 4:1911
 mixed farming in, 4:1917 (photo)
 nationalism in, 1:517
 nation-states after colonialism and, 1:517
 natural growth rate in, 4:1981
 natural openness to trade in, 5:2218
 Negritude movement and, 2:1029
 nomadic pastoralism in, 2:597
 political geography in, 1:512
 political map of, 6:3154
 population growth of, 5:2233 (fig.), 5:2241
 Portuguese colonies in, 1:509
 post glacial period in, 1:459
 potential water availability in, 2007, 2050, 6:3059 (fig.)
 poverty rates in, 5:2274
 prehistoric exploration of, 2:1050
 railroads in, 5:2363
 refugees, 5:2378
 renewable water resources and availability in, 6:3057 (table)
 semi-arid desert biome in, 1:218, 1:219 (photo)
 slash-and-burn preindustrial agriculture in, 1:48
 slave trade and, 1:511–512, 1:512–513
 soil erosion in Baringo District, Kenya, 4:1682 (photo)
 squatter settlements in, 5:2682
 sustainable development for, 2:1005
 Third World debt crisis and, 2:688
 transboundary hazardous waste dumping in, 1:384
 tropical arid deserts in, 1:221
 tropical deciduous forest in, 1:231, 1:232, 1:232 (photo)
 tropical monsoon climate in, 1:454
 tropical rain forest of, 1:234, 1:235, 1:453
 tropical savanna in, 1:239, 1:240, 1:240 (photo), 1:241 (photo), 1:242, 1:243 (photo)
 tropical scrub in, 1:244, 1:245
 tropical/subtropical hyperarid deserts in, 1:222
 tropical/subtropical semiarid deserts in, 1:219
 Tuareg preindustrial agriculture in, 1:48
 undernourishment in, 3:1487, 3:1488 (table)
 West African Sahel drought and, 2:717–718, 2:972, 2:989
 “white man’s burden,” 2:1027
 women’s lives in, 3:1097
 See also **African Union** (AU); Sub-Saharan Africa; *specific nation*
- African Union** (AU), 1:25–26
- economic development focus of, 1:25
 functions of, 1:25
 human rights and social justice issues and, 1:25
 membership of, 1:25
 New Partnership for Africa’s Development (NEPAD) developed by, 1:25
 Organization of African Unity (OAU) precursor of, 1:25
 pan-Africanism with practical orientation focus of, 1:25
 peacekeeping focus of, 1:25
 supporters and critics of, 1:25
- Agamben, Giorgio**, 1:26–27
- “coming community” theory of, 1:27
 ethics and biopower issues focus of, 1:26
 existing space views of, 1:26
homo sacer (“bare life”), 1:26–27
 hybridity-animality of human beings, 1:27
 Nazi Holocaust focus of, 1:26
 philosophical areas of, 1:26
 power relations focus of, 1:26
 spaces inside *vs.* outside the law and, 1:26
- Agarwal, Anil, 3:1575
 Agarwal, Bina, 2:819–820

- Agassiz, Louis, 4:2180
- Agent-based models (ABMs), 1:27–31**
- abstract *vs.* empirical spatially explicit ABS, 1:29
 - “action at a distance,” 1:29
 - actor-network theory and, 1:8
 - agent-agent interaction and, 1:29
 - agent architecture and, 1:28–29
 - agent attributes, 1:28
 - agent behavior rules in, 3:1215
 - agents and environments elements of, 1:28–29
 - applications of, 1:29–30
 - cellular automata *vs.*, 1:29
 - city growth and change and, 1:187
 - complex systems observation and, 1:28
 - components of, 1:28–29
 - computer programs as agents and action units of, 1:27
 - construction process of, 1:30
 - decision making and, 1:29
 - digital representations of systems and, 1:27
 - direct representation of individual behavior element of, 1:29
 - endogenous interrelationships in, 1:29
 - geocomputation and, 3:1215
 - heuristics and, 1:29
 - land use and cover change models and, 4:1738
 - object-oriented programming used in, 1:28
 - reactive *vs.* proactive models and, 1:29
 - real-world geographic problems applications of, 1:29–30
 - relocation of agent factor and, 1:28
 - slum formation, analysis of, 1:28
 - spatially differentiated environment of, 1:27
 - spatiotemporal resolution of, 1:29
- Agglomeration economies, 1:31–32**
- benefits of, 1:31
 - capitalism, 1:32
 - central business districts, 1:378–379
 - clusters and, 1:480–482
 - division of labor and, 2:780–781
 - economies of scale and, 2:853–854, 5:2395
 - economies of scope and, 2:854–855
 - factors affecting location of firms and, 3:1077–1080
 - flexible production and, 1:32, 3:1125–1127
 - incubator zones and, 3:1551–1553
 - industrial districts and, 3:1576–1577
 - industrialized agriculture and, 1:43
 - innovation geographies and, 3:1597–1599
 - learning regions and, 4:1766–1768
 - marketing linkages of, 1:31
 - in primate cities, 5:2291
 - production linkages and, 1:31
 - R&D geographies and, 5:2435
 - regional science and, 5:2395
 - Allen Scott’s work and, 5:2519
 - service linkages and, 1:31
 - urbanization economies feature of, 1:31
 - vertically disintegrated production feature of, 1:31
- AGILE. See Association of Geographic Information Laboratories for Europe (AGILE)**
- Aging, the aged. *See Elderly, geography and the*
- Aglietta, Michel, 5:2399, 5:2401
- Agnese, Battista, 4:1814 (fig.)
- Agnew, John, 1:32–33**
- critical geopolitics work of, 1:32, 3:1252, 3:1420
 - dimensions of place and, 5:2574
 - electoral geography work of, 2:883
 - European Union elitism views of, 2:1037
 - human geography work of, 1:32–33, 3:1199–1200
 - international political economic work of, 1:32
 - place-based electoral geography work of, 1:32
 - publications of, 1:32
 - stateless hegemony, 3:1420
 - “territorial trap,” international relations work of, 1:32
- Agrawal, Arun, 1:530
- Agricultural biotechnology, 1:33–35**
- agrobiodiversity and, 1:49–50
 - bioreactors to feed the poor (early 1900s) and, 1:33
 - biotechnology definitions and, 1:33
 - “Coordinated Framework” management and regulation of, 1:34
 - ecological risk and, 1:34, 1:278–279
 - Ecological Society of America criticism of, 1:34
 - genetically modified organisms and, 3:1197–1199
 - genetic engineered organisms (GEOs), DNA manipulation and, 1:33–34
 - geographies of food and, 3:1144–1146
 - herbicide-tolerant seeds controversy and, 1:34
 - “ice minus” bacterium development example of, 1:33–34
 - organic agriculture and, 4:2094–2096
 - Posilac (bovine growth hormone) controversy and, 1:34
 - regulation of, 1:33–34
 - risk categories of, 1:34
 - social and environmental controversy, 1:33
 - See also Adaptation to climate change*
- Agricultural intensification, 1:35–36**
- biodiversity affected by, 2:938
 - capital *vs.* labor increases and, 1:35
 - Conditions of Agricultural Growth* (Boserup) and, 1:36
 - definitions of, 1:35
 - “extensive” to “intensive” systems scale and, 1:35
 - forest clearance impacts and, 2:938
 - global food demands and, 1:35
 - Green Revolution controversy and, 1:35
 - interrelating factors of, 1:36
 - population growth rates and, 1:35–36
 - preindustrial agriculture *vs.*, 1:47–49
 - rise of complex societies and, 1:35
 - societal and environmental change processes and, 1:35
 - Soviet collective farming and, 2:543
 - sustainable food production, land use systems and, 1:35
 - See also Adaptation to climate change; Agricultural land use; Agriculture, industrialized*
- Agricultural land use, 1:36–43**
- agricultural intensification and, 1:35–36
 - agrobiodiversity and, 1:49–50
 - biofuels production and, 1:201–204
 - categories and classifications used in, 1:36–37, 1:37 (fig.)
 - cellular automata used in, 1:370, 1:371 (fig.)
 - climate extreme events adaptations and, 1:10
 - coastal dead zones and, 1:486–488
 - crops and livestock production uses, in 1:36
 - factors driving change in, 1:39, 1:41–42
 - land covers, 1987 census of agriculture and, 1:40 (fig.)
 - land use conversions and, 1:37, 1:38 (table)
 - land value factor and, 1:37
 - major cropland uses, U.S., 1992–2004, 1:39 (table)
 - major uses of land, U.S., 1992–2004, 1:37 (fig.)
 - mixed farming and, 4:1914–1917
 - protecting agricultural land and, 1:43
 - shares of land in major uses, U.S., 1:41 (fig.)
 - shifts between cropland and forest land, U.S., 1982–1997 and, 1:37, 1:38 (fig.)
 - urban sprawl, U.S., 1992–1997, 1:42 (fig.)

- as world's largest economic sector, 1:36
- See also* **Adaptation to climate change**
- Agricultural maps**
 - U.S. cropland and forestland shifts, 1982–1997, 1:38 (fig.)
 - U.S. land covers, 1987 census of agriculture, 1:40 (fig.), 1:40 (table)
 - U.S. shares of land in major uses, 1:41 (fig.)
- Agriculture, industrialized, 1:43–47**
 - agriculture biotechnology and, 1:43–44
 - biofuels sources issue and, 1:47
 - biological homogenization issues and, 1:43–44
 - concentrated animal-feeding operations (CAFOs), “factory farms” and, 1:44, 1:45 (photo)
 - declining share of total workforce, “de-peasantization” and, 1:43
 - economies of scale issues and, 1:44
 - external costs of and subsidies for, 1:45–46
 - as foundation of modern societies, 1:43
 - geographies of food and, 3:1144–1146
 - global food prices increase and, 1:47
 - harvesting corn silage, 1:46 (photo)
 - livestock revolution and, 1:44
 - methane emissions issue and, 1:45
 - Montfort feedlot, Greeley, Colorado, 1:45 (photo)
 - multinational corporations' role and, 1:44–45, 5:2220
 - nitrogen cycle and, 4:2028–2029
 - Ogallala Aquifer and, 1:44
 - social issues associated with, 1:46–47, 1:58
 - soil fertility issues and, 1:43–44
 - Soviet collective farming and, 2:543
 - yield gains *vs.* ecological problems and, 1:43–44
 - See also* **Agrofoods; Environmental impacts of agriculture**
- Agriculture, preindustrial, 1:47–49**
 - agricultural intensification and, 1:35–36
 - Asian rice paddy cultivation and, 1:48–49, 1:48 (photo)
 - centers of domestication and, 1:374–378
 - crop rotation and, 2:627–630
 - cultivation techniques and, 1:48, 2:696
 - domestication of plants and, 2:784–786
 - human or animal labor power used in, 1:47
 - nomadic herding and, 1:48, 4:2029–2032
 - peasant-based production and, 1:48
 - slave-based and feudal social systems and, 1:48
 - subsistence *vs.* profit production of, 1:47–48
- Agrobiodiversity, 1:49–51**
 - biophysical landscape diversity and, 1:50
 - crops diversity and, 1:50
 - definition of, 1:49
 - diversity of socioeconomic processes and, 1:50
 - domestication of plants and, 2:784–786
 - genetically modified organisms and, 3:1197–1199
 - government policies and, 1:50
 - hybridization of plants and animals and, 3:1504–1506
 - indigenous ecological knowledge and, 1:50
 - slash-and-burn agriculture and, 1:49
 - small-landholding agricultural biodiversity and, 1:49–50
 - See also* **Adaptation to climate change; Agrofoods;**
 - Crop genetic diversity**
- Agrochemical pollution, 1:51–53**
 - air-curtain orchard sprayer, apple tree pesticides, 1:52 (photo)
 - bioaccumulation concept and, 1:52
 - biological magnification and, 1:52, 1:53
 - chemical spills, environment, and society and, 1:382–384
 - DDT and, 1:52, 1:53
 - drift and runoff effects and, 1:53
 - effects of, 1:51–52
 - environmental justice campaign against, 2:960
 - fungicides use and, 1:53
 - Green Revolution controversy and, 1:52
 - heavy metals list and, 1:51
 - herbicides use and, 1:53, 3:1420–1421
 - in India, 1:52–53
 - insects resistance to pesticides and, 1:52
 - nitrates and phosphates fertilizers and, 1:51
 - nonpoint sources of pollution and, 4:2039–2040
 - nontarget organisms destruction and, 1:52
 - organophosphates, 4:2100–2101
 - pesticide residues in humans and, 1:53
 - types of agrochemicals and, 1:51
 - water filtration and, 3:1115
- Agroecology, 1:54–58**
 - adaptation to climate change, extreme events and, 1:10
 - agrochemical pollution and, 1:51–53, 2:939
 - agroecosystem schematic diagram and, 1:55 (fig.)
 - agroforestry and, 1:55, 5:2579
 - agroforestry home garden example, Tasco, Mexico, 1:55, 1:56 (photo), 1:57
 - alternative food network initiatives and, 1:57
 - Community Agroecology Network (CAN) and, 1:57
 - critiques, challenges, and future trends, 1:58
 - definition of, 1:54
 - early work in, 1:54
 - energy flow process of, 1:55
 - farmer organizations and social movements and, 1:57
 - food system focus of, 1:54, 1:57
 - geographies of food and, 3:1144–1146
 - influential individuals in, 1:54
 - interdisciplinary approaches, 1:54, 1:58
 - local or indigenous agriculture and, 1:54
 - natural ecosystem and traditional agricultural models and, 1:54–56
 - new pest species and, 1:10
 - nutrient cycling process of, 1:56
 - organic agriculture and, 4:2094–2096
 - participatory action research and, 1:57
 - permaculture and, 4:2152–2153
 - plantations and, 5:2192–2195
 - population-regulating mechanisms process of, 1:56
 - production and farmer profit reductions issue and, 1:58
 - researcher-NGO partnerships and, 1:57
 - resilience/stability processes of, 1:56
 - small-scale and peasant agriculture focus of, 1:57
 - social, economic, and cultural basis of, 1:56–57
 - sustainability and, 1:10, 1:57
 - sustainable agroecosystems and, 1:54
 - See also* **Adaptation to climate change; Agrofoods**
- Agrofoods, 1:58–60**
 - “fast” foods and, 1:59
 - final consumer factors and, 1:59
 - food distribution factors and, 1:59
 - food production process factors and, 1:58–59
 - foods high in carbohydrates issue and, 1:59
 - “fractions” of whole produce and, 1:59
 - “functional foods” (nutraceuticals) and, 1:59–60
 - geographies of food and, 3:1144–1146
 - “nonfood foods” and, 1:59
 - organic agriculture and, 4:2094–2096
 - transformation of foods and, 1:59
- Agroforestry, 1:60–62**
 - agriculture *vs.* forestry concepts and, 1:60

- ancient agroforestry systems and, 1:61
 cultural, demographic, and environmental
 processes in, 1:61–62
 definition, 5:2579
 indigenous agriculture and, 3:1557, 5:2579
 indigenous agroforestry and, 1:60–62, 5:2579
 planting peanuts, Mali, West Africa, 1:61 (photo)
 “scientific agroforestry” field of study and, 1:60
 social conservation and, 5:2579
 social factors in, 1:62
 space and time elements of, 1:60
taungya system (southeast Asia), 1:60
 AGS. *See* American Geographical Society (AGS)
 AIDS. *See* HIV/AIDS, geography of
 Airborne Real-Time Cueing Hyperspectral Enhanced
 Reconnaissance (ARCHER), 1:18
Air masses, 1:62–65
 Arctic air masses, Antarctica and Siberia, 1:63
 classification system of, 1:63–64
 deep moist convection (DMC) and, 1:64
 definition of, 1:62
 differential advection, 1:63–64
 dryline or Marfa front concepts and, 1:63
 equatorial *vs.* superior air and, 1:63
 migration rate of air mass factor and, 1:65
 source regions of, 1:63
 subtropical *vs.* ocean surfaces and, 1:63
 surface moisture factor and, 1:64
 surface temperature factor and, 1:64
 topography factor and, 1:64–65
 trajectory of air mass factor and, 1:65
 vertical character of primary air mass types and, 1:63
 Air pollution. *See* Ambient air quality; Atmospheric pollution
Alaska
 Arctic National Wildlife Refuge, domestic fuel supply in, 2:901
 Barrow, 1:450
 beaver dam in, 1:274 (photo)
 boreal forests usage in, 3:1164
 circumpolar peoples’ environmental knowledge
 systems research and, 3:1566
 Columbia Glacier in, 3:1328
 Captain James Cook’s exploration of, 2:576
 fjords in, 3:1121
 Gilkey Glacier in, 3:1330 (photo)
 glacier in, 3:1333
 Ice Ages and, 1:457
 ice caps and ice fields in, 3:1328
 Melvin Marcus’s glaciology work in, 4:1850
 permafrost in, 1:215, 4:2154
 polar climate in, 1:450, 1:451
 rat eradication from Rat Island, Alaskan Aleutian
 Island Chain and, 2:992
 Red Dog zinc open-pit mine in, 4:2087
 Russian colonization of, 1:512
 sea ice minimum in, 2003–2005, 3:1525 (photo)
 shrub tundra of, 1:248
 subarctic climate in, 1:441
 sustainable agriculture, lingonberry field, 6:2745 (photo)
 Trans-Alaska Pipeline System, 4:2151 (photo)
 tundra polygons, northern slope, 4:2150 (photo)
 tundra vegetation in, 1:248 (table)
 tussock and sedge-dwarf shrub tundra of, 1:248
 wet tundra of, 1:249
Albania
 COMECON membership of, 2:593 (table)
 comparative indicators of unmet basic needs in,
 2003, 5:2644 (fig.)
 economically active females in, 3:1190 (table)
 particulate matter pollution in, 1:151
Albedo, 1:65–66
 albedos of natural surfaces and, 1:66 (table)
 clouds and, 1:479–480
 deforestation and urbanization factors in, 1:66
 explanation of, 1:65
 geographic and seasonal variations in, 1:66
 glaciers and, 3:1323
 global environmental change and, 3:1335
 planetary albedo, 1:65–66
 polar climate and, 1:449
 seasonal changes factor in, 1:66
 solar zenith angle factor in, 1:66
 Albrecht, Jochen, 1:72
 Aleksandrova, V., 1:247
 Alesina, Alberto, 5:2217
 Alexander, Lewis, 5:2307
 Alexander the Great, 2:1051
Algeria
 anticolonialism in, 1:94
 Isabelle Eberhardt exploration of, 2:1057
 economically active females in, 3:1190 (table)
 France colonization of, 1:514
 guerrilla conflicts in, 2:692
 independence of, 1:517, 2:692
 oil exports from, 4:2073
 OPEC membership of, 4:2099, 4:2100 (fig.)
 poverty rates in, 5:2274
al-Idrisi, 1:66–67
 Geographus Nubiensis (the Nubian geographer) name and, 1:66
 IDRISI based geographic analysis system and, 1:67
 longitudes and latitudes used by, 1:67
 maps of, 1:66–67, 1:350, 3:1461, 3:1521, 4:2179
 world geographies written by, 1:66
 world map of, 1:67, 1:351 (fig.)
 Alker, Hayward, 2:824
 Allen, Chris, 4:2168
 Alonso, William, 5:2236, 5:2393, 5:2394, 5:2395
 Alps, 3:1087
 Althusser, Louis
 Marxist geographies work of, 5:2270, 5:2706
 Marxist geography work of, 4:1863
 Altieri, Miguel, 1:54
Altitude, 1:67–68
 absolute altitude and, 1:68
 adiabatic temperature changes and, 1:15–17, 1:17 (fig.)
 angular altitude and, 1:68
 barometric altitude and, 1:68
 definition of, 1:67
 elevation and height, 1:68
 meridian altitude and, 1:68
Amazon River, Amazonia
 biodiversity of, 3:1172
 biota and climate of, 1:264
 contemporary frontier of, 3:1171–1172
 deforestation in, 1:319, 1:527 (fig.), 2:696, 2:698, 4:1697
 domestication of camu camu trees in, 1:377, 1:377 (photo)
 ecosystem decay of, 2:858
 extractive reserves in, 2:1072–1073
 floodplain crop cultivation and, 3:1132
 floodplain of, 3:1129 (photo)
 flowing through Amazon rain forest, 5:2473 (image)

- global climate regulation factor and, 3:1172
 Alexander von Humboldt's travels in, 3:1482
 hunting and gathering tribes in, 3:1492
 indigenous environmental practices in, 3:1568
 indigenous forestry in, 3:1569
 land use and cover change in, 4:1736
 malaria and, 4:1817
 mercury from gold mining and, 4:2087
 resource exploitation in, 5:2220
 sustainable forests in, 3:1164
 tragedy of the commons example in, 1:527 (fig.)
 tropical rain forest of, 1:234, 1:453, 1:454
 tropical savanna climate in, 1:455
- Ambient air quality, 1:68–70**
 acid rain and, 1:69
 air particle monitor and, 1:69 (photo)
 atmospheric particulates and, 1:149–151
 atmospheric pollution and, 1:151–155
 carbon dioxide levels and, 1:68–69
 definition of, 1:68
 emission of polluting substances into the air and, 1:69
 Lake Nyos disaster, Cameroon,
 West Africa, and, 1:68–69
 London's "killer fog" example and, 1:69, 1:70
 Los Angeles smog and, 1:69
 mixed layer of pollutants and, 1:69
 mixing depth or mixing height of pollutants and, 1:70
 ozone levels and, 1:70
 photochemical smog and, 1:70, 4:2171–2173
 pollutant removal processes and, 1:70
 pollution potential of the atmosphere and, 1:69
 quality as objective, 1:68
 secondary pollutants and, 1:70
 synoptic conditions and, 1:69–70
 thresholds of pollutants, WHO standards of, 1:68
 vertical temperature atmospheric structure and, 1:69
- American Association of Geographers, 3:1492
 American Cartographic Association, 4:1939
American Geographical Society (AGS), 1:70–71
 "AGS Fliers' and Explorers' Globe" and, 1:70
 Arctic, Antarctic, and Andean exploration and, 1:70
 exploration and cartography work of, 1:71, 3:1463
 founding and mission of, 1:70, 4:2180
Geographical Review journal of, 3:1463
 library, 1:71
 Transcontinental Excursion sponsored by, 1:71
 Wilson's "14 Points," Paris Peace Conference and, 1:70
 John Kirtland Wright and, 6:3138
See also American Geographical Society (AGS): noted members;
 Association of American Geographers (AAG)
- American Geographical Society (AGS): noted members
 Isaiah Bowman, 1:295, 3:1465
 Törsten Hägerstrand, 3:1398
 Hou Renzhi, 3:1444
 Melvin Marcus, 4:1850
 John Russell Mather, 4:1871
- American Geophysical Union, 3:1245
 American Housing Survey (AHS) data, 4:1998–1999
 American Planning Association, land-based classification standard
 system of, 4:1730–1731, 4:1730 (tables), 4:1731 (tables)
 American Society for Environmental History, 2:929
 American Society of Landscape Architects, 4:1699
 American Society of Photogrammetry, 1:15
 Americans with Disabilities Act, 1:5
 Amin, Ash, 5:2268, 5:2352
- Amnesty International, 1:96, 3:1480
 Eyes on Darfur project, 3:200
- Analytical operations in GIS, 1:71–72**
 automatic generation of scripts and, 1:72
 buffer operation in, 1:7
 database queries and, 1:71
 data editing and, 2:680–681
 data format conversion, 2:681–682
 data querying, 2:684–685
 geostatistics and, 3:1261–1265
 GIS design and, 3:1290–1293
 Map Algebra operations and, 1:72
 object-centered operations and, 1:72
 overlay operation example of, 1:71–72, 1:72 (fig.)
 universal GIS operations and, 1:72
See also GIS specific subject
- Anarchism and geography, 1:73–74**
 alter-globalization and environmental direct-action
 movements and, 1:73, 1:74
 antiauthoritarianism and, 1:73
Antipode journal and, 1:73
 current scholarship trends in, 1:74
 definition of anarchism and, 1:73
 early anarchist geographers and, 1:73
 individualism, ecological preservation elements of, 1:73
 Peter Kropotkin's work in, 1:73, 4:1668–1669, 5:2211
 mutual collaboration and decision making elements of, 1:73
 radical geography of 1960s and 1970s and, 1:73–74
 Élisée Reclus's work in, 1:73, 5:2371–2372
 Situationist International (SI) political and
 artistic movement and, 1:73–74
 voluntary and self-sustaining society focus of, 1:73
- Anaximander, 1:74–75**
 Anaximander's map (re-creation), 1:74 (fig.), 1:75
 authored works attributed to, 1:74
 equinoxes discovered by, 2:1009
 first map of the world, 3:1460
 gnomon invented by, 3:1460
 hydrologic cycle understood by, 1:74
 natural phenomena studied by, 1:74
- Anderson, Benedict, 3:1527
 Anderson, James, 4:1728
 Anderson, Kay, 3:1530, 5:2338, 5:2340
 Anderson, Nels, 4:2121
 Andreev, V., 1:247
 Andropov, Uri, 2:594
- Angola
 cholera in, 1:402
 Cold War and, 1:505
 economically active females in, 3:1190 (table)
 independence of, 1:512, 2:692
 OPEC membership of, 4:2099, 4:2100 (fig.)
- Animal geographies, 1:75–79**
 animal agency and subjectivity and, 1:78–79
 animal rights, 1:75–76
 animals, culture and society and, 1:75–77
 anthropocentric, human thinking and, 1:78
 Bruce Braun and, 2:831
 conceptual boundaries and, 1:77–78
 coupled human and animal systems and, 2:597–598
 as cultural geography subfield, 1:75
 domestication of animals and, 2:781–783
Dream (Franz Marc) and, 1:76 (painting)
Elephant (Franz Marc) and, 1:78 (painting)
 ethics, humans, and other animals and, 1:78–79

- feminist environmentalist geographies and, 3:1092–1094
human-dolphin encounter spaces example and, 1:77
material boundaries and, 1:77
moral status of animals, 1:78–79
reconceptualizing animals as strange people and, 2:832
social theory and geography interplay and, 1:75
speciesism and, 1:76
Sarah Whatmore and, 2:831, 2:832
Jennifer Wolch and, 2:831
zoogeography and, 1:75
- Annales School** (of history), 1:79–80
areal differentiation and, 3:1465
Lucien Febvre and, 3:1090
founders, founding of, 1:79
genres de vie “geohistorical” approach of, 1:80
geographical landscapes and, 1:79
La terre en P volution humaine (Febvre) and, 1:80, 3:1090
layered view of historical time and, 1:80
“longue dur e,” 1:80
Possibilisme, 1:80, 3:1465
- Anselin, Luc**, 1:80–81
academic appointments of, 1:81
award and honors received by, 1:81
books and publications of, 1:80
Walter Isard’s influence on, 3:1628
regional science studies of, 1:81
Spatial Econometrics written by, 1:80, 5:2393, 5:2635
spatial software developed by, 1:80
- Antarctica**
air temperatures in, 1:451
circumpolar Antarctic cyclone belt and, 1:451
Captain James Cook’s exploration of, 2:576
daily values of total column ozone, 5:2700 (fig.)
exotic species in, 2:1048
exploration of, 2:1055
glacial/interglacial cycles in, 1:457
Ice Ages and, 1:457
ice sheets, rising temperatures and, 1:92, 3:1344, 3:1526, 5:2204
ice streams in, 3:1326
katabatic winds of, 1:451, 4:2149
polar climate in, 1:449, 1:451
polar desert in, 1:451
political map of, 6:3155
rates of surface elevation change from satellite measurements, 5:2207 (fig.)
sea ice, ice shelves, and ice sheets areas of, 3:1324 (fig.), 5:2205, 5:2206 (fig.)
sub-Antarctic islands and, 1:451
temperature increases in, 1:452
Wilkins Ice Shelf and, 5:2207, 5:2208 (fig.)
See also Ice
- Antevs, Ernst**, 1:81–82
clay-varve glacial dating method and, 1:82
climate variations and tree rings analysis work of, 1:82
glacial geology and geomorphology work of, 1:81–82
human-environment interaction work of, 1:82–83
paleobotanist work of, 1:82
pluvial lakes and arroyos studies of, 1:82
science of pollen and spores work of, 1:82
- Anthony, Susan B., 3:1095
- Anthropocene** geologic epoch, 3:1334
- Anthropogenic climate change**, 1:82–92
acidification of surface oceans and, 1:91
atmospheric energy variations and, 1:161–165
aviation factor in, 1:182
carbon dioxide concentration, Hawai’i monthly average, 1:83 (fig.)
cities and, 2:943
climate change projections and, 1:90–92
climate models, 1:85–86
climate models, their uses, 1:87–89, 1:88 (fig.), 1:89 (fig.)
complexity of climate models illustration, 1:88 (fig.)
confidence levels in IPCC findings and, 1:84 (table)
drought risk and hazard and, 2:790–794
extreme weather projections and, 1:92
future global CO₂ emissions projections, 1:87 (fig.)
future precipitation changes and, 1:90
global climate change scenarios and, 1:84–85, 1:86 (fig.)
greenhouse gas emissions scenarios and, 1:84–85, 1:86 (fig.)
“ice-albedo feedback” loop and, 1:89–90
Intergovernmental Panel on Climate Change (IPCC) and, 1:82, 5:2204
IPCC assessment reports and, 1:82–83, 5:2554 (fig.)
IPCC Special Report on Emissions Scenarios (SRES) and, 1:84, 5:2553
Keeling Curve and, 1:82, 1:83 (fig.)
Kyoto Protocol and, 1:83, 2:900
melting ice and rising sea level projections and, 1:90, 1:92
mountain glaciers affected by, 3:1328–1333
negative feedback mechanism and, 1:90
one-dimensional climate models and, 1:87
Paleoclimate Modeling Intercomparison Project and, 1:86
“permafrost-climate feedback” loop and, 1:90
physical climatology and, 1:472
Poles, North and South and, 5:2203–2209
positive feedback mechanism and, 1:89–90
potential future climate changes and impacts, 1:84–85, 1:85 (fig.)
precipitation change projections and, 1:90, 1:91 (fig.)
solar and terrestrial radiation and, 5:2346–2349
species extinctions and, 2:1070
three-dimensional “general circulation models” (GCMs) of, 1:87, 1:89 (fig.)
total global annual CO₂ emissions 1900–2100, 1:85 (fig.)
unknowns in predicting climate change and, 1:92
“water vapor feedback loop” and, 1:89, 1:91
See also Atmospheric composition and structure; Climate change; Climate policy
- Anthropogeography**, 1:93
Anthropogeographie (Ratzel, 1882) and, 1:93
environmental determinism and, 2:916–918
Influences of Geographic Environment (Semple) and, 1:93, 3:1464, 5:2531–2532
prevailing cultural discourses and, 1:93
social Darwinism, 1:93
- Antiglobalization**, 1:94–98
Americanization and, 1:94–95
anti-intellectualism of U.S. culture and, 1:95
antisystemic movements and, 1:99–100
environmental groups and, 1:96
grassroots antiglobalization and, 1:95–96
historic globalization resistance examples and, 1:94
Jihad vs. McWorld (Barber) and, 1:94
NGOs (nongovernmental organizations) and, 1:94, 1:96
nonviolent antiglobalization and, 1:94–95
radical Islamists and, 1:97
religious fundamentalism and, 1:97
tribal and indigenous cultures preservation and, 1:96
U.S. celebration of violence and, 1:95
U.S. tolerance of inequality and social injustice and, 1:95

- violent antiglobalization and, 1:96–97
 in Western Europe, 1:94–95
 World Trade Organization protests, Manila and, 1:95 (photo)
 xenophobic violence against immigrants and, 1:97
See also Globalization
- Antipodes, 1:98–99**
 antichrone austral hemisphere zone and, 1:98
 biblical topography issues and, 1:98
 Christian Purgatory and, 1:98
 definitions of, 1:98
 Plato's reference to, 1:98
 Renaissance imaginary and, 1:98
 theory of zones, geographic speculation and, 1:98
- Antisystemic movements (ASMs), 1:99–100**
 antiglobalization and, 1:94–97
 Critical Mass organization, San Francisco and, 1:100
 definition of, 1:99
 global scope of resistance of, 1:99
 "Guerrilla Gardening," Washington D.C. and, 1:100
 humor and absurdism of civil disobedience direct action and, 1:100
 "Mayday Monopoly" protests, London and, 1:100
 methods and tactics of protest and, 1:100
 participatory forms of democratic practice elements of, 1:99
 patterns and aspects of protest and, 1:99
 post-1945 period, 1:99
 Reclaim the Streets, street parties/theater and, 1:100
 Seattle anti-WTO protests and, 1:100
 "situationist" Paris student dissent movement and, 1:100
 small-scale *vs.* large mass demonstrations and, 1:100
 violent tactics issue of, 1:100
- APEC. *See* Asia-Pacific Economic Cooperation (APEC)
- Appleton, Jay, 4:1716
- Applied geography, 1:100–102**
 careers in, 1:102
 Christaller's central place theory and, 1:409–410
 Committee on Applied Geography definition of, 1:101
 controversy, 1:101
 cost-benefit analysis used in, 2:592–593
 examples of, 1:101
 geodemographics and, 3:1215–1217
 geographic science and human behavior and, 1:100
 natural and social sciences merger and, 1:100
 theory to skills transition and, 1:101
- Aquaculture, 1:102–104**
 agricultural intensification and, 1:102
 "blue revolution," 1:103–104
 definition of, 1:102
 development and evolution of, 1:102–103
 economies of scale and, 1:104
 fisheries, Chios Island, Greece, 1:103 (photo)
 fish farming and, 3:1119–1121
 Food and Agriculture Organization (FAO) and, 1:102, 5:2193
 GIS remote sensing technology and, 1:104
 impacts of, 1:103–104
 industrialization of, 1:103
 marine and freshwater culture activities of, 1:102
 marine aquaculture and, 4:1853–1855
 negative impacts of, 1:104
 research trends in, 1:104
 seafood market demand increase and, 1:102
 sociocultural and cultural impacts of, 1:104
 state-supported industrialization of, 1:102
 for subsistence purposes, 1:103
See also Marine aquaculture
- Arabia
 colonization of, 1:513–514
 dromedary camel domesticated in, 2:783
- Archipelago, 1:105–106**
 definition, explanation of, 1:105
 evolutionary study and, 1:106
 Galapagos Islands adaptive radiation example and, 1:14–15, 1:106
 individual countries as, 1:105
 Isles of Sicily archipelago, 1:105 (photo)
 small islands and, 3:1634–1637
 world's largest archipelagos and, 1:105
- Architecture and geography, 1:106–108**
 Berkeley School of cultural geography and, 1:106
 embodied geographies of architectural inhabitation, 1:108
 folk architecture and the vernacular landscape and, 1:106
 green building and, 3:1367–1369
 David Harvey and, 1:106–107
 inhabiting architectural spaces and, 1:107–108
 J. B. Jackson and, 1:106
 landscape architecture and, 4:1698–1701
 landscape design and, 4:1703–1705
Landscape magazine (Jackson) and, 1:106
 hotel lobby interior and, 1:107 (photo)
 new urbanism and, 4:2024–2027
 polyvocal methodology, 1:108
 power and, 1:106–107
 user consumption of architectural environments, 1:108
- Archive of American Folk Song, 4:1968 (photo)
- Arctic**
 amplified warming in, 5:2204
 Arctic Climate Impact Assessment and, 3:1566
 Arctic National Wildlife Refuge in, 6:3093 (photo)
 exploration of, 2:1055
 glaciers in, 3:1333
 high arctic and, 1:450
 Ice Ages and, 1:457
 nomadic pastoralism in, 2:597
 polar climate in, 1:449–450
 polar desert of, 1:451
 polar semidesert in, 1:249, 1:451
 political map of, 6:3156
 precipitation in, 1:450–451
 sea ice minimum, 1979–1981, 3:1524 (photo)
 sea ice minimum, 1982–2008, 5:2205 (fig.)
 temperature increases in, 1:452
 tundra of, 1:247
 tussock and sedge-dwarf shrub tundra of, 1:249
See also Ice
- Arctic Ocean**
 air masses of, 1:63
 William Baffin, exploration of, 2:1055
 permafrost degradation and, 4:2157
 polar climate in, 1:450
 rising temperatures, positive feedbacks and, 1:462
 sea ice decline in, 1:462
- Arendt, Hannah, 5:2378
- Argentina**
 Buenos Aires as primate city, 5:2291 (photo)
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 glaciers in, 3:1332
 human rights violations in, 3:1480
 poverty rates in, 5:2274
 silver trade and, 1:511

- squatter settlements in, 5:2682
 state-funded infrastructure projects and, 3:1551
Zonda wind in, 1:384
- Argumentation maps, 1:108–110**
 argumentation theory and, 1:108–109
 cartography and GIS concepts and, 1:109
 geocollaboration and, 1:109
 geographic data modeling and, 1:108–109
 geospatial data modeling principles and, 1:108
 issue-based information systems and, 1:109
 participatory planning using GIS technology and, 1:108–109
 Toulmin argumentation model and, 1:109
- Arid topography, 1:110–116**
 alluvial fans, 1:113
 arroyos in American southwest, 1:113
 badlands, 1:114
 bajada landform of alluvial fans, 1:114
 desert lakes, 1:115–116
 desert pavement and, 1:113
 desert piedmonts, 1:114–115
 desert plants, Eastern Utah, 1:115 (photo)
 dry climate and, 1:428–435
 low relief, shield and platform setting of, 1:111–112, 1:112 (photo)
 mass wasting, 1:113
 mountain and basin desert setting of, 1:111, 1:111 (photo)
 paleolakes, 1:116
 pediments, 1:113–114
 physical geography of, 1:110
 piping process of badlands and, 1:113
 playas terminal lakebeds, 1:115
 rain storm effects on, 1:110
 rockfall, rockslides, 1:113
 sand dunes, 1:116
 sheetwash, 1:113
 structural setting of, 1:110–111
 surface runoff and desert streams, 1:113–114
 terminal lakes, Dead Sea (Israel) and Caspian Sea, 1:115
 volcanic and tectonic, large-scale relief features of, 1:110–111, 1:111 (photo)
 weathering, rock varnish, and crusts, 1:112–113, 2:719–722
 wind erosion and, 1:116
- Aristotle, 1:116–117**
 air, water, earth, and fire planet elements and, 1:116
 animal and plant distributions views of, 1:117
 earth's habitable zone views of, 1:116–117
 environmental determinism views of, 1:2
 geocentric model (immobile Earth as center of universe) and, 1:116, 3:1460
 ideal size of political unit views of, 5:2217
Meteorologica text of, 1:117
 stream erosion in landscape formation and, 3:1245
- Arizona**
 azurite and malachite secondary copper minerals, Bisbee, 4:1910
 Church Rock Mine open-pit mine in, 4:2087
 Gus Pearson Natural Area, Flagstaff, 3:1167 (photo)
bogan, Navajo Indian Reservation, 3:1571 (photo)
 sediment data collection, Little Colorado River, Grand Canyon, 5:2552 (photo)
 sustainable aquifer management in, 3:1389
 Tempe Women's Club Park, Demonstration Garden, 6:3144 (photo)
- Armenia**
 Collective Security Treaty Organization (CSTO) membership of, 2:536
 Commonwealth of Independent States (CIS) membership of, 2:536 (table)
 economically active females in, 3:1190 (table)
- Armstrong, Marc, 1:117–118**
 computational geography work of, 1:117
 GIScience work of, 1:117
 parallel processing methods for geographic problem solving and, 1:117
 spatial multicriteria evaluation work of, 1:117
- Arnstein, Sherry, 4:2126–2127**
- Art and geography, 1:118–121**
Aether: The Journal of Media Geography and, 1:118
 art tourism and, 1:119
 cartography definition and, 1:118
 Denis Cosgrove and, 2:590
 creative industry reshaping geography and, 1:119–120
 creative literature and, 1:118
 Dotty Wotty House, Detroit, Michigan, 1:119 (photo)
 "Geography as an Art" (Meinig) and, 1:118, 4:1880
 humanistic geography and, 1:118
 landscape paintings and representation and, 1:118
 OJ (Obstruction of Justice) House and the Oval Room display, city of Detroit, 1:120 (photo)
 photography and, 4:2176–2178
 portrayal of cities through art and, 1:119
 production of art and, 1:118
 urban space transformation and, 1:119–120
You Are Here: The Journal of Creative Geography and, 1:118
- Arthur, Brian, 4:2133**
- Aruba, 1:512**
- ASEAN. See Association of Southeast Asian Nations (ASEAN)**
- Asia**
 acid rain in, 1:6–7
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
 Afro-Asiatic languages and, 4:1750 (fig.)
 agricultural industrialization in, 1:47
 aquaculture in, 1:103
 Asian monsoon and, 4:1940–1941
 Association of Southeast Asian Nations (ASEAN) and, 1:126–131, 1:127 (fig.)
 automobile industry in, 1:169
 basin and range topography in, 1:186
 Bering land bridge, North America and, 1:213
 boreal forests in, 1:214–217
 as center of domestication (East Asia), 1:376
 China's foreign direct investment in, 3:1155
 cholera in, 1:401
 climate change adaptation research in, 1:9
 colonialism, end of, 1:517
 colonialism of, 1:514–515
 colonial migrations of, 1500–1914, 3:1542, 3:1543 (fig.)
 COMECON membership and, 2:593
 decolonization in, 2:691, 2:692
 deforestation statistics in, 2:696
 democratization in, 2:702
 desert biome in, 1:218
 export processing zones in, 2:1067
 financial crisis of 1997–1998 and, 4:2022
 foreign aid to, 3:1152
 forest fragmentation in, 3:1159
 gender inequalities in, 3:1589
 Great American Exchange and, 3:1362
 Greek exploration of, 2:1051
 green building programs in, 3:1369
 humid continental climate of, 1:439

- hydroelectric power in, 3:1509
ibe wind in, 1:384
 import substitution industrialism (IAI) in, 3:1550
 installed generating capacity values since 1950 in, 3:1511, 3:1511 (table)
 land degradation estimates in, 4:1680 (table), 4:1681
 land privatization in, 5:2494
 marine aquaculture in, 4:1853
 midlatitude deciduous forest in, 1:223–225
 military expenditures in, 4:1899 (table)
 natural bridge to North America and, 2:1050
 newly industrializing countries in, 4:2022 (fig.)
 nomadic pastoralism in, 2:597
 polar climate in, 1:449
 political map of, 6:3158
 population growth of, 5:2233 (fig.), 5:2241
 potential water availability in, 2007, 2050, 6:3059 (fig.)
 prehistoric exploration of, 2:1050
 renewable water resources and availability in, 6:3057 (table)
 rice paddy cultivation in, 1:48–49, 1:48 (photo)
 severe midlatitude climate in, 1:439, 1:440 (fig.)
 silver trade and, 1:511–512
 Sino-Tibetan language family in, 4:1751, 4:1752 (fig.)
 soil erosion in, 5:2585
 squatter settlements in, 5:2682
 temperate, semiarid deserts in, 1:219
 temperate arid deserts in, 1:221
 temperate hyperarid deserts in, 1:222
 Third World debt crisis and, 2:688
 transboundary hazardous waste dumping in, 1:384
 tropical arid deserts in, 1:221
 tropical monsoon climate in, 1:454
 tropical rain forest of, 1:234
 tropical scrub in, 1:244
 tropical/subtropical semiarid deserts in, 1:219
 tundra of, 1:247
 undernourishment in, 3:1488 (table)
 water stress ratio in, 3:1516
 women's lives in, 3:1097
See also Asia-Pacific Economic Cooperation (APEC); *specific nation*
- Asia-Pacific Economic Cooperation (APEC)**
 Australia's role in, 1:121
 criticisms of, 1:121–122
 decision making by consensus of, 1:121
 diversity of membership limitations of, 1:121–122
 interdependence among Asia-Pacific economies and, 1:121
 membership of, 1:121, 1:122 (fig.)
 nonbinding commitment basis of, 1:121
 trade and investment liberalization agenda of, 1:121
 trade blocs included in, 1:121
 treaty obligation non-requirement of, 1:121
- ASMs. *See* Antisystemic movements (ASMs)
- Association of American Geographers (AAG), 1:122–123**
 AAG Center for Global Geography Education project, 3:1234
 activities sponsored by, 1:122
 Communications Geography Specialty Group of, 2:541
 Conference of Latin Americanist Geographers (CLAG) and, 2:567–568
 Cultural Ecology Specialty Group of, 2:632
 Environmental Perception and Behavioral Geography (EPBG) Group of, 2:978
 founding of, 3:1464
 geographic research focus of, 1:123
 geomorphology and, 3:1245
- Guidelines for Geographic Education*
 (AAG and NCGE) and, 3:1233
 journals of, 3:1464
 as a nonprofit scientific and educational society, 1:122
 organization of, 1:122
 Political Ecology Specialty Group of, 2:633
 professional development programs of, 1:123
 publications of, 1:122–123
 spatial analysis, business geography and, 1:305
 specialty groups of, 1:123
See also Association of American Geographers (AAG): noted members; **Canadian Association of Geographers (CAG)**
Association of American Geographers (AAG): noted members
 Ronald Abler, 1:1
 John Agnew, 1:32
 Brian Berry, 1:193
 Isaiah Bowman, 1:296
 Harlan Burrows, 1:185
 Anne Buttner, 1:308
 Andrew Clark, 1:417
 Reginald College, 3:1349
 William Morris Davis, 2:687, 3:1464
 Törsten Hägerstrand, 3:1398
 Richard Hartshorne, 3:1403
 John Brinkerhoff Jackson, 4:1642
 R. J. Johnston, 4:1643
 David Ley, 4:1777–1778
 Melvin Marcus, 4:1850
 John Russell Mather, 4:1871–1872
 Richard Morrill, 4:1945
 James Parsons, 4:2121
 Lewis Peirce, 4:1772–1773
 Ellen Churchill Semple, 5:2531–2532
 Griffith Taylor, 6:2777
 Glenn Trewartha, 5:2245, 5:2246, 6:2882–2883
 Gilbert White, 6:3095
 Derwent Whittlesey, 6:3097
 Wilbur Zelinsky, 6:3147–3148
- Association of Geographic Information Laboratories for Europe (AGILE), 1:123–126**
 annual conferences of, 1:126
 European GIS conference series of, 3:1286
 European Science Foundation GISDATA Scientific Programmers and, 1:123
 Exhibition on Geographical Information Systems Conferences and, 1:123
 GIScience research topics and, 3:1288 (table)
 governing organization of, 1:126
 membership of, 1:123, 1:124–125 (table)
 mission of, 1:126, 3:1286
 organizational liaisons of, 1:126
 publications of, 1:126
- Association of Southeast Asian Nations (ASEAN), 1:126–131**
 APEC and, 1:121
 ASEAN Free Trade Area (AFTA), 1:127, 1:130–131
 ASEAN Regional Forum (ARF), 1:127, 1:130
 Asian Development Bank and, 1:128
 constructivist theory of international relations and, 1:129–130
 economic profiles of ASEAN countries, 1:128, 1:129 (table)
 foreign direct investment issues (China and India) and, 1:130
 historical context of, 1:127–128, 1:128 (table)
 institution building issue and, 1:128–129, 1:131
 intra *vs.* extraregional trade and, 1:129
 membership of, 1:127, 1:127 (fig.)
 NAFTA and EU and, 1:127, 1:128

- postcolonial southeast Asia conditions and, 1:128
 preferential trade arrangements (PTAs) and, 1:130
 regionalism model of, 1:126–127, 1:127 (fig.), 1:128–130
 “relational control” foundational model of, 1:127–128
 security issues and, 1:129
 supranational integration feature of, 6:2727
 tariff reduction exclusions and, 1:130
 views on sovereignty, 1:129–130
- Atlanta, Georgia
 airline hub in, 1:181
 CO₂ emissions in, 3:1377
 suburban development pattern in, 5:2714 (fig.), 5:2715
- Atlantic Ocean
 Antarctic Convergence zone and, 1:451
 atmospheric energy variations and, 1:163–165
 coastline landforms of, 4:1689
 Dansgaard-Oeschger Oscillations and, 1:457–458
 Hadley cell and, 3:1395–1397
 Edmond Halley’s 1700 chart of, 1:357 (fig.)
 Hurricane Katrina and, 3:1493
 major tectonic areas of, 5:2196 (fig.)
 Medieval Warm Period climate change in, 1:459
 mild, midlatitude climate and, 1:436–437
 Norwegian Current of, 1:450
 ocean-atmosphere variabilities drought factor in, 2:792
 polar climate in, 1:450
 staghorn coral faunal relict and, 1:470
- Atmospheric circulation, 1:131–136**
 bora, mistral, coho winds and, 1:135
 Coriolis force and, 2:586–587
 dust devils and, 1:135
 duststorms, sandstorms and, 1:135
 equatorial trough, intertropical convergence zone (ITCZ) and, 1:132, 1:453, 4:1940
 extratropical cyclones and, 2:650–654
 Ferrel cells of the midlatitudes and, 1:132–133
 Hadley cells of the tropics and, 1:132, 3:1395–1397
 high-latitude polar cells and, 1:133
 hurricanes, typhoons, cyclones and, 1:134
 jet stream upper tropospheric winds and, 1:133
 katabatic winds and, 1:135, 1:451, 4:2149
 macroscale circulation features and, 1:132–134
 mesoscale circulation features and, 1:134–135
 microscale circulation features and, 1:135–136
 monsoons and, 1:134, 4:1940–1945
 mountain climate and, 1:443–449
 ocean circulation and, 4:2058–2064
 photochemical smog and, 4:2171–2173
 planetary scale features of, 1:135–136
 polar cells of the high latitudes and, 1:132–133
 polar or midlatitude jet stream and, 1:133
 Ross by waves (midlatitudes) and, 1:133, 1:134
 Santa Ana wind and, 1:135
 sea breezes, lake breezes and, 1:134–135
 solar energy (insulation) factor in, 1:131
 spatial and temporal classification system of, 1:132
 subtropical high-pressure zone and, 1:132
 subtropical jet stream and, 1:133
 synoptic and dynamic climatology and, 1:472–473
 synoptic scale systems and, 1:133–134
 thunderstorms and, 1:135
 topography, land and water distribution, land surface type factors in, 1:131
 tornados and, 1:135–136
 tropopause element in, 1:132
 valley breeze and, 1:135
 waterspouts and, 1:135–136
See also Atmospheric moisture; Atmospheric specific subject; El Niño-Southern Oscillation (ENSO)
- Atmospheric composition and structure, 1:136–140**
 absolute zero temperature, atom movement and, 1:139
 aerosols, suspended particulates and, 1:137–138
 atmospheric pressure and, 1:155–157
 carbon dioxide concentration and, 1:136–137
 chlorofluorocarbons (CFCs) and, 1:138
 density of the atmosphere and, 1:138
 gaseous composition of the atmosphere and, 1:136–138
 homosphere *vs.* heterosphere “shell” and, 1:140
 ionosphere layer and, 1:140
 jet contrails and, 1:137, 1:148
 mesopause region and, 1:140
 mesosphere thermal layer and, 1:139–140
 nitrogen, oxygen, and argon gases concentration and, 1:136
 oxygen concentration *vs.* altitude levels and, 1:138
 ozone concentrations and, 1:138, 1:139
 roads affecting, 2:952
 stratopause boundary and, 1:139
 stratosphere thermal layer and, 1:139
 temperature definition, stratosphere thermal layer and, 1:139
 thermal structure of atmosphere and, 1:138–140
 thermosphere thermal layer and, 1:140
 trace gasses composition and, 1:137
 tropopause boundary and, 1:139
 troposphere thermal layer and, 1:139, 1:157
 water vapor and, 1:137
See also Atmospheric specific subject
- Atmospheric energy transfer, 1:140–143**
 air mass characteristics and, 1:62–65
 baroclinic systems and, 1:142
 convective boundary layer (CBL) and, 1:141
 Coriolis force and, 2:586–587
 deep moisture convection (DMC) and, 1:141
 El Niño-Southern Oscillation (ENSO) and, 2:889
 extratropical cyclones and, 1:142, 2:650–654
 frictional torque as tangential stress and, 1:143
 global angular momentum (Earth’s axis rotation) source of, 1:140–141, 1:142–143
 greenhouse gases of water vapor and, 1:141
 Hadley cells and, 3:1395–1397
 heat and temperature and, 1:141–142
 heat energy from sun source of and, 1:140–141
 latent heat and, 4:1761–1762
 lower planetary boundary layer (PBL) and, 1:141
 Madden-Julian oscillation (MJO) 60-day cycle and, 1:143
 moist deep convection and, 1:142
 mountain *vs.* frictional torque and, 1:142–143
 ozone levels and, 1:141
 Pacific frictional torque and, 1:143
 positive *vs.* negative mountain torque and, 1:143
 Rossby wave trains and, 1:143
 torque, 1:142
 Type A *vs.* Type B cyclones and, 1:142
 urbanization effects and, 1:141
 Wien’s law and, 1:141
See also Atmospheric specific subject; El Niño-Southern Oscillation (ENSO)
- Atmospheric moisture, 1:143–149**
 air mass characteristics and, 1:62–65
 atmospheric rivers and, 1:146
 changes in, 1:148–149

- characteristics of, 1:144–146
- climatology and, 1:148
- cloud attributes and, 1:147
- clouds and, 1:144, 1:476–480
- cloud types and cloud structure measures and, 1:147–148
- condensed (liquid) and sublimated (ice) water
 - in clouds and, 1:143
- direct observation *vs.* remote sensing and, 1:146–147
- diurnal temperature range (DTR) and, 1:144, 1:148
- dry line of Central U.S. and, 1:146
- El Niño and La Niña events and, 1:148
- GPS remote sensing measurement of, 1:160
- greenhouse gas-induced “global warming” and, 1:148
- Hadley cells and, 3:1395–1397
- hot towers, Hadley cell and, 1:146
- humidity and, 1:145, 3:1485–1486
- hydroclimatology and, 1:473
- incoming solar radiation *vs.* earth-emitted long
 - wave radiation and, 1:144
- interannual variations in, 1:148
- Intertropic Convergence Zone (ITCZ) and, 1:146, 1:148, 6:2832
- latent heat and, 4:1761–1762
- long-wave (cloud) image of Australian sector and, 1:145 (fig.)
- measures of, 1:144–145
- moisture transport (qV , advection of moisture by vector wind)
 - and, 1:146
- monitoring of, 1:146–148
- planetary boundary layer (PBL) location of, 1:144
- slantwise convection and, 1:146
- spatial variations in, 1:148
- Special Sensor Microwave/Imager (SSM/I) climatologies and,
 - 1:147, 1:148
- static stability measures and, 1:145–146
- temperature-evaporation-humidity feedback and, 1:145
- tropical-extra-tropical cloud bands (TECBs, moisture bursts)
 - and, 1:146
- tropical rainfall measuring mission (TRMM) climatologies
 - and, 1:148, 1:160
- vertical air motions and, 1:146
- “warm pool” of highest sea-surface temperatures and, 1:145
- water vapor and, 1:143–144
- water vapor spatial variations and, 1:146
- See also Atmospheric circulation; Atmospheric specific subject;*
 - El Niño–Southern Oscillation (ENSO)
- Atmospheric particulates across scales, 1:149–151**
 - aerodynamic diameter feature of, 1:149–150
 - anthropogenic PM effect on cloud development and, 1:150
 - anthropogenic *vs.* natural sources of, 1:149
 - characteristics of, 1:150 (table)
 - components of, 1:149
 - course to ultrafine size continuum of, 1:150, 1:153–154
 - human health affected by, 1:150–151, 1:154
 - particulate matter (PM) and, 1:149
 - secondary particles and, 1:150
 - size fractions categorization of, 1:149–150
 - solar and terrestrial radiation and, 5:2346–2349
 - See also Atmospheric pollution; Atmospheric specific subject*
- Atmospheric pollution, 1:151–155**
 - air filtration and, 3:1115
 - air quality indices of, 1:151
 - atmospheric particulates and, 1:149–151
 - carbon monoxide pollutant, 1:151–152
 - cities and, 2:942
 - Clean Air Acts (1970, 1990) and, 1:330, 2:899,
 - 2:900, 2:925, 2:960, 2:966, 2:984
 - coal source of sulfur dioxide and, 1:153
 - computer simulations to monitor, 1:154
 - criteria air pollutants and, 1:151
 - dispersion and dilution and, 1:154
 - fine particulate matter pollutant, 1:153–154
 - greenhouse gasses and, 1:152
 - human health affected by, 1:154
 - manufacturing and, 2:945
 - mobile monitoring of, 1:154
 - monitoring of, 1:154
 - National Ambient Air Quality Standards and, 2:984
 - oxides of nitrogen pollutant, 1:152
 - ozone secondary pollutant, 1:152–153
 - personal monitors of, 1:154
 - pollution control technology’s waste products and, 2:945
 - primary *vs.* secondary classification of, 1:151
 - reduction of, 1:154
 - sulfur dioxide pollutant, 1:153
 - sunlight component of ozone and, 1:153
 - temperature inversions and smog, Mexico City,
 - 1:152 (photo), 1:154
 - urban area factor in, 1:151, 1:152, 1:153
 - volatile organic compounds pollutants, 1:153
 - volcanic activity, carbon cycle and, 1:328
 - See also Acid rain; Atmospheric particulates across scales;*
 - Atmospheric specific subject*
- Atmospheric pressure, 1:155–157**
 - adiabatic temperature changes and, 1:15–17
 - air mass characteristics and, 1:62–65
 - barometer measurement instrument and, 1:155
 - definitions, 1:155
 - density measure and, 1:155
 - dynamic processes changes and, 1:156
 - extratropical cyclones and, 2:650–654
 - force, Newton’s second law and, 1:155
 - gravitation acceleration and, 1:155
 - Hadley cells and, 3:1395–1397
 - imbalance in mass and/or heat across space and, 1:155–156
 - inches measurement unit of, 1:155
 - International System (SI) measurement units of, 1:155
 - inverse barometer effect and, 1:497
 - mass of the atmosphere, Pascal’s law and, 1:155
 - pressure change and, 1:156
 - pressure gradient force (PGF) and, 1:156
 - pressure gradients and, 1:155–156
 - quasi-geostrophic (QG) theory and, 1:156
 - temperature, mass, volume changes and, 1:156
 - upper-level disturbances and, 1:156
 - vertical pressure profile and, 1:156–157
 - See also Atmospheric specific subject*
- Atmospheric remote sensing, 1:157–161**
 - active *vs.* passive instruments and, 1:158, 1:159
 - advanced very high resolution radiometer, channels of, 1:159,
 - 1:160 (table)
 - Committee on Earth Observation Satellites and, 1:160
 - definitions of, 1:157
 - Doppler radar active system and, 1:158, 1:159
 - electromagnetic spectrum and, 1:158, 1:158 (fig.)
 - electromagnetic spectrum and, 1:158 (fig.)
 - future trends in, 1:161
 - geosynchronous or geostationary spacecraft orbits and, 1:159
 - Global Precipitation Measurement Mission, 1:160
 - GOES-R and NPOESS next generation operational
 - satellites and, 1:160
 - ground-based systems of, 1:161

- history of space-borne atmospheric remote sensing, 1:159–160
infrared radiometers, pyranometers and, 1:158
Moderate Resolution Imaging Spectroradiometer (MODIS)
 multispectral sensor and, 1:158, 1:252, 2:974, 3:1542,
 4:1738, 4:1740, 4:1960
NASA's Tropical Rainfall Measuring Mission (TRMM) and,
 1:159, 1:160
next generation operational satellites and, 1:160
Nimbus Series, microwave remote sensing and, 1:159–160
numerical weather prediction (NWP) models and, 1:160
physical parameters or variables measured by, 1:157–158
polar-orbiting satellites and, 1:159
resolution characteristic of, 1:158
Satellite Meteorology (Vander Haar and Kidder), 1:159–160
space-borne systems of, 1:160
technology advances in, 1:160–161
TRIOS I and, 1:159
wind profilers and, 1:160
See also Atmospheric specific subject; Biophysical remote sensing
- Atmospheric variations in energy, 1:161–165**
adiabatic processes and, 1:162
Atlantic Multi-decadal Oscillation (AMO) and, 1:165
atmospheric mass factor in, 1:161
backscattering (reflection) of radiation and, 1:161–162
Coriolis force and, 2:586–587
coronosphere of the sun and, 1:163
Dalton Minimum and, 1:163
differential heating and, 2:740–742
Earth's upper and lower atmosphere and, 1:161
El Niño, La Niña and, 1:164
extratropical cyclones and, 2:650–654
Great Pacific Climatic Shift and, 1:164
Maunder Minimum period and, 1:163
Modern Maximum period and, 1:163
numerical models and, 1:162
ocean temperature measurements and, 1:164
Pacific and Atlantic Ocean oscillations and, 1:163–165
Pacific Decadal Oscillation (PDO) and, 1:164
solar constant concept and, 1:162, 1:163
solar energy and, 1:161–163
solar energy variations and, 1:162–163
urban *vs.* rural climate stations measure of, 1:164
volcanic eruptions and, 1:163
*See also Atmospheric specific subject; El Niño-Southern
Oscillation (ENSO)*
- Atoll, 1:165–169**
atoll environments and social issues and, 1:167–168
Bikini Atoll, 1:166, 1:167
climate change and, 1:168
Reginald Daly's glacial control theory of, 1:166
Darwin's subsidence origin theory and, 1:166, 1:167 (fig.), 2:585
definition, explanation of, 1:165
Eniwetok Atoll, 1:166
formation of, 1:166–167, 1:167–168 (figs.), 2:583
geomorphic features of, 2:585, 2:585 (fig.)
Kwajalein Atoll, 1:167–168
low islands and, 3:1635–1638, 3:1636 (photo), 3:1637 (photo)
Marshall Islands atolls, 1:166, 1:166 (photo), 3:1637 (photo)
Midway Atoll, U.S. territory, 2:583
Mururoa and Fangataufa atolls, French Polynesia, 1:167–168
nuclear testing on, 1:167–168, 2:956
Edward Purdy's karst control theory of, 1:166–167, 1:167 (fig.)
AU. *See African Union (AU)*
Augelli, John P., 2:567
Auletta, Ken, 6:2998
- Australia
ANZUS treaty and, 1:505
APEC membership of, 1:121
Australian monsoon and, 4:1941
bird species richness in, 1:262 (fig.)
birthrates in, 2:708
British colonization of, 1:515, 3:1222
cadastral systems, land ownership and, 1:315
Cape Bauer, South Australia, 4:1717 (photo)
chenier ridge, Princess Charlotte Bay, 1:491 (photo)
Closer Economic Relations (CER) Free Trade
 Agreement (FTA) and, 1:121
coal in, 1:485
coastal erosion and deposition in, 1:491–492, 1:491 (photo)
colonial migrations of, 1500–1914, 3:1542, 3:1543 (fig.)
Captain James Cook's exploration of, 2:576
critical human geography in, 2:618, 2:620
deposit refund systems in, 2:742
as drought prone region, 2:787
drug substitution programs in, 2:799
dry climates in, 1:429, 1:430 (fig.)
ecological footprint and biocapacity of, 2:827 (table)
economically active females in, 3:1190 (table)
ecotourism certification in, 2:873
El Niño-Southern Oscillation (ENSO) and, 2:887, 2:888
indigenous environmental knowledge, resource
 management and, 3:1565
energy feed-in tariffs (FIT) in, 2:901
environmental management legislation in, 2:969
environmental history studies in, 2:929
environmental privatization in, 4:2009
European rabbit introduced in, 2:1048, 2:1049 (photo)
foreign aid flow from, 3:1152
GIS pioneering in, 3:1283
green building programs in, 3:1368, 3:1371
greenhouse gas emissions of, 5:2220
groundwater usage in, 3:1386, 3:1387
herbicide use in, 3:1421
housing policy in, 3:1448
hunting and gathering tribes in, 3:1492
incubator zones in, 3:1552
indigenous and community conserved areas in, 3:1561
Indo-European languages in, 4:1749, 4:1750 (fig.)
installed capacity for electricity production forecast, 2010,
 3:1268 (fig.)
Kyoto Protocol of 1997, GHG emissions and, 1:463
Lake Eyre regional basin lowpoint in, 1:114
land degradation estimates in, 4:1680 (table)
long-wave cloud image of, 1:145 (fig.)
lower birth rates in, 4:1981
Melbourne's air quality measurement and, 1:69
midlatitude deciduous forest in, 1:224
midlatitude grasslands in, 1:228
monsoons in, 2:741
morphine-rich narcotics produced in, 2:797 (table)
national drought policy of, 2:793
New South Wales GHG Reduction Scheme,
 carbon markets, 1:331 (table)
Oyster Bay, 1:492 (photo)
political map of, 6:3157
poppy thebaine production in, 2:796
postmodernism in, 2:619
potential water availability in, 2007, 2050, 6:3059 (fig.)
prehistoric exploration of, 2:1050
rabbit population in, 3:1474

- redistricting in, 5:2376–2377
 renewable water resources and availability in, 6:3057 (table)
 sacred Ayers Rock, 6:2769 (photo)
 spectacled flying fox extinction in, 2:1070–1071
 Sydney, Airbus A380 Superjumbo airline and, 1:180
 tropical arid deserts in, 1:221
 tropical monsoon climate in, 1:455
 tropical rain forest of, 1:234, 1:261
 tropical savanna climate in, 1:455
 tropical savanna in, 1:239, 1:241
 tropical scrub in, 1:244, 1:246
 tropical/subtropical semiarid deserts in, 1:219
 Twelve Apostles, coastal erosion and deposition, 1:489, 1:489 (photo)
 Water Resource Management Act, environmental entitlement and, 2:924
 wind erosion, pan field, 6:3113 (photo)
- Austria**
 AGILE membership of, 1:124 (table)
 economically active females in, 3:1190 (table)
 European Union (EU) membership of, 2:1035
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Network of GMO Free Regions in, 3:1610
- Automobile industry, 1:169–171**
 auto alley in the U.S. and Mexico, 1:170–171, 1:170 (fig.)
 built-where-sold paradigm of, 1:169–170
 early history of, 1:169
 European motor vehicle production and, 1:171
 Fordism and, 3:1148–1151
 Ford Motor Company and, 1:169
 fuel source changes factor in, 1:171
 global sourcing strategies of, 1:170–171
 Industrial Revolution and, 3:1582
 statistics, 1:169
 technology transfer in, 2:747
- Automobility, 1:171–175**
 commuting and, 2:553–555
 cultural, perceptual, and psychological changes and, 1:173
 economic, social, and spatial impacts of automobile, 1:171
 European automobile origins and, 1:171–172
 Ford Model T and, 1:172
 Ford's assembly line production and, 1:172
 gender differences, 1:172
 Germany's *autobahnen* and, 1:173
 internal combustion engine and, 1:172
 Italy's *autostrade* and, 1:173
 middle class necessity and, 1:172
 popularity and necessity of, 1:173
 road improvements and, 1:172
 time-space compression, suburbanization and, 1:172–173
 U.S. Interstate Highway System and, 1:173–174, 1:174 (fig.)
See also Automobile industry
- Avalanches, 1:175–179**
 avalanche-relevant mountain weather and, 1:175–176
 avalanche terrain and, 1:176
 calving of ice blocks and, 1:176
 debris avalanches, 1:177–178, 1:178 (photo)
 explanation of, 1:175
 ice avalanches, 1:176–177
 landslides and, 4:1720–1723
 rock avalanches, 1:178–179
 slush avalanches, 1:177
 snow avalanches, 1:175–176, 1:177 (photo)
 snowpack metamorphism factor and, 1:176
 struzstrom failures of rock avalanches and, 1:178–179
- Aviation and geography, 1:179–182**
 Airbus A380 and, 1:179–180
 aircraft technology factor and, 1:179–180
 airline network development and, 1:179
 environment affected by, 1:179, 1:182
 hub-and-spoke network example and, 1:180, 1:180 (fig.), 4:2017
 impact of, 1:179
 low-cost carriers (LCCs) and, 1:181
 point-to-point services example and, 1:181 (fig.)
 secondary airports and, 1:181
 Singapore and Sydney and, 1:180
 urban and regional development patterns and, 1:179
 Wizz Air network and, 1:181–182, 1:181 (fig.)
- Azerbaijan**
 Collective Security Treaty Organization (CSTO) membership of, 2:536
 Commonwealth of Independent States (CIS) membership of, 2:536 (table)
 economically active females in, 3:1190 (table)
 GUAM Organization for Democracy and Economic Development co-founded by, 2:538
 HIV/AIDS in, 3:1438
- Azores, 2:1051**
- Bachelard, Gaston, 4:1769
 Bacon, Francis, 2:893, 4:1928
 Baghdad, 1:402
 Bagnold, R. A., 2:801, 4:1896–1897
 Bahamas, 1:512
 Bahrain, 3:1190 (table)
 Baldwin, Richard, 2:781
 Bale, John, 5:2680
 Balkan states, 2:1038
 Baltimore, Maryland
 CO₂ emissions in, 3:1377
 fruit and vegetable canning industry in, 4:1821
- Bangladesh**
 cholera in, 1:402
 clothing exports from, 6:2186 (fig.)
 deficient calorie consumption in, 3:1487
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 marine aquaculture in, 4:1854 (fig.)
 monsoon season floods and, 3:1135
 textile exports from, 6:2816 (fig.)
 water supply contamination and, 3:1387
- Baran, Paul, 2:712
 Barber, Benjamin, 1:94
 Barlow, Philip, 5:2407
 Barnes, Trevor, 4:1897
- Barrier islands, 1:183–185**
 barrier reefs (coral reefs) and, 2:583
 Bora Bora, French Polynesia (barrier reef) and, 2:583
 formation theories of, 1:183, 1:185, 2:583
 island overstepping and, 1:183
 long wave *vs.* mixed *vs.* short wave barriers and, 1:183
 physical characteristics of, 1:183
 small islands and, 3:1634–1637
 washover fans, Santa Rosa Island, northwest Florida, 1:183, 1:184 (photo)
 wave-dominated barrier island, Santa Rosa Island, northwest Florida, 1:184 (photo)
- Barrow, Christopher, 2:1003

- Barrows, Harlan, 1:185–186**
 environmental determinism and, 1:185
 geography as human ecology views of, 1:185, 2:894, 2:895, 2:896–897
 Richard Hartshorne influenced by, 3:1402
 history *vs.* historical geography and, 1:185
 Ellen Churchill Semple and, 1:185
 water resources conservation work of, 1:185
- Barthes, Roland, 5:2270
- Bartlett, Richard, 3:1572
- Bash, Jeffrey, 2:993–994
- Basin and range topography, 1:186**
 crustal extension causes of, 1:186
 diastrophic processes formation of, 1:186
 faulting and, 3:1085–1088
 geographic locations of, 1:186
 graben rock and horst block rock structures and, 1:186, 2:604
 half-grabens tilted fault blocks and, 1:186
- Bassett, Karl, 2:633
- Batty, Michael, 1:187**
 cities as fractals theorization of, 2:561
 city systems work of, 1:187
 complex systems theory work of, 2:560
 complex systems work of, 2:560
 GIScience contributions of, 1:187
- Baudrillard, J., 2:574
- Bayesian statistics in spatial analysis, 1:187–189**
 Bayesian kriging, spatial interpolation and, 5:2648
 Bayesian maximal entropy (BME) to study natural systems and, 1:187
 cellular automata used in, 1:370
 core knowledge basis of, 1:188
 scientific applications of, 1:188
 software applications of, 1:188
 spatial autocorrelation and, 5:2607–2608
 spatial coordinate systems of, 1:188
 stochastic theory and epistematics principles fusion and, 1:187
- Beakhurst, Grahame, 5:2212
- Beazley, Charles, 5:2252, 5:2253
- Bebbington, Anthony, 3:1557
- Beck, Ulrich, 2:837, 5:2515
- Begg, Robert, 4:2109
- Behaim, Martin, 3:1461, 4:2179
- Behavioral geography, 1:189–190**
 assumptions of, 1:189–190
 cognitive mapping (Tolman) and, 1:189, 4:1881
 constructivism learning theory and, 1:189
 contributions of, 1:190
 criticisms of, 1:190
 Environmental Perception and Behavioral Geography (EPBG) Group of AMG and, 2:978
 everyday life geographies and, 2:1042–1045
 explanation of, 1:189
 geographies of emotion and, 2:891–892
 hierarchy of spatial human development and, 1:189
 human spatial decisions and problem solving and, 1:189, 1:190
 mental maps and, 4:1881–1883
 methods of, 1:190
 mixed methods used in, 1:190
 nonvisual geographies and, 4:2042
 resulting data formats of, 1:190
 theoretical basis of, 1:189–190
 understanding processes focus of, 1:190
- Beijing, China
 Hou Renzhi historical research on, 3:1443
 rural migrant worker, urban waste management in, 5:2497 (photo)
- Belarus**
 Collective Security Treaty Organization (CSTO) membership of, 2:536
 Commonwealth of Independent States (CIS) membership of, 2:536, 2:536 (table)
 economically active females in, 3:1190 (table)
 European bison extinction in, 2:1071
- Belgium**
 AGILE membership of, 1:124 (table)
 coal energy source in, 3:1582
 colonial empire of, 1:509, 1:509 (fig.)
 economically active females in, 3:1190 (table)
 European Union (EU) membership of, 2:1035
 first textile factories in, 3:1583
 gully erosion in, 3:1393
 particulate matter pollution in, 1:151
- Belize, 4:1854 (fig.)
- Bell, Daniel, 5:2262–2263, 6:2843
- Bell, Scott, 2:615
- Bell, Thomas L., 4:1969
- Belyea, Barbara, 3:1563
- Bengal**
 British colonization of, 1:514
 Chinese exploration of, 2:1054
 Great Bengal Famine of 1843 and, 3:1084
- Benin, 3:1190 (table)
- Benjamin, Walter, 2:573–574
 class-based analysis of representations and consumption and, 4:1862
 how to read urban spaces and, 5:2298
 literature geographies and, 4:1788, 5:2298
 ordinariness views of, 2:1043
- Bennett, Hugh, 5:2585
- Benneworth, Paul, 1:482
- Bensin, Basil, 1:54
- Bentham, Jeremy, 4:2116, 5:2272
- Bentley, Ian, 4:2168
- Berger, P., 5:2297
- Bering land bridge, 1:213
- Berkeley, George, 2:893
- Berkeley School, 1:191–192**
 California School name and, 1:191
 characteristics of study and, 1:191
 critiques and decline of, 1:192
 cultural geography, architecture and, 1:106, 1:191, 1:192, 4:1967
 diffusion, cultural geography and, 2:745, 2:746
 environmental determinism *vs.*, 1:191
 fieldwork study methods used by, 1:191
 folk culture and geography and, 3:1142–1144, 4:1967
 holistic view of culture and, 3:1458
 human culture impact on landscapes focus of, 1:191, 3:1458
 isolation of school factor and, 1:191
 key people, dissertations of, 1:192
 music and sound studies of, 4:1967
 origins of, 1:191
See also Berkeley School: noted scholars
- Berkeley School: noted scholars
 Luc Anselin, 1:80–81
 Harold Brookfield, 3:1458
 James Parsons, 4:2120–2121
 Carl Sauer, 1:191, 1:192, 2:641, 2:746, 3:1429, 3:1458, 3:1465, 4:1990, 5:2433

- Berners-Lee, Tim, 2:646
- Berry, Brian, 1:192–194**
- central place theory and, 1:382
 - education and academic positions of, 1:192–193
 - globalization issues and, 1:193
 - positivism and quantitative revolution and, 1:193
 - publications of, 1:193
 - quantitative modeling work of, 1:192
 - regional development work of, 1:193
 - spatial analysis work of, 5:2603
 - urban and economic geography work of, 1:192, 1:193, 1:382, 3:1466, 5:2307
- Bertness, Mark, 4:1658
- Berube, A., 2:1075
- Bhabha, Homi, 3:1528, 3:1529
- Bhaskar, Roy, 3:1278
- Bhopal, India, chemical disaster, 1:194–195**
- environmental justice activism, 1:194–195, 4:2158
 - remedial remediation neglect and, 1:194
 - second-generation of victims of, 1:194
 - victims of, 1:194, 1:195 (photo)
- Bhutan, 3:1190 (table)
- Biblical mapping, 1:195–197**
- antipodes and, 1:98
 - “Bible atlas” and, 1:197
 - biblical *vs.* science debates and, 4:1808–1809
 - explanation of, 1:195, 1:197
 - Holy Land research map and, 1:196 (fig.)
 - William Lynch’s Dead Sea exploration and, 4:1808–1809
 - maps’ use in Bible creation issue and, 1:197
 - religious geographies and, 5:2405–2409
 - T-in-O maps, 1:347, 1:349 (fig.), 3:1461, 6:2845 (fig.)
- Biodiversity, 1:197–201**
- agrobiodiversity and, 1:49–50
 - alien or invasive species and, 3:1337
 - alpha *vs.* beta diversity and, 1:198
 - biota total numbers and, 1:198
 - community evenness at local level and, 1:198
 - Convention on Biological Diversity and, 3:1604
 - definition of, 1:197
 - environmental markets of, 4:2009
 - environmental stability factor in, 1:198
 - epsilon, regional diversity and, 1:198
 - exotic species and, 2:1048–1050
 - extinctions and, 2:1069–1072
 - gamma, landscape-level diversity and, 1:198
 - geographical area hypothesis and, 1:199
 - geometrical constraints hypothesis and, 1:200
 - global environmental change and, 3:1337
 - Great American Exchange and, 3:1361–1362
 - greater landmasses factor in, 1:199
 - hotspots of, 1:200–201, 1:201 (fig.)
 - human-caused extinction and, 3:1337
 - intermediate disturbance hypothesis, 1:198
 - International Convention on Biological Diversity and, 3:1561, 3:1568, 6:2748
 - keystone species and, 4:1655–1658
 - landscape biodiversity and, 4:1701–1703
 - land use and cover change impact on, 4:1736
 - latitudinal biodiversity gradients and, 1:198–200, 1:260, 1:260 (fig.)
 - measures and maintenance of, 1:198
 - particular locations, 1:199
 - productivity hypothesis of, 1:199–200
 - Simpson and Shannon-Weiner Indices measures of, 1:198
 - species-area relationship and, 1:199
 - species turnover concept and, 1:198
 - theory of island biogeography and, 1:199, 5:2672
 - See also* Conservation; Conservation zoning;
- Crop genetic diversity**
- Biofuels, 1:201–204**
- Brazil, 1:202
 - carbon neutrality issue, 1:201
 - cellulose ethanol and, 1:203
 - corn as animal feed, 1:201, 1:203
 - definition, examples of, 1:201
 - economic issues, 1:201
 - environmental impacts of, 1:201
 - ethanol and biodiesel as vehicle fuel and, 1:201–202
 - Germany, 1:203
 - industrialized agriculture and, 1:47
 - Malaysia, 1:203–204
 - palm oil biodiesel and, 1:203–204
 - Renewable Energy Road Map (EU commission) and, 1:203
 - United States, 1:202–203
 - utilization issues and, 1:201
- Biogeochemical cycles, 1:204–208**
- biosphere and, 1:204–205
 - biota and climate and, 1:257–264
 - carbon cycle and, 1:206
 - carbon cycle, 1:206
 - chemistry of Earth’s surface and, 1:204
 - climate change and, 6:2772–2773
 - coastal dead zones and, 1:486–488
 - Earth’s intersecting cycles and, 1:205
 - Gaia hypothesis and, 1:204
 - geography of, 1:207
 - hydrogen and oxygen cycles, 1:205–206
 - intersecting cycles of Earth and, 1:205
 - land use and cover change and, 4:1736
 - nitrogen cycle, 1:205, 1:206–207, 4:2028–2029
 - nutrient cycles and, 4:2052–2055
 - phosphorus cycle and, 4:2169–2171
 - photosynthesis importance and, 1:205
 - rock-derived cycles, 1:207
 - spatial patterns of, 1:207
 - See also* Carbon cycle; Nitrogen cycle
- Biogeography, 1:208–214**
- age of exploration and, 1:208–209
 - animal geographies and, 1:75–79
 - biodiversity and, 1:197–201
 - biological species concept (Mayr) and, 1:210
 - biomes map and, 1:212 (fig.)
 - botanical geography and, 1:208–209
 - Buffon’s Law and, 1:208
 - cladistics (phylogenetic classification) definition (Mayr) and, 1:210
 - climatic relicts and, 1:467–471
 - continental drift (Wegener) and, 1:209
 - corridors, filters, and sweepstakes dispersals pathways and, 1:213
 - definition of, 1:208
 - Jared Diamond’s work in, 2:734, 5:2216
 - dispersal biogeography, 1:211, 1:213
 - ecological distributions and, 1:209
 - ecological mapping and, 2:832–834
 - ecological zones and, 2:834–844
 - geographic isolation from vicariant events, reproductive isolation and, 1:211, 1:212 (fig.)

- global biotic plant regions and, 1:208
- human impacts of distributions and, 1:213
- invasion and succession and, 3:1627
- island biogeography theory (MacArthur and Wilson), 1:210
- issues and themes of, 1:208
- jump dispersal and, 1:213
- landscape and wildlife conservation and, 4:1696–1698
- law of the minimum (Liebig) and, 1:209
- mapping biotic regions and, 1:209
- micro *vs.* macro evolution and, 1:209
- new species from geographic isolation and, 1:210
- organism-environment relationship focus of, 1:208
- plate tectonics and, 5:2195–2199
- reproductive isolation and, 1:211
- science of taxonomy and, 1:208
- spatial distributions of organisms and, 1:210–211
- species ecological niches and, 1:210–211
- species with life forms classification and, 1:210
- timeline of 1600–1850: age of reason, 1:208–209
- timeline of 1850–1900: evolution by natural selection, 1:209
- timeline of 1900–1950: continental drift and ecology, 1:209–210
- timeline of 1950–present: ecological and historical theories, 1:210
- vegetation development theories (Howles and Clements) and, 1:209–210, 4:2180
- vegetation dynamics focus of, 1:208
- vicariance biogeography (Croizat) and, 1:210
- vicariant event boundaries and, 1:211
- Wallace's Line boundary area and, 1:209, 1:234
- zoogeography and, 1:209
- See also* Biogeography: noted individuals
- Biogeography: noted individuals
 - Luc Anselin, 1:80–81
 - Comte de Buffon, 1:208
 - Frederic Clements, 1:209–210, 4:2180
 - Henry Cowles, 1:209, 4:2180
 - Leon Croizat, 1:210
 - Charles Darwin, 1:209
 - Johann Reinhold Forster, 1:208
 - Henry Gleason, 1:210
 - Alexander von Humboldt, 1:208–209, 3:1463, 5:2447
 - Justus Liebig, 1:209
 - Carl Linnaeus, 1:208
 - R. H. MacArthur, 1:210
 - Ernst Mayr, 1:210
 - Christen Raunkiaer, 1:210
 - Philip Ludley Sclater, 1:209
 - Arthur Tansley, 1:210
 - Alfred Russel Wallace, 1:209
 - Alfred Wegener, 1:209
 - Robert Harding Whittaker, 1:210
 - E. O. Wilson, 1:210
- Biome: boreal forest, 1:214–217**
 - as biodiversity conversation resource, 1:215
 - broad-leaved deciduous trees in, 1:215
 - carbon cycle and, 1:214, 1:215
 - coniferous tree species in, 1:214
 - commercial timber harvest disturbance in, 1:217
 - coniferous tree species in, 1:215
 - cultural significance of, 1:217
 - endangered species and, 1:216
 - energy development projects disturbances in, 1:217
 - forest degradation and, 3:1156–1159
 - forest fragmentation and, 3:1159–1163
 - forest land use and, 3:1163–1165
 - geographic boundary definitions of, 1:214
 - high northern latitudes location of, 1:214
 - Holocene warm period and, 1:459
 - indigenous cultures of, 1:217
 - insect infestation disturbance in, 1:217
 - large and small herbivorous species of, 1:215
 - natural and human-caused disturbances in, 1:216–217
 - Northern Ontario, Canada, 1:216 (photo)
 - peat fires, peat mining disturbances and, 1:216–217
 - peatlands formation and, 1:215
 - permafrost distribution and, 1:215
 - prey species of, 1:215–216
 - severe midlatitude climate and, 1:442
 - vegetative form boundary definitions of, 1:214–215
 - warming trends, vegetation shifts and, 1:214
 - wildland fires disturbances and, 1:216
 - See also* Periglacial environments
- Biome: desert, 1:218–223**
 - arid deserts, features of, 1:218, 1:220–221
 - arid deserts, flora and fauna of, 1:220–221
 - arid deserts, location of, 1:221
 - arid deserts, overgrazing in, 1:220 (photo)
 - arid deserts, springbok of Kalahari Desert, 1:221 (photo)
 - aridity measure, calculation and, 1:218
 - categorization of, 1:218
 - description of, 1:218
 - dry climate and, 1:428–435
 - hyperarid deserts, features of, 1:218, 1:221–223
 - hyperarid deserts, flora and fauna of, 1:222, 1:222 (photo)
 - hyperarid deserts, location of, 1:222
 - hyperarid deserts, sand dunes, 1:223 (photo)
 - semiarid deserts, features of, 1:218–219
 - semiarid deserts, flora and fauna of, 1:219
 - semiarid deserts, location of, 1:219–220
 - semiarid deserts, wildebeest of East Africa, 1:219 (photo)
 - See also* Dunes; Environmental management: drylands
- Biome: midlatitude deciduous forest, 1:223–226**
 - alfisols *vs.* ultisols soil variations in, 1:224–225
 - climate variations in, 1:224
 - disturbances in, 1:226
 - geographic locations of, 1:223–224
 - human-induced disturbances and, 1:226
 - insect disturbances and, 1:226
 - leaf loss and leafing out timing and, 1:225
 - light variations in, 1:225
 - mild midlatitude climate and, 1:435–349
 - mountain ranges and glaciers factors affecting, 1:224
 - old-growth forest, primary forest rarity and, 1:226
 - passenger pigeon extinction and, 1:224
 - productivity diversity in, 1:225
 - second-growth forest and, 1:226
 - severe midlatitude climate and, 1:440–441
 - shade tolerance variations in, 1:225
 - structure and composition of, 1:223–224
 - tree associations in, 1:224
 - tropical deciduous forest *vs.*, 1:223
 - white-tailed deer prevalence in, 1:224
- Biome: midlatitude grassland, 1:227–230**
 - animal use of, 1:229
 - construction grasses and, 1:229
 - domesticated grain crops and, 1:229
 - geographic locations of, 1:227
 - grass seed dispersal mechanisms and, 1:227
 - grass species of, 1:227–229, 1:228 (fig.)

- human interactions and maintenance and, 1:229
 nutrient rich soil and, 1:229
 overgrazing damage and, 1:229
 photosynthetic grass types and, 1:227, 1:228 (fig.)
See also Biome: midlatitude grassland: grasses
- Biome: midlatitude grassland: grasses**
Andropogoneae, 1:228
Andropogon gerardii, 1:227
Arundinaria, 1:229
Aveneae, 1:228
Chloridoideae, 1:227, 1:228
Nassella, 1:229
Paniceae, 1:228
Phragmites, 1:229
Piptochaetium, 1:229
Poa pratensis, 1:227
Puccinellia nutalliana, 1:227
Spartina, 1:229
Spinifex, 1:228–229
Stipa, 1:229
Stipeae, 1:228, 1:229
Titiceae, 1:228
- Biome: tropical deciduous forest, 1:230–233**
Adansonia (baobab), Western Madagascar, 1:231, 1:232 (photo), 1:239
 bush fallow farming practiced in, 1:301–302
 in East Africa, 1:232 (fig.)
 evergreen to deciduous forests transition and, 1:230
 fauna diversity in, 1:231–232
 features of, 1:230
 forest degradation and, 3:1156–1159
 forest fragmentation and, 3:1159–1163
 forest land use and, 3:1163–1165
 fuel wood and charcoal sources and, 1:232
 geographic locations of, 1:230
 mammal population densities in, 1:232
 midlatitude deciduous forest *vs.*, 1:223
 road construction factor in, 1:232
 seasonally wet and dry or monsoon climates and, 1:230
 seasonal rainfall patterns of, 1:230–231
 semi-evergreen forest, Tina River, Kenya, 1:233 (photo)
 soil conditions in, 1:231
 tree species composition of, 1:230–231
 tropical rain forest *vs.*, 1:230
 tropical savanna *vs.*, 1:230
 tropical scrub similarities to, 1:245
 valuable timber harvesting and, 1:232
See also Biome: midlatitude grassland: grasses
- Biome: tropical rain forest, 1:234–239**
 biodiversity hotspots in, 1:200, 1:200 (fig.)
 biogeographical patterns of diversity in, 1:234–235
 broad-leaved evergreen trees and, 1:235
 cloud forests and, 1:237, 1:238 (photo), 1:239 (photo)
 community plant types and, 1:237
 competition for light, nutrients, and reproduction in, 1:235–236
 day lengths of, 1:234
 decomposition and chemical weathering in, 1:236
 deforestation rates and, 1:238, 4:1683–1684
 ecological structure, function, and dynamics of, 1:235–237
 extractive reserves and, 2:1072–1073
 faunal diversity in, 1:236
 forest degradation and, 3:1156–1159
 forest land use and, 3:1163–1165
 geographic locations of, 1:234
 heath forests, Kerangus in Sabah, Malaysia, 1:237, 1:237 (photo)
 human interactions with, 1:237–238
 interdependencies among animals in, 1:236
 montane cloud forests, Eastern Arc mountains, 1:238 (photo)
 montane cloud forests, Mt. Kinabalu, Sabah, Malaysia, 1:239 (photo)
 monthly precipitation of, 1:234
 oldest, most weathered landscapes in the world and, 1:236
 physical environment of, 1:234
 plant adaptations in, 1:235–236, 1:235 (photo), 1:236 (photo)
 structural layers of, 1:235
 tall emergent trees in, 1:235 (photo)
 temperature conditions of, 1:234
 tropical deciduous forest *vs.*, 1:230
 woody plant groups and, 1:235
- Biome: tropical savanna, 1:239–243**
 acacia-dominated savanna on black-cotton soils, Kenya, 1:241 (photo)
 agricultural and pastoral populations conflict and, 1:243
 biogeographical patterns of diversity in, 1:239
 bush fallow farming practiced in, 1:301–302
 climatic conditions in, 1:239–240
 disturbance ecology and derived savannas, 1:241–243
 ecological adaptations of, 1:240–241
 fire factor and, 1:242
 geographical location of, 1:239
 gerenuk browning, arid bush savanna and, 1:242 (photo)
 grasses and woody plants mixture in, 1:239, 1:240–241
 grazing and browsing by animals and, 1:241
 large animal diversity in, 1:242
 Masai Mara, Kenya, 1:240 (photo), 1:243 (photo)
 plant adaptations in, 1:240–241
 rainfall seasonality of, 1:240
 savanna and, 1:239
 soil conditions in, 1:241
 topical to subtropical wet-dry climate of, 1:239–240
 tropical deciduous forest and tropical scrub overlap with, 1:239
 tropical deciduous forest *vs.*, 1:230
 tropical scrub similarities to, 1:244, 1:245
- Biome: tropical scrub, 1:244–246**
 annual precipitation gradient of, 1:244
 evolutionary convergence and, 1:244
 fire and, 1:244
 geographic locations of, 1:244
 herbivore disturbances and, 1:245
 human interaction disturbances and, 1:245
 multi-stemmed woody plants of, 1:244
 soil characteristics of, 1:244
 thorn woodland plants of, 1:244
 tropical deciduous forest similarities to, 1:245
 tropical savanna similarities to, 1:244, 1:245
 vulnerable species protection needs and, 1:245–246
 wind disturbances and, 1:245
 woody plant invasion in, 1:245
- Biome: tundra, 1:246–251**
 Arctic geographical definition and, 1:247
 climate changes in, 1:247
 geographic locations of, 1:247
 Low *vs.* High Arctic tundra and, 1:249
 mixed and coniferous forests of, 1:247
 mixed vegetation types and, 1:249, 1:250 (photo)
 North American *vs.* Eurasian continent variations and, 1:247, 1:248 (table)

- peat depths and, 1:249
- polar semideserts, 1:249
- polar semideserts and, 1:249
- shrub tundras, 1:247–248
- soil formation and characteristics of, 1:249–251
- soil podzolization soil formation process and, 1:250
- subzones within, 1:247
- true tundra and, 1:249
- tundra definition and, 1:246
- tussock and sedge-dwarf shrub tundras, 1:248–249
- wet tundras, 1:249
- Zackenbergl valley, northeastern Greenland, 1:250 (photo)
- See also* Periglacial environments; Permafrost
- Biophysical remote sensing, 1:251–254**
 - advances in and applications of, 1:254
 - atmospheric remote sensing and, 1:157–161
 - canopy reflective indices of, 1:254
 - electromagnetic radiations interpretation and, 1:251
 - enhanced vegetation index of, 1:254
 - Fire Weather index of, 1:254
 - individual green vegetation factor in, 1:253
 - leaf area index (LAI) technology of, 1:254
 - MODIS Terra Image of Greece and, 1:252 (photo)
 - nighttime *vs.* daytime images and, 1:252–253
 - physical quality of life measures of, 1:254
 - plant canopy productivity information
 - importance and, 1:251
 - predictive abilities of, 1:251
 - remote sensing definition and, 1:251
 - soil moisture electromagnetic radiation factor and, 1:253
 - topography factor in, 1:252–253
 - vegetation, spectrally different classifications of, 1:253–254
 - warm-and-cool patterns displayed by, 1:251
 - water behavior patterns displayed by, 1:252
 - wind patterns displayed by, 1:251–252
- Bioregionalism, 1:255**
 - criticism of, 1:255
 - definition of, 1:255
 - ecosheds and, 2:857
 - human-ecological relations framework of, 1:255
 - interdisciplinary nature of, 1:255
 - normative characteristic of, 1:255
 - permaculture and, 4:2152–2153
 - sustainability development and, 1:255
 - themes of, 1:255
- Biosphere reserves, 1:256–257**
 - biogeochemical cycles and, 1:204–208
 - cities and, 2:942–943
 - core, buffer, and transition zones of, 1:256
 - ecodevelopment strategies in developing
 - countries and, 1:256
 - environmental protection function of, 1:256
 - financial support issues of, 1:257
 - functions demonstrated by, 1:256
 - humans and natural landscapes connections and, 1:257
 - Our Common Future* (World Commission on Environment and Development) and, 1:256, 6:2737
 - parks and reserves and, 4:2117–2120
 - periodic review by UNESCO and, 1:256–257
 - scientific research and education function of, 1:256, 1:257
 - Seville Strategy of 1995 (UNESCO) and, 1:256
 - socio-ecological systems focus of, 1:257
 - sustainable resource use function of, 1:256, 1:257
 - UNESCO creation and recognition of, 1:256
 - watersheds or landscape-level features basis of, 1:256
- Biota and climate, 1:257–264**
 - altitudinal gradient factor and, 1:262
 - biodiversity and, 1:197–201
 - biota's influence on climate and, 1:263–264
 - biotic environment and, 1:257
 - bird species, Australia, and, 1:262 (photo)
 - boreal forest biome and, 1:214–217
 - carbon sinks, plants and, 1:264
 - climate as cause *vs.* constraint on diversity issue, 1:262
 - climate opportunity *vs.* threat and, 1:258
 - climate-plant relationships and, 1:259–260
 - climate's influence on biota and, 1:258–263
 - climatic envelope modeling, 1:259
 - climograph and, 1:259, 1:259 (fig.)
 - conservation biogeography and, 1:264
 - current and future research directions in, 1:265
 - definitions, 1:257
 - depth gradient of oceans factor and, 1:262–263
 - evolution, organisms adapting to climate and, 1:258–259
 - historical biogeography and, 1:258
 - latitude diversity gradient and, 1:198–200, 1:260, 1:260 (fig.)
 - macroecology field and, 1:260
 - ocean salinity and Earth's surface temperature constants and, 1:263–264
 - phenology of plants, climate change and, 1:263
 - photosynthesis process and, 1:258, 1:259, 1:263
 - Plectrohyla exquisita* frog, Cusuco National Park, Honduras, 1:261 (photo)
 - spatial patterns of species richness and, 1:262
 - species dispersal factor and, 1:263
 - species richness and, 1:260–263, 1:260 (fig.), 1:262 (fig.)
 - species traits factors and, 1:263
 - sun's angle of incidence factor and, 1:263
 - temperature and ambient conditions and, 1:258, 1:259 (fig.)
 - tropical montane rain forest, Cusuco National Park, Honduras, 1:261 (photo)
 - tundra biome and, 1:246–250
 - See also* Biota and soils; Biota and topography; Biota migration and dispersal
- Biota and soils, 1:264–270**
 - animal bioturbations' subprocesses and, 1:267–269, 1:268 (fig.), 1:274
 - biota role in soil formation and its bioturbation, 1:267–269
 - computer animation and, 1:269
 - five factors soil formation model and, 1:265–266
 - gatekeeper soil documents and, 1:265–266
 - 1993 *Soil Survey Manual* and, 1:265–266
 - 1999 *Soil Taxonomy* and, 1:265–266
 - organisms (numbers of) in soil and, 1:267
 - research trends in, 1:264
 - rooted plants environments and, 1:266
 - slough mud and, 1:264–265
 - soil bioturbation, 1:265
 - soil definitions and, 1:265–266
 - soil forming underwater concept and, 1:265
 - soil paradigms and, 1:265
 - thicknesses and whole soil bioturbations and, 1:269
 - two-layered bioturbation and, 1:268 (fig.)
 - universal soil definition and, 1:266–267
 - See also* Biota and climate; Biota and topography; Biota migration and dispersal
- Biota and topography, 1:270–276**
 - alluvial bar of River Allier, France, and, 1:272 (photo)
 - beaver dam, Alaska, 1:274, 1:274 (photo)
 - below-ground burrowing animals and, 1:274

- biogeography and, 1:270
 biogeomorphology and, 1:270, 1:271–272
 bioturbation and, 1:267–269, 1:268 (fig.), 1:274
 buildings concentrations and, 1:275, 1:275 (photo)
 control of topography by microorganisms, insects,
 and animals, 1:273–274
 control of topography since Precambrian era and, 1:273
 control of topography through human activities at
 a global scale, 1:275–276
 crayfishes activity and, 1:274
 definitions, 1:270–271
 deforestation of Mediterranean catchments and, 1:275
 earthworm activity and, 1:274
 exogenous weather agents topographic component, 1:271
 global warming, climate change and, 1:276
 landform materials topographic component and, 1:271
 large mammals and, 1:274
 life as an evolving force concept and, 1:272
 Manhattan from Empire State Building, New York City, 1:275 (photo)
 photosynthesis process and, 1:273
 plant control of topography on continents and, 1:273
 sedimentary and biochemical cycles and, 1:273
 tectonics topographic component and, 1:271
 topography: definition by substrate cohesion and physiochemical
 agents and, 1:270–271
 topography: significant control through biota and, 1:271–272
 trees' topography modification and, 1:273
See also Biota and climate; Biota and soils;
 Biota migration and dispersal
Biota migration and dispersal, 1:276–278
 biodiversity and, 1:197–201
 bird migrations and, 1:276–277
 breeding experience of dispersing individual and, 1:277
 definitions, 1:276
 dispersal process stages and, 1:277
 genetic control and environmental variation factors in,
 1:277–278
 habitat variability and, 1:277
 invasion and succession and, 3:1627
 mate or mating cues as triggers of, 1:277
 seasonal cues as triggers of, 1:277
 See also Biota and climate; Biota and soils; Biota and
 topography
Biotechnology and ecological risk, 1:278–279
 agricultural biotechnology and, 1:33–34
 applications of, 1:278
 ecological risk and, 1:279
 Farm-Scale Evaluations (U.K.) and, 1:279
 genetically modified organisms (GMOs) and, 1:278–279,
 3:1197–1199
 geography and holism and, 1:279
 GMO crops, ecological risk of, 1:279
 GMO crops, first and second generation and, 1:278
 herbicide tolerant (HT) “super weeds” and, 1:279
 plant “gene escape” issue and, 1:279
 recombinant DNA *vs.*, 1:278
 risk assessment *vs.* risk analysis” and, 1:278
 selective plant breeding example of, 1:278
 “super fish,” 1:278
 terminology, 1:278
Biotechnology industry, 1:280–282
 agricultural biotechnology and, 1:33–34
 definitions, 1:280
 district clustering of, 1:280–281, 1:281 (fig.)
 federal research funds and, 1:280
 government involvement in, 1:280
 industry statistics and, 1:280
 national science policies and, 1:280
 pharmaceutical firms and, 1:280
 research universities and scientists importance to, 1:281
 U.S. biotechnology centers and, 1:281 (fig.)
 venture capital importance in, 1:280
 See also Agricultural biotechnology
Biruni, 1:282–284, 1:282 (image)
 astronomical work of, 1:282
 chorography and physical geography work of, 1:283, 3:1461
 early education of, 1:282
 empirical science, experimental and comparative
 methods of, 1:282
 mathematical geography work of, 1:283
 publications of, 1:282–283
 theory of solar motion work of, 1:282
 Bivand, Roger, 5:2637
 Black, James Wallace, 4:2176
 Black Sea, 1:487–488
Blaikie, Piers, 1:284–285
 comparative environmental policy work of, 1:284
 India, Nepal, and Himalayas work of, 1:284
 political ecology (PE) work of, 1:284, 5:2213
 publications of, 1:284
Blaut, James, 1:285–286
 academic life of, 1:285
 colonialism work of, 1:285, 4:1862
 Eurocentrism work of, 1:285, 2:1030, 4:1862
 multi-disciplinary work of, 1:285
 publications of, 1:285
 social justice work of, 1:285
 spatial cognition of children work of, 1:285
Blindness and geography, 1:286–288
 acoustic production of space and, 1:286
 Reginald Golledge's work in, 1:286, 1:287 (photo)
 humanistic geography and, 1:286
 navigation aids for visually impaired and, 1:286–287
 navigation system for visually impaired, 1:287 (photo)
 nonvisual space negotiation and, 1:286
 policy implications, 1:286
 social experience of visually impaired in public spaces, 1:286
 spatial competence achievement and, 1:286
 Bliss, L. C., 1:249
 Bloch, Marc, 3:1090
 Bloom, George, 3:1449
 Bloomley, Nicholas, 4:1764
 Blumer, Herbert, 3:1625
 Blunt, Alison, 5:2325
 Boas, Franz, 5:2323
Body, geography of, 1:288–291
 behavioral geography and, 1:288
 blindness and geography and, 1:286–287
 Judith Butler's feminist geographies work and, 1:289
 disability geographies and, 2:757–759
 embodied geography and, 1:289
 empirical knowledge and, 1:290
 ethnomethodological account and, 1:289
 face-to-face interaction rituals and, 1:289
 feminist accounts and, 1:289
 Michel Foucault's work and, 1:289
 gender as socially constructed phenomenon and, 1:289
 gendering of space, social inequalities and, 1:289
 Erving Goffman's work and, 1:289
 humanistic geography and, 1:288

- knowledge production, situated knowledge and, 1:290
 Marxist geography and, 1:288
 methodology after performative turn and, 1:290
 mind-body dualism and, 1:288
 nonrepresentational theory and, 1:290
 “Othering” of the body and, 1:288
 performative turn of, 1:289–290
 poststructuralist account and, 1:289
 power and knowledge relationship and, 1:289
 theory of bodily mediated lifeworld and, 1:288
 time-geography and, 1:288
 traditional geographical view and, 1:288
 transparent reflexivity and, 1:290
 Yi-Fu Tuan’s work and, 1:288
- Bolivia**
 agrobiodiversity in, 1:50
 coca production in, 2:798
 deforestation in, 2:696
 economically active females in, 3:1190 (table)
 environmental privatization in, 4:2009
 Heavily Indebted Poor Countries initiative, and, 2:690
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
 Internet access in, 2:749
 silver trade and, 1:511
 tropical deciduous forest in, 1:230
 tropical scrub in, 1:245
 water privatization in, 5:2317
- Bondi, Liz, 2:892**
- Booth, Charles, 5:2565–2566**
- Borderlands, 1:291–292**
 common concerns of bordering populations and, 1:291
 cross-border cooperation and, 2:630–631
 degree of cross-border interaction and, 1:291–292
 globalization processes and, 1:292
 interaction and passage between political regions and, 1:291, 1:292
 La Paz Agreement (U.S. and Mexico) and, 1:291
 multispectral image of U.S.-Mexico border, California, 4:1955 (photo)
 superimposition of borders, ethnic societies and, 1:292
 Tijuana, Mexico, U.S. border, 1:291 (photo)
See also **Borders and boundaries**
- Borders and boundaries, 1:292–294**
 borderlands and, 1:291–292
 cross-border cooperation and, 2:630–631
 definitions, 1:292
 deterritorialization and reterritorialization and, 2:722–724
 deterritorialization and, 2:722–724, 3:1340–1341
 ecoregions, 2:855–856
 globalization, transnationalism factors and, 1:294, 3:1341–1342
 identity and power elements in, 1:292
 international wars and, 3:1341
 nationalism and, 4:1978–1981
 nation concept and, 4:1971–1974
 nation-state concept and, 1:293
 political borders and, 1:293
 restructuring and proliferation of, 1:294
 reterritorialization and, 2:722–724
 as social phenomenon, 1:293
 social relations *vs.* state borders and, 1:293
 South Korean demilitarized zone and, 1:293 (photo)
 as spaces of hybridity and synthesis, 1:294
 spatial perspective of, as one-dimensional lines, 1:293–294
 territorialization between human groups and, 1:292–293
See also **Borderlands**
- Bordieu, Pierre, 2:1043**
- Boserup, Ester, 1:49**
 agricultural intensification views of, 1:36
 agroforestry practices and, 1:62
Conditions of Agricultural Growth written by, 1:36
 world and regional population factors and, 5:2238
- Bosnia-Herzegovina**
 AGILE membership of, 1:124 (table)
 cultural annihilation in, 3:1200
 economically active females in, 3:1190 (table)
 Hajji Alija Mosque, Počitelj, 5:2406 (photo)
 hate groups in, 3:1407
 human rights violations in, 3:1480
- Boston, Massachusetts**
 “Big Dig” infrastructure construction in, 3:1595
 central business district of, 1:379
 high-tech economic geography and, 2:851, 2:885, 3:1426, 3:1598, 5:2435, 5:2436
 megapolis element of, 3:1355–1356
 musical instrument industry in, 4:1821
 rail hub in, 5:2358
- Botswana**
 economically active females in, 3:1190 (table)
 David Livingstone exploration of, 2:1057
- Boughassi, Carmina, 1:294–295**
 advanced chemical techniques developed by, 1:243
 Antarctica travels of, 1:242–243
 paleogeographies studied by, 1:243
 penguin seasonal migration patterns work of, 1:294
- Bourdieu, Pierre**
 built environment work of, 1:298–299
 classed capitals and classed habitus concepts and, 1:421–422
 classing of spaces and subjectivities work of, 1:421, 4:1786
 self-reflexivity qualitative method and, 5:2325
 structuration theory and, 3:1278
- Bowman, Isaiah, 1:295–296**
 American liberal internationalism and, 1:295
 Council of Foreign Relations co-founded by, 1:295, 3:1465
 ethnic minorities status and, 5:2222
 geopolitics influence of, 1:295–296, 3:1250, 3:1465, 4:1990, 5:2222, 5:2307
 Johns Hopkins and, 1:296, 3:1465
 Latin America and the Andes focus of, 1:295, 3:1465
 Paris Peace Conference and, 1:295, 5:2307
 political geography of natural resources and, 5:2222
 settlement geography views of, 5:2536
 United Nations work of, 1:296
 Derwent Whittlesey and, 6:3097–3098
- Boyden, Stephen, 3:1458**
- Boyle, Ray, 3:1283**
- Bracken, L. J., 3:1512**
- Braudel, Fernand, 1:79, 3:1090, 4:2070**
- Braun, Bruce, 2:831, 4:1993, 4:1997, 5:2339–2340**
- Brazil**
 agricultural landownership distribution in (2003), 4:1949 (figs.)
 agroforestry in, 1:57
 automobile industry in, 1:169
 biofuels produced in, 1:202
 Gilberto Câmara, GIScience and remote sensing work of, 1:319
 China-Brazil Earth Resources Satellites and, 1:319
 Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 deforestation in, 1:319, 2:696, 2:698
 drought prone region in, 2:787
 ecological footprint and biocapacity of, 2:827 (table)

- economically active females in, 3:1190 (table)
 El Niño-Southern Oscillation (ENSO) and, 2:889
 ethanol production in, 1:202
 extractive reserves in, 2:1072–1073
 forest fragmentation in, 3:1159
 gated communities in, 3:1181
 green building programs in, 3:1369
 greenhouse gas emissions and, 1:462, 1:463
 green tourmaline on quartz, 4:1909 (photo)
 hydroelectric power in, 3:1509, 3:1509 (fig.), 3:1510
 import substitution industrialism (IAI) in, 2:1064
 income distribution, percentile of world income in, 5:2641 (fig.)
 indigenous agroforestry in, 1:60
 industrialization in, 3:1583, 4:2020
 Itaipu-Binacional hydropower system in, 3:1510 (photo)
 land granting system in, 4:1949
 land inequalities in, 4:1693
 Landless Workers Movement (MST) demonstration, 4:1695 (photo)
 land use and cover change in, 4:1736
 market-based land reform in, 4:1695
 migrant family in Caluba, 4:1894 (photo)
 Movimento Sem Terra land reform in, 4:1948–1951
 multinational corporations investment in, 5:2220
 as newly industrializing country, 4:2023
 population growth in, 5:2241
 Portuguese colony in, 1:509, 1:512
 remote sensing imagery and, 1:319
 remote sensing software industry in, 1:319
 slave trade in, 1:511
 squatter settlements in, 5:2682, 5:2684
 state-funded infrastructure projects and, 3:1551
 steel industry in, 5:2689
 tree species in, 1:199
 tropical deciduous forest in, 1:230
 tropical rain forest deforestation in, 1:238
 tropical rain forest of, 1:234
 tropical savanna in, 1:239
 tropical scrub in, 1:244
 Turcurui-Tocantins Rivers hydroelectric dam in, 3:1509, 3:1509 (photo)
 World Social Forum and, 1:414–415
See also Amazon River, Amazonia
- Breland, T., 1:54
 Breton, André, 4:1768
 Brezhnev, Leonid, 2:594
- Britain
 Anglocentrism in, 2:1030 (table)
 Arab countries colonized by, 1:514
 Australia colonized by, 3:1222
 British Association for the Advancement of Science (BA), 3:1601
 British East India Company of, 1:510
 Cambridge electronics region in, 3:1127
 Chinese opium trade and, 1:515
 coal energy source in, 3:1582
 Colonial Development Act (1929) and, 3:1151
 colonial empire building by, 1:509, 1:509 (fig.), 1:510, 1:512, 2:667
 colonial superiority, 3:1221, 3:1222 (cartoon)
 common law and, 2:965
 East India Company and, 1:514
 English as God's chosen people concept and, 4:1979
 everyday lives of people studies in, 2:1045
 foreign aid from, 3:1151–1152
 greenbelts in, 3:1363–1364, 3:1365 (fig.)
- Greenwich Mean Time (GMT) and, 5:2363
 high-speed trains in, 5:2364
 hunger conceptual debates and, 3:1486
 imperial geographical imagination of, 3:1221–1222, 3:1222 (cartoon)
 India colonized by, 1:514, 3:1222
 industrialization in, 3:1583
 national geographical society in, 3:1462
 National Health Service in, 3:1413
 North American colonialization by, 1:512
 Pax Britannica and, 3:1584
 Portsmouth at three visualization scales and, 4:1834, 4:1835 (fig.)
 race-built ships of, 1:510
 railroads in, 5:2357
 railroad technology to India from, 2:747
 regional environmental planning in, 5:2385 (table)
 regional environmental planning policy in, 5:2384, 5:2385 (table), 5:2386
 retail park in Southampton, 4:1838 (fig.)
 solid waste collection in, 5:2373
 in southeast Asia, 1:515
 standard railroad time and, 5:2363
 Stonehenge, summer solstice, 5:2597 (photo), 5:2598
 textile industry in, 3:1583–1584
 trade with Portugal, comparative advantage of, 2:556, 2:557 (table)
 Viking exploration of, 2:1051
 wind turbines, Royd Moore, South Yorkshire, 6:3109
See also Institute of British Geographers (IBG)
- British Columbia
 community forests in, 2:550
 fjords in, 3:1121
 surveillance of operations in port of Vancouver, 6:2734 (photo)
 Vancouver Public Library architecture, 1:107
- Brokensha, David, 3:1557
 Brookfield, Harold, 2:713, 3:1458, 5:2213
 Brown, Lancelot, 4:1699
 Brown, Michael, 4:2136, 5:2539
 Brown, W. C., 4:1896
- Brownfields, 1:296–298**
 cities and suburbs location of, 1:296–297
 definition of, 1:296
 environmental planning and, 2:982
 landfills and, 4:1684–1686
 Love Canal and, 4:1808
 Menomonee River Valley, Milwaukee, Wisconsin, and, 1:297 (photo)
 redevelopment of, 1:297–298, 4:1700
 Superfund sites on National Priorities List (NPL) and, 1:297
- Brunei
 APEC membership of, 1:121
 ASEAN membership of, 1:128 (table), 1:129 (table)
- Bruner, Jerome, 1:391
 Bruno, Giuliana, 4:1876
 Bruno, John, 4:1658
 Brunsdon, C., 3:1226
 Bruun, Per, 1:494
 Brzezinski, Zbigniew, 3:1251
 Buber, Martin, 2:1046
 Bucek, Milan, 4:2109
 Buchanan, James, 5:2215
 Budds, Jessica, 4:1996
 Budyko, M., 1:432–433
 Buenos Aires, Argentina, 5:2291 (photo)

Built environment, 1:298–300

- GHG emissions of, 3:1375–1376
- government regulation of, 1:298
- grounded capital and, 5:2639–2640
- historic preservation and, 3:1435
- Hong Kong example of, 1:299 (photo)
- interdisciplinary element of, 1:298
- landscape architecture history and, 4:1699
- society and culture reflected by, 1:298–300
- spatial fix and, 5:2639–2640

Bulgaria

- COMECON membership of, 2:593 (table)
- economically active females in, 3:1190 (table)
- European Union (EU) membership of, 2:1035
- international outsourcing between Western Europe and, 4:2109 (fig.)

Bullard, Robert, 2:986**Bunge, William, 1:300–301**

- Brian Berry and, 1:192
- children's health and survival focus of, 1:300
- countermapping used by, 2:595, 3:1645
- Detroit Geographical Expedition urban fieldwork of, 1:300, 4:1862, 5:2350
- early years of, 1:300
- Fitzgerald* written by, 1:118, 1:300
- mapping never-before-shown variables, 1:300, 2:595
- Nuclear War Atlas* written by, 1:300
- as quantitative and scientific geographer, 1:300, 3:1466
- radical geography and, 1:300, 3:1466, 3:1645, 5:2350
- regional geography and literature work of, 1:118, 1:300, 5:2238

Bunsen, Robert, 3:1542**Burgess, Ernest, 1:386, 1:387–388, 1:387 (fig.), 3:1112, 3:1449, 4:1728, 5:2323****Burkina Faso**

- economically active females in, 3:1190 (table)
- poverty rates in, 5:2274

Burma

- British colonization of, 1:515, 1:516
- colonization of, 1:516
- drug culture in, 2:799
- nation-state after colonialism in, 1:517
- opium and heroin production in, 2:797

Burundi

- economically active females in, 3:1190 (table)
- undernourishment in, 3:1487

Bush, Vannevar, 6:2740–2741**Bush fallow farming, 1:301–302**

- agricultural goals of, 1:301
- criticism of, 1:301–302
- crop diversity and, 1:301
- as ecologically sound agroforestry, 1:302
- geographic locations of practice, 1:301
- land rotation between different uses and, 1:301
- shifting cultivation and, 1:301
- soil nutrients replenished by, 1:302
- swidden/slash-and-burn cultivation and, 1:301–302, 2:696
- tropical forest biodiversity threatened by, 1:301–302
- varieties of methods of, 1:301

Business cycles and geography, 1:302–305

- business services element in, 1:304
- capitalism instability and, 1:302
- communication technology element in, 1:303
- “creative destruction,” 1:303
- factors affecting location of firms and, 3:1077–1080
- Industrial Revolution and, 1:303, 3:1581–1586

information technology and, 1:303**innovation geographies and, 3:1597–1599****Kondratiev waves and, 1:302, 1:303–304****Simon Kuznets' work in, 1:303****regulation theory and, 5:2399–2402****Joseph Schumpeter's work in, 1:303****spatial division of labor and, 1:304*****Spatial Divisions of Labor* (Massey) and, 1:304****uneven development in space and, 1:304*****See also* Crisis (economic); Kondratiev waves, business cycles****Business geography, 1:305–306****in academia, 1:305–306****business decisions enhanced by, 1:305****business models for geographic information systems and, 1:306–308****Certified Commercial Investment Manager academic program and, 1:305****cost-benefit analysis used in, 2:592–593****distance-decay retail consumer demand interactions and, 1:305****e-commerce and, 2:844–846****factors affecting location of firms and, 3:1077–1080****future of, 1:306****geodemographics and, 3:1215–1217****geographic management systems technology and, 1:305****geospatial technologies and, 1:305****location analysis methods and, 1:305****qualitative elements of, 1:305****real estate geographies and, 5:2367–2369****spatial management objectives element of, 1:305****spatial tracking of products and, 1:305****undergraduate degree program model in, 1:306****Business models for geographic information systems****(GIS), 1:306–308****applications of, 1:306–307****business strategy and, 1:308****cost-benefit analysis used in, 2:592–593****databases element of, 1:308****decision support systems (DSSs) and, 1:307****distributed computing and, 2:774–776****Enterprise GIS, 2:911–913****Enterprise Resource Planning (ERP) system and, 1:307****GIS-IT business alignment model and, 1:308****management models of, 1:308****managing spatial data and, 1:308****models of, examples, 1:307****spatial decision support system (SDSS) and, 1:307****Web and mobile spatial applications of, 1:307****Butler, Judith, 1:289, 3:1192, 3:1529, 4:2042****Buttimer, Anne, 1:308–309****academic career of, 1:308*****genres de vie* life worlds, 1:309, 3:1476****Törsten Hägerstrand's collaboration with, 3:1398****phenomenology views of, 4:2167****philosophy of geography views of, 1:309****professional positions held by, 1:308–309****qualitative methods and, 5:2324****recentering the human subject views of, 2:1046****research themes of, 1:309****social and humanist geography work of, 1:308–309, 2:1046, 3:1476, 4:1786, 4:2167****social justice work of, 1:309****sustainable development work of, 1:308–309****time-space rhythms and, 6:2836*****Values in Geography* written by, 4:2167****Butzer, Karl, 2:633**

- CA. *See* Cellular automata (CA)
- Cabot, John and Sebastian, 4:2179
- Cadastral systems, 1:311–318**
- cadastre* (parcel), in land administration and, 1:311, 1:312 (fig. 2)
 - cellular automata use and, 1:370
 - construction of a cadastral mapping, 1:312 (fig)
 - digitizing and, 2:757
 - Doomsday Book of William the Conqueror and, 1:313
 - early Italian cadastral map and, 1:314 (fig.)
 - equity issues and, 1:316–317
 - exploration, colonialism and, 1:313–314
 - geodetic surveying profession and, 1:311
 - history of, 1:312–314, 1:314 (fig.)
 - importance and societal benefits of, 1:314–316
 - land tenure issues and, 1:316
 - large scale characteristic of, 1:311, 1:313 (fig.)
 - legal basis of land ownership and, 1:311, 1:316
 - 19th-century European cadastral map, Pielnia, Poland, 1:315 (fig.)
 - “poll tax,” “head tax” and, 1:312
 - Public Land Survey System (PLSS) and, 1:311
 - real property description formats and, 1:311
 - reform issues and, 1:316
 - Roman Empire, 1:341
 - technology advances and, 1:316–317
 - three dimensions of land rights cadastral map, 1:316, 1:317 (fig.)
 - utilities management and, 3:1315–1316
 - written land registry and surveyed parcel map elements in, 1:311, 1:312 (fig. 1)
- CAD systems, 1:318–319**
- geospatial information exchange and, 1:318
 - terms related to, 1:318–319
 - topographic modeling and, 1:318
 - uses of, 1:318
 - vector-based GIS and, 1:318
- CAG. *See* Canadian Association of Geographers (CAG)
- Cairo, Egypt, and particulate matter pollution, 1:151
- California
- agglomeration economies in, 1:32
 - agroforestry in, 1:57
 - ASTER image of Old Fire/Grand Prix Fire Complex, San Bernardino mountains, 5:2321 (image)
 - Bodie State Historic Park cultural landscape example, 4:1705
 - California-Arizona border flood (2008), 3:1135
 - California Environmental Quality Act (CEQA), 4:1746
 - California Integrated Waste Management Board report, 2:986–987
 - cancer-oriented migrant studies and, 1:335
 - Coastal Protection Act (1972) controversy and, 4:1746
 - coastline landforms of, 4:1689
 - community garden planning, Echo Park area of Los Angeles, 2:548 (photo)
 - Death Valley in, 3:1549
 - Del Mar, digital ortho quarter quad of, 1:21 (photo)
 - desert varnish, Death Valley, 2:722 (photo)
 - drug use in, 2:798
 - electricity crisis of 1999–2001 in, 2:901
 - Endangered Species Act (1973) and, 4:1746
 - energy feed-in tariffs (FIT) in, 2:901
 - first landfill in Fresno, 4:1684
 - flow map of migration (1995–2000) from, 3:1139 (figs.)
 - genetically engineered organism issues in, 1:33
 - geological and seismic velocity model of Santa Clara Valley area, 6:2824 (fig.)
 - glaciers in, 3:1333
 - Grass Valley/Slide Fire near Lake Arrowhead/Running Springs, San Bernardino mountains, 6:2820 (photo)
 - greenhouse gas emissions and, 1:463
 - immigration studies of (W. Clark) and, 1:418
 - katabatic winds, Santa Ana winds, 1:135
 - Loma Prieta earthquake, October 17, 1989, 2:812 (fig.)
 - Loma Prieta earthquake (landslide), October 17, 1989, 4:1722 (photo)
 - Long Valley Caldera (volcano) in, 4:1688
 - Los Angeles River and, 5:2476
 - Los Angeles smog and, 1:69
 - Mammoth Pacific geothermal plant, Sierra Nevadas, 5:2429 (photo)
 - mineral deposits, mining in, 4:1911
 - multispectral image of Death Valley in, 4:1954 (photo)
 - multispectral image of U.S.-Mexico border, 4:1955 (photo)
 - new urbanism, Laguna West, Sacramento County, 4:2026–2027, 4:2026 (photo)
 - oil industry in, 4:1822
 - organic farm in San Juan Bautista, 4:2095 (photo)
 - particulate matter pollution in, 1:151
 - polluted groundwater supplies in, 2:742
 - Premier Gardens Zero Energy Home Community, Sacramento, 5:2550 (photo)
 - Redwood National Park forest restoration in, 3:1167–1168
 - risk assessment map for Whiskeytown Fire, Redding, 2008, 6:3101 (fig.)
 - San Andreas fault zone in, 1:186, 2:605, 3:1087
 - San Francisco earthquake (1906) and, 3:1087
 - Spanish colonialism in, 1:512
 - sustainable aquifer management in, 3:1389
 - teamsters NAFTA protest, San Diego, 4:2045 (photo)
 - transform plate boundaries in, 5:2198
 - tree species in, 1:199
 - trough blowouts, foredune system, Guadalupe, 6:3112 (photo)
 - two-layered biomantle, Carmel and, 1:268 (fig.)
 - University of California, Berkeley, 4:1660 (photo)
 - urban sprawl, San Gabriel mountains, Los Angeles County, 6:2989 (photo)
 - urban sprawl of San Jose, 6:2988 (photo)
 - wildfires, Southern California, 2007, 6:2037 (photo)
 - zoning districts in San Leandro, 6:3149 (fig.)
- See also* Los Angeles, California; San Francisco, California; Silicon Valley, California
- Callicott, J. Baird, 2:925
- Callon, Michael, 1:8
- Câmara, Gilberto, 1:319**
- China-Brazil Earth Resources Satellites and, 1:319
 - National Institute for Space Research work of, 1:319
 - open access to geospatial data and software work of, 1:319
 - real-time monitoring of deforestation of Brazilian Amazon rain forest, 1:319
 - SPRING, a free GIS developed by, 1:319
 - TerraLib, open-source GIS library developed by, 1:319
- Cambodia
- ASEAN membership of, 1:128 (table), 1:129 (table)
 - Cold War and, 1:504
 - counterurbanization in, 2:543
 - deforestation in, 2:696
 - economically active females in, 3:1190 (table)
 - French colonization of, 1:515
 - HIV/AIDS in, 3:1438
 - human rights violations in, 3:1480
 - income ratio relative to slum population in, 2006, 5:2644 (fig.)

- Khmer Rouge destruction of space in, 3:1201–1202
 Vietnam incursion in, 1:130
- Cameroon
 economically active females in, 3:1190 (table)
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
 Campbell, Lisa, 1:526
- Camus, Albert, 2:1046
- Canada
 Aboriginal people in urban spaces and, 5:2337
 acid rain in, 1:7
 APEC membership of, 1:121
 Arctic archipelago, 1:105
 Arctic bird species and, 1:199
 automobile industry in, 1:169, 1:170
 automobility in, 1:172
 boreal forest in, 1:216 (photo)
 branch plant economy in, 4:1822
 as British Empire colony, 1:509
 Burgess Shale, Canadian Rocky Mountains in, 1:14
 business geography university departments in, 1:305
 Canada Geographic Information System (CGIS), 3:1282, 3:1302, 5:2454
 Canada Land Inventory project, 1963–1995 and, 5:2454
 Canadian Association of Geographers (CAG) and, 1:319–320, 3:1464
 Canadian Society of Landscape Architects and, 4:1699
 carbon or climate change taxes in, 4:1857
 carbon trading market in, 1:330
 chinook conditions, Saskatchewan, 1:395 (fig.)
 communal fishing lands, James Bay Amerindian community in, 1:534
 community forests in, British Columbia, 2:550
 critical human geography in, 2:620
 deposit refund systems in, 4:1857
 drug substitution programs in, 2:799
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 environmental management example, Great Whale River Hydro-Electric Project, Quebec, 2:969–970
 foreign aid flow from, 3:1152
 forest degradation in, 3:1157 (fig.), 3:1158
 genetically modified organisms, crops and, 1:279
 glacial geology studies of, 1:81
 green building programs in, 3:1364, 3:1371
 Hudson Bay Company in, 1:512
 humid continental climate of, 1:439, 1:440
 indigenous reserves, reservations in, 3:1570–1572
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Internet access in, 2:845
 lowland tundra terrain, Southern Banks Island, Arctic Canada, 4:2148 (photo)
 Mackenzie Delta periglacial region, northwestern Arctic Canada, 4:2149 (photo)
 manufacturing regional areas in, 4:1821
 musical content regulation in, 4:1968–1969
 musk ox faunal relict in, 1:470
 NAFTA and, 1:121, 1:129, 4:2044–2046
 National Standard on Sustainable Forest Management and, 2:915
 NATO membership of, 4:2048 (fig.)
 nuclear reactors in, 4:2052
 oil production in, 4:2099
 peat fires in, 1:216 (photo)
 permafrost in, 1:215
 polar desert of, 1:451
 political map of, 6:3163
 public-private partnerships in, 5:2312
 Public Safety Canada disaster preparedness in, 2:763
 recombinant bovine growth hormone, milk issues and, 3:1198
 redistricting in, 5:2376–2377
 resource geographies in, 5:2447–2449
 shrub tundra of, 1:248
 subarctic climate in, 1:441
 surveillance of operations in port of Vancouver, 6:2734 (photo)
 Trail Smelter Case, sulfur dioxide pollution and, 2:967
 tundra vegetation in, 1:248 (table)
 undernourishment in, 3:1488
 university business geography programs in, 1:306
 urbanized area definition in, 5:2239
 U.S./Canada borderlands, 1:292
 Vancouver Public Library architecture, 1:107
 wet tundra of, 1:249
- Canadian Association of Geographers (CAG), 1:319–320**
 formation of, 1:319–320
 meetings of, 1:320
 mission of, 1:319
 publications of, 1:320
 regional divisions of, 1:320
 study groups of, 1:320
 university, public, and private membership in, 1:319
See also Association of American Geographers (AAG)
- Canadian Society of Landscape Architects, 4:1699
- Canary Islands
 invasion of species in, 3:1473
 Phoenicians exploration of, 2:1051
- Cancer, geography of, 1:320–324**
 breast cancer and environmental links research, 2:615
Cancer Incidence in Five Continents (Int'l. Agency for Research on Cancer) and, 1:321–322
 cancer maps and, 1:320–321
 examples of, 1:321–323
 female breast cancer, Long Island, 3:1193
 female breast cancer, Michigan, 1:322, 1:324 (figs.)
 female breast cancer incidence rates, Nordic countries, 1:322 (fig.)
 Törsten Hägerstrand's space-time mobility paths and, 1:321
 latency periods, individual mobility and, 1:321
 measures and rates of, 1:321
 modifiable areal unit problem (MAUP) issue and, 1:321
 spatial analysis of, 1:321
 spatial analytic algorithms used and, 1:321
 spatial regression analysis and, 1:321
 spatial resolution of the data issue and, 1:321
 temporal development, female breast cancer incidence rates, Nordic countries, 1:323 (fig.)
See also Carcinogens
- Cape Verde
 economically active females in, 3:1190 (table)
- Carbonation, 1:325**
 calcium carbonate formation, formula and, 1:325
 carbonic acid formation, formula and, 1:325
 caverns formation and, 1:366–368, 1:367 (photo)
 caves and caverns formation and, 1:325
 karst topography and, 4:1649–1654
 ocean water and, 1:325, 1:327–328
 rock weathering and, 1:325, 1:326–327
 speleotherms formation and, 1:325
 stalactites and stalagmites formation and, 1:325
 travertine calcium carbonate formation and, 1:325
- Carbon cycle, 1:325–329**
 abiotic component of, 1:206

- agriculture impact on, 2:938, 2:939
 atmosphere, 1:326 (table), 1:328
 atmosphere, hydrosphere, lithosphere and biota linked by, 1:325–326
 biologic pump concept and, 1:328
 biota and, 1:326
 boreal forest biome and, 1:214, 1:215
 carbon building blocks of life and, 1:206
 carbon pools in modern Earth, 1:326 (table)
 forest land use and, 3:1164
 fossil fuels, climate instability and, 1:206, 2:601
 global level of spatial scale and, 2:863–864
 global oxygen cycle and, 1:205–206
 greenhouse effect and, 1:326, 1:327
 human emissions factor in, 1:206, 2:601
 hydrologic cycle and, 1:205–206
 land use and cover change impact on, 4:1736
 lithosphere, 1:326–327, 1:326 (table)
 major fluxes in, 1:326, 1:327 (table)
 manufacturing and, 2:945
 nitrogen cycle and, 4:2028–2029
 oceans and, 1:206, 1:327–328
 oil fields and, 2:947
 peat and, 4:2142–2143
 permafrost degradation and, 4:2156
 photosynthesis and, 1:326, 1:327 (table)
 respiration and, 1:206
 rock weathering and, 1:325, 1:326–327
 sustainable forestry and, 6:2759
 Urey reaction and, 1:327
 Venus, Earth, and Mars, carbon in atmospheres of, 1:326
 volcanic activity and, 1:327, 1:328
See also Carbonation; Greenhouse gases (GHGs)
Carbon trading and carbon offsets, 1:329–335
 allowance-based *vs.* project-based markets and, 1:330
 cap” on total emissions and, 1:330
 carbon markets, trading volume and value, 1:329, 1:332 (table)
 carbon markets and emissions trading, critiques of, 1:332, 1:334–335
 carbon offsets growth projections, 1:333 (fig.)
 carbon tax issue and, 1:334–335
 carbon trading under International Climate Regime and, 1:330, 1:332, 1:333 (fig.)
 Clean Air Act (CAA, U.S.) and, 1:330
 climate policy and, 1:462–464
 current carbon markets and, 1:330, 1:332
 definitions, 1:329
 environmental markets for, 4:2009
 European Union’s Emissions Trading Scheme and, 1:330, 1:331 (table), 1:334
 grandfathering of allowances issue and, 1:334
 greenhouse gas emissions and, 1:329, 1:330, 1:334
 Kyoto Protocol and, 1:330, 1:332, 1:333 (fig.), 2:900, 4:1857
 luxury *vs.* survival emissions issue and, 1:334
 optimal pollution level concept and, 1:329–330
 privatization of “atmospheric sink” issue and, 1:332, 1:334
 social and political contexts, 1:334
 social costs of economic activity and, 1:329–330
 theoretical foundations of carbon trading and, 1:329–330
 voluntary markets and, 1:330
See also Climate policy; Greenhouse gases (GHGs)
Carcinogens, 1:335–337
 cancer cluster investigations and, 1:336
 cancer geography and, 1:320–324
 definitions, 1:335
 immigrant studies and, 1:335–336
 lists of, 1:335
 reliable data in studies of, 1:336
 Cardoso, Fernando, 2:713
Caribbean islands
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
 British Empire colonies in, 1:514
 coca cultivation in, 2:797
 Cold War and, 1:504
 colonial powers in, 1:512
 HIV/AIDS in, 3:1438
 land inequalities in, 4:1693
 military expenditures in, 4:1899 (table)
 neoliberalist policies in, 4:2012
 plantations in, 5:2192
 political map of, 6:3162
 population growth of, 5:2233 (fig.)
 poverty rates in, 5:2275
 slave trade in, 1:511–512
 tropical deciduous forest in, 1:230
 tropical rain forest of, 1:234
 undernourishment in, 3:1488, 3:1488 (table)
 Carlowitz, Hans Carl von, 6:2737
 Carney, Judith, 3:1100
 Carpenter, Steve, 5:2439
Carrying capacity, 1:337
 British colonialism, African populations and, 1:337
 definition of, 1:337
 human populations and, 1:337, 5:2238–2239
 laboratory experiments, 1:337
 living organisms and natural systems and, 1:337
 tourism industry, 2:955
 Pierre-François Verhulst’s logistic equation and, 1:337
 Carson, Rachel
 conservation efforts of, 2:570
 endangered marine environment and, 4:2068
 environmental ethics work of, 2:925, 6:2743
Silent Spring written by, 2:831, 2:934–935, 2:980–981, 4:2158, 6:2743
 sustainable agriculture and, 6:2743
 Cartier, Jacques, 4:2179
Cartograms, 1:338–339
 area estimation difficulty in, 1:339
 continuous *vs.* noncontiguous cartograms, 1:338–339
 explanation of, 1:338
 linear or distance cartograms, 1:338
 thematic variable distribution factor in, 1:339
 Waldo Tobler, computer program production of, 1:338
 2004 presidential election cartogram map, 2:880, 2:880 (fig.)
 value-by-area cartogram, 1:338, 1:338 (fig.)
Cartography, 1:339–345
 Age of Exploration maps, 1:342
 ancient and indigenous civilization maps and, 1:341
 animated maps, 1:344
 art component of, 1:339
 cartograms and, 1:338–339
 cartographer definition and, 1:339
 cartographic ethics and, 1:344
 cartographic or mapmaking process and, 1:342–343
 categories of maps and map uses and, 1:339–340
 choropleth map, 1:343
 cognition and perception skills in, 1:339, 1:343
 color in map design and, 1:516–522
 countermapping and, 2:595–596

- data representation or symbolism and, 1:343
- decision-making process assistance and, 1:340
- definition of, 1:339
- digital maps and GPS technology and, 1:344
- dot maps and, 2:787–790
- dynamic and interactive displays and, 2:804–808
- Earth's circumference estimation and, 1:341
- electronic atlases and, 2:884
- equivalent *vs.* conformal *vs.* equidistant map projection and, 1:342
- flow maps and, 3:1138–1139
- geodesy and, 3:1217–1219
- Geographia* (Ptolemy) and, 1:341
- geographic change over time and, 1:340
- geometric measures and, 3:1240–1241
- geovisualization and, 1:344
- Good's Interrupted Homolosine projection and, 3:1351, 3:1351 (fig.)
- graduated or proportional symbol map, 1:343
- Greek and Roman Empire maps and, 1:341–342
- How Maps Work* (MacEachren) and, 4:1811
- indigenous cartographies and, 3:1561–564
- interactive maps, 1:344
- isopleth maps and, 3:1638–1639
- latitude and longitude coordinate system and, 1:342
- Look of Maps* (Robinson) and, 1:343
- map generalization and, 4:1835–1841
- map scale, generalization, coordinate systems, and map projections and, 1:342
- Middle Ages maps, 1:341–342
- modern cartography and, 1:344
- multivariate mapping and, 4:1963–1967
- navigation or wayfinding purposes of, 1:339
- Ortelius's Map of Palestine and the Holy Lands, 1:341 (fig.)
- Peutinger Table, Roman road network map, 1:341
- privacy issues and, 1:344
- reference map classification, 1:340, 1:340 (fig.)
- Renaissance maps, 1:342
- representations of space and, 5:2432–2433
- resources management and, 1:340
- science component of, 1:339
- social, cultural, and ethical aspects of, 1:344
- statistical maps, 1:340
- technology advances in, 1:343–344
- thematic map classification, 1:340, 1:340 (fig.)
- 3D and virtual reality map displays, 1:344
- T-O maps, 1:341–342, 1:349
- trap streets and, 6:2877
- trends or patterns display and, 1:340
- university programs of, 1:342
- user feedback maps and, 1:343
- visual variables and, 1:343
- Web-based maps and, 1:344, 1:359
- Western cartography history and, 1:340–342
- See also* Cartography: noted individuals; **Cartography, history of**; **Environmental mapping**; **Map design**; **Map projections**; **Map visualization**; **Political maps**; **United States: maps**; **World maps**
- Cartography: noted individuals
 - al-Idrisi's world map, 1:66–67, 1:350, 1:351 (fig.), 3:1461
 - Balbi and Guerry, 1:355
 - Chimborazo, 1:355
 - Dud Dudley, 1:355
 - Eratosthenes, 1:341
 - Edmond Halley, 1:355, 1:357 (fig.)
 - Brian Harley, 3:1401–1402
 - Jodocus Hondius, 1:342
 - Alexander von Humboldt, 1:355
 - Gerardus Mercator, 1:342, 1:350, 1:353 (fig.), 3:1461, 4:1883–1885
 - Mark Monmonier, 4:1938–1938
 - Ortelius, 4:2104–2106
 - Abraham Ortelius, 1:341 (fig.), 1:342, 1:350
 - Prince Henry the Navigator, 1:342
 - Claudius Ptolemy, 1:341, 1:347, 1:348 (fig.), 1:350, 5:2300, 5:2387
 - Erwin Raisz, 5:2364–2365
 - Arthur Robinson, 1:343, 4:1844, 4:1845 (fig.), 5:2364
 - John Snow, 1:355
 - Bradford Washburn, 1:356 (fig.)
 - Edward Wright, 1:350, 1:353 (fig.)
- Cartography, history of, 1:345–364**
 - Anaximander's work and, 1:74–75
 - base map of, satellite image, Ukraine, 1:360, 1:360 (fig.)
 - Book of Roger* (al-Idrisi) and, 1:350
 - cadastral systems and, 1:311–318
 - celestial map, 1:346, 1:346 (fig.)
 - climatic, biotic, and sociocultural environment mapping and, 1:355
 - cognitive maps, 1:346
 - Christopher Columbus and, 1:74–75, 4:2179
 - community infrastructure organization function and, 1:346
 - contour lines and, 1:350, 1:356 (fig.)
 - cosmological maps, 1:346–347
 - cuneiform writing on clay tablets, 1:346, 1:347 (fig.)
 - cyberspace mapping concept and, 2:540
 - Digital Chart of the World and, 1:362
 - digital databases and, 1:362
 - digital elevation model (DEM) base and, 1:350
 - dual functions of maps and, 1:345–346
 - engraving and printing, painting reproduction, 1:359, 1:360 (fig.)
 - environmental management function of, 1:346, 1:350, 1:359
 - environmental sustainability function and, 1:362, 1:364
 - Eratosthenes and, 2:1010–1011
 - GIS in environmental management and, 1:364
 - Good's Interrupted Homolosine projection and, 3:1351, 3:1351 (fig.)
 - GPS mapping systems and, 1:362
 - graphic design and communication and, 1:362, 1:363 (fig.)
 - hachures technique and, 1:354, 1:354 (fig.)
 - Brian Harley and, 3:1401–1402
 - Hipparchus and, 3:1428
 - indigenous cartographies and, 3:1561–564
 - Islamic geographers and, 1:350
 - isobaths lines and, 1:354, 1:355 (fig.)
 - map visualization and, 1:350
 - Mediterranean Sea navigation and, 1:350
 - Mercator projection map, 1:342, 1:350, 1:353 (fig.), 4:1843, 4:1843 (fig.), 4:1883–1885, 6:3168
 - in 19th and 20th centuries, 1:357, 1:359, 1:362
 - Ordnance Survey map, 1:354, 1:354 (fig.)
 - Ortelius and, 4:2104–2106
 - portolan chart, Mediterranean and North Atlantic navigation, 1:350, 1:352 (fig.)
 - portolan charts and, 5:2251–2252
 - printing, commercialization, and democratization of maps and, 1:350
 - Erwin Raisz and, 5:2364–2365
 - symbolization of data and map design and, 1:359, 1:362, 1:362 (fig.), 1:363 (fig.)

- terrain elevation measurement methods and, 1:354, 1:355 (fig.)
 textbook development and, 1:359
Theatrum Orbis Terrarum (Ortelius) and, 1:350
 timeline of prehistoric and ancient origins, 1:346–347
 timeline of medieval and Renaissance cartography, 1:347, 1:350
 timeline of national topographic mapping, 1:350, 1:353–354 (figs.), 1:354, 1:362
 timeline of thematic maps, 1:342, 1:354–357
 timeline of 21st century, 1:362, 1:364
 T-in-O maps, 1:341–342, 1:347, 1:349 (fig.), 3:1461, 6:2845 (fig.)
 tint screens, “graphic middle ground” symbols, 1:363 (fig.)
 topographic mapping, 1:350, 1:353–354 (figs.), 1:354, 1:356 (fig.)
 topographic mapping, Mount Everest, 1:356 (fig.)
 in the 21st century, 1:362, 1:364
 U.S. Census decennial maps, 1:358 (fig.)
 wayfinding function of, 1:345
 Web-based mapping services and, 1:344, 1:359
 World Geodetic System, 1:362
See also Cartography; Map projections
- Case, Robbie, 1:391
- Casey, Edward, 2:892, 4:2168
- Caspian Sea, 1:115
- Castells, Manuel, 1:364–366**
 books written by, 1:365–366
 cross-cultural theory of urban social change and, 1:365
 empirical research of, 1:365–366
 global socioeconomic transformations work of, 1:364–365
 informal economy studied by, 3:1591
 information technology and, 1:365, 5:2670
 Henri Lefebvre and, 4:1769
 Marxist theory work of, 1:365, 1:366, 5:2670, 5:2706–2707, 5:2707 (table)
 space of flows and, 5:2600–2601, 5:2670
 talents and interests of, 1:364–365
 technology as force of social change views of, 1:365
 urban politics, planning, and policy work of, 1:365
Urban Question written by, 4:1769
- Castoriadis, Cornelius, 4:2144
- Caucasus Mountains, avalanche, 1:177 (photo)
- Caverns, 1:366–368**
 carbonation and, 1:325
 Carlsbad Caverns and, 1:368
 Cave of Crystals, Chihuahua, Mexico, 1:368
 host rock materials and, 1:366–367
 hydrogen sulfide gas process and, 1:368
 karst topography and, 4:1649–1654
 locations and sizes of, 1:368
 Mammoth Cave limestone cavern, Kentucky, 1:367, 1:367 (photo)
 solution type caverns, 1:366–367
 speleogenesis process and, 1:367–368
 speleotherms and, 1:368
 water tables and, 1:367
- Caves. *See* Caverns
- CBA. *See* Cost-benefit analysis (CBA)
- CBC. *See* Cross-border cooperation (CBC)
- CBNRM. *See* Community-based natural resource management (CBNRM)
- Cellular automata (CA), 1:368–371**
 agent-based models *vs.*, 1:29
 complexity theory and, 2:559–561
 complex systems models and, 2:566–567
 definition and explanation of, 1:368
 geocomputation examples of, 3:1215
 geographic applications of, 1:370
 geography and, 1:370
 geometrically fixed neighborhoods viewed by, 1:29
 GIS and, 1:370, 3:1313
 history and development of, 1:369
 land use and cover change models and, 4:1738
 land use change over time, 1:371 (fig.)
 mathematical formalism of, 1:369–370
 model calibration and validation procedures in, 1:370
 MOLAND (Monitoring Land Cover/Use Dynamics) project in Europe and, 3:1313
 neighborhoods types used in procedures of, 1:369, 1:369 (fig.)
 transition rules element in, 1:369–370, 3:1215
- Census, 1:371–373**
 American Community Survey (ACS) and, 1:372, 1:373 (table)
 Census 2000 and, 1:372
 Census 2010 and, 1:372
 census tracts and, 1:374, 2:669 (fig.)
 data security and, 1:372
 Decennial Census of Population and Housing (U.S. Census Bureau) and, 1:371–373
 definition of, 1:371
 economic census and, 1:372
 federal funds distribution and, 1:373
 geographic databases and GIS software and, 1:372
 population density by census tract and block group, Guilford County, North Carolina, 2:669 (fig.)
 preparations for, 1:372
 survey *vs.*, 1:371
 technology advances and, 1:372
 Topologically Integrated Geographic Encoding and Referencing—automated mapping database and, 1:372
- Census tracts, 1:374**
 changes in tract geography and, 1:374
 demographic changes tracking and, 1:374
 development and growth of, 1:374
 geography of disease mapping and, 2:772
 neighborhoods concept and, 4:1998
 redefinitions of (1960, 2010) and, 1:374
See also Census
- Center for Earth System Analysis Research (CESAR), San Diego State University, 1:24 (photo)
- Centers of domestication, 1:374–378**
 Amazon basin, 1:377, 1:377 (photo)
 animal domestication and, 1:376
 crop domestication areas and, 1:374–375, 1:375 (photo)
 cultural landscapes concept (Sauer) and, 1:376, 3:1465
 dog as oldest domesticated animal and, 1:376
 domestication of animals and, 2:781–783
 domestication of plants and, 2:784–786
 explanation of, 1:374
 Fertile Crescent crops and animals, 1:375, 1:376
 in situ and adjacent domestication of camu camu trees, 1:377, 1:377 (photo)
 natural fires and, 1:376
 natural mutations and, 1:376
 predomestication cultivation and, 1:375–376
 seed dispersal mechanisms and, 1:376
 village-based agricultural economies and, 1:375
- Central Africa
 Bantu or Niger-Kordofanian languages in, 4:1751
 malaria in, 4:1816

- Central African Republic
 economically active females in, 3:1190 (table)
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
- Central America
 agroforestry in, 1:57
 bush fallow farming practiced in, 1:301–302
 as center of crop domestication, 1:376
 Central American Common Market (CACM) and, 3:1550–1551
 colonial migrations of, 1500–1914, 3:1543
 deforestation in, 2:696
 domino theory and, 2:787, 3:1224
 forest fragmentation in, 3:1159
 geothermal energy use in, 3:1267 (fig.), 3:1269
 midlatitude grasslands in, 1:228 (fig.), 1:229
 military expenditures in, 4:1899 (table)
 plantation model in, 3:1362
 political map of, 6:3164
 slash-and-burn preindustrial agriculture in, 1:48
 tropical deciduous forest in, 1:230
 tropical monsoon climate in, 1:455
 tropical rain forest of, 1:234
 tropical scrub in, 1:244
 undernourishment in, 3:1488
- Central Asia
 Aral Sea water diversion issue and, 2:939
 ecological footprint and biocapacity of, 2:827 (table)
 glaciers in, 3:1332–1333
 HIV/AIDS in, 3:1438
 military expenditures in, 4:1899 (table)
 mineral deposits, mining in, 4:1911
 people living in extreme poverty and, 3:1082 (table)
 Silk road and, 2:1053
- Central business district (CBD), 1:378–380
 agglomeration economics of, transportation
 factor and, 1:378–379
 American *vs.* European CBDs and, 1:378
 definition of, 1:378
 Salt Lake City, Utah, 1:378 (photo)
 specialized business services and, 1:379
 suburbanization and, 1:379
 technology advances and, 1:379
- Central place theory, 1:380–382
Central Places in Southern Germany (Christaller) and, 1:380, 4:1798
 Walter Christaller's development of, 1:409–410,
 4:1798, 5:2329, 5:2393, 6:3008
 as city systems model, 1:380
 development theory and, 2:730
 formation of financial centers and, 3:1116, 3:1117
 geographies of consumption and, 2:575
 limitations of, 1:382
 location theory and, 4:1798
 Atsuyuki Okabe and, 4:2076–2077
 overlapping market areas and, 1:381, 1:381 (fig.)
 positivist school of thought and, 1:381–382, 3:1295
 range and threshold of each good and, 1:380, 1:380 (fig.)
 retail trade geographies and, 5:2462–2463
 urban hierarchy of central places and, 1:380–381,
 1:381 (figs.), 4:1798
 James Vance and, 6:3008
- Cerf, Vinton, 2:646
- Certeau, Michel de. *See* de Certeau, Michel
- Ceylon, British colonization of, 1:514
- Chad
 economically active females in, 3:1190 (table)
 undernourishment in, 3:1487
- Chadwick, Edwin, 3:1595
- Chamberlin, T. C., 3:1275
- Chambers, Robert, 3:1557, 4:2123
- CHANS. *See* Coupled human and natural systems (CHANS)
- Charlesworth, Andrew, 5:2442
- Charlton, M. E., 3:1226
- CHAS. *See* Coupled human and animal systems (CHAS)
- Chatley, Herbert, 3:1238
- Chavis, Benjamin, Rev. Dr., 2:985
- Chemical spills, environment, and society, 1:382–385
 agrochemical pollution and, 1:51–53
 brownfields and, 1:296–298
 chemical elements and compounds and, 1:382
 chemical industry importance and, 1:382
 chemical problems and, 1:382–383
 chemical spills, 1:383, 1:383 (photo)
 classifications of, 1:383
 development paradox, 1:384
 Frankfurt, Germany, chemical spill, 1:383 (photo)
 Love Canal and, 4:1806–1808
 modern society development and, 1:384
 PCBs and, 5:2226
 replacement paradox, 1:384
 Responsible Care program (chemical industry)
 and, 2:587–588
 transboundary hazardous waste dumping and, 1:384
 waste management and, 1:384
- Chen, J., 2:1061
- Chernobyl nuclear accident, 1:385–386
 fatality figures of, 1:386
 Peter Gould and, 3:1357
 human errors and design flaws causes of, 1:385–386
 nuclear energy and, 4:2050–2052
- Chicago, Illinois
 aerial view of, 6:2937 (photo)
 Cabrini-Green public housing project in, 5:2302 (photo), 5:2303
 See also Chicago School
 central business district of, 1:379, 1:379 (photo)
 Chicago Climate Exchange, carbon markets and, 1:331 (table)
 ChicagoCrime.org, crime data and, 5:2305
 Croatian neighborhood festival, Bridgeport neighborhood in,
 4:2000 (photo)
Hobo (N. Anderson), Chicago homeless study, 4:2121
Master Plan of Residential Land Use of Chicago (Hoyt)
 and, 3:1449
One Hundred Years of Land Values in Chicago (Hoyt), 3:1449
 railway hub in, 5:2358, 5:2360 (photo)
 urban fringe watershed of, GIS application and,
 3:1313, 3:1314 (fig.)
- Chicago School, 1:386–390
 alienation of cities and, 1:387
 case studies technique developed by, 1:386
 central business district (CBD) of, 1:387 (fig.), 1:388
 Chicago as American industrial city prototype and, 1:386
 city as urban jungle metaphor and, 1:386
City essays collection and, 1:386
 concentric ring model of urban social structure (Burgess) and,
 1:387–388, 1:387 (fig.)
 crime rates studied by, 2:607
 debt crisis, neoliberalism and, 2:689
 fieldwork in human geography and, 3:1103–1104
 filtering or trickle-down theory of housing supply
 and, 1:388, 3:1114
Gemeinschaft and *Gesellschaft* concepts and, 1:387
 impacts of, 1:389

- interactionist sociology and, 3:1104
 interviewing and, 3:1625–1626
 Los Angeles School *vs.*, 1:389, 4:1803
 multiple nuclei model of urban growth (Harris and Ullman) and, 1:389, 1:389 (fig.)
 origins of, 1:386
 participant observation methodology and, 4:2121–2122
 racial residential segregation studies of, 5:2344
 sector model of urban growth (Hoyt) and, 1:388–389, 1:388 (fig.)
 sense of community absent in cities and, 1:387
 social Darwinism and, 5:2562
 social ecology and, 2:607
 socially disorganized neighborhoods studied and, 2:607
 spatial turn and, 5:2669
 urban population density issue and, 5:2238
 urban social structure models and, 1:387–389
 urban spatial structure models of, 6:2985 (fig.)
 zone of transition and, 1:388, 1:388 (fig.)
See also Chicago School: noted individuals
- Chicago School: noted individuals
 Ernest Burgess, 1:386, 1:387–388, 1:387 (fig.)
 Chauncey Harris, 1:389, 1:389 (fig.)
 Homer Hoyt, 1:388–399, 1:388 (fig.)
 Roderick McKenzie, 1:386, 5:2562
 George Herbert Mead, 3:1625
 Robert Park, 1:386
 Frederick Tönnies, 1:387
 Edward Ullman, 1:389, 1:389 (fig.), 5:2329
 Louis Wirth, 1:387, 4:1936
- Childe, Gordon, 2:1029
- Childhood spatial and environmental learning, 1:390–392**
 Jerome Bruner's cognitive growth theory and, 1:391
 cartographic-scale spaces challenge and, 1:390
 challenges in teaching young children and, 1:390
 cognitive learning in early and middle childhood and, 1:390–391
 cognitive resources and, 1:391
 developmental and learning theories and, 1:390–391
 geographic learning from immediate and visible and, 1:390
 Jean Piaget's developmental learning theory and, 1:391
 spatial primitives concept and, 1:391
See also Children, geography of
- Children, geography of, 1:392–394**
 academic journals of, 1:394
 children as active agents concept and, 1:392
Children's Experience of Place (Hart) and, 1:392
 early research in, 1:392
 multidisciplinary foundation of, 1:392
 summary of research on, 1:393 (table), 1:394
See also Childhood spatial and environmental learning;
 Education, geographies of
- Chile
 basin and range topography in, 1:186
 Cold War and, 1:504, 1:505
 cooper mine underground processing facility, 4:1912 (photo)
 economically active females in, 3:1190 (table)
 El Niño-Southern Oscillation (ENSO) and, 2:887, 2:889
 El Tatio geothermal area in, 3:1273
 environmental privatization in, 4:2009
 fjords in, 3:1121
 forest plantations in, 5:2195
 glaciers in, 3:1332
 human rights violations in, 3:1480
 inequalities in resource access and, 4:1996
 marine aquaculture in, 4:1854, 4:1854 (fig.)
- neoliberal economic policies in, 2:1066, 4:2023
 neoliberalist policies in, 4:2012
 as newly industrializing country, 4:2023
 San Rafael Glacier in, 3:1328
 social movements research in, 1:365
 squatter settlements in, 5:2684
 water management in, 4:1996
- China
 AAG specialty groups focus on, 1:122
 acid rain in, 1:7
 APEC membership of, 1:121
 aquaculture in, 1:102–103
 automobile industry in, 1:169, 1:170
 biomass for energy production, Guangdong Province, 5:2454, 5:2455 (fig.)
 Boxer Rebellion in, 1:515
 British trade balance, opium and, 1:515
 built environment of, 1:299
 camel domesticated in, 2:783
 China-Brazil Earth Resources Satellites, 1:319
 Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 climate change action plans in, 2:902
 clothing exports from, 6:2186 (fig.)
 coal production in, 1:483–484, 1:485 (fig.), 2:902
 CO₂ emissions in, 3:1377, 3:1454
 Cold War and, 1:505
 collectivized farming in, 2:543
 colonialism resisted by, 1:514–515
 colonial migrations of, 1500–1914, 3:1543
 Cultural Revolution in, 2:543
 desert biome in, 1:218
 desertification in Dunhuang, Gansu province, 2:716 (photo)
 domino theory and, 3:1224
 Dong Zhi winter solstice celebration in, 5:2598
 drought in, 2:791
 dry climate in, Flaming Mountain, Xinjiang, 1:428 (photo)
 earthquake losses in, 4:1984
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 economic restructuring in, 5:2460
 ecotourism in, 2:870
 electronic waste pollution in, 1:502
 ethnocentrism in history of, 2:1027
 export-oriented industrialization (EOI) in, 2:1064
 fertility levels in, 2:709
 foreign aid from, 3:1153
 foreign direct investment by, 1:130, 3:1155
 foreign direct investment in, 4:2022
 forest plantations in, 5:2195
 gated communities in, 3:1181
 GDP of, 3:1382, 3:1383 (fig.), 4:2022–2023
 girls' education inequalities, Gansu, 5:2642 (fig.)
 GIS pioneering in, 3:1283
 Great American Exchange and, 3:1362
 Great Leap Forward in, 2:542, 2:543
 green building programs in, 3:1369
 greenhouse gas emissions of, 1:462, 1:463, 1:464, 2:902
 groundwater usage in, 3:1386, 3:1387
 historical climate records in, 1:456
 HIV/AIDS in, 3:1438, 3:1439
 Hou Renzhi, modern study of geography in, 3:1443–1444
 human rights violations in, 3:1480
 humid continental climate of, 1:440
 hydroelectric power in, 3:1507, 3:1509, 3:1510

- Ibn Battuta exploration of, 2:1054, 3:1519, 4:2179
 IMF voting rights of, 3:1617
 import substitution industrialization in, 3:1551
 incubator zones in, 3:1552
 industrialized agriculture in, 1:44
 industrialization in, 2:542, 3:1580, 3:1583, 4:2020
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Internet access limitations in, 2:750
 Internet content regulated in, 2:724
 Japanese colonization in, 1:514
 Japanese electronics industry in, 2:885
 karst topography, Li River, Guilin, 4:1650 (photo)
 Kyoto Protocol of 1997, greenhouse gas emissions and, 1:463
 land inequality in, 4:1693
 land use and cover change in, 4:1736
 Mandarin language in, 4:1751, 4:1753
 Maoist version of Marxism in, 4:1861
 marine aquaculture in, 4:1853, 4:1854 (fig.)
 metropolitan development in, 1:299
 military expenditures in, 4:1898, 4:1899 (table)
 Mongols preindustrial agriculture in, 1:48
 multinational corporations investment in, 5:2220
 nationalization in, 2:542
 new bridge construction, Guizhou Province (2006), 5:2489 (photo)
 as newly industrializing country, 4:2022–2023, 4:2022 (fig.)
 next generation nuclear reactors in, 4:2051
 nuclear power in, 2:902
 oil imports of, 4:2073
 oil production in, 4:2099
 opium and heroin production in, 2:796–797
 Opium Wars and, 1:515
 particulate matter pollution in, 1:151
 Marco Polo's exploration of, 2:1053
 population growth in, 5:2241
 prairie restoration in, 5:2279
 remittance flows to, 5:2412
 rice paddy cultivation in, 1:48
 Roman exploration of, 2:1051
 rural migrant worker, Beijing, 5:2497 (photo)
 satellite dishes illegal in, 2:750
 search for new route to, 2:1054
 Shenzhen Special Economic Zone (SEZ) in, 2:1067
 Silk road and, 2:1053
 silkworm domestication in, 2:783
 silver trade and, 1:512
 Special Economic Zones in, 4:2022 (fig.)
 strike-slip faults in, 3:1087
 Taiping Rebellion and, 1:515
 as technology diffusion center, 2:746
 textile exports from, 6:2815 (fig.), 6:2816 (fig.)
 Three Gorges Dam controversy and, 2:542
 topographic mapping in, 1:350
 total factor productivity (TFP) of, 6:2780 (table)
 transnational corporations in, 3:1154
 Typhoon Nina (1975), flash flood, Banqiao Reservoir, 3:1125
 undernourishment in, 3:1487
 urbanization in, 2:543
 U.S. industry moving to, 2:700
 waste management in, 5:2372
 wind and solar energy in, 2:902
 Yellow River flash flood (2008) in, 3:1124
- Chinooks/foehns**, 1:394–395
 environmental consequences of, 1:394
 explanation of, 1:394–395, 1:447–448
 mountain climate and, 1:447–448
 onset conditions of, 1:394, 1:395 (fig.)
 zero-order fronts and, 3:1172
- Chiodo, J., 3:1220
- Chipko movement**, 1:395–396
 ecofeminist movement of, 1:395–396, 2:818–819
 Indian Himalayas origin of, 1:395
 popularity and significance of, 1:396
 social forestry and, 5:2563
 tree felling resistance movement and, 1:395–396
 tree huggers and, 1:395–396, 1:396 (fig.)
 women as protectors of the Earth and, 2:818–819
- Chipman, Jonathan, 4:1783
- Chisholm, George, 2:848, 2:850, 2:851, 4:1990
- Chisholm, Nicholas, 2:560
- Chlorinated hydrocarbons (CHCs)**, 1:397–400
 aliphatic CHCs, 1:397
 aromatic CHCs, 1:397
 cancer and, 1:397
 chlorobenzene, 1:397, 1:398 (fig.)
 chloroform, 1:397, 1:398 (fig.)
 composition of, 1:396
 DDT, 1:398–399, 1:399 (fig.)
 dense nonaqueous-phase liquid form of, 1:396
 dichloroacetic acid, 1:397, 1:398 (fig.)
 dioxins, 1:399
 disinfection by-products (DBPs) origin of, 1:396
 food chain accumulation of, 1:397
 heterocyclic CHC, 1:399, 1:399 (fig.)
 PCBs and, 1:397–399, 5:2225–2226
 PCP, 1:397, 1:399 (fig.)
 pesticides and, 4:2157–2158
 trichloroethene, 1:397, 1:398 (fig.)
 U. S. Environmental Protection Agency regulation of, 1:397
- Chlorofluorocarbons (CFCs)**, 1:400–401
 climate change effect of, 1:400, 1:463
 commercial applications of, 1:400
 composition of, 1:400
 global warming and ozone-depleting effects of, 1:138, 1:400, 2:984, 3:1336
 Montreal Protocol, of Vienna Convention for the Protection of the Ozone Layer and, 1:400–401, 1:462, 3:1336, 3:1374, 5:2244, 6:2763
 numbering system of, 1:400
- Chodorow, Nancy, 3:1095–1096
- Cholera, geography of**, 1:401–403
 El Tor biotype of, 1:401
 environmental factors of, 1:401, 1:402–403
 interannual climate variability factor in, 1:402
 oral rehydration salts treatment and, 1:403
 primary *vs.* secondary types of, 1:401
 John Snow's work and, 1:401–402, 2:770
 in the 21st century, 1:402
Vibrio cholerae bacteria and, 1:401, 1:403
V. cholerae O139 type of, 1:401
- Chomsky, Noam, 5:2705
- Chorley, Richard**, 1:403–404
 Davisian geomorphology challenged by, 1:403
 general systems theory supported by, 1:403
 geomorphology work of, 1:403–404
Network Analysis in Geography (Haggett and Chorley), 4:2017
 quantification approach of, 1:403, 3:1400, 3:1466, 4:2017
 RGS award of, 5:2487

Chorology, 1:404–405

- Annales School and, 3:1465
- areal differentiation and, 1:404, 3:1465
- Geographia Generalis* (Varenius) and, 1:404, 5:2387
- geography and topography *vs.*, 1:404
- Geography* (Ptolemy) and, 1:404
- Geography* (Strabo) and, 1:404, 3:1460
- Localities School and, 1:405
- positivism replacement of, 1:405
- specific *vs.* general geography (Varenius) and, 1:404
- use values of places work (Ritter) and, 1:404

Chorology: notable individuals

- Richard Hartshorne, 1:405, 3:1465–1466
- Immanuel Kant, 1:404
- Alfred Kettner, 1:404
- Ptolemy, 1:404, 5:2300, 5:2387
- Karl Ritter, 1:404
- Fred Schaefer, 1:405, 3:1466
- Varenius, 1:404, 4:2179, 5:2387
- Paul Vidal de la Blache, 1:404, 3:1465

Choropleth maps, 1:406–408

- cartograms and, 1:338–339
- classed map of U.S. population density, 1:406, 1:406 (fig.)
- daisy metric maps and, 2:669–671
- data classification and, 1:407
- geography of disease mapping and, 2:772
- interactive change of color technique and, 2:806 (fig.), 2:808
- as most common map, 1:406
- multivariate mapping, U.S. murder rates and families in poverty and, 4:1965, 4:1965 (photo)
- Natural Breaks classification method used by, 1:407
- normalization, 1:406
- representation, 1:406
- sequential, divergent, or qualitative symbolization used in, 1:407–408, 1:408 (fig.)
- symbolization and, 1:407–408
- 2004 presidential election, 2:879 (fig.)
- unclassed map of U.S. population density, 1:406, 1:407 (fig.)
- U.S. population density by state and, 1:406 (fig.)
- as value-by-area or value-by-population maps, 1:406

Chouinard, Vera, 2:619

Chrisman, Nicholas, 1:408–409

- “Cartographic Data Structures” co-authored by, 1:408
- Exploring Geographic Information Systems* written by, 1:408
- GEOIDE, research funding and, 1:408
- GIS development work of, 1:408
- role of time in geographic information and measurement theory and, 1:408

Christaller, Walter, 1:409–410

- Central Places in Southern Germany* written by, 1:380, 4:1798
- central place theory of, 1:380, 1:409–410, 4:1798, 4:1805, 4:2077, 5:2329, 5:2393, 5:2433, 6:3008
- community sizes, 1:409
- decision making on settlement growth and contraction and, 1:410
- Economics of Location* (Lösch) and, 1:410
- hexagon-shaped trade areas and, 1:409, 4:1798, 4:1805
- hierarchy of places nearing spatial equilibrium and, 1:409, 4:1798, 4:1805
- highway development plans and, 1:410, 4:1798
- internalizing externalities within hierarchy of administrative zones and, 1:409
- location theory and, 3:1628
- August Lösch and, 1:410, 3:1628
- Nazi party membership and service of, 1:410

Atsuyuki Okabe and, 4:2077

spatial interdependence between places and, 1:409–410

Christopherson, Robert, 1:452

dunes work of, 2:801 (fig.), 2:802 (fig.)

Church, Richard, 4:1793

Churchill, Ellen, anthropogeography work of, 1:93

Cicero, 5:2572

Circuits of capital, 1:410–412

- capitalist value circulation process and, 1:410–411
- circuit of culture and, 1:412
- commodity-capital circuit, 1:411, 1:411 (fig.), 1:412
- commodity chains and, 1:524
- Euromarkets and, 2:1030–1032
- geographic applications of, 1:412
- Karl Marx and, 1:410
- Doreen Massey’s spatial divisions of labor and, 1:412, 4:1866–1867
- money-capital circuit, 1:410–411, 1:411 (fig.)
- productive-capital circuit, 1:411, 1:411 (fig.)
- spatial and temporal interruptions of, 1:411 (fig.)
- See also* Crisis (economic)

CIS. *See* Commonwealth of Independent States (CIS)

Citizen’s Clearinghouse for Hazardous Waste, 4:1808

Citizenship, 1:412–414

- cosmopolitanism and, 2:590–592
- cultural and ethnic diversity of societies and, 1:413
- definitions, 1:412–413
- excluded and marginalized groups and, 1:412–413
- geographical definition variations and, 1:412
- geography and citizenship intersections and, 1:412
- global and cross-cultural perspective on, 1:413–414
- immigration and, 3:1542–1545
- multicultural citizenship and, 1:413
- neoliberal global capitalism and, 1:413
- political power organization element in, 1:413
- regional free trade and, 1:413
- rights and responsibilities with a society and, 1:412–413
- social and economic justice and, 1:413–414
- spatial unevenness of wealth and, 1:413–414
- transnational environmental issues and, 1:413

Civil society, 1:414–416

- accountability issue, 1:415
- beneficial examples of, 1:415–416
- citizenship and, 1:412–414
- communication technology advances and, 1:414
- critics of, 1:415
- definitions, 1:414
- governance and, 3:1357–1359
- grassroots organizations and, 1:414
- nationalism and, 4:1978–1981
- nongovernmental organizations (NGOs) and, 1:414
- World Social Forum and, 1:414–415

CLAG. *See* Conference of Latin Americanist Geographers (CLAG)

Clark, Andrew, 1:416–417

- academic career of, 1:416
- contributions of, 1:417
- European colonization effects focus of, 1:416
- as father of historical geography, 1:416, 3:1429
- major monographs of, 1:416
- publications of, 1:416–417
- regional geography and, 3:1429
- students of, 1:416

Clark, Andy, 4:1882

Clark, Colin, 5:2240, 5:2263

Clark, Gordon, 3:1118

Clark, William, 6:2741

- Clark, William, 1:417–418
 criticism of, 1:418
 human ecology work of, 3:1459
 immigration studies of, 1:418
 mobility and migration studied by, 1:417–418
 National Academy of Science service of, 1:417
 school districts and residential segregation work of, 1:418
- Clark, William (Lewis and Clark expedition), 4:1773–1777
- Clarke, John Innes, 5:2247
- Class, geography and, 1:418–422**
 appearance of class and, 1:421
 capitalism and, 1:419
 character assumed from locale and, 1:420, 1:421 (photo)
 classed capitals and classed habitus concepts
 (Bourdieu) and, 1:421–422
 definitions and analysis of, 1:419
 employment location and dislocation element of, 1:419
 ethnic segregation and, 2:1022–1026
 gentrification and, 3:1203–1208
 global rich *vs.* global poor and, 1:419
 identification boundaries (us/them) and, 1:420
 inequality geographies and, 3:1589
 justice/injustice geographies and, 3:1643–1645
 life changes and sense of belonging and, 1:418, 1:420–422
 movements within spaces and, 1:418–419
 peasants and peasantry and, 4:2137–2142
 place and space intersection and, 1:419, 1:420
 postindustrialism and, 1:420
 regeneration of urban landscapes and, 1:420, 1:422
 scales of comparison and, 1:418
 sense of place and, 1:418, 1:419, 1:420
 social construction characteristic of, 1:419
 spatial segregation and, 1:420–421
 traditional class and gender roles and, 1:419
 “white flight” and, 1:420, 2:962, 2:986
 working class masculinity *vs.* feminist consumption
 spaces and, 1:419
See also Class, nature and
- Class, nature and, 1:423–425**
 bourgeoisie *vs.* proletariat and, 1:423
 capitalism, alienation from nature and, 1:424
 class, life paths, life chances and, 1:423
 environmental justice movement and, 1:425
 external *vs.* universal ideologies of nature and, 1:424
 landscaping of nature and, 1:425
 as objects of analysis, 1:423
 race and gender issues and, 1:425
 species-being of humans and, 1:424
Uneven Development (N. Smith) and,
 1:423–424, 5:2351
 urban political ecology and, 1:425
See also Class, geography and
- Clean Air Status and Trends Network, 1:6
- Clements, Frederic, 2:866, 4:2180
- Cleveland, Cutler, 2:896
- Client-server architecture, 1:426–428**
 distributed GIS and, 1:427–428
 Enterprise GIS, 2:911–913
 examples of, 1:426
 explanation of, 1:426
 geospatial examples of, 1:426
 GIS software and, 1:426
 Open Geospatial Consortium standards and, 1:426
 stateless *vs.* stateful, 1:427
 synchronous *vs.* asynchronous, 1:427
 thin *vs.* thick clients and, 1:426–427
 virtual globes applications and, 1:426
See also Client-server architecture: examples
- Client-server architecture: examples
 Arc GIS Desktop, 1:426
 ENVI, 1:426
 Google Earth, 1:426
 Google Maps, 1:426
 Microsoft Virtual Earth, 1:426
 NASA World Wind, 1:426
 Quantum GIS, 1:426
 Web Coverage Service (WCS), 1:426
 Web Feature Service (WFS), 1:426
 Web Map Service (WMS), 1:426
- Climate: dry, 1:428–435**
 air subsidence in general circulation factors in,
 1:430, 1:430 (fig.)
 aridity index classification of, 1:433
 aridity *vs.* drought and, 1:429
 basin and range topography and, 1:186–187
 classifications of dry climates and, 1:432–433
 definition of, 1:428–429
 desert biome and, 1:218–223
 diurnal surface temperature, Northern Sahara desert, 1:434 (fig.)
 early civilizations and, 1:428
 factors contributing to, 1:430–431
 Flaming Mountain, Xinjiang, China, 1:428 (photo)
 global distribution of world deserts and, 1:430 (fig.)
 hyperarid climates and, 1:428, 1:433
 indices of, 1:432–433
 locations of, 1:429–432
 Sahara, North Africa and, 1:429
 semiarid climates, humidity provinces and, 1:432, 1:433
 solar radiation element of, 1:433
 temperature element of, 1:433–435
 vertical temperature and moisture profile and,
 1:431–432, 1:431 (fig.)
See also Environmental management: drylands
- Climate: midlatitude, mild, 1:435–439**
 climate change and, 1:438–439
 climate phenomenon of, 1:435–436
 continental interior weather conditions, 1:436
 diversity within, 1:435–436
 droughts, 1:438
 El Niño Southern Oscillation and, 1:435–436, 1:437
 extratropical cyclones and, 2:650–654
 flooding, 1:437–438
 humid summer weather in, 1:436
 hurricanes, 1:437
 large scale weather and climate features of, 1:435, 1:437–438
 latitudinal climate variability and, 1:436
 marine and continental locations of, 1:436–437
 midlatitude grassland biome and, 1:227–230
 nor’easter storm systems and, 1:436
 rainfall in, 1:436
 tornadoes and, 1:437
 vegetation, Warwick, New York, 1:438 (photo)
 vegetative cover and human adaptations in, 1:437
 weather and climate in, 1:435
See also Climate: midlatitude, severe
- Climate: midlatitude, severe, 1:439–442**
 animals living in, 1:441, 1:442
 biome diversity in, 1:440
 boreal forest or taiga biome located in, 1:442
 deciduous tree cycle and, 1:440

- extratropical cyclones and, 2:650–654
- fires in, 1:440–441
- four seasons in, 1:441
- grasslands of, 1:440–441
- human settlement in, 1:442
- humid continental, 1:439–441
- Köppen map of humid continental and subarctic (microthermal) climates, 1:439, 1:440 (fig.)
- Köppen symbols of, 1:441
- locations of, 1:439, 1:440 (fig.)
- microthermal climate type and, 1:439
- midlatitude grassland biome and, 1:227–230
- Murmansk, Russia in, 1:442
- permafrost subsoil characteristic of, 1:441–442
- precipitation in, 1:441
- soil varieties in, 1:441, 1:442
- subarctic, 1:441–442
- thunderstorms and, 6:2832
- tundra biome and, 1:246–250
- See also* Climate: midlatitude, mild
- Climate: mountain, 1:443–449**
 - altitude factor in, 1:443
 - anabatic flow of air, 1:447
 - climate change and variability and, 1:448–449
 - clouds, 1:446, 1:447 (photo)
 - continentality factor in, 1:443
 - El Niño/Southern Oscillation and, 1:448
 - environmental lapse rate factor in, 1:444
 - environmental processes exaggeration in, 1:443
 - Fisher Peak, North Cascades National Park, Washington, 1:444
 - foehn wind, 1:447–448
 - internal disturbances factor in, 1:449
 - katabatic flow of air, 1:447, 4:2149
 - latitude factor in, 1:443
 - mean annual temperatures, North Cascades, Washington, 1:445 (fig.)
 - microclimates and, 1:448
 - mini-rain-shadow zones and, 1:444
 - Mt. St. Helens, 1:447 (photo)
 - orographic effect and, 1:444
 - precipitation and clouds factors in, 1:446, 1:448
 - rain-shadow effect and, 1:444
 - solar radiation factor in, 1:444–445
 - temperature factor in, 1:445–446, 1:445 (fig.), 1:448–449
 - temperature inversions and, 1:444
 - wind factor in, 1:446–447
- Climate: polar, 1:449–452**
 - albedo coefficient and, 1:449
 - Antarctica, 1:451
 - Antarctic Convergence zone and, 1:451
 - Arctic, 1:449–450
 - causes of, 1:449
 - climate changes and, 1:451–452
 - cyclones, polar cyclones, and anticyclones and, 1:451
 - glacial mountains of Spitsbergen, Norway, and, 1:450 (photo)
 - locations of, 1:449
 - maritime *vs.* continental polar climates and, 1:450
 - See also* Ice; Periglacial environments; Permafrost
- Climate: tropical humid, 1:452–455**
 - atmospheric lifting mechanisms, 1:453
 - causal factors of, 1:452–453
 - characteristics and classification of, 1:453
 - Christopherson's climate categories and, 1:452
 - climate definition and, 1:452
 - deforestation in, 2:696
 - extensiveness of, 1:452
 - forest layers in, 1:455
 - humidity and, 3:1485–1486
 - intertropical convergence zone (ITCZ) and, 1:132, 1:453–454, 4:1940, 6:2832
 - maritime equatorial (mE) air masses of, 1:453–454
 - monsoons and, 4:1940–1945
 - orographic atmospheric lifting process and, 1:453
 - precipitation in, 1:453–454
 - subcategories of, 1:453
 - temperatures in, 1:453
 - tropical forest, Sachatamia, Ecuador, 1:454 (photo)
 - tropical monsoon climate, 1:454–455, 2:741
 - tropical rain forest biome and, 1:234–239
 - tropical rain forest climate, 1:453–454, 1:454 (photo)
 - tropical savanna climate, 1:455
 - Tropics of Cancer and Capricorn boundaries of, 1:452
- Climate change, 1:455–461**
 - on atolls, 1:168
 - Beaufort wind scale measure and, 1:456
 - biota and climate and, 1:257–264
 - climatic relicts and, 1:467–471
 - climatology and, 1:475
 - as coupled human and natural system, 2:601–602
 - Dansgaard-Oeschger Oscillations and, 1:457–458
 - ecological and carbon footprints and, 2:570–571
 - ecoregions and, 2:855–856
 - ecotones and, 2:867
 - El Niño-Southern Oscillation (ENSO) and, 2:886–890
 - environmental refugees and, 2:989–991
 - fossil fuel burning and deforestation factors in, 1:328
 - geological record and, 1:457–459
 - geophysical, biological, and chemical proxy variables and, 1:456–457
 - glacial/interglacial cycles and, 1:457–459, 1:458 (fig.)
 - greenhouse gasses increase and, 1:461
 - Heinrich events and, 1:457–458
 - historical records timescale of, 1:456
 - Holocene (postglacial period) and, 1:459, 1:470
 - Ice Age records and, 1:457
 - instrumental records of, 1:456
 - land use and cover change impact on, 4:1736
 - La Niña and, 4:1754–1757
 - Little Ice Age and, 1:459, 3:1333, 3:1335
 - Maunder Minimum sunspot activity and, 1:459
 - mountain glaciers affected by, 3:1328–1333
 - natural hazards and risk analysis and, 4:1985
 - past millennium and, 1:459–461, 1:460 (fig.)
 - permafrost affected by, 4:2154–2157
 - in polar climate, 1:451–452
 - Poles, North and South and, 5:2203–2209
 - precipitation measurement and, 1:456
 - proxy records of, 1:456–457
 - satellite climate recording and, 1:456
 - sea surface temperature measures issue and, 1:456
 - solar and terrestrial radiation and, 5:2346–2349
 - solar output factor in, 1:459
 - symptoms and effects of, 6:2770–2773
 - temperature scales and, 1:456
 - variation in surface air temperature in Northern Hemisphere and, 1:460 (fig.)
 - volcanic activity, carbon cycle and, 1:328
 - volcanic eruptions factor in, 1:461
 - Vostok time series and ice volume and, 1:458 (fig.)
 - wind speed at sea measures and, 1:456

- See also* Adaptation to climate change; Albedo; Anthropogenic climate change; Biota and climate; Global environmental change; Social and economic impacts of climate change
- Climate maps**
 long-wave cloud image, Australian sector, 1:145 (fig.)
 modeled precipitation map, winter and summer months, 1:91 (fig.)
- Climate policy, 1:462–465**
 assigned amount units concept and, 1:463
 carbon dioxide emissions and, 1:462
 carbon trading and carbon offsets and, 1:329–335
 chlorofluorocarbons phase out and, 1:462
 Clean Development Mechanism (CDM) and, 1:463
 climatology and, 1:475
 common but differentiated responsibility principle and, 1:462
 Copenhagen international climate change summit and, 1:463
 Intergovernmental Panel on Climate Change (IPCC) and, 1:462, 5:2204, 5:2552, 5:2554 (fig.)
 Joint Implementation (JI) and, 1:463
 Kyoto Protocol of 1997 and, 1:83, 1:330, 1:332, 1:333 (fig.), 1:462–463, 2:900, 2:945, 3:1358, 3:1374, 3:1605, 4:1857, 5:2244
 land use, land use change, and forestry (LULUCF) activities and, 1:463
 Montreal Protocol (1987) and, 1:400–401, 1:462, 3:1336, 3:1374, 5:2244, 6:2763
 national policies and compliance and, 1:463–464
 ozone layer and, 1:462
 post-Kyoto period and, 1:464
 UN Framework Convention on Climate Change (UNFCCC) and, 1:9, 1:462, 2:945, 3:1374, 5:2220, 5:2244, 6:2748–2749
 United Nations Environment Programme (UNEP) and, 1:462
- Climate types, 1:465–469**
 applied classification approach and, 1:466
 atmospheric energy variations and, 1:161–165
 biota and climate and, 1:257–264
 climate classification and, 1:466–467
 climate controls and factors, 1:466
 climate definitions and, 1:465
 data and statistics, 1:465–466
 ecoregions and, 2:855–856
 ecotones and, 2:865–869
 empirical classification approach and, 1:466
 genetic classification approach and, 1:466
 Grosswetter genetic classification approach and, 1:467
 Köppen climate classification system and, 1:465, 1:467–469
 mild, midlatitude climate and, 1:435–349
 precipitation measures and, 1:465–466
 seasonal patterns and, 1:465
 Strahler classification system and, 1:467
 temperature measures and, 1:465
 Thornwaite classification system, 1:467
See also Atmospheric energy transfer; Biota and climate; Climate: *specific climate*; Köppen-Geiger climate classification
- Climatic relict, 1:469–471**
 American pika faunal example, 1:470–471
 climate zone shifts or single climatic variable changes and, 1:469–470
 European strawberry tree floral example and, 1:470
 faunal climatic relicts, 1:470
 floral climatic relicts, 1:470
 future climatic relicts, 1:470–471
 global climate changes and, 1:469
- Holocene climate changes and, 1:459, 1:470
 Joshua tree floral example and, 1:470
 marine fauna relict and, 1:470
 musk ox faunal example and, 1:470
 Norwegian mugwort floral example and, 1:470
 staghorn coral faunal example and, 1:470
- Climatology, 1:471–476**
 atmospheric energy variations and, 1:161–165
 biota and climate and, 1:257–264
 climate change and, 1:475
 climate models and, 1:474
 climatology resources and, 1:473–475
 Coriolis force and, 2:586–587
 data sources for, 1:474–475, 1:671
 definition of, 1:671
 dendrochronology and, 2:711
 differential heating and, 2:740–742
 geospatial techniques and, 1:473–474, 1:671
 geostatistics and, 1:474
 health and medical climatology, 1:473
 hydroclimatology, 1:473
 interdisciplinary characteristic of, 1:671
 microclimatology, 1:472
 oceanic circulation and, 4:2058–2064
 paleoclimatology, 1:471–472
 physical climatology, 1:472
 as physical geography subdiscipline, 1:671
 proxy data sources and, 1:472
 subdisciplinary studies within, 1:671
 synoptic and dynamic climatology, 1:472–473
 C. Warren Thornthwaite and, 6:2821–2822
See also Atmospheric *specific subject*; Biota and climate; Climate types; Köppen-Geiger climate classification
- Closer Economic Relations (CER) Free Trade Agreement (FTA), 1:121
- Clouds, 1:476–480**
 adiabatic temperature changes and, 1:15–17
 aerosol-cloud-precipitation interactions and, 1:479–480
 aerosol indirect effects and, 1:479–480
 altitude classification of, 1:476
 atmospheric particulates and, 1:149–151
 Bergeron-Findeisen mechanism and, 1:478–479
 classification (WMO) of, 1:476, 1:477 (photo), 1:478
 cloud condensation nuclei (CCN) and, 1:478
 cloud-seeding experiments and, 1:478
 condensational droplet growth and, 1:478
 first indirect or Twomey effect and, 1:479
 formation and development of, 1:478–479
 global climate influenced by, 1:476, 1:479–480
 global cloud climatologies development and, 1:479
 global radiation balance function of, 1:476, 1:479
 Hallet-Mossop ice multiplication process and, 1:478
 homogeneous nucleation, freezing of liquid droplets and, 1:478
 hydrometeors and, 1:476
 hydrometer composition classification of, 1:478
 Intergovernmental Panel on Climate Change and, 1:480
International Cloud Atlas (WMO) and, 1:476
 International Satellite Cloud Climatology Project and, 1:478
 mother cloud origin and, 1:476
 precipitation distinguished from, 1:476
 riming ice-phase particle growth process and, 1:479
 second direct, cloud lifetime, or Albrecht effect and, 1:479
 solute effect (Raoult's law) and, 1:478
 terminal fall velocity of, 1:476

- water cycling function of, 1:476
See also Atmospheric moisture
- Clusters, 1:480–482**
 competitive advantage and, 2:558–559
 competitive diamond concept (Porter) and, 1:481, 1:481 (fig.)
 creative destruction concept (Porter) and, 1:481
 definition of, 1:480
 economic localization and increasing returns and, 1:481
 external industrial economies' factors and, 1:480
 human and economic geography and, 1:480
 importance of local context and, 1:481
 industrial districts and, 1:480, 2:851–852
 industrial to knowledge-based economy shift and, 1:482
 knowledge, relational proximity and, 1:482, 5:2435–2436
 knowledge as core production factor and, 1:482
 knowledge-based geographical clustering and, 6:2781
 Alfred Marshall's work and, 1:480–481, 1:482
 new industrial districts and, 1:482, 2:851–852
 Porter's competitive diamond and, 1:481–482, 1:481 (fig.)
 Michel Porter's work and, 1:481–482, 1:482 (fig.)
 R&D geographies and, 5:2435–2436
 temporality of, 1:482
- Coal, 1:483–486**
 in China, 1:483–484, 1:485 (fig.)
 Coal fields and Rank coverage and, 1:485 (fig.)
 coalification degree classifications of, 1:483
 emissions issue of, 1:483, 1:485–486
 future trends, 1:485–486
 global reserves of, 2:903 (fig.), 2:906 (fig.)
 in other countries, 1:485
 strip mining and, 5:2701–2702
 in the U.S., 1:483, 1:484 (fig.)
 Coase, Ronald, 1:329–330, 4:1857
- Coastal dead zones, 1:486–488**
 bacteria in benthic zone and, 1:486
 in Gulf of Mexico, 1:207, 1:486, 1:487 (photo), 1:488, 1:502, 2:939
 hypoxic conditions in, 1:486, 1:502
 inorganic fertilizers and, 1:488
 nitrogen cycle and, 4:2029
 phytoplankton role in, 1:486, 1:487 (photo), 1:502
 seasonal physical factors of, 1:486–487
 storms or hurricanes and, 1:486
- Coastal erosion and deposition, 1:488–496**
 barrier islands and, 1:183–185
 beach rotation and, 1:491
 Bruun rule and, 1:494, 1:495 (fig.), 1:496
 chemical effects factor in, 1:493–494
 chenier ridge, Princess Charlotte Bay, Northern Australia, 1:491 (photo)
 coastal deposition, 1:489–490
 coastal erosion, 1:489, 1:490 (photo)
 as coastal hazard, 1:498
 coastal morphodynamics and, 1:488
 coral reefs and, 2:581–584
 definitions, 1:488
 deltas and, 2:702–705
 dunes factor in, 1:492, 1:499
 erosion from nor'easter, Outer Banks, North Carolina, 1:500
 factors affecting, 1:488
 floodplains and, 3:1128–1133
 human interference factor in, 1:493 (photo), 1:494
 longshore currents and, 1:491
 longshore transport and, 1:491–492
 overstepping and, 1:496
- Oyster Bay, Australia, 1:492 (photo)
 progradation, transgression (deposition) and, 1:489–490
 prograding, eroding, and stationary coast categories and, 1:488
 reefs, tombolos, and biota factors in, 1:492–493, 1:492 (photo)
 retrograding, encroaching, or receding coasts and, 1:489
 rollover and, 1:496
 sea-level change factor in, 1:494, 1:496
 sea wall collapse, French coast, 1:493 (photo)
 shoreface responses to sea-level rise and, 1:495 (fig.)
 shoreline monitoring and predictions, 1:496
 tidal currents factor in, 1:492
 Twelve Apostles, Australia and, 1:489, 1:489 (photo)
 wave climate factor in, 1:490–492
- Coastal hazards, 1:496–500**
 climate change and, 1:499–400
 coastal hazard zone and, 1:498–499
 coastal property assets and, 1:497
 defenses against, 1:498–499
 deltas and, 2:704
 dunes defense against, 1:499
 erosion, 1:498
 erosion, Outer Banks, North Carolina, 1:499 (photo)
 explanation of, 1:492–493
 flooding, 1:497–498
 Intergovernmental Panel on Climate Change and, 1:500
 inverse barometer effect and, 1:497
 mean sea level and, 1:497
 oil spills and, 4:2073–2076
 rip currents and, 1:498
 run-up caused by waves and, 1:498
 set-up of waves and, 1:498
 storm surge and, 1:497
 swash of waves and, 1:498
 tide and, 1:497–498
See also Hurricanes, physical geography of;
 Hurricanes, risk and hazard
- Coastal zone and marine pollution, 1:500–504**
 atmospheric carbon dioxide concentrations and, 1:501
 climate-induced sea level changes and, 1:500–501
 coastal dead zones and, 1:486–488, 1:502, 2:939
 coastal zone definition and, 1:500
 economic attributes of coastal zone and, 1:500
 electronic waste and, 1:502
 excessive nutrients, 1:502
 future issues and challenges, 1:503–504
 global biogeochemical cycles and, 1:501
 heavy metals, 1:501–502
 human interaction disturbances and, 1:500
 marine aquaculture and, 4:1853–1855
 marine litter, 1:502–503, 1:503 (photo)
 Minamata disease, mercury poisoning and, 1:501–502
 nonpoint sources of pollution and, 4:2039–2040
 ocean acidification and, 1:501
 oil fields and, 2:946–948
 oil pollution, 1:503
 oil spills and, 4:2073–2076
 persistent organic pollutants (POPs), 1:501
 physical attributes of coastal zone and, 1:500
 population attributes of coastal zone and, 1:500
 radioactive substances, 1:503
 sewage, 1:501
- Cockburn, Alex, 5:2212
 Codd, Edgar, 2:671
 Cognitive mapping, 1:189, 5:2609–2610
 Cohen, Saul, 3:1250

Cold War, geography of, 1:504–505

- American geographical imagination and, 3:1223–1224
- Committee on the Present Danger (CPD) and, 3:1251
- containment and domino theory principles of, 1:504–505
- democracy *vs.* communism and, 1:504
- domino theory and, 1:505, 2:787, 3:1224
- geopolitics and, 2:611, 3:1250–1252
- global divisions of power and, 1:504
- international criminal court and, 3:1606
- Henry Kissinger and, 3:1251
- Sir Halford Mackinder's Heartland model and, 4:1813
- nationalist movements during, 2:691–692
- NATO and, 4:2047
- new Cold War potential and, 4:2048
- North Atlantic Treaty Organization and, 1:505
- nuclear annihilation fear and, 3:1224
- nuclear weapons and, 4:2052
- political geography and, 5:2222–2223
- See also* **Commonwealth of Independent States (CIS)**

Collaborative GIS, 1:506–508

- applications of, 1:507, 1:507 (fig.)
- collaborative process component in, 1:507
- components of, 1:506–507, 1:506 (fig.)
- definition of, 1:506
- geocollaboration and, 3:1209–1211
- geospatial databases role in, 1:507
- GIS and GIScience collaborative link and, 1:507
- GIS design and, 3:1290–1293
- GIS technology and, 1:506
- humanistic GIScience and, 3:1474–1478
- planning and decision-making tasks applications of, 1:506
- user interfaces component of, 1:507
- Web server element in, 1:507
- See also* **GIS specific subject**

Collins, Harry, 5:2518**Colombia**

- Cerrejon coal mine in, 4:2086
- Conference of Latin Americanist Geographers held in, 2:568
- ecological footprint and biocapacity of, 2:827 (table)
- economically active females in, 3:1190 (table)
- glaciers in, 3:1332
- human rights atrocities in, 3:1481
- illicit drug cultivation in, 2:797
- indigenous and community conserved areas in, 3:1561
- market-based land reform in, 4:1695
- “narcoterrorism” and, 2:798
- tropical scrub in, 1:245

Colonialism, 1:508–518

- Africa, 1:512–513
- African political geography and, 1:512
- Arab world, 1:513–514
- James Blaut's work and, 1:285–286
- British imperial geographical imagination and, 3:1221–1222
- capitalist economy factor in, 1:511
- Christian missionaries and, 1:517
- colonial dependence and, 2:713
- colonial empires prior to 1914 and, 1:513 (fig.)
- community-based natural resource management and, 2:550
- cultural and ideological processes and, 1:517
- decolonialization and, 1:509
- disease and, 1:516
- drug discoveries and, 2:795
- East Asia, 1:514–515
- economic, political, and cultural impact of, 1:508, 1:516
- education systems and, 1:517

effects of, 1:516–517

- end of, 1:517
- environmental resources and, 5:2447–2448
- European Age of Exploration and, 1:508
- European conquest factors and, 1:509–511
- European definitions of humanity and, 5:2340
- European racial thought and, 5:2339–2340
- European shipbuilding and ocean navigation skills and, 1:510
- Europe changed by, 1:508
- famine and, 1:516
- fight against, 1:508
- forestlands administration and, 2:552
- genocide and, 1:516
- impacts of, 1:508
- imperialism and, 3:1545–1548
- independence movements and, 1:517
- Industrial Revolution era of, 1:509
- inequalities in colonized societies and, 1:516
- land reform after, 4:1492–1692
- Latin America, 1:511–512
- mercantilist trade policies and, 1:508
- mining settlements and, 4:1911
- nation-states after, 1:517
- neocolonialism and, 4:2002–2005
- North America, 1:512
- Oceania, 1:515–516
- ocean navigation factor in, 1:510
- Orientalism and, 4:2101–2104
- plantations and, 5:2192
- polarized spaces and, 1:516
- preindustrial mercantile era of, 1:508
- ship-based empires and, 1:510
- silver flows, 16th to 18th centuries and, 1:513 (fig.)
- silver trade and, 1:511–512
- slave trade and, 1:512, 1:516
- smallpox disease and, 1:511
- South Asia, 1:514
- southeast Asia, 1:515
- Spanish encomienda land grant system and, 1:512
- telegraph technology and, 3:1221–1222
- temporal and spatial unevenness of, 1:508–509, 1:509 (fig.)
- uneven landscapes and commodity export-dependent economies and, 4:1692
- water supply issues and, 5:2316–2317
- “white man's burden” and, 2:1021, 2:1027
- world development and world systems theories and, 1:508
- See also* **Decolonization; Neocolonialism; Race and empire**

Colorado

- cardboard recycling, Englewood, 5:2374
- Colorado National Monument, 5:2483 (photo)
- gated community in, 3:1182 (photo)
- hazardous waste and garbage mixture in Lowry Landfill, 4:1685 (photo)
- sedimentary layers, Artist's Point, Colorado National Monument, 5:2521 (photo)
- solar hot water system, Adams County Detention Facility, Denver, 5:2595 (photo)
- Steamboat Springs geothermal area in, 3:1273

Color in map design, 1:518–520

- color associations and, 1:519–520, 1:519 (fig.)
- color connotations and, 1:518–519
- color interactions and, 1:520
- definitions in, 1:518
- functions of, 1:518
- hardiness zones in U.S. example of, 1:519 (fig.)

- hue differences in color and, 1:518
- light source and, 1:520
- map conventions and, 1:520
- psychological reactions of viewers and, 1:519
- saturation of color in, 1:518
- See also* Map design
- Columbus, Christopher, 1:520–522**
 - explorations of, 1:521, 3:1461, 4:2179
 - financing obtained by, 1:511
 - historical legacy of, 1:521
 - legal claims and battles, 1:521
 - maps and charts of, 1:521
 - Ptolemy's influence on, 1:520, 5:2300
 - resources of, 1:520
 - sense of geography, religion and, 1:521
- COMECON. *See* Council for Mutual Economic Assistance (COMECON)
- Committee on Earth Observation Satellites, 1:160
- Commodity chains, 1:522–525**
 - actor-network theory and, 1:524
 - alternatives to GCC approach and, 1:524
 - buyer-driven commodity chains and, 1:523
 - capitalism geographies and, 1:524–525
 - captive value chains and, 1:523–524
 - circuits of capital and, 1:410–412
 - circuits of culture and, 1:524
 - “cultural turn” in human geography and, 1:522
 - definition of, 1:522
 - ethical consumption practices and, 1:525
 - factors in, 1:523
 - Gary Gereffi's work and, 1:522–524
 - global commodity chain (GCC) and, 1:522
 - governance structures and, 1:522–523
 - hierarchy value chains and, 1:524
 - industrial upgrading decisions and, 1:524
 - input-output structure dimension of, 1:522
 - interfirm linkages element of, 1:522
 - labor unions application of, 1:524–525
 - market governance and, 1:523
 - modular value chains and, 1:523
 - outsourcing and, 4:2108–2110
 - producer-driven chains and, 1:523
 - production and consumption analysis using, 1:522
 - relational value chains and, 1:523
 - revised typology of governance and, 1:523–524
 - territoriality dimension of, 1:522
 - vertical relationships focus and, 1:522
- Commoner, Barry, 2:570
- Common pool resources (CPRs), 1:525–528**
 - benefits and costs of, 1:525
 - definition of, 1:525
 - ecological economics and, 2:820–824
 - environmental entitlements and, 2:921–925
 - environmental services and, 2:1000–1002
 - examples of, 1:525
 - free rider problem of, 1:525
 - fugitive resources and, 1:526, 1:527 (fig.)
 - geographical typology of, 1:526, 1:528
 - geography and, 1:526
 - humans and spatial environment interaction and, 1:526
 - migratory resources and, 1:526, 1:527 (fig.)
 - open-access resource and, 1:526, 1:527 (fig.)
 - Elinor Ostrom's work in, 1:525, 1:529
 - research examples of, 1:526
 - scale and space issues in, 1:526
 - spatial adjustment for river basin conflict resolution
 - example of, 1:527 (fig.)
 - tragedy of open-access resources (Ostrom) and, 1:525–526, 1:529
 - Tragedy of the Commons thesis (Hardin) and, 1:525–526
 - user incentives, 1:525
 - See also* Common property resource management; Commons, tragedy of the
- Common property resource management, 1:528–532**
 - common/communal property rights and, 1:529–530
 - common property resources (CPRs) and, 1:528
 - community-based natural resource management and, 2:549–551
 - community forestry and, 2:551–553
 - conditions for success of, 1:530, 1:531 (table)
 - CPRs examples and, 1:528
 - explanation of, 1:528
 - free rider problem and-529, 1:528
 - global common resources issues and, 1:530–531
 - governmentality and conservation and, 3:1359–1360
 - indigenous water management and, 3:1573–1576
 - open-access property rights and, 1:529, 1:530
 - Elinor Ostrom's work, 1:529
 - principles of difficulty or exclusion and subtractability, 1:528–529, 1:530
 - private property rights and, 1:529, 1:530
 - property rights systems for governing CPRs and, 1:529–530
 - state or government property rights and, 1:529
 - tragedy of open access and, 1:529
 - tragedy of open-access resources (Ostrom) and, 1:529
 - Tragedy of the Commons (Hardin) and, 1:529
 - See also* Common pool resources (CPRs); Commons, tragedy of the; Distribution of resource access; Governance
- Commons, tragedy of the, 1:532–535**
 - common pool resources (CPRs) and, 1:525–528
 - commons or common pool resources definition and, 1:532
 - communal property solution to, 1:534
 - critiques, 1:534–535
 - current research, 1:535
 - desertification resulting from, 2:716
 - destruction of the commons and, 1:525–526
 - developing world examples of, 1:532–533, 1:533 (photo)
 - distribution of resource access and, 2:779
 - examples of, 1:532–533, 1:533 (photo)
 - excludability and subtractability issues and, 1:532
 - fisheries example of, 1:532
 - forests, pasture, grazing land examples of, 1:532–533
 - free-riders issue in, 1:532
 - global warming example of, 1:533
 - groundwater resources and, 3:1388
 - Garrett Hardin's thesis of, 1:525–526, 1:532
 - influence and, 1:534
 - natural resources management policies and, 1:529, 1:532
 - nomadic herding and, 4:2032
 - Elinor Ostrom's work in, 1:525, 1:534
 - overpopulation and pollution examples of, 1:533
 - pollution of the commons and, 1:533
 - socialism or privatization as solutions to, 1:533–535
 - social justice perspective on, 1:535
 - solution, 1:533–534
 - sustainable fisheries and, 6:2755
 - See also* Common pool resources (CPRs); Common property resource management
- Commonwealth of Independent States (CIS), 2:536–537**
 - CIS Joint Armed Forces High Command and, 2:536
 - Collective Security Treaty Organization (CSTO) and, 2:536–537

- context and genesis of, 2:536
- criticism of, 2:537
- current status and prospects of, 2:537
- economic affairs in, 2:537
- economic and political focus of, 2:536
- Economic Council and Economic Court of, 2:537
- governing functions of, 2:536
- GUAM Organization for Democracy and Economic Development and, 2:537
- membership of, 2:536 (table)
- military cooperation within, 2:536–537
- Minsk Agreement and, 2:536
- Soviet Union collapse and, 2:536
- Communications geography, 2:537–542**
 - Ronald Abler's contributions to, 1:1–2
 - background, 2:538–539
 - closed-circuit television systems in cities and, 2:541
 - cultural geography issues and, 2:538
 - current and future trends in, 2:541
 - cyberspace and virtual space and, 2:539–540, 2:646–648
 - economic changes issues in, 2:540–541
 - geographical patterns of economic activity and, 2:851
 - geography element in, 2:539
 - Habermas's public sphere concept and, 2:541
 - ICTs and social impacts of, 2:540
 - ICTs and space relationship focus of, 2:537–538
 - ICTs surveillance and self-surveillance and, 2:541
 - information society and, 3:1593–1594
 - interdisciplinary nature of, 2:538
 - media, geopolitics/political geography issues in, 2:541
 - network accessibility issues and, 2:539
 - popular geopolitics and, 2:541
 - research areas of, 2:537–538
 - spatial barriers elimination and, 2:539
 - spatial science and modeling theme of, 2:539
 - timeline of fiber optic networks and 24/7 communication technologies, 2:539
 - timeline of geography of ICT networks research, 2:538–539
 - timeline of humanist, Marxist, and behavioral geography approaches, 2:538
 - timeline of Internet, digitization, computer communication technologies and, 2:538
 - timeline of political and economic goal facilitation, 2:538–539
 - timeline of social issues and changes, fulfilling human potential fulfillment, 2:538
 - timeline of space representations research, 2:538
 - timeline of transportation geography and spatial analysis, 2:538
 - transportation geography and, 2:539
 - urban structures issues and, 2:539
- Communism and geography, 2:542–545**
 - architecture, ideology, and public space and, 2:543–544
 - collectivization and, 2:542–543
 - communist cities and, 2:543–544
 - Council for Mutual Economic Assistance and, 2:593–595
 - Five Year Plans (Soviet Union) and, 2:542
 - Great Leap Forward (China) and, 2:542, 2:543
 - housing and, 2:544
 - impact and influence of, 2:542
 - industrialization and, 2:542
 - Moscow, May Day celebrations and, 2:544, 2:544 (photo)
 - public space in communist countries, 2:543–544, 2:544 (photo)
 - renaming of places after heroes and, 2:543
- Community-based conservation, 2:545–547**
 - activities associated with, 2:545–546
 - benefits of, 2:545
 - community garden planning, Echo Park area of Los Angeles, California, 2:548 (photo)
 - concepts related to, 2:544
 - ecosystem management and, 2:545
 - efficacy and appropriateness criticisms of, 2:546–547
 - evaluating success of, 2:546
 - indigenous and community conserved areas, 3:1557–1561
 - indigenous environmental knowledge and, 3:1354–1567
 - multistakeholder participation and, 4:1956–1959
 - skill levels issue and, 2:547
 - See also* **Community-based environmental planning (CBEP); Community-based natural resource management (CBNRM)**
- Community-based environmental planning (CBEP), 2:547–549**
 - advantages of, 2:548
 - applications of, 2:549
 - capacity of communities issue and, 2:548
 - communicative action (Habermas) and, 2:548
 - community participation element in, 2:548
 - conceptual ancestry and rationale of, 2:547–548
 - definition of, 2:547
 - democratic effects of, 2:548
 - indigenous knowledge *vs.* technical skills and, 2:548
 - limitations and criticism of, 2:548–549
 - outcomes and legitimacy of, 2:548
 - participatory planning and, 4:2126–2129
 - place-based environmental management element of, 2:547–548
 - scale of environmental issues and, 2:548–549
 - Seeing Like a State* (Scott) and, 2:548
 - top-down planning approach *vs.*, 2:548
 - See also* **Community-based conservation; Community-based natural resource management (CBNRM); Environmental planning**
- Community-based natural resource management (CBNRM), 2:549–551**
 - adaptive harvest management and, 2:551
 - bioregionalist promise concept (Paehlke) and, 2:551
 - colonialism and, 2:550
 - community forestry and, 2:551–553
 - community forestry example of, 2:550
 - defining characteristics of, 2:550
 - ecosystem-based river basin management and, 3:1620
 - environmental entitlements and, 2:921–925
 - feedback effect concept (McCay and Jentoff) and, 2:551
 - flow resources focus of, 2:549–551
 - local ownership or access and use rights feature of, 2:549–550
 - open-access resources and, 2:550
 - as a practice, 2:549–550
 - as a process, 2:550
 - securing management authority and, 2:550
 - sense of place and belonging and, 2:551
 - sustainable management benefit of, 2:550–551
 - See also* **Community-based conservation; Community-based environmental planning (CBEP)**
- Community forestry, 2:551–553**
 - building local capacities in, 2:552
 - capacity building and, 2:552
 - central issues in, 2:552–553
 - community-based natural resource management and, 2:549–551
 - definition of, 2:551–552
 - enabling participation issue in, 2:552–553
 - goal of, 2:552
 - indigenous forestry and, 3:1569–1570
 - participation and building community capacities in, 2:552
 - participatory research and, 2:552
 - See also* **Social forestry**

- Commuting, 2:553–555**
 commute definition and, 2:553
 commuting paradox concept and, 2:554
 commuting and, 2:553
 Compact City or Polycentricity Policy (Europe) and, 2:555
 costs of, 2:554
 disutility features of, 2:554
 from exurbs, 2:1075
 gender differences in, 3:1096–1097
 geographic dispersal of economic activities and, 2:554
 GIS in transportation and, 3:1311–1312
 Susan Hanson's work in, 3:1400–1401
 long distance and excess commuting and, 2:554
 New Urbanism movement (U.S.), 2:555
 physiological and psychological impacts of, 2:554–555
 positive utility features of, 2:555
 research objectives, 2:553
 separation of work from residence place and, 2:554
 urban sprawl and suburban development and, 2:554
- Comoros**
- Comparative advantage, 2:556–558**
 absolute advantage and, 2:556
 capitalism's success attributed to, 2:556
 division of labor and, 2:780–781
 economic geography implications of, 2:556–557
 factor-price equalization and, 2:557
 free trade and, 2:556
 Heckscher-Ohlin multi-factor approach to trade theory and, 2:557, 5:2395
 large *vs.* small markets and, 2:556–557
 location quotients and, 4:1796–1797
 newly industrializing countries and, 4:2021
 production factors in, 2:557
 regions, cities, or countries specialized production or export and, 2:556
 Ricardo's two-country, two-product theory of, 2:556–557, 2:557 (table)
 transportation element of, 2:557
- Competitive advantage, 2:558–559**
 comparative advantage and, 2:556–558
 demand conditions of, 2:559
 determining factors of, 2:558
 dynamic and changing nature of, 2:558
 factor conditions or production factors of, 2:559
 high value-added goods and, 2:558
 nation's attributes to increase, 2:558–559
 networks access factor in, 2:559
 productivity growth element in, 2:558
 social creation of innovation focus of, 2:558
 state support factor in, 2:559
- Complexity theory, 2:559–561**
 algorithmic, deterministic, and aggregate complexities (Manson) and, 2:560
 cellular automata and, 1:368–371
 chaos theory and, 2:560
 cities as fractals theory (Batty) and, 2:561
 complex adaptive systems explained by, 2:559
 complex systems models and, 2:561–567
 conceptualizing space, time, and space-time (Massey) and, 2:560, 4:1866–1867
 contributors to, 2:560
 definitions of, 2:559–560
 dispersed and decentralized control of, 2:560
 distributed artificial intelligence foundation of, 2:560
 ecotones and, 2:867
 emergence phenomenon and, 2:560
 equilibrium element in, 2:560
 evolutionary economic geography and, 2:668
 general systems theory (GST) and, 2:560
 geographic applications of, 2:560
 intra-disciplinary nature (O'Sullivan) of, 2:560
 landscape ecology and, 2:867
 land use and land cover change application of, 2:561
 multiagent systems tool of, 2:560–561
 physical geography and human geography commonalities (Massey) and, 2:560
 positive feedback loops in, 2:560
 segregation experiments (Schelling) using, 2:560
 spatial behavior research (Batty) and, 2:561
 tools of, 2:560–561
 urban systems research (Batty) and, 2:560
See also Complexity theory: noted individuals
- Complexity theory: noted individuals**
 Michael Batty, 2:560
 Nicholas Chisholm, 2:560
 John Holland, 2:560
 David Livingston, 2:560
 Steven Manson, 2:560
 Doreen Massey, 2:560, 4:1866–1867
 David O'Sullivan, 2:560
 Dawn Parker, 2:561
 Jonathon Raper, 2:560
 Thomas Schelling, 2:560
 Ludwig von Bertalanffy, 2:560
- Complex systems models, 2:561–567**
 from analysis to synthesis of, 2:561–562
 applications of, 2:563–567
 “butterfly effect,” chaos theory and, 2:563
 cellular automata and, 1:368–371, 2:567
 complex adaptive systems (CAS) and, 2:561
 complexity theory and, 2:559–561
 computer simulations use of, 2:567
 conceptual models in, 2:563, 2:564 (fig.)
 continuous space-and-time models of, 2:565–566
 coupled map lattices *vs.* cellular automata models and, 2:566–567
 discrete space-and-time models of, 2:566–567
 discrete temporal models of, 2:563, 2:565, 2:565 (fig.)
 emergent properties feature of, 2:562
 examples of, 2:562
 explanation of, 2:561
 feedback processes in, 2:562
 global chaotic stability concept and, 2:565
 industrial ecology and, 3:1577–1579
 Kolmogorov (K-) or Kolmogorov complexity and, 2:562
 Lyapunov exponents feature of, 2:562
 mathematical models in, 2:563–567
 Moore neighborhood of coupled map lattices and, 2:566–567
 nonlinearity processes element of, 2:562
 Jonathan Phillips's work in, 2:562
 Von Neumann neighborhood of coupled map lattices and, 2:566
See also Agent-based models (ABMs)
- Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA), 4:1808**
- Comte, Auguste, 4:1800**
- Conditions of Agricultural Growth (Boserup), 1:36**
- Condorcet, Nicolas de, 3:1433, 4:1819, 4:1860, 4:2015**
- Conference of Latin Americanist Geographers (CLAG), 2:567–568**
 John P. Augelli and, 2:567
 Arch C. Gerlach and, 2:567

- governing structure of, 2:568
- Preston James and, 2:567
- Latin American Specialty Group of, 2:567
- meetings of, 2:568
- printed and electronic publications of, 2:568
- specialty groups of, 2:567
- working committees of, 2:567
- Conflation, 2:568–569**
 - data fusion and, 2:568
 - definition of, 2:568
 - map-to-map *vs.* map-to-image *vs.* image-to-map conflation and, 2:569
 - match-and-merge conflation strategy and, 2:568–569
 - spatial data conflation software and, 2:569
 - USGS/Census map conflation system and, 2:568–569
- Congo River, tropical rain forest of, 1:453, 1:454
- Connell, John, 4:1969
- Connell, Robert, 4:1865
- Conrad, Joseph, 4:1787
- Conservation, 2:569–571**
 - Civilian Conservation Corps and, 2:570
 - definitions, 2:569
 - ecological and carbon footprints and, 2:570–571
 - Everglades restoration and, 2:1038–1039
 - fossil fuel use and greenhouse gas emission issues and, 2:570
 - global wildlife conservation and biodiversity and, 2:570
 - keystone species and, 4:1655–1658
 - landscape and wildlife conservation and, 4:1696–1698
 - national parks and, 2:569–570
 - National Park Service and, 2:570
 - neo-Malthusianism and, 2:570
 - parks and reserves and, 4:2117–2120
 - pollution, social justice, environmental movement and, 2:570
 - population growth issues and, 2:570
 - Soil Conservation Service and, 2:570
 - sustainable development and, 2:570
 - U.S. Environmental Protection Agency and, 2:570
 - U.S. movement of, 2:569–570
 - whole earth ecosystem and, 2:570
 - See also* Conservation: noted individuals; **Conservation zoning**
- Conservation: noted individuals, 2:570
 - Rachel Carson, 2:570, 4:2158
 - Barry Commoner, 2:570
 - Paul Ehrlich, 2:570
 - Barry Goldwater, 2:570
 - George Perkins Marsh, 2:569, 4:1858–1859, 4:2180
 - Clifford Pinchot, 2:570
 - Franklin D. Roosevelt, 2:570
 - Theodore Roosevelt, 2:569–570
 - Henry David Thoreau, 2:569
- Conservation International, 2:871
- Conservation zoning, 2:571–572**
 - bounded zones with rules and, 2:571
 - definition and explanation of, 2:571
 - ocean conservation zoning and, 2:572
 - political features of, 2:572
 - rural conservation zoning and, 2:571–572
 - spatial planning strategy of, 2:571
 - sustainable communities and, 2:571
 - urban planning and, 2:571
 - See also* **Conservation**
- Constructivist learning theory
 - behavioral geography and, 1:189
 - heterogeneous constructivism (Demeritt), critical GIS and, 2:614
 - social construction of space and, 5:2297
- Consumption, geographies of, 2:572–576**
 - Walter Benjamin's work, 2:573–574
 - central place theory and, 2:575
 - class, gender, ethnicity, and power factors of, 2:573
 - commodities as distillations of signs (Benjamin) and, 2:573–574
 - commodities as embodiments of social relations (Marxism) and, 2:573
 - commodity chains and, 1:522–525
 - commodity fetishism concept and, 2:573
 - consumption as a social process and, 2:574
 - definitions, 2:572
 - economic landscapes and, 2:575
 - geographies of food and, 3:1144–1146
 - geography of tourism and, 2:575
 - global economy and, 2:575
 - humanistic geography and, 2:574–575
 - impact of, 2:572
 - Keynesian demand management and, 2:572
 - Mall of America, Bloomington, Minnesota, and, 2:574 (photo), 2:575
 - Marxist interpretation of, 2:573
 - mass production and, 2:572
 - neoclassical economics and, 2:572–573
 - postmodernist consumption analysis and, 2:574
 - principles of, 2:574–575
 - production relationship to, 2:572
 - recycling of municipal solid waste and, 5:2372–2375
 - symbolic value of commodities and, 2:574
 - theoretical perspectives on, 2:572–574
 - world economy changes and, 2:572
 - See also* **Agrofoods; Food, geography of**
- Convention on Biological Diversity (CBD)
 - biodiversity definition of, 6:2748
- Convention on International Trade in Endangered Species of Wild Fauna and Flora, 3:1604
- Convention on Migratory Species, 3:1604
- Cook, Captain James, 2:576–577**
 - Alaska and Hawaiian islands explored by, 2:576
 - Antarctic explored by, 2:576
 - Cook Islands explored by, 2:576
 - Earth's resources studied by, 5:2447
 - New Zealand and Australia explorations of, 2:576
 - Northwest Passage sought by, 2:576
 - Pacific Ocean travels of, 2:575, 3:1461
 - St. Lawrence River mapped by, 2:576
- Cook, Ian, 1:524
- Cooke, Philip, 4:1791
- Coordinate geometry, 2:577–579**
 - Cartesian coordinate system used in, 2:577
 - distortion issues and, 2:578
 - geocentric coordinate system, 2:578–579, 2:578 (fig.)
 - geometric measures and, 3:1240–1241
 - projecting objects from 3D model to 2D map and, 2:578
 - scale and distance unit implications of 3D model coordinate system and, 2:577, 2:577 (fig.)
 - 3D modeling software and, 2:577
 - See also* **Coordinate systems; Coordinate transformations**
- Coordinate systems, 2:579–580**
 - absolute methods of specifying location and, 2:579
 - coordinate geometry and, 2:577–579
 - curvature of the earth issue and, 2:579
 - Earth Centered, Earth Fixed X, Y, Z system (ECEF) system, 2:579
 - geocoding and, 3:1208–1209
 - geometric correction and, 3:1239–1240

- local plane coordinate systems, 2:579
 longitude, latitude, and altitude examples of, 2:579
 map projections and, 2:579, 4:1841–1849
 Military Grid Reference System (MGRS), 2:580
 national grid systems, 2:579–580
 participatory mapping and, 4:2124–2125
 projection parameters and, 2:579
 surveyors and engineers use of, 2:579
 Universal Transverse Mercator (UTM) system of, 2:580
See also Coordinate geometry; Coordinate transformations; Earth's coordinate grid
- Coordinate transformations, 2:580–581**
 affine transformation and, 2:581
 control points element of, 2:581
 coordinates conversion or alteration and, 2:580–581
 definitions, 2:580–581
 geometric correction and, 3:1239–1240
 GIScience applications of, 2:580
 local models and, 2:581
 map projections and, 2:581
 polynomial models in, 2:581
See also Coordinate geometry; Coordinate systems
- Cope, Meghan, 2:615
 Copernicus, 1:116
- Coral reef, 2:581–584**
 atolls, 2:583
 barrier reefs, 2:583
 biodiversity conservation and, 3:1635
 climate and, 2:583
 Coron Island, coral island seascape, Tagbanwa people, the Philippines, 3:1560 (photo)
 fauna harvesting for aquarists and, 2:583
 formation of, 2:583
 fringing reefs, 2:583
 geographic locations of, 2:581–582
 hard *vs.* soft corals and, 2:583
 low islands and atoll structures and, 3:1635–1638, 3:1636 (photo), 3:1637 (photo)
 in Mariana Islands, Guam, 2:582 (photo)
 protein richness of, 2:582
 as resource at risk, 2:582–583
 species richness and biodiversity of, 2:582
 tourism economy and, 2:582–583
 volcanoes and, 2:583
See also Coral reef geomorphology
- Coral reef geomorphology, 2:584–586**
 beginnings of, 2:584–585
 explanation of, 2:584
 geomorphic features of, 2:584, 2:585 (fig.)
 global debate on future of, 2:586
 intrareef-platform scale of, 2:586
 landforms and, 2:584
 plate tectonics and, 2:586
 reef sedimentary landforms *vs.*, 2:584, 2:585 (fig.)
 short-term geological and long-term geological timescales and, 2:584
 space and timescale of relevance to, 2:585–586
- Corbridge, Stuart, 3:1200, 3:1420
- Coriolis force, 2:586–587**
 atmospheric circulation and, 1:132, 1:133, 2:586–587
 Coriolis effect and, 2:587
 Coriolis parameter definition and, 2:587
 Earth's rotation element in, 2:586, 3:1395
 El Niño-Southern Oscillation (ENSO) and, 2:888
 equator and, 2:1008
 as a fictitious force, 2:587
 hurricanes and, 1:134
 magnitude of, 2:587
 Northern *vs.* Southern Hemisphere and, 2:586
 ocean circulation and, 2:586–587
 oceanic circulation and, 4:2058–2064
- Cornish, Vaughan, 4:2175
- Corporate voluntary environmental initiatives and self-regulation, 2:587–589**
 advocates *vs.* critics of, 2:589
 catalyst factors in, 2:589
 categories of, 2:588
 eco-efficiencies and, 2:587, 2:588–589
 eco-labeling and accreditation programs and, 2:588
 explanation of, 2:587
 financial benefits of, 2:588–589
 Global Reporting Initiative (GRI) and, 2:588
 government regulation *vs.*, 2:587
 International Organization for Standardization and, 2:588
 liability issues and, 2:588
 market-based environmental incentives *vs.*, 2:587
 perceived obligation motivations and, 2:588
 product stewardship programs and, 2:588
 Responsible Care program (chemical industry) and, 2:587–588
- Cosgrove, Denis, 2:589–590**
 art and geography, 1:118
 class and nature, 1:425
 “crisis of representation,” 2:589, 2:590
 cultural landscape studies of, 2:590, 4:1863
 geographic imagination and knowledge representation work of, 2:589, 3:1221, 5:2432
 iconography and, 2:590
 landscape depiction and mapping focus of, 2:589, 2:590, 5:2432, 6:2810–2811
 Marxist geography, 4:1863
 “One-World, Whole-Earth” *Apollo* space mission and, 4:2175
 “spatial turn” and, 5:2668
 symbolic landscapes and, 2:590, 4:1863
 vision and geography, 2:590, 6:3025
- Cosmopolitanism, 2:590–592**
 antinationalism and antipatriotism of, 2:591
 Bahá'í faith and, 2:591
 as a ethical, moral, and political philosophy, 2:590
 feminism and, 2:591
 globalization and, 2:591
 Hierocles's circle model and, 2:591
 humanitarian interventions and, 2:591–592
 meanings associated with, 2:590
 moral universalism and, 2:590
 neoliberalism and, 2:591
 origins of, 2:590–591
 postpositivism and, 2:591
 Renaissance and Enlightenment thinkers and, 2:591
 shared humanity and, 2:590
- Costanza, Robert, 5:2446
- Costa Rica
 bird species in, 1:199
 Conference of Latin Americanist Geographers held in, 2:568
 Costa Rican National Grid coordinate system, 2:579–580
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 ecotourism certification in, 2:873
 ecotourism in, 2:870
 greenhouse gas emissions and, 1:463

- installed capacity for electricity production
 - forecast, 2010, 3:1268 (fig.)
- sea turtle conservation, as common resource in, 1:526
- trading blocs and, 3:1550
- Cost-benefit analysis (CBA)**, 2:592–593
 - criticism of, 2:593
 - definition and applications of, 2:592
 - ex ante*, *vs. ex post*, *vs. in medias res* uses of, 2:592
 - net present value provided by, 2:592
 - steps in process of, 2:592–593
- Cote d'Ivoire, 3:1190 (table)
- Council for Mutual Economic Assistance (COMECON)**, 2:593–595
 - barter process in, 2:594
 - bilateral trade and, 2:594
 - dissolution of, 2:594
 - governing structure of, 2:593–594
 - independence from Soviet Union and, 2:594
 - limitations of, 2:594
 - membership of, 2:593 (table)
 - multilateral trade and, 2:594
 - price-setting markets absence in, 2:594
 - Solidarity movement (Poland) and, 2:594
 - Soviet Union and, 2:593–594
- Countermapping**, 2:595–596
 - cartographic forms of, 2:595
 - focus areas of, 2:595
 - indigenous cartography and, 2:595
 - public participation GIS (PPGIS) and, 2:595
 - social injustice focus of, 2:595–596, 3:1645
- Counterurbanization**, 2:596–597
 - deconcentration from urban to rural areas and, 2:596
 - definition of, 2:596
 - in France, 2:596
 - industrial to postindustrial society shift and, 2:596–597
 - suburbanization *vs.*, 2:596
- Coupe, Patty, 4:1882
- Coupled human and animal systems (CHAS)**, 2:597–599
 - as an analytical concept, globalization and, 2:598
 - animal geographies and, 1:75–79
 - characteristics of, 2:597, 2:598 (fig.)
 - coupled human and natural system (CHANS) and, 2:598 (fig.)
 - Domestication of animals, 1:75–79
 - human/animal integral interdependent system and, 2:597–598
 - multidisciplinary nature of, 2:598
 - nomadic pastoralism and, 2:597
 - spatial and temporal movement elements in, 2:598
- Coupled human and natural systems (CHANS)**, 2:599–604
 - biophysical and socioeconomic sphere linkages and, 2:600
 - carbon dioxide levels and, 2:601–602
 - characteristics of, 2:598 (fig.), 2:599, 2:600–601
 - climate change as, 2:601–602
 - coupled human and animal systems (CHAS) and, 2:598 (fig.)
 - cross-scale measurement difficulties and, 2:600
 - distance relationships and, 2:600
 - environmental determinism and, 2:599
 - future directions and challenges of, 2:603
 - gains from, 2:603
 - hazards research and, 2:599
 - human-environment relations research and, 2:599–600
 - land use and cover change (LUCC) and, 2:602
 - linkages across spheres and nonlinear changes over time
 - examples and, 2:602
 - long-term impacts, legacy effects and, 2:601
 - methods and tools used in, 2:602
 - modeling approaches to, 2:602
 - natural hazards and, 2:600–601
 - nonlinear systems and behavior and, 2:601
 - political, economic, and ecological linkages and, 2:600
 - positive and negative feedback loops elements of, 2:600, 2:602
 - reciprocal effects element of, 2:600
 - research areas and, 2:599–600
 - research funding and, 2:599
 - scale element of, 2:600
 - scale mismatches over time and, 2:601
 - synergistic and cumulative effects of local processes and, 2:600
 - systems approach to, 2:602–603
 - theoretical framework of, 2:602–603
 - theory of adaptive change and, 2:603
 - unique properties over time and, 2:600–601
- Cousteau, Jacques, 4:2068
- Cowles, Henry, 1:209, 4:2180
- Cox, Kevin, 5:2575
- CPRs. *See* **Common pool resources (CPRs)**
- Cranberry Glades Botanical Area, West Virginia, 2:868 (photo)
- Crang, Philip, 1:524
- Cranz, Galen, 4:1700
- Creamer, N., 1:54
- Creed, Clara, 2:1043–1044
- Creep**, 2:604–605
 - aseismic creep, 2:604, 2:605
 - definition of, 2:604
 - downhill creep, 2:604–605
 - expansion and contraction cycles and, 2:604
 - mass wasting and, 4:1868–1871
 - rock-mass creep, or deep creep and, 2:604
 - sagging or settlement, grabens, and antislope scarps from
 - downhill creep and, 1:186, 2:604
 - snow on slopes effects and, 2:605
 - soil creep effects and, 2:605
 - types of, 2:604
- Cresswell, Tim, 3:1419
- Crime, geography of**, 2:605–609
 - approaches and issues in, 2:606
 - Cartographic School of Criminology and, 2:606–607
 - Chicago School of social ecology and, 2:607
 - conflict school *vs.* consensus school of criminal law and, 2:606
 - crimes per population base metric of, 2:606
 - criminal law as cause of crime and, 2:606
 - environmental criminology and, 2:608
 - fear geographies and, 3:1088
 - geographical profiling and, 2:608
 - GIS technology and, 2:608
 - history, 2:606–607
 - International Criminal Court (ICC) and, 3:1605–1608
 - location quotients, spatial variation of crime and, 2:606
 - mobility of offenders factor in, 2:607
 - National Crime Victimization Surveys data and, 2:606
 - police report data and, 2:606
 - poverty and illiteracy factors and, 2:607
 - self-report data and, 2:606
 - social disorganization factor in, 2:607, 2:608
 - spatial variation of crime across urban areas research
 - and, 2:607–608
 - timeline of 1960s–1980s, 2:607–608
 - timeline of 1990s, 2:608
 - violent crime *vs.* crime against property and, 2:606
 - See also* **Law, geography of**
- Crisis (economic)**, 2:609–610
 - capitalist crisis in production and, 2:609–610

- discursive nature of crisis diagnosis and, 2:609
flexible accumulation and, 2:610
Fordism crisis and, 2:610
geography of uneven development concept and, 2:610
Limits to Capital (Harvey) and, 2:609–610, 4:1862, 5:2350–2351
mainstream economics, localized system and, 2:609
Marxist crisis theories and, 2:609–610
over accumulation theory of crisis and, 2:609, 2:610
recurring economic crises and, 2:609
spatial fixes limitations and, 2:610
- Critical geopolitics, 2:610–613**
“axis of evil” (G. W. Bush) and, 2:612
cognitive elements *vs.* affective elements and, 2:613
critical human geography and, 2:705–706
environmental security and, 2:998–1000
Eurocentrism and, 2:1028–130
explanation of, 2:610
feminist critiques of, 2:613
formal geopolitics, 2:611–612
future trends in, 2:612–613
genocide geographies and, 3:1200
goal of, 2:610
heartland/rimland model of, 2:611–612, 4:1812
Nazi aggression justification and, 2:611
nonrepresentational theory and, 2:612–613
oceans and, 4:2069
origins of, 2:611
popular geopolitics, 2:612
power and knowledge elements in, 2:611, 5:2224
practical geopolitics, 2:612
World War II Axis powers and, 2:612
See also Critical geopolitics: noted individuals; **Geopolitics**
- Critical geopolitics: noted individuals**
John Agnew, 1:32–33
Michel Foucault, 2:611
Henry Kissinger, 2:611
Henri Lefebvre, 2:611, 4:1768–1770, 4:2043
Halford Mackinder, 2:611, 4:1812–1813
Nicholas Spykman, 2:611
- Critical GIS, 2:613–616**
applications of, 2:615
breast cancer and environmental links research using, 2:615
epistemology and, 2:614
external *vs.* internal critique of, 2:614
feelings and emotions in GIS analysis and, 2:615
feminism and, 2:615
GIS researchers and social critics collaboration and, 2:614
goal and agenda of, 2:613–614
heterogeneous constructivism (Demeritt) and, 2:614
human geographers and GIScientists conflict origin of, 2:614
neighborhood mapping project using, 2:615
ontology, essence of being and, 2:614–615
public participation GIS (PPGIS) and, 2:615–616
qualitative methods incorporated into, 2:615
social networking and Web 2.0 applications and, 2:615
See also Critical GIS: noted individuals; **GIScience**
- Critical GIS: noted individuals**
Scott Bell, 2:615
Meghan Cope, 2:615
David Demeritt, 2:614
Sarah Elwood, 2:615
Rina Ghose, 2:616
Piotr Jankowski, 2:616
LaDonna Knigge, 2:616
Mei-Po Kwan, 2:615, 4:1674
Sara McLafferty, 2:615
Timothy Nyerges, 2:616
John Pickles, 4:2182–2813
M. Reed, 2:615
- Critical human geography, 2:616–621**
actor-network theory and, 1:8
Antipode (Wisner and Peet, eds.) and, 1:73, 2:618, 4:2144, 5:2350
Cincinnati Mini-Conference in Critical Geography and, 2:619
Condition of the Working Class in England in 1844 (Engels) and, 2:617
Critical Geography Forum online (U.K.) and, 2:620
critical studies of nature and, 2:623–624
democracy and, 2:705–706
disabled activists and, 2:619
emancipatory politics, progressive social change and, 2:616
ethics and geography and, 2:1013–1016
existentialist geographies and, 2:1046–107
extreme geography and, 2:1073–1074
feminist geography and, 2:618
“The Geography of Women: An Historical Introduction” essay (Hayford) and, 2:618
historical geographies of knowledge production facet of, 2:616
hybrid geographies and, 3:1502–1504
Institute of British Geographers and, 2:619–620
International Conference of Critical Geography, 2:620
International Critical Geography Group and, 2:619–620
journals of, 2:617
justice/injustice geographies and, 3:1643–1645
Marxism and, 2:618–619
medical geographies and, 4:1878
Nordic Symposium on Critical Geography and, 2:618, 2:619
“On Not Excluding Half the Human in Human Geography” essay (Monk and Hanson), 2:618
postmodernism and, 2:619
radical geographers and, 2:618, 2:619
Royal Dutch Shell and, 2:619–620
Royal Geographical Society and, 2:619–620
sexuality geographies and, 5:2538–2540
socialism and, 5:2571
Social Justice and the City (Harvey) and, 2:618, 3:1405, 4:1862, 5:2350, 5:2442
theoretical foundations of, 2:616
See also Critical human geography: noted individuals; **Humanistic geography**
- Critical human geography: noted individuals**
Vera Chouinard, 2:619
Michael Dear, 2:619
Pierre George, 2:617
Anthony Giddens, 3:1277–1278
Ali Grant, 2:619
Derek Gregory, 3:1380–1381, 4:1787
Susan Hanson, 2:618
Brian Harley, 3:1401–1402
David Harvey, 2:618, 3:1404–1406, 4:1862, 5:2350, 5:2442
Alison Hayford, 2:618
Anatole Kopp, 2:617
Peter Kropotkin, 2:617, 5:2211
Yves Lacoste, 2:617
Henri Lefebvre, 2:617
Karl Marx, 2:617
Linda McDowell, 2:618
Janice Monk, 2:618
Gunnar Olsson, 4:2077–2078

- Joe Painter, 2:620
 Richard Peet, 2:618, 4:2144
 John Pickles, 4:2182–2813
 Élisée Reclus, 2:617, 5:2371–2372
 Milton Santos, 2:618
 Ken Saro-Wiwa, 2:619–620
 Jean Tricart, 2:617
 Ben Wisner, 2:618
 Karl Wittfogel, 2:617
- Critical studies of nature, 2:621–625**
 actor-network theory and, 2:623–624
 biological ecofeminism and, 2:623
 class and nature and, 1:423–425
 constructing nature and, 2:621–622
 critical race theory and, 5:2338
 deep-green, deep-ecology philosophies and, 2:624
 denaturalizing gender and socializing nature in, 2:622–623
 ecosystemic approach to nature and, 2:625
 environmental determinism and, 2:621
 environmental discourse and, 2:918–921
 environmental justice and, 2:625
 feminist geographical research and, 2:622–623
 gender and nature and, 3:1194–1197
 geography definitions and, 2:621
 hybrid geographies research and, 2:624
 Marxism and, 2:624–625
 nature definitions and views on, 2:621
 political ecology and, 2:622
 politicizing nature and denaturalizing hazards and, 2:622
 post-humanism, interspecies connections and, 2:623–624
 urbanization of nature and, 2:625
- Croatia
 bluefin tuna farm, mid Adriatic, 4:2066 (photo)
 economically active females in, 3:1190 (table)
- Croke, J., 3:1512
- Cronon, William, 4:1995, 5:2339
- Crop genetic diversity, 2:625–627**
 crop breeding programs decrease of, 2:626
 definition of, 2:625–626
 domestication bottleneck process and, 2:626
 domestication of plants and, 2:784–786
 gene banks and, 2:626
 genetic erosion concept and, 2:626
 genetic resource conservation programs and, 2:626–627
 Germplasm Enhancement for Maize project and, 2:626 (photo)
 hybridization of plants and, 3:1504–1506
 International Treaty on Plant Genetic Resources for Food
 and Agriculture (ITPGRFA) and, 2:626
 measurement methods of, 2:626
 toxic levels of, 2:626
- Crop rotation, 2:627–630**
 agrochemical use and, 2:627
 alternative crop rotation and, 2:628 (photo)
 cropping pattern changes and, 2:629–630
 crop properties and rotation benefits of, 2:628, 2:628 (fig.)
 in developing world, 2:627
 fallow farming and, 2:627
 mixed farming and, 4:1914–1917
 pest control by using, 2:628
 social, economic, and environmental factors in, 2:627
 weed control by using, 2:629
- Cross-border cooperation (CBC), 2:630–631**
 borderlands and, 1:291–292
 cross-border spatial integration and, 2:630
 economic, cultural, and political benefits of, 2:630
- European Union integration process and, 2:630
 Euroregions and, 2:630, 2:631 (fig.)
 goal to transcend barrier function of borders and, 2:630
 multilevel governance networks and, 2:630
See also **Borders and boundaries**
- Cruikshank, George, 3:1363
- Crump, J., 2:1075
- Cuba
 Cold War and, 1:505
 domino theory and, 3:1224
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 economic restructuring in, 5:2460
 ecotourism in, 2:870
 Guantánamo Bay military prison in, 1:25, 3:1381, 4:1764
 human rights atrocities in, 3:1481
 Alexander von Humboldt's travels in, 3:1482
 Spanish colony of, 1:512
 sustainable agriculture success in, 6:2744
- Cultural ecology, 2:631–634**
 current trends in, 2:633–634
 William Denevan's work in, 2:632
 discourse analysis, critical theory used in, 2:632
 empirical feedback element in, 2:632
 energy and human ecology and, 2:895–896
 geospatial technologies used in, 2:632
 Hugo Grotius and, 4:2065
 historical development of, 2:632–633
 human adaptation to and of environment focus of,
 2:632, 2:895–896
 human agency issue and, 2:632
 human ecology and, 2:633, 2:895–896
 indigenous agriculture and, 3:1556
 issues addressed by, 2:632
 journals specializing in, 2:633
 land use and cover change field and, 2:633
 local food and subsistence systems focus of, 2:633
 mixed methods used in, 2:632
 Bernard Nietschmann's work in, 2:632
 oceans and, 4:2065
 political ecology and, 2:632–633, 5:2211, 5:2212
 postmodernism, poststructuralism and, 2:632
 quantitative methods and, 2:632
 Julian Steward's work in, 2:632
 systems ecology and, 2:632, 2:895–896
 toponophilia concept (Tuan) and, 2:637, 3:1476
- Cultural geography, 2:634–640**
 Berkeley School and, 1:191, 1:192
 critical approaches within, 2:637–639
 cultural hearth areas and, 3:1142
 cultural turn and, 2:644–646
 culture as a thing *vs.* as a process and, 2:634–635
 culture definitions and, 2:634–635
 current status of, 2:639
 empiricist approaches within, 2:637
 Enlightenment and, 2:910–911
 folk culture and, 3:1142–1144
 folk *vs.* popular culture and, 2:637, 3:1142
 French Annales School of history and, 1:79–80
 geomancy and, 3:1238–1230
 globalization and, 3:1347
 humanistic approaches within, 2:637, 3:1476–1477
 Jerusalem's Wailing Wall and, 2:638 (photo)
 landscape interpretation and, 2:635–636
 morphology concept (Sauer) and, 2:636

- music and sound geographies and, 4:1967–1970
 non-Anglophone traditions in, 2:636
 oceans and, 4:2069–2070
 place and, 5:2186
 religious geographies and, 5:2405–2409
 research subjects of, 2:639
 sequent occupance and, 5:2534–2535
 sexualized aspects of spatiality and, 2:639
 themes in, 1:191, 3:1142
 toponophilia (love of place) concept (Tuan) and, 2:637, 3:1476
 urban culture and, 3:1142
 U.S. vs. British traditions in, 2:635–636
See also Art and geography; Cultural geography: noted individuals; Sauer, Carl; Tuan, Yi-Fu; specific individuals
- Cultural geography: noted individuals**
 Kay Anderson, 5:2338, 5:2340
 Denis Cosgrove, 2:589–590, 5:2432
 Stuart Hall, 3:1142
 W. G. Hoskins, 2:636
 Don Mitchell, 4:1913–1914
 James Parsons, 4:2120–2121
 Friedrich Ratzel, 2:636
 Carl Ortwin Sauer, 2:635–636, 3:1465, 4:1990, 5:2212, 5:2433
 Yi-Fu Tuan, 2:637, 3:1476, 4:2167
 Paul Vidal de la Blache, 2:636, 3:1464, 3:1465, 3:1476, 5:2387
 Raymond Williams, 3:1142, 5:2297
- Cultural landscape, 2:640–644**
 behavioralist approach to study of, 2:642
 Berkeley School and, 2:635–636, 2:641–642
 Bodie State Historic Park, California, and, 4:1705
 deeper meanings of, 2:642
 early development of, 2:640–642
 environmental determinism and, 2:641–642
 geomancy and, 3:1238–1239
 human modification of Earth's surface focus of, 2:640
landscaef, *landschap*, and *landschaft* terms and, 2:640, 2:641
 landscape architecture and, 4:1698–1701
 landscape as something that is lived concept and, 2:642
 landscape design and, 4:1705
 landscape interpretation and, 4:1713–1715
 landscape morphology and, 2:640, 2:641, 2:643 (fig.)
 landscape quality assessment and, 4:1715–1718
 meanings embedded in, 2:643–644
 mental mapping study approach and, 2:642–643
 origins of, 2:640
 palimpsest concept and, 4:2111–2112
 Park Güell, Barcelona, Spain, and, 2:641 (photo)
 “reading” the landscape and, 2:642, 2:643
 religious geographies and, 5:2405–2409
 research approaches to, 2:642–644
 sense of place and, 2:642
 sequent occupance and, 5:2534–2535
 symbolism element in, 2:643
 time element in, 2:643
 UNESCO definition of, 4:1705
 vernacular landscape concept (Jackson) and, 2:642
See also Architecture and geography; Art and geography;
Cultural landscape: noted individuals
- Cultural landscape: noted individuals**
 Denis Cosgrove, 2:589–590, 5:2432
 J. B. Jackson, 2:642
 Fred Kniffen, 2:642
 Peirce Lewis and, 4:1772–1773
 Carl Sauer, 1:376, 2:635–636, 2:640–642, 2:641, 2:643 (fig.),
 3:1429, 3:1465, 4:1990, 5:2433
- Otto Schlüter, 2:640, 2:641
 Paul Vidal de la Blache, 2:640, 2:641, 3:1465, 5:2387
 Wilbur Zelinsky, 2:642
- Cultural turn, 2:644–646**
 Denis Cosgrove's work and, 2:589–590, 5:2432
 criticism of, 2:850
 culture and embeddedness terms in, 2:849
 cyborg ecologies and, 2:649
 definition of, 2:644
 ecological imaginaries and, 2:829
 everyday life geographies and, 2:1045
 feminist methodologies origins and, 3:1098
 gendered character of labor markets (Massey) and, 2:852,
 4:1866–1867
 geography of enterprise and, 2:850
 inequalities and injustices and, 2:645
 interdisciplinarity of cultural studies and, 2:645
 issues addressed and, 2:645–646, 3:1429
 issues of, 3:1404
 knowledge and meaning making enmeshed within power
 practices and, 2:645
 knowledge produces the world concept, impact of, 2:644–645
 music and sound geographies and, 4:1967–1968
 “new” geographies, 2:645
 objective knowledge impossibility and, 2:645
 origins of, 2:645
 place and politics of representation and, 6:2810
 poststructuralism and, 2:645, 2:849–850
 text/textuality issues and, 6:2810
- Curacao, Dutch colony of, 1:512
 Cutter, Susan, 2:963
- Cyberspace, 2:646–648**
 Advanced Research Projects Agency of U.S. Department of
 Defense and, 2:646
Atlas of Cyberspace and, 2:540, 2:646
 digital convergence of different media and, 2:646–647
 digital divide and, 2:647, 2:748–753
 e-commerce and, 2:844–846
 history and dimensions of, 2:646–648
 hybrid nature of, 2:647
 illegal activities and, 2:648
 Internet domain names growth and, 2:647, 2:647 (fig.)
 Internet *vs.*, 2:646
 mapping cyberspace concept and, 2:540
 material infrastructures element of, 2:647
 as mirror of society, 2:648
 social networks in, 2:648
 “surface Web” *vs.* “invisible” or “deep Web” and, 2:648
 TCP-IP (transfer control protocol, Internet protocol)
 element of, 2:646
 virtual world, 2:647
 World Wide Web creation and, 2:646
See also Communications geography
- Cyborg ecologies, 2:649, 2:649–650**
 actor-network theory and, 2:649
 “A Cyborg Manifesto” (Caraway) and, 2:649
 cultural turn, return to the material and, 2:649
 definition, explanation of, 2:649
 discourse in constituting the world and, 2:649
Hybrid Geographies (Whatmore) and, 2:649–650
 nature, culture, animals and human, object and subject
 boundaries and, 2:649
 as a political metaphor, 2:649
 purification and mediation modernity processes and, 2:649
 relational character of the world element of, 2:649–650

- science studies scholars and, 2:649
Simians, Cyber, and Women (Caraway) and, 2:649
 synthetic and organic interconnections and, 2:649
We Have Never Been Modern (Latour), 2:649
See also Cyborg ecologies: noted individuals
- Cyborg ecologies: noted individuals
 Gilles Deleuze, 2:649
 Felix Guattari, 2:649
 Donna Haraway, 2:649
 Bruno Latour, 2:649, 3:1503
 Sarah Whatmore, 2:649–650, 3:1503
- Cyclones: extratropical, 2:650–654**
 atmospheric circulation and energy transfer patterns of, 2:650
 Bergen school of meteorology and, 2:650–651
 comma-cloud shape of, north-central United States, south-central Canada, 2:651 (image)
 extratropical cyclogenesis, 2:652–653
 incipient frontal wave and, 2:652, 2:652 (fig.)
 life cycle evolution of, 2:652 (figs.)
 mature occlusion and, 2:653, 2:654 (fig.)
 mature open wave and, 2:652–653, 2:653 (fig.), 2:654 (fig.)
 midlatitude weather patterns of, 2:650
 Norwegian Cyclone Model of, 2:652
 polar front theory (PFT), 2:650–652
 Rossby-wave configuration and, 2:652
 stacked low, low-pressure profile rearrangement and, 2:653
 stationary front and, 2:652, 2:652 (fig.)
 tropical cyclones and, 2:651–652
 weather events associated with, 2:650
- Cyclones: occluded, 2:654–661**
 case study, timeline of, 2:657, 2:658 (fig.)
 case study, total precipitation distribution, 2:659, 2:659 (fig.)
 case study, distribution of shorter-period precipitation amounts, 2:659–661, 2:660 (fig.)
 explanation of, 2:654
 frontal development from maturity to occlusion and, 2:655–657, 2:656 (fig.)
 jet streams and surface weather interaction and, 2:654–655
 middle latitude weather changes and, 2:654
 Rossby waves and, 2:654–655
 upper airflow and surface extratropical cyclone formation and, 2:655 (fig.)
 Westerlies and, 2:654
- Cyprus
 cats domestication in, 2:783
 economically active females in, 3:1190 (table)
 European Union (EU) membership of, 2:1035
- Czechoslovakia
 Cold War and, 1:504
 collapse of, 4:1978
 COMECON membership of, 2:593 (table)
 conservation and environmental education movement in, 2:1032
 economically active females in, 3:1190 (table)
 industrialization in, 2:542
- Czech Republic
 acid rain in, 1:7
 AGILE membership of, 1:124 (table)
 automobile industry in, 1:171
 green roof of superstore, Prague, 6:2993 (photo)
- Dacey, Michael, 1:192, 3:1466
 Daguerre, Louis Jacques Mandé, 4:2175
 Dahmann, N., 4:1804
 Dalby, Simon, 3:1252
 Daly, Herman, 2:835, 2:896, 5:2446, 6:2749
 Daly, Reginald, 1:166
Dangermond, Jack, 2:663–664
 ArcGIS developed by, 2:663
 Environmental Systems Research Institute (ESRI)
 co-founded by, 2:663
 spatial analysis methods work of, 2:663–664
 Daniels, Stephen, 1:118, 1:425, 2:590
Darby, Henry Clifford, 2:664–665
Doomsday Book written by, 2:664
 historical geography work of, 2:664
 horizontal *vs.* vertical approach preferred by, 2:664
 medieval England focus of, 2:664
 Darwin, Charles
 atoll subsidence origin theory of, 1:166, 2:585
 Earth's resources studied by, 5:2447
 earthworms observed by, 1:274
 evolution by natural selection work of, 1:209, 2:916
 Galapagos Islands archipelagoes, adaptive radiation and, 1:106
 hybridization views of, 3:1504–1505
 Origin of Species written by, 1:209, 4:2179–2180
Darwinism and geography, 2:665–668
 collective knowledge and, 2:666
 competition and survival of the species and, 2:666
 complexity theory and, 2:668
 Darwinian view of evolution and, 2:665
 William Morris Davis's cycle of life work and, 2:666
 economic landscapes as layers of accumulation and, 2:666
 environmental determinism in geography and, 2:667, 3:1429
 evolutionary economics and, 2:668
 evolution as change through time and, 2:665, 2:666, 4:2179–2180
 geographic impact of, 2:665
 historicism and, 3:1434
 island biogeography and, 3:1635
 Peter Kropotkin's work and, 2:667–668, 5:2211
 Lamarckian evolutionary theory and, 2:666, 2:667, 3:1464
 Pierre-Simon Laplace's probability work and, 2:667
 layering geological metaphor and, 2:666
 Marxist economic geography and, 2:666
 natural selection and struggle for existence issue and, 2:667–668
 organic life and the environment relationship (Ratzel) and, 2:665, 2:666–667
 organism analogy and, 2:666–667
 organization and ecology, 2:666–667
 part-whole dilemma and, 2:666–667
 random nature of original variations work of, 2:665–666
 recent developments, 2:668
 Social Darwinism and, 3:1464
 Herbert Spencer and, 3:1434, 3:1464
Dasymetric maps, 2:669–671
 choropleth mapping origins of, 2:669
 population density by census tract and block group, Guilford County, North Carolina, 2:668, 2:669 (fig.)
 population density using dasymetric mapping, Guilford County, North Carolina, 2:668, 2:670 (fig.)
 treatment of boundaries of political units and, 2:669
 J. K. Wright's work in, 2:670
Database management systems (DBMS)
 benefits of, 2:671
 business models for GIC, 1:308
 client-server architecture and, 1:426–428
 Edgar Codd's relational database work and, 2:671
 conflation and, 2:568–569
 Jack Dangermond's work in, 2:663–664
 data editing and, 2:680–681

- data indexing and, 2:682–684
- definition and history of database models and, 2:671
- environmental mapping, 2:974–976
- error propagation and, 2:1011–1012
- ESRI ARC/INFO coverage format and, 2:674
- ESRI shapefile format and, 2:674, 2:685 (fig.)
- foreign key element of, 2:672, 2:673 (fig.)
- geodatabase format and, 2:674
- geography applications of, 2:674
- GIS data formats and, 2:671, 2:674
- metadata and, 4:1885
- network *vs.* hierarchical model of, 2:671
- normalization database design process and, 2:672
- object-relational model of, 2:671
- one-to-one, one-to-many, many-to-many relationships and, 2:672, 2:673 (fig.)
- primary key identifier element of, 2:672
- query language and methods in, 2:672–674, 2:684–685, 2:685 (fig.)
- referential integrity and, 2:672
- relational database management systems and, 2:671–674
- relational database structure and design and, 2:671–672
- research application of, 2:671
- SELECT command in, 2:672–673
- spatial databases and, 2:671, 2:674
- standard structured query language (SQL) and, 2:671, 2:672–673, 2:676, 2:684–685
- structure and design of relational databases and, 2:671–672, 2:672 (fig.)
- See also* GIS software; GIS specific subject
- Database versioning**
 - branching and versioning in the set approach and, 2:676, 2:676 (fig.)
 - goals of set concept in, 2:676
 - hierarchical structure and, 2:675
 - integrity of data and, 2:675
 - merging of sets and, 2:675
 - parallel lineage tree with active versions at tips, 2:676, 2:676 (fig.)
- Data classification schemes, 2:677–679**
 - assigning data elements to a class and, 2:677
 - choropleth maps and, 1:406–408
 - equal interval classification, 2:677 (fig.), 2:678
 - error propagation and, 2:1011–1012
 - interquartile range classification, 2:678, 2:678 (fig.)
 - natural breaks classification, 2:677 (fig.), 2:678
 - standard deviation classification, 2:678–679, 2:678 (fig.)
 - supervised classification and, 5:2725
- Data compression methods, 2:679–680**
 - error propagation and, 2:1011–1012
 - GIS and geospatial information applications of, 2:680
 - JPEG3000 and MPEG4 and, 2:679
 - “lossy” *vs.* “lossless” compression methods and, 2:679
 - problems solved by, 2:679
 - variable resolution compression method and, 2:680
 - vector quantization (VQ) lossy data compression method and, 2:679–680
- See also* Data format conversion
- Data editing, 2:680–681**
 - accuracy assessment and, 2:680–681
 - data error examples and, 2:680
 - data format conversion and, 2:681–682
 - definition of, 2:680
 - delta value element in, 2:681
 - error magnitude evaluation and, 2:680–681
 - error propagation and, 2:1011–1012
 - imputation procedures used in, 2:681
 - spatial *vs.* aspatial data and, 2:680
- Data format conversion, 2:681–682**
 - error propagation and, 2:1011–1012
 - examples of, 2:681
 - geographic information systems (GIS) use of, 2:681–682
 - Geospatial Data Abstraction Library (GDAL) and, 2:682
 - GIS software programs and, 2:682
 - lossless *vs.* lossy conversion and, 2:681
 - transformational languages and, 2:682
 - vector data to raster representation conversion (lossy) and, 2:681–682
- See also* Data compression methods
- Data indexing, 2:682–684**
 - B-tree nontrivial data index and, 2:683, 2:683 (fig.)
 - functions of, 2:682
 - goal of, 2:682
 - grid indexing and, 2:683
 - Antonin Guttman and, 2:683
 - minimum bounding rectangles (MBRs) or bounding boxes and, 2:684
 - nonspatial data indexing, 2:682–683
 - quad trees and, 2:684
 - R-tree and R*-tree data structure and, 2:683–684
 - spatial data indexing, 2:682, 2:683–684
- Data querying in GIS, 2:684–685**
 - Canadian Geographic Information System (CAGIS), 2:674
 - connecting with other database management systems and, 2:684
 - data duplication prevention and, 2:684
 - Dual Independent Map Encoding (DIME), U.S. Census Bureau and, 2:674
 - ESRI shapefile format and, 2:674, 2:685 (fig.)
 - GIS data formats and, 2:674
 - join and link functions and, 2:684
 - key fields and, 2:684
 - relational database practices and, 2:684
 - spatial queries in, 2:685
 - standard structured query language (SQL) and, 2:671, 2:672–673, 2:676, 2:684–685
- See also* Database management systems (DBMS); GIS software; GIS specific subject
- Datums, 2:685–686**
 - Earth shapes and, 2:686
 - equator and prime meridian as zero points and, 2:686
 - equatorial datums and, 2:1009
 - examples of, 2:686
 - functions of, 2:685
 - network of monuments and, 2:686
 - vertical, horizontal, and complete datums, 2:685–686
- David, Paul, 4:2133
- Da Vinci, Leonardo, 3:1245
- Davis, John, 4:2179
- Davis, Mike, 2:688, 4:1803
- Davis, William Morris, 2:686–687**
 - Isaiah Bowman influenced by, 1:295
 - criticism of, 3:1246
 - cycle of erosion developed by, 1:191, 3:1246, 4:2180, 5:2534
 - cycle of life views of, 2:666, 3:1245, 3:1279
 - geomorphic cycle (geographical cycle) created by, 2:686–687, 3:1241–1242, 3:1246, 4:2180
 - Grove Karl Gilbert and, 3:1279
 - impact of, 2:687
 - morphogenic terms of, 2:687
 - nature-society views of, 4:1989

- Walther Penck and, 4:2145
 physical geography work of, 3:1463
 RGS award of, 5:2448
- Dawson, George, 5:2448
- Day, Richard, 1:74
- Deacon, Robert, 5:2446
- Dead Sea, 4:1808–1809
- Dear, Michael, 2:687–688**
 extreme geography views of, 2:1074
 geography and social theory alignment and, 2:687
 human geography work of, 2:686, 2:687
 Los Angeles School of urbanism and, 2:688, 4:1803, 4:1804, 5:2268
 postmodernism work of, 2:619, 2:687–688, 5:2264, 5:2266, 5:2268, 5:2351
Postmodern Urban Condition written by, 5:2266, 5:2268
 radical geography and, 5:2351
 social justice issues and policy focus of, 2:688, 5:2266
 structuration theory and, 5:2710
- de Beauvoir, Simone, 3:1095
- Debord, Guy, 4:1769
- Debt and debt crisis, 2:688–691**
 Baker Plan response to, 2:689
 Brady Plan response to, 2:689
 debt cancellation solution to, 2:690–691
 debt sustainability issue and, 2:690
 globalized political activism response to, 2:690
 Heavily Indebted Poor Countries (HIPC, World Bank) initiative and, 2:690
 history of, 2:688–689
 International Monetary Fund (IMF) and, 2:689, 3:1615–1618
 Jubilee Coalition and, 2:690, 2:691
 Make Poverty History campaign and, 2:690
 Mexico's debt default and, 2:688–689
 Multilateral Debt Reduction Initiative, 2:690
 neocolonialism and, 4:2002–2005
 neoliberalist thought, 2:688–689, 2:690
 resistance to Third World debt and, 2:690–691
 responses and solutions to, 2:689–690
 social and human costs of, 2:689
 structural adjustment and, 2:689
 2008 financial crisis and, 2:691
- de Certeau, Michel, 2:1043, 4:1769, 5:2230, 5:2442
- Deciduous forest. *See* **Biome: midlatitude deciduous forest; Biome: tropical deciduous forest**
- Decolonization, 2:691–692**
 Cold War and, 2:691–692
 disintegration of large European empires and, 2:691
 guerrilla conflicts and, 2:692
 imperialism and, 3:1545–1548
 India's peaceful independence and, 2:692
 political, economic, and ideological changes of, 2:692
 white superiority, racism challenged by, 2:692
 world systems theory and, 2:691
- Deep ecology movements, 2:692–695**
 bioregionalism, 1:255
 cultural geography, situationism and landscape aesthetics and, 2:694
 deep green design and development and, 3:1372–1373
 ecofeminism and, 2:817–820
 ecological justice and, 2:831
 ecological self-realization process and, 2:693, 2:695
 environmental ethics and, 2:925–927
 fellow travelers and, 2:695
 Gaia organic wholeness, Earth systems science and, 2:693, 2:695
- Gaia theory and, 3:1175–1178
 impact of, 2:692–693
 levels of questioning and articulation of, 2:693, 2:694 (table)
 nature and self are one theme of, 2:692–693
 political platform of, 2:693–695, 2:694 (table)
 “shallow ecology” *vs.*, 2:692
 “think like a mountain” concept (Seed) and, 2:692
See also Deep ecology movements: noted individuals; **European green movements**
- Deep ecology movements: noted individuals
 Joseph Beuys, 2:695
 Mahatma Gandhi, 2:693
 Stephan Harding, 2:695
 James Lovelock, 2:695
 Joanna Macy, 2:695
 Arne Naess, 2:692–693, 2:694
 John Seed, 2:693
 George Sessions, 2:693
 Baruch Spinoza, 2:693
- Defoe, Daniel, 4:1787
- Deforestation, 2:695–699**
 agroforestry and, 1:60–62
 biological integrity of tropical ecosystems and, 2:699
 carbon dioxide in atmosphere changes and, 1:328
 causes of, 2:697–698
 commercial logging and, 2:698
 ecosystem decay and, 2:858–862
 explanatory framework of, 2:696–697
 forest fragmentation and, 3:1159–1163
 forest land use and, 3:1163–1165
 fuelwood harvesting and, 2:698
 impacts of, 2:698–699, 3:1334, 3:1335
 industrialized farming and, 2:698
 land change science (LCS) and, 2:696, 2:697
 land degradation from, 4:1683–1684
 from land use and cover change, in Sabah, Malaysia, 4:1737 (photo)
 logging and slash-and-burn agriculture and, 2:697 (photo)
 Mediterranean catchments, 1:275
 midlatitude deciduous forest biome and, 1:223–226
 small-scale farming and, 2:697–698
 socioeconomic, technological, and ecological conditions and, 2:698
 species extinctions and, 2:699
 statistics, 2:696
 tropical deciduous forest biome and, 1:230–233
 tropical rain forest biome and, 1:234–239
See also **Forest degradation**
- De Geer, Gerard, clay-varve glacial dating method of, 1:82
- Deindustrialization, 2:700–702**
 automobile industry and, 2:700
 brownfields and, 1:296–298
 explanation of, 2:700
 industrialization *vs.*, 2:700
 labor force decline and, 2:700, 2:701 (fig.)
 Manufacturing Belt, Rust Belt and, 2:701–702, 4:1823–1824
 production processes shift and, 2:700–701
 steel industry and, 2:700–701
 textile industry and, 2:700
- Deinstitutionalization, Doreen Massey's work in, 4:1866–1867
- Deleuze, Gilles, 2:649, 2:722, 4:2041–2042, 4:2070, 5:2273
- Del Mar, California, 1:21 (photo)
- Delta, 2:702–705**
 estuaries and, 2:703–704
 fans, 2:703

- flooding risk and, 2:704
- fluvial landforms and, 2:702
- formation process of, 2:702
- human population, urbanization of, 2:704
- Mississippi Delta, Louisiana, 2:703 (photo)
- Netherlands deltas and, 2:702–703
- Nile River delta in Egypt and, 2:702
- spatial scale ranges of, 2:702
- types and classifications of, 2:703
- Denmark, wind power development in, 2:902
- Demeritt, David, 2:614
- Demko, George, 5:2307
- Democracy, 2:705–707**
 - critical geographies of, 2:705–706
 - definitions, 2:702
 - electoral geographies of liberal-representative democracy, 2:705
 - geographies of democratic theory and, 2:706
 - influence and exercise of power and, 2:706
 - nation, nation-state and, 2:702
 - normative democratic concepts in political processes and, 2:706–707
 - radical democracy and, 2:705–706
 - theorizing democracy geographically and, 2:706–707
- Democratic Republic of Congo
 - bananas grown in, North Kivu province of, 3:1145 (photo)
 - Belgian colonies in, 1:509
 - cholera in, 1:402
 - economically active females in, 3:1190 (table)
 - GDP per capital in, 3:1382
 - human rights atrocities in, 3:1481
 - independence of, 1:512
 - tropical rain forest deforestation in, 1:238
 - tropical rain forest of, 1:234
 - undernourishment in, 3:1487
- Demographic transition, 2:707–710, 2:708 (fig.)**
 - birth, death, and growth rates stages of, 2:707, 2:708 (fig.)
 - criticisms of theory and, 2:710
 - fertility rate and, 3:1102–1103
 - Industrial Revolution and, 3:1581–1586
 - Malthusian population growth notions and, 2:707
 - stage I: preindustrial society, 2:707–709
 - stage II: early industrial society, 2:709
 - stage III: late industrial society, 2:709
 - stage IV: postindustrial society, 2:709–710
 - zero population growth and, 2:709
 - See also* Population pyramid
- Dendrochronology, 2:710–712**
 - annual tree rings' analysis and, 2:710
 - applications of, 2:710–711
 - climatology application of, 2:711
 - cross-dating technique and, 2:710, 2:711 (fig.)
 - Andrew Douglass's work in, 2:710
 - drought evidence and, 2:792
 - Greek derivation of, 2:710
 - Ellsworth Huntington's work and, 2:711
 - International Tree-Ring Data Bank and, 2:712
 - landscape geography and, 2:712
 - paleoclimatology and, 2:711
 - physical geography and, 2:711
 - principles of, 2:710
 - technology advances and, 2:712
- Denevan, William, 2:632
- Denmark
 - AGILE membership of, 1:124 (table)
 - biotechnology industry in, 1:280
 - cancer incidence and mortality in, 1:321–322, 1:322 (fig.), 1:323 (fig.)
 - coastal dead zones of, 1:487
 - colonial empire of, 1:509 (fig.)
 - competitive advantage areas in, 2:558
 - critical human geography in, 2:620
 - economically active females in, 3:1190 (table)
 - energy feed-in tariffs (FIT) in, 2:901
 - European Union (EU) membership of, 2:1035
 - foreign aid flow from, 3:1152
 - integrated production network, Kalundborg, 3:1579
 - Jutland high-tech region in, 3:1127
 - pollution taxes in, 4:1857
- Denton, N., 5:2345
- Dependency theory, 2:712–714**
 - colonial dependence and, 2:713
 - core *vs.* periphery elements in, 5:2219
 - criticisms of, 2:714
 - decolonization and, 2:692
 - development of underdevelopment concept and, 2:713
 - financial-industrial dependence and, 2:713
 - import substitution industrialization and, 3:1549–1551
 - inequality geographies and, 3:1586–1590
 - modernization theory and, 2:712, 2:713, 4:1931–1935
 - neocolonialism and, 4:2002–2005
 - newly industrializing countries and, 4:2021–2024
 - political economy of resources and, 5:2219–2220
 - social construction of poverty and, 2:713
 - solutions to, 2:713
 - technological-industrial dependence and, 2:713
 - underdevelopment and, 2:712–713
 - United Nations Economic Commission for Latin America (ECLA) and, 2:712–713
 - See also* Dependency theory: noted individuals; **Developing world**; **Development theory**
- Dependency theory: noted individuals
 - Paul Baran, 2:712
 - Fernando Cardoso, 2:713
 - Theotonio Dos Santos, 2:713
 - Enzo Falleto, 2:713
 - André Gunder Frank, 2:713
 - Celso Furtado, 2:713
 - Raúl Prebisch, 2:712
- Derechos, 2:714–715**
 - bow echos and, 2:714
 - climatology of, 2:714
 - dangers of, 2:714
 - plow wind (Canada) and, 2:714
 - progressive *vs.* serial derechos and, 2:714
 - Spanish derivation of, 2:714
- Derrida, Jacques, 3:1563, 4:1754, 4:2102, 5:2267, 5:2270–2271, 5:2351, 5:2712
- Descartes, René
 - Cartesian rationalism, absolute space and, 1:3
 - environmental ethics and, 2:926
 - rationalism and empiricism and, 2:893
- Desertification, 2:715–719**
 - combating of, 2:718–719
 - crop farming practices and, 2:715, 2:716
 - deforestation and, 2:716
 - desert biome and, 1:218–223
 - dry climate and, 1:428–435
 - in Dunhuang, Gansu province, China, 2:716 (photo)
 - evolving understandings of, 2:717–718
 - forms/examples of, 2:715

- geographic locations of, 2:715–716
human *vs.* biophysical causes of, 2:715, 2:716–717
Sahelian grasslands south of Sahara Desert and, 2:717–718, 2:972, 2:989
soil degradation in dryland areas and, 2:715–716
tragedy of the commons and, 2:716
UN conferences on, 2:718–719, 2:972–973, 3:1335
U.S. Dust Bowl and, 2:717
world-wide pervasiveness of, 2:717
See also Dunes
- Desert varnish, 2:719–722**
arid topography and, 1:112–113
Death Valley, California, 2:719, 2:722 (photo)
Tanzhuo Liu's work and, 2:719–710
polygenetic formation model of, 2:719, 2:721 (photo)
rock coating categories and, 2:720 (table)
rock varnish and, 2:719
varnish microlaminations (VMLs) tool and, 2:719–720, 2:722 (photo)
- Deskaheh of Cayuga people, 3:1553
- Deterritorialization and reterritorialization, 2:722–724**
borderlands and, 1:291–292
borders and boundaries, 1:293–294
capitalism, power, and identity elements of, 2:722–723
Cold War end and, 2:723, 2:724
cultural and social issues and, 2:723
Gilles Deleuze and, 2:722
globalization and, 2:723
globalized network flows and, 2:724, 3:1339–1340, 3:1341
Felix Guattari and, 2:722
nation-state changes and, 2:723, 2:724
political economy changes and, 2:723
reterritorialization processes and, 2:723–724
social life and territorial moorings relationship and, 2:722
spatial dimensions of capital accumulation and, 2:722
spatial reconfiguration and rebordering of social relations and, 2:724
territorial organization of power and, 2:722
- Detroit, Michigan
automobile industry in, 1:169, 1:171, 1:172
Dotty Wotty House in, 1:119 (photo)
electronic music festival in, 6:2858 (photo), 6:2859 (photo)
Heidelberg Project and “Detroit. Demolition. Disneyland.” in, 1:120
OJ (Obstruction of Justice) House and The Oval Room and, 1:120 (photo)
- Developing world, 2:724–729**
African Union (AU) and, 1:25
carbon emissions issues and, 1:334
civil society and, 1:414–416
coastal zone and marine pollution and, 1:501
CO₂ emissions, GHGs and, 3:1337
commodity chains in industrial decision-making and, 1:524
crop rotation methods in, 2:627
debt crisis and, 2:688–689
definition, 2:724
dependency theory and, 2:712–714
disease, drought, and distance to world markets factors and, 2:725, 2:725 (fig.)
diseases in, 2:726–727
drought and, 2:727–728, 2:793
drugs and, 2:795–996
early industrial societies in, 2:709
ecotourism industry in, 2:870
electronic waste and, 1:502
emerging markets and, 2:890–891
emigration in, 4:1893–1894
fertility rates decline in, 4:2015
food geographies and, 3:1145
foreign aid to, 3:1151–1153
foreign direct investment in, 3:1155–1156
forestland management in, 2:552
geography and economic development and, 2:725
greenhouse gas emissions, Kyoto Protocol and, 1:463
Green Revolution and, 2:939
homelessness in, 3:1442
housing policy in, 3:1447
Human Development Index and, 2:725 (fig.), 5:2573
import substitution industrialism in, 2:1063, 3:1549–1551
informal economy and, 3:1590–1592
landlocked status and, 2:726
land reform in, 4:1692–1696
land tenure issues and, 1:316, 1:317
malaria and, 2:726–727
marine aquaculture in, 4:1854, 4:1854 (fig.)
modernization theory and, 4:1931–1935
nation-states after colonialism in, 1:517
natural hazards and disasters and, 2:726
neocolonialism and, 4:2002–2005
new international division of labor and, 4:2019–2021
nongovernmental organizations (NGOs) and, 1:414–416
opium and heroin production in, 2:796–797
participatory learning and action used in, 4:2123
participatory rural appraisal used in, 4:2130
peasants and peasantry and, 4:2137–2142
plant diseases and pests factors and, 2:727
population growth and poverty relationship and, 2:726
population pyramid for, 5:2250 (fig.)
public water services in, 5:2316–2317
remittances and, 5:2411–2414
rural-urban migration in, 5:2495–2496
soil fertility factor and, 2:728
structural development programs in, 2:1065, 5:2703–2704
sweatshop labor in, 2:575
tragedy of the commons examples in, 1:532–533
transnational corporations and, 4:2004
Tropic of Cancer relevance to, 2:725–726
urbanization of hunger and, 3:1489
urban migration in, 5:2232
urban storm water management in, 6:2992, 6:2992 (photo)
waste management issues in, 1:384
women's lives in, 3:1097
World Development Report 1992 (World Bank) and, 2:1004
See also Development theory
- Development theory, 2:729–733**
capitalism evolution theories and, 2:729
central places theory and, 2:730
classical political economists and, 2:729
critiques of, 2:732–733
demographic transition and, 2:707–710
dependency theory and, 2:712–714, 2:732
developing countries modernization and, 2:730
East Asian “tigers” and, 2:731
economic multipliers theory and, 2:730
export-led development and, 2:1063–1066
externalities and, 2:1068–1069
foreign aid and, 3:1151–1153
growth and modernization theories and, 2:730
historical idealism and, 2:729
historical materialism and, 2:729

- import substitution industrialization and, 3:1549–1551
informal economy and, 3:1590–1592
innovation diffusion studies and, 2:730
Kuznets curve model and, 2:730
modernization theory and, 4:1931–1935
neocolonialism and, 4:2002–2005
neoliberalism and the new institutionalism in, 2:730–731
newly industrializing countries and, 4:2021–2024
origins of, 2:729
peasants and peasantry and, 4:2137–2142
polarization and cumulative causation and, 2:730
political ecology and, 2:732–733
postcolonial and postdevelopment theories and, 2:732, 2:733, 5:2261
radical political economy and, 2:732
recent trends in, 2:731–732
regional growth pole theory and, 2:730
social capital concept and, 2:731
social evolution theories and, 2:729
Solow-Swan growth theory and, 2:730
sustainable development theory and, 2:731
transportation geography and, 6:2875
world-systems theory and, 2:732
See also Development theory: noted individuals
- Development theory: noted individuals
Robert Bates, 2:731
Brian Berry, 2:730
Lawrence Brown, 2:730
Walter Christaller, 2:730
Ronald Coase, 2:731, 4:1857
Evsey Domar, 2:730
Michel Foucault, 2:732
André Gunder Frank, 2:732
Peter Gould, 2:730
Antonio Gramsci, 2:732, 5:2230
Törsten Hägerstrand, 2:730
Roy Harrod, 2:730
Friedrich Hayek, 2:730, 2:781, 4:2011
Friedrich Hegel, 2:729
Albert Hirschman, 2:730
John Maynard Keynes, 2:730
Simon Kuznets, 2:730
Arthur Lewis, 2:730
Thomas Robert Malthus, 2:729, 4:1819–1820
Karl Marx, 2:729
John Stuart Mill, 2:729
Akin Mobogunje, 2:730
Gunnar Myrdal, 2:730
Douglass North, 2:731
Richard Peet, 4:2144
François Perroux, 2:730
Michael Polanyi, 2:729
Raúl Prebisch, 2:732
David Ricardo, 2:729
Everett Rogers, 2:730
Walter Rostow, 2:730
Adam Smith, 2:729
Robert Solow, 2:730
Robert Swan, 2:730
Thorstein Veblen, 2:729
Immanuel Wallerstein, 2:732
Max Weber, 2:729, 4:1931–1932
Georg Wilhelm, 2:729
Oliver Williamson, 2:731
Dewsbury, J. D., 4:2042
- Diamond, Jared, 2:734**
biological diversity studies of, 2:734, 4:1697, 5:2216, 5:2545, 5:2548
Collapse written by, 2:734, 2:930
environmental determinism views of, 2:917
Guns, Germs, and Steel written by, 1:509, 2:734, 2:917, 2:930, 5:2216
human geography studies of, 2:734, 2:917, 5:2216
New Guinea studies of, 2:734
power and wealth distribution work of, 2:917, 5:2216
- Diaspora, 2:734–735**
academic themes of, 2:735
cultural loss and, 2:735
displacement and resettlement themes and, 2:735
hybrid and personal identities formation and, 2:735
meanings of, 2:734–735
policy-making and, 2:735
transnationalism theme and, 2:735
- Diastrophism, 2:736–737**
basin and range topography and, 1:186–187
epeirogeny and, 2:736
eustasy and, 2:737
igneous processes and, 2:737
isostasy and, 2:736–737
mountain building orogenesis and, 2:736
orogenesis types and, 2:736
tectonic processes study and, 2:736
types of, 2:736
- Diaz, Robert J., 1:488
DiBiase, David, 4:1826
Dickens, Peter, 2:850
Dickens, Charles, 6:2879 (image)
Diderot, Dennis, 4:1928
- Difference, geographies of, 2:737–740**
as analytical concept, 2:737–738
blindness and geography and, 1:286–287
class, gender, race, and sexuality differences and, 2:738
dynamic and fluid features of, 2:739
forms of difference and, 2:737
gender example of, 2:738–739
geographies of exclusion and, 2:738
geographies of indifference and, 2:739
hybridity and, 2:739–740
identity assertion and, 2:739
identity geographies and, 3:1527–1531
masculinity geographies, 2:738
measure of separation concept and, 2:737
multiple identities and, 2:739
Other/Otherness and, 4:2106–2107
power element in, 2:739
quantitative *vs.* qualitative approaches to, 2:738
relational difference element of, 2:739
theoretical and methodological approaches to, 2:738–740
whiteness, 2:738
- Differential heating, 2:740–742**
daily and seasonal insulation variations and, 2:741
energy transfer processes and, 2:740
evaporation over water *vs.* land and, 2:741
land *vs.* water surfaces and, 2:740
latent heat and, 4:1761–1762
monsoon climates and, 2:741
sea *vs.* land breezes and, 2:741
specific heat of water *vs.* land and, 2:740–741
temperature and precipitation patterns and, 2:741
- Differential vulnerabilities to hazards, 2:742–745**
coping with hazards and, 2:742, 2:743 (photo)

- definition of, 2:742
- drought risk and hazard and, 2:790–794
- environmental justice and, 2:744
- examples of, 2:742
- fossil fuels risks and, 2:743–744
- Hurricane Katrina example of, 2:743, 4:1985–1986
- immediate *vs.* creeping hazards and, 2:742
- less wealthy *vs.* wealthy societies and, 2:742–744
- natural *vs.* technological hazards and, 2:744
- Tsunami of 2004, Indian Ocean example of, 2:743
- women, children, elderly, and disabled at risk and, 2:744
- See also* Disaster prediction and warning; Disaster preparedness; Environmental justice
- Diffusion, 2:745–748**
 - in the automobile industry, 2:747
 - Berkeley School *vs.* Lund School (Sweden) and, 2:745, 2:746
 - British railroad technology to India example of, 2:747
 - British textile technology to U.S. example of, 2:747
 - capitalist development and, 2:746
 - China as innovation center and, 2:746
 - culture circles of diffusion theory and, 2:745
 - Eurocentric *vs.* other-centric diffusion, 2:746
 - evolutionary perspective on, 2:745
 - global economy rhythms and, 2:746
 - innovation *vs.*, 2:747
 - Japanese Datsun automobile from Germany example of, 2:747
 - location theory and, 4:1799
 - in modernization theory, 4:1933
 - nature of culture and, 2:745
 - origins of, 2:745
 - problems associated with, 2:747
 - spatial diffusion over time and, 2:746, 4:1799
 - technology innovation, diffusion, and adoption elements of, 2:745
 - technology transfer and development in, 2:747
 - as theme in geography, 2:746
 - as theme in history, 2:746–747
 - utopian theory of culture exchange and, 2:745
 - See also* Diffusion: noted individuals
- Diffusion: noted individuals**
 - Derek Gregory, 3:1380–1381, 4:1787
 - Törsten Hägerstrand, 3:1397–1399, 4:1799, 5:2329
 - Peter Hall, 2:746
 - Nikolai Kondratiev, 2:746
 - Joseph Needham, 2:746
 - Joseph Schumpeter, 2:746
 - Nikolai Pavlov, 2:745
- Digital divide, 2:748–753**
 - broadband delivery services (U.S.) and, 2:752
 - cyberspace and, 2:647
 - economically disenfranchised and, 2:745
 - gender differences in access (U.S.) and, 2:750–751
 - generational differences (U.S.) in, 2:750
 - global view on, 2:748–750
 - information technology skills and, 2:745
 - Internet availability and costs and, 2:749
 - Internet penetrate rates and, 2:749 (fig.)
 - Internet political constraints and, 2:749–750
 - racial or ethnic differences (U.S.) in, 2:751
 - school computer use (U.S.) and, 2:752
 - social mobility and, 2:745
 - socioeconomic differences (U.S.) in, 2:751–752
 - United States and, 2:750–752
- Digital terrain model (DTM), 2:753–756**
 - applications of, 2:756
 - basic concepts of, 2:753–754
 - data acquisition for generation of, 2:754–755
 - data measurement techniques and, 2:754–755
 - data sampling strategies and, 2:754
 - definition of, 2:753
 - digital surface model (DSM) and, 2:753–754
 - DTM-based terrain analysis and, 2:755
 - interpretation of, 2:755
 - modeling approaches for surface reconstruction in, 2:755
 - point-to-point visibility *vs.* point-to-area visibility analysis and, 2:755
 - quality and accuracy of, 2:755–756
 - random-to-grid interpolation and, 2:755
 - terms related to, 2:753
 - terrain definitions and, 2:753
 - triangle-based *vs.* grid-based modeling and, 2:755
 - Triangulated Irregular Network (TIN) data model and, 6:2883–2884
- Digitizing, 2:756–757**
 - cadastral mapping and, 2:757
 - digital representation or digital image product of, 2:753
 - digitizing cursor tool of, 2:757
 - digitizing error and, 2:1012
 - digitizing tablet tool of, 2:756–757
 - GIS application editing tools used with, 2:757
 - GIS applications of, 2:756
 - process of, 2:757
- Dinosaur extinction, 1:15
- Disability, geography of, 2:757–759**
 - biomedical models of disability and, 2:757
 - “cause” of disability, 2:757
 - chronic illnesses as disability and, 2:758
 - disability definitions and, 2:757
 - mental illness and learning disabilities and, 2:758
 - nature of research in, 2:757
 - participatory processes in research issue and, 2:759
 - research power dynamics and, 2:759
 - research topics of, 2:758
 - social models of disability and, 2:757–758
 - sociospatial experiences of disability and, 2:757
 - wheelchair tennis and, 2:758 (photo)
 - See also* Blindness and geography
- Disaster prediction and warning, 2:759–763**
 - interpretations of warnings and, 2:761
 - lead time in prediction factor and, 2:760
 - myths and exaggerations, interpretation influenced by, 2:762
 - natural hazards and risk analysis and, 4:1983–1989
 - natural *vs.* technological disaster types and, 2:759
 - notification types and goals in, 2:761
 - participants in the communication process in, 2:761
 - prediction technologies used, 2:759–760
 - process steps and technologies employed in, 2:761
 - receipt and interpretation of warnings in, 2:761–762
 - remote sensing in disaster response and, 5:2424–2428
 - “Reverse 911” notifications and, 2:761
 - social stratification factor in, 2:761–762
 - three-dimensional numerical studied of tornadoes and, 2:760
 - tsunami early warning buoy and, 2:760 (photo)
 - warning communication process and, 2:761–762
 - Warning Decision Support System (WDSS) and, 2:760
 - weather Web sites and, 2:762
 - See also* Disaster preparedness; Natural hazards and risk analysis
- Disaster preparedness, 2:763–766**
 - Bhopal, India, chemical disaster and, 1:194–195

- collaborative GIS application and, 1:507 (fig.)
community-level preparedness and, 2:764, 2:765
decision-making behavior and, 2:766–767
Disaster Mitigation Act of 2000 and, 2:763, 2:765
disaster response and, 2:763
emergency management perspective on, 2:763–764
emergency management phases and, 2:764 (fig.)
Federal Emergency Management Agency (FEMA) and, 2:763
Flood Control Acts and, 2:763
general mode of risk communication and, 2:767
hazards and disaster research and, 2:765–766
individual preparedness and, 2:764, 2:765
National Flood Insurance Program and, 2:763, 2:764
natural hazards and risk analysis and, 4:1983–1989
Natural Hazards Research and Applications Information Center and, 2:763
natural *vs.* willful hazards and, 2:765
psychological and attitudinal factors in, 2:765
response and recovery elements in, 2:764
risk, vulnerability, and resilience factors in, 2:763
situational or cognitive factors in, 2:765
socioeconomic status factor in, 2:765
Gilbert White, floodplain management and, 2:763
See also Disaster prediction and warning; Natural hazards and risk analysis
- Discourse and geography, 2:766–769**
discourses shape our conception of the world and, 2:766
discourse theory application to geography, 2:767–769
discursive aggregation principle of, 2:767
environmental discourse and, 3:1454
everyday life geographies and, 2:1042–1045
Michel Foucault's work in, 2:766, 2:767, 2:769
geographic concept of scale example and, 2:768
geographic space, rules of discursive construction and, 2:768
geography of poverty discourse example and, 2:768–769
human dimensions of global environmental change and, 3:1454
language and geographic analysis and, 4:1754
objects are discursive constructs concept and, 2:766
Orientalism and, 4:2101–2104
Other/Otherness and, 4:2106–2107
poverty maps, 2:768–769
power, knowledge, and truth relationship with, 2:767
selection principle of, 2:767
social institutions' role in, 2:766–767
space definition and, 2:768
See also Environmental discourse; Literature, geography and
- Disease, geography of, 2:769–774**
cancer, 1:320–324
cholera, 1:401–403
current methods used in, 2:772–773
in developing world, 2:726–727
developments in, 2:771–772
disease mapping (Snow) and, 2:770
geographic codes of health data and, 2:771
GIS development and, 2:771
Peter Haggett's work in, 3:1399–1400
health and medical climatology and, 1:473
Health Insurance Portability and Accountability Act (HIPAA) and, 2:771–772
historical foundations of, 2:770
HIV infection, global, 2:770 (fig.)
inequities, 2:771
Kriging geostatistical technique and, 2:772
malaria, 4:1816–1819
mapping methods and, 2:772
Markov Chain Monte Carlo statistics and, 2:772–773
Minamata disease, mercury poisoning, 1:501–502
modifiable areal unit problem of mapping and, 2:772
physical environment quality factor in, 2:770
population density factor and, 2:771
public health applications and, 2:769–770
qualitative research methods and, 2:773
SaTScan cluster detection statistic and, 2:772
John Snow's work in, 2:770
social and economic conditions, population demographic factors and, 2:771
spatial autocorrelation spatial analysis method and, 2:773
spatial distribution and spread patterns of disease and, 2:769
spatial patterning causes and, 2:770–771
statistical analysis methods and, 2:772–773
susceptible-infected-recovered (SIR) simulation model and, 2:773
See also Carcinogens; Drugs, geography of; HIV/AIDS, geography of
- Disease, land use and cover change impact on, 4:1736–1737
- Distance decay, 2:774–776**
definition of, 2:774
examples of, 2:774, 2:775 (fig.)
human geography application of, 2:774
Edward Jarvis's work in, 2:775–776
migration and spatial interaction studies (Ravenstein) and, 2:775–776
Newton's fundamental law of attraction, 2:774
principle of least action (Moreau de Maupertuis) and, 2:774
spatial-temporal analysis element of, 2:774
Tobler's first law of geography of, 2:774
- Distributed computing, 2:776–778**
distributed component object servers and, 2:778
distributed database and file servers and, 2:777–778
generic database servers and, 2:777
geographic information systems (GIS) development and, 2:776–777
goal of, 2:777
Internet GIS and, 3:1620–11623
open and interoperable environments and protocols and languages used in, 2:777
operating frameworks of, 2:777
stand-alone file servers and, 2:777
- Distribution of resource access, 2:778–780**
common resources access and, 2:779
definition of, 2:778–779
ecological economics and, 2:820–824
human-resource relationship focus of, 2:778–779
land cover dynamics and, 2:779
power relations in societies and among locations and, 2:779–780
technology advances and, 2:779
tragedy of the commons (Hardin) and, 2:779
See also Commons, tragedy of the; Resource tenure
- Distribution of resources access**
mining geographies and, 4:1911–1913
“resource curse” hypothesis and, 4:1913, 5:2217, 5:2693
- Division of labor, 2:780–781**
benefits of, 2:780
circuits of capital and, 1:410–412
communication technology and, 2:781
comparative advantage and, 2:556–558
gendered division of labor and, 3:1195, 3:1196, 3:1439
geographical division of labor dimensions, 2:780–781
increasing returns concept and, 2:780
individuals and societies interdependence and, 2:781
individual *vs.* firm *vs.* others located elsewhere levels of, 2:780
Adam Smith and, 2:780

- transportation technology and, 2:781
 wealth and economic development and, 2:780
See also **New international division of labor**
- Doctors Without Borders, 1:96
- Dodge, Martin, 2:646
- Dodge, Stanley, 5:2534
- Dokuchaev, V. V., 4:2180
- Domestication centers. *See* **Centers of domestication**
- Domestication of animals, 2:781–784**
 centers of domestication and, 1:374–378
 cultural ecological change process and, 2:782
 diffusion element in, 2:782
 dogs, 2:783
 early geographers' writing, 2:782
 gazelle, 2:783
 historic waves of, 2:783
 Neolithic Revolution, 2:781
 newer domestications and, 2:783
 Old and New World domestications and, 2:783
 reindeer, Mongolia, 2:782 (photo)
 role of ritual and religion in, 2:782
 sheep, goats, pig, cattle, chickens, cats, 2:783
 wild populations divergences and, 2:782–783
See also **Domestication of plants**
- Domestication of plants, 2:784–786**
 climate conditions factor in, 2:785–786
 crop diversity and, 2:786
 dispersal of agriculture and the Columbian Exchange in, 2:786
 domestication, definition and, 2:784
 domestication syndrome and, 2:784
 factors in process of, 2:784
 genetic and evolutionary process of, 2:784
 geographic centers of, 1:374–378, 2:784–785, 2:785 (fig.), 2:786
 human role in, 2:784
 origin and evolution of agriculture and, 2:784
 results of, 2:784
 themes in study of, 2:784
 timing of, 2:785–786
See also **Crop genetic diversity; Domestication of animals**
- Dominican Republic**
 Conference of Latin Americanist Geographers held in, 2:568
 economically active females in, 3:1190 (table)
 HIV/AIDS in, 3:1438
- Domino theory, 2:786–787**
 Cold War and, 1:505, 2:787
 communism containment and, 2:787
 First, Second, and Third World geopolitical world model and, 2:786–787
 origins of concept and, 2:787
- Domosh, Mona, 2:590, 3:1431
- Dorpale, Andreas, 3:1250
- Dos Santos, Theotonio, 2:713
- Dot density maps, 2:787–790**
 aggregated data and, 2:788, 2:789 (fig.)
 geographic pattern representation and, 2:787–788
 one-to-many design considerations in, 2:788–790
 one-to-one *vs.* one-to-many dot maps and, 2:788
- Dougenik, James, 1:408
- Douglass, Andrew, 2:710
- Dove, Michael, 6:2741
- Dowd, Charles, 5:2363
- Downing, Andrew Jackson, 4:1699
- Downs, Anthony, 5:2214
- Drake, Sir Francis, 4:2179
- Drought risk and hazard, 2:790–794**
 agricultural drought, 2:791
 Arkansas (U.S.) lake example and, 2:788 (photo)
 climate causes of, 2:792
 climate change and, 2:794
 in developing world, 2:727–728
 drought prone regions of the world and, 2:787
 drylands environmental management and, 2:971–973
 El-Niño-Southern Oscillation (ENSO) and, 2:792, 2:793
 hydrological drought, 2:791
 indices of, 2:792
 Intergovernmental Panel on Climate Change and, 2:793
 mega-droughts and, 2:792
 meteorological drought, 2:791
 monitoring networks and, 2:792
 National Drought Mitigation Center drought monitor, 2:787–788, 2:792
 ocean-atmosphere variabilities factor in, 2:792
 Pacific and Atlantic tropical ocean-atmosphere circulation prediction and, 2:793
 participatory research on human agency and, 2:793
 planning for, 2:793
 political ecology research on, 2:793
 prediction, monitoring, and mitigation in, 2:792–793
 pyrogeography and, 5:2319–2322
 remote sensing monitoring of, 2:792
 social construction of, 2:793
 socioeconomic and policy choice factors in, 2:787
 socioeconomic drought, 2:791
 tree ring evidence of, 2:792
 types of, 2:790–792
 vulnerability and, 2:793
- Drugs, geography of, 2:794–800**
 addiction, health problems, and treatment, 2:799
 alcohol and, 2:795
 coca cultivation and, 2:797
 colonialism and, 2:795
 designer drugs and, 2:799
 developing world and, 2:796–798
 ethnobotanists research and, 2:795
 GIS tools used in, 2:800
 global production of licit raw narcotics, 2003–2008 and, 2:797 (table)
 harm reduction policies and, 2:799
 historical drug geographies and, 2:795–796
 HIV/AIDS and, 2:799
 indigenous identities and cultural practices and, 2:795
 International Opium Commission, Shanghai (1909) and, 2:796
 marijuana decriminalization and, 2:798
 “narcoterrorism” and, 2:798
 narcotic production since UN regulation and, 2:796
 opium licit and illicit uses and, 2:795–796
 opium poppies, Northern Tasmania, Australia, 2:798 (photo)
 overview of, 2:794
 “poppy straw process” and, 2:796
 rebellious youth cultures and, 2:799
 spatial approaches to analysis and policing in, 2:799–800
 synthetic drugs and, 2:798–799
 traditional drug practices and, 2:795
 UN regulation and, 2:796
- Dry adiabatic lapse (DALR) rate, 1:15–16
- DTM. *See* **Digital terrain model (DTM)**
- Dubai, as hub port, 5:2254
- Duncan, Jim, 4:1777
- Dunes, 2:800–803**
 R. A. Bagnold's dune building work, 2:801

- barchans dune type, 2:801–802
- barrier islands and, 1:183–185
- coastal dunes, 2:803
- coastal erosion and deposition and, 1:492
- conceptual model of coastal dune ecology, 2:564 (fig.)
- cross section of, 2:801 (fig.)
- dome, star, and reversing dune types, 2:802
- factors and variations in, 2:800–801
- internal structure of, 2:801
- linear or longitudinal dune type, 2:802
- lunette dune type, 2:802
- morphology classification of, 2:801
- paleodune type, 2:802
- parabolic dune type, 2:802
- sand seas or erg dune types, 2:802
- star dunes, Namibia Desert, southwest Africa, 2:803 (photo)
- star dune type, 2:802
- transverse dune type, 2:802
- types of, 2:802 (fig.)
- Dunning, John, 3:1154
- Durand, Loyal, 5:2536, 5:2537
- Durkheim, Émile
 - classic social theory of, 3:1277
 - modernity and commodification relationship and, 4:1936
 - social sciences *vs.* natural sciences and, 5:2513
- Dust storm, satellite image of, 1:20 (photo)
- Dutton, Geoff, 1:408
- Dynamic and interactive displays, 2:804–808**
 - animated display and, 2:804
 - animated maps and, 2:804
 - brushing technique and, 2:805 (fig.), 2:808
 - cellular automata and, 1:368–371
 - computer animation and, 2:804
 - data manipulation and, 2:807 (fig.), 2:808
 - definitions, 2:804
 - dynamic filtering technique and, 2:806 (fig.), 2:808
 - fly-through displays and, 2:804
 - functions of, 2:808
 - interactive change of color technique and, 2:806 (fig.)
 - interactive maps and globes and, 2:804
 - location-based services (LBSs) and, 4:1794–1796
 - thematic maps and, 2:804
 - Web-based interactive displays and, 2:804
- Dynamic climatology, 1:472–473
- Eager, Bill, 5:2373
- Earle, Carville, 2:809–810
 - American past and present studied by, 2:809
 - capitalist crises focus of, 2:809
 - historical geography work of, 2:809–810
 - publications of, 2:809–810
- Earle, Sylvia, 4:2068
- Earthquakes, 2:810–815**
 - bracketed duration measure of, 2:811
 - in Calabria, Southern Italy, 1783–1785, 2:812
 - collisional plate margins and, 2:810
 - creep and, 2:604–605
 - in El Salvador, 1986 and 2001, 2:814
 - epicenter determination and, 2:811
 - faulting and, 3:1085–1088
 - frequencies of seismic waves measure of, 2:811
 - Gujarat earthquake (2001) and, 4:1986
 - in Haiti, 2010, 2:813
 - human effects from, 2:813–814
 - hypocentral depth measure of, 2:810–811
 - Japanese Chuetsu earthquake, 2004, 2:811
 - in Kobe, Japan, 1995, 2:814
 - landslides resulting from, 2:811–812
 - in Loma Prieta, California, October 17, 1989, 2:812 (fig.), 4:1722 (photo)
 - magnitude as surrogate measure of strong motion and, 2:810
 - measuring of, 2:811
 - mechanisms of, 2:810–811
 - in Mexico City, 1985, 2:811
 - “hot spots” of intraplate seismicity and, 2:810
 - physical effects of, 2:811–813
 - postearthquake relief efforts, 2:814–815
 - real-time earthquakes, Google view of, 3:1355 (fig.)
 - Richter scale and, 2:810
 - search and rescue factors in, 2:814
 - seismic measures, 2:811
 - seismicity distribution and, 2:810
 - seismic performance of structures and, 2:814
 - seismic resistance of building materials and, 2:814
 - seismic wave types and, 2:810
 - subduction zones and, 2:810
 - tectonic plates patterns and, 2:810
 - Tonga Trench earthquakes, South Pacific, 2:811
 - transcurrent plate margins and, 2:810
 - tsunamis, seismic sea waves and, 2:812–813
 - in 2003, 2:813 (fig.)
 - See also* Plate tectonics
- Earth’s coordinate grid, 2:815–816**
 - coordinate geometry and, 2:577–579
 - coordinate transformations and, 2:580–581
 - datums and, 2:685–686
 - equator and, 2:1008–1009
 - geodesy and, 3:1217–1219
 - geographic databases and, 2:816
 - geometric measures and, 3:1240–1241
 - local and regional coordinate systems and, 2:815–816
 - map distortions and, 2:816
 - Gerardus Mercator’s projection map and, 2:815, 3:1461, 4:1843, 4:1843 (fig.), 4:1883–1885, 6:3168
 - Plate Carrée map projection and, 2:815, 4:1844, 4:1846 (fig.)
 - Ptolemy’s longitude and latitude lines and, 2:815, 5:2300
 - Royal Observatory, Greenwich, England, as zero origin for longitude, 2:815
 - See also* Coordinate geometry; Coordinate systems; Coordinate transformations
- Earth Summit. *See* United Nations Conference on Environment and Development (UNCED)
- East Africa
 - British Empire colonies in, 1:509, 1:514
 - coastal zone and marine pollution and, 1:501
 - HIV/AIDS origins in, 3:1437
 - land inequalities in, 4:1693
 - Masai preindustrial agriculture in, 1:48
 - normal faults in, 3:1086
 - tropical deciduous forest in, 1:230, 1:231, 1:232
 - tropical humid climate in, 1:453
 - tropical rain forest of, 1:234
 - tropical savanna climate in, 1:455
 - tropical savanna in, 1:239, 1:241, 1:242, 1:243
- East Asia
 - adults and children living with HIV in 2007 in, 3:1437 (fig.)
 - colonization of, 1:514–515
 - cross-border cooperation and, 2:630
 - developed countries in, 2:725 (fig.)
 - domesticated dogs from, 2:783

- economic development success in, 3:1152
 electronics manufacturing in, 2:885–886
 export-oriented “tigers” in, 2:731
feng shui and, 3:1238–1239
 foreign aid to, 3:1152
 geomantic applied arts in, 3:1238
 government and industry links in, 3:1581
 hydropower in, 3:1507
 industrialization in, 3:1583
 land reform in, 4:1693
 military expenditures in, 4:1899 (table)
 newly industrializing countries in, 4:2021, 4:2022 (fig.)
 people living in extreme poverty and, 3:1082 (table)
 poverty rates in, 5:2274
 prehistoric exploration of, 2:1050
 sewage entering coastal zones of, 1:501
 U.S. industry moving to, 2:700
 wind-and-water geomancy variant and, 3:1238
See also specific countries of
- Eastern Europe, political map of, 6:3161
- Eastman, Ronald, 2:815–816**
 GIS, remote sensing, and cartography fields of, 2:815–816
 Idrisi and Cartalinx software developed by, 2:815
 land use planning and environmental and biodiversity modeling work of, 2:815
- Ecofeminism, 2:817–820**
 Chipko environmental movement (Indian Himalaya) and, 1:395–396, 2:818–819, 2:820, 5:2563
 criticism of, 3:1195
 deep ecology movements and, 2:692–695
 differences among women and, 2:819
 ecological feminism and feminist political ecology from, 2:817, 2:818–820
 environmental ethics and, 2:926
 essentialism and, 2:817, 2:831
 feminist environmentalist geographies and, 3:1092–1094
 feminist historical materialists and, 3:1195
 Gaia theory and, 2:819, 3:1175–1178
 gendered division of labor and, 3:1195
 gender-nature relations and, 3:1195
 global women’s movement and, 2:819
 historical materialism and women’s knowledge in, 2:819–820
 mutual inferiorization and, 2:831
 patriarchy, 2:817–819, 3:1195
 social ecofeminists and, 3:1195
 spirituality and, 2:817, 2:818, 2:819
Staying Alive (Shiva) and, 2:818–819
 traditional ecological knowledge and, 2:819
Woman and Nature (Griffin) and, 2:817
 women of color and, 2:819
 women’s connections to nature and, 2:817, 2:818, 2:831
See also Deep Ecology; Ecofeminism: noted individuals; Feminist specific subject; Gender and nature
- Ecofeminism: noted individuals**
 Bina Agarwal, 2:819–820
 Susan Griffin, 2:817
 James Lovelock, 2:819
 Carolyn Merchant, 2:818, 2:819
 Sherry Ortner, 2:817
 Val Plumwood, 2:831
 Vandana Shiva, 2:818–819
- Ecological economics, 2:820–824**
 carbon trading and carbon offsets and, 1:329–335
 command-and-control regulations and, 2:822
 economy as subset of the environment and, 2:821
 ecosystem goods and services and, 2:820
 efficient resource allocation and, 2:822–823
 empirical applications and testing of, 2:896
 energy and human economics and, 2:896
 “Energy Return on Investment” (EROI) and, 2:896
Entropy Law and the Economic Process (Georgescu-Roegens) and, 2:896
 environment and economy relationship theme in, 2:821
 equitable resource distribution in, 2:823
 future issues, 2:823
 growth-based and steady-state economies and, 2:896
 growth *vs.* development: themes and policies in, 2:822–823
 multidisciplinary characteristic of, 2:820–821
 natural resources, as capital and, 2:820–822
 open-access resources and, 2:821
 optimal scale of the economy and, 2:822
 Pigouvian taxes per pollution unit and, 2:822
 population density and, 5:2238
 positive or negative externalities, 2:821–822
 sustainability, 2:821–822
 temporal distribution of resources and, 2:823
- Ecological fallacy, 2:824–825**
 contextual fallacies and, 2:824
 cross-level fallacy and, 2:824
 cross-sectional and longitudinal fallacies and, 2:824
 errors arising from ecological inference and, 2:824
 individualistic fallacy and, 2:824
 Modifiable Areal Unit Problem and, 2:824
 William Robinson’s work in, 2:824
 selective fallacy and, 2:824
 stereotyping or geographic profiling examples of, 2:824
 universal fallacy and, 2:824
- Ecological footprint, 2:825–828**
 biocapacity concept and, 2:825
 carbon footprint and, 2:570–571
 conservation and, 2:570
 definition of, 2:826–828
 ecological deficits and, 2:825
 ecological footprint analysis method and, 2:825–826
 ecological footprints and biocapacities for selected countries, 2005, 2:827 (fig.)
 ecological modernization and, 2:832–834
 ecological overshoot and, 2:825
 ecological resource accounting and, 2:825
 environmental planning and, 2:982
 Global Footprint Network measurement of, 2:825, 2:828
 humanity’s ecological footprint, 1961–2005 and, 2:825–826, 2:826 (fig.)
 mass flow balance, 2:825
 sustainability requirements and, 2:825, 2:828
 war, 2:956
- Ecological imaginaries, 2:828–830**
 “cultural turn” and “green turn” and, 2:829
 explanation of, 2:827
 ideologies and conceptions of nature and society and, 2:827
 livability and sustainability examples of, 2:829
 origins of, 2:829
 representational and material spatial strategies and, 2:829
 urban theories and, 2:829
 uses of, 2:829–830
 utopian or dystopian themes and, 2:829–830
See also Environmental imaginaries
- Ecological justice, 2:830–832**
 animal geographies and, 2:831–832
Animal Liberation (Singer) and, 2:831

- animal rights (Singer) and, 2:831
- deep ecology movements and, 2:692–695, 2:831
- definitions of, 2:830
- ecofeminism (Plumwood) and, 2:831
- environmental ethics and, 2:925–927
- environmental justice and, 2:959
- equal rights of nature doctrine (Næss) and, 2:831
- geographers' contributions to, 2:831–832
- human's moral obligations to other species and, 2:830
- instrumental grounds of, 2:830
- justice to nature and, 2:830
- legal rights for nature (Stone) and, 2:831
- "moral considerability" and, 2:830
- moral grounds of, 2:830
- political ecology and, 2:832
- religious grounds of, 2:830
- Silent Spring* (Carson) and, 2:831
- See also Ecological justice: noted individuals;
- Environmental justice**
- Ecological justice: noted individuals
 - Bruce Braun, 2:831
 - Rachel Carson, 2:830
 - Luc Ferry, rights of nature, 2:831
 - Brendan Gleeson, 2:830
 - Aldo Leopold, 2:830
 - Nicholas Low, 2:830
 - Roderick Nash, rights of nature, 2:831
 - Arne Næss, deep ecology, 2:831
 - Val Plumwood, ecofeminism, 2:831
 - Peter Singer, animal rights, 2:831
 - Christopher Stone, legal rights for nature, 2:831
 - Sarah Whatmore, 2:831, 2:832
 - Jennifer Wolch, 2:831
- Ecological mapping, 2:832–834**
 - boundaries determination issue and, 2:833
 - climate in ecosystem differentiation and, 2:833–834
 - ecoregions and, 2:855–856
 - empirical boundary determination methods and, 2:833
 - genetic approach to study and delineate ecosystems and, 2:833
 - hierarchical schemes of ecosystem units and, 2:833
 - knowledge of processes to determine landscapes
 - concept and, 2:833
 - land management and planning applications of, 2:832
 - levels of, 2:832
 - macroclimate factors and, 2:834
 - mesoscale of climate factors and, 2:834
 - microscale of climate factors and, 2:834
 - sites, landscape mosaic, and ecoregions perception
 - levels of, 2:833
 - spatial hierarchy approach to, 2:833
- Ecological modernization, 2:835–838**
 - capitalism critiques and, 2:836
 - criticism of, 2:835
 - diverse environmental values and, 2:835
 - empirical testing of through policy processes and, 2:837
 - globalization and, 2:835
 - goals of, 2:835
 - harmful effects of, 2:835
 - institutional and cultural dynamics of, 2:836–837
 - neoliberalism emergence and, 2:836
 - origins and development of, 2:836–837
 - positive-sum solutions to zero sum problems and, 2:835
 - reflexive ecological modernization (Hajer and Beck), 2:837
 - sustainable development and, 2:835
 - techno-corporatist form (Hajer) of, 2:836, 2:837
 - theory of, 2:836–837
 - See also Ecological modernization: noted individuals
- Ecological modernization: noted individuals
 - Ulrich Beck, 2:837
 - Maarten Hajer, 2:836–837
 - Joseph Huber, 2:836
 - Martin Jänicke, 2:836–837
 - Arthur Mol, 2:836
 - Gert Spaargaren, 2:836
- Ecological regimes, 2:838–840**
 - definition of, 2:839
 - empirical analysis of, 2:839–840, 2:839 (fig.), 2:840 (fig.)
 - integration of social and physical structures and, 2:838–839
 - nature and culture coevolution and, 2:838
 - regulation, 2:838–839
 - See also Ecological regimes: noted individuals
- Ecological regimes: noted individuals
 - Mariana Fisher-Kowalski, 2:839
 - Christoph Görg, 2:838
 - Rolf Peter Sieferle, 2:839
- Ecological risk analysis (ERA), 2:840–843**
 - analysis or modeling *vs.* valuation and, 2:841
 - as different complex problems analysis, 2:840–841
 - environmental planning and, 2:841–842
 - environmental risk and, 2:840–841
 - as impact analysis method, 2:840–841
 - land use change application of, 2:841–842
 - Multicriteria Landscape Assessment and
 - Optimization tool and, 2:842
 - sectoral approaches using, 2:841
 - Soil and Water Assessment Tool and, 2:842
 - sustainability impacts assessment tools and, 2:843
 - systems behavior assessed by, 2:840
 - tools and GIS applications for, 2:842–843
 - utility value analysis methods compared with, 2:842
- Ecological Society of America, 1:34
- Ecological zones, 2:843–844**
 - definition of, 2:843–844
 - ecoregions and, 2:855–856
 - ecotones and, 2:865–869
 - ecotope, biome, and niche landscape ecology
 - concepts and, 2:844
 - factors in, 2:844
 - regional scale of, 2:844
- E-commerce and geography, 2:844–846**
 - business-to-business sales and, 2:845
 - business-to-consumer sales and, 2:845
 - centralizing force of, 2:845–846
 - change in economy's spatial organization and, 2:844
 - death of geographical distance and, 2:844–845
 - definitions, 2:844
 - Internet access factor in, 2:845
 - skilled labor exception to, 2:845
 - small- and medium-sized enterprises use of, 2:845–846
 - tangible and intangible goods and, 2:844
 - tangible products transportation and, 2:845
- Economic base analysis, 2:846–848**
 - aggregation sensitivity of, 2:847
 - assignment export identification method and, 2:847
 - basic *vs.* nonbasic regional economy sectors and, 2:846
 - bifurcation process in, 2:846–847
 - cross-hauling assumption in, 2:847
 - demand-driven theory nature of, 2:846
 - economic impact analysis use of, 2:846
 - input-output models and, 3:1599–1601

- limitations of, 2:847
- location quotient export identification method and, 2:847
- location quotients and, 4:1796–1797
- minimum-requirements approach in, 2:847
- regional economic growth theory and, 2:846
- surveys of local businesses export identification method and, 2:847
- Economic geography, 2:848–853**
 - agglomeration economies and, 1:31–32
 - capitalist accumulation and crisis issues (Harvey) and, 2:849, 3:1467
 - central place theory and, 2:575
 - circuits of capital and, 1:410–412
 - commodity chains and, 1:522–525
 - comparative advantage and, 2:556–558
 - competitive advantage and, 2:558–559
 - core areas of, 2:850–852
 - “cultural turn” and, 2:849–850
 - development theory and, 2:729–733
 - division of labor and, 2:780–781
 - economic base analysis and, 2:846–848
 - economies of scale and, 2:853–854
 - economies of scope and, 2:854–855
 - environmental impacts of economic activity and, 2:851
 - Euromarkets and, 2:1030–1032
 - factors affecting location of firms and, 3:1077–1080
 - finance geographies and, 3:1115–1118
 - firms and finance and, 2:850–851
 - Fordism and, 3:1148–1151
 - frameworks of, 2:848
 - French regulation theory and, 2:849
 - gendered character of labor markets (Massey) and, 2:852, 4:1866–1867
 - geographies of consumption and, 2:572–575
 - geography of enterprise and, 2:850
 - geography of tourism and, 2:575
 - globalization and neoliberalism in, 2:850
 - Global Shift* (Dicken) and, 2:850
 - Handbook of Commercial Geography* (Chisholm) and, 2:848
 - high-tech and creative economies and, 2:851–852
 - history of, 2:848–850
 - incubator zones and, 3:1551–1553
 - Industrial and Commercial Geography* (J. R. Smith) and, 2:848
 - industrial capitalism issues and, 2:849
 - industrial districts and, 2:851–852
 - industrial restructuring issues (Massey) and, 2:849, 4:1790–1791, 4:1866–1867
 - Industrial Revolution and, 3:1581–1586
 - information and communications technologies (ICTs) and, 2:540
 - information societies, 2:540
 - innovation geographies and, 3:1597–1599
 - Internet and role of place in, 2:540
 - knowledge spillover and, 4:1663–1664
 - labor and work and, 2:852
 - Manufacturing Belt and, 4:1820–1824
 - money geographies and, 4:1936–1938
 - natural resources studies and, 2:851
 - nature and environment in, 2:851
 - Nature of Geography* (Hartshorne) and, 2:849, 3:1403, 5:2387, 5:2433
 - neoliberal post-Fordism and, 5:2400–2401
 - oceans and, 4:2067–2068
 - outsourcing and, 4:2108–2110
 - path dependence theory and, 4:2133–2135
 - post-Fordism transformation and, 2:849
 - quantitative revolution in, 2:849
 - radical geography and, 2:849
 - regional approach to, 2:848–849
 - regulation theory and, 5:2399–2402
 - service industries and, 2:540
 - transportation and communication in, 2:851
 - transportation geography and, 6:2875
 - typological regional classification scheme (C. F. Jones) and, 2:849
- See also Business cycles and geography; Business geography; Business models for geographic information systems (GIS); Economic geography: noted individuals; Globalization*
- Economic geography: noted individuals
 - George Chisholm, 2:848, 2:850, 2:851, 4:1990
 - Peter Dicken, 2:850
 - Richard Florida, 2:851
 - Masahisa Fujita, 5:2395
 - Richard Hartshorne, 2:849, 4:1801, 5:2387–2388, 5:2433
 - David Harvey, 2:849, 2:851, 3:1467, 4:1862, 5:2350, 5:2442
 - Clarence Fielden Jones, 2:849
 - Paul Krugman, 5:2395
 - Lionel Lyde, 2:848
 - Doreen Massey, 2:849, 2:852, 4:1790–1791, 4:1866–1867, 4:2136, 5:2351
 - J. Russell Smith, 2:848, 2:850, 2:851
 - Neil Smith, 2:851, 5:2351, 5:2551–2552
 - Anthony Venables, 5:2395
 - Ray Whitbeck, 2:848–849
- Economics. *See Agglomeration economies*
- Economies of scale, 2:853–854**
 - definition of, 2:853
 - economies of scale and, 2:853–854
 - economies of scope and, 2:854–855
 - geographic location factor in, 2:855
 - long-run average costs and, 2:853, 2:854 (fig.)
 - oligopolistic market structures and, 2:854–855
- Economies of scope, 2:854–855**
 - byproducts production and, 2:855
 - combinations of output focus of, 2:854
 - definition of, 2:854
 - economies of scale *vs.*, 2:854
 - examples of, 2:854–855
- Ecoregions, 2:855–856**
 - bioregionalism and, 1:255
 - boundaries determination issue and, 2:855
 - climate types and, 2:855–856
 - ecoclimate zones or ecological zones and, 2:855
 - ecological mapping and, 2:832–834
 - ecological zones and, 2:834–844
 - ecosheds and, 2:857
 - ecosystems and, 2:855
 - ecosystems of different climates and, 2:855
 - ecotones and, 2:865–869
 - landforms variations and, 2:856
 - macroclimatic units and, 2:855
 - macroscale ecosystems patterns and, 2:855
 - natural ecoregions of the earth and, 2:855, 2:856 (fig.)
 - subzones or provinces of, 2:855–856
 - vegetation features and, 2:856
- Ecoshed, 2:857**
 - community watershed rehabilitation management and, 2:857
 - definition of, 2:857
 - ecology and watershed terms and, 2:857
 - Gail Feenstra's work, 2:857
 - foodshed and, 2:857

- healthy food and clean water benefits of, 2:857
social ecosystem similarity to, 2:857
- Ecosystem decay, 2:858–862**
Amazon rain forest, 2:858
area factor and, 2:860–861
Biological Dynamics of Forest Fragments Project and, 2:858, 2:859, 2:859 (photo), 2:860
edge effects factors and, 2:858–860, 2:859 (photo), 2:860 (fig.), 2:867, 3:1161
extinction rates and, 2:861
immigration-to-extinction ratio and, 2:861
island biogeographic theory and, 2:861
isolation and, 2:861–862
Thomas Lovejoy and, 2:858, 2:859, 2:861
plants and animals affected by, 2:859–860
reproductive success of species and, 2:861
species-area relationship and, 2:860–861
species' individual responses factor in, 2:861–862
- Ecosystems, 2:862–865**
biodiversity and, 1:197–201
biome and ecological zone and, 2:862
community-based conservation and, 2:545–547
definition of, 2:862
ecological mapping and, 2:832–834
ecological zones and, 2:834–844
ecoregions and, 2:855–856
ecosheds and, 2:857
ecosystem decay and, 2:858–862
ecotones and, 2:865–869
function categories of, 2:862–863
global level of spatial scale and, 2:863–864
human actions and, 2:864
intermediate level of spatial scale and, 2:863
keystone species and, 4:1655–1658
local level of spatial scale and, 2:863
management strategies of, 2:545, 2:864
Millennium Ecosystem Assessment and, 2:862, 2:864
passive support to active component transition in, 2:862–863
resilience, resistance, stability, and persistence of, 2:863
- Ecotone, 2:865–869**
alpine tree line (forest-tundra) ecotone, Glacier National Park, Montana, 2:865 (photo)
complexity theory and, 2:867
crendulated, advancing tree line (forest-tundra) ecotone, Glacier National Park, Montana, 2:866 (photo)
definition of, 2:865
ecological zones and, 2:834–844
edge effect and, 2:858–860, 2:859 (photo), 2:860 (fig.), 2:867, 4:1669
global climate change and, 2:867
krummholz, 4:1669 (photo)
landscape ecology and, 2:867
lower tree line (forest-grassland) ecotone, Yellowstone National Park, Wyoming, 2:868 (photo)
meadow-forest ecotone, Cranberry Glades Botanical Area, West Virginia, 2:868 (photo)
research issues, 2:866
scale dependent structural characteristics and dynamics of, 2:866
technology advances and, 2:869
upper and lower tree line ecotones, Rocky Mountain National Park, Colorado, 2:866 (photo)
water-riparian and riparian-desert scrub ecotones, Grand Canyon, Arizona, 2:868 (photo)
- Ecotourism, 2:869–874**
advocacy and watchdog groups of, 2:872
certification of, 2:872–873
continuum of, 2:871 (fig.)
criteria of, 2:869–870
criticisms of, 2:872, 2:873
definition issues and, 2:869
environmental impacts of tourism and, 2:953–955
examples of, 2:871–872
forms of, 2:870, 2:870 (fig.)
future of, 2:873
“greenwashing” and ecotourism and, 2:871, 2:871 (fig.)
International Ecotourism Society and, 2:869
mainstreaming detriments of, 2:871
origins of, 2:870
practice of, 2:870–872
promoters of, 2:871
successful models of, 2:871–872
sustainable development concept and, 2:870, 2:873
Sustainable Tourism Stewardship Council (Rainforest Alliance) and, 2:873
- Ecuador**
agrobiodiversity in, 1:50
as center of crop domestication, 1:376
early-morning smog, Quito, 4:2172 (photo)
economically active females in, 3:1190 (table)
ecotourism in, 2:870
Alexander von Humboldt's travels in, 3:1482
indigenous agriculture in, 3:1557
marine aquaculture in, 4:1854 (fig.)
oil exploration pollution, 4:2076
OPEC membership of, 4:2099, 4:2100 (fig.)
poverty rates in, 5:2274
tropical rain forest, Sachatamia, 1:454 (photo)
tropical rain forest of, 1:234
- Education, geographies of, 2:874–876**
challenges and issues of, 2:875
city-school relationship and, 2:874
education, space, and civil society interactions and, 2:874
educational spaces' multiple purposes and meanings, 2:874
geographic education *vs.*, 2:874
institutional discrimination practices and, 2:874
knowledge geographies and, 4:1659–1663
lifelong learning process and, 2:874
Pedagogy of the Oppressed (Freire) and, 2:875
as political consensus agencies, 2:875
rural schools and, 2:874
schools definition and, 2:874
themes and topics of, 2:874
Theory and Resistance in Education (Giroux) and, 2:875
University of California, Berkeley, 4:1660 (photo)
See also Geography education
- Edwards, J., 2:777
- Egenhofer, Max, 2:876–877**
GIS work of, 2:876
international industry standards and, 2:876
publications of, 2:876–877
research fields of, 2:876
research record of, 2:877
- Egypt**
British colonialism of, 1:514
community organization maps in, 1:346
cosmological maps and, 1:346–347
ecological footprint and biocapacity of, 2:827 (table)
economically active females in, 3:1190 (table)
French colonialism of, 1:514
“gift of the Nile” (Herodotus), 3:1422

- Derek Gregory's work, 3:1381
 Nile River delta in, 2:702
 poverty rates in, 5:2274
 Ehrlich, Paul, 2:570, 4:1820, 5:2545
 Einstein, Albert, 2:970, 5:2403–2404
 Eisenman, Peter, 5:2264
 Elazar, Daniel, 2:880
- Elderly, geography and the, 2:877–878**
 aging population trends and, 2:877
 changing location and migration patterns of, 2:877
 emergent environments and enduring policy dilemmas of, 2:878
 geographic concentrations of elderly and, 2:877
 independence and age-in-place desires of, 2:878
 Older Americans Act (U.S.) and, 2:878
 participant observation research methodology (Rowles) and, 4:2122
 service provision and care provisions for, 2:878
 space and place experiences of, 2:877–878
- Electoral geography, 2:879–884**
 aggregate nature of electoral data and, 2:883
 liberal-representative democracy and, 2:702
 micro or precinct level electoral data and, 2:883
 “neighborhood effect” and, 2:879, 2:883
 place-based studies of, 2:883
 political geography and, 5:2223
 political parties evolution and, 2:880–881
 redistricting and, 2:881, 5:2375–2377
 roll-call analysis of, 2:881–882, 2:882 (fig.)
 scale in application of, 2:882–883
 spatial dynamics of political life and, 2:879, 2:882–883
 spatial patterns of votes focus of, 2:879
 traditional uses of, 2:879–881
 2004 presidential election cartogram map and, 2:880, 2:880 (fig.)
 2004 presidential election choropleth map and, 2:879, 2:879 (fig.)
 U.S. political cultural regions and, 2:880
 world-systems perspective on, 2:881
See also Electoral geography: noted individuals
- Electoral geography: noted individuals**
 John Agnew, 2:883
 Daniel Elazar, 2:880
 R. J. Johnston, 4:1643
 André Siegfried, 2:879, 5:2223
 Peter Taylor, 2:881
- Electronic atlases, 2:884**
 benefits of, 2:884
 definition of, 2:884
 interactive capabilities of, 2:884
 Internet access to, 2:884
 media mapping and, 4:1951–1953
 visualization of geostatistical data and, 2:884
- Electronics industry, geography of, 2:885–886**
 Boston concentration of, 2:851, 2:885, 3:1426, 3:1598, 5:2435, 5:2436
 core and boundaries of, 2:885
 definition of, 2:885
 division of labor in, 2:885
 economic development potential from, 2:885–886
 flexible production and, 3:1126–1127
 Japan and, 2:885
 Japanese electronics manufacturing and, 2:885–886
 R&D functions of, 2:885
 regional development relative to, 2:885
 routine production functions of, 2:885
 Silicon Valley concentration of, 2:851, 2:885, 2:886, 3:1127, 5:2435, 5:2436, 5:2519
 Stanford University and, 2:885
See also High technology
- Electronics industry, geography of: lead firms**
 Apple, 2:885
 Bell Labs, 2:885
 Hewlett-Packard, 2:885
 Intel, 2:885
 Sony, 2:885
 Western Electronics, 2:885
- Elkin, S. L., 4:1746–1747
 Elliot, Robert, 2:992
 Ellwood, Sarah, 2:615
- El Niño-Southern Oscillation (ENSO), 2:886–890**
 Atlantic hurricanes and, 1:165
 atmospheric moisture and, 1:148
 beach rotation and, 1:491
 cholera and, 1:402
 Coriolis force and, 2:888
 drought and, 2:792
 global impacts of, 2:886, 2:888–889, 2:889 (images), 3:1336
 global weather and, 2:887
 Hadley Cell Circulation and, 2:887–888
 history of, 2:887
 Humboldt Current and, 2:887
 Inter-Tropical Convergence Zone (ITCA) and, 2:888, 2:889
 long-term changes in, 2:889–890
 mean sea level changes and, 1:497
 midlatitude, mild climate and, 1:435–436
 mountain climate and, 1:448
 oceanic and atmospheric phenomenon of, 2:886, 3:1336
 Pacific Decadal Oscillation (PDO) and, 1:164
 phases of, 2:886–887
 physics of, 2:887–888, 2:889 (images)
 South Asian monsoon and, 4:1943–1944
 synoptic and dynamic climatology and, 1:473
 teleconnections atmospheric linkages and, 2:886, 2:889–890, 6:2790
 volcanic eruptions and, 1:163
 Walker Cell Circulation and, 2:888, 2:889
 Gilbert Walker's contributions to, 2:887
 water surface and subsurface temperatures and, 2:888
- El Salvador**
 Cold War and, 1:504
 earthquakes in, 2:814
 economically active females in, 3:1190 (table)
 human rights violations in, 3:1480
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
- Emanuel, Kerry, 3:1495
 Emel, Jody, 3:1093
- Emerging markets, 2:890–891**
 Antoine van Agtmael and, 2:890
 closed-end *vs.* open-end country funds and, 2:891
 financial instruments used in, 2:891
 identification criteria of, 2:890
 International Finance Corporation (IFC) and, 2:890
 international securities issuance by, 2:890
 net equity flows of, 2:890–891
 newly industrializing countries and, 4:2021–2024
 World Bank and, 2:890
- Emotions, geography and, 2:891–892**
 cultural geography and, 2:639
 fear geographies and, 3:1088–1089

- feminist geographers, dualisms and, 2:892
- financial markets and, 2:892
- intangibility of emotions and, 2:891–892
- political geographies and, 2:892
- sense of place and, 2:892
- “writing of the world” and, 2:892
- Empiricism, 2:893–894**
 - abstraction and causation limitations of, 2:849–850
 - British Enlightenment origins of, 2:893
 - derivation of word and, 2:893
 - empirical work *vs.*, 2:894
 - fact-opinion dichotomy and, 2:849
 - Richard Hartshorne work and, 2:893, 3:1402–1403, 4:1801, 5:2387–2388, 5:2433
 - inductive logic and, 2:893
 - logical positivism and, 2:893
 - theory and, 2:893–894
- Energy and human ecology, 2:894–897**
 - biofuels production and, 1:201–204
 - Chicago School of Urban Sociologists and, 2:894
 - critique of, 2:896–897
 - cultural ecology and, 2:895–896
 - ecological economics and, 2:896
 - ecological flows of energy and matter and, 2:895
 - energetic efficiencies of energy sources and, 2:896
 - energy as ecological concept, 2:894–895
 - energy flows measurement and, 2:895–896
 - energy models and, 2:897–899
 - Energy Return on Investment (EROI), 2:896, 2:897
 - entropy concept and, 2:895
 - Entropy Law and the Economic Process* (Georgescu-Roegen) and, 2:896
 - entropy law of thermodynamics and, 2:896
 - gardening practices, Maring people of New Guinea research example of, 2:895–896
 - geography as human ecology (Barrows) and, 2:894
 - growth-based and steady-state economies, 2:896
 - holistic energy approach of, 2:894, 2:897
 - human ecological approach to energy and, 2:895–896
 - laws of thermodynamics and, 2:895
 - nuclear energy and, 4:2050–2052
 - photosynthesis process and, 2:895
 - systems ecology approach (Odum) and, 2:894–895
 - See also* Energy and human ecology: noted individuals;
 - Energy policy**
- Energy and human ecology: noted individuals
 - Harlan Barrows, 2:894, 2:895, 2:896–897
 - Cutler Cleveland, 2:896
 - Herman Daly, 2:896
 - Nicholas Georgescu-Roegen, 2:896
 - Howard Odum, 2:894–895
 - Roy Rappaport, 2:895–896
 - Gilbert White, 2:894
- Energy models, 2:897–899**
 - differences in, 2:898
 - energy return on investment (EROI) and, 2:896
 - energy system characterized by, 2:897
 - energy system components and, 2:897
 - frameworks of, 2:898
 - functions of, 2:897–898
 - geographic perspective of, 2:898
 - GIS spatial analyses modeling, 2:898–899
 - input-output (IO) models, 2:898
 - optimization-based models, 2:898
 - partial equilibrium models, 2:898
 - regional econometric models, 2:898
 - results interpretation differences in, 2:898
 - second-generation model, 2:898
 - simulation models, 2:898
 - spatial perspective importance and, 2:898–899
 - system dynamics models, 2:898
 - top-down *vs.* bottom-up models and, 2:898
 - See also* Energy and human ecology; Energy models: specific models
- Energy models: specific models**
 - AIDAIR modeling framework, 2:899
 - FOSSIL2, 2:898
 - IDEAS (Integrated Dynamic Energy Analysis Simulation), 2:898
 - LEAP (Long Range Energy Alternatives Planning System), 2:898
 - MARKAL, 2:898
- Energy policy, 2:899–902**
 - access to resources issue and, 2:899
 - biofuels production and, 1:201–204, 2:900, 2:901
 - carbon dioxide capture and geologic storage and, 2:900
 - coal and, 1:483–486, 2:900
 - cost and economic impact issues and, 2:899
 - domestic fossil fuel supply and, 2:899, 2:900, 2:901
 - environmental and energy security issues and, 2:901
 - environmental damage and global climate change issues and, 2:899
 - environmental law and, 2:965–967
 - future, 2:902
 - GHG emissions and, 2:900
 - greenhouse gas emissions (U.S.) and, 2:900
 - hydroelectric power and, 3:1506–1512
 - Kyoto Protocol and, 2:900
 - natural gas, 2:901
 - neoliberal energy policy and, 2:900, 2:901
 - nuclear power, 2:899, 2:901
 - OPEC oil embargo and, 2:899–900
 - Organization of the Petroleum Exporting Countries (OPEC) and, 4:2097–2100
 - other countries and, 2:901–902
 - renewable energy and, 2:900–901
 - strategy of maximum extraction and, 2:901
 - Three Mile Island nuclear accident and, 2:899
 - U.S. policy and, 2:899–901
 - wind and solar energy and, 2:900
 - See also* Energy policy: U.S. policies; Petroleum
- Energy policy: U.S. policies**
 - Atoms for Peace program, 2:899
 - Clean Air Act (1970), 2:899, 2:900
 - Corporate Average Fuel Economy (CAFE) standards, 2:900
 - Energy Independence and Security Act (2007), 2:901
 - Energy Policy and Conservation Act (1975), 2:900
 - Federal Energy Regulatory commission (FERC), 2:900
 - Federal Water Power Act (1920), 2:899
 - National Energy Conservation Policy Act (1978), 2:899
 - National Energy Policy Plan, 2:900
 - National Energy Policy Report, 2:901
 - North American Electric Reliability Council, 2:899
 - Nuclear Waste Policy Act, 2:899
 - Price-Anderson Act (1957), 2:899
 - Public Utility Holding Company Act (1935), 2:899
 - renewable portfolio standards (RPS) and, 2:901
 - Rural Electrification Act (1936), 2:899
 - U.S. Department of Energy formation, 2:900
- Energy resources, 2:903–910**
 - biofuels production and, 1:201–204
 - biomass energy, 2:907

- ecological economics and, 2:820–824
 end use efficiency and conservation as, 2:908–909
 energy models and, 2:897–899
 fossil fuels, 2:904–907
 geothermal energy, 3:1265–1270
 global coal reserve by country, 2:906 (fig.)
 global gas reserve by country, 2:905 (fig.)
 global reserves of energy sources by type, 2:903 (fig.)
 global reserves of oil by country, 2:904 (fig.)
 global uranium reserves by country, 2:909 (fig.)
 hydroelectric power and, 3:1506–1512
 hydropower, 2:907–908
 nonrenewable resources and, 4:2039–2041
 nuclear energy and, 4:2050–2052
 Organization of the Petroleum Exporting Countries (OPEC)
 and, 4:2097–2100
 renewable energy sources, 2:908
 uranium and nuclear power, 2:908
See also Energy and human ecology; Energy policy; Petroleum
- Engels, Friedrich, 2:544 (photo)
Condition of the Working Class in England in 1844
 written by, 2:617
 Karl Marx and, 4:1859
- England. *See* Britain; United Kingdom
- Enitrea, 3:1190 (table)
- Enlightenment, 2:910–911**
 centrality of space and, 2:910
 critical reason, progress, utility, and order emphasized by,
 2:910, 2:911
 definitions, 2:910
 as a discourse and process, 2:910
 as a geographical phenomenon, 2:910
 geography as tool to understand and explain the
 world and, 2:910–911
 nation word origins and, 4:1971–1972
 plural usage of, 2:910
 potential of the world and, 2:911
 universal human rights concept and, 3:1480
- Enterprise GIS, 2:911–913**
 explanation of, 2:911
 IT infrastructure of an organization and, 2:911
 organizational issues of, 2:912–913
 overview of an example of, 2:913, 2:913 (fig.)
 requirements of, 2:911–912
 technical issues of, 2:912
 three-tier client-server architecture and, 2:912 (fig.)
- Environmental certification, 2:914–916**
 accountability issue, 2:915
 Agenda 21 (UN), global sustainable development
 action plan, 2:914
 definition of, 2:914
 forest certification example of, 2:914–915
 Forest Stewardship Council, 2:915
 future market developments, 2:915
 global reach and local specificity of, 2:915
 International Federation of Organic Agriculture Movements
 (IFOAM), 2:914
 ISO 14001 Standard for Environmental Management Systems
 (organic agriculture), 2:914
 management system *vs.* performance standards and, 2:914
 National Standard on Sustainable Forest
 Management (Canada), 2:915
 organic agriculture standards and, 2:914, 4:2094–2096
 origins of, 2:914–915
 process of, 2:914
 product *vs.* process standards and, 2:914
 Programme for Endorsement of Forest Certification, 2:915
 Rainforest Alliance certification scheme, 2:914
 Sustainable Forestry Initiative, 2:915
 UK Woodlands Assurance Scheme, 2:915
See also Fair trade and environmental certification
- Environmental determinism, 2:916–918**
 as an ancient belief, 2:916
 anthropogeography and, 1:93
 Berkeley School and, 1:191–192
 cause-and-effect relationships and, 2:917
 chorology and, 1:404–405
 climate factors in society and, 3:1428–1429
 connections between people and place and, 2:1020, 5:2338
 critical studies of nature and, 2:621
 criticisms, 2:917, 3:1464–1465
 cultural landscape (Sauer) and, 2:641–642
 environment holds sway over humanity and, 2:916
 ethnicity and nature and, 2:1019–1022, 3:1428–1429, 3:1464
 Eurocentrism and, 3:1434
 evolutionary theory and, 2:916–917, 3:1464
Guns, Germs, and Steel (Diamond) and, 2:734,
 2:917, 5:2216
 hierarchy of competing races focus of, 3:1464
 Lamarckian evolutionary theory and, 2:667, 3:1464
 nation building and, 4:1972
 neo-environmental determinism and, 2:917
 oceans ignored by, 4:2065
 Orientalism and, 4:2102–2103
 social Darwinism and, 2:1014
See also Environmental determinism: noted individuals;
- Race and empire**
- Environmental determinism: noted individuals**
 Aristotle, 2:916
 Harlan Barrows, 1:185
 James Blaut's critique of, 1:285
 Jared Diamond, 2:734, 2:917
 Lucien Febvre, 3:1090
 Hippocrates, 2:916
 Ellsworth Huntington, 2:667, 3:1429, 3:1464, 4:1990, 4:1991
 Immanuel Kant, 4:1648
 Montesquieu, 2:916
 Plato, 2:916
 Frederick Ratzel, 2:916, 3:1464, 5:2246
 Ellen Churchill Semple, 2:667, 2:917, 3:1429, 3:1464, 4:1990,
 4:1991, 5:2531–2532
 Herbert Spencer, 2:916, 3:1464
 George Tatham's criticism of, 2:917
 Griffith Taylor, 3:1464, 6:2777
 Frederick Jackson Turner, 2:667
- Environmental discourse, 2:918–921**
 conceptual underpinnings of, 2:918–919
 critical insights of, 2:918
 deconstruction process and, 2:921
 difference making in, 2:920–921
 discursive strategies and, 2:920
 environmental knowledge and, 2:919
 material outcomes and effects of, 2:919–920
 nature-society theory and, 4:1995–1996
 normalizing power and, 2:920–921
 objects of, 2:919
 operation of, 2:919–920
 power of, 2:920–921
- Environmental entitlements, 2:921–925**
 applications of, 2:923–924

- community-based natural resource management (CBNRM) and, 2:921–922, 2:923–924
- criticisms and prospects, 2:924
- definition of, 2:923
- from economic entitlements to, 2:922–923
- endowments as rights and resources social actors have and, 2:923
- entitlement mapping and, 2:922
- environmental resources linked to, 2:921
- environmental services and, 2:1000–1002
- institutional perspectives on, 2:923
- “new” ecologies, 2:922
- people and natural resources link and, 2:922
- people-environment interactions structure and, 2:923
- reconceptualizing CBNRM approaches and, 2:922
- supply-driven to demand- and access-driven perspectives on well-being and, 2:922
- sustainable development in developing countries and, 2:921
- See also* Environmental entitlements: noted individuals;
- Environmental rights**
- Environmental entitlements: noted individuals
- Melissa Leach, 2:921, 2:922–923
- Robin Mearns, 2:921, 2:922–923
- Ian Scoones, 2:921, 2:922–923
- Amartya Sen, 2:921, 2:922, 2:924
- Environmental ethics, 2:925–927**
- anthropocentric arguments, 2:926
- biocentrists and, 2:926
- bioregionalism and, 1:255
- Clean Air Act (1970), 2:925
- Clean Water Act (1972), 2:925
- deep ecology movements and, 2:692–695
- Earth Day and, 2:925
- ecofeminism and, 2:926
- ecological justice and, 2:830–832
- ecological modernization and, 2:832–834
- Endangered species Act (1973) and, 2:925
- Green Revolution environmental activism and, 2:925
- holistic, ecological approach of, 2:926
- human behavior and environmental and ecological crises focus of, 2:925
- intrinsic value concept and, 2:926
- National Environmental Policy Act (1970) and, 2:925
- origins of, 2:925
- social ethics and, 2:925, 2:926
- speciesism and, 2:926
- See also* Environmental ethics: noted individuals
- Environmental ethics: noted individuals
- J. Baird Callicott, 2:925
- Rachel Carson, 2:925
- Garrett Hardin, 2:925
- Aldo Leopold, 2:926
- Tom Regan, 2:926
- Peter Singer, 2:926
- Lynn White, 2:925
- Environmental history, 2:927–932**
- agroecology (Worster) and, 2:929
- American Society for Environmental History and, 2:929
- colonialism’s effects and, 2:928, 2:931
- definition of, 2:927
- development of, 2:927–930
- ecological footprint and, 2:825–828, 2:931
- ecological history and, 2:929
- ecological interpretation of history (Leopold) and, 2:929
- ecological restoration projects and, 2:932
- ecology and geography origins of, 2:929
- ecosystem concept (Tansley), 2:929
- environmental movement and, 2:929
- environmental sustainability issue and, 2:927, 2:931
- European Society for Environmental History, 2:929
- examples and applications of, 2:931–932
- framework of, 2:928 (fig.)
- Guns, Germs and Steel* (Diamond) and, 2:930, 5:2216
- holistic approach to study of, 2:929, 2:930
- human agent in environmental change and, 2:927, 2:928, 2:928 (fig.), 2:929, 2:930, 2:931, 2:932
- Industrial Revolution and, 2:928
- International Consortium of Environmental History Organization and, 2:929
- landscape ecology (Troll) and, 2:929
- as landscape management and planning tool, 2:931–932
- long-term quantitative data shortage limitation of, 2:930–931
- Man and Nature* (Marsh) and, 2:928, 2:991, 4:2180
- maps and spatial representations of change and, 2:931
- methods used in, 2:930–931
- narrative synthesis methods used in, 2:930
- overgeneralization caution and, 2:932
- qualitative and quantitative methods used in, 2:930, 2:931
- spatial studies of, 2:930
- themes in study of, 2:927, 2:930
- theory of plant succession (Clements) and, 2:929, 4:2180
- Walden* (Thoreau) and, 2:928
- See also* Environmental history: noted individuals
- Environmental history: noted individuals
- Frederic Clement, 2:929
- Alfred Crosby, 2:930
- Jared Diamond, 2:930, 5:2216
- Aldo Leopold, 2:929
- Charles Mann, 2:930
- George Perkins Marsh, 2:928, 4:2180, 5:2584
- Pierre Poivre, 2:928
- Carl Sauer, 2:928, 3:1464, 3:1465, 4:1990
- Arthur Tansley, 2:929
- Henry David Thoreau, 2:928
- Carl Troll, 2:929, 4:1714
- Alexander von Humboldt, 2:928
- Eugen Warming, 2:929
- Environmental imaginaries, 2:932–934**
- business spatial imaginaries and, 2:933
- change and transformation and, 2:933
- creativity factor in, 2:933
- explanation of, 2:933
- globalization as spatial imaginary and, 2:933
- global North application of, 2:933
- race, class, and gender factors in, 2:933
- regional component of, 2:933
- role of place in, 2:933
- spatial and social imaginaries and, 2:932–933
- See also* Ecological imaginaries
- Environmental impact assessment (EIA), 2:934–937**
- beyond the project and, 2:936
- cost-effectiveness issue and, 2:937
- definition of, 2:934
- ecological risk analysis (ERA) and, 2:840–843
- enduring concerns, 2:936–937
- environmental impact statements (EISs) and, 2:935, 2:958–959
- environmental movement of 1960s and, 2:934
- environmental studies *vs.*, 2:934
- federal policies, laws and, 2:935
- follow-up and monitoring of projects and, 2:937

- International Association for Impact Assessment and, 2:934
- long-term goals of, 2:937
- National Environmental Policy Act (NEPA, 1970) and, 2:935, 4:1716
- origins of, 2:934–935
- prediction of environmental impacts and, 2:937
- process step 1: project description, 2:935
- process step 2: screening, 2:935
- process step 3: scoping, 2:936, 2:958
- process step 4: impact prediction, 2:936
- process step 5: impact management, 2:936
- process step 6: Draft EIS preparation, 2:936
- process step 7: public and technical review, 2:936
- process step 8: final EIS preparation and decision, 2:936
- process step 9: implementation and follow-up, 2:936
- public involvement issue and, 2:937
- purpose and objectives of, 2:934–935
- Silent Spring* (Carson) and, 2:934–935
- strategic environmental assessment (SEA) and, 2:936
- See also* Environmental impact assessment (EIA)
- Environmental impacts of agriculture, 2:937–940**
 - agricultural intensification and, 1:35–36
 - agricultural revolution and, 2:938
 - biotechnology and ecological risk and, 1:278–279
 - coastal dead zones and, 1:486–488, 2:939
 - forest clearance: ecosystem and atmospheric impacts of, 2:938
 - Green Revolution and modern farming in, 2:939
 - Green Revolution controversy and, 1:35, 1:50
 - herbicides use and, 3:1420–1421
 - impact areas and, 2:937–938
 - nitrogen and phosphorus cycles and, 2:939
 - pesticides and nutrient loading and, 2:939
 - water supplies and, 2:938–939
 - See also* Agricultural intensification
- Environmental impacts of cities, 2:940–944**
 - Anthropocene Epoch concept and, 2:942
 - anthrosphere and, 2:943
 - atmosphere and, 2:942
 - biosphere and, 2:942–943
 - built environment and, 1:299
 - city's metabolism and, 2:940, 2:941
 - Earth systems affected by, 2:941–943
 - ecological footprint of, 2:940, 2:941
 - environmental degradation from, 2:940
 - factors of, 2:941
 - future options, 2:943
 - geography issues and, 2:943–944
 - geosphere and, 2:941–942
 - green building and, 3:1367–1369
 - history of, 2:941
 - hydrosphere and, 2:942
 - Industrial Revolution and Green Revolution and, 2:941
 - landfills and, 4:1684–1686
 - Los Angeles, California, example of, 2:940–941
 - megacities and global cities and, 2:940
 - solid wastes and, 2:941–942
- Environmental impacts of manufacturing, 2:944–946**
 - brownfields and, 1:296–298
 - chlorinated hydrocarbons (CHCs) and, 1:396–400
 - coal use effects and, 2:944
 - electricity and smokeless fuels and, 2:944
 - energy and, 2:944–945
 - geography of impacts and, 2:944, 2:945–946
 - Kyoto Protocol and, 2:945
 - local, continental, and global impacts and, 2:945–946
 - manufacturing definition and, 2:944
 - materials and, 2:945
 - motorized machinery and division of labor elements of, 2:944
 - “nuisance” pollution and, 2:945
 - theorizing environmental protection and, 2:946
 - UN Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution and, 2:945
 - water and, 2:945
- Environmental impacts of oil fields, 2:946–948**
 - catastrophic events and, 2:947
 - direct *vs.* indirect impacts and, 2:946
 - ecocide, 2:953
 - environmental impacts of pipelines and, 2:948–951
 - GHG emissions and, 2:947
 - Kuwaiti oil well fires and, 2:955, 2:956 (photo)
 - onshore and offshore development impacts and, 2:946–947
 - in situ vs. ex situ* remediation of, 2:951
- Environmental impacts of pipelines, 2:948–951**
 - above and beneath surface effects and, 2:949 (fig.)
 - different types of pipelines and, 2:948
 - ground penetrating radar leak detection and, 2:949
 - leak detection and, 2:949–951, 2:950 (fig.)
 - monitoring and remediation, 2:951
 - pipeline integrity monitoring and, 2:949
 - remote sensing leak detection and, 2:949, 2:950
 - transported substances variations and, 2:948
- Environmental impacts of roads, 2:951–953**
 - atmospheric systems affected by, 2:952
 - hydrospheric processes affected by, 2:951–952
 - living systems and, 2:951, 2:952
 - natural processes affected by, 2:952
 - nonliving systems and, 2:951–952
 - road construction impacts and, 2:951
 - road ecology and, 2:952
 - roads, definition, 2:951
 - traffic function of roads and, 2:951
- Environmental impacts of tourism, 2:953–955**
 - carrying capacity concept and, 2:955
 - cumulative nature of, 2:953
 - direct effects of, 2:953–954
 - ecotourism and sustainable tourism and, 2:955
 - environment at the core of, 2:953
 - indirect effects of, 2:954
 - induced effects of, 2:954
 - litter in Namib-Naukluft Park, Namibia, Africa, 2:954 (photo)
 - local, regional, and global scales of, 2:954–955
 - quantification issue and, 2:955
 - time and scale impacts of, 2:953
 - tourism definition and, 2:953
 - type and intensity of, 2:953
 - See also* Ecotourism
- Environmental impacts of war, 2:955–957**
 - ecocide, 2:955
 - ecological footprint of war and, 2:956
 - Environmental Modification Convention and, 2:957
 - guerrilla warfare ecosystem impact and, 2:957
 - Kuwaiti oil well fires example of, 2:955, 2:956 (photo)
 - National Defense Authorization Act (2003) and, 2:957
 - NATO bombing of Pancevo, Serbia, example of, 2:953
 - policy prioritization issues and, 2:956–957
- Environmental impact statement (EIS), 2:958–959**
 - environmental impact assessment (EIA) and, 2:934–937, 2:958–959
 - National Environmental Policy Act (NEPA, 1970) and, 2:958, 2:966, 4:1716

- origins of, 2:958
- scoping process of, 2:936, 2:958
- UN Conference on Environment and Development and, 2:938
- World Commission on Environment and Development and, 2:938, 2:958, 6:2737
- Environmental justice, 2:959–965**
 - adaptive capacities and local resiliencies and, 2:964
 - alternative environmentalism and, 2:960
 - Basel Action Network (BAN) and, 3:1610
 - Bhopal, India, chemical disaster and, 1:194–195, 4:2158
 - brownfields and, 1:296–298
 - changing methodologies of, 2:963–964
 - class, race, and gender and, 1:425
 - class and nature and, 1:423–425
 - Climate Action Network (CAN) and, 3:1610
 - Clean Air Act (1990) and, 2:960
 - climate justice and, 2:987
 - compensatory equity concept and, 2:962
 - definition of, 2:985
 - demand distribution concept and, 2:962
 - differential enforcement of environmental laws and, 2:962
 - differential vulnerability and, 2:742–744
 - ecological justice and, 2:830–832, 2:959
 - environmental racism and, 2:959, 2:985–989
 - equitable distribution concept and, 2:962
 - ethnicity and nature and, 2:1021–1022
 - geographer's contributions to, 2:960–962
 - hazardous waste landfills and communities of color and, 2:960, 2:961 (photo)
 - Hurricane Katrina, differential vulnerabilities and, 2:964, 4:1985–1986
 - institutional discrimination, 2:962
 - intentional targeting and, 2:962
 - international environmental movements and, 3:1608–1612
 - landfill in Warren County, North Carolina, 2:960, 2:961 (photo), 2:986
 - landfills and, 4:1684–1686
 - Love Canal and, 4:1806–1808
 - market-based distribution of equity and, 2:962
 - market mechanisms and, 2:962
 - methods and measurement issues and, 2:963–964
 - minority groups' exposure to environmental hazards focus of, 2:959–960
 - National Environmental Justice Advisory Council and, 2:960
 - new analysis techniques and, 2:964
 - organizations in support of, 2:960
 - PCBs and, 5:2226
 - pesticide research and, 4:2158
 - public participation ineffectiveness and, 2:963
 - quantitative and qualitative analysis methods used in, 2:963–964
 - Rainforest Action Network (RAN) and, 3:1610
 - regional racial formations and, 2:963
 - research, 2:959, 2:964
 - scale affects and, 2:964
 - sociodemographic change and, 2:963
 - successful campaigns, 2:960
 - vulnerability and choice mechanisms and, 2:962
 - waste incineration and, 6:3048–3049
 - “white flight” and, 1:420, 2:962, 2:986
 - white privilege and, 2:962
 - See also* **Environmental rights**
- Environmental law, 2:965–967**
 - Clean Air Acts (1970, 1990) and, 1:330, 2:899, 2:900, 2:925, 2:960, 2:966, 2:984
 - Clean Water Act, 2:925, 2:966, 5:2476
 - criminalization in, 2:966–967
 - description of, 2:965
 - environmental impact statements (EIS) and, 2:966
 - Federal Water Pollution Control Act, 2:966
 - hazardous wastes laws and, 2:966
 - international law, 2:967
 - National Ambient Air Quality Standards and, 2:966
 - National Environmental Policy Act (NEPA, 1970), 2:925, 2:935, 2:958, 2:966, 3:1284, 4:1716
 - natural resources use legislation and, 2:966
 - pollution control laws and, 2:966
 - Resource Conservation and Recovery Act and, 2:966
 - state laws and, 2:965–966
 - Superfund site legislation and, 2:966, 4:1808, 4:1857
 - tort law and, 2:965
 - toxic substance legislation and, 2:966
 - Trail Smelter Case, sulfur dioxide pollution and, 2:967
 - U.S. common law, 2:965
 - U.S. federal law, 2:965–966
 - wetlands and endangered species legislation and, 2:966
- Environmental management, 2:967–970**
 - biosphere reserves and, 1:256–267
 - collaborative GIS application and, 1:507 (fig.)
 - community-based natural resource management and, 2:549–551
 - connectivity and relationships with, 2:969–970
 - “cultural flow” water management approach, 2:970
 - Ronald Eastman's work in, 2:815–816
 - ecological mapping and, 2:832–834
 - environmental planning vs., 2:981
 - environmental restoration and, 2:991–994
 - Eurocentric science and, 2:968, 2:970
 - Everglades restoration example of, 2:1038–1042
 - governmentality and conservation and, 3:1359–1360
 - Great Whale River Hydro-Electric Project, Quebec, Canada, example of, 2:969–970
 - human-environment relations focus of, 2:967–969
 - indigenous perspectives on, 2:969
 - issues of, 2:968–969
 - local geographic context importance in, 2:968–969
 - maps and, 1:346, 1:350, 1:359
 - George Perkins Marsh and, 4:1858–1859, 4:2180, 5:2584
 - natural sciences as means of classification and, 2:967–968
 - nomadic herding and, 4:2032
 - people, place, and species interrelationships and, 2:967–968, 2:969
 - scientific perspective on, 2:968
 - Western natural science and, 2:968
 - See also* **Common pool resources (CPRs); Common property resource management; Commons, tragedy of the; Conservation; Corporate voluntary environmental initiatives and self-regulation; Environmental impact assessment (EIA); Environmental impact statement (EIS); GIS in environmental management; Governance**
- Environmental management: drylands, 2:971–973**
 - challenges in, 2:971–972
 - community-based management and, 2:973
 - diversified livelihoods of communities and, 2:971
 - dryland farmer strategies and, 2:971–972
 - drylands ecological diversity and, 2:971
 - institutional dimensions of, 2:972–973
 - Maasai women of Kenya, local water harvesting, 2:972 (photo)
 - mobility, flexibility, and opportunism elements in, 2:971
 - pastoralism management strategies and, 2:971
 - resource access issues and, 2:973

- silvopastoralism and, 2:971
- soil management strategies and, 2:972
- Environmental mapping, 2:973–976**
 - components of, 2:974 (fig.)
 - definition of, 2:973
 - examples of, 2:976
 - multidisciplinary features of, 2:973
 - stage 1: problem definition, 2:974
 - stage 2: data acquisition, 2:974–975
 - stage 3: preprocessing, 2:975
 - stage 4: data storage/archiving, 2:975
 - stage 5: analysis, 2:976
 - stage 6: visualization, 2:976
 - stages in process of, 2:975 (fig.)
- Environmental perception, 2:977–980**
 - behavior affected by, 2:979
 - behavioral geography and, 1:189–190
 - cognition and, 2:977
 - definition of, 2:077
 - Environmental Perception and Behavioral Geography (EPBG)
 - Group of AMG and, 2:978
 - landscape quality assessment and, 4:1715–1718
 - local *vs.* large-scale perceptions and, 2:979
 - mental maps and, 2:978, 2:979
 - multidisciplinary feature of, 2:978
 - perspective variable in, 2:978
 - range of space that can be perceived and, 2:977
 - research, 2:977–978
 - risk and fear in the landscape perceptions and, 2:979
 - senses used in, 2:977
 - spatial cognition, 2:977
 - spatial decision making and, 2:979
 - spatial visualization and, 2:978
 - universe of geography study and, 2:977
- Environmental planning, 2:980–983**
 - accreditation process and, 2:981
 - brownfields and, 1:296–298
 - conservation movement phase of, 2:980
 - current issues in, 2:981–982
 - definition of, 2:980
 - ecological footprint reduction theme in, 2:982
 - ecological risk analysis (ERA) and, 2:840–843
 - ecosystem-approach to, 2:981–982
 - environmental management *vs.*, 2:981
 - environmental restoration and, 2:991–994
 - human environmental impacts and, 2:980
 - Internet-based spatial analysis tools and, 2:981
 - professional urban planning and, 2:981
 - public consultation process and, 2:981
 - public health movement phase of, 2:980–981
 - public participatory GIS tools and, 2:981
 - smart growth, 2:982, 5:2240
 - spatial analysis from remote sensing and
 - GIS and, 2:982
 - sustainability *vs.*, 2:982–983
 - See also* Community-based environmental planning (CBEP);
Regional environmental planning
- Environmental protection, 2:983–985**
 - benefits and costs of, 2:984
 - chlorinated hydrocarbons (CHCs) and, 1:396–400
 - definitions, 2:983
 - environmental goods and services depletion issue and, 2:983
 - human-environment interaction and, 2:983, 2:984
 - international organizations in support of, 2:984
 - oceans and, 4:2067–2068
 - scale of problems factor in, 2:984
 - See also* Environmental Protection Agency (EPA)
- Environmental Protection Agency (EPA)
 - Acid Rain Control Program of, 4:1857
 - agricultural biotechnology regulated by, 1:34
 - biotechnology research funds and, 1:280
 - chlorinated hydrocarbons regulated by, 1:397
 - conservation and, 2:570
 - emissions trading systems and, 4:1857
 - pesticides regulated by, 4:2158
- Environmental racism, 2:985–989**
 - causal ordering studies and, 2:986
 - climate justice and, 2:987
 - definition of, 2:985
 - Dumping in Dixie* (Bullard) and, 2:986
 - empirical evidence of, 2:986
 - environmental justice and, 2:959–965, 2:985
 - Environmental Justice Strategic Plan of EPA and, 2:987
 - environmental policy and, 2:986
 - ethnicity and nature and, 2:1021–1022
 - executive orders, 2:987
 - First People of Color Leadership Summit (1991) and, 2:985
 - GIS tool in study of, 2:986
 - grassroots activists and, 2:985, 2:988
 - Gulf Coast Tenants Union and, 2:985
 - hazardous waste landfill locations and, 2:986–987
 - Hurricane Katrina and, 2:987
 - indigenous rights and international human rights and, 2:988
 - institutional discrimination and racism and, 2:985–986, 2:987
 - international agreements and, 2:988
 - lead exposure and, 2:986
 - networks and organizations, 2:988
 - not-in-my-backyard (NIMBY) campaigns and, 2:986–987
 - “Precautionary Principle” and, 2:988
 - racial entitlement motivation and, 2:985
 - remedies for, 2:987–988
 - Southwest Organizing Project and, 2:985
 - state policies and, 2:987
 - structured disadvantaged, 2:985–986
 - Title VI of Civil Rights Act of 1964 and, 2:987–988
 - toxic tort claims and, 2:988
 - Toxic Wastes and Race at Twenty* (Bullard) and, 2:986
 - Toxic Wastes and Race in the United States*
 - report (GAO) and, 2:986
 - toxins in fish and, 2:986
 - “white flight” and, 1:420, 2:962, 2:986
 - See also* Environmental justice
- Environmental refugees, 2:989–991**
 - climate change element and, 2:989
 - “climate refugees,” 2:990
 - definition of, 2:989–990
 - legal status and, 2:989–990
 - maximalist *vs.* minimalist perspectives on, 2:990
 - migration linked to deteriorating environmental conditions and, 2:989
 - numbers of, 2:989
 - political refugees *vs.*, 2:989
 - politics of, 2:990–991
- Environmental restoration, 2:991–994**
 - active *vs.* passive forms of, 2:993
 - definitions, 2:991
 - Everglades restoration example of, 2:1038–1042
 - Florida Everglades ecosystem restoration project and, 2:992
 - forest restoration and, 3:1166–1168
 - historical roots of, 2:991–992

- implementation and contemporary debates on, 2:992–994
 landscape quality assessment and, 4:1715–1718
Man and Nature (Marsh) and, 2:928, 2:991, 4:2180
 George Perkins Marsh and, 2:928, 2:991–992, 4:2180, 5:2584
 physical landscape elements focus of, 2:991
 rat eradication from Rat Island, Alaskan Aleutian
 Island Chain and, 2:992
 success assessment and, 2:993–994
- Environmental rights, 2:994–998**
 clean water rights case sample of, 2:995–997, 2:996 (table),
 2:997 (fig.)
 environmental entitlements and, 2:921–925
 environmental services and, 2:994
 hierarchical structure power characteristics and, 2:995
 international watershed management and, 3:1618–1620
 systems, characteristics, and environmental justice in, 2:995–997
- Environmental security, 2:998–1000**
 “The Coming Anarchy” (Kaplan) and, 2:999
 definitions, 2:998
 Environmental Change and Acute Conflict Project, University of
 Toronto, 2:998
 environmental services and, 2:1000–1002
 natural resources in peace negotiations and, 2:999
Our Common Future (World Commission on Environment and
 Development) and, 2:998, 6:2737
 policy debates, 2:998
 research programs, 2:998–999
 resource abundance and violence issues and, 2:999
 Worldwatch Institute and, 2:998
- Environmental services, 2:1000–1002**
 bee pollination, 2:1000
 ecosystem services and functions and, 2:1000, 2:1000 (table)
 evolution of inquiry in, 2:1001
 indigenous and community conserved areas (ICCAs) and,
 3:1557–1561
 market *vs.* nonmarket damages from loss of, 2:1000–1001
 Millennium Ecosystem Assessment project (UN) and, 2:1001
 storm protection by coastal wetlands, 2:1001
 vegetation erosion control services, 2:1000
See also **Environmental rights**
- Environmental Systems Research Institute (ESRI), 1:340 (figs.),
 2:663, 2:674, 2:685, 2:685 (fig.), 2:876, 3:1230, 3:1258,
 3:1307, 3:1622–1623, 4:1918, 4:1952, 5:2634
- Environment and development, 2:1002–1006**
 conflict over meanings and, 2:1006
 critical objectives for, 2:1004
 economic policy-making integration with environmental
 considerations and, 2:1002
 environmental security and, 2:998–1000
 Everglades restoration and, 2:1038–1042
 extractive reserves and, 2:1072–1073
 gender and environmental hazards and, 3:1186–1188
 institutional origins of, 2:1002–1003
 international cooperation challenges and, 2:1006
 Johannesburg Declaration on Sustainable
 Development and, 2:1005
 Johannesburg Plan of Implementation for Sustainable
 Development and, 2:1005
 making sense of, 2:1005–1006
 optimism and warning, 2:1002
 slow pace of change and, 2:1006
 Symposium on Patterns of Resource Use, Environment and
 Development Strategies and, 2:1003
 UN Conference on Environment and Development
 and, 2:1004–1005
- UN Conference on the Human Environment
 and, 2:1003, 6:2747
 World Commission on, 2:1003–1004
 World Conservation Strategy and, 2:1003
World Development Report (World Bank) and, 2:1004
 World Summit on Sustainable Development (WSSD), 2:1005,
 6:2738, 6:2750, 6:2907
See also **Developing world; Environmental history; United
 Nations Conference on Environment and Development
 (UNCED)**
- Epistemology, 2:1007–1008**
 belief we call knowledge and, 2:1007
 death penalty example and, 2:1007
 defensible propositions and, 2:1007
 definition of, 2:1007
 demonstrable propositions and, 2:1007
 dispute over defensible propositions and, 2:1007
 geography and, 2:1007–1008
 logical positivism and, 2:1007–1008
 ontology and, 4:2081–2083
 ontology definition and, 2:1007
 postmodern epistemology and, 5:2267–2268
 post-positivist epistemology and, 2:1008
 preferred propositions and, 2:1007
 realism and, 5:2369–2371
 rules of knowledge formation and, 2:1007
 subjective expressions of individual taste and, 2:1007
- EPZ. *See* **Export processing zones (EPZ)**
- Equator, 2:1008–1009**
 celestial, astronomic, galactic, geomagnetic equators and, 2:1008
 Coriolis force and, 2:1008
 datums and, 2:1009
 definition of, 2:1008
 Earth’s circumference measurement and, 2:1010
 equinoxes and, 2:1009–1010
 geodetic equator and, 2:1008
 multicontextual meanings of, 2:1008–1009
 Polaris, zero latitude location and, 2:1008
- Equinox, 2:1009–1010**
 Milesian Anaximander’s discovery of, 2:1009
 ancient cultures and, 2:1009
 definition and derivation of, 2:1009
 precession of the equinoxes (Hipparchus) and, 2:1009–1010
 vernal *vs.* autumnal equinox and, 2:1009
- ERA. *See* **Ecological risk analysis (ERA)**
- Eratosthenes, 2:1010–1011**
 coastline transformation ideas of, 2:1010
 Earth’s circumference measured by, 2:1010, 3:1460
 Hipparchus’s criticism of, 3:1428
 known world mapped by, 2:1010, 2:1051
 meridians and parallels, 2:1010
 Nile River mapped by, 2:1010
 spherical astrolabe invented by, 2:1010
- Eritrea
 locusts infestation in, 2:727
 undernourishment in, 3:1487
- Error propagation, 2:1011–1012**
 attribute error, 2:1011–1012
 calculation error, 2:1011
 computational error, 2:1012
 control of, 2:1011
 critique of, 2:1012
 digitizing error, 2:1012
 measurement error, 2:1011, 2:1012
 origin of error, relative importance of, 2:1011–1012

- positional error, 2:1012
- random noise error, 2:1011, 2:1012
- sampling error, 2:1011
- specification error, 2:1011, 2:1012
- Escobar, Arturo, 3:1101, 5:2272
- Estes, J., 4:1656
- Estonia, 3:1190 (table)
- Ethics, geography and, 2:1013–1016**
 - alternative traditions of, 2:1014
 - animals and nature issue and, 2:1015
 - challenges of, 2:1015–1016
 - definitions, 2:1013
 - empirical objection issue and, 2:1015
 - environmental ethics and, 2:925–927
 - ethics definition and, 2:1013
 - as form of discursive power, 2:1013
 - geography as root and fruit of moral understanding and, 2:1015–1016
 - intangible *vs.* tangible dimension issue and, 2:1015
 - internal and external domains of, 2:1014–1015
 - logical positivism and, 2:1013
 - moral geographies examples and, 2:1013–1014
 - political and academic life and, 2:1013
 - practical reasoning and, 2:1014
 - social change and, 2:1013
 - truth and trust moral values and, 2:1014
 - well-being and, 2:1013
- Ethiopia**
 - ecological footprint and biocapacity of, 2:827 (table)
 - economically active females in, 3:1190 (table)
 - Ethiopian Women's Organization, 1:96
 - installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 - Italian colony of, 1:509
 - Kushitic language in, 4:1749
 - locusts infestation in, 2:727
 - soil erosion in, 5:2585
- Ethnicity, 2:1016–1019**
 - assimilation and, 2:1017
 - citizenship and, 1:413–414
 - definition issues and, 2:1016, 2:1019
 - dominant groups role and, 2:1017
 - Eastern spiritualism and, 2:1021
 - ethnic groups as marginalized minorities and, 2:1017
 - ethnocentrism and, 2:1027
 - external attributes and, 2:1016–1017
 - genocide geographies and, 3:1199–1202
 - geography of differences and, 2:737–740
 - immigrants' experiences and, 2:1017–1018
 - individual characteristics and, 2:1016
 - race, physical attributes and, 2:1017
 - race, social construction of, 2:1017
 - race and empire and, 5:2335–2337
 - role of race and, 2:1017–1018
 - role of space and place and, 2:1018–1019
 - situational and dynamic nature of, 2:1016
 - as a social construction, 2:1016
 - spatial distribution of ethnic groups and, 2:1018–1019
 - symbolic ethnicity and, 2:1017
 - See also* Ethnicity and nature; Ethnic segregation; Ethnocentrism; Race and racism; Racial segregation
- Ethnicity and nature, 2:1019–1022**
 - anticolonial nationalism and, 2:1020
 - communities and specific landscape links and, 2:1019
 - connections between people and place and, 2:1020
 - environmental determinism and, 2:1020
 - environmental racism and environmental justice and, 2:1021–1022
 - essentialized identities concept and, 2:1019–1020
 - ethnic cleansing and, 2:1020
 - Israel and Palestine examples of, 2:1020
 - nationalism and nature and, 2:1020
 - noble savage, 2:1020–1021
 - strategic essentialism, 2:1021
 - "white man's burden," 2:1021
 - race and empire and, 5:2335–2337
 - See also* Environmental justice; Ethnicity; Ethnic segregation
- Ethnic segregation, 2:1022–1026**
 - African Americans in United States, 2:1024, 2:1025–1026 (figs.), 2:1026
 - causes of, 2:1022–1023
 - William Clark's work, 1:417–418
 - definition of, 2:1022
 - dissimilarity index measure of, 2:1023
 - ethnic enclave *vs.* ghetto paradigms and, 2:1024
 - ethnic social solidarity and, 2:1023
 - gated communities and, 3:1181–1183
 - ghettos and, 3:1275–1277
 - home loan restrictions and zoning laws and, 2:1023
 - housing discrimination cause of, 2:1023
 - inequality geographies and, 3:1589
 - local and geographic scales of, 2:1022
 - meaning of, 2:1023–1026
 - measurement of, 2:1023
 - Native Americans and Japanese Americans examples of, 2:1023
 - positive and negative implications of, 2:1023–1024
 - relining and blockbusting restrictions and, 2:1023
 - self-segregation and, 2:1023
 - socioeconomic status factors and, 2:1023
 - See also* Ethnicity; Ethnicity and nature; Racial segregation; Segregation and geography
- Ethnocentrism, 2:1027**
 - definition of, 2:1027
 - ethnic cleansing and, 2:1027
 - ethnocide and genocide and, 2:1027
 - European colonialism and, 2:1027
 - geographical imagination and, 3:1221–1225
 - Holocaust and, 2:1027
 - manifest destiny (U.S.) and, 2:1027
 - nationalism and, 4:1978–1981
 - "white man's burden," 2:1027
 - See also* Ethnicity; Eurocentrism
- Ethnomethodology, 1:289**
- Eurasia**
 - polar semidesert in, 1:249
 - shrub tundra of, 1:248
 - tundra of, 1:247
 - tundra vegetation in, 1:248 (table)
- Eurocentrism, 2:1028–1030**
 - James Blaut's work and, 1:285–286
 - colonialism and, 2:1029
 - contra-Eurocentrist movement and, 2:1029
 - critical race theory and, 5:2338
 - criticism of, 2:1030
 - definition of, 2:1028–1029
 - environmental determinism and, 3:1434
 - environmental management and, 2:968, 2:970
 - European economic and sociopolitical power and, 2:1029
 - Europe/Asia continental division and, 2:1028
 - geographical imagination and, 3:1221–1225, 3:1429

- historicism and, 3:1434
- hybridity concept and, 2:1030
- Indocentrism and, 2:1029
- Negritude movement and, 2:1029
- origins of, 2:1029
- Protestant work ethic (Weber) concept and, 2:1028–1029, 4:1931–1932
- race and empire and, 5:2335–2337
- race-based slavery and, 2:1029
- structure of, 2:1029, 2:1030 (table)
- sub-altern studies, South Asian historiography and, 2:1029
- subdivisions of, 2:1029–1030
- toponymies or place names and, 2:1028
- United Nations and, 2:1029
- See also* **Ethnocentrism; European Union (EU)**
- Euromarket, 2:1030–1032**
 - definition of, 2:1030
 - economic geographies altered by, 2:1031
 - economic globalization and, 2:1031
 - economic space expanded by, 2:1030
 - Eurodollar market created in London (1957) and, 2:1031
 - national currencies and, 2:1030
 - offshore finance and, 4:2071–2073
 - origins of, world economy and, 2:1031
 - state and national jurisdictions and, 2:1031–1032
 - unregulated and untaxed legal space, 2:1031
 - virtual money space, placelessness of, 2:1031
 - See also* **European Union (EU)**
- Europe**
 - acid rain in, 1:6–7
 - adults and children living with HIV in 2007 in, 3:1437 (fig.)
 - Alps glaciers in, 3:1333
 - antiglobalization sentiment in, 1:94–95
 - applied geography in, 1:101
 - arms industry consolidation in, 4:1901
 - Association of Geographic Information Laboratories for Europe and, 1:123–126
 - atmospheric pollution in, 1:154
 - automobile industry in, 1:169, 1:171
 - automobility in, 1:171–172
 - biodiesel produced in, 1:202
 - birthrates in, 2:708
 - Blaeu's map of Europe, mid 17th century, 6:2803 (fig.)
 - boreal forests in, 1:214–217
 - brownfield redevelopment in, 1:298
 - central business districts in, 1:378
 - Chernobyl nuclear accident and, 1:385, 3:1357
 - cholera in, 1:401
 - Christaller's highway development plans and, 1:410
 - coal energy source in, 3:1582
 - colonial empires prior to 1914 and, 1:509 (fig.)
 - colonial migrations of, 1500–1914, 3:1543
 - Common Agricultural Policy in, 4:1914, 4:1915
 - Compact City or Polycentricity Policy, travel behavior modification in, 2:555
 - competitive advantage areas in, 2:558
 - deindustrialization impacts in, 2:945
 - democratization in (Eastern Europe) and, 2:702
 - deposit refund systems in, 4:1857
 - developed countries in, 2:725 (fig.)
 - drug trafficking and, 2:798
 - ecological footprint and biocapacity of, 2:827 (table)
 - environmental history studies in, 2:929
 - environmental privatization in, 4:2009
 - European Convention of Human Rights and, 3:1480
 - fertility levels in, 2:709
 - foehn* warm, dry, gusty, downslope wind in, 1:384
 - forest fragmentation in, 3:1159
 - genetically modified foods in, 3:1198
 - geothermal energy use in, 3:1267 (fig.)
 - green building programs in, 3:1369
 - groundwater usage in, 3:1386
 - herbicide use in, 3:1421
 - high-speed trains in, 5:2364
 - historical climate records in, 1:456
 - HIV/AIDS in, 3:1438
 - housing policy in, 3:1448
 - humid continental climate of, 1:439, 1:440
 - hydroelectrical power in, 3:1507
 - Indo-European languages and, 4:1749, 4:1750 (fig.)
 - industrialization in, 3:1583
 - industrialized agriculture in, 1:46
 - international outsourcing between Western Europe and Bulgaria and, 4:2109 (fig.)
 - kabatic winds in, 1:135
 - land degradation estimates in, 4:1680 (table)
 - lower birth rates in, 4:1981
 - marine aquaculture in, 4:1853
 - Medieval Warm Period climate change in, 1:459
 - midlatitude, mild climate of, 1:435
 - midlatitude deciduous forest in, 1:223–224
 - military expenditures in, 4:1899 (table)
 - military-industrial complex in, 4:1900
 - MOLAND (Monitoring Land Cover/Use Dynamics) project in, 3:1313
 - musk ox faunal relict in, 1:470
 - national geographical society in, 3:1462
 - NATO membership of, 4:2048 (fig.)
 - natural openness to trade in, 5:2218
 - oil imports of, 4:2073
 - people living in extreme poverty and, 3:1082 (table)
 - petroleum consumption in, 4:2164 (fig.)
 - population growth of, 5:2233 (fig.), 5:2241
 - potential water availability in, 2007, 2050, 6:3059 (fig.)
 - prehistoric exploration of, 2:1050
 - preindustrial agriculture in, 1:47–49
 - public urban water systems in, 5:2316
 - severe midlatitude climate in, 1:439, 1:440 (fig.)
 - Silk road and, 2:1053
 - as technology diffusion center, 2:746
 - topographic mapping of, 1:350, 1:354
 - undernourishment in, 3:1488
 - university business geography programs in, 1:305
 - U.S. industry move to, 2:700
 - See also* **Colonialism; Eurocentrism; Europe: maps; European green movements; European Union (EU); specific nation**
- Europe: maps
 - European Union (EU) membership and, 2:1036 (fig.)
 - Wizz air point-to-point airline services, 1:181–182, 1:181 (fig.)
- European green movements, 2:1032–1034**
 - criticism of, 2:1034
 - diversity in, 2:1034
 - environmentalism and, 2:1032
 - “environmentalisms of the poor” and, 2:1034
 - German Green Party and, 2:1032, 2:1033–1034
 - Greenpeace and, 1:96, 3:1612
 - international environmental movements and, 3:1608–1612
 - Marxist/Left politics and, 2:1032
 - New Left activism and, 2:1032
 - organizational and political forms of, 2:1032

- political heterogeneity of, 2:1032
 Vattenfall atomic power plant protest, Hamburg, Germany, 2:1033 (photo)
See also European green movements: noted individuals
 European green movements: noted individuals, 2:1032
 Rudolf Bahro, 2:1032
 Jose Bové, 2:1032
 Bruno Latour, 2:1032
 European Science Foundation GISDATA Scientific Programmers, 1:123
European Union (EU), 3:1034–1038
 APEC *vs.*, 1:121
 carbon trading and, 1:330
 clothing exports from, 6:2186 (fig.)
 Common Fisheries Policy of, 6:2755–2756
 criticism of, 2:1036
 cross-border cooperation and, 2:630
 democratic deficit of, 2:1036
 Draft of the European Constitution and, 2:1035
 Emissions Trading Scheme and, 1:330, 1:331 (table), 1:334
 Emissions Trading System in, 4:1857
 energy policies of, 2:902
 Euro common currency and, 2:1035
 Euromarkets and, 2:1030–1032
 European Coal and Steel Community and, 2:1035
 European Economic and Monetary Union within, 2:1035
 evolution of, 2:1035
 expansion phases of, 2:1035, 2:1038
 foreign aid flows from, 3:1152
 foreign direct investment and, 3:1155
 future of, 2:1037–1038
 genetically modified foods label issue in, 3:1198
 GHG emissions and, 2:902
 high-speed trains and, 5:2364
 integration, 2:1035, 2:1036–1037
 Kyoto Protocol of 1997 and, 1:462–463, 2:900, 3:1374
 limited powers of, 2:1037
 Lisbon Treaty (Reform Treaty) and, 2:1035
 mediator and facilitator role of, 2:1038
 membership of, 2:1035
 members of, 2:1035, 2:1036 (fig.)
 movement against genetically modified organisms in, 3:1609–1610
 multilevel governance in, 2:1037
 national power and, 2:1036–1036
 NATO and, 4:2046–2048
 “Network of GMO Free Regions” and, 3:1610
 offshore finance centers regulation and, 4:2071
 recombinant bovine growth hormone, milk issues and, 3:1198
 regional environmental planning in, 5:2384
 spatial data infrastructures initiative in, 5:2167
 spatial planning in, 5:2384
 structure of, 2:1034
 supranational economic activity, glocalization and, 3:1347
 supranational integration feature of, 6:2727, 6:2729
 territoriality and spatial selectivity of, 2:1037
 textile exports from, 6:2815 (fig.)
 tuna harvesting in, 4:2066 (photo)
 UNFCCC ratified by, 3:1374
 Water Electrical and Electronic Equipment (WEEE) and, 6:2763
 Evans, Estry, 1:118
 Evans, Robert, 5:2518
Everglades restoration, 2:1038–1042
 anthropogenic changes in Everglades and, 2:1038–1039, 2:1039 (images)
 Comprehensive Everglades Restoration Plan (CERP) and, 2:1039, 2:1040–1041
 drainage projects and, 2:1039–1040
 Everglades Forever Act (1994) and, 2:1039
 historical context of, 2:1039–1040
 levee system construction and, 2:1040
 natural habitat restoration goal of, 2:1040, 2:1041 (photo)
 natural hydrology restoration goal of, 2:1040
 specific projects of, 2:1040–1041
 Swamp Lands Act of 1950 and, 2:1039
 water conservation areas creation and, 2:1040
Everyday life, geography and, 2:1042–1045
 choreography of existence concept (Giddens) and, 2:1044
 “cultural turn” and, 2:1045
 definition of, 2:1042–1043
 EuroFEM model for implementing change and, 2:1045
 everyday life as staging of drama approach to, 2:1043
 feminist scholars and, 2:1042, 2:1043–1044, 2:1045
 geographies of emotion and, 2:891–892
 GIS applications to, 2:1045
 humanistic geographic tradition of, 2:1043, 2:1044–1045
 masculine understanding of the world and, 2:1043–1044
 origins of concept, 2:1043–1044
 participant observation and, 4:2121–2122
 people-place relations analysis and, 2:1044–1045
Presentation of Self in Everyday Life (Goffman) and, 2:1043
 reproduction of human society and, 2:1042
Secret Life of Cities (Jarvis) and, 2:1042
 situationist approach to, 2:1043
 spatial and temporal rhythms of, 2:1044
 symbolic interactionism and, 2:1043
See also Everyday life, geography and: noted individuals
 Everyday life, geography and: noted individuals
 Pierre Bourdieu, 2:1043
 Michel de Certeau, 2:1043, 4:1769, 5:2230
 John Eyles, 2:1042
 Anthony Giddens, 2:1044, 5:2289
 Erving Goffman, 2:1043
 Clara Greed, 2:1043–1044
 Törsten Hägerstrand, 2:1043, 2:1044
 Henri Lefebvre, 2:1042, 2:1043, 4:1768–1770, 4:2043
 Georg Simmel, 2:1043
 Dorothy E. Smith, 2:1043
 Exhibition on Geographical Information Systems Conferences, 1:123
Existentialism and geography, 2:1046–1048
 “biography of landscape” (Samuels) concept and, 2:1046
 definitions, 2:1046
 European philosopher/scholars of, 2:1046
 existential Marxism approach (Heidegger) of, 2:1046–1047, 3:1467
 existential phenomenology approach (Lefebvre and Sartre) of, 2:1046, 4:2166–2167
 humanistic geography and, 2:1046
 influence and impact of, 2:1046–1047
 phenomenology of being and spatial ontology link and, 2:1046
 subjectivity of human reasoning and, 2:1046
See also Existentialism and geography: noted individuals
 Existentialism and geography: noted individuals
 Martin Buber, 2:1046
 Anne Buttimer, 2:1046, 3:1476
 Albert Camus, 2:1046
 Franz Fanon, 2:1047

- Martin Heidegger, 2:1046, 2:1047, 3:1467, 4:2166
 Karl Jaspers, 2:1046
 Henri Lefebvre, 2:1046, 4:1768–1770
 Gabriel Marcel, 2:1046
 José Ortega y Gasset, 2:1046
 John Pickles, 2:1046, 4:2182–2183
 Edward Relph, 2:1046, 3:1467, 4:2167, 5:2410–2411
 Edward Said, 2:1047, 4:1787
 Marwyn Samuels, 2:1046
 Jean-Paul Sartre, 2:1046, 2:1047
 Yi-Fu Tuan, 2:1046, 4:2167
- Exotic species, 2:1048–1050**
 biodiversity and, 3:1337
 dispersal prevention strategies and, 2:1049
 European rabbit introduction in Australia and, 2:1048, 2:1049 (photo)
 extinctions and, 2:1069–1072
 forest fragmentation and, 3:1163
 forest restoration and, 3:1168
 global environmental change and, 3:1337
 Great American Exchange and, 3:1361–1362
 high-resource environments and, 2:1048–1049
 human movement factor in, 2:1048
 invasion and succession and, 3:1627
 native species and ecosystems, 2:1048–1049
 repeated introductions of, 2:1048
 species- *vs.* habitat-focused treatments of, 2:1049
- Exploration, 2:1050–1059**
 Africa, 2:1051, 1057
 ancient history and, 2:1051
 Arab explorers, 2:1053–1054
 Arctic and Antarctic, 2:1055
 astrolabe invention, 2:1054
 Chinese discoveries and, 2:1054
 circumnavigation of the globe and, 2:1055
 division between humans and nature and, 2:1055, 2:1056 (fig.)
 Enlightenment and, 2:1055
 European age of discovery and, 2:1054–1055
 historical map of the Old World, as Ptolemy knew it, 2:1056 (fig.)
 imaginary geographies and, 2:1055
 indigenous people's rights violated by, 2:1050
 Islam and, 2:1053–1054
 Lewis and Clark expedition and, 4:1773–1777
 magnetic compass and, 2:1054
 Mediterranean Sea by Greeks, 2:1051
 Mediterranean Sea by Phoenicians, 2:1051
 Mediterranean Sea by Romans, 2:1051
 New World discovery, impact of, 2:1055
 Norse discovery of America issue and, 2:1051
 for Northwest and Northeast Passages, 2:1055, 2:1057
 prehistoric exploration and, 2:1050–1051
 reasons for exploration and, 2:1050
 scientific exploration (Cook) and, 2:1055
 sternpost rudder invention and, 2:1054
 Viking explorers, 2:1051–1053
 Vineland map, 15th-century from 13th-century original, 2:1051, 2:1052 (fig.), 2:1053
 women explorers, 2:1057–1058
See also **Colonialism**; Exploration: noted explorers
- Exploration: noted explorers
 Alexander the Great, 2:1051
 Roald Amundsen, 2:1055, 2:1057
 William Baffin, 2:1055
 Richard Francis Burton, 2:1057
- John Cabot, 2:1054, 2:1055
 Cheng Ho, 2:1054
 Christopher Columbus, 1:520–521, 3:1461, 4:2179
 Captain James Cook, 2:575, 2:1055, 3:1461
 Alexandra David-Néel, 2:1057
 Bartolomeu Dias, 2:1054, 3:1461
 Isabelle Eberhardt, 2:1057
 Eratosthenes of Cyrene, 2:1051
 Vasco da Gama, 2:1054, 3:1178–1179
 Sir Walter William Herbert, 2:1055
 Henry Hudson, 2:1055
 Alexander von Humboldt, 3:1482–1485
 Ibn Battuta, 2:1054, 3:1519–1520, 4:2179
 Mary Henrietta Kingsley, 2:1057
 David Livingstone, 2:1057
 Simon Lucas, 2:1057
 Ferdinand Magellan, 3:1461, 4:1813–1815, 4:2179
 Adolf Erik Nordenskiöld, 2:1055
 William Edward Parry, 2:1055, 2:1057
 Robert Edwin Peary, 2:1055
 Ida Pfeiffer, 2:1057, 2:1058 (fig.)
 Marco Polo, 2:1053, 2:1053 (fig.), 3:1461
 Pytheas, 2:1051
 John Ross, 2:1055
 Robert Scott, 2:1055
 John Flanning Speke, 2:1057
 Amerigo Vespucci, 2:1054, 6:3041
- Exploratory spatial data analysis (ESDA), 2:1059–1063**
 confirmatory analysis step in, 2:1059
 descriptive statistical methods and, 2:1061
 detecting local clusters and, 2:1061
 distance view based on geostatistics and, 2:1061
 evidence collection step in, 2:1059
 exploratory data analysis (EDA) and, 2:1059
 future directions of, 2:1061–1062
 Geographical Analysis Machine (GAM) and, 2:1061
 geovisual analytics (GA) research field and, 2:1062
 GIScience tool of, 2:1059
 global spatial autocorrelation and, 2:1060–1061
 inferential statistical cluster detection methods and, 2:1061
 Kulldorff's spatial scan statistic and, 2:1061
 lattice *vs.* geostatistical spatial association and, 2:1060
 LISA map and, 2:1060–1061
 machine-learning and data-mining computational methods and, 2:1062
 Moran scatter plots and, 2:1060–1061, 2:1061 (fig.)
 neighborhood view of spatial autocorrelation and, 2:1060
 SaTScan and, 2:1061, 2:1062 (fig.)
 scan statistical method and, 2:1061
 spatial association and, 2:1060
 spatial autocorrelation and, 2:1059–1061, 5:2607–2608
 spatial data and, 2:1059–1061
 “spatial smooth” *vs.* “spatial rough” data and, 2:1060
 Tobler's First Law of Geography and, 2:1059, 4:1648
 J. W. Tukey's work in, 2:1057
 variogram autocorrelation visualization tool and, 2:1061
 visualization of high-risk clusters of cervical cancer in U.S. and, 2:1062 (fig.)
 visualization of spatial distribution and, 2:1060
- Export-led development, 2:1063–1066**
 comparative *vs.* competitive advantage, 2:1063
 declining terms of trade and, 2:1065
 definition of, 2:1063
 economic base analysis and, 2:846–848

- export-oriented industrialization (EOI) and, 2:1063, 2:1064–1065
- foreign direct investment (FDI) and, 3:1153–1156
- global free trade model of, 2:1065
- Heckscher-Ohlin model and, 2:1065, 5:2395
- import substitution industrialism, 2:1064, 3:1549–1551
- models and theories on, 2:1063–1065
- new international division of labor and, 4:2019–2020
- newly industrializing countries and, 4:2021–2024
- outcomes, 2:1065–1066
- Richard Peet's views, 2:1063
- role of the state, 2:1063
- “strong” *vs.* “weak” development and, 2:1063
- structural adjustment programs and, 2:1065–1066
- structuralism perspective on, 2:1064
- sustainable development and poststructuralism and, 2:1063
- Export processing zones (EPZ), 2:1066–1068**
- competition in, 2:1067–1068
- critiques, 2:1067–1068
- definition of, 2:1066
- developmental trend in, 2:1068
- economic gain objective of, 2:1067
- export-led development and, 2:1063–1066
- foreign investment concentration in, 2:1067
- history and developmental functions of, 2:1067
- industrial production process division and, 2:1067
- labor and, 2:1068
- Labor, international division of, 4:2019–2020
- policies of, 2:1066
- Shenzhen Special Economic Zone (SEZ) and, 2:1067
- structural adjustment and, 2:1065
- transnational corporations and, 2:1067, 2:1068
- Externalities, 2:1068–1069**
- definition of, 2:1068–1069
- geographers' study of, 2:1069
- knowledge spillover and, 4:1663–1664, 5:2395
- network externalities and, 2:1069
- positive and negative results of, 2:1069
- Extinctions, 2:1069–1072**
- anthropogenic climate change and, 2:1070, 3:1337
- biodiversity and, 1:197–201, 3:1337
- climatic relicts and, 1:467–471
- definition of, 2:1069
- ecological and cultural place of the species and, 2:1070–1071
- enclosed spaces, global connections and, 2:1071
- European bison in Belarus, 2:1071
- from hybridizations, 3:1505
- functional extinction and, 2:1070
- geographic distribution of, 2:1070
- Gyps* vultures in India, 2:1070, 2:1070 (photo)
- human/nonhuman entanglements in place and, 2:1069, 2:1070
- interrupted spaces and, 2:1071, 3:1335
- island species and, 3:1635
- keystone species, 2:1070
- rates of, 2:1069–1070
- spectacled flying fox in Australia, 2:1070–1071
- 2005 Millennium Ecosystem Assessment and, 2:1070
- Extractive reserves, 2:1072–1073**
- Brazilian Amazon and, 2:1072
- definition of, 2:1072
- economic and conservation viability issues and, 2:1072
- enforcement issues and, 2:1072
- land tenure model and, 2:1072
- Chico Mendes and, 2:1072
- origins of, 2:1072
- rubber tappers movement (Amazon), 2:1072–1073
- social justice and, 2:1072
- Extreme geography, 2:1073–1074**
- definition of, 2:1073–1074
- Globehead! Journal of Extreme Geography* and, 2:1074
- Nikolas H. “Ni4k” Huffman and, 2:1074
- hyperradical postmodern attitudes of, 2:1074
- proponents of, 2:1074
- Exurbs, 2:1074–1076**
- characteristics of, 2:1074
- commuting and, 2:553–555
- counterurbanization and, 2:596–597
- critics of, 2:1074
- decentralization of employment factor of, 2:1075
- definition of, 2:1074
- economic factors and, 2:1075
- Exurbanites* (Spectorsky) and, 2:1075
- low-density character of, 2:1075
- rising housing costs factor of, 2:1075
- rural ideal, rural landscape focus of, 2:1075
- settlement patterns classification and, 2:1075
- statistics, 2:1074–1075
- stereotypical vision of, 2:1074
- U.S. Census Bureau study of, 2:1074–1075
- viability of, 2:1075–1076
- voting patterns of, 2:1075
- Eyles, John, 2:1042
- Facebook, 2:648, 3:1478
- Factors affecting location of firms, 3:1077–1080**
- capital contexts and, 3:1079
- capital intensification in different industries and, 3:1080
- corporate decision making and, 3:1080
- corporate division of labor and, 3:1080
- fixed *vs.* liquid capital and, 3:1079
- Infosys Technologies, Mysore, India and, 3:1078
- innovation geographies and, 3:1597–1599
- investment capital and, 3:1079
- labor factor, 3:1077–1078
- labor process political factors and, 3:1078
- land availability and cost and, 3:1078–1079
- management factor, 3:1080
- manufacturing move to suburban locations and, 3:1079
- R&D technical skills and, 3:1080
- relative productivity of labor and, 3:1078
- securing capital and, 3:1079–1080
- skilled labor markets and, 3:1078
- transportation costs and, 3:1079
- unionization of labor and, 3:1078
- Faeroe Islands, cancer incidence and mortality in, 1:322 (fig.), 1:323 (fig.)
- Fair trade and environmental certification, 3:1080–1082**
- accountability focus of, 3:1080
- certification logos and, 3:1080
- definition of, 3:1080
- examples of, 3:1080–1081
- Fair Trade-certified products and, 3:1081
- forest certification and, 3:1081
- networks of, 3:1080
- organic products and, 3:1081
- social activist organizations and, 3:1081
- statistics, 3:1081
- See also* Corporate voluntary environmental initiatives and self-regulation; Environmental certification
- Falleto, Enzo, 2:713

Famine, geography of, 3:1082–1085

- boom famines, Great Bengal Famine of 1843 and, 3:1084
- definition and meaning of, 3:1082–1083
- entitlement theory (Sen) of, 3:1084
- famine-prone regions, world-wide, 3:1083 (fig.)
- gender differences in, 3:1097
- gender inequalities and, 3:1084
- geophagy and, 3:1248
- GIS early warning systems for, 3:1301
- Great American Exchange and, 3:1362
- health, welfare provision, and community access contexts of, 3:1084
- Malthusian population principle, and, 3:1082–1083, 4:1819–1820
- neo-Malthusianism and, 4:2015–2016
- new mappings of, 3:1085
- in Niger, 2005, 4:1986
- people living in extreme poverty and, 3:1082 (table)
- political functions of, 3:1084
- Poverty and Famines* (Sen) and, 3:1084
- technical or managerial approach to, 3:1084
- See also* **Hunger**

Fanon, Franz, 2:1047, 3:1528

FAO. *See* **Food and Agriculture Organization (FAO)**

Farish, Matthew, 4:1897

Faulting, 3:1085–1088

- definition of, 3:1085
- dip-slip faults, 3:1086–1087
- earthquakes and, 3:1085
- extension, compression, and lateral shear movement types and, 3:1085
- fault line scarp and, 3:1088
- fault plane motion and orientation and, 3:1085–1086
- fault scarps, 3:1088
- folding and, 3:1140–1142
- footwall and, 3:1086, 3:1086 (fig.)
- hanging wall and, 3:1086, 3:1086 (fig.)
- normal fault, 3:1086, 3:1086 (fig.)
- normal fault, Basin and Range Province, Utah and Nevada and, 3:1086
- oblique slip and, 3:1086
- reverse fault, 3:1086–1087, 3:1087 (fig.)
- San Andreas Fault in California and, 3:1087
- strike-slip faults, 3:1087–1088, 3:1087 (fig.)
- thrust fault, 3:1087, 3:1087 (fig.)
- transform faults, 3:1087–1088

FDI. *See* **Foreign direct investment (FDI)**

Fear, geographies of, 3:1088–1089

- affective and emotional geographies and, 3:1089
- earliest studies of, 3:1088
- effects of crime and, 3:1088
- fear definition and, 3:1088
- fearful label and, 3:1088
- feminist geographers and, 3:1088
- genocide geographies and, 3:1199–1202
- globalized terrorism fear and, 3:1089
- hope, geographies of, 3:1089
- landscape and crime studies and, 3:1088
- media role in, 3:1089
- movement patterns of, 3:1089
- race and globalized fear, 3:1089
- structural vulnerability and insecurity and, 3:1088
- urban development, fortified city and, 3:1088–1089

Featherstone, D., 5:2574–2575

Febvre, Lucien, 3:1090

- Annales School and, 1:79–80, 3:1090

Marc Bloch and, 3:1090

Fernand Braudel and, 3:1090

criticism of, 3:1090

Henry Clifford Darby influenced by, 2:664

environmental possibilism and, 3:1465

human-environment relationship work of, 3:1090

La terre en Pévolution humaine written by, 1:80, 3:1090

la tradition vidalienne and, 1:80

regional monograph technique of, 3:1090

Paul Vidal de la Blache and, 3:1090, 3:1465

Federated States of Micronesia (FSM)

biodiversity conservation and, 3:1635

as biodiversity conservation “hot spot,” 3:1635

Chuuk Lagoon from satellite imagery, Chuuk

State, 3:1635 (photo)

coping with hazards and, 2:743 (photo)

deposit refund systems in, 2:742

high island of Tonowas, Chuuk State, 3:1635 (photo)

indigenous water management and, 3:1573

Malayo-Polynesian languages in, 4:1753, 4:1753 (fig.)

Feenstra, Gail, 2:857

Fellmann, Jerome, 3:1274

Feminist environmentalism, 3:1090–1092

Chipko movement and, 1:395–396

community activism and, 3:1091

criticism of, 3:1091

Françoise d'Eaubonne and, 3:1091

domination of nonhuman nature and, 3:1090–1091

ecofeminism and, 2:817–820, 3:1091

patriarchal practices, gender power differentials and, 3:1092

sexism within environmental movement, 3:1091

suffrage and abolition movements and, 3:1091

women as “moral mothers” and, 3:1091

Women's Pentagon Action and, 3:1091

See also **Feminist specific subject; Gender and nature**

Feminist environmentalist geographies, 3:1092–1094

gender and environmental hazards and, 3:1186–1188

gendered landscapes and identities in, 3:1094

gendered power relations in participatory decision-making and, 3:1094

gendered relations of global development and environments, 3:1093–1094

masculinity and, 3:1094

See also **Feminist environmentalist geographies: noted feminists; Feminist specific subject**

Feminist environmentalist geographies: noted feminists

Jody Emel, 3:1093

Cathy Nesmith, 3:1092

Sarah Radcliffe, 3:1092

Gillian Rose, 3:1094, 3:1468, 5:2484–2485

Joni Seager, 3:1092–1093

Feminist geographies, 3:1095–1098

body, geographies of, 1:289

capitalism and, 1:419

citizenship and, 1:414

Committee on the Status of Women in

Geography and, 3:1234

critical geopolitics criticized by, 2:613

critical GIS and, 2:615

critical human geography and, 2:618

deconstructionism and, 5:2271

dual-systems *vs.* single-systems model of, 4:2136

EuroFEM and, 2:1045

everyday life and, 2:1042, 2:1043–1044, 2:1045

female labor force, “glass ceiling” concept and, 3:1096

- feminist epistemologies and, 1:290, 3:1097
 feminist methodologies and, 3:1097
 feminist politics and, 3:1095–1096
 feminization of poverty and, 3:1097
 gay and lesbian geographies and, 3:1184
 gender and geography and, 3:1188–1194
 gender and space intersection and, 3:1096
 gender differences in commuting and, 3:1096–1097
 gendered division of labor and, 3:1195, 3:1196, 3:1439
 gendered geographical knowledge and, 3:1097–1098
 gendered language and, 4:1754
 “gender gap” in voting patterns and, 3:1097
 geography and feminism in, 3:1096–1097
 geography of emotions and, 2:892
 “The Geography of Women: An Historical Introduction” essay (Hayford), 2:618
 historical geography and, 3:1431
 home and family life, 3:1439
 identity formation and, 3:1530
 masculine geographies and, 2:1043–1044, 4:1865–1866
 “On Not Excluding Half the Human in Human Geography” essay (Monk and Hanson), 2:618
 panopticon and, 4:2116–2117
 patriarchal geographies and, 3:1096, 4:2135–2136
 “pink-collar ghettos,” 1:419
 postcolonial feminists and, 3:1096, 5:2261
 postmodern feminists and, 3:1096
 qualitative methods and, 3:1097
 radical geography and, 5:2351
 researcher bias and, 3:1431
 resistance geographies and, 5:2442
 social construction of gender and, 1:289, 3:1431
 social geography and, 5:2567–2568
 space and place and, 3:1431, 3:1530, 4:1644
 women in the developing world and, 3:1097
See also **Ecofeminism**, 2:817–820; Feminist geographies: noted feminists; *Feminist specific subject*; **Gender and nature**
- Feminist geographies: noted feminists**
 Susan B. Anthony, 3:1095
 Judith Butler, 1:289
 Nancy Chodorow, 3:1095–1096
 Simone de Beauvoir, 3:1095
 Sarah Elwood, 2:615
 Betty Friedan, 3:1095
 Clara Greed, 2:1043–1044
 Nicky Gregson, 1:290
 Susan Hanson, 2:618, 3:1400–1401
 Donna Haraway, 3:1097
 Sandra Harding, 3:1097
 Alison Hayford, 2:618
 bell hooks, 3:1095
 Mei-Po Kwan, 2:615, 4:1674
 Audrey Lorde, 3:1095
 Doreen Massey, 4:1866–1867
 Linda McDowell, 3:1097, 3:1400, 3:1468, 4:2136
 Sara McLafferty, 2:615
 Janice Monk, 2:618
 Gillian Rose, 1:290, 3:1094, 3:1097, 3:1400, 5:2484–2485
 Elizabeth Cady Stanton, 3:1095
- Feminist methodologies**, 3:1098–1100
 cultural turn origins of, 3:1098
 definition of, 3:1098
 feminist institutional ethnography (D. E. Smith) and, 2:1043
 feminist methodologies and, 3:1097
 gendered spaces and places focus of, 3:1098
- intersectionality, and transversalism and, 3:1099
 Orientalism and, 4:2104
 participatory action research and, 3:1099
 power relationships theme in, 3:1097, 3:1098, 3:1099, 3:1530
 qualitative, quantitative, and mixed methodologies and, 3:1097, 3:1099
 reflexivity in knowledge production and, 3:1099
 researcher role and, 3:1098, 3:1099
 Gillian Rose and, 5:2484–2485
 situatedness of knowledge production and, 3:1099
 Dorothy E. Smith and, 2:1043
See also *Feminist specific subject*
- Feminist political ecology**, 3:1100–1102
 anarchism and geography and, 1:73, 1:74
 culture, race, and gender issues and, 3:1101
 culture and place emphasis in, 3:1101
 DAWN (Development Alternatives for Women of a New Era), 3:1102
 distribution of resource access and, 2:779–780
 ecofeminism and, 2:817–820
 ecological justice and, 2:830–832
 gender and development focus of, 3:1100
 gender and nature and, 3:1195–1196
 gendered and racialized landscape formations and, 3:1101
 gendered division of labor, 1:419, 3:1195
 gendered land and resource tenure systems and, 3:1101
 gendered power relations and, 3:1101
 gendered resources distribution and, 3:1101
 International Working Group on Women and the Politics of Place and, 3:1101
 maldevelopment (Shiva) and, 3:1101
 multidisciplinary features of, 3:1100–1101
 policy and advocacy framework of, 3:1102
 politicized environment concept and, 3:1195
 sustainable development focus of, 3:1100, 3:1101
 urban and rural environmental and social justice issues and, 3:1100, 3:1101
See also Feminist political ecology: noted contributors; *Feminist specific subject*
- Feminist political ecology: noted contributors**
 Judith Carney, 3:1100
 A. Escobar, 3:1101
 Donna Haraway, 3:1100
 Wendy Harcourt, 3:1101
 Betsy Hartmann, 3:1100
 Heidi Hartmann, 4:2136
 Cindy Katz, 3:1100
 Carolyn Merchant, 3:1100
 Jan Momsen, 3:1100
 Val Plumwood, 3:1100
 Marianne Schmink, 3:1100
 Joni Seager, 3:1100
 Vandana Shiva, 3:1101
 Juanita Sundberg, 3:1101
 Sylvia Walby, 4:2136
- Feng shui*, 3:1238–1239
 Ferrel, William, 1:132
 Fertile Crescent
 animal domestication in, 1:376
 crops domestication in, 1:375
- Fertility rate**, 3:1102–1103
 age-specific fertility rate (ASFR) and, 3:1103
 crude birth rate (CBR) and, 3:1102
 definition of, 3:1102
 in demographic transition stages, 2:708–710

- general fertility rate (GFR) and, 3:1102
 natural growth rate and, 4:1981–1983
 population pyramid and, 5:2249–2250
 total fertility rate (TFR) and, 3:1103
- Field, Richard, 1:261 (photos)
- Fieldwork in human geography, 3:1103–1105**
- Chicago School of urban sociology and geography and, 3:1103–1104
 - clarity element in, 3:1104
 - communication, trust, and timing elements of, 3:1104
 - credibility, transferability, dependability, and confirmability elements in, 3:1104–1005
 - decline in, 3:1103
 - evaluation of, 3:1104–1105
 - formal training opportunities decline in, 3:1103
 - future of, 3:1105
 - geographical experience of the elderly example of, 3:1104
 - inner city as a frontier outpost work (Ley) and, 3:1104, 3:1476
 - interactionist sociology and, 3:1104
 - interviewing and, 3:1625–1627
 - life in the ghetto fieldwork (Wirth), 3:1103
 - power relationships between researcher and observed and, 3:1104
 - qualitative methodologies and, 3:1105
 - in teaching geography, 3:1105
 - triangulation process and, 3:1104–1105
- See also* Fieldwork in human geography: noted geographers
- Fieldwork in human geography: noted geographers**
- D. Gilbertson, 3:1105
 - C. Hunt, 3:1105
 - Jennifer Hyndman, 3:1104
 - M. Kent, 3:1105
 - David Ley, 3:1104, 3:1476
 - Graham Rowles, 3:1104
 - Carl Sauer, 3:1103, 3:1465
 - Louis Wirth, 3:1103
 - Wilbur Zelinsky, 3:1103
- Fieldwork in physical geography, 3:1105–1110**
- advanced field seminars and, 3:1107–1108
 - aerial photograph and satellite imagery skills and, 3:1108
 - criticism of, 3:1106
 - data sources of, 3:1106
 - field camp research programs and, 3:1108
 - field courses and, 3:1107
 - field safety and security in, 3:1109
 - field trips and, 3:1107
 - GIScience mapping tools and, 3:1105
 - instruction methods in, 3:1106–1109
 - “life before science” adage and, 3:1109
 - map reading skills and, 3:1108
 - media and, 3:1109–1110
 - multidisciplinary topics in, 3:1107
 - personal and cultural sensitivity skills in, 3:1107
 - prior training and classroom work links to, 3:1107
 - procedures of, 3:1106
 - specialized nature of data in, 3:1106–1107
 - student objectives in, 3:1108–1109
 - techniques of, 3:1106
 - themes of, 3:1108
- Fietelson, Eran, 1:526
- Fiji
- British colonization of, 1:514
 - economically active females in, 3:1190 (table)
- Film and geography, 3:1110–1111**
- affective nature of film and, 3:1111
 - author-text-reader (A-T-R model) and, 3:1110–1111
 - crisis of representation and, 3:1110
 - cultural texts produced from, 3:1110
 - film as modern-day cartography concept and, 3:1111
 - naturalized assumptions issue and, 3:1110
 - photography and, 4:2176–2178
 - realism through representation issue and, 3:1110
 - reality effect produced by, 3:1110
 - socially mediated treatment of meaning and, 3:1111
- See also* Film and geography: noted individuals
- Film and geography: noted individuals**
- Roger Manvell, 3:1110
 - Eugen Wirth, 3:1110
 - J. K. Wright, 3:1110
- Filtering, 3:1111–1114**
- Chicago School of urban studies and, 1:388, 3:1114
 - definition of, 3:1111
 - downward socioeconomic status shift of residents and, 3:1112
 - gentrification *vs.*, 3:1112
 - housing policies and, 3:1112
 - housing policies research and, 3:1114
 - ladders metaphors use and, 3:1111–1112
 - laissez-faire politics and, 3:1112, 3:1114
 - Laws of Migration* (Ravenstein) and, 3:1113
 - model of sectoral land use patterns (Hoyt) and, 3:1112
 - model of urban concentric zones (Burgess) and, 3:1112
 - neighborhood life cycles and, 3:1112
 - push factor of immigrants and, 3:1112
 - residential mobility patterns and, 3:1111–1112
 - spatial dimension of, 3:1112
 - substandard housing end product of, 3:1114
 - urban social geography and, 3:1112
 - vacancy chains and, 3:1113–1114, 3:1113 (fig.)
- See also* Filtering: noted scholars
- Filtering: noted scholars**
- Ernest Burgess, 3:1112
 - Homer Hoyt, 3:1112
 - Richard Ratcliff, 3:1114
 - Ernst George Ravenstein, 3:1113
- Filtration, 3:1114–1115**
- air filtration, 3:1115
 - definition of, 3:1114
 - granular-medium water filtration, 3:1115
 - purposes of, 3:1114–1115
 - reverse osmosis and, 3:1115
 - semipermeable-membrane filtration, 3:1115
 - solids and sludge from water filtration and, 3:1115
 - surface membrane water filtration, 3:1115
 - water filtration, 3:1115
- Finance, geography of, 3:1115–1118**
- autonomous research field of, 3:1115
 - central-place theory and, 3:1116, 3:1117
 - comparative institutionalism and, 3:1117–1118
 - cultures of company business strategy and, 2:850–851
 - disciplinary perspectives on, 3:1116–1118
 - Economic Backwardness in Historical Perspective* (Gershenkron) and, 3:1117
 - emerging markets and, 2:890–891
 - Euromarkets and, 2:1030–1032
 - financial-center literature and, 3:1117
 - financial division of labor and, 3:1116
 - formation of financial centers (Kindleberger) and, 3:1116
 - functions of money and, 3:1116
 - gaining synthesis in, 3:1118
 - geography of enterprise and, 2:850–851

- global city indices and, 3:1117
- international financial centers and, 2:851
- International Monetary Fund (IMF) and, 3:1615–1618
- metropolitan service economies and, 3:1117
- money geographies and, 4:1936–1938
- multimethod, multitheoretical, and multidisciplinary approach to, 3:1118
- offshore finance and, 4:2071–2073
- origins of, 3:1116
- performativity and, 3:1116
- policy interventions and, 3:1117
- relational geography and, 3:1117
- rise in financial markets challenges and, 3:1115–1116
- social studies of finance and, 3:1117
- space, place, and money relationships and, 2:850–851
- “space shrinking” property of money and, 3:1116
- spatial distribution of financial value production and, 3:1116
- telecommunications technology and, 6:2785–2786
- transnational developments and, 3:1117–1118
- See also* Finance, geography of: noted individuals
- Finance, geography of: noted individuals
 - Gordon Clark, 3:1118
 - Alexander Gershenkron, 3:1117
 - Charles Kindleberger, 3:1116
 - Donald MacKenzie, 3:1116–1117
 - Saskia Sassen, 3:1117
 - Peter Taylor, 3:1117
 - Dariusz Wojcik, 3:1118
- Finland
 - acid rain in, 1:7
 - AGILE membership of, 1:124 (table)
 - cancer incidence and mortality in, 1:322 (fig.), 1:323 (fig.)
 - carbon or climate change taxes in, 4:1857
 - critical human geography in, 2:620
 - economically active females in, 3:1190 (table)
 - European Union (EU) membership of, 2:1035
 - Lapps preindustrial agriculture in, 1:48
 - next generation nuclear reactors in, 4:2051
 - Ural Altaic or Finno-Ugric languages in, 4:1751 (fig.)
- Fischhendler, Italy, 1:526
- Fisher, Peter, 3:1118–1119**
 - GIScience work of, 3:1118–1119
 - International Journal of Geographic Information Science (IJGIS)* and, 3:1118–1119
 - publications of, 3:1119
 - societal impacts of geographic technologies work of, 3:1119
 - uncertainty models work of, 3:1119
- Fisher-Kowalski, Mariana, 2:839
- Fish farming, 3:1119–1121**
 - aquaculture and, 1:102–104
 - Atlantic salmon in Norway example of, 3:1119–1120
 - Blue Revolution and, 2:1120
 - culture as a cultivation process and, 2:1120
 - culture of, 3:1120–1121
 - culture, meanings of, 2:1120–1121
 - culturing and domestication processes and, 2:1120
 - global wild fisheries decline and, 2:1120
 - international economic development and, 2:1120
 - marine aquaculture and, 4:1853–1855
 - water trading permit systems and, 4:1857
 - Raymond Williams and, 2:1120
- Fjords, 3:1121–1123**
 - characteristics of, 3:1121
 - erosion rates and, 3:1121
 - erosive powers of outlet glaciers and, 3:1121
 - irregular longitudinal profile of, 3:1122, 3:1123 (fig.)
 - linear nature of, 3:1122
 - locations of, 3:1121
 - overdeepened trough landform of, 3:1122–1123
 - preglacial landscape factor and, 3:1121–1122
 - rock mass strength factor and, 3:1121
 - Sognefjorden fjord, Norway, 3:1121, 3:1122 (photo), 3:1123 (fig.)
- Flash floods, 3:1123–1125**
 - canyon flash flood, 3:1124
 - dam and levee failures and, 3:1124–1125
 - deaths from, 3:1125
 - definition of, 3:1123
 - ice dams and, 3:1124
 - impermeable surfaces factor in, 3:1549
 - infrastructural failures and, 3:1124
 - in Iowa, 3:1124 (photo)
 - Storm Events database and, 3:1125
 - urbanization contributing factor to, 3:1123
 - See also* Flash floods: examples
- Flash floods: examples
 - Big Thompson River flood (1976), Colorado, 3:1124
 - Hurricane Katrina storm surge, levee failures, 3:1125
 - Typhoon Nina (1975), Banqiao Reservoir, China, 3:1125
 - Yellow River (2008), China, 3:1124
- Fleure, Herbert, 3:1458
- Flexible production, 3:1125–1127**
 - agglomeration economies and, 1:32
 - core competencies focus and, 3:1126
 - customization of output and, 3:1127
 - definition of, 3:1125–1126
 - deindustrialization and, 2:701–702
 - Fordism economies of scale and, 3:1126
 - Fordism *vs.*, 3:1148–1151
 - increased subcontracting and, 3:1126
 - in industrial districts, 3:1576–1577
 - industrialization and, 3:1580–1581
 - information technologies use in, 3:1126–1127
 - just-in-time inventory systems and, 3:1126
 - Los Angeles School of urban economy and, 4:1803–1805
 - microelectronics revolution and, 3:1126
 - noneconomic factors and, 3:1127
 - post-Fordism and, 3:1125–1126
 - productivity increase and, 3:1126
 - quality control in, 3:1127
 - vertical disintegration and, 3:1126
- Flint, Colin, 4:1897
- Flocculation, 3:1127–1128**
 - aggregates *vs.* flocs and, 3:1127
 - cohesion mechanism needed for, 3:1128
 - collision mechanism needed for, 3:1127–1128
 - composite particle and, 3:1127
 - definition of, 3:1127
 - floc density and, 3:1128
 - floc settling velocity and, 3:1128
 - flocs units and, 3:1127
 - secondary particle size analysis and, 3:1128
 - terms related to, 3:1127
 - water quality and, 3:1127
- Floodplain, 3:1128–1133**
 - Amazon River, 3:1129 (photo)
 - backwater modeling and, 3:1131
 - base level and climate changes and, 3:1128
 - crop cultivation on, 3:1132
 - cycle of land use on, 3:1132–1133, 3:1132 (fig.)

- definition and description of, 3:1128
- delineation methods of, 3:1131–1132
- development of, 3:1128–1130
- features of, 3:1130 (fig.)
- flash floods and, 3:1123–1125
- hydrographs of, 3:1131, 3:1132 (fig.)
- hydrological floodplains, 3:1130
- landforms of, 3:1128
- Nile River and Mississippi River floodplain land use and, 3:1130 (photo)
- tectonic deformation and, 3:1128, 3:1129 (photos), 3:1133 (fig.)
- topographic floodplains, 3:1130, 3:1131 (fig.)
- types of, 3:1130–1131
- uses of, 3:1132–1133
- water flow and sediment transport over, 3:1131
- White Volta River, Ghana, 3:1129 (photo)
- Leopold Wolman's model of, 3:1128, 3:1130
- See also Rivers*
- Floods, 3:1133–1137**
 - antecedent environmental condition factors and, 3:1134
 - in arid regions, 3:1135
 - causal mechanisms of, 3:1133, 3:1134–1135
 - coastal flooding measurement and, 3:1136
 - discharge measurement and, 3:1135
 - drainage basin factors in, 3:1134, 3:1134 (fig.)
 - extensive *vs.* intensive events and, 3:1136
 - flashy *vs.* sluggish streams and, 3:1134, 3:1135 (fig.)
 - flood depths measures and, 3:1135–1136
 - flood recession agriculture and, 3:1134
 - flow velocity measures and, 3:1136
 - forecasting and warning systems and, 3:1137
 - frequency component of, 3:1136
 - geomorphology of shorelines and, 3:1135
 - human intervention in drainage basins and, 3:1136
 - magnitude and severity of, 3:1135–1136
 - mitigation of, 3:1136–1137
 - in mountainous areas, 3:1135
 - nonstructural mitigation of, 3:1137
 - positive outcomes from, 3:1133–1134
 - precipitation and, 3:1134
 - relocation from, 3:1137
 - shoreline environments and, 3:1135
 - storm surge height and, 3:1136
 - stream cross-section and floodplain and, 3:1134 (fig.)
 - structural mitigation of, 3:1136–1137
 - In United States, 2008, 3:1134–1135
 - See also Floodplain; Floods: examples; Rivers*
- Floods: examples**
 - Big Thompson, Colorado (1976), 3:1135, 3:1136
 - California-Arizona border (2008), 3:1135
 - Hurricane Ike, Texas, 3:1136
 - Hurricane Katrina, 3:1135
 - Mississippi River at St. Louis (1993), 3:1135
- Florida**
 - barrier islands in, 1:184 (photos)
 - Celebration, Osceola County, new urbanism, 4:2025 (photo)
 - Florida Everglades ecosystem restoration project, 2:992
 - Hurricane Katrina and, 3:1493
 - hurricane risk in, 3:1500
 - hurricanes in, 3:1501
 - Kennedy Space Center Launch Complex in, 4:1975 (photo)
 - land cover in Leon County, 4:1709 (fig.), 4:1710 (table)
 - sea and lake breeze fronts in, 1:135
 - Seaside, Walton County, resort town, new urbanism, 4:2025 (photo)
- Spanish colonialism in, 1:512
- stagnant coral faunal relict and, 1:470
- tropical humid climate in, 1:453
- See also Everglades restoration*
- Florida, Richard, 1:119–120, 2:851, 5:2263
- Flow, 3:1138**
 - floods and, 3:1133–1137
 - fluids in motion, 3:1138
 - liminar flow, 3:1138
 - Reynolds number (Re) dimensional parameter of, 3:1138
 - rising cigarette smoke example of, 3:1138
 - turbulent flow, 3:1138
 - See also Flow maps*
- Flow maps, 3:1138–1140**
 - computer-generated flow map (Tobler) of California migration (1995–2000) and, 3:1139, 3:1139 (fig.)
 - dynamic maps and, 3:1138
 - economic geography and, 3:1139
 - Flow Mapper software (Tobler) and, 3:1139 (fig.)
 - flow mapping software (Phan) and, 3:1139, 3:1139 (fig.)
 - kriskogram and, 3:1139, 3:1140 (fig.)
 - Minard's 1864 flow map and, 3:1138, 3:1139 (fig.)
 - movement of phenomena between locations depicted by, 3:1138
 - origins of, 3:1138
 - quantitative data of, 3:1138
 - types of, 3:1138
 - See also Flow*
- Flow maps: noted individuals**
 - Yongwan Chun, 3:1139, 3:1140 (fig.)
 - Henry Drury Harness, 3:1138
 - Doantam Phan, 3:1139
 - Waldo Tobler, 3:1139
 - Ningchuan Xiao, 3:1139, 3:1140 (fig.)
- Folding, 3:1140–1142**
 - anticline *vs.* syncline features of, 3:1141
 - antiforms *vs.* synforms features of, 3:1141
 - approaches to studies of, 3:1141
 - axial surface feature of, 3:1141
 - bending folds and, 3:1142
 - causes of, 3:1142
 - chevron folds and, 3:1141
 - conditions prevalent in, 3:1140–1141
 - definition of, 3:1140
 - descriptive terminology of form classification
 - categories of, 3:1141
 - face and vergence features of, 3:1141
 - faulting and, 3:1085–1088
 - fold nappes feature of, 3:1141
 - fold tightness and, 3:1141
 - gentle *vs.* isoclinal folds and, 3:1141
 - hinge zone or fold nose feature of, 3:1141
 - monocline *vs.* structural bench features of, 3:1141
 - overturned *vs.* recumbent fold and, 3:1141
 - parallel, competent, or concentric folds and, 3:1141
 - parallel folds and, 3:1141
 - passive folding and, 3:1142
 - plunge inclination of, 3:1141
 - ptygmatic folds and, 3:1141
 - similar folds and, 3:1141
 - structural basin and, 3:1141
 - symmetrical *vs.* asymmetrical fold and, 3:1141
 - upright *vs.* inclined fold features of, 3:1141
- Folk culture and geography, 3:1142–1144**
 - Berkeley School of cultural geography and, 3:1142
 - cultural geography and, 3:1142

- cultural hearth areas and, 3:1142
 definition of, 3:1142
 music and sound geographies and, 4:1967–1969
 popular culture *vs.*, 3:1142
 popular geography and, 3:1143
 urban culture and, 3:1142
See also Folk culture and geography: noted individuals
- Folk culture and geography: noted individuals**
 Stuart Hall, 3:1142
 Allan Pred, 3:1143–1144
 Carl Sauer, 3:1142
 Johann Gottfried von Herder, 3:1143
 Raymond Williams, 3:1142
- Food, geography of, 3:1144–1146**
 agriculture as oldest marker of civilization and, 3:1144
 development process role of, 3:1144–1146
 ecosheds and, 2:857
 famine geographies and, 3:1082–1085
 food sovereignty farmers' movements and, 3:1146
 General Agreement on Trade and Tariffs and, 3:1145–1146, 4:2045
 genetic engineering and biotechnology and, 3:1145
 geophagy and, 3:1248–1249
 global food connections and, 3:1146
 green revolution technologies and, 3:1145
 industrialized food production and, 3:1145
 neoliberal globalization and, 3:1146
 neo-Malthusianism and, 4:2015–2016
 organic agriculture and, 4:2094–2096
 power geographies and, 3:1144
 social meanings and environmental practices associated with, 3:1144–1145
 von Thünen geographic model of, 3:1144
See also Agrofoods; Consumption, geographies of; Food and Agriculture Organization (FAO); Hunger
- Food and Agriculture Organization (FAO), 3:1146–1148**
 aquaculture, 1:102
 forests and land use statistics of, 3:1147–1148
 geographies of food and, 3:1144–1146
 geography studies' statistics of, 3:1148
 governing structure of, 3:1146–1147
 history and constitution of, 3:1146–1147
 international organizations within, 3:1147
 plantation development and, 5:2193
 secretariat role in, 3:1147
 studies of, 3:1147
 sustainable fisheries and, 6:2754
 sustainable forestry and, 6:2758
 United Nations and, 3:1146, 3:1147, 6:2754
 World Forestry Congress and, 3:1147
- Foodprint analysis. *See* Ecological footprint**
- Food, Jo, 3:1189**
- Fordism, 3:1148–1151**
 centralized production and direct resources control features of, 3:1149
 definition of, 3:1148–1149
 displacement of, 3:1150
 economies of scale and high output volumes from, 3:1149
 Antonio Gramsci's views on, 3:1149
 greenfield facilities and, 3:1149
 Industrial Revolution and, 3:1582, 3:1584
 machine-paced production methods and, 3:1149, 3:1150 (fig.)
 mass production and mass consumption linked by, 3:1149
 modernity, rationality, and efficiency characteristics of, 3:1149
 outsourcing and, 4:2108–2110
 post-Fordism and, 2:849, 3:1125–1126, 3:1194, 5:2264, 5:2399, 5:2400–2401
 production of decentralized parts and, 3:1149
 regulation theory and, 5:2399–2402
 social theorists and, 3:1149
 spatial requirements of, 3:1149
- Foreign aid, 3:1151–1153**
 absorptive capacity of recipient countries and, 3:1153
 Britain and U.S. histories of, 3:1151–1152
 controversies, 3:1153
 definition of, 3:1151
 developing world benefits from, 3:1151–1153
 East Asian economic development success and, 3:1152
 geographies of, 3:1152–1153
 history of, 3:1151–1152
 measures of, 3:1152
 modern international developments in, 3:1152
 positive *vs.* negative effects of, 3:1153
 purpose of, 3:1151
 study of spatial distributions of, 3:1152
 types of, 3:1151
 UN Millennium Development Goals and, 3:1152, 5:2220
- Foreign direct investment (FDI), 3:1153–1156**
 acquire controlling interests in established firms and, 3:1153
 in China, 4:2022
 definition of, 3:1153
 John Dunning's eclectic paradigm of, 3:1154
 emerging economies and, 3:1155–1156
 establishing new firms overseas and, 3:1153
 human capital interactions of, 3:1155
 impacts of, 3:1154
 importance of, 3:1154–1155
 in India, 4:2023
 market orientation *vs.* asset orientation and, 3:1154
 NAFTA and, 4:2044
 new international division of labor and, 4:2020
 newly industrializing countries and, 4:2021
 ordinary (common stock) component of, 3:1153
 organizational and geographical networks linked by, 3:1153
 purposes of, 3:1155
 retained earnings component of, 3:1153
 theories of, 3:1154
 transnational corporations (TNCs) and, 3:1153, 3:1154
 Raymond Vernon's locational product life cycle concept and, 3:1154
- Forest degradation, 3:1156–1159**
 boreal forest belt zones and, 3:1157–1158
 boreal forest conifer species and, 3:1158
 closed-crown forest degradation and, 3:1157 (fig.), 3:1158
 definition of, 3:1156
 from deforestation, 3:1157
 ecosystem and atmospheric impacts of, 2:938
 ecosystem decay and, 2:858–862
 estimating extent of, 3:1156–1157
 fire and, 3:1158
 forest fragmentation and, 3:1159–1163
 human-related activities as cause of, 3:1156
 lichen woodland zone and, 3:1158
 Mediterranean Aleppo pine or Holm oak example of, 3:1157
 in Northern Hemisphere, 3:1157–1158
 stand disturbances, Eastern Canada, 3:1157 (fig.), 3:1158
 tropical deciduous forest biome and, 1:230–233
 tropical rain forest biome and, 1:234–239
See also Forest fragmentation; Forest land use; Forest restoration

Forest fragmentation, 3:1159–1163

- agroforestry and, 1:60–62
- biophysical environment changes and, 3:1161–1163
- bird species affected by, 3:1161–1162
- boreal forest biome and, 1:214–217
- compensatory effects of, 3:1161
- connective vegetation structures and, 3:1160
- core species populations and, 3:1161
- definition of, 3:1159
- edge effects of, 3:1161
- equilibrium theory of island biogeography and, 3:1159
- exotic species invasions and, 3:1163
- extractive reserves and, 2:1072–1073
- global climatic change implications of, 3:1163
- midlatitude deciduous forest biome and, 1:223–226
- patches and corridors and, 4:2131–2133
- pervasiveness of, 3:1159
- pesticides and, 3:1163
- plant and animal species adaptation and, 3:1159
- plant seed dispersal and survival affected by, 3:1159–1161, 3:1161 (fig.), 3:1162 (fig.)
- population dynamics changes and, 3:1159–1161
- reforestation and, 3:1159
- sea of human land use around and, 3:1161
- selective tree cutting and, 3:1163
- “single large or several small” (SLOSS) nature preserves debate and, 3:1161
- tropical deciduous forest biome and, 1:230–233
- in the tropics, 3:1159
- See also* Deforestation; Forest degradation; Forest land use; Forest restoration

Forest land use, 3:1163–1166

- agricultural and urban areas transition of, 3:1165
- agroforestry and, 1:60–62
- boreal forest biome and, 1:214–217
- carbon cycle and, 3:1164
- carbon sinks, 3:1164
- cellular automata used in, 1:370, 1:371 (fig.)
- climate systems and, 3:1164
- deforestation process of forest transition and, 3:1165
- degradation process of forest transition and, 3:1165
- degree of disturbance and, 3:1164
- environmental services and, 3:1164
- forest definition and, 3:1163
- forest density measurement and, 3:1165
- forest fair trade certification and, 3:1081
- forest plantations and seminatural forests and, 3:1164
- forest spatial coverage changes and, 3:1165
- Forest Stewardship Council and, 3:1081
- forest types and spatial distribution in, 3:1164
- global net deforestation and, 3:1165
- indigenous forest dwellers and, 3:1164
- indirect drivers of forest change and, 3:1165
- midlatitude deciduous forest biome and, 1:223–226
- modified natural forests and, 3:1164
- nontimber products use and, 3:1164
- primary forests and, 3:1164
- proximate *vs.* underlying processes of forest change and, 3:1165
- reforestation process of forest transition and, 3:1165
- regeneration process of forest transition and, 3:1165
- slash pine plantation, Georgia (U.S.), 6:2835 (photo)
- subsistence economies and, 3:1164
- tropical, temperate, and boreal forest types and, 3:1163, 3:1164
- tropical deciduous forest biome and, 1:230–233

water cycles and, 3:1164

See also Food and Agriculture Organization (FAO); Forest degradation; Forest fragmentation; Forest restoration; Timber plantations

Forest restoration, 3:1166–1168

- boreal forest biome and, 1:214–217
- conservation of species and, 3:1166
- ecological restoration definition and, 3:1166
- ecosystem productivity and, 3:1166
- endangered species support and, 3:1168
- exotic species removal, 3:1168
- forest degradation and, 3:1156–1159
- forest landscape restoration (FLR) and, 3:1168
- goals and purposes of, 3:1166
- Gus Pearson Natural Area, Flagstaff, Arizona, and, 3:1167 (photo)
- implementation of, 3:1166–1167
- key elements of, 3:1167
- landscape-scale, geographic perspective in, 3:1168
- midlatitude deciduous forest biome and, 1:223–226
- multiple-scale systems with place-based approach integration and, 3:1168
- Redwood National Park, California, example of, 3:1167–1168
- tropical deciduous forest biome and, 1:230–233
- watershed-scale restoration and, 3:1167–1168
- See also* Food and Agriculture Organization (FAO); Forest degradation; Forest fragmentation; Forest land use

Formosa, 1:514

Foscue, Edwin, 4:1873

Foster, George, 4:2137

Fotheringham, A. Stewart, 3:1168–1169

- geographically weighted regression (GWR) co-developed by, 3:1169, 3:1226
- geographic information science research of, 3:1168–1169
- journals edited by, 3:1169
- quantitative geography work of, 3:1169
- spatial interaction modeling work of, 3:1169
- spatial statistics research of, 3:1169, 5:2395–2396
- Strategic Research in Advanced Geotechnologies group led by, 3:1169

Foucault, Michel

- analytics of government work of, 3:1359
- biopolitics work of, 5:2539
- critical geopolitics work of, 2:611
- Discipline and Punish* written by, 4:2116
- discourse, power, knowledge, and truth relationship and, 2:767, 2:769, 3:1563, 4:1863, 5:2267, 5:2271–2272
- discourse theory work of, 2:766, 2:767, 2:769, 4:1754, 4:2102, 5:2326
- gender geographies and, 3:1192
- governmentality and conservation and, 3:1359
- History of Sexuality* written by, 3:1528
- Madness and Civilization* written by, 5:2271
- Marxist geography work of, 4:1863
- panopticon concept and, 4:2116
- Richard Peet influenced by, 4:2144
- postmodernism and, 5:2267
- poststructuralism, power and knowledge work of, 1:289, 3:1468, 5:2271–2272, 5:2712
- Edward Said influenced by, 4:2102
- sea as arena for culture formation and, 4:2070
- time-space discourse of, 3:1433

Fourier, Charles, 4:1860

France

AGILE membership of, 1:124 (table)

- antiglobalization, anticolonialism in, 1:97
- Arab countries colonized by, 1:514
- automobile industry in, 1:169, 1:171
- automobility in, 1:171
- biotechnology industry in, 1:280
- civic nationalism in, 4:1979
- coal energy source in, 3:1582
- colonial empire of, 1:509, 1:509 (fig.), 1:512
- counterurbanization in, 2:596
- cultural nationalism in, 4:1980
- ecological footprint and biocapacity of, 2:827 (table)
- economically active females in, 3:1190 (table)
- Egypt colonized by, 1:514
- European Union (EU) membership of, 2:1035
- federalism political model and, 2:1036
- Francocentrism of, 2:1030 (table)
- GDP of, 3:1382, 3:1383 (fig.)
- hate groups in, 3:1407
- high-speed trains in, 5:2364
- hydroelectricity in, 3:1507
- income distribution, percentile of world income, 5:2641 (fig.)
- Indochina colonization by, 1:515
- industrialization in, 3:1583
- installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
- Kyoto Protocol of 1997 and, 1:463
- Marxism in, 2:617
- military expenditures in, 4:1898, 4:1899 (table)
- Minard's flow map of wine exports from (1864), 3:1139 (fig.)
- Minutely network system in, 2:646
- morphine-rich narcotics produced in, 2:796, 2:797 (table)
- movement against genetically modified organisms in, 3:1610
- national boundaries identification and, 4:1972
- national geographical society in, 3:1462
- nuclear reactors in, 4:2052
- pays* rural areas, chorology of, 1:404
- pollution taxes in, 4:1857
- Prestige* oil tanker spill and, 4:2076
- public urban water systems in, 5:2316
- railroads in, 5:2358, 5:2359 (fig.)
- Rhones-Alps technology area in, 5:2435
- small village settlement, Liausson, 5:2536 (photo)
- SPOT multitemporal imaging system of, 4:1959, 4:1960
- student dissident movement in, 1:100
- total factor productivity (TFP) of, 6:2780 (table)
- vegetation on alluvial bar, River Alliet, 1:272 (photo)
- See also* Paris, France
- Francis, Charles, 1:54
- Frank, Andrew, 3:1169–1170**
- dependency theory work of, 2:713
- International Conference on Spatial Information Theory established by, 3:1170
- journals edited by, 3:1170
- National Center for Geographic Information and Analysis co-founded by, 3:1170
- ontological aspects of geographic information work of, 3:1170
- quantitative reasoning and natural linguistics work of, 3:1170
- spatial data analysis and GIScience work of, 3:1169–1170
- Frankfurt Institute for Social Research, 2:617, 3:1419
- Frankfurt School
- culture industry analysis and, 5:2230
- Karl Wittfogel and, 2:617
- Fraunhofer, Joseph von, 3:1542
- Freire, Paulo, 2:875
- French Guiana, 1:234
- Frey, W., 2:1075
- Friedan, Betty, 3:1095
- Friedman, Milton, 4:1934, 4:2011
- Friedman, Thomas, 3:1224
- Friends of the Earth International, 3:1612–1613
- Frobisher, Martin, 4:2179
- Frontiers, 3:1170–1172**
- Amazonia's contemporary frontier and, 3:1171–1172
- borderlands and, 1:291–292
- boundaries between principalities or states and, 3:1170–1171
- decennial censuses and, 3:1170–1171
- European *vs.* American usages of, 3:1170
- meaning of, 3:1170
- Native Americans and disputed space and, 3:1171
- "The Significance of the Frontier in American History" essay (Turner), 3:1171
- Fronts, 3:1172–1174**
- anafront, 3:1173
- Bjerknes cyclone model and, 3:1173–1174
- Chinook winds and, 3:1172
- cold fronts, 3:1173
- definition of, 3:1172
- dryline and, 3:1172
- frontal lift and, 3:1173
- greatest temperature changes examples and, 3:1172
- instant occlusions and, 3:1174
- lift and, 3:1174
- mesoscale convective system (MCS) and, 3:1173
- "nor'easters" and, 3:1174
- occluded fronts, 3:1173–1174
- polar lows and, 3:1174
- split fronts, 3:1172–1173
- stationary fronts, 3:1174
- thermal or moisture discontinuity of, 3:1172
- warm fronts, 3:1173
- zero-order fronts, 3:1172
- FSM. *See* Federated States of Micronesia (FSM)
- Fujita, Masahisa, 5:2395
- Fullilove, Mindy, 4:2168
- Furtado, Celso, 2:713
- Gabon, 3:1190 (table)
- Gaia theory, 3:1175–1178**
- atmospheric carbon dioxide climate regulation and, 3:1176
- biogeochemical cycles and, 1:204
- biogeochemical recycling and, 3:1176
- current trends in, 3:1177
- Dasyworld mathematical model and, 3:1176
- debates, 3:1176–1177
- deep ecology and, 2:693, 2:695, 3:1177
- Earth as a single living organism theme of, 3:1175–1176
- Earth systems science and, 3:1177
- ecofeminism and, 3:1177
- Gaia organic wholeness, Earth systems science and, 2:693, 2:695
- Gaia word origins and, 3:1175
- geophysiology, Earth system science and, 3:1175–1176
- global temperature evidence of, 3:1175–1176
- Goldilocks hypothesis of life on Earth and, 3:117501176
- humans as planetary disease issue and, 3:1176–1177
- James Lovelock's Gaia hypothesis origin of, 3:1175, 3:1177
- Lynn Margulis's work in, 3:1177
- planetary self-regulation by biosphere and, 3:1176
- spectrum of Gaian hypotheses and, 3:1177, 3:1177 (table)
- theory of ecological succession and, 3:1175

- Galapagos Islands
 adaptive radiation and, 1:106
 archipelago formation of, 1:105
 Darwin and, 1:106, 1:107
 ecotourism and, 2:870
 finches evolution and, 1:14–15
 mockingbird varieties of, 1:209
- Gama, Vasco da, 3:1178–1179**
 Africa circumnavigated by, 2:1054, 3:1178–1179, 3:1461, 4:2179
 spice trade route search of, 3:1178–1179
- Gambia, 3:1190 (table)
- Game ranching, 3:1179–1181**
 Jocus de P. Bothma and, 3:1180
 capital requirements of, 3:1180
 for-profit type of, 3:1079
Game Ranch Management (Bothma) and, 3:1180
 growth of, 3:1179–1180
 Wouter van Hoven and, 3:1180
 management and profitability of, 3:1180
 mathematical modeling research used in, 3:1180
 purposes of, 3:1079
 scientific management o, 3:1180
 South Africa and, 3:1179–1180
 wildlife conservation by, 3:1079
- Gannett, Henry, 5:2307
- Garnier, Jacqueline Beaujeu, 5:2247
- Garrison, William, 1:192, 3:1274, 3:1466, 3:2329, 4:1945, 4:2017, 6:2846
- Gasset, Oretaga y, 2:1046
- Gast, John, 3:1223 (fig.)
- Gated community, 3:1181–1183**
 amenities and infrastructures of, 3:1181
 cultural, social, economic, and political development factors in, 3:1182–1183
 definition of, 3:1181
 forms and contexts variations of, 3:1183
 impact debate, 3:1181–1182, 3:1182 (photo)
 inequality geographies and, 3:1589
 lifestyle communities category of, 3:1181
 prestige communities category of, 3:1181
 retirement communities and, 3:1181
 safety element of, 3:1182
 security zones category of, 3:1181
 social segregation result of, 3:1181
 in Sunbelt areas, 4:2002
 tax reduction issue of, 3:1181
 in urban environments, 3:1181, 3:1589
 urban secession issue of, 3:1181
 urban services availability in, 3:1182–1183
- Gatrell, J, 3:1541
- Gaustad, Edwin, 5:2407
- Gays and lesbians, geography and/of, 3:1183–1185**
 feminist geography and, 3:1184
 fractured and hybridized subjectivities and, 3:1184
 gay spaces, impacts on urban landscapes and, 3:1183
 geographies on sexualities and, 3:1184
Mapping Desire (Bell and Vallentine) and, 3:1184
 post-Fordist and neoliberal perspectives on, 3:1184
 postmodern and poststructural perspectives on, 3:1184
 queer geography and, 3:1184
 queer theory and, 3:1184
 spatial concentration of San Francisco's gay community and, 3:1183–1184
 urban politics and, 3:1183
See also Gays and lesbians, geography and/of: noted scholars; **Sexuality, geography and/of**
- Gays and lesbians, geography and/of: noted scholars
 David Bell, 3:1184
 Jacquelyn Beyer, 3:1183
 Manuel Castells, 3:1183–1184
 E. M. Ettore, 3:1183
 Bill Ketteringham, 3:1183
 Don Lee, 3:1183
 Bob McNee, 3:1183
 Karen Murphy, 3:1183
 Gill Valentine, 3:1184
 Barbara Weightman, 3:1183
- Gazetteers, 3:1185–1186**
 content standards for, 3:1185
 functions of, 3:1185, 3:1186
 Geographic Names Information System (GNIS) digital gazetteer and, 3:1185
 geospatial search functions of, 3:1185–1186
 information retrieval role of, 3:1185
- GDP/GNP. *See* **Gross domestic product/gross national product** (GDP/GNP)
- Geddes, Patrick, 4:1700, 4:2126, 5:2372
- Geertz, Clifford
 culture defined by, 2:634
 postmodern research methods and, 5:2266
- Gehry, Frank, 5:2264
- Geiger, Rudolf, 4:1665
- Gender and environmental hazards, 3:1186–1188**
 conceptual level dimensions of, 3:1186
 externally driven forces and, 3:1187
 gender division of labor and household space and, 3:1187
 gender relation changes and, 3:1187–1188
 micro politics of household and community power and, 3:1187
 social, political, economic, and cultural processes of, 3:1186
 social norms and roles of behavior and responsibility and, 3:1186–1187
 social production and reproduction roles and, 3:1187
 socioeconomic status and age factors and, 3:1187
 vulnerability concept and, 3:1186–1187
- Gender and geography, 3:1188–1194**
 capitalism and patriarchy relationship issue and, 3:1189
 Committee on the Status of Women in Geography, 3:1234
 economically active females and, 3:1189, 3:1190 (table)
 ethnographic methods and, 3:1193
 European colonialization, dominant power relations and, 3:1191
 evolution of, 3:1188–1189
 feminist criticism of political economy and, 3:1191
 feminist geography and, 3:1188
 future trends in, 3:1193–1194
 gender definition an, 3:1188
 gendered bodies and, 3:1192
 gendered transnational migration and, 3:1192
 geography of differences and, 2:737–740
 GIScience and, 3:1193
 inequality geographies and, 3:1589
 issues concerning, 3:1188
 labor market participation and commuting patterns and, 3:1188
 Marxist geography and, 3:1188–1189
 masculine geographies and, 4:1865–1866
 methodology and, 3:1192–1193
 origins of, 3:1188
 patriarchic geographies and, 4:2135–2136
 postcolonial feminism and, 3:1191–1192

- postmodern feminism and, 3:1191
 poststructural approach to, 3:1191
 power relation inequities and, 3:1188, 3:1193
 quantitative *vs.* qualitative methods and, 3:1193
 social construction of gender and, 3:1188
 social difference and, 3:1189–1191
 spatial and social processes and, 3:1193
 spatial and social separation of home and waged work
 theme of, 3:1189
 spatial dynamics, social processes, and power relations
 themes in, 3:1188, 3:1193
 spatial patterns of women's activities focus of, 3:1188
Theorizing Patriarchy (Walby) and, 3:1189
 time-space geographies of urban women and, 3:1193
 uneven power relations and oppressive patriarchal structures
 and, 3:1191
 urban spatial patterns and, 3:1189
 women as domestic servants and sex workers and, 3:1192
 women of global South and, 3:1191
See also Feminist specific subject; Gender and geography:
 noted geographers
 Gender and geography: noted geographers
 Judith Butler, 3:1192
 Jo Foord, 3:1189
 Michel Foucault, 3:1192
 J. K. Gibson-Graham, 3:1191, 5:2351
 Nicky Gregson, 3:1189
 Susan Hanson, 3:1189, 3:1400–1401, 3:1468
 Mei Po Kwan, 3:1193
 Nina Lauri, 3:1193
 Doreen Massey, 2:852, 4:1866–1867
 Sara McLafferty, 3:1193
 Janice Monk, 3:1189
 Richa Nagar, 3:1193
 Geraldine Pratt, 3:1192
 Gillian Rose, 5:2484–2485
 Melissa Wright, 3:1192
 Gender and nature, 3:1194–1197
 actor-network theory and, 3:1196
 class and nature and, 1:423–425
 denaturalizing gender, socializing nature and, 2:622–623
 ecofeminism and, 2:817–820, 3:1195
 environmental justice and, 1:425
 feminist environmentalism and, 3:1090–1094
 feminist political ecology and, 3:1195–1196
 feminized landscape and, 3:1196
 gender and environmental hazards, 3:1186–1188
 gendered division of labor and, 3:1195
 gender in social theory and, 3:1194
 global South research focus and, 3:1195–1196
 landscape and the masculine gaze and, 3:1196, 4:2043
 Marxist theory and, 3:1196
 Mr and Mrs Andrews painting (Gainsborough) and, 3:1196
 nature *vs.* culture and, 3:1194
 new ontological politics and, 3:1196–1197
 production and reproduction spheres and, 3:1195
 queer theory and, 3:1196
 sex/gender distinction and, 3:1194
 social construction of nature and, 3:1196
 social ecofeminists and, 3:1195
 social *vs.* biological category of gender and, 3:1194
 visual methodologies and, 3:1196
 See also Feminist specific subject
 Genderen, Pohl, 3:1533
 Genderen, Van, 3:1533
 Genetically modified organisms (GMOs), 3:1197–1199
 animals, 3:1197–1198
 benefits of, 3:1197
 biotechnology and ecological risk and, 1:278–279
 definitions, 3:1197
 environmental markets for, 4:2009
 food crops and, 3:1198
 food labels issue and, 3:1198
 human insulin example of, 3:1197
 hybridization and, 3:1503–1506
 movement against, 3:1609–1610
 natural processes *vs.*, 3:1197
 neo-Malthusianism and, 4:2016
 Network of GMO Free Regions and, 3:1610
 organic agriculture and, 4:2094–2095
 plants, 3:1198
 potential risks of, 3:1197, 3:1198
 recombinant bovine growth hormone, milk issues and, 3:1198
 terms related to, 3:1197
 See also Agricultural biotechnology
 Genocide, geographies of, 3:1199–1202
 Armenian genocide (1915) and, 3:1201
 belonging and identity and, 3:1201
 contested postgenocide space and, 3:1202
 Convention on the Prevention and Punishment of the Crime of
 Genocide (UN) and, 3:1199
 creation of an imagined “other” and, 3:1201
 critical geopolitical element of, 3:1200
 destruction of place and erasure of space in, 3:1201–1202
 exclusion and fear geographies and, 3:1201
 Eyes on Dafur project (Amnesty International),
 3:1200, 3:1200 (images)
 as field of study, 3:1199
 gender, space, and, 3:1202
 genocide definition and, 3:1199
 Genocide Prevention Mapping Initiative and, 3:1200
 GIS and spatial analysis mapping technologies and, 3:1200–
 1201, 3:1200 (images)
 human rights geographies and, 3:1480–1481
 International Criminal Court (ICC) and, 3:1605–1608
 Jewish Holocaust example of, 3:1199, 3:1202
 Khmer Rouge, Cambodia example of, 3:1201–1202
 knowledge of places and, 3:1199
 mapping technologies and, 3:1200
 memorialization and tourism issues and, 3:1202
 nationalism, regionalism, sense of place and, 3:1201
 Ovaherero, Namibia, genocidal event and, 3:1202
 research issues in, 3:1199
 sense of place definition and, 3:1201
 studies of, 3:1199–1201
 terms related to, 3:1199
 territory, identity, and power issues of, 3:1199
 as transformed space, 3:1201
 U.S. Holocaust Memorial Museum and, 3:1200
 Gentrification, 3:1203–1208
 “back-to-the-city” movement of people and, 3:1204
 behavioral perspective on, 3:1203
 capital- and occupational-centered class concepts
 and, 3:1203–1204
 as capital investment, 3:1204, 3:1205 (fig.), 3:1206 (table)
 as class colonization and displacement, 3:1203–1204
 countercultural hippy movement views and, 3:1207
 “cultural new class” and, 3:1207
 culture and, 3:1207
 definitions, 3:1203

- devalorization and revalorization processes and, 3:1204, 3:1205 (fig.)
- female gentrifiers and, 3:1206
- female paid employment and, 3:1206
- filtering *vs.*, 3:1112
- frontiersmanship, cultural representation of, 3:1207
- gated communities and, 3:1181–1183
- gentrifiers as developers and, 3:1204
- gentrifier types and, 3:1204, 3:1206 (fig.)
- law in urban planning policy and, 4:1766
- logical positivist spatial science perspective on, 3:1203
- managerial and structuralist approaches to, 3:1203
- marginal gentrifier and, 3:1204
- neoliberalism approach to, 3:1207
- new-built construction issue and, 3:1204
- performance of reproductive labor issue and, 3:1206
- positivist urban models and, 3:1203
- postindustrial society and, 5:2263
- production-side theory and, 3:1204
- production-side *vs.* consumption-side perspectives on, 3:1203
- property investment process and, 3:1204
- range of agents involved in, 3:1204
- regeneration and, 3:1207
- rent-gap concept and, 3:1204, 3:1205 (fig.), 5:2430–2431
- reproductive labor and gender in, 3:1206
- Neil Smith's work in, 3:1204, 3:1206 (fig.), 3:1206 (table), 5:2551
- social difference and agents of, 3:1205–1206
- suburban space aversion and, 3:1207
- supergentrification urban centers and, 3:1204
- term origins and, 3:1203
- value of the term and, 3:1206
- Geocoding, 3:1208–1209**
 - applications of, 3:1208
 - components of, 3:1208
 - definition of, 3:1208
 - geodesy and, 3:1217–1219
 - Geographic Names Information System and, 3:1209
 - geolibraries and, 3:1234–1235
 - GEOnet Names Server (GNS) and, 3:1209
 - methods of, 3:1208
 - network data model and, 4:2019
 - parcel databases and, 3:1208–1209
 - by place names, 3:1209
 - by postal code, 3:1209
 - reverse geocoding and, 3:1209
 - by street address, 3:1208–1209, 4:2019
 - U.S. Census TIGER data files and, 3:1208
- Geocollaboration, 3:1209–1211**
 - awareness issues and, 3:1210
 - computer-supported collaborative work (CSCW) and, 3:1209–1210, 3:1210 (fig.)
 - crisis management example and, 3:1210
 - definition of, 3:1209
 - GIScience and, 3:1209
 - Google Maps example of, 3:1211, 4:2006
 - Hurricane Katrina and, 3:1211
 - mapping “mashups,” 3:1211, 3:1478, 5:2305
 - multidisciplinary nature of, 3:1209
 - OpenStreetMap project and, 3:1211
 - organizational geocollaboration and, 3:1210–1211
 - research perspective of, 3:1210
 - social mediation research perspectives on, 3:1211
 - spatial data infrastructures (SDIs) and, 3:1210–1211
 - time-place matrix of, 3:1210, 3:1210 (fig.)
 - unique geographic issues in, 3:1210
 - volunteered geographic information (VGI) and, 3:1211
 - Web 2.0 technologies and, 3:1211
- Geocomputation, 3:1211–1215**
 - as both art and science, 3:1212
 - classification and clustering algorithms and, 3:1214
 - computational geometry and, 3:1212
 - data set size issue in, 3:1212, 3:1213
 - definition of, 3:1211
 - disambiguation issue and, 3:1213
 - Fourier mathematical analysis concept and, 3:1213
 - GeoComputation conference and, 3:1211, 3:1213
 - geodesy and, 3:1217–1219
 - geostatistics and, 3:1261–1265
 - geovisualization applications of, 3:1212, 3:1213–1214
 - GIS analytical operations and, 1:71–72
 - GIScience applications of, 3:1212
 - high-performance computing and, 3:1425–1426
 - linear data arrangement issue and, 3:1213
 - modeling geographic processes and, 3:1215
 - Morton ordering disk storage and, 3:1213
 - multidisciplinary applications of, 3:1212
 - multidisciplinary feature of, 3:1212
 - quadtree data structure and, 3:1213
 - remote sensing applications of, 3:1212
 - research issues in, 3:1212–1215
 - spatial analysis applications of, 3:1212
 - spatial autocorrelation and, 3:1214
 - spatial optimization methods and, 3:1215
 - U.S. decennial census and, 3:1214
- Geodemographics, 3:1215–1217**
 - academia research in, 3:1217
 - classification function of, 3:1216
 - criticisms and future research, 3:1217
 - data collection and, 3:1216
 - generalization criticism of, 3:1217
 - geographic unit of study component of, 3:1216
 - GIS technology advances and, 3:1216
 - mapping of classification schemes and, 3:1216
 - mobility issues of, 3:1217
 - niche marketing and, 3:1216
 - private applications of, 3:1216
 - public applications of, 3:1216–1217
 - statistical relevance and validity issues of, 3:1217
 - target group component of, 3:1216
 - Web-based geodemographics and, 3:1217
 - where a person lives and lifestyle choices links and, 3:1215
- Geodesy, 3:1217–1219**
 - angles and distance, triangulation methods used in, 3:1218
 - applications of, 3:1218
 - datums and, 2:685–686
 - Earth's shape and size focus of, 3:1217
 - geocoding and, 3:1208–1209
 - geoid definition and, 3:1218
 - gravity and shape link issue in, 3:1218
 - hierarchical process, 3:1217–1218
 - International Terrestrial Reference Frame and, 3:1218
 - long- *vs.* short-wavelength components of, 3:1218
 - meanings of, 3:1217
 - science of map projections and, 3:1218–1219
- Geographical ignorance, 3:1219–1220**
 - “Bizarro” cartoon and, 3:1219 (image)
 - Geographic Literacy Study and, 3:1219
 - geography education and, 3:1232–1234
 - high school and university curriculums and, 3:1220

- public office candidates literacy issue and, 3:1220
- technology optimists and, 3:1220
- Geographical imagination, 3:1221–1225**
 - British imperial outlook on, 3:1221–1222
 - Cold War fears and American changes in, 3:1223–1224
 - Denis Cosgrove's work and, 2:589–590, 3:1221, 5:2432
 - definition of, 3:1221
 - domino theory and, 3:1224
 - "flattening" of the world belief and, 3:1224
 - globalization and, 3:1338
 - Derek Gregory's work and, 3:1221, 3:1380–1381
 - how people *see* the world factors and, 3:1221
 - imagination, social and spatial impacts of, 3:1223
 - literature geographies and, 4:1785–1788
 - manifest destiny (U.S.), 3:1222–1223, 3:1223 (fig.)
 - Native American land loss and relocation and, 3:1223
 - neoliberalism and, 3:1224
 - "our" places and "other" places relationships and, 3:1221
 - social and spatial identity constructions and, 3:1221
 - telegraph technology and, 3:1221–1222
 - United States as "great melting pot," 3:1223
- Geographically weighted regression (GWR), 3:1225–1232**
 - applications of, 3:1229–1231, 5:2329
 - background, 3:1225–1226
 - bandwidth and scale elements of, 3:1227–1229, 3:1230 (fig.)
 - bias *vs.* variance of local parameter estimates and, 3:1229
 - "borrowing" data and, 3:1229
 - correlations between two variables search and, 3:1214
 - definition and explanation of, 3:1225
 - effective number of parameters (ENP) element in, 3:1229
 - ESRI's ArcGIS 9.3 and, 3:1230
 - A. Stewart Fotheringham's work in, 3:1169, 3:1226
 - functions of, 3:1225–1226
 - geocomputation of data sets and, 3:1214
 - geographical weighting function of, 3:1228 (figs.)
 - geostatistics and, 3:1261–1265
 - GWR module in R and, 3:1230
 - GWR 3.0 software and, 3:1230
 - independent parameter estimates element in, 3:1229
 - limitations of, 3:1226, 3:1230–1231
 - multivariate analysis methods and, 4:1961–1962
 - operationalization of, 3:1226–1227
 - regression analysis and, 3:1225
 - SAM ecological software and, 3:1230
 - social, health, and environmental data applications of, 3:1229–1230
 - spatial dependency issue and, 3:1226
 - spatial heterogeneity issue of, 3:1226
 - spatial weighting function of, 3:1227 (fig.), 3:1230 (fig.), 5:2329
 - Stata software and, 3:1230
 - statistical function of, 3:1225
 - Terraseer's software and, 3:1230
 - time series *vs.* spatial data determined by, 3:1226
- Geographic information systems (GIS), 3:1232**
 - applications of, 3:1232
 - cost-benefit analysis used in, 2:593
 - decision making support function of, 3:1232
 - definition of, 3:1232
 - distributed computing and, 2:774–776
 - elements of, 3:1232
 - GIS *vs.* GIScience and, 3:1285
 - Michael Goodchild's work in, 3:1349–1350
 - landscape interpretation using, 4:1715
 - media mapping and, 4:1951–1953
 - medical geographies and, 4:1878
 - network analysis in, 4:2017–2018
 - Daniel Sui and, 1:319
 - surveillance and, 6:2734
 - users of, 3:1232
 - Web-based services and, 3:1232
 - See also* **Business models for geographic information systems (GIS); GIScience; GIS specific subject; Public participation GIS (PPGIS)**
- Geography education, 3:1232–1234**
 - advanced placement (AP) courses and, 3:1233
 - Commission on College Geography (AAG) and, 3:1233
 - Committee on the Status of Women in Geography, 3:1234
 - in elementary and secondary education, 3:1233
 - Enhancing Departments and Graduate Education (EDGE) and, 3:1234
 - federally funded projects and, 3:1234
 - focus of, 3:1232–1233
 - geographical ignorance and, 3:1219–1220
 - Geography Faculty Development Alliance and, 3:1234
 - Geography for Life* (Goals 2000) and, 3:1233
 - Goals 2000: Educate America Act (1994) and, 3:1233
 - Guidelines for Geographic Education* (AAG and NCGE) and, 3:1233
 - knowledge geographies and, 4:1659–1663
 - National Assessment of Educational Progress and, 3:1233
 - National Center for Geographic Information and Analysis and, 4:1976–1977
 - National Geographic Society grants and, 3:1233, 4:1977–1978
 - national reform movement in, 3:1233
 - Phoenix Project and, 3:1234
 - in postsecondary education, 3:1233–1234
 - professional development programs and, 3:1233
 - research on higher education teaching and learning issues and, 3:1233
 - state geographic alliances network and, 3:1233
 - undergraduate, master's and doctoral degrees in, 3:1234
 - See also* **Childhood spatial and environmental learning; Education, geographies of**
- Geolibraries, 3:1234–1235**
 - definition of, 3:1234–1235
 - geographical information *vs.* dereference information and, 3:1235
 - Michael Goodchild and, 3:1234, 3:1235
 - holdings indexed by location feature of, 3:1235
 - research challenges of, 3:1235
- Geologic Society of America (GSA), 3:1245**
- Geologic timescale, 3:1235–1238**
 - carbon-15 dating method and, 3:1237
 - correlation process used in, 3:1237
 - Earth's age speculation and, 3:1237
 - Earth's magnetic field reversals factor and, 3:1237
 - hierarchic intervals of, 3:1235, 3:1236 (table), 3:1237
 - International Commission of Stratigraphy and, 3:1237
 - law of superposition and, 3:1237
 - mass extinction events element of, 3:1235
 - Milankovitch cycles and, 3:1238
 - orbital tuning process and, 3:1238
 - paleomagnetism and cyclic stratigraphy interpolation methods and, 3:1237
 - plate tectonics and, 5:2195–2199
 - radioactive isotopes dating method and, 3:1237
 - sedimentary fossils basis of, 3:1235
 - sediment deposition cyclic patterns and climate change factor in, 3:1237–1238
 - separate and incompatible versions disputes and, 3:1237
 - See also* **Climate change; Geologic timescale: noted geologists**

- Geologic timescale: noted geologists
 Henri Becquerel, 3:1237
 Arthur Holmes, 3:1237
 Milutin Milankovitch, 3:1237
 Sir Roderick Impey Murchison, 3:1237
 Adam Sedgwick, 3:1237
- Geomancy, 3:1238–1239**
 African “science of sand” variant of, 3:1238
 Herbert Chatley’s work in, 3:1238
 Chinese “wind-and-water” variant of, 3:1238
 definition of, 3:1238
 East Asian variants of, 3:1238
feng shui and, 3:1238–1239
 landform divination and, 3:1238–1239
 landscape *vs.* compass feng shui schools and, 3:1238
- Geometric correction, 3:1239–1240**
 definition of, 3:1239
 image-to map *vs.* image-to-image rectification and, 3:1239
 intensity (or pixel value) interpolation element in, 3:1239–1240
 internal *vs.* external errors and, 3:1239
 methods and procedures in, 3:1239–1240
 registration element of process, 3:1239
 spatial interpolation element in, 3:1239–1240
 systematic *vs.* nonsystematic sources of, 3:1239
- Geometric measures, 3:1240–1241**
 centroid measures, 3:1240
 challenges of, 3:1240
 classification issue of, 3:1240
 function of, 3:1240
 geometric properties categories and, 3:1240
 geometry and geography roots of, 3:1240
 intensity measures, 3:1240
 laws of addition and transitivity and, 3:1240
 orientation measures, 3:1240
 range measures, 3:1240
 shape measures, 3:1240
- Geomorphic cycle, 3:1241–1244**
 climatic geomorphology and, 3:1243
 context and objectives of, 3:1241
 criticisms regarding, 3:1243–1244
 Darwin’s work and, 3:1241
 William Morris Davis and, 3:1241–1242, 4:2180
 definition of, 3:1241
 denudation chronology component of, 3:1242
 essential components of, 3:1241–1243
 Grove Karl Gilbert’s work and, 3:1279, 4:2180–2181
 Grade, concept of, 3:1243
 landscape development cycle in, 3:1242
 model of landscape development (Davis) and, 3:1241, 4:2180
 peneplain stage of, 3:1242, 3:1243
 river development cycle in, 3:1242
 sigmoidal slope profile issue in, 3:1242
 slope development cycle in, 3:1242
 variables in, 3:1242
 youth, maturity, and old age stages of, 3:1242
See also Geomorphology
- Geomorphology, 3:1244–1248**
 associations in field of, 3:1245
 avalanches and, 1:175–179
 barrier islands and, 1:183–185
 as basic and applied science, 3:1244
 Binghamton Geomorphology Symposium and, 3:1245
 carbonation and, 1:325
 carbon-14 dating technique and, 3:1245
 climatic geomorphology and, 3:1245
 coral reef geomorphology and, 2:584–586
 cosmogenic isotope dating technique and, 3:1245
 dating landforms techniques and, 3:1245–1246
 definition of, 3:1244
 driving forces in, 3:1245
 dunes and, 2:800–803
 Earth system science and, 3:1244
 field and laboratory methods of, 3:1245
 folding and, 3:1140–1142
 fundamental concepts of, 3:1246–1248
 future trends in, 3:1246–1248
 geologic timescale and, 3:1235–1238
 global and local factors in landform development and, 3:1247
 gully erosion and, 3:1392–1394
 history of, 3:1245–1246
 human-induced disturbances and, 3:1247
To Interpret the Earth (Schumm), 3:1247
 journals of, 3:1245
 karst topography and, 4:1649–1654
 landform development through catastrophic forces and, 3:1245
 landform interpretation factors and, 3:1247
 mountain glaciers and, 3:1328–1333
 multidisciplinary applications of, 3:1244
 optically stimulated luminescence (OSL) dating technique and, 3:1245
 physiography and, 3:1245
 potassium dating technique and, 3:1245
 probabilistic modeling approach to, 3:1245
 quaternary geomorphology and, 3:1244
 radioisotope dating technique and, 3:1245
 reductionist approach to, 3:1244–1245
 “relaxation time” after disturbances and, 3:1247
 resisting framework concept in, 3:1245
 rock weathering and, 5:2477–2484
 uniformitarianism and, 3:1245, 4:2179–2180
See also Geomorphic cycle; Geomorphology: noted individuals
- Geomorphology: noted individuals**
 Ernst Antevs, 1:81–82
 Aristotle, 3:1245
 William Buckland, 3:1245
 Herbert Louis Büdel, 3:1246
 Comte de Buffon, 3:1245
 Richard Chorley, 1:403–404, 3:1246
 William Morris Davis, 2:686–687, 3:1246, 4:2180
 Nicolas Desmarest, 3:1245
 Charles Dutton, 3:1245–1246
 Grove Karl Gilbert, 3:1279
 Herodotus, 3:1245
 William Holmes, 3:1245
 Roger L. B. Hooke, 3:1247
 Robert Horton, 3:1246
 James Hutton, 3:1245, 4:2179
 Georges-Louis LeClerc, 3:1245
 Luna Leopold, 3:1246
 Charles Lyell, 3:1245, 4:2180
 Walther Penck, 3:1246, 4:2145
 Jean Baptiste Perrault, 3:1245
 John Phillips, 3:1245
 Jonathan Phillips, 3:1247
 John Playfair, 3:1245
 John Wesley Powell, 3:1245, 5:2276–2277
 William Rubey, 3:1246
 Horace-Bénédict de Saussure, 3:1245
 Stanley Schumm, 3:1246, 3:1247
 Adam Sedgwick, 3:1245

- Strabo, 3:1245
 Arthur Strahler, 3:1246, 5:2697–2698
 Jean Tricart, 3:1246
 Abraham Gottlob Werner, 3:1245
 M. Gordon Woman, 3:1246
- Geophagy, 3:1248–1249**
 “Cachexia Africana,” 3:1249
 calabash chalk (Africa), 3:1248–1249
 earth eating, 3:1248
 famine and, 3:1248
 health risks of, 3:1248
 nutritional deficiency compensated by, 3:1248
 pica and, 3:1248
 religious rituals and, 3:1248
- Geopolitics, 3:1249–1252**
 academic manifestations form of, 3:1252
 African Union (AU) and, 1:25
 biologized international relations and, 3:1464
 Cold War and, 1:504–505, 3:1250–1252
 Committee on the Present Danger (CPD) and, 3:1251
 critical geopolitics and, 3:1251–1252, 5:2224
 cultural geopolitics and, 3:1464
 domino theory and, 2:786–787
Geographical Pivot of History (Mackinder) and, 3:1464
Geography and Politics in a Divided World (Cohen)
 ad, 3:1250–1251
 geopolitical revival: the Kissinger factor, 3:1251
 German prosperity after WWI (Haushofer) and,
 3:1249–1250, 3:1464
 global capitalism and, 3:1251
 imperialism and, 3:1545–1548
 land- and sea-based powers relationship and, 3:1249
 media power and, 2:541, 3:1252
 nations and, 3:1464, 4:1971–1974
 NATO and, 4:2046–2048
 Nazism, 3:1249
 Organization of the Petroleum Exporting Countries (OPEC)
 and, 4:2097–2100
 origins of, 3:1249–1251
 peace literature and, 3:1251
 policy-orientated geographical template form of, 3:1252
 popular geopolitics and, 2:541
 social Darwinism and, 3:1464
 Soviet Union collapse and, 3:1251
 world-systems theory and, 3:1251
See also Communism and geography; Political geography
- Geopolitics: noted individuals**
 Isaiah Bowman, 3:1250, 3:1465, 4:1990
 Zbigniew Brzezinski, 3:1251
 Saul Cohen, 3:1250
 Simon Dalby, 3:1252
 Andreas Dorpalen, 3:1250
 Richard Hartshorne, 3:1250
 Karl Haushofer, 3:1249–1250, 3:1407–1408, 3:1464
 Henry Kissinger, 3:1251
 Rudolf Kjellen, 3:1249, 3:1464
 Halford Mackinder, 1:611, 3:1251, 3:1464, 4:1812–1813,
 5:2222
 Alfred Thayer Mahan, 4:1815–1816
 Friedrich Ratzel, 3:1249, 3:1464, 5:2221–2222
 Nicholas Spykman, 3:1250
 Robert Strausz-Hupe, 3:1250
 Gerard Toal, 3:1252
 Father Edmund Walsh, 3:1250
 Hans Weigert, 3:1250
- George, Pierre, 2:617, 5:2247
 Georgescu-Roegen, Nicholas, 2:896
 Georgia (country)
 Collective Security Treaty Organization
 (CSTO) membership of, 2:536
 Commonwealth of Independent States
 (CIS) membership of, 2:536 (table)
 economically active females in, 3:1190 (table)
 GUAM Organization for Democracy and Economic
 Development co-founded by, 2:538
 HIV/AIDS in, 3:1438
 human rights atrocities in, 3:1481
 Georgia (state)
 hurricane risk in, 3:1500
 slash pine plantation, Georgia (U.S.), 6:2835 (photo)
- Geosensor networks (GSNs), 3:1252–1255**
 applications of, 3:1254
 as a distributed spatial database system (DBS), 3:1253
 as a environmental microscope, 3:1253
 explanation of, 3:1252–1253
 failure-prone nature of, 3:1253
 geographical applications of, 3:1254
 intelligent data collection and processing and, 3:1253
 mobile deployment of, 3:1254
 Open GIS Consortium and, 3:1254
 research networks established with, 3:1254
 for resource-constrained computing environments, 3:1253
 reusable sensor platforms and, 3:1254
 sensor nodes element of, 3:1252–1253
 sensor webs and, 3:1254
 spatiotemporal nature of data collection tasks and, 3:1253–1254
 technology constraints of, 3:1253
 wireless sensor network technology and, 3:1253
- Geoslavery, 3:1255–1256**
 Alzheimer’s disease patients locator use of, 3:1256
 child monitoring use of, 3:1256
 code of practice for (U.K.), 3:1256
 corporate use of, 3:1255–1256
 criminal justice system offender management
 and, 3:1255 (photo)
 definition of, 3:1255
 panopticon and, 4:2116–2117
 personal location devices and, 3:1255, 3:1255 (photo)
 socially unacceptable uses of, 3:1256
- Geospatial industry, 3:1256–1260**
 aerial photography and, 3:1257
 CAD software tools and, 3:1258
 commercial database spatial data and, 3:1258
 Jack Dangermond and, 2:663–664
 database capabilities within, 3:1258
 data distribution modes in, 3:1258
 data from functionality separation and, 3:1256–1257
 data production sectors of, 3:1257–1258
 data production technologies of, 3:1257
 GIS software and, 3:1258
 GPS technology and, 3:1257
 Internet and mobile capabilities in, 3:1258–1259
 Internet trends regarding, 3:1257–1258
 local, state, federal agencies use of, 3:1257
 national-scale transportation data and, 3:1257
 Open GIS Consortium (OGC) and, 3:1259, 4:2085
 personal digital assistants (PDAs) and, 3:1259
 relational data model and, 3:1258
 remote sensing technology and, 3:1257
 shapefile vector data format and, 3:1258

- software, 3:1258–1259
- Web-based interactive maps and, 3:1257
- Web-based spatial data clearinghouses and, 3:1258
- See also* Geospatial Semantic Web; Legal aspects of geospatial information; Privacy and security of geospatial information; Usability of geospatial information
- Geospatial semantic web, 3:1260–1261**
 - client-server architecture and, 1:426–428
 - definition of, 3:1260
 - ESRI and MapQuest and, 3:1260
 - geospatial semantics and, 3:1260
 - geospatial web and, 3:1260
 - Open Geospatial Consortium and, 3:1260, 4:2085
 - OWL (Ontology Web Language) and, 3:1260
 - RCCS (Regional Connection Calculus) and, 3:1260
 - RDF (Resource Description Framework) and, 3:1260
 - semantic web and, 3:1260–1261
 - spatialization of the Web and, 3:1260
 - Web scale application challenge of, 3:1260
 - See also* Geospatial industry; Legal aspects of geospatial information; Privacy and security of geospatial information; Usability of geospatial information
- Geostatistics, 3:1261–1265**
 - applications of, 3:1261
 - Bayesian statistics in spatial analysis and, 1:187–188
 - bivariate dependence in, 3:1262
 - climatology and, 1:474
 - cokriging and, 3:1265
 - compete spatial law concept and, 3:1262
 - covariance function and, 3:1262
 - definition of, 3:1261
 - deterministic and probabilistic models of, 3:1261
 - indicator kriging algorithm and, 3:1265
 - isotropic *vs.* anisotropic variogram and, 3:1263
 - Daniel Krige's work in, 3:1261–1265
 - lag and, 3:1262
 - Georges Matheron's work in, 3:1261, 3:1263
 - mining industry origins of, 3:1261
 - multipoint probability distribution and, 3:1261
 - point pattern analysis and, 5:2201–2202
 - random field model of, 3:1262
 - semivariogram and semivariance and, 3:1262–1263
 - sequential simulation algorithms, 3:1265
 - spatial statistics and, 5:2665–2666
 - spatial variability focus of, 3:1261
 - stationarity and, 3:1262
 - strict *vs.* second-order, *vs.* intrinsic stationarity and, 3:1262
 - variable prediction goal of, 3:1261
 - variogram cloud and, 3:1263
 - variography and, 3:1262–1263
 - See also* Geostatistics: kriging algorithms
- Geostatistics: kriging algorithms**
 - best linear unbiased predictor property and, 3:1263
 - kriging algorithms used in, 3:1263, 3:1264–1265
 - kriging limitations and, 3:1265
 - kriging variance and, 3:1263, 3:1264
 - kriging weights and, 3:1263–1264
 - kriging with an external drift technique and, 3:1264–1265
 - kriging with a trend model and, 3:1264
 - multi-Gaussian kriging and, 3:1265
 - normal-scores transformation and, 3:1265
 - ordinary kriging and, 3:1264
 - quantifying prediction uncertainty in, 3:1265
 - simple kriging and, 3:1263–1264
 - spatial autocorrelation (spatial dependence) and, 3:1263
 - uncertainty measures in, 3:1264
 - universal kriging and, 3:1264
- Geothermal energy, 3:1265–1270**
 - agricultural applications of, 3:1269
 - aquaculture applications of, 3:1270
 - definition of, 3:1265
 - direct use of geothermal heat and, 3:1269–1270
 - Earth's generation of, 3:1266, 3:1266 (fig.)
 - geothermal field classification and, 3:1269
 - geothermal history and, 3:1267
 - geothermal potential, 3:1268–1269, 3:1269 (fig.)
 - geothermal system and, 3:1266–1267, 3:1266 (fig.)
 - greenhouse heating and, 3:1269
 - heat content of Earth's crust estimation and, 3:1266
 - heat source, reservoir and fluid elements of, 3:1266, 3:1266 (fig.)
 - human recovery and use of, 3:1265, 3:1266, 3:1268–1269, 3:1269 (fig.)
 - installed capacity and energy production of, 3:1267 (fig.)
 - installed capacity forecast for electricity production, 2010, 3:1268 (fig.)
 - present use of, 3:1267–1268
 - radioactive elements decay and, 3:1266, 3:1270
 - as a renewable energy, 3:1270
 - space and district heating systems and, 3:1269
 - space cooling option and, 3:1269
 - water- *vs.* vapor-dominated geothermal systems and, 3:1269
 - See also* Geothermal features
- Geothermal features, 3:1270–1274**
 - acidic surface water and, 3:1271–1272
 - definition of, 3:1270
 - fumarole, Spirit Lake, Kamania County, Washington, 3:1271 (photo)
 - fumaroles and, 3:1271–1272
 - geographical distribution of, 3:1273
 - geysers and, 3:1272–1273
 - Hawaiian volcanic islands and, 3:1273
 - high *vs.* low temperature geothermal areas and, 3:1270–1271
 - hot springs and, 3:1272
 - Iceland and, 3:1273
 - mud pots/mud pools/paint pots and, 3:1272
 - Pacific Ring of Fire and, 3:1273
 - radioactive elements decay and, 3:1266, 3:1270
 - rhyolites geysers and, 3:1272
 - siliceous sinters and, 3:1272
 - sinters deposits and, 3:1272
 - sources of, 3:1270
 - sulfurous gases (solfatara) and, 3:1271–1272
 - tectonic plates and, 3:1273
 - travertines deposits and, 3:1272
 - volcanoes and, 3:1273
 - water vapor to gas ratio and, 3:1271
 - Yellowstone geothermal area and, 3:1273
 - Yellowstone National Park and, 3:1273
 - See also* Diastrophism
- Geovisualization**
 - cartograms and, 1:338–339
 - cartography and, 1:350
 - decision support for, 3:1213–1214
 - geocomputation in, 3:1212
 - geographically weighted regression (GWR) and, 3:1214
 - geographic decision support and, 3:1214
 - interactive maps and, 1:344
 - Alan MacEachren's work and, 4:1811–1812
 - multivariate mapping application and, 4:1963–1966
 - Donna Peuquet's work and, 4:2165

- uncertainty in geographic data sets and, 3:1214
See also Cartography; Dynamic and interactive displays; Map visualization; Three-dimensional data models
- Gerlach, Arch C., 2:567
- Germany
 acid rain in, 1:7
 agglomeration economies in, 1:32
 AGILE membership of, 1:124 (table)
 antiglobalization, anticolonialism in, 1:97
 atlases and maps produced in, 1:356–357
 automobile industry in, 1:169, 1:171
 automobility in, 1:172
 Baden-Württemberg high-tech region in, 3:1127, 5:2435
 biodiesel production in, 1:203
 biofuels produced in, 1:203
 biotechnology industry in, 1:280
Central Places in Southern Germany (Christaller), 1:380
 Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 coal energy source in, 3:1582
 colonial empire of, 1:509, 1:509 (fig.)
 COMECON membership of, 2:593 (table)
 competitive advantage areas in, 2:558
 criminal justice system offender management in, 3:1255 (photo)
 cultural nationalism in, 4:1980
das Volk national identity and, 4:1979
 deposit refund systems in, 2:742
 digital height model and, 2:753
 ecological footprint and biocapacity of, 2:827 (table)
 ecological modernization theory developed in, 2:836
 economically active females in, 3:1190 (table)
 energy feed-in tariffs (FIT) in, 2:901
 energy policies in, 2:902
 environmental certification standards in, 2:914
 ethnic nationalism and, 4:1979
 European Union (EU) membership of, 2:1035
 federalism political model and, 2:1036
 Frankfurt chemical spill, 1:383 (photo)
 GDP of, 3:1382, 3:1383 (fig.)
 German Green Party (*Die Grünen*), 2:1032, 2:1033–1034
 Germanocentrism of, 2:1030 (table)
 green design and development in, 3:1371
 gully erosion in, 3:1393
 hate groups in, 3:1407
 high-speed trains in, 5:2364
 immigration laws of, 3:1545
 industrialization in, 3:1583
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Kyoto Protocol of 1997 and, 1:463
 military expenditures in, 4:1899 (table)
 national geographical society in, 3:1462
 nuclear power plant in Lower Saxony, 4:2051 (photo)
 particulate matter pollution in, 1:151
 population dynamics in, 2:807 (fig.)
 regional governance in, 5:2392
 “science” of geopolitics in, 3:1249–1250
 wind power development in, 2:902
- Gershenkron, Alexander, 3:1117
- Getis, Arthur, 3:1274–1275
 award and honors received by, 3:1274
 economic activity patterns analysis work of, 3:1274
 William Garrison and, 1:192, 3:1274
 geographic education advanced by, 3:1274
 publications of, 3:1274
- quantitative revolution in geography and, 3:1274
 service and leadership roles of, 3:1274
 spatial analysis and spatial econometrics work of, 3:1274
 spatial statistics work of, 3:1274
- Getis, Judith, 3:1274
- Ghana
 economically active females in, 3:1190 (table)
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
 White Volta River floodplain in, 3:1129 (photo)
- Ghetto, 3:1275–1277
 capitalist social and economic organization and, 3:1276–1277
 clashing ideologies regarding, 3:1275–1277
 definition controversy regarding, 3:1275
 ethnic segregation and, 2:1024
 human choice and, 3:1275–1276
 liberal and radical perspectives on, 3:1275–1276
 neoconservative perspective on, 3:1275
 postindustrial economy realities and, 3:1276
 Harold Rose and, 3:1275
 South Bronx ghetto neighborhood, 3:1276 (photo)
 subculture and 3:1275–1276
- GHGs. *See* Greenhouse gases (GHGs)
- Ghose, Rina, 2:616
- Gibbs, Lois, 4:1807–1808
- Gibson, William, 2:646, 4:1969
- Gibson-Graham, J. K., 3:1191, 5:2351
- Giddens, Anthony, 3:1277–1279
 agency and institutionalized practice and, 3:1278
 British “third-way” politics of, 3:1277
Capitalism and Modern Social Theory written by, 3:1277
 critical human geography and, 3:1277
 distanciation of, 6:2840
 duality of social structures and, 3:1278
 European social geography and, 3:1277
 Derek Gregory and, 3:1380
 new regional geography debates and, 3:1277
 relative space and, 5:2403
 social praxis concept and, 3:1278
 social theory and, 3:1277–1278
 space as social creation and, 5:2297
 structuration theory of, 3:1277, 3:1380, 4:1863, 5:2289, 5:2403
- Gilbert, Grove Karl, 3:1279–1280
 geomorphology work of, 3:1245, 3:1275, 4:2180–2181
 time-independent modeling and, 3:1275
 U.S. Geological Survey service of, 3:1275
- Gilbertson, D., 3:1105
- Gilder, George, 6:2998
- Gilroy, Paul, 4:2070
- Giordano, Mark, common pool resources work of, 1:526, 1:527 (fig.)
- Giroux, Henry, 2:875
- GIS. *See* Geographic information systems (GIS); GIS specific subject
- GIS, environmental model integration and, 3:1280–1281
 component-based modeling and, 3:1280
 function of, 3:1280
 interoperable modeling approach of, 3:1280
 meta-information types and, 3:1280
 primitive components identification issue and, 3:1280
 semantic compatibility issue and, 3:1280
 semantic interoperability feature of, 3:1280
See also GIS, specific subject
- GIS, history of, 3:1281–1284
 automated address matching (U.S. Census Bureau) and, 3:1282
 conceptual landscape of, 3:1281
Design With Nature (McHarg) and, 3:1281

- DIME (Dual Independent Map Encoding, U.S. Census Bureau) and, 3:1282
- engineering contributions to, 3:1284
- geodata translation and, 3:1281–1282
- government organizations and, 3:1282
- Harvard Laboratory for Computer Graphics and, 3:1282, 3:1283, 3:1304
- interactive geographic analysis tool and, 3:1283
- labor-intensive data digitization factor in, 3:1283
- mainstream implementations of, 3:1283–1284
- natural resource inventory systems development and, 3:1284
- object-based image analysis (OBIA) and, 4:2057–2058
- origins of GIS and, 3:1281
- pioneering centers in GIS and, 3:1282–1283
- raster-based GIS and, 3:1282–1283
- remote sensing and, 3:1282–1283
- space age technology and computerized information factors in, 3:1281
- spatial data overlay mapping methods and, 3:1281
- state agencies GIS developments and, 3:1284
- technology prerequisites for, 3:1281–1282
- virtual Earth geobrowsers and, 3:1284
- See also* Critical GIS; GIS, history of: noted individuals; GIS, *specific subject*
- GIS, history of: noted individuals
- Ray Boyle, 3:1283
- Max Egenhofer, 2:876–877
- Herman Hollerith, 3:1281
- Ian McHarg, 3:1281
- Roger Tomlinson, 3:1281, 6:2847
- GIScience, 3:1284–1289**
- ArcGIS and, 2:663, 2:684, 2:685 (fig.), 3:1538, 3:1624, 4:1709, 4:1785, 4:1826, 4:1952
- Association of Geographic Information Laboratories for Europe (AGILE) and, 3:1286
- brief history of, 3:1285–1286
- cellular automata and, 1:368–371
- cellular automata and agent-based simulations issues in, 3:1212
- certification, accreditation, and licensure issues in, 3:1289
- client-server architecture and, 1:426–428
- collaborative GIS with, 1:507
- coordinate transformations in, 2:580
- definition of, 3:1284–1285
- digitizing and, 2:756–757
- education in, 3:1287–1289
- feminist geographies and, 3:1193
- geocomputation in, 3:1212
- GeoVISTA Center, Penn State and, 4:1811
- GIScience & Technology Body of Knowledge* and, 3:1288–1289
- GIS vs. GIScience and, 3:1285
- high-performance computing and, 3:1425–1426
- Internet GIS and, 3:1620–11623
- issues addressed by, 3:1285
- map algebra and, 4:1824–1825
- media mapping and, 4:1951–1953
- mobile GIS and, 4:1918–1921
- multidisciplinary foundation of, 3:1285
- National Center for Geographic Information and Analysis (NCGIA) and, 3:1286
- organizations related to, 3:1286
- participatory GIScience and, 5:2305
- peer-reviewed journals of, 3:1286
- Project Varenus (NCGIA) and, 3:1286
- research topics examples in, 3:1287, 3:1288 (table)
- scale issues and, 3:1287
- spatial data acquisition and integration research and, 3:1287
- University Consortium for Geographic Information Science (UCGIS) and, 3:1286
- GIScience: noted individuals**
- Gilberto Camara, 1:319
- Nicholas Chrisman, 1:408
- Jack Dangermond, 2:663–664
- Max Egenhofer, 2:876–877
- Peter Fisher, 3:1118–1119
- Andrew Frank, 3:1169–1170
- Michael Goodchild, 3:1285, 3:1349–1350
- Piotr Jankowski, 4:2055–2056
- Werner Kuhn, 4:1672–1673
- Timothy Nyerges, 4:2055–2056
- Daniel Sui, 1:319
- GIS design, 3:1290–1293**
- application domains of, 3:1290
- arc-node data model in, 3:1291
- definition of process and, 3:1290
- Enterprise GIS and, 2:911–913
- field-based approach to model selection, 3:1291
- georelational relational logical data model in, 3:1292
- hardware and software components of, 3:1290
- logical data model choices in, 3:1292
- object-based approach to model selection, 3:1291
- object oriented relational logical data model in, 3:1292
- object relational logical data model in, 3:1292
- people component of, 3:1290
- as powerful research tool, 3:1290
- procedure component of, 3:1290
- raster data model in, 3:1291
- spaghetti data model in, 3:1291
- spatial data model selection in, 3:1291–1292
- steps in, 3:1290–1292
- system implementation in, 3:1292
- system requirements component of, 3:1292
- system scope definition in, 3:1290–1291
- user needs analysis in, 3:1290
- vector data model of, 3:1291
- See also* GIScience; GIS *specific subject*
- GIS implementation, 3:1293–1294**
- academic career of, 1:186
- accessibility calculations and, 1:5
- Advanced Spatial Analysis* (Batty) and, 1:187
- aerial imagery processed by, 1:21–22
- AGILE and, 1:123–126
- analytical operations in, 1:71–72
- Luc Anselin and, 1:80–81
- applied geography field of, 1:102
- Marc Armstrong's work in, 1:117
- Michael Batty's contributions to, 1:187
- behavioral geography and, 1:189–190
- business geography and, 1:305–306
- CAD systems and, 1:318–319
- components of, 3:1293
- cost-benefit analysis of, 3:1294
- econometrics foundation of, 1:80
- Enterprise GIS and, 2:911–913
- functional specifications development and, 3:1294
- genocide geographies and, 3:1200–1201, 3:1200 (images)
- GIS analytical operations and, 1:71–72
- GIS database design component of, 3:1293–1294
- implementation plan development and, 3:1293
- Internet GIS and, 3:1620–11623
- needs analysis and, 3:1293

- Spatial Econometrics* (Anselin) and, 1:80
- strategic plan development and, 3:1293
- system design component of, 3:1293
- topographic modeling and, 1:318
- user issues in, 3:1294
- workflow element of, 3:1294
- See also **Analytical operations in GIS; Business models for geographic information systems (GIS); GIScience; GIS specific subject**
- GIS in archaeology, 3:1294–1296**
 - catchment areas modeling in, 3:1295
 - cultural resource management (CRM) application and, 3:1295
 - digital terrain model (DTM) and, 3:1295
 - excavation recording and, 3:1296
 - landscape archaeology application and, 3:1295
 - movement modeling and, 3:1295
 - site territories and hierarchies modeling and, 3:1295
 - spatial relationships foundation of, 3:1294–1295
 - visibility modeling and, 3:1295–1296
- GIS in disaster response, 3:1296–1298**
 - community-focused information dissemination and, 3:1297
 - criticisms and further development, 3:1297
 - damage assessment and, 3:1296
 - decision-making support tool of, 3:1296
 - emergency planning tool of, 3:1296
 - examples of, 3:1296–1297
 - preparedness phase of, 3:1297
 - real-time 3D GIS and, 3:1297
 - reconstruction and preparedness tool of, 3:1296
 - reconstruction phase of, 3:1296
 - recovery and rebuilding phase of, 3:1296, 3:1297
 - remote sensing in disaster response and, 5:2424–2428
 - risk mitigation information and, 3:1296
 - scope assessment phase of, 3:1296
 - secondary effects assessment phase of, 3:1296
 - sharing information tool of, 3:1296
 - technology advances in, 3:1296
 - user interfaces and training limitations of, 3:1297
 - See also **Remote sensing in disaster response**
- GIS in environmental management, 3:1298–1300**
 - air and water pollution monitoring and, 3:1299
 - cartography applications and, 1:364
 - climatology geospatial techniques and, 1:473–474
 - daily activities applications of, 3:1298–1299
 - ecological risk analysis (ERA) and, 2:842–843
 - emergency services and, 3:1298
 - environmental decision making and, 3:1298, 3:1299
 - environmental mapping and, 2:975
 - environmental planning public participatory GIS tools and, 2:981
 - floodplain delineation and, 3:1131
 - geographic database used in, 3:1298
 - GIS in archaeology and, 3:1294–1296
 - land surface and subsurface applications of, 3:1298
 - limitations of, 3:1299
 - natural resources management application of, 3:1299
 - precision farming applications of, 3:1299
 - spatial error and uncertainty issues and, 3:1299
 - spatial relationships of biophysical factors application of, 3:1298
- GIS in health research and health care, 3:1300–1302**
 - cancer studies and, 1:336
 - cartographic visualization and, 3:1300
 - critical perspectives in, 3:1301–1302
 - early warning and prediction systems and, 3:1300–1301
 - geography of disease and, 2:771
 - infectious disease tracking system and, 3:1300, 3:1301 (fig.)
 - pattern analysis and, 3:1300
 - public participation GIS (PPGIS) techniques and, 3:1301–1302
 - space-time clustering, cancer rates and, 1:321
 - spatial patterns of health care inequities and, 3:1302
 - surveillance systems, emergency management and, 3:1300, 3:1301 (fig.)
 - urban pandemic quarantines and, 3:1300
- GIS in land use management, 3:1302–1305**
 - agriculture and landscape GIS applications and, 3:1298–1299
 - cadastral systems and, 1:311, 1:316
 - Canada Geographic Information System origins of, 3:1302
 - computer-assisted overlay techniques and, 3:1304
 - data development and software accessibility areas of, 3:1304
 - Ronald Eastman's work in, 2:815–816
 - ecological inventory process prior to, 3:1303
 - floodplain delineation and, 3:1131
 - future trends in, 3:1304
 - Geographic Information Retrieval and Analysis System (GIRAS) and, 3:1302–1303
 - GIS in archaeology and, 3:1294–1296
 - Harvard University's Laboratory for Computer Graphics and, 3:1282, 3:1283, 3:1304
 - land ownership (cadastral) data and, 3:1303
 - Land Use and Land Cover (LULC) data sets and, 4:1732
 - land use (cadastral) data sets and, 4:1732
 - land use definition and, 3:1302
 - land use inventory and mapping, 3:1302–1303
 - land use suitability analysis and, 3:1303–1304
 - local zoning/land use data and, 4:1732
 - manual interpretation of aerial photography data sets and, 4:1732
 - map algebra, 3:1304
 - Minnesota Land Management Information System and, 3:1302
 - National Land Cover Database (NLCD) data sets and, 4:1732
 - Natural Resources Conservation Service (NRCS) and, 3:1303
 - New York Land Use and Natural Resources Inventory System and, 3:1302
 - soil survey digitization (USDA) and, 3:1303, 3:1303 (photo)
 - spatial decision support and, 3:1304
 - terms related to, 3:1303
 - USGS nationwide inventory of land cover and land use and, 3:1302
 - Web-based GIS and, 3:1304
- GIS in local government, 3:1305–1307**
 - agriculture use of, 3:1306
 - asset management systems and, 3:1305–1306
 - computer-aided dispatch (CAD) systems and, 3:1306
 - department location and staff and, 3:1305
 - distributed *vs.* centralized environments and, 3:1305
 - emergency services and law enforcement and, 3:1306
 - environmental management and, 3:1306
 - GIS in public policy and, 3:1307–1311
 - Health and Human Services use of, 3:1306
 - jurisdiction size factor in, 3:1305
 - parks and recreation departments' use of, 3:1306
 - planning and zoning and, 3:1306
 - public facility and infrastructure management and, 3:1305–1306
 - public information and education and, 3:1306
 - public interactive applications and, 3:1306
- GIS in public policy, 3:1307–1311**
 - accessibility improvement and, 3:1308
 - applications and impact of, 3:1308–1310
 - collaborative decision making improvement and, 3:1307
 - cost effectiveness issue and, 3:1307–1308

- criticism of, 3:1310
- democratization of GIS technology and, 3:1308
- implementation barriers and, 3:1310
- new media dissemination systems and, 3:1308
- overview of, 3:1307–1308
- participatory GIS and, 3:1308
- power flows element in, 3:1309–1310
- public goods allocation improvement and, 3:1308
- public participation GIS (PPGIS) and, 3:1308
- public service delivery impacted by, 3:1309
- real-time visualization trend in, 3:1308
- spatial justice and, 3:1307, 3:1310
- trends in, 3:1308
- Web functionality feature and, 3:1308
- GIS in transportation, 3:1311–1312**
 - data models and operations and, 3:1311
 - GIS-T term and, 3:1311
 - geonomadism or geosurveillance and, 3:1311
 - intelligent transportation systems (ITS) advances and, 3:1312
 - linear referencing system (LRS) and, 3:1311–1312
 - network analysis and, 4:2017–2018
 - network data model and, 4:2018–2019
 - network links and nodes and, 3:1311
 - origin-destination matrices and, 3:1312
 - policy goals of, 3:1311
 - shortest-path problems and, 3:1312
 - space-time accessibility issues and, 3:1312
 - technology advances in, 3:1311
 - urban transportation modeling system (UTMS) and, 3:1312
 - Web-based public participation tools and, 3:1311
- GIS in urban planning, 3:1313–1315**
 - augmentation maps and, 1:108–110
 - cellular automata models and, 3:1313
 - GIS in local government and, 3:1305–1307
 - GIS in transportation and, 3:1311–1312
 - MOLAND (Monitoring Land Cover/Use Dynamics) project in Nigeria and, 3:1313
 - new urbanism or non-traditional planning and, 3:1313
 - smart growth principles and, 3:1313, 5:2240
 - spatial layers and dimensions of cities and, 3:1313
 - urban fringe watershed of Chicago application of, 3:1313, 3:1314 (fig.)
- GIS in utilities, 3:1315–1316**
 - address geocoding and, 3:1316
 - data use examples and, 3:1315–1316
 - examples of, 3:1315
 - GIS data layers *vs.* utility data needs and, 3:1315–1316
 - linear referencing process and, 3:1316
 - micro- to macroscale applications and, 3:1315
 - natural gas example of, 3:1315
 - network analytic functions and, 3:1316
 - other business systems integrated with, 3:1316
 - 3D analysis and, 3:1316
 - topographical data models and, 3:1315
 - utility management and operations and, 3:1315–1316
 - utility networks modeled in GIS and, 3:1315
 - vector and network data models and, 3:1315
- GIS in water management, 3:1316–1318**
 - digital elevation model (DEM) and, 3:1316–1317
 - elements in, 3:1316–1317
 - flood protection practices and, 3:1317
 - human water usage effectiveness and, 3:1316–1317
 - HYDR01K digital elevation model (USGS) and, 3:1317–1318
 - hydrologic analysis and modeling and, 3:1317–1318
 - monitoring of, 3:1299
 - National Elevation Dataset and National Hydrography Dataset (USGS) and, 3:1317
 - new generation software and, 3:1318
 - tasks in, 3:1317
 - water management categories and, 3:1317
 - water rights conflict and, 3:1317
 - watershed and stream network delineation and, 3:1317
- GIS software, 3:1318–1321**
 - application examples and, 3:1318
 - ArcGIS, 3:1230, 3:1312, 3:1318, 3:1321, 3:1538, 3:1624, 4:1709, 4:1785, 4:1826, 4:1952
 - ArcInfo Workstation and Network Analysis, 3:1282, 3:1312
 - ArcView, 3:1309, 3:1312, 3:1624
 - Caliper Corporation's TransCAD software, 4:1785
 - categories of, 3:1320–1321, 3:1321 (fig.)
 - concepts of, 3:1318–1319
 - data acquisition element of, 3:1319–1320
 - definition of, 3:1318
 - Environmental Systems Research Institute (ESRI) and, 1:340 (figs.), 2:663, 2:674, 2:685, 2:685 (fig.), 3:1230, 3:1258, 3:1307, 3:1321, 3:1622–1623, 4:1918, 4:1952
 - free and open-source software and, 3:1321
 - Geographic Resources Analysis Support System (GRASS) and, 4:2085
 - image processing using, 3:1536, 3:1538
 - layers to simulate data management tasks and, 3:1319, 3:1319 (fig.)
 - manufacturers and projects in, 3:1321
 - MapObjects software, 4:1952
 - Open Source Geospatial Foundation and, 4:2088–2089
 - raster representation of a geographic phenomenon and, 3:1318–1319
 - tasks accomplished by, 3:1320 (fig.)
 - typical tasks accomplished with, 3:1319–1320
 - user interface example and, 3:1319 (fig.)
 - vectorization and, 6:3009–3010
 - vector representation of a geographic phenomenon and, 3:1319
 - water management software and, 3:1317
 - See also* GIS software: noted individuals;
 - Open Source GIS (OSGIS)**
- GIS software: noted individuals
 - Gilberto Câmara, 1:319
 - Jack Dangermond, 2:663–664
 - Ronald Eastman, 2:815–816
- GIS Web services, 3:1321–1323**
 - access geographic data services and, 3:1322
 - categories of, 3:1321, 3:1322 (fig.)
 - challenges of, 3:1321
 - client-server architecture and, 1:426–428
 - computational capability of, 3:1322
 - discovery services and, 3:1321–1322
 - distributed GIS and, 3:1321
 - Geography Markup Language (GML) and, 3:1321
 - Internet GIS and, 3:1620–11623
 - interoperability specifications and, 3:1321, 3:1322, 3:1623–1625
 - Kehole Markup Language (KML) and, 3:1321
 - OGC's Catalogue Services Specification and, 3:1322
 - Open Geospatial Consortium (OGC) and, 3:1321
 - orchestration services and, 3:1323
 - spatial data infrastructure (SDI) and, 3:1321
 - visualization services and, 3:1323
 - Web Feature Service (WFS) and Web Coverage Service (WCS) and, 3:1321
 - WebMap server, 3:1321
 - Web Processing Service (WPS) and, 3:1322
 - workflow languages and, 3:1323

Glacier National Park, Montana, 2:865 (photo), 2:866 (photo)

Glaciers: continental, 3:1323–1328

- ablation, mass loss and, 3:1323
- accumulation line and equilibrium line and, 3:1323
- Ernst Antevs's work in, 1:81–82
- basal sliding rates and, 3:1326, 3:1326 (fig.)
- climate change and, 6:2772
- deformation rate and, 3:1325–1326
- dry snow zone and, 3:1323
- fjords and, 3:1121–1123
- glacier word derivation and, 3:1323
- global glacial isostatic adjustment process and, 3:1345
- Greenland Ice Sheet, 3:1325 (fig.)
- ice as a polycrystalline solid and, 3:1325–1326
- ice caps and, 3:1325
- ice sheets and, 3:1323–1324, 3:1324 (fig.), 3:1325 (fig.)
- ice shelf and, 3:1324 (fig.), 3:1325
- ice streams and, 3:1326
- landforms created by, 4:1689–1690
- moraines and striations and, 3:1327
- moulins and, 3:13256
- outlet glaciers, 3:1325
- past glaciation evidence and, 3:1327
- planet's temperature maintenance and, 3:1323
- Poles, North and South and, 5:2203–2209
- regulation process and, 3:1326, 3:1326 (fig.)
- sea level affected by, 3:1327, 3:1344
- sea-level fingerprint of ice melt concept and, 3:1344
- temperature profile of, 3:1326–1327
- tidewater glaciers, 3:1325
- water stores function of, 3:1323
- West and East Antarctic Ice Sheets, 3:1324 (fig.)

See also Ice; Periglacial environments; Permafrost

Glaciers: mountain, 3:1328–1333

- ablation and accumulation zones of, 3:1330, 3:1331 (photo), 3:1333
- alpine glaciers, 3:1328
- Ernst Antevs's work in, 1:81–82
- beauty and importance of, 3:1328
- crevasses formation and, 3:1329, 3:1331 (photo)
- deformation process of, 3:1329
- development of, 3:1328
- distribution of, 3:1332–1333
- Easton Glacier, Washington, 3:1331 (photo)
- equilibrium line and, 3:1331
- firm or granular ice and, 3:1328
- fjords and, 3:1121–1123
- flow rates of, 3:1328–1329
- formation of, 3:1328
- Gilkey Glacier, Alaska, 3:1330 (photo)
- glacier flour and, 3:1331
- glacier retreat and, 3:1330–1331, 3:1333
- global warming and, 3:1333
- ice avalanches and, 1:176–177
- ice caps or ice fields and, 3:1328
- landforms created by, 4:1689
- Little Ice Age and, 1:459, 3:1333, 3:1335
- Lyman Glacier, Washington, 3:1329 (photo)
- mass balance and terminus response of, 3:1330–1331, 3:1332 (fig.), 3:1333
- moraines and, 3:1330 (photo)
- movement of, 3:1328–1329
- ogives and, 3:1330
- polar *vs.* temperate types of, 3:1328
- recent behavior of, 3:1333

sea level affected by, 3:1344

surging glaciers and, 3:1328–1329

water supply and, 3:1331–1332

World Glacier Monitoring Service and, 3:1333

See also Ice

Glacken, Clarence, 4:2167

Glacken, Peter, 6:2737

Glaeser, Edwin, 5:2395

Glass, Judith, 3:1203

Glass, Ruth, 5:2263

Glassie, Henry, 1:118, 3:1435, 4:1773, 5:2536, 5:2537

Gliessman, Stephen, 1:54

Global environmental change, 3:1334–1338

acid rain and, 3:1336–1337

Anthropocene, new geologic epoch and, 3:1334

atmospheric changes and, 3:1336–1337

biodiversity and, 3:1334, 3:1337

climate change factor in, 3:1334

deforestation and, 2:695–699

habitat fragmentation and, 3:1336

human impacts on Earth and, 3:1334–1335

institutions and local governance and, 3:1334

land cover and land use with, 3:1334–1335

ocean changes from, 3:1336

ozone depletion and, 1:400–401, 3:1336

pesticides and fertilizers and, 3:1334

rate of change increase and, 3:1334

societal implications of, 3:1337

soil degradation during, 3:1335

spatial, temporal, and sociopolitical locales of, 3:1334

urban heat island effect and, 3:1336

urbanization and, 3:1336

water resources and, 3:1335–1336

Younger Dryas Northern Hemisphere cooling (Pleistocene) and, 3:1336

Global Institute for Sustainable Forestry, 1:96

Globalization, 3:1338–1342

antisystemic movements and, 1:99–100

border flows factor and, 3:1339

borderlands' societies interaction and, 1:292

citizenship and, 1:413–414

cross-border cooperation and, 2:630

definition of, 3:1338

detritorialization and, 2:722–724, 3:1338, 3:1340–1341

ecological modernization and, 2:832–834

economic geography and, 2:850

economic globalization, Euromarket and, 2:1031

globalized networks and, 3:1339–1340, 3:1341

historical context and implications of, 3:1341–1342

human identity and subjectivity and, 3:1341

human rights and, 3:1481

information and communications technologies (ICTs), economic geography and, 2:540

internationalization *vs.*, 3:1340

nation-state borders and, 1:293–294

neoliberal global networks and, 3:1341

neoliberalism and, 2:850

Organisation for Economic Co-operation and Development (OECD) and, 4:2096–2097

popular culture, 5:2229–2230

qualitative transformations and, 3:1341–1342

reterritorialization and, 2:722–724

social status and power accessibility and, 3:1339

socioeconomic transformations of, information

technology and, 1:365

- sovereignty concept and, 3:1340
space and time compression and, 3:1339
steel industry and, 5:2691–2692
technological change geographies and, 6:2781–2781
transborder activities and, 3:1339
transnationalization and denationalization in,
3:1338, 3:1339–1340
transportation and communications technology and, 3:1339
urban underclass and, 6:2998
See also Antiglobalization; European Union (EU); Glocalization
- Global positioning system (GPS), 3:1342–1344**
accuracy levels of, 3:1343
atmospheric moisture measured by, 1:160
data production technology of, 3:1257
definition of, 3:1342
differential GPS and, 3:1257
differential GPS (DGPS) and, 3:1343–1344
Federal Aviation Administration Wide Area Augmentation
System and, 3:1343
geoslavery and, 3:1255–1256
geospatial industry and, 3:1257
location-based services (LBSs) and, 4:1794–1796
media mapping and, 4:1951–1953
military applications of, 3:1257
Navigation Message bit stream and, 3:1343
origins of, 3:1342
Precise Positioning Service (PPS) of, 3:1343
real-time, code-phase DGPS and, 3:1343–1344
receiver coordinate location and, 3:1257
satellites' orbits and, 3:1343
Selective Availability degradation feature of, 3:1257
shoreline changes detected by, 1:496
Standard Positioning Service (SPS) of, 3:1343
U.S. Department of Defence (DoD) and, 3:1342
Wide Area Augmentation System (WAAS) and, 3:1257
See also Coordinate systems
- Global sea-level rise, 3:1344–1346**
anthropogenic climate change and, 1:90, 1:92
anthropogenic factors in, 3:1345
coastal seal-level change measures and, 3:1344–1345
coastal zone and marine pollution and, 1:500–501
El Niño-Southern Oscillation (ENSO) and, 1:497
glacial ice melt and, 1:90, 1:92, 3:1327, 3:1344
global glacial isostatic adjustment process and, 3:1345
greenhouse gas emissions and, 3:1346
Intergovernmental panel on Climate Change (IPCC) predictions
and, 3:1346, 5:2204
La Niña and, 1:497
linear trends in mean sea level, 1955–2003, 3:1345 (fig.)
Meltwater Pulse 1A, last deglaciation and, 3:1346
ocean-syphoning effect and, 3:1345
plate tectonics and, 1:494
Poles, North and South and, 5:2203–2209
satellite measurements of, 3:1344
spatial variability in patterns of, 3:1344
static sea-level change and, 3:1344
temporal fluctuations in, 3:1344
volcanic eruptions and, 3:1345
- Global South**
balance-of-payment crises and state indebtedness in, 4:1694
displaced persons and refugees from, 4:1895
ecofeminism and, 3:1195
feminist political ecology and, 3:1195–1196
income ratio relative to slum population, global
South countries, 5:2644 (fig.)
- megacities, global cities grown and, 4:1891
multiple social identities, race and, 3:1189
neoliberalism and, 4:2010–2015
population living on less than \$1 per day, 5:2275 (fig.)
postcolonial feminism and, 3:1191
- Global warming. *See* Anthropogenic climate change;**
Chlorofluorocarbons (CFCs); Greenhouse gases (GHG);
Stratospheric ozone depletion
- Globes. *See* Cartography; Map projections; Virtual globes**
- Glocalization, 3:1346–1348**
cultural geography and, 3:1347
definition of, 3:1346–1347
financial capital as productive capital and, 3:1347
globalization resistance and, 3:1348
local socioeconomic characteristics and trends and, 3:1347
McDonald's restaurant in New Delhi example of,
3:1347 (photo)
nation-state regulation weakening and, 3:1348
neoliberalism and, 3:1347–1348
spatial hybridity vision and, 3:1347
supranational governance institutions and, 3:1347
- GMOs. *See* Genetically modified organisms (GMOs)**
- Godwin, William, 4:1819, 4:2015**
- Goffman, Erving, 1:289**
everyday life as staging of drama and, 2:1043
Presentation of Self in Everyday Life written by, 2:1043
- Goldwater, Barry, 2:570**
- Golledge, Reginald, 3:1348–1349**
anchor point theory of spatial cognition and, 1:189
behavioral geography and disability geography work of, 3:1349
blindness and geography work of, 1:286–287
environmental perception work of, 2:977
navigational aids developed by, 1:286–287, 1:287 (photo)
research interests of, 3:1349
service work of, 3:1349
“spatial competence” achievement and, 1:286
- Good, I. J., 2:1059**
- Goodchild, Michael, 3:1349–1350**
academic career of, 3:1349
geolibrary development work of, 3:1234, 3:1235
GIS analytic operations work of, 1:71–72, 5:2604–2605
GIScience field defined by, 3:1285, 3:1349
location-allocation modeling work of, 4:1793
nongeographic Internet, Web 2.0 and, 4:2005
publications of, 3:1350
service work of, 3:1350
- Goode, J. Paul, 3:1350–1352**
academic career of, 3:1351
American cartography work of, 3:1350–1351, 3:1351, 5:2364
criticism of, 3:1351–1352
Goode's Interrupted Homolosine projection and,
3:1351, 3:1351 (fig.), 6:3169
Goode's World Atlas and, 3:1352
Richard Hartshorne influenced by, 3:1402
Mercator projection criticized by, 3:1351
service work of, 3:1351
- Google Earth, 3:1352–1355**
application programming interface (API) and, 5:2305
client-server architecture and, 1:426
DEM (digital elevation model) and, 3:1352, 3:1354 (fig.)
development of, 3:1352
environmental planning spatial analysis tools and, 2:981
functions of, 3:1352, 3:1353 (fig.)
GIS tool functions of, 3:1352, 3:1355
Google and, 3:1258

- Google data visualization tools and, 3:1259
 Google Maps and, 1:426, 2:981, 3:1211, 3:1259, 3:1478, 4:2006, 5:2305, 5:2611
 Google Map StreetView and, 3:1478, 4:2006
 humanistic GIScience and, 3:1478
 Keyhole Markup Language (KML) and, 3:1355, 3:1478, 3:1624, 4:2085
 layers of information provided by, 3:1352, 3:1355
 map animation and, 4:1826
 Mauna Kea from ocean floor in 3D and, 3:1354 (fig.)
 ocean floors viewed with, 3:1352, 3:1354 (fig.)
 real-time earthquakes viewed with, 3:1355 (fig.)
 search technology of, 3:1352
 spatial cognition and, 5:2611
 spatial data, interactive map features of, 3:1257, 3:1284
 as Web-based GIS *vs.* Internet GIS, 3:1620
- Gorbachev, Mikhail, 2:594
- Görg, Christoph, 2:838
- Goss, John, 2:575
- Gottmann, Jean, 3:1355–1356**
 idiographic to nomothetic traditions shift and, 3:1355–1356
Megapolis written by, 3:1355–1356
 spatial theory and, 3:1355
 state system work of, 5:2222–2223
 urban geography work of, 3:1355–1356
 Paul Vidal de la Blache and, 3:1355
- Gould, Peter, 3:1356–1357**
 academic career of, 3:1356
 AIDS geographies work of, 3:1356, 3:1357
 behavioral geography and, 1:189
 cognition and mental maps work of, 3:1356
 extreme geography and, 2:1074
 geographic philosophy issues work of, 3:1356
 David Ley and, 4:1777
 quantitative mathematical revolution work of, 3:1356–1357
 social geography and, 5:2566
Spatial Organization co-authored by, 3:1357
- Governance, 3:1357–1359**
 civil society and, 1:414–416, 3:1357
 collective action, common pool resources management and, 3:1358
 definition of, 3:1357
 different scales of, 3:1358
 environmental governance, 3:1357–1358
 formal institutions of, 3:1358
 governance of watershed example of, 3:1358
 human dimensions of global environmental change and, 3:1453
 intergenerational equity and, 3:1358
 Kyoto Protocol example of, 3:1358
 multilevel governance issues and, 3:1358
 public-private partnerships and, 5:2312–2313
 UN Millennium Development Goals and, 3:1358, 5:2220
- Governmentality and conservation, 3:1359–1360**
 commons *vs.* individual property rights and, 3:1359
 conservation zones and, 2:571–572
 environmental citizenship and, 3:1359–1360
 environmental management and, 2:967–970, 3:1359–1360
 Foucault's analytics of government and, 3:1359
 governable spaces, 3:1360
 governance and, 3:1357–1360
 governmentality and, 3:1360
 issues addressed by, 3:1359
 measurement and statistics tools of, 3:1360
 nonstate actors and, 3:1359
 power relations issues and, 3:1359–1360
 space and scale concepts in, 3:1360
See also Governance
- GPS. *See* Global positioning system (GPS)
- Gramsci, Antonio, 2:1029
 cultural hegemony and, 3:1419, 3:1420, 5:2230
 Fordism views of, 3:1149
 ideology, Marxism and, 4:1862, 5:2230
 Marxist economic determinism opposed by, 3:1419
- Grand Canyon, Arizona
 sediment data collection, Little Colorado River, 5:2552 (photo)
 water-riparian and riparian-desert scrub ecotones, 2:868 (photo)
- Grand Rapids, Michigan, 4:1821
- Grand Teton National Park, Wyoming, 4:2119 (photo)
- Grant, Ali, 2:619
- Graves, C., 3:1222 (cartoon)
- Gravity model, 3:1361**
 applications of, 4:1798
 criticism of, 3:1361
 definition of, 3:1361
 location theory and, 4:1798
 Newton's law of gravitation basis of, 3:1361, 4:1798
 Ravenstein's formulation and, 3:1361
 theoretical principle of, 3:1361
 Thünen model and, 4:1728, 4:1798, 4:1799 (fig.), 6:2832–2834
 types of, 3:1361
- GRD. *See* Ground reference data (GRD)
- Great American Exchange, 3:1361–1362**
 crops and livestock and, 3:1362
 definition of, 3:1361–1362
 disease transmission and, 3:1362
 ideas and people, 3:1362
Maps and the Columbian Encounter (Harley) and, 3:1401–1402
 plants and animals of, 3:1362–1363, 3:1362 (table)
- Greece
 acid rain in, 1:7
 AGILE membership of, 1:124 (table)
 aquaculture, fisheries in, 1:103 (photo)
 basin and range topography in, 1:186
 Corinth Canal, 6:2873 (photo)
 cultural nationalism in, 4:1980
 European Union (EU) membership of, 2:1035
 Herodotus and, 3:1421–1422
 marine aquaculture in, 4:1854 (fig.)
 Network of GMO Free Regions in, 3:1610
 remote sensing image of, 1:252 (photo)
- Greed, Clara, 2:1043–1044
- Greenbelts, 3:1363–1367**
 Britain's industrialization and urbanization and, 3:1363–1364
 contemporary greenbelts and, 3:1364–1365
 Council for the Preservation of Rural England (CPRE) and, 3:1363
 criticism of, 3:1365
 George Cruikshank, London and, 3:1363
 definition of, 3:1363
 Greenbelt, Maryland and, 3:1364
 Greenbelt movement, Kenya tree planting program and, 3:1610
 historical formation of, 3:1363–1364
 Ebenezer Howard, 3:1363
 London's Greenbelt and, 3:1363
 open space and, 4:2091–2094
 restricted development zoning and, 3:1365
 "ribbon" development restriction and, 3:1363
 role and purpose of, 3:1365
See also Green design and development
- Green building, 3:1367–1369**
 approaches to, 3:1367

- building certification systems flexibility and, 3:1368
- costs associated with, 3:1368
- criticism of, 3:1369
- definitions, 3:1367
- dimensions of, 3:1367
- energy-efficient measures in, 3:1368 (photo)
- global programs of, 3:1368–1369
- green collar job movement and, 3:1369
- high-performance buildings and, 3:1367
- historic preservation and, 3:1435–1436
- issues addressed by, 3:1367
- Leadership in Energy and Environmental Design (LEED) and, 3:1367, 3:1368–1369
- U.S. Green Building Council (USGBC) and, 3:1367
- See also* Greenbelts; Green design and development
- Green design and development**, 3:1369–1373
 - as appropriate technology, 3:1369–1370
 - autonomy and communality and, 3:1372
 - bionics, biomimicry, biomimetics and, 3:1372
 - deep green design and, 3:1372–1373
 - designers of, 3:1370
 - design for need movement and, 3:1370
 - design for the real world (Papanek) and, 3:1372
 - dweller control over house-building and, 3:1373
 - ecological modernist perspectives on, 3:1372
 - environmentally friendly products and, 3:1370–1371
 - environmental resource and impact dimensions of, 3:1370
 - government and corporate involvement in, 3:1372
 - greenbelts and, 3:1363–1367
 - green capitalism, 3:1370–13722
 - Intermediate Technology Development Group and, 3:1370
 - international green developments and, 3:1371
 - landscape architecture and, 4:1700
 - light green design and development and, 3:1369–1372
 - low-carbon design and eco-housing development in, 3:1371–1372
 - Our Common Future* (Brundtland Report) and, 3:1370, 6:2747
 - self-reliance and communality emphasis of (Kropotkin and Owen) and, 3:1372
 - Small Is Beautiful* (Schumacher) and, 3:1370
 - smart growth planning and, 3:1371, 3:1372, 5:2240
 - sustainable communities and, 3:1371
 - sustainable development and, 3:1370–1371, 3:1372–1373
 - techniques of, 3:1370–1371
 - technology advances element in, 3:1370
 - See also* Green belts; Green building; Green design and development: noted individuals
- Green design and development: noted individuals**
 - Peter Kropotkin, 3:1372
 - Arthur Mol, 3:1369
 - Arne Næss, 3:1369
 - Robert Owen, 3:1372
 - Victor Papanek, 3:1372
 - David Pepper, 3:1372
 - Ernst Schumacher, 3:1370, 3:1372
 - Gert Spaargaren, 3:1369
- Greene, William, 1:81
- Greenhouse gases (GHGs)**, 3:1373–1380
 - acid rain, greenhouse gas trading and, 1:7
 - agricultural contributions to, 2:938, 2:939
 - alternative fuels and, 3:1375
 - ancient ice cores study and, 3:1374
 - anthropogenic climate change and, 1:84–85, 1:86 (fig.)
 - anthropogenic fossil fuel, energy factors and, 3:1374–1375
 - atmospheric moisture and, 1:148
 - atmospheric pollution and, 1:151–155, 1:152
 - built environment energy demand and, 3:1375–1376
 - carbon capture, storage, sequestration control strategies and, 3:1377
 - carbon cycle and, 1:325–329, 2:945
 - carbon footprint concept and, 2:570–571
 - carbon markets, carbon trading and, 1:331 (table)
 - chlorofluorocarbons and, 1:400–401, 2:984
 - climate change and, 1:461
 - climate policy and, 1:462–464
 - coal-generated electricity and, 3:1377–1378
 - corporate greenhouse, core countries and, 5:2220–2221
 - CO₂ sources and their control in, 3:1375–1377
 - developed *vs.* developing countries comparisons and, 3:1377
 - energy end-use efficiency control strategy and, 3:1375–1376
 - F-gases and, 3:1374
 - functions of, 3:1373
 - global scale of, 2:984
 - global sea-level rise and, 3:1346
 - greenhouse gas trading between nations, Kyoto Protocol and, 3:1374, 4:1857
 - hydrogen to supplant hydrocarbon fuels and, 3:1377
 - ice melt and, 3:1524
 - increase in, climate change adaptation and, 1:9, 1:11
 - industrial sector and, 3:1376
 - institutional framework, 3:1374
 - International Panel on Climate Change and, 3:1374
 - land use and cover change impact on, 4:1736
 - low-carbon energy supply control strategy and, 3:1376–1377
 - low-emission fossil fuel technologies and, 3:1377
 - manufacturing and, 2:945
 - mitigation options, 3:1375–1377
 - Montreal Protocol on Substances that Deplete the Ozone Layer and, 3:1374
 - naturally occurring *vs.* anthropogenic GHGs and, 3:1373
 - nuclear fission, 3:1377
 - oil fields and, 2:947
 - ozone-depleting substances and, 3:1374
 - permafrost degradation and, 4:2156
 - photochemical smog and, 4:2171–2173
 - radioactive forcing and climate sensitivity to, 3:1374–1375, 3:1375 (fig.)
 - regional trends in, 3:1379
 - tourism industry and, 2:954–955
 - UN Framework Convention on Climate Change and, 1:9, 2:462, 2:945, 3:1374, 5:2220, 5:2244, 6:2748–2749
 - urban geography of emissions and, 3:1377–1379
 - U.S. GHG emissions by type and source, 3:1376 (fig.)
 - water vapor, atmospheric energy transfer and, 1:141
 - See also* Adaptation to climate change; Anthropogenic climate change; Carbon trading and carbon offsets; Climate policy
- Greenland**
 - Atlantic Multi-decadal Oscillation and, 1:165
 - climate change adaptation research in, 1:9
 - fjords in, 3:1121
 - glacial/interglacial cycles in, 1:457
 - Greenland Ice Sheet and, 3:1325 (fig.)
 - Ice Ages and, 1:457
 - ice cap of, 3:1336
 - ice sheets, rising temperatures and, 1:92, 1:462, 3:1344, 3:1522, 3:1524, 3:1526, 5:2204–2005, 5:2206 (fig.)
 - ice streams in, 3:1326
 - Jakobshaven Isbrae glacier, west coast and, 5:2205
 - musk ox faunal relict in, 1:470
 - polar climate in, 1:449, 1:450
 - polar semidesert in, 1:249

- precipitation in, 1:450–451
 surface meltwater draining to glacier bottom and, 5:2205
 tundra, Zackenberg valley, 1:250 (photo)
 tundra vegetation in, 1:248 (table)
 Viking exploration of, 2:1051
 wet tundra of, 1:249
- Greenpeace, 1:96, 3:1612
- Green Revolution
 agricultural intensification controversy and, 1:35, 2:939
 agrochemical pollution of, 1:52
 “blue revolution” (aquaculture) and, 1:103–104
 greater food availability from, 5:2241
 herbicides and pesticides environmental impact and, 2:939
 indigenous agriculture *vs.*, 3:1555–1556
 pesticide nutrient loading and, 2:939
 small farmer agrobiodiversity affected by, 1:50
- Gregory, Derek, 3:1380–1382
Colonial Present (written by), 3:1381
Geographical Imagination written by, 3:1380–1381
 geographical imagination work of, 3:1221
 humanistic geography focus of, 3:1380
 Orientalism views of, 3:1381, 4:1787, 4:2103
 politics of representation and, 3:1381
 postcolonial work of, 3:1381
 postmodernism and, 3:1380
 research areas of, 3:1380
 spatial diffusion work of, 3:1380
 spatiality of U.S. human rights abuses and, 3:1381
 structuration theory and, 5:2710
 Western imaginative geographies and, 3:1381
- Gregson, Nicky, 1:290, 3:1189
- Grenada, Cold War and, 1:504, 1:505
- Grey, Lewis, 4:2040, 4:2041
- Griffin, Susan, 2:817
- Gross domestic product/gross national product (GDP/GNP), 3:1382–1384
 definitions, 3:1382
 GDP per capita and, 3:1382, 3:1383 (fig.), 3:1384
 limitations of, 3:1382, 3:1384
 newly industrializing countries and, 4:2021–2024
 spatial characteristic of, 3:1382
 world’s GDP (2007) and, 3:1382, 3:1383 (fig.)
- Grosvenor, Gilbert, 3:1463, 4:1977
- Grotius, Hugo, 4:2066, 5:2252
- Ground reference data (GRD), 3:1384–1385
 calibration and validation processes of, 3:1384
 continuous data, 3:1384
 error and uncertainty in, 3:1384
 error propagation and, 2:1011–1012
 forms of data and, 3:1384
 functions of, 3:1384
 geocoding and, 3:1208–1209
 ground truth data and, 3:1384
 in situ *vs.* drive-by mapping data collection and, 3:1384
 remote sensing products and, 3:1384
 thematic data, 3:1384
- Groundwater, 3:1385–1390
 active *vs.* deep groundwater and, 3:1386
 agrochemical pollution of, 3:1387
 anthropogenic pollution sources and, 3:1387–1388
 aquifers and aquifer properties and, 3:1386–1386, 3:1387, 3:1389
 artesian wells and, 3:1385
 carbonation and, 1:325
 caverns formation and, 1:366–368, 1:367 (photo)
 chlorinated hydrocarbons (CHCs) and, 1:396–400
 definition of, 3:1385
 drawdown and cone of depression extraction effects of, 3:1385
 extraction methods and, 3:1386
 flow of, 3:1138
 geographical distribution and importance of, 3:1385, 3:1386
 groundwater-based agriculture and, 3:1387
 groundwater hydrology and, 3:1385–1386
 groundwater mining or fossil groundwater extraction and, 3:1387
 human-environment interactions involving, 3:1389
 human organization, management, and policy, 3:1388–1389
 hydrology and, 3:1513–1518
 karst topography and, 4:1649–1654
 legal frameworks, 3:1389
 mathematical modeling approaches to, 3:1386
 mechanized pumps extraction method, 3:1386
 ocean-aquifer interactions and, 3:1386
 pathogenic microorganisms pollution of, 3:1387–1388
 physical characteristics of, 3:1385–1386
 pollution of, 3:1387–1388
 pollution remediation and, 3:1388
 qanats extraction method, 3:1386
 rural electrification programs and, 3:1387
 saline-freshwater interface and, 3:1386
 salinity issue and, 3:1388
 soil moisture and, 3:1385
 sustainable aquifer management and, 3:1389
 technology factors and, 3:1388
 tragedy of the commons concept and, 3:1388
 transboundary aquifers and, 3:1389
 use of, 3:1386–1387
 water logging condition of, 3:1388
 water table and, 3:1385
See also Rivers; Water pollution
- Growth machine, 3:1390–1391
 American exceptionalism notion and, 3:1390
 communities as instruments of profit and, 3:1390
 conflicts, 3:1390
 doctrine of value-free development and, 3:1390
 local business elites as primary actors in, 3:1390
 pervasiveness of, 3:1390
 urban planning as a “rational science” and, 3:1390
- Growth poles, 3:1391–1392
 definition of, 1390:1391
 disadvantages of, 3:1391
 regional development, 3:1391
 regional growth pole theory (Perroux) and, 2:730, 3:1391
 supporters of, 3:1391
 trickle-down effects issue, 3:1391
 unequal regional development and, 3:1391
See also Growth poles: noted scientists
- Growth poles: noted scientists
 Albert Hirschman, 3:1391
 Gunnar Myrdal, 3:1391
 François Perroux, 3:1391
 Michael Porter, 3:1391
- GSNs. *See* Geosensor networks (GSNs)
- Guadeloupe, 1:512
- Guam
 coral reef, Mariana Islands, 2:582 (photo)
 human-induced invasion of species in, 3:1474
- Guantánamo Bay military prison, 1:25
- Guatemala
 Cold War and, 1:504

- communal land ownership in, 2:552
 Conference of Latin Americanist Geographers held in, 2:568
 deforestation in, 2:696
 economically active females in, 3:1190 (table)
 human rights violations in, 3:1480
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
 indigenous identities manipulation studies in, 3:1101
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Internet links illegal in, 2:750
 land inequalities in, 4:1693
 marine aquaculture in, 4:1854 (fig.)
 sediment erosion in, 3:1334
 soil erosion in, 5:2585
 trading blocs and, 3:1550
 Guattari, Felix, 2:649, 2:722, 4:2070
 Guinea
 economically active females in, 3:1190 (table)
 Negritude movement and, 2:1029
 tropical rain forest of, 1:453
 Guinea-Bissau, 1:402, 3:1190 (table)
 Gulf of Mexico, dead zone in, 1:207, 1:486, 1:487 (photo), 1:488, 2:939
Gully erosion, 3:1392–1394
 causes of and factors in, 3:1392–1393
 definition of, 3:1392
 ephemeral and permanent erosion and, 3:1392–1393
 ephemeral gully erosion, Western Iowa, 5:2465 (photo)
 on-site and off-site damages from, 3:1393
 prevention and control of, 3:1393
 socioeconomic problems resulting from, 3:1393
 in southeast Spain, 3:1392 (photo), 3:1393 (photo)
 velocity measurement of, 3:1393
 Gunderson, Lance, 5:2439
 Guyana
 economically active females in, 3:1190 (table)
 open-pit Elizabeth Gold Mine, Mahdia, 4:2087 (photo), 4:2088 (photo)
 tropical rain forest of, 1:234
Guyot, Arnold, 3:1394
 Louis Agassiz's influence on, 3:1394
 alpine glaciation research of, 3:1394
 geography education reform views of, 3:1394
 physical geography work of, 3:1394
 Carl Ritter and, 3:1394
 teleological views of, 3:1394
 GWR. *See* Geographically weighted regression (GWR)
 Habermas, Jürgen, 4:1754
 communicative action, 2:548, 4:2043
 public sphere work of, 2:541
 Hack, John T., 3:1275
 Hadley, George, 1:132
Hadley cell, 3:1395–1397
 Atlantic tropical cyclones and, 3:1397
 Bermuda High and Pacific High elements of, 3:1397
 components of, 3:1396 (fig.)
 definition of, 3:1395
 El Niño-Southern Oscillation (ENSO) and, 2:888, 3:1397
 energy transfer element in, 3:1397
 idealized global circulation and, 6:3105 (fig.)
 Intertropical Convergence Zone (ITCZ) or equatorial low, 3:1395–1397, 6:2832
 La Niña and, 4:1755
 meridional overturning atmospheric circulation model of, 3:1395
 Northeast and Southeast trade winds and, 3:1395, 3:1396 (fig.)
 potential widening of, 3:1397
 seasonal precipitation variations and, 3:1396
 subtropical jet stream at poleward edge of, 3:1395
 surface flow from poles to equator and, 3:1395, 3:1396 (fig.)
 Haackel, Ernst, 2:666, 5:2366
Hägerstrand, Törsten, 3:1397–1399
 Anne Buttmer's collaboration with, 3:1398
 diffusion of innovations research of, 3:1397, 3:1398, 4:1799, 5:2329
 GIS developments and, 3:1312
 human geography contributions of, 3:1397–1399
 individual behavior in space and time research of, 3:1397
 Monte Carlo simulation technique of, 3:1397, 3:1399
 population movements research of, 3:1397, 3:1398
 projects of daily life and, 2:1044
 quantitative methods in geography work of, 5:2327, 5:2329
 service work of, 3:1398–1399
 spatial diffusion work of, 3:1397, 3:1398, 3:1399, 4:1799
 time-geography work of, 1:5, 1:288, 1:321, 2:1043, 2:1044, 3:1312, 3:1398, 3:1399, 4:1905, 5:2289, 5:2654, 6:2837–2839
Haggett, Peter, 3:1399–1400
 academic career of, 3:1399
 infectious diseases geographies focus of, 3:1399–1400
 Locational Analysis in Human Geography written by, 3:1400
 Network Analysis in Geography (Haggett and Chorley), 4:2017
 publications of, 3:1400
 quantitative methods and location analysis work of, 3:1399, 3:1400, 4:2017
 urban and regional geography work of, 3:1399, 3:1466
 Hahn, Carole, 1:479
 Hahn, Eduard, 2:782
 Haining, R. R. P., 2:1060
 Haiti
 economically active females in, 3:1190 (table)
 French colony of, 1:512
 HIV/AIDS in, 3:1438
 humanitarian assistance, hurricane relief operations in, 3:1487 (photo)
 2010 earthquake in, 2:813
 undernourishment in, 3:1488
 Hajer, Maarten, 2:836–837
 Half Dome, Sierra Nevadas, 3:1354 (fig.)
 Hall, James, 3:1409
 Hall, Peter, 4:1987
 Hall, Stuart, 3:1142, 3:1528
 Halling, Crawford, 5:2437–2438
 Halloway, S., 5:2345
 Handicap International, 1:96
Hanson, Susan, 3:1400–1401
 academic career of, 3:1400
 critical human geography work of, 2:618
 Gender, Work, and Space written by, 3:1401
 gendered geographies work of, 3:1189, 3:1400, 3:1401, 3:1468
 mixed-methods research of, 3:1401
 “On Not Excluding Half the Human in Human Geography”
 essay co-written by, 2:618
 publications of, 3:1400–1401
 service work of, 3:1400
 urban labor markets and urban transportation work of, 3:1400, 3:1401
 Haraway, Donna, 2:649, 3:1097, 3:1100
 Harcourt, Wendy, 3:1101
 Hardin, Garrett, 2:925
 “lifeboat ethics” and, 4:1820
 tragedy of the commons work of, 1:525–526, 1:529, 1:532, 1:533–535, 2:779

- Harding, Sandra, 3:1097
- Harkey, D., 2:777
- Harley, Brian, 3:1401–1402**
 academic career of, 3:1402
 books written by, 3:1402
 history of cartography focus of, 3:1401–1402, 3:1563
Maps and the Columbian Encounter published by, 3:1401–1402
- Harness, Henry Drury, 3:1138
- Harris, Chauncey, 1:389, 1:389 (fig.)
- Harris, Cole, 3:1431
- Harris, Trevor, 5:2304
- Harrison, Richard, 5:2364
- Harrower, Mark, 4:1826
- Hart, Roger, 1:392
- Hartmann, Betsy, 3:1100
- Hartmann, Heidi, 4:2136
- Hartshorne, Richard, 3:1402–1404**
 academic career of, 3:1402
 “areal differentiation,” 3:1403, 3:1531, 5:2387–2388
 as Association of American Geographers president, 3:140
 chorology work of, 1:405, 3:1402, 3:1403, 3:1423,
 3:1465–1466, 3:1531
 empiricist geography work of, 2:893, 3:1429, 3:1465–1466,
 4:1801, 5:2326
 geopolitics of Nazism and, 3:1250
 Alfred Hettner and, 3:1402, 3:1423, 3:1465, 5:2387
 Immanuel Kant’s influence on, 3:1402, 3:1403, 4:1649
 location served as form of explanation views of, 1:405
 logical positivism and, 3:1403, 5:2388
 Midwest agricultural, urban, and economic landscapes
 focus of, 3:1402
Nature of Geography written by, 2:849, 3:1403, 5:2387, 5:2433
 oceans views of, 4:2065
 regions as mental concepts views of, 1:405, 3:1403, 3:1429,
 3:1465–1466, 3:1531, 5:2387–2388, 5:2433
 Carl Ritter and, 5:2471
 Fred Schaefer’s criticism of, 1:405, 3:1403, 3:1466, 4:1801,
 5:2326, 5:2388, 5:2511
 spatial determinism and, 1:405, 3:1403
- Harvest management. *See* Adaptive harvest management
- Harvey, David, 3:1404–1406**
 absolute space defined by, 5:2403
 academic career of, 3:1404
 accumulation by disposition, 4:2138
 Brian Berry conflict with, 1:193
 books written by, 3:1405–1406
 capitalist accumulation and crisis work of, 2:849, 3:1467,
 4:2138, 5:2265
 cities as postmodern objects, 5:2268
Condition of Postmodernity written by, 3:1405, 5:2265, 5:2268
Explanation in Geography written by, 3:1404
 geographical explanation of capitalist crisis dynamics and,
 2:609–610
 governmentality and conservation, 3:1360
 historical materialism work of, 3:1404, 3:1467, 4:1862, 5:2638
 human geography work of, 3:1404
 Henri Lefebvre and, 4:1769, 5:2297, 5:2403
Limits to Capital written by, 2:609, 4:1862, 5:2350–2351
 Marxism political economy work of, 3:1404, 3:1405,
 3:1467, 4:1862, 4:2138, 5:2350, 5:2403, 5:2442,
 5:2567, 5:2638, 5:2669
 mixed methods used by, 3:1404
 nature in capitalism context work of, 2:851
 neoliberalism criticized by, 4:2013
 population-resource theory views of, 4:1820
- positivism in geography views of, 3:1404
- postmodern geography work of, 3:1469, 5:2264, 5:2265, 5:2268
- power and cultural symbolism and, 1:106–107
- quantitative revolution role of, 3:1404
- radical geography and, 2:618
- relational space defined by, 5:2403
- relative space defined by, 5:2403
- RGS award of, 5:2487
- Neil Smith and, 5:2551
- social geography work of, 5:2567, 5:2574
- Social Justice and the City* written by, 2:618, 3:1405, 3:1467,
 4:1862, 5:2350, 5:2442, 5:2551, 5:2567
- social justice movement and, 3:1404–1405
- social reproduction work of, 3:1404
- space and place research of, 3:1404–1405, 3:1467, 4:1862,
 5:2458, 5:2669
- spaces of representation and, 5:2602
- spatial fix, 3:1467, 4:1862, 5:2638–2640
- spatial variation work of, 3:1404
- time, space, and space-time themes of, 3:1404, 3:1467, 4:1788,
 4:1862, 5:2297, 6:2844
- urban underclass explained by, 6:2998
- violent globalization and, 1:96–97
- Richard Walker and, 6:3043–3044
- Harwood, R., 1:54
- Hate, geographies of, 3:1406–1407**
 “center-margin” identities and, 3:1406
 genocide geographies and, 3:1199–1202
 “inside” societal norms, boundaries and, 3:1406
 “marginalized” identities and, 3:1406
 neo-Confederate movement example of, 3:1407
 proliferation of, 3:1407
 Southern Poverty Law Center tracker of hate groups and,
 3:1406–1407
 unequal power relations and, 3:1406
- Haushofer, Karl, 3:1407–1408**
 geopolitical teaching and writing of, 3:1407–1408, 3:1464
 German prosperity after WWI views of, 3:1249–1250
 Germany expansionist views of, 3:1408, 5:2222
 Rudolf Hess and, 3:1408
 journal of geopolitics created by, 3:1249
 Nazism and, 3:1407–1408, 5:2222, 5:2366
 pan-region organization of world and, 3:1250, 5:2222
 Friedrich Ratzel and, 5:2366
 spatial relationships of countries focus of, 3:1250
- Hawai’i
ahupua’a watershed management system in, 3:1575
 atmospheric carbon dioxide levels measured in,
 1:82, 1:83 (fig.)
 avian extinctions from, 3:1630
 Big Island hot spot volcano in, 4:1688
 Captain James Cook’s exploration of, 2:576
 Hawai’i fruit fly area wide pest management program and,
 4:2160 (photo)
 high island geography of, 3:1634–1635
 Malayo-Polynesian languages in, 4:1753, 4:1753 (fig.)
 mass wasting processes on Hawaiian Islands and, 4:1689
 volcanic islands of, 3:1273
- Hawley, Amos H., 3:1458
- Hayami, Yujiro, 6:2737
- Hayden, D., 2:1075
- Hayden, Ferdinand, 3:1408–1409**
 explorations of, 3:1408–1409
 geologic reconnaissance skills of, 3:1409
 Missouri valley stratigraphy work of, 3:1409

- Hayek, Friedrich
 collective forms of social and economic organization
 and, 4:2011
 development theory and, 2:730
 division of labor, division of knowledge views of, 2:781
 free markets views of, 4:2011
Road to Serfdom written by, 4:2011
- Hayford, Alison, 2:618
- Haynes, Kingsley, 5:2395–2396
- Hays, J. D., 2:711
- Hazardous waste
 landfills and communities of color and, 2:960, 2:961 (photo)
 laws and, 2:966
 transboundary hazardous waste dumping and, 1:384
See also Chemical spills, environment, and society;
 Landfills; Love Canal
- Health and health care, geography of, 3:1409–1414**
 cancer geography and, 1:320–324
 caregiving process and, 3:1414
 cholera and, 1:401–403
 collaborative GIS application and, 1:507 (fig.)
 composition factors in, 3:1411
 contextual factors in, 3:1411, 3:1411 (table)
 definitions, 3:1409
 degenerative diseases and, 3:1410
 devolution policies and, 3:1414
 disability geographies and, 2:757–759
 economic development factors and, 3:1410
 elderly geographies and, 2:877–878
 environmental hazards issues and, 3:1412
 environmental justice issues and, 3:1412
 formal health care and, 3:1412–1414
 GIS health care applications and, 3:1300–1302
 global geographic health inequalities and, 3:1410, 3:1410 (fig.)
 global scale of, 3:1413
 health and medical climatology and, 1:473
 Health Insurance Portability and Accountability Act (HIPAA)
 and, 2:771–772
 health policy changes and, 3:1413–1414
 health transition model of, 3:1410
 home and community settings of, 3:1414
 humanly created conditions and, 3:1410
 informal care and, 3:1414
 land use and cover change impact on, 4:1736–1737
 life expectancy by country (2008) and, 3:1410 (fig.)
 location of health services factor in, 3:1412
 mental health services, deinstitutionalization and, 3:1413–1414
 national scale of, 3:1413
 place role in, 3:1411–1412
 primary *vs.* secondary *vs.* tertiary services and, 3:1412
 privatization and, 3:1413–1414
 public funded providers and, 3:1413
 regional and local geographic health inequalities, 3:1411
 rural area health services and, 3:1413
 service need and geographical accessibility
 relationship and, 3:1413
 territorial organization of health care and, 3:1412–1413
 therapeutic landscapes and, 3:1412
 “transformation to wellness,” landscape interactions and, 3:1412
 uneven geographies of, 3:1409
 unhealthy landscapes and, 3:1412
See also Blindness and geography; Carcinogens; Disease,
 geography of; Drugs, geography of; GIS in health research
 and health care; HIV/AIDS, geography of
- Health and medical climatology, 1:473
- Heavy metals as pollutants, 3:1415–1418**
 adverse health effects of, 3:1417
 agrochemical pollution and, 1:51–53
 anthropogenic sources of, 3:1415
 in aquatic sediments, 3:1416–1417
 aquatic sediment standards and, 3:1418
 atmospheric deposition and, 3:1416
 atmospheric emissions of lead and, 3:1415
 beneficial effects of, 3:1417
 bioaccumulation and, 3:1417
 chemical spills, environment, and society and, 1:382–384
 daily provisional tolerable intake values and, 3:1418
 definition issues and, 3:1415
 density, atomic weight, atomic number parameters of, 3:1415
 environmental distribution of, 3:1415–1417
 Industrial Revolution and, 3:1415
 lead exposure, 3:1415, 3:1417, 3:1418
 mercury exposure, 3:1415
 Norilsk Nickel’s copper plant, Russia, and, 3:1416 (photo)
 in organisms, 3:1417
 plant health standards and, 3:1418
 in plants, 3:1417
 regulatory limits, 3:1417–1418
 in soils, 3:1417
 sources of, 3:1415
 toxicity parameter of, 3:1415
 toxic metals or trace metal, 3:1415
 in water, 3:1416
 water quality standards and, 3:1418
 wet or dry deposition of, 3:1416
- Heckscher, Eli, 2:557, 2:1065, 5:2395
- Hegel, Georg Wilhelm Friedrich
 development of rational consciousness doctrine of, 3:1433
 historical circumstances and, 3:1433
 phases of history, 3:1433
 social evolution theory of, 2:729
 time synonymous with change and, 3:1433
- Hegemony, 3:1418–1420**
 consent element of, 3:1418–1419
 construction of commemorative places and, 3:1419
 counter hegemonic movements and, 3:1419
 cultural hegemony (Gramsci) and, 3:1419, 5:2230
 definition of, 3:1418–1419
 global scale of, 3:1419
 maintaining hegemony (Gramsci) and, 3:1420
 Marxism origins of, 3:1419
 national scale inequalities and, 3:1589
 neo-Marxist critique of ideology and, 3:1419
 prime modernity and, 3:1419
 social construction of space and place and, 3:1419
 social production of space concept (Soja and Lefebvre)
 and, 3:1419
 U.S. and, 3:1420
See also Hegemony: noted individuals
- Hegemony: noted individuals
 John Agnew, 3:1420
 Stuart Corbridge, 3:1420
 Tim Cresswell, 3:1419
 Antonio Gramsci, 3:1419, 3:1420, 5:2230
 Ernesto Laclau, 3:1419, 3:1420
 Henri Lefebvre, 3:1419
 Herbert Marcuse, 3:1419
 Chantal Mouffe, 3:1420
 Neil Smith, 3:1420
 Edward Soja, 3:1419

- Peter Taylor, 3:1419
Immanuel Wallerstein, 3:1419
- Heidegger, Martin
appropriation for lived environmental ethic and, 5:2410
“being in the world,” 2:1046, 4:2042
existential phenomenology work of, 2:1046, 3:1467, 4:2166
Edward Relph and, 5:2410
- Heilbroner, Robert, 4:1805
- Heisenberg, Werner, 5:2324
- Henry, Nick, 1:482
- Herbicides, 3:1420–1421**
classification of, 3:1421
cost-effectiveness of, 3:1420–1421
environmental impact of, 2:939
pesticides and, 4:2157–2158
as pesticide subclass, 3:1420
synthetic organic herbicide development and, 3:1421
toxicity to humans and animals of, 3:1421
- Herbst, Jeffrey, 5:2217
- Herodotus, 3:1421–1422**
Egypt as “the gift of the Nile,” 3:1422, 3:1460
ethnicity focus of, 3:1421–1422
father of ethnography and of history, 3:1422
geography and history and, 5:2215
Greek ethnocentrism of, 3:1422
Histories written by, 5:2215
- Hess, Rudolf, 3:1408
- Hettner, Alfred, 3:1422–1423**
academic career of, 3:1422
chorology work of, 1:404, 5:2387
constitutive role of culture and, 3:1423
environmental determinism criticized by, 3:1423
fieldwork emphasis of, 3:1422
Richard Hartshorne influenced by, 3:1402, 3:1423, 3:1465, 5:2387
humans and the environment focus of, 3:1422
influences on, 3:1422
Immanuel Kant’s influence on, 3:1422, 4:1649
methodology focus of, 3:1423
organic analogies of the Earth views of, 2:667
regional synthesis work of, 3:1423, 3:1465
relational views of space and, 3:1422
- Heuristic methods in spatial analysis, 3:1423–1425**
Bayesian statistics in spatial analysis and, 1:187–188
evolutionary algorithms and, 3:1424
exact methods *vs.*, 3:1423
function of, 3:1423–1424
“greedy” heuristic methods, 3:1424
metaheuristic methods, 3:1424
spatial analysis use of, 3:1424
- High-performance computing (HPC), 3:1425–1426**
advantages of, 3:1425
Beowulf-style cluster and, 3:1425
cluster computing and, 3:1425
definition of, 3:1425
for floating point operations (FLOPS), 3:1425
geocomputation and, 3:1211–1215
Geosciences Network (GEON) and, 3:1425
GIS grid projects and, 3:1425
grid computing and, 3:1425
limits of, 3:1425–1426
parallel computing as mainstream of, 3:1425
serial to parallel-processing migration and, 3:1425
service-oriented architecture (SOA) platform of, 3:1425
software programming models used in, 3:1425
- High technology, 3:1426–1427**
definition of, 3:1426
- “enabling” industries and, 3:1426
flexible production and, 3:1126–1127
geographic distribution of, 3:1426
industrial contexts of, 3:1426
locational factors, 3:1426
public policy strategies, 3:1426–1427
research and development use of, 3:1426
Silicon Valley, California, 3:1427 (photo)
small production footprints characteristic of, 3:1426
See also Electronics industry, geography of
- Hill, Christopher, 5:2441
- Hinchliffe, Steve, 4:1996
- Hipparchus, 3:1428**
cartography and astronomy work of, 3:1428
equatorial calculations of, 3:1428
gnomon used by, 3:1428
instrumentation used by, 3:1428
longitude and latitudes calculated by, 3:1428, 3:1460, 5:2300
precession of the equinoxes and, 2:1009–1010, 3:1428
solar year calculated by, 3:1428
stereographic projection developed by, 3:1428
- Hispaniola Spanish colony, 1:512
- Historical geography, 3:1428–1433**
Capital’s Utopia (Mosher) and, 3:1431
consistencies within, 3:1429
cultural landscapes (Sauer, Berkeley School), 3:1429
cultural turn and, 3:1404, 3:1429
definition of, 3:1428
early historical geography, 3:1429
environmental determinism and, 3:1428–1429
everyday life geographies (Meinig) and, 3:1430
feminist geography and, 3:1430–1431
French Annales School of history and, 1:79–80
historical materialist geography and, 3:1430
humanism, historical materialism, and postmodernism and, 3:1430
journals of, 3:1432
Lie of the Land (Mitchell) and, 3:1430, 4:1913–1914
Marxist geography and, 3:1430
as a methodology (Clark), 3:1428
new critical historical geography issues and, 3:1428, 3:1429–1431
“new” cultural geography and, 3:1430
positivism and, 3:1429
postmodernism and, 3:1404
power relations issues and, 3:1430–1431
practice of, 3:1431
production of space issues and, 3:1430–1431
quantitative revolution and, 3:1429, 3:1432
regional geography (Clark) and, 3:1429
regional narratives and, 3:1429
relevance of, 3:1431–1432
Shaping of America (Meinig) and, 3:1430, 4:1879–1880
social identity issues and, 3:1430–1431
social production of space and, 3:1431
socio-spatial relations of the production of space and, 3:1430
theory of sequent occupance (Whittlesey), 3:1429
timeline of 1890s–1920s, 3:1429
timeline of 1920s–1950s, 3:1429
timeline of 1950s–1970s, 3:1429
timeline of 1970s: new critical historical geography, 3:1429–1430
timeline of 1980s: new cultural geography, 3:1930–1931
See also Environmental history; Historical geography: noted geographers, historians, scholars
- Historical geography: noted geographers, historians, scholars
Andrew Clark, 1:416–417, 3:1428, 3:1429
Henry Clifford Darby, 2:664–665
Mona Domosh, 3:1431

- Caerville Earle, 2:809–810
 Brian Harley, 3:1401–1402
 Cole Harris, 3:1431
 Richard Hartshorne, 3:1429, 5:2387–2388
 David Harvey, 3:1430
 Ellsworth Huntington, 3:1429, 3:1464, 4:1990, 4:1991
 Donald Meinig, 3:1430, 3:1431–1432, 4:1879–1880
 Don Mitchell, 3:1430, 3:1431, 4:1863, 4:1913–1914
 Carl Sauer, 3:1429, 3:1464, 3:1465, 5:2433
 Fred Schaefer, 3:1429, 3:1466
 Ellen Churchill Semple, 3:1429, 5:2531–2532
 Derwent Whittlesey, 3:1429
- Historicism, 3:1433–1434**
 definition of, 3:1428
 Enlightenment, Orientalism and, 3:1434
 Eurocentrism of, 3:1434
 “evolution” and “progress” (Spencer) and, 3:1434
 linear zed time and marginalized space and, 3:1433
 origins of, 3:1433
 post-positivism and, 3:1434
Poverty of Historicism (Popper) and, 3:1434
 time-space compression theme in, 3:1433
See also Historicism: noted individuals
- Historicism: noted individuals
 Nicolas de Condorcet, 3:1433, 4:1819
 Michel Foucault, 3:1433
 Georg Hegel, 3:1433
 Immanuel Kant, 3:1434, 4:1647–1649
 Karl Marx, 3:1433–1434
 Karl Popper, 3:1434
 Edward Soja, 3:1433, 5:2593
 Herbert Spencer, 3:1433, 3:1434
 Arnold Toynbee, 3:1433, 3:1434
- Historic preservation, 3:1434–1436**
 built environment and, 3:1435
 critics of, 3:1436
 definition of, 3:1434
 economics, sustainability, and lace making issues in, 3:1435–1436
 “green” building standards and, 3:1435–1436
 historic row houses, Capitol Hill, Washington, D.C., 3:1435 (photo)
 issues of, 3:1434–1435
 “Main Street” program, National Trust for Historic Preservation and, 3:1435–1436
 National Register of Historic Places and, 3:1436
 sociocultural values and, 3:1436
 standards for, 3:1436
 terms associated with, 3:1434
- Historic preservation: noted cultural, humanistic geographers
 Henry Glassie, 3:1435
 J. B. Jackson, 3:1435
 Fred Kniffen, 3:1435
 David Lowenthal, 3:1435, 3:1476
 David Seamon, 3:1435, 4:2168
 Yi-Fu Tuan, 3:1435, 3:1476
- HIV/AIDS, geography of, 3:1436–1439**
African AIDS Epidemic (Iliffe) and, 3:1437
 antiretroviral therapy for, 3:1438
 drug geographies and, 2:799
 “the gay plague” description of, 3:1438
 global HIV infection and, 2:770 (fig.)
 Peter Gould’s work in, 3:1356, 3:1357
 HIV-1 and HIV-2 forms of, 3:1436
 malaria relationship with, 2:727
 simian immunodeficiency virus (SIV) origin of, 3:1436
 social and economic consequences of, 2:727
 spatial-temporal trends of, 3:1437–1438
 UNAIDS statistical estimates, 3:1436–1437, 3:1437 (fig.)
 unprotected heterosexual sex and, 3:1438
- Hobbes, Thomas, 4:1928, 4:1979
 Hobsbawm, Eric, 4:1972, 4:1980, 4:2141, 5:2441
 Holland
 foreign aid flow from, 3:1152
 Saturday market stalls in, 2:1044 (photo)
See also Netherlands
- Holland, John, 2:560
 Hollerith, Herman, 3:1281
 Holling, C. S., 2:863
 Holmgren, David, 4:2152
 Holocaust, 2:1027
- Home, 3:1439–1440**
 definitions of, 3:1439
 exploitation and exclusion of women in, 3:1439
 feminist geographies and, 3:1439
 gendered division of labor and, 3:1439
 homelessness and, 3:1439, 3:1440–1442
 life-course stages, class, and sexuality factors and, 3:1439
 migrant “homeland” meaning and, 3:1439
 “Not in My Backyard” (NIMBY) and, 4:2049
 urban forms, housing design, familial relationships and, 3:1439
See also Housing and housing markets
- Homelessness, 3:1440–1443**
 absolute *vs.* relative homelessness and, 3:1440
 Central Park, New York City, 3:1441 (photo)
 chronic homelessness, 3:1440
 definitions, 3:1440
 depression, substances abuse outcomes and/or causes of, 3:1440–1441
 episodic homelessness, 3:1440
 holistic research perspectives on, 3:1440–1441
 homeless women and, 3:1441–1442, 3:1442 (photo)
 “home” meaning for, 3:1439
 individual agency model of, 3:1440
 life events and public policies intersection and, 3:1441
 pathways into and out of, 3:1441
 politicized definitions of, 3:1440
 spatiality of, 3:1441
 “street sweeps” and, 3:1442
 structural model of, 3:1440
 suburban and rural homelessness, 3:1441
 transitional homelessness, 3:1440
 visible *vs.* invisible homelessness and, 3:1441
- Honduras
 Conference of Latin Americanist Geographers held in, 2:568
 domino theory and, 3:1224
 economically active females in, 3:1190 (table)
 Heavily Indebted Poor Countries initiative (World Bank) and, 2:690
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
 tropical rain forest, Cusuco National Park, 1:261 (photo)
- Hong Kong
 APEC membership of, 1:121
 British control of, 1:515
 built environment of, 1:299 (photo)
 clothing exports from, 6:2186 (fig.)
 command and control economy in, 1:304
 container terminal, Victoria Harbor, 6:2864 (photo)
 economically active females in, 3:1190 (table)
 export-oriented industrialization (EOI) in, 2:1064
 export trade success of, 2:731
 foreign direct investment in China by, 3:1155

- as gateway port, 5:2254
- industrialization in, 3:1583, 4:2020
- international financial center of, 1:299 (photo)
- market economy free port of, 2:1067
- textile exports from, 6:2816 (fig.)
- urban metabolism of, 6:2964, 6:2964 (table)
- U.S. industry moving to, 2:700
- hooks, bell, 3:1095, 3:1439
- Hopper, Edward, 1:118
- Horkheimer, Max, 4:1862, 5:2230
- Horton, Robert, 5:2697
- Hoskins, W. G., 2:636
- Hotelling, Harold, 4:2040, 4:2041, 5:2445
- Hou Renzhi, 3:1443–1444**
 - academic career of, 3:1443
 - Cultural Revolution and, 3:1443
 - historical Beijing research of, 3:1443
 - Huang Ho River basis research of, 3:1443
 - modern study of geography in China and, 3:1443–1444
 - service work of, 3:1444
- Housing and housing markets, 3:1444–1446**
 - affordable housing issue and, 3:1446
 - American Housing Survey (AHS), 4:1998–1999
 - attributes and peculiarities of, 3:1444
 - built environment and, 1:298–299
 - commodity and investment features of, 3:1444
 - discrimination issue and, 3:1446
 - employment, demographics, and income factors in, 3:1446
 - ethnic segregation and, 2:1023
 - exurbs, 2:1074–1076
 - factors affecting, 3:1446
 - Federal Housing Administration and, 3:1446
 - filtering process and, 3:1110–1111
 - foreclosures and, 3:1445 (photo)
 - gated communities and, 3:1181–1183
 - gentrification and, 3:1203–1208
 - ghettos and, 3:1275–1277
 - homelessness and, 3:1440–1442
 - housing configuration, housing stock and, 3:1444–1446
 - housing definition and, 3:1444
 - housing market definition and, 3:1445–1446
 - housing market variables and, 3:1445–1446
 - Homer Hoyt's work and, 3:1448–1450
 - law of supply and demand and, 3:1445
 - neighborhoods and, 3:1444, 4:1998–2002
 - new urbanism and, 4:2024–2027
 - physical, family, and social functions of, 3:1444
 - problems in, 3:1446
 - production and consumption of, 3:1444
 - public housing and, 5:2303–2304
 - real estate geographies and, 5:2367–2369
 - seller and buyer interactions and, 3:1446
 - U.S. housing ownership, 1900–2000 and, 4:1965 (fig.)
- Housing policy, 3:1447–1448**
 - building codes, occupancy standards and, 3:1447
 - disadvantaged populations and, 3:1448
 - exclusionary zoning and, 3:1447
 - filtering process and, 3:1110–1111
 - goals of, 3:1447
 - health and safety basis of, 3:1447
 - land use restrictions basis of, 3:1447
 - mixed-income developments and, 3:1448
 - owning *vs.* renting and, 3:1447
 - physical goals of, 3:1447
 - “secondary markets” of mortgages and, 3:1448
 - social goals of, 3:1447–1448
 - sufficient credit supply factor in, 3:1447–1448
 - uneven development issue and, 3:1448
- Howard, Ebenezer, 3:1363, 5:2372
- Howard, Luke, 1:476
- Hoyos, Carlos, 3:1495
- Hoyt, Homer, 3:1448–1450**
 - academic career of, 3:1449
 - books written by, 3:1449
 - Federal Housing Administration developed by, 3:1448, 3:1449
 - Homer Hoyt Institute and, 3:1448, 3:1449
 - map overlay procedures developed by, 3:1449, 3:1450
 - model of sectoral land use patterns work of, 3:1112
 - neighborhood change models of, 3:1449
 - One Hundred Years of Land Values in Chicago*
 - dissertation of, 3:1449
 - private sector and public service work of, 3:1449
 - real estate market analysis work of, 3:1448–1449
 - sector theory of urban land development of, 3:1448–1449
 - service work of, 3:1449
 - spatial pattern of urban land use and, 3:1449
 - suburban expansion work of, 3:1450
- HPC. *See* **High-performance computing (HPC)**
- Hu, Shunfu, 4:1952
- Huber, Joseph, 2:836
- Human dimensions of global environmental change, 3:1450–1455**
 - adaptation research and, 3:1452
 - anticipatory responses and, 3:1452
 - contextual factors in, 3:1452
 - coping strategies and, 3:1452
 - cumulative local changes and, 3:1451
 - deforestation and, 2:695–699
 - drivers of, 3:1451
 - ecosystem or environmental services effects of, 3:1451–1452
 - environmental discourse and, 3:1454
 - equity and social justice issues and, 3:1453–1454
 - global-scale changes and, 3:1451
 - governance and, 3:1453
 - impacts of, 3:1451–1452
 - mitigation efforts and, 3:1453
 - multiple-stressor approaches to, 3:1452
 - neoliberal resource management and, 3:1453
 - physical processes and, 3:1451
 - policy measures and technological responses to, 3:1453
 - privatization and, 3:1453
 - resilience frameworks and, 3:1452
 - socioeconomic causes of, 3:1451
 - systemic-focused research examples and, 3:1451
 - topography changes and, 1:275–276
 - Billie Lee Turner, II and, 6:2891–2892
 - vulnerability research and, 3:1452
 - See also* **Environmental history**
- Human ecology, 3:1455–1460**
 - adaptation focus of, 3:1455–1459
 - anthropology discipline, 3:1456
 - biological ecosystem analysis and, 3:1458
 - biology discipline, 3:1459
 - Chicago School and, 3:1458
 - coupled human and animal systems and, 2:597–598
 - cultural ecology and, 2:633
 - cultural landscapes and, 3:1458–1459
 - definition of, 3:1455
 - demography discipline, 3:1456
 - ecology definition and, 3:1455
 - environmental entitlements and, 2:921–925

- emotional geography and, 3:1459
 evolution and natural selection and, 3:1458
 family and consumer sciences discipline, 3:1456
 geography discipline, 3:1458–1459
 holistic approach to, 3:1459
Human Ecology (Hawley) and, 3:1458
 interdisciplinary roots of, 3:1455–1456
 interpretations of, 3:1456–1459, 3:1457 (table)
 landscape ecology (Troll) and, 3:1458, 4:1714
 mapping of social phenomena and, 3:1458
 medical geographies and, 4:1877–1878
 medicine discipline, 3:1456
 origins of, 3:1455
 quality of life issue and, 3:1455
 regional landscapes and, 3:1458
 sociology discipline, 3:1456
 spatial analysis approach and, 3:1458
 urban analysis discipline, 3:1458
See also **Energy and human ecology**; Human ecology: noted individuals
- Human ecology: noted individuals**
 Harlan Barrows, 1:185
 Stephen Boyden, 3:1458
 Harold Brookfield, 3:1458
 Ernest Burgess, 3:1458
 William Clark, 3:1459
 Herbert Fleure, 3:1458
 Amos H. Hawley, 3:1458
 Ian McHarg, 3:1459
 Roderick McKenzie, 3:1458
 Markus Nauser, 3:1455
 Robert Park, 3:1458
 Carl Sauer, 3:1458
 Dieter Steiner, 3:1455
 Charles Thornthwait, 3:1455
 Carl Troll, 3:1458, 4:1714
 Paul Vidal de la Blache, 3:1458, 5:2387
- Human geography, history of, 3:1460–1470**
 anthropogeography and, 1:93
 antipodes and, 1:98
 cultural geography and chorology in, 3:1465–1466
 Enlightenment and, 2:910–911
 environmental determinism and, 2:916–918
 European human geography in the 19th century and, 3:1462–1463
 feminism and, 3:1468
 French *Annales* School of history and, 1:79–80
 geography as ontology *vs.* epistemology and, 3:1460
 geopolitics and environmental determinism in, 3:1464–1465
 humanistic geography and, 3:1467–1468
 Institute of British Geographers (IBG) and, 3:1601–1603
 location theory and, 4:1799
 Marxist geographies and, 3:1466–1467
 “more than human” geography and, 4:1993
 North American geography, development of, 3:1463–1464
 panopticonism and, 4:2116
 population geography and, 5:2246
 positivism and the quantitative revolution in, 3:1466
 postmodernism and poststructuralism in, 3:1468–1469
See also **Cartography**; **Cartography, history of**; **Environmental history**;
 Historical geography, history of: *specific timeline below*
- Human geography, history of: premodern geographies**
 Abu Al-Raihan al Biruni, 1:282–284, 3:1461
 al-Idrisi, 1:66–67, 3:1461, 4:2179
 Anaximander, 1:74–75, 3:1460
 Arab Empire, 3:1461
 Aristotle, 1:116–117, 3:1460
 classical Greece, 3:1460
 Eratosthenes, 2:1010–1011, 3:1460
 exploration, 3:1461
 feudal Europe, 3:1461
 Herodotus, 3:1421–1422, 3:1460
 Hipparchus, 3:1428, 3:1460
 Ibn Batu, 3:1461
 Ibn Khaldūn, 3:1461
 Marco Polo, 2:1053, 3:1461
 Ptolemy, 3:1460–1461, 5:2300, 5:2387
 Roman empire, 3:1460–1461
 Strabo, 3:1245, 3:1460
 Thales, 3:1460
 T-in-O maps, 1:341–342, 1:347, 1:349 (fig.), 3:1461, 6:2845 (fig.)
- Human geography, history of: Renaissance and Enlightenment**
 Martin Behaim, 3:1461, 4:2179
 break with theology and, 3:1461–1462
 cadastral maps, atlases, 3:1461
 cartography technology and, 3:1461
 Christopher Columbus, 1:520–521, 3:1461, 4:2179
 Captain James Cook, 2:575, 3:1461
 Bartolomeu Dias, 3:1461
 exploration and, 2:910–911, 3:1461
 Vasco da Gama, 3:1461, 4:2179
 Immanuel Kant, 3:1434, 3:1462, 4:1647–1649
 Ferdinand Magellan, 3:1461, 4:1813–1815, 4:2179
 Gerardus Mercator, 3:1461
 Varenus, 3:1461–1462, 4:2179, 5:2387
- Human geography, history of: European human geography, 19th century, 5:2211, 3:1463**
 colonialism, 3:1463
 Alexander von Humboldt, 3:1462, 3:1482–1485, 5:2211
 industrialization, urbanization and, 3:1463
 Peter Kropotkin, 3:1463
 national geographical societies, 3:1463
 panopticon and, 4:2116–2117
 Élisée Reclus, 1:73, 2:617, 3:1463, 5:2211, 5:2371–2372
 Carl Ritter, 3:1462–1463, 4:2180, 5:2387, 5:2470–2471
- Human geography, history of: North American geography development**
 American Geographical Society and, 3:1463
 Association of American Geographers, 3:1464
 Harlan Barrows, 3:1463
 Chicago School and, 3:1463–1464
 construction of American identity and, 3:1463
 William Morris Davis, 3:1463, 3:1464, 4:2180
 J. Paul Goode, 3:1350–1352, 3:1463, 5:2364, 6:3169
 Richard Hartshorne, 3:1463, 5:2387–2388
 Thomas Jefferson, 4:1642–1643
 George Perkins Marsh, 4:1858–1859, 4:2180
 Matthew Fontaine Maury, 4:1872–1873
 Jedediah Morse, 3:1463, 4:1946
 National Geographic Society and, 3:1463
 Carl Sauer, 3:1463
 university geographical programs and, 3:1463–1464
 westward expansion, 3:1463
 Gilbert White, 3:1463
 Derwent Whittlesey, 3:1463
- Human geography, history of: geopolitics and environmental determinism**
 biologized international relations (Ratzel), 3:1464
 Isaiah Bowman, 1:295–296, 3:1464
 classical geopolitics (Kjellen and Ratzel), 3:1464
 environmental determinism (Semple), 3:1464–1465, 4:1990, 4:1991, 5:2531–2532

- environmental possibilism (Sauer and Vidal de la Blache), 3:1464–1465
- globe as integrated political system, 3:1464
- Alfred Thayer Hahan, 4:1815–1816
- Richard Hartshorne, 3:1402–1403, 3:1429, 5:2387–2388
- Karl Haushofer, 3:1407–1408, 3:1464
- Ellsworth Huntington, 3:1464
- Rudolf Kjellen, 3:1464
- Jean Baptiste Lamarck, 3:1464
- Sir Halford Mackinder, 3:1464, 4:1812–1813, 5:2222
- nation-states as organic, biological organism (Ratzel), 3:1464
- population geography and, 5:2246
- Friedrich Ratzel, 3:1464
- Carl Sauer, 3:1464
- Ellen Churchill Semple, 3:1464, 4:1990, 4:1991, 5:2531–2532
- social Darwinism, 3:1464
- Herbert Spencer, 3:1464
- Paul Vidal de la Blache, 3:1464, 3:1465, 5:2387
- World War II, 3:1465
- Human geography, history of: cultural geography and chorology
- Annales School, 3:1465
- chorology, 3:1465
- empiricist cultural geography, 3:1466
- Lucien Febvre, 3:1465
- Richard Hartshorne, 3:1465, 5:2387–2388
- Alfred Hettner, 3:1422–1423, 3:1465, 5:2387
- John Leighly, 3:1465
- Carl Sauer, 3:1465
- Paul Vidal de la Blache, 3:1465, 3:1476, 5:2387
- Derwent Whittlesey, 3:1465
- Human geography, history of: positivism and quantitative revolution
- William Bunge, 3:1466, 3:1645, 5:2238, 5:2350
- Richard Chorley, 3:1466
- Michael Dacey, 3:1466
- William Garrison, 3:1466
- Peter Haggett, 3:1466, 4:2017
- John Nystuen, 3:1466
- logical positivism, Vienna Circle, 3:1466
- spatial demographics and political districting (Morrill), 3:1466
- University of Washington, 3:1466
- Human geography, history of: Marxist geographies, 3:1467
- centrality of class, 3:1466
- economic determinism, 3:1467
- David Harvey, 3:1404–1406, 3:1467, 4:1862, 5:2350
- historical materialism (Harvey), 3:1467
- power and politics of society, 3:1466
- production process and labor, 3:1466
- Neil Smith, 3:1466, 5:2551–2552
- Social Justice and the City* (Harvey), 3:1467, 4:1862, 5:2350
- Michael Storper, 3:1467, 4:1863, 5:2695–2696
- time and space studies (Harvey), 3:1467, 4:1862
- Richard Walker, 3:1467
- Human geography, history of: humanistic geography
- body geographies, 3:1468
- criticisms of, 3:1468
- Martin Heidegger, 3:1467, 4:2166
- Edmund Husserl, 3:1467, 3:1475, 4:2166
- phenomenology and existentialism and, 3:1467
- Edward Relph, 3:1467, 3:1476, 4:2167
- sense of space and place, 3:1467–1468
- textual meanings and, 3:1467
- Yi-Fu Tuan, 3:1467, 3:1476, 4:1786, 4:2167, 6:2890–2891
- Human geography, history of: geography and feminism
- gender differences in commuting, 3:1468
- gendered resources allocation, 3:1468
- gendered social reality and, 3:1468
- grounded theory, 3:1468
- Susan Hanson, 3:1468
- Linda McDowell, 3:1468, 4:2136
- participant observation, 3:1468
- patriarchal inequality and, 3:1468
- Gillian Rose, 3:1468
- socially constructed gender roles, 3:1468
- standpoint theory, 3:1468
- Human geography, history of: postmodernism and poststructuralism
- actor-network theory and, 3:1469
- critics of, 3:1469
- deconstruction, 3:1468
- discourses role, 3:1468
- Michel Foucault, 3:1468
- David Harvey, 3:1469
- knowledge and power, 3:1468
- Bruno Latour, 3:1469
- Diane Massey, 3:1469
- metanarratives, 3:1469
- role of language and ideology in social life and, 3:1468
- Edward Soja, 3:1469, 5:2351, 5:2593
- Human-induced invasion of species, 3:1470–1474**
- carnivore species introduction, 3:1473
- definition of, 3:1470
- ecosystems affected by, 3:1472
- examples of Balearic lizard and midwife toad examples of, 3:1473
- examples of brown tree snake, 3:1473–1474
- examples of Great American Exchange and, 3:1361–1362
- examples of rabbits in Australia, 3:1474
- examples of water hyacinth, Mississippi Delta, 3:1471 (photo)
- examples of weasel, 3:1473
- exotic species and, 2:1048–1050
- extinctions and, 2:1069–1072, 3:1337
- future trends in, 3:1474
- historically recent invasions and, 3:1473–1474
- hybridization and genetic contamination and, 3:1472
- intentional causes of, 3:1471
- invasion and succession and, 3:1627
- invasive capacity determination and, 3:1471
- invasiveness of the species factor in, 3:1470
- involuntary causes of, 3:1472
- large engineering projects and, 3:1473
- maritime traffic increase and, 3:1473
- mutualisms elimination and, 3:1472
- opportunistic predators and, 3:1473
- parasites and pathogens and, 3:1472
- past invasions on islands and, 3:1472–1473
- as predators and competitors, 3:1472
- prehistoric extinctions and, 3:1472
- susceptibility and suitability of a territory factor and, 3:1470
- transportation methods factor in, 3:1473
- tropical scrub biome and, 1:245–246
- Humanistic geography, 3:1474–1478**
- anarchism and, 1:73–74
- Bhopal, India, chemical disaster and, 1:194–195, 4:2158
- body and mind interface and, 3:1477
- brief history of, 3:1474–1475
- construction of knowledge and, 3:1476
- critical historical geography and, 3:1430
- critics of, 3:1477
- cultural geography and, 3:1477

- cultural landscape geographies (Vidal de la Blache)
and, 3:1476, 5:2387
as dimension of cultural geography, 2:637
ethics and geography and, 2:1013–1016
everyday life geographies and, 2:1042–1045, 3:1430
existentialist geographies and, 2:1046–1047, 3:1467
fieldwork in, 3:1103–1105
geographies of consumption and, 2:574–575
geographies of emotion and, 2:891–892
geography of identity and the body and, 3:1476–1477
ghetto and, 3:1275–1277
hermeneutics, study of meanings and, 3:1474
human connections to space focus of, 2:637
human geography fieldwork and, 3:1103–1005
humanism definition and, 2:637
humanistic GIScience and, 3:1474–1478
humanistic thought and, 3:1475–1477
identity formation and, 3:1476–1477
identity geographies and, 3:1527–1531
language and geographic analysis and, 4:1754
literature narratives of place and, 4:1786
Marxism *vs.*, 3:1477
phenomenology and existentialism approaches of,
3:1474–1475, 4:2167
positivism and, 3:1476
qualitative research and, 3:1476
researcher inserted into research and, 3:1476
sense of space and place and, 3:1476–1477
Shaping of America (Meinig) and, 3:1430, 4:1879–1880
topophilia (love of space) concept (Tuan) and, 2:637, 3:1467,
3:1476, 4:2167
See also **Critical human geography**
- Humanistic geography:** noted individuals
Anne Buttner, 1:309, 3:1476, 4:1786, 4:2167
Derek Gregory, 3:1380
Martin Heidegger, 3:1475, 4:2166
Edmund Husserl, 3:1467, 3:1475, 4:2166
Søren Kierkegaard, 3:1474–1475
David Levy, 3:1476
David Lowenthal, 3:1476, 4:2167
Donald Meinig, 3:1430, 4:1879–1880
Gunnar Olsson, 4:2077–2078
Douglas Pocock, 4:1786
Edward Relph, 3:1476, 4:2167, 5:2410–2411
Jean-Paul Sartre, 3:1475
Yi-Fu Tuan, 3:1476, 4:1786
Paul Vidal de la Blache, 3:1476, 5:2387
- Humanistic GIScience, 3:1478–1479**
alternative conceptualizations explored by, 3:1478
critical GIScience and, 3:1478
definition of, 3:1478
emotional mapping, 3:1479
examples of, 3:1478
feminist GIS and, 3:1478
goal of, 3:1478
human subjectiveness in, 3:1478
Mei-Po Kwan's work in, 3:1478, 4:1674
local ethnographies and, 3:1478
mapping and visualization technology and, 3:1478–1479
multimedia forms and, 3:1478
neogeography, Web-based “mash-ups” and, 3:1211, 3:1478,
3:1624, 5:2305
nonrepresentational theory and, 3:1479
ontological and epistemological implications of, 3:1479
performative theory of truth and, 3:1479
researcher in center of research and, 3:1479
social networking and, 3:1478
volunteered geographic information (VGI) and, 3:1478
Web 2.0 technology and, 3:1478
See also **Critical GIS; GIS specific subject; Public participation GIS (PPGIS)**
- Human rights, geography and, 3:1480–1481**
Giorgio Agamben's work and, 1:26–27
antisystemic movements and, 1:99–100
cultural rights and, 3:1480
definition, 3:1480
globalization processes and, 3:1481
grassroots antiglobalization activities and, 1:96
Holocaust and, 3:1480
human rights documents and, 3:1480
Human Rights Watch and, 1:96
international organizations and, 3:1480
local context of, 3:1480–1481
locality, movement, and nature-society relations themes in, 3:1480
mass atrocities and, 3:1481
spatial scales of analysis of, 3:1480
Universal Declaration of Human Rights list and, 3:1480
U.S. countering terrorism, human rights violations and, 3:1481
U.S. human rights abuses, Guantanamo Bay, Cuba, and, 3:1381
See also **Environmental rights**
- Human Rights Watch, 3:1480
- Humboldt, Alexander von, 3:1482–1485**
agnostic, holistic view of nature and, 3:1462
continentality, 3:1462
Cosmos written by, 3:1462, 4:2175, 4:2180, 5:2211
domestication of animals study of, 2:782
evolution and, 2:666
Alfred Hettner influenced by, 3:1422
Humboldt Current and, 2:887, 3:1462
inequality of fortunes, 5:2211
isolines, isotherms used by, 3:1462, 3:1484
Thomas Jefferson and, 3:1484, 4:1642
landscape definition of, 4:1713
Latin America and Siberia travels of, 3:1462
latitude diversity gradient observed by, 1:198, 3:1484
Map of the Kingdom of New Spain created by,
3:1483 (fig.), 3:1484
Matthew Fontaine Maury and, 4:1872
modern geographer co-founded by, 5:7471
physical geography work of, 4:2180, 5:2447
as pioneer of modern geography, 3:1484, 4:2180
“Renaissance man” label of, 3:1482
science from a philosophical perspective and, 3:1484
scientific travels of, 3:1482, 3:1484
South American tribes studied by, 3:1462
“taking photographic pictures” and, 4:2175
- Hume, David, 2:893, 4:1647, 4:1928
- Humidity, 3:1485–1486**
absolute humidity, 3:1485
adiabatic temperature changes and, 1:15–17
dew-point temperature, dew-point depression and, 3:1485
mixing ratio parameter of, 3:1485
relative humidity, 3:1485
sling hygrometer measurement of, 3:1485
specific humidity, 3:1485
water vapor content and temperature factors in, 3:1485
See also **Atmospheric moisture**
- Hungary**
AGILE membership of, 1:124 (table)
Cold War and, 1:504

- economically active females in, 3:1190 (table)
 industrialization in, 2:542
 morphine-rich narcotics produced in, 2:796, 2:797 (table)
 Wizz Air and, 1:181–182, 1:181 (fig.)
- Hunger, 3:1486–1489**
 British *vs.* U.S. conceptual debates, 3:1486
 deficient calorie consumption and, 3:1487–1488
 definition and measurement of, 3:1486
 “depoliticization” of, 3:1489
 famine geographies and, 3:1082–1085
 food insecurity and, 3:1488, 4:2015
 globalization, urbanization, and depoliticization of, 3:1488–1489
 Haitian humanitarian assistance, hurricane relief operations in, 3:1487 (photo)
 human beings and food relationship complexity and, 3:1486
 Robert Kates’s work, 4:1654–1655
 neo-Malthusianism and, 4:2015–2016
 physical and mental effects of, 3:1487
 shift of responsibility for, 3:1489
 socially acceptable diet and, 3:1488
 spatial patterns of hunger and, 3:1488–1489
 undernourishment by region, 2009, 3:1487, 3:1488 (table)
 undernutrition *vs.* malnutrition and, 3:1486–1488
 urbanization of hunger and, 3:1489
- Hunt, C., 3:1105
- Hunt, Terry, 3:1473
- Hunting and gathering, 3:1489–1492**
 agriculture emergence and, 3:1490
 animistic religious beliefs and, 3:1490–1491
Australopithecus and *Homo* genuses and, 3:1490
 birth and death rates and, 3:1491
 domestication of animals and, 2:781–783, 3:1490
 early trade networks and, 3:1490
 egalitarian cultures and, 3:1490–1491
 fire, needle and thread innovations and, 3:1490
 gendered division of labor and, 3:1490
 modern existence of, 3:1492
 nation-state development and, 3:1491–1492
 nomadism and, 4:2033
 organized warfare and, 3:1490
 paleolithic art and, 3:1491
 pygmy subsistence hunter, Cameroon and Central African Republic, 3:1491 (photo)
 seasonal rhythms of plants and animals and, 3:1490
 stone and bone tools and, 3:1490
 symbols and abstract thought and, 3:1491
- Huntington, Ellsworth, 3:1492–1493**
 academic career of, 3:1492
 American Eugenics Society and, 3:1492
 dendrochronology, tree-ring dating work of, 2:711
 environmental determinism work of, 2:667, 3:1429, 3:1464, 3:1492, 4:1990, 4:1991
 explorations of, 3:1492–1493
 “geodeterminism” of, 3:1492
 publications of, 3:1492–1493
 role of climate in human demography and development and, 3:1492
- Hurricane Katrina, 3:1493–1496**
 costliness of, 3:1493
 differential vulnerabilities and, 2:743, 2:964, 4:1985–1986
 engineering failures in New Orleans during, 3:1494
 environmental racism issues and, 2:987, 4:1985–1986
 evacuation efforts and, 3:1493–1494, 4:1986
 Federal Emergency Management Administration and, 3:1494
 flooding from, 3:1135
 future hurricane forecasting and, 3:1494–1495
- GIS spatial decision support system, insurance companies and, 1:307
 infrastructure failure during, 3:1594
 institutional racism and, 2:987
 lack of preparedness for, 3:1501
 mapping mashup of, 3:1211
 as midlatitude extreme weather, 1:437
 New Orleans and, 3:1493–1494, 3:1495 (photo), 4:1986
 “refugees” of, 5:2377
 Saffir-Simpson Hurricane Damage Potential Scale and, 3:1493
 scipionus.com Web site, 3:1211
 storm history of, 3:1493–1494
 storm surge, flash floods and, 3:1125, 3:1494
 “total dissipation index,” potential destructiveness measure, 3:1494–1495
 TRMM observation of, 1:160
 Web mapping mashup, 5:2305
- Hurricanes, physical geography of, 3:1496–1499**
 atmospheric circulation explanation of, 1:134
 coastal dead zones and, 1:486
 Coriolis effect and, 1:134
 damage from, 3:1498
 extratropical cyclones and, 2:650–654
 eye of a hurricane and, 3:1496, 3:1497, 3:1498
 flooding from, 3:1498
 global hurricane activity and, 3:1499
 landfall of, 3:1498
 large-scale wind streams and, 3:1497–1498
 low air pressure over warm ocean waters and, 3:1496
 in mild midlatitude climate, 1:437
 modeling studies of, 3:1499
 ocean water temperatures factor of, 3:1495, 3:1499
 parabola-shaped track of, 3:1497–1498
 pressure differences factor in, 3:1496
 radius of maximum winds and, 3:1497
 Saffir-Simpson Hurricane Damage Potential Scale and, 3:1493, 3:1496–1497
 size variations of, 3:1497
 slope of the continental shelf factor in, 3:1498
 storm surge and, 3:1498
 tracking of, 3:1499
 watches and warnings for, 3:1499
 winds from, 3:1496–1498
See also Hurricane Katrina; Hurricanes, physical geography of: specific hurricane; Hurricanes, risk and hazard
- Hurricanes, physical geography of: specific hurricane**
 Florida Keys Hurricane (1935), 3:1497
 Galveston Hurricane (1900), 3:1500
 Hurricane Andrew (1992), 3:1497
 Hurricane Camille (1969), 3:1497, 3:1500
 Hurricane Celia (1970), 3:1500
 Hurricane Dennis (2005), 1:486, 3:1494
 Hurricane Floyd (1999), 1:486
 Hurricane Francis (2004), 3:1497 (photo)
 Hurricane Georges (1998), 3:1494
 Hurricane Ike (2008), 3:1501 (photo)
 Hurricane Irene (2005), 1:486
 Hurricane Ivan (2004), 3:1494
 Hurricane Lili (2002), 3:1494
 Hurricane Mitch (1998), 4:1986
 Hurricane Rita (2005), 3:1493
- Hurricanes, risk and hazard, 3:1499–1502**
 Atlantic hurricanes and, 1:165
 coastal population growth and, 3:1500
 damage from, 3:1498
 economic losses from, 3:1500

- evacuation strategies, 3:1501
- forecasting techniques, 3:1501
- geography of risk and, 3:1500
- hazards from, 3:1500–1501
- high-speed winds, 3:1500
- preparedness, 3:1501
- protective measures, 3:1501
- rainfall and flooding, 3:1500
- Saffir-Simpson Hurricane Damage Potential Scale and, 3:1493, 3:1496–1497
- storm surge and, 3:1500
- tornadoes, 3:1500–1501
- “total dissipation index,” potential destructiveness measure of, 3:1494–1495
- warning systems and, 3:1500, 3:1501
- See also Hurricane Katrina; Hurricanes, physical geography of*
- Husserl, Edmund, 3:1467, 3:1475, 4:2166
- Hybrid geographies, 3:1502–1504**
 - actor-network theory (Latour) and, 1:8, 3:1503
 - critical landscape studies and, 3:1502
 - cyborg ecologies and, 2:648–650
 - definition of, 3:1502
 - elements from multiple origins and, 3:1502
 - genetically modified organisms (GMOs) and, 3:1197–1199, 3:1503–1504
 - geography of differences and, 2:740
 - “golden” rice and oranges examples of, 3:1503–1504
 - integration across disparate categories and, 3:1502
 - military conversions and, 3:1504
 - national wildlife refuges and, 3:1504
 - obliteration of prior categories and, 3:1502
 - radical philosophy and, 3:1503
 - relationships emphasis and, 3:1503
 - technology and land use and, 3:1503
 - U.S. National Wildlife Refuge System and, 3:1504
 - See also Hybrid geographies: noted individuals*
- Hybrid geographies: noted individuals
 - Bruno Latour, 1:8, 3:1503, 4:1996
 - Jonathan Murdoch, 3:1503
 - Sarah Whatmore, 3:1503
- Hybridization of plant and animal species, 3:1504–1506**
 - agro-ecosystem diversity and, 3:1505
 - benefits of, 3:1505
 - biological species concept and, 3:1505
 - corn (maize) example of, 3:1505
 - Charles Darwin and, 3:1505
 - definition of, 3:1504
 - diversification barriers from, 3:1504–1505
 - domestic dogs example of, 3:1505
 - extinction from, 3:1505
 - genetic erosion from introgressive hybridization and, 3:1505
 - heterosis, or hybrid vigor from, 3:1505
 - interfamilial hybrids, 3:1505
 - intergeneric hybrids, 3:1505
 - interspecific hybrids, 3:1505
 - intraspecific hybrids, 3:1505
 - limitations of, 3:1506
 - offspring health and genetic limitations from, 3:1505
 - reticulate speciation from, 3:1505
 - speciation result from, 3:1505
 - types of hybrids and, 3:1505
- Hydroclimatology, 1:473
- Hydroelectric power, 3:1506–1512**
 - definition of, 3:1506
 - efficiency of, transmission distance factor and, 3:1507
 - expansion measures of, 3:1507, 3:1508 (figs.)
 - Michael Faraday’s invention of, 3:1506
 - future trends in, 3:1511, 3:1512
 - global inequities in, 3:1507–1511
 - hydroelectric systems planning and building and, 3:1507
 - hydropower dams and, 3:1507
 - industrial diffusion of, 3:1506–1507, 3:1509
 - installed generating capacity values since 1950 and, 3:1510, 3:1511 (table)
 - Itaipu-Binacional hydropower system, Brazil, and, 3:1510 (photo)
 - superconductivity technology and, 3:1507
 - Tennessee Valley Authority and, 3:1507
 - transmission system for, 3:1507
 - Turcurui-Tocantins Rivers hydroelectric dam, Brazil, and, 3:1509, 3:1509 (photo)
 - in the United States, 3:1507
 - See also Hydrological connectivity*
- Hydrological connectivity, 3:1512–1513**
 - applications of, 3:1513
 - dam management issue and, 3:1517
 - definition of, 3:1512
 - disconnection types and, 3:1512
 - ecohydrology and, 3:1513
 - human intervention impact studies and, 3:1516–1517
 - hydro agent model of, 3:1513
 - indices of, 3:1512–1513
 - irrigation network management and, 3:1518
 - Lagrangian particle-tracking model and, 3:1513
 - landscape and storm characteristics and, 3:1512
 - Network Index and, 3:1512
 - nonpoint source pollution risk modeling and, 3:1513
 - ParFlow model and, 3:1513
 - Phosphorus Index (P-Index) and, 3:1513
 - semiarid environmental conditions and, 3:1512
 - simulation models of, 3:1513
 - storm temporal characteristics and, 3:1512
 - strength of factors and, 3:1512
 - Sullivan County’s Interactive Mapping Application (SCI-MAP) and, 3:1513
 - temperate environment conditions and, 3:1512
 - water movement options and, 3:1512
 - water pollutants and, 3:1517
- Hydrology, 3:1513–1518**
 - above-ground throughfall and, 3:1515
 - capillary water of soil moisture and, 3:1515
 - catchment or drainage basis cycle and, 3:1515
 - climate change and, 6:2771
 - definition of, 3:1513–1514
 - Earth’s rotation factor in, 3:1514
 - Earth’s total water calculation and, 3:1514
 - future water shortages and, 3:1517–1518
 - GIS in water management and, 3:1316–1318
 - global water scarcity predictions and, 3:1516
 - gravitational force factor in, 3:1514
 - gravitational water of soil moisture and, 3:1515
 - hydrogen and oxygen biogeochemical cycle and, 1:205–206
 - hydrological accounting systems and, 3:1515
 - hygroscopic water of soil moisture and, 3:1515
 - International Hydrological Decade (1960s) and, 3:1515
 - land use and cover change impact on, 4:1736, 4:1737 (photo)
 - multidisciplinary elements of, 3:1514–1515
 - permafrost degradation and, 4:2156–2157
 - physical laws applied in, 3:1514
 - precipitation intensity and volume and, 3:1515

- social aspects of water use and, 3:1515
- solar energy factor in, 3:1514
- surface hydrologic cycle and, 3:1514–1515
- tectonic water cycle and, 3:1514
- underground water flows and, 3:1514
- volcanic eruptions and, 3:1514
- water balance equations and, 3:1515
- water conflict between nation-states and, 3:1516
- water law and, 3:1518
- water scarcity index and, 3:1516
- world hydrological accounting system and, 3:1515–1516
- yearly fluxes of water through upper crust and, 3:1514
- See also* Groundwater; Rivers
- Hyndman, Jennifer, 3:1104
- Iberiocentrism, 2:1030 (table)
- IBG. *See* Institute of British Geographers (IBG)
- Ibn Battuta, 3:1519–1520**
 - Ibn Khaldūn and, 3:1520
 - North African origins of, 3:1519
 - travel hardships experienced by, 3:1519–1520
 - travel literature written by, 3:1519–1520, 4:2179
 - travels of, 2:1054, 3:1461, 3:1519–1520, 4:2179
- Ibn Khaldūn, 3:1520–1522**
 - al-Idrisi's *Geography* and, 3:1521
 - Arab historian, 3:1520–1521
 - autobiography of, 3:1520
 - as founder of multiple disciplines, 3:1521
 - Muqaddima* written by, 3:1521
 - theory of cyclical progress of, 3:1521
 - theory of world history of, 3:1520–1521
 - travels of, 3:1520–1521, 4:2179
 - urban environment as cradle of culture and, 3:1521
- ICC. *See* International Criminal Court (ICC)
- ICCAs. *See* Indigenous and community conserved areas (ICCAs)
- Ice, 3:1522–1526**
 - abrupt climate change and, 3:1524
 - climate change and, 1:455–461, 3:1522, 6:2772
 - continental glaciers and, 3:1323–1328
 - cryosphere, ice-based environment and, 3:1522, 3:1523 (fig.)
 - Earth-observing satellites and, 3:1524, 3:1524 (fig.), 3:1525 (fig.)
 - environmental change factor of, 3:1522
 - fossil fuel consumption and, 3:1525–1526
 - geomorphic actions of, 3:1522
 - ice avalanches and, 1:176–177
 - Intergovernmental Panel on Climate Change and, 3:1525
 - modeling of, 3:1524–1526
 - mountain glaciers and, 3:1328–1333
 - Northwest Passage opening and, 3:1522
 - polar climate and, 1:449–452
 - Poles, North and South and, 5:2203–2209
 - projected temperatures, 21st century, 3:1526 (fig.)
 - research programs, 3:1522
 - retreating of, 3:1522–1524
 - See also* Periglacial environments; Permafrost
- Iceland
 - cancer incidence and mortality in, 1:322 (fig.), 1:323 (fig.)
 - documented history of climate in, 1:456
 - geothermal energy use in, 3:1267
 - “Geysir” geothermal geyser in, 3:1273
 - glaciers in, 3:1333
 - Ice Ages and, 1:457
 - individual transferable quotas (ITQs) in, 6:2756
 - installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 - Kyoto Protocol of 1997, GHG emissions and, 1:463
 - marine aquaculture in, 4:1854 (fig.)
 - mid-Atlantic tectonic ridge system and, 5:2197
 - normal faults in, 3:1086
 - tundra vegetation in, 1:248 (table)
 - Viking exploration of, 2:1051
 - volcanoes in, 3:1273
- Iceland, J., 5:2345
- Idaho, 5:2469
- Identity, geography and, 3:1527–1531**
 - agency of decentered subjects and, 3:1529
 - binary oppositions and, 3:1529
 - Black Skin, White Masks* (Fanon) and, 3:1528
 - boundaries, construction of, 3:1529
 - boundaries between “us” and “them” and, 3:1527
 - changing geographies and, 3:1530–1531
 - citizenship and, 1:412–414
 - co-constitution with territory, space, place, and landscape and, 3:1530
 - conceptual approaches to, 3:1527–1528
 - cosmopolitanism and, 2:590–592
 - as dialectical process, 3:1528
 - discourses focused on, 3:1528
 - ethnic segregation and, 2:1022–1026
 - ethnocentrism and, 2:1027
 - external ascriptions of, 3:1527–1528
 - feminist geographies and, 3:1530
 - fluid and situational features of identities and space and, 3:1527
 - functions of, 3:1527
 - geographical imagination and, 3:1221–1225
 - geographies of emotion and, 2:891–892
 - geography of differences and, 2:739
 - globalization, transnationalism and, 3:1527, 3:1530–1531
 - group identity and, 3:1528–1529, 3:1530
 - hybridity feature of, 3:1529–1530
 - identities and space relationships and, 3:1530
 - identity politics and, 3:1528–1529
 - “in between” hybridity and, 3:1530
 - labeling and categorization of, 3:1528
 - landscapes of humanistic geography and, 3:1530
 - multiple identifications and, 3:1527
 - nation concept and, 4:1971–1974
 - nation-state systems, national identity and, 3:1527
 - negotiation of new meanings and representations and, 3:1529–1530
 - Other/Otherness and, 4:2106–2107
 - performativity feature of, 3:1529
 - postcolonialism and, 3:1528, 5:2261
 - poststructuralism, postmodernity and, 3:1528
 - social construction of, 3:1527
 - social group boundaries and, 3:1527
 - spatial phenomena and, 3:1527
 - television and, 6:2791–2793
 - uneven power relations and, 3:1528
 - urban social geography studies and, 3:1530
 - within-group differences, power imbalances and, 3:1527
- Idiographic, 3:1531–1532**
 - chorology, areal differentiation and, 3:1531
 - definition of, 3:1531
 - Richard Hartshorne's work and, 3:1531
 - Doreen Massey's changing spatial division of labor work and, 3:1532, 4:1790–1791, 4:1866–1867
 - nomothetic *vs.*, 4:2034–2035
 - regions in changing spatial division of labor and, 3:1532
 - Fred Schaefer's critique of regional geography and, 3:1531–1532
 - uniqueness of places and, 3:1531–1532

IGU. *See* International Geographic Union (IGU)

Illinois, 5:2278. *See also* Chicago, Illinois

Image enhancement, 3:1532–1533

contrast enhancement, 3:1532–1533

evaluation of quality of, 3:1532

Fourier transform, 3:1533

functions of, 3:1532, 3:1533

remote sensing and, 3:1532

spatial filtering, 3:1533

See also Image specific subject

Image fusion, 3:1533–1534

color-related techniques of, 3:1533

combination of multisource images and, 3:1533

definition of, 3:1533

Pohl and Van Genderen's work in, 3:1533

limitations of, 3:1534

methods of, 3:1533–1534

statistical/numerical methods of, 3:1533

terms related to, 3:1534

See also Image specific subject

Image interpretation, 3:1534–1536

computer analysis of digital images approach to, 3:1535

conversion of similar pixels approach to, 3:1535–1536

explanation of, 3:1534

extraction of meaningful information by, 3:1534

functions of, 3:1536

Ikonos sensors and, 3:1534

Landsat Thematic Mapper series and, 3:1534

limitations of, 3:1536

process of, 3:1534–1535, 3:1535 (fig.)

remote sensing image source and, 3:1536

visual approach to, 3:1534–1535

See also Image specific subject

Image processing, 3:1536–1538

classification and, 3:1537–1538

enhancement and, 3:1537

functions of, 3:1536

fuzzy classification and, 3:1537–1538

geometric correction and, 3:1536

georeferencing and, 3:1536

GIS software and, 3:1536, 3:1538

hybrid image classification and, 3:1538

photogrammetric methods and, 4:2173–2175

preprocessing and, 3:1536–1537

radiometric correction process and, 3:1536–1537

raster format of digital imagery and, 3:1538

supervised image classification and, 3:1537

unsupervised classification and, 3:1537

uses of, 3:1536

visual interpretability increase and, 3:1537

See also Image specific subject

Image registration, 3:1538–1540

area-based feature matching methods and, 3:1539

definition of, 3:1538

feature-based feature matching methods and, 3:1539

feature detection and extraction in, 3:1538–1539

geometric correction and, 3:1239–1240

image mosaic example and, 3:1538, 3:1539 (fig.)

image resampling and, 3:1540, 3:1540 (fig.)

image transformation and image resampling in, 3:1540

purposes of, 3:1538

steps in, 3:1538

transformation selection and, 3:1539

Image texture, 3:1540–1541

definition of, 3:1540

first-order texture statistics and, 3:1540

gray level co-occurrence matrices (GLCM) and, 3:1541

image-processing algorithms and, 3:1541

parameters control and, 3:1541

second-order texture statistics and, 3:1541

Imaging spectroscopy, 3:1541–1542

dark lines in the solar spectrum and, 3:1542

definition of, 3:1541

imaging spectrometer in space and, 3:1542

LiDAR and airborne laser scanning and, 4:1778–1779

James Maxwell's equations of electromagnetic waves and, 3:1542

microwave/RADAR data and, 4:1888–1890

Moderate Resolution Imaging Spectroradiometer and, 1:158,

1:252, 2:974, 3:1542, 4:1738, 4:1740, 4:1960

multispectral imagery and, 4:1953–1956

Newton's corpuscular theory and, 3:1542

photogrammetric methods and, 4:2173–2175

terms related to, 3:1541

Treatise of Light (Newton) and, 3:1542

uses of, 3:1541–1542

wave theory and, 3:1542

Imbrie, J., 2:711

IMF. *See* International Monetary Fund (IMF)

Immigration, 3:1542–1545

cancer studies of immigrants and, 1:335

citizenship and, 1:413

William Clark's work, 1:417–418

definition of, 3:1542

diaspora and, 2:734–735

documented *vs.* undocumented s and, 3:1544

economic migrants and, 3:1545

Ellis Island, 3:1544 (photo)

emigrant, 3:1544

entry *vs.* exit visas and, 3:1544

environmental migrants and, 3:1545

free or volitional *vs.* forced immigration and, 3:1544

global slave trade and, 3:1544

guest workers and, 3:1544

immigrant and, 3:1544

jus sanguinis, right of blood and, 3:1545

jus soli, citizenship by birth and, 3:1545

labor niches and, 3:1545

naturalization and, 3:1545

political migrants and, 3:1545

political refugee *vs.* seeking political asylum and, 3:1545

push and pull factors of, 3:1544–1545

requisite conditions of, 3:1542

rights of citizenship and, 3:1545

skilled, semi-skilled, and unskilled laborers and, 3:1545

“sojourner” international migration and, 3:1545

transnational households and, 3:1545

U.S. immigration laws and, 3:1545

See also Migration

Imperialism, 3:1545–1548

asymmetrical core-periphery relationship and, 3:1546, 3:1547, 5:2219

colonialism and, 3:1546

colony definition and, 3:1546

core regions concept and, 3:1546

cultural hegemony established by, 3:1547

definition of, 3:1545–1546

empires' collapse and, 3:1547–1548

geographical imagination and, 3:1221–1225

geopolitical characteristics of, 3:1546

globally diffuse networks and, 3:1548

ideology of effects colonization of the mind and, 3:1547

- ideology support and, 3:1546
- new despatialized form of, 3:1548
- people subsumed within boundaries of empire and, 3:1547
- social hierarchies established by, 3:1547
- “soft power” domination and, 3:1548
- specifics of alien rule and, 3:1546
- “unipolar preponderance” concept and, 3:1548
- See also* Colonialism
- Impermeable surfaces, 3:1548–1549**
 - anthropogenic impermeable surfaces, 3:1548–1549
 - flash floods and, 3:1549
 - lava flows, 3:1549
 - natural processes impermeable surfaces, 3:1548, 3:1549
 - salt in evaporating waters and, 3:1549
 - subsoil accumulations of iron and aluminum and, 3:1549
 - urbanization of watersheds and, 3:1549
 - water pollution caused by, 3:1549
- Import substitution industrialization (ISI), 3:1549–1551**
 - advantages of, 3:1551
 - in developing world, 3:1549–1551
 - export-led development and, 2:1063–1066
 - high tariffs on imported goods and, 3:1550
 - “infant industry” (List) concept and, 3:1550
 - infant industry model (IIM) of, 3:1550
 - Latin American Free Trade Association and, 3:1551
 - Latin American Integration Association and, 3:1551
 - Friedrich List’s work and, 3:1550
 - newly industrializing countries and, 4:2021–2024
 - practice of, 3:1550–1551
 - results of, 3:1551
 - Singer-Prebisch thesis and, 3:1550
 - state-funded infrastructure projects and, 3:1551
 - state interventions and, 3:1550
 - supporters of, 3:1550
 - theoretical roots and background of, 3:1550
 - trading blocs and, 3:1550–1551
 - United Nations Economic Commission for Latin America (ECLA) and, 3:1550
 - value-added industries and, 3:1550
- Imrie, Rob, 1:108
- Incubator zones, 3:1551–1553**
 - benefits of, 3:1552
 - Ben Franklin Partnership Program and, 3:1552
 - business support services provided by, 3:1551
 - definition of, 3:1551
 - growth of, 3:1552
 - history of, 3:1551–1552
 - industrial districts and, 3:1576–1577
 - industrial sector varieties and, 3:1552
 - National Business Incubation Association and, 3:1551–1552
 - new products to market and, 3:1552–1553
 - role in economic development of, 3:1552–1553
 - services provided by, 3:1552
 - Small Business Administration and, 3:1552
 - U.S. incubator zones and, 3:1552
- India**
 - acid rain in, 1:7
 - agrobiodiversity in, 1:50
 - antiglobalization, anticolonism in, 1:97
 - automobile industry in, 1:169
 - Bhopal chemical disaster in, 1:194–195, 4:2158
 - bovine domestication in, 2:783
 - British colonialism in, 1:516, 3:1222
 - British East India Company in, 1:514
 - British railroad technology and, 2:747
 - cadastral systems, land ownership and, 1:315
 - cattle grazing as common resource in, 1:526
 - China’s foreign direct investment in, 3:1155
 - chipko movement and, 1:394–395, 1:395 (fig.), 5:2563
 - cholera in, 1:401
 - Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 - climate change action plans in, 2:902
 - clothing exports from, 6:2186 (fig.)
 - coal in, 1:485
 - coastal litter, Mumbai, 1:503 (photo)
 - CO₂ emissions in, 3:1377
 - colonial migrations of, 1500–1914, 3:1543
 - crop centers of domestication in, 1:374
 - Alexandra David-Néel exploration of, 2:1057–1058
 - deficient calorie consumption in, 3:1487
 - deposit refund systems in, 4:1857
 - drought in, 2:791
 - ecological footprint and biocapacity of, 2:827 (table)
 - economically active females in, 3:1190 (table)
 - El Niño–Southern Oscillation (ENSO) and, 2:887
 - energy policies in, 2:902
 - extreme weather events in, 5:2666 (fig.)
 - foreign aid from, 3:1153
 - foreign direct investment by, 1:130
 - foreign direct investment in, 4:2023
 - gendered land reform in, 4:1694
 - green building programs in, 3:1369
 - greenhouse gas emissions of, 1:462, 1:463, 1:464
 - Green Revolution, rice and wheat in, 3:1555–1556
 - groundwater usage in, 2:783
 - Gyps* vultures extinction in, 2:1070, 2:1070 (photo)
 - HIV/AIDS in, 3:1438, 3:1439
 - human rights atrocities in, 3:1481
 - hydroelectric power in, 3:1510
 - Ibn Battuta exploration of, 2:1054, 3:1519
 - import substitution industrialization in, 3:1551
 - income ratio relative to slum population in, 2006, 5:2644 (fig.)
 - independence movement in, 2:692
 - Indocentrism and, 2:1029
 - Indo-European languages and, 4:1749, 4:1750 (fig.)
 - industrialization in, 3:1580
 - informal sector of economic activity in, 3:1591
 - Infosys Technologies, Mysore, 3:1078
 - Internet access in, 2:845
 - joint forestry management in, 2:552
 - Khonoma Tragopan Sanctuary, Angami tribe of Nagaland, 3:1558, 3:1558 (photo)
 - Kyoto Protocol of 1997, greenhouse gas emissions and, 1:463
 - marine aquaculture in, 4:1853
 - McDonald’s restaurant in New Delhi and, 3:1347 (photo)
 - military expenditures in, 4:1899 (table)
 - military-industrial complex in, 4:1900
 - monsoons in, 1:134, 2:741, 4:1985–1986
 - morphine-rich narcotics produced in, 2:796, 2:797 (table)
 - multinational corporations investment in, 5:2220
 - National Disaster Management in, 2:763
 - nationalism in, 1:517
 - Naxalite peasant movement and, 4:2141
 - as newly industrializing country, 4:2022 (fig.), 4:2023
 - next generation nuclear reactors in, 4:2051
 - NGOs and rural development research in, 3:1193
 - oil imports of, 4:2073
 - opium production in, 2:795
 - particulate matter pollution in, 1:151

- per capita income inequality in West Bengal districts, 5:2643 (fig.)
pesticides use in, 1:52–53
Phoenicians exploration of, 2:1051
population growth in, 5:2241
railroads in, 5:2363
remittance flows to, 5:2412
remote sensing multitemporal imaging satellite of, 4:1959
rice paddy cultivation in, 1:48
Roman exploration of, 2:1051
search for new route to, 2:1054
Sepoy Rebellion, anticolonialism in, 1:94, 1:508, 1:514
shopping mall restructuring construction, 5:2459 (photo)
silver trade and, 1:512
social forestry in, 5:2563–2564
squatter settlements in, 5:2682
steel industry in, 5:2689, 5:2690, 5:2691
Subaltern Studies Collective and, 5:2260
as symbol of distance and mystery (Herodotus), 3:1422
textile exports from, 6:2815 (fig.), 6:2816 (fig.)
total factor productivity (TFP) of, 6:2780 (table)
tropical deciduous forest in, 1:230
tropical humid climate in, 1:453
tropical monsoon climate in, 1:454–455
tropical rain forest of, 1:234
tropical savanna climate in, 1:455
tropical savanna in, 1:239, 1:240
tropical scrub in, 1:244
Tsunami of 2004, Indian Ocean and, 6:2888–2890
waste management in, 5:2372
water supply contamination and, 3:1387
water treatment technologies in, 3:1574
wind and solar energy in, 2:902
woodfuel for cooking, Maharashtra, 6:3123 (photo)
Yamunotri Temple, Indian Himalayas, 5:2407 (photo)
- Indiana (Southern) flood, June 2008, 5:2426 (figs.), 5:2427 (fig.)
- Indian Ocean
Antarctic Convergence zone and, 1:451
Arab exploration and trade and, 2:1053
atmospheric angular momentum in, 1:143
atmospheric energy variations and, 1:164
cyclones in, 1:134
Vasco de Gama exploration of, 2:1054, 3:1178 (fig.), 3:1461
major tectonic areas of, 5:2196 (fig.)
Tsunami of 2004 and, 6:2888–2890, 6:2889 (fig.)
See also Tsunami of 2004, Indian Ocean
- Indigeneity**, 3:1553–1555
definition of, 3:1553, 3:1554–1555
Deskaheh of Cayuga and, 3:1553
ethnocentrism and, 2:1027
European colonialism and, 3:1553, 3:1555
“Indigenous and Tribal Population Convention,” of
International Labour Organization, 3:1553–1554
indigenous forest dwellers and, 3:1164
indigenous peoples’ movement and, 3:1553–1554
indigenous ways of knowing, nature-society theory and, 4:1996
land loss and, 2:1021
noble savage concept, 2:1020–1021, 3:1362
origin of term and, 3:1553
paternalistic views toward, 2:1020–1021
political status of indigenous peoples and, 3:1553
self-determination and, 3:1554
self-identification as “first peoples” or “first nations” and,
3:1554–1555
Six Nations of the Iroquois Confederacy and, 3:1553
strategic essentialism and, 3:1554
- “strategic essentialism” and, 2:1021
UN policy and actions regarding, 3:1554
ways of knowing, ethical codes and, 3:1553
“white man’s burden,” 2:1021
See also Indigenous specific subject
- Indigenous agriculture**, 3:1555–1557
agrobiodiversity and, 1:50
agroecology and, 1:54
agroforestry and, 1:60–62, 3:1557, 5:2579
as alternative development basis, 3:1555
cultural ecology, agrarian populism and, 3:1556
dominant modernization paradigm *vs.*, 3:1555–1556
extensive *vs.* intensive cultivation methods and, 3:1557
“farmer first” paradigm and, 3:1557
Green Revolution and, 3:1555–1556
indigenous irrigation and, 3:1557
indigenous knowledge focus of, 3:1555
learning from smallholder practice and, 3:1557
local control *vs.* origin and, 3:1555
new farming methods, Andranolava, Madagascar, 3:1555–1556
place-bound tradition and, 3:1555
rainwater harvesting and, 3:1557
raised field cultivation in wetlands and, 3:1557
shifting cultivation and, 5:2540–2543
swidden cultivation and, 3:1557
in West Africa, 3:1556–1557
See also Indigenous specific subject
- Indigenous and community conserved areas (ICCAs)**, 3:1557–1561
characteristics of, 3:1559
Coron Island, coral island seascape, Tagbanwa people, the
Philippines, 3:1560 (photo)
definition of, 3:1557–1558
diversity of, 3:1559
future, 3:1561
geographies of, 3:1559
global climate change and, 3:1560
international conservation forums and, 3:1558–1559
International Convention on Biological Diversity
and, 3:1561, 3:1568
International Union for Conservation of Nature and, 3:1561
Khonoma Tragopan Sanctuary, Angami tribe of Nagaland,
India, and, 3:1558, 3:1558 (photo)
points of view classification of, 3:1559
significance of, 3:1559–1561
strengths and weaknesses of, 3:1560–1561
threats to, 3:1561
world’s oldest protected areas and, 3:1558
See also Indigenous specific subject
- Indigenous cartographies**, 3:1561–1564
Bdote Memory Map of Dakota people, 3:1563
cartobibliographic record of, 3:1561–1562
characteristics of, 3:1562
Columbian Encounter conferences and, 3:1562
countermapping and, 2:595
definition of, 3:1561
diversity in, 3:1561–1562
Euro-American map deconstruction and, 3:1563
examples of, 3:1561–1562
GIS technology and, 3:1563
History of Cartography Project and, 3:1562–1563
Hudson’s Bay Company maps and, 3:1562
indigenous self-determination and, 3:1563
justice geographies and, 3:1645
Lewis and Clark expedition maps, 3:1562
New Spain maps and, 3:1562

- nonindigenous perception difficulty and, 3:1562
 Pepamateiati Nitassinat Web site and, 3:1563
 performative structures of, 3:1562
 processual approach to, 3:1562
 storied place names and, 3:1563
 technology and global media impact on, 3:1563
 theoretical perspectives on, 3:1562–1563
See also Indigenous cartographies: noted individuals; **Indigenous specific subject**
- Indigenous cartographies:** noted individuals
 Barbara Belyea, 3:1562
 Jacques Derrida, 3:1562, 4:1754
 Michel Foucault, 3:1562
 Brian Harley, 3:1562
 Robert Runderstrom, 3:1562, 3:1563
- Indigenous environmental knowledge, 3:1564–1567**
 Fikret Berkes's research on, 3:1564
 Gregor Cajete's research on, 3:1565
 central paradox study of, 3:1564, 3:1566
 characteristics and interpretation of, 3:1564–1565
 circumpolar peoples research and, 3:1566
 community-based conservation paradigm and, 3:1568
 cultural values focus of, 3:1564
 dichotomies of, 3:1568
 “ecological imperialism” concept and, 3:1565
 ethnocentrism of Western tradition and, 3:1564
 European colonialism and, 3:1565
 heritage paradigms *vs.*, 3:1564
 historic studies of, 3:1564
 holistic and inclusive environment approaches and, 3:1565
 indigenous ways of knowing, nature-society theory and, 4:1996
 indigenous writers and, 3:1566
 mutual reciprocity theme in, 3:1565
 native science (Cajete) and, 3:1565
 in natural resource management, 3:1565
 overgeneralization risk and, 3:1564
 permaculture and, 4:2152–2153
 relationships between living beings focus of, 3:1564
 research on, 3:1566
 resource management and, 3:1565–1566
 Mere Roberts' Maori research and, 3:1566
 role of fire example and, 3:1565
 romanticization danger and, 3:1565–1566, 3:1569
 sacredness of the living world and, 3:1564–1565
 situated knowledge and, 5:2548–2549
 Sandie Suchet's research on, 3:1565
 sustainability issue and, 3:1565, 3:1568
 terms related to, 3:1564
 territory and place, indigenous identities and, 3:1564
 UN Permanent Forum on Indigenous Issues and, 3:1564
See also **Indigenous specific subject**
- Indigenous environmental practices, 3:1567–1568**
 Amazonian rubber tappers and, 2:1072–1073
 behaviors, knowledge, beliefs and, 3:1567
 community-based natural resource management and, 2:549–551
 Convention on Biological Diversity and, 3:1561, 3:1568
 definition of, 3:1567
 diverse and local condition specific features of, 3:1567
 “environmental” label implications and, 3:1568
 European colonialism misconceptions and, 3:1568
 examples of, 3:1567
 extractive reserves and, 2:1072–1073
 nomadic herding and, 4:2029–2032
 nonindigenous construct of, 3:1567–1568
 “practices” label implications and, 3:1568
 sociocultural context of, 3:1567
 stewardship of the environment and, 2:1020–1022
 sustainable development issues and, 3:1568
 transmission methods of, 3:1567
 UN Conference on Environment and Development and, 3:1568
 world's fragile ecosystems protected by, 3:1568
- Indigenous forestry, 3:1569–1570**
 agroforestry and, 1:60–62
 Amazonian rubber tappers and, 2:1072–1073
 benefits of, 3:1569
 climate change and, 3:1570
 community-based natural resource management and, 2:549–551
 conventional or scientific forestry *vs.*, 3:1569
 Declaration on the Rights of Indigenous Peoples and, 3:1569
 definition of, 3:1569
 exclusionary forestry policy and, 3:1570
 geographic locations of, 3:1569
 local culture, norms, and values and, 3:1569
 modern democratic society values and, 3:1569
 oppressive practices perpetuated by, 3:1569–1570
 ownership rights of forests and, 3:1569
 romanticization danger and, 3:1565–1566, 3:1569
 state-dominated forestry failure and, 3:1569
 subsidiarity principle, justification of, 3:1569
 sustainability issue and, 3:1569
See also **Indigenous specific subject**
- Indigenous reserves, 3:1570–1572**
 administration of, 3:1572
 in Canada, 3:1570–1571
 colonial processes and, 3:1570
 cultural importance of, 3:1570
 culture, traditions, and languages protected by, 3:1572
 economic development limitations on, 3:1572
 federal government programs and, 3:1572
 First Nations' and Native Americans' land ownership and, 3:1570
 General Allotment Act (1887, U.S.) and, 3:1572
hogan, Navajo Indian Reservation, Arizona, 3:1571 (photo)
 Indian Act (Canada) and, 3:1570, 3:1572
 Indian Removal Act (U.S.) and, 3:1571
 reduction in size of, 3:1571–1572
 reservations and, 3:1570
 self-government agreements and, 3:1572
 social conditions of, 3:1572
 subjugative control over, 3:1572
 taxation exemption of, 3:1572
 title to lands and, 3:1572
 treaty negotiations, missionary grants and, 3:1571
 two forms of government on, 3:1572
 U.S. Indian Reorganization Act (1934) and, 3:1570, 3:1572
See also **Indigenous specific subject**
- Indigenous water management, 3:1573–1576**
 access and, 3:1573
 bunds water collection method, 3:1575
 culture and, 3:1573
 definition of, 3:1573
 foreign technologies mixed with, 3:1573, 3:1575 (photo)
 gender factors in, 3:1573, 3:1574 (photo)
 international watershed management and, 3:1618–1620
 pits water collection, 3:1575
 ritual factors in, 3:1573
 runoff harvesting collection method, 3:1575
 “sakau” drink, Pohnpei, Federated states of Micronesia, example of, 3:1573
 scales of, 3:1573
 sharing water and, 3:1573

- social structures and, 3:1573
 subsistence economies and, 3:1573
 techniques for collecting and treating water in, 3:1573–1575
 water as “common pool resource” and, 3:1573
 water collection technologies and, 3:1574–1575
 watershed delineation and management and, 3:1575
 water treatment technologies and, 3:1574
See also Indigenous specific subject
- Indochina**
 French colonies in, 1:509, 1:515
 textile exports from, 6:2815 (fig.), 6:2816 (fig.)
 tropical deciduous forest in, 1:230
 tropical rain forest of, 1:234
 tropical savanna climate in, 1:455
- Indonesia**
 APEC membership of, 1:121
 ASEAN membership of, 1:127, 1:128, 1:128 (table), 1:129, 1:129 (table)
 biodiesel produced in, 202
 cholera in, 1:401
 clothing exports from, 6:2186 (fig.)
 coal in, 1:485
 colonization of, 1:516
 countermapping forests of, 2:595
 deforestation in, 2:696, 5:2193
 Dutch East Indies Company in, 1:515
 economically active females in, 3:1190 (table)
 El Niño–Southern Oscillation (ENSO) and, 2:887, 2:888
 forest fragmentation in, 3:1159
 Grasberg–Erstberg copper mine in, 4:2086
 Grasberg–Erstberg open-pit mine in, 4:2087
 HIV/AIDS in, 3:1438
 income distribution, percentile of world income, 5:2641 (fig.)
 independence of, 2:692
 industrialization in, 3:1583, 4:2022, 4:2022 (fig.)
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Internet access in, 2:845
 island species variations in, 1:209
 Japanese electronics industry in, 2:885
 “jungle rubber” smallholder plantations in, 5:2195
 Malay archipelago and, 1:105
 Malayo–Polynesian languages in, 4:1753, 4:1753 (fig.)
 marine aquaculture in, 4:1853, 4:1854 (fig.)
 monsoons in, 1:134
 tropical rain forest of, 1:234
 Tsunami of 2004, Indian Ocean and, 6:2888–2890
 tsunami of 2004 and, 4:1985
 volcanic structures in, RADAR image, 4:1889 (fig.)
- Industrial districts, 3:1576–1577**
 agglomeration economies and, 1:31–32
 clusters and, 1:480–481, 1:480–482, 1:482
 cooperation and competition within, 3:1576
 creative industrial districts and, 2:851–852
 definition controversy and, 3:1576
 flexible production and, 3:1125–1127, 3:1576
 innovation geographies and, 3:1597–1599
 lead time minimization and, 3:1576
 learning regions and, 4:1766–1768
 Los Angeles School of urban economy and, 4:1803–1805
 Alfred Marshall’s work and, 1:480–481, 1:482
 network of relationships and knowledge sharing in, 3:1576
 small- to medium-sized enterprises (SMEs) and, 3:1576
 specialization within, 3:1576
 structural changes in, 3:1576
- Industrial ecology, 3:1577–1580**
 behavioral studies and, 3:1579
 challenges faced by, 3:1579–1580
 change in existing systems and, 3:1578–1579
 chemical spills, environment, and society and, 1:382–384
 closed-loop cycles fueled by solar energy and, 3:1578
 “cradle to cradle” concept and, 3:1577, 3:1578
 design for environment approach to, 3:1579
 ecological analogy and, 3:1578
 ecosystem processes and product life cycles and, 3:1578
 energy balances and resource flow accounting and, 3:1578
 environmental effects of industry and, 3:1577
 environmental impact assessments and, 3:1578
 environmental impacts of manufacturing and, 2:940–944
 evaluation of existing systems and, 3:1578
 future trends in, 3:1579–1580
 integrated production network, Kalundborg, Denmark, example of, 3:1579
 interdisciplinary research topics of, 3:1577
 levels of analysis: tools and applications in, 3:1578
 life cycle assessments (LCAs) of, 3:1578
 mutualism strategies examples of, 3:1579
 network of production and consumption and, 3:1577
 policy development and, 3:1579–1580
 practical applications of, 3:1579
 small- vs. large-scale applications of, 3:1579
 social context, 3:1579
 socioeconomic environment factor in, 3:1577
 sustainable use of resources goal of, 3:1577
 systems modeling and, 3:1578
 systems perspective on, 3:1577
 unintended rebound effects and, 3:1577
See also Corporate voluntary environmental initiatives and self-regulation
- Industrialization, 3:1580–1581**
 advanced manufacturing functions and, 3:1580
 Communism and, 2:542
 conditions and forces of, 3:1580–1581
 core-periphery development unevenness and, 3:1581, 5:2219
 definition of, 3:1580, 3:1581
 environmental impacts of manufacturing and, 2:940–944
 Fordism and, 3:1148–1151
 government and industry links and, 3:1581
 import substitution industrialization and, 3:1549–1551
 Industrial Revolutions and, 3:1580, 3:1581–1586
 initial stages of, 3:1580
 Manufacturing Belt and, 4:1820–1824
 spatial unevenness of, 3:1581
 trade policies and, 3:1581
- Industrialized agriculture. *See* Agriculture, industrialized; Agriculture, preindustrial**
- Industrial Revolution, 3:1581–1586**
 agricultural industrialization and, 3:1582
 assembly line and, 3:1582
 business cycles and, 1:303
 capitalism and, 3:1581, 3:1583, 3:1586
 child labor and, 3:1584, 3:1585 (photo)
 class conflict during, 3:1585
 coal as energy source and, 3:1582
 colonialism and, 1:509
 complex process elements of, 3:1581
 consequences of, 3:1584–1586
 cycles of industrialization and, 3:1583–1584
 division of labor and, 3:1582
 electronics industry wave of, 3:1584

- environmental impacts of, 2:928, 2:941
- factory system and, 3:1582
- Fordist systems of mass production and, 3:1582, 3:1584
- geography of, 3:1583
- global economy and, 3:1586
- heavy industry wave of, 3:1584
- inanimate energy dimension of, 3:1581–1582
- industrialization definition and, 3:1581
- interchangeable parts and, 3:1582
- international finance and, 3:1586
- labor unions and, 3:1585
- Malthusian population principle of famine and, 3:1586, 4:1819–1820
- Manufacturing Belt and, 4:1820–1824
- middle class growth and, 3:1582
- modern working class and, 3:1584
- organized labor markets and, 3:1584
- petrochemicals and automobile industry wave of, 3:1584
- population growth rates and demographic composition and, 3:1586
- producer services and, 3:1584
- productivity increase dimension of, 3:1582
- rise of modernity and, 3:1584
- running water energy source and, 3:1581
- spinners at Cherryville Mfg. Co., North Carolina, 3:1585 (photo)
- standard of living improvements and, 3:1582
- steam engine energy source and, 3:1581–1582
- technology innovation dimension of, 3:1582, 3:1584
- textile industry wave of, 3:1583–1584
- urbanization and, 3:1585–1586
- wood as energy source and, 3:1582
- Industrial Revolution: noted individuals
 - Henry Ford, 3:1582
 - Thomas Malthus, 3:1586, 4:1819–1820
 - Thomas Newcomen, 3:1582
 - Adam Smith, 3:1582
 - James Watt, 3:1582
 - Eli Whitney, 3:1582
- Inequality and geography, 3:1586–1590**
 - class-based conflict and, 3:1587
 - dependency theories and, 3:1587
 - educational geographies and, 2:874–875
 - ethics and geography and, 2:1013–1016
 - David Harvey's work in, 3:1404–1406, 3:1467, 5:2350
 - human geographers and, 3:1587
 - importance of, 3:1587–1588
 - inequity and poverty relationship issue and, 3:1589
 - inevitability of, 3:1587–1588
 - marginalized groups and, 3:1587
 - Marxism influence and, 3:1587, 3:1588
 - measurement of, 3:1588
 - policy issues and, 3:1587
 - political issues, 3:1587
 - postcolonialism and, 3:1587
 - postmodernism and poststructuralism and, 3:1587
 - spatial differences examination and, 3:1586–1587
 - welfare and justice issues and, 3:1587
 - welfare states and, 3:1590
- Informal economy, 3:1590–1592**
 - absence of institutional regulation in, 3:1590–1591
 - characteristics of, 3:1591–1592
 - conditions of work in, 3:1590
 - contradictions within, 3:1591
 - definition of, 3:1590
 - dependency structures in, 3:1591
 - formal economy connection of, 3:1591
 - heterogeneous feature of, 3:1591
 - Informal Economy* (Portes and Castells), 3:1591
 - informal sector of economic activity and, 3:1591
 - institutional management form in, 3:1590–1591
 - marginal economy and, 3:1591
 - politico-economic process of, 3:1591
 - self-employed and, 3:1591
 - status of labor affected in, 3:1590
 - universality of, 3:1591
 - work process affected by, 3:1590–1591
- Information society, 3:1593–1594**
 - codification, infrastructure, and education importance to, 3:1594
 - cyberspace and, 2:646–648
 - digital age of information and, 3:1593
 - economic benefits of, 3:1593
 - explicit *vs.* tacit information layers and, 3:1593
 - exposure and access inequities and, 3:1593
 - information and communication technologies and, 3:1593
 - information economy and, 3:1593
 - information pattern layers and, 3:1593
 - Internet technology and, 3:1593
 - knowledge geographies and, 4:1659–1663
 - modern societies dependence on, 3:1594
 - radio and phone technology and, 3:1593
 - spatial economic patterns and, 3:1593
 - telegraph and, 3:1593
 - television and, 3:1593
 - value-added information, tradability of, 3:1594
- See also Communications geography*
- Infrastructure, 3:1594–1597**
 - commodity and information flows of globalization and, 3:1594
 - externalities issue and, 3:1595–1596
 - “hidden hand” behind urban development and nation building, 3:1594
 - Hurricane Katrina and, 3:1594
 - individual *vs.* social benefits and, 3:1596
 - interurban *vs.* intra-urban infrastructures and, 3:1595
 - I-35 bridge collapse over Mississippi River and, 3:1596 (photo), 3:1597
 - Thomas Jefferson and, 3:1595, 4:1642
 - military term of, 3:1594
 - neoliberalism and, 3:1596–1597
 - nonrivalness and nonexcludability issues in, 3:1595
 - public and private works and, 3:1594–1595
 - public *vs.* private infrastructure and, 3:1595
 - quality of life and social well-being and, 3:1596
 - role of government in, 3:1595–1597
 - social disaster from lack of, 3:1594
 - support network of society and, 3:1594
 - urban infrastructure concealment and, 3:1595
- Innovation, geography of, 3:1597–1599**
 - colocation element in, 3:1598
 - common knowledge base and, 3:1598
 - competitive advantage and, 2:558–559
 - diffusion and, 2:745–748
 - knowledge spillover and, 3:1598, 4:1663–1664
 - learning regions and, 4:1766–1768
 - local linkage and collaboration issue in, 3:1598
 - “location-scanning” perspective on, 3:1598
 - Alfred Marshall's “industrial districts” research and, 3:1597–1598
 - qualitative and dynamic perspectives on, 3:1598
 - regionally based prosperity and, 3:1598
 - “resources allocation” and, 3:1598
 - spatial agglomeration of economic activity and, 3:1597
 - spatial clustering and, 3:1598

- spin-off formation issue in, 3:1598–1599
 tacit knowledge issue in, 3:1599
See also **High technology**
- Input-output models**, 3:1599–1601
 analytical purposes and applications of, 3:1601
 economic base analysis and, 2:846–848
 explanation of, 3:1599–1600
 forward and backward economic links between industries and, 3:1599–1600, 3:1600 (table)
 interindustry interdependencies and, 3:1600
 Walter Isard and, 3:1628
 Wassily Leontief's development of, 3:1599–1600
 matrix of monetary transactions and, 3:1600, 3:1600 (table)
 openness and closure, 3:1600–1601
- Institute of British geographers.** *See* **Association of American Geographers** (AAG)
- Institute of British Geographers (IBG)**, 3:1601–1603
 academic geographers membership of, 3:1601–1602
 Association of British Climatologists group of, 3:1602–1603
 British Association for the Advancement of Science, 3:1601
 British Geomorphological Research Group and, 3:1602
 founding and early years of, 3:1601, 3:1602
 functions of, 3:1601
 Geographical Association and, 3:1601
 growth of, 3:1602–1603
 international contacts promoted by, 3:1602
 journal of, 3:1602
 Quantitative Methods group of, 3:1602–1603
 Royal Geographical Society (RGS) and, 3:1601–1602, 3:1603, 5:2485–2487
 study groups of, 3:1602–1603
- Intergovernmental environmental organizations and initiatives**, 3:1603–1605
 atmospheric issues organizations, 3:1605
 collective action on regional issues and, 3:1605
 endangered species protection organizations, 3:1605
 international environmental law and, 2:967
 international environmental movements and, 3:1608–1612
 international environmental organizations and, 3:1604–1605
 ocean pollution and safety organizations, 3:1605
 similarities and links among, 3:1605
 sustainable use of species and, 3:1604
 UN's role in, 3:1603–1604
See also Intergovernmental environmental organizations and initiatives: specific organizations
- Intergovernmental environmental organizations and initiatives: specific organizations**
 Convention on Biological Diversity, 3:1604
 Convention on International Trade in Endangered Species of Wild Fauna and Flora, 3:1604
 Convention on Migratory Species, 3:1604
 International Maritime Organization, 3:1604–1605
 International Whaling Commission, 3:1604
 Kyoto Protocol, 3:1605
 Ozone Secretariate, 3:1605
 Regional Fishery Management organizations, 3:1604
 UN Conference on Environment and Development, 3:1609
 UN Conference on the Human Environment (UNCHE), 3:1604, 6:2747
 UN Economic Commission for Europe, 3:1605
 UN Environmental Programme (UNEP) and, 3:1604
 UN Millennium Development Goals and, 3:1604
 UN World Commission on Environment and Development and, 3:1604, 5:2220
- UN World Summit on Sustainable Development and, 3:1604, 6:2738, 6:2750
- Intergovernmental Panel on Climate Change (IPCC)**, 1:45
 anthropogenic climate change and, 1:82–83, 1:84, 1:84 (table), 1:86 (fig.), 1:87 (fig.), 1:88 (fig.), 1:89 (fig.), 3:1374, 4:1985, 5:2552, 5:2554 (fig.)
 carbon dioxide levels and, 1:82–85
 climate policy and, 1:462
 climatic relicts and, 1:470
 cloud feedbacks, global climate change assessment and, 1:480
 coastal hazards and, 1:500
 global mean radioactive forcing by GHGs and, 3:1375 (table)
 global sea-level rise predictions of, 3:1346
 greenhouse gases and, 3:1374
 ice sheet change data of, 3:1525
 International Polar Year and, 5:2204
 sea level data of, 3:1525
 snow and ice melt and, 5:2204
 Working Groups and Task Force of, 1:82
- International Agency for Research on Cancer**, 1:335
- International Association of Landscape Ecology**, 4:1706
- International Association of Geomorphologists**, 3:1245
- International Cartographic Association**, 1:118
- International Consortium of Environmental History Organization**, 2:929
- International Convention on Biological Diversity (CBD)**, 1:33, 1:49, 3:1561, 3:1568, 3:1604
- International Criminal Court (ICC)**, 3:1605–1608
 accountability issues of, 3:1605–1606
 “American exceptionalism” issue and, 3:1606
 Coalition for the International Criminal Court and, 3:1607
 Cold War period and, 3:1606
 “complementarity” principle and, 3:1606
 formation of, 3:1606–1607
 functions of, 3:1605
 Hague and, 3:1607
 historical background of, 3:1606
 impacts of, 3:1607–1608
 jurisdiction of, 3:1605, 3:1607
 NGOs role in, 3:1607
 objectors to, 3:1606
 participant members of, 3:1608
 Peace Palace, The Hague, Netherlands, and, 6:3130 (photo)
 as product and producer of globalization, 3:1605
 restrictions on powers of, 3:1606–1607
 Rome Statute of, 3:1607
 Rwanda genocide and, 3:1606
 Sierra Leone and Cambodia tribunals and, 3:1606
 state power unchallenged by, 3:1607–1608
 “trigger” mechanisms of, 3:1606–1607
 Uganda, Sudan, Congo, and Central African Republic cases of, 3:1607
 “victor's justice” issue and, 3:1607
 Yugoslavia breakup, violence during, 3:1606
- International environmental movements**, 3:1608–1612
 antinuclear movement, 3:1609
 Basel Action Network (BAN) and, 3:1610
 Climate Action Network (CAN) and, 3:1610
 definition of, 3:1608
 environmental problems geographic scales and, 3:1609
 functions of, 3:1608
 global environmental justice movement, 3:1610
 Greenbelt movement, 3:1610
 intergovernmental organizations and initiatives and, 3:1603–1605
 international institutions and, 3:1611

- international political opportunity structures and, 3:1611
- movement against genetically modified organisms, 3:1609–1610
- “Network of GMO Free Regions” and, 3:1610
- “new social movements” characteristics and, 3:1608–1609
- origins and development of, 3:1608–1609
- political opportunities and, 3:1610–1611
- Rainforest Action Network (RAN) and, 3:1610
- UN Conference on Environment and Development and, 2:835, 3:1568, 3:1609
- See also* European green movements
- International environmental NGOs, 3:1612–1614**
 - forms of, 3:1612
 - goals of, 3:1612
 - international environmental movements and, 3:1608–1612
 - international environmental think tanks and, 3:1614
 - international environmental umbrella organizations and, 3:1614
 - international mass membership organizations, 3:1612–1613
 - multilateral environmental agreements and, 3:1613
 - national mass membership organizations operating as, 3:1613–1614
 - See also* International environmental NGOs: specific organizations
- International environmental NGOs: specific organizations
 - Environmental Defense Fund, 3:1613
 - European Federation for Transport and Environment and the European Environmental Bureau (EEB), 3:1614
 - Friends of the Earth International, 3:1612–1613
 - Greenpeace, 3:1612
 - International Institute for Environment and Development, 3:1614
 - National Audubon Society, 3:1613
 - National Resources Defense Council, 3:1613
 - National Wildlife Federation, 3:1613
 - Nature Conservancy, 3:1614
 - Öko-Institute (Germany), 3:1614
 - Sierra Club, 3:1613
 - UN Biodiversity Convention and, 3:1613
 - World Resources Institute, 3:1614
 - World Watch Institute, 3:1614
 - World Wide Fund for Nature, 2:871, 3:1612, 3:1613 (photo)
- International Farmers’ Movement. *See* Via Campesina (International Farmers’ Movement)
- International Geographic Union (IGU), 3:1614–1615**
 - Ronald Abler’s service to, 1:1
 - academic geographers membership of, 3:1614
 - Anne Buttner’s service to, 1:309
 - commissions and task forces of, 3:1615
 - communications geography and, 2:541
 - English and French working languages of, 3:1615
 - Geography of the Information Society and, 2:541
 - governing organization of, 3:1615
 - International Council of Science and, 3:1615
 - International Social Sciences Council and, 3:1615
 - Melvin Marcus and, 4:1850
 - objectives of, 3:1614–1615
- International Geosphere-Biosphere Programme (IGBP), 4:1735
- International Human Dimensions Programme (IHDP) on Global Environmental Change, 4:1735
- International Institute of Agriculture (Rome), 1:54
- International Maritime Organization (IMO), 3:1604–1605
- International Monetary Fund (IMF), 3:1615–1618**
 - antiglobalization issues and, 1:96
 - Articles of Agreement of, 3:1615
 - assets controlled by, 3:1615
 - Bretton Woods Conference and, 3:1615, 3:1616
 - colonial powers domination of, 5:2261
 - “conditionalities” to receive a loan and, 3:1616
 - convertability of member currencies and, 3:1616
 - credit-orientation feature of, 3:1616
 - demonstration against, West Berlin, 1988, 5:2443 (photo)
 - enforcement mechanisms of, 3:1616, 3:1617
 - exchange rate management by, 3:1618
 - floating exchange rates and, 3:1616
 - functions of, 3:1616–1618
 - General Arrangements to Borrow funding of, 3:1617
 - global remittance flows, 2007 and, 5:2412 (fig.)
 - governance by, 3:1358
 - Heavily Indebted Poor Countries debt relief and, 3:1617
 - IMF Institute and, 3:1618
 - Mexican debt default and, 2:688–689
 - Monetary and Capital Markets Department of, 3:1618
 - neocolonialism policies of, 4:2003
 - neoliberal economic policies of, 5:2220, 5:2459, 6:2750
 - neoliberal environmental policy and, 4:2008
 - NIC export-led development and, 2:165
 - offshore financial centers oversight by, 3:1618
 - “pegs” to regulate exchange rates and, 3:1616
 - Poverty Reduction and Growth Facility of, 3:1617
 - Poverty Reduction Strategy Papers and, 4:2014
 - regional remittance flows, 2007 and, 5:2413 (fig.)
 - Reports on the Observance and Codes of, 3:1618
 - restructuring reform of, 3:1617–1618
 - Special Drawing Rights of, 3:1617
 - Special Missions and Resident Advisors of, 3:1618
 - structural adjustment of economies role of, 3:1616, 5:2703
 - Structural Adjustment Programs (SAPs) of, 1:96, 2:1065, 4:1694, 4:2008, 4:2012
 - subscription funding source and, 3:1617
 - supranational economic activity, globalization and, 3:1347
 - surveillance functions of, 3:1618
 - technical assistance provided by, 3:1618
 - transparency standards and, 3:1618
 - U.S. shortage of currency and, 3:1616
 - voting power allocation of, 3:1617
- International Satellite Cloud Climatology Project (ISCCP), 1:478
- International Union for Conservation of Nature and Natural Resources, 1:470
- International Union for Conservation of Nature (IUCN), 4:2117
- International watershed management, 3:1618–1620**
 - adaptive watershed management approach to, 3:1620
 - community-based water resources management and, 3:1620
 - Convention on the Protection and Use of Transboundary Watercourses and International Lakes and, 3:1619
 - conventions and treaties in, 3:1619
 - definition of, 3:1618
 - ecosystem-based river basin management approach to, 3:1620
 - establishing effective practices in, 3:1619–1620
 - flexible and integrative framework for, 3:1619–1620
 - GIS in water management and, 3:1316–1318
 - Helsinki Rules on the Uses of the Waters of International Rivers* and, 3:1619
 - integrated water resources management (IWRM) strategy of, 3:1619
 - Ramsar Convention on Wetlands of International Importance and, 3:1619
 - stages in process of, 3:1619–1620
 - subfields of geography and, 3:1619
 - transboundary, national, and international scales of, 3:1618–1619
 - UN Convention on the Law of the Non-Navigational Uses of International Watercourses and, 3:1619
- International Whaling Commission, 3:1604

Internet

- Advanced Research Projects Agency of U.S. Department of Defense and, 2:646
- electronic atlases and, 2:884
- environmental mapping data collection and, 2:974
- environmental planning spatial analysis tools and, 2:981
- geospatial data use and, 3:1257–1258
- geospatial semantic web and, 3:1260
- geospatial software capabilities and, 3:1258
- Google, 3:1258
- Google Maps, 3:1258, 4:2006
- information society and, 3:1593–1594
- Internet-based GIS programs and, 3:1258
- Internet-based retail trade and, 5:2464
- Internet penetration rate and, 2:749 (fig.)
- MapQuest, 3:1258, 3:1260, 3:1284
- map services and, 3:1259
- mobile capabilities and, 3:1258–1259
- nongeographic Internet, Web 2.0 and, 4:2005–2006
- “spacelessness” of, 5:2313
- spatial analysis and, 5:2603–3604
- TCP-IP (transfer control protocol, Internet protocol) element of, 2:646
- time-space compression and, 6:2844
- Web-based spatial data clearinghouses and, 3:1258
- Web Mapping Service (WMS) and, 3:1259
- See also* Cyberspace; Google Earth; Internet GIS; Privacy and security of geospatial information; Virtual and immersive environments; Virtual geographies

Internet GIS, 3:1620–1623

- alternative names of, 3:1620
- architecture of, 3:1621–1622, 3:1621 (fig.)
- augmentation maps and, 1:108–110
- CAD systems and, 1:318
- client-server architecture and, 1:426–428
- client tier of, 3:1621–1622, 3:1621 (fig.)
- data compression methods and, 2:679–680
- data sharing type of, 3:1622, 3:1622 (table)
- data storage tier of, 3:1621 (fig.), 3:1622
- electronic atlases and, 2:884
- functions of, 3:1620
- future trends in, 3:1622–1623
- geospatial cyberinfrastructure and, 3:1621
- Google Maps and, 1:426, 4:2006
- information sharing type of, 3:1622, 3:1622 (table)
- International Organization for Standardization (ISO) Technical Committee 211 (TC211) and, 3:1621
- Internet information relay system and, 3:1620
- “internetworking” framework components and, 3:1620
- knowledge sharing type of, 3:1622, 3:1622 (table)
- Microsoft Virtual Earth and, 1:426
- middleware tier of, 3:1621 (fig.), 3:1622
- mobile GIS and, 4:1918–1921
- Open Geospatial Consortium (OGC) and, 3:1621
- prototypes of, 3:1620–1621
- remote sensing data and software, open access to, 1:319
- spatial information dissemination and, 3:1621
- Web-based GIS *vs.*, 3:1620
- Web-based maps and, 1:344
- Xerox PARC Map Viewer (1993) and, 3:1621

Interoperability and spatial data standards, 3:1623–1625

- data interoperability and, 3:1624
- Dublin core metadata standard and, 3:1624
- early exchange formats and, 3:1624
- eXtensible Markup Language (SML) and, 3:1624

- functional units of, 3:1623
- Geography Markup Language (GML) and, 3:1624
- geospatial Web services standards and, 3:1624
- GIS environmental model integration and, 3:1280
- International Organization for Standardization (ISO) and, 3:1623
- interoperability definition and, 3:1623
- interoperable data discovery in catalog services and, 3:1478
- ISO Technical Committee 211 (ISO/TC211) and, 3:1623, 3:1624
- Keyhole Markup Language (KML) and, 3:1355, 3:1478, 3:1624, 4:2085
- metadata and, 4:1885
- ontological foundations of geographical data and, 4:2078–2081
- open geodata standards and, 4:2083–2085
- Open Geospatial Consortium (OGC) and, 3:1623
- raster data and, 3:1624
- spatial data infrastructure (SDI) and, 3:1623
- syntactic *vs.* semantic interoperability and, 3:1623
- technical interoperability and, 3:1623
- Web 2.0 mash-ups and, 3:1211, 3:1478, 3:1624, 5:2305
- Web service interoperability standards and, 3:1624

Interviewing, 3:1625–1627

- Herbert Blumer’s symbolic interactionism and, 3:1625
- Chicago School urbanographies and, 3:1625
- conversational nature of, 3:1625
- definition of, 3:1625
- ethical challenges of, 3:1626
- interrelated research types and, 3:1625
- interview “data” as text and, 3:1626
- George Herbert Mead’s work in, 3:1625
- participant observation and, 4:2121–2122
- phenomenology and, 3:1625
- qualitative social science research method of, 3:1625
- reflexivity and, 3:1625
- researcher as instrument element of, 3:1625, 3:1626
- structured to unstructured continuum of, 3:1626
- subjective meanings of participants in, 3:1626

Invasion and succession, 3:1627

- changes to ecological communities through time and, 3:1627
- definitions of, 3:1627
- exotic species and, 2:1048–1050
- invasion as a negative process and, 3:1627
- physical transportation agents and, 3:1627
- primary *vs.* secondary succession and, 3:1627
- See also* Human-induced invasion of species

Iowa

- ephemeral gully erosion, Western Iowa, 5:2465 (photo)
- prairie restoration in, 5:2278
- same-sex marriage supporters, Iowa City, 5:2332 (photo)
- watershed management of Union Grove Lake, Tama County, 6:3073 (photo)

Iran

- automobile industry in, 1:169
- “axis of evil” concept (G. W. Bush) and, 2:612
- basin and range topography in, 1:186
- camel domesticated in, 2:783
- Cold War and, 1:504, 1:505
- economically active females in, 3:1190 (table)
- global petroleum trade and, 2:900
- goats domestication in, 2:783
- groundwater usage in, 3:1386
- human rights atrocities in, 3:1481
- oil sources in, 4:2163
- OPEC membership of, 4:2099, 4:2100 (fig.)
- opium and heroin production in, 2:797

- Iraq**
 “axis of evil” concept (G. W. Bush) and, 2:612
 bovine domestication in, 2:783
 British colonization of, 1:514
 cholera in, 1:402
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 global petroleum trade and, 2:900
 human rights atrocities in, 3:1481
 oil sources in, 4:2163
 OPEC membership of, 4:2099, 4:2100 (fig.)
 road surveyor and construction, Dhi Qar Province, 6:2736
 sheep domestication in, 2:783
- Ireland**
 AGILE membership of, 1:124 (table)
 cultural nationalism in, 4:1980
 economically active females in, 3:1190 (table)
 ethnic (Catholics and Protestants) self-segregation in, 2:1023
 European Union (EU) membership of, 2:1035
 foreign direct investment from, 3:1156
 Industrial Development Authority, rural development in, 5:2488
 mixed farming patterns in County Armagh, Northern Ireland, 4:1914–1915, 4:1916 (fig.), 4:1917
 national boundaries identification and, 4:1972
 Newgrange summer solstice in, 5:2598
 occluded cyclone weather in, 2:657–661
 protests, Catholic and Protestant neighborhoods, Belfast, 5:2525 (photo)
 public-private partnerships in, 5:2312
 U.S. foreign direct investment in, 3:1155
 Viking exploration of, 2:1051
- Isaac, Erich**, 2:782
- Isard, Walter**, 3:1627–1628
 academic career of, 3:1628
 building cycles and transportation development work of, 3:1628
 economic geography work of, 3:1627
 as father of regional science, 1:81, 3:1627, 5:2393, 5:2394
 journals founded by, 3:1628
 location theory work of, 3:1628
 Peace Science discipline founded by, 3:1628
 publications of, 3:1628
 Regional Science Association founded by, 3:1628, 5:2393
 research fields of, 3:1627–1628
- ISI**. *See* **Import substitution industrialization (ISI)**
- Island biogeography**, 3:1629–1634
 adaptive radiation process and, 1:14–15, 3:1630–1631
 anthropogenic changes and, 3:1629
 archipelagoes and, 1:105–106
 atolls and, 1:165–169
 biodiversity and, 1:197–201
 biotas of islands *vs.* continental biotas and, 3:1629
 conservation biogeography and, 3:1631–1632, 3:1633 (fig.), 3:1634
 continental fragments and, 3:1629
 continental islands and, 3:1629
 Jared Diamond’s work in, 2:734
 dynamic equilibrium model if ETIB and, 3:1630
 ecosystems of islands and, 3:1629
 endemic species and, 3:1629
 equilibrium theory of island biogeography (ETIB) and, 3:1630–1631, 3:1631 (fig.)
 forest patches as, 4:2131
 fragmentation research and, 3:1631–1632, 3:1633 (fig.)
 general dynamic model (GDM) of, 3:1632 (fig.)
 “hot spots” and of endangered and extinct species and, 3:1629–1630, 3:1630 (table)
 human-induced invasion of species and, 3:1473–1474
 island “ontogeny” and, 3:1630, 3:1632 (fig.)
 island theories and, 3:1630–1631
 island types and, 3:1629
 MacArthur-Wilson model of, 1:199, 1:210, 5:2672
 natural experiments replication and, 3:1629
 natural island landcover and, 3:1629
 oceanic islands and, 3:1629
 significance of islands and, 3:1629–1630
 SLOSS debate and, 3:1632
 true islands *vs.* habitat islands and, 3:1629
See also **Islands, small**
- Islands, small**, 3:1634–1637
 archipelagoes and, 1:105–106
 atolls and, 1:165–169
 biodiversity conservation challenge and, 3:1635
 Chuuk Lagoon from satellite imagery, Chuuk State, Federated States of Micronesia, and, 3:1636 (photo)
 Conference of the Parties to the Conservation on Biological Diversity and, 3:1635
 coral reefs and, 2:581–584, 3:1635
 Darwin’s theory of evolution and, 3:1635
 global climate change and, 3:1637
 habitat diversity of, 3:1635
 high island of Tonowas, Chuuk State, Federated States of Micronesia, and, 3:1635 (photo)
 high islands, 3:1634–1635
 low islands, Marshall Islands, 3:1637 (photo)
 low islands and atoll structures and, 3:1634, 3:1635–1637
 Micronesia region of Pacific Ocean and, 3:1635, 3:1635 (photo), 3:1636 (photo)
 saltwater intrusion and, 3:1636
 small-island developing states designation and, 3:1634
 Wilson’s theory of island biogeography and, 3:1635, 5:2672
- Isopleth maps**, 3:1638–1639
 choropleth maps and, 1:406–408
 continuity between high and low centers and, 3:1638, 3:1638 (fig.)
 contour maps and, 3:1638 (fig.)
 definition of, 3:1638
 isarithm and isogram and, 3:1638
 isoline maps and, 3:1638
 isometric *vs.* isopleth mapping and, 3:1638
 isopleth interval and, 3:1638
 lines of equal value to portray patterns and, 3:1638
 specialized names for different data and, 3:1639 (table)
 as thematic map, 3:1638
- Israel**
 AGILE membership of, 1:124 (table)
 antiglobalization, anticolonism in, 1:97
 British colonization of, 1:514
 central place theory in urban planning in, 1:382
 Dead Sea in, 1:115
 deposit refund systems in, 4:1857
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 human rights atrocities in, 3:1481
 incubator zones in, 3:1552
 “natural ethnicity” of a region concept and, 2:1020
- Isthmus of Panama**, 1:213
- Italy**
 agglomeration economies in, 1:32
 AGILE membership of, 1:124–125 (table)
 automobile industry in, 1:169, 1:171
 coal energy source in, 3:1582

- colonial empire of, 1:509, 1:509 (fig.)
community-based natural resource management in, 2:549
competitive advantage areas in, 2:558
early cadastral map from, 1:314 (fig.)
earthquakes in Calabria, 1783–1785, 2:812
ecological footprint of, 2:826, 2:827 (fig.)
economically active females in, 3:1190 (table)
Emilia-Romagna high-tech region in, 3:1127, 3:1598, 4:1766, 4:1767, 5:2519
European Union (EU) membership of, 2:1035
GDP of, 3:1382, 3:1383 (fig.)
groundwater usage in, 3:1386
hydroelectricity in, 3:1507
industrialization in, 3:1583, 4:2020
installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
Italo-centrism in, 2:1030 (table)
Larderello chemical industry zone in, 3:1267
Lombardy knowledge region in, 5:2435
military expenditures in, 4:1899 (table)
Mount Etna and, 2:605
movement against genetically modified organisms in, 3:1610
national geographical society in, 3:1462
particulate matter pollution in, 1:151
percentage of economically active females in, 3:1190 (table)
railroads in, 5:2358
San Marco Square and Palazzo Ducale, Venice, 5:2314 (photo)
“science” of geopolitics in, 3:1249, 3:1250
total factor productivity (TFP) of, 6:2780 (table)
Vineyards, Chianti region, Tuscany, 6:3116 (photo)
- Jackson, John Brinkerhoff, 4:1641–1642**
academic career of, 4:1641
American popular landscape focus of, 4:1641
architecture, historic preservation, and urban planning interests of, 4:1641
Association of American Geographers award of, 4:1642
cultural landscape analysis work of, 3:1435, 4:1641
folk-architecture documentation work of, 1:106
influences on, 4:1641
Landscape: The Human Geography of the Southwest magazine and, 4:1641
Peirce Lewis influenced by, 4:1773
- Jackson, Peter, 1:108, 1:524
Jackson, William Henry, 3:1409
Jacobs, Allan, 4:2025
Jacobs, Jane, 4:2025, 4:2126, 5:2395
- Jamaica
British colony of, 1:512
economically active females in, 3:1190 (table)
land inequalities in, 4:1693
- James, Preston, 2:567, 5:2534
Jameson, Frederick, 5:2264
Janelle, Don, 5:2404
Jänicke, Martin, 2:836–837
Jankowski, Piotr, 2:616, 4:2056
- Japan
above-ground park, Tokyo, 6:2934 (photo)
acid rain in, 1:7
APEC membership of, 1:121
as archipelago island formation, 1:105
ASEAN membership of, 1:129
automobile industry in, 1:169, 1:170, 2:700
basin and range topography in, 1:186
birthrates in, 2:708
carbon trading market in, 1:330
Chuetsu earthquake (2004) in, 2:811
colonialism resisted by, 1:508, 1:514
colonial migrations of, 1500–1914, 3:1543
competitive advantage areas in, 2:558
densely inhabited districts definition in, 5:2239
deposit refund systems in, 4:1857
earthquake losses in, 4:1984
East and southeast Asian economic bloc proposed by, 1:128
ecological footprint and biocapacity of, 2:827 (table)
economically active females in, 3:1190 (table)
electronics and pop culture content, Akihabara, Tokyo, and, 2:886
electronics manufacturing in, 2:885–886
energy policies in, 2:901–902
environmental history studies in, 2:929
“environmental miracle” of, 2:943
fertility levels in, 2:709
fishing cooperatives in, 1:534
foreign aid flow from, 3:1152
foreign direct investment and, 3:1155
GDP of, 3:1382, 3:1383 (fig.)
geothermal wells in, 3:1267
government and industry links in, 3:1581
green building programs in, 3:1368
greenhouse gas emissions of, 5:2220
herbicide use in, 3:1421
high-speed trains in, 5:2364
historical climate records in, 1:456
industrialization in, 3:1580, 3:1583
installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
Japan–South Korea World Baseball Classic game, Dodger Stadium, Los Angeles, 5:2681 (photo)
just-in-time inventory systems and, 3:1126, 5:2401
Kobe earthquake, 2:814
Kyoto Protocol of 1997, greenhouse gas emissions and, 1:462–463, 3:1374
land reform in, 4:1693
life expectancy in, 3:1410
lower birth rates in, 4:1981
military expenditures in, 4:1899 (table)
military-industrial complex in, 4:1900
Minamata disease, mercury poisoning and, 1:501–502
next generation nuclear reactors in, 4:2051
oil imports of, 4:2073
PCBs contamination in, 5:2226
petroleum consumption in, 4:2164 (fig.)
railroads in, 5:2358
rice paddy cultivation in, 1:48
rock garden at Kongobuji Temple, Mount Koya, 4:1704 (photo)
“science” of geopolitics in, 3:1249
steel industry in, 5:2689, 5:2690
textile exports from, 6:2815 (fig.), 6:2816 (fig.)
Tokyo airline networks, 1:179
topographic mapping in, 1:350
tuna harvesting in, 4:2066 (photo)
undernourishment in, 3:1488
Ural Altaic or Finno-Ugric languages in, 4:1751 (fig.)
See also Tokyo, Japan
- Jarvis, Edward, 2:775–776
Jarvis, H., 2:1042
Jasanoff, Sheila, 5:2518
Jaspers, Karl, 2:1046
Java, 1:209
Jefferson, Mark, 5:2290

- Jefferson, Thomas, 4:1642–1643
 “equality of opportunity” and, 5:2573
 federal infrastructure investment and, 3:1595
 Alexander von Humboldt and, 4:1642
 interests of, 4:1642
 Land Ordinance of 1784, survey format written by, 4:1642
 land ordinance system and, 3:1464
 Lewis and Clark expedition and, 3:1464, 4:1642, 4:1773–1777
 Louisiana Purchase and, 4:1642
 Map of the Kingdom of New Spain by Baron von Humboldt, 3:1463 (fig.), 3:1464
 public education geography supported by, 4:1642
 Township and Range land survey method and, 4:1642, 6:2861
 universal human rights and, 5:2573
 westward expansion and, 3:1464
- Jellico, Geoffrey, 4:1699
 Jellico, Susan, 4:1699
 Jencks, Christopher, 5:2264
 Jenkins, Alan, 4:1897
 Jenny, Hans, 5:2585
 Jensen, Jens, 5:2278
 Jensen, Ole, 2:1037
 Jensen, R., 3:1541
 Jentoff, Svein, 2:551
 Jerusalem
 Biblical map of, 1:196 (fig.)
 T-in-O maps, 1:347, 1:349 (fig.)
 Wailing Wall of, 2:638 (photo)
- Jihad vs. McWorld* (Barber), 1:94
 Johannessen, Carl, 2:782
 Johansson, Olga, 4:1969
 Johnson, D. L., 1:267
 Johnson, D. N., 1:267
 Johnson, D. W., 4:1896
 Johnson, Samuel, 4:1985
 Johnson, Simon, 5:2218
 Johnston, Peter, 5:2264
Johnston, R. J., 4:1643
 academic career of, 4:1643
 British electoral system focus of, 4:1643
 history of human geography since WWII and, 4:1643
 human geography focus of, 4:1643
 political and electoral geography work of, 4:1643
 three dimensions of place and, 5:2574
 urban social geography work of, 4:1643
- Jones, Clarence Fielden, 2:849
 Jones, Clive, 4:1657
 Jordan
 British colonization of, 1:514
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
- Jordan, Terry, 5:2537
- Justice, geography of, 4:1643–1645**
 antisystemic movements and, 1:99–100
 attaining justice and, 4:1644
 citizenship and, 1:413–414
 countermapping and, 2:595–596, 3:1645
 denouncing and correcting injustices and, 4:1644–1645
 ecological justice and, 2:830–832
 ethics and geography and, 2:1013–1016
 geography subfields and, 3:1645, 4:1644
 goals of work in, 4:1644
 human rights geographies and, 3:1480–1481
 indigenous cartography and, 3:1645
 inequality geographies and, 3:1586–1590
 International Criminal Court (ICC) and, 3:1605–1608
 justice definition work and, 4:1644
 multidisciplinary fields and, 3:1645
 spatial approach to, 4:1644–1645
 “spatial turn” in academic fields and, 3:1645
 See also Democracy; Environmental justice; Law, geography of; Social justice
- Justice, geography of: noted individuals
 William Bunge, 3:1645
 David Harvey’s work in, 3:1404–1406, 3:1467, 5:2350
 Will Kymlicka, 4:1644
 John Rawls, 4:1644
 Élisée Reclus, 1:73, 2:617, 3:1463, 5:2211, 5:2371–2372
 Charles Taylor, 4:1644
- Kabak, K. I., 1:326–327
 Kahn, Robert, 2:646
 Kaika, Maria, 3:1595
 Kalahari Desert, 1:239
 Kammen, Daniel, 6:2741
 Kansas
 “natural systems agriculture” in, 6:2745–2746
 prairie restoration in, 5:2278, 5:2278 (photo), 5:2281
- Kant, Immanuel, 4:1647–1649**
 Cartesian view of absolute space and, 4:1648
 chorology and, 1:404
 contributions to geography, 4:1648–1649
 cosmopolitanist doctrine of, 4:1648–1649
 Critique of Pure Reason written by, 4:1647
 environmental deterministic views of, 4:1648
 ethics and epistemology interests of, 4:1647
 Richard Hartshorne influenced by, 3:1402–1403, 4:1649, 5:2387–2388
 Alfred Hettner influenced by, 3:1422, 4:1649
 human knowledge organization developed by, 4:2179
 David Hume’s influence on, 4:1647
 international confederation of nations idea of, 4:1648
 metaphysics *vs.* theoretical and empirical science and, 4:1647–1648
 Newtonian notion of absolute time and space and, 4:1648
 normative theories of transnational relations of, 4:1648–1649
 noumena views of, 4:1647, 4:1648
 people and their relations to material world and, 4:1648
 perception issues and, 4:1647
 physical geography work of, 4:1647, 4:1648, 4:2179
 rational mind views of, 4:1647
 regions as mental constructs views of, 3:1403, 3:1462
 space existing prior to experience and, 4:1648
 time and space philosophies of, 3:1462, 4:1647–1648
 Tobler’s First Law and, 4:1648
 “Towards Perpetual Peace” essay of, 4:1648
 universal ideologies of nature and, 1:424
- Kaplan, D., 5:2345
 Kaplan, Rachel, 4:1716
 Kaplan, Robert, 2:999, 4:2016
 Kaplan, Stephen, 4:1716
- Karst topography, 4:1649–1654**
 atolls formation and, 1:166–167, 1:168 (fig.)
 bare karst, 4:1650, 4:1653
 baselevel polja, 4:1652
 biokarsts, 4:1654
 blind valley, 4:1652
 border polja, 4:1652
 chalk rock and, 4:1649
 characteristics of, 4:1649–1650
 clints, 4:1653
 coastal karrens, 4:1654

- cockpit karst, 4:1652
collapse dolines, 4:1651
corridor karsts, 4:1654
corridors and streets, 4:1653
covered karst, 4:1650–1651
cutters, 4:1653
decantation flutings, 4:1653
decantation runnels, 4:1653
definition of, 4:1649
eggbox topography, 4:1652
epikarst *vs.* endokarst, 4:1651
fluvial aspects of, 4:1652
fluviokarst, 4:1650
free karst, 4:1651
glaciokarst, 4:1650
half-blind valleys, 4:1652
impounded karst, 4:1651
karren fields, 4:1653
karren smaller forms, 4:1652
labyrinth Karsts or giant grikelands, 4:1654
landforms created in, 4:1690
limestone bedrock and, 4:1649
limestone pavements, 4:1653
Li River, Guilin, China, 4:1650 (photo)
meader caves, 4:1652
microfissures, 4:1653
micropits and etched surfaces, 4:1653
mogotes (haystack hills), 4:1652
natural bridges, 4:1652
phreatic caves, 4:1651
phytokarst, 4:1654
pinnacle karsts and stone forests, 4:1653
pipino hills, 4:1652
pond dolines, 4:1651
psuedokarst, 4:1650
rock solubility and, 4:1649
rounded solution runnels or rundkarren, 4:1653
ruinform karsts, 4:1653–1654
shallow phreatic, epiphreatic, or water table caves, 4:1651
sinkholes, or doline types of, 4:1651
size scale classification of, 4:1651
smaller forms of, 4:1652–1653
solution bevels, 4:1653
solution dolines, 4:1651
solution flutes or rillenkarren, 4:1653
solution notches, 4:1653, 4:1654
solution pans, 4:1653
solution pipes, shafts, or wells, 4:1653
solution pits, 4:1653
solution ripples and fluted scallops, 4:1653
solution runnels or rinnenkarren, 4:1653
solution slots or grikes and kluftkarren, 4:1653
solution spikes or spitzkarren, 4:1653
splitkarren or solution fissures, 4:1653
steepheads and pocket valleys, 4:1652
stream-sink dolines, or ponors, 4:1651
structural polja, 4:1652
subsidence dolines, 4:1651
suffusion dolines, 4:1651
thermokarst, 4:1650
true karst, 4:1650
tufa and travertine deposits, 4:1652
undercut solution runnels (Hohlkarren), 4:1653
uvalas and polje, 4:1651–1652
vodose caves, 4:1651
- Kates, Robert, 4:1654–1655**
ending hunger focus of, 4:1654
human use of the earth focus of, 4:1654
nature-society relationships and, 4:1654
risk assessment perspectives of, 4:1654
service work of, 4:1654
sustainability focus of, 4:1654
Gilbert White and, 4:1654
- Katz, Cindi, 3:1100, 4:1996
Katz, Eric, 2:992
- Kazakhstan**
coal in, 1:485
Collective Security Treaty Organization (CSTO)
membership of, 2:536
Commonwealth of Independent States (CIS) membership
of, 2:536 (table)
economically active females in, 3:1190 (table)
HIV/AIDS in, 3:1438
horse domesticated in, 2:783
- Kellert, Stephen, 2:550
Keltie, John Scott, 1:100
Kempton, Murray, 4:1999
Kendall, Katherine, 4:1656
Kent, M., 3:1105
- Kenya**
ecological footprint and biocapacity of, 2:827 (table)
economically active females in, 3:1190 (table)
glaciers in, 3:1332
Greenbelt movement, Kenya tree planting program, 3:1610
income ratio relative to slum population in, 2006, 5:2644 (fig.)
installed capacity for electricity production forecast, 2010,
3:1268 (fig.)
Kikuyu language in, 4:1751
locusts infestation in, 2:727
Maasai ecotourism in, 2:871
Maasai women, local water harvesting, 2:972 (photo)
Machakos land use study, 5:2234
malaria and HIV/AIDS relationship and, 2:727
Masai nomads with cattle, 4:2031 (photo)
population pyramid for, 5:2250 (fig.)
squatter settlements in, 5:2684
total factor productivity (TFP) of, 6:2780 (table)
tropical deciduous forest in, 1:231 (photo)
tropical savanna in, 1:240, 1:240 (photo), 1:241 (photo),
1:243 (photo)
- Keough, Sara Beth, 4:1968
Kern, S., 5:2403
Keynes, John Maynard, 3:1616, 4:1820, 4:2011
- Keystone species, 4:1655–1658**
biogeographic distributions and, 4:1655–1656
debates, 4:1658
definition of, 4:1655
examples of keystone modifier, North American beaver (*Castor canadensis*), 4:1656
examples of keystone modifier, North American bison (*Bison bison*), 4:1657–1658, 4:1657 (photo)
examples of predator sea otter (*Enhydra lutris*), 4:1656
examples of predator starfish (*Pisaster*) in
intertidal zone, 4:1656
examples of whitebark pine (*Pinus albaulis*) in alpine and
subalpine ecosystems, 4:1656
extinctions of, 2:1070
foundation species *vs.*, 4:1655
keystone architectural and, 4:1655
keystone modifiers, 4:1657–1658

- keystone plants, 4:1656
- keystone predators, 4:1656
- system-based perspective on, 4:1658
- thresholds element in, 4:1655
- See also* Keystone species: noted individuals
- Keystone species: noted individuals
 - Mark Bertness, 4:1658
 - John Bruno, 4:1658
 - J. Estes, 4:1656
 - Clive Jones, 4:1657
 - Katherine Kendall, 4:1656
 - L. Scott Mills, 4:1658
 - Robert Paine, 4:1655, 4:1656
 - John Stachowicz, 4:1658
- Kidder, S. Q., 1:160
- Kiefer, Ralph, 4:1783
- Kierkegaard, Søren, 3:1474–1475
- Kindleberger, Charles, 3:1116
- King, Clarence, 3:1409
- Kirchhoff, Gustav, 3:1542
- Kirchin, Rob, 2:646
- Kirk, William, 2:977, 4:2167
- Kissinger, Henry, 2:611
- Kittler, Friedrich, 4:1874
- Kjellén, Rudolf, 3:1249, 3:1464, 5:2222
- Klages, K., 1:54
- Klahr, David, 1:391
- Kniffen, Fred, 1:106
 - cultural landscape work of, 2:642
 - historic preservation and, 3:1435
 - settlement geography work of, 5:2535, 5:2536–2537
- Knigge, LaDonna, 2:616
- Knowledge, geography of, 4:1659–1663**
 - centers of power and, 4:1662
 - communication technologies and, 4:1659
 - cultural preservation and, 4:1662
 - Robert Geipel's work in, 4:1659
 - geographies of creativity and, 4:1661–1662
 - geographies of education and, 4:1659–1661, 4:1660 (photo)
 - geographies of science and, 4:1661
 - information society and, 3:1593–1594
 - innovation geographies and, 3:1597–1599
 - knowledge and education and, 4:1659
 - knowledge and power and, 4:1659
 - knowledge definition and, 4:1659
 - knowledge regions and, 5:2435
 - language of instruction issue and, 4:1662
 - learning regions and, 4:1766–1768
 - nation-states and, 4:1662
 - schools as ethnic resistance sites and, 4:1662
 - school system socialization and, 4:1662
 - social survey movement and, 4:1659
 - spatial disparities in, 4:1659
- See also* Education, geographies of; Knowledge spillovers
- Knowledge spillovers, 4:1663–1664**
 - definition of, 4:1663
 - economic growth and, 4:1663
 - externalities and, 2:1068–1069, 5:2395
 - innovation geographies, tacit knowledge and, 3:1599
 - Jacobs spillover perspective, 4:1663
 - knowledge externalities and, 4:1663
 - locally bounded spillovers and, 4:1663
 - MAR spillovers perspective and, 4:1663
 - nonexcludability and, 4:1663
 - nonrivalness and, 4:1663
 - Porter spillover perspective, 4:1663
 - tacit knowledge and, 4:1663
 - technology diffusion and, 6:2780
 - urban growth affected by, 4:1663, 5:2395
- See also* Knowledge, geography of
- Kobayashi, A., 5:2335
- Kohn, Hans, 4:1978
- Kohonen, Teuvo, 5:2526
- Komiyama, Hiroshi, 6:2738
- Kondratiev, Nikolai, 1:302–304
- Kondratiev waves, business cycles, 1:303–304
 - business services element in, 1:304
 - “creative destruction” concept and, 1:303
 - information technology and, 1:303
 - Simon Kuznets' evaluation of, 1:303
 - Joseph Schumpeter's evaluation of, 1:303
 - spatial development of labor and, 1:304
 - technology diffusion element of, 1:303
- Kong, Lily, 4:1968
- Kopp, Anatole, 2:617
- Köppen, Wladimir, 4:1664–1665**
 - books written by, 4:1664
 - botany work of, 4:1664
 - climatology work of, 4:1664, 4:2180
 - fields of study by, 4:1664
 - forecasting work of, 4:1664
 - temperature regions and vegetation growth research of, 4:1664, 4:1665
- See also* Köppen-Geiger climate classification
- Köppen-Geiger climate classification, 4:1665–1668**
 - A-type climates, 1:467, 4:1665–1666
 - B-type climates, 1:467–468, 4:1665–1666
 - climate symbols and defining criteria of, 4:1666 (table)
 - C-type climates, 1:468, 4:1665–1666
 - dry climate and, 1:432
 - D-type climates, 1:468–469, 4:1665–1666
 - E-type climates, 1:469, 4:1665–1666
 - Rudolf Geiger and, 4:1665
 - humid continental and subarctic climates, 1:439, 1:440 (fig.)
 - humid *vs.* dry climates and, 4:1665–1666
 - subsidiary classification properties of, 4:1665–1666, 4:1666 (table)
 - temperature and precipitation data of, 1:465
 - Alfred Wegener and, 4:1665
 - world climate map based on, 4:1666, 4:1667 (table)
 - world's land area occupied by each climate type and, 4:1667 (table)
- Korea
 - domino theory and, 3:1224
 - industrialization in, 4:2020
 - Japanese colonization of, 1:514
 - rice paddy cultivation in, 1:48
 - textile exports from, 6:2815 (fig.), 6:2816 (fig.)
- Kosek, Jake, 5:2339
- Kreizman, Gregg, 3:1308
- Kropotkin, Peter, 4:1668–1669**
 - anarchist beliefs of, 4:1668
 - Arts and Crafts Movement and, 4:1669
 - bioregionalism supported by, 4:1669
 - cooperation among species studied by, 2:667–668, 3:1463
 - decentralized self-governing communities and, 3:1463
 - free trade and comparative advantage visions of, 4:1668
 - geographic anarchism, radical geography work of, 1:73, 2:617
 - green design and development work of, 3:1372
 - Mutual Aid* written by, 5:2211
 - Élisée Reclus and, 4:1669, 5:2372
 - self-reliance and communality work of, 3:1372

- Siberia exploration of, 4:1668
 spatial hierarchies work of, 3:1463
 “What Geography Ought to Be” essay written by, 2:617, 3:1463
- Krugman, Paul, 5:2365, 5:2395
- Krummholz, 4:1669–1672**
 definition of, 4:1669
 ecotone of, 4:1669 (photo)
 Engelmann spruce and, 4:1669
 factors affecting type and degree of, 4:1670
 flag krummholz, 4:1670–1671, 4:1670 (photo)
 flag mat krummholz, 4:1671, 4:1671 (photo)
 forms of, 4:1670–1671
 importance of, 4:1671–1672
 mat krummholz, 4:1671, 4:1672 (photo)
 microclimate factors and, 4:1669–1670
 quaking aspen and, 4:1669
 term derivation and, 4:1669
 windward growth of, 4:1670 (photo)
- Kuhn, Thomas, 5:2557
- Kuhn, Werner, 4:1672–1673**
 academic career of, 4:1673
 Conference of Spatial Information Theory and, 4:1673
 geodesy studied by, 4:1673
 geoinformatics work of, 4:1672, 4:1673
 GIScience work of, 4:1672–1673
 Open Geospatial Consortium, 4:1673
 research fields of, 4:1673
 semantics of spatial information work of, 4:1672–1673
- Kuwait
 economically active females in, 3:1190 (table)
 Kuwaiti oil well fires, 2:955, 2:956 (photo)
 oil sources in, 4:2163
 OPEC membership of, 4:2099, 4:2100 (fig.)
- Kuznets, Simon, 1:303
- Kwan, Mei-Po, 4:1674**
 feminist geography work of, 2:615, 4:1674
 gender and geography work of, 3:1193
 geovisualization work of, 4:1674
 GIS systems work of, 4:1674
 three-dimensional data modeling and, 4:1674
 time-geography work of, 4:1674
 transportation geography work of, 4:1674
- Kyem, Peter Kwaku, 3:1308–1309
- Kymlicka, Will, 4:1644
- Kyoto Protocol of 1997. *See* Climate policy
- Kyrgyzstan
 Collective Security Treaty Organization (CSTO)
 membership of, 2:536
 Commonwealth of Independent States (CIS) membership
 of, 2:536 (table)
 economically active females in, 3:1190 (table)
- Labor, geography of, 4:1675–1679**
 “agency” conceptualization and, 4:1678
 “capitalist imperative” and, 4:1676
Capital’s Utopia (Mosher) and, 2:852
 CIO picketers, Greensboro, Georgia (1941), 4:1677 (photo)
 classical location theory and, 4:1675
 contemporary labor geography and, 4:1676–1677
 economic landscapes and geography and, 2:852, 4:1675
 environmental determinism and, 4:1675
 feminist geographers and, 4:1678
 feminist spatial science and, 2:852
 Fordism and, 3:1148–1151
 future trends in, 4:1678
 gender and race relations in labor markets and, 4:1678
 gendered character of labor markets (Massey) and, 2:852,
 4:1790, 4:1866–1867
 geographical dilemma facing workers and, 4:1677, 4:1678
 Andrew Herod and, 4:1675, 4:1676, 4:1678
 historical roots of, 4:1675–1676
 informal economy and, 3:1590–1592
 internationally mobile labor market and, 2:852
 labor definition and, 4:1675
 labor unions, commodity chain analysis and, 1:524–525
 local labor militancy and, 4:1676
 location of firms factors and, 3:1077–1080
 Marxism and, 4:1675
 “master collective agreements” and, 4:1677
 Linda McDowell and, 4:1678, 4:2136
 neoliberal economic restructuring and, 4:1676
 quantitative revolution and, 4:1675
 radical geography and, 4:1675
 remittances from migration and, 5:2413–2414
 Rust Belt to Sun Belt shift and, 4:1676
 “scale appropriateness” of labor strategy and, 4:1677
 subdiscipline of economic geography and, 4:1675
 textile industry strike, Lawrence, Massachusetts (1912), and,
 4:1676 (photo)
 trade union decline and, 4:1676
 unpaid labor geography and, 4:1678
- Lacan, Jacques, 3:1528
- Laclau, Ernesto, 3:1419, 3:1420
- Lacoste, Yves, 2:617
- Laflamme, R., 2:753
- Laidlaw, Walter, 1:374
- Lake Nyos carbon dioxide disaster, Cameroon, West Africa,
 1:68–69
- Lamarck, Jean-Baptiste
 environmental determinism of, 3:1464
 evolution work of, 2:666, 2:667, 5:2561
- Lamb, Hubert, 2:711
- Land degradation, 4:1679–1684**
 anthropogenic causes of, 4:1681
 definition of, 4:1679
 deforestation, 4:1683–1684
 ecosystem decay and, 2:858–862
 environmental restoration and, 2:991–994
 estimates of, 4:1680 (table)
 estimates of global extent by type and, 4:1680 (table)
 exploitation of marginal lands and, 4:1683
 factors responsible for, 4:1680, 4:1681–1682, 4:1681 (fig.)
 gully erosion and, 3:1392–1394
 increasing population and, 4:1683–1684
 open-pit mining and, 4:2086–2088
 pervasiveness of, 4:1679
 poverty and, 4:1683
 soil erosion in Baringo District, Kenya, East Africa, 4:1682 (photo)
 terms related to, 4:1679
- Landfills, 4:1684–1686**
 design regulations, 4:1686
 disposal of, 4:1686
 environmental issues of, 4:1685
 first landfill in Fresno, California, and, 4:1684
 geography of least political resistance, 4:1686
 hazardous waste and garbage mixture in Lowry Landfill,
 Colorado, 4:1685 (photo)
 hazardous waste landfills and, 4:1684
 hazardous waste landfills and communities of color and, 2:960,
 2:961 (photo)

- history of, 4:1684–1685
- incineration alternative to, 4:1685
- industrial wastes and, 4:1685
- leachate and gas emissions from, 4:1684, 4:1685
- long-term care and monitoring of, 4:1684
- Love Canal and, 4:1806–1808
- nonhazardous wastes and, 4:1685
- open dumps and, 4:1684
- Resource Conservation and Recovery Act, 4:1684–1685
- siting of, 4:1686
- U.S. Superfund sites at, 4:1684
- Warren County, North Carolina, environmental justice example and, 2:960, 2:961 (photo), 2:986
- Landforms, 4:1686–1692**
 - anthropogenic influences on, 4:1686–1687, 4:1691–1692
 - Atlantic *vs.* Pacific coastline landforms and, 4:1689
 - basin and range topography and, 1:186
 - calderas and pyroclastic deposits (volcanoes) and, 4:1688
 - definition of, 4:1686
 - dunes and, 2:800–803
 - eolian landforms, 4:1690
 - erosion creation process of, 4:1686
 - fjords and, 3:1121–1123
 - fluvial erosion, Canyonlands National Park, Utah, 4:1691
 - fluvial landforms, 4:1690
 - formation process classification of, 4:1686
 - Grand Prismatic Spring, in Midway Geyser Basin, Yellowstone National Park, 4:1687 (photo)
 - Hawaiian island volcanic chain and, 4:1688–1689
 - karst landforms, 4:1690
 - landform formation and sculpting process of, 4:1689–1690
 - mass wasting processes on Hawaiian Islands and, 4:1689
 - natural processes of, 4:1687
 - periglacial landforms, 4:1690
 - plate tectonics creation process of, 4:1686
 - polygenetic processes and, 4:1690
 - rift zone volcanism and, 4:1688
 - rivers creation of, 4:1690
 - role of scale in, 4:1690–1691
 - volcanoes and, 4:1687–1689
- See also* Geomorphic cycle; Geomorphology; Volcanoes
- Land reform, 4:1692–1696**
 - “agrarian reform” *vs.*, 4:1696
 - “Alliance for Progress” in Latin America and, 4:1694
 - balance-of-payment crises and state indebtedness and, 4:1694
 - barriers to, 4:1694
 - Brazil’s Landless Workers Movement (MST), 4:1695 (photo)
 - coalitions across borders and, 4:1695
 - collectivization and, 4:1693
 - colonial antecedents to, 4:1692
 - decolonization and, 4:1693
 - in developing world, 4:1692
 - “from above” *vs.* “from below,” 4:1694, 4:1696
 - gender issues overlooked in, 4:1694
 - Green Revolution input-intensive techniques barrier to, 4:1694
 - land inequality and, 4:1693
 - land tenure reform *vs.*, 4:1725
 - La Via Campesina example of, 4:1695
 - Movimento Sem Terra (MST) and, 4:1948–1951
 - 1970s and, 4:1693–1694
 - 1990s land struggles and, 4:1694–1695
 - peasants and peasantry and, 4:2137–2142
 - Political economy, 4:2137–2142
 - post–World War II period and, 4:1693
 - redistribution of private or public lands and, 4:1692
 - social struggle and, 4:1693
 - World Bank and, 4:1695
- Landsat satellites, 3:1283, 4:1954, 4:1959, 4:1974, 4:2114
- Landsat Data Continuity Mission proposal and, 5:2356
- radiometric resolution and, 5:2356
- Landscape and wildlife conservation, 4:1696–1698**
 - animal ecological uniqueness factor in, 4:1697
 - animal geographies and, 1:75–79
 - animal mobility factor in, 4:1697
 - animal size factor in, 4:1697
 - animals moving across landscapes and, 4:1696
 - animal specialist *vs.* generalist habitat type factor and, 4:1697
 - animal territoriality factor in, 4:1697
 - applications to resource management and conservation and, 4:1697–1698
 - Canadian Society of Landscape Architects and, 4:1699
 - categorization approach to study of, 4:1696
 - computer-based modeling used in, 4:1697–1698
 - Jared Diamond’s biodiversity studies and, 4:1697
 - environmental impacts of roads and, 2:951–953
 - evolutionary ecology and, 4:1696
 - game ranching and, 3:1179–1181
 - GIS software and GPS technology and, 4:1697
 - habitat corridors concept and, 4:1697
 - human-caused environmental change and, 4:1697
 - human-wildlife conflict and, 4:1698
 - open space and, 4:2091–2094
 - parks and reserves and, 4:2117–2120
 - particular species protection strategies and, 4:1697–1698
 - patch dynamics and, 4:1697
 - patches and corridors and, 4:2131–2133
 - patch mosaic theory and, 4:1696–1697
 - process and patterns relationship research and, 4:1696
 - research on wildlife-landscape interactions and, 4:1696–1697
 - site specific *vs.* species-specific approaches to, 4:1697–1698
 - size, connectivity, and protected area shape and, 4:1697
 - spatial configurations of habitat identification and, 4:1697
 - species ecology and habitat spatiality approaches to, 4:1697–1698
 - theory of island biogeography and (MacArthur and Wilson) and, 4:1696
- Landscape architecture, 4:1698–1701**
 - American Society of Landscape Architects and, 4:1699, 4:1700
 - art and landscape relationship and, 4:1700
 - built environment and, 4:1699
 - Central Park, New York City and, 4:1700
 - current environmental sustainability issue and, 4:1701
 - current state of, 4:1701
 - definitions of, 4:1698, 4:1699
 - demarcating the field issues and, 4:1698
 - Design on the Land* (Newton) and, 4:1699
 - Design With Nature* (McHarg), 4:1700
 - divisions within, 4:1698
 - employment statistics, 4:1700
 - Encyclopedia of Gardening* (Loudon) and, 4:1699
 - garden design and landscape gardening history and, 4:1699
 - geography similarities to, 4:1698
 - GIS area of, 4:1698
 - Granite Garden* (Spirn) and, 4:1700
 - greenways and brownfields, repair and restoration of, 4:1700
 - history and theory of, 4:1699–1700
 - human settlement instructions and, 4:1700
 - international, large-resort development and, 4:1700
 - International Federation of Landscape Architects and, 4:1700
 - landscape analysis (McHarg) and, 4:1700
 - Landscape Architecture Magazine* and, 4:1700

- landscape design and, 4:1703–1705
 landscape gardener and, 4:1699
Landscape of Man (Geoffrey and Jellicoe), 4:1699
 landscape urbanism and, 4:1701
 national parks and public works projects and, 4:1700
 Parc de La Villette (Paris) competition and, 4:1700
 park design and planning eras and, 4:1700
 physical *vs.* human dimensions of, 4:1698
Politics of Park Design, A History of Urban Parks in America (Cranz), 4:1700
Ten Books on Architecture (Vitruvius) and, 4:1699
 term origins and, 4:1699–1700
 transdisciplinary approach to, 4:1698
 urban park renovation and, 4:1700
 urban planning and, 4:1700
See also Architecture and geography; Landscape architecture:
 noted architects, botanists
- Landscape architecture:** noted architects, botanists
 Lancelot Brown, 4:1699
 Galen Cranz, 4:1700
 Andrew Jackson Downing, 4:1699
 Patrick Geddes, 4:1700, 4:2126
 Geoffrey and Susan Jellicoe, 4:1699
 John Loudon, 4:1699
 I. McHarg, 4:1700
 Lewis Mumford, 4:1700
 Norman Newton, 4:1699
 Frederick Law Olmsted, 4:1699
 Ann Spirn, 4:1700
 Christopher Tunnard, 4:1700
- Landscape biodiversity, 4:1701–1703**
 abiotic factors and, 4:1701
 alpha *vs.* beta *vs.* gamma diversity scales and, 4:1702
 anthropogenic impacts on biodiversity and, 4:1701–1702
 biotic factors and human land use relationship and, 4:1701
 composition and structural factors in, 4:1702
 connectivity between patches of, 4:1702
 contextual factors in, 4:1702
 habitat fragmentation issue and, 4:1702
 habitat shape factor in, 4:1702
 hierarchical organization of, 4:1701
 landscape ecology and, 4:1701
 organizing principles of, 4:1702–1703
 patches and corridors and, 4:2131–2133
 pattern and process relationship focus of, 4:1701
 remote sensing and spatial mapping tools and, 4:1702
 scaling issues awareness in, 4:1702–1703
 spatial and temporal scales focus of, 4:1702
- Landscape design, 4:1703–1705**
 Bodie State Historic Park cultural landscape example and, 4:1705
 cultural landscape issues and, 4:1705
 Healing Garden School (Ulrich) and, 4:1704–1705
 history of, 4:1703
 landscape architecture and, 4:1698–1701, 4:1703
 landscape urbanism issues and, 4:1704
 rock garden at Kongobuji Temple, Mount Koya, Japan, and, 4:1704 (photo)
 sustainability issues and, 4:1703–1704
 sustainable campus landscape design and, 4:1705
 therapeutic landscape design and, 4:1704–1705
 21st-century challenges of, 4:1703–1705
 World Heritage Committee of UNESCO and, 4:1705, 4:1716
See also Landscape design: noted individuals
Landscape design: noted individuals
 A. J. Downing, 4:1703
 Lawrence Halprin, 4:1703
 Dan Kiley, 4:1703
 J. C. Loudon, 4:1703
 Roberto B. Marx, 4:1703
 Gilbert Laing Meason, 4:1703
 Frederick Law Olmsted, 4:1703
 Martha Schwartz, 4:1703
 Roger S. Ulrich, 4:1704–1705
- Landscape ecology, 4:1705–1713**
 complete randomization neutral model, 4:1710, 4:1711 (fig.)
 complexity theory and, 2:867
 definition of, 4:1705
 development of, 4:1705–1707
 ecological zones and, 2:834–844
 ecology-centered, spatial view of, 4:1707
 ecotones and, 2:867
 environmental impacts of roads and, 2:951–953
 European *vs.* North American traditions in, 4:1707
 forest degradation and, 3:1156–1159
 forest fragmentation and, 3:1159–1163
 fundamental concepts in, 4:1707–1708
 future trends in, 4:1712
 GIS software used in, 4:1709, 4:1709 (fig.)
 hierarchy and scale in, 4:1708
 humanity and landscape composition relationship in, 4:1705
 hybrid human-natural systems and, 4:1708
 International Association of Landscape Ecology and, 4:1706
 land cover in Leon County, Florida and, 4:1709 (fig.), 4:1710–1711, 4:1710 (table)
 landscape and wildlife conservation and, 4:1696–1698
 landscape biodiversity and, 4:1701–1703
 landscape dynamics and, 4:1708
 landscape metrics and, 4:1707, 4:1709–1710, 4:1714–1715
 methodology used in, 4:1708–1712
 modeling techniques of, 4:1707
 neutral model and process-based models in, 4:1710–1712, 4:1711 (fig.)
 patch dynamics and, 4:1697, 4:1708–1709
 patch mosaic theory and, 4:1696–1697
 pattern metrics and, 4:1708–1710
 pattern-process interactions and, 4:1707–1708
 patterns and, 4:1707
 process-based models and, 4:1712
 randomization with fractal approach neutral model, 4:1710, 4:1711 (fig.), 4:1712
 randomization with hierarchical randomization neutral model, 4:1710, 4:1711 (fig.), 4:1712
 RULE software and, 4:1711 (fig.), 4:1712
 simulated forest landscapes using neutral models and, 4:1711 (fig.)
 size, edge, shape, diversity, and contagion metrics and, 4:1709–1710
 society-centered, holistic view of, 4:1707
 spatial autocorrelation and, 4:1707
 spatial heterogeneity and, 4:1707
 spatial pattern and ecological process relationship and, 4:1701
 subjects included in, 4:1705, 4:1706 (fig.)
 theoretical approaches to, 4:1707
 Carl Troll and, 3:1458, 4:1705, 4:1714
- Landscape interpretation, 4:1713–1715**
 aerial photographs and, 4:1714
 chorological approach to, 4:1713
 cultural geography and, 2:635–636
 definition (Humboldt) of, 4:1713
 disciplines related to, 4:1713
 gender differences in, 4:1714

- geomancy and, 3:1238–1230
 geomorphology and plant ecology origins of, 4:1713
 GIS technology and, 4:1715
 historical context factor in, 4:1714
 landscape architecture and, 4:1698–1701
 landscape definition and, 4:1713
 landscape design and, 4:1703–1705
 landscape ecology and, 4:1714
 landscape metrics and, 4:1714–1715
 landscape analysis concept (Hoskins) and, 2:636
 Peirce Lewis and, 4:1713, 4:1772–1773
 Kevin Lynch and, 4:1714
 masculine gaze concept and, 3:1196, 4:2043
 mental mapping technique and, 4:1714
 Don Mitchell's work and, 4:1913–1914
 palimpsest concept and, 4:2111–2112
 physical environment knowledge and, 4:1714
 place legibility concept and, 4:1714
 principles of, 4:1713–1714
 qualitative examination of social relations and, 4:1714
 quantitative approach to, 4:1714–1715
 reading the landscape and, 4:1713–1714
 remote sensing and, 4:1715
 seeing with eyes and thinking about what
 is seen and, 4:1713
 structure, function, and change themes in, 4:1713
 technology and, 4:1714–1715
 theoretical influences on, 4:1714
 Carl Troll and, 4:1714
 urban landscape interpretation and, 4:1714
- Landscape quality assessment, 4:1715–1718**
 affective theory (Ulrich) on, 4:1716
 applications for, 4:1717–1718
 Cape Bauer, South Australia, and, 4:1717 (photo)
 definition of, 4:1715
 digital terrain model (DTM) and, 2:753–756
 evolutionary perspectives on, 4:1716
 experiential studies of, 4:1717
 habitat theory (Orian) of, 4:1716
 health benefits from, 4:1716
 information-processing theory (Kaplan) on, 4:1716
 local and national identities and, 4:1716
 national parks and, 4:1716
 origins of terms and, 4:1715
 physical studies of, 4:1717
 preference studies of, 4:1717
 prospect-refuge theory (Appleton) of, 4:1716
 Scenery Management System and, 4:1717
 scenic quality and, 4:1715
 science of measurement and, 4:1716–1717
 self-image of a region, sense of place and, 4:1716
 significance of, 4:1716
 terms associated with, 4:1715
 theoretical basis of, 4:1716
 Visual Resource Management systems (VMS) and, 4:1717
 World Heritage Areas and, 4:1716, 4:1717–1718
See also Landscape quality assessment: noted individuals
- Landscape quality assessment: noted individuals
 Jay Appleton, 4:1716
 Stephen and Rachel Kaplan, 4:1716
 Gordon Orian, 4:1716
 Roger Ulrich, 4:1716
- Landscape restoration, 4:1718–1720**
 ecosystems application of, 4:1718
 emotional, socioeconomic, and cultural elements of, 4:1718
 environmental, socioeconomic, and cultural problems
 relationships and, 4:1719
 ethical issues, 4:1719
 Everglades restoration example of, 2:1038–1042
 forest restoration and, 3:1166–1168
 integrated theoretical framework of, 4:1718
 landscape perspective on, 4:1718
 multifaceted nature of environmental problems and, 4:1718
 multistakeholder approach to, 4:1719–1720
 nongovernmental organizations and, 4:1719
 “reference state,” original or predisturbance condition and, 4:1719
 restore word origin and, 4:1718
 revalorization process and, 4:1718–1719
 reversibility issues and, 4:1719
 sustainability and natural resource management themes in, 4:1718
 variables in, 4:1718–1719
See also Environmental restoration
- Landslide, 4:1720–1723**
 classification and causes of, 4:1720–1722
 classification of mass movements and, 4:1721 (table)
 debris avalanches and, 1:177–178, 1:178 (photo)
 definition of, 4:1720
 environmental consequences of, 4:1720, 4:1722
 Gros Ventre Slide, Grand Teton National Park, Wyoming,
 4:1721 (photo), 4:1723
 landslide dams and, 4:1722
Landslides and Engineering Practice (Varnes), 4:1720
 Loma Prieta, California, earthquake and, 4:1722 (photo)
 mass wasting and, 4:1868–1871
 research, 4:1723
 rock avalanches and, 1:178–179
 shear stress and shear strength factors in, 4:1720, 4:1722
 shear stress factors and, 4:1720–1721
 social consequences of, 4:1722–1723
- Land tenure, 4:1723–1725**
 adaptation paradigm transition and, 4:1724
 capital/poverty/property rights approach to, 4:1724
 “community” aspect of tenure security and, 4:1724
 decision making and, 4:1723
 definition of, 4:1723
 evidence-based “argument for claim” to land
 rights and, 4:1724
 formal *vs.* informal or traditional *vs.* indigenous types of, 4:1724
 identity-based claims to land and, 4:1724
 loan collateral and, 4:1723
 paradigms in, 4:1724
 rights recognition approach to, 4:1724
 tenure security and, 4:1723–1724, 4:1725–1726
 types of, 4:1724
See also Distribution of resource access; Land tenure reform
- Land tenure reform, 4:1725–1726**
 definition of, 4:1725
 economic transactions approach to, 4:1725
 ideological, social, political, and economic perspectives of,
 4:1725, 4:1726
 inequities, 4:1726
 international development and, 4:1725
 land policy reform and, 4:1725
 land reform *vs.*, 4:1725
 legal and social relations concerning land and, 4:1725
 political or ethnic motivations of, 4:1725
 resistance to, 4:1726
 social relations approach to, 4:1725
 tenure security and, 4:1725–1726
See also Land reform

Land use, 4:1726–1732

- agricultural land use category, 4:1730
- Anderson land use classification scheme and, 4:1728–1730, 4:1729 (table)
- barren land use category, 4:1730
- Burgess model of urban social structure and, 1:386, 1:387–388, 1:387 (fig.), 3:1112, 3:1449, 3:1458, 4:1728
- changes in over time and, 4:1727
- concentric zone model of, 4:1728
- definition issues and, 4:1726
- forest land use category, 4:1730
- functional models of spatial interaction and trade and, 4:1727
- geographic models of, 4:1727–1728
- GIS and, 4:1732
- land area classifications and, 4:1727
- land-based classification standard system (LBCS) and, 4:1730–1731, 4:1730 (tables), 4:1731 (tables)
- land cover and, 4:1726
- locally unwanted land uses (LULUs) and, 4:1727
- “not in my backyard” (NIMBY) advocacy and, 4:1727
- open space and, 4:2091–2094
- perennial snow or land use category, 4:1730
- rangeland land use category, 4:1730
- regulation of, 4:1726–1727
- space-time convergence models and, 4:1727–1728
- spatial characteristics of, 4:1727
- Thünen concentric farm-land use model and, 4:1728
- transportation planning and, 4:1728
- tundra land use category, 4:1730
- urban and built-up land classification of, 4:1729–1730, 4:1729 (table)
- urban *vs.* rural land use regulation and, 4:1727
- valuation of land uses and, 4:1727
- wetland land use category, 4:1730
- zoning laws and, 4:1727
- See also* Land use analysis; Land use and cover change (LUCC); Land use and land cover mapping; Land use history; Land use planning

Land use analysis, 4:1733–1734

- basic reasoning in, 4:1733
- built land cover and, 4:1733
- characteristics of scale and, 4:1733
- definitions in, 4:1733
- digital terrain model (DTM) and, 2:753–756
- ecological risk analysis (ERA) and, 2:840–843
- forest land cover and, 4:1733
- GIS applications in, 3:1302–1305
- land change model of, 4:1733
- land cover definition and, 4:1733
- methodological and conceptual challenges in, 4:1733
- participatory exercises used in, 4:1734
- quantitative and qualitative techniques used in, 4:1733
- scenario analysis and, 4:1734
- social data collection and, 4:1733
- See also* Agricultural land use; Distribution of resource access; Land use; Land use and cover change (LUCC); Land use and land cover mapping; Land use history; Land use planning

Land use and cover change (LUCC), 4:1734–1739

- aerial photography monitoring of, 4:1737
- albedo of Earth’s surface and, 3:1335, 4:1735
- biodiversity affected by, 4:1736
- biogeochemical cycles affected by, 4:1736
- biological impacts on, 3:1334–1335
- built environment and, 1:298–300
- carbon cycle research and, 4:1735

- causes of, 3:1335
 - change detection measurement of, 4:1738
 - consequences of, 4:1736–1737
 - coupled human and natural systems (CHANS) and, 2:602
 - cultural ecology and, 2:633
 - definitions, 4:1734
 - deforestation, hydrologic cycling in Sabah, Malaysia, and, 4:1737 (photo)
 - deforestation and, 2:695–699, 3:1334, 4:1734–1735
 - global environmental change and, 3:1334–335
 - human health affected by, 4:1736–1737
 - human impacts and, 3:1334
 - hydrologic cycle affected by, 4:1736
 - International Geographical Union (IGU), 4:1735–1736
 - International Geosphere-Biosphere Programme (IGBP) and, 4:1735
 - International Human Dimensions Programme (IHDP) on Global Environmental Change and, 4:1735
 - LUCC research and, 4:1734–1736, 4:1736 (fig.)
 - Man and Nature* (Marsh, 1864) and, 4:1734, 4:2180
 - George Perkins Marsh and, 4:1734, 4:2180, 5:2584
 - measuring of, 4:1738
 - modeling of, 4:1738
 - Moderate Resolution Imaging Spectroradiometer (MODIS) monitoring of, 4:1738
 - monitoring of, 4:1737–1738
 - multitemporal imaging and, 4:1959–1960
 - NASA Land Cover and Land Use Change research program and, 4:1736
 - remote sensing monitoring of, 4:1737–1738
 - satellite imagery monitoring of, 4:1737–1738
 - transition matrices measurement of, 4:1738
 - Billie Lee Turner, II and, 6:2891–2892
 - USGS nationwide inventory of land cover and land use of, 3:1302
 - See also* Land use; Land use analysis; Land use and land cover mapping; Land use history; Land use planning
- Land use and land cover mapping, 4:1739–1741**
- applications of, 4:1740–1741
 - archived image data and, 4:1741
 - “cartographic standards” component of, 4:1739
 - complexity theory and, 2:561
 - continuous space-and-time models and, 2:566
 - definitions, 4:1738
 - GIS applications in, 3:1302–1305
 - image interpretation and, 3:1534–1536
 - information extraction governed by rules of generalization and, 4:1739
 - integrated global monitoring system of, 4:1739–1740, 4:1739 (table)
 - international initiatives in, 4:1741
 - “interpretation process” component of, 4:1739
 - land cover in Leon County, Florida and, 4:1709 (fig.), 4:1710 (table)
 - land cover *vs.* land use and, 4:1739
 - land processes revealed through, 4:1739
 - maps and dynamic land monitoring of, 4:1740–1741
 - moderate-, fine-, and resolution satellite data and, 4:1740
 - multispectral image of U.S.-Mexico border, California, and, 4:1955 (photo)
 - multispectral imagery and, 4:1953
 - multitemporal imaging and, 4:1741, 4:1959–1960
 - Dawn Parker’s work in, 2:561
 - process of, 4:1739
 - secondary outputs of land cover characteristics and, 4:1739
 - in situ observations and, 4:1740

- “thematic” component of, 4:1739
 UN Land Cover Classification System and, 4:1740
 uses of and importance of, 4:1739
See also Land use; Land use analysis; Land use and cover change (LUCC); Land use history; Land use planning
- Land use history, 4:1741–1744**
 definition of, 4:1741
 examples of, 4:1742–1743
 land use impact on global ecosystems and, 4:1741
 natural archives and, 4:1742
 remote sensing techniques and, 4:1742
 research topics and methods and, 4:1742
 scientific disciplines covered in, 4:1742
 timeline of early agriculture, 4:1742
 timeline of medieval Europe, 4:1742, 4:1743 (fig.)
 timeline of European settlement in North America, 4:1742–1743
 written sources and, 4:1742
See also Environmental history; Land use; Land use analysis; Land use and cover change (LUCC); Land use and land cover mapping; Land use planning
- Land use planning, 4:1744–1747**
 built environment and, 1:298–300
 California Environmental Quality Act and, 4:1746
 California’s Coastal Protection Act (1972) controversy and, 4:1746
 cellular automata used in, 1:370
 changing revenue sources and, 4:1747
 Coastal Zone Protection Act (1972, 1996) and, 4:1746
 conservation zones and, 2:571–572
 Constitutional requirements, 4:1744, 4:1746–1747
 definition of, 4:1744
 ecological risk analysis (ERA) and, 2:840–843
 economic development policy and, 4:1745
 Endangered Species Act (1973) and, 4:1746
 environmental issues and, 4:1745–1746
 general-law city *vs.* home rule (charter) city and, 4:1744–1745
 large-scale land use planning and, 4:1746
 legal framework for, 4:1744
 local decision makers and economic interests link and, 4:1745
 open space and, 4:2091–2094
 Oregon Land Use Act (1973) and, 4:1746
 participatory planning and, 4:2126–2129
 planning, zoning, and local economic development in, 4:1745
 state and local authority and, 4:1744–1745
 “urban growth machine” relationship and, 4:1745
 urban land use and greenhouse gas emissions issues and, 4:1746
 water availability issues and, 4:1746
 Yucca Mountain nuclear waste repository issue and, 4:1744
See also Land use; Land use analysis; Land use and cover change (LUCC); Land use and land cover mapping; Land use history; Regional environmental planning
- Land-water breeze, 4:1747–1748**
 definition of, 4:1747
 differential heating and, 2:741
 land breeze and, 4:1747–1748
 water breeze (sea breeze) and, 4:1747, 4:1748 (fig.)
- Lane, Belden, 5:2408**
- Languages, geography of, 4:1748–1754**
 African languages, 4:1751
 Afro-Asiatic languages, 4:1749, 4:1750 (fig.)
 Asian languages, 4:1751–1753
 Austro-Asiatic language, 4:1753
 Baltic languages, 4:1749
 Bantu or Niger-Kordofanian languages, 4:1751, 4:1753 (fig.)
 Berber language, 4:1749
 Celtic languages, 4:1749
 Dravidian tongues, 4:1753
 English language, 4:1749
 Finnish and Estonian languages, 4:1749
 geographic analysis of, 4:1754
 Germanic languages, 4:1749
 Hungarian language, 4:1749, 4:1751
 Indo-European languages, 4:1749, 4:1750 (fig.)
 Indo-Pacific language, 4:1753
 William Jones and, 4:1749
 Kushitic language, 4:1749
 language and geographic analysis in, 4:1754
 language death and, 4:1753–1754
 language definitions and, 4:1748
 language families and, 4:1748
 language functions and, 4:1748
 Latin-based Romance languages, 4:1749
 Malayo-Polynesian languages, 4:1753, 4:1753 (fig.)
 Mandarin language, 4:1751, 4:1753
 Mongol and Manchu languages, 4:1751
 national languages and, 4:1749
 Native American languages, 4:1753
 poststructuralist authors and, 4:1754
 printing technology and, 4:1749
 representation of space and, 4:1754
 semantic and historic relationship of, 4:1748
 Semitic language, 4:1749
 Sino-Tibetan language, 4:1751, 4:1752 (fig.)
 Slavic languages, 4:1749
 South American languages, 4:1753
 Swahili trade language, 4:1751
 Thai-Kadai language, 4:1753
 Turkic languages, 4:1751
 Ural-Altaic (Finno-Ugric) languages, 4:1749, 4:1751
- La Niña, 4:1754–1757**
 atmospheric moisture and, 1:148
 atmospheric Rossby wave train associated with, 4:1755, 4:1755 (fig.)
 beach rotation and, 1:491
 boreal winter and summer weather conditions and, 4:1755
 decadal-scale variability of, 4:1755, 4:1757
 definition of, 4:1754
 delayed-oscillator theory, 4:1755
 global atmospheric circulation changes and, 4:1755
 global precipitation and temperature anomalies associated with (1988), 4:1755, 4:1756 (fig.)
 global warming trends and, 4:1757
 “high” phase of El Niño-Southern Oscillation and, 4:1754–1755
 mean sea level changes and, 1:497
 ocean dynamical thermostat mechanism and, 4:1757
 Pacific Decadal Oscillation (PDO) and, 1:164
 George Philander and, 4:1754
- Laos**
 ASEAN membership of, 1:128 (table), 1:129 (table)
 Cold War and, 1:504
 economically active females in, 3:1190 (table)
 French colonization of, 1:515
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
 opium and heroin production in, 2:797
- Laplace, Pierre-Simon, 2:667**
- Lapse rate, 4:1757–1761**
 adiabatic temperature changes and, 1:15–17, 4:1757–1758, 4:1758 (fig.)
 air parcel movement and, 4:1759–1761, 4:1759 (fig.)
 applications of, 4:1758–1759
 atmospheric hazards and, 4:1759–1761, 4:1759 (fig.), 4:1760 (fig.)
 definition of, 4:1757

- dry adiabatic lapse rate, 4:1757, 4:1758 (fig.)
 environmental lapse rate, 4:1757, 4:1759 (fig.)
 latent heat and, 4:1761–1762
 mountain example of, 4:1758–1759, 4:1758 (fig.)
 normal lapse rate, 4:1757, 4:1758 (fig.)
 temperature inversion and, 4:1761 (fig.)
 wet adiabatic lapse rate, 4:1758, 4:1758 (fig.)
- Larkin, Robert, 5:2247
- Latent heat, 4:1761–1762**
 adiabatic temperature changes and, 1:15–17
 definition of, 4:1761
 International System of Units for, 4:1761
 latent heat of evaporation and, 4:1761
 latent heat of fusion and, 4:1761
 ocean heat budget and, 4:1761–1762
 temporal mean of latent heat, Mediterranean Sea and, 4:1761–1762, 4:1762 (fig.)
- Latin America
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
 agroecology emphasis in, 1:54
 agroforestry in, 1:57, 5:2579
 AGS library maps of, 1:71
 “Alliance for Progress” land reform in, 4:1694
 Andes expeditions, American Geographical Society and, 1:295
 automobile industry in, 1:169
 Isaiah Bowman’s work, 1:295
 Cartagena Declaration on Refugees (1984) and, 5:2378
 Central American Common Market and, 3:1550–1551
 chain of exploitation from core to periphery and, 2:712–713
 China’s foreign direct investment in, 3:1155
 Cold War and, 1:504–505
 colonialism, end of, 1:517
 colonialization of, 1:511–512
 COMECON membership and, 2:593
 Conference of Latin Americanist Geographers (CLAG) and, 2:567–568
 critical geographers in, 2:618
 decolonization in, 2:691
 deforestation in, 2:696, 2:698
 democratization in, 2:702
 dependency theory and, 2:712–713
 export processing zones in, 2:1067
 fertility levels in, 2:709
 foreign aid to, 3:1152
 gender inequalities in, 3:1589
 geopolitics in, 3:1252
 hacienda plantation form in, 5:2193
 Heavily Indebted Poor Countries initiative (World Bank) and, 2:690
 HIV/AIDS in, 3:1438
 Alexander von Humboldt’s studies of, 3:1462
 import substitution industrialism (IAI) in, 2:1064, 3:1550–1551
 inequality geography and, 3:1587
 land inequalities in, 4:1693
 land privatization in, 5:2494
 Latin American Free Trade Association and, 3:1551
 Latin American Integration Association and, 3:1551
 marine aquaculture in, 4:1854, 4:1854 (fig.)
 Movimento Sem Terra (MST) in, 4:1948–1952
 nationalism in, 1:509
 neoliberalist policies in, 4:2012
 newly industrializing countries in, 4:2022, 4:2022 (fig.), 4:2023
 North American Free Trade Agreement (NAFTA) and, 4:2023
 people living in extreme poverty and, 3:1082 (table)
 population growth of, 5:2233 (fig.)
 poverty rates in, 5:2274, 5:2275
- Carl Sauer’s cultural landscape work in, 3:1458
 sewage entering coastal zones of, 1:501
 silver flows, 16th to 18th centuries and, 1:513 (fig.)
 squatter settlements in, 5:2682
 Third World debt crisis and, 2:688
 trading blocs in, 3:1550–1551
 undernourishment in, 3:1488 (table)
 United Nations Economic Commission for Latin America (ECLA) and, 2:712–713
 women’s lives in, 3:1097
- Latitude, 4:1762–1763**
 angle differences in, 4:1763
 athermal latitude, 4:1763
 conformal latitude, 4:1763
 coordinate geometry and, 2:577–579
 coordinate systems and, 2:579–580
 datums and, 2:685–686
 definition of, 4:1762
 Earth’s coordinate grid and, 2:815–816
 equator and, 2:1008–1009
 Eratosthenes’s work and, 2:1010
 geocentric latitude, 4:1763
 geodesy and, 3:1217–1219
 geodetic latitude, 4:1763
 geographic latitude definition and, 4:1763
 isometric latitude, 4:1763
 parametric latitude, 4:1763
 rectifying latitude, 4:1763
 units and formats of, 4:1763
- Latour, Bruno
 actor-network theory and, 1:8, 2:649, 5:2272
 built environment, society and culture and, 1:298–299
 modernity redefinition views of, 4:1931
 networks, hybrid geographies and, 3:1503
 nonrepresentational theory and, 4:2042
 poststructuralism work of, 3:1469, 5:2272
 scientific knowledge production and, 4:1996
 space as series of networks and, 5:2272
- Latvia, 3:1190 (table)
- Lauri, Nina, 3:1193
- Laurini, R., 4:1952
- Lavellée, Théophile, 4:1896
- Law, geography of, 4:1763–1766**
 built environment issues and, 4:1765
 community and identity issues and, 4:1765
 critical legal studies and, 4:1764, 4:1765
 environmental law and, 2:965–967
 geographies of resistance and, 4:1766
 global space organization and, 4:1764
 Guantanamo Bay, Cuba and, 4:1764
 how law frames space and, 4:1765
 law in urban planning policy and, 4:1766
 “law-space nexus” and, 4:1764
 legal aspects of geospatial information and, 4:1770–1772
 legal connection between law and space focus of, 4:1764
 legal geography and, 4:1763
 lived geographies of law issues and, 4:1765–1766
 methodological frameworks in, 4:1765
 noncollaborative nature of, 4:1764
 origins of relationship and, 4:1764
 police work ethnographies and, 4:1765–1766
 positivist and normative perspectives on, 4:1764
 power emphasis in, 4:1765
 privacy and autonomy issues and, 4:1766
 property law and, 4:1764

- research directions, 4:1765–1766
 spatial organization of relations of power and rule emphasis in, 4:1765
 “stateless” and “lawless” spaces and, 4:1764
 trade and human migration issues and, 4:1765
See also Crime, geography of
- Law, John, 1:8, 5:2273
- Leach, Melissa, 2:921, 2:922–923
- Learning regions, 4:1766–1768**
 agglomeration economies and, 1:31–32
 American *vs.* European contexts of, 4:1766–1767
 definition of, 4:1766–1767
 economic geography and, 4:1767
 evolutionary and institutional economics and, 4:1767
 industrial areas and, 4:1766
 innovation as contextualized social process and, 4:1766
 Italy’s Emilia-Romagna area example of, 4:1766, 4:1767, 5:2519
 knowledge geographies and, 4:1659–1663
 knowledge spillover and, 4:1663–1664
 narrow *vs.* broad innovation system definition and, 4:1767
 post-Fordist societies as learning economies and, 4:1766
 regional innovation system concept and, 4:1767–1768
 regionally-based development coalitions perspective on, 4:1767
 rational development coalitions and, 4:1767
- Lebanon, 1:514, 3:1190 (table)
- Lees, Loretta, 1:107–108
- Lefebvre, Henri, 4:1768–1770**
 activism of, 4:1768–1768
 alienation views of, 4:1769
 Gaston Bachelard and, 4:1769
 Henry Bergson criticized by, 4:1769
 books written by, 4:1769
 capitalism framework of space and, 5:2297
 Manuel Castells and, 4:1769
 critical geopolitics work of, 2:611
 critical human geography work of, 2:617
 cultural studies work of, 4:1768–1769
 Michel de Certeau and, 4:1769
 everyday life views of, 2:1042, 4:1768, 4:1769
 existential Marxism work of, 2:1046–1047, 4:1769
 David Harvey and, 4:1769, 5:2297, 5:2403
 interdisciplinary nature of his work and, 4:1768
 Don Mitchell, 4:1769
 “public space” work of, 2:1047
 Catherine Régulier and, 4:1769
 rhythm analysis work of, 2:1043
 Right to the City movement and, 5:2352
 Edward Soja and, 4:1769, 5:2593
 space as a social production, 2:1047, 3:1419, 4:1768, 4:1769, 4:1862, 5:2297, 5:2431–2432, 5:2669
 spaces of representation and, 5:2602
 spatial character of capitalism and, 4:1768, 4:1769
 urban geographies work of, 2:1047, 4:1769, 5:2352
 visual knowledge views of, 4:2043
- Legal aspects of geospatial information, 4:1770–1772**
 codes of ethics and, 4:1771
 copyright issues, 4:1771
 digital intellectual property and, 4:1771
 evidentiary admissibility of GIS products issues, 4:1771–1772
 Fourth Amendment, in our homes *vs.* public space and, 4:1771
 Freedom of Information Act (FOIA) and, 4:1770
 GIS evidence as “hearsay” and, 4:1771
 GIS products as art issue and, 4:1771
 GIS products’ authentication and, 4:1771–1772
 intellectual property rights issues, 4:1770–1771
 liability issues, 4:1770
 privacy and confidentiality issues, 4:1771
 property rights issues, 4:1770
 public access and data ownership issues, 4:1770
 World Intellectual Property Organization and, 4:1771
See also Geospatial industry; Geospatial semantic web; Law, geography of; Privacy and security of geospatial information; Usability of geospatial information
- Leibniz, Gottfried, 5:2402
- Leighly, John, 1:191
- Leimgruber, W., 4:1852 (figs.)
- Lejano, Raul, 3:1309
- Lemkin, Raphael, 3:1199
- Lengerich, E., 2:1061
- Leontief, Wassily, 3:1599–1600
- Leopold, Aldo
 conservation movement and, 2:981
 ecological interpretation of history work of, 2:929
 land ethics work of, 2:926
 prairie restoration work of, 5:2278
Sand County Almanac written by, 5:2278
- LeSage, Jim, 5:2637
- Lesotho**
 economically active females in, 3:1190 (table)
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
- Levin, Simon, 5:2438
- Levins, Richard, 4:2131
- Lévi-Strauss, Claude, 5:2270, 5:2706
- Levy, David, 3:1104
- Lewis, Meriwether, 4:1773–1777
- Lewis, Peirce, 4:1772–1773**
 AAG service of, 4:1772
 academic career of, 4:1772
Axioms for Reading the Landscape written by, 4:1773
 cultural geography and landscapes work of, 4:1772–1773
 landscape interpretation work of, 4:1713–1714, 4:1772–1773
 space, place, and landscape work of, 4:1772–1773
- Lewis and Clark expedition, 4:1773–1777**
 expedition details and, 4:1773–1777
 geographical knowledge from, 3:1464
 Thomas Jefferson and, 3:1464, 4:1642
 Louisiana purchase and, 4:1774–1775 (fig.)
 misconceptions derived from, 4:1776
 Northwest Passage search and, 4:1773
 Westward expansion initiated by, 4:1776–1777
- Ley, David, 4:1777–1778**
Black Inner City as Frontier Outpost written by, 4:1777, 4:2122
 Jim Duncan and, 4:1777
 gentrification views of, 3:1207, 4:1777
 Peter Gould and, 4:1777
 humanistic geography work of, 4:1777–1778
 landscape geography work of, 4:1777
 Marxist geography work of, 4:1863
 participant observation methodology of, 4:2122
 postmodernism and, 5:2268
 qualitative research work of, 4:1777, 4:2122
 research topics of, 4:1777
 service work of, 4:1777–1778
 structure and agency in social analysis and, 4:1863
 urban and social geography work of, 4:1777, 5:2567
 urban ethnography work of, 3:1476, 4:1777, 5:2567
- Leyshon, Andrew, 4:1968
- Liberia**
 economically active females in, 3:1190 (table)
 independence of, 1:512
- Libya**

- economically active females in, 3:1190 (table)
 Italian colony of, 1:509
 Simon Lucas's exploration of, 2:1057
 oil exports from, 4:2073
 OPEC membership of, 4:2100 (fig.)
- LiDAR and airborne laser scanning, 4:1778–1779**
 characteristics of LiDAR sensors and, 4:1778–1779
 Continuous LiDAR and, 4:1779
 discrete-return LiDAR and, 4:1779
 measurement method used in, 4:1778
 multiple-return LiDAR and, 4:1779
 profiling LiDAR and, 4:1779
 remote sensing technology of, 4:1778
 scanning LiDAR and, 4:1779
See also Aerial imagery: data; Aerial imagery: interpretation
- Lieblein, G., 1:54
- Lightning, 4:1779–1783**
 atmospheric electrical charges and, 4:1779–1780
 characteristics of, 4:1780–1781
 within the cloud, between clouds, and cloud-to-ground
 types of, 4:1780
 cloud electrification, 4:1779–1780
 cloud-to-ground lightning and, 4:1780 (photo)
 detection of, 4:1781
 Earth's electrical field and, 4:1779–1780
 fatalities related to, 4:1781–1782
 “forked” appearance of, 4:1781
 Benjamin Franklin, 4:1779
 geographical studies of, 4:1782
 geographic visualization and mapping techniques and, 4:1782
 GIS technology and, 4:1782
 impacts of, 4:1781–1782
 land use role in, 4:1782
 lightning channels of, 4:1781
 magnetic direction finders and, 4:1781
 National Interagency Fire Center and, 4:1782
 National Lightning Detection Network and, 4:1781
 noninducting charging mechanism and, 4:1780
 positive flash type of, 4:1781
 property and agricultural damage from, 4:1782
 regional lightning networks and, 4:1781
 return stroke of, 4:1781
 satellite lightning sensors and, 4:1781, 4:1782
 scientific perspective on, 4:1779
 thunder and, 4:1781
 urban area lightning climatology studies and, 4:1782
 wildland fires ignited by, 4:1782
- Lillesand, Thomas, 4:1783–1784**
 academic career of, 4:1783
 interdisciplinary research activities of, 4:1783–1784
 publications authored by, 4:1783
Remote Sensing and Image Interpretation co-written by, 4:1783
 remote sensing work of, 4:1783–1784
 service work of, 4:1783–1784
- Linear referencing and dynamic segmentation, 4:1784–1785**
 dynamic segmentation definition and, 4:1784
 geometric nodes and arcs and, 4:1784
 GIS in utilities management and, 3:1316
 GIS software and, 4:1785
 graph theory and, 4:1785
 linear features examples and, 4:1784
 linear referencing system and, 4:1784
 logical data model in, 4:1785
 mile-post tables and, 4:1784
 utilities and transportation networks and, 4:1784
- Literature, geography and, 4:1785–1788**
 cooking scene from *Robinson Crusoe*, 4:1788 (image)
 “cultural turn” and, 4:1787
 fields of, 4:1785
 form *vs.* content of literature and, 4:1787
 historical-geographical literary analysis and, 4:1786
 humanistic geography, narratives of place and, 4:1786
 literature as an aesthetic category, 4:1786, 4:1787
 literature as site of ideological critique and, 4:1786–1787
 Marxist geographers and, 4:1786
 notions of truth and, 4:1787
 postcolonial geographic imagination and, 4:1787
 sociospatial relations and geographical reality images and,
 4:1785
 spatial history of the novel and, 4:1786
 spatiality expressions and, 4:1787–1788
 spatial metaphors and, 4:1785–1786
 “structures of feeling” and, 4:1787–1788
 study of narrative and, 4:1785–1786
 text and context relationship element in, 4:1785
 truth and fiction relationship and, 4:1787
 uneven distribution of cultural capital and, 4:1786–1787
See also Literature, geography and: noted individuals
- Literature, geography and: noted individuals, 4:1788
 Walter Benjamin, 4:1788, 5:2298
 Pierre Bourdieu, 4:1786, 4:1787
 Anne Buttner, 4:1786
 Joseph Conrad, 4:1787
 Daniel Defoe, 4:1787
 David Harvey, 4:1788, 4:1862
 James Joyce, 4:1788
 Franco Moretti, 4:1786
 Douglas Pocock, 4:1786
 Edward Said, 4:1787
 Yi-Fu Tuan, 4:1786
 J. K. Wright, 4:1786
- Lithuania
 Clean Development Mechanism (CDM), carbon offsets and,
 1:333 (fig.)
 economically active females in, 3:1190 (table)
- Liu, Tanzhuo, 2:719–720
- Liverman, Diana, 2:793
- Livingston, David, 2:560
- Livingstone, David, 4:1789–1790**
 books written by, 4:1789
 Enlightenment as a geographical phenomenon views of, 2:910
 geographical knowledge as a cultural product views of, 4:1789
Geographical Tradition written by, 4:1789
 geography of scientific knowledge and, 4:1789
 honors received by, 4:1789
 re-interpretation of theory work of, 5:2231
 science and religion conflict and, 4:1789
- Llewelyn, Mark, 1:108
- Lloyd, Robert, 2:977
- Locality, 4:1790–1792**
 Changing Urban and Regional System (CURS, U.K.)
 and, 4:1790–1791
 definition of, 4:1790
 Economics and Social Research Council (U.K.), 4:1790–1791
 empiricism and, 4:1790
 interdisciplinary research, 4:1790–1791
 Localities School and, 1:405
 Marx's historical materialism and, 4:1790
 Doreen Massey's work in, 2:852, 4:1790–1791, 4:1866–1867
 significance of locality studies and, 4:1791

- sociospatial relationships and, 4:1791
- spatial scale debates and, 4:1791
- territorial to relational views of spatiality and, 4:1791
- See also* Glocalization
- Locally unwanted land uses (LULUs), 4:1792–1793**
 - explanation of, 4:1792
 - health threats and, 4:1792
 - measures to overcome resistance and, 4:1792
 - NIMBY acronym (not in my backyard) and, 4:1792
 - “Not in My Backyard” (NIMBY) and, 4:2049
 - political conflict dynamics and, 4:1792
 - public intervention justification and, 4:1792
 - waste incineration and, 6:3048–3049
- Location-allocation modeling, 4:1793–1794**
 - challenges of, 4:1794
 - definition of, 4:1793
 - exact approach to, 4:1793–1794
 - examples of demand to be served and, 4:1793
 - facility types in, 4:1793
 - heuristic approach to, 4:1794
 - location theory and, 4:1799
 - mathematical representation of, 4:1793
 - practical applications of, 4:1794
 - prominent geographers working in, 4:1793
 - spatial optimization model of, 4:1793, 4:1799
 - variants of, 4:1793
- Location-based services (LBSs), 4:1794–1796**
 - access feature of, 4:1795
 - applications of, 4:1796
 - features and technologies of, 4:1794–1796, 4:1795 (fig.)
 - geoslavery and, 3:1255–1256
 - GIS *vs.*, 4:1794
 - localization feature of, 4:1795
 - location-based social networks (LBSNs) and, 4:1796
 - location *vs.* position and, 4:1795
 - mobile GIS and, 4:1918–1921
 - neogeography and, 4:2005–2006
 - questions answered by, 4:1794
 - scalability feature, 4:1795
 - spatial decision making based on mobility and position and, 4:1794
 - spatiotemporal modeling and analysis and, 4:1795
 - visualization feature, 4:1795
 - See also* Global positioning system (GPS)
- Location quotients, 4:1796–1797**
 - definition of, 4:1796–1797
 - economic base analysis and, 2:846–848
 - economic geography application of, 4:1796
 - function of, 4:1796
 - New York City banking *vs.* U.S. banking example of, 4:1797
 - reference region choice and, 4:1797
 - regional structural composition comparisons using, 4:1796
- Location theory, 4:1798–1800**
 - abstract laws application and, 4:1798
 - applications of, 4:1799
 - Cartesian view of absolute space and, 4:1798
 - Central Places in Southern Germany* (Christaller) and, 4:1798
 - central place theory and, 1:380–382, 1:409–410, 4:1798
 - Conomics of Location* (Lösch) and, 4:1798
 - decline in popularity of, 4:1799
 - definition of, 4:1798
 - economic base analysis and, 2:846–848
 - economies of scale and, 2:854
 - empirical world and theoretical world relationship and, 4:1798
 - externalities and, 2:1068–1069
 - factors affecting location of firms and, 3:1077–1080
 - Germany economic geography and, 4:1798
 - GIS and, 4:1799
 - gravity models and, 4:1798
 - human geography and, 4:1799
 - human spatial behavior and, 4:1799
 - industrial location theory (A. Weber) and, 4:1798
 - limitations of, 4:1799
 - location-allocation models and, 4:1799
 - logical positivism and, 4:1798
 - methodological individualism and, 4:1799
 - neoclassical economics and, 4:1798
 - network and graph theory and, 4:1798–1799
 - quantitative methods and, 4:1798
 - quantitative methods used in, 4:1799
 - space devoid of social relations and, 4:1798
 - spatial diffusion and, 4:1799
 - Thünen model and, 4:1798, 4:1799, 4:1799 (fig.), 4:1801–1802, 6:2832–2834
 - See also* Location theory: noted individuals
- Location theory: noted individuals
 - Walter Christaller, 1:409–410, 3:1628, 5:2393
 - Derek Gregory, 3:1380
 - Törsten Hägerstrand, 4:1799
 - Walter’s Isard, 3:1628
 - August Lösch, 3:1628, 4:1798, 4:1805–1806
 - Johann Henrich von Thünen, 4:1799 (fig.)
 - von Thünen, 3:1628, 5:2393, 5:2394
 - Alfred Weber, 3:1628, 4:1798, 5:2393
- Locke, John, 2:893, 4:1928, 4:1971, 4:1979
- Logan, J. R., 4:1745
- Logical positivism, 4:1800–1802**
 - Brian Berry’s work and, 1:193
 - correspondence theory of truth and, 4:1801
 - criticisms of, 4:1801, 4:1802
 - decline of, 4:1802
 - deductive reasoning in scientific theorizing and, 4:1800
 - demonstrable propositions and, 2:1007–1008
 - empiricism and, 2:893
 - epistemology and, 2:1007–1008
 - ethics and geography and, 2:1013
 - expressions of preference and, 2:1007
 - falsification principle (Popper) and, 4:1801
 - founding leaders of, 4:1800
 - gentrification and, 3:1203
 - growth of, 4:1800
 - Hartshorne *vs.* Schaefer and, 1:405, 3:1403, 3:1466, 4:1801, 5:2326, 5:2388
 - historical origins of, 4:1800
 - human geography models and, 4:1801
 - location models and, 4:1801
 - location theory and, 4:1798
 - metaphysical speculation and, 4:1800
 - neoclassical economic modeling and, 4:1801–1802
 - nomothetic and, 4:2035, 5:2388
 - positivism in geography and, 4:1801–1802
 - positivism *vs.*, 4:1800–1801
 - quantitative revolution and, 4:1801
 - realism and, 5:2369–2371
 - regional geography and, 5:2388
 - scientific rules of knowledge collection and, 4:1801
 - Töbner’s First Law and, 4:1801–1802
- London, England, 4:2006
 - Anglocentrism in, 2:1030 (table)
 - Goggle Maps API, www.londonprofiler.org and, 4:2006

- infrastructure networks in, 3:1597
 “London Greenbelt,” 3:1363–1364, 3:1371
 national geographical society in, 3:1462
 railroad line and, 5:2357, 5:2358
 as supergentrification urban center, 3:1204
 wildlife corridors in Wandsworth, southwest London, 6:2944 (photo)
See also United Kingdom
- Longitude, 4:1802–1803**
 coordinate geometry and, 2:577–579
 coordinate systems and, 2:579–580
 datums and, 2:685–686
 Earth’s coordinate grid and, 2:815–816
 equator and, 2:1008–1009
 Eratosthenes’s work and, 2:1010
 geodesy and, 3:1217–1219
- Longley, Paul, 3:1308, 5:2603
- Lorde, Audrey, 3:1095
- Lorentz, H. A., 1:89
- Lorimer, Hayden, 4:2041
- Los Angeles, California
 command and control economy in, 1:304
 community garden planning, Echo Park area of, 2:548 (photo)
 environmental impact of, 2:940–941
 as gateway port, 5:2254
 Japan–South Korea World Baseball Classic game, Dodger Stadium, 5:2681 (photo)
 population migration flow studies in, 1:417
 smog in, 1:69
 waste incinerator environmental justice issue in, 2:960
See also Los Angeles School
- Los Angeles School, 4:1803–1805**
 changes in residential space and, 4:1804
 Chicago School *vs.*, 1:389, 4:1803
 flexible production and, 4:1803
 flexible production and, 4:1804
 gentrification and, 4:1804
 globalized urban areas, international economy and, 4:1804
 Los Angeles as exemplar of contemporary capitalism and, 4:1803
 postmodernism and, 4:1804
 production systems as core of urban analysis and, 4:1803–1804
 regulation and regime theory and, 4:1804
 spatial structure of capitalism and, 4:1803
 state urban planning processes and, 4:1804
 urban division of labor and, 4:1803–1804
 urban political economy and, 4:1803
See also Los Angeles School: noted individuals
- Los Angeles School: noted individuals, 4:1804
 Mike Davis, 4:1803
 Michael Dear, 2:688, 4:1803, 4:1804
 Allen Scott, 4:1803, 4:1863, 5:2519–2520
 Edward Soja, 2:688, 4:1803, 5:2593
 Michael Storper, 4:1803, 4:1863, 5:2695–2696
- Lösch, August, 4:1805–1806**
 central place theory and, 1:410, 4:1805
 Walter Christaller and, 1:410, 4:1805
Economics of Location written by, 4:1798
 hierarchy of places work of, 4:1805
 location theory and, 3:1628, 4:1798, 4:1805, 5:2393, 5:2394, 5:2433
 logical positivism of, 4:1805
 regional science and, 4:1805
 Joseph Schumpeter and, 4:1805
Spatial Organization of the Economy written by, 4:1805
- Loudon, John, 4:1699
- Louisiana
 hot rooftops, Baton Rouge, Louisiana, 6:2947 (image)
- Hurricane Camille (1969), 3:1500
 Hurricane Katrina and, 3:1493–1494
 hurricanes in, 3:1501
- Louisville, Kentucky, 4:1821
- Love Canal, 4:1806–1808**
 brownfields and, 4:1808
 Citizen’s Clearinghouse for Hazardous Waste and, 4:1808
 Comprehensive Environmental Restoration, Compensation, and Liability Act and, 4:1808
 discovery of contamination in, 4:1806–1807
 environmental monitoring of, 4:1805–1806, 4:1807 (photo)
 Lois Gibbs and, 4:1805–1806
 hazardous waste management prior to, 4:1806
 hazardous waste policy influenced by, 4:1807–1808
 historical geography of, 4:1806
 Hooker Chemical and Plastics Corporation and, 4:1805
 locally unwanted land uses (LULUs) and, 4:1792
 Superfunds and, 4:1808
- Lovejoy, Thomas, ecosystem decay work of, 2:858, 2:859, 2:861
- Lovelock, James, 1:204, 2:819, 3:1175
- Loveridge, Scott, 5:2394
- Lowenthal, David, 2:977, 3:1435, 3:1476, 4:2167
- Luckman, T., 5:2297
- Lukacs, Georg, 4:1862
- Lund School of cultural geography (Sweden), 2:745
- Luxembourg
 European Union (EU) membership of, 2:1035
 foreign aid flow from, 3:1152
- Luxembourg, Rosa, 4:1862
- Lyde, Lionel, 2:848
- Lynch, Kevin, 4:1714, 5:2609–2610
- Lynch, William, 4:1808–1809**
 biblical *vs.* science debates and, 4:1808–1809
 Dead Sea Bible references and, 4:1808, 4:1809
 Dead Sea explored and mapped by, 4:1808–1809
 publications of, 4:1809
- Maathai, Wangari, 3:1610
- MacArthur, Robert, theory of island biogeography and, 1:199, 3:1631 (fig.), 4:1696, 5:2672
- Macau, 1:514
- MacCabe, Charles, 3:1219–1220
- Macchu Pichu, 1:295
- MacEachren, A. M., 2:789, 2:1061
- MacEachren, Alan, 4:1811–1812**
 cartography and GIScience research fields of, 4:1811–1812
 (Cartography)³ diagram published by, 4:1811
 criticism of, 4:1812
 dynamic and interactive displays and, 4:1811
 geographic visualization of, 4:1811
 GeoVISTA Center, Penn State established by, 4:1811
 geovisual analytics work of, 4:1811–1812
 heartland geopolitical model and, 4:1812
How Maps Work written by, 4:1811
 map categorization work of, 4:1811
 visual analytics and, 4:1811
- Macedonia, 3:1190 (table)
- Machlup, Fritz, 3:1593
- MacKenzie, Donald, 3:1116–1117
- Mackinder, Sir Halford, 4:1812–1813**
 anthropogeography views of, 1:93, 4:1989, 4:1990
 Cold War predictions and, 4:1813
 criticism of, 4:1812–1813
 Euro-Asian landmass focus of, 3:1464, 4:1812–1813
Geographical Pivot of History written by, 3:1464, 5:2222

- geopolitical Heartland model of, 4:1812–1813
 geopolitics work of, 2:611, 3:1251, 3:1464, 4:1812–1813, 4:1896, 5:2222, 5:2404
 Karl Haushofer influenced by, 3:1407–1408
 Heartland theory of, 4:1813, 5:2222
 holistic approach of, 4:1992
 imperial rivalry and, 5:2404
 London School of Economics and, 3:1251
 RGS award of, 5:2487
- Madagascar**
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 forest fragmentation in, 3:1159
 Malayo-Polynesian languages in, 4:1753, 4:1753 (fig.)
 marine aquaculture in, 4:1854 (fig.)
 new farming methods in, 3:1556 (photo)
 tropical deciduous forest in, 1:230, 1:231, 1:232 (photo), 1:233 (photo)
 tropical monsoon climate in, 1:455
 tropical rain forest of, 1:234, 1:236
 tropical savanna in, 1:239
 tropical scrub in, 1:244
- Madeira**, 2:1051
- Madison, James**, 5:2584
- Magellan, Ferdinand**, 4:1813–1815
 Bartolomé de las Casas and, 4:1813
 circumnavigation of the globe by, 3:1461, 4:1813–1815, 4:1814 (fig.), 4:2179
 expedition's first-hand accounts and, 4:1815
- Mahan, Alfred Thayer**, 4:1815–1816
 geopolitical importance of sea power focus of, 4:1815
Influence of Sea Power Upon History written by, 4:1815, 4:1893
 military geography work of, 4:1893
 Theodore Roosevelt's "Great White Fleet" and, 4:1816
 U.S. colonialism and, 4:1815–1816
- Maine**, 1:534
- Malacca**, 1:514
- Malacca Straits**, 1:515
- Malanson, G.**, 2:866 (photos)
- Malaria, geography of**, 4:1816–1819
 anopheles mosquito and, 4:1816
 cultural interventions and, 4:1817
 DDT insecticide control strategy and, 4:1817
 developing world and, 2:726–727
 genetic immunity to, 4:1817
 Global Malaria Eradication Program and, 4:1817
 global warming and, 4:1817
 HIV/AIDS relationship with, 2:727
 human resistance differences and, 4:1817
 infection exposure resistance to, 4:1817
 parasite characteristics and, 4:1816–1817
 plasmodium parasite and, 4:1816
 symptoms of, 4:1816
 underdevelopment relationship to, 4:1817
 wetland drainage and, 4:1817
 world malaria transmission areas and, 4:1818 (fig.)
- Malawi**, 3:1190 (table)
- Malaysia**
 acid rain in, 1:7
 APEC membership of, 1:121
 ASEAN Free Trade Area and, 1:130
 ASEAN membership of, 1:127, 1:128, 1:128 (table), 1:129, 1:129 (table)
 biodiesel production in, 1:203–204
 biofuels produced in, 1:203–204, 202
- British colonization of, 1:515
 Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 deforestation from land use and cover change, Sabah, 4:1737 (photo)
 deforestation in, 2:696
 economically active females in, 3:1190 (table)
 forest fragmentation in, 3:1159
 guerrilla conflicts in, 2:692
 industrialization in, 3:1583, 4:2020, 4:2022, 4:2022 (fig.)
 Japanese electronics industry in, 2:885
 Malay archipelago and, 1:105
 Malayo-Polynesian languages in, 4:1753, 4:1753 (fig.)
 marine aquaculture in, 4:1854 (fig.)
 plantations in, 5:2192
 rice farming in, 1:48 (photo)
 satellite dishes illegal in, 2:750
 tea plantation Cameron Highland, Pahang, 5:2193 (photo)
 tropical rain forest of, 1:234, 1:237, 1:237 (photo), 1:238 (photo)
 Vision 2020 and, 4:2022
- Mali**, 3:1190 (table)
- Malinowski, Bronislaw**, 5:2323
- Malkki, L.**, 5:2380
- Mall of America**, Bloomington, Minnesota, 1:107, 2:574 (photo), 2:575
- Malpas, Jeff**, 4:2168
- Malta**, European Union (EU) membership of, 2:1035
- Malthusianism**, 4:1819–1820
 agricultural intensification and, 1:36
 carrying capacity concept and, 5:2238–2239
 definition of, 4:1819
 demographic transition and, 2:707
 environmental security scholarship and, 2:999, 4:1820
Essay on the Principle of Population (Malthus) and, 4:1819, 4:2015
 fertility restrictions of families and, 4:1819
 international policy and, 4:1820
 John Maynard Keynes and, 4:1820
 Thomas Robert Malthus and, 4:1819, 4:2015, 6:2747
 natural resources finitude and, 4:1820, 4:2015
 neo-Malthusianism and, 4:1819, 4:1820, 4:2015–2016
 political economy meaning and, 5:2214
 population and land degradation debate and, 5:2233–2234
Population Bomb (Ehrlich) and, 4:1820
 "population principle" of famine and, 3:1082–1083, 3:1586
 "principles" of population and, 4:1819
 resource wars, or greenwar concepts and, 4:1820
 social intervention via social welfare and, 4:1819
See also Neo-Malthusianism; Sustainable development
- Mamdani, Mahmood**, 3:1570
- Manchuria**, 1:514
- Manson, Steven**, 2:560
- Manufacturing Belt**, 4:1820–1824
 agglomeration economics and, 4:1821
 creative destruction pattern and, 4:1822, 4:1824
 decline and restructuring of, 4:1822–1824
 dynamics and geography of, 4:1821–1822
 industrialization and, 3:1580–1581, 4:1820–1821
 Industrial Revolution and, 3:1584
 Mittal Steel's Cleveland Works, Ohio, 4:1823 (photo)
 regional specialization and, 4:1821
 Rust Belt and Snowbelt and, 4:1824
 second industrial revolution (1880s) and, 4:1822
 Sunbelt and, 4:1822
 trade unions and, 4:1822
 westward expanding industrial belt and, 4:1821
- Manzer, Ronald**, 2:874

Map algebra, 4:1824–1825

cartographic modeling and, 4:1824
 definition of, 4:1824–1825
 linear referencing and dynamic segmentation, 4:1784–1785
 local, focal, and zonal operations categories and, 4:1825
 raster data model and, 4:1824–1825
 self-organizing maps and, 5:2526–2628
 spatial analytic tasks decomposed by, 4:1825
 spatial scope of operations and, 4:1825
 spatio-temporal data sets and, 4:1825
 three-dimensional spaces and, 4:1825
 for vector fields, 4:1825

Map animation, 4:1825–1828

Adobe Flash and Microsoft PowerPoint tools and, 4:1826
 ArcGIS, Google Earth, and NASA World Wind and, 4:1826
 categories of, 4:1826
 definition of, 4:1825
 duration, rates of change, and order of maps variables in, 4:1826
 dynamic and interactive displays and, 2:804–808
 early map animations and, 4:1825–1826
 GIS and satellite remote sensing and, 4:1826
 history of, 4:1825–1826
 technology advances and interactive animation in, 4:1826–1827
 visual variables and, 4:1826, 4:1827 (fig.)
See also Map animation: noted individuals

Map animation: noted individuals

David DiBiase, 4:1826
 Mark Harrower, 4:1826
 Norman Thrower, 4:1826
 Waldo Tobler, 4:1826

Map design, 4:1828–1832

aesthetic considerations, visual design lessons, 4:1828–1829
 base map and, 4:1829–1830
 cartograms and, 1:338–339
 cartographic abstraction in, 4:1829–1830
 color in map design and, 1:516–522
 data classification schemes and, 2:677–679
 directional indicator and, 4:1831
 dot maps and, 2:787–790
 elements of a map, 4:1830–1831
 figure achieved by closure *vs.* differentiation, or contour and, 4:1828, 4:1829 (fig.)
 figure-ground relationships and, 4:1828, 4:1829 (fig.)
 flow maps and, 3:1138–1139
 inset maps and, 4:1831
 internal consistency and, 4:1828
 interparallelism form of internal consistency and, 4:1828
 legend and, 4:1831
 map animation and, 4:1825–1828
 map generalization and, 4:1835–1841
 map image definition and, 4:1828
 map projections and, 4:1841–1849
 map visualization and, 4:1849–1850
 neat lines and, 4:1831
 scale indicator and, 4:1831
 selection and generalization of themes in, 4:1830
 simplicity and, 4:1829
 symbolization strategies in, 4:1830
 title and, 4:1831
 21st Century map design and, 4:1831
 visual balance and, 4:1828

Map evaluation and testing, 4:1832–1833

effectiveness and efficiency issues of maps and, 4:1832
 functional map use research and, 4:1832
 interview technique of, 4:1833

map functions and, 4:1832
 map generalization and, 4:1835–1841
 map production process and, 4:1832
 map visualization and, 4:1849–1850
 new map types and, 4:1832
 observation technique of, 4:1833
 participant observation technique of, 4:1833
 perceptual/cognitive map use research and, 4:1832
 product analysis technique of, 4:1833
 qualitative and quantitative character of, 4:1833
 questionnaire technique of, 4:1833
 user-centered approach to map design and, 4:1832
 user-centered design approach and, 4:1832

Map generalization, 4:1833–1841

agent-based modeling and, 4:1834
 application of cartographic license concept and, 4:1836, 4:1836 (fig.)
 cartographic generalization, 4:1834, 4:1836, 4:1836 (fig.), 4:1837, 4:1838 (fig.)
 “cartographic syntax” framework research and, 4:1840
 data enrichment concept and, 4:1837
 decision-making in, 4:1837
 definition of, 4:1833–1834
 digital paradigm shift and, 4:1834
 evaluation of, 4:1837, 4:1839
 “eyes of the cartographer” requirement and, 4:1834, 4:1839, 4:1840 (fig.)
 isopleth maps and, 3:1638–1639
 model and cartographic generalization and, 4:1834–1836, 4:1836 (fig.)
 model generalization, 4:1834, 4:1836–1837, 4:1836 (fig.), 4:1838 (fig.)
 mutiscale processes interaction and, 4:1833–1834
 Portsmouth, England, at three scales and, 4:1834, 4:1835 (fig.)
 primary digital landscape model (DLM) and, 4:1834, 4:1836 (fig.)
 retail park in Southampton, England, 4:1838 (fig.)
 secondary DLMs and, 4:1834, 4:1836 (fig.)
 techniques to improve map legibility and, 4:1834 (fig.), 4:1839 (fig.)
 Voronoi modeling example and, 4:1837, 4:1839, 4:1840 (fig.)

Map projections, 4:1841–1849

Albers equal-area projection, of North America, 4:1846 (fig.), 4:1847
 Buckminster Fuller or “Dymaxion map” projection, 6:3169
 compromise projections and, 4:1842
 conformity (shape) property of, 4:1842
 coordinate geometry and, 2:577–579
 coordinate system and datum elements of, 4:1841
 coordinate transformations and, 2:580–581
 direction property of, 4:1842
 distance property of, 4:1842
 equal area or equivalence property of, 4:1842
 geodesy and, 3:1217–1219
 geometric measures and, 3:1240–1241
 Good’s Interrupted Homolosine projection and, 3:1351, 3:1351 (fig.)
 interrupted Goode homolosine projection, 3:1351, 3:1351 (fig.), 6:3169
 Lambert conformal conic projection, of North America, 4:1846 (fig.), 4:1847–1848
 Mercator projection, 4:1843 (fig.)
 Mollweide projection, 4:1844, 4:1844 (fig.), 6:3152–3153, 6:3169
 Plate Carrée projection, 4:1844, 4:1846 (fig.)
 portolan charts and, 5:2251–2252
 projection definition and, 4:1841
 projection properties and, 4:1842

- properties of matching purpose of, 4:1841
- Robinson projection, 4:1844, 4:1845 (fig.)
- samples of, 4:1842–1848
- Sinusoidal projection, 4:1844, 4:1846 (fig.), 4:1847
- T-in-O maps and, 6:2844–2846
- variables in, 4:1841–1842
- visualization of, 4:1841–1842
- Winkel Tripel projection, 4:1844, 4:1845 (fig.)
- See also Mercator, Gerardus*
- MapQuest, 3:1258, 3:1260, 3:1284, 3:1308
- Maps
 - al-Idrisi medieval geographer, map maker and, 1:66–67, 4:2179
 - Animaximander's map (recreation), 1:74–75, 1:74 (fig.)
 - cadastral map examples, 1:313–315 (figs.), 1:317 (fig.)
 - cancer maps, 1:322 (fig.), 1:324 (fig.)
 - Euroregions of cross-border cooperation and, 2:631 (fig.)
 - mobile map services spatial applications and, 1:307
 - See also Agricultural maps; Argumentation maps; Cartography; Cartography, history of; Map projections; Map visualization; Political maps; United States: maps; World maps*
- Map visualization, 4:1849–1850
 - accessibility and applicability of, 4:1849
 - active spatial analysts and mapping participants and, 4:1849
 - analog to digital cartography shift and, 4:1849
 - cartograms and, 1:338–339
 - color in map design and, 1:516–522
 - data classification schemes and, 2:677–679
 - definition of, 4:1849
 - dynamic and interactive displays and, 2:804–808
 - environmental mapping and, 2:976
 - familiarity with and expectations from, 4:1849–1850
 - flow maps and, 3:1138–1139
 - geovisualization field and, 4:1849
 - information technology advancements and, 4:1849
 - isopleth maps and, 3:1638–1639
 - Werner Kuhn's work in, 4:1672–1673
 - map animation and, 4:1825–1828
 - map generalization and, 4:1835–1841
 - media mapping and, 4:1951–1953
 - multivariate mapping and, 4:1963–1967
 - nanogeography and, 4:1849
 - viewer interaction and, 4:1849
 - See also Environmental mapping*
- Marble, Duane, 1:192, 3:1466, 5:2603
- Marc, Franz
 - Dream*, 76
 - Elephant*, 77
- Marcel, Gabriel, 2:1046
- Marcus, Melvin G., 4:1850–1851
 - academic career of, 4:1850
 - glaciology and mountaineering interests of, 4:1850
 - human-environment interactions studies of, 4:1850
 - John Russell Mather and, 4:1872
 - service work of, 4:1850
- Marcuse, Herbert, 3:1419, 3:1420, 4:1862
- Marginal regions, 4:1851–1853
 - agents of social transformation and innovation and, 4:1852
 - associated region, 4:1851
 - dead angle place or region, 4:1851
 - definition of, 4:1851
 - different ways to view, 4:1851–1853
 - diversity of human societies perspective on, 4:1851–1852, 4:1852 (fig.)
 - geometrical marginality and, 4:1852
 - gross domestic product (GDP) per capita perspective on, 4:1851
 - isolated region, 4:1851
 - materialistic perspective on, 4:1851, 4:1852 (fig.)
 - peripheries *vs.*, 4:1851
 - political perspective on, 4:1852
 - positive side to, 4:1852
 - social marginality perspective on, 4:1851, 4:1852 (fig.)
- Margulis, Lynn, 1:204
- Marine aquaculture, 4:1853–1855
 - aquatic organisms diversity and, 4:1853
 - balancing growth with sustainability and, 4:1853–1855
 - definition of, 4:1853
 - diversity in, 4:1853
 - environmental impacts of, 4:1854
 - fish farming and, 3:1119–1121
 - nations most reliant on, 4:1854 (fig.)
 - opponents of, 4:1854–1855
 - production and distribution in, 4:1853
 - social tensions in coastal communities and, 4:1854
 - statistics, 4:1853
 - water quality degradation issue and, 4:1854
 - wetlands privatization and, 4:1854
 - world's fisheries decline and, 4:1853
 - See also Aquaculture*
- Maritime trade. *See Ports and maritime trade*
- Mark, David M., 4:1855–1856
 - academic career of, 4:1855
 - algorithmic flow modeling work of, 4:1855
 - cross-disciplinary collaboration of, 4:1856
 - D8 flow routing algorithm developed by, 4:1855
 - ethnophysiography and, 4:2080
 - ethnophysiography work of, 4:1856
 - fractal nature of geographic phenomena work of, 4:1855
 - GIScience research of, 4:1855–1856
 - publications of, 4:1855
 - service work of, 4:1856
 - topographic data modeling work of, 4:1855
 - triangulated irregular networks (TINs) work of, 4:1855
- Market-based environmental regulation, 4:1856–1858
 - Acid Rain (control) Program and, 4:1857
 - carbon trading and carbon offsets and, 1:329–335
 - cost-effectiveness focus of, 4:1856–1867
 - criticisms, 4:1858
 - definition of, 4:1856
 - deposit refund systems and, 4:1857
 - environmental charge/tax systems and, 4:1857
 - EPA's Acid Rain Control Program and, 4:1867
 - greenhouse gas trading between nations, Kyoto Protocol and, 4:1857
 - neo-liberal features of, 4:1856
 - pay-as-you-throw or unit-pricing policy and, 4:1857
 - payments for environmental services (PES) and, 4:1858
 - pollution tax and, 4:1857
 - Superfund Program, 4:1857
 - tradable permits and, 4:1857
 - water trading permit systems and, 4:1857
 - See also Corporate voluntary environmental initiatives and self-regulation*
- Markusen, Ann, 1:119, 4:1902
- Marsh, George Perkins, 4:1858–1859
 - conservation work of, 2:569, 2:928, 4:2180, 5:2515, 5:2584
 - environmental history and restoration work of, 2:991–992
 - as first environmentalist, 4:1858
 - forest management practices and, 4:1859, 5:2584
 - land use and cover change (LUCC) work of, 4:1734
 - Man and Nature* written by, 2:928, 2:991, 4:1858, 4:1859, 4:2180
 - Smithsonian Institution and, 4:1859
 - world travels of, 4:1859

- Marshall, Alfred, 1:480–481
Marshall Islands atoll, 1:166, 1:166 (photo)
Martin, Deborah, 5:2575
Martin, Philippe, 2:781
Martinique, 1:512
Marx, Karl, 2:544 (photo)
 classic social theory of, 3:1277
 critical human geography and, 2:617
 cultural turn concept origins and, 2:645
 historical record a series of production modes and, 3:1433–1434
 modernity and commodification relationship and, 4:1936
 political economy meaning and, 5:2214
 social evolution theories of, 2:729
Marx, Leo, 2:1075
Marxism, geography and, 4:1859–1865
 academic versions of, 4:1862
 anarchism and geography and, 1:73, 1:74
 body geography and, 1:288
 books written by, 4:1860
 bourgeoisie *vs.* proletariat and, 1:423
 capitalism must grow to survive concept and, 4:1861, 4:1864
 centrality of labor, political economy and, 4:1860
 circuits of capital and, 1:410
 class, capitalism, and uneven development themes in, 3:1189, 4:1861
 class and nature and, 1:423–424
 commodities as embodiments of social relations and, 2:573
 critical human geography and, 2:617
 critical studies of nature and, 2:624–625
 criticism of, 4:1864
 cultural geography and, 4:1863
 denaturalization of nature and, 4:1863–1864
 dependency theory and, 4:1862
 dialectics and, 4:1860
 economic determinism and, 4:1860
 economic landscape changes over time and, 2:666
 environmental justice and, 2:625, 4:1863
 environmental politics and, 4:1863
 existential Marxism and, 2:1046–1047
 feminist scholars and, 4:1863
 foundations of, 4:1860–1861
 Frankfort School version of, 4:1862
 gender and geography and, 3:1188–1189
 gender and nature and, 3:1196
 gendered division of labor and, 3:1196
 geographies of consumption and, 2:573
 historical materialism and, 4:1860, 4:1862
 holistic focus of structuralist ontology and, 4:1860
 humanistic geography and, 4:1786
 human-nature interactions and, 4:1863
 human relations with the natural world and, 1:423
 inequality geography and, 3:1587, 3:1588
 international political economy and, 4:1862
 labor theory of value and, 4:1860–1861
 Limits to Capital (Harvey) and, 3:1405, 4:1862, 5:2350–2351
 logical positivism criticism and, 4:1802
 Malthusianism and, 4:1863
 Maoist version of, 4:1861
 Marxism in geography and, 4:1862–1864
 Marxist crisis theories and, 2:609–610
 Marxist spatial analysis and geography and, 2:617
 Karl Marx's and worldview and, 4:1859–1862
 Marx's publications and, 4:1860
 natural hazards, class, race, and gender relations and, 4:1863–1864
 neo-Marxist dependency theory and, 2:712
 nonstructuralist version of, 4:1862
 overproduction issue and, 4:1861
 panopticon and, 4:2116–2117
 place and, 5:2186
 political ecology and, 4:1863, 5:2211–2212
 political geography and, 5:2223
 production cycle (Harvey) and, 4:1862, 5:2669
 production *vs.* consumption contraction and, 4:1861
 radical geography and, 4:1861, 5:2223
 resistance geographies and, 5:2441–2442
 ruling class as the “public interest” and, Thompson:1863
 social and intellectual impact of, 4:1859
 social constructivism and, 4:1863
 socialism and, 5:2571
 Social Justice and the City (Harvey) and, 5:2442
 social justice geographies and, 4:1644
 socio-spatial relations under capitalism and, 3:1430
 Edward Soja and, 5:2593
 space as a social and historical product (Lefebvre) and, 4:1862, 4:1864
 Stalinist version of, 4:1861
 state linked to class interests and, Thompson:1863
 structuralist ontology and, 4:1860
 structuration theory (Giddens) and, 4:1863
 structure and agency in social analysis and, 4:1863
 subaltern studies and, 5:2711–2712
 “theory of scale” and, 5:2506–2507
 underdevelopment and, 4:1862
 uneven development under capitalism and, 3:1430, 4:1862
 Union of Socialist Geographers and, 4:1862
 urban division of labor and, 4:1863, 4:1864
 Urban Question (Castells) and, 1:364
 use values *vs.* exchange values and, 4:1860–1861
 Richard Walker and, 6:3043–3044
 workers' movements and, 4:1860
 world-systems theory and, 4:1862
 See also **Communism and geography**; **Marxism, geography and**;
 noted geographers and scholars; **Socialism and geography**
Marxism, geography and: noted geographers and scholars
 Thodor Adorno, 4:1862
 Louis Althusser, 4:1863, 5:2270
 Walter Benjamin, 4:1862
 Brian Berry, 1:193
 James Blaut, 4:1862
 William Bunge, 4:1862
 Manuel Castells, 1:365–366
 Condorcet, 4:1860
 Denis Cosgrove, 4:1863
 Frederich Engels, 4:1859
 Michel Foucault, 4:1863
 Charles Fourier, 4:1860
 Andre Gunder Frank, 4:1862
 Antonio Gramsci, 4:1862
 David Harvey, 1:193, 3:1404, 3:1405, 3:1467, 4:1862, 5:2350
 Georg Hegel, 4:1860
 Max Horkheimer, 4:1862
 Henry Lefebvre, 4:1768–1770, 4:1862
 David Ley, 4:1863
 Georg Lukacs, 4:1862
 Rosa Luxembourg, 4:1862
 Herbert Marcuse, 4:1862
 Don Mitchell, 3:1430, 4:1863, 4:1913
 Richard Peet, 4:2144
 David Ricardo, 4:1860
 Comte de Saint-Simon, 4:1860
 Allen Scott, 4:1863

- Adam Smith, 4:1860
 Neil Smith, 4:1863, 5:2551–2552
 Edward Soja, 4:1862, 5:2351, 5:2593
 Michael Storper, 4:1863, 5:2695–2696
 E. P. Thompson, 4:1862, 4:1863
 Richard Walker, 4:1863
 Michael Watts, 4:1863, 4:1996, 4:2139
- Masculinities and geography, 4:1865–1866**
 class, sexuality, and “race” relationships to, 4:1866
 Florida State College football, 4:1865 (photo)
 gay and lesbian geographies and, 3:1183–1185
 media role in, 4:1866
 patriarchic geographies and, 4:2135–2136
 processes and relationships that define variations in, 4:1865–1866
 spatial implications of, 4:1866
 spatial inequalities, dualistic distinctions and, 4:1866
See also Sexuality, geography and/of
- Massachusetts
 textile industry strike, Lawrence (1912), 4:1676 (photo)
 Wheelabrator waste-to-energy plant, Worcester, 5:2373 (photo)
See also Boston, Massachusetts
- Massey, Doreen, 4:1866–1868**
 “conceptualizing space, time, and space-time,” 2:260
 fieldwork of, 4:1866
 gender and feminist geographies work of, 4:1867, 4:2136
 gendered character of labor markets views of, 2:852, 4:2136
 industrial restructuring work of, 2:849, 4:1790–1791, 4:1866
 localities school and, 3:1532
 new regional geography and, 5:2388
 power geometries and relational space work of, 4:1867, 5:2405
 regional geography and, 4:1867, 5:2388
 segregation measures work of, 5:2344–2345
 social activism of, 4:1866
Space, Place, and Gender written by, 4:1867
 spatial division dynamics and, 1:419, 4:1791, 4:1866–1867, 4:1875, 4:2136, 5:2297, 5:2351, 5:2601
 “spatial divisions of labor,” circuits of capital and, 1:412, 3:1532
Spatial Divisions of Labor written by, 1:304, 4:1866, 5:2351
- Massey, Douglas, 4:1893–1894
- Mass wasting, 4:1868–1871**
 bog burst and, 4:1869
 clockstreams and, 4:1871
 colluvium and, 4:1871
 debris avalanche and, 4:1869
 definition of, 4:1868
 flowing motions in, 4:1868
 fluidized granular flow and, 4:1868
 gelifluction and, 4:1871
 lateral spreads or “quick-clay” failures and, 4:1869
 long-runout-zone slope failures and, 4:1869
 matrix classification of, 4:1868
 Mount Rainier National Park, Washington, and, 4:1870 (photo)
 mudflow and, 4:1868
 permafrost environments, 4:1871
 ploughing blocks and, 4:1871
 rates of motion factor in, 4:1868
 rockslide and, 4:1869
 slides and, 4:1868
 slope failures and, 4:1869
 snow-creep force and, 4:1869–1870
 soil creep and, 4:1869–1871
 sturzstrom landslide and, 4:1869
 talus and, 4:1869
 terms related to, 4:1868
 topple failure and, 4:1868
 in tundra lowlands, 4:2149
 types of material subject to, 4:1868
 types of motion in, 4:1868
 water as motivating agent in, 4:1869
 water system phases element in, 4:1868
- Mather, John Russell, 4:1871–1872**
 academic career of, 4:1871
 climatic water budget work of, 4:1871–1872
 publications of, 4:1872
 service work of, 4:1871–1872
- Matveyeva, N. V., 1:249
- Matzke, Gordon, 1:526
- MAUP. *See Modifiable areal unit problem (MAUP)*
- Mauritania, 3:1190 (table)
- Mauritius, 3:1190 (table)
- Maury, Matthew Fontaine, 4:1872–1873**
 “Diagram of the Winds” created by, 4:1872
 as father of oceanography, 4:1872
 Alexander von Humboldt and, 4:1872
 Naval Observatory and, 4:1872
Physical Geography of the Sea written by, 4:1872
 physical survey of Virginia by, 4:1873
 religious orientation of, 4:1872
 Wind and Current Charts maintained by, 4:1872–1873
- Maxwell, James, 3:1542
- Mayer, Ernst, 2:734
- Mayhew, Henry, 2:607
- McBryde, F. Webster, 4:1897
- McCay, Bonnie, 2:551
- McCormack, Derek, 4:2042
- McDowell, Linda, 2:618, 3:1097, 3:1468, 4:2136, 5:2325
- McHarg, I., 4:1700
- McHarg, Ian, 3:1281, 3:1303
 human ecology work of, 3:1459
 map overlay procedure and, 3:1449
- McKay, Henry, 2:607
- McKenzie, Roderick, 3:1458, 5:2562
- McKnight, Tom L., 4:1873–1874**
 academic career of, 4:1873
 Australia and North America travels of, 4:1873
 awards and honors received by, 4:1874
 Community College/UCLA Geographic Alliance developed by, 4:1873
Physical Geography written by, 4:1873
Regional Geography of Anglo-America co-authored by, 4:1873
 textbooks written by, 4:1873–1874
- McLafferty, Sara, 2:615, 3:1193
- McLuhan, Marshall, 1:416, 4:1874
- Mead, George Herbert, 3:1625
- Mearns, Robin, 2:921, 2:922–923
- Media and geography, 4:1874–1877**
 active role of consumer and, 4:1875
 affective and kinetic aspects of, 4:1875
 alternative geographic narratives revealed by, 4:1875
 body as a site of crisis and, 4:1876
 changed meanings and, 4:1875–1876
 difference sensory forces present in, 4:1875
 “fictional” texts and, 4:1876
 film and, 3:1110–1111
 functions of, 4:1874
 gender relations and, 4:1875
 geographical imagination and, 4:1876
 information communication technology (ICT) and, 2:541
 Diane Massey, space-social power structures and, 4:1875
 meaning and expression generation and, 4:1874
 media, medium definitions and, 4:1874

- media as text, and textual metaphor use and, 4:1876
- media in different geographic discourses and, 4:1875
- media to craft place images and, 2:541
- “the medium is the message” phrase and, 4:1874
- “mixed media” and, 4:1876
- nationalism and media culture and, 4:1875
- photography and, 4:2176–2178
- postmodernism and, 4:1876
- powerful transformative potential of, 4:1874–1875
- public and private interconnections and, 4:1875
- qualitative methodology and, 4:1876
- spatiality of social interaction and, 4:1876–1877
- spectorial topoanalysis (Bruno) and, 4:1876
- visualization approaches and, 4:1875
- visual *vs.* aural geographic metaphors and, 4:1875, 4:1876
- Medical geography, 4:1877–1879**
- behavioral role in, 4:1877
- cancer geography and, 1:320–324
- cholera and, 1:401–403
- cluster analysis applied to, 4:1878
- critical approaches to, 4:1878
- critical race studies and, 4:1878
- databases and analytical tools development, 4:1879
- digitization of health information and, 4:1878
- feminist methods and, 4:1878
- future directions, 4:1879
- genetics role in, 4:1877
- GIS and spatial analysis of, 4:1878
- GIS health care applications and, 3:1300–1302
- global political economy factors research and, 4:1879
- habitat component in, 4:1877–1878
- habitats of disease vectors and, 4:1879
- Peter Haggett’s work in, 3:1399–1400
- health applications of remote sensing and, 4:1879
- HIV/AIDS studies and, 4:1879
- human ecology and, 4:1877–1878
- human-environment interactions and, 4:1877
- impact of climate change studies and, 4:1879
- integrative nature of health and, 4:1877
- issues addressed by, 4:1877
- local, regional, and global contexts of, 4:1877
- malaria geographies and, 4:1816–1819
- migration and health studies and, 4:1879
- multidisciplinary nature of, 4:1878
- postmodern perspectives on, 4:1878
- power structures and, 4:1878
- structuralist interpretation and, 4:1878
- See also* Carcinogens; Disease, geography of; Drugs, geography of; GIS in health research and health care; Health and health care, geography of; HIV/AIDS, geography of
- Mediterranean Sea**
- Greek and Roman exploration of, 2:1050
- map of from portolan atlas (ca. 1544), 5:2252 (fig.)
- sewage discharge into, 1:501
- temporal mean of latent heat and, 4:1762 (fig.)
- Viking exploration of, 2:1051
- Meek, Fielding Bradford, 3:1409
- Meigs, Peveril, 1:192
- Meinig, Donald, 4:1879–1880**
- core, domain, and sphere concepts of, 4:1880
- criticism of, 4:1880
- cultural landscape work of, 2:642, 4:1879, 4:2111
- “Geography as an Art” views of, 1:118
- language focus of, 4:1880
- palimpsest landscape and, 4:2111
- regional geography work of, 4:1880
- Shaping of America* written by, 3:1430, 4:1879–1880
- understanding of place work of, 3:1431–1432
- Meliker, J. R., 1:324 (figs.)
- Mental maps, 4:1881–1883**
- aligning spatial information and, 4:1882–1883
- cartography, wayfinding and, 1:347, 1:350
- cognitive information source and, 4:1881
- cognitively salient environmental elements and, 4:1882
- definition of, 4:1881
- distortions in, 4:1881–1883
- exteroceptive senses and, 4:1881
- Peter Gould’s work in, 3:1356
- hierarchical organization of spatial knowledge and, 4:1882, 4:1882 (fig.)
- organizing spatial knowledge and, 4:1882–1883
- “007 principle” (Clark) and, 4:1882
- proprioceptive information and, 4:1881
- secondary sources and, 4:1881
- simplification of complex spatial relationships and, 4:1882
- terms synonymous with, 4:1881
- urban landscape interpretation and, 4:1714
- vestibular information and, 4:1881
- visual information and, 4:1881
- Menzies, Nicholas, 2:552
- Mercator, Gerardus, 4:1883–1885**
- Age of Exploration and, 4:1883
- atlas* (term) coined by, 4:1883
- cartography work of, 1:342, 1:350, 1:353 (fig.), 3:1461
- European expansionism aided by, 4:1884
- Mercator projection map of, 4:1843, 4:1843 (fig.), 4:1883–1884, 4:1884 (fig.), 6:3168
- Ortelius and, 4:2106
- Ptolemy’s *Geography* and, 4:1883
- Merchang, Carolyn, 2:818
- Merchant, Carolyn, 2:819, 3:1100
- Merleau-Ponty, Maurice, 4:2042, 4:2166, 4:2168
- Mesoamerica**
- as center of domestication, 1:376
- indigenous cartographies in, 3:1561
- Metadata, 4:1885–1886**
- analysis and decision making use of, 4:1885
- applications of, 4:1885
- definition of, 4:1885
- error propagation and, 2:1011–1012
- formats for, 4:1885
- information contained in, 4:1885
- interoperability and spatial data standards and, 3:1623–1625, 4:2078, 4:2085
- maintenance and documentation of, 4:1885
- national and international standards of, 4:1885
- Open Source GIS and, 4:2091
- role played by, 4:1885
- situational evaluation of data usability and, 4:1885
- Metropolitan area, 4:1886–1888**
- census tracts and zip-code-based areas and, 4:1886, 4:1888
- “consolidated” *vs.* “primary” metropolitan areas and, 4:1886
- definition of, 4:1886
- largest U.S. metropolitan areas, 2007, 4:1888 (table)
- large U.S. metropolitan areas and, 4:1887 (fig.)
- as legal units, 4:1886
- “megapolis” concept (Gottmann) and, 3:1355–1356
- New England County Equivalent Metropolitan Areas and, 4:1886
- related settlement terms and, 4:1888
- rules for delimitation of, 4:1886, 4:1888

- U.S. Census, “metropolitan districts” term and, 4:1886
 U.S. metropolitan population (2000) and, 4:1886 (table)
- Mexico**
 agroforestry home garden, Cupilco, Tabasco, 1:56 (photo), 1:57
 air masses of, 1:63
 APEC membership of, 1:121
 automobile industry in, 1:169, 1:170, 1:170 (fig.)
 basin and range topography in, 1:186
 blue agave plantation, Tequila, 5:2194 (photo)
 Cave of Crystals, Chihuahua, 1:368
 as center of crop domestication, 1:376
 Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 clothing exports from, 6:2186 (fig.)
 common resources (water) management with U.S. and, 1:526, 1:527 (fig.)
 Conference of Latin Americanist Geographers held in, 2:568
 debt default crisis of, 2:688–689
 deforestation in, 2:697 (photo)
 domino theory and, 2:787, 3:1224
 drought prone region in, 2:787
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 genetically modified organisms, crops and, 1:279
 geothermal energy use in, 3:1267
 greenhouse gas emissions and, 1:463
 groundwater usage in, 3:1386
 Alexander von Humboldt’s travels in, 3:1482
 industrialization in, 3:1583
 inequality differences among regions in, 3:1589
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 land inequality in, 4:1693
 Mammoth Cave, Kentucky, 1:368
 Mexico City, temperature inversions and smog in, 1:152 (photo)
 Mexico-U.S. migration system, 4:1893–1894
 monsoons in, 1:134
 NAFTA and, 1:121, 4:2044–2046
 as newly industrializing country, 4:2023
 oil production in, 4:2099
 Optimitcheskaya Cave, West Ukraine, 1:368
 political map of, 6:3164
 remittance flows to, 5:2412
 silver trade and, 1:511
 social movements research in, 1:365
 Spanish colonization of, 1:511
 spatial adjustment for river basin conflict resolution with U.S. and, 1:527 (fig.)
 state-funded infrastructure projects and, 3:1551
 textile exports from, 6:2816 (fig.)
 Tijuana/U.S. borderlands and, 1:291, 1:291 (photo)
 tropical deciduous forest in, 1:230, 1:233
 tropical humid climate in, 1:453
 tropical scrub in, 1:244
 undernourishment in, 3:1488
- MFN.** *See* **Most favored nation status (MFN)**
- Michigan**
 automobile industry in, 1:169, 1:171, 4:1822
 female breast cancer rates in, 1:322, 1:324 (figs.)
- Microclimatology,** 1:472
- Microsoft Virtual Earth,** 1:426
- Microwave/RADAR data,** 4:1888–1890
 advantages over optical sensors of, 4:1888–1889
 applications of, 4:1889–1890, 4:1889 (figs.), 4:1890 (fig.)
 backscatter and, 4:1889
 Doppler effect in processing and, 4:1889
 feature analysis application of, 4:1888
 interferometric RADAR and, 4:1888
 operational characteristics of, 4:1889
 passive *vs.* active microwave, 4:1888
 Radio Detection and Ranging (RADAR) and, 4:1888–1890
 remote sensing for Earth surface information and, 4:1888
 shaded-relief appearance benefit of, 4:1889
 Side Looking Airborne Radar (SLAR) and, 4:1889
 space-borne RADAR use and, 4:1889–1890
 Synthetic Aperture Radar (SAR) and, 4:1889
 vertical *vs.* horizontal polarizations of, 4:1889
- Middle East**
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
 Afro-Asiatic language in, 4:1750 (fig.)
 Arab exploration of, 2:1053
 birthrates in, 2:708
 British Empire colonies in, 1:509
 cholera in, 1:401
 CO₂ emissions in, 3:1377
 Cold War and, 1:504
 “colonial present” in, 5:2337
 desert biome in, 1:218
 drought in, 2:791
 ecological footprint and biocapacity of, 2:827 (table)
 environmental history studies in, 2:929
 fertility levels in, 2:709
 Derek Gregory’s work, 3:1381
 groundwater resource in, 3:1386
 Ibn Battuta exploration of, 2:1054, 3:1519, 4:2179
 Indo-European languages in, 4:1749, 4:1750 (fig.)
 military expenditures in, 4:1899 (table)
 normal faults in, 3:1086
 oil sources in, 4:2163
 people living in extreme poverty and, 3:1082 (table)
 Silk Road and, 2:1053
 squatter settlements in, 5:2682
 temperate arid deserts in, 1:221
 temperate hyperarid deserts in, 1:222
 tropical arid deserts in, 1:221
 tropical/subtropical hyperarid deserts in, 1:222
 tropical/subtropical semiarid deserts in, 1:220
See also specific country
- Migration,** 4:1890–1896
 absorption and dispersion theory of, 4:1893
 Andrew Clark’s contributions to study of, 1:417–418
 definition of, 4:1890
 diaspora and, 2:734–735
 distance decay theory and, 2:774–776
 emigration and, 4:1891
 environmental refugees and, 2:989–991
 forms of, 4:1890–1893
 gender differences in, 3:1097
 global environmental change and, 3:1337
 immigration and, 3:1542–1545, 4:1891
 internal migration, 4:1890
 internal patterns of movement and, 4:1893
 international criminal groups and, 4:1895
 international migration, 4:1891, 4:1893–1894
 interurban migration *vs.* intra-urban residential mobility and, 4:1891
 irregular migration, 4:1893
 land degradation and, 5:2232
 “laws of migration” (Ravenstein) and, 4:1893
 megacities, global cities grown and, 4:1891
 Mexico-U.S. migration system and, 4:1893–1894
 migrant family in Caluba, Brazil, and, 4:1894 (photo)

- net regional U.S. migration (2007) and, 4:1891 (fig.)
 nomadism *vs.*, 4:2033
 remittances and, 5:2413–2414
 residential mobility and, 4:1890
 temporary spatial mobility *vs.*, 4:1890
 theoretical explanations for, 4:1893–1895
 “tied movers” concept and, 4:1893
 urban population densities and, 5:2241
 U.S. average annual rate of domestic net migration by county (2000–2004), 4:1892 (fig.)
 voluntary *vs.* involuntary migration and, 4:1893, 4:1895
- Military geography, 4:1896–1898**
 academic geography and, 4:1896–1897
 Cold War and, 4:1897
 definition of, 4:1896
 early Greek origins of, 4:1896
 environmental impacts of war and, 2:955–957
 fields and disciplines of, 4:1896–1897
 imperialism, nation-state formations and, 4:1896
 issues addressed in, 4:1896
 NATO and, 4:2046–2048
 peace and peacetime studies and, 4:1897
 revitalization of, 4:1897
 technology advances and, 4:1896
 Vietnam War and, 4:1897
 war, imperialism, and geography relationship and, 4:1897
 wartime experiences and, 4:1896
 World War II and, 4:1896
See also Military geography: noted scholars
- Military geography: noted scholars**
 Edward Ackerman, 4:1897
 R. A. Bagnold, 4:1896–1897
 Trevor Barnes, 4:1897
 W. C. Brown, 4:1896
 Matthew Farish, 4:1897
 Colin Flint, 4:1897
 Alfred Thayer Hahan, 4:1815–1816
 Alan Jenkins, 4:1897
 D. W. Johnson, 4:1896
 Théophile Lavellée, 4:1896
 Halford Mackinder, 4:1896
 Alfred Thayer Mahan, 4:1896
 F. Webster McBryde, 4:1897
 Julian Minghi, 4:1897
 Trevor Paglen, 4:1897
 Eugene Palka, 4:1897
 David Pepper, 4:1897
 Albrecht von Roon, 4:1896
 Fred Schaefer, 4:1897
 Arnon Soffer, 4:1897
 Sun Tzu, 4:1896
 Thucydides, 4:1896
 Harold Winters, 4:1897
 Rachel Woodward, 4:1897
- Military spending, 4:1898–1905**
 accelerating costs and, 4:1901
 advanced weaponry proliferation and, 4:1898
 arms trade and, 4:1902
 Cold War and, 4:1900
 “cost-plus” contracting practice and, 4:1901
 defense mergers and, 4:1901
 definition of, 4:1898
 expenditure data veracity and, 4:1898, 4:1903–1904
 geographic patterns of military expenditures and, 4:1898, 4:1902
 geopolitical power production and, 4:1898–1899
 market exchange rate (MER) calculations of, 4:1898–1899
 military-industrial complex and, 4:1898, 4:1899–1902
 national military spending by country, 4:1899 (tables)
 nuclear weapons funding in U.S. budget and, 4:1903
 pricing mechanism *vs.* market economy operations and, 4:1901
 procurement and RDT&E expenditures and, 4:1900
 as proportion of gross domestic product (GDP), 4:1901
 purchasing parity power (PPP) calculation of, 4:1899
Rise of the Gunbelt (Markusen) and, 4:1902
 “smart weapons” and, 4:1900
 Stockholm International Peace Research Institute data on, 4:1898
 subcontracting and outsourcing and, 4:1901
 technology advances and, 4:1900
 transnational impacts of, 4:1902
 undervaluation of U.S. military budget and, 4:1903
 U.S. Defense Advanced Research Projects Agency and, 4:1900
 U.S. defense budget as percent of GDP (1948–2005) and, 4:1904 (fig.)
 U.S. Gunbelt (2008), 4:1903 (fig.)
 U.S. hegemony in world affairs relative to, 4:1899
 U.S. impacts of, 4:1902
 war preparation and, 4:1898
 World War II model of warfare and, 4:1900
- Miller, Byron, 5:2575
 Miller, C., 2:753
 Miller, Christopher, 5:2305
 Miller, Daniel, 1:108
Miller, Harvey J., 4:1905
 academic career of, 4:1905
 awards and honors received by, 4:1905
 Törsten Hägerstrand and, 4:1905
 people-based spatial analysis views of, 4:1905
 service work of, 4:1905
 space-time accessibility work of, 4:1905
 time-geography research of, 4:1905
 transportation geography work of, 4:1905
- Millerer-Raaffort, F., 4:1952
 Mills, Edwin, 5:2236, 5:2395
 Mills, L. Scott, 4:1656, 4:1658
 Milton, John, 4:1971, 4:1479
 Milwaukee, Wisconsin, 1:297 (photo)
- Minerals, 4:1905–1911**
 atomic structure factor in, 4:1907
 azurite and malachite secondary copper minerals, Bisbee, Arizona, 4:1910
 calcite group species and, 4:1906, 4:1907 (photo)
 characteristics and classification of, 4:1906–1907
 chemical alteration forming environment of, 4:1909–1910
 chemistry classification hierarchy of, 4:1906
 crystallization from magma forming environment of, 4:1909
 definition of, International Mineralogical Association and, 4:1905–1906
 as enablers of civilization, 4:1906
 extrinsic factors in development of, 4:1907
 green tourmaline on quartz, Minas Gerais, Brazil, 4:1909 (photo)
 “habit,” overall appearance of, 4:1907
 halite crystals, internal cubic structure of, 4:1906 (photo)
 industrial *vs.* ore minerals and, 4:1906
 Millerite in calcite geode from Milwaukee, Wisconsin, 4:1908 (photo)
 mineral forming environments and, 4:1908–1910
 mining geographies and, 4:1911–1913
 names derivation of, 4:1906–1907, 4:1908 (photo)
 open-pit mining and, 4:2086–2088
 precipitation from aqueous solution forming environment of, 4:1908–1909
 quartz crystal varieties and, 4:1907, 4:1908 (photo)

- recrystallization in the solid forming environment of, 4:1910
 strip mining and, 5:2701–2702
 Minghi, Julian, 4:1897
- Mining and geography, 4:1911–1913**
 colonial mining settlements and, 4:1911
 cooper mine underground processing facility, Chile, 4:1912 (photo)
 global mining production systems and, 4:1912
 human labor exploitation and, 4:1911–1912
 mining and the environment and, 4:1912–1913
 mining definition and, 4:1911
 mining frontier and, 4:1911
 mining technologies and, 4:1911–1912
 open-pit mining and, 4:2086–2088
 Raw Materials Group and, 4:1911
 “resource curse” hypothesis and, 4:1913, 5:2217, 5:2693
 strip mining and, 5:2701–2702
 sustainable economic development issues and, 4:1912–1913
 untested technologies in, 4:1913
 U.S. Geological Survey data on, 4:1911
See also **Minerals**
- Minnesota
 Mall of America, Bloomington, 1:107, 2:574 (photo), 2:575
 Minnesota Land Management Information System, 3:1302
 Minnesota Pollution Control Agency, 1:69 (photo)
- Misan, 1:402
- Mississippi River, Mississippi Delta
 “dead zone” area of, 1:207, 1:486–487, 1:488, 2:939
 Deepwater Horizon oil spill, Mississippi Delta, 4:2074 (photo)
 floodplain crop cultivation and, 3:1132
 floodplain land use of, 3:1130 (photo)
 floods (1993), 3:1137
 French colonization of, 1:512
 Hurricane Katrina and, 3:1494
 I-35 bridge collapse over Mississippi River, 3:1596 (photo)
 Louisiana purchase and, 4:1773, 4:1774–1775 (fig.)
 Map of the Kingdom of New Spain by Baron von Humboldt, 3:1483 (fig.), 3:1484
 Mississippi Delta, Louisiana, 2:703 (photo)
 St. Louis flood (1993) and, 3:1135
 water hyacinth invasion of Mississippi Delta, 3:1471 (photo)
- Missouri, Pruitt-Igoe public housing project, St Louis, 5:2303
- Mitchell, Don, 4:1913–1914**
 academic career of, 4:1913
 awards and honors received by, 4:1913
 California landscape, labor relations and, 3:1430, 4:1913
 Community Geography Initiative and, 4:1913
 cultural geography work of, 2:643, 4:1863, 4:1913–1914
 laws, rights, and public space relationship and, 4:1913
 Henri Lefebvre and, 4:1769
Lie of the Land written by, 3:1430, 4:1913
 Marxism concepts of, 3:1430, 4:1863, 4:1913
 narrative use and, 3:1431
 People’s Geography Project founded by, 4:1913
 power relation tied to class interests and, 4:1863, 4:1913
 radical geography and, 5:2352
 Right to the City movement and, 5:2352
 social justice approach to geography of, 4:1913, 5:2352
 social struggles of exploited labor workers work of, 3:1430, 4:1913
 urban public spaces issues studied by, 4:1913
- Mitchem, Jamie, 2:762
- Mixed farming, 4:1914–1918**
 case studies of, 4:1914–1917
 changed regional farming pattern, County Armagh, Northern Ireland, 4:1916 (fig.)
 changes in rewards from agriculture and, 4:1916 (fig.)
- definition of, 4:1914
 in Eastern Mallorca, Spain, 4:1915 (photo)
 factors affecting, 4:1914
 mixed enterprises and, 4:1917
 multiscales affected by, 4:1914
 in Southern Africa, 4:1917 (photo)
 in the United Kingdom, 4:1914
- Mobile GIS, 4:1918–1921**
 ad hoc wireless systems and, 4:1919
 alternative display methods limitation of, 4:1920
 architecture of, 4:1919 (fig.)
 bandwidth issues and, 4:1918
 cellular phones and, 4:1919
 client-server architecture of, 4:1918
 communication networks of, 4:1918
 components and communications for, 4:1918–1919
 data-editing capabilities and, 4:1918
 definition of, 4:1918
 ESRI’s ArcPad and, 4:1918
 field-based GIS and, 4:1918, 4:1920
 future directions, 4:1920
 geoslavery and, 3:1255–1256
 GIS software and, 4:1918
 Google’s iPhone mobile map and, 4:1918
 limitations of, 4:1920
 location-based services (LBSs) and, 4:1794–1796, 4:1918, 4:1919–1920
 Mapinfo’s MapXtend and, 4:1918
 MapXtend and, 4:1918
 narrowband *vs.* broadband wireless systems and, 4:1918–1919
 neogeography and, 4:2005–2006
 server-side components of, 4:1918
 Wi-Fi or WiMAX communication systems and, 4:1918–1919
 wireless service coverage issues and, 4:1918
See also **Global positioning system (GPS)**
- Mobility, 4:1921–1923**
 absolute mobility and, 4:1921
 access to means of mobility and, 4:1921
 airport example of, 4:1921
 automobility and, 1:171–175
 aviation and, 1:179–182
 Andrew Clark’s contributions to study of, 1:417–418
 commuting and, 2:553–555
 different mobilities, different geographies and, 4:1921
 distance decay theory and, 2:774–776
 encountering difference feature of, 4:1922
 human characteristics and, 4:1921
 location-based services (LBSs) and, 4:1794–1796
 migration and, 4:1890–1896
 motion as normal and meaningful and, 4:1921
 relational nature of, 4:1921–1922, 4:1922 (photo)
 relative immobility or moorings and, 4:1921
 significance in the journey and, 4:1922
 social inequalities in, 4:1922–1923
 space is interconnected networks through which flows occur and, 4:1921
 technology advances and, 4:1921
 traveling meaningfulness and, 4:1922
- Models and modeling, 4:1923–1928**
 agent-based model, 4:1927, 4:1927 (fig.)
 analytical mathematical models, 4:1926
 authenticity of a model and, 4:1925
 Brian Berry and, 1:193
 cellular automata form of, 4:1926
 climatology models and, 1:474

- dynamic modeling process and, 4:1924, 4:1924 (fig.)
 everyday decision making and, 4:1923
 formal modeling and, 4:1923–1924
 forms of models and, 4:1923
 GIS map models, 4:1927 (fig.)
 graphical model form of, 4:1925–1926
 input-output models and, 3:1599–1601
 Walter Isard and, 3:1627–1628
 location-allocation modeling, 4:1793–1794
 maps as models and, 4:1926
 mental models and, 4:1924
 mixing model paradigms and, 4:1927 (fig.)
 model definition and, 4:1923
 modeling paradigms and, 4:1926–1928
 modeling process and, 4:1923–1925
 modeling purpose and, 4:1923
 model utility and, 4:1925–1926, 4:1925 (fig.)
 monocentric model of urban form and, 5:2236–2237
 nomothetic *vs.*, 4:2034–2035
 object-oriented programming model, 4:1926–1927
 parsimony principle, art of leaving things out and, 4:1925
 physical model form of, 4:1925–1926
 problem of problem formulation and, 4:1925
 relative transparency element in, 4:1925
 science of modeling and, 4:1924–1925
 spatially extended models, 4:1927–1928
 statistical models, 4:1926
 stock-and-flow models, 4:1926, 4:1927 (fig.)
See also **Agent-based models** (ABMs)
- Moderate Resolution Imaging Spectroradiometer (MODIS)
 multispectral sensor, 1:158, 1:252, 2:974, 3:1542, 4:1738, 4:1740, 4:1960
- Modernity, 4:1928–1931**
 cyborg ecologies, purification and mediation processes of, 2:649
 “dark side” of, 4:1928
 definition of, 4:1928
 Enlightenment and, 4:1928
 Eurocentrism of, 4:1928
 feminism and, 4:1930
 human agency and, 4:1929
 independent self concept and, 4:1929
 late modernity and, 4:1931
 multiple modernities and, 4:1930
 newness and progress in, 4:1929–1930
 new social order and, 4:1928, 4:1930–1931
 one universally right and true way of being, knowing, and doing perspective of, 4:1929
 “otherness” concept and, 4:1929
 postcolonialism and, 4:1930
 poststructural challenge to, 4:1929–1930
 “risk society” concept and, 4:1931
 roots of, 4:1928–1929
 scientific reasoning and, 4:1928–1929
See also Modernity: noted scholars; **Modernization theory**
- Modernity: noted scholars
 Francis Bacon, 4:1928
 Dennis Diderot, 4:1928
 Anthony Giddens, 4:1931
 Thomas Hobbes, 4:1928
 David Hume, 4:1928
 Bruno Latour, 4:1931, 4:1996
 John Locke, 4:1928
 Voltaire, 4:1928
- Modernization theory, 4:1931–1935**
 bureaucracies emergence and, 4:1932
 capitalism and, 4:1931–1932
 criticisms, 4:1934
 cultural traditions and, 4:1933
 democratic transition model and, 4:1933
 dependency theory and, 2:712–714, 4:1934
 developing countries, airplane take off analogy and, 4:1932–1933
 development theory and, 2:730
 ecological modernization and, 2:832–834
 international development patterns and, 4:1931
 newly industrializing countries and, 4:2021–2024
 origins of, 4:1931–1932
 Parsonian Turn and, 4:1932–1934
 political theorizations of, 4:1933–1934
 population control programs and, 4:1933
 rational economic development and, 4:1932
 rationalization (Weber) and, 4:1931–1932
 spatial diffusion on two scales and, 4:1933
Stages of Economic Growth (Rostow) and, 4:1932–1933
 structural functionalism concept (Parsons) and, 4:1932
 Western, developed world ethnocentrism of, 4:1931, 4:1932, 4:1934
 world-systems theory and, 4:1934
See also **Modernity**; Modernization theory: noted scholars
- Modernization theory: noted scholars
 Robert Bellah, 4:1933
 Milton Friedman, 4:1934, 4:2011
 Samuel Huntington, 4:1934
 David McClelland, 4:1933
 Talcott Parsons, 4:1932
 Walter Rostow, 4:1932–1933
 K. H. Silvert, 4:1934
 Max Weber, 4:1931–1932
- Modifiable areal unit problem (MAUP), 4:1935**
 aggregated data sources and, 4:1935
 ecological fallacy and, 2:824
 methods of analysis applied to, 4:1935
 modifiable and, 4:1935
 resolution of data analysis and, 4:1935
 scale and aggregation problem of, 4:1935
 statistical and geographical elements of, 4:1935
 within-area homogeneity and, 4:1935
- Mol, Arthur, 2:835, 2:836, 3:1369
- Moldova
 Commonwealth of Independent States (CIS) membership of, 2:536 (table)
 economically active females in, 3:1190 (table)
 Euroregions, cross-border cooperation and, 2:631 (fig.)
 GUAM Organization for Democracy and Economic Development co-founded by, 2:538
- Mollison, Bill, 4:2152
- Mollweide, Carl, 4:1844, 4:1844 (fig.), 6:3152–3153, 6:3169
- Molotch, H. L., 4:1745
- Momsen, Jan, 3:1100
- Money, geographies of, 4:1936–1938**
 “Bretton Woods system” and, 4:1936
 capitalism and, 4:1936
 Chicago School of sociality and, 4:1936
 dollar pegged to gold and, 4:1936
 electronic funds transfer systems and, 4:1937–1938
 emerging markets and, 2:890–891
 Euromarkets and, 2:1030–1032, 4:1936–1937
 finance and space relationship and, 4:1936
 finance geographies and, 3:1115–1118
 fixed exchange rate system and, 4:1936
 floating exchange rates and, 4:1936, 4:1938
 foreign currency trading and, 4:1938

- General Agreement on Tariffs and Trade and, 4:1936
hypermobility of capital and, 4:1936–1937
investment to speculation shift and, 4:1937–1938
microelectronics revolution and, 4:1937
modernity and commodification and, 4:1936
NASDAQ fully automated electronic marketplace and, 4:1937
national capital markets integration and, 4:1937
nation-state relationship to, 4:1938
offshore finance and, 4:2071–2073
private capital flows and, 4:1938
securitization of global finance and, 4:1938
sociology of money origins of, 4:1936
stateless money emergence and, 4:1936
time-space compression of capitalism and, 4:1936
trade balances and foreign exchange markets and, 4:1936
various currencies and, 4:1937 (photo)
volatile nature of, 4:1937–1938
See also Money, geographies of: noted geographers, scholars
- Money, geographies of: noted geographers, scholars
Émile Durkheim, 4:1936
Karl Marx, 4:1936
Georg Simmel, 4:1936
Max Weber, 4:1936
- Mongolia
COMECON membership of, 2:593 (table)
domesticated reindeer in, 2:782 (photo)
economically active females in, 3:1190 (table)
- Monk, Janice, 2:618, 3:1189
- Monmonier, Mark, 4:1938–1939**
academic career of, 4:1938
awards and honors received by, 4:1939
cartography work of, 4:1938–1939
computer algorithms in statistical mapping work of, 4:1939
interactive and digital cartography work of, 4:1939
publications of, 4:1939
service work of, 4:1939
social-mapping projects of, 4:1939
- Monsoons, 4:1940–1945**
African monsoon, 4:1941
Asian monsoon, 4:1940–1941, 4:1985–1986
atmospheric circulation explanation of, 1:134, 2:741
Australian monsoon, 4:1941
characteristics and predictability of, 4:1943–1944
characteristics of, 4:1940
cross-equatorial flows and, 4:1940
definition of, 4:1940
derivation of, 4:1940
differential heating and, 2:741
El-Niño-Southern Oscillation (ENSO) and, 2:792
global change and the South Asian monsoon, 4:1944
Holocene warm period and, 1:459
in India, 1:134, 2:741, 4:1985–1986
Inter-Tropical Convergence Zone (ITCZ) and, 4:1940–1944
intertropical deciduous forest, 1:230
monsoonal regions identification and, 4:1940
North American monsoon, 4:1941–1943
oceanic circulation and, 4:2058–2064
seasonal reversal in mean summer and winter winds of, 4:1943 (fig.)
social impacts of, 4:1943
South American monsoon, 4:1941
South Asian monsoon, 4:1943–1944
three-dimensional circulation associated with, 4:1940, 4:1941 (fig.)
tropical monsoons, 1:454, 1:455
tropical savanna climate, 1:455
- Montana, Yankee Doodle copper mining tailings pond and, 4:2087
- Montello, David, 1:189
- Montreal Protocol (1987), 1:400–401, 1:462, 3:1336, 3:1374, 5:2244, 6:2763
- Moore, Donald, 5:2339
- Moos, Adam, 5:2710
- Morehouse, Scott, 1:408
- Morley, David, 6:2791
- Morocco
African Union nonmembership status of, 1:25
clothing exports from, 6:2186 (fig.)
economically active females in, 3:1190 (table)
France colonization of, 1:514
income ratio relative to slum population in, 2006, 5:2644 (fig.)
poverty rates in, 5:2274
textile exports from, 6:2816 (fig.)
- Morrill, Richard, 4:1945–1946**
academic career of, 4:1945–1946
Brian Berry and, 1:192
books written by, 4:1945–1946
William Garrison and, 4:1945
quantitative revolution work of, 4:1945–1946
service work of, 4:1945
social and spatial justice views of, 4:1945
spatial demographics and political districting and, 3:1466
Walter Tobler and, 4:1945
- Morrison, J. L., 1:344
- Morse, Jedediah, 4:1946–1947**
construction of American identity and, 3:1463
father of American geography and, 3:1463
as founder of American geography, 4:1946
geographic imaginaries and, 4:1946
geography textbooks written by, 4:1946
theological views of, 4:1946
- Mortality rate, 4:1947**
biological factors and, 4:1947
causes of, 4:1947
crude mortality rate definition and, 4:1947
definition of, 4:1947
in demographic transition stages, 2:708–710
“epidemiological transition” and, 4:1947
infant mortality rates and, 4:1947
morbidity *vs.*, 4:1947
natural growth rate and, 4:1981–1983
population pyramid and, 5:2249–2250
preindustrial social contexts of, 4:1947
- Moscow May Day celebrations, 2:544 (photo)
- Mosesso, John J., 1:274–(photo)
- Most favored nation status (MFN), 4:1948**
definition of
early U.S. treaties and alliances and, 4:1948
normal trade relation (NTR) status and, 4:1948
unconditional *vs.* conditional MFN status and, 4:1948
U.S. use of, 4:1948
- Mouffe, Chantal, 3:1419, 3:1420
- Mountain Trust (Nepal), 1:96
- Mount Everest, 1:356 (fig.)
- Mount Kilimanjaro, 1:453
- Movimento Sem Terra (MST), 4:1948–1951**
agricultural landownership distribution, in Brazil, 2003, 4:1949 (figs.)
biofuel agriculture and, 4:1951
Brazil land granting system and, 4:1949
Brazil land reform and, 4:1949
challenges faced by, 4:1950–1951
donatários and, 4:1949
expropriation of land and, 4:1949–1950

- intermittent peasant rebellions and, 4:1949–1950
- Landless Rural Workers Movement and, 4:1948
- latifúndia* system and, 4:1949–1951
- official government numbers of land reform beneficiaries and, 4:1950 (table)
- political and economic activism of, 4:1950
- praxis of, 4:1950–1951
- purpose of, 4:1948–1952
- socioeconomic context of, 4:1949–1950
- urban centers and, 4:1951
- Via Campesina international peasant's movement and, 4:1948
- Mozambique
- economically active females in, 3:1190 (table)
 - GDP per capital in, 3:1382
 - independence of, 2:692
 - Internet access in, 2:749
- MST. *See* **Movimento Sem Terra (MST)**
- Mugerauer, Robert, 4:2168
- Muir, John, 2:981
- Multimedia mapping, 4:1951–1953**
- Apple's Hypercard software and, 4:1952
 - augmentation maps and, 1:108–110
 - BBC's Domsday Project and, 4:1952
 - definition of, 4:1951
 - development stages of, 4:1951–1952
 - digital mapping, multimedia content, and GPS convergence and, 4:1952
 - electronic atlases and, 2:884, 4:1952
 - ESRI MapObjects software and, 4:1952
 - GeoVideio software and, 4:1952
 - Glasgow Online digital atlas and, 4:1952
 - Good's World Atlas and, 4:1952
 - hypermap and, 4:1952
 - hypermedia system and GIS integration and, 4:1952
 - Hypersnige, 4:1952
 - integrated multimedia approach system implementation process and, 4:1952
 - interactive map and, 4:1951–1952
 - MediaMapper software, 4:1952
 - media types used in, 4:1951
 - multimedia hypertext, or hypermedia and, 4:1952
 - multimedia information in GIS and, 4:1952
 - Red Hen Systems and, 4:1952
- Multispectral imagery, 4:1953–1956**
- Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and, 4:1954 (photo)
 - airborne platform for, 4:1954
 - ASTER spectral library and, 4:1954
 - astronomy applications of, 4:1953
 - automated image classification and, 4:1953–1954
 - black-and-white *vs.* true-color photographs and, 4:1953
 - charge coupled device (CCD) arrays and, 4:1954
 - Death Valley, California, 4:1954 (photo)
 - definition of, 4:1953
 - digital imaging technology and, 4:1953
 - Earth remote sensing application of, 4:1953
 - Earth Resources Technology Satellite and, 4:1954
 - film-based multispectral imaging systems and, 4:1954
 - first orbital multispectral photograph and, 4:1954–1955
 - frame sensors *vs.* line sensors and, 4:1954
 - general principles of imaging and, 4:1953
 - image interpretation and, 3:1534–1536
 - laboratory-based spectral databases and, 4:1954
 - Landsat satellites and, 4:1954, 4:1955
 - land use and land cover mapping application of, 4:1953, 4:1955 (photo)
 - LiDAR and airborne laser scanning and, 4:1778–1779
 - multilayer data set and, 4:1953
 - panchromatic imagery and, 4:2112–2115
 - radiometry and, 4:1953
 - reflectivity differences and, 4:1954
 - satellite remote sensing and, 4:1955
 - spectral radiometry principles and, 4:1953
 - spectral signature and, 4:1953
 - U.S.-Mexico border, California, 4:1955 (photo)
 - USGS digital spectral library and, 4:1954
 - See also* **Aerial imagery: data; Aerial imagery: interpretation**
- Multistakeholder participation, 4:1956–1959**
- assessment framework for, 4:1958
 - benefits of, 4:1956
 - decision analysis complexity and, 4:1956
 - development processes examples and, 4:1956
 - ethical perspective on, 4:1956–1957
 - external stakeholders and, 4:1957, 4:1959
 - methods and tools of, 4:1958–1959
 - positive *vs.* negative outcomes of, 4:1956–1957
 - power relations issues and, 4:1958–1959
 - purposes for participation and, 4:1956–1957
 - social learning *vs.* information purposes and, 4:1957
 - stakeholder category examples and, 4:1956
 - stakeholder identities and, 4:1957–1958
 - stakeholder mapping and, 4:1957–1958
 - subprocesses of, 4:1958
 - timeline of participation and, 4:1958
- Multitemporal imaging, 4:1959–1961**
- Advanced Very High Resolution Radiometer (AVHRR) of NOAA and, 4:1960
 - aerial photography and, 4:1959
 - applications of, 4:1960–1961
 - artificial neural networks use and, 4:1960
 - course spatial resolution and, 4:1959–1960
 - definition of, 4:1959
 - digital analysis techniques for, 4:1960
 - Earth observing satellite systems and, 4:1959–1960
 - human-geography applications of, 4:1960–1962
 - Landsat satellites and, 4:1959
 - Moderate Resolution Imaging Spectrometer (MODIS) and, 4:1960
 - multidate images and, 4:1960
 - multitemporal studies and, 4:1959–1960
 - multiple land use and land cover change monitored by, 4:1959
 - physical geography studies and, 4:1960
 - preprocessing techniques and, 4:1960
 - principal components analysis (PCA) and, 4:1960
 - remote sensing data and, 4:1959
 - satellite systems and, 4:1959–1960
 - spatial, spectral, and temporal resolution selection and, 4:1959–1960
 - spectral change vector analysis and, 4:1960
 - study objectives and, 4:1960
 - very high resolution and, 4:1960
 - See also* **Aerial imagery: data; Aerial imagery: interpretation**
- Multivariate analysis methods, 4:1961–1962**
- aspatial *vs.* aspatial contexts of, 4:1962
 - canonical correlation analysis, 4:1961
 - cluster analysis technique, 4:1962
 - definition of, 4:1961
 - dependence techniques and, 4:1961–1962
 - factor analysis technique, 4:1962
 - GIScience use of, 4:1961
 - interdependence techniques and, 4:1962

- logistic regression modeling, 4:1961
- multidimensional scaling, perceptual mapping technique, 4:1962
- multiple discriminate analysis, 4:1961
- multiple regression analysis, 4:1961
- multivariate analysis of covariance (MANCOVA), 4:1962
- multivariate analysis of variance (MANOVA) and, 4:1961–1962
- “quantitative revolution” and, 4:1961
- technique selection factors and, 4:1962
- univariate analysis of variance (ANOVA), 4:1962
- Multivariate mapping, 4:1963–1967**
 - complex data relationships and, 4:1963
 - definition of, 4:1963
 - geovisualization course, U.S. murder rates example of, 4:1963–1966
 - human cognitive factors and perception elements in, 4:1963
 - U.S. murder rates, possible factors, 4:1964 (fig.)
 - U.S. murder rates and families in poverty, 4:1965 (fig.)
 - U.S. of housing ownership, 1900–2000, 4:1966 (fig.)
 - visual variables of, 4:1963
- Mumford, Lewis, 4:1700, 5:2719
- Murdoch, Jonathan, 3:1503
- Murray, Charles, 6:2998
- Music and sound, geography of, 4:1967–1970**
 - Archive of American Folk Song and, 4:1968 (photo)
 - Berkeley School of cultural geography and, 4:1967
 - Canadian musical content regulation and, 4:1968–1969
 - contemporary music genres and, 4:1967
 - corporate aspects of music market and, 4:1968
 - cultural geography studies of, 4:1967
 - “cultural turn” in economic geography and, 4:1967–1968
 - discordant sounds and, 4:1969
 - Larry Ford and, 4:1967
 - home studios factor and, 4:1968
 - lyrics significance and, 4:1967
 - melodic element variations and, 4:1967
 - Mountain Music Festival, Asheville, North Carolina, 1930s, 4:1968 (photo)
 - “new cultural geography” and, 4:1968–1969
 - “the next big thing” in modern music and, 4:1969
 - nontraditional music outlets and, 4:1968
 - origin and diffusion of musical styles and, 4:1967
 - place names and, 4:1967
 - popular culture ambient sounds and, 4:1969
 - recording technology and, 4:1967
- Muth, Richard, 5:2236, 5:2395
- Myanmar**
 - ASEAN membership of, 1:128, 1:128 (table), 1:129 (table)
 - economically active females in, 3:1190 (table)
 - HIV/AIDS in, 3:1438
 - human rights issues in, 1:130
 - plantations in, 5:2192
- Myers, Norman, 2:989, 2:990
- MySpace, 2:648
- Nabane, Nontokozo, 1:526
- NAFTA. *See* North American Free Trade Agreement (NAFTA)
- Nagar, Richa, 3:1193
- Namibia**
 - cholera in, 1:402
 - economically active females in, 3:1190 (table)
 - !Kung hunting and gathering tribe in, 3:1492
 - Ovaherero genocidal event in, 3:1202
- Narain, Sunita, 3:1575
- NASA. *See* National Aeronautics and Space Administration (NASA)
- Næss, Arne, 3:1369
- Natal, 3:1180
- Nation, 4:1971–1974**
 - Benedict Anderson and, 4:1972
 - collective group emphasis (Herder) and, 4:1972
 - definitions of, 4:1971
 - detrterritorialization and reterritorialization and, 2:722–724
 - Enlightenment scholars and, 4:1971–1972
 - environmental determinism and, 4:1972
 - Johann Gottfried Herder and, 4:1972
 - Eric Hobsbawm and, 4:1972
 - identity geographies and, 3:1527–1531
 - imagined communities concept (Anderson) and, 4:1972
 - invented traditions concept (Hobsbawm) and, 4:1972
 - multiple meanings of, 4:1971–1973
 - nation-state ideal and, 4:1973
 - nature as national identity determinant and, 4:1972
 - politicized ethnic, racial, and tribal groups and, 4:1973
 - race- and genetic-based spatial distributions and, 4:1972
 - resources availability (Rousseau) and, 4:1971–1972
 - Jean-Jacques Rousseau and, 4:1971–1972
 - security of citizens (Rousseau) and, 4:1971–1972
 - self-awareness and, 4:1973
 - self-governance requires territory and, 4:1973
 - shared culture and, 4:1972
 - Anthony Smith and, 4:1972–1973
 - true age of nations (A. Smith) and, 4:1972–1973
 - vernacular languages and, 4:1972
 - word derivation and, 4:1971
- National Academy of Sciences
 - Isaiah Bowman’s service to, 1:296
 - William Clark’s service to, 1:417
 - Robert Kates’ service to, 1:296
- National Aerial Photography Program (NAPP), 1:19
- National Aeronautics and Space Administration (NASA), 4:1974–1975**
 - Aqua* satellite, Earth’s water cycle and, 4:1974
 - ASTER spectral library of, 4:1954
 - atmospheric remote sensing and, 1:158 (fig.), 1:160 (fig.)
 - collaborative activities of, 4:1974
 - communication and weather satellites and, 4:1974
 - Earth observation satellites and, 4:1974
 - Dwight D. Eisenhower and, 4:1974
 - Greenland Ice Sheet image, 3:1325 (fig.)
 - Hubble Space Telescope and, 4:1974
 - imaging spectrometer in space and, 3:1542
 - Kennedy Space Center Launch Complex, Florida, and, 4:1975 (photo)
 - Land Cover and Land Use Change research program of, 4:1736
 - Landsat satellites co-developed by, 3:1283, 3:1534, 4:1954, 4:1955, 4:1959, 4:1974, 4:2114
 - Mercury and Gemini missions and, 4:1974
 - mission directives of, 4:1974
 - National Advisory Committee on Aeronautics (NACA) and, 4:1974
 - panchromatic imagery technology and, 4:2114
 - raster-based GIS developed by, 3:1283
 - remote sensing advances by, 4:1974
 - remote sensing defined by, 1:157
 - sea ice minimums and, 3:1524 (photo), 3:1525 (photo)
 - Soviet satellite launch and, 4:1974
 - space exploration missions and, 4:1974
 - Terra* Earth-orbiting mission and, 4:1974
 - Tropical Rainfall Measuring Mission (TRMM) of, 1:159, 1:160
 - WorldWind and, 1:426, 3:1284, 4:1826
- National Agriculture Imagery Program (NAIP), 1:19, 1:21
- National Assessment of Educational Progress (NAEP), 3:1233
- National Atmospheric Deposition Program, 1:6
- National Business Incubation Association, 3:1551–1552
- National Cancer Institute, 1:335

National Center for Geographic Information and Analysis (NCGIA), 4:1975–1976

establishment of, 4:1975
 Geography and Regional Science program (Ablar) of, 4:1975
 GIScience field establishment and, 3:1285–1286, 4:1975
 GIS education materials and, 4:1976
 mission of, 4:1975
 National Science Foundation and, 4:1975
 Project Varenus (GIScience) and, 3:1286
 research initiatives of, 4:1975–1976

See also National Center for Geographic Information and Analysis (NCGIA): noted members

National Center for Geographic Information and Analysis (NCGIA): noted members

Ronald Ablar, 1:1, 4:1975
 Andrew Frank co-founder of, 3:1170
 Michael Goodchild, 3:1349
 David M. Mark, 4:1856

National Council for Geographic Education (NCGE), 4:1976–1977

conferences and meetings of, 4:1977
 excellence in geography education focus of, 4:1977
 geography in the American curriculum focus of, 4:1976
 governing organization of, 4:1977
Guidelines for Geographic Education (AAG and NCGE) and, 3:1233
 membership policy of, 4:1976
 George J. Miller founder of, 4:1976
 mission of, 4:1976
 publications of, 4:1976–1977
 special interest groups of, 4:1977

National Environmental Policy Act (NEPA, 1970), 2:925, 2:935, 2:958, 2:966, 3:1284, 4:1716

National Geographic Society, 4:1977–1978

American foreign policy and, 3:1463
 conservation and environmental awareness of, 4:1978
 cultural understanding of geography shaped by, 4:1977
 educational mission of, 4:1978
 field research projects funded by, 4:1978
 founding of, 4:1977
 geography education funded by, 3:1233
 Gilbert Grosvenor and, 3:1463, 4:1977
 mission of, 4:1977

National Geographic magazine of, 3:1463, 4:1977–1978

National Geospatial-Intelligence Agency, 4:2165

National High Altitude Photography (NHAP) program, 1:19

National Institutes of Health (NIH), 1:280

Nationalism, 4:1978–1981

borderlands and, 1:291–292
 civic nationalism and, 4:1978–1979
 collective nationalism and, 4:1979
 collectivism *vs.* self-determination and, 4:1979
 compulsory public education and, 4:1980
 cosmopolitanism and, 2:591–592
 cultural nationalism and, 4:1979–1980
 definition of, 4:1978
 English as God's chosen people concept and, 4:1979
 ethnicity and nature and, 2:1020–1021
 ethnic nationalism and, 4:1979
 ethnocentrism and, 3:1027
 geopolitics and, 3:1249–1252
 German *das Volk* and, 4:1979
 history of, 4:1979–1981
 identity geographies and, 3:1527–1531, 6:2802–2083
 mass production and mass media and, 4:1980
 multinational states and, 4:1980
 national identity concept and, 4:1978

nation concept and, 4:1971–1974
 nation-state borders and, 1:293–294
 peripheral nationalism and, 4:1980
 political ideology and, 4:1978
 political nationalism and, 4:1980–1981
 popular sovereignty and, 4:1979
 post-World War I territorial settlements and, 4:1980
 sovereignty of the people concept and, 4:1979
 state nationalism and, 4:1980
 types of, 4:1978–1979

See also Nationalism: noted individuals

Nationalism: noted individuals

Thomas Hobbes, 4:1979
 Eric Hobsbawm, 4:1980
 Hans Kohn, 4:1978
 John Locke, 4:1979
 John Milton, 4:1979

National Priorities List (NPL), 1:297

National Science Foundation

Ronald Ablar's service to, 1:1
 biotechnology research funds and, 1:280
 Michael Goodchild's service to, 3:1285
 Integrative Graduate Education and Research Traineeship program of, 4:1856
 David M. Mark's service to, 4:1856
 National Center for Geographic Information and Analysis (NCGIA) and, 4:1975
 Donna Peuquet's service to, 4:2165
 quantitative revolution and, 3:2329

National Toxicology Program, 1:335

National Weather Service, 3:1123

Native Americans

assimilation attempts, national identity and, 4:1980
 Deskaheh, leader of the Cayuga and, 3:1553
 diseases and, 3:1362
 Great American Exchange and, 3:1362
hogan, Navajo Indian Reservation, Arizona, 3:1571 (photo)
 indigenous reserves, reservations and, 3:1570–1572
 land loss of, 3:1223
 “nature” regarded as a living landscape views of, 4:1993
 “The Redman's Appeal for Justice” (Deskaheh) and, 3:1553
 Rousseau's “noble savage” concept and, 3:1020–1022, 3:1362
 Six Nations of the Iroquois Confederacy and, 3:1553

NATO. *See* North Atlantic Treaty Organization (NATO)

Natural growth rate (NGR), 4:1981–1983

definition of, 4:1981
 demographic change and, 4:1981
 fertility rate decline and, 4:1981, 4:1983, 4:1983 (fig.)
 world natural growth rates, 1950–2050, 4:1983 (fig.)
 world natural growth rates, 2007, 4:1981, 4:1982 (fig.)
 world population levels, 7000 BC to AD 2000, 4:1981, 4:1982 (fig.)
See also Population pyramid

Natural hazards and risk analysis, 4:1983–1989

capacity for protective action and coping and, 4:1984
 case studies in, 4:1985–1986
 climate extremes and, 4:1983
 coastal hazards and, 1:496–500
 continuum of magnitude of, 4:1984
 control over resources factor in, 4:1985
 differential vulnerability and, 2:742–744
 disaster magnitude and trends in, 4:1984
 drought risk and hazard and, 2:790–794
 Earth's crust movements and, 4:1983
 environmental perceptions of, 2:979
 failure to learn from failure and, 4:1986–1987

- flash floods and, 3:1123–1125
 floods and, 3:1133–1137
Global Assessment of Disaster Risk Reduction 2009 (UN) and, 4:1984
 human rights implications, 4:1985
 Hurricane Katrina and, 4:1985–1986
 Hyogo Framework of Action (HFA) of UN and, 4:1987
 international framework for disaster risk reduction and, 4:1987
 Robert Kates' work, 4:1654–1655
 knowledge from natural hazard experience and, 4:1985
 landslides and, 4:1720–1723
 lightning, 4:1779–1783
 lightning and, 4:1779–1783
 marginalized groups and, 4:1984
 meteor in Tunguska, Siberia (1908), and, 4:1983
 monsoon in Mumbai and, 4:1985–1986
 natural hazard, term ambiguity and, 4:1984–1985
 Niger famine and, 4:1986
 place, locality, and communication factors in, 4:1987–1988
 “planning” definition and, 4:1987
 power relations factor in, 4:1985, 4:1987
 remote sensing in disaster response and, 5:2424–2428
 risk analysis and, 4:1984
 risk reduction and, 4:1986–1987
 root causes of disaster risk and, 4:1985
 sustainable development and climate change links to, 4:1985
 UN International Strategy for Disaster Reduction and, 4:1987
 vulnerability and, 4:1984, 4:1986, 4:1992
See also Disaster preparedness; GIS in disaster response; Natural hazards and risk analysis; Risk analysis and assessment
- Nature, 4:1989–1994**
 academic geography fragmentation and, 4:1990
 biophysical phenomena and, 4:1990
 class and nature and, 1:423–425
 climatic geography and, 4:1990
 critical theories of society and, 4:1992
 cultural ecology and, 4:1992
 deep ecology movements and, 2:692–695
 definitions, 4:1989
 “denaturalizing nature” (N. Smith and Braun) and, 4:1993, 5:2551–2552
 Earth systems science and, 4:1992
 economic geography and, 4:1990
 environmental determinism and, 4:1990, 4:1991
 environmentalists, “end of nature” views (McKibben) and, 4:1992–1993
 geography and the nature-society interface and, 4:1989–1990
 geography as a world discipline and, 4:1989
 hazards and disasters geography and, 4:1992
 human-environment geography revival and, 4:1992
 human-environment geography schism and, 4:1991
 human geography and, 4:1990, 4:1991, 4:1992–1993
 “human nature” and, 4:1991
Hybrid Geographies (Whatmore) and, 4:1993
 ideals and actualities, early-20th-century gap and, 4:1989–1990
 lack of books and theory, 4:1991
 local ecology and, 4:1992
Man's Role in Changing the Face of the Earth (W. Thomas) and, 4:1991
 “more than human” geography and, 4:1993
 Native American views of, 4:1993
 “new” cultural and rural geography and, 4:1993
 nonrepresentational geography and, 4:1993
Physical Geography (Somerville) and, 4:1989
 physical geography subdivisions and, 4:1991
 political ecology and, 4:1992
 political geography and, 4:1990, 4:1992
 post-1945 changes and, 4:1990–1991
 production of nature concept (N. Smith) and, 4:1993, 5:2351, 5:2551–2552
 racism buttressed by naturalism and, 4:1995
 radical economic geographers and, 4:1992–1993
 recent developments in, 4:1991–1993
 regional-scale study of landforms and, 4:1990
 as socially constructed idea (Braun) and, 4:1993
 spatial analysis and, 4:1991
 “spatial sciences” and, 4:1991
 sustainability science and, 4:1992
 “unity of geography” concept and, 4:1991
See also Critical studies of nature; Nature: noted scholars; Nature-society theory
- Nature: noted scholars**
 Isaiah Bowman, 4:1990
 Bruce Braun, 4:1993, 4:1997, 5:2339–2340
 George Chisholm, 4:1990
 William Morris Davis, 4:1989, 4:2180
 Alexander von Humboldt, 4:1989
 Ellsworth Huntington, 4:1990, 4:1991
 Halford Mackinder, 4:1989, 4:1990, 4:1992
 Bill McKibben, 4:1992
 Friedrich Ratzel, 4:1989
 Carl Sauer, 4:1990, 4:1992
 Ellen Semple, 4:1990, 4:1991
 Neil Smith, 4:1992–1993, 5:2351
 C. P. Snow, 4:1991
 Mary Somerville, 4:1989
 William Thomas, 4:1991
 Paul Vidal de la Blache, 4:1989
 Sarah Whatmore, 4:1993
- Nature Conservancy, 2:871**
- Nature-society theory, 4:1994–1998**
 bioregionalism and, 1:255
 challenges to, 4:1994–1995
 class and nature and, 1:423–425
 cyborg ecologies and, 2:648–650
 deep ecology and, 4:1995
 deep ecology movements and, 2:692–695
 ecofeminism and, 2:817–820
 ecological imaginaries and, 2:828–830
 ecological justice and, 2:830–832
 ecological modernization and, 2:832–834
 environmental discourse and, 2:918–921, 4:1995–1996
 exploitation of people and nature and, 4:1996
 extinctions and, 2:1069–1072
 feminist and ecofeminist theories and, 4:1996
 feminist environmentalism and, 3:1090–1092
 gender and nature and, 3:1194–1197
 hybrid geographies and, 3:1502–1504
 indigenous ways of knowing and, 4:1996
 land and resources access issue and, 4:1996
 linguistic contexts of, 4:1995–1996
 nature as opposite of society and, 4:1995–1996
 nature from culture, nature from society separations and, 4:1994
 nature term and, 4:1994
 political ecology and, 4:1996
 politicized construction of social natures and, 4:1995
 power and space relationship issues and, 4:1996
 putting political back into ecology and, 4:1996
 rethinking the divide between nature and society in, 4:1996–1997
 romantic view of nature and, 4:1995
 scientific knowledge production and, 4:1993

- social constructivism, 4:1995
 social dimensions of nature and, 4:1995
 social equity, resources management and, 4:1996
 social justice and, 4:1996
 “true nature” and, 4:1995
 universal nature to global nature shift and, 4:1997
See also **Critical studies of nature**; Nature; Nature-society theory: noted scholars
- Nature-society theory: noted scholars
 Bruce Braun, 4:1993, 4:1997, 5:2339–2340
 Jessica Budds, 4:1996
 Donna Haraway, 4:1996
 Steve Hinchliffe, 4:1996
 Cindi Katz, 4:1996
 Bruno Latour, 4:1996
 Paul Robbins, 4:1996
 Michael Watts, 4:1996
 Sarah Whatmore, 4:1996
 Nauser, Markus, 3:1455
- NCGE. *See* **National Council for Geographic Education (NCGE)**
- NCGIA. *See* **National Center for Geographic Information and Analysis (NCGIA)**
- Negritude movement, 2:1029
- Neighborhood, 4:1998–2002**
 American Housing Survey (AHS) data and, 4:1998–1999
 behavioral hazards and physical conditions in, 4:2000–2001
 census tracts and, 4:1998
 collective self-regulation and, 4:2002
 Croatian neighborhood festival, Chicago, 4:2000 (photo)
 definition of, 4:1998
 ethnic segregation and, 2:1023
 federal, state, and local improvement programs and, 4:2001–2002
 gated communities and, 4:2002
 gender-related differences in neighborhood quality and, 4:2000
 haven concept and, 4:1999
 homeowner and neighborhood associations and, 4:2002
 home quality and neighborhood quality relationship and, 4:1998
 housing and housing markets and, 3:1444
 Homer Hoyt’s work and, 3:1449–1450
 Mott Street, Chinatown, New York City, and, 4:1999 (photo)
 neighborhood life cycle theory and, 4:2001
 neighborhood quality and, 4:1998–2001
 neighborhood quality control and, 4:2001–2002
 popular names for, 4:1998
 racial transition in, 4:2001
 redlining and, 4:2001
 unsafe neighborhood perceptions and, 4:1999–2000
 urban renewal programs and, 4:2001
 wards, political districts and, 4:1998
- Nelson, A., 2:1075
- Neocolonialism, 4:2002–2005**
 cheap raw materials and unskilled labor elements in, 4:2003
 decolonized countries and, 4:2002–2003
 de facto Western control and, 4:2003, 4:2004–2005
 definition of, 4:2002–2003
 economic dependence element in, 4:2003
 economic surplus extraction element of, 4:2003, 4:2020
 imperialism and, 3:1545–1548
 local elites element in, 4:2003
 multinational or transnational corporations elements in, 4:2004
 plantations and, 5:2192
 trade determination of international control and, 4:2004–2005
 unequal trade element of, 4:2003
 U.S. role in, 4:2004–2005
 Western foreign aid element of, 4:2003
- Western lending practices, Bretton Woods institutions and, 4:2003–2004
- See also* **Decolonization**
- Neogeography, 4:2005–2007**
 Application Programming Interfaces (API) and, 4:2006
 Asynchronous Javascript And XML (AJAX) technology and, 4:2005–2006
 cellular automata and, 1:368–371
 collaboration and openness features of, 4:2006
 “crowd sourcing” concept and, 4:2006
 definition of, 4:2005
 ethical implications of, 4:2006
 eXtensible Markup Language and, 4:2006
 geosensor networks and, 3:1252–1254
 Google Maps and, 4:2006
 Google Street View and, 4:2006
 humanistic GIScience and, 3:1474–1478
 Internet GIS and, 3:1620–11623
 mobile GIS and, 4:1918–1921
 nongeographic Internet, Web 2.0 and, 4:2005–2006
 OpenStreetMap and, 4:2006
 participatory mapping and, 4:2124–2125
 Web GIS and, 4:2006
 Web-mapping technology and, 4:2005–2006
 “wikification of GIS” concept (Sui) and, 4:2006
- Neoliberal environmental policy, 4:2007–2010**
 agricultural implications of market liberalization and, 4:2009
 biopiracy concept and, 4:2008
 criticisms of, 4:2007–2008
 debt payments and foreign exchange earnings and, 4:2007
 definition of, 4:2007
 direct and indirect policies and, 4:2007
 ecotourism and, 2:872
 environmental degradation and, 4:2008
 environmental governance supported by, 4:2007
 environmental privatization critics and, 4:2008
 environmental services privatization and, 4:2009
 export agricultural and, 4:2009
 foreign investment and, 4:2009
 free trade and, 4:2007, 4:2008–2009
 goals and tools of, 4:2007
 human rights issues and, 4:2008
 import-substitution, “command-and-control” approaches *vs.*, 4:2007
 income disparity and poverty and, 4:2007–2008
 international organizations criticism and, 4:2008
 market liberalization and, 4:2008–2009
 movement against genetically modified organisms and, 3:1610
 multinational institutions and, 4:2007
 natural-resource-dependent sectors and, 4:2007
 nature-society theory and, 4:1994–1998
 new environmental markets and, 4:2009–2010
 nongovernmental environmental certification systems and, 4:2010
 policies promoted by, 4:2007
 privatization and marketization issues and, 4:2009–2010, 5:2494
 resource geography and, 5:2450
 spatial conservation strategies and, 5:2668
 structural adjustment programs (SAPs) and, 4:2008, 4:2012
 trade negotiations and, 4:2008
 transnational corporations criticism and, 4:2008
 varied outcomes and social responses to, 4:2010
- See also* **Neoliberalism**
- Neoliberalism, 4:2010–2015**
 civil society advocacy against, 1:414

- classical liberalism combined with social conservatism and, 4:2010
 criticism of, 2:836
 criticisms of, 4:2013–2014
 debt crisis and, 2:689, 2:690
 definition of, 4:2010
 development of, 4:2010–2012
 ecological modernization theory (EMT) and, 2:836–837
 economic geography and, 2:850
 energy policy of, 2:900–901
 export-led development and, 2:1065–1066
 Fordism mass production and, 4:2011–2012
 free markets promoted by, 2:850, 4:2011
 Milton Friedman and, 4:2011
 gay and lesbian geographies and, 3:1184
 geographical imagination and, 3:1224
 global free trade and, 2:1065
 globalization and, 2:850, 3:1341
 global North and, 4:2011–2112
 global South and, 4:2012
 governance ideology, glocalization and, 3:1347–1348
 government delivery of infrastructure and, 3:1596–1597
 gentrification and, 3:1207
 growth theory and, 2:730–731
 Friedrich Hayek and, 4:2011
 income inequalities and poverty levels associated with, 4:2013–2014
 inequality geographies and, 3:1589
 Keynesian demand management approach and, 4:2011–2012
 labor responsiveness capital dynamics and, 4:2013
 laissez-faire capitalism and, 4:2011
 in Latin America and Chile, 4:2012
 liberalism *vs.*, 2:836
 market regulation removal and, 4:2013
 neoliberal philosophies term and, 4:2010
 new institutionalism and, 2:732–733
 newly industrializing countries and, 4:2021–2024
 oil price crisis (1974) and, 4:2012
 Poverty Reduction Strategy Papers and, 4:2013–2014
 proponents of, 4:2011
 protest against in Panama City and, 4:2014 (photo)
 public-private partnerships and, 5:2312–2313
 public space and, 5:2315
 Ronald Reagan and, 3:1596
 regulation theory and, 5:2400
 responsible autonomy issue in, 2:836
 restructuring and, 5:2459
 rural development and, 5:2490
 state and civil society social relationship and, 4:2013
 states, markets, and civil society relationships and, 4:2012–2013
 Structural Adjustment Programs (SAPs) and, 4:2008, 4:2012, 5:2703–2704
 supply and demand forces and, 4:2011
 sustainable development and, 2:836
 tenets of, 2:836
 uneven development criticism of, 4:2013, 6:2901–2902
 urban underclass and, 6:2998
 Washington Consensus term and, 4:2012
 welfare services reduction and, 4:2013
See also Neoliberal environmental policy
- Neo-Malthusianism, 4:2015–2016**
 agricultural intensification and, 1:36, 4:2015
 birth control decriminalization and, 4:1819
 “The Coming Anarchy” essay (Kaplan) and, 4:2016
 conservation and, 2:570
 critical studies of nature and, 2:625
 definition of, 4:2015
 demographic transition and, 2:707
 environmental security scholarship and, 2:999, 4:2016
Essay on the Principle of Population (Malthus) and, 4:1819, 4:2015
 eugenics movement and, 4:1819
 fertility rates decline and, 4:2015
 food insecurity persistence and, 4:2015
 genetically modified crops and, 4:2016
 Malthusianism and, 4:1819–1820
 political ecology, critical studies of nature and, 2:622, 5:2212
 population and land degradation debate and, 5:2233–2234
 post-Cold War thinking and, 4:2016
 resources shortages and, 4:2016
 U.S. anti-immigration policies and, 4:2015
- Nepal**
 Annapurna Conservation Area Project of ecotourism in, 2:871–872
 soil erosion in, political ecology and, 2:622
 water supply contamination and, 3:1387
- Nesmith, Cathy, 3:1092**
- Nestle, Marion, 3:1198**
- Netherlands**
 AGILE membership of, 1:125 (table)
 carbon or climate change taxes in, 4:1857
 central place theory in urban planning in, 1:382
 colonial empire of, 1:509 (fig.), 1:510, 1:511, 1:512
 deltas of, 2:702–703
 Dutch East India Company of, 1:510
 economically active females in, 3:1190 (table)
 European Union (EU) membership of, 2:1035
 green design and development in, 3:1371
 “heroin parks” in, 2:799
 Indonesia colonized by, 1:515
 national geographical society in, 3:1462
 Peace Palace, The Hague, 6:3130 (photo)
 pollution taxes in, 4:1857
 storm surge defense structures in, 1:497
- Network analysis, 4:2016–2018**
 definition of, 4:2016
 early applications of, 4:2016–2017
 geographic applications of, 4:2017
 GIS and, 4:2017–2018, 4:2019
 GIS in utilities management and, 3:1316
 graph theory and, 4:2016–2017
 hierarchy in networks and, 4:2017
 hub-and-spoke airline networks and, 4:2017
 hydrological connectivity and, 3:1512–1513
 interurban *vs.* intraurban network level analysis, 4:2016
 later developments in, 4:2017
 linear referencing and dynamic segmentation, 4:1784–1785
 link-node structure of, 4:2016
 matrix representations of, 4:2016
Network Analysis in Geography (Haggett and Chorley) and, 4:2017
 network data model and, 4:2018–2019
 network elements and, 4:2016
 planar *vs.* nonplanar networks and, 4:2016
 quantitative revolution and, 4:2017
 shortest-path algorithms and, 4:2017
 small-region (small-world) networks and, 4:2017
 spatial allocation application of, 4:2019
 spatial analysis of transport networks and, 4:2016, 4:2017
 structural change over time studies and, 4:2017
 transport geography field and, 4:2017
See also Network analysis: noted individuals
- Network analysis: noted individuals**
 Richard Chorley, 4:2017

- William Garrison, 4:2017
 Peter Haggett, 4:2017
- Network data model, 4:2018–2019**
 address matching, geocoding applications of, 4:2019
 attributes of, 4:2018
 closest facility and allocation applications of, 4:2019
 definition of, 4:2018
 edges and junctions elements of, 4:2018–2019
 geodatabase network and, 4:2019
 geometric features of, 4:2018
 GIS in utilities management and, 3:1316
 hierarchies in, 4:2018
 network analysis and, 4:2016–2018
 shortest-path analysis and, 4:2019
 topology networks and, 4:2019
- Nevada**
 Beowawe Geyser Field in, 3:1273
 normal fault, Basin and Range Province in, 3:1086
 nuclear weapons site in, 5:2469
 suburban sprawl, Las Vegas, 5:2717 (photo)
 Valley of Fire and, 3:1575
 Yucca Mountain nuclear waste repository issue and, 4:1744
- Nevidimova, O., 3:1130**
- New Caledonia, 1:244**
- Newfoundland**
 John Cabot exploration of, 2:1054
 Canadian musical content regulation and, 4:1968–1969
 Captain James Cook's exploration of, 2:576
 Viking exploration of, 2:1051
 Vineland map, 15th-century from 13th-century original, 2:1051, 2:1052 (fig.), 2:1053
- New Guinea**
 gardening practices, Maring people of New Guinea
 research and, 2:895–896
 glaciers in, 3:1332
 hunting and gathering tribes in, 3:1492
See also Papua New Guinea
- New international division of labor, 4:2019–2021**
 criticism of, 4:2020–2021
 definition of, 4:2019
 foreign direct investment, international subcontracting and, 4:2020
 global factory term and, 4:2020
 industrialization and deindustrialization patterns and, 4:2020
 newly industrializing countries and, 4:2021–2024
 “old” international division of labor and, 4:2019
 preconditions of, 4:2020
 production decentralization and, 4:2020
 surplus value extraction and, 4:2003, 4:2020
 transnational corporations role in, 4:2020
 uneven capitalist development and, 4:2019
 “well-disciplined” labor concept and, 4:2020
 women in labor force and, 4:2020
- New Jersey**
 cancer-oriented migrant studies and, 1:335
 Green Acres program in, 4:2093
 open space regulation in, 4:2093
- Newly industrializing countries (NIC), 4:2021–2024**
 APEC and, 1:121–122
 ASEAN and, 1:126–131
 China and, 4:2022–2023, 4:2022 (fig.)
 comparative advantage concept and, 4:2021
 definitions, 4:2021
 dependency theory and, 4:2021
 developing countries and, 4:2023
 development theory and, 4:2021
 export-oriented industrialization (EOI) in, 2:1064–1065
 foreign direct investment and, 4:2023
 global free trade and, 2:1065
 import substitution to export-led industrialization shift and, 4:2021
 India and, 4:2023
 land reform and, 4:2023
 Malaysia, 4:2022, 4:2022 (fig.)
 modernization theory and, 4:1931–1935, 4:2021, 4:2023
 neoclassical economic thought and, 4:2021
 neoliberal policies and, 4:2023
 new international division of labor and, 4:2019–2020
 newly industrializing economies term and, 4:2021
 North American Free Trade Agreement (NAFTA) and, 4:2023
 problems associated with, 4:2023
 U.S. intervention and, 4:2021–2022
 world map of, 4:2022 (fig.)
 world-systems theory and, 4:2021, 4:2023
- New Mexico**
 composite map of wildfire hazard, Jemez Mountains, 5:2232 (image)
 Landsat Thematic Mapper image, Cerro Grande Fire, 5:2321 (image)
 nuclear weapons site in, 5:2469
 water-sharing in irrigation in, 1:534
- New Orleans, Louisiana**
 French colonization of, 1:512
 Guste New Homes Public Housing, 5:2303 (photo)
 Hurricane Katrina and, 3:1493–1494, 3:1495 (photo)
 Shuttle Imaging Radar image of, 4:1890 (fig.)
- Newton, Isaac, 2:774, 3:1542, 4:1648**
- Newton, Norman, 4:1699**
- New urbanism, 4:2024–2027**
 American dream redefinition and, 4:2024
 Celebration, Osceola County, Florida, and, 4:2025, 4:2025 (photo)
 Congress for the New Urbanism, 4:2024
 definition of, 4:2024
Directory of New Urbanism and, 4:2027
 Kentlands, Maryland and, 4:2025
 Laguna West, Sacramento County, California, 4:2026–2027, 4:2026 (photo)
 livable places manifesto (Appleyard) and, 4:2025
 Orenco Station, Portland, Oregon, 4:2026 (photo), 4:2027, 4:2027 (photo)
 origins of movement and, 4:2024–2027
 “pedestrian pocket” concept and, 4:2026
 postmodernism and, 4:2024, 5:2268
 Seaside, Walton County, Florida, resort town and, 4:2025, 4:2025 (photo)
 sustainable communities design movement and, 4:2026
 traditional-neighborhood development and, 4:2024
 transit-oriented development (TOD) and, 4:2024, 5:2240
 Village Homes, Davis, California, and, 4:2026
 walkability and physical activity focus of, 4:2024
See also New urbanism: noted individuals
- New urbanism: noted individuals**
 Donald Appleyard, 4:2025
 Peter Calthorpe, 4:2026
 Judy Corbett, 4:2026
 Michael Corbett, 4:2026
 Andrés Duany, 4:2025
 Allan Jacobs, 4:2025
 Jane Jacobs, 4:2025, 4:2126
 Douglas Kelbaugh, 4:2026
 Léon Krier, 4:2024–2025
 Elizabeth Plater-Zyberk, 4:2025
 Jacquelyn Robertson, 4:2025

- Robert A. M. Stern, 4:2025
 Sym Van der Ryn, 4:2026
- New York City, New York
 airline networks in, 1:179
 central business district of, 1:379
 Central Park's landscape architecture and, 4:1700
 Central Park's open space in, 4:2092 (photo)
 command and control economy in, 1:304
 Dr. Martin Luther King Jr. Boulevard in Harlem, 5:2190 (photo)
Economic Status of the New York Metropolitan Region (Hoyt) and, 3:1450
 garment industry in, 3:1583, 4:1821
 homeless in Central Park, 3:1441 (photo)
 infrastructure networks in, 3:1597
 Manhattan view from Empire State Building, 1:275 (photo)
 Mott Street, Chinatown, 4:1999 (photo)
 Regional Plan Association in, 3:1449
 September 11, 2001, terrorist attacks in, 1:97, 1:294, 2:541, 2:738, 2:763, 3:1252, 4:2047–2048, 4:2103, 5:2224, 6:2806 (photo), 6:2871
 SoHo gentrification in, 3:1207
 South Bronx ghetto neighborhood in, 3:1276 (photo)
 spatial point suburban development pattern in, 5:2714 (fig.), 5:2715
 as supergentrification urban center, 3:1204
 UN headquarters in, 6:2904 (photo)
 U.S. Postal Service “green” roof, 6:2995 (photo)
 wildlife corridors in Central Park, 6:2944 (photo)
 World Trade Center symbolism in, 6:2768 (photo)
- New York (state)
 cancer-oriented migrant studies and, 1:335
 Dutch colonies in, 1:512
 open space regulation in, 4:2093
- New Zealand
 ANZUS treaty and, 1:505
 APEC membership of, 1:121
 as archipelago island formation, 1:105
 avian extinctions from, 3:1630
 birthrates in, 2:708
 as British colony, 1:516
 Andrew Clark's work, 1:416–417
 Closer Economic Relations Free Trade Agreement and, 1:121
 colonial migrations of, 1500–1914, 3:1542, 3:1543 (fig.)
 Captain James Cook's exploration of, 2:576
 critical human geography in, 2:618, 2:620
 economically active females in, 3:1190 (table)
 fjords in, 3:1121
 foreign aid flow from, 3:1152
 forest plantations in, 5:2195
 geothermal energy use in, 3:1267
 glaciers in, 3:1332
 green building programs in, 3:1368
 greenhouse gas emissions of, 5:2220
 high-temperature geothermal fields in, 3:1273
 individual transferable quotas (ITQs) in, 6:2756
 Indo-European languages in, 4:1749, 4:1750 (fig.)
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 large land birds extinction, tragedy of the commons example in, 1:533
 lower birth rates in, 4:1981
 Malayo-Polynesian languages in, 4:1753, 4:1753 (fig.)
 Maori native population in, 1:516
 marine aquaculture in, 4:1854 (fig.)
 midlatitude deciduous forest in, 1:224
 Nor'wester warm, dry, gusty, downslope wind in, 1:384
 political map of, 6:3157
 postmodernism in, 2:619
 species variations in, 1:209
 transform plate boundaries in, 5:2198
 urban green space, Auckland, 6:2943 (photo)
 vicariance biogeography in, 1:211
- NGR. *See* **Natural growth rate** (NGR)
- NIC. *See* **Newly industrializing countries** (NIC)
- Nicaragua
 Cold War and, 1:504, 1:505
 domino theory and, 2:787, 3:1224
 economically active females in, 3:1190 (table)
 Heavily Indebted Poor Countries initiative (World Bank) and, 2:690
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 marine aquaculture in, 4:1854 (fig.)
 poverty rates in, 5:2274
 trading blocs and, 3:1550
- Nicholls, W., 5:2575
- Nietschmann, Bernard, 2:632
- Nietzsche, Friedrich, cultural turn concept origins and, 2:645
- Niger
 economically active females in, 3:1190 (table)
 famine in, 4:1986
 GDP per capital in, 3:1382
- Nigeria
 cholera in, 1:402
 economically active females in, 3:1190 (table)
 income ratio relative to slum population in, 2006, 5:2644 (fig.)
 MOLAND (Monitoring Land Cover/Use Dynamics) urban planning project in, 3:1313
 oil extraction activities, human rights violations, Niger River Delta and, 2:619–620
 oil exports from, 4:2073
 oil sources in, 4:2163
 OPEC membership of, 4:2099, 4:2100 (fig.)
 tropical rain forest of, 1:453
- Nile River delta, 2:702
 crop cultivation on, 3:1132
 floodplain soil fertility on, 3:1245
 land use on, 3:1130 (photo)
- Nitrogen cycle**, 4:2028–2029
 agriculture and, 4:2028–2029
 as biogeochemical cycle, 1:206–207
 coastal hypoxic dead zones and, 4:2029
 complexity of, 4:2028
 “dead zone” in Gulf of Mexico and, 1:207, 1:486, 1:487 (photo), 1:488, 2:939
 definition of, 4:2028
 “fixing” of “reactive nitrogen” and, 1:206
 Haber-Bosch process and, 4:2028–2029
 human activity affect on, 4:2028
 legumes cultivation and, 4:2028
 manure and soil additives and bat guano and coal-based ammonium sulfate and, 4:2028
 nitrifying bacteria and, 4:2028
 nitrogen “cascade” issue and, 1:207
 nitrogen-fixing bacteria and, 4:2028
 nitrogen-fixing crops, fertilizer production and, 1:206–207
 nitrogenous fertilizers and, 4:2029
 nutrient cycles and, 4:2052–2055
 photosynthesis and, 1:205, 1:206
 regulating policies and, 4:2029
 regulatory role of, 4:2028
- Noble savage concept, 2:1020–1021

Nomadic herding, 4:2029–2033

camp group, clan, tribe, and confederation hierarchies of, 4:2032
 characteristics of, 4:2030
 coupled human and animal systems and, 2:597–598
 derivation of term and, 4:2029
 dung-stubble connection and, 4:2030–2031
 environmental management and, 4:2032
 herding groups and, 4:2031–2032
 labor needs and, 4:2031–2032
 Masai nomads with cattle, Southern Kenya, 4:2031 (photo)
 military potential of, 4:2032
 modern developments in, 4:2032
 nomadic Tuareg herders and camels, Sahara Desert, Mali, West Africa, 4:2034 (photo)
 overgrazing prevention and, 4:2030
 pastoralist drylands environmental management and, 2:971
 pastoral zone changes and, 4:2029–2030
 pasture ownership and, 4:2032
 political power to enforce pastoral rights and, 4:2031
 as preindustrial agriculture method, 1:48
 private ownership of herds and, 4:2032
 regional spatial framework of, 4:2030
 resource rights and, 4:2030–2031
 “tragedy of the commons” and, 4:2032
 vertical and horizontal movements in, 4:2030
See also Nomadism

Nomadism, 4:2033–2034

aimless wandering myth and, 4:2033
 animal herders and, 4:2033
 coupled human and animal systems and, 2:597–598
 definition of, 4:2033
 examples of, 4:2033
 hobo image and, 4:2033
 hunting and gathering and, 3:1489–1492
 migration *vs.*, 4:2033
 mobility behavior pattern of, 4:2033
 nomadic Tuareg herders and camels, Sahara Desert, Mali, West Africa, 4:2034 (photo)
 regular movements of, 4:2033
 rotational grazing and, 4:2033
 transhumanence seasonal oscillation and, 4:2033
See also Nomadic herding

Nomothetic, 4:2034–2035

absolute space and, 4:2035
 criticism of, 4:2035
 definition of, 4:2034
 empiricism rejected by, 4:2035
 exceptionalism (Schaeffer) and, 4:2034
 features of, 4:2035
 Jean Gottmann and, 3:1355–1356
 idiographic-nomothetic debate and, 4:2034–2035
 logical positivism and, 4:2035, 5:2388
 quantitative revolution and, 4:2034–2035, 5:2329
 role of theory and explanation and, 4:2035
 spatial analysis and location theory and, 4:2035
 statistics and mathematical models and, 4:2035
 systematic *vs.* regional geography debate and, 4:2034–2035

Nongovernmental organizations (NGOs), 4:2035–2038

accountability issue, 1:415, 4:2037
 activities variations among, 4:2035–2036
 antiglobalization and, 1:96
 antisystemic movements and, 1:99–100
 beneficial examples of, 1:415–416
 as civil society component, 1:414–416
 criticism of, 4:2037–2038

definition of, 4:2035
 donor organizations and, 4:2037
 elitism criticism of, 1:415
 governance at national and international scales and, 4:2038
 grassroots organizations and, 1:414, 4:2036
 international NGOs *vs.* community-based organizations (CBOs) and, 4:2036
 local, national, and international scales of, 4:2036
 marginalized groups advocacy by, 4:2036
 objectives variations among, 4:2035
 political or charitable motivation of, 4:2036
 power issues, 4:2037
 praise and criticism of, 4:2037–2038
 professionalizing activities issue and, 4:2037
 recent history of, 4:2036–2037
 telecommunications advances and, 1:415 (photo)
 “third sector” perspective of, 4:2037
 transnational networks of, 4:2036–2037
 variations among, 4:2035

Nonpoint sources of pollution (NPS), 4:2038–2039

common NPSs, 4:2038–2039
 controlling NPSs, 4:2039
 definition of, 4:2038
 impermeable surfaces factor in, 3:1549
 insecticides and fertilizers as, 4:2039
 livestock fecal material as, 4:2039–2040

Nonrenewable resources, 4:2039–2041

discount rate issue and, 4:2040
 empirical relevance issue and, 4:2040
 examples of, 4:2039
 Grey and Hotelling-style models of, 4:2040, 5:2445
 human-made resources replacement of, 4:2040
 optimal extraction of, 4:2039–2040
 optimal extraction of, history and potential future models of, 4:2041
 optimal extraction of, model challenges and, 4:2040–2041
 partial equilibrium approach to, 4:2040–2041
 sustainability issues and, 4:2041
 systems view, 4:2041
 traditional models of, 4:2040
See also Petroleum

Nonrepresentational theory (NRT), 4:2041–2042

actor-network theory and, 1:8
 affect, practice, and performance interplay and, 4:2041
 “being-in-the-world” concept and, 4:2042
 bodily performances concept and, 1:290
 cartographies of the virtual and, 4:2041–2042
 cultural geography and, 2:639
 definition of, 4:2041
 gay and lesbian geographies and, 3:1185
 geography of emotions and, 2:892
 habitual practices and tacit knowledge elements of, 1:290
 inherent instability of lived spatiality and, 2:639
 “more-than-representational theory” term and, 4:2041
 movement focus of, 2:639
 performance as free-floating venture, 1:290
 text to practice focus of, 1:290
 witnessing of the world and, 4:2042
See also Nonrepresentational theory (NRT): noted scholars

Nonrepresentational theory (NRT): noted scholars

Judith Butler, 4:2042
 Gilles Deleuze, 4:2041–2042
 J. D. Dewsbury, 4:2042
 Martin Heidegger, 4:2042, 4:2166
 Bruno Latour, 4:2042
 Derek McCormack, 4:2042

- Maurice Merleau-Ponty, 4:2042
 Nigel Thrift, 1:290, 4:2042, 6:2827–2829
 John Wylie, 4:2042
- Nonvisual geographies, 4:2042–2044**
 behavioral geography and, 4:2042
 body language and, 4:2043
 definition of, 4:2042
 Habermas's theory of communicative interaction and, 4:2043
 hegemony of vision and, 4:2043
 Henri Lefebvre and, 4:2043
 masculine gaze concept and, 3:1996, 4:2043
 poststructuralism and, 4:2042
 "smellscape" and "soundscape" concepts of, 4:2043
 social construction of vision, ocularcentrism and, 4:2042–2043
 social theory and behavioral geography boundary and, 4:2042
 social theory and cognitive-behavioral studies and, 4:2043
 space and time compression and, 4:2043
 symbolic understanding of space and, 4:2042
- Normandy, 2:1051
- North Africa**
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
 Afro-Asiatic language in, 4:1749, 4:1750 (fig.)
 Arab exploration of, 2:1053
 desert biome of, 1:218
 groundwater usage in, 3:1386
 HIV/AIDS in, 3:1438
 military expenditures in, 4:1899 (table)
 people living in extreme poverty and, 3:1082 (table)
 Sahara desert, dry climate of, 1:429
 Sahara shield and platform topography in, 1:111
 undernourishment in, 3:1488
- North America**
 acid rain in, 1:6
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
 Albers equal-area projection map of, 4:1846 (fig.)
 atmospheric pollution in, 1:152, 1:153, 1:154
 automobile industry in, 1:169–171, 1:170 (fig.)
 barrier islands in, 1:183–185, 1:184 (photos)
 Basin and Range, mountain and basin desert setting in, 1:111
 beaver dams in, 1:274, 1:274 (photo)
 Bering land bridge, Asia and, 1:213
 biogeography dispersal modes in, 1:213
 birthrates in, 2:708
 boreal forests in, 1:214–217, 1:216 (photo)
 cadastral systems, land ownership and, 1:315
 colonial migrations of, 1500–1914, 3:1543
 colonization of, 1:512
 cranberry farming, domestication centers and, 1:377
 cross-border cooperation and, 2:630
 deforestation in, 2:696
 deindustrialization impacts in, 2:945
 developed countries in, 2:725 (fig.)
 fertility levels in, 2:709
 forest fragmentation, bird species and, 3:1161–1162
 forest fragmentation in, 3:1159, 3:1160 (fig.)
 forest plantations in, 5:2195
 genetically modified foods in, 3:1198
 genetically modified organisms, crops and, 1:279
 geothermal energy use in, 3:1267 (fig.)
 glacial geology studies of, 1:81
 glacial/interglacial cycles in, 1:457
 glaciers in, 3:1333
 groundwater usage in, 3:1386
 herbicide use in, 3:1421
 HIV/AIDS in, 3:1438
 indigenous cartography in, 3:1562
 industrialization in, 3:1583
 Isthmus of Panama, South America and, 1:213
 Lambert conformal conic map projection of, 4:1846 (fig.)
 land degradation estimates in, 4:1680 (table)
 lower birth rates in, 4:1981
 midlatitude, mild climate of, 1:435
 midlatitude deciduous forest in, 1:223–226
 military expenditures in, 4:1899 (table)
 Native American eradication in, 1:512
 North American monsoon, 4:1941, 4:1943
 petroleum consumption in, 4:2164 (fig.)
 playas of, 5:2199–2200
 polar climate in, 1:449
 political map of, 6:3163
 population growth of, 5:2233 (fig.), 5:2241
 potential water availability in, 2007, 2050, 6:3059 (fig.)
 prehistoric exploration of, 2:1050
 renewable water resources and availability in, 6:3057 (table)
 San Andreas fault zone in, 1:186
 severe midlatitude climate in, 1:439, 1:440 (fig.)
 temperate, semiarid deserts in, 1:219
 temperate arid deserts in, 1:221
 transboundary aquifers in, 3:1389
 transcurrent plate margins (earthquakes) and, 2:810
 tropical monsoon climate in, 1:454, 2:741
 tropical/subtropical hyperarid deserts in, 1:222
 tropical/subtropical semiarid deserts in, 1:220
 tundra of, 1:247–248
 vicariance biogeography in, 1:211
See also specific nation
- North American Free Trade Agreement (NAFTA), 4:2044–2046**
 APEC and, 1:121
 benefits of, 4:2044–2045
 capital mobility restrictions issue and, 4:2044
 criticism of, 4:2045
 environmental issues and, 4:2008
 foreign direct investment provision of, 4:2044
 future controversies, 4:2046
 goals of, 4:2044
 intra-industry trade (IIT) element of, 4:2044
 Latin American newly industrializing countries and, 4:2022 (fig.), 4:2023
 merchandise trade and, 4:2044
 provisions of, 4:2044
 sidebar agreements of, 4:2044
 supranational economic activity, globalization and, 3:1347
 supranational integration feature of, 6:2727
 teamsters protest against, San Diego, California, 4:2045 (photo)
 trade diversion issue and, 4:2045–2046
 transnational corporations and, 4:2044
 U.S. industrial employment issue and, 4:2046
 World Trade Organization and, 4:2045
- North Atlantic Treaty Organization (NATO), 4:2046–2048**
 Afghanistan actions of, 4:2048
 Bosnia civil war and, 4:2047
 Cold War and, 4:2047
 Europe's post–World War II recovery and, 4:2047
 humanitarian and combat activities of, 4:2047
 Kosovo peacekeeping activities of, 4:2047
 members of, 4:2047, 4:2048 (fig.)
 nuclear weapons issue and, 4:2047
 original members of, 4:2047
 principle of, 4:2046–2047
 Russia issue and, 4:2048

- September 11 terrorist attacks and, 4:2047–2048
 Serbian bombings of, 4:2047
 Soviet Union, Warsaw Pact and, 4:2047
 Soviet Union attack deterrence issue and, 4:2047
 Soviet Union collapse and, 4:2047
 uncertain future of, 4:2048
- North Carolina
 hurricane risk in, 3:1500
 Mountain Music Festival, Asheville, 1930s, 4:1968 (photo)
 Research Triangle Park in, 5:2435, 5:2436
- Northern Hemisphere
 air masses of, 1:63
 Aleutian low and Icelandic low pressure cells in, 1:133
 atmospheric angular momentum in, 1:142–143
 continuous, discontinuous, sporadic, and isolated permafrost in, 4:2155 (fig.)
 Coriolis force and, 2:586
 dry climates in, 1:429–430, 1:430 (fig.)
 forest degradation in, 3:1157–1158
 glacial/interglacial cycles in, 1:457–459
 Hadley cell atmospheric circulation in, 3:1395
 humid continental and subarctic climates, 1:440 (fig.), 1:441–442
 Little Ice Age in, 1:459, 3:1333, 3:1335
 midlatitude cyclones in, 1:134
 periglacial environments of, 4:2147 6, 4:2147 (fig.)
 polar climate in, 1:450
 surface air temperature variations over past millennium in, 1:460 (fig.)
 volcanic eruptions in, 1:163
See also specific country
- North Korea
 “axis of evil” concept (G. W. Bush) and, 2:612
 collectivized farming in, 2:543
 demilitarized zone (DMZ) of, 1:293 (photo)
 economically active females in, 3:1190 (table)
 human rights atrocities in, 3:1481
 humid continental climate of, 1:440
 South Korea borderlands and, 1:292, 1:293 (photo)
- North Pole. *See Poles, North and South*
- North Vietnam
 collectivized farming in, 2:543
- Norway
 AGILE membership of, 1:125 (table)
 Atlantic salmon fish farming in, 3:1119–1120
 cancer incidence and mortality in, 1:322 (fig.), 1:323 (fig.)
 carbon or climate change taxes in, 4:1857
 cultural nationalism in, 4:1980
 economically active females in, 3:1190 (table)
 energy policies in, 2:902
 European Union (EU) membership of, 2:1035
 foreign aid flow from, 3:1152
 glacial loss in, 3:1333
 glacial mountains of Spitsbergen, Norway, 1:450 (photo)
 hydroelectric power in, 3:1509
 Kyoto Protocol of 1997 and, 1:463
 marine aquaculture in, 4:1854 (fig.)
 North Sea oil reserves and, 2:902
 Norwegian Current and, 1:450
 Norwegian mugwort as floral climatic relict and, 1:470
 oil production in, 4:2099
 Sognefjorden fjord in, 3:1121, 3:1122 (photo), 3:1123 (fig.)
- Not in My Backyard (NIMBY), 4:2049–2050
 criticism of, 4:2049
 environmental justice and, 4:2049
 environmental threat examples and, 4:2049
 landfill disposal sites and, 4:1686
 land use regulation and, 4:1727
 locally unwanted land uses (LULUs) and, 4:1792, 4:2049
 spatial distribution of undesirable effects and, 4:2049
 strength variables and, 4:2049
 structuralist interpretation of, 4:2049
 toxic waste landfills, environmental racism and, 2:987, 4:1686
 urban development process and, 4:2049
 waste incineration and, 6:3048–3049
- Novak, Jakub, 5:2710
- NPS. *See Nonpoint sources of pollution (NPS)*
- NRT. *See Nonrepresentational theory (NRT)*
- Nuclear energy, 4:2050–2052**
 antinuclear movement and, 3:1609
 boiling water *vs.* pressurized water reactors and, 4:2049
 Chernobyl nuclear accident and, 1:385–386, 1:385 (photo), 3:1357
 geography of fear, geography of necessity and, 4:2051–2052
 global reserves of uranium and, 2:903 (fig.), 2:909 (fig.)
 Greenpeace and, 3:1612
 low-carbon power produced by, 3:1337
 next generation of reactors and, 4:2050–2051
 nuclear arms race and, 4:2052
 nuclear fission and, 4:2049
 nuclear politics and, 4:2050–2051
 nuclear power plant in Lower Saxony, Germany, 4:2051 (photo)
 nuclear terrorism issue and, 4:2052
 nuclear testing and, 1:167–168, 2:956
Nuclear War Atlas (Bunge) and, 1:300
 Nuclear Waste Policy Act (U.S.), 2:899
 pros and cons of, 4:2049
 remediating former nuclear weapons sites, risk analysis and, 5:2469–2470
 subatomic nuclear energy and, 4:2050
 THORP nuclear power-reprocessing plant, UK controversy and, 5:2517
 Three Mile Island nuclear accident and, 2:899
 Three Mile Island nuclear power plant, Middletown, Pennsylvania, 6:2827 (photo)
 uranium resources and, 2:908, 4:2049
 U.S. electricity demands and, 4:2052
 U.S. energy policies and, 2:899, 2:901
 U.S. Energy Policy Act (2005) and, 4:2051
 Vattenfall atomic power plant protest, Hamburg, Germany, 2:1033 (photo)
 Yucca Mountain nuclear waste repository issue, Nevada and, 4:1744
- Nussbaum, Martha, 2:591
- Nutrient cycles, 4:2052–2055**
 assessment methods of, 4:2053–2055
 coastal dead zones and, 1:486–488
 definition of, 4:2052
 in ecosystems, 4:2053
 forest ecosystems and, 4:2053, 4:2054 (fig.)
 macronutrients and micronutrients and, 4:2052
 mineralization process and, 4:2053
 nitrogen cycle and, 4:2028–2029, 4:2053
 nutrient fluxes and, 4:2053
 nutrient stock variations and, 4:2053
 nutrient turnover and, 4:2053
 pesticides and, 2:939
 phosphorus cycle and, 4:2169–2171
 rock-derived nutrients cycling and, 1:207
 solid-phase-associated fluxes and, 4:2053
 Water-bound fluxes and, 4:2053
- Nyerges, Timothy, 4:2055–2056
 academic career of, 4:2055
 critical geographies and, 2:615

- enhanced adaptive structuration theory term of, 4:2056
 GIScience curriculum work of, 4:2055
 Piotr Jankowski and, 4:2056
 service work of, 4:2055–2056
 spatial data focus of, 4:2055
 Nystuen, John, 1:192, 3:1466
- OBIA.** *See* **Object-based image analysis (OBIA)**
- Object-based image analysis (OBIA)**, 4:2057–2058
 explanation of, 4:2057
 GEOBIA acronym and, 4:2058
 image interpretation and, 3:1534–1536
 image-objects element of, 4:2057
 ontological foundations of geographical data and, 4:2078–2081
 pixel-based methods *vs.*, 4:2057
 segmentation step in, 4:2057
 vector GIS and, 4:2057
 visual interpretation replication and, 4:2057
- Oceania**
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
 bush fallow farming in, 1:301
 bush fallow farming practiced in, 1:301–302
 coca cultivation in, 2:797
 colonization of, 1:515–516
 deforestation in, 2:696
 geothermal energy use in, 3:1267 (fig.), 3:1269
 glaciers in (New Zealand), 3:1332
 invasion of species in, 3:1472–1473
 land degradation estimates in, 4:1680 (table)
 marine aquaculture in, 4:1853
 military expenditures in, 4:1899 (table)
 political map of, 6:3157
 potential water availability in, 2007, 2050, 6:3059 (fig.)
 renewable water resources and availability in, 6:3057 (table)
 undernourishment in, 3:1488 (table)
- Oceanic circulation**, 4:2058–2064
 absolute vorticity and, 4:2059
 Agulhas western boundary current and, 4:2064
 atmospheric energy variations and, 1:163–165
 boundary currents and, 4:2059–2060
 climate change and, 6:2770–2771
 Coriolis force and, 4:2058, 4:2059, 4:2060, 4:2061, 4:2062 (fig.)
 currents, eddies, and water mass formation in, 4:2064
 East Arabian Current and, 4:2064
 Ekman transport and, 4:2058–2059, 4:2060, 4:2061
 El Niño–Southern Oscillation (ENSO) and, 2:886–890, 4:2058, 4:2062 (fig.)
 equatorial current systems and, 4:2061–2063, 4:2061 (fig.)
 forces affecting ocean circulation and, 4:2058, 6:2770–2771
 global environmental change and, 3:1336
 gyres and, 4:2058–2059
 Kelvin and Rossby waves and, 4:2061–2062
 La Niña and, 4:1754–1757
 major currents that drive oceanic circulation and, 4:2059 (fig.)
 meridional overturning circulation, 3:1336
 monsoonal current reversals and, 4:2063–2064
 monsoonal cycle and, 4:2058, 4:2063, 4:2063 (fig.)
 Northern Hemisphere high-pressure gyre and, 4:2060 (fig.)
 periglacial environment changes and, 4:2149–2150
 pressure gradients and geostrophic currents and, 4:2060–2061, 4:2060 (fig.), 4:2061 (fig.), 4:2062 (fig.)
 Somali current and, 4:2064
 thermohaline circulation and, 4:2058, 4:2149–2150
 weather and climate determined by, 4:2058, 4:2059 (fig.)
- Younger Dryas Northern Hemisphere cooling (Pleistocene) and, 3:1336
- See also* **El Niño–Southern Oscillation (ENSO)**; **La Niña**
- Oceans**, 4:2064–2071
 Atlantic Multi-decadal Oscillation (AMO) and, 1:165
 Atlantic Ocean cool and warm phases and, 1:164–165
Black Atlantic (Gilroy) and, 4:2070
 bluefin tuna farm, mid Adriatic, Croatia, and, 4:2066 (photo)
 carbon cycle and, 1:206
 coastal hazards and, 1:496–500
 coastal state's exclusive economic zone (EEZ) and, 4:2069
 conservation zoning in, 2:572
 contemporary issues, 4:2066–2070
 coral reefs and, 2:581–584
 Coriolis force and, 2:586–587
 cultural geography issue and, 4:2069–2070
 delineation of ocean space and, 4:2069
 development of ocean territories and, 4:2069–2070
Devil and the Deep Blue Sea (Rediker) and, 4:2070
 Earth's climate and, 4:2068
 economic geography issues and, 4:2066–2068
 El Niño–Southern Oscillation (ENSO) and, 2:886–890
 endangered marine environment and, 4:2066–2067, 4:2068
 “Great Pacific Climatic Shift” and, 1:164
 as integral space of society, 4:2069
 environmental geography issues and, 4:2066–2068
 extinctions from, 3:1630 (table)
 freedom of the seas doctrine, 4:2066
 global environmental change and, 3:1336
 heat content of, 1:163–164
 hypoxia of, 3:1336
 Indian Ocean, 1:164
 industrial effluents and, 4:2068
 La Niña and, 4:1754–1757
Mare Liberum (Grotius) and, 4:2066
 Maximum Minimum Temperature Systems and, 1:164
 monsoons and, 4:1940–1945
 National Ocean Industries Association and, 4:2067
 nature as social construct and, 4:2068
 oceans as a space of nature and, 4:2065
 ocean-using industries and, 4:2067
 oil and gas drilling platform, Pacific Ocean, 4:2067 (photo)
 oil spills and, 4:2073–2076
 Pacific Decadal Oscillation (PDO) and, 1:164
 Pacific Ocean cool and warm phases and, 1:164
 political geography issue and, 4:2068–2069
 political geography issues and, 4:2069–2070
 poststructuralism and, 4:2069
 public awareness, 4:2068
 sea as arena for culture formation and, 4:2070
 sea-level rise and, 3:1327, 3:1336
 as space of mobility, 4:2068–2069
 statistics, 4:2064–2065, 4:2067
 Strabo and, 4:2065
 technology advances and, 4:2066–2067
 UN Convention on the Law of the Sea and, 4:2069
 world-ocean and “seven seas” terms and, 4:2064
 world-systems theory and, 4:2069
See also **Hurricanes**, **physical geography of**; **Hurricanes**, **risk and hazard**; **Oceans**: noted scholars
- Oceans**: noted scholars
 Fernand Braudel, 4:2070
 Gilles Deleuze, 4:2070
 Michael Foucault, 4:2070
 Paul Gilroy, 4:2070

- Felix Guattari, 4:2070
 Richard Hartshorne, 4:2065
 Marcus Rediker, 4:2070
 Ellen Churchill Semple, 4:2065
- Odum, Howard, 2:894–895
- OECD. *See* Organisation for Economic Co-operation and Development (OECD)
- Offshore finance, 4:2071–2073**
 anti-money-laundering policies and, 4:2072
 Bretton Woods fixed exchange rates issue and, 4:2071
 definition of, 4:2071
 development of, 4:2071
 Eurodollar market factor in, 4:2071
 Euromarkets and, 2:1031
 Financial Action Task Force (FATF) and, 4:2072–2073
 low-tax jurisdictions and, 4:2071 (fig.), 4:2072 (fig.)
 Middle East petrodollar recycling factor in, 4:2071
 offshore financial centers (OFCs) and, 4:2071
 offshore-onshore tensions and, 4:2071–2072
 problems of modern global economy and, 4:2071
 savings tax agreement (EU) and, 4:2072
 spatial distribution of OFCs and, 4:2071–2072
 supranational regulatory and supervisory bodies and, 4:2071–2072
 technology advances factor in, 4:2071
- OGC. *See* Open Geospatial Consortium (OGC)
- Ohio
 Mittal Steel's Cleveland Works, 4:1823 (photo)
 road map, 1938, 1:359 (fig.)
- Ohlin, Bertil, 2:557
- Oil spills, 4:2073–2076**
 causes of, 4:2073
 cleaning of, 4:2075
 coastal areas vulnerability to, 4:2073
 Deepwater Horizon oil spill, Mississippi Delta, 4:2074 (photo), 4:2075
 definition of, 4:2073
 environmental sensitivity to, 4:2075–2076
 ocean oil spills and, 4:2074–2075, 4:2075 (fig.)
 oil characteristics and, 4:2073
 oil-exporting areas and, 4:2073
 oil types and, 4:2073
 political and economic conflicts, 4:2076
 socioeconomic and political aspects, 4:2076
 “weathering” of oil and, 4:2074
- Okabe, Atsuyuki, 4:2076–2077**
 city systems work of, 4:2077
Encyclopedia of Voronoi Diagrams written by, 4:2076
 GIS humanities and social sciences applications and, 4:2076
 spatial analysis on networks and, 4:2076
 Voronoi diagrams work of, 4:2076
- Oklahoma
 “colored” water cooler, Oklahoma City, 1939, 5:2345 (photo)
 first tornado captured by NSSL Doppler radar,
 Union City (1973), 6:2853 (photo)
 spillway at Broken Bow Reservoir, Mountain Fork River,
 McCurtain County, 6:3077 (photo)
- Oldenburg, Ray, 4:2168
- Oliver, John E., 1:467
- Olmsted, Frederick Law, 4:1699
- Olson, Mancur, 5:2215
- Olsson, Gunnar, 4:2077–2078**
 deconstructionism within poststructuralist geography and, 4:2077
 limits of language, limits of understanding and, 4:1754
 post-positivist geography and, 4:2077
 quantitative work of, 4:2077
 radical cartography of power views of, 4:2077–2078
- Omaha, Nebraska
 African Americans in, 2000, 2:1025 (fig.)
 poverty in, 2:1026 (fig.)
 Whites in, 2000, 2:1025 (fig.)
- Oman, 3:1190 (table)
- Ontological foundations of geographical data, 4:2078–2081**
 application context factor in, 4:2080
 background context of, 4:2079–2080
 bona fide boundary and, 4:2080–2081
 critical GIS and, 2:614–615
 cultural differences role in, 4:2080
 ethnophysiology term and, 4:2080
 flat boundary and, 4:2081
 “geopragmatic” view and, 4:2080
 humanistic GIScience and, 3:1479
 Werner Kuhn's work in, 4:1672–1673
 metadata and, 4:1885, 4:2078–2079, 4:2085
 ontological commitments definition and, 4:2079
 ontology definition and, 4:2079
 Donna Peuquet's work and, 4:2165
 postmodern ontologies and, 5:2265–2266
 semantic heterogeneities definition and, 4:2079–2080
 semantic interoperability definition and, 4:2079–2080
 semantic similarity definition and, 4:2079–2080
 spatial granularity element in, 4:2081
 term ambiguities and, 4:2078–2079
- Ontology, 4:2081–2083**
 abstractions and, 4:2082
 critical geography and, 4:2083
 criticism of, 4:2083
 definition of, 4:2081
 diversity recognition and, 4:2082
 epistemology and methods transition and, 4:2082
 flat ontology and, 4:2082
 Andrew Frank's work in, 3:1170
 geographic methods and, 4:2082
 geographic technology and, 4:2083
 GIS and, 4:2083
 humanistic GIScience and, 3:1479
 Marxist geographies and, 4:2082
 ontology of a study and, 4:2082
 ontology role in geography and, 4:2081–2082
 physical and cultural geography and, 4:2082
 place, environment, society, and philosophy
 interconnectedness and, 4:2082
 postmodern geography and, 4:2082
 realism and, 5:2369–2371
 relations among features and, 4:2082
 scale and generalization structures and, 4:2082
 spatial ontologies and, 4:2081–2082
 transformative nature of, 4:2082
See also Ontological foundations of geographical data
- OPEC. *See* Organization of the Petroleum Exporting Countries (OPEC)
- Open geodata standards, 4:2083–2085**
 data conversion and, 4:2084
 definition of, 4:2083
 functions of, 4:2083–2084
 geodata storage and transmission complexities and, 4:2081
 International Standards Organization/Technical Committee
 211 and, 4:2084–2085
 interoperability and spatial data standards and, 3:1623–1625
 ISO 19101:2002 and, 4:2084
 ISO 191** family of standards and, 4:2084
 metadata and, 4:1885, 4:2085

- Open Geospatial Consortium (OGC) and, 4:2083, 4:2084, 4:2085–2086
- See also* **Open Geospatial Consortium (OGC); Open Source Geospatial Foundation (OSGeo); Open Source GIS (OSGIS)**
- Open Geospatial Consortium (OGC), 4:2085–2086**
- basic spatial operations defined by, 4:2084
 - Canadian Geospatial Data Infrastructure interoperability project and, 4:2085
 - client-server architecture standards of, 1:426
 - Egenhofer and Herring's nine-intersection scheme and, 6:2848–2849
 - functions of, 4:2085
 - Geographic Resources Analysis Support System (GRASS) and, 4:2085
 - geospatial industry focus of, 3:1259
 - geospatial semantic Web and, 3:1260
 - GIS Web services and, 3:1321, 5:2528
 - Google's Keyhole Markup Language (KML) and, 3:1624, 4:2085
 - implementation standards of, 4:2085
 - International Standards Organization/Technical Committee 211 (ISO-TC 211) and, 4:2084–2085
 - Internet GIS and, 3:1621
 - interoperability and spatial data standards and, 3:1623–1625
 - interoperability focus of, 4:2085
 - OGC Specification Program, consensus process and, 4:2084
 - open geodata standards and, 4:2083, 4:2084
 - Open GIS Abstract Specification and, 4:2084, 4:2085
 - Open GIS Simple Features Interface Standard (SFS) and, 4:2084
 - open-source GIS software and, 4:2085
 - semantic interoperability and, 4:2085
 - Specification Program standards and, 4:2085
 - standards for geographic information exchange and, 4:2085
 - Web Coverage Service of, 4:2084
 - Web Feature Service of, 4:2084
 - Web Map Service and, 4:2084
 - Web services standards and, 4:2084
 - “well-known text” and “well-known binary” formats of, 4:2084
 - Kuhn Werner and, 3:1673
- See also* **Open geodata standards; Open Geospatial Consortium (OGC); Open Source Geospatial Foundation (OSGeo); Open Source GIS (OSGIS); Spatial data infrastructures (SDI)**
- Open-pit mining, 4:2086–2088**
- ancient mines and, 4:2086
 - Church Rock Mine, Arizona and, 4:2087
 - coal extraction and, 4:2086
 - commonly mined minerals and, 4:2086
 - environmental effects of, 4:2086–2087
 - EPA's Toxic Release Inventory and, 4:2087
 - Grasberg-Erstsberg open-pit mine, Indonesia and, 4:2087
 - human health affected by, 4:2087–2088
 - hydraulic practice and, 4:2086–2087
 - Industrial Revolution resource needs and, 4:2086
 - mining company responsibilities and, 4:2088
 - opencast mine examples and, 4:2086
 - quarrying definition and, 4:2086
 - Red Dog zinc mine, Alaska and, 4:2087
 - “shoot-and-shove” coal mining practices and, 4:2086
 - St. Elizabeth Gold Mine, Mahdia, Guyana, 4:2087 (photo), 4:2088 (photo)
 - Surface Mining Control and Reclamation Act (1977) and, 4:2088
 - terms related to, 4:2086
 - Yankee Doodle copper mining tailings pond, Montana, and, 4:2087
- Openshaw, S., 2:824
- Open Source Geospatial Foundation (OSGeo), 4:2088–2089**
- educational outreach activities of, 4:2089
 - governance of, 4:2089
 - history of, 4:2089
- Open Source GIS and, 4:2089
- Open Source Software for Geoinformatics conference series of, 4:2089
- projects of, 4:2089
 - services and mission of, 4:2088–2089
- See also* **GIS software; Open geodata standards; Open Geospatial Consortium (OGC); Open Source GIS (OSGIS)**
- Open Source GIS (OSGIS), 4:2090–2091**
- Free Software Foundation and, 4:2090
 - free source code feature of, 4:2090
 - functionality of, 4:2091
 - interoperability and, 4:2090
 - meta data management and, 4:2091
 - Open Geospatial Consortium (OGC) and, 4:2090
 - Open GRASS Foundation (OGF) and, 4:2090
 - Open Source Geospatial Foundation and, 4:2090
 - Open Source Initiative and, 4:2090
 - organizations and, 4:2090
 - philosophy, development methods, and community in, 4:2090–2091
 - services provided by, 4:2091
 - software projects and, 4:2090
 - specific software titles and, 4:2090
 - virtual developer and user communities and, 4:2091
- See also* **GIS software; Open geodata standards; Open Geospatial Consortium (OGC); Open Source Geospatial Foundation (OSGeo)**
- Open space, 4:2091–2094**
- access element of, 4:2092
 - Central Park, 4:2092 (photo)
 - collaborative approaches to, 4:2093–2094
 - conflicts over uses of, 4:2092–2093
 - definitions and values of, 4:2092–2093
 - federal Land and Water Conservation Fund and, 4:2093
 - greenspace term and, 4:2092
 - land trusts and, 4:2093
 - management and protection of, 4:2091–2092
 - meaning of at various scales and, 4:2901–2092
 - purchase of, 4:2093
 - recreational open spaces and, 4:2092–2093
 - regulatory protection approach to, 4:2093
 - “smart-growth” programs and, 4:2093
 - watershed conservancies and, 4:2093
- Ord, J. Keith, 3:1274
- Oregon
- new urbanism, Orenco Station, Portland, 4:2017, 4:2026 (photo), 4:2027, 4:2027 (photo)
 - Oregon Land Use Act (1973) and, 4:1746
- Orfali, R., 2:777
- Organic agriculture, 4:2094–2096**
- certification process of, 4:2094
 - Community Sponsored Agriculture and, 4:2095
 - crop rotation and, 2:627–630
 - definition of, 4:2094
 - diverse organic farm in San Juan Bautista, California, and, 4:2095 (photo)
 - ecosheds and, 2:857
 - environmental certifications in, 2:914
 - Environmental Working Group and, 4:2095
 - fair trade certification and, 3:1081
 - International Federation of Organic Agriculture Movements (IFOAM) and, 2:914
 - ISO 14001 Standard for Environmental Management Systems and, 2:914
 - mixed farming and, 4:1914–1917
 - organic food labels and, 4:2095
 - organic milk and, 4:2094

- pesticide residue and GMOs issues and, 4:2094–2095
 U.S. organic food market and, 4:2094–2095
 USDA National Organic Standards and, 4:2094
 “USDA Organic” seal categories and, 4:2095
- Organisation for Economic Co-operation and Development (OECD), 4:2096–2097**
 biotechnology definition and, 1:33
 CO₂ emissions, GHGs of developing countries and, 3:1377
 critics of, 4:2096
 foreign aid and, 3:1151–1153
 functions of, 4:2096
 members of, 4:2096, 4:2097 (fig.)
 mission of, 4:2096
 official development assistance (ODA) and, 3:1151
 offshore finance centers regulation and, 4:2071
 poverty data of, 5:2275
 public water service in, 5:2316
 recent activities of, 4:2096
- Organization of the Petroleum Exporting Countries (OPEC), 4:2097–2100**
 advantages of, 4:2097
 alternative oil sources and, 4:2099
 cartel definition and, 4:2097
 demand growth for oil and, 4:2098
 history of, 4:2098–2099, 4:2163
 long-term stability of, 4:2099–2100
 member nation conflicts and, 4:2099
 member profiles and, 4:2099–2100, 4:2100 (2100)
 member states, functions and operations of, 4:2098
 oil embargo by Arab oil producers and, 4:2099
 oil shortages, rising oil prices and, 4:2099, 4:2163
 Organization of Arab Petroleum Exporting Countries and, 4:2099
 Persian Gulf War and, 4:2099
 unstable structural conditions of, 4:2097–2098
 U.S. invasion of Iraq and, 4:2099
 world political factors affecting, 4:2098–2099
- Organophosphates, 4:2100–2101**
 chemical warfare and, 4:2101
 definition of, 4:2100
 Gulf War syndrome and, 4:2101
 mechanism of, 4:2101
 nerve gasses and pesticides use of, 4:2101
 pesticides and, 4:2157–2158
 Gerhard Schrader and, 4:2101
 toxic properties of, 4:2100–2101
 Tokyo subway sarin attack and, 4:2101
- Orian, Gordon, 4:1716
- Orientalism, 4:2101–2104**
 agency *vs.* power and, 4:2103
 celebratory representation of the noble savage and, 2:1021
 critiques of Said’s *Orientalism* and, 4:2103–2104
 definitions, 4:2101–2102
 development geographies and, 4:2104
 dialectic between author and discursive body and, 4:2102
 environmental determinism and, 4:2102–2103
 essentializing representations and, 4:2102–2103
 exoticized Orient and, 4:2102
 feminist scholarship, 4:2104
 gender issues in, 4:2104
 geography and, 4:2103
 globalization of popular culture and, 5:2229
 Derek Gregory’s work and, 3:1381, 4:1787, 4:2103
 historicism and, 3:1434
 humanism *vs.* anti-humanism conflict and, 4:2103
 imaginative geography and, 4:2102
 institutional Orientalism and, 4:2102–2103
 literature and art and, 4:2104
 masculine worldview of, 4:2103
 modern context of, 4:2104
 “the Occident” (the West) *vs.*, 4:2101–2102
Orientalism (Said) and, 4:2102–2103, 5:2259–2260, 5:2272
 pejorative Orient representation and, 4:2102
 positionality and, 5:2258
 postcolonial studies and, 4:2103, 4:2104
 riverine despotism, “hydraulic empires” theory and, 5:2215
 Edward Said’s work and, 2:1030, 4:1787, 4:2101–2104, 5:2259–2260, 5:2272
 Self and the Other separation and, 4:2102, 5:2272
 September 11, 2001, and, 4:2103
 textual representations and, 4:2103
 use within geographic subfields by, 4:2104
- Ortelius, 4:2104–2106**
 cartography work of, 1:341 (fig.), 1:342, 1:350, 4:2104–2106
 empirical approach of, 4:2106
 historical atlas efforts of, 4:2106
 Gerardus Mercator and, 4:2106
Theatrum Orbis Terrarum, atlas of the world and, 4:2105 (fig.), 4:2106
- Ortner, Sherry, 2:817
- OSGeo. *See* Open Source Geospatial Foundation (OSGeo)
- Ostrom, Elinor, 1:525, 1:529, 1:534
- Oswin, Natalie, 5:2332–2333
- Other/Otherness, 4:2106–2108**
 animal geographies, “inappropriate/d other” concept and, 1:78
 Simone de Beauvoir and, 4:2107
 colonialism, racism, and patriarchy and, 4:2107
 colonial mappings of the Other and, 4:2106
 critical race theory and, 4:2107
 ethnocentrism and, 2:1027
 explanation of, 4:2106
 geographical imagination and, 3:1221–1225
 human behavior stereotypical notion of
 place and, 4:2107
 human geography and, 4:2107
 marginalization and exclusion and, 4:2106
 noble savage concepts and, 2:1020–1022
 Orientalism and, 4:2101–2104
 “Othering” of the body, body geographies and, 1:288
 postcolonialism and, 4:2107
 poststructuralism and, 5:2272
 power and control elements in, 4:2107
 power dynamics element in, 4:2106
 process of Othering and, 4:2107
 Edward Said’s *Orientalism* work and, 4:2106–2107, 5:2259–2260, 5:2272
 space and identity issues and, 4:2107
 territory and borders concepts and, 4:2107
 urban geography and, 4:2107
See also Ethnicity; Sexuality, geography and/of
- Our Common Future* (World Commission on Environment and Development), 1:256, 5:2220
- Outsourcing, 4:2108–2110**
 definition of, 4:2108
 domestic *vs.* international outsourcing and, 4:2108
 economic and sociocultural consequences of, 4:2108
 Global Production Networks (GPN) and, 4:2108–2109
 Global Value Chains (GVC) Initiative and, 4:2108–2109
 international outsourcing between Western Europe and Bulgaria and, 4:2109 (fig.)
 as restructuring technique, 5:2458

- spatial aspects of, 4:2108
See also Division of labor
- Owen, Robert, 3:1372
- Ozone layer
 volcanic eruptions and, 1:163
See also Chlorofluorocarbons (CFCs); Stratospheric ozone depletion
- Ozone Secretariate, 3:1605
- Pachamama Alliance, 1:96
- Pacific Ocean
 Antarctic Convergence zone and, 1:451
 atmospheric angular momentum in, 1:143
 atmospheric energy variations and, 1:163–165
 atolls in, 1:165–168, 1:166 (photo)
 coastline landforms of, 4:1689
 conservation zoning in, 2:572
 Captain James Cook's exploration of, 2:575
 Hadley cell, 3:1395–1397
 invasion of species in, 3:1472–1473
 major tectonic areas of, 5:2196 (fig.)
 mild, midlatitude climate and, 1:436–437
 ocean-atmosphere variabilities drought factor in, 2:792
 oil and gas drilling platform, Pacific Ocean, 4:2067 (photo)
 sewage entering coastal zones of, 1:501
 Tonga Trench earthquakes, South Pacific and, 2:811
 typhoons in, 1:20 (photo), 1:134
 “warm pool” of sea-surface temperatures in, 1:145
See also El Niño-Southern Oscillation (ENSO)
- Paehlke, Robert, 2:551
- Paglen, Trevor, 4:1897
- Paine, Robert, 4:1655, 4:1656
- Painter, Joe, 2:620
- Pakistan
 basin and range topography in, 1:186
 clothing exports from, 6:2186 (fig.)
 deficient calorie consumption in, 3:1487
 economically active females in, 3:1190 (table)
 groundwater usage in, 3:1386
 independence of, 2:692
 nation-state after colonialism in, 1:517
 opium and heroin production in, 2:797
 population growth in, 5:2241
 textile exports from, 6:2815 (fig.), 6:2816 (fig.)
- Paleoclimatology, 1:671–672
- Palestine
 Biblical map of, 1:196 (fig.)
 British colonization of, 1:514
 economically active females in, 3:1190 (table)
 human rights atrocities in, 3:1481
 “natural ethnicity” of a region concept and, 2:1020
 Ortelius's Map of Palestine and the Holy Lands, 1:341 (fig.)
- Palimpsest, 4:2111–2112**
 applications of, 4:2112
 criticism of, 4:2112
 definition of, 4:2111
 “intertext” and, 4:2112
 landscape as a palimpsest and, 4:2111
 layering element in, 4:2111
 Donald Meinig and, 4:2111
 mythogeography and, 4:2112
 “new cultural geography” and, 4:2111
 origins of term and, 4:2111
 Carl Sauer and, 4:2111
 semiotic model of, 4:2112
 spatial diffusion theory and, 4:2112
- symbolic landscape as, 4:2111–2112
 temporal change of landscape (Sauer) and, 4:2111
 Derwent Whittlesey and, 4:2111
- Palka, Eugene, 4:1897
- Pallasmaa, Juhani, 4:2168
- Panama
 bird species in, 1:199
 domino theory and, 3:1224
 economically active females in, 3:1190 (table)
 Magellan's portage across Isthmus of Panama, 4:1814 (fig.)
 marine aquaculture in, 4:1854 (fig.)
 Panama Canal and, 5:2254
- Panchromatic imagery, 4:2112–2115**
 aerial photography use of, 4:2112, 4:2113–2114
 application of, 4:2114–2115
 definition and explanation of, 4:2112–2113
 digital space-borne sensors and, 4:2114
 example of, 4:2113 (fig.)
 IKONOS high-spatial resolution commercial sensor
 and, 4:2113 (fig.), 4:2114
 Landsat satellite program and, 4:2114, 4:2115 (photo)
 map production and, 4:2115
 multiresolution data fusion and, 4:2115
 panchromatic band characteristics on Earth-imaging satellites
 and, 4:2115 (table)
 panchromatic film and, 4:2112, 4:2113–2114
 photogrammetry and, 4:2114–2115
 satellite based sensors and, 4:2114
 SPOT satellite (France) and, 4:2114, 4:2115 (photo)
 Hermann Carl Vogel's work in, 4:2113
- Pandian, Anand, 5:2339
- Panopticon, 4:2116–2117**
 Bentham's panopticon, 4:2116, 5:2271
 critical panopticism and, 4:2116
Discipline and Punish (Foucault) and, 4:2116
 Michel Foucault and, 4:2116
 Foucault's panopticon, 4:2116
 geospatial technologies and, 4:2117
 as prison model, 4:2116
 as social theory, 4:2116
- Papanek, Victor, 3:1372
- Papua New Guinea
 APEC membership of, 1:121
 Jared Diamond's biodiversity studies of, 2:734
 economically active females in, 3:1190 (table)
 forest fragmentation in, 3:1159
 human-induced invasion of species in, 3:1473–1474
 installed capacity for electricity production forecast,
 2010, 3:1268 (fig.)
 Malay archipelago and, 1:105
 species variations on, 1:209
 tropical rain forest of, 1:234
- Paraguay
 deforestation in, 2:696
 economically active females in, 3:1190 (table)
 hydroelectric power in, 3:1509
- Paris, France
 command and control economy in, 1:304
 infrastructure networks in, 3:1597
 railroad system in, 5:2358, 5:2359 (fig.)
- Park, Robert, 3:1458, 5:2323
- Parker, Dawn, 2:561
- Parks and reserves, 4:2117–2120**
 American wilderness as culture-free nature concept (Cronon)
 and, 5:2339

- Ar Rub'al Khali Wildlife Management Area, Saudi Arabia and, 4:2118
- conflicts, 4:2118
- connected parks or corridors development and, 4:2118
- corridor regions and, 4:2118
- definition of, 4:2117
- ecotourism and, 2:869–874
- effectiveness of, 4:2118–2120
- forms of, 4:2117
- “fortress conservation” concept and, 4:2119
- global coverage and location of, 4:2117–2118
- Grand Teton National Park, Wyoming, 4:1721 (photo), 4:1723, 4:2119 (photo)
- indigenous and community conserved areas (ICCAs) and, 3:1557–1561
- International Union for Conservation of Nature (IUCN) and, 4:2117
- “islandization” of parks issue and, 4:2118
- Kibale National park, Uganda, 4:2118
- mixed outcomes of, 4:2119–2120
- open space and, 4:2091–2094
- patches and corridors and, 4:2131–2133
- protection function of, 4:2117
- protection types and, 4:2117
- Parsons, James, 4:2120–2121**
- AAG service work of, 4:2121
- Berkeley School and, 4:2120
- biogeography work of, 4:2121
- cultural biogeography work of, 4:2121
- field observation and, 4:2121
- generalist research of, 4:2120–2121
- Green Turtle and Man* written by, 4:2121
- Carl Sauer's influence on, 4:2120–2121
- Participant observation, 4:2121–2122**
- anthropology roots of, 4:2121
- black inner city as frontier outpost example (Ley) of, 4:2122
- characteristics of, 4:2122
- Chicago School of sociology and, 4:2121
- clarity and validity of, 4:2122
- definition of, 4:2121
- ethnography and, 4:2121
- feminist geographers and, 4:2122
- Hobo* (N. Anderson) and, 4:2121
- human geography fieldwork and, 3:1103–1005
- interviewing and, 3:1625–1627
- methodology of, 4:2121
- mixed methodologies and, 4:2122
- older people's experience of space (Rowles), example of, 4:2122
- positivism *vs.*, 4:2122
- qualitative methods and, 5:2325
- situated knowledge research and, 5:2548–2549
- space and social conflict research and, 4:2122
- See also* Participant observation: noted individuals
- Participant observation: noted individuals
- Nels Anderson, 4:2121
- David Ley, 4:2122
- Bronislaw Malinowski, 4:2121
- Graham Rowles, 4:2122
- Participatory learning and action (PLA), 4:2123–2124**
- Robert Chambers and, 4:2123
- community development intermediary organizations (CDIOs) and, 4:2123
- definition of, 4:2123
- methodologies used in, 4:2123
- participation, learning, and action elements in, 4:2123
- rapid rural appraisal (RRA) and, 4:2123
- sustainable development and, 4:2123
- See also* Participatory mapping (PM); Participatory planning; Participatory rural appraisal (PRA)
- Participatory mapping (PM), 4:2124–2125**
- approaches to, 4:2124
- countermapping and, 4:2123–2124
- countermapping and, 2:595–596
- definition of, 4:2124
- examples, applications of, 4:2124
- geocollaboration and, 3:1209–1211
- GIS and, 4:2125
- indigenous-community PM projects and, 4:2125
- levels of local participation in, 4:2124
- participatory action research and, 4:2123–2124
- reductionist criticism of, 4:2125
- terms related to, 4:2124
- work flow steps in, 4:2124–2125
- See also* Participatory learning and action (PLA); Participatory planning; Participatory rural appraisal (PRA); Public participation GIS (PPGIS)
- Participatory planning, 4:2126–2129**
- advocacy approach of, 4:2025
- Arnstein's *Ladder of Citizen Participation* and, 4:2126–2127, 4:2126 (fig.)
- augmentation maps and, 1:108–110
- bottom-up strategy of, 4:2128
- ecological risk analysis (ERA) and, 2:840–843
- Patrick Geddes and, 4:1700, 4:2126
- information and communication technologies (ICTs) to empower, 4:2128
- Jane Jacobs and, 4:2126
- limited-dialogue strategies of, 4:2128
- multistakeholder participation and, 4:1956–1959
- stakeholder engagement spectrum and, 4:2127–2128, 4:2127 (fig.)
- sustainable development and, 4:2126
- top-down strategies of, 4:2128
- urban system dimensions and, 4:2126
- wheel of participation and, 4:2126, 4:2129 (fig.)
- Wilcox's five stances of participation and, 4:2127–2128, 4:2128 (table)
- See also* Governance; Participatory learning and action (PLA); Participatory mapping (PM); Participatory rural appraisal (PRA)
- Participatory rural appraisal (PRA), 4:2130**
- definition of, 4:2130
- developing world applications of, 4:2130
- local knowledge focus of, 4:2130
- participatory research and, 4:2130
- rapid rural appraisal (RRA) and, 4:2123, 4:2130
- techniques and methods of, 4:2130
- tyranny of participation and, 4:2130
- See also* Participatory learning and action (PLA); Participatory mapping (PM); Participatory planning
- Patches and corridors in wildlife conservation, 4:2131–2133**
- conservation management and, 4:2131
- corridors' functions and, 4:2131
- fragmented landscapes and, 4:2131
- functional connectivity concept and, 4:2132
- functions of, 4:2131
- indigenous and community conserved areas (ICCAs) and, 3:1557–1561
- landscape and wildlife conservation and, 4:1696–1697
- landscape biodiversity and, 4:1701–1703
- landscape-level experiments and, 4:2131–2132
- local extinction and recolonization processes and, 4:2131
- matrix characteristics factor and, 4:2131, 4:2132
- metapopulations (Levins) within, 4:2131

- natural areas fragmentation and, 4:2131
 parks and reserves and, 4:2117–2120
 patches, island biogeography principles and, 4:2131
 patch size and connectivity factors and, 4:2132
 South Carolina's pine forest habitat example of, 4:2131–2132
 in tropical and temperate landscapes, 4:2131
- Path dependence, 4:2133–2135**
 Brian Arthur's work and, 4:2133
 ball-and-urn models and, 4:2133
 causal possibility, contingency, closure, and constraint elements in, 4:2133
 contingent accidents, microlevel chance events and, 4:2133
 criticism of, 4:2135
 Paul David's work and, 4:2133
 definition of, 4:2133
 development path of a regional system and, 4:2134 (fig.)
 economic versions of, 4:2133–2134
 increasing returns version of, 4:2133
 institutional hysteresis version of, 4:2133–2134
 nonergodicity characteristic of, 4:2133
 regional lock-in and, 4:2134–2135, 4:2134 (fig.)
 Mark Setterfield's work in, 4:2133–2134
 spatial systems evolution and, 4:2134–2135
 stochastic systems theory and, 4:2133
 systems and processes governed by their own history and, 4:2133
 technological lock-in version of, 4:2133
 types, degrees, and causes of, 4:2135
- Patriarchy, geography and, 4:2135–2137**
 Michael Brown and, 4:2136
 dual-systems *vs.* single-systems model of feminist geography and, 4:2136
 feminist geography and, 4:2136
 feminist political geography and, 4:2136
 gender domination focus of, 4:2135–2136
 gendered division of labor issue and, 4:2136
 geography subdivisions and, 4:2136
 Heidi Hartmann's feminist social theory and, 4:2136
 interlocking systems of power and, 4:2136
 locations of patriarchal relations and, 4:2136
 patriarchy across space and place and, 4:2136
 patriarchy definition and, 4:2135
 patriarchy's main elements and, 4:2136
 private *vs.* public spheres of, 4:2136
 Lynn Staeheli and, 4:2136
 systemic nature of patriarchy and, 4:2135–2136
 views of gender within feminist geography and, 4:2136
 Sylvia Walby and, 4:2136
- PCBs. *See* Polychlorinated biphenyls (PCBs)
- PE. *See* Political ecology (PE)
- Peake, L., 5:2335
- Peasants and peasantry, 4:2137–2142**
 accumulation by dispossession concept (Harvey) and, 4:2138–2139
 agribusiness impact on, 4:2139–2140, 4:2141
 banditry, peasant protest and, 4:2141
 capitalist society and, 4:2138–2140
 class-differentiation, class-based identities and, 4:2140
 conservative *vs.* revolutionary peasants and, 4:2140
 de-agrarianization of, 4:2140
 differentiation among, 4:2139
 discourses, 4:2137
 everyday form of resistance by, 4:2141
 folk society, folk-urban continuum and, 4:2137
 gender division of labor and, 4:2139
 historic and geographic contexts of, 4:2137
- India's Naxalite movement and, 4:2141
 land reform and, 4:1692–1696
 “limited good” model of, 4:2137
 Marxist process-oriented view of, 4:2137–2138
 Movimento Sem Terra (MST) and, 4:1948–1951
 multiclass mobilization of peasants and, 4:2140–2141
 neoliberal capitalism and, 4:2137, 4:2140
 new peasant movements (NPMs) and, 4:2141
 peasant farmer carrying straw, Hoi An, Vietnam, 4:2138 (photo)
 peasant identity, agency and, 4:2140–2141
 peasants as commodity producers and, 4:2139
 peasants definition and, 4:2137
 poor, middle, and rich peasants and, 4:2139, 4:2140
 precapitalist peasant communal production mode and, 4:2139
 preindustrial agriculture and, 1:47–49
 primitive accumulation concept (Marx) and, 4:2138
 self-sufficient economy model of, 4:2137–2138
 as society, culture, or economy, 4:2137–2138
 studies of, 4:2137
 “weapons of the weak” concept and, 4:2141
See also Developing world; Peasants and peasantry: noted scholars
- Peasants and peasantry: noted scholars**
 George Foster, 4:2137
 David Harvey, 4:2138
 Eric Hobsbawm, 4:2141
 Robert Redfield, 4:2137
 James Scott, 4:2141
 Teodor Shanin, 4:2137
 Nanda Shrestha, 4:2141
 E. P. Thompson, 4:2141
 Daniel Thorner, 4:2137
 Michael Watts, 4:2139
- Peat, 4:2142–2143**
 in boreal forest biome, 1:215, 1:216–217
 climate change and, 4:2143
 definition of, 4:2142
 ecological importance of, 4:2142–2143
 locations of, 4:2142
 peat bog, Maamturk Mountains near Cong, Ireland, 4:2143 (photo)
 peatland destruction, global warming and, 4:2143
- Peck, Jamie, 4:2013, 4:2014
- Peet, R., 5:2335
- Peet, Richard, 4:2144**
 anarchism and, 1:73
Antipode edited by, 1:73, 2:618, 4:2144
 books written by, 4:2144
 environmental imaginaries and, 2:933
 export-led development views of, 2:1063
 Marxism scholarship of, 4:2144
Modern Geographical Thought and, 4:2144
 nature and society relationship studies of, 4:2144
 political ecology and development studies and, 4:2144
 postmodernism views of, 4:2144
 radical geography and, 4:2143
 spatial imaginaries and, 2:932
- Peluso, Nancy, 2:595, 5:2192, 5:2213
- Penck, Walther, 4:2145**
 William Morris Davis and, 4:2145
 geomorphology work of, 4:2145
 Lester King influenced by, 4:2145
 parallel retreat of slopes, 4:2145
- Pennsylvania
 Amish farm, Lancaster County, 5:2494 (photo)
 graveyard and steel mill, Bethlehem, 5:2690 (photo)
 Three Mile Island nuclear power plant, Middletown, 6:2827 (photo)

Pepper, David, 3:1372, 4:1897

Periglacial environments, 4:2145–2152

- block-fields or kurums and, 4:2149
- boreal forest, or taiga and, 4:2146
- Circumpolar Active Layer Monitoring program and, 4:2150
- climate change and, 4:2149–2151
- climate features of, 4:2146
- climate warming and, 4:2149–2150
- construction techniques in, 4:2151–2152
- drinking water availability issue and, 4:2151
- ecosystems of, 4:2146–2147, 4:2147 (fig.)
- environmental concerns, 4:2149–2152
- frost heave problems and, 4:2151
- frost weathering of soils and, 4:2149
- geomorphic processes in, 4:2148
- ground-ice slumps and, 4:2148
- high northern latitudes location of, 4:2146, 4:2147 (fig.)
- human-induced terrain damage and, 4:2152
- human occupancy and, 4:2149–2152
- intense frost and permafrost characteristics of, 4:2145
- International Permafrost Association and, 4:2150
- katabatic winds and, 4:2149
- landscapes and, 4:2147–2149
- locations of, 4:2145–2146
- natural resources of, 4:2146
- in the Northern Hemisphere, 4:2147 (fig.)
- oil and gas exploration issues and, 4:2152
- paraglacial landscapes and, 4:2147
- pingos, Mackenzie Delta region, northwestern Arctic Canada, 4:2149 (photo)
- pingos and, 4:2148
- pipeline construction issues and, 4:2151 (photo), 4:2152
- polar desert terrain and, 4:2146
- Poles, North and South and, 5:2203–2209
- proglacial landscapes and, 4:2147
- solifluction and, 4:2149
- Trans-Alaska Pipeline System, 4:2151 (photo)
- tree line boundary of, 4:2146
- tundra polygons, northern slope of Alaska, 4:2150 (photo)
- tundra polygons and, 4:2148
- tundra polygons terrain, Southern Banks Island, Arctic Canada and, 4:2148 (photo)

See also Ice

Permaculture, 4:2152–2153

- agroecological production methods and, 4:2152
- definition of, 4:2152
- ethics of, 4:2153
- David Holmgren and, 4:2152
- human habitats and self-sufficient community food production, 4:2152
- local agrarian production techniques and, 4:2152
- Bill Mollison and, 4:2152
- principles and, 4:2153
- systems ecology and geography synthesis and, 4:2152

Permafrost, 4:2153–2157

- active layer of, 4:2154, 4:2156 (fig.)
- in Alaska and Canada, 1:215
- boreal forest and, 1:215
- climate change and, 1:461, 4:2154
- continuous, discontinuous, sporadic, and isolated permafrost in Northern Hemisphere and, 4:2154, 4:2155 (fig.)
- definition of, 4:2153
- degradation of, 4:2154
- degradation of, impacts, 4:2154–2157
- “dry” permafrost and, 4:2154

- greenhouse gas emissions and, 4:2156
- hydrology systems affected by, 4:2156–2157
- “permafrost-climate feedback” loop and, 1:90
- Poles, North and South and, 5:2203–2209
- severe midlatitude climate, 1:441–442
- soils of, 4:2154
- thermokarst processes and, 4:2154, 4:2156
- variable thickness of, 4:2154

See also Periglacial environments

Perry, David, 3:1595

Persia, 2:1054

Peru

- agrobiodiversity in, 1:50
- APEC membership of, 1:121
- basin and range topography in, 1:186
- Cathedral of Santa Domingo, Cuzco, 5:2406 (photo)
- cholera in, 1:401
- coca production in, 2:798
- Conference of Latin Americanist Geographers held in, 2:568
- debris avalanche, Yungay, 1:178 (photo)
- ecological footprint of, 2:827, 2:827 (fig.)
- economically active females in, 3:1190 (table)
- El Niño-Southern Oscillation (ENSO) and, 2:889
- Alexander von Humboldt’s travels in, 3:1484
- in situ and adjacent domestication of camu camu trees in, 1:377, 1:377 (photo)
- land use practices, wildlife survival in, 1:77
- llama and guinea pig domesticated in, 2:783
- marine aquaculture in, 4:1854 (fig.)
- mineral deposits, mining in, 4:1911
- nongovernmental organizations (NGOs) in, 1:415
- social movements research in, 1:365
- Spanish colonization of, 1:511, 1:516
- squatter settlements in, 5:2684
- tropical rain forest deforestation in, 1:238
- tropical rain forest of, 1:234

Pesticides, 4:2157–2158

- agrochemical category of, 4:2157
- biomagnification process and, 2:939
- classification systems of, 4:2157
- DDT, 4:2158
- definition of, 4:2157
- environmental impact of, 2:939
- environmental justice issues and, 4:2158
- Environmental Protection Agency (EPA) and, 4:2158
- hydrocarbon pesticides, 4:2158
- inorganic pesticides, 4:2157
- nutrient loading and, 2:939
- organophosphates, 4:2100–2101, 4:2158
- political ecology issues and, 4:2158
- research related to, 4:2158
- Silent Spring* (Carson) and, 4:2158
- synthetic pesticides, 4:2157

Pest management, 4:2158–2161

- Bio Energetic Synchronization Technique (BEST) and, 4:2160 (photo)
- biological control methods of, 4:2160–2161
- chemical control (pesticides) methods of, 4:2160
- coordinated management strategy, systematized decision making and, 4:2159
- “creation” of new pests and, 4:2159
- cultural control methods of, 4:2161
- definition of, 4:2158–2159
- differences in problems and priorities, 4:2159
- exotic species and, 2:1048–1050
- GIS mapping techniques and, 4:2161

- Hawaii fruit fly area wide pest management program and, 4:2160 (photo)
 history of, 4:2159
 human-animal conflict research and, 4:2159
 human geography and, 4:2161
 individual to national scales of, 4:2159
 integrated pest management (IPM) and, 4:2159–2160
 mechanical control methods of, 4:2161
 organophosphates and, 4:2100–2101
 “pest” as subjective, context-dependent classification and, 4:2159
 pest control *vs.*, 4:2159
 physical geography and, 4:2161
 regional, national, and international legislation, 4:2159
 threat level assessment of, 4:2159–2160
 varietal control methods of, 4:2161
- Petchenik, Barbara, 3:1402
- Peters, Gary, 5:2247
- Petroleum, 4:2161–2164**
 Baku-Tbilisi-Ceyhan Pipeline Company and, 4:2163
 coal and, 1:483–486
 coastal and marine pollution and, 1:503
 crude oil term and, 4:2161
 environmental impacts of oil fields and, 2:946–948
 environmental impacts of pipelines, 2:948–951
 environmental transformations from, 4:2163–2164
 Exxon Mobil and, 4:2162
 gasoline demands and, 4:2162
 geography of petroleum consumption and, 4:2164 (fig.)
 geological elements in formation of, 4:2161
 global reserves of, 2:903 (fig.), 2:904 (fig.)
 major petroleum-producing countries and, 4:2163, 4:2163 (fig.)
 new geographies of distribution of, 4:2163
 oil and gas drilling platform, Pacific Ocean, 4:2067 (photo)
 oil crisis of 1973–1974, 4:2163
 oil fields discoveries and, 4:2163
 oil industry global players and, 4:2162
 oil pipeline construction and, 4:2162–2163
 oil spills and, 4:2073–2076
 OPEC cartel and, 4:2097–2100, 4:2163
 petroleum-producing countries and, 4:2163 (fig.)
 political importance of, 4:2162
 Standard Oil Company and, 4:2162
 storage and refining techniques and, 4:2162
 technical term definition of, 4:2161
 transnational economic petroleum networks and, 4:2164
 transportation issues and, 4:2162
 well drilling technology and, 4:2162
 World War I, World War II and, 4:2162–2163
- Peuquet, Donna, 4:2165**
 academic career of, 4:2165
 geographic representation work of, 4:2165
 geovisualization and geographic databases work of, 4:2165
 multiagent systems research of, 4:2165
 “The Ontology of Fields” workshop co-developed by, 4:2165
 service work of, 4:2165
- Phenomenology, 4:2165–2169**
 academic “right” *vs.* “left,” 4:2168–2169
Being and Time (Heidegger) and, 4:2166
 being-in-the-world concept (Heidegger) and, 4:2167
 body subject concept (Merleau-Ponty) and, 4:2166, 4:2168
 constitutive or transcendental phenomenology (Husserl) and, 4:2166
 criticisms, 4:2168–2169
 current trends in, 4:2167–2168
 definition of, 4:2165
 early phenomenological work in geography and, 4:2167
 existential insidedness (Relph) and, 4:2167
 existentialist geographies and, 2:1046–107, 4:2166
 existential phenomenology and, 4:2166–2167
 geographic issues addressed by, 4:2165–2166
 history and nature of, 4:2166
 humanist geography and, 4:2167
 intentional human awareness and, 4:2166–2167
 interviewing and, 3:1625
 life-world concept and, 4:2167
 lived space concepts in, 4:2167–2168
 natural attitude, acceptance of life-world and, 4:2167
Phenomenology of Perception (Merleau-Ponty) and, 4:2166
Place and Placeness (Relph) and, 4:2167
 place ballet concept (Seamon) and, 4:2168
 positionality and, 5:2257–2248
 positivism and, 4:2167
 responsive environment concept (Bentley) and, 4:2168
 sense of place concept in, 4:2168
 spatial-temporal regularity of individuals and, 4:2168
 third places concept and, 4:2168
 topophilia concept (Tuan) and, 4:2167
See also Phenomenology: noted scholars
- Phenomenology: noted scholars**
 Chris Allen, 4:2168
 Ian Bentley, 4:2168
 Anne Buttimer, 4:2167
 Edward Casey, 4:2168
 Mindy Fullilove, 4:2168
 Clarence Glacken, 4:2167
 Martin Heidegger, 4:2166
 Edmund Husserl, 4:2166
 William Kirk, 4:2167
 David Lowenthal, 4:2167
 Jeff Malpas, 4:2168
 Maurice Merleau-Ponty, 4:2166, 4:2168
 Robert Mugerauer, 4:2168
 Ray Oldenburg, 4:2168
 Gunnar Olsson, 4:2166
 Juhani Pallasmaa, 4:2168
 John Pickles, 2:1046, 4:2182–2183
 Edward Relph, 4:2167
 David Seamon, 4:2168
 Ingrid Leman Stefanovic, 4:2168
 Kay Toombs, 4:2168
 Yi-Fu Tuan, 4:2167, 6:2890–2891
 J. K. Wright, 4:2167
- Philadelphia, Pennsylvania**
 Baldwin Locomotive Works in, 4:1821
 textile production in, 4:1821
- Philander, George, 4:1754**
- Philippines**
 antiglobalization in, 1:95 (photo)
 APEC membership of, 1:121
 ASEAN membership of, 1:127, 1:128 (table), 1:129, 1:129 (table)
 Coron Island, coral island seascape, Tagbanwa people, 3:1560 (photo)
 economically active females in, 3:1190 (table)
 forest fragmentation in, 3:1159
 hacienda plantation form in, 5:2193
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Japanese electronics industry in, 2:885–886
 Malay archipelago and, 1:105
 Malayo-Polynesian languages in, 4:1753, 4:1753 (fig.)
 marine aquaculture in, 4:1854 (fig.)
 market-based land reform in, 4:1695
 Mount Pinatubo’s eruption, 1991, 6:3028 (photo)

- nongovernmental organizations (NGOs) in,
1:415, 1:415 (photo)
- Philippine Association for Conservation and Development
and, 1:96
- silver trade and, 1:512
- Spanish colonization of, 1:515
- squatter settlements in, 5:2682
- tropical rain forest of, 1:234
- volcanic eruptions in, 1:163
- Philipps, Jonathan, 2:562
- Phillips, C. W., 3:1402
- Philo, Chris, 5:2266
- Phosphorus cycle, 4:2169–2171**
biochemical reactions role of, 4:2169
deep ocean storage and, 4:2170–2171
global transfer of phosphorus and, 4:2170
human activities and, 4:2171
low bioavailability feature of phosphorus and, 4:2169–2170
ocean biota and, 4:2170
particulate fraction and, 4:2170
rivers role in, 4:2170
surface ocean and, 4:2170
- Photochemical smog, 4:2171–2173**
air quality criteria and, 4:2172
definition of, 4:2171
early-morning smog, Quito, Ecuador, 4:2172 (photo)
geographic factors in, 4:2172
ground-level ozone in, 4:2171
health effects of, 4:2173
ingredients in, 4:2171
nitric oxide in, 4:2171
peroxyacetyl nitrates (PAN) formation and, 4:2172
reactions formulas and, 4:2171
reduction of, 4:2173
sunlight and, 4:2171
transport of pollutants and, 4:2172–2173
volatile organic compounds in, 4:2171
- Photogrammetric methods, 4:2173–2175**
accuracy measures of, 4:2174
activities contained within, 4:2175
aerial photograph flight runs and, 4:2174
applications and subfields of, 4:2175
central-perspective projection element in, 4:2174
close-range photogrammetry and, 4:2174
image processing methods of, 4:2175
metric properties of, 4:2174
object displacements in, 4:2174
purpose of, 4:2173
standard approach of, 4:2173–2174
stereometry principles and, 4:2173
triangulation principle in, 4:2173
- Photography, geography and, 4:2175–2178**
aerial, repeat, and photogrammetry photography types and, 4:2176
James Wallace Black, 4:2176
chronologically replicated photographic views and, 4:2176
cultural geographies and, 4:2177
Louis Jacques Mandé Daguerre's method and, 4:2175
early photographic techniques and, 4:2173–2175
environmental organizations use of, 4:2177
environmental photography, photographers and, 4:2177
exploratory expeditions and, 4:2176–2177
geographical imagination and, 4:2177
geographic knowledge acquisition and, 4:2175–2176, 4:2177
Geography Lesson daguerreotype and, 4:2176 (photo)
GIS and digital imaging and, 4:2175
- Nadar and, 4:2176
- National Geographic Society and, 4:1977–1978
- negative-positive process and, 4:2175
- “One-World, Whole-Earth” *Apollo* space mission (Cosgrove)
and, 4:2175
- people and place relationships and, 4:2177
- phototypography, or photogrammetry and, 4:2176
- popular geography and, 4:2177
- satellite imagery and, 4:2176
- silver-coated copper plate method and, 4:2175
- space and place scholarly issues and, 4:2177
- William Henry Fox Talbot and, 4:2175
- teaching and learning applications of, 4:2177
- vertical and oblique aerial photographic techniques and, 4:2176
- Physical climatology, 1:472
- Physical geography, history of, 4:2178–2182**
Ernst Antevs' work in, 1:81–82
Richard Chorley's geomorphology work and, 1:403–404
dendrochronology and, 2:711
fieldwork in, 3:1105–1110
Gaia theory and, 3:1175–1178
geomorphic cycle and, 3:1241–1244
timeline of early Greeks and Romans, 4:2178
timeline of Middle Ages to 1800, 4:2178–2179
timeline of 1800–1950, 4:2179–2181
timeline of 1950–2000, 4:2181
timeline of 21st century, 4:2181–2182
See also Geomorphic cycle; Geomorphology; Physical geography,
history of: *specific timeline below*
- Physical geography, history of: early Greek and Roman
Aristotle, 4:2178
Earth as a spherical shape and, 4:2178
Earth's circumference calculation and, 4:2178
Eratosthenes, 4:2178
Geographica (Strabo) and, 4:2178
Guide to Geography (Ptolemy) and, 4:2178
latitude and longitude concepts (Ptolemy) and, 4:2178, 5:2300
Ptolemy, 4:2178, 5:2300, 5:2387
Roman empire expansion and, 4:2178
Strabo, 4:2178
- Physical geography, history of: Middle Ages to 1800
al-Idrisi, 4:2179
Arab geographers, 4:2179
Martin Behaim, 4:2179
Geographia generalis (Varenus) and, 4:2179, 5:2387
geography branches of knowledge (Kant) and, 4:2179
geography subdivisions (Varenus) and, 4:2179, 5:2387
human knowledge subdivisions (Kant) and, 4:2179
Ibn Battutah, 4:2179
Ibn Khaldūn, 4:2179
Immanuel Kant, 4:2179
knowledge organization (Kant) and, 4:2179
Renaissance exploration and, 4:2178, 4:2179
spherical globe (Behaim) and, 4:2179
technology advances and, 4:2179
Viking exploration and, 4:2178
- Physical geography, history of: 1800–1950
Louis Agassiz, 4:2180
American Geographical Society and, 4:2180
Frederic Clements, 4:2180
climate classification (Köppen) and, 4:2180
Henry Cowles, 4:2180
cycles of erosion and landscape development
(W. M. Davis) and, 4:2180
Charles Darwin, 4:2180

- data collection and classification and, 4:2181
 William Morris Davis, 4:2180
 V. V. Dokuchaev, 4:2180
 geographical societies and, 4:2180
 geography subviews and, 4:2180
 G. K. Gilbert, 4:2180–2182
 glaciation research (Agassiz) and, 4:2180
 human degradation of environment (Marsh) and, 4:2180
 Alexander von Humboldt, 4:2180
 James Hutton, 3:1245, 4:2179–2180
 Wladimir Köppen, 4:2180
Kosmos (Humboldt) and, 4:2180
 landscape evolution research (Gilbert) and, 4:2180–2181
 Charles Lyell, 4:2179–2180
 George Perkins Marsh, 4:2180
 pedology (Dokuchaev) and, 4:2180
 plant succession theories (Clements and Cowles) and, 4:2180
Principles of Geology (Lyell) and, 4:2180
 Carl Ritter, 4:2180, 5:2387, 5:2470–2471
 theory of evolution and, 4:2180
 theory of uniformitarianism and, 4:2179–2180
 Alfred Wallace, 4:2180
- Physical geography, history of: 20th century, second half**
 academic departments and, 4:2181
 biodiversity issues and, 4:2181
 global warming issues and, 4:2181
 Arnold Guyot, 3:1394
 Ferdinand Hayden, 3:1408–1409
 human activities issues and, 4:2181
 Walther Penck, 4:2145
 physical geography as a discipline and, 4:2181
 quantitative revolution and, 4:2181
 remote sensing and GIS tools and, 4:2181
 systems-theory approach to, 4:2181
 C. Warren Thornthwaite, 6:2821–2822
- Physical geography, history of: 21st century**
 environmental issues and, 4:2182
 human population growth issues and, 4:2182
 information-processing technology and, 4:2182
 interdisciplinary collaborations and, 4:2182
 measurement technology advances and, 4:2182
 remote sensing and satellite technology and, 4:2182
 resource consumption issues and, 4:2182
- Piaget, Jean, 1:391, 5:2609, 5:2610
 Pick, J., 1:308
- Pickles, John, 4:2182–2183**
 alternative mappings of contemporary society and, 4:2183
 changing global economic geographies and, 4:2183
 Counter-Cartographies Collective and, 4:2183
 critical cartography work of, 4:2183
 critical GIS and critical geography work of, 4:2182–2183
 critical social theory and, 4:2182, 4:2183
 existentialism and, 2:1046
 globalization of apparel industry studied by, 4:2183
Ground Truth written by, 4:2182
A History of Spaces written by, 4:2183
 phenomenology and spatiality work of, 4:2183
 political economies of power and development work of, 4:2183
 regional analysis work of, 4:2109
- Pigou, Arthur, 4:1857
- Pilgrimage, 5:2184–2186**
 criticism of, 5:2184
 cultural and political developments related to, 5:2184
 definition of, 5:2408
 group rituals and, 5:2184
- Holy Mecca in Saudi Arabia, 5:2185 (photo)
 importance of, 5:2184
 modern tourism and, 5:2185
 national shrines and, 5:2184
 as religious focal points, 5:2184
 revived interest in, 5:2184
 as sacred demand response, 5:2184
 sacred places, religious geographies and, 5:2407–2408
 site examples of, 5:2184
See also Religion, geography and
- Pinchot, Gifford, 2:570
 Pinder, John, 2:1037
 Piraro, Dan, 3:1219 (image)
 Pittsburgh, Pennsylvania, 4:1821
- Place, 5:2186–2188**
 building and dwelling connections and, 5:2187
 decentering of authoritative knowledge and, 5:2187
 geographical self, 5:2187
 home as a metaphor for, 5:2186–2187
 human agency and, 5:2187
 human geography and, 5:2186
 human identity and, 5:2187
 humanist geography and, 5:2186–2187
 integrative approaches regarding, 5:2187
 locality studies and, 4:1790–1792
 palimpsest concept and, 4:2111–2112
 place is associational and, 5:2187
 production of space and, 5:2297–2298
 Edward Relph, 5:2410–2411
 social production of spaces and, 5:2187
 space/place issue and, 5:2186
 spatial science and, 5:2186
- Place names, 5:2188–2191**
 conflicts of use and spellings of, 5:2189
 Dr. Martin Luther King Jr. Boulevard in Harlem, New York City, and, 5:2190 (photo)
 function of, 5:2188
 gazetteers and, 3:1185–1186
 geocoding and, 3:1208–1209
 image-generating power of, 5:2189
 naming as resistance by marginalized groups and, 5:2190
 permanence of, 5:2189
 powerful connotations and, 5:2189
 power relations and, 5:2189
 sense of order and familiarity and, 5:2189
 as spatial reference, 5:2189
 study of, 5:2190
 as symbols, 5:2189
 taking ownership of places and, 5:2189
 toponymy and, 6:2840–2850
 United Nations Group of Experts on Geographical Names (UNGEGN) and, 5:2189
- Place promotion, 5:2191–2192**
 academic foci, 5:2191–2192
 city image reformation and, 5:2191
 critical perspectives on, 5:2191–2192
 definition of, 5:2191
 historical context of, 5:2191
 investment capital attraction and, 5:2191
 marketing efforts and, 5:2191
 mass transit evolution and, 5:2191
 railroads, frontier development and, 5:2191
 suburbs and, 5:2191
 tourism and, 5:2191
- Plantations, 5:2192–2195**
 agro-economic production and, 5:2192

- biofuels crops and, 5:2194
- blue agave plantation, Tequila, Mexico, 5:2194 (photo)
- boom crops of, 5:2193
- characteristic variations of, 5:2192–2193
- colonial and postcolonial history of, 5:2192
- community-based natural resource management and, 5:2194
- definition of, 5:2192
- deforestation and, 5:2193
- ecological effects of, 5:2195
- forest conservation mechanisms and, 5:2194–2195
- forest industries and, 5:2195
- global development institutions and, 5:2193
- global forestry institutions and, 5:2194–2195
- Great Depression and, 5:2193
- hacienda form of, 5:2193
- land and resource conflicts, 5:2194
- as organizational form, 5:2192
- payments for ecosystem services and, 5:2195
- rural insurgencies suppression and, 5:2192
- smallholder plantations and, 5:2195
- social countermovements and, 5:2194
- state control, political-economic power and, 5:2192
- state subsidies and, 5:2194–2195
- tea plantation Cameron Highland, Pahang, Malaysia, and, 5:2193 (photo)
- total institutions, characteristics of, 5:2192
- Plate tectonics, 5:2195–2199**
 - African rift system and, 5:2197
 - aseismic creep and, 2:605
 - convergent (destructive/active) plate boundaries and, 5:2196, 5:2197 (fig.), 5:2198
 - coral reef morphology and, 2:586
 - divergent (constructive) plate boundaries and, 5:2196, 5:2197–2198, 5:2197 (fig.)
 - driving forces in, 5:2198–2199
 - Earth's composition and, 5:2195–2197
 - explosive volcanism and, 5:2198
 - faulting and, 3:1085–1088
 - geologic timescale and, 3:1235–1238
 - geomorphology of Earth's crust and, 5:2195
 - gravity factor in, 5:2198
 - hot spots and, 5:2197
 - Iceland and, 5:2197
 - major lithospheric plates, plate boundaries, directions and rates of, 5:2196, 5:2196 (fig.)
 - Pacific Ring of Fire and, 3:1273
 - paleoclimatology and, 1:471
 - seafloor spreading and continental drift concepts and, 5:2195
 - sea level changes and, 1:494
 - slab pull factor in, 5:2198–2199
 - subduction rollback and, 5:2199
 - teothermal features and, 3:1273
 - transform (conservative) plate boundaries and, 5:2198
 - See also* Diastrophism; Earthquakes; Geomorphic cycle; Geomorphology; Landforms
- Platforms and sensors**
 - LiDAR and airborne laser scanning and, 4:1778–1779
 - See also* Remote sensing
- Plato**
 - absolute space views of, 1:2
 - antipodes, 1:98
 - conservation views of, 5:2584
 - environmental determinism views of, 1:2
 - ethics views of, 2:1013
 - ideal size of political unit views of, 5:2217
 - political impact of geography and, 5:2215
 - social justice issues and, 5:2572
- Playas, 5:2199–2201**
 - definition of, 5:2199
 - ecosystem functions of, 5:2199–2200
 - Great Basin lakes and, 5:2199
 - North American High Plains of Great Plains and, 5:2199
 - origins of, 5:2199
 - playa and associated lunette and, 5:2200 (photo)
 - playa lake term and, 5:2199
 - small playa in winter wheat field, High Plains, 5:2200 (photo)
 - terms related to, 5:2199
- Plumwood, Val, 2:831, 3:1100
- Pohnpei, 3:1634
- Point pattern analysis, 5:2201–2202**
 - complete spatial randomness (CSR) and, 5:2201
 - definition of, 5:2201
 - first-order properties of a spatial point pattern and, 5:2201–2202
 - geographic quantitative revolution and, 5:2201
 - interevent distances distribution and, 5:2201–2202
 - local clustering examination using, 5:2202
 - plant ecology and, 5:2201
 - quadrat methods and, 5:2201–2202
 - as spatial statistics branch, 5:2201
 - theoretical models used in, 5:2201
 - trends for events to exhibit a pattern and, 5:2201
- Point sources of pollution, 5:2203**
 - air pollution, 5:2203
 - area sources and, 5:2203
 - atmospheric dispersion modeling and, 5:2203
 - atmospheric pollution and, 1:151–155
 - definition of, 5:2203
 - emissions trading systems to control, 5:2203
 - government regulation of, 5:2203
 - Love Canal and, 4:1806–1808
 - mobile sources and, 5:2203
 - nonpoint sources of pollution and, 4:2039–2040
 - oil spills and, 4:2073–2076
 - photochemical smog and, 4:2171–2173
 - stationary sources and, 5:2203
- Poland**
 - acid rain in, 1:7
 - AGILE membership of, 1:125 (table)
 - automobile industry in, 1:171
 - cancer rates studies of, 1:336
 - Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 - coal energy source in, 3:1582
 - COMECON membership of, 2:593 (table)
 - ecological footprint and biocapacity of, 2:827 (table)
 - economically active females in, 3:1190 (table)
 - energy policies in, 2:902
 - escape to nature movement in, 2:1032
 - industrialization in, 2:542
 - 19th-century cadastral map, Pielnia, Poland, 1:315 (fig.)
- Polar front theory (PFT), 2:650–652
- Poles, North and South, 5:2203–2209**
 - Aristotle's views on, 1:117
 - climate change and, 5:2203–2204
 - continental glaciers and, 3:1323–1328
 - continental ice sheets and, 5:2204
 - definition of, 5:2203
 - equator and, 2:1008–1009
 - Fourth Assessment of the International Panel on Climate Change and, 5:2204

- Hadley cells and, 3:1395–1397
 International Polar Year and, 5:2204
 polar climate and, 1:449–452
 sea ice and, 5:2204
 tundra biome and, 1:246–250
See also Antarctica; Arctic; **Glaciers: continental**; Greenland; Ice; Periglacial environments; Permafrost; Poles, North and South: North Pole; Poles, North and South: South Pole
- Poles, North and South: North Pole**
 amplified warming in, 5:2204
 Arctic Ocean location of, 5:2204
 discovery controversy, 1:295
 exploration of, 2:1055
 Greenland ice sheet, 5:2204–2205, 5:2206 (fig.)
 polar climate of, 1:449
 sea ice and, 5:2204, 5:2205 (fig.)
 sea ice minimum, 1979–1981, 3:1524 (photo)
 sea ice minimum, 1982–2008, 5:2205 (fig.)
 subarctic climate in, 1:441
- Poles, North and South: South Pole**
 Antarctica ice sheet and, 5:2206 (fig.), 5:2207–2208
 Antarctic sea ice and, 5:2204
 exploration of, 2:1055
 new rifts form on Antarctic ice shelf, 5:2207
 rates of surface elevation change from satellite measurements, 5:2207, 5:2207 (fig.)
- Political ecology (PE), 5:2009–2214**
 animal geographies and, 2:832
 bioregionalism and, 1:255
 Piers Blaikie's work in, 1:284
 carbon trading and carbon offsets and, 1:329–335
 chipko movement and, 1:395–396
 community forestry and, 2:551–553
Cosmos (Humboldt) and, 5:2211
 critiques and new directions in, 5:2213–2214
 critiques of, 5:2213–2214
 cultural ecology and, 2:632–633, 5:2211–2212
 definition of, 5:2209
 distribution of resource access and, 2:779–780
 drought, famine in West Africa example of, 2:622
 drought research and, 2:793
Earth: A Descriptive History (Reclus) and, 5:2211
 ecological justice and, 2:832
 environmental conservation issues and, 2:832, 5:2210, 5:2212
 environmental refugees and, 2:989–991
 environmental security and, 2:998–1000
 extractive reserves and, 2:1072–1073
 inequality of fortunes (Humboldt) and, 5:2211
 multidiscipline origins and features of, 5:2209, 5:2212
 nature-society relationship and, 2:832
 neo-Malthusianism and, 2:622, 5:2212
 neo-Marxism and, 5:2212
 pesticide research and, 4:2158
 political economy and, 5:2211
 “the politicized environment” and, 2:622
 politicizing nature, denaturalizing hazards and, 2:622
 postcolonial resource issues and, 5:2212
 power struggle context of environmental conflict and, 5:2210
 social and political dynamics, 5:2210
 social construction of environmental problems and, 5:2209–2210
 social justice and, 5:2212
 soil erosion in Nepal example of, 2:622
 themes and goals in current research, 5:2209–2210
 Third World political ecology term and, 5:2213
 “third world” *vs.* “first world” strands of, 4:1992
 timeline of early colonial and ecological critiques, 5:2210–2211
 timeline of interdisciplinary influences on, 5:2211–2212
 timeline of modern reemergence since 1970s, 5:2212–2213
 timeline of new directions of, 5:2213–2214
 unequal environmental power relations and, 5:2210
 uneven environmental exposure and vulnerability and, 5:2210
See also Common pool resources (CPRs); Common property resource management; Commons, tragedy of the; European green movements; Feminist political ecology; Political ecology (PE): noted individuals
- Political ecology (PE): noted individuals**
 Grahame Beakhurst, 5:2212
 Piers Blaikie, 5:2213
 Harold Brookfield, 5:2212
 Alex Cockburn, 5:2212
 Charles Darwin, 5:2211
 Suzanna Hecht, 5:2213
 Alexander von Humboldt, 5:2211
 Peter Alexivich Kropotkin, 5:2211
 Karl Marx, 5:2211–2212
 Richard Peet, 4:2144
 Nancy Peluso, 2:595, 5:2213
 Élisée Reclus, 5:2211, 5:2371–2372
 Carl Sauer, 5:2212
 Alfred Russel Wallace, 5:2211
 Michael Watts, 5:2213
 Eric Wolf, 5:2212
 Karl Zimmerer, 5:2213
- Political economy, 5:2214–2219**
 biodiversity theory (Diamond) and, 5:2216
Calculus of Consent (Buchanan and Tullock) and, 5:2214
 “curse of natural resources” concept and, 4:1913, 5:2217–2218
 definition of, 5:2214
 disease environment and, 5:2216–2217
 economic theory of democracy (Downs) and, 5:2214
 game theory and, 5:2215
 general geography and, 5:2215–2216
Guns, Germs, and Steel written by, 5:2216
 “hydraulic empires” theory (Wittfogel) and, 5:2215
 institutional economics and, 5:2215
 key concepts in, 5:2214–2215
Logic of Collective Action (Olson) and, 5:2144
 natural resources and, 5:2217–2218
 optimal country size and, 5:2217
Oriental Despotism (Wittfogel) and, 5:2215
 political and economic decision making focus of, 5:2214
 political ecology and, 5:2211, 5:2216
 public choice theory and, 5:2214–2215
 rent seeking and, 5:2217
 trade element in, 5:2218
 utility maximizing individuals element in, 5:2215
See also Political economy: noted individuals
- Political economy of resources**
Political economy: noted individuals
 Daron Acemoglu, 5:2216
 James Buchanan, 5:2215
 Jared Diamond, 5:2216
 Anthony Downs, 5:2214
 Jeffrey Herbst, 5:2217
 Simon Johnson, 5:2216
 Mancur Olson, 5:2215
 Richard Peet, 4:2144
 James Robinson, 5:2216
 Gordon Tullock, 5:2215
 Karl Wittfogel, 5:2215

Political economy of resources, 5:2219–2221

- core *vs.* periphery elements in political and economic systems, 5:2219
- dependency theory and world systems approach to, 5:2219
- ecological economics and, 2:820–824
- ecological justice and, 2:830–832
- ecological modernization and, 2:832–834
- economic globalization and, 5:2220
- multinational corporations and, 5:2220
- political economy disciplines and, 5:2219
- strip mining and, 5:2701–2702
- sustainable development and, 5:2220–2221

See also **Political economy**

Political geography, 5:2221–2225

- African colonialism, 1:512
- African Union (AU) and, 1:25
- Berlin Conference of 1884 and, 1:512
- citizenship and, 1:412–414
- Cold War and, 1:504–505, 5:2222–2223
- critical geopolitics and, 3:1251–1252, 5:2224
- criticism of, 5:2222–2223
- current trends in, 5:2225
- democracy and, 2:705–707
- domino theory and, 2:786–787
- electoral geography and, 2:879–883, 5:2223
- geographical justifications to pursue national goals and, 5:2222
- geopolitics and, 3:1249–1252
- “geopolitics” term (Kjellén) and, 5:2222
- GIS technology and, 5:2224
- Heartland theory (Mackinder) and, 5:2222
- human rights geographies and, 3:1480–1481
- location theory and, 5:2223
- Marxism and, 5:2223
- media power and, 2:541
- military geography and, 4:1896–1897
- nationalism and, 4:1978–1981
- nation concept and, 4:1971–1974
- nation-state borders and, 1:293–294, 5:2224
- natural resources issues and, 5:2224
- New World* (Bowman) and, 5:2222
- oceans and, 4:2068–2069
- origins of, 5:2221–2222
- pan-region world organization concept (Haushofer) and, 3:1407–1408, 5:2222
- political economy and, 5:2223
- political science and, 5:2223
- Politische Geographie* (Ratzel) and, 5:2221–2222
- popular geopolitics and, 2:541
- postmodernism and, 5:2223–2224
- poststructuralism and, 5:2223–2224
- quantitative revolution in, 5:2223
- radical democracy and, 2:705–706
- radical geography and, 5:2223
- redistricting and, 5:2375–2377
- spatial analysis and, 5:2223
- state systems (Gottman), 5:2222–2223
- territory concept in, 6:2802, 6:2803 (fig.)
- transnational democracy and, 2:706
- 21st century and, 5:2224–2225
- See also **Communism and geography**; **Geopolitics**; **Political geography**: noted individuals
- Political geography: noted individuals
 - John Agnew, 1:32–33
 - Jean Gottman, 5:2222–2223
 - Karl Haushofer, 3:1407–1408
 - R. J. Johnston, 4:1643

Rudolf Kjellén, 5:2222

Sir Halford Mackinder, 5:2222

Friedrich Ratzel, 5:2221–2222

Andre Siegfried, 2:879, 5:2223

Peter Taylor, 6:2778

Political maps

- Africa, 6:3154
- Antarctica, 6:3155
- Arctic Region, 6:3156
- Asia, 6:3158
- Australia, 6:3157
- Blau’s map of Europe, mid 17th century, 6:2803 (fig.)
- Caribbean, 6:3162
- Eastern Europe, 6:3161
- Euroregions of cross-border cooperation and, 2:631 (fig.)
- geography of roll-call vote to amend Voting Rights Act, Pennsylvania, 2:882 (fig.)
- New Zealand, 6:3157
- North America: Mexico and Central America, 6:3164
- North America: United States and Canada, 6:3163
- Oceania, 6:3157
- South America, 6:3165
- southeast Asia, 6:3159
- 2004 presidential election, 2:879 (fig.)
- Western Europe, 6:3160
- World map, Mollweide Projection, 6:3152–3153, 6:3169
- See also **World maps**

Polo, Marco

- explorations of, 2:1053, 2:1053 (fig.), 3:1461
- travel writing of, 6:2878 (image)

Polychlorinated biphenyls (PCBs), 5:2225–2226

- adverse effects of, 5:2226
- applications of, 5:2225–2226
- chemical spills, environment, and society and, 1:382–384
- definition of, 5:2225
- disposal options for, 5:2226
- environmental contamination incidents and, 5:2226
- landfill in Warren County, North Carolina, environmental justice example and, 2:960, 2:961 (photo), 2:986
- Stockholm Convention on Persistent Organic Pollutants and, 5:2226
- Toxic Substance Control Act (1976) and, 5:2226
- U.S. ban of manufacture of, 5:2226

Popper, Deborah, 5:2279

Popper, Frank, 5:2279

Popper, Karl, 3:1434, 4:1801

Popular culture, geography and, 5:2226–2231

- art and geography and, 1:118–120
- artisan popular culture, 5:2227
- audience responses factor in, 5:2231
- Captain America and Spiderman examples of, 5:2228 (photo)
- cultural geography *vs.*, 2:637, 3:1142
- Cultural Studies and, 5:2230–2231
- folk culture and, 3:1142–1144, 5:2229
- forms of, 5:2226
- geography and, 5:2227
- globalization and time-space compression of, 5:2229–2230
- globalizing Western culture and, 5:2227
- grassroots, oral side of modern life and, 3:1142
- hegemony and, 5:2230
- “high” culture and, 5:2226–2227
- hybridity and change features of, 3:1142
- mass consumption and, 5:2226
- mass media and, 5:2227
- material culture and practice and, 5:2226–2227

- meaning and ideology used in, 5:2230–2231
 media and geography and, 4:1874–1877
 music and sound geographies and, 4:1967–1969
 Orientalism, 5:2229
 origins of, 5:2227
 participatory popular culture, 5:2227
 popular geographies of production and consumption and, 5:2227–2229
 poststructuralism and, 5:2230–2231
 urban and industrial characteristics of, 3:1142
 Web 2.0 technology and, 5:2227
 world distribution of, 5:2227–2228
- Population and land degradation, 5:2232–2236**
 agricultural intensification and, 5:2235
 carrying capacity and, 1:337, 5:2238–2239
 common property tenure systems factor in, 5:2234
 conservation and, 2:570
 debate, 5:2232–2234
 degradation definition and, 5:2232
 desertification and, 2:715–719
 ecological modernization and, 2:832–834
 food security issue and, 5:2233–2234
 human population affected by, 5:2232, 5:2234–2235
 land use and land cover changes and, 5:2234–2235
 Machakos, Kenya case study of, 5:2234
 migration and, 5:2232
 in mountainous regions, 5:2235
 neo-Malthusian theory and, 5:2233–2234
 population burden on natural resources and sustainability and, 5:2232
 population growth and, 4:1683
 population growth by region and, 5:2232, 5:2233 (fig.)
 poverty factor in, 5:2233–2234
 soil erosion effects and, 5:2235
 UN Convention to Combat Desertification (UNCCD) and, 5:2232, 5:2234
 urbanism land use changes and, 5:2232
- Population and land use, 5:2236–2237**
 agricultural intensification and, 1:36
 agrobiodiversity and, 1:49–50
 bid-rent process and, 5:2236–2237, 5:2237 (fig.), 5:2328
 carrying capacity and, 1:337, 5:2238–2239
 household common utility function element in, 5:2236
 land reform and, 4:1692–1696
 locational rent gradient concept and, 5:2236
 modern human settlement patterns and, 5:2236
 monocentric model of urban form and, 5:2236–2237, 5:2237 (fig.)
 Thünen's theory of agricultural land use and, 5:2236, 6:2832–2834
 transport costs and market value elements in, 5:2236
 urbanism land use changes and, 5:2232
- Population density, 5:2238–2240**
 arable land availability calculations and, 5:2238–2239
 carrying capacity concept and, 5:2238–2239
 from center to periphery decline in, 5:2240
 chaos in population dynamics and, 2:565 (fig.)
 definition of, 5:2238
 density gradient concept (Clark), 5:2240
 ecology and, 5:2238
 frontiers and, 3:1170–1172
 global and rural population densities, 5:2238–2239, 5:2239 (fig.)
 global population density and, 5:2241, 5:2242 (fig.)
 islands of mankind concept (Bunge) and, 5:2238
 natural resources relationship to, 5:2238
 origins of concept and, 5:2238
 science of ecology and, 5:2238
 smart growth policies and, 5:2240
 suburban density clusters and, 5:2240
 transit-oriented development (TOD) and, 4:2024, 5:2240
 urban population density, 5:2239–2240
 urban sprawl management and, 5:2240
 world population densities and, 5:2239 (fig.)
- Population, environment, and development, 5:2240–2245**
 agricultural intensification and, 1:36, 5:2243
 agricultural subsistence crops and, 5:2243
 agrobiodiversity and, 1:49–50
 conservation and, 2:570
 development geography and, 5:2243–2245, 5:2244 (fig.)
 ecological modernization and, 2:832–834
 ecosystem exploitation by humans and, 5:2243
 environment and, 5:2241–2243
 Everglades restoration and, 2:1038–1042
 export crops and, 5:2243
 family planning programs and, 5:2241
 fertilizer and pesticide use and, 5:2243
 forest harvesting and, 5:2243
 global population density and, 5:2241, 5:2242 (fig.)
 international institutions' efforts and, 5:2244–2245
 Kyoto Protocol and, 5:2244
 Malthusianism and, 4:1819–1820
 Montreal Protocol and, 5:2244
 ocean exploitation and, 5:2243
 population growth models and, 5:2241
 population statistics and, 5:2240–2241
 sustainability issues and, 5:2244
 water quality issues and, 5:2241, 5:2243
- Population geography, 5:2245–2249**
 academic courses on, 5:2247–2248
 census and, 1:371–373
 continuous space-and-time models and, 2:566
 criticism of, 5:2249
 definition of, 5:2245
 demographic research and, 5:2248
 demographic transition and, 2:707–710
 demography and, 5:2245, 5:2246–2247
 elderly geographies and, 2:876–878
 fertility rate and, 3:1102–1103
 future trends in, 5:2248–2249
 historical population geography and, 5:2248
 human geography development and, 5:2246
 immigration and, 3:1542–1545
 issues examined by, 5:2245, 5:2249
 Malthusianism and, 4:1819–1820
 mapping techniques and, 5:2246
 migration research and, 5:2248
 mixed-methods issue and, 5:2249
 mortality rate and, 4:1947
 natural growth rate and, 4:1981–1983
 pluralist approach in, 5:2249
Population, Space and Place journal and, 5:2249
 population maps focus and, 5:2246
 quantitative data and, 5:2246
 regional population geography and, 5:2248
 research areas in, 5:2247–2248
 roots and growth of, 5:2245–2247
 textbooks on, 5:2247
 tools and techniques of, 5:2245
 See also Population geography: noted scholars; Population pyramid
- Population geography: noted scholars, 5:2247**
 Jacqueline Beaujeu-Garnier, 5:2247
 John Innes Clarke, 5:2247
 Pierre George, 5:2247

- Robert Larkin, 5:2247
 Gary Peters, 5:2247
 Fredrich Ratzel, 5:2246
 Glenn Trewartha, 5:2245–2246, 5:2247, 6:2882–2883
 John Weeks, 5:2247
 Wilbur Zelinsky, 5:2247
- Population pyramid, 5:2249–2251**
 natural growth rate and, 4:1981–1983
 population age-sex structure and, 5:2249–2250, 5:2250 (fig.)
- Porteous, D., 4:2043
- Porter, Michael
 clusters and competitive diamond work of, 1:481–482, 1:481 (fig.)
Competitive Advantage of Nations written by, 5:2435
 competitive advantage work of, 2:558–559
- Portes, Alejandro, 3:1591
- Portolan charts, 5:2251–2253**
 coastline representation accuracy of, 5:2252
 as “first true maps” (Beazley) and, 5:2252
 island representations on, 5:2252–2253
 Magellan’s circumnavigation route, 4:1814 (fig.)
 map of Western Mediterranean from portolan atlas (ca. 1544) and, 5:2252 (fig.)
 Mediterranean and North Atlantic navigation and, 1:350, 1:352 (fig.)
 rhumb lines network of, 5:2252
 simplistic projection feature of, 5:2252
 spatiality elements of, 5:2252
 territory and mobility conceptions on, 5:2252
- Ports and maritime trade, 5:2253–2257**
 break-bulk cargo *vs.* containerized freight and, 5:2253
 concession agreements element in, 5:2257
 economies of scale issue and, 5:2254, 5:2255 (fig.)
 gateways and hubs in, 5:2254–2256, 5:2256 (fig.)
 global trade and, 5:2253
 largest available containership, 1970–2007 and, 5:2255 (fig.)
 maritime routes element of, 5:2253
 maritime shipping and inland distribution convergence and, 5:2256–2257
 maritime transportation technology and, 5:2253
 new flows of maritime shipping and, 5:2255–2256, 5:2256 (fig.)
 Panama and Suez Canal physical capacities and, 5:2254
 pendulum service concept and, 5:2254–2255
 point-to-point shipping network and, 5:2254–2255
 “portainers,” 5:2254
 ports as valuable resources and, 5:2253–2254
 privatized port operations and, 5:2256–2257
 shipping companies and port operators and, 5:2256–2257
 slow speed and dock port delay drawbacks to, 5:2253
 traffic at fifty largest container ports and, 5:2256 (fig.)
- Portugal
 AGILE membership of, 1:125 (table)
 cartography in, Age of Exploration, 1:342
 colonial empire of, 1:509, 1:509 (fig.), 1:510, 1:511, 1:512
 economically active females in, 3:1190 (table)
 European Union (EU) membership of, 2:1035
 Vasco da Gama’s exploration and, 2:1054, 3:1178–1179
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Lusocentrism of, 2:1030 (table)
 “science” of geopolitics in, 3:1250
 in South Asia, 1:514
 trade with England, comparative advantage of, 2:556, 2:557 (table)
- Positionality, 5:2257–2258**
 definition of, 5:2257
 knowledge and, 5:2257
 qualitative research and, 5:2257
- researcher and researched relationship and, 5:2258
 researcher self-criticism technique and, 5:2258
 strategic location *vs.* strategic position and, 5:2257, 5:2258
 structures of power, privilege issues and, 5:2258
 “us” and “them,” “othering” and, 5:2258
 use of third person strategy and, 5:2257
 value-free research issue and, 5:2257
- Positivism**
 central place theory and, 1:381–382, 3:1295
 chorology replaced by, 1:405
 decline of, 4:1802
 gentrification and, 3:1203
 Derek Gregory’s work and, 3:1380–1381
 humanistic geography and, 3:1476–1477
 participant observation *vs.*, 4:2122
 phenomenology and, 4:2167
 post-positivist geography and, 3:1434
 qualitative methods criticism and, 5:2323–2324
 quantitative methodology and, 3:1429
 radical geography and, 5:2350
See also Logical positivism
- Post, Lauren, 1:192
- Postcolonialism, 5:2259–2262**
 anarchism and geography and, 1:73, 1:74
 challenge to Western power and knowledge and, 5:2259
 citizenship and, 1:412
 colonialism and empire experiences and, 5:2259
Colonial Present (Gregory) and, 3:1381
 critical development geographers and, 5:2261
 critical historical geographies and, 5:2261
 critical Marxist framework, unequal power distribution and, 5:2260
 criticism, 5:2260
 European colonialization, dominant power relations and, 3:1191
 geography’s subfields and, 5:2260–2261
 historical development, 5:2259–2260
 identity geographies and, 3:1528, 5:2261
 imaginative geographies (Said) and, 5:2261
 inequality geographies and, 3:1587
 interdisciplinary features of, 5:2259
 lingering colonial links and, 5:2259
 literature, exposition of postcolonial geographical imaginations and, 4:1787
 Orientalism and, 4:2101–2104, 4:2103
 postcolonial feminism and, 3:1191–1192, 5:2261
 postcolonialism term debate and, 5:2259
 postcolonial term and, 5:2259
 postcolonial theory term and, 5:2259
 race and hybridity and, 5:2260
 representational analyses of, 5:2260
 resistance geographies and, 5:2442
 self-reflexive perspective on, 5:2325
 silencing of colonial people and, 5:2260
 spatiality of colonialism and, 5:2261
 strategic essentialism (Spivak) and, 5:2260
 Subaltern Studies Collective and, 5:2260
 tourism geographers and, 5:2261
 transnational migrations and, 5:2261
See also Postcolonialism: noted scholars
- Postcolonialism: noted scholars**
 Homi Bhabha, 5:2259, 5:2260
 Aimé Césaire, 5:2260
 Frantz Fanon, 5:2260
 Derek Gregory, 3:1381
 Edward Said, 5:2259–2260, 5:2259–2261
 Gayatri Spivak, 5:2259, 5:2260

Postindustrial society, 5:2262–2264

- class and geography intersection and, 1:420
- Coming of Post-Industrial Society* (Bell) ad, 5:2262
- components and/or dimensions of, 5:2262
- counterurbanization and, 2:596–597
- “creative class” and, 5:2263
- criticism of, 5:2263
- leisure-based, service sector economies in, 1:420
- low-value service *vs.* specialized, knowledge-intensive service and, 5:2263
- Marxist theories and, 5:2262, 5:2263
- nation-state as unit of analysis of, 5:2263
- “new middle class” of elite service workers and, 5:2263
- as a predictor of change, 5:2262
- producer services and, 5:2263
- “regeneration” of urban landscapes and, 1:420
- social transformation of, 5:2262
- urban gentrification discourse and, 5:2263
- See also* Postindustrial society: noted individuals

Postindustrial society: noted individuals

- Daniel Bell, 5:2262–2263
- Colin Clark, 5:2263
- Richard Florida, 5:2263
- Ruth Glass, 5:2263
- David Riesman, 5:2262

Postmodernism, 5:2264–2269

- architecture field and, 5:2264
- as attitude, 5:2265–2267
- complexity and fluidity elements in, 5:2265
- conceptual approaches to identities and, 3:1527–1528
- Condition of Postmodernity* (Harvey) and, 3:1405, 5:2265, 5:2268
- consumption analysis and, 2:574
- crisis of representation and, 2:619
- critical historical geography and, 3:1430
- critical human geography and, 2:619
- cultural ecology and, 2:633
- “differences within the same” concept and, 5:2266–2267
- discourse analysis and, 3:1587
- Enlightenment perspectives rejected by, 5:2267
- epistemology in, 5:2267
- gay and lesbian geographies and, 3:1184
- identities in popular culture and, 5:2265
- impacts of, 5:2268
- inequality geographies and, 3:1587
- issues of, 3:1404
- language analysis and, 4:1754
- limitations of theory concept and, 5:2267
- Los Angeles School and, 4:1804
- metanarratives or grand theories of, 5:2265–2266
- modern views on knowledge, rejection of, 5:2267–2268
- new urbanism and, 4:2024–2027, 5:2268
- nonhierarchical and localized ontologies and, 5:2266
- objects and approaches in, 5:2268
- ontologies in, 5:2265–2267
- organizational changes in economic production and, 5:2265
- particularization of critique issue and, 5:2267
- political geography and, 5:2223–2224
- post-Fordism term and, 5:2264
- postmodern feminism and, 3:1191
- Postmodern Urban Condition* (Dear) and, 5:2268
- postpositivist epistemology and, 2:1008, 3:1295
- poststructuralism and, 2:619
- qualitative research methods and, 5:2266
- radical geography and, 5:2351
- relativist perspective on, 5:2266

- situatedness of knowledge issue and, 5:2267
- social justice and, 2:688
- term as an approach to understanding the world, 5:2264
- term as object of study and, 5:2264–2265
- text/textuality issues in, 6:2809–2810
- totalizing views of the world rejected by, 3:1191
- uneven power relations and oppressive patriarchal structures and, 3:1191
- urban design and social life studies and, 5:2264
- See also* Postmodernism: noted architects, geographers, scholars

Postmodernism: noted architects, geographers, scholars

- Ash Amin, 5:2268
- Michael Dear, 2:687–688, 5:2264, 5:2266, 5:2268, 5:2351
- Jacques Derrida, 5:2266, 5:2351
- Peter Eisenman, 5:2264
- Michael Foucault, 5:2266
- Clifford Geertz, 5:2266
- Frank Gehry, 5:2264
- Derek Gregory, 3:1380–1381
- David Harvey, 5:2264, 5:2265, 5:2268, 5:2350
- Frederick Jameson, 5:2264, 5:2268
- Christopher Jenks, 5:2264
- Peter Johnston, 5:2264
- David Ley, 5:2268
- Jean-François Lyotard, 5:2266
- Peter Mohnston, 5:2264
- Chris Philo, 5:2266
- Edward Soja, 5:2264, 5:2593
- Nigel Thrift, 5:2268, 6:2827
- Robert Venturi, 5:2264

Poststructuralism, 5:2270–2273

- actor-network theory and, 1:8, 5:2272–2273
- body geographies and, 1:289
- conceptual approaches to identities and, 3:1527–1528
- critical human geography and, 2:619
- cultural discourse of landscapes and, 5:2271
- cultural ecology and, 2:633
- cultural evolution and, 5:2270
- Cultural Studies and, 5:2230–2231
- cultural turn concept and, 2:645, 2:849–850
- deconstruction method and, 3:1191, 5:2271
- definition of, 5:2270
- feminism and, 4:1930
- gay and lesbian geographies and, 3:1184
- geography and, 5:2271–2273
- inequality geographies and, 3:1587
- international relations theory and, 4:2069
- language and geographic analysis and, 4:1754
- logic of identity and meaning in society and, 5:2270–2271
- marginalized groups in Western thought and, 5:2272
- modernity challenged by, 4:1929–1930
- multiple meanings of space and, 5:2272
- multiplicity of meanings element in, 5:2270, 5:2271
- nonvisual geographies and, 4:2042
- oceans as integral space of society and, 4:2069
- origins of, 5:2270–2271
- panopticon and, 4:2116–2117
- philosophizing of space and, 5:2272
- political geography and, 5:2223–2224
- postmodernism and, 2:619
- postpositivist epistemology and, 2:1008
- poststructural feminism and, 3:1191
- power and knowledge relationship and, 1:289
- power of discourse element in, 5:2270
- radical geography and, 5:2351

- space as area of contested meaning and, 5:2273
space as networks connected through linkages and, 5:2272–2273
spatiality reconfiguration and, 5:2271
structuralism and, 5:2270
study of culture and, 5:2270
subaltern studies and, 5:2712
subjective meanings in text and, 5:2270
text/textuality issues and, 6:2809
theory of language and, 5:2270
See also Poststructuralism: noted geographers, scholars
- Poststructuralism:** noted geographers, scholars
Giorgio Agamben, 1:26–27
Louis Althusser, 5:2270
Roland Barthes, 5:2270
Jeremy Bentham, 5:2272
Michel de Certeau, 5:2230
Gilles Deleuze, 4:2041, 5:2273
Jacques Derrida, 5:2270–2271, 5:2351
Arturo Escobar, 5:2272
Michel Foucault, 1:289, 5:2271
Bruno Latour, 5:2272
John Law, 5:2273
Claude Lévi-Strauss, 5:2270
Gunnar Olsson, 4:2077–2078
Edward Said, 5:2272
Ferdinand de Saussure, 5:2270
Nigel Thrift, 6:2827
- Poverty, 5:2274–2276**
absolute *vs.* relative measures of, 5:2274
causes of, 5:2275–2276
definition of, 5:2274
demographic and geographic distribution of, 5:2274–2275, 5:2275 (fig.)
extreme poverty definition and, 5:2274
famine geographies and, 3:1082–1085
feminization of, 3:1097
ghetto and, 3:1275–1277
homelessness and, 3:1440–1442
income-based measures of, 5:2274
inequality geographies and, 3:1586–1590
land degradation and, 4:1683
Malthusianism and, 4:1819–1820
neo-Malthusianism and, 4:2015–2016
peasants and peasantry, 4:2137–2142
population living on less than \$1 per day, 5:2275 (fig.)
poverty thresholds and, 5:2274
public housing and, 5:2303–2304
UN Human Poverty Index (HPI) and, 5:2274
“working poverty” concept and, 5:2276
See also Hunger
- Powell, John Wesley, 5:2276–2277**
American geomorphology work of, 5:2276–2277
Smithsonian service of, 5:2277
streams classification work of, 3:1245
USGS service of, 3:1409, 5:2277
water issues work of, 5:2277
Western U.S. explored by, 3:1245, 5:2276–2277, 5:2448
- PPGIS.** *See* Public participation GIS (PPGIS)
- PPPs.** *See* Public-private partnerships (PPPs)
- PRA.** *See* Participatory rural appraisal (PRA)
- Prairie restoration, 5:2278–2279**
bison restoration and, 5:2279
diversity recovery efforts and, 5:2278
Jens Jensen and, 5:2278
Aldo Leopold and, 5:2278
midlatitude grassland biome and, 1:227–230
Nature Conservancy and, 5:2278
Deborah and Frank Popper, 5:2279
prairie burn, Manhattan, Kansas, 5:2278 (photo)
short-grass prairie restoration and, 5:2279
Society for Ecological Restoration and, 5:2279
See also Environmental restoration; Prairies
- Prairies, 5:2279–2281**
definition of, 5:2279
dust storms and, 5:2280–2281
fires and, 5:2280
geographic locations of, 5:2279
grasslands term and, 5:2279
limited precipitation in, 5:2279
midlatitude grassland biome and, 1:227–230
mixed-grass prairie and, 5:2279–2280
North American grasslands and, 5:2279–2280
range management and, 5:2281
short *vs.* tallgrass prairies and, 5:2279–2280
temperature changes and, 5:2280
Williams Prairie preserve, Houston, Texas, 5:2281 (photo)
See also Prairie restoration
- Pratt, A., 2:1042**
- Pratt, Geraldine, 3:1192**
- Prebisch, Raúl, 2:712**
- Precipitation, global, 5:2282–2287**
active microwave sensing and, 5:2282–2283
blended techniques sensing and, 5:2284–2286
critical nature of, 5:2282
El Niño-Southern Oscillation (ENSO) and, 2:886–890, 5:2282
Global Precipitation Measurement (GPM) mission and, 5:2285–2286, 5:2286 (fig.)
hydrology and, 3:1513–1518
in situ measurements and, 5:2282
La Niña and, 4:1754–1757
passive microwave sensing and, 5:2284
radar-estimated accumulated precipitation, U.S., 5:2283 (fig.)
rain gauges measures and, 5:2282
remote sensing techniques and, 5:2282–2286
surface-based radar systems and, 5:2282–2283, 5:2283 (fig.)
TRMM-accumulated 3 hourly rainfall estimates and, 5:2284–2285 (fig.)
Tropical Rainfall Measuring Mission (TRMM) and, 5:2284–2286
visible and infrared radiation sensing, 5:2283–2284
- Precipitation formation, 5:2287–2288**
adiabatic temperature changes and, 1:15–17
Bergeron Findeisin precipitation formation and, 5:2288
clouds and, 1:476–480
collision and coalescence precipitation formation and, 5:2288
humidity and, 3:1485–1486
hydroclimatology and, 1:473
hygrophobic condensation nuclei and, 5:2287
hygroscopic condensation nuclei and, 5:2287
lifting mechanism of, 5:2287
processes of, 5:2287–2288
types of, 5:2288
See also Atmospheric moisture
- Pred, Allan, 5:2288–2290**
American manufacturing, urban growth patterns work of, 5:2289
circular and cumulative feedback loops and, 3:1381
ethnicity and race geographies work of, 5:2289
folk culture work of, 3:1143–1144
Anthony Giddens and, 5:2289
Derek Gregory and, 3:1381

- Törsten Hägerstrand's work and, 3:1398, 5:2289
 historical geography work of, 5:2289
 language in making of place and people and, 5:2289
 social theory work of, 5:2288–2289
 spatial diffusion work of, 3:1398
 Stockholm, Sweden research of, 5:2289
 structuration and, 5:2289
 time-geography and, 6:2838
 urban geography work of, 5:2288–2289
Violent Geographies co-edited by, 3:1381
- Primate cities, 5:2290–2291**
 agglomeration economies of, 5:2291
 Buenos Aires, 5:2291 (photo)
 definition of, 5:2290
 developing countries examples of, 5:2290
 Mark Jefferson and, 5:2290
 rank-size rule and, 5:2365
 rural-urban migration and, 5:2291
 uneven development reflected in, 5:2290
- Privacy and security of geospatial information, 5:2292–2293**
 access rules and, 5:2292
 data consumer perspective, 5:2293
 geodemographics and product marketing debate and, 5:2292
 geospatial information technology and, 5:2292
 individual level of, 5:2292
 law geographies and, 4:1766
 legal aspects of geospatial information and, 4:1770–1772
 panopticon and, 4:2116–2117
 public security, health, and welfare issues and, 5:2292
See also Geospatial industry; Geospatial semantic web; Legal aspects of geospatial information; Usability of geospatial information
- Producer services, 5:2293–2295**
 definition of, 5:2293
 examples of, 5:2293
 increase in, 5:2293
 information technology impact on, 5:2294
 interregional or international trading of, 5:2295
 low productivity feature of, 5:2294
 nontraded interdependencies, 5:2294–2295
 outsourced work and, 5:2294
 uneven geographical distribution of, 5:2294–2295
 unstandardized nature of, 5:2294
- Product cycle, 5:1195–2296**
 changing nature of product demand and, 5:2295
 core regions and, 5:2296
 geographic correlates for stages of, 5:2296
 international scale of, 5:2296
 multinational corporations in developing countries and, 5:2296
 national scale of, 5:2296
 simplistic criticism of, 5:2296
 subnational scale of, 5:2296
 supply conditions variations and, 5:2295–2296
 Raymond Vernon and, 5:2296
 vertical integration and, 5:2296
- Production of space, 5:2297–2298**
 absence of fixed meanings, 5:2298
 globalization, time-space compression and, 5:2297
 social constructionist perspective on, 5:2297–2298
 space as product of economic, political, and social relations and, 5:2297
 “space” *vs.* “place” and, 5:2297
See also Production of space: noted scholars
- Production of space: noted scholars**
 Walter Benjamin, 5:2298
 P. Berger, 5:2297
- Anthony Giddens, 5:2297
 David Harvey, 5:2297
 Henri Lefebvre, 4:1768–1770, 5:2297
 T. Luckmann, 5:2297
 Doreen Massey, 5:2297
 Raymond Williams, 5:2297
- Pruitt, Evelyn, 5:2414
- Psychoanalysis, geography and, 5:2298–2300**
 criticism of, 5:2299
 disciplines influenced by, 5:2299
 “extimacy” concept and, 5:2299
 free association technique and, 5:2298
 Sigmund Freud and, 5:2298
 Freudian dream analysis to analyze cities and, 5:2299
 Freudian-Lacanian analysis and, 5:2298–2299
 geography of emotions and, 2:892
 interviews analysis and, 5:2299
 object relations theories and, 5:2299
 Oedipus complex, slavery racial oppression and, 5:2299
 othering process and, 5:2299
 potential space, 5:2299
 “sandplay” and, 5:2299
 sexuality important theme in, 5:2298
 sociospatial exclusions and, 5:2299
 spatiality of psychoanalytic categories and, 5:2299
 unconscious desire element in, 5:2299
- Ptolemy, 5:2300–2301**
 citizenship and geography intersections and, 1:412
 Christopher Columbus influenced by, 1:520
Geographia written by, 1:341, 1:404, 3:1461, 4:1883, 5:2300, 6:3041
 geography *vs.* topography *vs.* chorography and, 5:2300
 Hipparchus and, 3:1428, 5:2300
 historical map of the Old World and, 2:1056 (fig.)
 latitude and longitude lines created by, 2:815
 optics and refraction studies of, 5:2300
 pseudoconic projected based on Ptolemy's writings and, 1:358 (fig.)
 regional geographic work of, 5:2387
 Strabo criticized by, 5:2300
 world maps of, 1:341, 1:347, 1:348 (fig.), 1:350, 5:2301 (fig.)
- Puar, J., 5:2333
- Public housing, 5:2302–2304**
 Cabrini-Green, Chicago, 5:2302 (photo), 5:2303
 contested space of, uneven human geography and, 5:2303
 definition of, 5:2302
 Department of Housing and Urban Development and, 5:2302
 Great Depression public works programs and, 5:2302
 Guste New Homes Public Housing, New Orleans, 5:2303
 Housing Act (1937) and, 5:2302
 location issues and, 5:2303
 Pruitt-Igoe project, St Louis, Missouri, example of, 5:2303
 stigmatism of, 5:2303
- Public participation GIS (PPGIS), 5:2304–2307**
 access inequities and, 5:2306
 antidemocratic implications issue and, 5:2304
 collaborative decision support GIS and, 5:2305
 community-integrated GIS and, 5:2304
 countermapping and, 2:595–596, 3:1209–1211
 critical GIS and, 2:615–616
 criticism of, 5:2305
 definition of, 5:2304
 empowerment of marginalized groups and, 5:2304
 ethical implications of, 5:2304
 GIS in public policy and, 3:1307–1311
 humanistic GIScience and, 3:1474–1478
 Hurricane Katrina Web mapping mashup example of, 5:2305

- implications of, 5:2306
- methods of, 5:2305
- participatory GIS and, 5:2304–2305
- participatory GIScience and, 5:2305
- participatory planning and, 4:2126–2129
- participatory rural appraisal and, 4:2130
- social, economic, and political power issue and, 5:2304, 5:2306
- social implications of, 5:2306
- spatial decision support systems (SDSS) and, 5:2305
- “volunteered” geographic data and, 5:2306
- Web-based grassroots GIS and, 5:2305–2306
- Web mapping mashups and, 5:2305–2306
- Web 2.0 technology and, 5:2305
- Public policy, geography of, 5:2307–2312**
 - collective existence and, 5:2308–2309
 - conceptual frameworks of, 5:2309–2310, 5:2309 (fig.)
 - definition of, 5:2307–2308
 - derivation of words and, 5:2308
 - geographical complexity of, 5:2310–2311
 - GIS and, 5:2307, 5:2311–2312
 - interdisciplinary methodology of, 5:2307–2308
 - modeling strategies of, 5:2309
 - objective *vs.* subjective policy-relevant problems and, 5:2310
 - policy categories and, 5:2310–2311
 - policy environment and, 5:2310
 - policy relevant institutions and, 5:2309–2310
 - public policy outputs and, 5:2310–2311
 - public-private partnerships and, 5:2312–2313
 - public sector employment and, 5:2308
 - U.S. federal government outlays per capita, 2005 and, 5:2310–2311, 5:2311 (fig.)
 - See also* Public policy, geography of: noted individuals
- Public policy, geography of: noted individuals
 - Lewis Alexander, 5:2307
 - Brian Berry, 5:2307
 - Isaiah Bowman, 5:2307
 - George Demko, 5:2307
 - Henry Gannett, 5:2307
 - Gilbert White, 5:2307
- Public-private partnerships (PPPs), 5:2312–2313**
 - definition of, 5:2312
 - international financial institutions support of, 5:2312
 - neoliberalism and, 5:2313
 - political controversy, 5:2312–2313
 - shared responsibility feature of, 5:2312
 - variations in, 5:2312
- Public space, 5:2313–2315**
 - at-risk nature of, 5:2315
 - civic spaces and, 5:2313
 - communications technology and, 5:2315
 - in communist countries and cities and, 2:543–544, 2:544 (photo)
 - cultural variations of, 5:2314
 - definitions of, 5:2313
 - fragmentation of, 5:2315
 - importance and functions of, 5:2313
 - law geographies and, 4:1766
 - nature of social relationships within, 5:2315
 - neoliberal economic policies and, 5:2315
 - public marketplace concept origins of, 5:2313–2314
 - San Marco Square and Palazzo, Ducale, Venice, 5:2314 (photo)
 - spacelessness of the Internet and, 5:2313
 - universal access issues and, 5:2314, 5:2315
 - See also* Urban specific subject
- Public water services, 5:2315–2319**
 - definition of, 5:2315
 - developing countries, independence, and colonial legacy in, 5:2316–2317
 - international water supply companies and, 5:2317
 - Millennium Development Goals and, 5:2318
 - natural monopoly characteristic of, 5:2316
 - organization in OECD countries of, 5:2316
 - recent trends in, 5:2317
 - regulation of, 5:2316
 - restructuring of, 5:2317–2318
 - successful public sector reform and, 5:2318
 - Washington Consensus and, 5:2317
- Puerto Rico
 - economically active females in, 3:1190 (table)
 - Spanish colony of, 1:512
- Pulido, Laura, 2:962
- Purch, Edward, 1:166–167
- Pyrogeography, 5:2319–2322**
 - Analytic Hierarchy Process and, 5:2322, 5:2322 (fig.)
 - ASTER imagery and, 5:2320, 5:2321 (image)
 - carbon cycle and, 5:2320
 - climate change and, 6:2771–2772
 - Fire-Climate-Society (FCS-1) model and, 5:2321 (fig.), 5:2322, 5:2322 (fig.)
 - fireshed variables and, 5:2319
 - geospatial mapping technology and, 5:2320
 - GIS integrations with, 5:2322
 - Landsat Thematic Mapper image, CerroGrande Fire, New Mexico, 5:2320, 5:2321 (image)
 - landscape renewal through, 5:2319
 - live-fuel moisture stress, 5:2320 (images)
 - Old Fire/Grand Prix Fire Complex, San Bernardino mountains, 5:2320, 5:2321 (image)
 - origins of, 5:2319
 - physical description of, 5:2319
 - processes of, 5:2319–2320
 - remote sensing and GIS technology and, 5:2320
 - space-time interactions between fire and people and, 5:2319
 - surface fire, 5:2319 (photo)
 - technologies used in, 5:2320–2322, 5:2320 (images)
 - in tropical savanna biome, 1:242
 - wildfire hazard, Jemez Mountains, New Mexico, 5:2322, 5:2322 (image)
- Pytheas, 2:1051
- Qatar
 - economically active females in, 3:1190 (table)
 - OPEC membership of, 4:2100 (fig.)
 - Qatar National Grid coordinate system of, 2:580
- Qian, W., 4:1940
- Qualitative methods, 5:2323–2326**
 - analysis of, 5:2325–2326
 - autographic narrative interview and, 5:2325
 - characteristics of, 5:2324–2325
 - Chicago School of sociology and, 5:2323
 - coding and classifying material and, 5:2325–2326
 - content and discourse analysis techniques and, 5:2326
 - critical GIS and, 2:615
 - development of, 5:2323–2324
 - focus group interviews and, 5:2325
 - generalization from, 5:2323
 - human geography fieldwork and, 3:1103–1005
 - in-depth data element of, 5:2324
 - individual cases element of, 5:2324
 - interviewing and, 3:1625–1627, 5:2325
 - media and geography and, 4:1876
 - Methodenstreit* and, 5:2323

- objective of, 5:2323
- observation methods and, 5:2325
- participant observation and, 4:2121–2122, 5:2325
- phenomenology and, 3:1625
- photographs and video and, 5:2325
- positionality and, 5:2257–2248
- positivism criticism of, 5:2323–2324
- previously unknown element in, 5:2324
- production of, 5:2325
- researcher perspective element in, 5:2324–2325
- self-reflexivity element in, 5:2325
- social theory in geography and, 5:2324
- sociology and anthropology origins of, 5:2323
- subjective focus of, 5:2323, 5:2324–2325
- thick description (Geertz) and, 5:2324
- written field notes and, 5:2325
- See also* **Feminist methodologies**; Qualitative methods: noted individuals
- Qualitative methods: noted individuals**
 - Alison Blunt, 5:2325
 - Franz Boas, 5:2323
 - Pierre Bourdieu, 5:2325
 - Ernest Burgess, 5:2323
 - Anne Buttner, 5:2324
 - Michel Foucault, 5:2326
 - Bronislaw Malinowski, 5:2323
 - Linda McDowell, 5:2325
 - Robert Ezra Park, 5:2323
 - Yi-Fu Tuan, 5:2324
- Quantitative methods, 5:2326–2329**
 - Bayesian statistics and, 1:187–188
 - bivariate and multivariate analyses and, 5:2328
 - criticism of, 5:2328
 - descriptive and inferential statistics and, 5:2327–2328
 - geocomputation and, 3:1211–1215
 - geographically weighted regression (GWR) and, 3:1225–1232
 - geomatics and, 5:2328
 - geostatistics and, 3:1261–1265
 - geotechnical innovations and, 5:2329
 - GIScience and, 5:2327
 - human geography and, 5:2327
 - impacts of, 5:2328–2329
 - inferential statistics and, 5:2327–2328
 - location-allocation modeling, 4:1793–1794
 - location theory and, 4:1798–1799, 4:1798–1800
 - map algebra and, 4:1824–1825
 - means compared over time and space and, 5:2327
 - measures of dispersion, frequency, and central tendency and, 5:2327
 - modeling in geography and, 5:2328
 - multivariate analysis methods and, 4:1961–1962
 - nonparametric techniques and, 5:2327
 - nonpositivist geography approaches and, 5:2328
 - origins of, 5:2327
 - parametric statistics and, 5:2327
 - point pattern analysis and, 5:2201–2202
 - positivist thinking and, 5:2328
 - quantitative temporal-spatial analyses and, 5:2327
 - race as a social category for quantitative analysis and, 5:2343
 - sample error and sample bias and, 5:2328
 - spatial autocorrelation and, 5:2607–2608
 - statistics in geography and, 5:2327
- See also* **Exploratory spatial data analysis (ESDA)**; **Feminist methodologies**; Quantitative methods: noted individuals; **Quantitative revolution**
- Quantitative methods: noted individuals**
 - Richard Chorley, 1:403–404, 5:2327
 - Törsten Hägerstrand, 5:2327
 - Richard Hartshorne, 5:2326
 - Fred Schaefer, 5:2326, 5:2329
 - Waldo Tobler, 5:2328
- Quantitative revolution, 5:2329–2331**
 - criticism of, 5:2330
 - historical geography subsumed by, 3:1429, 3:1432
 - institutionalization of, 3:2329–2330
 - logical positivism and, 4:1801, 5:2326
 - modeling and statistics focus of, 3:1429
 - multivariate analysis methods and, 4:1961–1962
 - network analysis and, 4:2017
 - “new geography” and, 5:2330
 - nomothetic *vs.*, 4:2034–2035, 5:2329
 - qualitative methods decline and, 5:2324
 - qualitative term and, 5:2329
 - representations of space and, 5:2433
 - socialism and, 5:2571
 - spatial analysis methods and, 5:2330
 - See also* **Feminist methodologies**; **Quantitative methods**; Quantitative revolution: noted individuals
- Quantitative revolution: noted individuals**
 - Brian Berry, 1:193
 - William Bunge, 1:300, 3:1466, 3:1645
 - Walter Christaller, 5:2329
 - William Garrison, 5:2329
 - Törsten Hägerstrand, 5:2329
 - Susan Hanson, 3:1401, 3:1468
 - Walter Isard, 5:2329
 - Thomas McCarty, 5:2329
 - Richard Morrill, 4:1945–1946
 - Fred Schaefer, 3:1466, 5:2329, 5:2511–2512
 - Andre Siegfried, 5:2223
 - Edward Ullman, 5:2329
- Queer theory, 5:2331–2333**
 - anarchism and geography and, 1:73, 1:74
 - criticism of, 5:2332
 - decoupling of gender identity and, 5:2331
 - gay and lesbian geographies and, 3:1183–1185
 - gender and nature and, 3:1196
 - impact of, 5:2331
 - normative constructs and social institutions and, 5:2331–2332
 - Natalie Oswin and, 5:2332–2333
 - poststructural critique of identity and, 5:2331
 - privilege issue and, 5:2332
 - queer geography and, 3:1184
 - queer term and, 5:2331
 - same-sex marriage issue and, 5:2332–2333
 - same-sex marriage supporters, Iowa City, Iowa, 5:2332 (photo)
 - sexuality and space scholarship and, 5:2331, 5:2333
 - See also* **Sexuality, geography and/of**
- Quine, Willard, 4:2079
- Race and empire, 5:2335–2337**
 - environmental determinism and, 5:2335, 5:2337
 - Eurocentrism and, 2:1028–1030, 5:2338
 - present-day forces of empire and, 5:2337
 - world’s hierarchy of races, school atlas (1883) and, 5:2336 (fig.)
 - See also* **Race and nature**; **Race and racism**; **Social Darwinism**
- Race and nature, 5:2337–2340**
 - American wilderness as culture-free nature example and, 5:2339
 - Kay Anderson and, 5:2338, 5:2340
 - class and nature and, 1:423–425

- critical race theory and, 5:2338
 cultural politics of, 5:2339
 environmental justice and, 2:959–965
 Eurocentrism and, 2:1028–1030, 5:2338
 European colonialism, racial thought and, 5:2339–2340
 European definitions of humanity and, 5:2340
 Carl von Linné and, 5:2338
 “natural” categories of, 5:2337
 nature as a social construct and, 5:2338–2339
 nature-culture binary and, 5:2338–2339
 nature of nature issue and, 5:2338
 Mary Louise Pratt, 5:2338
 social nature scholarship and, 5:2338–2339
See also Environmental determinism; Ethnicity and nature; Race and racism; Racial segregation; Social Darwinism
- Race and racism, 5:2340–2344**
 antiracism research agenda and, 5:2341
 assigning race and counting racial groups in, 5:2343–2344
 critical race studies in geography and, 5:2341
 digital divide (U.S.) and, 2:751
 “the end of race” and, 5:2343
 environmental determinism and, 5:2338
 environmental justice and, 2:959–965
 ethnic segregation and, 2:1022–1026
 geographic contingency of, 5:2341–2342
 geography of differences and, 2:737–740
 inequality geographies and, 3:1589
 justice/injustice geographies and, 3:1643–1645
 physical feature differences and, 5:2340
 quantitative approaches to, 5:2343
 race counting quantitative data and, 5:2343
 racial hierarchies within white privilege and, 5:2342
 racialization and, 5:2341–2342
 racialized landscapes and, 5:2342
 racism, inequality between social groups and, 5:2341
 racism as ideology of difference and, 5:2341
 relational perspectives on, 5:2342
 social construction of places and, 5:2342
 social construction of race and, 5:2341
 social Darwinism and, 5:2340
 U.S. Census racial data and, 5:2343
See also Environmental determinism; Environmental justice; Environmental racism; Ethnicity; Ethnicity and nature; Ethnic segregation; Race and empire; Race and nature; Racial segregation; Social Darwinism
- Racial segregation, 5:2344–2346**
 Chicago School and, 5:2344
 choice or preference element in, 5:2345
 “colored” water cooler, Oklahoma City, 1939, 5:2345 (photo)
 Dissimilarity Index, spatial separation measure of, 5:2344
 economic status and, 5:2345
 ghettos and, 3:1275–1277
 hypersegregated metropolitan areas and, 5:2344–2345
 immigrant assimilation models and, 5:2344
 inequality geographies and, 3:1589
 institutionalized mortgage and housing practices and, 5:2345
 racial residential segregation and, 5:2344
 white as standard or norm and, 5:2345–2346
See also Ethnic segregation; Segregation and geography
- Radcliffe, Sarah, 3:1092
- Radiation: solar and terrestrial, 5:2346–2350**
 albedo, ratio of reflected to incident light and, 5:2348
 atmospheric window terrestrial wavelength and, 5:2349
 definitions, 5:2346
 electromagnetic radiation and, 5:2346–2347
 global energy budget and, 5:2349
 human activity factor in, 5:2346, 5:2349
 Mie scattering of radiation and, 5:2348
 photons element in, 5:2346
 radiation at Earth’s surface and, 5:2348
 Rayleigh scattering of radiation and, 5:2347–2348
 solar constant concept and, 5:2347
 solar radiation, geographical aspects of, 5:2348
 solar radiation, top of the atmosphere and, 5:2347
 solar radiation, transmission of, 5:2347–2348
 solar spectrum regions and, 5:2347
 terrestrial radiation, in the atmosphere, 5:2349
 zenith angle between surface and sun and, 5:2347
See also Adaptive radiation; Albedo
- Radical democracy, 2:705–706
- Radical geography, 5:2350–2353**
 anarchism and geography and, 1:73–74
Antipode and, 1:73, 2:618, 4:2144, 5:2350
 Detroit Geographical Expedition and Institute and, 1:300, 4:1862, 5:2350
 feminist critique of, 5:2351
 justice/injustice geographies and, 3:1643–1645, 5:2223
 Marxist theoretical frameworks and, 5:2350–2351
 origins of, 5:2350–2351
 political geography and, 5:2223
 positivism and, 5:2350
 postmodern and poststructural influences on, 5:2351
 praxis of, 5:2352
 redefinitions of, 5:2351–2352
 regulation theory and, 5:2399–2402
 researcher/researched barrier and, 5:2350
 social, spatial, and economic structures in human agency and, 2:618
 socialism and, 5:2571
Social Justice and the City (Harvey) and, 5:2350
 social justice geographies and, 4:1644
 social movement issues and, 5:2350
 uneven development issue and, 5:2350
See also Critical human geography; Radical geography: noted individuals
- Radical geography: noted individuals
 A. Amin, 5:2352
 James Blaut, 1:285–286
 William Bunge, 1:300, 3:1466, 3:1645, 5:2350
 Michael Dear, 5:2351
 Jacques Derrida, 5:2351
 J. K. Gibson-Graham, 5:2351
 David Harvey, 5:2350–2351
 H. Lefebvre, 5:2352
 Doreen Massey, 5:2351
 D. Mitchell, 5:2352
 Richard Peet, 2:618, 4:2144
 Neil Smith, 5:2351
 Edward Soja, 5:2351
 Nigel Thrift, 5:2352, 6:2827–2830
 Ben Wisner, 2:618
- Radiometric correction, 5:2353–2355**
 function of, 5:2353
 geometric correction and, 3:1239–1240
 overview of, 5:2353, 5:2354 (fig.)
 sensor radiometric calibration and, 5:2353–2354
 spectral characterization and, 5:2355
 surface reflectance retrieval and, 5:2354–2355
See also Radiometric normalization; Radiometric resolution
- Radiometric normalization, 5:2355–2356**
 applications of, 5:2355

- calibration models and, 5:2355
 definition of, 5:2355
 localized approaches to, 5:2356
 regression tree normalization and, 5:2355–2356
See also Radiometric correction; Radiometric resolution
- Radiometric resolution, 5:2356–2357**
 definition of, 5:2356
 Landsat Data Continuity Mission proposal and, 5:2356
 limitations of, 5:2356
 microwave/RADAR data and, 4:1888–1890
 Multispectral Scanner on Ladsats 1–3 and, 5:2356
 pixel bit depth element of, 5:2356
 spatial, temporal, spectral, and radiometric resolutions and, 5:2356
See also Radiometric correction; Radiometric normalization
- Rae, John, 1:492 (photo)
- Railroads and geography, 5:2357–2364**
 in Britain, 5:2357
 Chicago railway hub and, 5:2360 (photo)
 economic effects of rail transportation and, 5:2362
 Florence-to-Rome line and, 5:2358
 in France, 5:2358, 5:2359 (fig.)
 Greenwich Mean Time (GMT) and, 5:2363
 high-speed trains, urban transit and, 5:2363–2364
 impact of, 5:2357, 5:2358–2359
 in Italy, 5:2358
 in Japan, 5:2358
 media and, 5:2362–2363
 Penydarren Tramroad, Wales and, 5:2357
 in Russia, 5:2357–2358
 social impacts of, 5:2362–2363
 standardization of time and, 5:2363
 George Stephenson, 5:2357
 telegraph and, 5:2359
 time-space compression and, 5:2358, 5:2360–2362
 tourism and, 5:2363
 Trans-Siberian railroad, 5:2357–2358
 travel experience and, 5:2360–2362
 twentieth century and, 5:2363–2364
 in United States, 5:2358–2359, 5:2360 (photo), 5:2361 (fig.)
- Raisz, Erwin, 5:2364–2365**
 academic career of, 5:2364
General Cartography co-authored by, 5:2364
 landscape representation work of, 5:2364–2365
 professionalization of cartography and, 5:2364
- Raitz, Karl, 5:2537
- Raivo, Petri, 5:2405
- Ranchin, T., 3:1533
- Randolph, John, 2:980
- Rank-size rule, 5:2365–2366**
 definition of, 5:2365
 empirical fit feature of, 5:2365
 formula of, 5:2365
 Paul Krugman and, 5:2365
 ordinary least squares bias feature of, 5:2365
 power exponent feature of, 5:2365
 “rank minus half” rule and, 5:2365
 George Kingsley Zipf and, 5:2365
- Raper, Jonathan, 2:560
- Rappaport, Roy, 2:895–896
- Ratcliff, Richard, 3:1114
- Ratzel, Friedrich, 5:2366**
Anthropogeographie written by, 2:666, 3:1464, 5:2246, 5:2366
 anthropogeography views of, 1:93, 4:1989
 Isaiah Bowman influenced by, 1:295
 domestication of animals and, 2:782
 environmental determinism work of, 2:917, 5:2246
 as father of human geography, 3:1464
 geopolitics work of, 3:1249, 5:2366, 5:2562
 Ernst Haeckel and, 5:2366
 Karl Haushofer influenced by, 3:1407, 3:1464, 5:2366
 Lamarckian evolutionary theory and, 5:2366
 living space, 3:1407–1408
 nation states views of, 3:1464, 5:2221–2222, 5:2562
 organic analogies of the Earth and, 2:666–667, 5:2562
 people and the land relationship views of, 2:666–667
Politische Geographie written by, 5:2221–2222, 5:2366
 population geography work of, 5:2246, 5:2366
 Ellen Churchill Semple influenced by, 5:2366, 5:2531
 Social Darwinism and, 5:2562
 state as superorganism views of, 3:1249, 3:1464
 Ravenstein, Ernst George, 2:775, 3:1113, 3:1361, 4:1893
- Rawls, John, 4:1644
- Real estate, geography and, 5:2367–2369**
 applications of, 5:2367
 dynamic iterative process of, 5:2368, 5:2369 (fig.)
 filtering process and, 3:1110–1111
 geospatial due diligence documentation and, 5:2368
 geospatial feasibility model and, 5:2367–2368, 5:2368 (fig.), 5:2369
 geospatial real estate market analysis and, 5:2367
 geospatial tests and, 5:2367–2369
 Homer Hoyt’s work and, 3:1448–1450
 “information arbitrage” and, 5:2367
 magnitude of profit opportunity element in, 5:2368–2369
 Real Estate Investment Trusts (REITs) and, 5:2367
See also Housing and housing markets
- Realism, 5:2369–2371**
 abstraction and, 5:2370
 agency and structure relationship and, 5:2370–2371
 as analytical framework and, 5:2369
 as an epistemology, 5:2370
 contingent conditions and, 5:2370
 empirical evidence and, 5:2370, 5:2371
 mechanisms and structures elements in, 5:2370
 necessary conditions and, 5:2370
 phenomena explained in terms of causality and, 5:2370
 realist ontology and, 5:2370
 social and natural sciences distinction and, 5:2369–2370
 structuration theory and, 5:2370–2371
- Reclus, Élisée, 5:2371–2372**
Earth: A Descriptive History written by, 5:2211, 5:2371
 environmental preservation work of, 3:1463
 geographic anarchism, radical geography work of, 1:73, 2:617, 5:2371–2372
 inequities in hegemonic structures views of, 5:2211
 Peter Kropotkin and, 4:1669, 5:2372
 published works of, 5:2371–2372
 social geography term of, 2:617
 social inequalities work of, 5:2371–2372
 town planning work of, 3:1463
- Recycling of municipal solid waste, 5:2372–2375**
 alternative theoretical approaches to, 5:2374
 cardboard recycling, Englewood, Colorado, 5:2374
 government decision making and, 5:2374
 landfills and, 4:1684–1686
 municipal solid waste term and, 5:2372–2373
 National Salvage Campaigns and, 5:2372
 political imperatives of, 5:2373
 recycling definition and, 5:2372
 research, 5:2373–2374
 social science of waste and, 5:2374

- sustainable consumption context of, 5:2372
 throwaway society, 5:2374
 waste incineration and, 6:3048–3049
 waste reduction, minimization, and reuse terms and, 5:2372
 waste term and, 5:2372
 Wheelabrator waste-to-energy plant, Worcester, Massachusetts, 5:2373 (photo)
- RED. *See* **Regional economic development (RED)**
- Redfield, Robert, 4:2137
- Redistricting, 5:2375–2377**
 bias levels and, 5:2375
 boundary delimitation (international context) and, 5:2375
 definition of, 5:2375
 electoral geography and, 2:881
 gerrymandering term and, 5:2375
 “The Gerry-Mander” political cartoon, 1812, 5:2376 (image)
 GIS data and, 5:2377
 packing *vs.* cracking strategies and, 5:2375
 racial and ethnic data element in, 5:2376
 reapportionment term and, 5:2375
 redistribution term and, 5:2375
 safe districts and, 5:2375
 scholarly geographic interest in, 5:2377
Shaw v. Reno and, 5:2376, 5:2377
 in United Kingdom, Canada, and Australia, 5:2376–2377
 in United States, 5:2375–2376
 Voting Rights Act (1965) and, 5:2375–2376
- Reed, M., 2:615
- Rees, William, 2:828
- Refugees, 5:2377–2380**
 Cartagena Declaration on Refugees (1984) and, 5:2378
 Convention Governing the Specific Aspects of Refugee Problems in Africa and, 5:2378
 Covenant on Economic, Social, and Cultural Rights and, 5:2378
 definitions of, 5:2377–2378
 Eurocentric definition of, 5:2378
 Huguenots refugees from France and, 5:2378
 humanitarian efforts and, 5:2380
 Hurricane Katrina and, 5:2377
 immigration and, 3:1542–1545
 International Covenant on Civil and Political Rights and, 5:2378
 international human rights law, 5:2378–2379
 legal meaning of, 5:2377–2378
 nonrefoulement principle and, 5:2378, 5:2379
 politicization of term and, 5:2377
 Refugee Convention and, 5:2378
 refugee warehousing and, 5:2379
 State House settlement, Hargesia, Somalia, 5:2379 (photo)
 United Nations High Commissioner for Refugees and, 5:2378–2379
 U.S. Committee for Refugees and Immigrants and, 5:2379
See also **Environmental refugees**
- Regan, Tom, 2:926
- Regional economic development (RED), 5:2380–2384**
 attracting and retaining capital and, 5:2380–2381
 definition of, 5:2380
 economic base analysis and, 2:846–848
 export-led development and, 2:1063–1066
 externalities and, 2:1068–1069
 growth poles and, 3:1391–1392
 importance of, 5:2380
 incubator zones and, 3:1551–1553
 inequality geographies and, 3:1589
 institutions and infrastructure in, 5:2382, 5:2383 (table)
 knowledge and competencies and, 5:2381–2382
 learning and innovation in regional economics and, 4:1767–1768
 mobility, sustainability, regional assets and, 5:2383 (table)
 modernization theory and, 4:1931–1935
 neoliberalism and, 5:2381
 organizational competence and, 5:2381–2382
 path dependence theory and, 4:2133–2135
 purpose of, 5:2380
 sustainable development factors and, 5:2380
See also **Gross domestic product/gross national product (GDP/GNP); Regional environmental planning; Regional geography; Regional governance; Regional science; Regions and regionalism**
- Regional environmental planning, 5:2384–2386**
 ecological risk analysis (ERA) and, 2:840–843
 environmental governance and, 5:2384
 land use changes and, 5:2384
 limitations of, 5:2386
 new regionalism approach, 5:2386
 policy context (England) of, 5:2385 (table)
 Regional Development Agencies Act (1998) and, 5:2384
 Regional Single Strategy and, 5:2384
 region scale variations and, 5:2384, 5:2385 (table)
 research, 5:2386
 spatial planning in EU and, 5:2384
 Strategic Environmental Assessment (SEA) Directive and, 5:2386
 sustainable development focus of, 5:2384
See also **Environmental planning; Regional economic development (RED); Regional geography; Regional governance; Regional science; Regions and regionalism**
- Regional Fishery Management organizations, 3:1604
- Regional geography, 5:2386–2389**
 areal differentiation and, 5:2387–2388
 classical regional geography and, 5:2387
 criticism of, 3:1429
 decline in popularity of, 3:1531–1532
Geographia Generalis (Varenius) and, 5:2387
 geographic imaginations and, 5:2387
 geography’s history and disciplinary identity and, 5:2386–2387
 glocalization and, 3:1346–1348
 holistic character of places and, 5:2387
 idiographic, uniqueness of each region and, 3:1531–1532
 local lifestyles, regional landscapes and, 5:2387
 logical positivism *vs.*, 5:2388
 new regional geography and, 5:2388–2389
 regional narratives, culture and settlement patterns and, 3:1429
 specific *vs.* general geography (Varenius) and, 5:2387
See also **Regional economic development (RED); Regional environmental planning; Regional geography: noted geographers; Regional governance; Regional science; Regions and regionalism**
- Regional geography: noted geographers
 Andrew Clark, 3:1429
 Richard Hartshorne, 3:1402–1403, 3:1531, 5:2387–2388
 Alfred Hettner, 5:2387
 Doreen Massey, 5:2388
 Ptolemy, 5:2387
 Carl Ritter, 5:2387, 5:2470–2471
 Fred Schaefer, 3:1466, 3:1531–1532, 5:2388
 Bernhard Varenius, 5:2387
 Paul Vidal de la Blache, 5:2387
- Regional governance, 5:2389–2393**
 administrative infrastructure in, 5:2390
 advantages of, 5:2390
 characteristics of, 5:2390
 criteria of, 5:2389–2390
 cross-border cooperation and, 2:630–631
 definition of, 5:2389

- Germany and, 5:2392
governance failure possibility and, 5:2390
institutional capabilities element in, 5:2390
intrasystemic relations and, 5:2390
international comparisons of, 5:2389
multi-actor level play in, 5:2390
public and private sectors of, 5:2390
regional government *vs.*, 5:2389–2390
self-regulation model and, 5:2389
statehood transformation and, 5:2389
structures of, 5:2390
United Kingdom and, 5:2390–2391
United States and, 5:2391–2392
See also Governance; Regional economic development (RED);
Regional environmental planning; Regional governance;
Regional science; Regions and regionalism
- Regional science, 5:2393–2396**
academic programs in, 5:2394
agglomeration issue and, 5:2395
Luc Anselin's work in, 1:80–81
central place theory and, 1:380–382, 5:2393
definition of, 5:2393
economies of scale and, 5:2395
future of, 5:2394
gravity model and, 5:2395–2396
growth of, 5:2393–2394
history of, 5:2393–2394
interregional flows of goods and population and, 5:2395
Walter Isard and, 3:1627–1628, 5:2393
journals focusing on, 5:2394
location theory and, 5:2393, 5:2394
methods in, 5:2395–2396
multidisciplinary features of, 5:2393
new economic geography and, 5:2395
quantitative analysis methods used in, 5:2395
Regional Science Association and, 5:2393–2394
regions, social issues, and science components of, 5:2393
spatial data analysis and, 5:2395–2396
supranational regional organizations and, 5:2394
“thinking globally” and, 5:2394
topics in, 5:2394–2395
transportation costs element in, 5:2395
urban economics and, 5:2395
urban residential land use issue and, 5:2395
See also Regional economic development (RED); Regional environmental
planning; Regional geography; Regional governance; Regional
science: noted individuals; Regions and regionalism
- Regional science: noted individuals**
William Alonso, 5:2236, 5:2393, 5:2394, 5:2395
Luc Anselin, 5:2393
Walter Christaller, 5:2393
Edward Glaeser, 5:2395
Jane Jacobs, 5:2395
August Lösch, 5:2393, 5:2394
Scott Loveridge, 5:2394
Edwin Mills, 5:2395
Richard Muth, 5:2395
Johann Heinrich von Thünen, 5:2393, 5:2394
Brigitte Waldorf, 5:2393
Alfred Weber, 5:2393, 5:2394
Alan Wilson, 5:2393
- Regional Science Association International (RSAI), 5:2396–2397**
Luc Anselin and, 1:81
conferences held by, 5:2397
European Regional Science Association and, 5:2397
- Walter Isard's founding of, 3:1628, 5:2393–2394, 5:2396
journals of, 5:2397
membership of, 5:2394
Pacific Regional Science Conference Organization and, 5:2397
Regional Science Association of the Americas and, 5:2397
structural organization of, 5:2396–2397
supraregional organizations and, 5:2394, 5:2396–2397
See also Association of American Geographers (AAG)
- Regions and regionalism, 5:2397–2399**
applications of regionalism and, 5:2398–2399
commonality maximization goal of, 5:2397–2398
Earth's major region divisions and, 5:2398
functional regions and, 5:2398
Richard Hartshorne's work in, 3:1402–1403, 3:1429,
3:1531, 5:2387–2388
Alfred Hettner and, 3:1422–1423, 3:1465, 5:2387
homogeneity basis of, 5:2397–2398
human geography courses and, 5:2398
idiographic, uniqueness of each region and, 3:1531
language regions and, 5:2398
learning and innovation in regional economics and, 4:1767–1768
locality studies and, 4:1790–1792
physical geography and, 5:2398
regionalism and, 5:2398–2399
regional science and, 5:2398–2399
regions as classification and categorization tool and, 5:2397
systematic geography and, 5:2398
See also Regional economic development (RED); Regional
environmental planning; Regional geography; Regional
governance; Regional science; Regional Science Association
International (RSAI)
- Regulation theory, 5:2399–2402**
Michel Aglietta and, 5:2399, 5:2401
capitalist theory and, 5:2399
critique, 5:2401–2402
flexible specialization and, 5:2400–2401
Fordism and, 3:1148–1151
Fordism and its demise in, 5:2399–2400
global capitalism and, 5:2401
historical background of, 5:2399
hyperaccumulation of new capitalism and, 5:2401
Japanese just-in-time production and, 5:2401
mode of regulation concept and, 5:2399
neoliberalism and, 5:2400
peripheral Fordism term and, 5:2400
post-Fordism, nature of, 5:2400–2401
regime of accumulation concept and, 5:2399
“social contract” element in, 5:2399
- Régulier, Catherine, 4:1769
- Reisman, David, 5:2262
- Relative/relational space, 5:2402–2405**
absolute space *vs.*, 1:2, 5:2402–2403
actor-network theory and, 1:8
airplanes and, 5:2404
Culture of Time and Space (Kern) and, 5:2403
definitions, 5:2403
geopolitics of imperial rivalry and, 5:2404
locality studies and, 4:1790–1792
Marxism and, 5:2403
measurement of time and, 5:2404
origin of, 5:2402
power geometries and relational space (Massey) and, 5:2405
production of space and, 5:2297–2298
scale of capital accumulation and, 5:2404
spatiality meaning (Kern) and, 5:2403

- technology advances and, 5:2403
 theory of relativity and, 5:2403–2404
 time-space compression and, 5:2404–2405
See also Relative/relational space: noted individuals
- Relative/relational space: noted individuals
 Albert Einstein, 5:2403–2404
 Anthony Giddens, 5:2403
 David Harvey, 5:2403
 Gottfried Leibniz, 5:2402
 Sir Halford Mackinder, 5:2404
 Doreen Massey, 4:1866–1867, 5:2351, 5:2405
 Neil Smith, 5:2404
- Religion, geography and, 5:2405–2410
 Al-Muqaddasi and, 5:2407
 belief systems and, 5:2405–2406
 biblical mapping and, 1:195–197, 1:196 (fig.)
 Cathedral of Santa Domingo, Cuzco, Peru, 5:2406 (photo)
 crossing and dwelling theory of religion (Tweed) and, 5:2409
 cultural geography and, 5:2406
 data acquisition issue and, 5:2406
 definition of, 5:2405
 diffusion principles and, 5:2406
 environment and, 5:2409
 Hajji Alija Mosque, Počitelj, Bosnia-Herzegovina, 5:2406 (photo)
 international institutions element in, 5:2406
 Lane's axioms of sacred space and, 5:2408
 mapping religious regions and, 5:2407
 necrogeography, landscapes of death and, 5:2409
New Historical Atlas of Religion in America (Gaustad and Barlow) and, 5:2407
 pilgrimage and, 5:2184–2186, 5:2408
 recent contributions in, 5:2409
 religions geography *vs.*, 5:2405
 religious diffusion, distributions, and regions in, 5:2406–2407
 religious landscapes and, 5:2408–2409
 religious taboos and, 5:2409
 sacred space and pilgrimage in, 5:2407–2408, 5:2409
 social, cultural, and environmental perspectives of, 5:2405
 social construction of identity issue and, 5:2409
 spatial nature of religious institutions and, 5:2406
 themes of, 5:2405
 Thomas Tweed and, 5:2409
 Yamunotri Temple, Indian Himalayas, 5:2407 (photo)
 Wilbur Zelinsky's work in, 5:2407
- Relph, Edward, 5:2410–2411
 books written by, 5:2410
 capitalist landscape work of, 3:1476
 environmental humility, 5:2411
 existential insideness and outsideness terms of, 4:2167, 5:2411
 Martin Heidegger and, 5:2410
 human care of landscapes work of, 2:1046, 3:1476
 human geographies work of, 2:1046, 3:1467, 5:2410–2411
 phenomenology of place work of, 4:2167, 5:2411
Place and Placedness written by, 4:2167, 5:2410–2411
 spirit of place *vs.* sense of place and, 5:2411
- Remittances, 5:2411–2414
 definitions of, 5:2411
 development and, 5:2414
 economic diversification strategy of, 5:2413–2414
 geographic explosion of, 5:2412, 5:2412 (fig.), 5:2413 (fig.)
 geographic importance of, 5:2412
 global remittance flows, 2007 and, 5:2412 (fig.)
 nonessential items purchased with, 5:2413
 regional remittance flows, 2007 and, 5:2413 (fig.)
- social remittances and, 5:2411–2412
 uses of, 5:2412–2413
- Remote sensing, 5:2414–2420
 advantages and disadvantages of, 5:2414–2415
 aerial photography and, 5:2416–2417
 aerial sensors and satellite sensors and, 3:1257
 atmospheric remote sensing and, 1:157–161
 biogeochemical cycle patterns, 1:207
 blackbody element in, 5:2415
 Gilberto Câmara's work in, 1:319
 climatology data collection and, 1:475
 data sets size issue in, 3:1212
 definition of, 5:2414
 digital image data and, 5:2416
 ecotones identification and, 2:869
 electromagnetic radiation (EMR) element in, 5:2415–2416
 extent or coverage image feature and, 5:2416
 floodplain delineation, 3:1131
 geocomputation in, 3:1212
 geosensor networks and, 3:1252–1254
 geospatial data production technology and, 3:1256–1257
 GIS landuse and land cover mapping and, 3:1302–1305
 ground reference data and, 3:1384–1385
 health applications of, 4:1879
 image data acquisition methods and, 5:2417
 image display methods and, 5:2419
 image enhancement and, 3:1532–1533
 image fusion and, 3:1533–1534
 image interpretation and, 3:1534–1536
 interpretation of, 5:2417–2419
 Landsat 7 image, Cape Cod, Massachusetts, 5:2417 (photo)
 landscape interpretation using, 4:1715
 land use and cover change, 4:1737–1738
 Thomas Lillesand, 4:1783–1784
 map animation and, 4:1826
 microwave/RADAR data and, 4:1888–1890
 Moderate Resolution Imaging Spectroradiometer (MODIS)
 multispectral sensor and, 1:158, 1:252, 2:974, 3:1542, 4:1738, 4:1740, 4:1960
 multispectral imagery and, 4:1953–1956
 multitemporal imaging and, 4:1959–1960
 object-based image analysis (OBIA) and, 4:2057–2058
 panchromatic imagery and, 4:2112–2115
 pipeline leaks, 2:949–951
 platform type of, 5:2416
 Evelyn Pruitt and, 5:2414
 pushbroom *vs.* whiskbroom sampling and, 5:2417
 radiometric correction and, 5:2353–2355
 radiometric normalization and, 5:2355–2356
 radiometric resolution and, 5:2356–2357
 raster-based GIS and, 3:1282–1283
 raster image of Earth's surface and, 3:1257
 resolution or grain image feature and, 5:2416
 sensor type of, 5:2416
 solar reflective EMR and, 5:2415
 stereoscope analysis tool and, 5:2418
 sun synchronous *vs.* geostationary satellite orbits and, 5:2416, 5:2421
 surveillance and, 6:2734
 types and sources of, 5:2416–2417
 USGS nationwide inventory of land cover and land use and, 3:1302
 vector data and, 3:1257
See also Aerial imagery: data; Aerial imagery: interpretation;
 Atmospheric remote sensing; Biophysical remote sensing;
 Image specific subject; Remote sensing: platforms and
 sensors; Remote sensing in disaster response

Remote sensing: platforms and sensors, 5:2420–2424

- active sensors, 5:2423
- aircraft platforms and, 5:2421
- atmospheric remote sensing and, 1:157–161
- future directions, 5:2423
- geostationary satellite platform and, 5:2421
- hyperspectral sensors, 5:2423
- Landsat satellites and, 5:2421
- multispectral imagery and, 4:1953–1956
- multispectral scanners, 5:2423
- multispectral sensors, 5:2423
- NASA Shuttle Radar Topographic Mission and, 5:2421
- panchromatic imagery and, 4:2112–2115
- panchromatic sensors, 5:2423
- passive *vs.* optical sensors and, 5:2422
- platforms, 5:2420–2421, 5:2420 (fig.), 5:2421 (fig.)
- real-aperture radar (RAR) and, 5:2423
- satellite platforms and, 5:2421
- sensors, 5:2421–2423, 5:2422 (fig.)
- sun-synchronous *vs.* geosynchronous satellite platforms and, 5:2421

See also Remote sensing

Remote sensing in disaster response, 5:2424–2428

- aircraft and, 5:2424
- anthropogenic disaster responses and, 5:2424
- current trends in, 5:2425
- decision support function of, 5:2425
- geopositioning satellites and, 5:2424
- geostationary satellites and, 5:2424
- GIS information integration and, 5:2424
- information sources integration and, 5:2424
- in situ devices and, 5:2424
- international agencies and initiatives of, 5:2425
- International Charter-Space & Major Disasters consortium and, 5:2424–2425
- micro unmanned aerial vehicles (MUAV) and, 5:2424
- natural disaster responses and, 5:2424
- real-time remote sensing ground stations and, 5:2425, 5:2427
- remote sensing definition and, 5:2424
- Southern Indiana flood, June 2008, 5:2426 (figs.), 5:2427 (fig.)
- vulnerable populations and, 5:2427

See also GIS in disaster response; Remote sensing

Renewable Fuel Standard (U.S.), 1:202–203**Renewable resources, 5:2428–2430**

- biofuels production and, 1:201–204
- breakthroughs in renewables and, 5:2430
- definition of, 5:2428
- ecological economics and, 2:820–824
- ecological modernization and, 2:832–834
- electricity sources development and, 5:2429
- geothermal energy, 3:1265–1270, 5:2429 (photo)
- hydroelectric power and, 3:1506–1512
- issues of scale and whole-systems analysis and, 5:2429–2430
- Mammoth Pacific geothermal plant, Sierra Nevadas, California, 5:2429 (photo)
- nonrenewable resources and, 4:2039–2041
- overdependence on, results of, 5:2428
- renewability factor in, 5:2428
- solar energy example of, 5:2428–2429

See also Adaptive harvest management

Rent-gap, 5:2430–2431

- actual *vs.* potential rents and, 5:2430
- back-to-the-city movement of capital and, 3:1204
- capital-centered account of gentrification and, 3:1204
- capitalist dynamics and, 5:2431
- corporate reclamation of inner city spaces and, 5:2430

- deindustrialization, suburban population migration and, 5:2430
- gentrification and, 3:1204, 3:1205 (fig.), 5:2430, 5:2431
- motivational implications of, 3:1204
- producer services and agglomeration economics and, 5:2430
- profitability of land in urban core and, 5:2430
- Neil Smith, 5:2430, 5:2551

Representations of space, 5:2431–2434

- actor-network theory and, 5:2434
- art and geography and, 1:118–120
- cartography and, 5:2432–2433
- conquest and empire and, 5:2432–2433
- cultural geography and, 5:2433
- cultural turn and, 5:2433–2434
- film and, 3:1110–1111
- lived spaces and, 5:2431
- mental maps and, 4:1881–1883
- military expeditions and, 5:2432–2433
- Nature of Geography* (Hartshorne) and, 5:2433
- nonrepresentational theory and, 5:2434
- ontological foundations of geographical data and, 4:2078–2081
- perceived space and, 5:2431
- photography and, 4:2176–2178
- physical space affected by, 5:2432
- quantitative revolution and, 5:2433
- reductionist feature of, 5:2433
- regional studies and cultural analysis and, 5:2433
- social relations shifts and, 5:2432
- theories of practice and, 5:2434
- theory of space and, 4:1768–1770, 5:2297, 5:2431–2432

See also Representations of space: noted individuals

Representations of space: noted individuals

- Walter Christaller, 5:2433
- Denis Cosgrove, 5:2432
- Jacques Derrida, 5:2433
- Michel Foucault, 5:2433
- Richard Hartshorne, 5:2433
- Henri Lefebvre, 4:1768–1770, 5:2297, 5:2431–2432, 5:2433
- August Lösch, 5:2433
- Gunnar Olsson, 4:2077–2078
- John Pickles, 2:1046, 4:2183
- Carl Sauer, 5:2433
- Ferdinand de Saussure, 5:2433
- Johann von Thünen, 5:2433

Research and development (R&D), geographies of, 5:2434–2437

- clustering and, 5:2435–2436
- Competitive Advantage of Nations* (Porter) and, 5:2435
- contextualizing R&D and, 5:2435
- definitions, 5:2434
- in electronics industry, 2:885–886
- Experimental Program to Stimulate Competitive Research (U.S.) and, 5:2437
- flexible accumulation process in, 5:2436
- knowledge regions and, 5:2435
- learning regions and, 4:1766–1768
- partnerships and collaborations feature of, 5:2436
- regional development and, 5:2435
- science and technology term and, 5:2435
- spatial issues of, 5:2434–2435
- spatialized public policy and, 5:2437
- technopoles concept and, 5:2435–2426
- triple helix model of, 5:2436
- university spinoffs of, 5:2436–2437

Resilience, 5:2437–2441

- adaptability and, 5:2440
- adaptive ecosystem management and, 5:2438

- backloop concept and, 5:2439
 Steve Carpenter, 5:2439
 coupled socio-ecological systems and, 5:2439–2440
 definitions of, 5:2437–2438
 ecosystem resilience and, 5:2438
 ecosystem stability and, 5:2437
 engineering resilience and, 5:2438
 extended keystone hypothesis and, 5:2439
 Carl Folke, 5:2440
 Lance Gunderson, 5:2439
 heuristic model of adaptive renewal cycles (Gunderson and Holling) and, 5:2439
 historical perspective and key elements of, 5:2438–2439
 Crawford Holling and, 5:2437–2438, 5:2439
 Simon Levin, 5:2438
 mentality elements of, 5:2440
 multiscale and multitemporal research on, 5:2438
 panarchy theory and, 5:2438
 Resilience Alliance network and, 5:2439
 theory of complex adaptive systems (Levin) and, 5:2438
 transformability and, 5:2440
- Resistance, geographies of, 5:2441–2444**
 American and French Revolutions and, 5:2441
 antiglobalization and, 1:94–97
 antisystemic movements and, 1:99–100
 countermapping and, 2:595
 critiques of, 5:2443–2444
 current research trends in, 5:2444
 evolution of, 5:2441–2443
 IMF and World Bank protestors, West Berlin, 5:2443 (photo)
 imperialism and, 3:1545–1548
 justice/injustice geographies and, 3:1643–1645
 law geographies and, 4:1766
Making of the English Working Class (Thompson) and, 5:2442
 malleability of identity and, 5:2442–2443
 Marxist theories and, 5:2441–2442
 “Not in My Backyard” (NIMBY) and, 4:2049
 postcolonialism and feminist geography and, 5:2442
 resistance term definitions and, 5:2441
 thirdspace concept and, 5:2442
Weapons of the Weak (Scott) and, 5:2442
See also Resistance, geographies of: noted geographers, scholars
- Resistance, geographies of: noted geographers, scholars
 Andrew Charlesworth, 5:2442
 Tim Cresswell, 5:2443–2444
 Michel de Certeau, 5:2442
 David Harvey, 5:2442
 Paul Routledge, 5:2444
 James Scott, 5:2442
 David Sibley, 5:2442
 Edward Soja, 5:2442
 E. P. Thompson, 5:2441, 5:2442
- Resnick, M., 5:2365
 Resource Conservation and Recovery Act (RCRA, 1976), 4:1684–1685
- Resource economics, 5:2445–2446**
 benefits of leaving resource in situ and, 5:2445
 discounting future profits controversy and, 5:2445–2446
 ecological economics and, 2:820–824
 ecological modernization and, 2:832–834
 environmental management and, 2:967–970
 Faustmann rule for forestry resources and, 5:2445
 maximum sustained yield concept and, 5:2445
 optimal extraction amounts issues and, 5:2445–2446
 past and future of, 5:2446
- scarcity rent rate concept (Hotelling) and, 5:2445
See also Energy and human ecology; Resource geography; Resource management, decision models in; Resource mapping; Resource tenure
- Resource geography, 5:2446–2451**
 capitalist production and, 5:2449–2450
 critical approaches to, 5:2448–2450
 cultural specific perspectives on, 5:2449
 Enlightenment exploration and, 5:2447
 Eurocentric perspectives on, 5:2449
 identity and politics of representation in, 5:2449
 imperial inventories, empires and resources and, 5:2447–2448
 management of natural capital, 5:2447, 5:2448
 multiscalar networks and, 5:2449
 neoliberal economic ideology and, 5:2450
 political economic and political-ecological networks and systems of, 5:2447, 5:2448–2450
 statistical picturing of, 5:2448
See also Resource economics; Resource management, decision models in; Resource mapping; Resource tenure
- Resource management, decision models in, 5:2451–2453**
 comprehensive decision support system and, 5:2453
 conservation zones and, 2:571–572
 cost-benefit analysis, 5:2451
 decision analysis, decision tree, 5:2453
 discrete choice models, 5:2451, 5:2452 (fig.)
 issues in, 5:2451
 mathematical optimization (mathematical programming) models, 5:2453
 multi-criteria evaluation (MCD) decision models, 5:2451, 5:2453
 Shared Vision Planning Framework and, 5:2453
 typology of, 5:2452 (fig.)
See also Resource economics; Resource geography; Resource mapping; Resource tenure
- Resource mapping, 5:2454–2456**
 biomass for energy production, Guangdong Province, China, 5:2454, 5:2455 (fig.)
 Canada Land Inventory project, 1963–1995 and, 5:2454
 definition of, 5:2454
 digital evaluation models and, 5:2454
 fuzzy classification concept and, 5:2454
 geospatial information technologies and, 5:2454
 GIS landuse and land cover mapping and, 3:1302–1305
 history of, 5:2454
 remote sensing and, 5:2454
 vector to raster format shift and, 5:2454
See also Environmental mapping; Resource economics; Resource geography; Resource management, decision models in; Resource tenure
- Resource tenure, 5:2456–2457**
 boundedness of societies, variations in, 5:2456
 colonialism and, 5:2456–2457
 decontextualized modern property systems and, 5:2457
 definition of, 5:2456
 institutionalization of resource property rights and, 5:2456
 resource geographies, human social formations and, 5:2456
 small-scale traditional societies and, 5:2457
 uneven resources distribution and, 5:2456
 universality claims and, 5:2456
See also Distribution of resource access; Resource economics; Resource geography; Resource management, decision models in; Resource mapping
- Restructuring, 5:2458–2461**
 accumulation regime changes and, 5:2458–2459
 capitalist competition and cost reduction and, 5:2458–2459

- capitalist restructuring and, 5:2459–2460
- corporate restructuring and, 5:2458
- definition of, 5:2458
- economic restructuring and, 5:2458–2460
- foreign direct investment and, 5:2458
- industrial restructuring and, 5:2458
- international organizations and, 5:2459
- micro *vs.* macro sales of, 5:2458
- neoliberal political economic strategy and, 5:2459
- outsourcing and, 5:2458
- service economies and, 5:2458
- shopping mall construction, Gurgaon, Haryana, India, and, 5:2459 (photo)
- in socialist countries, 5:2459–2460
- Sunbelt transition and, 5:2458
- transnational corporations and, 5:2458
- Retail trade, geography of, 5:2461–2464**
 - business geography and, 1:305–306
 - Census of Retail Trade data and, 5:2462
 - central place theory and, 5:2462
 - Consumer Expenditures Annual Reports* and, 5:2462
 - customer demographic and behavioral analyses and, 5:2461
 - discounters and, 5:2462
 - GIS technology, location decision making and, 5:2462
 - gravity model theory and, 5:2462–2463
 - grocers as dominant retailers and, 5:2461
 - Internet-based retail trade and, 5:2464
 - issues relevant in, 5:2461
 - law of retail gravitation and, 5:2462–2463
 - retail establishments and spatial changes in, 5:2461–2462
 - sales, outlets, and selling space elements in, 5:2461
 - spatial interaction models of, 5:2463
 - suburban customers and, 5:2462
 - supercenters and, 5:2462
 - theories and models of retail trade location and, 5:2462–2463
 - Walmart, Southern California, 5:2463 (photo)
- ReVelle, Charles, 4:1793
- Rey, Sergio, 5:2637
- RGS. *See* Royal Geographical Society (RGS); Russian Geographical Society (RGS)
- Rhodes, Cecil, 3:1224
- Ricardo, David
 - Marx influenced by, 4:1860
 - political economy meaning and, 5:2214
 - specialization views of, 2:780
 - two-country, two-product theory of, 2:556–557, 2:557 (table)
- Richards, Paul, 3:1556
- Richardson, Tim, 2:1037
- Rifkin, Jeremy, 1:33
- Rill erosion, 5:2464–2466**
 - definition of, 5:2464
 - density of, 5:2465
 - ephemeral gully erosion, Western Iowa, 5:2465 (photo)
 - erosion gullies and, 5:2464
 - erosion rills and, 5:2464
 - gully erosion and, 3:1392–1394
 - “microrills” or “traces” and, 5:2464
 - midslope element in, 5:2465
 - process of, 5:2464–2465
 - upslope migration of, 5:2465
- Ringmann, Matthias, 6:3041
- Risk analysis and assessment, 5:2466–2470**
 - benefit-cost analysis and, 5:2468
 - definitions, 5:2466
 - dose-response assessment and, 5:2466–2467
 - ecological risk analysis (ERA) and, 2:840–843
 - economics and, 5:2468
 - ethics/morality issues and, 5:2468
 - exposure assessment and, 5:2467
 - exposure pathways and, 5:2467
 - “fate and transport” of hazardous materials and, 5:2467
 - flash floods and, 3:1123–1125
 - hazard identification and, 5:2466
 - laboratory experiments and, 5:2466
 - making choices about risks and, 5:2468
 - natural hazards and risk analysis and, 4:1983–1989
 - no observed adverse effect (NOAE) and, 5:2466
 - political issues and, 5:2469
 - public reaction and, 5:2468–2469
 - remediating former nuclear weapons sites example of, 5:2469–2470
 - risk assessment and, 5:2466
 - risk characterization and, 5:2467–2468
 - risk management and, 5:2468
 - risk-related policy issues and, 5:2468
 - short-term *vs.* long-term emissions and, 5:2467
 - threshold level issues and, 5:2466–2467
 - See also* Natural hazards and risk analysis
- Ritter, Carl, 5:2470–2471**
 - evolutionary theory and, 2:666
 - Arnold Guyot and, 3:1394
 - Richard Hartshorne and, 5:2471
 - Alfred Hettner influenced by, 3:1422
 - human geographies work of, 3:1462–1463, 4:2180, 5:2387, 5:2471
 - modern geographer co-founded by, 5:7471
- Ritter, Paul, 1:404
- Rivers, 5:2471–2477**
 - Amazon River, South America, 5:2472, 5:2473 (image)
 - bed and bank configuration form and, 5:2475
 - channel patterns forms and, 5:2475–2476
 - channel slope and, 5:2475
 - Clean Water Act (1972) and, 5:2476
 - climate change and, 5:2472
 - dams and, 5:2476
 - deltas and, 2:702–705, 5:2472
 - drainage networks and, 5:2472–2474
 - dynamic equilibrium process and, 5:2474
 - features of, 5:2471
 - floodplains and, 3:1128–1133
 - flow mechanics and regime factors process and, 5:2474
 - flow of, 3:1138
 - geography of, 5:2472
 - geology and climate variables and, 5:2472
 - human impacts on, 5:2472, 5:2476
 - humanity impacted by, 5:2476
 - hydroelectric power and, 3:1506–1512
 - hydrological connectivity and, 3:1512–1513
 - hydrologic cycle and, 5:2471
 - hydrology and, 3:1513–1518
 - international watershed management and, 3:1618–1620
 - longitudinal profile of, 5:2475
 - Nile, longest river and, 5:2472, 5:2476
 - pollution of, 5:2476
 - processes and forms, 5:2474–2476
 - sediment transport and deposition process and, 5:2475
 - stream term and, 5:2472–2473
 - variations in, 5:2472
 - See also* Amazon River, Amazonia
- Robbins, Paul, 1:526, 4:1996
 - cultural ecology work of, 2:632, 4:1996
 - nature-society theory and, 4:1996

- Robertson, H. M., 2:1029
- Robinson, Arthur, 1:343, 4:1844, 4:1845 (fig.), 5:2364
- Robinson, James, 5:2218
- Robinson, William, 2:824
- Rock weathering, 5:2477–2484**
- animal weathering, 5:2479
 - biomechanical processes, 5:2479
 - carbonation, carbon cycle and, 1:325, 1:326–327
 - chelation chemical weathering, 5:2480
 - chemical weathering, 5:2479–2480
 - Colorado National Monument, Colorado, 5:2483 (photo)
 - creep and, 2:604–605
 - cryostatic pressure, 5:2477
 - crystals expansion and growth and, 5:2477–2478
 - dehydration and, 5:2480
 - environmental and microscale factors in, 5:2481 (fig.)
 - fractures, 5:2483
 - gnammas (rock basins), 5:2482
 - hoodoos (rock pinnacles), 5:2482
 - hydration chemical weathering, 5:2480
 - hydrolysis or incongruent dissolution chemical weathering, 5:2479, 5:2480 (image)
 - hydrostatic pressure and, 5:2478
 - karren (solution channels), 5:2482
 - mechanical type of, 5:2477–2479
 - microscale chemical weathering, 5:2480 (image)
 - multiple weathering agents, 5:2482 (photo)
 - oxidation chemical weathering, 5:2480
 - petrology, mineralogy, and geologic-structure factors in, 5:2483
 - phosphorus cycle and, 4:2169–2171
 - pressure unloading and, 5:2478–2479
 - rock-derived nutrients cycling and, 1:207
 - small-scale landforms and, 5:2482
 - solution or congruent dissolution chemical weathering, 5:2479
 - sources of weathering agents, climate and biotic influences on, 5:2481 (fig.), 5:2483–2484
 - tafoni, or honeycomb wreathing on sandstone wall, Colorado, 5:2482 (photo)
 - tafoni (honeycomb-like hollows), 5:2482
 - temperature changes and, 5:2478
 - thermal weathering, 5:2478
 - time, scale, and the geomorphic system factors in, 5:2480–2483
 - tot, near Crow Creek, Wyoming, 5:2478 (photo)
 - well-developed wreathing rind and, 5:2481 (photo)
- Rogers, Will, 1:317
- Romania
- AGILE membership of, 1:125 (table)
 - Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 - clothing exports from, 6:2186 (fig.)
 - COMECON membership of, 2:593 (table)
 - economically active females in, 3:1190 (table)
 - European Union (EU) membership of, 2:1035
 - Euroregions, cross-border cooperation and, 2:631 (fig.)
 - plastic and trash pollution, Bicz Lake, Romania, 6:3053 (photo)
 - textile exports from, 6:2816 (fig.)
- Roon, Albrecht von, 4:1896
- Rooney, John, 5:2680
- Roosevelt, Franklin D., 2:570
- Roosevelt, Theodore, 2:569–570
- Rose, Gillian, 5:2484–2485
- critical visual methodologies and, 5:2485, 6:3026
 - cultural politics of landscape work of, 5:2484
 - emotional geographies work of, 2:892
 - explicit sexualization of knowledges and, 5:2485
 - Feminism and Geography* written by, 5:2484
 - feminist environmentalist geographies work of, 3:1094
 - feminist geographies work of, 1:290
 - feminist use of reflexivity, 5:2484
 - gendered geographical knowledge work of, 3:1097, 5:2484–2485
 - performative and visual methodologies work of, 5:2484
 - psychoanalysis and, 5:2484
 - Visual Methodologies* written by, 5:2485
- Rose, Harold, 3:1275
- Rose, K., 5:2365
- Rose, Mamaris, 3:1204
- Roukova, Poli, 4:2109
- Rousseau, Jean-Jacques, 3:1020–1022, 4:1971–1972
- Routledge, Paul, 5:2444, 5:2574–2575
- Rowles, Graham, 3:1104, 4:2122
- Royal Geographical Society (RGS), 5:2485–2487**
- Action Plan for Geography and, 5:2486
 - awards and honors given by, 5:2487
 - colonial exploration and, 5:2486
 - Crossing Continents project of, 5:2486
 - education focus of, 5:2486
 - Geography Outdoors program of, 5:2486
 - Institute of British Geographers (IBG) and, 3:1601–1603, 5:2485, 5:2486
 - R. J. Johnston and, 4:1643
 - journals of, 5:2486
 - mission and purpose of, 5:2486
 - policy work of, 5:2486–2487
 - unlocking archives initiative of, 5:2486
- RSAI. *See* **Regional Science Association International (RSAI)**
- Rudé, George, 5:2441
- Rundstrom, Robert, 3:1562, 3:1563
- Rural development, 5:2487–2491**
- actor-network theory and, 5:2490–2491
 - case study research on, 5:2491
 - contemporary research, 5:2490–2491
 - definitions, 5:2487, 5:2488
 - endogenous development, 5:2487
 - fluidity and malleability, 5:2488
 - focus of, 5:2488–2490
 - “frontier” zones of state expansion and, 5:2488
 - growth pole modernist strategy of, 5:2488
 - history of, 5:2487
 - Industrial Development Authority (Ireland) and, 5:2488
 - integrated approach to, 5:2487
 - land management and commodity foci of, 5:2488–2489
 - measurement and assessment of, 5:2490
 - neoliberal policies toward, 5:2490
 - new bridge construction, Guizhou Province, China (2006), 5:2489 (photo)
 - peasants and peasantry, 4:2137–2142
 - rural as discourse and, 5:2488
 - rural land use regulation and, 4:1727
 - social sustainability element in, 5:2490
 - social theory and, 5:2490
 - social welfare and, 5:2490
 - systems theory, integrated approach to, 5:2490
 - Tennessee Valley Authority project and, 5:2488
 - U.S. rural population (2000) and, 4:1886 (table)
 - See also* **Rural geography; Rural-urban migration**
- Rural geography, 5:2491–2495**
- agricultural issues and, 5:2492
 - Amish farm, Lancaster County, Pennsylvania, 5:2494 (photo)
 - definition of, 5:2491
 - ecotourism and, 5:2493

- environmental and conservation issues and, 5:2494
 environmental geography and, 5:2492
 future directions, 5:2495
 gender issues in, 5:2493
 globalization context of, 5:2492–2493
 isolation of rural places and, 5:2493
 natural resources conflicts and, 5:2491
 peasants and peasantry, 4:2137–2142
 privatization of resources (neoliberalism) and, 5:2494
 quality and community issues and, 5:2494–2495
 quality of life element of, 5:2493
 regional approach to geography and, 5:2492
 regional or national identity and, 5:2492
 rural cultures and, 5:2493
 rural economies and, 5:2492–2493
 rural environment knowledge and, 5:2492
 rural migrations and, 5:2493
 rural politics and, 5:2493–2495
 urban population migration and, 5:2492
See also Rural development; Rural-urban migration
- Rural-urban migration, 5:2495–2498**
 demographics of, 5:2496
 in developing countries, 5:2495–2496
 Harris-Todaro model of, 5:2495
 household strategy approach to, 5:2496
 impacts of, 5:2496–2497
 Lewis dual sector model of, 5:2496
 migrant worker, Beijing, China, 5:2497 (photo)
 neoclassical theories on, 5:2495–2496
 primate cities and, 5:2291
- Rushbrook, D., 5:2333
- Rushton, Gerard, 4:1793
- Russia**
 acid rain in, 1:7
 Alaska colonized by, 1:512
 APEC membership of, 1:121
 automobile industry in, 1:169
 birthrates in, 2:708
 Chernobyl nuclear accident in, 1:385–386
 cholera in, 1:401
 Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 coal in, 1:483, 1:485
 colonial migrations of, 1500–1914, 3:1543
 Commonwealth of Independent States (CIS) membership of, 2:536
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 environmental history studies in, 2:929
 ethnic nationalism and, 4:1979
 European Union (EU) membership of, 2:1035
 fertility levels in, 2:709
 fossil fuels produced in, 2:902
 GDP of, 3:1382, 3:1383 (fig.)
 hate groups in, 3:1407
 HIV/AIDS in, 3:1438, 3:1439
 homeless women, St. Petersburg, 3:1442 (photo)
 horse domesticated in, 2:783
 humid continental climate of, 1:440
 IMF voting rights of, 3:1617
 industrialization in, 4:2020
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 Kyoto Protocol of 1997, GHG emissions and, 1:463
 land inequality in, 4:1693
 military expenditures in, 4:1898, 4:1899 (table)
 military-industrial complex in, 4:1900
 multinational corporations investment in, 5:2220
 Murmansk, 1:442
 national geographical society in, 3:1462
 NATO and, 4:2048
 new Cold War and, 4:2048
 Norilsk Nickel's copper plant, 3:1416 (photo)
 oil production in, 4:2099
 oil sources in, 4:2163
 prairie restoration in, 5:2279
 railroads in, 5:2357–2358
 subarctic climate in, 1:441
 taiga boreal forests in, 1:214
 urbanization in, 2:543
 Viking exploration of, 2:1051
See also Communism and geography; Soviet Union
- Russian Federation**
 Collective Security Treaty Organization (CSTO) membership of, 2:536
 Commonwealth of Independent States (CIS) membership of, 2:536 (table)
- Russian Geographical Society (RGS), 5:2498**
 academic and applied activities of, 5:2498
 founding of, 5:2498
 Peter Kropotkin and, 4:1668–1669
 mission of, 5:2498
 name changes of, 5:2498
- Ruttan, Vernon, 6:2737
- Rwanda**
 cultural annihilation in, 3:1200
 economically active females in, 3:1190 (table)
 ethnic cleansing, ethnicity of place and, 2:1020
 hate groups in, 3:1407
 independence of, 1:512
- Ryan, Clare, 2:993–994
- Saarinen, Thomas, 3:1219–1220
- Sachs, Wolfgang, 2:1002
- Safina, Carl, 4:2068
- Sagan, Carl, 3:1335
- Sahara Desert**
 basin and range topography in, 1:186
 desert biome of, 1:218
 diurnal surface temperature, Northern Sahara desert, 1:433–434, 1:434 (fig.)
 dry climate of, 1:429
 dust storm in, 1:21 (photo)
 nomadic Tuareg herders and camels, Mali, West Africa, 4:2034 (photo)
 tropical savanna border on, 1:239
- Sahlins, Marshall, 1:167
- Sahrawi Arab Republic, 1:25
- Said, Edward, 1:508, 2:1030, 2:1047, 4:1787, 4:1876
 discursive representations and, 5:2259–2260
 imaginative geographies and, 4:2102, 5:2261
 Orientalism and, 4:2101–2104, 4:2106–2107, 5:2259–2260, 5:2272
 postcolonial studies and, 4:2103, 5:2259–2260
 poststructuralism and, 5:2272
 process of Othering and, 4:2107
- Saint-Simon, Comte de, 4:1860
- Salt Lake City, Utah, 1:378 (photo)
- Samuels, Marwyn, 2:1046
- San Andreas fault zone, 1:186, 2:605
- Sanchez, T., 2:1075
- San Francisco, California**
 central business district of, 1:379
 earthquake (1906) in, 3:1087

- industrialism in, 4:1822
 spatially concentrated gay community in, 3:1183–1184
 Santos, Milton, 2:618
 Saro-Wiwa, Ken, 2:619–620
 Sartre, Jean-Paul
 existentialist Marxism of, 2:1046, 2:1047
 history as an accumulation outflow of spatialized acts and, 2:1047
 Henri Lefebvre and, 4:1768
 Sassen, Saskia, 3:1117
Satellites and geography, 5:2499–2504
 Arabsat and, 5:2502
 base map of Ukraine and, 1:359, 1:360 (fig.)
 China-Brazil Earth Resources Satellites and, 1:319
 Communication Satellite Corporation and, 5:2501
 Communications Satellite Act and, 5:2501
 Condor Alliance of Andean Nations and, 5:2502
 contemporary satellite industry and, 5:2503–2504
 Direct Broadcast Satellites (DBS) and, 5:2503
 electromagnetic frequency spectra allocation issue and, 5:2501
 European Telecommunications Satellite Organization and, 5:2502
 Eutelsat and, 5:2502
 fiber optics and, 5:2503–2504
 global sea-level rise measured by, 3:1344
 history of, 5:2499–2500
 hurricane tracking and, 3:1497 (photo), 3:1499
 indigenous telecommunications satellite, 5:2503
 Inmarsat and, 5:2502
 International Satellite Organization and, 5:2501–2502
 land use and cover change and, 4:1737–1738
 map animation and, 4:1826
 national sovereignty issues and, 5:2501
 Palapa satellites and, 5:2503
 panchromatic band characteristics on Earth-imaging satellites and, 4:21115 (table)
 panchromatic imagery and, 4:2114
 Peacesat and, 5:2502
 Rascom and, 5:2502
 regulation of global satellite industry and, 5:2500–2503
 satellite climate recording and, 1:456
 Satellite Meteorology (Vander Haar and Kidder), 1:159–160
 sea ice, 3:1524–1525, 3:1524 (fig.), 3:1525 (fig.)
 spillovers from satellite footprints and, 5:2501
 SPOT satellite (France) and, 4:2114, 4:2115 (photo)
 Sputnik launch and, 5:2499
 spy satellites and, 5:2499
 typhoon satellite image and, 1:20 (photo)
 UN International Telecommunications Union (ITU) and, 5:2500–2501
 World Administrative Radio Conference and, 5:2501
 world's international satellite earth stations and, 5:2503 (fig.)
 See also **Global positioning system (GPS); Remote sensing**
 Saturated adiabatic lapse rate (SALR), 1:16–17
 Saucher, Sandie, 3:1565
 Saudi Arabia
 Ar Rub'al Khali Wildlife Management Area in, 4:2118
 economically active females in, 3:1190 (table)
 Holy Mecca in, 5:2185 (photo)
 IMF voting rights of, 3:1617
 military expenditures in, 4:1899 (table)
 oil sources in, 4:2163
 OPEC membership of, 4:2098, 4:2099, 4:2100 (fig.)
Sauer, Carl, 5:2504–2506
 academic career of, 5:2505
 agency of humans on Earth and, 5:2505–2506
 background and reputation of, 5:2505
 Berkeley School and, 1:191–192, 2:641, 2:746, 3:1142, 3:1429, 3:1458, 3:1465, 5:2504
 cultural geography and, 2:635–636, 3:1465, 4:1990, 5:2212, 5:2504
 cultural landscape work of, 1:376, 2:635–636, 2:641, 3:1429, 3:1458, 3:1465, 4:1990, 4:1992, 5:2505
 destructive exploitation and, 5:2505
 diffusion work of, 2:746
 diversity and scholarship of, 5:2505
 domestication of animals work of, 2:782
 environmental determinism and, 2:641–642, 3:1464, 3:1465, 5:2212
 fieldwork views of, 3:1103, 3:1465
 folk culture and, 3:1142
 human ecology views of, 3:1458
 John Brinkerhoff Jackson influenced by, 4:1641
 Peirce Lewis influenced by, 4:1773
 “The Morphology of Landscape” essay of, 2:641, 2:643 (fig.), 4:1990
 polymath term to describe, 5:2504
 service work of, 5:2505
 settlement geography work of, 5:2536
 temporal change in landscapes and, 4:2111
 Saussure, Ferdinand de, 5:2270
 Sayer, Andrew, 5:2370
Scale, social production of, 5:2506–2509
 applicability debate, 5:2507–2508
 as dynamic construct, 5:2507
 locality studies and, 4:1790–1792
 Marxist theory of scale and, 5:2506–2507
 modifiable areal unit problem and, 4:1935
 ontological foundations of geographical data and, 4:2078–2081
 See also **Scale in GIS**
Scale in GIS, 5:2509–2511
 map scale, 5:2509, 5:2510 (fig.)
 project scale, 5:2509–2511
 sample neighborhood mapped at three scales and, 5:2510 (fig.)
 scale definition and, 5:2509
 spatial scale, 5:2509–2511
 Scandinavia
 forest plantations in, 5:2195
 GDP per capital in, 3:1382, 3:1383 (fig.)
 industrialization in, 3:1583
 welfare states in, 3:1590
 See also *specific country*
Schaefer, Fred, 5:2511–2512
 chorology work of, 1:405, 3:1466
 exceptionalism term of, 4:2034
 Richard Hartshorne criticized by, 1:405, 3:1403, 3:1466, 4:1801, 5:2326, 5:2388
 historical geography work of, 3:1429
 methodology work of, 3:1403
 positivism and, 3:1403, 3:1466, 4:1801
 quantitative revolution and, 3:1466, 5:2326, 5:2511
 regional geography critiqued by, 3:1466, 3:1531–1532, 4:1897
 theoretical scientific geography ideas of, 5:2511
 Schein, L., 5:2333
 Schelling, Thomas, 2:560
 Schimper, A. F. W., 1:234
 Schlüter, Otto, 2:640, 2:641
 Schmidt, Allan, 1:408
 Schmink, Marianne, 3:1100
 Schumacher, Ernst, 3:1370, 3:1372, 6:2737
 Schumpeter, Joseph, 1:303, 3:1593, 4:1805
Science, technology, and environment, 5:2512–2515
 civic epistemology, 5:2518
 ecological crisis, risk society and, 5:2515

- late modernity issue of, 5:2512
 natural *vs.* social sciences and, 5:2513
 North Sea Brent Spar oil platform controversy and, 5:2517
 nuclear power issue example and, 5:2515
 politics of research and, 5:2517
 rationalization and instrumentalization of environment
 issue and, 5:2512
 science, to explain natural phenomena and, 5:2513
 science and technology as social activities and, 5:2515
 science word origins and, 5:2512–2513
 search for knowledge and, 5:2513
 social and ethical dimensions of, 5:2517–2518
 technology goal orientation and, 5:2514–2515
 technology *vs.* technique and, 5:2514
 technology word origins and, 5:2513
 THORP nuclear power-reprocessing plant, UK, controversy
 and, 5:2517
 using GPS equipment on a farm, Northern Louisiana, 5:2514 (photo)
See also Science and technology studies (STS)
- Science and technology studies (STS), 5:2516–2519**
 definition of, 5:2516
 institutional models, public engagement approaches and, 5:2518
 journals of, 5:2516
 knowledge geographies and, 4:1659–1663
 phase 1: the sociology of scientific knowledge, 5:2516
 phase 2: from epistemology to politics and public engagement,
 5:2517–2518
 phase 3: critical debates, 5:2517–2518
 professional societies of, 5:2516
 science wars and, 5:2516
 socially constructivist approaches of, 5:2516
 sociology of scientific knowledge (SSK) and, 5:2516
 Alan Sokal, 5:2516
 “Sokal affair” and, 5:2516
 Brian Wynne, 5:2517, 5:2518
- Scoones, Ian, 2:921, 2:922–923, 2:1005
- Scotland, 3:1371
- Scott, Allen, 5:2519–2520**
 academic career of, 5:2519
 agglomeration economies work of, 5:2519
 cultural economies of cities work of, 5:2519–2520
 cultural industries work of, 5:2520
 industrial organization and change work of, 5:2519–2520
 location-allocation analysis modeling work of, 5:2519
 Los Angeles School of urbanism and, 2:688, 4:1803, 5:2519
 music and sound geographies work of, 4:1968
 small firm networks, outsourcing and, 4:2108
 urban division of labor and, 4:1803–1804, 4:1863, 5:2519
 urban geography work of, 5:2519–2520
- Scott, J. C., 2:548
- Scott, James, 4:2141, 5:2192
- SDI. *See* Spatial data infrastructures (SDI)
- SDSS. *See* Spatial decision support systems (SDSS)
- Seager, Joni, 3:1092–1093, 3:1100
- Seamon, David, 3:1435, 4:2168
- Second Life, 2:648
- Sedimentary rock, 5:2520–2521**
 biochemical sedimentary rocks, 5:2521
 chemical sedimentary rocks, 5:2521
 clastic sedimentary rocks, 5:2520–2521
 folding and, 3:1140–1142
 importance of, 5:2520
 sedimentary layers, Artist’s Point, Colorado National
 Monument, 5:2521 (photo)
See also Geomorphic cycle; Geomorphology; Sedimentation
- Sedimentation, 5:2521–2523**
 air and water motion and, 5:2522–2523
 from cessation of gravity-induced motion, 5:2522
 definition of, 5:2521–2522
 flocculation and, 3:1127–1128
 in Little Colorado River, Grand Canyon, Arizona, 5:2552 (photo)
 natural or artificial formation of, 5:2522
See also Sedimentary rock
- Segregation and geography, 5:2523–2526**
 Catholic and Protestant neighborhoods, Belfast, Ireland,
 5:2525 (photo)
 census units measure of, 5:2524
 consequences of, 5:2525–2526
 as cultural defense, 5:2524
 de facto segregation, 5:2524
 de jure segregation, 5:2524
 educational geographies and, 2:874–875
 gated communities and, 3:1181–1183
 gentrification and, 3:1203–1208
 ghettos and, 3:1275–1277
 human geography topic of, 5:2523
 income, life cycle, lifestyle, race and ethnicity types of, 5:2523
 index of dissimilarity, or D index of, 5:2523–2524
 inequality geographies and, 3:1589
 measures of, 5:2523–2524
 overt discrimination, 5:2524
 proximity to similar people preference and, 5:2524–2525
 reasons for, 5:2524–2525
 segregation definition and, 5:2523
 thematic map displays of, 5:2523
 types of, 5:2524
See also Ethnic segregation
- Self-organizing maps (SOMs), 5:2526–2528**
 applications of, 5:2527
 definition of, 5:2526
 distance measurement and, 5:2527
 distances in a space of multiple attributes feature of, 5:2526
 GeoSOM and, 5:2527
 hexagons element of, 5:2526–2527
 iterative processes of, 5:2526
 Teuvo Kohonen and, 5:2526
 methodological elements of, 5:2526
 spatially divergent self-organization (Phillips) and, 2:562
 Tobler’s first law of geography and, 5:2526
- Semantic interoperability, 5:2528–2529**
 domain ontology and, 5:2529
 folksonomies and, 5:2529
 GIS distributed network services and, 5:2528
 GIS environmental model integration and, 3:1280
 interoperability and spatial data standards and, 3:1623–1625
 Werner Kuhn’s work in, 4:1672–1673
 ontological foundations of geographical data and, 4:2078–2081
 ontology term and, 5:2528–2529
 Open Geospatial Consortium (OGC) and, 5:2528
 semantic reference systems and, 5:2529
 service-oriented architecture (SOA) of, 5:2528
 service provider, service broker, and user interface and, 5:2528
 shared understanding of meaning of exchanged data and,
 5:2528–2529
 syntactic interoperability and, 5:2528
 top-level ontology and, 5:2529
See also Semantic reference systems
- Semantic reference systems, 5:2529–2531**
 GIS environmental model integration and, 3:1280
 Werner Kuhn’s work in, 4:1672–1673

- ontological foundations of geographical data and, 4:2078–2081
 ontologies as reference frames and, 5:2530
 physical sensor and, 5:2531
 semantic datums and sensors in, 5:2530–2531
 spatial and temporal reference systems and, 5:2529–2530
See also Semantic interoperability
- Semple, Ellen Churchill, 5:2531–2532**
 academic career of, 5:2531
 books written by, 5:2531
 Harlan Burrows and, 1:185
 environmental determinism views of, 2:667, 2:917, 3:1429, 3:1464, 4:1990, 4:1991, 5:2531–2532
 environment as supreme agent of influence views of, 2:917, 3:1464, 4:1990
 Richard Hartshorne influenced by, 3:1402
Influences of Geographic Environment written by, 1:93, 3:1464, 5:2531
 ocean views of, 4:2065
 Friedrich Ratzel's influence on, 5:2366, 5:2531
- Sen, Amartya, 2:921, 2:922, 2:924
 famine views of, 4:1988, 4:2015
Poverty and Famines written by, 3:1084
 poverty definition and, 5:2274
- Senegal
 economically active females in, 3:1190 (table)
 Negritude movement and, 2:1029
 poverty rates in, 5:2274
- Sense of place, 5:2532–2534**
 creating and contesting place and, 5:2533
 definition of, 5:2532
 generalized and reductionistic perspective on, 5:2533
 genius loci, spirit of place concept and, 5:2533
 geographical imagination and, 3:1221–1225
 group studies of place and, 5:2532
 humanistic geography origins of, 5:2532
 individual perspective on and element in, 5:2532
 issues related to, 5:2532
 landscape quality assessment and, 4:1715–1718
 phenomenology and, 4:2167–2168
 representations of place and, 5:2533
 sacred and indigenous places and, 5:2533
 third places concept and, 4:2168
See also Sense of place: noted scholars
- Sense of place: noted scholars
 Chris Allen, 4:2168
 Ian Bentley, 4:2168
 Edward Casey, 4:2168
 Mindy Fullilove, 4:2168
 Jeff Malpas, 4:2168
 Robert Mugerauer, 4:2168
 Ray Oldenburg, 4:2168
 Edward Relph, 2:1046, 3:1467, 4:2167, 5:2410–2411
 David Seamon, 4:2168
 Ingrid Leman Stefanovic, 4:2168
 Kay Toombs, 4:2168
 Yi-Fu Tuan, 6:2890–2891
- September 11, 2001, terrorist attacks. *See Terrorism, geography of*
- Sequent occupance, 5:2534–2535**
 applications of, 5:2534
 as a biotic phenomenon, 5:2534
 discrete historical layers and, 5:2534
 Stanley Dodge and, 5:2534
 ecological and development language of, 5:2534
 endogenous changes and, 5:2534
 human adaptation to the environment and, 5:2534
- Preston James and, 5:2534
 landscapes interpretation and, 6:3097
 legacy of, 5:2535
 model of landscape change and, 5:2534
 occupance word and, 5:2534
 regional comparisons element in, 5:2534–2535
 rejuvenation and, 5:2534
 reshaping of landscape and, 5:2534
 visibility of relics element in, 5:2535
 Derwent Whittlesey and, 5:2534, 6:3097–3098
- Serbia
 AGILE membership of, 1:125 (table)
 cultural nationalism in, 4:1980
- Setterfield, Mark, 4:2133–2134
- Settlement geography, 5:2535–2537**
 anthropocentric nature of, 5:2535
 definition of, 5:2535
 European *vs.* American studies of, 5:2536
 folk housing studies and, 5:2536
 frontiers and, 3:1170–1172
 holistic and sustainability elements in, 5:2536
 Liausson, France, 5:2536 (photo)
 rural landscape element in, 5:2536
See also Settlement geography: noted geography, scholars
- Settlement geography: noted geography, scholars
 Isaiah Bowman, 5:2536
 Loyal Durand, Jr., 5:2536, 5:2537
 Henry Glassie, 5:2535, 5:2536, 5:2537
 Cole Harris, 5:2537
 John Fraser Hart, 5:2537
 Terry Jordan, 5:2536, 5:2537
 Fred Kniffen, 5:2535, 5:2536–3537
 Allen Noble, 5:2537
 Karl Raitz, 5:2536, 5:2537
 Carl Sauer, 5:2535, 5:2536
 Kirk Stone, 5:2536, 5:2537
 William Syckoff, 5:2537
 Glen Trewartha, 5:2537, 6:2882–2883
 William Wyckoff, 5:2536
- Sevilla-Guzmán, Eduardo, 1:57
- Sexuality, geography and/of, 5:2538–2540**
 biopolitics (Foucault) and, 5:2539
 body scale of, 5:2538, 5:2539
 Manuel Castells and, 5:2538
City and the Grassroots (Castells) and, 5:2538
 cognitive accounts of public spaces and, 5:2539
 “compulsory heterosexuality” and, 5:2538
 critical health geography and, 5:2538
 criticisms of scholarly work on, 5:2539–2540
 gay and lesbian geographies and, 3:1183–1185
 gay and lesbian tourism and travel research and, 5:2540
 “gay landscape” work (Castells) and, 5:2538
 gender and geography and, 3:1188–1194
 heteronormativity and, 5:2538
 heteropatriarchy and, 5:2538
 HIV/AIDS map and modeling and, 5:2538
 institutionalization of heterosexuality and, 5:2539
 intersections of space and sexual politics and, 5:2539
 “in the closet” spatial metaphor and, 5:2539
 legal, health, and welfare issues and, 5:2539
 masculine geographies and, 4:1865–1866
 nature-society relationships element in, 5:2538
 patriarchic geographies and, 4:2135–2136
 queer theory and, 5:2538
 same-sex marriage issue and, 5:2539

- spatial element in, 5:2538
- transnational capitalist global space and, 5:2539–2540
- voting patterns analysis and, 5:2539
- Shab, Tushaar, 3:1389
- Shackleton, Nicholas, 5:2487
- Shaler, Nathaniel Southgate, 4:1789
- Shanin, Teodor, 4:2137
- Shaw, Clifford, 2:607
- Sheppard, Eric, 5:2601
- Shifting cultivation, 5:2540–2543**
 - agricultural intensification and, 1:36
 - agrobiodiversity and, 1:49–50
 - agroforestry and, 5:2541
 - characteristics of, 5:2540–2541
 - crop rotation and, 2:627–630
 - ecological and economic dimensions of, 5:2541–2543
 - harvest of dry-season crops and, 5:2541
 - indigenous environmental knowledge and, 5:2540, 5:2542–2543
 - indigenous forest dwellers and, 5:2542
 - in situ biodiversity and, 5:2542–2543
 - intercropping practice and, 5:2541
 - mixed farming and, 4:1914–1917
 - origins of, 5:2541–2542
 - potential sustainability of, 5:2542
 - production cycle of, 5:2541
 - staple crops varieties and, 5:2541
 - staple grains and, 5:2541
 - swidden or slash-and-burn cultivation terms and, 5:2540
 - tropical agricultural colonization and, 5:2542
 - tropical deforestation from, 5:2540, 5:2542
- Shiva, Vandana, 2:818–819, 3:1101
- Shoreline protection, 1:10
- Shortest-path problem, 5:2543–2544**
 - algorithms used in, 5:2543
 - function and purpose of, 5:2543
 - network analysis technique of, 5:2543
 - transportation and routing problems and, 5:2543–2544
 - types of, 5:2543
 - Web-based mapping and, 5:2544
- Siberia
 - Alexander von Humboldt's travels in, 3:1462
 - indigenous cartographies in, 3:1561
 - permafrost melting in, 3:1522
 - polar climate in, 1:450
 - polar semidesert in, 1:249, 1:451
 - sea ice minimum in, 2003–2005, 3:1525
 - shrub tundra of, 1:248
 - tussock and sedge-dwarf shrub tundra of, 1:248, 1:249
 - Valley of Geysers, Kamchatka Peninsula in, 3:1273
 - wet tundra of, 1:249
- Sibley, David, 2:892, 5:2442
- Sieferle, Rolf Peter, 2:839
- Siegel, A. W., 5:2609, 5:2610
- Siegfried, André, 2:879, 5:2223
- Siegler, Robert, 1:391
- Sierra Leone
 - Crocodile River, Freetown, 6:2896 (photo)
 - economically active females in, 3:1190 (table)
 - income ratio relative to slum population in, 2006, 5:2644 (fig.)
- Silicon Valley, California, high-tech economic geography and, 2:851, 2:885, 2:886, 3:1127, 3:1426, 3:1427 (photo), 3:1598, 5:2435, 5:2436, 5:2519
- Simmel, Georg
 - modernity and commodification relationship and, 4:1936
 - ordinariness views of, 2:1043
 - qualitative methodology and, 5:2323
 - urban sociology work of, 2:1043
- Simoons, Elizabeth, 2:782
- Simoons, Frederick John, 1:192, 2:782
- Singapore
 - Airbus A380 “Superjumbo” airline and, 1:180
 - APEC membership of, 1:121
 - ASEAN Free Trade Area and, 1:130
 - ASEAN membership of, 1:127, 1:128, 1:128 (table), 1:129, 1:129 (table)
 - British colonization of, 1:515
 - command and control economy in, 1:304
 - economically active females in, 3:1190 (table)
 - export-oriented industrialization (EOI) in, 2:1064
 - export trade success of, 2:731
 - foreign direct investment from and to, 3:1156
 - foreign direct investment in China from, 3:1155
 - as hub port, 5:2254
 - industrialization in, 3:1583, 4:2020
 - Japanese electronics industry in, 2:885
 - Malay archipelago and, 1:105
 - music and national identity in, 4:1968
 - as newly industrializing country, 4:2022, 4:2022 (fig.)
 - public housing in, 5:2304
 - U.S. foreign direct investment in, 3:1155
 - U.S. industry moving to, 2:700
- Singer, A., 2:1075
- Singer, Peter, 2:926
- Single large or several small (SLOSS) debate, 5:2544–2548**
 - controversy, 5:2546–2547, 5:2667
 - Jared Diamond's biodiversity studies and, 4:1697, 5:2216, 5:2545
 - dynamic equilibrium model of biogeography and, 5:2545 (fig.)
 - Paul Ehrlich and, 5:2545
 - equilibrium theory of island biogeography and, 5:2544–2546, 5:2545 (fig.)
 - forest fragmentation and, 3:1161
 - habitat islands and conservation in, 5:2545–2546, 5:2546 (fig.)
 - island biogeography and, 3:1632, 5:2548
 - landscape and wildlife conservation and, 4:1697
 - landscape biodiversity and, 4:1701–1703
 - Robert MacArthur, 5:2544
 - Robert MacArthur and, 5:2545
 - nature preserves, 3:1161
 - patches and corridors and, 4:2131–2133
 - Population Bomb* (Ehrlich) and, 5:2545
 - refuge design and, 5:2546
 - species-area relationship and, 5:2673
 - John Terborgh, 5:2545
 - E. O. Willis and, 5:2545
 - Edward O. Wilson and, 5:2544, 5:2545
- Situated knowledge, 5:2548–2549**
 - deep ecology movements and, 2:692–695
 - economic geography research and, 5:2549
 - ethnoecology or ethnoscience and, 5:2548–2549
 - geography subfields investigation of, 5:2548
 - GIS's social implications and, 5:2549
 - indigenous knowledge and, 5:2548–2549
 - interviewing and, 3:1625–1627
 - participant observation and, 4:2121–2122, 5:2548–2549
 - positionality and, 5:2257–2248
 - research issues related to, 5:2548
 - spatial, temporal, sociocultural, and political economic contexts of, 5:2549
 - terms related to, 5:2548

- Situationist International (SI) political and artistic movement, 73–74
 Six Nations of the Iroquois Confederacy, 3:1553
 Skelton, R. A., 3:1402
 Slash-and-burn/swidden cultivation technique
 deforestation and, 2:698
 preindustrial agriculture and, 1:48, 1:301–302
 Slater, David, 2:706
 SLOSS. *See* Single large or several small (SLOSS) debate
 Slovakia
 acid rain in, 1:7
 economically active females in, 3:1190 (table)
 European Union (EU) membership of, 2:1035
 Greenpeace Slovakia and Mother Earth movements in, 2:1033
 Slovenia
 AGILE membership of, 1:125 (table)
 economically active females in, 3:1190 (table)
 European Union (EU) membership of, 2:1035
 Small Business Innovation Research (SBIR), 1:280
 Small Business Technology Transfer (STT), 1:280
Smart growth, 5:2550–2551
 definition of, 5:2550
 eco-housing development, green design and, 3:1371
 environmental planning and, 2:982
 greenbelts and, 3:1363–1367
 green building and, 3:1367–1369
 land use policies and, 5:2551
 leapfrog development and, 5:2551
 Premier Gardens Zero Energy Home Community, Sacramento, California, 5:2550 (photo)
 regional environmental planning and, 5:2386
 smart growth planning and, 3:1372
 in urban planning, 3:1313, 5:2240, 5:2550–2551
 urban sprawl detrimental effects and, 5:2550–2551
 Smith, Adam
 comparative advantage work of, 2:556
 division of labor views of, 2:780, 3:1582, 4:1860
 labor theory of value and, 4:1860
 Marx influenced by, 4:1860
 political economy meaning and, 5:2214
 Smith, Adrian, 4:2109
 Smith, Dorothy E., 2:1043
 Smith, J. Russell, 2:848, 2:850, 2:851
Smith, Neil, 5:2551–2552
 academic career of, 5:2551
 capital-centered account of gentrification and, 3:1204
 class and nature work of, 1:423–424
 Endgame of Globalisation written by, 5:2552
 external *vs.* universal ideologies of nature and, 1:424
 gentrification as capital investment work views of, 3:1204, 3:1205 (fig.), 3:1206 (table), 3:1207, 5:2551
 David Harvey and, 5:2551
 International Critical Geography Group and, 5:2552
 Marxist geographies work of, 3:1467, 4:1863, 5:2506–2507, 5:2551–2552
 material reproduction of self and, 5:2560
 nature within capitalism context work of, 2:851, 3:1467, 4:1992–1993
 new geography or spatial science and, 5:2551
 production of nature, 5:2551–2552
 production-side theory and, 3:1204
 radical geography and, 5:2351
 relative space views of, 5:2404
 rent-gap hypothesis and, 5:2430, 5:2551
 scale appropriateness of labor strategy and, 4:1677, 5:2506–2507
 Uneven Development written by, 1:423–424, 4:1863, 5:2351, 5:2551–2552
 uneven geographical development (UGD) and, 5:2551–2552
 Snow, John
 cartography work of, 1:355
 geography of cholera work of, 1:401–402, 2:770, 3:1595
Social and economic impacts of climate change, 5:2552–2556
 assessments of, 5:2553
 biological “social mind” and, 5:2561
 criticisms of, 5:2555–2556
 current knowledge, 5:2553–2555
 geographic perspectives on, 5:2556
 Hurricane Katrina and, 5:2553
 impact analyses of, 5:2555–2556
 Intergovernmental Panel on Climate Change and, 5:2552
 nature-society issue of, 5:2556
 observed trends and, 5:2555
 place-based studies of, 5:2556
 projected levels of climate change and, 5:2554
 quantitative assessments of, 5:2553
 spatial systems importance in, 5:2556
 Special Report on Emission Scenarios (SRES) and, 5:2553
 Herbert Spencer and, 5:2561–2562
 Paul Vidal de la Blache and, 5:2561
Social construction of nature, 5:2557–2561
 class and nature and, 1:423–425
 ecological imaginaries and, 2:828–830
 ecosystem science construction example of, 5:2558–2559
 environmental discourse and, 2:918–921
 environmental management and, 2:967–970
 externalist perspective on, 5:2558
 extrascientific, social nature of, 5:2560
 gender and nature and, 3:1194–1197
 human interactions in, 5:2559–2560
 hybrid geographies and, 3:1502–1504
 invasive species example of, 5:2558
 knowing nature and, 5:2557–2558
 George Perkins Marsh’s work in, 4:1858–1859, 4:2180
 nature of nature and, 5:2338, 5:2557
 positivist perspective of nature and, 5:2557
 post-positivist perspective on, 5:2558
 social production of nature and, 5:2557, 5:2559–2560
 Structure of Scientific Revolutions (Kuhn) and, 5:2557
 See also Critical studies of nature
Social Darwinism, 5:2561–2563
 anthropogenography and, 1:93
 Chicago School and, 5:2562
 ethical geographies and, 2:1014
 ethnocentrism and, 2:1027
 Eurocentrism and, 2:1029, 5:2338
 global hierarchy of societies and, 5:2562
 Jean Baptiste Lamarck and, 5:2561
 pseudoscience of, 5:2561
 race as “scientific” human classification method and, 5:2338
 racial and ethnic inequalities justified by, 5:2562
 Friedrich Ratzel’s geopolitical ideology and, 5:2562
 Alfred Russel Wallace and, 5:2211
 See also Darwinism and geography
Social forestry, 5:2563–2564
 centralized to decentralized forest management shift and, 5:2563
 Chipko Movement and, 5:2563
 community forestry and, 2:551–553, 5:2564
 definition of, 5:2563
 forestry for local people concept and, 5:2563
 in India, 5:2563

- midlatitude deciduous forest biome and, 1:223–226
 terms associated with, 5:2563, 5:2564
 tropical deciduous forest biome and, 1:230–233
 Jack Westoby and, 5:2563
- Social geography, 5:2564–2569**
 anarchism and geography and, 1:73–74
 applied and theoretical research and, 5:2568
 behavioral approach to, 5:2566
 blindness and geography and, 1:286–287
 blurring boundaries of, 5:2569
 Charles Booth and, 5:2565–2566
 Anne Buttimer's work in, 1:309, 4:1786
 capitalism element in, 5:2566
 children and youth geographies and, 5:2568
 cultural turn and, 5:2569
 current issues, 5:2568–2569
 definition of, 5:2564
 diversity feature of, 5:2564–2565
 feminist geography and, 5:2567–2568
 gated communities and, 3:1181–1183
 Peter Gould and, 5:2566
 David Harvey and, 5:2567, 5:2568
 history of, 5:2565–2566
 human and physical geography and, 5:2564–2565
 humanistic approach to, 5:2566–2567
 individual decision making and, 5:2566
 international migration and, 5:2568
 issues addressed by, 5:2565
 David Ley and, 5:2567
 Marxist theory and, 5:2567
 meanings attributed to place4s and, 5:2566
 residential decision making and, 5:2566
 sexuality and sexual orientation issues and, 5:2568
 social identities and behavior and, 5:2568
Social Justice and the City (Harvey) and, 5:2567, 5:2568
 social phenomena in space analysis and, 5:2564
 space and place focus of, 5:2564–2565
 structuralist approach to, 5:2567
 suburban housing and, 5:2566
- Socialism and geography, 5:2569–2572**
 communism *vs.*, 5:2569–2570
 critical human geography and, 5:2571
 democratic socialism and, 5:2570
 economic development theories and, 5:2571–2572
 forms of socialism and, 5:2569–2570
 geographical discourse and, 5:2570–2572
 Leninist socialism and, 5:2570, 5:2572
 Marxist socialism and, 5:2570
 quantitative revolution and, 5:2571
 radical geography and, 5:2571
 socialism term interpretations and, 5:2569
 utopian socialism and, 5:2570
See also Communism and geography; Socialism and geography:
 noted geographers, individuals, scholars
- Social justice, 5:2572–2574**
 anarchism and geography and, 1:73–74
 antisystemic movements and, 1:99–100
 call to action by, 5:2573
 cosmopolitanism and, 2:590–592
 countermapping and, 2:595–596
 critical cultural geography and, 2:638
 critical studies of nature and, 2:625
 democracy and, 2:705–707
 ecological justice and, 2:830–832
 educational geographies and, 2:874–875
 environmental justice and, 2:959–965
 ethics and geography and, 2:1013–1016
 homelessness and, 3:1440–1442
 human dimensions of global environmental change
 and, 3:1453–1454
 human rights geographies and, 3:1480–1481
 inequality geographies and, 3:1586–1590
 International Criminal Court (ICC) and, 3:1605–1608
 justice/injustice geographies and, 3:1643–1645
 measures of, 5:2573
 participatory learning and action and, 4:2123–2124
 philosophical perspective of, 5:2572–2573
 social justice environmentalism term and, 2:959
 social scientific inquiry and, 5:2573
 UN Human Development Index (HDI) and, 5:2573
See also Democracy; *Environmental justice*; *Justice, geography of*
- Social justice: noted geographers, individuals, scholars**
 James Blaut, 1:285
 Anne Buttimer, 1:309
 David Harvey, 3:1404–1406, 3:1467, 4:1862
 Thomas Jefferson, 5:2573
- Social movements, 5:2574–2576**
 antiglobalization movements and, 1:96
 antisystemic movements and, 1:99–100
 civil society and, 1:414–416
 countermapping and, 2:595–596
 dimensions of place (Agnew) and, 5:2574
 institutional and state frameworks of, 5:2575
 labor unions and, 5:2575
 mobilization issues and, 5:2575
 networks and mobilization elements of, 5:2574–2575
 peace movement and, 5:2575
 peasants and peasantry, 4:2137–2142
 place-based collective action frames and, 5:2575
 research, 5:2574
 scales factor in, 5:2575
 spatial context of, 5:2574
*See also Social movements: noted individuals, geographers,
 scholars*
- Social movements: noted individuals, geographers, scholars**
 John Agnew, 5:2574
 Kevin Cox, 5:2575
 D. Featherstone, 5:2574–2575
 Andy Herod, 5:2575
 Deborah Martin, 5:2575
 Byron Miller, 5:2575
 W. Nicholls, 5:2575
 Paul Routledge, 5:2574–2575
 Raymond Williams, 5:2574
- Society for Ecological Restoration International, 3:1166**
 Soffer, Arnon, 4:1897
- Soil conservation, 5:2576–2580**
 agroforestry, 5:2579
 agronomic methods of, 5:2576, 5:2577–2579, 5:2578 (photo)
 ancient societies and, 5:2579
 ancient stone-faced terraces, Island of the Sun, Lake Titicaca,
 Andean South America, 5:2579, 5:2579 (photo)
 beans intercropped with maize and, 5:2577 (photo)
 bench and platform terraces and, 5:2576 (photo)
 check dams, 5:2576
 conservation tillage, 5:2578
 contour plowing, 5:2577
 contour ridges planted with wheat and maize and, 5:2577 (photo)
 cover crops and, 5:2578
 definition of, 5:2576

- diversion ditches, 5:2577
 history and geography of, 5:2579–2580
 implementation challenges and, 5:2580
 indigenous conservation measures, 5:2578
 international agencies and, 5:2580
 mechanical methods of, 5:2576–2577, 5:2578 (photo)
 strip cropping, 5:2578–2579
 terraces, 5:2577
- Soil degradation, 5:2581–2582**
 definition of, 3:1335, 5:21581
 desertification and, 2:715–719, 2:972–973, 3:1335
 geographic variation of soil resources and, 5:2582
 global environmental change and, 3:1335
 Great Plains, Dust Bowl regions and, 5:21581
 human and physical variables in, 5:2582
 human impacts on soil and, 3:1335
 Natural Resources Conservation Service and, 5:21581
 soil desertification and, 5:2582
 soil erosion, water runoff, Castilla-La Mancha, Spain, 5:2581 (photo)
See also Land degradation; Soil depletion; Soil erosion
- Soil depletion, 5:2582–2583**
 calcium, 5:2582–2583
 definition of, 5:2582
 global soil nutrient deficit data and, 5:2583
 in low-latitude countries, 5:2583
 natural nutrient cycle and, 5:2583
 nitrogen, phosphorus, and potassium losses and, 5:2583
 sustainable agriculture and, 5:2582
See also Soil degradation; Soil erosion
- Soil erosion, 5:2583–2585**
 ancient civilizations and, 5:2584
 creep and, 2:604–605
 definition of, 5:2583
 factors affecting, 5:2583–2584
 geographic extent of, 5:2585
 Great Plains, Dust Bowl and, 5:2584
 gully erosion and, 3:1392–1394
 history of, 5:2584–2585
 human actions and, 5:2584–2585
 management practices reduction of, 5:2584
 rill erosion and, 5:2464–2466
 Soil Conservation Service and, 5:2585
 vegetation reduction of, 5:2584
 water runoff, Castilla-La Mancha, Spain, 5:2581 (photo)
 in wheat field, Washington state, 5:2584 (photo)
See also Land degradation; Soil degradation; Soil depletion
- Soils, 5:2585–2592**
 agrillic horizons and, 5:2587
 animals and, 5:2590
 calcic horizons in, 5:2587
 cation exchange capacity attribute of, 5:2589–2590
 classification systems of, 5:2590, 5:2592
 clay minerals in, 5:2587
 clorpt equation (Jenny) of, 5:2585
 eluvial horizons and, 5:2586
 human interaction and, 5:2590
 illuvial horizons and, 5:2586
 layers (horizons) in, 5:2585, 5:2586 (fig.)
 mineral-based particles in, 5:2587
 nitrogen cycle and, 5:2590
 particle size, ability to hold water and, 5:2587
 peat and, 4:2142–2143
 pH attribute of, 5:2589
 plant growth support function of, 5:2589
 salt deposition in, 5:2586–2587
 soil chemistry, soil parent material and, 5:2589
 soil definition and, 5:2585
 soil-forming factors and, 5:2585–2586
 soil organisms and, 5:2590
 soil peds, soil structure and, 5:2588
 soil profile and, 5:2586
 soil separates in, 5:2587
 soil textural classification and, 5:2587
 soil textural triangle and, 5:2588 (fig.)
 typical Mollisol profile, 5:2591 (photo)
 typical Oxisol profile, 5:2592 (photo)
 typical Spodosol profile, 5:2591 (photo)
 water critical to formation of, 5:2586
See also Soil conservation; Soil degradation; Soil depletion;
 Soil erosion
- Soja, Edward, 5:2593–2594**
 academic career of, 5:2593
 class struggle over social production of space and, 3:1419, 4:1862
 Michel Foucault and, 5:2593
 historicism, despatialized consciousness and, 3:1433
 Henri Lefebvre and, 4:1769, 5:2593
 Los Angeles School of urbanism and, 2:688, 4:1803, 5:2593
 Marxism in geography and, 4:1862, 5:2351, 5:2593
Postmetropolis written by, 5:2593
Postmodern Geographies written by, 5:2593
 postmodern geography work of, 3:1469, 5:2264, 5:2351, 5:2593
 social justice and inequality issues and, 5:2593
 spaces of representation and, 5:2602
 “spatial turn” work of, 5:2593, 5:2670
 thirdspace, 5:2442, 5:2602
 “tialectics,” 5:2593
 urban and political geography theories of, 5:2593
- Sokal, Alan, 5:2516
- Solar energy, 5:2594–2596**
 centralized utility-scale installations and, 5:2595
 concentrating *vs.* nonconcentrating social energy technologies
 and, 5:2594
 early average values of, 5:2594
 grid-connected distributed installations and, 5:2595
 national energy policies and, 2:900, 2:902
 off grid installations and, 5:2595
 passive *vs.* active solar energy technology and, 5:2594
 solar hot water system, Adams County Detention Facility,
 Denver, Colorado, 5:2595 (photo)
 thermal *vs.* photovoltaic energy technology and, 5:2594
- Solstices, 5:2596–2598**
 Christmas holidays and, 5:2597–2598
 European midsummer festivals and, 5:2597
 in non-European cultures, 5:2598
 pre-Christian religious traditions and, 5:2597–2598
 Stonehenge, summer solstice, 5:2597 (photo), 5:2598
 summer solstice, 5:2596–2597
 sun stoppage, 5:2596
 winter solstice, 5:2597
- Somalia**
 ass domesticated in, 2:783
 economically active females in, 3:1190 (table)
 human rights atrocities in, 3:1481
 Kushitic language in, 4:1749
 locusts infestation in, 2:727
 State House refugee settlement, Hargesia, 5:2379 (photo)
- Somerville, Mary, 4:1989
- SOMs. *See* Self-organizing maps (SOMs)
- Sonnenfeld, David, 2:835
- Sontag, Susan, 4:1876

South Africa

- Berg* warm, dry, gusty, downslope wind in, 1:384
- Big Hole diamond mine in, 4:2086
- British Empire colonies in, 1:509
- casuarinas in dunes, Zululand, 6:2881 (photo)
- coal in, 1:485
- critical geographers in, 2:618
- economically active females in, 3:1190 (table)
- environmental privatization in, 4:2009
- ethnic segregation in, 2:1022
- game ranching in, 3:1179–1181
- gated communities in, 3:1181
- greenhouse gas emissions and, 1:463
- groundwater usage in, 3:1386
- income ratio relative to slum population in, 2006, 5:2644 (fig.)
- market-based land reform in, 4:1695
- midlatitude grasslands in, 1:228–229
- newly industrializing country of, 4:2022 (fig.)
- next generation nuclear reactors in, 4:2051
- public-private partnerships in, 5:2312
- tropical deciduous forest in, 1:231
- vineyard, Constantia region, Cape Winelands, 6:3118 (photo)

South America, 3:1193

- AGS's Millionth Map of, 1:295
- Amazon River basin, tropical rain forests of, 1:132
- Amazon River flowing through rain forest in, 5:2473 (image)
- ancient conservation, stone-faced terraces, Island of the Sun, Lake Titicaca, 5:2579 (photo)
- bush fallow farming practiced in, 1:301–302
- cadastral systems, land ownership and, 1:315
- as center of crop domestication, 1:376
- cholera in, 1:401
- coca cultivation in, 2:797
- colonial migrations of, 1500–1914, 3:1543
- crop domestication process and centers in, 1:375 (photo)
- deforestation in, 2:696
- developing countries in, 2:725 (fig.)
- dry climates in, 1:429, 1:430 (fig.)
- El Niño–Southern Oscillation (ENSO) and, 2:887
- forest fragmentation in, 3:1159
- gender and livelihoods research in, 3:1193
- geothermal energy use in, 3:1267 (fig.), 3:1269
- glaciers in, 3:1332
- groundwater usage in, 3:1386
- Alexander von Humboldt's travels in, 3:1462, 3:1482
- hunting and gathering tribes in, 3:1492
- hydroelectric power in, 3:1507, 3:1509
- indigenous agriculture in, 3:1557
- Isthmus of Panama, North America and, 1:213
- land degradation estimates in, 4:1680 (table)
- midlatitude deciduous forest in, 1:224
- midlatitude grasslands in, 1:228, 1:228 (fig.), 1:229
- military expenditures in, 4:1899 (table)
- Millionth Map project of, 1:295
- monsoons in, 2:741, 4:1941
- plantation model in, 3:1362
- political map of, 6:3165
- population growth of, 5:2241
- potential water availability in, 2007, 2050, 6:3059 (fig.)
- renewable water resources and availability in, 6:3057 (table)
- soil erosion in, 5:2585
- species variations in, 1:209
- temperate, semiarid deserts in, 1:219
- temperate arid deserts in, 1:221
- transboundary aquifers in, 3:1389

- tropical deciduous forest in, 1:230, 1:232, 1:233
- tropical humid climate in, 1:453
- tropical rain forest of, 1:234, 1:237, 1:453
- tropical savanna in, 1:239, 1:241, 1:455
- tropical/subtropical hyperarid deserts in, 1:222
- tropical/subtropical semiarid deserts in, 1:220
- vicariance biogeography in, 1:211

See also specific country

South Asia

- adults and children living with HIV in 2007 in, 3:1437 (fig.)
- chickens domestication in, 2:783
- climate change, greenhouse gas emissions and, 1:464
- coastal zone and marine pollution and, 1:501
- Cold War and, 1:504
- colonization of, 1:514
- deficient calorie consumption in, 3:1487
- developed countries in, 2:725 (fig.)
- El Niño–Southern Oscillation (ENSO) and, 2:889
- fertility levels in, 2:709
- groundwater importance in, 2:783
- HIV/AIDS in, 3:1438
- land inequalities in, 4:1693
- malaria in, 4:1816
- military expenditures in, 4:1899 (table)
- monsoon, 4:1943–1944
- people living in extreme poverty and, 3:1082 (table)
- poverty rates in, 5:2274
- prehistoric exploration of, 2:1050
- sewage entering coastal zones of, 1:501
- Silk Road and, 2:1053
- social movements in, 5:2574
- sub-altern studies, South Asian historiography and, 2:1029
- transboundary aquifers in, 3:1389
- tropical humid climate in, 1:453
- undernourishment in, 3:1488

See also specific country

South Carolina

- hurricane risk in, 3:1500
- nuclear weapons site in, 5:2469
- pine forest habitat in, 4:2131–2132

South Dakota, 6:3093 (photo)

Southeast Asia

- adults and children living with HIV in 2007 in, 3:1437 (fig.)
- Association of Southeast Asian Nations (ASEAN) and, 1:126–131, 1:127 (fig.)
- biota studies of, 1:209
- bovine domestication in, 2:783
- bush fallow farming in, 1:301–302
- as center of domestication, 1:374, 1:376
- chickens domestication in, 2:783
- Chinese exploration of, 2:1054
- cholera in, 1:401, 1:402, 1:402 (fig.)
- coastal zone and marine pollution and, 1:501
- Cold War and, 1:504, 1:505
- colonial migrations of, 1500–1914, 3:1543
- colonization of, 1:515
- COMECON and, 2:593
- deforestation in, 2:696
- developing countries in, 2:725 (fig.)
- domino theory and, 2:787, 3:1224
- drug culture in, 2:799
- electronic waste pollution in, 1:502
- El Niño–Southern Oscillation (ENSO) and, 2:887
- forest fragmentation in, 3:1159
- HIV/AIDS in, 3:1438

- hunting and gathering tribes in, 3:1492
- indigenous forestry in, 3:1569
- Japanese colonization in, 1:514
- land use and cover change in, 4:1736
- malaria in, 4:1816
- Malayo-Polynesian languages in, 4:1753, 4:1753 (fig.)
- mining frontier in, 4:1911
- monsoons in, 2:741
- nationalism in, 1:517
- opium and heroin production in, 2:796–797
- plantations in, 5:2192
- political map of, 6:3159
- rice fields in, RADAR image, 4:1889 (fig.)
- sewage entering coastal zones of, 1:501
- slash-and-burn preindustrial agriculture in, 1:48
- South China Sea, tropical rain forests of, 1:132
- taungya* agroforestry system used in, 1:60
- timber from, 1:238
- tropical deciduous forest in, 1:232
- tropical humid climate in, 1:453
- tropical rain forest of, 1:237, 1:453
- See also specific country*
- Southern Hemisphere
 - air masses of, 1:63
 - atmospheric angular momentum in, 1:143
 - Coriolis force and, 2:586
 - dry climates in, 1:429, 1:430 (fig.)
 - Hadley cell atmospheric circulation in, 3:1395
 - midlatitude cyclones in, 1:134
 - polar climate in, 1:449
 - See also specific country*
- South Korea
 - APEC membership of, 1:121
 - automobile industry in, 1:169
 - Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 - demilitarized zone (DMZ) of, 1:293 (photo)
 - deposit refund systems in, 4:1857
 - economically active females in, 3:1190 (table)
 - export-oriented industrialization (EOI) in, 2:1064
 - export trade success of, 2:731
 - foreign aid from, 3:1153
 - foreign direct investment in China from, 3:1155
 - hydropower in, 3:1507
 - import substitution industrialization in, 3:1551
 - incubator zones in, 3:1552
 - industrialization in, 3:1580, 3:1583
 - Japanese electronics industry in, 2:885
 - Japan-South Korea World Baseball Classic game, Dodger Stadium, Los Angeles, 5:2681 (photo)
 - land reform in, 4:1693
 - newly industrializing country of, 4:2021, 4:2022 (fig.)
 - North Korea borderlands and, 1:292, 1:293 (photo)
 - Pohang Iron and Steel Company, Pohang, 5:2691 (photo)
 - restricted development zoning in, 3:1364–1365
 - squatter settlements in, 5:2682
 - steel industry in, 5:2689, 5:2690
- South Madagascar, 2:827 (table)
- South Pole. *See Poles, North and South*
- South Vietnam, 2:543
- Sovereignty, 5:2598–2600**
 - antiglobalization nationalism and, 5:2600
 - Cold War and, 5:2599
 - context-reflective nature of, 5:2598–2599
 - definition of, 5:2598
 - derivation of, 5:2599
 - detritorialization and, 3:1340
 - geopolitical context of, 5:2599–2600
 - globalization and, 3:1340
 - International Court of Justice (ICJ) and, 5:2599
 - international law and, 5:2599
 - international recognition element in, 5:2599
 - Magna Carta and, 5:2599
 - Peace of Westphalia legal precedent for, 5:2599
 - theoretical components of, 5:2598
 - UN Law of the Sea and, 5:2599
- Soviet Union
 - capitalist restructuring in, 5:2459–2460
 - Chernobyl nuclear accident and, 1:385–386
 - Cold War and, 1:504–505, 2:691–692, 3:1223–1224, 3:1250–1251
 - collapse of, 3:1251, 4:1978
 - COMECON membership of, 2:593–594, 2:593 (table)
 - Five Year Plans in, 2:542, 2:543
 - geopolitics in, 3:1251
 - human rights violations in, 3:1480
 - hydroelectric power in, 3:1507
 - industrialization in, 3:1583
 - Moscow, May Day celebrations and, 2:544 (photo)
 - NATO and, 4:2047
 - natural growth rate in, 4:1981
 - Stalinist version of Marxism in, 4:1861
 - state nationalism in, 4:1980
 - Warsaw Pact and, 4:2047
 - See also Communism and geography; Russia*
- Spaargaren, Gert, 2:836, 3:1369
- Space. *See Absolute space*
- Space of flows, 5:2600–2601**
 - Manuel Castells and, 5:2600
 - circuits of capital and, 1:410–412
 - Doreen Massey, 5:2601
 - mobility and, 4:1918–1921
 - networks of interconnectiveness and, 5:2601
 - postmodernist power concept and, 5:2600–2601
 - relative/relational space and, 5:2402–2405
 - Eric Sheppard, 5:2601
 - spaces of representation and, 5:2601
 - time-space compression and, 5:2600–2601
- Spaces of representation/representational spaces, 5:2602–2603**
 - challenges to, 5:2602–2603
 - conceived space and, 5:2602
 - definitions, 5:2602
 - everyday life geographies and, 2:1042–1045
 - Henri Lefebvre's work and, 4:1768–1770, 5:2297, 5:2602
 - life-world, 5:2602
 - lived spaces and, 5:2602
 - media and geography and, 4:1874–1877
 - perceived space and, 5:2602
 - production of space and, 5:2297–2298
 - Edward Soja and, 5:2602
 - space of flows and, 5:2601
 - “third-space” concept and, 5:2602
 - time-space compression and, 5:2601
- Spain
 - AGILE membership of, 1:125 (table)
 - agroforestry in, 1:57
 - automobile industry in, 1:169
 - Catalonia technology region in, 5:2435
 - colonial empire of, 1:509, 1:509 (fig.), 1:511, 1:512
 - Conference of Latin Americanist Geographers held in, 2:568
 - ecological footprint and biocapacity of, 2:827 (table)

- economically active females in, 3:1190 (table)
 encomienda land grant system of, 1:512
 energy feed-in tariffs (FIT) in, 2:901
 European Union (EU) membership of, 2:1035
 groundwater usage in, 2:783
 gully erosion in, 3:1392 (photo), 3:1393 (photo)
 high-speed trains in, 5:2364
 Hispanocentrism of, 2:1030 (table)
 Ibn Battuta exploration of, 2:1054, 3:1519
 Inca rebellions against, 1:508
 industrialization in, 3:1583
 Kyoto Protocol of 1997 and, 1:463
 Latin America colonized by, 1:511–512
 mixed field in Eastern Mallorca, 4:1915 (photo)
 morphine-rich narcotics produced in, 2:796, 2:797 (table)
 movement against genetically modified organisms in, 3:1610
 Park Guell, Barcelona, 2:641 (photo)
 Philippines controlled by, 1:515
Prestige oil tanker spill and, 4:2076
 “science” of geopolitics in, 3:1250
 silver trade and, 1:511–512, 1:513 (fig.)
 social movements research in, 1:365
 soil erosion, water runoff, Castilla-La Mancha, 5:2581 (photo)
 wind power development in, 2:902
- Spatial analysis, 5:2603–2607**
Advanced Spatial Analysis (Batty) and, 1:186
 Luc Anselin’s work in, 1:80–81
 artificial intelligence and, 3:1212
 Brian Berry’s work and, 1:193
 cancer geography and, 1:320–324
 central place theory and, 1:380–382
 client-server architectures and, 5:2603
 continuous space-and-time models and, 2:565–566
 data mining techniques and, 3:1212
 data sets size and analysis issues in, 3:1212
 definitions, 5:2603
 descriptive summary classification of, 5:2605
 discrete space-and-time models and, 2:566–567
 dispersion and, 5:2605
 field view representational model of, 5:2604
 fragmentation statistics and, 5:2605
 functions of, 5:2603
 future trends in, 5:2605–2606
 geocomputation and, 3:1211–1215
 geographical analysis definition and, 5:2603
 geostatistics and, 3:1261–1265
 Arthur Getis’s work in, 3:1274
 GIS analytical operations and, 1:71–72, 5:2604
 GIS and GIScience frames of, 5:2603
 hypothesis testing and, 5:2605
 Internet and, 5:2603–3604
 linear referencing and dynamic segmentation and, 4:1784–1785
 locational analysis and, 5:2603
 map algebra and, 4:1824–1825
 measurement classification of, 5:2605
 medical geographies and, 4:1878
 modeling and simulation approach to, 5:2605
 multidisciplinary roots of, 5:2603
 object view representational model of, 5:2604
 Open Source Geospatial Foundation and, 4:2088–2089
 Open Source GIS and, 4:2090–2091
 optimization methods of, 5:2605
 point pattern analysis and, 5:2201–2202
 representational forms and types of, 5:2604–2605
 sensor webs and, 5:2603
- simple query form of, 5:2604–2605
Spatial Analysis (Berry and Marble, eds.) and, 5:2603
 spatial autocorrelation and, 5:2607–2608
 spatial autocorrelation measures and, 5:2605
 transformation classification of, 5:2605
 urban analysis dimension of human ecology and, 3:1458
See also GIS specific subject; Heuristic methods in spatial analysis; Spatial specific subject
- Spatial autocorrelation, 5:2607–2608**
 definition and functions of, 5:2607
 Geary’s *C* and, 5:2607–2608
 geocomputation and, 3:1214
 geographically weighted regression (GWR) and, 3:1225–1232, 5:2329
 geostatistics and, 3:1261–1265
 Getis statistic (*Gi*) and, 5:2608
 hypothetical images, hot spots and cold spots, 5:2608 (fig.)
 hypothetical images, positive and negative spatial autocorrelation and, 5:2607 (fig.)
 Mora’s *I* and, 5:2607
 patchy appearance of landscape and, 4:1707
 simple kriging geostatistics and, 3:1263
 spatial statistics and, 5:2664–2665
See also Exploratory spatial data analysis (ESDA)
- Spatial cognition, 5:2608–2612**
 behavioral geography and, 1:189–190
 blindness and geography and, 1:286–287
 cognition *vs.*, 5:2608–2609
 cognitive maps and cognitive mapping in, 5:2609–2610
 definition of, 5:2608–2609
 environmental perception and, 2:977–980
 exocentric frame of reference and, 5:2610
Image of the City (Lynch) and, 5:2609–2610
 Internet factor in, 5:2611
 knowledge acquisition and, 5:2610
 landmark knowledge and, 5:2610
 legibility element in, 5:2610
 macrotensis theory (Siegel and White) and, 5:2610
 mental maps and, 4:1881–1883
 Piaget’s developmental theory and, 5:2610
 public participation GIS and, 5:2611
 rat maize behavior foundation of, 5:2609
 recent research in, 5:2611
 route knowledge and, 5:2610
 sequential acquisition of spatial knowledge and, 5:2609
 spatial abilities and individual differences in, 5:2610–2611
 spatial knowledge acquisition by children and, 5:2609
 spatial updating and, 5:2611
 survey knowledge and, 5:2610
 vision element in, 5:2610–2611
See also Childhood spatial and environmental learning; Spatial specific subject
- Spatial cognitive engineering, 5:2612–2616**
 applications of, 5:2615–2616
 cognitive engineering *vs.*, 5:2612–2614
 cognitive user parameters and, 5:2614–2615, 5:2615 (fig.)
 generic, group, and individual user categories and, 5:2614, 5:2615 (fig.)
 goal of, 5:2612
 gulf between execution and evaluation and, 5:2612, 5:2613 (fig.)
 location-based decision services and, 5:2615
 Donald Norman and, 5:2612
 origins of, 5:2612
 psychological user *vs.* physical system variables and, 5:2612, 5:2613–2614, 5:2613 (fig.)
 spatial and temporal aspects of, 5:2613–2614

- user categorization into generic, group, and individual, 5:2615 (fig.)
- user-centered system design and, 5:2612
- wayfinding and, 5:2614
- See also Spatial specific subject*
- Spatial data infrastructures (SDI), 5:2616–2623**
 - architecture model in, 5:2619–2620
 - characteristics of, 5:2616
 - data indexing and, 2:682–684
 - data models of, 5:2620–2623
 - definition and function of, 5:2616
 - early incompatibility of, 5:2616–2617
 - geographical markup language (GML) and, 5:2620
 - geolibraries and, 3:1234–1235
 - history of, 5:2616–2617
 - INSPIRE architecture and, 5:2619–2620, 5:2621 (fig.)
 - integrated model of, 5:2622 (fig.)
 - international SDI initiatives and, 5:2167
 - interoperability and spatial data standards and, 3:1623–1625
 - metadata encoding and, 5:2620
 - OGC filter encoding (FE) and, 5:2620
 - Open GIS Consortium (OGC) and, 5:2617
 - process model of, 5:2618–2619, 5:2619 (fig.), 5:2620 (fig.)
 - roles, process, and architecture overview of, 5:2618 (fig.), 5:2622 (fig.), 5:2623
 - roles and responsibilities of, 5:2617–2618
 - SDI committee role and, 5:2617
 - SDI service customer role of, 5:2617–2618
 - SDI service provider role and, 5:2617
 - service models and, 5:2620–2621, 5:2621 (fig.), 5:2623
 - spatial operators and query language and, 5:2620
 - spatial statistics and, 5:2664
 - U.S. national SDI and, 5:2167
 - view, download, transformation, and invoke service types and, 5:2623
 - Web services and, 5:2167
 - See also Exploratory spatial data analysis (ESDA); GIS specific subject; Spatial specific subject*
- Spatial data integration, 5:2623–2625**
 - conflation and, 2:568–569
 - definition and functions, 5:2623–2624
 - differential elements in, 5:2623–2624
 - general-purpose data mining methods and, 5:2625–2626
 - horizontal data integration and, 5:2624
 - interoperability and, 5:2624
 - metadata and, 4:1885, 5:2624
 - modifiable areal unit problem and, 4:1935
 - spatial data quality assessment and, 5:2624
 - standards for, 5:2624
 - temporal data integration task and, 5:2624
 - vertical data integration and, 5:2624
 - See also Exploratory spatial data analysis (ESDA); GIS specific subject; Spatial specific subject*
- Spatial data mining, 5:2625–2627**
 - challenges in, 5:2625
 - computational, statistical, and visual approaches to, 5:2626
 - computational efficiency of, 5:2626
 - decision trees and neural networks heuristics and, 3:1214
 - discriminate analysis and, 3:1214
 - geocomputation and, 3:1214
 - knowledge discovery from data and, 5:2625
 - pattern complexity and hypothesis generation in, 5:2626
 - real-world problems issues and, 5:2626–2627
 - spatial nonstationarity and, 5:2626
 - steps in, 5:2625
 - tasks in, 5:2625
 - transparency limitations issues and, 3:1214
 - U.S. decennial census and, 3:1214
 - visual presentation and understandability of, 5:2626
 - See also Exploratory spatial data analysis (ESDA); Spatial specific subject*
- Spatial data models, 5:2627–2629**
 - critiques of, 5:2628
 - error propagation and, 2:1011–1012
 - functions of, 5:2627
 - GIScience and, 3:1284–1289
 - object data model, 5:2627, 5:2628
 - Open Source Geospatial Foundation and, 4:2088–2089
 - Open Source GIS and, 4:2090–2091
 - operations examples performed by, 2:674
 - raster data model, 5:2627
 - spaghetti data structure, 5:2628
 - “spatially enabled” tables and, 2:674
 - spatial references and, 5:2627
 - topological data structure, 5:2628
 - Triangulated Integrated Network (TIN) model, 5:2627, 5:2628
 - vector data model, 5:2627–2628
 - See also Exploratory spatial data analysis (ESDA); GIS specific subject; Spatial specific subject*
- Spatial data structures, 5:2629–2631**
 - conceptual and local levels of, 5:2629
 - conflation and, 2:568–569
 - database management systems and, 2:671–674, 2:674
 - data format conversion and, 2:681–682
 - functions of, 5:2629
 - irregular tree raster data structure and, 5:2630, 5:2631 (fig.)
 - quad-tree raster data structure and, 5:2630, 5:2631 (fig.)
 - raster data structures, 5:2630–2631, 5:2631 (fig.)
 - r-tree raster data structure and, 5:2630, 5:2631 (fig.)
 - vector data structures: geometry, 5:2629, 5:2630 (fig.)
 - vector data structures: topology, 5:2629–2630, 5:2630 (fig.)
 - See also Exploratory spatial data analysis (ESDA); GIS specific subject; Spatial specific subject*
- Spatial decision support systems (SDSS), 5:2631–2635**
 - approaches and frameworks of, 5:2632
 - artificial intelligence or Expert System (ES) capabilities and, 5:2633
 - components of, 5:2632–2633, 5:2632 (fig.)
 - cost-benefit analysis used in, 2:593
 - criticisms, 5:2634
 - database management system (DBMS) and, 5:2632, 5:2632 (fig.)
 - definition of, 5:2632
 - dialogue, data, and model (DDM) paradigm of, 5:2632, 5:2632 (fig.)
 - dialogue generation and management system (DGMS) and, 5:2632 (fig.), 5:2633
 - ESRI’s applications for, 5:2634
 - examples of, 5:2633–2634
 - GIS capabilities and, 5:2632
 - GIS land use management and, 3:1304
 - government agencies and, 5:2634
 - hardware and software technology advances and, 5:2633
 - IDRISI’s Decision Support and Integrated Land and Water Information System (ILWIS) and, 5:2633–2634
 - model base management system (MBMS) and, 5:2632, 5:2632 (fig.)
 - SDSS development tools and, 5:2633
 - SDSS generators and, 5:2633
 - semistructured decision problems and, 5:2632
 - technologies of, 5:2633
 - Web-based SDSS and, 5:2633
 - Web technologies and, 5:2633
 - weighted linear combination (WLC) method and, 3:1304
 - See also GIS specific subject; Heuristic methods in spatial analysis; Spatial specific subject*

Spatial econometrics, 5:2635–2638

Luc Anselin's work in, 1:80–81, 5:2635, 5:2637
 aspatial process and, 5:2636
 bioregionalism and, 1:255
 conditional autoregressive process and, 5:2636
 criticisms, 5:2637–2638
 functional forms of interdependence and, 5:2635–2637
 functions of, 5:2635
 multidirectional causal associations and, 5:2635
 multidisciplinary applications of, 5:2635
 open-source computational tools for, 5:2637
 quantitative geography and, 5:2635
 recent developments, 5:2637
 regional science and, 5:2635
 software advances in, 5:2637
 space-time lag process and, 5:2636–2637
Spatial Econometrics (Anselin) and, 1:80
 spatial error process and, 5:2636
 spatial lag process and, 5:2636
 time-series analysis and, 5:2635
See also **Exploratory spatial data analysis (ESDA)**; **Spatial specific subject**

Spatial fix, 5:2638–2640

capital accumulation and, 5:2639
 grounded capital and the built environment in, 5:2639–2640
 David Harvey and, 5:2638, 5:2639
 Marxist geographies and, 5:2638
 relative/relational space and, 5:2402–2405
 spreading out of capital and, 5:2638–2639
See also **Spatial specific subject**

Spatial inequality, 5:2640–2645

dynamic of change across different spatial scales and, 5:2642
 educational geographies and, 2:874–875
 girls' education, Gansu, China, 5:2642 (fig.)
 income ratio relative to slum population, global
 South countries, 5:2644 (fig.)
 local, national, regional, or global scale of, 5:2641–2642
 per capita income in West Bengal districts, India, 5:2643 (fig.)
 quantification of, 5:2640
 quantitative analysis and, 5:2643
 socioeconomic clustering feature of, 5:2640, 5:2641 (fig.)
 unequal distribution in goods or services and,
 5:2640–2641, 5:2642 (fig.)
 world income distribution across four countries, 5:2641 (fig.)
See also **Spatial specific subject**

Spatial interaction models, 5:2645–2647

applications of, 3:1169
 competing destination model (Fotheringham) and, 3:1169
 destination-specific attributes in, 5:2645
 discrete zone systems element of, 5:2645
 distance decay theory and, 2:774–776
 A. Stewart Fotheringham's work in, 3:1169
 functions of, 5:2645
 mathematical expression of, 5:2646
 network analysis and, 4:2016–2018
 network data model and, 4:2018–2019
 neural spatial interaction models and, 5:2647
 origin-destination variables in, 5:2645
 origin-specific attributes in, 5:2645
 spatial information processing linked to, 3:1169
 spatial interaction definition and, 3:1169
See also **GIS specific subject**; **Spatial specific subject**

Spatial interpolation, 5:2647–2649

Bayesian kriging and, 5:2648
 computation of, 5:2648

deterministic interpolation and, 5:2648
 functions of, 5:2647
 geometric correction and, 3:1239–1240
 geostatistics and, 3:1261–1265
k-nearest neighbor search example of, 5:2648
 point *vs.* are entities and, 5:2648
 taxonomy and, 5:2647–2648
 Tobler's first law of geography and, 5:2648

See also **GIS specific subject**

Spatialization, 5:2649–2653

alternate meanings of, 5:2652–2653
 challenges in, 5:26512652
 data sets to be spatialized and, 5:2650
 definition and purpose of, 5:2649
 dimensionality reduction techniques and, 5:2650–2651
 dimensional reduction concept and, 5:2650
 examples of, 5:2651
 geographic knowledge domain example of, 5:2652 (fig.)
 graph layout methods of, 5:2651
 methods of dimensionality reduction and spatial layout in,
 5:2650–2651
 network of influential authors example of, 5:2652 (fig.)
 network structure data sets and, 5:2650
 production of space and, 5:2297–2298
 sound spatialization term and, 5:2653
 spatial layout approaches of, 5:2651
 spatial metaphors and, 5:2649
 tree map method and, 5:2651
 types of applications and data in, 5:2649–2650
See also **Spatial specific subject**

Spatially integrated social science, 5:2654–2655

analytical approaches to, 5:2654–2655
 definition of, 5:2654
 development of, 5:2654
 geographically weighted regression and, 5:2655
 geographic contexts of, 5:2654
 integrative computer-based tools and, 5:2654
 Markov random field segmentation and, 5:2655
 place-or locality-based analysis approach to, 5:2655
 social spaces and, 5:2654
 space and place elements in, 5:2654
 spatial analysis approach to, 5:2655
 time-geography and space-time behavior examples of, 5:2654
See also **Spatial specific subject**

Spatial multicriteria evaluation (spatial MCE), 5:2655–2657

alternatives identification and, 5:2656
 analytical hierarchy process (AHP) and, 5:2656
 applying a decision rule in, 5:2656–2657
 Marc Armstrong's work in, 1:117
 criteria and standardizing data values in, 5:2656
 criticisms, 5:2657
 generating criteria weights in, 5:2656
 ideal-point analysis (IPA) and, 5:2656
 identifying alternatives, 5:2656
 integrative origins of, 5:2655
 methodology of, 5:2655–2657
 outranking techniques and, 5:2656–2657
 semistructured problems and, 5:2655
 sensitivity analysis in, 5:2657
 terms related to, 5:2655
See also **GIS specific subject**; **Spatial specific subject**

Spatial optimization methods, 5:2657–2659

artificial intelligence heuristics and, 3:1215
 formulating an objective function element in, 5:2657–2658
 functions of, 5:2657

- genetic algorithm, 5:2659
 genetic algorithms, 3:1215
 geocomputation and, 3:1215
 GIS analytical operations and, 1:71–72
 greedy algorithm, 5:2658
 heuristics used in, 5:2658–2659
 limitations of, 3:1215
 location-allocation modeling, 4:1793–1794, 5:2657
 metaheuristics algorithm, 5:2659
 naive or random strategy algorithm, 5:2658
 simulated annealing, 3:1215
 simulated annealing algorithm, 5:2658
 single and multiple objectives approach to, 5:2658
 tabu search list, 5:2658–2659
 total enumeration algorithm, 5:2658
See also GIS specific subject; Heuristic methods in spatial analysis; Spatial specific subject
- Spatial resolution, 5:2659–2663**
 aerial photography and, 5:2662–2663
 analog maps and, 5:2660–2661
 definition of, 5:2659
 error propagation and, 2:1011–1012
 field data and, 5:2663
 general considerations in, 5:2659–2660
 geographically relevant parameters in, 5:2660, 5:2660 (fig.)
 image interpretation and, 3:1534–1536
 modifiable areal unit problem and, 4:1935
 optimal spatial resolution determination, 5:2663
 raster data and, 5:2662–2663 (fig.)
 satellite images and, 5:2662–2663 (fig.)
 vector data and, 5:2661–2662, 5:2661 (fig.)
See also Spatial specific subject
- Spatial statistics, 5:2664–2666**
 Bayesian statistics and, 1:187–188
 exploratory spatial data analysis (ESDA) and, 5:2665
 Geary's ratio and, 5:2665
 geostatistics and, 3:1261–1265, 5:2665–2666, 5:2666 (fig.)
 Arthur Getis's work in, 3:1274
 kriging methods and, 5:2665–2666, 5:2666 (fig.)
 Moran's *I* measure and, 5:2665
 multivariate analysis methods and, 4:1961–1962
 point pattern analysis and, 5:2201–2202
 spatial autocorrelation, 5:2664–2665, 5:2665 (fig.)
 spatial data and, 5:2664
See also GIS specific subject; Spatial specific subject
- Spatial strategies of conservation, 5:2667–2668**
 biogeography and resource management and, 5:2667
 boundary delineation issues and, 5:2667
 conservation zones and, 2:571–572
 human-environment relations approach to, 5:2667
 indigenous conservation strategies and, 5:2667–2668
 landscape biodiversity and, 4:1701–1703
 neoliberal environmental governance and, 5:2668
 parks and reserves and, 4:2117–2120
 patches and corridors and, 4:2131–2133
 political ecology and, 5:2667
 single large or several small (SLOSS) controversy and, 5:2667
 species-specific conservation and, 5:2667
See also Landscape and wildlife conservation
- Spatial turn, 5:2668–2671**
 biodiversity crisis and, 5:2671
 Chicago School and, 5:2669
 cultural turn and, 2:644–646
 cyberspace and the Internet and, 5:2670–2671
 GIS technology and, 5:2671
 global ecology and environmental problems and, 5:2671
 globalization and, 5:2670
 historical fall and rise of spatiality and, 5:2669–2670
 historicists perspectives on, 5:2669
 Marxist social theory and, 5:2669
 Orientalism and, 5:2669
 reasons for, 5:2670–2671
 social Darwinism and, 5:2669
 space and place elements in, 5:2669
 “space of flows” (Castells) and, 5:2670
See also Spatial turn: noted geographers, scholars
- Spatial turn: noted geographers, scholars**
 Manuel Castells, 5:2670
 Denis Cosgrove, 5:2668
 David Harvey, 5:2669
 Immanuel Kant, 5:2670
 Edward Soja, 5:2593, 5:2670
 Herbert L. Spencer, 5:2669
- Species-area relationship, 5:2671–2674**
 Arrhenius model of, 5:2672
 biodiversity and, 1:197–201
 biosphere reserves and, 1:256–267
 community ecology and biogeography and, 5:2671
 equilibrium model of island biogeography and, 5:2672
 forest degradation and, 3:1156–1159
 forest fragmentation and, 3:1159–1163
 Gleason model of, 5:2672
 invasion and succession and, 3:1627
 island fragmented habitat model and, 5:2673
 MacArthur-Wilson model of island biogeography and, 5:2672–2673
 migration and dispersal of biota and, 1:276–278
 single large or several small (SLOSS) debate and, 5:2673
 species richness and, 5:2671
See also Landscape and wildlife conservation
- Spectorsky, A., 2:1075
- Spectral characteristics of terrestrial surfaces, 5:2674–2676**
 asphalt, concrete, and steel and, 5:2675
 human-made materials, 5:2675–2676
 monitoring Earth's materials through time importance and, 5:2674
 multispectral imagery and, 4:1953–1956
 natural materials and, 5:2674–2675
 resolution of sensory systems and, 5:2674
 soil, 5:2675
 spectral remote sensors and, 5:2674
 vegetation, 5:2674–2675
 water, 5:2675
See also Spectral resolution; Spectral transformations
- Spectral resolution, 5:2676–2678**
 Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and, 5:2676
 black-and-white film, 5:2676
 color film, 5:2676
 definition of, 5:2676
 hyperspectral sensors and, 5:2677–2678, 5:2677 (fig.)
 image interpretation and, 3:1534–1536
 Landsat's thematic mapper (TM) and, 5:2676
 multispectral imagery and, 4:1953–1956, 5:2672, 5:2676
 narrowly defined contiguous spectral bands, 5:2677 (fig.)
 number of bands used factor in, 5:2676
 spectral bands at various spectral resolutions and, 5:2676, 5:2677 (fig.)
 width assigned to each band factor in, 5:2676
See also Spectral characteristics of terrestrial surfaces; Spectral transformations
- Spectral transformations, 5:2678–2679**
 arithmetic operations/band calculations and, 5:2678–2679

- color transformation, 5:2679
- conditional operations and, 5:2678–2679
- division or rationing of spectral bands and, 5:2678
- explanation of, 5:2678
- maximum value composite method and, 5:2678–2679
- normalization of spectral response patterns and, 5:2678
- Normalized Difference Vegetation Index and, 5:2679
- principal components transformation (PCT), 5:2679
- spectral ratios and vegetation indices in, 5:2679
- vegetation indices (VIs) and, 5:2679
- See also* Spectral characteristics of terrestrial surfaces;
- Spectral resolution**
- Spencer, Herbert
 - biological principles applied to study of society by, 2:916
 - history as linear movement and, 3:1433
 - social Darwinism and, 3:1464, 5:2561–2562
 - survival of the fittest work of, 2:666, 3:1434, 3:1464, 5:2561, 5:2669
- Spirn, Ann, 4:1700
- Spivak, Gayatri, 5:2259, 5:2260, 5:2712
- Spolaore, Enrico, 5:2217
- Sports, geography of, 5:2680–2682**
 - John Bale and, 5:2680
 - geopolitics and nationalism issues and, 5:2680
 - Japan-South Korea World Baseball Classic game, Dodger Stadium, Los Angeles, 5:2681 (photo)
 - location of sports franchises and playing facilities and, 5:2681
 - Olympics and, 5:2680
 - physical and human geographies factors in, 5:2680
 - physical geography factors and, 5:2681–2682
 - political geography of sports and, 5:2680
 - recruitment issues and, 5:2680
 - John Rooney and, 5:2680
 - sense of identity and attachment and, 5:2680–2681
 - topics and issues in, 5:2680
- Springfield, Massachusetts, 4:1821
- Springfield, Ohio, 4:1821
- Spykman, Nicholas, 2:611, 3:1250
- Squatter settlements, 5:2682–2685**
 - characteristics of, 5:2682, 5:2683
 - cultural differences in, 5:2683–2684
 - cultural terms for, 5:2682
 - definition of, 5:2682
 - established neighborhoods from, 5:2683
 - globalization and, 5:2685
 - housing associations or cooperatives and, 5:2684
 - in Istanbul and Ankara, Turkey, 5:2683 (photo)
 - lack of low-cost housing and, 5:2685
 - land invasion issue and, 5:2684
 - legalization of, 5:2683–2684
 - negative views, 5:2682
 - political system factors and, 5:2684
 - solidarity factor and, 5:2684
 - squatter housing term and, 5:2682
 - terms associated with, 5:2682
 - Third World context of, 5:2682, 5:2685
 - traditional land tenure values and, 5:2684
 - usufruct rights and, 5:2684
 - violence and crime issues and, 5:2684
- Sri Lanka
 - economically active females in, 3:1190 (table)
 - human rights atrocities in, 3:1481
 - income distribution, percentile of world income, 5:2641 (fig.)
 - monsoons in, 4:1943
 - Phoenicians exploration of, 2:1051
 - tropical deciduous forest in, 1:230
 - tropical rain forest of, 1:234
 - Tsunami of 2004, Indian Ocean and, 6:2888–2890
 - tsunami of 2004 and, 4:1985
- Stachowicz, John, 4:1658
- Staeheli, Lynn, 4:2136
- Stalin, Joseph, 2:542, 2:543, 2:594
- Stamp, L. Dudley, 5:2487
- Standing, Guy, 4:1893
- Stanislawski, Dan, 1:192
- Stanton, Elizabeth Cady, 3:1095
- State, 5:2685–2688**
 - city-states type of, 5:2687
 - civil society and, 1:414–416
 - country and nation terms and, 5:2685–2686
 - definitions of, 5:2685–2686
 - government term and, 5:2686
 - modern state emergence and, 5:2687–2688
 - nationalism and, 4:1978–1981
 - nation-state type of, 5:2687
 - political entities and, 5:2686
 - recognition factor and, 5:2686
 - suprastate and, 5:2688
 - unitary or federal internal structure and, 5:2686–2687
 - world's political map and, 5:2686
- Stea, David, 1:189
- Steel industry, geography of, 5:2688–2693**
 - alternative raw materials and, 5:2691
 - credit issues and, 5:2693
 - directly reduced iron production and, 5:2691, 5:2692
 - Dutch-British Corus Group example and, 5:2692
 - Essar Group (India) example and, 5:2692
 - globalization and, 5:2691–2693
 - graveyard and steel mill, Bethlehem, Pennsylvania, 5:2690 (photo)
 - Industrial Revolution and, 5:2688–2689
 - internationalization feature of, 5:2688
 - internationalization of, 5:2692
 - Japanese-American joint ventures and, 5:2690
 - macroeconomic factors and, 5:2693
 - minimills and, 5:2689–2690, 5:2692
 - Mittal Steel (India) example and, 5:2692
 - neoliberal policies and, 5:2689
 - Nippon Steel (Japan) example and, 5:2692
 - nontariff barriers and, 5:2690
 - oil prices and, 5:2693
 - Pohang Iron and Steel Company, Pohang, South Korea, 5:2691 (photo)
 - raw material locations and, 5:2689
 - “resource curse” concept and, 5:2693
 - state-owned industry and, 5:2692
 - technology and, 5:2689–2691
 - transportation advances and, 5:2689
 - unions and, 5:2690
- Stefanovic, Ingrid Leman, 4:2168
- Steiner, Dieter, 3:1455
- Steinitz, Carl, 3:1304
- Stereoscopy and orthoimagery, 5:2693–2695**
 - baseline and, 5:2695
 - binocular vision term and, 5:2694
 - depth perception and, 5:2693–2694
 - explanations of, 5:2693–3694
 - monocular vision and, 5:2694
 - orthoimagery and, 5:2695
 - parallax element in, 5:2694
 - photogrammetric methods and, 4:2173–2175
 - relative photogrammetric accuracy *vs.* angle of intersection, 5:2694, 5:2694 (fig.)

- stereogram or stereopair and, 5:2694
 stereoscopic vision or stereovision and, 5:2694
 Stevens, Albert, 4:1882
 Steward, Julian, 2:632
 Stimson, Robert, 2:977
 St. Lawrence River, 2:576
 Stockholm Convention on Persistent Organic Pollutants, 1:501, 5:2226
 Stoddard, David, 2:665
 Stone, Kirk, 5:2536, 5:2537
Storper, Michael, 5:2695–2696
 academic career of, 5:2695
 Los Angeles School of urbanism and, 2:688, 4:1803, 5:2696
 Marxist human geography and, 3:1467, 4:1863
 regional change dynamics work of, 5:2696
 small firm networks, outsourcing and, 4:2108
 spatiality of capitalism work of, 5:2695
 urban division of labor work of, 4:1863, 5:2696
 Richard Walker and, 6:3043–3044
Strabo, 5:2696–2697
 area studies of, 5:2697
 citizenship views of, 1:412
 ethics and, 1:404, 2:1013
 Geographica written by, 1:404, 3:1460, 5:2696–2697
 ocean views of, 4:2065, 5:2697
 Ptolemy's criticism of, 5:2300
 regions emphasized by, 5:2300, 5:2697
 river delta factors work of, 3:1245
Strahler, Arthur, 5:2697–2698
 climate classification system of, 1:467
 creationism issue and, 5:2697–2698
 Earth science education and, 5:2698
 geomorphology work of, 5:2697–2698
 Robert Horton and, 5:2697
 pioneering papers by, 5:2697–2698
 quantitative work of, 5:2697
 Strahler order number, 5:2697–2698
Stratospheric ozone depletion, 5:2698–2701
 chlorofluorocarbons and, 1:400–401, 3:1336, 5:2700
 daily values of total column ozone, Antarctica, 5:2700 (fig.)
 Dobson units (DU) measure of, 5:2699
 EP/TOMS ozone measuring and, 5:2699–2700, 5:2699 (fig.)
 “good ozone” and, 5:2698
 ozone-depleting chemicals and, 5:2700
 ozone functions and, 5:2698–2699
 Ozone Monitoring Instrument (OMI) and, 5:2699
 South Pole location of ozone hole issue and, 5:2700–2701
 Strausz-Hupe, Robert, 3:1250
Strip mining, 5:2701–2702
 area stripping type of, 5:2702
 contour stripping type of, 5:2702
 geographic locations of, 5:2701–2702
 Industrial Revolution origins of, 5:2701
 mountain top coal removal and, 5:2702
 overburden concept and, 5:2701
 regulation of, 5:2702
 surface mining techniques and, 5:2701
Structural adjustment, 5:2703–2704
 decentralization and, 5:2703–2704
 explanation of, 5:2703
 export-oriented industrialization and, 2:1065–1066
 export processing zones and, 2:1065
 exports of primary products and, 2:1065–1066
 inequalities issues of, 5:2704
 international lending institutions and, 5:2703
 land reform and, 4:1692–1696
 liberalization and, 5:2703
 privatization of state-owned enterprises and, 5:2703
 reforms within, 5:2703–2704
 repercussions from, 5:2704
 “urban bias” in national development and, 5:2704
 Washington Consensus and, 5:2703
Structuralism, 5:2705–2708
 Louis Althusser, 5:2706
 Manuel Castells, 5:2706–2707
 Noam Chomsky and, 5:2705
 communication (symbolic) systems in anthropology and, 5:2706
 creative role of language and, 5:2705
 geography and, 5:2706–2708
 language study origins of, 5:2705
 Claude Lévi-Strauss and, 5:2706
 Marxist geography and, 5:2706
 negative and positive features of, 5:2707
 origins of, 5:2705
 Talcott Parsons and, 4:1932
 political systems analysis and, 5:2705
 poststructuralism and, 5:2705
 realism and, 5:2369–2371
 as science of objects, 5:2706
 social geography and, 5:2567
 social practices and spatial organization, 5:2707 (table)
 tenets and history of, 5:2705–2706
Structuration theory, 5:2708–2711
 actors element in, 5:2709
 duality of structure element in, 5:2709
 empirical applications of, 5:2710
 essentials in, 5:2708
 place and, 5:2186
 realism and, 5:2369–2371
 school closing example of, 5:2708–2709
 spatiality and duality issues and, 5:2710
 structures element in, 5:2709
 two versions of, 5:2709–2710
 types of behavior in, 5:2710
 See also Structuration theory: noted geographers, scholars
 Structuration theory: noted geographers, scholars
 Roy Bhaskar, 3:1278
 Pierre Bourdieu, 3:1278
 Anthony Giddens, 3:1277–1278, 5:2289, 5:2297, 5:2403, 5:2708, 5:2709–2710
 Derek Gregory, 3:1380, 5:2710
 Allan Pred, 5:2289–2290
STS. *See* Science and technology studies (STS)
Subaltern studies, 5:2711–2713
 critiques, 5:2712
 Eurocentrism and, 2:1029
 geography implications of, 5:2711
 goal of, 5:2711
 Antonio Gramsci and, 2:1029, 5:2711
 Indocentrism and, 2:1029
 Marxism and, 5:2711–2712
 origins of, 5:2711
 poststructuralism and, 5:2712
 subaltern definition debates and, 5:2711
 Subaltern Studies (Guha, ed.), 5:2711
 sustainability studies and, 6:2753
 uneven development and, 6:2902
Sub-Saharan Africa
 adults and children living with HIV in 2007 in, 3:1437 (fig.)
 agrobiodiversity in, 1:50

- anticolonialism in, 1:94
 Bantu or Niger-Kordofanian languages in, 4:1751, 4:1752 (fig.)
 birthrates in, 2:708
 debt crisis and, 2:688
 desertification in, 5:2582
 diseases in, 2:726
 fertility levels in, 2:709
 Heavily Indebted Poor Countries initiative (World Bank) and, 2:690
 HIV/AIDS epidemic in, 2:727, 3:1438–1439
 industrialized agriculture in, 1:47
 Internet access in, 2:845
 malaria in, 4:1816, 4:1817
 military expenditures in, 4:1899 (table)
 nongovernmental organizations (NGOs) in, 1:415
 people living in extreme poverty and, 3:1082 (table)
 poverty rates in, 5:2274, 5:2275
 remittance flows to, 5:2412
 undernourishment in, 3:1488 (table)
- Suburban land use, 5:2713–2716**
- edge cities and, 5:2713
 exurbs and, 2:1074–1076
 interregional shifts in, 5:2713–2715
 interstate highway system and, 5:2713
 intraregional suburbanization and, 5:2713
 monocentric to polycentric spatial organization pattern and, 5:2713
 spatial point patterns and, 5:2714 (fig.)
 streetcar suburbs and, 5:2713
 suburban term and, 5:2713
 three waves of suburbanization and, 5:2713
 transit-oriented development and, 5:2713
See also Suburbs and suburbanization
- Suburbs and suburbanization, 5:2716–2721**
- automobility and, 1:172–175
 “bourgeois utopias” and, 5:2716
 built environment, social and cultural features and, 1:299–300
 city central business districts and, 1:379
City in History (Mumford) and, 5:2719
 commuting and, 2:553–555
 contested process of, 5:2719–2720
 counterurbanization and, 2:596–597
 dysfunctions associated with, 5:2720
 edge cities and, 5:2718
 issues regarding, 5:2716
 major stages of, 5:2716–2718
 metropolitan political fragmentation and, 5:2720
 “new towns” and, 5:2718
 smart growth and, 5:2550–2551
 streetcar suburbs and, 5:2716–2717
 suburban sprawl, Las Vegas, Nevada, 5:2717 (photo)
 suburbs, definition, 5:2716
 suburb word origin and, 5:2716
 urban pathology analysis and, 5:2719
 urban sprawl, 5:2720
 Richard Walker and, 6:3043–3044
See also Suburban land use
- Sudan**
- African Union peace keeping in, 1:25
 economically active females in, 3:1190 (table)
 hate groups in, 3:1407
 human rights atrocities in, 3:1481
 human rights violations in, 3:1480
 independence of, 1:512
 locusts infestation in, 2:727
 oil exports from, 4:2073
- Suez Canal, 5:2254**
- Sui, Daniel, 5:2721–2722**
- academic career of, 5:2721
 digital spatial technologies work of, 5:2722
 GIScience work of, 5:2721–2722
 media geographies work of, 4:1875
 neogeography work of, 4:2006, 5:2721
- Suitability analysis, 5:2722–2723**
- Sumatra, 1:209**
- Sunbelt, 5:2723–2725**
- geographic locations of, 5:2723
 immigration gateways in, 5:2723
 as industrial restructuring strategy, 5:2458
 manufacturing relocation from Rust Belt to, 5:2723
 map of, 5:2724 (fig.)
 monolithic characteristic of, 5:2724
 population growth in, 5:2723
 producer services growth in, 5:2723
 term connotation and, 5:2723
 urban growth in, 5:2458
- Sundberg, Juanita, 3:1101**
- Sun Tzu, 4:1896**
- Superfund sites on National Priorities List (NPL), 1:297, 4:1684, 4:1808, 4:1857**
- Supervised classification, 5:2725**
- data collection methods and, 5:2725
 definition of, 5:2725
 parametric *vs.* nonparametric classification algorithms and, 5:2725
 quality and quantity of training samples factors in, 5:2725
 unsupervised classification and, 6:2914–2915
- Supranational integration, 6:2726–2729**
- ASEAN and, 6:2727
 Barents Euro-Arctic region and, 6:2728 (fig.), 6:2729
 case examples of, 6:2727–2729
 common goals element of, 6:2726
 cross-border “nonstandard regions” and, 6:2726–2727
 cultural character of, 6:2726
 definition of, 6:2726
 European Union (EU) and, 6:2727–2728
 Euroregions and, 6:2729
 globalization of world economy factor of, 6:2726
 interregional competition and, 6:2726
 multilateral *vs.* bilateral nature of, 6:2726–2727
 NAFTA and, 6:2727
 NATO and, 4:2046–2048
 political and economic importance of, 6:2726
 process of, 6:2727
 rescaling of nationstates and, 6:2726
 smaller-scale supranational integration and, 6:2729
 sovereignty and, 6:2726
 top-down *vs.* bottom-up nature of, 6:2727
- Surface water, 6:2729–2732**
- coastal landforms, 6:2731
 cryosphere, ice sheets and glaciers and, 6:2730
 dams and, 6:2732
 drainage basins, watersheds and, 6:2730
 floods, 3:1133–1137
 flow of, 3:1138
 fluvial landforms, 6:2731
 geography of, 6:2730
 geomorphology and, 6:2731
 glaciers, 6:2731
 global climate change effects on, 6:2732
 humans and, 6:2732
 hydrological connectivity and, 3:1512–1513

- hydrology and, 3:1513–1518
- international watershed management and, 3:1618–1620
- irrigated agriculture and, 6:2732
- lakes and ponds, 6:2731
- oceans and seas, 6:2731
- runoff, 6:2730
- streams and rivers, 6:2730–2731
- See also* Groundwater
- Suriname, 1:234
- Surveillance**, 6:2733–2735
 - definition of, 6:2733
 - fixing of attributes to things and, 6:2733
 - geoslavery and, 3:1255–1256
 - GIS and remote sensing and, 6:2734
 - operations in port of Vancouver, Canada, 6:2734 (photo)
 - panopticism and, 6:2733
 - panopticon and, 4:2116–2117
 - synopticism and, 6:2733
- Surveying**, 6:2735–2737
 - absolute and differential GPS and, 6:2736
 - cadastral systems and, 1:311–318
 - census *vs.*, 1:371
 - closed-loop traverse type of, 6:2735
 - closed traverse type of, 6:2735
 - closure error in, 6:2736
 - definition of, 6:2735
 - distances, heights, and angles measures in, 6:2735
 - geometric measures and, 3:1240
 - GPS technology and, 6:2736
 - inaccuracy issue in, 6:2735–2736
 - link traverse type and, 6:2735
 - open traverse type of, 6:2735
 - road surveyor, Dhi Qar Province, Iraq, 6:2736
 - terms related to, 6:2735
 - tools used in, 6:2735
 - total station concept in, 6:2735
 - traversing and, 6:2735
 - triangulation and, 6:2735
 - trilateration and, 6:2735
- Sustainability science**, 6:2737–2742
 - basic and applied science of, 6:2740–2741
 - Brundtland Commission report on sustainable development and, 6:2737, 6:2747
 - concept of, 6:2737–2740
 - ecological economics and, 2:820–824
 - ecological footprint and, 2:825–828
 - ecological imaginaries and, 2:828–830
 - ecological modernization and, 2:832–834
 - emergence of, 6:2737–2738
 - global systems assessment and, 6:2738–2739
 - healthy functioning of human systems and, 6:2739
 - human-environment interaction origins of, 6:2737
 - human survival and, 6:2738–2739
 - Rober Kates' work, 4:1654–1655
 - knowledge systems and, 6:2738
 - multiple systems integration and, 6:2739–2740
 - postnormal research paradigm and, 6:2740
 - research framework for, 6:2741
 - UN Commission on Sustainable Development (UNCSD) and, 6:2738
 - UN Conference on Environment and Development (UNCED) and, 6:2737–2738, 6:2746
 - World Commission on Environment and Development (WCED) and, 6:2737
 - World Summit on Sustainable Development and, 6:2738
 - See also* Adaptive harvest management; Energy and human ecology; Sustainability science: noted individuals
- Sustainability science: noted individuals
 - Vannevar Bush, 6:2740–2741
 - Hans Carl von Carlowitz, 6:2737
 - William Clark, 6:2741
 - Michael Dove, 6:2741
 - Peter Glacken, 6:2737
 - Yujiro Hayami, 6:2737
 - Daniel Kammen, 6:2741
 - Hiroshi Komiyama, 6:2738
 - Vernon Ruttan, 6:2737
 - E. F. Schumacher, 6:2737
 - Kazuhiko Takeuchi, 6:2738
 - Billie Lee Turner, II, 6:2891–2892
- Sustainable agriculture**, 6:2742–2746
 - agricultural intensification and, 1:36
 - agriculture's roots and, 6:2742
 - agroecology and, 1:57
 - alternative agriculture and, 6:2744–2746
 - from crisis to opportunity in, 6:2744
 - crop genetic diversity and, 2:625–627
 - crop rotation and, 2:627–630
 - Cuban experience and, 6:2744
 - ecological erosion and, 6:2743
 - energy inefficiency of, 6:2744
 - food production trends and, 6:2746
 - genetic erosion and, 6:2743
 - global environmental change and, 1:36
 - industrial agriculture and, 6:2742–2743
 - lingonberry field, Alaska, 6:2745 (photo)
 - local knowledge element in, 6:2745
 - natural systems agriculture and, 6:2745–2746
 - organic agriculture and, 4:2094–2096
 - pesticides and, 6:2743
 - Silent Spring* (Carson) and, 6:2743
 - social erosion and, 6:2743
 - superpests and, 6:2743
 - technology advances and, 6:2745
 - See also* Adaptation to climate change; Adaptive harvest management; Agricultural land use
- Sustainable cities**, 6:2746–2747
 - Aalborg Charter and, 6:2746
 - definition of, 6:2746
 - ethical resource use and, 6:2746–2747
 - European Conference on Sustainable Cities and Towns and, 6:2746
 - natural capital maintenance and, 6:2747
 - social justice and, 6:2746
 - UN Conference on Environment and Development (UNCED) and, 6:2746
- Sustainable development**, 6:2747–2752
 - Agenda 21 (UN), global sustainable development action plan and, 2:914, 2:1004–1005, 6:2737–2738, 6:2746, 6:2748
 - biosphere reserves and, 1:256–267
 - brownfields and, 1:296–298
 - Anne Buttner's work in, 1:309
 - capitalism, globalism and, 6:2750–2751
 - cellular automata used in, 1:370
 - conservation and, 2:570
 - criticism of UNCED approach to, 6:2749–2750
 - Herman Daly's "evils of growthmania" views and, 2:835
 - definition of, 3:1370
 - ecological modernization and, 2:835–836
 - economic self-sufficiency and, 2:835

- ecotourism and, 2:869–874
 environmental impact assessment and, 2:934–937
 environmental planning and, 2:982–983
 equitable and sustainable climate change regime and, 6:2751
 feminist political ecology and, 3:1100–1102
 global commons and, 6:2749
 green design and development and, 3:1369–1373
 indigenous environmental knowledge and, 3:1354–1567
 international programs of, 5:2220
 Johannesburg Declaration on Sustainable Development and, 2:1005
 Rober Kates' work, 4:1654–1655
 Thomas Malthus's term and, 6:2747
 natural hazards and risk analysis and, 4:1985
 neoliberalism and, 2:836
 neoliteral economic agenda and, 6:2750
Our Common Future (Brundtland Report) and, 2:1003, 3:1370, 6:2747, 6:2748
 political economy of resources and, 5:2220–2221
 population growth and resource use balance and, 5:2244–2245
 questioning current objectives in, 6:2748–2749
 regional economic development and, 5:2380–2384
 Maruice Strong and, 6:2748
 transportation geography and, 6:2875
 UN debates, 6:2747–2748
 UNDEED's global management approach to, 6:2749
 United Nations Conference on Environment and Development (UNCED) and, 1:256, 2:1004–1005, 6:2737–2738, 6:2746
 World Commission on Environment and Development (WCED) and, 2:835, 2:1003–1004, 5:2220, 6:2747
 World Conservation Strategy and, 2:1003
 World Summit on Sustainable Development (WSSD) and, 2:1005, 6:2738, 6:2750, 6:2907
See also **Regional environmental planning; Sustainable development alternatives; Sustainable specific activity; World Summit on Sustainable Development**
- Sustainable development alternatives, 6:2752–2754**
 critical sustainability studies and, 6:2753
 ecological footprint and, 2:825–828
 green design and development and, 3:1369–1373
 local engagement and, 6:2753
 subaltern sustainability, 6:2753
 sustaining the environment, 6:2752–2753
 sustaining the system and, 6:2752–2753
 systemic intervention and, 6:2752–2753
- Sustainable fisheries, 6:2754–2757**
 Code of Conduct for Responsible Fisheries and, 6:2757
 collapsing fisheries and, 6:2754–2755
 community-based natural resource management and, 2:549, 2:550
 eco-labeling, green consumerism and, 6:2757
 European Union policy and, 6:2755–2756
 exclusive economic zones (EEZs) and, 6:2757
 fish farming and, 3:1119–1121
 friendlier fishing gear and, 6:2757
 government responses to, 6:2755–2756
 individual transferable quotas (ITQs) and, 6:2756
 international policy responses to, 6:2757
 maximum sustained yield concept and, 5:2445
 tragedy of the commons, 6:2755
 UN actions, 6:2757
 UN Food and Agriculture Organization and, 6:2754
See also **Adaptive harvest management; Aquaculture; Marine aquaculture**
- Sustainable forestry, 6:2758–2763**
 boreal forest biome and, 1:214–217
 carbon cycle and, 6:2759
 casuarinas in dunes, Zululand, South Africa, 6:2881 (photo)
 challenges in, 6:2760–2761
 community-based natural resource management and, 2:549–551
 conservation concessions and, 6:2762
 definition of, 6:2758
 economic challenges in, 6:2760–2761
 environmental certifications in, 2:914–915
 Faustmann rule for forestry resources and, 5:2445
 forest certification and, 6:2762
 forest concession challenges in, 6:2761
 forest productivity and, 6:2759–2760
 Forest Stewardship Council and, 2:915
 innovations in, 6:2762
 institutional challenges in, 6:2761
 managed natural forests, global extent of, 6:2758
 midlatitude deciduous forest biome and, 1:223–226
 Montreal Process and, 6:2758–2759
 National Standard on Sustainable Forest Management (Canada) and, 2:915
 political challenges in, 6:2761
 Programme for Endorsement of Forest Certification and, 2:915
 reduced-impact logging (RIL) and, 6:2762
 secondary forest management and, 6:2762
 slash pine plantation, Georgia (U.S.), 6:2835 (photo)
 social dimensions of, 6:2760
 social (tenurial) challenges in, 6:2761
 Sustainable Forestry Initiative and, 2:915
 sustainable forestry management goals and, 6:2758
 sustainable urban forestry (SUF) and, 6:2762
 themes in, 6:2758
 tropical deciduous forest biome and, 1:230–233
 UK Woodlands Assurance Scheme and, 2:915
 UN Food and Agriculture Organization and, 6:2758
See also **Adaptive harvest management**
- Sustainable production, 6:2763–2767**
 AccountAbility's standards and, 6:2763
 agroecology and, 1:57
 benign outputs and, 6:2764
 biofuels production and, 1:201–204
 brownfields and, 6:2766
 Anne Buttmer's work in, 1:309
 Clean Air Act (1990) and, 6:2763
 commodity chains in, 6:2765
 community-based natural resource management and, 2:549–551
 ecological footprint and, 2:824–828
 eliminating waste and, 6:2764
 facility construction and, 6:2766
 frameworks of, 6:2764–2766
 Global Reporting Initiative guidelines and, 6:2763
 goods and services and, 6:2764
 industrial ecology and, 3:1577–1579
 ISO standards and, 6:2763
 life cycle view of, 6:2766
 logistics management and, 6:2766
 material and energy flows, simplified supply chain and, 6:2765 (fig.)
 Montreal Protocol and, 6:2763
 motivation for, 6:2763–2764
 product end-of-use options and, 6:2766
 Social Accountability International standards and, 6:2763
 supply chains and, 6:2765, 6:2765 (fig.), 6:2766
 value chains in, 6:2765
See also **Adaptation to climate change; Adaptive harvest management**
- Swaziland**
 economically active females in, 3:1190 (table)
 life expectancy in, 3:1410

Sweden

- AGILE membership of, 1:125 (table)
- biotechnology industry in, 1:280
- cancer incidence and mortality in, 1:321–322, 1:322 (fig.), 1:323 (fig.)
- carbon or climate change taxes in, 4:1857
- coastal dead zones of, 1:487
- critical human geography in, 2:620
- economically active females in, 3:1190 (table)
- European Union (EU) membership of, 2:1035
- foreign aid flow from, 3:1152
- glacial loss in, 3:1333
- green design and development in, 3:1371
- Internet access in, 2:845
- Lund School of cultural geography in, 2:745
- national geographical society in, 3:1462
- paleontology expeditions in, 1:81

Swidden cultivation. *See* Slash-and-burn/swidden cultivation technique

Switzerland

- AGILE membership of, 1:125 (table)
- biotechnology industry in, 1:280
- economically active females in, 3:1190 (table)
- foreign aid flow from, 3:1152
- heroin parks in, 2:799
- hydroelectricity in, 3:1507
- revalorization (revitalization) work in, 4:1718–1719
- tourism in, alpine and lake landscapes for, 6:2856
- tourism in, Hotel Wetterhorn, 6:2855 (photo)
- World Economic Forum and, 1:415

Swyngedouw, Eric, 3:1360, 3:1595, 5:2560

Sykora, Ludek, 5:2710

Symbolism and place, 6:2767–2770

- art and geography, 1:118–120
- built environment and, 6:2767
- conflicted interpretations and, 6:2768
- Denis Cosgrove's work and, 2:589–590, 5:2432
- cultural landscape and, 2:643
- film and, 3:1110–1111
- geographical imagination and, 3:1221–1225
- geographic examples of, 6:2767
- literature geographies and, 4:1785–1788
- place names and, 5:2188–2190
- purposeful building construction and, 6:2767–2768
- sacred Ayers Rock, Australia, 6:2769 (photo)
- sense of place and, 5:2532–2534
- T-in-O maps and, 6:2844–2846
- vernacular residential landscapes and, 6:2769
- World Trade Center example, 6:2768 (photo)

See also Architecture and geography

Symmons-Symonolewicz, K., 4:1973

Symptoms and effects of climate change, 6:2770–2773

- air temperature, 6:2770
- biogeographical impacts from, 6:2772–2773
- fires, 6:2771–2772
- hydrologic cycle changes, 6:2771
- ice sheets and glaciers, 6:2772
- ocean changes, 6:2770–2771

Synoptic climatology, 1:472–473

Syria

- economically active females in, 3:1190 (table)
- France colonization of, 1:514
- pig domestication in, 2:783

Tahiti, 2:576

Taipei

- textile exports from, 6:2815 (fig.), 6:2816 (fig.)

Taiwan

- APEC membership of, 1:121
- arsenic in drinking water, cancer mortality rates in, 1:321
- deposit refund systems in, 4:1857
- export-oriented industrialization (EOI) in, 2:1064
- export trade success of, 2:731
- import substitution industrialization in, 3:1551
- industrialization in, 3:1580, 3:1583, 4:2020
- Japanese colonization of, 1:514
- Japanese electronics industry in, 2:885
- land reform in, 4:1693
- newly industrializing country of, 4:2021, 4:2022 (fig.)
- PCBs contamination in, 5:2226
- steel industry in, 5:2689
- U.S. industry moving to, 2:700

Tajikistan

- Collective Security Treaty Organization (CSTO) membership of, 2:536
- Commonwealth of Independent States (CIS) membership of, 2:536 (table)
- economically active females in, 3:1190 (table)
- HIV/AIDS in, 3:1438

Takeuchi, Kazuhiko, 6:2738

Tanzania

- economically active females in, 3:1190 (table)
- glaciers in, 3:1332
- tropical deciduous forest in, 1:230, 1:231
- tropical savanna in, 1:241

Taphonomy, 6:2775–2776

- actualism strategy and, 6:2775–2776
- archaeological accumulation and, 6:2776
- biostratigraphy *vs.* diagenesis and, 6:2775
- comparative method used in, 6:2776
- definition of, 6:2775
- direct and indirect evidence and, 6:2775
- histories of fossils and, 6:2776
- morphological and qualitative variables and, 6:2776
- multidisciplinary focus of, 6:2775
- origins of term and, 6:2775
- positive contributions of, 6:2775
- taphonomic modes and, 6:2776

Tatham, George, 2:917

Taylor, Charles, 4:1644

Taylor, Griffith, 6:2777–2778

- academic career of, 6:2777
- Australia studies of, 6:2777
- books written by, 6:2777
- environmental determinism and, 3:1464, 6:2777
- eugenics and, 3:1464
- Harold Innis and, 6:2777
- publications of, 6:2777
- Scott's Antarctic Terra Nova Expedition and, 6:2777
- service work of, 6:2777

Taylor, Peter, 6:2778

- finance geographies work of, 3:1117
- hegemonies in capitalist world economy views of, 3:1419
- Marxist theory of scale and, 5:2506–2507
- political geography work of, 2:880, 6:2778
- scale hierarchies work of, 6:2778
- world-systems theory and, 2:880, 6:2778

Technological change, geography of, 6:2779–2782

- diffusion and, 2:745–748, 6:2780–2781
- economic growth theory and, 2:851–852, 6:2779
- globalization and, 6:2781–2782
- innovation geographies and, 3:1597–1599
- knowledge spillovers and, 6:2779

- learning regions and, 4:1766–1768
- nonrivalry and nonexcludability concepts and, 6:2779
- as production component, 6:2779–2780
- public *vs.* private goods and, 6:2779
- spatial clustering and, 6:2781
- tacit *vs.* codified knowledge and, 6:2780–2781
- technology definitions and, 6:2779
- total factor productivity and, 6:2779, 6:2780 (table)
- See also* Electronics industry, geography of; High technology
- Telecommunications and geography, 6:2782–2789**
 - back office and call center relocations and, 6:2786–2788
 - cyberspace and, 2:646–648
 - digital divide and, 2:748–753
 - e-commerce and, 2:844–846
 - fiber-optic and, 6:2784 (fig.)
 - fiber optics and, 6:2783–2785, 6:2784 (fig.)
 - finance and, 6:2785–2786
 - geographical patterns of economic activity and, 2:851
 - global cities and, 6:2786
 - information society and, 3:1593–1594
 - misconceptions, 6:2783
 - urban telecommunications infrastructures and, 6:2788–2789
 - See also* Communications geography
- Teleconnections, 6:2789–2790**
 - atmosphere and ocean interdependencies and, 6:2789–2790
 - correlation analysis, 6:2790
 - definition of, 6:2789
 - El Niño-Southern Oscillation and, 6:2790
 - ocean changes and, 6:2789–2790
 - statistical techniques identification of, 6:2790
 - strength, phase, and location of, 6:2790
 - weather patterns and, 6:2789–2790
 - See also* El Niño-Southern Oscillation (ENSO)
- Television and geography, 6:2790–2793**
 - distribution and consumption process of, 6:2791
 - domestic space concept and, 6:2791
 - geographies of television and, 6:2791
 - geographies on television and, 6:2791, 6:2792 (photo)
 - geopolitics/political geography and, 2:541
 - production and packaging processes of, 6:2791
 - social role of television and, 6:2790–2791
 - space, identify and, 6:2791–2793
- Temperature changes. *See* Adiabatic temperature changes
- Temperature patterns, 6:2793–2796**
 - air mass characteristics and, 1:62–65
 - atmospheric circulation factor in, 6:2795–2796
 - cloud cover and water vapor effects on, 6:2795
 - derechos and, 2:714–715
 - El Niño-Southern Oscillation (ENSO) and, 2:886–890
 - humidity levels factor in, 6:2795
 - La Niña and, 4:1754–1757
 - latent heat and, 4:1761–1762
 - latitude and, 6:2793–2794
 - oceans factor in, 6:2795–2796
 - polar albedo factor and, 6:2794
 - principle of continentality and, 6:2794–2795
 - radiation with low sun angle factor in, 6:2794
 - reflective cooling of clouds and, 6:2795
 - seasonal variability in, 6:2794
 - solar and terrestrial radiation and, 5:2346–2349
 - solar radiation factor in, 6:2793
 - specific heat differences between surface materials factor in, 6:2794–2795
 - topography impact on, 6:2795
 - water surface evaporation factor in, 6:2794
- Temporal GIS, 6:2796–2797**
 - change history of individual entities and, 6:2797
 - continuous view of time and, 6:2797
 - functions of, 6:2796
 - GIS static view of time and, 6:2796
 - lifelines of individual geographic entities and, 6:2797
 - lifelines of moving objects and, 6:2797
 - mathematical models used in, 6:2797
 - Donna Peuquet's work and, 4:2165
 - snap-shot model of, 6:2796
 - space-time composite model of, 6:2796–2797
 - spatiotemporal data and, 6:2796
 - time component of spatial analysis and, 6:2796
 - time point and time interval elements in, 6:2796
 - time-stamping and, 6:2796
 - See also* Temporal resolution
- Temporal resolution, 6:2798**
 - definition of, 6:2798
 - GIScience role of, 6:2798
 - GIS role of, 6:2798
 - multitemporal image comparisons and, 6:2798
 - remote sensing definition of, 6:2798
 - See also* Temporal GIS
- Tennessee**
 - Hurricane Katrina and, 3:1494
 - nuclear weapons site in, 5:2469
- Terrain analysis, 6:2798–2801**
 - catchment/watershed attributes and, 6:2799–2800
 - digital terrain model (DTM) and, 2:753–756, 6:2799
 - local morphology attributes and, 6:2799
 - natural components and terrain features and, 6:2799
 - square-grid digital elevation model and, 6:2799, 6:2800 (fig.)
 - Triangulated Irregular Network (TIN) data model and, 6:2883–2884
- Territory, 6:2801–2804**
 - behavior and, 6:2802
 - Blaeu's map of Europe, mid 17th century and, 6:2803 (fig.)
 - conflicts and, 6:2803–2804
 - definitions, 6:2801
 - exclusion from, 6:2801
 - functions of, 6:2801
 - locality studies and, 4:1790–1792
 - national identity and, 6:2802–2803
 - nation concept and, 4:1971–1974
 - network *vs.*, 6:2804
 - political history and, 6:2802
 - politics and social behavior and, 6:2801
 - thing *vs.* process of, 6:2801
- Terrorism, geography of, 6:2804–2808**
 - al-Qaeda and, 1:97
 - antiglobalization violence and, 1:97
 - definition of, 6:2805
 - fear geographies and, 3:1089
 - future research issues in, 6:2808
 - geographical components of, 6:2805
 - intertextuality term and, 6:2809
 - Timothy McVeigh, Oklahoma bombing and, 1:97
 - multidimensional nature of, 6:2804–2805
 - nation-state borders and, 1:294
 - political jurisdiction locations and, 6:2806
 - radical Islamists and, 1:97
 - September 11, 2001, terrorist attacks and, 1:97, 1:294, 2:541, 2:738, 2:763, 3:1252, 4:2047–2048, 4:2103, 5:2224, 6:2806 (photo), 6:2871
 - situational characteristics of terrorist acts and, 6:2807–2808
 - spatial and locational characteristics of, 6:2804

- spatial strategy of terrorist violence and, 6:2805
treatment and control of space and, 6:2805–2806
- Texas**
coastal “dead zones” in, 1:486
“Gunbelt” of, 4:1902
Hurricane Ike floods in, 3:1136
hurricanes in, 3:1501
oil industry in, 4:1822
Spanish colonialism in, 1:512
Williams Prairie preserve, Houston, 5:2281 (photo)
- Text/textuality, 6:2808–2812**
border identities and, 6:2811
cultural anthropology and, 6:2809
cultural turn, place and politics of representation and, 6:2810
definition issues and, 6:2808–2809
discourse on, 6:2809–2810
film and, 3:1110–1111
geography and, 6:2810–2811
hermeneutic approach to, 6:2810
intertextuality term and, 6:2809
landscapes and, 6:2809
literature geographies and, 4:1785–1788
national identities and, 6:2811
postmodernism and, 6:2809–2810
poststructuralism and, 6:2809
reading of text and, 6:2809
social context of, 6:2809
sociology, anthropology, and human geography and, 6:2811
transnational identities and, 6:2811
Writing Worlds (Barnes and Duncan), 6:2810
See also Languages, geography of; Text/textuality: noted scholars
- Text/textuality: noted scholars**
Duncan, J., 6:2810
T. Barnes, 6:2810
James Clifford, 6:2809
S. Daniels, 6:2810
Clifford Geertz, 6:2809
George Marcus, 6:2809
Paul Ricoeur, 6:2809, 6:2810
J. M. W. Turner, 6:2810
Stephen Tyler, 6:2809
- Textile industry, 6:2812–2819**
commodity chain perspective and, 6:2814–2816
fashion, agglomeration, and place in, 6:2818
Industrial Revolution and, 3:1583–1584
international trade and development and, 6:2813–2814
labor rights, gender, and business ethics in, 6:2817
leading clothing-exporting countries, 6:2186 (fig.)
leading textile-exporting countries, 6:2815 (fig.)
production sequence in, 6:2813 (fig.)
reworking labor process in, 6:2817–2818
structure of global commodity chains and, 6:2186 (fig.)
theoretical themes in, 6:2813
- Thacker, Andrew, 4:1785
- Thailand**
APEC membership of, 1:121
ASEAN membership of, 1:127, 1:128 (table), 1:129, 1:129 (table)
automobile industry in, 1:169
British colonization of, 1:515
clothing exports from, 6:2186 (fig.)
drug culture in, 2:799
economically active females in, 3:1190 (table)
forest fragmentation in, 3:1159
HIV/AIDS in, 3:1438
industrialization in, 3:1583, 4:2020, 4:2022, 4:2022 (fig.)
installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
Japanese electronics industry in, 2:885
marine aquaculture in, 4:1854 (fig.)
market-based land reform in, 4:1695
opium and heroin production in, 2:797
textile exports from, 6:2816 (fig.)
tropical scrub in, 1:244
Tsunami of 2004, Indian Ocean and, 6:2888–2890
- Thales, 6:2819**
accomplishments of, 6:2819
human geography and, 3:1460
Milesian school and, 6:2819
natural phenomena studied by, 6:2819
rational explanation through observation and, 6:2819
travels of, 6:2819
- Thermal imagery, 6:2819–2821**
acquisition in, 6:2820–2821
applications for, 6:2821
Grass Valley/Slide Fire near Lake Arrowhead/Running Springs, San Bernardino mountains, California, 6:2820 (photo)
remote sensing platforms and, 6:2821
thermal radiation principle and, 6:2820
- Thom, Bruce, 1:488
Thompson, D’Arcy, 1:369
Thompson, E. P., 4:1862, 4:1863, 4:2141, 5:2441, 5:2442, 5:2711–2712
Thoreau, Henry David, 2:569, 2:981
Thorner, Daniel, 4:2137
Thornes, John, 4:1875
- Thornthwaite, C. Warren, 6:2821–2822**
Berkeley School and, 1:192
climate classification system of, 1:432, 1:467, 6:2822
climatic water budget work of, 4:1871
climatology work of, 6:2821–2822
human ecology views of, 3:1455
potential evapotranspiration (PE), 6:2821–2822
service work of, 6:2822
water balance methods of, 6:2821
- Thorpe, Harry, 3:1402
- Three-dimensional data models, 6:2822–2825**
digital elevation model for Greene County, Missouri, 6:2823 (fig.)
digital terrain model (DTM) and, 2:753–756
geological and seismic velocity model of Santa Clara Valley area, 6:2824 (fig.)
GIScience and, 3:1284–1289
Mei-Po Kwan’s work in, 4:1674
quasi-3D data modeling and, 6:2822–2823
true-3D data modeling and, 6:2825
- Three Mile Island nuclear accident, 6:2825–2827**
event description and, 6:2825–2826
government warnings during, 6:2826
nuclear energy and, 4:2050–2052
nuclear regulation impact of, 6:2825
Three Mile Island nuclear power plant, 6:2827 (photo)
- Thrift, Nigel, 6:2827–2830**
academic career of, 6:2827
culture and technology work of, 6:2829
economic geography of Australia and, 6:2827
emotional geographies and, 2:892
Törsten Hägerstrand and, 3:1398
human geography work of, 6:2827–2828
international financial system work of, 6:2828–2829
multifield contributions of, 6:2827
new urbanism work of, 5:2268

- nonrepresentational theory and, 1:290
 nonrepresentational theory work of, 1:290, 4:2042
 postmodernism and, 6:2827
 poststructuralism and, 6:2827
 publications of, 6:2827–2828
 questions of time and, 6:2827
 radical geography and, 5:2352
 regional effects of globalism and, 6:2828
 time geography work of, 6:2836
 urban geography work of, 6:2828
- Thucydides, 4:1896
- Thunderstorms, 6:2830–2832**
 air mass thunderstorms term and, 6:2830
 approaching thunderstorm with lead gust front and, 6:2831 (photo)
 atmospheric circulation explanation of, 1:135
 derechos term and, 6:2830
 Intertropical Convergence Zone (ITCZ) location factor in, 6:2832
 lightning and, 4:1779–1783
 Mesoscale Convective Complexes (MCCs) and, 6:2831
 as mesoscale system, 6:2830
 in midlatitudes, 6:2832
 multicell thunderstorms and, 6:2830–2831
 ordinary cell thunderstorms and, 6:2830
 supercell thunderstorms and, 6:2831
 supercell tornadoes and, 6:2851
- Thünen model, 6:2832–2834**
 agricultural land use and, 6:2832–2834
 bid-rent curve and, 5:2328, 6:2833–2834, 6:2833 (fig.)
 concentric farm-land use model and, 4:1728, 5:2236
 economic rent, location rent concept and, 6:2832
 as first model of land markets, 4:1798
 food geographies and, 3:1144
 location theory and, 3:1628, 4:1798, 4:1799 (fig.), 5:2393, 5:2433, 6:2832–2834
 August Lösch and, 3:1628, 4:1805
 modern human settlement patterns and, 4:1728
- Tibet
 bovine domestication in, 2:783
 human rights atrocities in, 3:1480, 3:1481
- Tickell, Adam, 4:2014
- Till, Karen, 3:1202
- Timber plantations, 6:2834–2836**
 benefits from, 6:2834
 casuarinas in dunes, Zululand, South Africa, 6:2881 (photo)
 costs associated with, 6:2834–2835
 nontimber forest products (NTFPs) and, 6:2834
 slash pine plantation, Georgia (U.S.), 6:2835 (photo)
- Time, geographies of, 6:2836–2837**
 Anne Buttimer and, 6:2836
 cycles and timetables, 6:2836
 demarcation of time for activities and, 6:2836
 Törsten Hägerstrand and, 6:2837–2838
 Julian calendar of AD 1020 and, 6:2836
 lived time and, 6:2837
 Jon May and, 6:2836
 nonlinear and chaotic characteristics of time and, 6:2836
 social time: the geographies of rhythms and, 6:2836–2837
 Nigel Thrift, 6:2836
 time-space and, 6:2836, 6:2837
 tools and technologies related to, 6:2836
See also Time-geography; Time-space compression
- Time-geography, 6:2837–2840**
 authority constraints and, 6:2838
 capability constraints and, 6:2838
 coupling constraints, 6:2838
 environmental issues and, 6:2839
 everyday life geographies and, 2:1042–1045
 Derek Gregory's work and, 3:1380
 Törsten Hägerstrand's work in, 1:5, 1:288, 1:321, 2:1043, 2:1044, 3:1312, 3:1398, 3:1399, 4:1799, 6:2837–2839
 Mei-Po Kwan's work in, 4:1674
 Harvey Miller and, 4:1905
 notational systems and, 6:2838–2839, 6:2839 (fig.)
 Allan Pred and, 5:2289–2290
 time-space compression and, 6:2838
See also Time, geographies of; Time-space compression
- Time-space compression, 6:2840–2844**
 air transportation example of, 6:2842
 automobility and, 1:171–175
 aviation and, 1:179–182
 capitalism and, 4:1936
 communication times and, 6:2844
 compression term and, 6:2840
 concept of, 6:2840–2842
 contemporary view in, 6:2843–2844
 cost-space compression and, 6:2842
 distanciation (Giddens) and, 6:2840
 evolution of, 6:2842–2843
 friction of distance, 6:2841
 globalization and technology advances and, 6:2843
 inequities in, 6:2843
 Internet element in, 6:2844
 mobility and, 4:1918–1921
 neovisual geographies and, 4:2043
 popular culture and, 5:2229–2230
 postindustrial perspective on, 6:2843
 production of space and, 5:2297–2298
 relative/relational space and, 5:2404–2405
 space of flows and, 5:2600–2601
 spatial and temporal scales of, 6:2840–2842
 technocratic views of communication and, 6:2843
 transportation speeds example of, 6:2840
 urban accessibility and, 6:2843
 velocities of transportation and, 6:2841 (fig.)
See also Globalization; Time, geographies of; Time-geography
- TIN. *See* Triangulated Irregular Network (TIN) data model**
- T-in-O maps, 6:2844–2846**
 antiquity origins of, 6:2845–2846
 biblical mapping and, 1:347, 1:349 (fig.), 3:1461
 definition of, 6:2844–2845
 Hereford *mappa mundi* and, 6:2845
 model of, 6:2845, 6:2845 (fig.)
 symbolism element in, 6:2845
 zonal map and, 6:2845
- Toal, Gerard, 3:1252
- Tobago, 3:1190 (table)
- Tobin, James, 4:1805
- Tobler, Waldo, 6:2846–2847**
 academic career of, 6:2846
 cartograms and, 1:338
 distance decay work of, 2:774
 fields of interest of, 6:2846
 “first law of geography” of, 1:405, 2:774, 2:1059, 4:1648, 4:1801–1802, 5:2328, 5:2526, 5:2648, 6:2847
 map animation by, 4:1826, 6:2846–2847
 mapping work of, 6:2846
 migration work of, 6:2846
 Newton's law and, 4:1802
 quantitative revolution and, 6:2846
- Tobler, Walter, 1:192, 4:1945

- Toffler, Alvin, 2:538, 6:2843
- Togo, 3:1190 (table)
- Tokyo, Japan
 above-ground park, 6:2934 (photo)
 command and control economy in, 1:304
 infrastructure networks in, 3:1597
- Tolman, Edward, 1:189, 4:1881
- Tomlin, C. Dana, 3:1304
- Tomlinson, Roger, 6:2847**
 academic career of, 6:2847
 Canada Geographic Information System (CGIS) developed by, 3:1282, 3:1302
 Census Bureau data work of, 3:1281
 as father of GIS, 6:2847
 natural resources information files work of, 3:1282
- Toombs, Kay, 4:2168
- Topological relationships, 6:2848–2849**
 definition of, 6:2848
 Egenhofer and Herring's nine-intersection scheme and, 6:2848–2849
 examples of, 6:2848, 6:2848 (fig.)
 GIS systems accessibility calculations and, 1:5
 Werner Kuhn's work in, 4:1672–1673
 projective relationships and, 6:2848
 self-organizing maps and, 5:2526–2628
 Triangulated Irregular Network (TIN) data model and, 6:2883–2884
- Toponymy, 6:2849–2850**
 disciplines linked to, 6:2850
 etymological origins of names research and, 6:2849
 Eurocentrism and, 2:1028
 gazetteers and, 3:1185–1186
 geocoding and, 3:1208–1209
 geography linked to, 6:2849–2850
 new applications for, 6:2850
 proper names focus of, 6:2849
 See also Place names
- Topophilia, 6:2850–2851**
 biophilia and biophobia and, 6:2850
 cognitive challenge element in, 6:2851
 ecological diversity element in, 6:2850–2851
 familiarity element in, 6:2851
 geography and environmental psychology intersection and, 6:2850
 love of space meaning of, 2:637
 spectrum of responses of, 6:2850
 synesthetic tendency element in, 6:2851
 Yi-Fu Tuan and, 6:2890–2891
- Tornadoes, 6:2851–2854**
 atmospheric circulation explanation of, 1:135–136
 conditions for formation of, 6:2852
 counterclockwise rotation of, 6:2852
 damage and casualties from, 6:2852–2854
 deadliest tornadoes examples and, 6:2854
 definition of, 6:2851
 early-warning systems and, 2:760, 6:2854
 Enhanced Fujita Scale to rank scale of, 6:2853
 first tornado captured by NSSL Doppler radar, Union City, Oklahoma (1973), 6:2853 (photo)
 gustnadoes and landspouts nonsupercell tornadoes, 6:2852
 mechanisms of, 6:2852
 middle latitudes location of, 6:2851
 outer-region *vs.* inner-region tornadoes, 6:2852
 regional occurrences and frequencies of, 6:2851
 seasonal patterns of, 6:2851
 suction vortices and, 6:2852
 supercell tornado within supercell thunderstorms, 6:2852
 three-dimensional numerical studies of, 2:760
 urban areas affected by, 2:762
 “watch” *vs.* “warning” notification of, 2:761
 waterspout and, 6:2852
- Tourism, 6:2854–2860**
 Stephen Britton and, 6:2857–2859
 conceptual models of, 6:2855
 consumption geographies and, 2:575
 coral reefs and, 2:582–583
 Detroit's electronic music festival and, 6:2858 (photo), 6:2859 (photo)
 environmental impacts of, 2:953–955
 migration, labor market factors and, 6:2959
 neo- and post-Fordist tourism, 6:2960
 resort morphology model (Pearce) of, 6:2855
 Swiss alpine and lake landscapes and, 6:2856
 in Switzerland, Hotel Wetterhorn, 6:2855 (photo)
 Tourism Geographies journal and, 6:2960
 tourism research and, 6:2857–2859
 tourist area cycle model (Butler) of, 6:2856–2857
 tourist area cycle model of, 6:2857 (fig.)
 tourist-historic city model of, 6:2855–2856
 See also Ecotourism
- Township and range system, 6:2861–2862**
 cadastral systems and, 1:311–318, 6:2861
 elements of, 6:2862 (fig.)
 influence of, 6:2862
 Thomas Jefferson and, 6:2861
 Northwest Ordinance of 1787 and, 6:2861
 public domain and, 6:2861
 spatial regularity of, 6:2861–2862
 township, sections, quarter sections units and, 6:2861
 U.S. Public Land Survey System and, 6:2861
- Toxic Substance Control Act (1976), 5:2226
- Toynbee, Arnold, 3:1433, 3:1434
- Trade, 6:2863–2866**
 APEC and, 1:121–122
 ASEAN and, 1:126–131
 comparative advantage and, 2:556–558
 competitive advantage and, 2:558–559
 container terminal, Victoria Harbor, Hong Kong, 6:2864 (photo)
 exchange rates and, 6:2865
 export-led development and, 2:1063–1066
 export processing zones and, 6:2865
 foreign direct investment (FDI) and, 3:1153–1156
 geographical effects of, 6:2865–2866
 geographical patterns in, 6:2863–2864
 import substitution industrialization and, 3:1549–1551
 most favored nation status and, 4:1948
 NAFTA and, 4:2044–2046
 newly industrializing countries and, 4:2021–2024
 Organization of the Petroleum Exporting Countries (OPEC) and, 4:2097–2100
 policy and customs in, 6:2864–2865
 quotas and, 6:2865
 tariffs and, 6:2865
 trade agreements and, 6:2865
 traded materials and, 6:2863
 typical gravity model of, 6:2864
 See also European Union (EU)
- Tragedy of the Commons. *See* Commons, tragedy of the
- Transnational corporation (TNC), 6:2866–2870**
 benefits of, 3:1154
 classic global organizational model and, 6:2868
 definition and measurement of, 6:2866–2867
 economic autonomy threatened by, 3:1154

- evolution of, 6:2867–2868
 export processing zones (EPZ) and, 2:1067, 2:1068
 factors influencing geography of, 6:2868–2869
 foreign direct investment and, 3:1153–1156
 impacts of, 6:2869
 information technology revolution and, 3:1154
 market-oriented production and, 6:2867
 NAFTA and, 4:2044
 national context factor and, 6:2868
 negative influences of, 3:1154
 neocolonialism perpetuated by, 4:2004
 neoliberal environmental policy and, 4:2008
 new international division of labor, 4:2020–2021
 organizational structure changes and, 6:2867–2868
 outsourcing and, 4:2108–2110
 ownership structure factor and, 6:2869
 related terms and, 6:2866
 sector factor and, 6:2868
 supply or cost-oriented production and, 6:2867
- Transnationalism, 6:2870–2872**
 APEC and, 1:121–122
 borderlands and, 1:291–292
 cosmopolitanism and, 2:591–592
 cross-border cooperation and, 2:630–631
 definition of, 6:2870
 denationalization and, 3:1339
 deterritorialization and, 3:1340–1341
 diaspora and, 2:735
 extent and intensity of, 6:2870–2871
 globalization process of, 3:1338
 globalized networks and, 3:1339–1340
 hypermobile migrants and, 6:2871
 identity geographies and, 3:1527–1531
 immigration and, 3:1542–1545
 September 11, 2001, attacks and, 6:2871
 terms related to, 6:2870
 transnational elites and, 6:2871
 “transnationalism from below” and, 6:2870
See also European Union (EU)
- Transportation geography, 6:2872–2877**
 accessibility/mobility distinctions in, 6:2873–2874
 aggregate *vs.* disaggregate approaches to, 6:2874
 air transportation studies and, 6:2876
 automobile studies and, 6:2875–2876
 automobility and, 1:171–175
 aviation and, 1:179–182
 commuting and, 2:553–555
 Corinth Canal, Greece, 6:2873 (photo)
 economy, environment and sustainability issues in, 6:2875
 environmental impacts of roads and, 2:951–953
 freight industry studies and, 6:2876
 geographical patterns of economic activity and, 2:851
 information and communication technologies and, 2:539
 Mei-Po Kwan’s work in, 4:1674
 Harvey Miller and, 4:1905
 mobility and, 4:1918–1921
 mobility *vs.* mobilities and, 6:2874
 modes and intermodalism focus in, 6:2875–2876
 network analysis and, 4:2016–2018
 network data model and, 4:2018–2019
 Panama Canal, 5:2254
 passenger and freight movement and, 6:2872–2873
 public *vs.* private dimensions of, 6:2874–2875
 railroads and, 6:2876
 shipping industry, containerization and, 6:2876
 Suez Canal, 5:2254
 time-space compression and, 2:539
See also GIS in transportation
- Trap streets, 6:2877–2878**
Alexandria Drafting Co. v. Amsterdam and, 6:2877
 copyright infringement lawsuits and, 6:2877
 definition of, 6:2877
 “editing the competition” concept and, 6:2877
- Travel writing, geography of, 6:2878–2880**
 al-Idrisi, medieval geographer and, 1:66–67, 4:2179
 “contact zones” and, 6:2879
 “empty” spaces, 6:2879
 Alexander von Humboldt, 3:1462, 3:1482, 3:1484
 Ibn Battuta, 2:1054, 3:1461, 3:1519–1520, 4:2179
 Ibn Khaldun, 3:1520–1521, 4:2179
 Marco Polo, 6:2878 (image)
 George Perkins Marsh, 4:1859
 Tom L. McKnight, 4:1873
Pictures From Italy (Charles Dickens, 1846) and, 6:2879 (image)
- Tree farming, 6:2880–2882**
 benefits of, 6:2881
 boreal forest biome and, 1:214–217
 casuarinas in dunes, Zululand, South Africa, 6:2881 (photo)
 commercial timber industry and, 6:2880
 debates and controversies, 6:2882
 functions of, 6:2880
 history of, 6:2880–2881
 plantation forestry term and, 6:2880
 slash pine plantation, Georgia (U.S.), 6:2835 (photo)
- Trewartha, Glenn, 6:2882–2883**
 population geography work of, 5:2245–2246, 5:2247, 6:2882–2883
 regional geography of Japan work of, 6:2883
 settlement geography work of, 5:2536, 5:2537
 weather and climate work of, 6:2882–2883
- Triangulated Irregular Network (TIN) data model, 6:2883–2884**
 functions of, 6:2884
 implementation of, 6:2883–2884
 linear referencing and dynamic segmentation and, 4:1784–1785
 terrain surfaces and, 6:2883
 topology structures and, 6:2883
 triangles element in, 6:2883
- Tricart, Jean, 2:617
 Trinidad, 3:1190 (table)
- Troll, Carl, 6:2884–2885**
 accomplishments of, 6:2884–2885
 high-mountain geography work of, 6:2884
 landscape ecology term and, 3:1458, 4:1705, 4:1714, 6:2884–2885
 service work of, 6:2885
- Tsunami, 6:2885–2888**
 earthquakes and, 2:812–813
 geography of and warning systems for, 6:2886–2887
 mechanics of, 6:2885–2886
 Pacific Tsunami Warning Center and, 6:2886
 prehistoric tsunamis and, 6:2887
 tsunami deposits, Maggie Kettle’s loch, Sullom Voe, Shetland Isles, 6:2888 (photo)
 tsunami early warning buoy and, 2:760 (photo)
 word derivation and, 6:2885
See also Tsunami of 2004, Indian Ocean
- Tsunami of 2004, Indian Ocean, 6:2888–2890**
 death toll of, 2:743, 2:813, 6:2888
 devastation caused by, 2:813
 differential vulnerabilities and, 2:743
 earthquake epicenter and, 6:2890
 efforts to avoid devastation and, 1:497

- learning from, 4:1986
 regional map of areas affected by, 6:2889 (fig.)
- Tuan, Yi-Fu, 6:2890–2891**
 body's role in being in the world work of, 1:288
 books written by, 6:2891
 creative possibilities of humans views of, 2:1046
 extreme geography views of, 2:1074
 historic preservation and, 3:1435
 humanistic geography work of, 1:118, 1:288, 2:892, 2:1046, 3:1467, 3:1476, 4:1786, 6:2890–2891
 humility and vitality in work of, 6:2891
 perception, experience, and cultural attitude and, 2:978
 phenomenology and, 4:2167
 qualitative methods and, 5:2324
 recentring the human subject views of, 2:1046
 “smellscapes” and “soundscape” concepts of, 4:2043
 “topophilia” (love of place), 2:637, 2:978, 3:1467, 3:1476, 4:2167, 6:2890–2891
- Tukey, J. W., 2:1060
- Tulloch, Gordon, 5:2215
- Tunisia
 clothing exports from, 6:2186 (fig.)
 economically active females in, 3:1190 (table)
 France colonization of, 1:514
- Tunnard, Christopher, 4:1700
- Turing, Alan, 1:369
- Turk, Andrew, 4:2080
- Turkey
 AGILE membership of, 1:125 (table)
 cave map, earliest known map and, 1:341
 clothing exports from, 6:2186 (fig.)
 crop centers of domestication in, 1:374
 economically active females in, 3:1190 (table)
 European Union (EU) membership status of, 2:1038
 installed capacity for electricity production forecast, 2010, 3:1268 (fig.)
 morphine-rich narcotics produced in, 2:796, 2:797 (table)
 NATO membership of, 4:2048 (fig.)
 newly industrializing country of, 4:2022 (fig.)
 pig domestication in, 2:783
 squatter settlements in, 5:2682, 5:2683, 5:2684
 squatter settlements in Istanbul and Ankara, 5:2683 (photo)
 strike-slip faults in, 3:1087
 textile exports from, 6:2815 (fig.), 6:2816 (fig.)
 urban storm drains in Pierene, 6:2991 (photo)
- Turkmenistan
 arid topography in, 1:112 (photo)
 camel domesticated in, 2:783
 Commonwealth of Independent States (CIS) membership of, 2:536, 2:536 (table)
 economically active females in, 3:1190 (table)
- Turner, Billie Lee, II, 6:2891–2892**
 human-environment relationships and, 6:2891–2892
 land change and sustainability work of, 6:2892
- Turner, Frederick Jackson, 2:667, 3:1171
- Tversky, B., 4:1882
- Tweed, Thomas, 5:2409
- Twitter, 3:1478
- Typhoon satellite image, 1:20 (photo)
- Typography in map design, 6:2892–2893**
 cartographic ontology and, 6:2893
 John B. Harley and, 6:2892–2893
 history of, 6:2893
 technology advances and, 6:2893
 typography definition and, 6:2892
- UCGIS. *See* University Consortium for Geographic Information Science (UCGIS)
- Uganda
 economically active females in, 3:1190 (table)
 Kibale National park in, 4:2118
- UHI. *See* Urban heat island (UHI)
- Ukraine
 base map of, satellite image, 1:359, 1:360 (fig.)
 Chernobyl nuclear accident in, 1:385–386, 1:385 (photo)
 Clean Development Mechanism (CDM), carbon offsets and, 1:333 (fig.)
 coal energy source in, 3:1582
 coal in, 1:485
 collectivized farming in, 2:543
 Commonwealth of Independent States (CIS) membership of, 2:536, 2:536 (table)
 ecological footprint and biocapacity of, 2:827 (table)
 Euroregions, cross-border cooperation and, 2:631 (fig.)
 famine in, 2:543
 GUAM Organization for Democracy and Economic Development co-founded by, 2:538
 HIV/AIDS in, 3:1438
 horse domesticated in, 2:783
 Kyoto Protocol of 1997, GHG emissions and, 1:463
 percentage of economically active females in, 3:1190 (table)
- Ulam, Stanislaw, 1:369
- Ullman, Edward, 1:389, 1:389 (fig.), 5:2329
- Underdevelopment, 6:2895–2899**
 Piers Blaikie's work in, 1:284
 cholera and, 1:401–403, 1:402 (fig.)
 critique of dependency school and, 6:2898
 critique of radical underdevelopment theory and, 6:2898
 Crocodile River, Freetown, Sierra Leone, 6:2896 (photo)
 current state of, 6:2898
 dependency theory and, 2:712–714
 import substitution industrialization and, 3:1549–1551
 modernization theory and, 4:1931–1935
 new international division of labor and, 4:2019–2021
 origins and evolution of concept, 6:2895–2898
 Wallersteinian world-systems theory and, 4:1862
See also Developing world
- UNEP. *See* United Nations Environment Programme (UNEP)
- Uneven development, 6:2899–2903**
 business cycles, spatial division of labor and, 1:304
 capitalism and, 3:1430
 class and nature and, 1:423–425
 current trends, 6:2902
 definition and measurement of, 6:2899–2900
 dependency theory and, 2:712–714
 development definitions and, 6:2899
 economic crisis and geography of, 2:610
 growth poles and, 3:1391–1392
 housing policies and, 3:1447, 3:1448
 in hydroelectric power, 3:1507–1511
 inequality geographies and, 3:1586–1590
 Marxism, capitalism and, 4:1862
 Don Mitchell's work and, 3:1430, 4:1913–1914
 modernization theory and, 4:1931–1935
 neo-Marxism, neoliberalism and, 6:2901–2902
 new international division of labor and, 4:2019–2021
 in postindustrial societies, 2:709–710
 primate cities and, 5:2290–2291
 problem of scale and, 6:2900–2901
 radical geography and, 5:2350–2352
 social struggles of exploited labor workers and, 3:1430
Spatial Divisions of Labor (Massey) and, 1:304, 4:1866, 5:2351

- subaltern uneven development and, 6:2902
 subnational regional scales and, 6:2901
 world-systems theory and, 6:2900
See also **Gross domestic product/gross national product** (GDP/GNP)
- Uniformitarianism, 3:1245, 4:2179–2180
- Union Carbide, 1:194–195
See also **Bhopal, India, chemical disaster**
- Union of Concerned Scientists, 1:96
- Union of Soviet Socialist Republics (USSR). *See* Russia; Soviet Union
- United Arab Emirates
 economically active females in, 3:1190 (table)
 OPEC membership of, 4:2099, 4:2100 (fig.)
- United Kingdom
 acid rain in, 1:7
 agglomeration economies in, 1:32
 AGILE membership of, 1:125 (table)
 Anglocentrism of, 2:1030 (table)
 as archipelago island formation, 1:105
 automobile industry in, 1:169, 1:171
 automobility in, 1:172
 biotechnology industry in, 1:280
 British Association for the Advancement of Science (BA), 3:1601
 British National Grid coordinate system and, 2:579
 brownfield redevelopment in, 1:298
 brownfields redevelopment in, 1:298
 business geography university departments in, 1:305
 carbon or climate change taxes in, 4:1857
 Changing Urban and Regional System (CURS) program in, 4:1790–1791
 coastal dead zones and, 1:488
 commuting studies in, 2:554
 competitive advantage areas in, 2:558
 critical human geography in, 2:620
 deindustrialization in, 2:700
 designer drug use in, 2:799
 digital ground model and, 2:753
 drug substitution programs in, 2:799
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 Economics and Social Research Council and, 4:1790
 energy policies in, 2:902
 environmental issues in, 2:1034
 European Union (EU) membership of, 2:1035
 GDP of, 3:1382, 3:1383 (fig.)
 GIS pioneering in, 3:1283
 greenbelts in, 3:1363–1364, 3:1365 (fig.)
 green building programs in, 3:1368–1369, 3:1371
 Green Party in, 2:1034
 hate groups in, 3:1407
 health inequities in, 3:1411
 herbicide-tolerant crops in, 1:279
 heroin parks in, 2:799
 housing policy in, 3:1447, 3:1448
 hydroelectricity installed in, 3:1506
 incubator zones in, 3:1552
 industrial studies in, clusters and, 1:480
 Kyoto Protocol of 1997 and, 1:463
 London, airline networks, 1:179
 London, cholera distribution in, 1:355, 1:401–402
 London, command and control economy in, 1:304
 London, crime studies, 2:607
 London, Kensal House modernist architecture, 1:108
 London, “killer smog” in, 1:69, 1:70
 London, Mayday Monopoly protests and, 1:100
 London, St. Paul’s Cathedral and, 1:107
 military expenditures in, 4:1898, 4:1899 (table)
 mixed farming in, 4:1915, 4:1917
 mobile phone-based location services standards in, 3:1256
 Network of GMO Free Regions in, 3:1610
 Ordnance Survey map, England, 1:354, 1:354 (fig.)
 protests, Catholic and Protestant neighborhoods, Belfast, Ireland, 5:2525 (photo)
 public-private partnerships in, 5:2312
 public urban water systems in, 5:2316
 redistricting in, 5:2376–2377
 regional environmental planning in, 5:2384
 regional governance in, 5:2390–2391
 social class studies in, 1:418
 soil erosion in, 5:2585
 Sustainable Livelihoods Framework, of environmental entitlements in, 2:924
 total factor productivity (TFP) of, 6:2780 (table)
 2008 financial crisis and, 2:691
 UK Woodlands Assurance Scheme and, 2:915
 urban village movement (Prince Charles) in, 4:2024
 U.S. cultural geography *vs.*, 2:635–636
 welfare state in, 3:1590
See also Britain; **Institute of British Geographers (IBG)**
- United Nations (UN)**, 6:2903–2905
 Agenda 21 document of, 5:2373
 Bali Action Plan and, 1:9
 Biodiversity Convention of, 3:1613
 Isaiah Bowman’s service to, 1:296
 cartography importance to, 6:2904
 Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries and, 3:1165
 Conference on Environment and Development and, 2:835, 3:1568, 3:1609
 Conference on the Human Environment and, 2:1003, 3:1604, 6:2747
 Convention on the Law of the Non-Navigational Uses of International Watercourses and, 3:1619
 Convention on the Law of the Sea and, 4:2069
 Convention on the Prevention and Punishment of the Crime of Genocide and, 3:1199
 counter-Eurocentrist movement and, 2:1029
 “Declaration on the Granting of Independence to Colonial Countries and Peoples of 1960” and, 3:1554
 Declaration on the Rights of Indigenous Peoples and, 3:1554, 3:1569
 desertification conferences of, 2:718–719, 2:972–973, 3:1335
 economic and social development work of, 6:2904–2905
 Economic Commission for Europe Convention on Long-Range Transboundary Air Pollution and, 2:945
 Economic Commission for Latin America (ECLA) and, 3:1550
 ecotourism supported by, 2:871
 environmental issues conferences of, 3:1604
 Food and Agricultural Organization of, 4:2067
 foreign direct investment and, 3:1155
 Forest Resources Assessment of the Food and Agriculture Organization of, 4:1741
 formation of, 6:2903
Global Assessment of Disaster Risk Reduction 2009 published by, 4:1984
 global HIV infection and, 2:770 (fig.)
 governance by, 3:1358
 guiding principles of, 6:2903
 Human Development Index and, 2:725 (fig.), 5:2573
 humanitarian affairs work of, 6:2904–2905
 human rights abuses and, 3:1480

- human right to water, legal contributions supporting, 2:995 (table)
- Hyogo Framework of Action (HFA) of, 4:1987
- illegal drugs trade and, 2:796
- indigenous peoples policy and actions of, 3:1554
- intergovernmental organizations and initiatives overseen by, 3:1604
- international environmental movements and, 3:1611
- international framework for disaster risk reduction and, 4:1987
- International Panel on Climate Change of, 2:943–944
- Land Cover Classification System (LCSS) of, 4:1740
- League of Nations and, 6:2903
- Martinez-Cobo Study by, 3:1554
- Millennium Ecosystem Assessment and, 2:862–863
- Millennium Development Goals and, 3:1152, 3:1358, 3:1604, 5:2220, 5:2274, 5:2317
- Millennium Ecosystem Assessment project (UN) and, 2:1001
- narcotics production regulated by, 2:796
- New York City headquarters of, 6:2904 (photo)
- Office for the Co-ordination of Humanitarian Affairs (UN-OCHA), 2:814
- organizations of, 6:2903–2904
- peace and security as primary goal of, 6:2904
- Peace Palace, The Hague, Netherlands, and, 6:3130 (photo)
- Permanent Forum on Indigenous Issues of, 3:1554, 3:1564
- political refugees, political asylum and, 3:1545
- population growth estimates of, 5:2241
- public-private partnerships supported by, 5:2312
- recycling of municipal solid waste issue and, 5:2373
- technology advances and, 6:2904
- UNAIDS and, 3:1436–1437, 3:1437 (fig.)
- UN Charter and, 6:2903
- UN Convention to Combat Desertification (UNCCD) and, 5:2232, 5:2234
- UNESCO World Heritage sites and, 1:216, 4:1705, 4:1716, 5:2406 (photo)
- UN Framework Convention on Climate Change (UNFCCC) and, 1:9, 1:462, 2:945, 3:1374, 5:2220, 5:2245, 6:2748–2749
- UN Group of Experts on Geographical Names (UNGEGN) and, 5:2189
- UN Human Poverty Index (HPI) of, 5:2274
- UN International Strategy for Disaster Reduction (UNISDR) and, 4:1987
- United Nations High Commissioner for Refugees and, 5:2378–2379
- Universal Declaration of Human Rights and, 3:1480
- Working Group on Indigenous People of, 3:1554
- World Commission on Environment and Development and, 3:1604, 5:2220
- world hydroelectricity maps and, 3:1508 (figs.)
- World Intellectual Property Organization and, 4:1771
- World Summit on Sustainable Development and, 2:1005, 3:1102, 3:1604, 6:2738, 6:2750
- world undernutrition and malnutrition estimates of, 3:1487
- See also* Food and Agriculture Organization (FAO); United Nations Conference on Environment and Development (UNCED); United Nations Education and Cultural Organization (UNESCO); United Nations Environment Programme (UNEP); World Summit on Sustainable Development
- United Nations Conference on Environment and Development (UNCED), 6:2905–2906**
- achievements of, 6:2906
- Agenda 21, global sustainable development action plan and, 2:914, 2:1004–1005, 6:2737–2738, 6:2746, 6:2747, 6:2748
- Agenda 21 action plan of, 6:2906
- Brundtland Commission and, 6:2905–2906
- criticism of, 6:2749–2750
- desertification issue and, 2:973
- Earth Summit term of, 2:981, 2:1004, 6:2747, 6:2748, 6:2907
- ecosystem approach to environmental planning and, 2:981
- environmental impact statements and, 2:958
- global management approach of, 6:2749
- Rio Declaration on Environment and Development (the Earth Charter) and, 2:1004
- sustainable cities and, 6:2746
- sustainable use of natural resources focus of, 6:2905–2906
- UN Conference on the Human Environment and, 2:1003, 3:1604, 6:2747
- UN Framework Convention on Climate Change (UNFCCC) and, 1:9, 1:462, 2:945, 3:1374, 5:2220, 5:2245, 6:2748–2749
- United Nations Educational, Scientific and Cultural Organization (UNESCO)
- biosphere reserves recognized by, 1:256
- endangered species and, 1:216
- Seville Strategy of 1995 and, 1:256
- soil classification system of, 5:2592
- soil conservation and, 5:2580
- World Heritage sites of, 1:216, 4:1705, 4:1716, 5:2406 (photo)
- United Nations environmental summits, 6:2906–2907**
- Earth Summit and, 6:2907
- first summit and, 6:2906–2907
- functions of, 6:2906
- Our Common Future* Brundtland Commission report and, 6:2907
- World Summit on Sustainable Development (WSSD) and, 2:1005, 6:2738, 6:2750, 6:2907
- United Nations Environment Programme (UNEP), 6:2907–2909**
- accomplishments of, 6:2909
- bilateral or multilateral environmental treaties and, 2:967
- climate policy and, 1:462
- contributors to, 6:2908
- creation of, 6:2907–2908
- desertification conferences and, 2:718–719, 2:973
- environmental governance role of, 3:1604
- environmental policy mandate of, 6:2908
- environmental secretariats of, 6:2908–2909
- establishment of, 2:1003
- funding of, 6:2908
- Global Environment Facility (GEF) and, 6:2908
- Intergovernmental Panel on Climate Change (IPCC) and, 1:82
- Millennium Ecosystem Assessment project and, 2:1001
- mission of, 3:1604
- pesticide deaths data of, 1:53
- postwar environmental assessment by, 2:957
- regional seas program of, 3:1604
- soil conservation focus of, 5:2580
- Vienna Convention for the Protection of Stratospheric Ozone and, 1:462
- World Conservation Strategy and, 2:1003
- World Meteorological Organization and, 1:462
- See also* Intergovernmental Panel on Climate Change (IPCC)
- United States**
- academic cartography programs in, 1:342
- acid rain in, 1:6–7
- airline deregulation in, 1:180
- airline networks in, 1:179–181
- air masses of, 1:63
- anthropogeography, Kentucky Appalachians and, 1:93
- anticolonialism, antiglobalization and, 1:94–95
- antiglobalization, anticolonism in, 1:97
- ANZUS treaty and, 1:505
- APEC membership of, 1:121

- applied geography academic programs in, 1:101
 arms trade in, 4:1902
 art tourism in, 1:119, 1:119 (photo)
 atmospheric energy variations in, 1:164
 automobile industry in, 1:169, 1:170 (fig.)
 automobility in, 1:172–174, 1:174 (fig.)
 basin and range topography in, 1:186
 biofuels produced in, 1:202–203
 biotechnology industry in, 1:280–281
 brownfield redevelopment in, 1:298
 cadastral systems, land ownership and, 1:315
 cancer studies of southern-born African Americans and, 1:336
 carbon trading and, 1:330, 1:331 (table)
 cholera in, 1:401
 Christaller's highway development plans and, 1:410
 Clean Air Act (CAA) and, 1:330
 climate variation studies in, 1:81–82
 clothing exports from, 6:2186 (fig.)
 coal energy source in, 3:1582
 coal regions of, 1:483, 1:484 (fig.)
 CO₂ emissions in, 3:1454
 Cold War and, 1:504–505, 2:691–692, 3:1223–1224, 3:1250–1251
 colonial empire building by, 1:511, 2:667
 common resources (water) management with Mexico and, 1:526, 1:527 (fig.)
 commuting studies in, 2:554
 competitive advantage areas in, 2:558
 countering terrorism, human rights violations and, 3:1481
 critical human geography in, 2:620
 cropland uses, 1992–2004, 1:39 (table)
 digital divide in, 2:750–751
 digital elevation model and, 2:753
 drought planning in, 2:793
 drought prone region in, 2:787, 2:791 (photo)
 dry climates in, 1:429, 1:430 (fig.)
 Eastern Utah desert in, 1:115 (photo)
 ecological footprint and biocapacity of, 2:827 (table)
 economically active females in, 3:1190 (table)
 elderly care and services environments in, 2:878
 energy policy of, 2:899–901
 environmental history studies in, 2:929
 environmental privatization in, 4:2009
 ethanol production in, 202
feng shui geomancy in, 3:1239
 fixed *vs.* flexible exchange rates and, 4:1936
 foreign direct investment in China from, 3:1155
 gated communities in, 3:1181
 GDP/GNP of, 3:1382, 3:1383 (fig.)
 genetically modified foods in, 3:1198
 genetically modified organisms, crops and, 1:279
 geocoding methods in, 3:1208
 geographical ignorance in, 3:1219, 3:1219 (image)
 geopolitics in, 3:1250
 geothermal areas in, 3:1273
 geothermal energy use in, 3:1267
 ghettos in, 3:1275–1277
 Great Salt Lake regional basin lowpoint in, 1:114
 greenbelts in, 3:1364
 greenhouse gas emissions of, 1:464, 3:1376 (fig.), 3:1377, 5:2220
 “Gunbelt” region of, 4:1902
 hardiness zones in, 1:519 (fig.)
 hate groups in, 3:1406–1407
 health inequities in, 3:1411
 heavy industry development in, 3:1584
 hegemony in, 3:1420
 housing policy in, 3:1447, 3:1448
 humid continental climate of, 1:439, 1:440
 hunger conceptual debates and, 3:1486
 hurricane losses in, 4:1984
 hydroelectrical power in, 3:1506, 3:1507
 immigration laws of, 3:1545
 immigration studies of (W. Clark) and, 1:418
 incubator zones in, 3:1552
 indigenous reserves and reservations in, 3:1570
 industrialization in, 3:1583
 industrialized agriculture in, 1:43–47
 international criminal court objects of, 3:1606
 Internet penetration rates in, 2:750, 2:750 (table)
 Kyoto Protocol of 1997 and, 1:463
 labor force decline, deindustrialization and, 2:700–701, 2:701 (fig.)
 land covers, 1987 census of agriculture, 1:40 (table)
 licit narcotics consumed in, 2:796
 manifest destiny, ethnocentrism of, 2:1027
 manifest destiny policies of, 3:1222–1223, 3:1223 (fig.)
 manufacturing regional areas in, 4:1821–1822
 midlatitude deciduous forest in, 1:223–226, 1:224–226
 midlatitude grasslands and grasses in, 1:227–228, 1:228 (fig.)
 military expenditures in, 4:1898, 4:1899 (table)
 military-industrial complex in, 4:1900
 monsoons in (southwestern), 1:134
 NAFTA and, 1:121, 1:129, 4:2044–2046
 Native American reservations, ethnic segregation and, 2:1022
 neocolonialism and, 4:2004–2005
 neoliberalist policies in global South and, 4:2012–2013
New Historical Atlas of Religion in America (Gaustad and Barlow) and, 5:2407
 New Urbanism movement in, 2:555
 oil imports of, 4:2073
 organic product certification in, 3:1081
 particulate matter pollution in, 1:151
 PC user statistics in, 2:750
 playas arid topography in, 1:115
 political map of, 6:3163
 population growth in, 5:2241
 population migration and mobility studies in, 1:417–418
 population pyramid for, 5:2250 (fig.)
 poverty threshold measure in, 5:2274
 public land management in, 2:552
 public urban water systems in, 5:2316
 racialized landscapes in, 5:2342
 railroads in, 5:2358–2359, 5:2360 (photo), 5:2361 (fig.)
 redistricting in, 5:2375–2376
 regional environmental planning in, 5:2386
 regional governance in, 5:2391–2392
 religious right in, 1:97
 social class studies in, 1:418
 soil classification system of, 5:2592
 soil erosion in, 5:2585
 spatial adjustment for river basin conflict resolution with Mexico and, 1:527 (fig.)
 State Plan Coordinate Systems of, 2:579
 sustainable forests in, 3:1164
 textile exports from, 6:2815 (fig.), 6:2816 (fig.)
 time zones established in, 5:2363
 total factor productivity (TFP) of, 6:2780 (table)
 transnational corporations in, 3:1154
 2008 financial crisis and, 2:691
 U.K. cultural geography *vs.*, 2:635–636
 undernourishment in, 3:1488
 university business geography programs in, 1:305, 1:306

- university regional science programs in, 1:81
- urbanization in, 3:1585–1586
- U.S. Agency for International Development (USAID) and, 2:871
- U.S./Canada borderlands and, 1:292
- U.S. Census decennial map (1870), 1:356, 1:358 (fig.)
- Utah's desert arid topography and, 1:111 (photo)
- watershed management in, 6:3072–3073
- water stress ratio in, 3:1516
- “working poverty” in, 5:2276
- Yellowstone National Park in, 3:1273
- zero-tolerance zones in, 2:800
- See also* **Foreign aid**; United States: maps
- United States: maps
 - average annual rate of domestic net migration by county (2000–2004), 4:1892 (fig.)
 - biotechnology, centers, 1:281 (fig.)
 - cropland and forestland shifts in, 1982–1997, 1:38 (fig.)
 - developed land increase in, 1992–1997, 1:42 (fig.)
 - housing ownership, 1900–2000, 4:1965 (fig.)
 - interstate highway system in, 1:174 (fig.)
 - kriskogram of interstate migration in, 3:1140 (fig.)
 - land covers, 1987 census of agriculture, 1:40 (fig.)
 - land use in, 1:37 (fig.)
 - large U.S. metropolitan areas and, 4:1887 (fig.)
 - live-fuel moisture stress, fire potential, 5:2320 (images)
 - metropolitan segregation levels, 2000, 2:1024 (fig.)
 - Midwest hub-and-spoke airline network, 1:180 (fig.)
 - murder rates, possible factors and, 4:1964 (fig.)
 - murder rates and families in poverty, 4:1965 (fig.)
 - NATO membership of, 4:2048 (fig.)
 - net regional U.S. migration (2007), 4:1891 (fig.)
 - Omaha, Nebraska, African Americans in, 2000, 2:1025 (fig.)
 - Omaha, Nebraska, poverty in, 2:1026 (fig.)
 - Omaha, Nebraska, Whites in, 2000, 2:1025 (fig.)
 - population sizes, Eastern U.S. cities, 2000, 6:2982 (fig.)
 - radar-estimated accumulated precipitation, 5:2283 (fig.)
 - railroad network, 5:2361
 - shares of land in major uses, 2002, 1:41 (fig.)
 - spatial resolution and vector data, counties in the U.S., 5:2661 (fig.)
 - Sunbelt, 5:2724 (fig.)
 - 2004 presidential election, 2:870 (fig.)
 - urban geography of carbon footprints, 3:1379 (fig.)
 - U.S. federal government outlays per capita, 2005, 5:2311 (fig.)
 - U.S. Gunbelt (2008), 4:1903 (fig.)
 - visualization of high-risk clusters of cervical cancer in U.S. and, 2:1062 (fig.)
- United States Census Bureau, 6:2909–2911**
 - address list update, 2009, 6:2910 (photo)
 - census tracts and, 1:374
 - counting racial groups and, 5:2343
 - Decennial Census of Population and Housing (U.S. Census Bureau) and, 1:371–373
 - digital data files technology of, 3:1283
 - Dual Independent Map Encoding (DIME) GIS data format and, 2:674
 - GIS automated address matching and, 3:1282
 - kriskogram of U.S. interstate migration and, 3:1140 (fig.)
 - largest U.S. metropolitan areas, 2007, 4:1888 (table)
 - large U.S. metropolitan areas, 2007, 4:1887 (fig.)
 - metropolitan districts, term, 4:1886
 - multi-racial census responses and, 5:2343
 - reference map classification and, 1:340 (fig.)
 - self-identification and, 5:2343
 - TIGER data files, geocoding by street address and, 3:1208, 3:1312
 - urbanized area defined by, 5:2239
 - U.S. metropolitan population (2000) and, 4:1886 (table)
- United States Environmental Protection Agency (EPA). *See* Environmental Protection Agency (EPA)
- United States Geological Survey (USGS), 6:2912–2913**
 - aerial photographs for mapping and, 1:15
 - digital spectral library of, 4:1954
 - fumarole, Spirit Lake, Kamania County, Washington, 3:1271 (photo)
 - Geographic Names Information System (GNIS) digital gazetteer and, 3:1185
 - Grove Karl Gilbert's service to, 3:1279
 - Grand Canyon publications of, 3:1245
 - Ferdinand Hayden's survey work for, 3:1409
 - Landsat satellites co-developed by, 3:1283, 4:1974
 - landslide data of, 4:1722–1723
 - mining data from, 4:1911
 - mudflow damage measurement, Upper Muddy River, Skamania County, Washington, 6:2912 (photo)
 - National Elevation Dataset and National Hydrography Dataset developed by, 3:1317
 - nationwide inventory of land cover and land use of, 3:1302
 - John Wesley Powell's service to, 3:1409, 5:2277
- United States National Climatic Data Center, 3:1125
- University Consortium for Geographic Information Science (UCGIS), 6:2913–2914**
 - GIScience research and education priorities of, 3:1286, 3:1287–1288, 3:1288 (table), 4:2165
 - David M. Mark's service to, 4:1856
 - membership of, 3:1286
 - mission and goals of, 3:1286
 - Timothy Nyerges' service to, 4:2055–2056
 - Donna Peuquet's service to, 4:2165
- Unsupervised classification, 6:2914–2915**
 - advantages of, 6:2915
 - algorithms used by, 6:2915
 - classifiers of, 6:2914–2915
 - digital image classification and, 6:2914
 - function of, 6:2914
 - supervised classification and, 5:2725, 6:2914
- Unwin, David, 6:2915–2916**
 - academic career of, 6:2915
 - computing/GIS work of, 6:2915–2916
 - quantitative geography work of, 6:2915–2916
 - teaching work of, 6:2915
- Unwin, Raymond, 3:1363
- Urban and regional development, 6:2916–2921**
 - built environment and, 1:298–300
 - “economies of speed,” 5:2362
 - future directions, 6:2920–2921
 - growth machine politics and, 3:1390
 - growth poles and, 3:1391–1392
 - inequality geographies and, 3:1589
 - informal economy and, 3:1590–1592
 - interregional commerce affected by, 5:2362
 - Interstate Commerce Act (1887) and, 5:2362
 - land grants and, 5:2362
 - markets expansion and, 5:2362
 - origins of, 6:2916–2918
 - railroads and, 5:2362
 - regeneration of urban landscapes and, 1:420, 1:422
 - urban governance and growth machine, urban regimes and regulation theory in, 6:2919–2920
 - urban population densities and, 5:2239–2240
- Urban and regional planning, 6:2922–2925**
 - Cities and Complexity* (Batty) and, 1:187
 - history of, 6:2922
 - landscape architecture and, 4:1698–1701

- participatory planning and, 4:2126–2129
- process of, 6:2924
- regional planning and, 6:2923–2924
- Urban Modeling* (Batty) and, 1:187
- urban planning and, 6:2922–2923
- Urban ecology, 6:2925–2927**
 - early developments in, 6:2925
 - future trends in, 6:2927
 - human ecology role in, 6:2925–2926
 - urban environmental sustainability and, 6:2926
- Urban environmental studies, 6:2927–2933**
 - atmospheric pollution and, 1:151, 1:152, 1:153
 - photochemical smog and, 4:2171–2173
 - urban air pollution and, 6:2931
 - urban climate and air quality in, 6:2929–2930
 - urban environmental sustainability and, 6:2932
 - urban landscapes and, 6:2928–2929
 - urban population density and, 5:2239–2240
 - urban vegetation and, 6:2932
 - urban water and, 6:2931
- Urban gardens, 6:2933–2935**
 - above-ground park, Tokyo, Japan, 6:2934 (photo)
 - benefits of, 6:2933
 - characteristics of, 6:2933
 - definition of, 6:2933
 - human well-being and, 6:2933–2934
 - lack of information on, 6:2934
 - landscape design and, 4:1703–1705
 - neighbor mimicry effect and, 6:2934
 - threats to, 6:2934–2935
 - variations in, 6:2933
- Urban geography, 6:2935–2942**
 - aerial view of Chicago, 6:2937 (photo)
 - behavior and humanist perspectives on, 6:2938
 - Brian Berry's work and, 1:193, 3:1466
 - cellular automata used in, 1:370, 1:371 (fig.)
 - closed-circuit television systems in cities and, 2:541
 - gated communities and, 3:1181–1183
 - gentrification and, 3:1203–1208
 - ghettos and, 3:1275–1277
 - Jean Gottmann's work in, 3:1355–1357
 - Homer Hoyt's work and, 3:1448–1450
 - information and communication technologies and, 2:539
 - law geographies and, 4:1766
 - megapolis (Gottmann) and, 3:1355–1356
 - metropolitan areas and, 4:1886–1888
 - new urbanism and, 4:2024–2027
 - origins and growth of, 6:2935–2938
 - "post-al" encounters in, 6:2939–2941
 - radical turn in, 6:2938–2939
 - rank-size rule and, 5:2365
 - regeneration of urban landscapes and, 1:420, 1:422
 - social justice geographies and, 4:1644
 - urban density and, 5:2239–2240
 - urban migration and, 5:2232
- Urban green space, 6:2942–2946**
 - in Auckland, New Zealand, 6:2943 (photo)
 - ecology in and of cities and, 6:2942–2943
 - engineered urban green space, 6:2944–2945
 - environmental services and, 6:2944
 - future of, 6:2946
 - greenbelts and, 3:1363–1367
 - health and well-being and, 6:2945
 - landscape design and, 4:1703–1705
 - negative perceptions, 6:2945–2946
 - social and cultural services and, 6:2945
 - wildlife corridors in Wandsworth, southwest London and Central Park, 6:2944 (photo)
- Urban heat island (UHI), 6:2946–2949**
 - air, surface, and underground locations of, 6:2946
 - construction materials factor in, 6:2948
 - description of, 6:2946
 - global warming and, 6:2948
 - hot rooftops, Baton Rouge, Louisiana, 6:2947 (image)
 - human and natural systems affected by, 6:2947–2948
 - latent heat exchange element in, 6:2948
 - nocturnal UHIs and, 6:2948
 - in small towns, 6:2948
 - urban climatology advances and, 6:2948
 - Urban Heat Island Pilot Project and, 6:2947 (image)
- Urban hierarchy, 6:2949–2951**
 - Brian Berry's work and, 1:193
 - central place theory and, 1:380–382
 - challenges faced by, 6:2951
 - Walter Christaller's central place theory and, 1:409–410, 5:2393
 - degree of primacy and, 6:2950–2951, 6:2951 (fig.)
 - economic development and, 6:2950, 6:2950 (fig.)
 - globalization and, 6:2951
 - Atsuyuki Okabe and, 4:2076–2077
 - population, settlements, and services in, 6:2949–2950, 6:2949 (fig.)
 - primate cities, 5:2290–2291
 - rank-size rule and, 5:2365
 - urban population sizes and, 6:2949
- Urbanization, 6:2952–2958**
 - future trends in, 6:2956–2957
 - global trends in, 6:2954–2956, 6:2955 (fig.), 6:2956 (table)
 - Jean Gottmann's work in, 3:1355–1357
 - Industrial Revolution and, 3:1582–1586
 - measurement of, 6:2953–2954
 - megacities and, 6:2957 (table)
 - megapolis (Gottmann) and, 3:1355–1356
 - selected size group of cities and, 6:2956 (table)
 - uneven growth between more- and less developed regions and, 6:2955 (fig.)
 - urban evolution and, 6:2952–2953
 - urban migration and, 5:2232
- Urban land use, 6:2958–2963**
 - application of models in, 6:2961–2963
 - central business districts (CBDs) and, 1:379–380
 - commuting and, 2:553–555
 - concentric zone model in, 6:2959, 6:2960 (fig.)
 - economic competition and accessibility and, 6:2958, 6:2958 (fig.)
 - global environmental change and, 3:1336
 - models of, 6:2959–2961
 - monocentric model of urban form and, 5:2236–2237
 - multiple-nuclei, 6:2960 (fig.), 6:2961
 - peripheral model of, 6:2961, 6:2962 (fig.)
 - regeneration of urban landscapes and, 1:420, 1:422
 - sector model in, 6:2959–2961, 6:2960 (fig.)
 - urban heat island effect and, 3:1336
 - urban land use regulation and, 4:1727
 - urban population densities and, 5:2239–2240
- Urban metabolism, 6:2963–2967**
 - environmental impacts of cities and, 2:940, 2:941
 - factors influencing, 6:2966
 - Hong Kong, 6:2964 (table)
 - indicator of sustainability in, 6:2964–2966
 - linear and circular patterns of, 6:2965 (fig.)
- Urban planning and geography, 6:2967–2972**
 - cellular automata used in, 1:370, 1:371 (fig.)

- growth machine politics and, 3:1390
 information and communication technologies and, 2:539
 integration of, 6:2971
 multiple dimensions of, 6:2970 (fig.)
 new urbanism and, 4:2024–2027
 participatory planning and, 4:2126–2129
 planning in, 6:2970–2971
 population of major world cities and, 6:2969 (fig.)
 regeneration of urban landscapes and, 1:420, 1:422
 UN estimates, total world and urban population, 1990–2030, 6:2967 (table), 6:2968 (fig.)
 urban geography and, 6:2967–2970
 urban political ecology and, 1:425
 urban population densities and, 5:2239–2240
See also Architecture and geography
Urban policy, 6:2972–2977
 developing world approaches to, 6:2976–2977
 growth machine politics and, 3:1390
 Keynesian influence on, 6:2973–2974
 law geographies and, 4:1766
 national differences in, 6:2972–2973
 neoliberal influence on, 6:2974–2976, 6:2976
 public housing and, 5:2303–2304
Urban solid waste management, 6:2978–2981
 environmental impacts of, 2:941–942
 facilities of, 6:2980
 informal sector in, 6:2979–2980
 landfills and, 4:1684–1686
 locally unwanted land uses (LULUs) and, 4:1792
 policy tools of, 6:2980–2981
 recycling of municipal solid waste and, 5:2372–2375
 waste generation and composition in, 6:2978–2979
 waste hierarchy and integrated waste management in, 6:2979
 waste incineration and, 6:3048–3049
Urban spatial structure, 6:2981–2987
 automobility and, 1:172–175
 Brian Berry's work and, 1:193
 central business districts (CBDs) and, 1:379–380
 Chicago School models of, 6:2985 (fig.)
Cities and Complexity (Batty) and, 1:187
 concentric zone model of, 6:2984, 6:2985 (fig.)
 diversity, spatial specialization, and urban futures of, 6:2986–2987
 economic functions in, 6:2981–2982
 environmental settings impact in, 6:2982–2983
 filtering process and, 3:1110–1111
 gentrification and, 3:1203–1208
 ghettos and, 3:1275–1277
 Homer Hoyt's work and, 3:1448–1450
 information and communication technologies and, 2:539
 intra-urban spatial structure models of, 6:2983–2986
 metropolitan areas and, 4:1886–1888
 multiple-nuclei model of, 6:2985 (fig.), 6:2986
 new urbanism and, 4:2024–2027
 patterns of interurban spatial structure and, 6:2981–2983
 patterns of intra-urban spatial structure and, 6:2983
 population sizes of Eastern U.S. cities, 2000 and, 6:2982 (fig.)
 regeneration of urban landscapes and, 1:420, 1:422
 sector model of, 6:2984–2986, 6:2985 (fig.)
 urbanization in the United States and, 6:2983
Urban Modeling (Batty) and, 1:187
 urban population densities and, 5:2239–2240
Urban sprawl, 6:2987–2990
 automobility and, 1:172–175
 central business districts (CBDs) and, 1:379–380
 commuting and, 2:553–555
 counterurbanization and, 2:596–597
 exurbs and, 2:1074–1076
 Jean Gottmann's work in, 3:1355–1357
 greenbelts and, 3:1363–1367
 megapolis (Gottmann) and, 3:1355–1356
 metropolitan areas and, 4:1886–1888
 monocentric model of urban form and, 5:2236–2237
 new urbanism and, 4:2024–2027
 in San Gabriel mountains, Los Angeles County, California, 6:2989 (photo)
 San Jose, California, 6:2988 (photo)
 smart growth and, 5:2550–2551
Urban storm water management, 6:2990–2993
 best management approaches to, 6:2991
 combined sewer overflow (CSO) and, 6:2991
 current approaches of, 6:2991–2992
 in developing countries, 6:2992
 drains in Pierene, Turkey, 6:2991 (photo)
 early examples of, 6:2990
 failure factors in, 6:2990
 flood risk management and, 6:2990
 green roof example of, 6:2991–2992, 6:2993 (photo)
 integrated approach to, 6:2992–2993
 unpredictability of surface water flows and, 6:2990
 varying precipitation levels factor in, 6:2990–2991
Urban sustainability, 6:2993–2997
 agenda in, 6:2993–2994
 practice of, 6:2995
 research perspective on, 6:2996–2997
 U.S. Postal Service green roof, New York City, 6:2995 (photo)
Urban underclass, 6:2997–2999
 culture of poverty and, 6:2998
 definition of, 6:2997
 ghettos and, 3:1275–1277
 David Harvey and, 6:2998
 increase in, 6:2997–2998
 informal economy and, 3:1590–1592
 level and intensity issues, 6:2998
 Gunnar Myrdal and, 6:2997
 neoliberalization and globalization causes of, 6:2998
 as neutral descriptor, 6:2997
 racial and class associations of, 6:2997
 service jobs factor and, 6:2997–2998
 as stigmatization term, 6:2997
 term controversy and, 6:2997
 underclass behavior and, 6:2998
 welfare system dysfunction and, 6:2998
 William Julius Wilson and, 6:2997
Urban water supply, 6:2999–3002
 contemporary political economies of water and, 6:3001–3002
 environmental impacts of, 2:942
 public water services and, 5:2315–2319
 technology, engineering, and urbanization of, 6:2999–3000
 water delivery organization in, 6:3000–3001
See also Groundwater
 Ulrich, Roger, 4:1716
 Uruguay, economically active females in, 3:1190 (table)
Usability of geospatial information, 6:3002–3004
 legal aspects of geospatial information and, 4:1770–1772
 metadata and, 4:1885
See also Geospatial industry; Geospatial semantic web; Legal aspects of geospatial information; Privacy and security of geospatial information
 U.S. Board of Geographic Names, Geographic Names Information System (GNIS) digital gazetteer and, 3:1185

- USDA. *See* U.S. Department of Agriculture (USDA)
- U.S. Department of Agriculture (USDA)
- agricultural biotechnology regulated by, 1:34
 - agricultural land protected by, 1:42–43
 - cropland and forestland shifts, 1:37 (fig.)
 - developed land increases and, 1:42 (fig.)
 - Economic Research Service of, 1:37–38 (figs., table)
 - Natural Resources Conservation Service (NRCS) and, 3:1303, 3:1303 (photo)
 - soil survey digitization and, 3:1303, 3:1303 (photo)
- U.S. Department of Transportation, 3:1312
- U.S. Environmental Protection Agency (EPA). *See* Environmental Protection Agency (EPA)
- U.S. General Accounting Office, 2:986
- USGS. *See* United States Geological Survey (USGS)
- USSR. *See* Russia; Soviet Union
- Utah
- Bingham Canyon copper mine and, 4:2086
 - fluvial erosion, Canyonlands National Park, 4:1691
 - Great Salt Lake and Bonneville Salt Flats in, 3:1549
 - Lake Bonneville, Bonneville Salt Flats in, 1:186
 - normal fault, Basin and Range Province in, 3:1086
 - Promontory Point, Union Pacific and Central Pacific lines and, 5:2358
- Uzbekistan
- Collective Security Treaty Organization (CSTO) membership of, 2:536
 - Commonwealth of Independent States (CIS) membership of, 2:536 (table)
 - economically active females in, 3:1190 (table)
 - GUAM Organization for Democracy and Economic Development co-founded by, 2:538
 - HIV/AIDS in, 3:1438
- Vagueness in spatial data, 6:3005–3007**
- core and boundary problem in, 6:3005
 - fuzzy minimum bounding rectangle (FMBR) and, 6:3006
 - fuzzy sets and, 6:3005
 - geometrical orientation relationships and, 6:3006
 - indiscernibility relation and, 6:3006–3007
 - spatial database definition and, 6:3005
 - spatially related properties and, 6:3006
 - spatial region descriptions and, 6:3005
 - spatial relationships and, 6:3006–3007
 - theory of rough sets and, 6:3006–3007
 - topological relationships and, 6:3006
 - uncertainty and, 6:3005
- Van Agtmael, Antoine, 2:890
- Vance, James, 6:3007–3008**
- academic career of, 6:3007
 - central place theory and, 6:3008
 - “the city of the realms” spatial model of, 6:3008
 - geography theory contributions of, 6:3007
 - mercantile model of, 6:3008
 - textbooks written by, 6:3007
 - urban, historical, and transportation work of, 6:3007–3008
- Vandermeer, John, 1:54
- Varenius, 6:3008–3009**
- chorology and, 1:404, 3:1461–1462
 - Geographia Generalis* written by, 1:404, 3:1461–1462, 4:2179, 5:2387
 - geography subdivisions views of, 4:2179
 - physical geography term and, 4:2179
 - specific *vs.* general geography and, 3:1462, 4:2179, 5:2387
- Varnes, D. J., 4:1720
- Vectorization, 6:3009–3010**
- definition of, 6:3009
 - GIS software programs and, 6:3009
 - line modeling, spaghetti modeling and, 6:3009
 - raster data processed using, 6:3009–3010
 - terms related to, 6:3009
 - vectorization terms and, 6:3009
- Venables, Anthony, 5:2395
- Venezuela
- economically active females in, 3:1190 (table)
 - oil sources in, 4:2163
 - OPEC membership of, 4:2099, 4:2100 (fig.)
 - tropical deciduous forest in, 1:231
 - tropical rain forest of, 1:234
 - tropical savanna in, 1:239, 1:241
 - U.S. foreign aid to, 3:1151
- Venturi, Robert, 5:2264
- Vernacular landscapes as expressions of environmental ideas, 6:3010–3012**
- examples of, 6:3011–3012
 - landscape architecture and, 4:1698–1701
 - landscape interpretation and, 4:1713–1715
 - tulip field, typical Dutch setting and, 6:3011 (photo)
- Vernon, Raymond, 3:1154, 5:2296
- Via Campesina (International Farmers’ Movement), 6:3013–3014**
- agrarian reform activism of, 6:3014
 - alternatives developed by, 6:3014
 - dramatic anticorporate actions of, 6:3013
 - GM campaign of, 6:3013
 - human rights campaigns of, 6:3014
 - International Federation of Agricultural Producers (IFAP) and, 6:3013
 - issues addressed by, 6:3013
 - as land reform example, 4:1695
 - Movimento Sem Terra (MST) and, 4:1948
 - nongovernmental organizations and, 6:3013
 - peasant movements and, 6:3013
 - rural social movements and, 6:3013
 - transnational regional agrarian coalitions and, 6:3013
- Victoria Falls, Africa, 2:1057
- Vidal de la Blache, Paul, 6:3014–3015**
- chorology work of, 1:404, 3:1465
 - cultural geography work of, 1:404, 2:636, 3:1465, 3:1476, 5:2387, 5:2561
 - cultural landscape work of, 2:640, 2:641, 3:1403, 3:1465, 3:1476, 5:2387
 - Henry Clifford Darby influenced by, 2:664
 - environmental determinism views of, 1:404, 3:1464, 5:2387
 - environmental possibilism and, 3:1464, 5:2387
 - as father of French Geography, 3:1465
 - Lucien Febvre and, 3:1090, 3:1465
 - French Annales School of history and, 1:79–80, 3:1465
 - Jean Gottmann and, 3:1355
 - Alfred Hettner influenced by, 3:1423, 3:1465
 - human ecology in geography work of, 3:1458
 - John Brinkerhoff Jackson influenced by, 4:1641
 - natural and human landscapes as inseparable view of, 2:640, 4:1989, 5:2387
 - organic analogies of the Earth views of, 2:667
 - Élisée Reclus and, 5:2372
 - society and nature as focus of geographic study and, 2:640
 - spatial theory work of, 3:1355
- Video games, geography and, 6:3015–3016**
- controversy, 6:3016
 - early games and, 6:3016
 - video game industry geography and, 6:3016
 - Web-based games and, 6:3016
 - “world-hood” or “spatiality” features of, 6:3015
 - World War II flight simulators origin of, 6:3016

- Vietnam
 anticolonialism in, 1:94
 APEC membership of, 1:121
 ASEAN membership of, 1:128 (table), 1:129 (table)
 Cambodian incursion by, 1:130
 clothing exports from, 6:2186 (fig.)
 Cold War and, 1:504, 1:505
 collectivized farming in, 2:543
 COMECON membership of, 2:593 (table)
 domino theory and, 2:787, 3:1224
 economically active females in, 3:1190 (table)
 economic restructuring in, 5:2460
 French colonization of, 1:515, 1:516
 guerrilla conflicts in, 2:692
 HIV/AIDS in, 3:1438
 independence of, 1:517
 Japanese electronics industry in, 2:885–886
 marine aquaculture in, 4:1854, 4:1854 (fig.)
 peasant farmer carrying straw, Hoi An, 4:2138 (photo)
 textile exports from, 6:2816 (fig.)
- Viewshed analysis, 6:3016–3018**
 calculation and analysis techniques and, 6:3017–3018
 definition of, 6:3016
 as form of geographical analysis, 6:3016–3017
 raster-based GIS operation and, 6:3017
 sample of, 6:3017 (fig.)
 structure of calculated viewsheds and, 6:3017–3018
 visibility analysis and, 6:3016
- Viking exploration, 2:1051–1053, 2:1052 (fig.)
- Virgil, 5:2584
- Virilio, Paul, 6:3018–3019**
 culture of speed and, 6:3018
 geography as product of warfare views of, 6:3018
 military technology and, 6:3018
 postmodern capitalism, time-space compression and, 6:3019
 social and spatial change theory and, 6:3018
 state as “means of destruction” and, 6:3018
 telecommunications and, 6:3018–3019
 tyranny of constant speed views of, 6:3019
- Virtual and immersive environments, 6:3019–3021**
 authenticity of virtual worlds and, 6:3019–3020
 cyberspace and, 2:646–648
 examples of, 6:3019, 6:3020
 Google Earth and, 3:1352–1355
 massively multiplayer online role-playing games and, 6:3020
 meaning of geography in, 6:3021
Second Life example of, 6:3019, 6:3020–3021
 universities and, 6:3021
 virtual environment definition and, 6:3019
 virtual worlds and, 6:3020–3021
- Virtual geographies, 6:3022–3023**
 collaborative virtual worlds and, 6:3022
 communication technology advances and, 6:3022
 computer and video games and, 6:3022
 cybergeography term and, 6:3022
 cyberspace term and, 6:3022
 definition of, 6:3022
 digital landscapes and, 6:3022
 individual Web sites and, 6:3022
 information and communication technologies (ICTs) and, 2:539–540
 networked virtual geographies and, 6:3022
 new notions of space and place, 6:3022
Second Life example of, 6:3022
 sense of immersion of, 6:3022
- virtual term and, 2:540
- Web-mapping applications and, 6:3022–3023
- Virtual globes, 6:3023–3025**
 client-server architecture and, 1:426
 examples of, 6:3023–3024
 geobrowsers and, 6:3023
 geospatial content in, 6:3024–3025
 global representation of data sets type of, 6:3024
 Google Earth and, 3:1352–1355, 6:3024
 history and popularization of, 6:3023–3024
 mirror of the real world type of, 6:3024
 NASA World Wind and, 6:3024
Snow Crash and, 6:3023
 types of, 6:3024
 Virtual Reality Modeling Language (VRML) and, 6:3023
 WebEarth open-source VRML application and, 6:3023
See also Google Earth
- Vision and geography, 6:3025–3027**
 art and geography, 1:118–120
 blindness and geography and, 1:286–287
 Dennis Cosgrove and, 6:3025
 Michel Foucault and, 6:3026
 gaze and, 6:3026
 iconography and, 6:3025–3026
 Lacanian film theory and, 6:3026
 ontology and, 6:3025
 photography and, 4:2176–2178
 poststructuralist theory and, 6:3026
 Gillian Rose and, 5:2484–2485, 6:3026
 social construction of landscape and, 6:3025
 technology advances and, 6:3026
- Vogel, Hermann Carl, 4:2113
- Volcanic eruptions as risk and hazard, 6:3027–3029**
 assessment of, 6:3027
 atmospheric hazards and, 6:3027–3028
 hazard maps of volcanoes and, 6:3027
 holistic volcano assessments and, 6:3028
 Mount Pinatubo’s eruption, Philippines, 1991 and, 6:3028 (photo)
 sulfur dioxide hazardous material and, 6:3028
 topography of areas near volcanoes and, 6:3027
 volcanoes’ functions and, 6:3027
 volcanoes near large cities and, 6:3028
See also Volcanoes
- Volcanoes, 6:3029–3033**
 aa lavas and, 6:3029
 aseismic creep and, 2:605
 barrier reefs and, 2:583
 Big Island of Hawai’i, 4:1688
 bummocks and, 6:3029
 caldera, 6:3030–3031
 carbon cycle and, 1:327, 1:328
 cinder cones, 6:3029
 climate change factor of, 1:461
 composite volcanoes and, 4:1687
 fall deposits and, 6:3029
 fringing reefs and, 2:583
 global sea-level rise and, 3:1345
 Great Rift Valley, East Africa, 6:3029
 Hawaiian island volcanic chain and, 4:1688–1689
 hazards of, 6:3032
 hot spot volcanoes, 4:1687–1688
 igneous rocks classification and, 6:3029
 landforms formed by, 4:1687–1689
 lava domes, 6:3029
 Long Valley Caldera, California, 4:1688

- low islands and atoll structures and, 3:1635–1638, 3:1636
 (photo), 3:1637 (photo)
 magma and, 6:3029
 magma intrusion and, 6:3029
 mass wasting processes on Hawaiian Islands and, 4:1689
 monitoring networks and, 6:3032
 morphology of, 6:3030–3032
 natural resources from, 6:3032
 Pacific Ring of Fire and, 3:1273
 pahoehoe morphological features and, 6:3029
 paleoclimatology and, 1:471–472
 plate tectonics and, 5:2195–2199
 rift zone volcanism and, 4:1688
 scenic landscapes of, 6:3032
 shield volcanoes, 6:3029–3030
 solar radiation affected by, 1:163
 stratovolcanoes, 6:3030
 subtle volcanoes, 4:1688
 teothermal features and, 3:1273
 tephra fragmented material and, 6:3029
 types of eruptions and, 6:3029–3030
 Volcanic Explosivity Index (VEI) and, 6:3029
 volcanism and, 6:3029
 wasting processes and, 4:1689
 Yellowstone caldera and, 4:1688 (fig.)
See also Volcanic eruptions as risk and hazard
- Volcanoes:** specific eruptions
 El Chichon (1982), 3:1345
 Mt. Etna, 2:605
 Mt. Krakatau (1883), 1:163, 3:1345
 Mt. Mazama (6800 BC), 6:3032
 Mt. Pinatubo (1991), 1:163, 3:1345
 Mt. St. Helens (1980), 1:163, 4:1687–1688, 6:3031 (photo)
 Mt. Tambora (1815), 1:461, 3:1345
 Voltaire, 4:1928
 Von Bertalanffy, Ludwig
 general systems theory of, 1:403, 2:560
 Vonder Haar, T. H., 1:160
 von Herder, Johann Gottfried, 3:1143
 von Thünen, Johann, 3:1144, 3:1628, 4:1728, 5:2433
See also Thünen model
- Voronoi diagrams,** 6:3033–3035
 applications of, 6:3034–3035, 6:3034 (fig.), 6:3035 (fig.)
 cellular automata use and, 1:370
 coordinate transformations and, 2:580–581
 Delaunay triangulation and, 6:3033, 6:3033 (fig.), 6:3034, 6:3034 (figs.)
Encyclopedia of Voronoi Diagrams (Okabe) and, 4:2076
 example of, 6:3033 (fig.)
 map generalization and, 4:1837, 4:1839, 4:1840 (fig.)
 Atsuyuki Okabe and, 4:2076–2077
 properties of, 6:3033–3034
- Vulnerability, risks, and hazards,** 6:3036–3039
 differential vulnerability and, 2:742–744
 gender and environmental hazards, 3:1186–1188
 hazards and, 6:3036
 hazards and vulnerabilities of megacities and, 6:3038–3039
 hazards and vulnerabilities of place, 6:3038–3039
 landslides and, 4:1720–1723
 lightning and, 4:1779–1783
 natural and technological hazards and, 6:3036–3037
 natural hazards and risk analysis and, 4:1983–1989
 remote sensing in disaster response and, 5:2424–2428
 resilience and, 6:3038
 risks and, 6:3037
- social vulnerability and, 6:3038
 vulnerability and, 6:3038
 wildfires, Southern California, 2007 and, 6:2037 (photo)
See also Disaster preparedness
- Wackernagel, Mathis, 2:828
 Walby, Sylvia, 4:2136
 Wald, L., 3:1533
 Waldorf, Brigitte, 5:2393
Waldseemüller, Martin, 6:3041–3043
 American on map of, 6:3041, 6:3042 (fig.)
 Carta Marina of, 6:3043
 human geography work of, 3:1461
 Ptolemy's maps and, 6:3041
 Matthias Ringmann and, 6:3041
 “Terra Nova” term and, 6:3043
 Amerigo Vespucci's discoveries and, 6:3041
- Wales**
 coal energy source in, 3:1582
 solid waste collection in, 5:2373
- Walker, Gilbert, Sir, 2:887, 2:888
Walker, Richard, 6:3043–3044
 American suburbanization work of, 6:3043
 books written by, 6:3043–3044
 economic geography work of, 6:3043–3044
 David Harvey and, 6:3043
 historic development of California work of, 6:3044
 Marxist geographies and, 3:1467, 6:3043
 urban division of labor work of, 4:1863
- Wallace, Alfred Russell, 1:199
 latitudinal biodiversity gradient explained by, 1:198
 Malay Archipelago and, 1:106, 1:107
 social Darwinism and, 5:2211
 social justice advocacy of, 5:2211
 theory of evolution via natural selection and, 1:199, 2:916, 5:2211
- Wallerstein, Immanuel, 3:1419
 Walsh, Edmund, Fr., 3:1250
- War, geography of,** 6:3044–3048
 analytical approaches to, 6:3046–3047
 environmental impacts of war and, 2:955–957
 environmental matrix and, 6:3045
 environmental matrix of, 6:3045, 6:3046 (fig.)
 evolution of, 6:3047–3048
 framework defined for, 6:3044
 genocide geographies and, 3:1199–1202
 military geography and, 4:1896–1897
 military operations environment and, 6:3044–3045
 military spending and, 4:1898–1905
 scales of analysis in, 6:3045–3046
- Warren, D. Michael, 3:1557
 Warren, Stephen, 1:479
- Washington, D.C.
 carbon footprint of, 3:1377–1378
 megapolis element of, 3:1355–1356
- Washington (state)
 Easton Glacier in, 3:1331 (photo)
 erosion in wheat field, 5:2584 (photo)
 fumarole, Spirit Lake, Kamania County, 3:1271 (photo)
 Lyman Glacier in, 3:1329 (photo)
 mass wasting, Mount Rainier National Park, 4:1870 (photo)
 Mt. St. Helens (1980) eruption and, 1:163, 4:1687–1688, 6:3031 (photo)
 nuclear weapons site in, 5:2469
 USGS mudflow damage measurement, Upper Muddy River, Skamania County, 6:2912 (photo)

Waste incineration, 6:3048–3049

- anti-incinerator arguments and, 6:3049
- benefits of, 6:3048
- definition of, 6:3048
- first incinerator and, 6:3048
- first waste-to-energy plant and, 6:3048
- incinerator technology advances and, 6:3048
- landfills and, 4:1684–1686
- “locally unwanted land uses” (LULUs) and, 6:3049
- “not in anyone’s backyard” (NIABY) and, 6:3049
- “not in my backyard” (NIMBY) and, 6:3049
- recycling of municipal solid waste and, 5:2372–2375
- social and environmental justice issues, 6:3049

Wastewater management, 6:3049–3052

- brief history of, 6:3050–3051
- diagram of, 6:3051 (fig.)
- flocculation and, 3:1127–1128
- flow of, 3:1138
- modern approaches to, 6:3051
- wastewater constituents and, 6:3050
- wastewater sources and, 6:3050
- wastewater treatment and, 6:3052

Water degradation, 6:3052–3056

- biological pollution and, 6:3054
- chemical water pollution and, 6:3053–3054
- eutrophication and, 6:3054
- indicators and assessment of, 6:3055
- manufacturing and, 2:945
- physical factors in, 6:3054
- plastic and trash pollution, Bicaz Lake, Romania, 6:3053 (photo)
- prevention measures of, 6:3055
- sources, distribution, and freshwater uses and, 6:3052–3053
- thermal pollution and, 6:3055
- water crises adaptation measures and, 1:11
- water stress and, 6:3053–3055
- See also* **Water management and treatment; Water needs; Water pollution; Watershed management; Watershed yield; Water supply siting and management**

Water management and treatment, 6:3056–3062

- background of, 6:3056
- drylands environmental management and, 2:971–973
- environmental markets of, 4:2009
- future problems in, 6:3060
- GIS in water management and, 3:1316–1318
- hydrology and, 3:1513–1518
- potable water treatment process and, 6:3060 (fig.)
- potential water availability, 2007, 2050, 6:3059 (fig.)
- renewable water resources and availability by continents and, 6:3057 (table)
- surface water diversion for agricultural needs and, 2:939
- timeline of international efforts in, 6:3060–3061
- total renewable freshwater resources per capita and, 6:3058 (fig.)
- water crises adaptation measures and, 1:11
- water needs and, 6:3056–3058
- water resources and, 6:3056
- water treatment and, 6:3058–3060
- See also* **Water degradation; Water needs; Water pollution; Watershed management; Watershed yield; Water supply siting and management**

Water needs, 6:3062–3066

- agriculture and, 6:3064
- biota needs and, 1:258
- cities, 2:943
- clean water rights case sample of, 2:995–997, 2:996 (table), 2:997 (fig.)

- drylands environmental management and, 2:971–973
- Earth’s ecosystems and, 6:3062–3063
- energy and, 6:3064
- free trade agreements on local governance of water and, 2:995
- human right to water, legal contributions supporting, 2:995 (table)
- lack of reliable information on use and, 6:3064–3065
- photosynthesis process and, 1:258
- public water services and, 5:2315–2319
- society and, 6:3064
- surface water diversion for agricultural needs and, 2:939
- water crises adaptation measures and, 1:11
- water quality and, 6:3063–3064
- water rate conceptual model with incline block rates and, 2:995, 2:997 (fig.)
- water use and, 6:3063
- wetlands at land-sea margin and, 6:3064
- World Commission on Dams and, 2:995

See also **Groundwater; Water degradation; Water management and treatment; Water pollution; Watershed management; Watershed yield; Water supply siting and management**

Water pollution, 6:3066–3070

- agrochemical pollution and, 1:51–53, 2:938–939, 3:1335, 3:1387
- anthropogenic sources of, 3:1387–1388
- anticlockwise loop and, 6:3069, 6:3070 (fig.)
- chlorinated hydrocarbons (CHCs) and, 1:396–400
- Clean Water Act and, 2:925, 2:966, 5:2476
- groundwater pollution and, 3:1387–1388
- hysteresis analysis and, 6:3069
- hysteresis loop and, 6:3069
- manufacturing and, 2:945
- National Primary and Secondary Drinking Water Regulations and, 2:984
- nonpoint sources of pollution and, 4:2039–2040
- oil spills and, 4:2073–2076
- sediment-rating curve and, 6:3068–3069, 6:3068 (fig.)
- urban polluting factors and, 2:943, 3:1335
- water crises adaptation measures and, 1:11
- water filtration and, 3:1115
- See also* **Coastal dead zones; Coastal zone and marine pollution; Water degradation; Water management and treatment; Water needs; Watershed management; Watershed yield; Water supply siting and management**

Watershed management, 6:3070–3074

- ecosheds and, 2:857
- flood protection and, 6:3074
- GIS in water management and, 3:1316–1318
- good governance and, 6:3074
- indigenous methods of, 3:1575
- indigenous water management and, 3:1573–1576
- international watershed management and, 3:1618–1620
- minimum flows and levels in, 6:3072–3073
- prior appropriation method and, 6:3072
- right to use doctrine and, 6:3072
- Union Grove Lake, Tama County, Iowa, 6:3073 (photo)
- U.S. philosophies of, 6:3072–3073
- water quality and, 6:3073
- water quantity and, 6:3071
- See also* **Water degradation; Water management and treatment; Water needs; Water pollution; Watershed yield; Water supply siting and management**

Watershed yield, 6:3074–3076

- factors affecting, 6:3075
- measurement importance and, 6:3074–3075
- regional context of, 6:3075–3076

- sediment yield definition and, 6:3075
 soil erosion models and, 6:3075
 spatial variability factor in, 6:3075–3076
 watershed definition and, 6:3075
 watershed size factor in, 6:3075
See also Groundwater; Water degradation; Water management and treatment; Water needs; Water pollution; Watershed management; Water supply siting and management
- Water supply siting and management, 6:3076–3078**
 GIS in water management and, 3:1316–1318
 global environmental change and, 3:1335–1336
 irrigation effects on, 3:1335
 public water services and, 5:2315–2319
 spillway at Broken Bow Reservoir, Mountain Fork River, McCurtain County, Oklahoma, 6:3077 (photo)
 water crises adaptation measures and, 1:11
See also Water degradation; Water management and treatment; Water needs; Water pollution; Watershed management; Watershed yield
- Watt-Cloutier, Sheila, 3:1525
- Watts, Michael, 6:3078–3079**
 African families work of, 4:1863
 contract farming and, 4:2139
 environmental entitlements work of, 2:924
 environmental imaginaries and, 2:933, 4:1863
 Marxist geography work of, 4:1863, 4:1996, 4:2139
 nature-society theory and, 4:1996
 Richard Peet and, 4:2144
 political ecology work of, 2:622, 4:1996, 5:2213
 spatial imaginaries and, 2:932
- Wæver, Ole, 2:1037
- Wayfinding, 6:3079–3081**
 blindness and geography and, 1:286–287
 cognitive-conceptual nature of, 6:3080
 definition of, 6:3079
 interactions in, 6:3080 (fig.)
 knowledge of one's environment element of, 6:3080, 6:3081
 landmarks research and, 6:3080
 location and navigation *vs.*, 6:3080
 mental maps and, 4:1881–1883
 multimodal environment features of, 6:3081
 route finding and planning and, 6:3080
 strategies of, 6:3081
- WCED. *See* World Commission on Environment and Development (WCED)
- Weather and climate controls, 6:3082–3085**
 clouds and, 1:476–480
 localized controls in, 6:3084
 major controls in, 6:3082–3084
 oceanic circulation and, 4:2058–2064
 seasonal changes on climate and, 6:3082
See also Albedo
- Weber, Alfred, 6:3085–3087**
 corporate location model of, 6:3085, 6:3085 (fig.)
 impact of, 6:3085
 location theory and, 3:1628, 4:1798, 5:2393
 model criticism and, 6:3086
 transportation costs and, 6:3085–3086, 6:3086 (fig.)
- Weber, Max
 capitalism origins views of, 4:1931–1932
 classic social theory of, 3:1277
 criticism of, 4:1932
 culture definition and, 2:634
 modernity and commodification relationship and, 4:1936
 Protestant work ethic, 2:1028–1029, 4:1931
 qualitative methodology and, 5:2323
- rationalization views of, 4:1931–1932
 social sciences *vs.* natural sciences and, 5:2513
- Web geoprocessing workflows, 6:3087–3089**
 architectural patterns for service chains and, 6:3088
 description of, 6:3088
 flexibility benefit of, 6:3088
 geoprocessing definition and, 6:3087
 potential of, 6:3088
 spatial data infrastructures (SDIs) and, 6:3086
 Web-based workflows definition and, 6:3087–3088
 Web service orchestration and, 6:3088
 workflow definition and, 6:3087
- Web service architectures for GIS, 6:3089–3092**
 business models for GIS and, 1:306–308
 data compression methods and, 2:679–680
 descriptions of, 6:3090–3092
 diagram of, 6:3091 (fig.)
 service-oriented architecture and, 6:3089–3090
See also GIS software; GIS Web services
- Weeks, John, 5:2247
- Wegener, Alfred, 4:1665
- Weigert, Hans, 3:1250
- Weimer, Arthur, 3:1449
- Weiner, Daniel, 5:2304
- West Africa**
 agrobiodiversity in, 1:50
 bush fallow farming in, 1:302
 carbon dioxide disaster, Cameroon, 1:68–69
 drought, famine in, 2:622, 2:727, 4:1996
 drug trafficking and, 2:798
 El Niño-Southern Oscillation (ENSO) and, 2:889
 food security in, 4:1996
 forest fragmentation in, 3:1159
 French colonies in, 1:509
 groundwater usage in, 3:1386
 HIV/AIDS in, 3:1438
 HIV-2 in, 3:1436
 Ibn Battuta exploration of, 2:1054, 3:1519
 indigenous agriculture in, 3:1556–1557
 indigenous cartographies in, 3:1562
 Niger famine, 2005 and, 4:1986
 nomadic Tuareg herders and camels, Sahara Desert, Mali, 4:2034 (photo)
 peanut farming in, 1:61 (photo)
 population growth of, 5:2233 (fig.)
 Sahel drought and, 2:717–718, 2:972, 2:989
 sewage entering coastal zones of, 1:501
 timber from, 1:238
 tropical rain forest of, 1:234
 tropical savanna climate in, 1:455
 tropical savanna in, 1:240
- Western Europe**
 political map of, 6:3160
- Western Hemisphere**
 AGS library maps of, 1:71
 mining frontier in, 4:1911
- Wetlands, 6:3092–3094**
 characteristics of, 6:3092–3093
 definition of, 6:3092
 gleying process and, 6:3092
 hydric soils and, 6:3093
 hydrophytic vegetation and, 6:3093–3094
 interior wetland classifications and, 6:3092
 marine aquaculture and, 4:1853–1855
 mottles and, 6:3092
 muck and peat soil of, 6:3092

- pothole wetland, South Dakota, 6:3093 (photo)
 saltwater interior wetlands and, 6:3092
 topography and water salinity classification of, 6:3092
 wetland hydrology and, 6:3092–3093
- Whatmore, Sarah
 animal geographies work of, 2:831, 2:832
Hybrid Geographies, 2:649–650
 nature-society theory and, 4:1993, 4:1996
- Whitbeck, Ray, 2:848–849
- White, Denis, 1:408
- White, Gilbert, 6:3094–3095**
 Harlan Barrows and, 6:3094
 domestic water use in East Africa, model of, 6:3095
 energy and human ecology work of, 2:894
 as father of floodplain management, 6:3094
 government service work of, 6:3095
 Robert Kates influenced by, 4:1654
 natural hazards paradigm of, 6:3095
 practical applied research views of, 6:3094
 service work of, 6:3095
 water policy issues and, 5:2307
- White, Langdon, 4:1873
- White, Lynn, 2:925, 5:2409
- White, S. H., 5:2609
- “White man’s burden,” 2:1021, 2:1027
- Whiteness, 6:3096–3097**
 color blindness myth and, 6:3096
 discourses, 6:3096
 environmental justice/injustice and, 2:962, 6:3096
 ethnocentrism and, 2:1027
 institutional racism and, 6:3096
 modern racial whiteness construct and, 6:3096
 national identities and, 6:3096
 racialized landscapes and, 6:3096
 terms associated with, 6:3096
 “white flight” and, 1:420, 2:962, 2:986
 white privilege and, 2:962, 6:3096
- Whittlesey, Derwent, 6:3097–3098**
 academic career of, 6:3097
 Isaiah Bowman and, 6:3097–3098
 Harvard’s geology department closing and, 6:3097
 historical geography work of, 3:1429
 sequent occupation work of, 5:2534–2535, 6:3097
 service work of, 6:3097
 theory of sequent occupation and, 3:1429, 4:2111
- WHO. *See* World Health Organization (WHO)
- Whorf, Benjamin, 4:1754
- Wikipedia, 3:1257
- Wilderness, 6:3098–3099**
 Arctic National Wildlife Refuge, 6:3093 (photo)
 definition of, 6:3098
 parks and reserves and, 4:2117–2120
 preservationists and, 6:3098
 protected lands and, 6:3098
 settlement era and, 6:3098
 social constructed nature of, 6:3098–3099
 as a therapeutic space, 6:3098
- Wildfires: risk and hazard, 6:3099–3102**
 at-risk term and, 6:3100
 fire behavior models and, 6:3100, 6:3101 (fig.)
 hazard term and, 6:3100
 pyrogeography and, 5:2319–2322
 risk analysis and, 6:3100
 risk assessment map for Whiskeytown Fire, Redding, California, 2008 and, 6:3101 (fig.)
- terrain factors in, 6:3100
 threat term and, 6:3099, 6:3100
 value of resources at risk and, 6:3100–3101
 vegetation or fuel factor in, 6:3100
 weather factors and, 6:3100
 wildfires as a spatial problem, 6:3099
- Wilhite, Donald, 2:787–788
- Wilkes, R., 5:2345
- Williams, Raymond, 1:118, 4:1787
 cultural geography work of, 3:1142
 fish farming research of, 2:1120
 “militant particularism,” 5:2574
 social construction of space work of, 5:2297, 5:2574
- Williamson, Hugh, 4:1642
- Wilson, Alan, 5:2393, 5:2395–2396
- Wilson, E. O., theory of island biogeography and, 1:199, 3:1635, 4:1696, 5:2672
- Wilson, Edward, 2:992
- Wilson, J., 2:1075
- Wilson, John, 6:3102–3103**
 academic career of, 6:3102–3103
 awards and honors received by, 6:3103
 books written by, 6:3103
 GIS work of, 6:3102
 journal work of, 6:3103
 service work of, 6:3103
 spatial analysis and environmental modeling work of, 6:3103
- Winchester, Simon, 4:1884
- Wind, 6:3103–3107**
 atmospheric circulation explanation of, 1:131–136
 chinook/foehn winds and, 1:394–395
 Coriolis force and, 2:586–587
 derechos and, 2:714–715
 differential heating and, 2:740–742
 formation of, 6:3104–3105
 Hadley cell model of, 3:1395–1397, 6:3105 (fig.)
 idealized global circulation and, 6:3105 (fig.)
 importance of, 6:3106–3107
 measurement of, 6:3106
 types of, 6:3105–3106
- Wind energy, 6:3108–3110**
 advantages of, 6:3108–3109
 chinook/foehn winds and, 1:394–395
 drawbacks in use of, 6:3109
 generating electricity from, 6:3108
 national energy policies and, 2:900
 natural phenomenon of, 6:3108
 wind turbines, Royd Moore, South Yorkshire, England, 6:3109
- Wind erosion, 6:3110–3115**
 abrasion forms from, 6:3114–3115
 abrasion process in, 6:3110–3111
 chinook/foehn winds and, 1:394–395
 deflation forms from, 6:3111–3114
 deflation process in, 6:3110
 dunes and, 2:800–803
 erosion processes of, 6:3110–3111
 hazards from, 6:3115
 landforms of, 6:3111–3115
 pan field, Western Australia, 6:3113 (photo)
 transport processes and, 6:3111
 trough blowouts, foredune system, Guadalupe, California, 6:3112 (photo)
 yardang field on Mars and, 6:3114 (photo)

- Wine, geography of, 6:3115–3117**
 ancient geographies and, 6:3115–3116
 books written about, 6:3117
 history and diffusion of wine grape and, 6:3115–3116
 physical variables in wine production and, 6:3116
 socioeconomic factors and, 6:3116
terrior concept and, 6:3116, 6:3117–3119
 vineyard, Constantia region, Cape Winelands, South Africa, 6:3118 (photo)
 vineyards, Chianti region, Tuscany, Italy, 6:3116 (photo)
 wine influence on environment and, 6:3117
 wine labels and, 6:3116
See also **Wine terrior**
- Wine terrior, 6:3117–3119**
 climate factors and, 6:3119
 definition of, 6:3117–3118
 importance of, 6:3118
 physical geography and wine growing effects on, 6:3118–3119
 soil factors and, 6:3119
 vineyard, Constantia region, Cape Winelands, South Africa, 6:3118 (photo)
 vineyard geography factors and, 6:3118–3119
See also **Wine, geography of**
- Winters, Harold, 4:1897
 Wirth, Louis, 3:1103, 4:1936
 Wisconsin
 Milwaukee brownfields in, 1:297 (photo)
 prairie restoration in, 5:2278
- Wise use movement, 6:3119–3120**
 ambiguity of, 6:3120
 antienvironmental and antifederal organizations features of, 6:3119
 decline of, 6:3120
 federal lobbying effort and, 6:3120
 Progressive-era conservation origins of, 6:3119
 property rights movement, 6:3120
 rural West location of, 6:3120
 social movements in global South and, 6:3120
- Wisner, Ben, 2:618
 Withers, Charles, 2:910, 2:911, 4:1789
- Wittfogel, Karl, 6:3120–3121**
 Asian civilization studied by, 6:3121
 Frankfurt School and, 2:617
 humanity's relationship with nature work of, 6:3120
 "hydraulic empires" theory of, 5:2215, 6:3121
Oriental Despotism written by, 5:2215
- Wittgenstein, Ludwig, 4:1754
 Wojcik, Dariusz, 3:1118
 Wolch, Jennifer, 2:831
 Wolf, Eric, 5:2212, 5:2711–2712
 Wolfram, S., 1:369
 Wolman, Leopold, 3:1128, 3:1130
- Wood, Denis, 6:3121–3122**
 critical cartography and, 6:3121–3122
 maps, mapping, and mapmaking processes focus of, 6:3121–3122
 maps as narrative texts and, 6:3121
 maps as sign systems and, 6:3121–3122
 politics embedded within maps and, 6:3121–3122
- Woodfuel, 6:3122–3124**
 for cooking, Maharashtra, India, 6:3123 (photo)
 in developing countries, 6:3122, 6:3123–3124
 global climate change and, 6:3122–3123
 limitations of, 6:3124
 sustainable development and, 6:3122–3123
- Woodward, David, 3:1402
 Woodward, Rachel, 4:1897
- World Bank, 6:3124–3126**
 antiglobalization issues and, 1:96
 colonial powers domination of, 5:2261
 demonstration against, West Berlin, 1988, 5:2443 (photo)
 ecotourism supported by, 2:871
 emerging markets and, 2:890
 Global Environment Facility (GEF) and, 6:2748
 globally diffuse network of, 3:1548
 Heavily Indebted Poor Countries initiative of, 2:690
 international environmental movements and, 3:1611
 International Monetary Fund (IMF) and, 3:1615–1618
 land reform policies of, 4:1695
 neocolonialism policies of, 4:2003
 neoliberal economic policies of, 5:2220, 5:2459, 6:2750, 6:3014
 neoliberal environmental policy and, 4:2008
 NIC export-led development and, 2:1065
 population growth estimates of, 5:2241
 poverty definitions of, 5:2274
 Poverty Reduction Strategy Papers and, 4:2014
 public-private partnerships supported by, 5:2312
 structural adjustment of economies role of, 5:2703
 Structural Adjustment Programs (SAPs) of, 2:1065, 4:1694, 4:2012
 supranational economic activity, glocalization and, 3:1347
World Development Report 1992 of, 2:1004
- World cities, 6:3126–3129**
 aviation and, 1:179–182
 critique of the concept, 6:3128–3129
 finance geographies and, 3:1115–1118
 historical development of term and, 6:3126–3128
 internal structure of, 6:3128–3129
 Los Angeles School of urban economy and, 4:1803–1805
 map of, 6:3127 (fig.)
 networking of, 6:3128
 primate cities and, 5:2290–2291
 telecommunication technology and, 6:2786
 urban telecommunications infrastructures and, 6:2788–2789
- World Commission on Environment and Development (WCED), 1:256, 2:835, 3:1604**
 environmental impact statements and, 2:938, 2:958
Our Common Future (Brundtland Report) environmental security publication of, 1:256, 2:998, 2:1003, 6:2747, 6:2748
 sustainable development, 2:870, 2:1003–1004, 5:2220, 6:2737–2738, 6:2747
- World Court, 6:3129–3131**
 accomplishments of, 6:3131
 early roots of, 6:3130
 functions of, 6:3130–3131
 International Court of Justice (ICJ) and, 6:3129
 judges and their terms and, 6:3130
 Peace Palace, The Hague, Netherlands, and, 6:3130 (photo)
 United Nations and, 6:3129
- World Economic Forum, 1:415
- World Health Organization (WHO), 6:3131–3132**
 carcinogen lists maintained by, 1:335
 disaster preparedness and response program of, 2:763
 Global Malaria Eradication Program of, 4:1817
 global public health initiatives function of, 6:3131
 primary health care contribution of, 6:3131
 standards of atmospheric particulates and, 1:151
 standards of pollutant thresholds and, 1:68
 United Nations creation of, 6:3131
- World maps
 adults and children living with HIV in 1007, 3:1437 (fig.)

- Afro-Asiatic languages, 4:1750 (fig.)
 angiosperm family richness, 1:260 (fig.)
 APEC members, 1:122 (fig.)
 Bantu or Niger-Kordofanian languages, 4:1752 (fig.)
 biodiversity hotspots, 1:200 (fig.)
 centers of plant domestication and agricultural origins, 2:785 (fig.)
 cholera outbreaks, 2006–2008, 1:402 (fig.)
 colonial empires prior to 1914, 1:509 (fig.)
 colonial migrations, 1500–1914, 3:1543 (fig.)
 continuous, discontinuous, sporadic, and isolated permafrost,
 Northern Hemisphere, 4:2155 (fig.)
 cryosphere, ice-based environment, 3:1523 (fig.)
 deserts, global distribution of, 1:430 (fig.)
 developing world, 2:725 (fig.)
 domestication of plants, 2:785 (fig.)
 ecoregion divisions of the world, 2:856 (fig.)
 Vasco da Gama's voyage routes, 3:1178 (fig.)
 GDP per capita, 2007, 3:1383 (fig.)
 geography of petroleum consumption, 4:2164 (fig.)
 global and world cities, 6:3127 (fig.)
 global patterns of precipitation change, 1:91 (fig.)
 global population density, 5:2252 (fig.)
 Good's Interrupted Homolosine projection, 3:1351, 3:1351 (fig.)
 historical map of the Old World, as Ptolemy knew it, 2:1056 (fig.)
 Human Development Index (HDI), 2:725 (fig.)
 Indo-European languages, 4:1750 (fig.)
 Indo-European languages, 4:1750 (fig.)
 installed capacity forecast for electricity production, 2010,
 3:1268 (fig.)
 Internet penetration, 2:749 (fig.)
 Köppen map of humid continental and subarctic climates, 1:440 (fig.)
 La Niña global precipitation and temperature anomalies
 (1988), 4:1756 (fig.)
 life expectancy by country (2008), 3:1410 (fig.)
 Magellan's circumnavigation of the globe, 4:1814 (fig.)
 major biomes, 1:212 (fig.)
 major lithospheric plates, plate boundaries, directions and rates
 of, 5:2196 (fig.)
 malaria transmission areas, 4:1818 (fig.)
 Malayo-Polynesian languages, 4:1753 (fig.)
 maritime traffic at fifty largest container ports, 5:2256 (fig.)
 Mercator projection map, 4:1843 (fig.), 4:1884 (fig.), 6:3168
 Mollweide projection map, 4:1844 (fig.), 6:3152–3153, 6:3169
 NATO membership, 2009, 4:2048 (fig.)
 newly industrializing countries (2008), 4:2022 (fig.)
 OECD members, 2008, 4:2097 (fig.)
 periglacial environments, Northern Hemisphere, 4:2146 (fig.)
 petroleum-producing countries and, 4:2163 (fig.)
 Plate Carrée projection map, 4:1846 (fig.)
 political map of, 6:3152–3153
 population living on less than \$1 per day, 5:2275 (fig.)
 population of major world cities, 6:2969 (fig.)
 pseudoconic projection based on Ptolemy's writings, 1:348 (fig.)
 Ptolemaic world map, 15th-century codex of Nicolaus
 Germanus, 5:2301 (fig.)
 Robinson projection map, 4:1845 (fig.)
 silver flows, 16th to 18th centuries, 1:513 (fig.)
 Sino-Tibetan languages, 4:1752 (fig.)
 Sinusoidal projection map, 4:1846 (fig.)
 submarine fiber-optic cables, 6:2784 (fig.)
 from *Theatrum Orbis Terrarum* (Ortelius, 1570), 4:2105 (fig.)
 time-space compression, 6:2841 (fig.)
 topographical map of the world and, 6:3166–3167
 total renewable freshwater resources per capita, 6:3058 (fig.)
 2003 earthquakes, 2:813 (fig.)
 Ural Altaic or Finno-Ugric languages, 4:1751 (fig.)
 Vineland map, 15th-century from 13th-century original, 2:1051,
 2:1052 (fig.), 2:1053
 by Martin Waldseemüller, 6:3042 (fig.)
 Winkel Tripel projection map, 4:1845 (fig.)
 world climate map based on Köppen-Geiger climate
 classification, 4:1667 (table)
 world development geography, 5:2244 (fig.)
 world electricity-generating capacity (2005), 3:1508 (fig.)
 world grasslands, 1:228 (fig.)
 world hydroelectricity installed capacity (2005), 3:1508 (fig.)
 world natural growth rates, 2007, 4:1982 (fig.)
 world population densities, 5:2239 (fig.)
 world's famine-prone regions, 3:1083 (fig.)
 world's international satellite earth stations, 5:2503 (fig.)
 See also World political maps
 World Meteorological Organization (WMO), 1:82, 1:462
 International Cloud Atlas published by, 1:476
 World Social Forum, 1:96, 1:414–415
 World Summit on Sustainable Development (WSSD), 6:3132–3133
 criticism of, 6:3132
 equity concerns, global economy issues and, 6:2750
 Millennium Goals and Agenda 21 evaluation by, 6:3132
 sustainability science and, 6:2738
 sustainable development focus of, 2:1005, 3:1102, 3:1604, 6:2738
 UN Committee on Sustainable Development and, 6:3132
 UN global earth summits and, 6:3132
 World-systems theory, 6:3133–3135
 colonialism and, 1:508, 1:511
 core *vs.* periphery elements in, 5:2219
 decolonization and, 2:691–692
 dependency theory and, 2:712–714
 development theory and, 2:732
 electoral geography and, 2:881
 imperialism and, 3:1545–1548
 import substitution industrialization and, 3:1549–1551
 modernization theory and, 4:1931–1935
 neocolonialism and, 4:2002–2005
 newly industrializing countries and, 4:2021–2024
 oceans as integral space of society and, 4:2069
 political economy of resources and, 5:2219–2220
 Peter Taylor and, 2:880, 6:2778
 tripartite system of power relations element in, 2:732
 uneven development and, 6:2900
 World Trade Organization (WTO), 6:3135–3136
 antiglobalization issues and, 1:96
 APEC *vs.*, 1:121
 demonstrations against, 1:95 (photo), 1:96
 export processing zones (EPZ) and, 2:1068
 forestry policies and, 4:2010
 free trade issue on food and, 3:1146, 4:2008
 General Agreement on Trade and Tariffs and, 3:1145–1146, 4:2045
 globally diffuse network of, 3:1548
 international environmental movements and, 3:1611
 most favored nation status of countries and, 4:1948, 4:2045
 NAFTA and, 4:2045
 neocolonialism policies of, 4:2003
 neoliberal economic policies of, 5:2220, 5:2459
 neoliberal environmental policy and, 4:2008
 Seattle anti-WTO protests and, 1:100
 supranational economic activity, globalization and, 3:1347
 turtle-protection issues and, 4:2010
 World Wide Fund for Nature (WWF), 2:871, 3:1612, 3:1613 (photo)
 World Wide Web. See Cyberspace
 World Wildlife Fund, 1:96

- Wright, Dawn, 6:3137
 academic career of, 6:3137
 ArcGIS Marine Data Model developed by, 6:3137
 awards and honors received by, 6:3137
 GIScience contributions of, 6:3137
 service work of, 6:3137
- Wright, Don, 1:488
- Wright, John Kirtland, 6:3138–3139
 AGS work of, 6:3138
 daseymetric maps and, 2:670
 exploration and mapping by, 6:3138
 history and geography relationship views of, 6:3138
 phenomenology and, 4:2167
 publications of, 6:3138
- Wright, Melissa, 3:1192
- Writing, 6:3139–3141
 academic writing and, 6:3140
 context of knowledge about places and, 6:3139
 experiential knowledge with linguistic implications and, 6:3139
 human geography fieldwork and, 3:1103–1005
 language role in constructing places and, 6:3139–3140
 literature geographies and, 4:1785–1788
 “objective” discourse and, 6:3140
 quality of writing and, 6:3140
 quantitative methods and, 6:3139
 symbol systems and, 6:3139
 understandings of places and spaces and, 6:3139
 writer qualities and self-awareness and, 6:3140
 writing as a tool and, 6:3139
See also Languages, geography of
- WSSE. *See* World Summit on Sustainable Development (WSSD)
- Wu, P., 2:1042
- Wyckoff, William, 5:2536, 5:2537
- Wylie, John, 4:2042
- Wynne, Brian, 5:2517, 5:2518
- Wyoming
 coal supply in, 1:483, 1:484 (fig.)
 Grand Teton National Park, 4:2119 (photo)
 Gros Ventre Slide, Grand Teton National Park in, 4:1721 (photo), 4:1723
- Xeriscaping, 6:3143–3145
 environmental benefits from, 6:3144
 geography of, in North America, 6:3145
 landscape management practices and, 6:3143–3144
 social dimensions of, 6:3145
 Tempe Women’s Club Park, Demonstration Garden, Arizona, 6:3144 (photo)
- Yamasaki, Minoru, 5:2303
- Yellowstone National Park, Wyoming, 2:868 (photo), 3:1273, 4:1909
- Yemen, 3:1190 (table)
- Young, Iris, 4:1644
- Yugoslavia
 collapse of, 4:1978
 COMECON membership of, 2:593 (table)
 ethnic cleansing, ethnicity of place and, 2:1020
- Yukon Territory
 tundra of, 1:247
 wet tundra of, 1:249
- Zaire, 6:2780 (table)
- Zambia, 3:1190 (table)
- Zanzibar, 2:1054
- Zelinsky, Wilbur, 6:3147–3148
 academic career of, 6:3147
 awards and honors received by, 6:3147–3148
 cultural landscape work of, 2:642
 fieldwork views of, 3:1103
 multidisciplinary work of, 6:3147
 population geography work of, 5:2247
 publications of, 6:3147
 religious geography work of, 5:2407
 service work of, 6:3147
 topics studied by, 6:3147
- Zielonka, Jan, 2:1038
- Zimbabwe
 CAMPFIRE ecotourism program, Zimbabwe, 2:871
 Communal Areas Management Programme for Indigenous Resources in, 2:549, 2:550
 communally owned forests and wildlife in, 1:526
 economically active females in, 3:1190 (table)
 game ranching in, 3:1180
- Zimmerer, Karl, 2:633, 5:2213
- Zimmerman, Erich, 5:2428
- Zoning, 6:3148–3150
 cadastral systems and, 1:311–318
 conservation zones and, 2:571–572
 criticisms, 6:3150
 economic functions of, 6:3150
 land segregation and, 6:3148
 legal functions of, 6:3150
 “negative” tool of, 6:3148
 “order” and “separation” functions of, 6:3148
 original function of, 6:3148
 political and economic functions of, 6:3148
 power relations and social inequities and, 6:3148, 6:3150
 in San Leandro, California, 6:3149 (fig.)
 social control functions of, 6:3150
 social disorganization discourse and, 6:3148
 spatial isolation of populations and, 6:3148
- Zukin, Sharon, 3:1207